# Nutrient Pollution in Casco Bay, Maine

## State of the Science and Recommendations for Action

### A Report of the Casco Bay Nutrient Council

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Casco Bay Estuary Partnership

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*Photo on cover: Casco Bay Estuary Partnership and Maine Department of Environmental Protection deploying a land-based nutrient monitor at a pier in South Portland.*

# Contents

# Executive Summary

The Casco Bay Nutrient Council, a group with wide representation including local and state government, wastewater treatment and stormwater management professionals, researchers, community development organizations, and water quality advocacy organizations, was convened in 2017 to develop recommendations to policymakers, regulators, and funders on how best to assess, understand, convey and reduce the negative impacts of nutrients on Casco Bay.

While in common usage "nutrients" are things that make food nutritious or healthy, nutrients in Casco Bay refers to nitrogen, phosphorus, and silica. These chemical elements boost plant growth in aquatic ecosystems and such effects can lead to negative impact on water quality. Available information suggests that most of the time nitrogen is the nutrient of primary concern in the Bay.

Concentration of nitrogen in the Bay is at a level of concern, even though Casco Bay is still relatively healthy compared to many similar bays on the East Coast. The Bay is experiencing preliminary ecological effects of excess nutrients, including algae blooms, damage to eelgrass beds, and coastal acidification. Population growth and climate change effects like warming waters and altered precipitation are likely to make the problem more severe in future. This combination heightens concern about Casco Bay's long term ability to provide habitat for commercially fished/farmed species and to provide a clean, healthy environment for recreation and tourism.

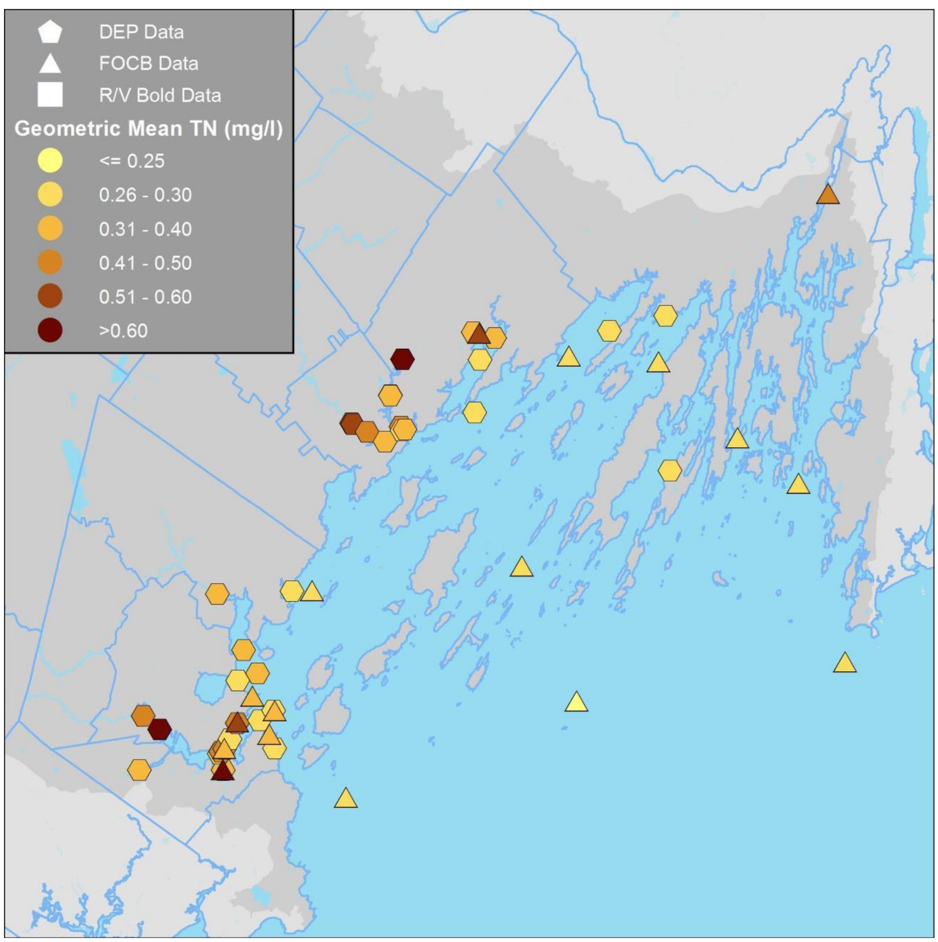
Primary sources of nutrients entering Casco Bay include human waste (entering the Bay principally via sewage), urban and suburban runoff, and atmospheric deposition. Different models draw different conclusions about the importance of agricultural runoff, but agriculture is not widespread in the Casco Bay watershed, so it appears to be less important than for most other bays in the northeastern United States.

Land use, in a broad sense, is an important driving force behind water quality impacts, including nutrient pollution. Urbanization spurs increases in runoff via growth in impervious cover, construction of drainage systems, and changes in vegetation and topography. Suburbanization increases vehicle miles traveled (contributing to atmospheric deposition of nitrogen), and reliance on on-site wastewater disposal.  Development also reduces nutrient assimilative capacity (and other ecosystem functions) of the watershed through destruction of wetlands, forests and flood plains.

Bay-wide nutrient loads do not tell the whole story. Indeed, Bay-wide totals obscure geographic variation in nitrogen entering the Bay and in levels of nitrogen found in Bay waters. Long before Casco Bay as a whole will show nutrient-related water quality problems, the most heavily impacted and most susceptible portions of the Bay may be degraded.

Data on the distribution of nitrogen in Casco Bay highlights several areas as of greatest concern. Elevated nitrogen levels are observed around Portland Harbor, the Harraseeket, the Royal River, and the upper New Meadows. All are areas with well-understood sources of nutrients like wastewater treatment facilities and (sub)urban runoff, restricted tidal circulation, or both. Additional areas of potential concern include densely settled locations in the Eastern Bay that rely on on-site wastewater treatment, and where no historical data on nutrients exists.

*Total Nitrogen (TN) data from Maine DEP (1996, 2013, 2016, 2017), Friends of Casco Bay (2007-2014), and EPA's OSV Bold cruises (2009, 2010, 2011). Sample sizes from 6 to 102.*



The Casco Bay Watershed region houses one quarter of Maine's population and one third of the total jobs and economic output in the state. Casco Bay itself is vitally important to the region and the State, having contributed $704 million in direct economic activity in 2016, and supporting some 18,500 jobs, including harvesting and processing of marine products. The Bay also contributes to the wellbeing of our communities in more intangible ways, from supporting tourism and providing recreational opportunities, to regulating water quality and sequestering carbon in coastal ecosystems. Many of the benefits the Bay provides would be diminished by poor water quality caused by excess nutrients.

Since the 1970s, substantial effort has gone into tackling water quality challenges nationwide, and Maine is no exception. Numerous laws, rules, policies, permits and programs are already in place to protect water quality, including the U.S. Clean Water Act, Maine Stormwater Management Law, and municipal Comprehensive Plans, among others. The Maine legislature has formally recognized Casco Bay as a state-wide priority for addressing nutrient pollution and developing coastal nutrient criteria. The large number of interconnected programs is both a strength and also a vulnerability for cost-effective implementation. The number of related programs complicates coordination of priorities and efforts across regulatory programs and jurisdictions. Integrated Water Quality Planning (currently being implemented by the City of Portland) and regional coordination (implemented in part by the Interlocal Stormwater Working Group and other regional entities) can help address programmatic complexity and improve cost-effectiveness.

Few citizens appreciate the capital and operating costs of clean water. Existing plans call for hundreds of millions of dollars in public investments in water quality in our region in coming decades, in the form not only of capital outlays and operations costs, but also maintenance, coordination, planning, land conservation and regulatory programs. Millions more will be spent by public and private entities complying with regulatory mandates.

Managing those costs requires both identifying cost-effective ways of protecting water quality, and also establishing stable and equitable funding mechanisms.

Efforts to communicate with the general public about water quality issues are highly varied, making them difficult to characterize and evaluate. Regional outreach efforts, mandated by municipal stormwater programs, deliver water-quality-related content using a variety of platforms and approaches, including classroom education, TV and online ads, social media, print materials, educational signage, and special events. Many programs aim not at educating the public, but changing behavior in ways likely to benefit clean water, such as reducing the use of lawn chemicals.

Private individuals and businesses control almost all the land in Maine and manage almost all stormwater control structures. Thus incentives and disincentives that influence decisions by individuals and businesses to reduce water pollution are likely to be an important part of the long-term strategy for reducing or managing nutrient loads. As a region, we need to find more effective voluntary tools to encourage private decisions that protect water quality. Possible efforts could include Green Certification Programs, training design professionals and landscape management operators, and working directly with landowners and businesses to identify and implement steps they can take to protect water quality.

The Nutrient Council has determined that action is warranted to prevent further negative impacts to Casco Bay, and recommends a number of creative and flexible approaches to nutrient monitoring and management in the Bay. These recommendations are meant to improve understanding of the effects of nutrients in the Bay, and to distribute responsibility for preventative measures throughout the community, including the use of regulatory tools, educational campaigns, scientific research and modeling, and creative and flexible treatment and load reduction strategies.

The following recommendations in the areas of Policy, Funding, Science, and Community Engagement are intended to strike an appropriate balance between urgency – "We need to act soon!" – and thoughtfulness – "Let's make sure we get it right."

## Policy

1. Encourage integrated planning and adaptive management across permits and municipalities.

2. Establish numerical nutrient criteria for marine waters.

3. Revise state rules and guidance for stormwater and site design to highlight stormwater controls (e.g. green infrastructure, gravel wetlands) that meet existing rules and also remove nitrogen from stormwater.

4. Create a forum to discuss ways to harmonize state and local policies and provide input on specific policy recommendations. Such a group needs to be broad based, and invite participation not only from urban and suburban communities, but rural Maine towns as well.

5. Develop tools and incentives to encourage the private sector to reduce nutrient loads through stormwater facility maintenance and good housekeeping. Enforce the rules that already exist.

6. Encourage municipalities to think and act in terms of watersheds when developing local policy, through preparation (and funding) of watershed management plans and building community awareness of watershed impacts.

7. Consider adoption of "Smart Growth" policies and strategies to reduce nutrient pollution (such as: consider watershed impacts during site design and planning reviews; create stronger incentives for implementation of BMPs; protect forests and wetlands; develop ordinances that encourage green infrastructure in new development; increase density, redevelopment, and infill in appropriate areas; manage and restrict fertilizer use).

8. Incorporate water quality/nutrient goals into comprehensive plans.

## Funding

9. Seek sustainable funding for outreach and education related to water quality, stormwater, and nutrient-related impacts.

10. Establish a dedicated regional monitoring fund to support ongoing and expanded regional water quality monitoring.

11. Expand the use of federal and state funding to support substantial costs of capital investment in water quality protection; nutrient management in particular.

## Science

12. Develop nutrient loading estimates that combine recently collected data on wastewater and CSO discharges with updated runoff models (which properly account for direct discharges to the Bay) to develop up-to-date estimates of loads from different sources.

13. Expand nutrient monitoring to measure nutrient concentrations in currently unmeasured sources, especially urban streams, stormwater outfalls, and CSO outfalls.

14. Conduct analysis to better understand the effects nutrients are having on the Bay, including sediment processes.

## Community Engagement

15. Share information on the importance of nutrient pollution to our waterways more broadly with policymakers and key decision makers.

16. Encourage innovation on the part of the public and private sectors to support nutrient reduction.

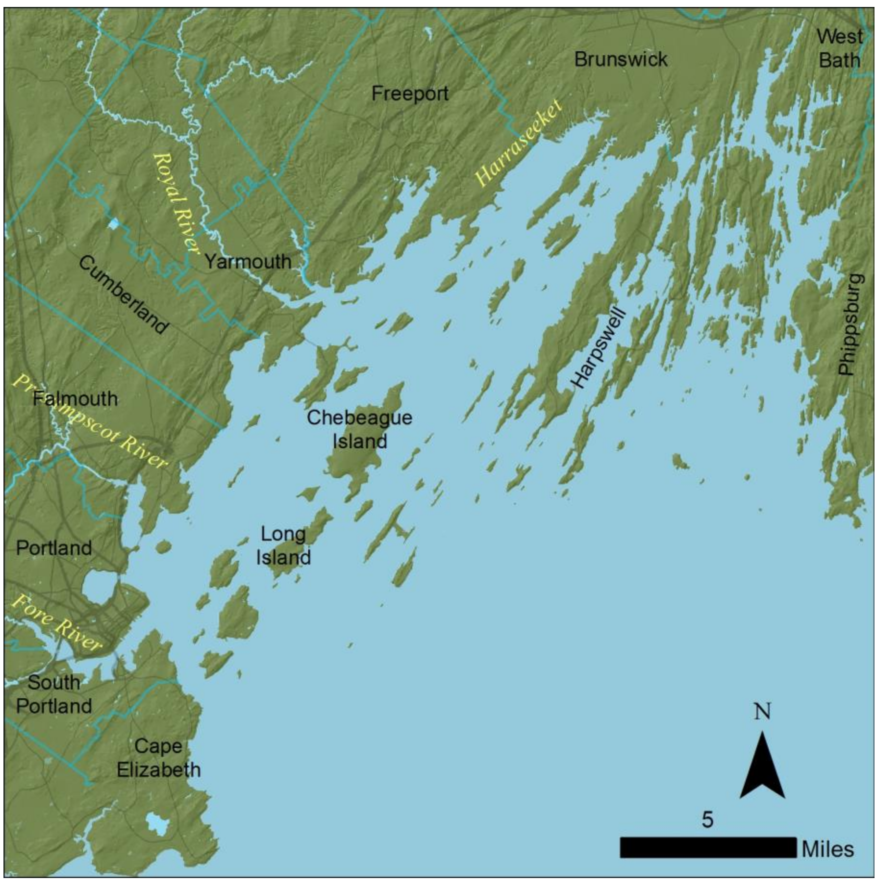
17. Establish a working group to recommend appropriate water quality criteria for nutrients in Casco Bay, which may include numeric goals, to be used throughout the Bay.

18. Continue the work of the Casco Bay Monitoring Network and periodically update the map and dataset of monitoring programs. Integrate emerging nutrient monitoring needs, activities, and funding models with other Bay monitoring.

# Chapter 1: The Problem

## A. Problem Background

The Casco Bay Watershed region houses one quarter of Maine's population and one third of the total jobs and economic output in the state (Wallace et al. 2017). Although two thirds of the watershed remains forested, the most heavily developed portions of the watershed – about 10% of the landmass – border tributaries and the Bay itself, with extensive impervious surface (CBEP 2015). The Portland metropolitan region, Maine's principal population center and economic hub, borders the Bay, with the Cities of Portland and South Portland at the southern end.




*Map of Casco Bay, Maine, showing coastal towns and major rivers*

Numerous streams in the Casco Bay watershed are impaired due to impacts of stormwater from impervious cover and associated urbanization. Certain areas of Casco Bay (while not formally designated as impaired due to nutrients) have shown signs of coastal eutrophication and hypoxia (CBEP 2015, CBEP 2016). The Maine legislature has formally recognized Casco Bay as a statewide priority for addressing nutrient pollution and developing coastal nutrient criteria (Maine 123rd Legislature 2007).

The source of concern about coastal eutrophication and hypoxia in Casco Bay is threefold: (1) elevated concentrations of nutrients, especially nitrogen, in portions of the Bay which may be beginning to experience negative impacts; (2) increasing human population in the region; and (3) increasing vulnerability of the Bay to the impacts of climate change. These concerns have reached a point where action is required to prevent future impairments.

Concentrations of nutrients, specifically nitrogen, in Casco Bay vary from place to place, with the highest documented levels in the Fore River, the Harraseeket, the Royal and Cousins Rivers, and the upper New Meadows (especially the impounded tidal waters of the New Meadows “lakes”). Nutrient concentrations in the offshore waters of Casco Bay tend to be moderate to low, with higher concentrations occurring in inshore waters where anthropogenic and terrestrial influences are strongest, where tidal mixing is muted, or both.

Portland Harbor and the waters surrounding it have among the highest total nitrogen (TN) concentrations observed anywhere on the Maine coast, with median conditions exceeding 90% of coastal nitrogen measurements in Maine (Cadmus Group 2009; CBEP 2015).

Recent evidence suggests that impacts from these high nitrogen levels are having isolated negative consequences. Reports of algal overgrowth of tidal flats are becoming more common (Miller 2016). Several significant algal blooms occurred in the Bay in 2017, including several of species new to the Maine coast (although a cause and effect relationship between nutrients and these blooms has not been conclusively established). High coastal nutrient concentrations may also be leading to enhanced acidification due to algal growth and decay (Cai et al. 2011, Wallace et al. 2014). Acidified coastal waters (below a pH of 7.4) are observed more than 10% of the time in 6 of 15 Casco Bay monitoring regions (CBEP 2015).

Population growth increases both point source (sewage) and nonpoint source (such as runoff and atmospheric deposition) nutrient loads to Casco Bay. Between 2000 and 2010, the population of communities that contribute to the watershed grew by 6.1 percent (CBEP 2015). Portland had one of the highest growth rates of any city in the northeast in 2014 (Murphy 2015). Population projections for the region vary depending on assumptions, but moderate population growth is likely over the next decade. Maine’s aging population means deaths are likely to outstrip births in our region soon, so longer-term estimates of population trends depend on anticipated rates of immigration (OPM 2016).

Climate change exacerbates the problems of high nutrient loads. In recent years, the Gulf of Maine has been warming faster than 99% of the world's oceans (Pershing 2015). Warmer waters both facilitate thermal stratification and increase respiration, increasing the risk of significant water quality problems triggered by nutrient loading (Rabelais et al. 2009).

A recent study suggests that precipitation changes expected because of climate change will increase nitrogen loading to northeastern coastal waters, exacerbating eutrophication (Sinha et al. 2017). Over the past century, total precipitation and extreme storms in the region have increased (CBEP 2015). Extreme storm events, especially following periods of drought, are likely to increase the pollutant loads delivered to Casco Bay. For example, Portland still has 31 active combined sewer overflow (CSO) points that, in the drought year of 2016, discharged 318.4 million gallons of untreated wastes to Casco Bay and its tributaries (Riley 2017). More extreme storms will increase the frequency and size of future CSO discharges.

Nutrient enrichment of coastal waters is a global challenge, leading to (inter alia) harmful algal blooms, fish kills, declining fisheries, disappearance of marine species, and development of persistent "dead zones" in coastal areas around the globe (Rabelais et al. 2009, Rabelais et al. 2014). Frequency and extent of dead zones are both increasing (Breitburg et al. 2018). Here in New England, nutrient pollution affects numerous coastal embayments, from Great Bay in New Hampshire, to Boston Harbor in Massachusetts, and Narragansett Bay in Rhode Island, and also affects many other, smaller water bodies (e.g., Alexander et al. 2001, Bricker et al. 2008, Castro et al. 2003, Latimer and Charpentier 2010, Whitall et al. 2007).

Casco Bay is showing signs of ecological change due to warming temperatures and nutrient enrichment. To date, Maine's cool waters, the Bay's robust tides and currents, and the relatively low human population of the watershed (compared to other New England bays) have made our Bay resilient to the moderate nutrient loads of the past, but there are limits to that resilience. Population trends and a changing climate will increase risk of negative ecological changes in coming years.

The Nutrient Council has asked whether we are at or near a critical point where increased nutrient loads would lead to harmful ecological change that may prove difficult or impossible to reverse. If we are approaching such a critical point, what action should we take to avoid potential negative consequences? Parts of the Bay are already showing signs of nutrient related stress, and current State law and the Clean Water Act do not allow discharges that further degrade water quality.

Awareness of potential "tipping points" in marine ecosystems has been growing, and specific recommendations have emerged regarding managing systems prone to them. A recent review suggests that taking explicit action regarding critical points leads to better outcomes:

> We suggest that early action to preserve system resilience is likely more practical, affordable, and effective than late action to halt or reverse a tipping point. We articulate a conceptual approach to management focused on linking management targets to thresholds, tracking early-warning signals of ecosystem instability, and stepping up investment in monitoring and mitigation as the likelihood of dramatic ecosystem change increases. This approach can simplify and economize management by allowing decision makers to capitalize on the increasing value of precise information about threshold relationships when a system is closer to tipping or by ensuring that restoration effort is sufficient to tip a system into the desired regime (Selkoe et al. 2015).

## B. Nutrient Pollution and Casco Bay

In common usage "nutrients" are things that make food nutritious or healthy. Ecologists use the term differently, to describe the elemental building blocks of aquatic organisms, especially phytoplankton. Often, the nutrients that matter are the chemical elements that are (sometimes) in short supply, known as limiting nutrients. Important nutrients that limit growth of aquatic plants and algae (and thus are of concern for protecting water quality) include nitrogen, phosphorus and silica. Nitrogen is an essential element for building proteins, and phosphorus is required to build nucleic acids, including DNA. All living organisms require both. Silica is an important nutrient in aquatic ecosystems because an important group of phytoplankton – the diatoms – rely on it to build structural shells, called frustules.

We apply fertilizer containing nitrogen and phosphorus to agricultural fields to increase crop yields, precisely because these two elements are often in short supply, and adding them to our fields can boost plant growth. When we add excess nutrients to coastal waters, we also boost plant growth, but the consequences are generally not benign.

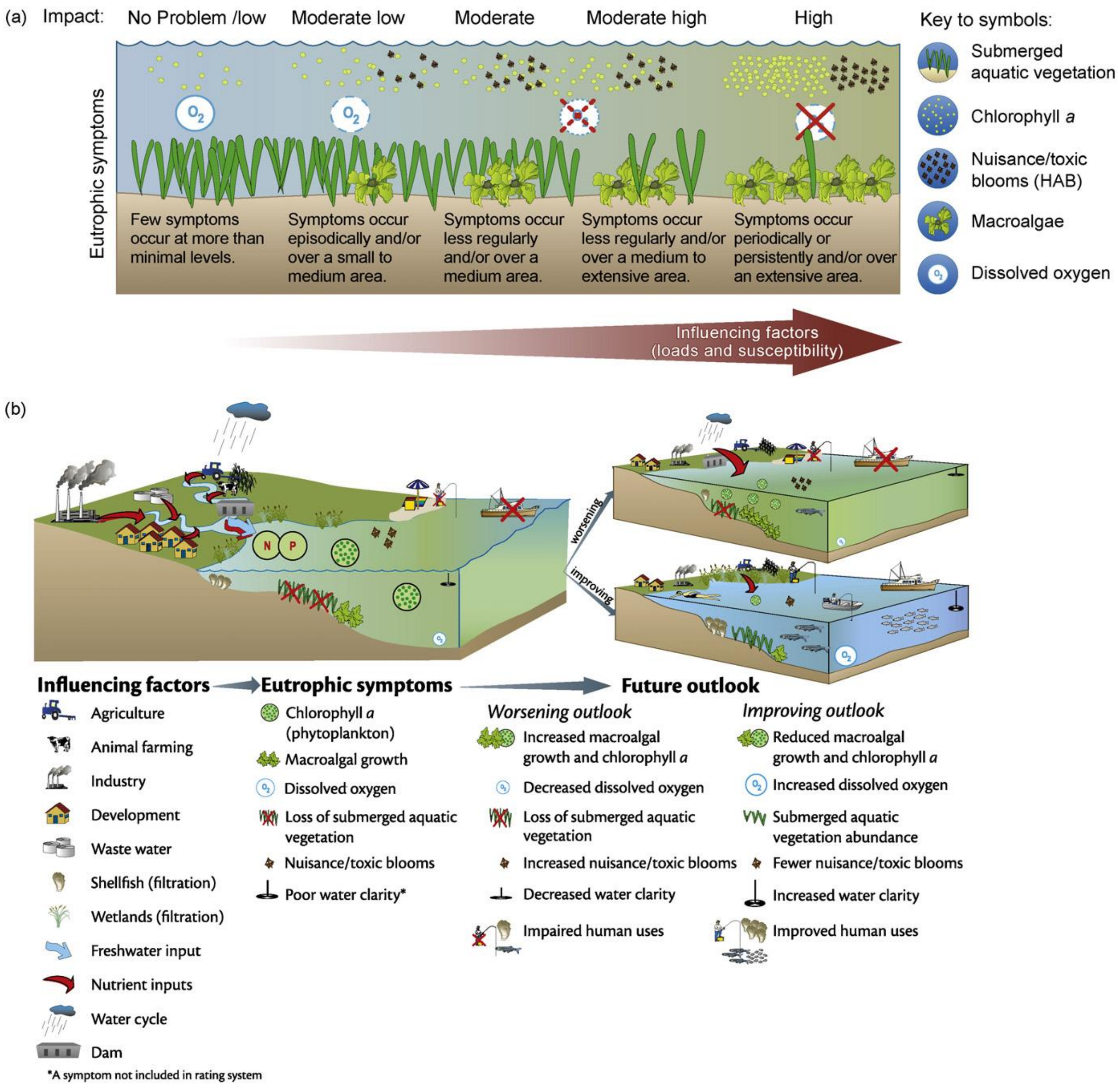
**Nutrient enrichment often leads to negative effects on water quality.** In aquatic ecosystems, these effects may include:

- Reduced water clarity due to increases in abundance of algae;
- Loss of eelgrass beds and damage to other aquatic habitats;

- Nuisance and toxic algal blooms (including not only phytoplankton, but also drift algae and benthic mats);
- Noxious odors;
- Reductions in diversity and abundance of marine organisms, including fish and shellfish;
- Closure of waters to the harvesting of shellfish;
- Coastal acidification;
- Low or no dissolved oxygen in the water;
- Mortality of aquatic organisms, especially those unable to migrate out of waters with low or no oxygen;
- Fish kills;
- Losses of ecological diversity and ecosystem function, reducing benefits to human communities.

In freshwater ecosystems (like many Maine lakes), phosphorous is usually the primary nutrient of concern. In marine systems, it is more likely to be nitrogen. In areas where fresh and salt waters mix, either nutrient may limit growth, or limitation may shift with weather or the seasons. The effects of silica tend to be more subtle, influencing composition of the plankton via relative abundance with the other macronutrients. When nitrogen and phosphorus are more available than silica, species composition of the plankton can shift away from diatoms towards other, often undesirable species. Thus while understanding silica in Casco Bay may be important in future, the element is not considered further here.

*One "Conceptual Model" of the effects of coastal nutrient enrichment on water quality*




Source: S.B. Bricker et al. 2008. Effects of nutrient enrichment in the nation's estuaries: A decade of change. Harmful Algae 8 (2008) 21–32

## C. Water Quality in Casco Bay

Water quality in Casco Bay is generally excellent compared to conditions in many coastal bays close to urban and suburban areas. Low dissolved oxygen conditions are rare (except in specific locations). Algal blooms (other than an annual red tide bloom that seasonally restricts shellfish harvests) are rare enough to be newsworthy. Bacterial contamination sufficient to restrict shellfish harvesting is, however, relatively widespread, with more than a quarter of Casco Bay softshell clam habitat permanently closed to harvest, and nearly half (45%) always or periodically subject to closures.

No waters in Casco Bay are formally listed in the 2016 Maine Integrated Water Quality Monitoring and Assessment Report (DEP 2018a, DEP 2018b) as impaired due to excess nutrients or eutrophication. Maine lacks numeric water quality criteria for nutrients, so waters designated as impaired due to nutrient pollution must show both (1) a violation of one of Maine's narrative water quality criteria (such as marine life support) or quantitative criteria (such as dissolved oxygen), and (2) a link to elevated nutrient levels or relevant biological indicators. Only a single marine waterbody in Maine has been listed as impaired for nutrients (in the Piscataqua River).

Low dissolved oxygen conditions are frequently related to excess nutrients and eutrophication. Two areas in Casco Bay, the Royal River and the upper New Meadows are considered impaired in part because they fail to meet state dissolved oxygen standards.

Thirteen areas in Casco Bay appear on Maine's "Nonpoint Source Priority Watersheds List" for marine waters[1]. While this list was not assembled based on nutrients, these are areas impacted by runoff, principally urban or suburban, which may be vulnerable to excess nutrient loads now or in the future.

[1] https://www.maine.gov/dep/land/watershed/nps_priority_list/NPS%20Priority%20List%2018-%20Marine.pdf

*List of Casco Bay waters on Maine Nonpoint Source Priority List*

| Marine Water | Area/Town |
|---|---|
| Anthoine Creek & Cove | South Portland |
| Bunganuc Creek | Brunswick |
| Harpswell Cove | Brunswick |
| Harraseeket River | Freeport |
| Little River and Bay | Freeport |
| Maquoit Bay | Brunswick |
| Mill Cove | South Portland |
| Mill Pond/Parker Head | Phippsburg |
| Mussell Cove | Falmouth |
| North Fogg Point | Freeport |
| Oakhurst Island | Harpswell |
| Upper New Meadows River upstream from Howard Point, including the lakes | Brunswick, Bath |
| Willard Beach | South Portland |

Harmful algae blooms (HABS) may be on the increase in Casco Bay. HABs include overgrowth of tidal flats by filamentous algae (especially species of *Ulva*), and both toxic and non-toxic blooms of phytoplankton. Red tides (a toxic algae bloom caused here by the dinoflagellate, *Alexandrium fundyensis*) occur regularly in Casco Bay. A spring bloom is triggered annually as offshore currents bring the toxic algae into Casco Bay, where it continues to thrive (Libby 2010). The 2017 red tide was unusually long and severe, leading to closure of shellfish harvesting in Casco Bay for nearly three months. An extensive bloom of a (apparently non-toxic) species of phytoplankton never before observed in Casco Bay (*Karenia mikimotoi*) occurred in September of 2017, forming a visible "brown tide," causing low dissolved oxygen conditions in portions of Casco Bay, and leading to widespread reports of odors and shellfish mortality. An unusual late-season toxic event also occurred in December of 2017, caused by a *Pseudo-nitzschia* (probably *P. australis*, also new to Maine in 2017), which led to additional closures of shellfish harvesting[2]. Conditions in 2018 have been more typical, with a shorter red tide event, fewer observations of overgrowth of tidal flats by filamentous algae, and no repeat of the *Karenia* and *Pseudo-nitzschia* blooms. (The role of nutrients in driving these events is uncertain - see below).

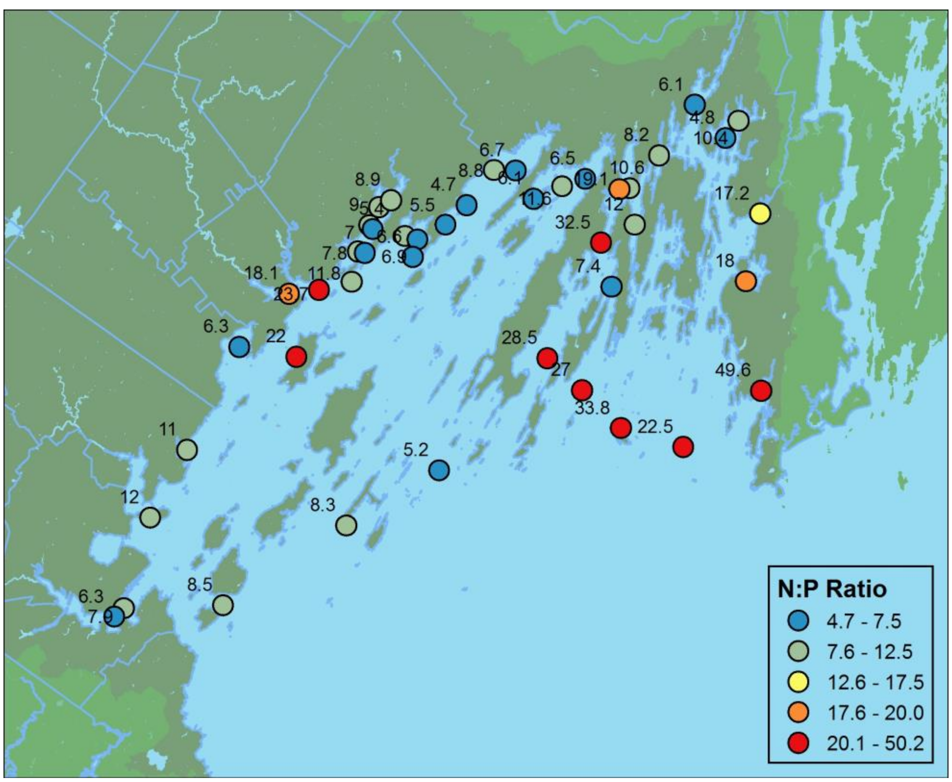
[2] Details of the 2017 phytoplankton blooms are derived from PowerPoint presentations and personal communications from Bryant Lewis, of Maine Department of Marine Resources Shellfish Sanitation Program.

## D. Nutrients and Water Quality in Casco Bay

It is likely that nitrogen usually functions as the limiting nutrient for phytoplankton growth in Casco Bay. That matches what one would expect based on principles of coastal ecology, but the idea is also supported by two lines of local evidence.

As a rule of thumb, it takes about 15 or 16 atoms of nitrogen for every atom of phosphorus to build algae cells. One can look at the relative abundance of available nitrogen and phosphorus and get a good idea of which nutrient is in short supply. By this metric, nitrogen is usually the limiting nutrient in Casco Bay. A 2007-2009 study monitoring red tide collected data on dissolved inorganic nutrients (dissolved inorganic nitrogen and orthophosphate) from 44 locations around the Bay fourteen times in spring and early summer of 2007 and 2008. The ratio of dissolved nitrogen to dissolved phosphorus (N:P ratios) can be calculated for each sample. While observed N:P ratios are highly variable, median ratios in the Bay as a whole and at most sample locations are suggestive of nitrogen limitation.

*Median dissolved Nitrogen to Phosphorus Ratios from 2007-2008 "Red Tide" study data. Medians based on 12 to 14 observations at each site. Reds and oranges suggest phosphorus limitation. Blues and greens suggest nitrogen is the limiting nutrient.*



Unattended monitoring devices recently began to collect water quality samples on an hourly basis in portions of the Bay. Friends of Casco Bay deployed a “continuous monitoring station” off Cousins Island, and University of Maine deployed three automated water quality monitoring buoys in the Eastern Bay. While no final analysis of these data has been reported, data is available either by request (FOCB) or online (UMaine) and informal analyses have been presented at several scientific meetings. Researchers have reported that as algal abundance climbed during an algal bloom in September of 2017, concentrations of dissolved nitrogen dropped, suggesting rapid uptake by bloom-forming algae.

HABs in coastal waters are often associated with excess nutrients (e.g., Bricker et al. 2008, Driscoll et al. 2003, Howarth and Marino 2006, Rabelais et al. 2009, Rabelais et al. 2014) and waters with elevated nutrients are at elevated risk for HABs.

The role of nutrients in causing or exacerbating recent Casco Bay blooms, however, remains uncertain. Mechanisms causing individual blooms are complex, making it difficult to draw simple conclusions about causation. The presence of new species of algae in Casco Bay (itself in part a reflection of larger processes like climate change and transport of marine organisms via global shipping) played a role. Overgrowth of tidal flats can be a natural phenomenon (DEP 2018a), but overgrowth events may be on the increase (Miller 2016), and severe events are likely to be uncommon in the absence of elevated nutrients. Seasonal cycles and offshore currents that bring toxic algae into the Bay trigger Casco Bay’s red tides (Libby 2010). The unusual September “brown tide” bloom appears to have occurred when *Karenia* entered the Bay on tidal currents, and found conditions to its liking.

But these complexities do not mean nutrients did not, or could not also play a part. Excess nutrients may increase the risk of blooms, or make blooms longer or more severe.

## E. Nitrogen Entering the Bay

Over the years, several research groups have estimated nitrogen loading to Casco Bay from terrestrial and atmospheric sources. While data from Casco Bay is reported in more than half a dozen academic papers, several draw their estimates in whole or in part from other studies, making it hard to evaluate the degree to which different estimates are independent of one another. CBEP staff have identified four mostly independent estimates of nitrogen loading to Casco Bay, using different approaches to estimate nutrient loads (Castro et al. 2003, Bricker et al. 2006, Whitall et al. 2007, Liebman et al. 2012). All estimates used regional or watershed-scale analyses to estimate nitrogen loads from the uplands entering the Bay.

While the models differ in allocation of nitrogen loads among sources, they are in fairly good agreement with regards to total nitrogen entering Casco Bay (see table). Based on this review, we can conclude that Casco Bay is likely to receive on the order of 1.0 to 1.2 million kilograms of nitrogen from all sources annually.

*Prior estimates of nutrient loading to Casco Bay from upland sources*

| Source | Estimate of N Load to Casco Bay (Kg N per year) |
|---|---|
| Alexander et al. 2001 | 1,193,898 |
| Castro et al. 2003 | 1,352,104 |
| Whitall et al. 2007 | 983,506† |
| Liebman et al. 2012 | 827,612†† |
| **Average** | **1,089,279** |

† Total derived via back calculation from data on watershed area and load per unit area
††Omits direct wastewater discharges to Casco Bay from East End and South Portland facilities

Existing watershed loading models of nutrients entering Casco Bay have qualitative similarities, but they differ in quantitative detail. They vary on overall estimates of loading by less than a factor of two; but they vary a lot on the importance of different sources. Issues include:

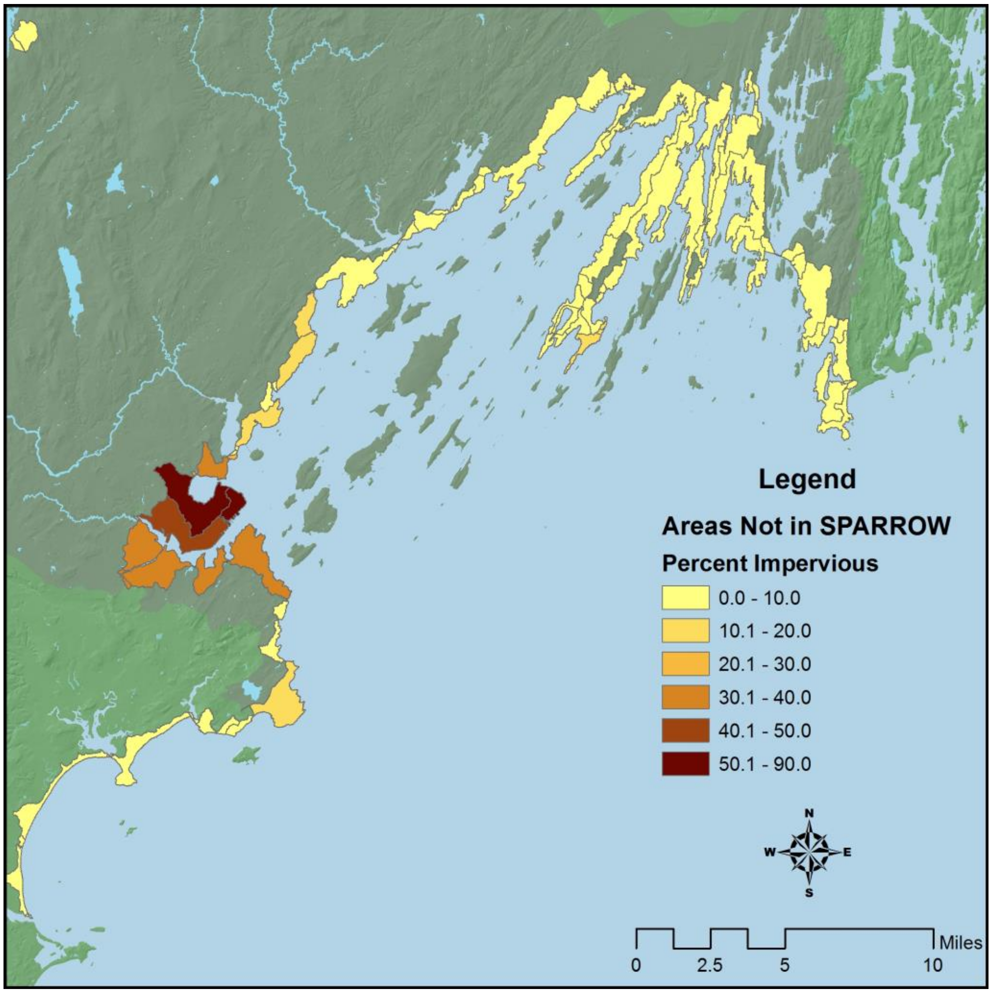
- Models used inconsistent data on wastewater treatment plant discharges (different years, different assumptions of volumes and concentrations) and some models may have in effect double counted some discharges. All major plants in our region now monitor nitrogen discharges, so we have access to excellent data on recent nutrient loads from wastewater plants.
- Estimates of atmospheric deposition from all the models we have evaluated trace back to the same data on atmospheric deposition of nitrogen in Casco Bay, and thus estimates of atmospheric deposition are broadly similar (but not identical because of different methods).
- The most significant differences among the historic models going forward relate to treatment of diffuse, or "nonpoint" sources in the watershed, especially runoff and (to a lesser extent) on-site wastewater disposal systems. For example, models deriving from the SPARROW model platform track discharges to the Bay from streams and rivers, but do not track direct discharges from urban areas directly to the Bay.

The Nutrient Council has reviewed and discussed the "SPARROW" model of nutrient loads to Casco Bay (Liebman et al. 2012) more thoroughly than the older models. The SPARROW model estimates nutrient delivery from the watershed, based principally on land use, atmospheric deposition, and wastewater discharges, modified by retention and removal of nutrients via the lands, wetlands, rivers, and lakes between sources and the Bay. The model reports nutrients entering the Bay via outlets where rivers and streams meet the Bay.

CBEP staff and others have put considerable effort into reviewing the technical details of this model, with the following results:

- Whitley Gilbert, a University of Maine graduate student working with Damian Brady, measured concentrations of major nutrients, including nitrogen, in several Casco Bay tributaries. Her preliminary results suggest the model does an excellent job estimating nutrient loads entering the Bay from tributaries. (*Pers. Com.*, 2018, see below).
- Since the model tracks nutrients entering the Bay via rivers and streams, it does not track nutrients from runoff from Casco Bay's islands, or from mainland areas that drain directly to the sea (without traversing a stream or river). The model omits nutrients in runoff from all of the Portland peninsula, most of South Portland, and nearby suburban coastal areas. The catchments omitted from the SPARROW model contain 14% of the total impervious area in the Casco Bay watershed, so it is likely that the SPARROW model results underestimate total, Bay-wide nitrogen loads in runoff by a roughly similar amount.
- The model provides no ready way to incorporate estimates of several potentially important sources of nutrients to Casco Bay, including septic tanks, overboard discharges, and combined sewer overflows. With the exception of CSOs, each of these sources is small compared to Bay-wide loads. Nevertheless, they may be locally significant, particularly in areas with no public sewer system.

*Mainland areas omitted from SPARROW model estimates of runoff-derived nutrients entering the Bay. The model also omits runoff from Casco Bay's major islands (not highlighted).*




Despite differences among them, all models support several conclusions:

(1) Loading to Casco Bay is on the low side compared to loadings to most large coastal bays and estuaries in the Northeast. Loadings are relatively low in absolute terms (on the order of one million kg of N annually), and also per square mile of watershed or per square mile of Bay.

(2) Using other northeastern estuaries as a guide, loads to Casco Bay are already at levels of concern, but not at levels comparable to estuaries with severe, chronic water quality problems.

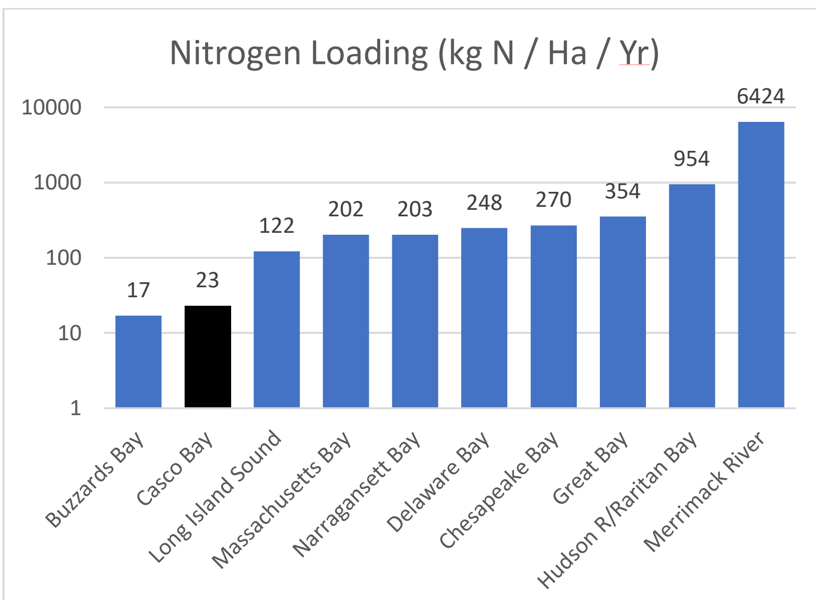
(3) Direct nitrogen discharges in wastewater are substantial, with different models reporting between 36% and 58% of total nitrogen loads coming from human waste. (Differences in these figures reflect different choices about what to include in this category, and how to estimate discharges).

(4) Runoff accounts for a substantial amount of nitrogen entering the Bay (23% to 64%, according to different models). The largest share of nitrogen entering the Bay in runoff comes from urban and suburban areas. Different models draw different conclusions about the importance of agricultural runoff, but agriculture only accounts for a small proportion of land use in the Casco Bay watershed.

(5) Atmospheric deposition of nitrogen constitutes a substantial fraction (from 13% to 35%) of total loadings.

Because capacity to handle nitrogen loads depends in part on the size of an estuary, relative loading among different estuaries is sometimes assessed by comparing loads on a per acre of estuary basis. By that standard, loading to Casco Bay is lower than to most other major northeastern estuaries, by a factor of five or more. However, nutrient pollution is a significant problem in all of the estuaries shown in the figure, including Buzzards Bay.

*Nitrogen loadings to major northeastern estuaries, on a per unit area of estuary basis. Note the log scale on the Y axis.*

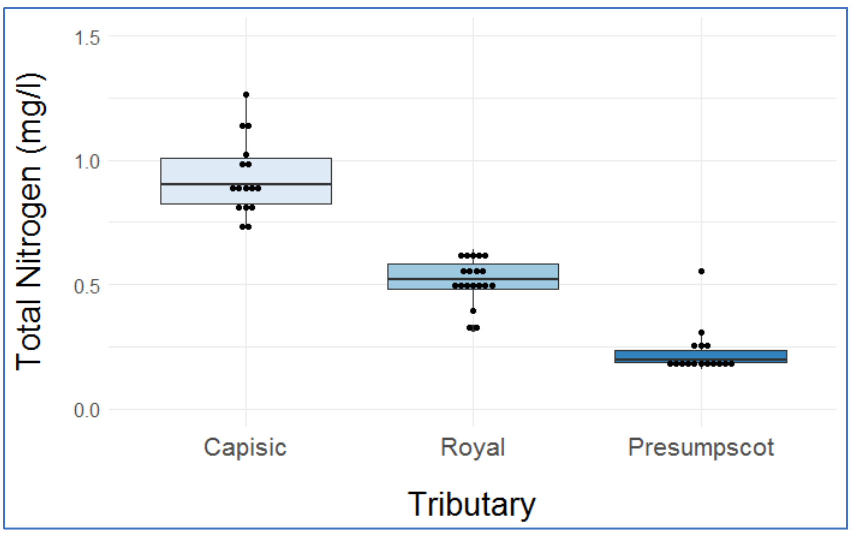



Source: Latimer and Charpentier 2010; based on data from Whitall et al. 2007

Relatively low total loadings and the mix of important nitrogen sources identified in these studies are not surprising. The population of the Casco Bay watershed is on the order of 240,000 (CBEP 2010), which is low compared to numbers of people in the watersheds of many other northeastern estuaries and bays. Despite substantial urbanization and suburbanization in our coastal towns, more than three quarters of the Casco Bay watershed remains in forest or wetland. Only 10% of the watershed is classified as developed (CBEP 2015). Agriculture is also relatively uncommon in the watershed today, accounting for only 8% of land area (CBEP 2015). Although agricultural lands, if improperly managed, can be an important source of nutrient pollution, the relatively low prevalence of agriculture in the landscape helps limit its overall impact on the Bay's water quality.

But Bay-wide nutrient loads do not tell the whole story. Indeed, Bay-wide totals obscure important geographic variation in nitrogen loads entering the Bay. Long before Casco Bay as a whole will show severe, chronic nutrient-related water quality problems, the most heavily impacted and most susceptible portions of the Bay may be seriously degraded.

*Total nitrogen concentrations in three Casco Bay tributaries 2017-2018*




Unpublished data courtesy of Whitley Gilbert, University of Maine

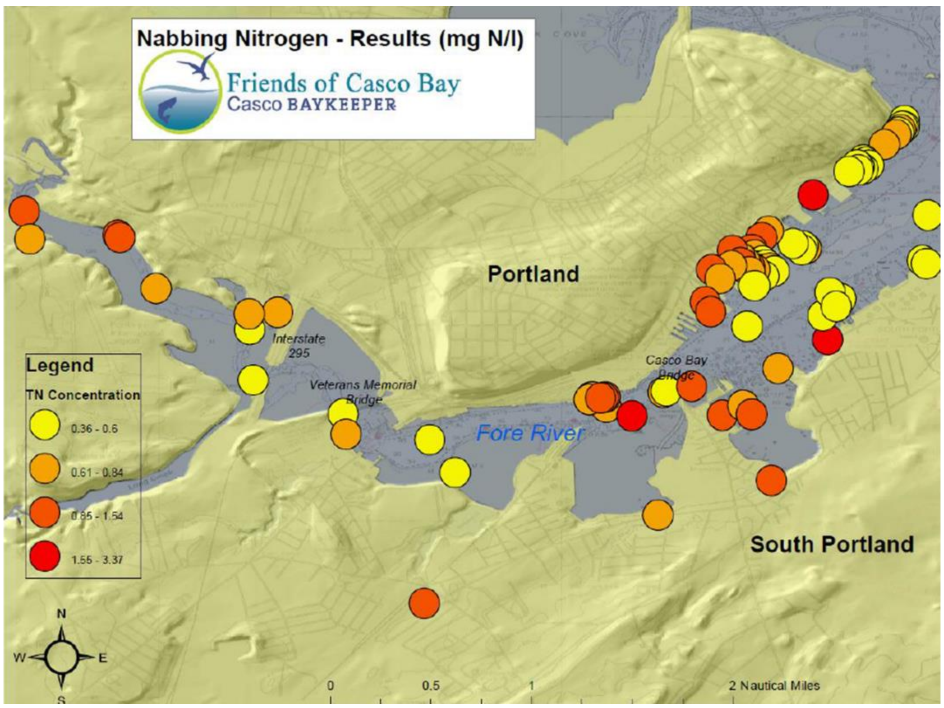
Both our urban lands and our wastewater discharges are concentrated in Portland and South Portland. The East End and South Portland wastewater treatment facilities together accounted for 81% of treated sewage discharged from the region's eight major wastewater treatment plants in 2017[3]. The watershed of the Fore River is 16.5% impervious area, and accounts for nearly one fifth (18.8%) of the impervious area in the Casco Bay watershed. The nearby Presumpscot River drains two thirds (65.5%) of the Casco Bay watershed, and 43.3% of the watershed's roadways, parking lots and rooftops. Thus the waters in and around Portland receive a high proportion of all nutrients entering the Bay from terrestrial sources. Portland Harbor, the Fore River, and nearby waters are likely to experience elevated levels of nutrients

[3] Peaks Island, Cape Elizabeth, South Portland, Portland's East End, Westbrook, Falmouth, Yarmouth, and Freeport. Calculation based on data from monthly reporting to DEP of average daily discharges.

earlier than most of the rest of the Bay. Data collected in 2017 and 2018 by University of Maine researchers show relatively high concentrations of nutrients in an urban stream, compared with the Bay's larger rivers.

Friends of Casco Bay's 2016 "Nitrogen Nabbing" event revealed high, spatially variable concentrations of nitrogen in Portland Harbor on a day following moderate rainfall. High concentrations were especially common close to the shore.

*Friends of Casco Bay's 2016 "Nitrogen Nabbing" event results*




Other locations where elevated nutrient loads can be expected to enter the Bay include the Royal River estuary, the Foresides (and other suburban waterfronts), the Harraseeket, and portions of Harpswell and Phippsburg:

- The Royal River drains 16.6% of watershed area, and 13.8% of impervious surfaces. While the town of Yarmouth has moderate imperviousness overall (10.1%), the portions of town that drain directly to the estuary have higher imperviousness (19.25%). The Yarmouth wastewater treatment facility, while small on a Bay-wide basis (2.6% of discharges from major WWTFs), discharges directly to the estuary.
- Collectively the suburban coastal drainages of Falmouth, Cumberland, Yarmouth, and Freeport, South Portland and Cape Elizabeth, which drain directly to the Bay, are

about 16.2% impervious. Almost all houses and businesses in these areas, are sewered, so runoff is the primary concern.

- The Harraseeket is a small, partially enclosed bay. While overall imperviousness in the watershed is moderate (6.2%), the bay receives runoff from almost all of downtown Freeport. In addition, the small Freeport wastewater treatment facility (about 1.2% of all wastewater discharges in our region) discharges to the Harraseeket.
- The peninsula and island towns of Eastern Casco Bay largely lack sewage infrastructure. While properly functioning septic systems reduce (but do not prevent) nutrient flow to downstream waters, poorly maintained overboard discharges and septic systems can be a significant source of nitrogen to downstream waters. While levels of imperviousness in Phippsburg and Harpswell are low (2.9% and 6.3% respectively), development is not uniformly distributed, and nutrient loads from runoff and septic tank leachate may be locally significant where homes and businesses congregate. Data has not yet been aggregated at the small scales needed to assess such local loads.

## F. Marine Nutrient Loads

All of the models discussed so far look at nutrient loads from the Casco Bay watershed, carried in river flows, runoff, and direct wastewater discharges, but ignore the potential role of nutrients entering the Bay from marine sources. Members of the Nutrient Council and others have discussed two principal sources of nutrients entering the Bay that these models do not account for:

- Nutrients entering the Bay from offshore waters, either from the Kennebec Plume, or from offshore waters more generally.
- Nutrients entering the Bay via the sediments (via groundwater discharge or "internal recycling" from the sediments).

**Kennebec Plume and Offshore Waters** – The Kennebec River is one of Maine's largest rivers and it discharges into the Gulf of Maine just east of Casco Bay. Because of prevailing offshore winds and currents, the plume of fresher water that develops at the mouth of the Kennebec is frequently entrained into the waters of Eastern Casco Bay. Because of the large watershed area drained by the Kennebec, total nutrients entering the Gulf of Maine in its plume are substantial.

Deep, offshore waters are a significant source of nutrients to the Gulf of Maine. Two types of deep waters, Labrador Slope Water (LSW) and Warm Slope Water (WSW) have been reported as the Gulf's major source of dissolved inorganic nutrients (Townsend et al. 2015).

Nevertheless, it is unlikely that either the Kennebec River plume or offshore waters are a significant net source of nutrients to Casco Bay, and especially to the Bay's inshore waters. Concentrations of nitrogen offshore are generally lower than observed inshore. As waters slosh in and out of the inner bay every day, driven by the Bay's strong tides, low concentration offshore waters flow into the Bay, while higher concentration inland waters flow out. Net transport of nutrients is likely to be from the Bay toward offshore waters, rather than the reverse, but this deserves further investigation with improved hydrodynamic and ecosystem-based models.

**Sediments** – Nutrients can enter the water column via the sediments in two ways. They can be entrained into the Bay via groundwater flows, or they can reenter the water column via "remineralization" – the process of releasing nutrients, as organic matter that has settled to the bottom of the Bay decomposes. Unfortunately, at present, we have no local data on movement of nutrients out of the sediments anywhere in Casco Bay.

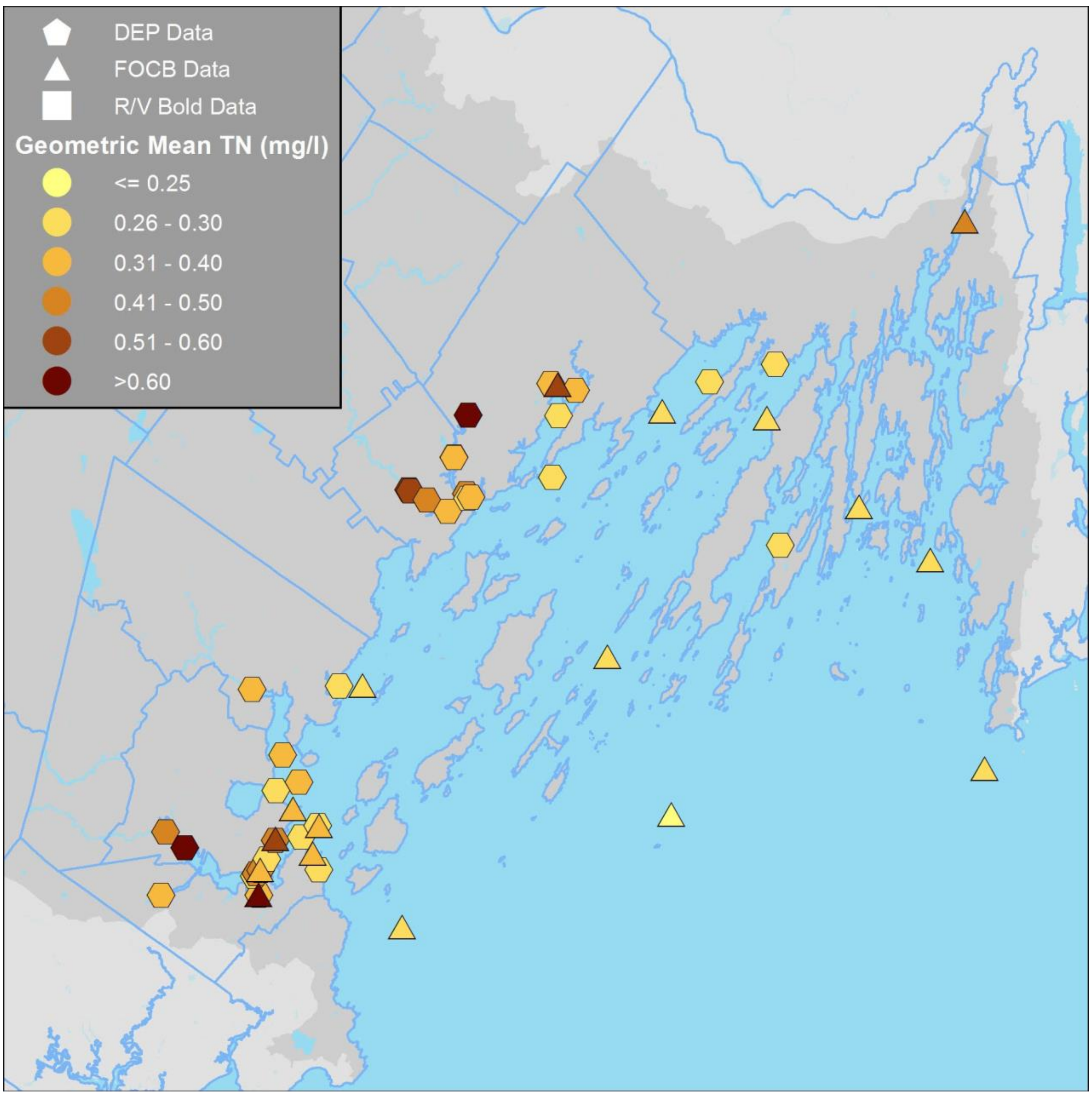
Sediment-derived nutrient loads are likely to be poorly represented in existing watershed-scale nutrient loading models for Casco Bay. Lack of data on sediment-derived nutrients is a potentially important limitation on our understanding of nutrients entering the Bay. Characterizing these loads may be especially important for addressing nutrient processes in specific areas, and will be essential should we proceed toward developing full ecosystem models of the Bay.

## G. Distribution of Nitrogen in Casco Bay

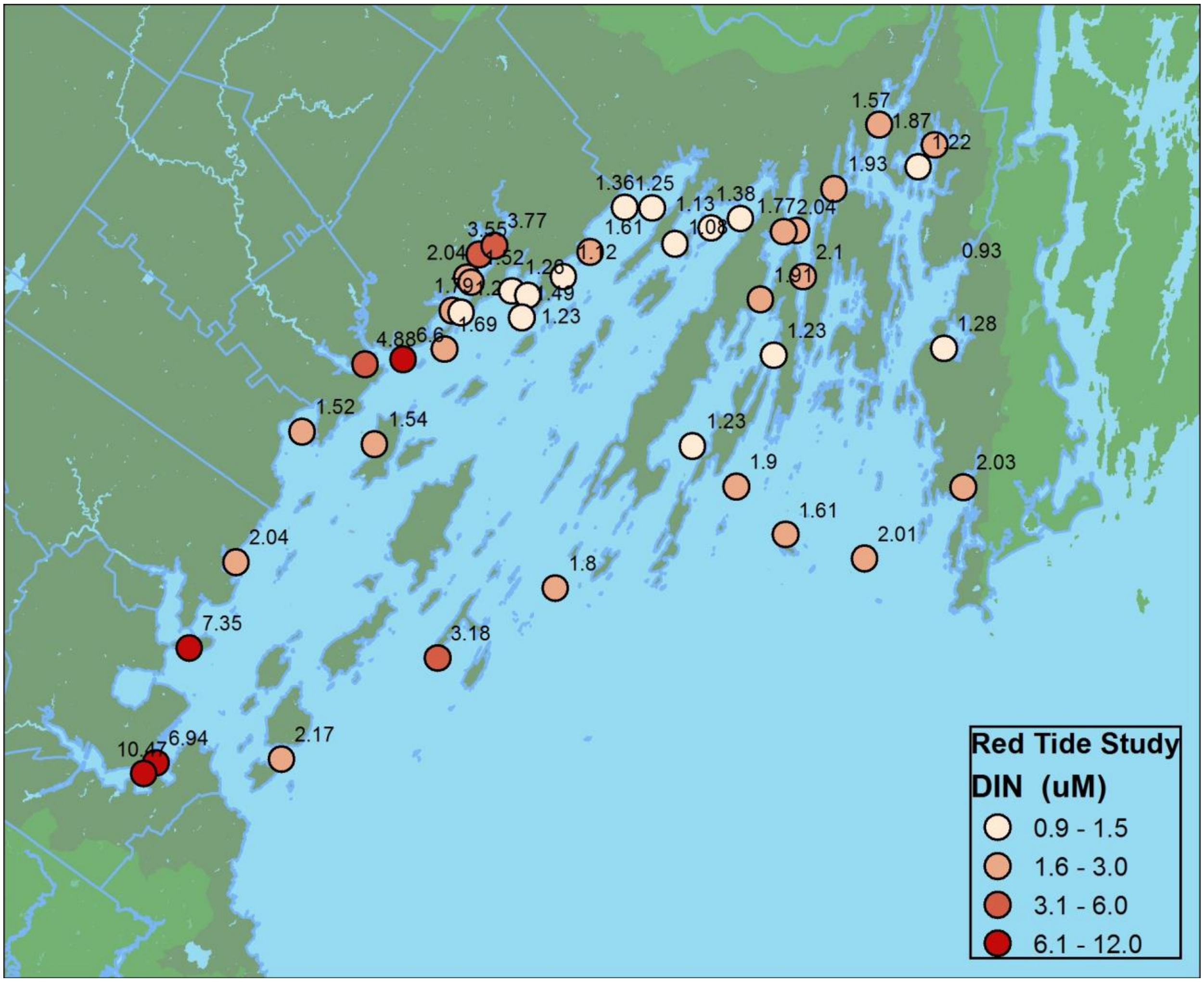
Friends of Casco Bay's long-term monitoring program collected data monthly from "profile" sites, and episodically from other sites around the Bay beginning in 2007. Data on nutrients (including Total Nitrogen) in the outer Bay area are available from cruises of U.S. EPA's OSV (Ocean Survey Vessel) Bold, in 2009, 2010, and 2011. CBEP funded a two-year effort to look at nutrients and red tide in Casco Bay, looking at ammonium, nitrate + nitrite, phosphate and silicate from some 40 locations around the Bay on 14 dates in 2007 and 2008. Maine DEP has gathered additional data on nitrogen in the Bay. All four data sets show similar patterns:

- Elevated nitrogen levels are predominately an inshore phenomenon, especially around Portland, the mouth of the Presumpscot, the Royal, and in the Harraseeket.
- Nutrients are sometimes entrained into Eastern Casco Bay from the Kennebec Plume, leading to slightly elevated nitrogen levels from time to time off Phippsburg and at the Mouth of the New Meadows. Elevated levels are likely related to river flow, but data are too sparse to be certain. Observed levels in the Eastern Bay seldom reach levels of concern.

*Total Nitrogen (TN) data from Maine DEP (1996, 2013, 2016, 2017), Friends of Casco Bay (2007-2014), and EPA's OSV Bold cruises (2009, 2010, 2011). Sample sizes from 6 to 102.*



*Concentrations of dissolved inorganic nitrogen from surface water samples, summer months, 2007-2008. All samples collected by boat. Elevated nitrogen levels are found inshore.*



# Chapter 2: What's at Risk

## A. Economic

A 2017 report by the Maine Center for Business and Economic Research (CBER) and commissioned by the Casco Bay Estuary Partnership (Wallace et al. 2017) assessed the size and importance of Casco Bay's "Ocean Economy." The report looked at five economic sectors in coastal towns in the Casco Bay Region: tourism, marine transportation, living resources, marine construction, and ship and boat building (excluding Bath Iron Works). Cumulatively, Casco Bay contributed $704 million in economic activity in 2016, supporting some 18,500 jobs via these five economic sectors alone. This constitutes approximately 4% of economic activity in the entire Casco Bay watershed region[4].

*Economic activity in five ocean-related economic sectors in Casco Bay's coastal towns (from Wallace et al. 2017)*

| | Employment | | | | Gross Regional Product | |
|---|---|---|---|---|---|---|
| **Ocean Economy Sector** | **Jobs 2016** | **Change (Absolute) 2006-16** | **Change (%) 2006-16** | **Share of Total** | **Number** | **Share of Total** |
| Tourism and Recreation | 14,797 | 1,561 | 12% | 80% | $491,643,093 | 70% |
| Marine Transportation | 2,433 | 1,246 | 105% | 13% | $125,955,604 | 18% |
| Living Resources | 1,139 | -217 | -16% | 6% | $76,012,659 | 11% |
| Marine Construction | 94 | 25 | 36% | 1% | $7,777,813 | 1% |
| Ship and Boat Building | 30 | 11 | 58% | 0% | $2,540,313 | 0% |
| **Ocean Economy Total** | **18,493** | **2,626** | **16%** | **-** | **$703,929,482** | **-** |

A substantial fraction of Bay-related economic activity is dependent upon water quality, although it is impossible to draw quantitative connections. Of the five economic sectors examined, living resources and tourism are most directly influenced by water quality. Cumulatively, those two sectors represent over 80% of total ocean-related economic activity in Casco Bay's coastal cities and towns.

The majority of the business activity (70%) and jobs (80%) in the Casco Bay economy were in tourism. The tourism economy is intimately linked to the state's maritime culture, marine resources, and reputation for a healthy environment, including clean water. The sector

[4] The economic study defined the study area at the zip code level, which often aligns with town boundaries. The Casco Bay Watershed region as reported is slightly larger than the Casco Bay watershed as hydrologically defined. See the original study for details.

includes both businesses (like restaurants) only indirectly linked to the Bay, as well as other enterprises (campgrounds, boat rental facilities, marinas, tour operators) where the link is much more direct. Significant declines in water quality would hit many tourism-related businesses and industries hard.

About 11% of economic activity and 6% of jobs in the Casco Bay economy were directly related to living resources. This activity includes harvesting of lobster, shellfish and finfish; aquaculture; and value-added processing and packaging of marine products. Many harvesting jobs are directly affected by the health of Casco Bay. For example, declines in Maine harvests of softshell clams in 2017 were attributed in part to declining abundance of shellfish and to extended prohibitions on harvesting shellfish due to harmful algal blooms. Processing jobs may be somewhat insulated from effects of deteriorating water quality, to the extent that processors can import unprocessed product from elsewhere instead of relying only on local harvests.

These estimates of the economic importance of the Bay are likely underestimates of the importance of the Bay to our region, for several reasons:

(1) The study does not capture all Bay-related economic activity. Many sectors that were not studied, like real estate, retail, and home construction, in part reflect the importance of seasonal visitors to our region, and thus are also dependent on healthy waters.
(2) The importance of the Bay economy varies across the region. Marine-related industries are less central to the economy of Portland, with its robust health-care, legal, financial, and manufacturing businesses than in the region's smaller communities, where alternative livelihoods are fewer.
(3) The study did not look at the effect of proximity to the Bay on real estate values, which can be substantial, but are a measure of wealth, and not of economic activity.
(4) A high quality of life attracts both people and businesses to the region, including in industries not related to the Bay, from health care to fine arts.
(5) The study made no effort to capture the value of various "ecosystem services." Ecosystem services, such as removal of pollutants, sequestration of carbon, or providing of recreational opportunities are poorly or not reflected in market transactions, but contribute to our region's quality of life.

## B. Recreation

Threats to recreation and enjoyment of the Bay are not yet dramatic compared to other northeastern water bodies such as Great Bay, Narragansett Bay, and Chesapeake Bay. However, without continued care and protection, the risks to Casco Bay could include:

- Visually unappealing, foul-smelling or toxic algal blooms affecting boaters, swimmers, fishers, hikers, birdwatchers, photographers, and picnickers;
- Impact on residents and visitors hoping to harvest shellfish or otherwise enjoy seafood from Casco Bay, as increased frequency or severity of toxic algal blooms make clams, mussels, oysters, and other shellfish inedible.

## C. Ecosystem Services

"Ecosystem services" refers to the value that healthy ecosystems provide to a community, such as provision of food, water and fiber; removal of pollutants; support for nutrient cycles; and recreational benefits. While some ecosystem services are well represented in markets (lobster harvests), others are represented indirectly (ecosystem services influence real estate prices), and others, especially public goods like nutrient removal or carbon sequestration, are hardly reflected in market transactions.

Although ecosystem services are sometimes put in precise monetary terms, developing accurate estimates is costly and time consuming, and beyond the scope of this report. This report provides a narrative overview of ecosystem services that may be at risk due to increases in nutrient loading to Casco Bay.

### 1. Cataloging Ecosystem Services

Ecosystem services can be cataloged in many ways. The Millennium Ecosystem Assessment (2005) established one commonly used approach, which classifies ecosystem services into four broad categories (many services fall within each category):

- Provisioning services, such as food, fiber, fuel, and water;
- Regulating services, such as regulation of climate, water quality, drought, and disease;
- Supporting services, such as primary production of organic matter and nutrient cycling; and

- Cultural services, such as aesthetic, recreational, spiritual, religious and other nonmaterial benefits.

The following table provides preliminary application of the Millennium Ecosystem Assessment Ecosystem Services Framework to nutrient pollution in Casco Bay. Supporting services are not included here, as they are the services that allow for the other ecosystem services to be present.

| Category | Relevant Subcategories | Impact of Nutrient Pollution |
|---|---|---|
| ***Provisioning Services*** | | |
| Food | Capture fisheries | • Increased nutrient loads could damage eelgrass beds, thus reducing habitat for commercially important species.<br>• Eutrophication could produce low dissolved oxygen conditions, killing sensitive species or driving them out of affected waters. |
| | Aquaculture | • Moderate increases in nutrients might increase growth of target species at some locations.<br>• Significant eutrophication could restrict locations where aquaculture is viable.<br>• Acidification can increase costs (e.g., for water pre-treatment) or reduce productivity of shellfish aquaculture. |
| | Wild foods | • Significant impact possible on sessile marine species. |
| Fiber | | |
| Genetic resources | | |
| Biochemicals, natural medicines, pharmaceuticals | | • Rockweed is harvested in Maine, in part to provide nutritional supplements. Casco Bay harvests are small, and largely restricted to the Eastern Bay. It is unclear what impact elevated nutrients would have on Casco Bay rockweed. |
| Fresh Water | | |
| ***Regulating Services*** | | |
| Air quality regulation | | |
| Climate regulation | Carbon sequestration | • Nutrient enrichment could eliminate eelgrass, reducing capacity for carbon sequestration.<br>• Increased nitrogen loading to tidal wetlands can reduce marsh stability, both releasing stored carbon and reducing carbon sequestration. |

| Category | Relevant Subcategories | Impact of Nutrient Pollution |
|---|---|---|
| ***Regulating Services (continued)*** | | |
| Water regulation | | |
| Erosion regulation | | • Where tidal wetlands buffer eroding or erodible shorelines, nutrient enrichment may reduce marsh stability, making shorelines more vulnerable.<br>• Eelgrass also reduces wave energy and helps to anchor sub-tidal sediment. Nutrient enrichment in Northern and Eastern Casco Bay could decrease the ability of eelgrass beds to stabilize sediment. |
| Disease regulation | | • Elevated nutrients may increase risk of exposure to phytotoxins from harmful algae. |
| Pest regulation | | • Impact of nutrient levels on marine "pests" – harmful invasive species like green crab, milky ribbon worm and colonial ascidians – has not been studied in Casco Bay. |
| Pollination | | |
| Natural hazard regulation | | |
| ***Cultural Services*** | | |
| Spiritual and religious values/ Inspiration | | • Potential decrease due to negative aesthetic impacts of poor water quality. |
| Cultural heritage values | | • Nutrient enrichment and declines in water quality may threaten traditional, long-standing or culturally significant activities, (marine harvests, lobstering, family shellfish harvesting), undercutting cultural heritage. |
| Aesthetic values | | • Reductions in water quality associated with elevated nutrient levels can lead to algal blooms, fish kills, and other unsightly or smelly conditions that reduce aesthetic enjoyment of the coast. |
| Education | | • Portions of Casco Bay are used as "living classrooms" by area schools and colleges. Severe eutrophication could make some locations unsuitable for those activities. |
| Recreation and ecotourism | | • If nutrient enrichment reduces public enjoyment of the Bay, it will strongly influence recreational use of the Bay and the broader regional tourism economy. |

## 2. Linking Ecosystem Services to Nutrients

The most important pathways linking nutrient loads to reductions in Casco Bay ecosystem services are likely to be via effects on water quality, impacts to coastal habitat, and acidification. (Much of the discussion that follows describes impacts in general terms because acute water quality impairments are still relatively uncommon in Casco Bay. Here we describe principally services that may be at risk if conditions worsen).

**Water Quality –** As already described, nutrients can have profound effects on water quality (e.g., Bricker et al. 2008, Castro et al. 2003, Driscoll et al. 2003, Howarth and Merino 2006, Rabelais et al. 2009, Rabelais et al. 2014, Whitall et al. 2007). The primary pathway leads from increased nutrients in coastal waters, to elevated primary production by phytoplankton and other marine algae. Some algae form nuisance blooms, or are themselves toxic, forming harmful algae blooms, or HABs. More generally, elevated productivity reduces water clarity, and is followed by increased decomposition and respiration, consuming dissolved oxygen. Where waters are vertically stratified, this can lead to deoxygenation of bottom waters, reducing habitat quality or quantity; and leading to odors and fish kills. This cascade of effects from elevated nutrient levels is called "eutrophication."

Eutrophication has numerous secondary effects directly related to ecosystem services derived from coastal areas. Reduced water clarity, algal blooms, and fish kills are unpleasant and directly influence people's ability to enjoy coastal areas. Low dissolved oxygen or no dissolved oxygen conditions drive away or kill marine life, not only reducing commercial and recreational harvests, but further degrading recreational opportunities dependent on observing marine wildlife and birds. Reduced water clarity shades submersed aquatic plants, like eelgrass, reducing growth and eventually eliminating important coastal habitats.

**Habitat – Eelgrass and Coastal Wetlands –** Seagrass beds provide important habitat, including for juveniles of commercially important species, and for baitfish that provide an important link in coastal food webs between plankton and larger organisms, from bluefish to bald eagles (Unsworth et al. 2018). Eelgrass beds improve water quality by reducing wave energy, trapping sediments, and reducing resuspension of fine sediments. Similarly, coastal wetlands such as salt marshes are important juvenile habitat for commercially important marine species, as well as for migratory and resident birds and wildlife. These wetlands provide important water quality benefits by sequestering and transforming nutrients. The dense vegetation of coastal wetlands can reduce wave energy, thus reducing shoreline erosion. Both eelgrass beds and salt marshes subsidize marine food webs by exporting high quality "detritus" that provides a significant food source for marine organisms, and indirectly supporting shellfish aquaculture. Both habitats also help regulate global climate by sequestering significant amounts of carbon in their sediments (McLeod et al. 2011).

Eelgrass and salt marshes are both vulnerable to nutrient enrichment (e.g. Driscoll et al. 2003, Deegan et al. 2012).

Eelgrass growth is often limited by light, and as nutrient concentrations increase, water clarity declines and density of epiphytes on eelgrass leaf blades increases. The result is that under elevated nitrogen levels, plants receives less light, and eelgrass beds decrease in density, retreat to shallower waters, or vanish entirely[5].

Salt marshes have long been thought of as an important bulwark against coastal nutrient enrichment, but research in Massachusetts (Deegan et al. 2012) has shown that long-term increases in nitrogen loading can lead to changes in how plants grow, reducing the structural integrity of the marsh. Plants grown under elevated nutrient levels allocate less of their growth to their roots, and since roots help bind marsh sediments, erosion increases.

**Coastal Acidification –** Acidification describes the process by which elevated levels of carbon dioxide entering ocean waters alter ocean chemistry, principally by reducing pH and altering carbonate chemistry. Acidification is often thought of as an open-ocean phenomenon, driven by global changes in atmospheric $CO_2$, but acidified conditions can arise close to shore due to terrestrial and inshore processes leading to reduced alkalinity, elevated dissolved $CO_2$, or both (Duarte et al. 2013, Wallace et al. 2014).

Nitrogen pollution contributes to coastal acidification via eutrophication. Elevated net primary production leads secondarily to increased respiration and decomposition. As organic matter decomposes, it releases carbon dioxide back into the environment, increasing dissolved $CO_2$, and triggering the same (but often stronger) chemical changes induced by increase in global atmospheric $CO_2$.

Coastal acidification has the potential to pose threats to marine organisms with carbonate shells, and thus to Maine's most important fisheries (Johnson et al. 2015). In 2017, more than 80% of the total landed value of Maine fisheries depended on organisms with shells, including lobster, softshell clams, scallops, oysters, and urchins (Maine Department of Marine Resources

[5] Other mechanisms can also lead to eelgrass declines. Recent (ca. 2012-2013) declines in eelgrass in Casco Bay were principally the result of damage caused by invasive green crabs (Neckles 2015). High sediment loads, independent of nutrient levels and algae growth can also reduce light availability to submersed vegetation. High suspended sediment loads from the Royal River may limit eelgrass abundance in the Royal River estuary.

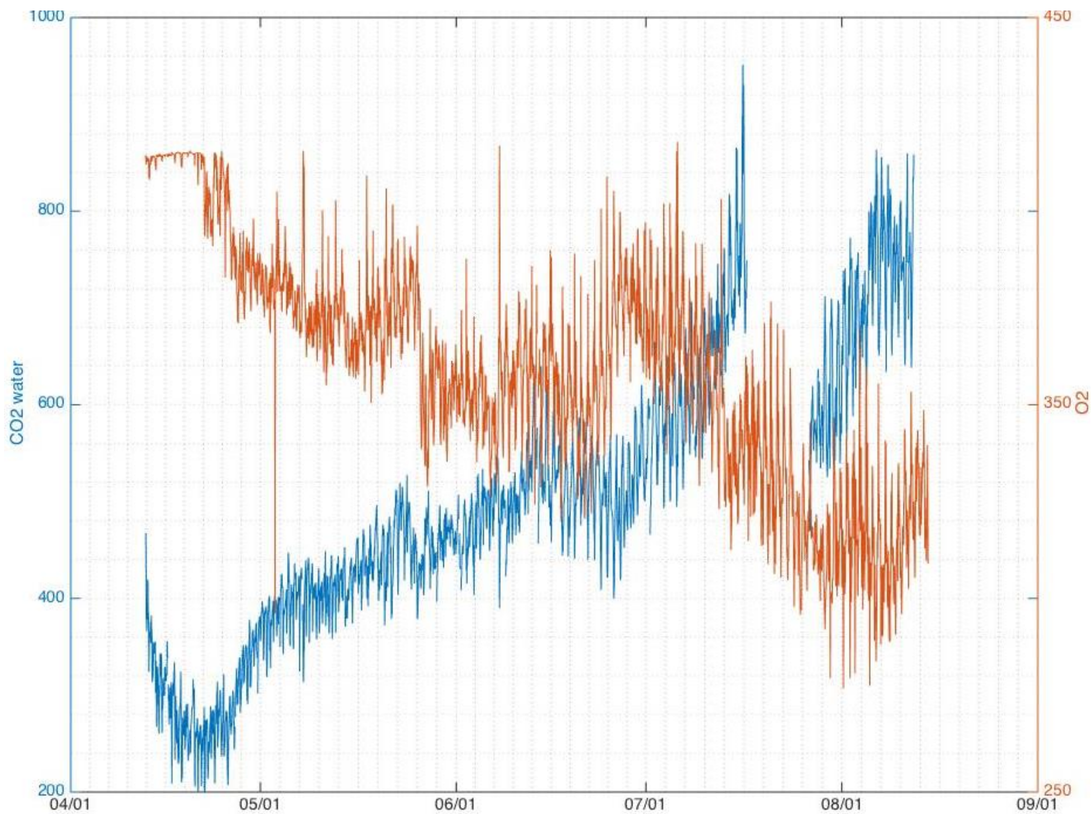
2018). Maine's commercial fisheries are probably more dependent on marine calcifying organisms than are fisheries anywhere else in the country. Evidence suggests the waters of the Gulf of Maine (and by extension, Casco Bay), may be especially susceptible to acidification (Wang et al. 2013, Gledhill et al. 2015).

The impacts of acidification on marine species is an active area of research, both globally and here in Maine. Effects have mostly been studied in the laboratory, thus omitting ecosystem-level interactions that may influence long-term outcomes. A review of species-level studies for commercially important species in the Gulf of Maine (Gledhill et al. 2015) shows that changes in carbonate saturation state can affect a variety of biological endpoints, including growth, reproduction, development, survival, feeding behavior, and morphology. Negative effects outnumber positive ones in the studies cited[6]. While the science is still incomplete, coastal acidification puts commercial and recreational fisheries at risk.

Locally, Friends of Casco Bay has shown that pH levels in Casco Bay tidal flats already reach problematic levels. Tidal flat surface pH (as measured by FOCB in Casco Bay) is closely correlated with "carbonate saturation state," which is the physiologically relevant chemical parameter. Mark Green of Saint Joseph's College has shown that a low saturation state (correlated with low pH) at levels seen in some Casco Bay tidal flats can dissolve shells of juvenile clams (Green et al. 2009) and suppress settlement of clam larvae (Green et al. 2013).

[6] It should be noted that most studies looked at larvae or juveniles and studied responses to steady-state water chemistry, with adequate food supplies, which may be a poor predictor of biological responses in complex nearshore environments. As in other areas of science, bias likely exists in the published literature towards studies that show a statistically significant response, since studies that fail to show any response (positive or negative) are difficult to publish.

*Carbon dioxide and oxygen at the Southern Maine Community College Pier in 2017. Oxygen ($O_2$, in orange) and carbon dioxide ($CO_2$, in blue) are negatively correlated, and show strong diurnal and seasonal patterns, as expected if $CO_2$ concentrations are closely coupled with primary productivity. (Graphic courtesy of Joe Salisbury, UNH.)*




Detailed acidification monitoring began in Casco Bay in 2015. Three monitoring stations are in operation as of fall of 2018. Data and preliminary analyses presented at meetings show clear seasonal and diurnal patterns, which reflect the importance of system metabolism (primary production, respiration, and decomposition, all tied to nutrient levels) on carbonate chemistry. Available data demonstrates that carbon dioxide concentrations (and thus carbonate chemistry and acidification) of Casco Bay is influenced by nutrient levels. Relative importance of nutrients versus other mechanisms controlling acidification in Casco Bay remains an active area of research.

# Chapter 3: What's Already Being Done

## A. Policy

For the purposes of this report, "policy and regulatory tools" means laws, policies and regulations adopted by formal government bodies, whether at the federal, state, county, or local municipal level. Numerous policies have the potential to influence nutrient loads to Casco Bay, and the policies adopted at different levels of government sometimes interact in complex or even counter-intuitive ways.

### 1. Tools

Numerous laws, rules, policies, and practices designed in whole or in part to protect water quality are already in place. Tools exist at local, regional, state, and federal levels. See Appendix A for a Matrix of Policy and Regulatory Tools Impacting Casco Bay.

Policy programs address numerous activities that can either threaten or benefit water quality, including:

- reducing pollutant discharges, including stormwater (the Federal Clean Water Act and related state laws and policies);
- land use planning ((local comprehensive plans, and ordinances);
- development site design (Maine Stormwater Management Law "Chapter 500", Site Location of Development and shoreland zoning rules); and
- financial incentives (grants, tax provisions, impact fees, low impact loan programs).

The list focuses on tools at work in coastal communities, although some of the tools are also at work in the broader watershed or region.

## 2. Casco Bay Community Guidebook

Greater Portland Council of Government's "Casco Bay Community Guidebook" (GPCOG 2017) highlighted policy responses to water quality and environmental concerns for ten municipalities in Cumberland County that border Casco Bay (this leaves out our Sagadahoc County coastal towns, including West Bath and Phippsburg). They focused on activities under four areas:

- Long range planning
- Land use regulation
- Incentives
- Direct action

**Long range planning –** All ten communities studied have state-approved comprehensive plans that consider environmental values alongside other community goals. All communities included open space conservation and habitat goals in their plans or in supplemental planning documents. Most also include explicit consideration of water resources. Conservation and habitat plans can have significant water quality implications to the extent that they facilitate protection of forests (which produce little runoff), or lands critical for trapping nutrients, like wetlands and floodplains. Availability of staff time and reliable data were identified as common barriers to incorporating environmental concerns more fully. Strong community support for conservation is essential.

*Photo: Brunswick Downtown Association*

### Spotlight on: Brunswick

Brunswick, Maine (pop. ~ 20,000) is a non-MS4 town that has utilized municipal home rule authority to improve water quality while taking into consideration the concerns of impacted stakeholders. For example, Brunswick adopted DEP rule Chapter 500 treatment requirements but reduced the state's treatment thresholds. Instead of 1 acre of disturbed area, Brunswick requires stormwater treatment for development activities with ¼ acre of disturbed area or redeveloped impervious area. Local developers report that because they are familiar with the Chapter 500 model they appreciate the town's relative consistency with those standards.

The stormwater management standards in Brunswick's Zoning Ordinance are found in Chapter 1, Section 1.7.2 (Definitions) and Chapter 4, Section 4.5.4 (Stormwater Management). For more information visit: http://www.brunswickme.org/departments/planning-development/zoning-ordinance-design-standards/

**Land use regulation –** The majority of communities in our region have land use or stormwater ordinances that go beyond state minimum requirements. The approach taken by each town to enhanced water quality protection, however, differs. Regional consistency among these regulations could simplify the regulatory process, while also improving water quality protections.

**Incentives –** The GPCOG report indicates that incentives, such as fees, streamlined permitting paths, or more permissive rules are uncommon in Casco Bay towns. The most widespread incentives in our region are incentives for compact development, which generally allow smaller lot sizes in exchange for conserving a portion of the land. A stormwater fee (which provides financial incentives for reduced impervious surfaces and improved stormwater management) has been implemented only in the city of Portland and in the Long Creek Watershed.

**Direct Action –** Local towns take numerous steps, often in terms of management of public assets like schools and parks, to reduce nutrient loads to Casco Bay. These include investing in municipal stormwater management, conservation of open space (generally less polluting than lawn or impervious area), limiting use of pesticides and fertilizer on town lands, and requiring that town projects use "Low Impact Development" principals to reduce their impact on water quality.

## 3. Integrated Planning and Collaboration

"Integrated Planning" is an approach used in municipalities to address stormwater, wastewater, and related environmental management systems simultaneously. It allows flexibility for a community to prioritize the compliance efforts that will provide greater environmental benefits for lower costs (Henderson 2018a, Henderson 2018b, EPA 2018).

The City of Portland is moving forward to develop an Integrated Plan to address legal obligations under intertwined stormwater, combined sewer overflow and wastewater discharge permits. City and PWD tasks and obligations under these permits are numerous and complex, including (inter alia):

- Implementation of Portland's Stormwater Service Charge;
- Installation of green infrastructure;
- Addressing water quality concerns during management of City properties, including schools and parks;
- Infiltration and Inflow studies;

- CMOM (Capacity Management Operations and Maintenance) programs;
- FOG (Fats, Oils and Grease) management;
- Construction of CSO storage facilities;
- Sewer separation projects;
- Flow monitoring programs;
- Public engagement, outreach and education;
- Management of peak wastewater flows;
- Reducing nutrient discharges from wastewater treatment plants; and
- Controlling odors.

The City will be looking at the big picture, considering the full range of legal obligations and actions scoring projects, and prioritizing projects and activities that bring the best water quality at the least cost. The City has formed a stakeholder group to provide input during the process, and has held the first stakeholder meeting.

The Integrated Planning process has the potential to achieve water quality goals in a more cost-effective way by prioritizing projects based on their anticipated water quality benefits, co-benefits and costs (social, environmental, and economic). An Integrated Plan can support adaptive management because water quality outcomes can be measured and actions changed based on success and failure.

## B. Funding

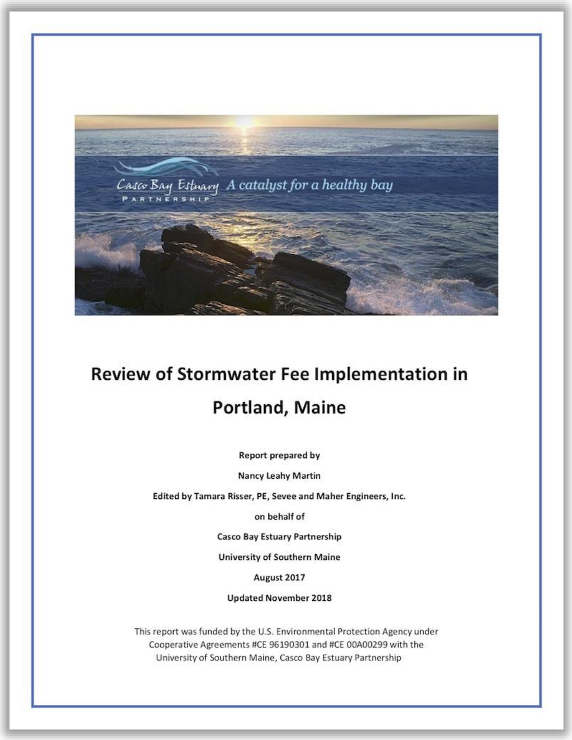
Long term reduction in nutrient loading to Casco Bay is likely to require significant capital investments. Those investments will be borne by a combination of government, developers, commercial landowners, and homeowners. Investment could take many forms, including:

- Stormwater retrofits,
- Green infrastructure,
- Responsible development and planning,
- Wastewater treatment plant operational changes, expansion or upgrades,
- Combined Sewer Overflow (CSO) abatement projects,
- Repair or replacement of failing septic tanks,
- Extension of sewer service to unsewered communities or properties,
- Protection of wetlands, floodplains and forests,
- Installation of best management practices to reduce nutrient loads from agricultural lands.

An important challenge for the future is to identify cost effective investments for reducing nutrient loads. But those investments need to be made in the context of existing programs. Few citizens appreciate the capital and operating costs of clean water. When budget push comes to budget shove, water infrastructure spending is all too likely to yield in the political arena to spending on more visible forms of public investment, from schools to roads. Yet capital investments are an important component of long-term solutions to reducing nutrient loads to the Bay.

Existing plans call for hundreds of millions of dollars in public investments on water quality in coming decades in the Casco Bay region, principally for investments in:

- Combined Sewer Overflow (CSO) abatement (Portland's "Phase III" CSO control plan came with an estimated 20-year price tag of $170 million);
- Wastewater treatment plants (PWD recently invested $12 million in an aeration upgrade to the East End wastewater treatment plant);
- Installation of "green infrastructure" and other stormwater management structures.



**Review of Stormwater Fee Implementation in Portland, Maine**

Report prepared by
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on behalf of
Casco Bay Estuary Partnership
University of Southern Maine
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Portland's stormwater fee is expected to capture $6 million annually, half of which offsets CSO control costs, and half of which funds the City's stormwater programs. The City is using those funds to cover water quality operations such as street sweeping and catch basin cleanouts, capital projects to reduce CSOs, and construction of green and gray infrastructure to reduce stormwater pollution. The stormwater service charge also provides a direct incentive (via reductions in fees and a credit system) for private landowners to reduce impervious surfaces and manage stormwater more effectively on their own properties.

Both the City of Portland and the City of South Portland are working on ambitious asset assessment, tracking and management programs to evaluate the condition of existing municipal water infrastructure. Regulatory mandates helped encourage our largest cities down that path, and will push other municipalities in the same direction in coming years. Asset management programs help water managers make the case for the importance of continued investment in water infrastructure, operation, and capacity. In addition, City of Portland staff report that their asset management programs have helped them prioritize investments in replacement of aging infrastructure and identify significant cost savings.

The City of Portland manages multiple Clean Water Act (CWA) permits, for discharges of wastewater, stormwater and CSOs. The City has recently begun "integrated planning" to identify cost-effective approaches to achieving clean water goals across multiple Clean Water Act permit obligations. EPA offers the integrated planning approach as an alternative for municipalities to "propose to meet multiple CWA requirements by identifying efficiencies from separate wastewater and stormwater programs and sequencing investments so that the highest priority projects come first" (EPA 2018). Portland plans to use a "triple bottom line" approach, which simultaneously considers social, environmental and financial considerations in evaluating overall performance, to develop clean water strategies. Integrated planning holds significant promise for reducing costs of clean water, while increasing public understanding of and support for investments in clean water.

Outside of the region's larger cities, investments in water quality also occur. Twelve Casco Bay watershed communities manage "Municipal Separated Storm Sewer System" or MS4 permits under the Clean Water Act. These permits require compliance with certain practices under six "Minimum Control Measures" to reduce polluted runoff. Compliance requires dedicated staff and ongoing investment by local government. The state has a long-standing program to eliminate "overboard discharges," where minimally treated human wastes are discharged to area waterways (there were more than 340 in our region in 2015).

Most of the treatment plants in Casco Bay's watershed have embarked on nutrient optimization efforts that have been included in the latest rounds of discharge permits. These efforts include regular seasonal monitoring for nitrogen (May through October) to document the seasonal average nitrogen loading from each facility. The optimization efforts include operational efforts to reduce effluent nitrogen loading with an annual report that summarizes the efforts along with planned efforts for the coming year.

Much of the recent success in reducing nitrogen discharges from these facilities can be attributed to the adaptive management nature of current permits and the flexibility afforded the plants, even in the absence of clear regulatory drivers to limit nitrogen discharges. Facilities can often be operated to realize seasonal reductions while still meeting other objectives (maintenance, wet weather management, etc.) without extensive and costly capital investments. The Portland Water District has been operating three of its treatment plants to optimize seasonal nitrogen loads. In 2018, the East End WWTF's monitoring efforts have documented nearly a 72% reduction in the estimated seasonal historic nitrogen discharge.

While utilities and municipalities principally carry out wastewater treatment investments, private businesses make much of the capital investment in stormwater treatment, in response to regulatory mandates. For most businesses, marginal increases in investment in stormwater do nothing to improve business performance. Financial incentives, therefore, are to minimize costs, not maximize water quality benefits.

Opportunities may exist to encourage private investment in stormwater treatment using a variety of incentive programs (as discussed below), or to facilitate public investment in stormwater treatment on private property. Private landowners invest in stormwater infrastructure as part of the site development process, and landowners cover long-term costs to repair and maintain those systems. Land trusts, water utilities, and municipalities invest in protection of forests and wetlands.

Because of the mix of private and public ownership, comprehensive catalogs of stormwater infrastructure do not exist in most areas. Catalogs have been developed in a few sub-watersheds as part of watershed management plans. Baseline data on existing water quality infrastructure will be needed from more of our region's developed areas to identify and prioritize stormwater treatment opportunities.

## C. Science

The three older watershed loading models of nutrients entering Casco Bay have qualitative similarities (as described above), but they differ in quantitative detail, making it a challenge to understand economically feasible alternatives for nutrient management.

A master's thesis from the University of Maine (UMaine) by Whitley Gilbert has recently provided data from 2017 to 2018 to constrain watershed loading models (see above). Analysis of the results will help us evaluate how well existing models (especially the spatially explicit SPARROW" model) work for estimating nutrient loads. Preliminary results show that the SPARROW model performs well at predicting nutrient loads entering the Bay from selected tributaries.

An updated hydrodynamic model of Casco Bay was developed last year by UMaine using the "FVCOM" modeling platform. It was developed principally to assess risk from storm surge and flooding, but can be repurposed to provide insight that may help evaluate nutrient pollution questions. Work has started on revised hydrodynamic models developed in part to look at water quality in Casco Bay. Current velocity data from multiple locations around the Bay, made as part of a 2014 NOAA study, are available to calibrate models.

CBEP has limited funding available in 2019 to support hydrodynamic modeling. Discussions are underway about the best way to proceed. One possibility is to commission model runs using UMaine models to look at movement of conservative tracers under policy-relevant weather conditions. Other strategies may be better if we can assemble funding from multiple sources to hire a consultant. Costs of either approach are not yet clear.

Substantial effort is now going into nutrient monitoring in and around Portland. A robust coalition is sharing data and other resources. 2017 and 2018 data is available. The nutrient monitoring partners deployed unattended nutrient monitoring sensors near the East End beach in Portland, and on a pier in South Portland, for the first time in 2018, although manufacturing delays and technical problems have limited the value of the 2018 data. DEP has begun a long-term eelgrass monitoring program at three eelgrass beds near Portland. These substantial new efforts in and around Portland follow a historical tradition of Bay-wide monitoring.

Models – whether conceptual, graphical, mathematical, or simulation-based – are an essential part of modern scientific practice, and have an important role to play in helping understand nutrient pollution in Casco Bay. Models may prove critical to evaluating point sources and related regulatory or permitting requirements. Models, however, always have limitations, and can contain errors, or be used inappropriately. At their best, models are a tool to help explore the implications of what we know (or think we know) about the Bay in a structured way. At their worst, models embed assumptions and biases in abstruse mathematical form, making them difficult for anyone, especially nonspecialists, to evaluate. The selection of modeling assistance should consider the need to produce a useful product that provides both quantitative and visual products to allow a varied audience to appreciate the output.

Models can provide insight into mechanisms or processes that would be difficult, expensive, or impossible to study in any other way. They can evaluate "what if scenarios" related to the management of nutrient sources, the area of direct or indirect impact from nutrient sources, or the expected benefits of policy decisions. But they are a tool, not an endpoint. They provide insight, not answers. Responsible use of models in the context of policy making (as here in the Nutrient Council) requires recognition that a model can either support robust discussion of ideas and policy alternatives, or discourage participation.

# D. Stakeholder Engagement: Education, Collaboration, and Shared Metrics

## 1. Education and Outreach

### Education

Several ongoing education programs address water quality or marine science themes with school-aged children, but few programs educate about marine water quality in general and nutrients in particular. Casco Bay education programs that do include nutrients as part of their curriculum include the Cumberland County Soil and Water Conservation District's (CCSWCD) "CONNECT" and affiliated YardScaping programs (in part being implemented on behalf of the Interlocal Stormwater Working Group, or ISWG), Portland Water District's (PWD) "WaterWays" program, and Friends of Casco Bay's (FOCB) "Casco Bay Curriculum."

In the past year CCSWCD provided over 7,000 contact hours to over 2,000 K-12 students through the "CONNECT" education program. CCSWCD incorporates service learning programs, such as storm drain stenciling and buffer planting, and many of the accompanying lessons focus on nutrient loads.

PWD's "WaterWays" program provides students with four weeks of water-related lessons, and reaches over 1,000 students, seven months a year, in multiple schools. Those lessons are focused on freshwater. PWD's "TroutKids" program and summer camp programs also provide general freshwater education.

FOCB's "Casco Bay Curriculum: A Changing Estuary" was developed to help teachers connect the classroom with coastal waters and to help students become good stewards of Casco Bay. The curriculum addresses what an estuary is and how Casco Bay has changed over time, and how climate change is affecting the Bay. Stand-alone activities include storm drain stenciling, and ocean acidification, and there are presentations and scientific readings that support the activities.

Many organizations in the Casco Bay region work in partnership to deliver marine science education programs. The University of Maine's Sustainable Ecological Aquaculture Network (SEANET) has worked with 4-H programs to develop marine science and aquaculture education content, and delivered it in Cumberland County via "Summer of Science" programs. The Island Institute collaborates with Hurricane Island Center for Science and Leadership and Herring Gut Learning Center to provide aquaculture education workshops for K-12 teachers from all across the coast of Maine. In these workshops, teachers explore aquaculture's potential to improve water quality and protect shellfish against the adverse impacts of ocean acidification.

Many schools in our region, particularly those focused on expeditionary learning, tackle marine or freshwater quality independently or in cooperation with regional leaders. Programs offered by these groups separately and cooperatively reach hundreds of students annually. For instance, last year a 6$^{th}$ grade science class at Portland's King Middle School conducted a learning expedition about stormwater runoff and its impacts on fresh and estuarine water bodies. Students worked with CCSWCD and CBEP staff to learn more about stormwater pollution and solutions. They put together public service announcements (PSAs) on stormwater issues, including nutrients, and presented them to community members at a final culmination event.

Related college level courses are offered by Southern Maine Community College (marine science) and University of Southern Maine (water quality). University of New England recently announced that they are expanding their presence in Portland; expanding marine science offerings in Portland will follow. The University of New England Center for Excellence in the Marine Sciences (CEMS) is an incubator for forward-looking academic, research and partnership programs. Working in tandem with the University's Department of Marine Sciences, CEMS aims to capitalize on new marine science, policy and marine management opportunities. It is not clear to what extent the college course curriculum focuses on nutrient-related issues.

Some Casco Bay area watershed groups and land trusts deliver educational programs that focus on water quality, both freshwater and coastal. For instance, Lakes Environmental Association (LEA) offers regular educational programs for students in grades 5-12. Most of these are focused on freshwater quality although LEA is interested in expanding to include the Casco Bay watershed. LEA does not really cover nutrient pollution but does provide lessons on how to reduce erosion.

Harpswell Heritage Land Trust (HHLT) offers hands-on place-based science to Harpswell Community School (K-5) classrooms, nature day camp for children, and public programs for people of all ages. They reach every student at Harpswell Community School and more than 1,000 people attend their public programs each year. There is some focus on marine water quality. HHLT does a weathering and erosion unit for 4th grade.

Particularly effective synergies can occur when school-based programs are linked to behavior change efforts, through service learning. Although from a program outside the Casco Bay watershed, students at Kittery's Traip Academy developed a public service announcement this spring as part of a water-related education and service learning program (https://youtu.be/xIzz6yTWmvQ). King Middle School, as part of the expeditionary learning unit detailed above, not only produced PSAs but worked with CCSWCD to design and plant a buffer along Back Cove.

Additional synergies occur when education and outreach programs are linked to emerging nutrient science. The scientific community regionally and nationally is working hard to improve our understanding of nutrient science. Those efforts can be tapped not only to improve our outreach efforts, but also to strengthen STEM education.

## Outreach

Public outreach efforts regarding water pollution and stormwater are led principally (in our region) by the Portland Water District, Cumberland County Soil and Water Conservation District (again, often on behalf of the ISWG communities), and Friends of Casco Bay. Outreach efforts undertaken under the auspices of ISWG are funded by local municipalities as obligations under their Municipal Separated Storm Sewer System (MS4) permits. A principal goal of these programs is encouraging changes of behavior that benefit water quality, such as reduction in the use of lawn chemicals that can pollute waterways (e.g., YardScaping and Bayscaping programs). For behavior change efforts to be successful, target audiences must already be aware of an issue, and make the connection between their personal behavior and adverse water quality. The programs currently use a combination of awareness-raising activities (such as TV and social media ads) and behavior change strategies (such as point of sale information, special events like the Urban Runoff road race, and workshops) to reach target audiences.

The Think Blue Maine Partnership is comprised of nearly 30 regulated stormwater municipalities, nested regulated entities (like colleges), Soil & Water Conservation Districts, the Maine DEP, and the University of Maine Cooperative Extension. To complete MS4 permit awareness-raising requirements, the Partnership, led by CCSWCD for ISWG, prepared a Stormwater Awareness Plan. The Stormwater Awareness Plan was designed to increase the public's understanding of stormwater. The goals of the program are (inter alia) to increase awareness of stormwater so that:

> 50% of homeowners, aged 35 – 55 ... will understand that water does run off their property, not all is absorbed, and it will carry with it pollutants, such as lawn chemicals, pet waste and oil drops. This polluted water will enter the storm drain system and discharge, untreated, directly to water bodies used for drinking, fishing and swimming (as quoted in CCSWCD 2018).

The effort delivers related content using a variety of platforms and approaches, including TV ads, online ads, press releases, social media, websites, various print materials, and special events. A recent online survey was used to evaluate effectiveness of the program (CCSWCD 2018). A main focal point of these awareness activities has been use of the Think Blue Maine logo and website, and the widely-recognized "rubber ducky" video and print campaign. This campaign used rubber duckies to represent nonpoint source pollution, helping people visualize the message quickly in a simple way. The first "ducky" advertisement and the associated communications strategy were developed in 2003, when Maine DEP spearheaded the statewide awareness program, hiring a marketing firm to conduct focus groups. The marketing firm tested the "ducky" ads to see if the target audience could understand the messaging.

YardScaping is the primary behavior change campaign for the ISWG group. YardScaping is a healthy lawn care program which encourages homeowners to transition to a chemical-free lawn by implementing one or more of the YardScaping practices (such as mowing high, and letting clippings lie to return nutrients to the lawn naturally). The Southern Maine Stormwater Working Group (SMSWG – the Towns of York, Kittery, Eliot, South Berwick and Berwick) also conducts YardScaping workshops. The two groups hold roughly 12 events annually, typically with ten to twenty participants. Program success is measured through surveys issued immediately after the workshops (to assess if the participants understand the concepts provided and if they plan to implement any of the YardScaping practices) and another survey issued 6 months to a year after the workshop (to assess if the participants actually implemented any of the practices; Rabasca 2018). The program strives to have 15% of college-educated homeowners between the ages of 35-55 residing in the ISWG region reduce their use of lawn chemicals.

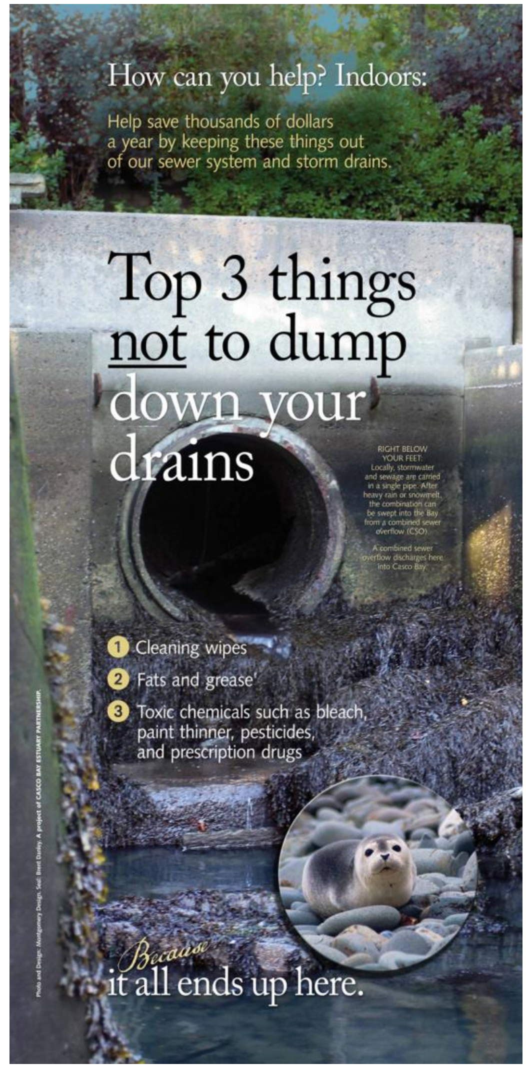
The follow-up surveys show a high percentage of participants adopting new practices. The total number of people implementing new practices is only a small portion of the target audience but interest and attendance continues to rise annually. In the last 5 years attendance for ISWG workshops has grown from 37 people annually attending to 131 people annually attending.

ISWG asks participants why they did not implement suggested practices. Common responses included the following: a lawn care company was used and would not implement some YardScape practices, participants did not have enough time to implement the practice, or the practice was too expensive. These are barriers that need to be addressed to facilitate additional behavior change. Although YardScaping workshops receive great feedback from participants, many participants are already implementing many of the YardScaping practices, and so the workshops may be “preaching to the choir.” To increase behavior change from traditional lawn care methods to YardScaping practices, additional education and outreach efforts are needed to reach additional members of the target audience. Additionally, focused efforts to educate and motivate lawn care companies to adopt YardScape practices would greatly increase the impact of the program.

The YardScaping program is based in part on the “Bayscaping” program developed by Friends of Casco Bay. FOCB holds Bayscaping “Neighborhood Socials” to engage and educate the community about nitrogen pollution.

Some municipalities are making extra efforts to communicate about water quality issues and what residents can do, via municipal websites, forums, and educational documents. For instance, the Town of Harpswell has a series of web pages on the environment, including pages on stormwater management and water quality, which includes the town’s document, “A Resident’s Conservation Guide to Casco Bay” that has tips for residents to help reduce polluted runoff. In South Portland the Water Resources Department, often in concert with the Conservation Commission, provides some educational information on their website and engages in stormwater management programs with City residents.

The Portland Water District held a series of tours and events at the East End WWTF during Clean Water Week of 2018.




Various educational signage projects around the region, particularly in Portland, include messages about good behaviors and activities that make people aware of nutrients and how to improve water quality. In Portland, for instance, signs in Bell Buoy Park created by FOCB, CBEP, and other partners highlight the importance of good lawn, pet, and car care practices that can keep pollutants, including nutrients, out of our Bay. Signage in the East Bay conveys similar messages as part of its overall educational narrative. Although we have some anecdotal knowledge about the use of these signs, no formal assessment has been completed to gauge follow-up behaviors.

The Presumpscot Regional Land Trust (PRLT) has a volunteer "Water Steward" program made up of about 35 volunteers sampling 40 different sites on the Presumpscot River and its tributaries. Volunteers learn about the types of water pollution and what causes them. PRLT does not have any specific programs focused on nutrient pollution.

Friends of Casco Bay has two citizen science volunteer programs, "Water Reporter" and "Color by Numbers." The first program engages citizens to use a Water Reporter smartphone app to record observations that help provide a better understanding of conditions in Casco Bay. "Color by Numbers" similarly works with volunteers to use a smartphone app to photograph and measure the color of the Bay. Both programs will provide measurements that will increase understanding of the environmental health of Casco Bay, while educating volunteers about pollution types and how they're impacting the Bay.

Under current MS4 stormwater permits, towns in our region have identified municipal leaders, especially town managers and elected officials, as an important target audience for education programs. These officials play an important role setting policies regarding land use, and establishing budgets for stormwater programs. The need to convey accurate information about causes and solutions for stormwater pollution to municipal officials never disappears, because of turnover among elected and appointed officials. Until 2013, Maine NEMO ("Nonpoint Education for Municipal Officials"), a part of the national NEMO network, provided related outreach and education. Changes in federal rules for watershed protection funding under "Section 319" of the Clean Water Act reduced availability of funds, contributing to the program's demise.

See Appendix B for a Matrix of Educational and Outreach Programs in Casco Bay, including a description of each program, the intended audience, whether it covers freshwater, marine/coastal, or both, the extent to which nutrients are included, and organization and contact information.

### Issues

Most existing awareness-raising, education and outreach programs in the region are focused on general water quality issues, and focus explicitly neither on coastal waters nor on nutrients (although many mention both). Behavior-change programs do target behaviors with direct impact on nutrient loading to the Bay, such as lawn care and fertilizer use. Implementation of a successful behavior change program could reduce nutrient loading to the Bay, especially via reductions in unnecessary use of fertilizer in urban and suburban areas. However, the costs of successfully implementing behavior change strategies should not be underestimated. These programs are costly and time consuming. Programs to change public attitudes and change behaviors can take decades of consistent effort to see results. Changes in attitudes towards smoking, for example, took more than a generation. Programs in our region operate with only modest funding. Significant progress is likely to require both consistent and increased funding over a period of many years.

Evaluating cost-effectiveness of education and outreach as a strategy for reducing nutrient loads will be difficult. While efforts are underway to evaluate effectiveness of outreach programs (Rabasca 2018, CCSWCD 2018), it is not clear how success reaching target individuals or inspiring self-reported changes in behavior translate into reductions in nutrient loads, especially as economic drivers continue to increase the total area of impervious surfaces and lawn in our region.

## 2. Private Actions to Reduce Nutrient Load

Private individuals and businesses control almost all land in Maine and manage almost all stormwater control structures. Thus incentives and disincentives that influence decisions by individuals and businesses to tackle activities that increase or reduce water pollution are likely to be an important component of any strategy for reducing or managing nutrient loads.

Private actions are likely to be among the most effective and cost-effective ways to reduce nutrient loading to Casco Bay, and yet they are among the most difficult to define, encourage, and document. Such private practices include:

- Use of "low impact development," "smart growth," and "sustainable site design" principals in site design;
- Use of "green infrastructure" features;
- Investment in improved stormwater management at the time of site redevelopment;
- Redevelopment of existing developed lands instead of conversion of forestlands to urban or suburban uses;
- Implementation of a variety of "good housekeeping" practices that reduce pollution.

Land development practices are shaped principally by the interplay between economic and regulatory regimes. Regulatory and quasi-regulatory programs that influence land use decisions are included in the list above.

Green Building Certification programs can shift the economic incentives for improved development practices. The best known is the LEED certification, but LEED provides few incentives for managing water quality or improving site design. A complementary site design standard has recently been developed, called the Sustainable Sites Initiative, or "SITES" (http://www.sustainablesites.org/). SITES "offers a comprehensive rating system designed to distinguish sustainable landscapes, measure their performance and elevate their value." To date, the rating system has received much less attention than the better known LEED certification.

A third approach to facilitating better land development practices is to train landscape architects, engineers, and environmental professionals who provide services to developers in modern stormwater and water quality practices. CCSWCD organizes the Maine Stormwater Conference every other year, which attracts a wide range of stormwater, water quality and land development professionals. Training alone, however, is unlikely to be very effective, as contractors and builders face significant incentives to reduce project cost, and thus are often loath to spend the time and effort to test emerging approaches to protect water quality until they are well tested and well understood by regulatory agencies.

Management practices that influence water quality are numerous. In urban and suburban lands they range from minimizing use of fertilizer on lawns and landscaping, to responsible maintenance of stormwater infrastructure, from placement of dumpsters to minimize or contain runoff, to regularly emptying catch basins so they function as designed.

Experience with the Long Creek Watershed Management District has shown that businesses often do not have the interest, expertise or incentives to take time to figure out how to manage their properties to reduce water pollution. But Maine is a state with a strong environmental ethic, and many land managers are willing to "do the right thing" if provided information on how to do so, provided costs are modest. Programs aimed at providing assistance to private business to reduce their energy use are common, but programs to provide similar assistance and incentives to reduce water quality impact are rare.

Responsible practices reduce water pollution from forest and agricultural lands as well. Programs through USDA's Natural Resources Conservation Service provide information and significant financial incentives for landowners to protect natural resources, including water.

Individual behaviors that protect water include reductions in use of fertilizer, following recommended schedules for inspection and maintenance of septic tanks, sustainable landscaping designs, reducing vehicle miles traveled or selection of automobiles with higher fuel efficiency or reduced emission of NOx. Many organizations advocate similar behavioral changes, but water quality benefits are often not emphasized, and effectiveness is uncertain.

# Spotlight on: Long Creek Watershed Management District

The Long Creek Watershed Management District (LCWMD) is an innovative mechanism for addressing stormwater impacts at a small watershed scale. The District, which was incorporated as a quasi-municipal corporation by the four towns with lands in the watershed (Portland, South Portland, Westbrook, and Scarborough) manages water quality on behalf of some 130 landowners, including private businesses, municipalities, and state highway agencies.

Certain landowners in the watershed (those with more than one acre of impervious surfaces) are required to get Clean Water Act permits for discharges of stormwater.* Landowners can either get individual permits for their discharges, by meeting Maine's "Chapter 500" stormwater standards, or they can become "participating landowners" in the LCWMD. The primary responsibilities of participating landowners are (1) to fund the work of the District (fees are currently assessed at $3,000 per acre of impervious surfaces per year), and (2) work with the District to implement stormwater management and stream restoration programs. The majority of eligible landowners in the watershed are participating landowners.

In return for landowner support, LCWMD is charged with implementing a Watershed Management Plan, through a combination of construction of new stormwater controls, stream restoration, and implementation of "good housekeeping" practices, including annual parcel inspections, street sweeping and catch basin cleanouts. The Watershed Plan served in lieu of a formal "TMDL" for the watershed, thus Long Creek is not included in the state's "Impervious Cover TMDL." The District also monitors conditions in Long Creek each year to help determine which actions to pursue.

The program has acted as an incubator for ideas on stormwater management in Maine. A primary lesson emerging from LCWMD is that "soft" stormwater management practices, such as outreach to landowners, street sweeping, and better maintenance of existing stormwater infrastructure can be highly cost-effective ways to reduce pollution. Annual parcel inspections have confirmed the value of working directly with landowners to improve stormwater management, both from a water quality and public awareness perspective.

Redevelopment in the Long Creek watershed has been both a blessing and a challenge. Redevelopment provides cost-effective opportunities to install improved stormwater management technologies, yet existing regulatory requirements provide few incentives for landowners to make those investments. LCWMD staff have worked closely with businesses and town planners to facilitate stormwater treatment upgrades during redevelopment that go beyond minimum requirements.

**The legal obligation on landowners stems from one of only a handful of times that "Residual Designation Authority" has been applied by EPA. RDA allows EPA to require permits to manage discharges (including stormwater) that otherwise would not require permits under the Clean Water Act if those discharges contribute to water quality impairment.*

## 3. Metrics and Evaluation

Currently, there is no approved "numerical nutrient criteria" in Maine setting allowable levels for nutrients in marine waters, including Casco Bay. Nutrient criteria have been under development by the state at least since 2007, when the Maine legislature passed a Resolve in favor of establishing nutrient limits, and declaring Casco Bay a priority for those efforts (Maine 123rd Legislature 2007). Yet development of criteria has been delayed, in part by technical challenges for developing standards that would apply to all of Maine's diverse and complex coast.

Because of significant site to site variation in conditions (such as bathymetry, hydrodynamics, and suspended sediment loads), Maine DEP's approach has been to avoid using a one-size-fits-all approach for all embayments, and instead uses a more flexible "Reasonable Potential" analysis to evaluate when specific pollutant discharges may impact water quality. DEP's reasonable potential analysis looks principally at two water quality endpoints: dissolved oxygen and, where eelgrass habitat exists, impact on eelgrass. DEP's approach relies on narrative, rather than numeric, criteria.

Research elsewhere in the northeast, including in Great Bay, in New Hampshire, has established approximate concentrations of nitrogen in cooler northeastern waters that are likely to risk impacts to eelgrass (a Total Nitrogen level of 0.32 mg/l or above), or risk low dissolved oxygen conditions (TN at 0.45 mg/l or above). Application of these levels in Casco Bay are based on analogy with other northeastern coastal waters, and not on local data.

While these numerical levels are used on a case-by-case basis in establishing discharge limits on permits, they do not have the broader Clean Water Act implications that numerical nutrient criteria would. For example, data showing exceedances of these ambient water quality concentrations (which are common at some monitoring locations in Casco Bay) do not automatically mean that the water body violates Clean Water Act standards, and thus gets listed as "impaired." Under the Clean Water Act, a violation of ambient water quality standards triggers additional requirements, such as development of a "Total Maximum Daily Load" or TMDL analysis to evaluate sources of pollutants and the water body's ability to assimilate those pollutants, and allocation of pollutant loads – and load reductions – among potential sources.

The status and challenges regarding other types of metrics and evaluation include the following:

**Behavior by residents, landowners –** Tracking of private behavior is generally difficult, expensive, and can be intrusive. Online surveys (e.g. CCSWCD 2018) are relatively inexpensive to administer, but suffer from significant response and self-reporting bias. Randomized surveys, which can better control for bias, are significantly costlier. In principle it is possible to track certain private behaviors indirectly through market transactions. For example, fertilizer use could be tracked by gathering data on sales. Tracking fertilizer use may require developing partnerships with companies that sell or apply fertilizer, who have little incentive to help a program that may reduce their eventual sales. And it is hard to figure out where and when fertilizer purchased at a particular location may be applied.

**Development patterns –** Regional population and housing trends can be captured with some fidelity via data from the U.S. Census or the related American Community Survey. Perspective on development patterns can also be arrived at by looking at changes in land use or land cover. However, regional, high-resolution data are updated infrequently. Maine's most recent high resolution (one meter pixel size) data on impervious cover is based on 2007 aerial images. Our most recent high resolution (five meter pixel size) land cover data traces back to 2004 imagery. More recent land cover data exists, but at lower (30 m pixel) resolution. Finer scale development patterns are more difficult to document. Town-level development activity can be tracked through local records, but most municipal data (e.g., building permits) is decentralized and difficult to access.

**Stormwater infrastructure –** It will be difficult to track changes in stormwater treatment without developing baseline information on existing infrastructure. Currently, the level of documentation of stormwater infrastructure varies from town to town. Towns facing MS4 permit obligations are required to track condition of municipal stormwater infrastructure, so local governments often have up-to-date catalogs of municipal infrastructure. Certain municipal efforts (like Falmouth's Route 1 corridor project) involve cataloging both private and public stormwater infrastructure. But private stormwater conveyances and treatment systems are generally not well documented, in the absence of a watershed planning effort[7].

Public records can provide data on levels of investment in stormwater infrastructure by the public sector, but formal records provide only a partial picture of municipal activities. Stormwater budgets are seldom broken out separately from engineering or other public works

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[7] Maine DEP recognizes eleven approved, up-to-date "nine element watershed plans" in the Casco Bay watershed. Three are for largely urban streams: Capisic Brook, Concord Gulley Brook, and Long Creek. See https://www.maine.gov/dep/water/grants/319-documents/WBPs%20Accepted%204-25-18.pdf

costs in town budgets. Conversely, not all community activities that benefit water quality are reflected in "stormwater" budgets.

Benefits of stormwater investments can be estimated based on nominal performance of selected stormwater technologies and evaluation of engineering designs. Such estimates rely on research carried out by the University of New Hampshire Stormwater Center, or on optimization tools (such as those developed by EPA for this purpose). Direct measurement of system performance is costly. Thus evaluation of stormwater system benefits is likely to be based on engineering estimates.

**Wastewater treatment facilities –** In contrast, the effectiveness of nutrient removal from wastewater treatment facilities is generally well documented through discharge and process monitoring, now generally required via permit conditions. All major wastewater treatment plants in our region are monitoring at least some nitrogen species in their effluent.

Many of the regional wastewater treatment plants have added monitoring and testing activities as permits have come up for renewal. Several plants are using nutrient optimization, an approach that is often less capital-intensive and more management-intensive. These are commendable efforts, and in the coming years much more new information will be available to help us understand the impacts of new wastewater treatment practices.

# Chapter 4: Recommendations for the Future

## A. Policy

### 1. Key Questions that Need to Be Answered

**What are the high-level outcomes of policy and regulation, for example to reduce net nutrient loads to the Bay, prevent a net increase in loads, constrain loads to a specific limit, or prevent any additional loading?**

While the ultimate goals of nutrient management are to protect Bay water quality and the ecosystem services the Bay generates, there is no simple statement of the implicit policy goals needed to achieve that purpose.

**How does regional or watershed planning best complement regulatory programs?**

Regulatory tools alone can all too readily lead to sub-optimal solutions, as leaders conceptualize water quality challenges in multiple regulatory silos, and in isolation from community aspirations. At its best, regional, integrated, or watershed planning pulls in not only water issues, but related issues about quality of life, economic development, equity, and public health to inform policy development. How can we best connect nutrient management discussions with planning to mutually support water quality and regional aspirations?

### 2. Specific Solutions

#### **Recommendation #1:** Encourage integrated planning and adaptive management across permits and municipalities.

"Integrated planning" in this context includes both formally defined Integrated Planning processes, other collaboration activities, and other "big-picture practices" such as adaptive management. These approaches should incentivize and encourage water quality outcomes, rather than prioritize methods for achieving them.

Ways to support integrated planning and collaboration include:

- Experiment with watershed-based pollution trading schemes.

- Develop data infrastructure to share data and information across municipal boundaries on water quality, stormwater BMPs, and implementation.
- Facilitate regional monitoring systems that can determine whether programs are having intended effects.
- Encourage adaptive management practices.
- Experiment with water quality-based permitting (vs. traditional performance-based permitting).

### **Recommendation #2:** Establish numerical nutrient criteria for marine waters.

### **Recommendation #3:** Revise state rules and guidance for stormwater and site design to highlight stormwater controls (e.g. green infrastructure, gravel wetlands) that meet existing rules and also remove nitrogen from stormwater.

### **Recommendation #4:** Create a forum to discuss ways to harmonize state and local policies and provide input on specific policy recommendations. Such a group needs to be broad based, and invite participation not only from urban and suburban communities, but rural Maine towns as well.

The state manages state water quality, habitat protection, and land use regulations, as well as administering many federal Clean Water Act regulatory programs. In addition, the state issues grants funded by both state (Lands for Maine's Future, Maine Natural Resource Conservation Program, Clean Water Bond) and federal ("Section 319" Watershed protection grants, State revolving loan fund SRF, Coastal Program) resources that can be tapped to fund projects to reduce nutrient loads. State policies shape municipal Clean Water obligations, draft permit requirements, and either facilitate or discourage innovative regulatory approaches that allow flexibility in achieving water quality objectives. State policies provide the background against which both local policies and private investments occur.

The Nutrient Council recognizes that the interplay between state and local policies is critical to success of efforts in Maine to protect water quality. Thus identifying opportunities to harmonize state and local policy approaches may prove especially effective in the long term.

**Recommendation #5:** Develop tools and incentives to encourage the private sector to reduce nutrient loads through stormwater facility maintenance and good housekeeping. Enforce the rules that already exist.

**Recommendation #6:** Encourage municipalities to think and act in terms of watersheds when developing local policy, through preparation (and funding) of watershed management plans and building community awareness of watershed impacts.

Municipal policies have the most direct impact on land use, and play an important role in shaping patterns of construction and subsequent nutrient loads from runoff.

Municipalities in the Casco Bay watershed, and even along the Casco Bay shore, vary widely in size, budget, and institutional capacity. Moreover, existing ordinances differ from town to town, making "one size fits all" policies unlikely. Regional support is likely to be critical to improving local policies and practices.

**Recommendation #7:** Consider adoption of "Smart Growth" policies and strategies to reduce nutrient pollution (such as: incorporate watershed impacts during site design and planning reviews; create stronger incentives for implementation of BMPs; require BMPs on projects below state thresholds; protect forests and wetlands; develop ordinances that encourage green infrastructure in new development; increase density, redevelopment, and infill appropriate areas; manage and restrict fertilizer use).

**Recommendation #8:** Incorporate water quality/nutrient goals into municipal comprehensive plans.

## B. Funding

### 1. Key Questions that Need to Be Answered

**How do the benefits of different capital investments compare?**

Ultimately, we need better estimates of benefits of different capital investments, especially estimates of short and long-term nutrient reduction benefits of distributed investments in stormwater management and good housekeeping practices. However, identifying investment costs and funding sources may be premature until the "trouble areas" are better defined. For example, are there relatively small maintenance tasks or repairs that could lead to great improvements in nutrient reduction? The City of Portland recently noted that video inspection of sewer lines documented that the capacity of some combined sewer lines was significantly reduced by accumulated sediment. Cleaning out the sediment restored lost capacity, and avoided CSO discharges.

We have reason to believe that, in the context of installing stormwater retrofits in an already developed landscape, the best bang for the buck will not be found with strict adherence to Chapter 500 stormwater standards. Once we have better defined our desired outcomes and the methods to achieve them, we will be better positioned to compare costs.

### 2. Timeframe

Clean water solutions involve long-term investments and come with long-term maintenance and operation costs. Clean Water Act permits come on a five-year cycle. While we cannot allow the promise of future investment to delay progress on clean water, neither should we allow permit cycles to block long-term opportunities to find cost-effective solutions. Efforts to begin conversations about policy innovation and legislative changes can and should begin quickly, even if passage of new laws, rules, or regulations, will require an extended timeframe.

## 3. Specific Solutions

### **Recommendation #9:** Seek sustainable funding for outreach and education related to water quality, stormwater, and nutrient-related impacts.

Funding is inadequate for a successful behavior change marketing campaign, or even to reach enough people with sufficient regularity to make nutrient issues familiar to most local citizens.

### **Recommendation #10:** Establish a dedicated regional monitoring fund to support ongoing and expanded regional water quality monitoring.

Monitoring programs appear costly, but they provide the only mechanism for assessing whether investments in water quality improvements are having their intended effects. Long-term monitoring is often difficult to fund from grant funds, since most foundations want their dollars to be spent on innovation, and after its first year or two, monitoring no longer looks like innovation. Yet a steady funding source is essential to cover staff costs, allow for reasonable investment and reinvestment in monitoring equipment, and develop data products for decision makers and the public. Monitoring programs in our region have long been cobbled together with funds from numerous sources, with little recognition of the key role that coastal monitoring plays in helping shape cost-effective water quality protection. Monitoring is just as important to the long term success of protecting water quality as are investments in treatment. Monitoring investments on the order of less than 10% of implementation costs could go a long way toward meeting this need.

### **Recommendation #11:** Expand the use of federal and state funding to support substantial costs of capital investment in water quality protection; nutrient management in particular.

# C. Science

## 1. Key Questions that Need to Be Answered

**What modeling do we need in order to determine the best "bang for the buck" for nutrient removal?**

Models are likely to be an essential component of developing our understanding of nutrient processes and evaluating alternative approaches to nutrient reductions, but they must be used with an awareness of model strengths and weaknesses.

There are several "tiers" of models that we have considered, including modeling of loads; modeling of transport of nutrients after they enter the Bay (hydrodynamics); and modeling of ecosystem processes and effects. (Another "model" of cost effectiveness of stormwater treatments, akin to what was presented to the Council by Rob Roseen, may turn out to be more of a watershed scale data collection and aggregation process.) The Council has expressed support for improvements in understanding nutrient loads as well as for improved understanding of hydrodynamics and the mixing process near major sources of nutrients. Both loading models and hydrodynamics models of the Bay exist, but have shortcomings with respect to developing policy and implementation priorities. It is less clear whether ecosystem-based models are needed at this time to continue to advance broadly supported discussion of public policy options (although they may be of increasing importance as we assess combined effects of climate change and nutrients on the Bay).

**How much can we expect to reduce nutrient loads via land-based nutrient reduction practices?**

We currently lack quantitative estimates of potential reductions in nutrient flow from land-based nutrient reduction practices, whether that is a robust stormwater retrofit program, or implementation of public outreach and education programs. Without such estimates, it is difficult to assess cost effectiveness of alternative nutrient reduction strategies.

Rob Roseen presented results to the Nutrient Council of a process applied in Coastal New Hampshire that produced recommendations about which stormwater mitigation systems have the best payback. Jamie Houle of the New Hampshire Stormwater Center and a growing number of consulting firms are capable of similar watershed-scale analyses. EPA Region 1 has commissioned development of "Opti-Tool," a stormwater optimization tool to address a similar need. While simpler "back of the envelope" calculations based on land use can provide a sense of the magnitude of potential nutrient reductions from widespread application of certain stormwater management tools, site specific analyses are necessary to identify cost-effective strategies.

As we gather this information we must remember that estimates of nutrient removal effectiveness of different stormwater management technologies sometimes assume that systems will be properly designed and maintained, and continue to function as designed. As the saying goes, "there are lots of ways to install stormwater systems *incorrectly*, and only a few ways to install them *correctly*."

**What is the role of nutrient remineralization from the sediments and advection of nutrients to Casco Bay from offshore waters?**

We lack robust information on nutrient remineralization. Some nutrients tend to settle out and get trapped in the mud, but those nutrients can find their way back into the water column. Nutrients are trapped in the sediments because they are trapped in organic or chemical forms that do not dissolve readily or that do not cross readily from the sediments into the water column. Decomposers in the sediments can transform nutrients to make them more mobile. Essentially, nutrients can shift, going from organic or mineral-bound solid forms on the bottom to dissolved forms in the water column.

We will need to know more about this process in Casco Bay, because it determines the relative importance of recycled nutrients, versus recent inputs of nutrients, in determining water quality.

**Are we justified in largely ignoring phosphorus for policy purposes?**

We have limited direct evidence that phosphorous never limits growth of phytoplankton in Casco Bay waters. Based on common ecological patterns in estuaries, and our indirect evidence, we have reason to presume that phosphorus does not often act as a limiting nutrient in Casco Bay. Phosphorus loads are unlikely to be a significant problem in the Bay as a whole, although they may be important in some areas of the Bay at certain times of year.

Scientific thinking has evolved away from the simple idea that a single nutrient controls primary production in estuaries. There is broad recognition that nitrogen and phosphorus can both limit primary production in coastal waters (e.g., Howarth and Marino 2006). EPA now recommends (EPA 2015) parallel development of nitrogen and phosphorus criteria for protecting water quality. A further issue is that controlling phosphorus in upstream waters (perhaps to protect lake or river water quality) may increase downstream export of nitrogen. At a watershed scale, concurrent consideration of both nutrients may be necessary.

Moreover, if phosphorus is impacting the Bay's freshwater tributaries, it indirectly impacts the health of the Bay. Ultimately it is impossible to isolate the Bay from its freshwater tributaries and the landscape on which they depend.

The approach taken in this report, to focus on nitrogen, is based on available information, but reflects a simplified view of the ecology of coastal waters. For the time being, we may be better off acknowledging that this question is not fully resolved, and being guided by the data and wisdom of scientists from University of Maine, DEP, FOCB, and elsewhere with regards to where and when phosphorus loads may be something we need to attend to.

**What was the connection between the 2017 harmful and nuisance algae blooms and the ambient nutrient concentrations?**

Without a better handle on that question, it is hard to know how close to important water quality thresholds we may be in Casco Bay.

## 2. Timeframe

We want a level of science that will allow us to move forward with confidence, especially when it comes to informing policy. We need better local science, but we know this will take time, and we are able and indeed need to take some actions even without detailed local data.

Many of the actions we recommend can take place relatively rapidly, within a few months or at most a couple of years. Others, such as establishing a robust regional monitoring framework, will take longer, in part because of the institutional innovations needed to design and fund such an effort regionally.

## 3. Specific Solutions

### **Recommendation #12:** Develop nutrient loading estimates that combine recently collected data on wastewater and CSO discharges with updated runoff models (which properly account for direct

discharges to the Bay) to develop up-to-date estimates of loads from different sources.

Identifying cost-effective strategies towards limiting nutrient loads to Casco Bay requires better understanding of the role of runoff in delivering nitrogen to the Bay, and especially to Portland Harbor and the Harraseeket. Existing watershed-wide models of nutrient loads are not sufficient to guide policy choices, and do not incorporate the latest data.

## **Recommendation #13:** Expand nutrient monitoring to measure nutrient concentrations in currently unmeasured sources, especially urban streams, stormwater outfalls, and CSO outfalls.

Existing freshwater monitoring is limited mostly to lakes, with few monitoring programs looking at flowing waters. While a robust volunteer monitoring program has been in place on the Presumpscot River for two decades, it focuses on bacteria and dissolved oxygen, not nutrients. Collection of nutrient data from urban streams and stormwater outfalls is even more limited, so we cannot readily document reductions in diffuse nutrients entering the Bay using existing monitoring infrastructure. Similarly, there does not appear to be much local data on concentrations of major nutrients in CSO effluent.

## **Recommendation #14:** Conduct analysis to better understand the effects nutrients are having on the Bay, including sediment processes.

Although there is general consensus among the Nutrient Council that there are signs of nutrient-related stress in the Bay and that halting any further degradation is an important goal, it is not clear how close Casco Bay is to an ecological "tipping point", that is, a dramatic ecosystem change that substantially increases the costs of mitigation or even leads to permanent undesirable conditions in the Bay. To better understand how close the Bay is to a tipping point, and better understand the urgency of actions required, we must first understand more about how current nutrients are affecting the Bay’s ecosystem. This includes the effects of nutrients resulting from sediment processes.

## D. Stakeholder Engagement: Education, Collaboration, and Shared Metrics

### 1. Key Questions that Need to Be Answered

**Who is our target audience and what is the specific message we are trying to convey?**

Marketing campaigns need to be commensurate with short-term and medium-term risk and perception of risk of environmental consequences due to nutrient pollution. We need clear statements of risk on which to build communications strategy, and better understanding of where our target audiences are with regards to concern about water quality, awareness of the role of nutrients.

**How critical is it to get nutrients into all water quality education efforts?**

If our goal is changes in behavior that reduce water pollution, it may not matter whether marketing materials focus on generic water quality goals, or specifically target nutrients. However, longer-term goals of ensuring that an informed electorate understands the reasons for investments in clean water may require more focus on nutrients directly.

**How much nitrogen is currently entering Casco Bay and how much can the Bay handle?**

We lack official standards for nutrient thresholds and we lack a clear set of numeric nutrient criteria. Understanding the total inputs and how much the Bay can handle will help describe the management targets. Being even more precise, i.e. having an estimate of nitrogen from various sources, might help identify opportunities to meet reduction goals. This requires both setting clear goals for receiving waters and continuing to improve our understanding of nutrients entering the Bay.

### 2. Specific Solutions

**Recommendation #15:** Share information on the importance of nutrient pollution to our waterways more broadly with policymakers and key decision makers.

Good water quality consistently polls as one of the most broadly supported of environmental goals. Protection of water quality represents a significant public investment, yet for the public, and thus for many elected officials, it is largely invisible. It can be difficult for key decision makers to understand the value of investment in clean water, especially in light of conflicting, and generally more visible, community needs such as schools, roads, or public safety. Educating elected officials about the mechanics of protecting water quality is thus an important part of ensuring long-term commitment of funds for water quality protection. Elected and appointed municipal officials have been a key target for stormwater-related outreach by the ISWG communities in our region.

## **Recommendation #16:** Encourage innovation on the part of the public and private sectors to support nutrient reduction.

Possibilities include:

- Facilitate installation of small, cost-effective stormwater retrofits that do not meet standard sizing criteria, but that still remove significant nutrients from stormwater.
- Encourage workforce development in the areas of green infrastructure maintenance and landscaping best practices.
- Explore development of a scalable, replicable, private stormwater district similar to Long Creek for other at-risk watersheds or at municipal or regional levels.

## **Recommendation #17:** Establish a working group to recommend appropriate water quality criteria for nutrients in Casco Bay, which may include numeric goals, to be used throughout the Bay.

While there are cautions to such an approach, having a clear nutrient threshold goal (which may include a numeric goal) – and understanding Casco Bay's current status in relation to that goal – would inform nearly all water quality work in the region, including many of the other solutions suggested in this report.

Some involved in water quality work may balk at setting thresholds, but it is becoming increasingly clear that having standards would provide clarity and relief for many, and would allow for the next chapter of progress to begin.

## **Recommendation #18:** Continue the work of the Casco Bay Monitoring Network and periodically update the map and dataset of monitoring programs. Integrate emerging nutrient monitoring needs, activities, and funding models with other Bay monitoring.

The Casco Bay Monitoring Network brings together organizations conducting monitoring in the Bay for three to four meetings a year, and is working on updating the Casco Bay Monitoring Plan. The Monitoring Network provides an existing forum to discuss emerging monitoring activities and needs. Discussion of monitoring specifically to address nutrients may require complementary conversations identifying regulatory drivers and obligations, but the forum provides a robust starting point, and a pool of considerable expertise on coastal monitoring.

Even though the monitoring locations shift somewhat from year to year, and it is sometimes hard to know what the future will bring given budget uncertainties, having a map of monitoring efforts is useful. A map and dataset that were developed by the Monitoring Network in 2016-2017 are available on Casco Bay Estuary Partnership's website (https://www.cascobayestuary.org/casco-bay-monitoring-network-2017-programs/)

See Appendix C for a List of Recommendations agreed to in principle by the Nutrient Council. See Appendix D for a list of Recommendations considered by the Nutrient Council but not advanced. See Appendix E for a discussion of Background on the Nutrient Council and this Report.

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# Appendix A: Matrix of Policy and Regulatory Tools Impacting Casco Bay

The following list of policy and regulatory tools focuses on tools at work in coastal communities, although some of these tools are also at work in the broader watershed or region. This is not an exhaustive list, but captures tools likely to have the most significant impact on Casco Bay.

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Group I a: Clean Water Act Rules, In Part** | | | |
| **MePDES / NPDES Permits** | Federal law, State permit | Discharge | Permits wastewater and other discharges; including provisions for "integrated planning" and "adaptive management." |
| **MS4 ("municipal separate storm sewer systems") Permits** | Federal law, State permit, Local implementation | Discharge | Requires medium and large municipalities to undertake measures to reduce harmful impact from stormwater runoff to the Bay. |
| **Maine Construction General Permit** | Federal law, State permit | Construction, Discharge | Mandates best practices to reduce runoff from construction sites. |
| **Multisector General Permit** | Federal law, State permit | Discharge | Requires certain best practices to reduce harmful impact of stormwater discharges from industrial entities. |

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Residual Designation Authority (e.g., at Long Creek)** | Federal law, State permit, Local implementation | Discharge | Allows EPA to require additional permits to address impairment of water quality. Applied in the Long Creek watershed to establish a watershed management district. |
| **Water Quality Standards** | State | Discharges | Sets qualitative and quantitative standards for Maine waters. |
| **Impaired Waters List** | State | | List of waters that do not meet water quality standards, and reasons they do not. |
| **TMDLs ("total maximum daily loads")** | State | Discharge | Identifies strategies for reducing pollutant loads to impaired waters. While not directly enforceable, may shape discharge limits in future permits. |
| **Group I b: State and Municipal Rules and Regulations** | | | |
| **Maine "Chapter 500"** | State | Construction; Discharge | Establishes stormwater management standards for activities licensed under the State's Stormwater Management Law and Site Location of Development Law. |

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Local Stormwater Ordinances** | Local | Construction, Discharge | Most towns in our region have stormwater ordinances that go beyond "Chapter 500" requirements in one way or another. |
| **Fertilizer or Pesticide Ordinances** | Local | Discharge | Limits use of fertilizer or pesticides thus reducing runoff. Local examples have focused on pesticides, not fertilizer. |
| **Group 2: Long Range Planning** | | | |
| **Interlocal Stormwater Working Group** | Local | Implementation | Assists local municipalities with implementing stormwater controls, especially under MS4 permits. |
| **Watershed Management Plans** | Local | Planning; Funding | Addresses water quality issues. Stakeholder-driven. Required to allow access to certain federal funds for watershed protection and restoration. |
| **Municipal Comprehensive Plans** | Local | Planning | Identifies municipal priorities, including for economic development and natural resources protection. About half of Comprehensive Plans in our region include formal consideration of water resources. |

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Watershed management tools offered by the COGs** | Local | Planning | |
| **Group 3: Land Use Regulation and Development Practices** | | | |
| **Maine Site Location of Development Law** | State | Land use; Design | Requires review of developments that may have a substantial effect upon the environment, principally for larger development projects. |
| **"Section 404" of the Federal Clean Water Act** | Federal Law, State or Federal permit | Land use | Limits "deposit of dredged or fill material" into wetlands and other waters, providing a disincentive for construction in wetlands. |
| **Maine Natural Resources Protection Act** | State | Land use | Limits development activity in or adjacent to certain natural resources, including rivers and streams, great ponds, and wetlands. |
| **Shoreland Zoning** | State guidance, Local implementation | Land Use | Requires towns to adopt ordinances to limit activities close to waterways, such as clearing of vegetation or construction. |
| **Local Habitat or Water Protection Ordinances, Policies and Procedures** | Local | Land use; Design; Construction | Most towns in our region have ordinances that provide protection beyond state standards to aquatic resources (such as protecting riparian areas, |

| | | | |
|---|---|---|---|
| | | | floodplains, wetlands, aquifers or shellfish beds). |
| **Tool** | **Scale** | **Type** | **What it Does / Impact on Casco Bay** |
| **Local incentives for less polluting development practices** | Local | Land use; Design | Most towns in our area provide incentives to encourage compact development. A few provide incentives for "Low Impact Development" practices, or allow transfer of development rights from environmentally sensitive to other areas. |
| **Erosion Sedimentation Control Law** | State | Construction | Limits soil erosion and discharge of sediment (and associated nutrients) during projects involving earth moving. |
| **Group 4: Financing and Financial Incentives** | | | |
| **"State Revolving Loan" funds (CWA)** | Federal funding, State administered | Funding | Provides low interest loans and loan forgiveness for construction of water infrastructure, such as wastewater treatment plants and sewer system upgrades. |
| **"Section 319" Grants (CWA)** | Federal funds, State administered grants, Local implementation | Planning, Funding | Provides grants to support implementation of watershed protection, principally via-the-ground projects that benefit water quality. |

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Long Creek Watershed Management District** | Local | Funding; implementation | Manages stormwater runoff on behalf of about 130 landowners in the Long Creek Watershed. The District is funded by a fee on impervious surfaces. |
| **City of Portland's Stormwater Fee** | Local | Funding | Funds municipal improvements to stormwater and combined sewer management. |
| **Water-quality "Impact Fees"** | Local | Development, Funding | Some municipalities require developers to pay an "impact fee" to address water quality concerns. |
| **Maine Natural Resources Conservation Fund (MNRCP)** | State | Development, Funding | Projects must either mitigate for impacts to wetlands and other aquatic sites, or pay into a state fund that funds habitat restoration and conservation efforts. |

| Tool | Scale | Type | What it Does / Impact on Casco Bay |
|---|---|---|---|
| **Tax incentives and disincentives** | Federal | Land Use | Federal and state tax policy has a variety of indirect effects on development practices. For example, the mortgage interest deduction incentivizes single family homes, thus encouraging suburbanization. Special treatment of real estate investments incentivizes conversion of forest land to other uses. Deductions for charitable donations provides incentives for donations of land for conservation. |
| **Group 5: Other Actions** | | | |
| **Outreach and Education** | State, Local | Education | Towns with MS4 permits support education and outreach programs to improve public understanding of stormwater and water quality issues. |
| **Limit fertilizer use on public lands** | Local | Implementation | |
| **Training first responders to manage water quality incidents** | | | Towns with MS4 permits |
| Train school and park employees on landscaping best practices | Local | Implementation | Towns with MS4 permits |

# Appendix B: Matrix of Educational and Outreach Programs in Casco Bay

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Island Institute**<br><br>Yvonne Thomas, ythomas@ islandinstitute.org<br><br>Rebecca Clark-Uchenna, rclark@ islandinstitute.org | A Climate of Change: The program uses aquaculture to help students learn about the marine environment and discusses nutrients and acidification. http://www. islandinstitute. org/aquaculture | Middle and high school students | Marine/ Coastal | The Educator's Guide for A Climate of Change: The Future of Aquaculture is designed to help middle and high school teachers bridge different ideas between the science and social aspects of aquaculture. There is an accompanying film. |
| | Ocean acidification research: Marine Scientist Susie Arnold disseminates results to interested public. | All ages | Marine/ Coastal | |
| **Gulf of Maine Research Institute**<br><br>Gayle Bowness, gayle@gmri.org | LabVenture: Nonpoint Source Pollution in my Schoolyard curriculum unit. | Grades 3-5, 6-8 | Both | Not sure how widely this is used. |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Wells Reserve at Laudholm Farm**<br><br>Suzanne Kahn, suzanne@ wellsnerr.org | Exploring Estuaries program. | Grades 3-5 | Marine/ Coastal | Nutrients are mentioned when they discuss human impacts on watersheds. |
| | System-Wide Monitoring Program: Water quality monitoring program, staffed by Jeremy Miller. | | Marine/ Coastal | There are occasional related educational programs in which nutrients are talked about. |
| **Maine SeaGrant**<br><br>Beth Bisson, beth.bisson@ maine.edu<br><br>Kristen Grant, kristen.grant@ maine.edu | Nothing specifically nutrient related. | | | |
| **University of Maine Cooperative Extension** | 4-H Science Toolkits - Exploring Maine Science & Aquaculture. | Youth ages 5-8 | Marine/ Coastal | Developed in partnership with Maine EPSCoR, based on the SEANET program. The toolkit is 12 activities that introduce marine science and the concept of aquaculture. The curriculum does not |

| | | | | |
|---|---|---|---|---|
| | | | | include any discussion of nutrients. |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Cumberland County Soil and Water Conservation District**<br><br>connect@ cumberlandswcd. org | CONNECT: Lessons that focus on clean water, marine ecosystems and agriculture. | K-12 | Both | Classroom and service learning education. Many lessons focus on nutrient loads. Mudflat Mayhem focuses on the science of coastal acidification. |
| | YardScaping. | Adults, and youth; YardScaping for 5th grade (part of CONNECT) | Both | Freshwater/saltwater based education varies with community. There are roughly 6 workshops a year with 10-20 participants; staff sees about 25% to 75% of participants adopt YardScaping practices. |
| | Municipal Education: Done partially through involvement with ISWG. Focuses on general stormwater and good housekeeping practices rather | Adults/ municipal staff and board members | Both, depending on location | |

| | | | | |
|---|---|---|---|---|
| | than being nutrient specific. | | | |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Portland Water District**<br><br>Sarah Plummer, splummer@ pwd.org | WaterWays Program: Teachers select from three themes - each theme includes four related lessons that are aligned with NGSS. The overarching goal is to teach students about the ways we use, share, pollute and protect water. | Sixth grade classes in Sebago Lake Watershed and PWD service area. | Both | Also other school year programming; TroutKids curriculum; summer camps. |
| **Maine Audubon**<br><br>Eric Topper, etopper@ maineaudubon.org | None related to nutrients. | | | |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Lakes Environmental Association**<br><br>Contact Alanna Doughty, alanna@ leamaine.org | A number of educational programs. | 5th, 6th, and 7th grades; high school; some public programs for adults | Freshwater but would like to broaden to include Casco Bay watershed | Not specific to nutrient pollution but look at erosion as a problem. There are lessons that look at phosphorus loading, how it affects water quality and habitat, and how to reduce erosion and therefore nutrient pollution in the watershed. |
| **Friends of Casco Bay**<br><br>Mary Cerullo, mcerullo@ cascobay.org | Casco Baykeeper Ivy Frignoca: Coordinates Maine Ocean and Coastal Acidification Partnership (MOCA), which educates adults via a newsletter, at meetings, and at workshops twice a year. | Adults, mostly colleagues | Coastal | |
| | Casco Bay Curriculum: One activity on ocean acidification cites nitrogen pollution as a cause of coastal acidification. | Teachers | Coastal | FOCB does not work directly with students, but rather with teachers. It is hard to assess success except for some anecdotal information from teachers who are using the activities. |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| | Bayscaping: a public education campaign to stop pollution from lawn care practices. Bayscaping reaches out to homeowners to encourage them to reduce their use of pesticides and fertilizers. | General public | Coastal | A staple of FOCB's Bayscaping outreach has been neighborhood socials, which connect neighbors with the notion that lawn care practices can affect the water quality of Casco Bay. |
| **Maine Water Environment Association**<br><br>Kristie Rabasca, krabasca@ integratedenv.com | Public education programs for the MS4 Stormwater General Permit communities; YardScaping workshops and materials. | MS4 Stormwater General Permit communitie s | Both, in the next year | MEWEA does not offer any educational programs on nutrients, but will be working on some awareness-raising around nutrients and stormwater impacts on fresh and marine waters in the next year. |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Presumpscot Regional Land Trust**<br><br>Toby Jacobs, toby@prlt.org | Water Steward program. | 35 volunteers at 40 different sites on the Presumpscot | Bacteria levels, DO, and conductivity are recorded | PRLT does not have any specific programs focused on nutrient pollution. Volunteers do learn about types of water pollution and what cause them, as well as the history and current state of water quality throughout the Presumpscot region. |
| **Harpswell Heritage Land Trust**<br><br>Julia McLeod, outreach@ hhltmaine.org | Nature day camp. | Preschool and elementary school | Both | Nature Day Camp combines fun, creativity, scientific inquiry and hands-on exploration. |
| | Harpswell Community School programs; 4th grade focuses on weathering and erosion. | K-12; reaches every student at the school | Both | Programming is during school day. The focus is on Harpswell science, with different topics for different grade levels, ranging from adaptations to weather to erosion. |
| | Public Programs: Short courses about Harpswell nature, lectures, and other activities. | Reaches over 1,000 people | Some focus on water quality, some marine | Content varies |

| Organization | Program | Audience | Freshwater, Marine/ Coastal, or both? | Additional Notes |
|---|---|---|---|---|
| **Maine DEP**<br><br>Beth Chase, beth.chase@maine .gov | Children's Water Festival | 4th-6th grades | Both | Content varies |
| **Maine Healthy Beaches Program**<br><br>Meagan Sims, University of ME Cooperative Extension, meagan.sims @maine.edu<br><br>Tracy Krueger, Maine Healthy Beaches Manager, tracy.krueger @maine.gov | Volunteer monitoring, water quality monitoring, outreach materials, biennial conference.<br><br>http://www. mainehealthy beaches.org/ resources.html #waterquality | General public, municipalities | Coastal | Materials and educational material are mostly focused on bacterial contamination, but there is some discussion on nutrients. |
| **Think Blue Maine Partnership** | Think Blue Maine video and print materials campaign | General public, plus targeted efforts for college-educated 35-55-year-olds | Both | Focus on getting people to visualize nonpoint source pollutants in stormwater runoff (awareness raising primarily). Fertilizer and pet waste are referenced. |

# Appendix C: List of Recommendations

## Policy

1. Encourage integrated planning and adaptive management across permits and municipalities.

2. Establish numerical nutrient criteria for marine waters.

3. Revise state rules and guidance for stormwater and site design to highlight stormwater controls (e.g. green infrastructure, gravel wetlands) that meet existing rules and also remove nitrogen from stormwater.

4. Create a forum to discuss ways to harmonize state and local policies and provide input on specific policy recommendations. Such a group needs to be broad based, and invite participation not only from urban and suburban communities, but rural Maine towns as well.

5. Develop tools and incentives to encourage the private sector to reduce nutrient loads through stormwater facility maintenance and good housekeeping. Enforce the rules that already exist.

6. Encourage municipalities to think and act in terms of watersheds when developing local policy, through preparation (and funding) of watershed management plans and building community awareness of watershed impacts.

7. Consider adoption of "Smart Growth" policies and strategies to reduce nutrient pollution (such as: incorporate watershed impacts during site design and planning reviews; create stronger incentives for implementation of BMPs; require BMPs on projects below state thresholds; protect forests and wetlands; develop ordinances that encourage green infrastructure in new development; increase density, redevelopment, and infill appropriate areas; manage and restrict fertilizer use).

8. Incorporate water quality/nutrient goals into municipal comprehensive plans.

## Funding

9. Seek sustainable funding for outreach and education related to water quality, stormwater, and nutrient-related impacts.

10. Establish a dedicated regional monitoring fund to support ongoing and expanded regional water quality monitoring.

11. Expand the use of federal and state funding to support substantial costs of capital investment in water quality protection; nutrient management in particular.

## Science

12. Develop nutrient loading estimates that combine recently collected data on wastewater and CSO discharges with updated runoff models (which properly account for direct discharges to the Bay) to develop up-to-date estimates of loads from different sources.

13. Expand nutrient monitoring to measure nutrient concentrations in currently unmeasured sources, especially urban streams, stormwater outfalls, and CSO outfalls.

14. Conduct analysis to better understand the effects nutrients are having on the Bay, including sediment processes.

## Stakeholder Engagement: Education, Collaboration, and Shared Metrics

15. Share information on the importance of nutrient pollution to our waterways more broadly with policymakers and key decision makers.

16. Encourage innovation on the part of the public and private sectors to support nutrient reduction.

17. Establish a working group to recommend appropriate water quality criteria for nutrients in Casco Bay, which may include numeric goals, to be used throughout the Bay.

18. Continue the work of the Casco Bay Monitoring Network and periodically update the map and dataset of monitoring programs. Integrate emerging nutrient monitoring needs, activities, and funding models with other Bay monitoring.

# Appendix D: Recommendations Considered but Not Advanced

## Nutrient Science

### **Nutrient Science Recommendation A2:** Generate a detailed nutrient monitoring plan and identify consistent funding to implement that plan.

We are not doing enough monitoring of ambient conditions to refine our understanding of nutrient processes. Current monitoring effort is ramping up, but it is still short of what is needed for comprehensive understanding. High intensity monitoring may not be needed every year or for the long term, but lack of understanding of nutrient sources and distribution reduces our ability to make wise strategic choices right now.

Initial estimates of the annual costs for a focused nutrient monitoring program are on the order of $100,000 to $250,000 per year. Broader programs could cost several times that. Cost-effective monitoring would require careful consideration of monitoring goals and policy actions to be informed by improved data.

### **Nutrient Science Recommendation A3:** Compile information on reductions in nutrient flow that can be expected from land-based practices.

and

### **Nutrient Science Recommendation A4:** Complete an assessment of the value of expanded investment in stormwater management.

In the short term (even before we conduct detailed analysis of potential benefits of stormwater retrofits), we need a preliminary statement about the magnitude of effects we can expect from land-based practices. For example: "The peninsula has ___ hectares of impervious surface. If we double the area treated with stormwater devices, we can reduce nutrient levels by 10%."

Information may include:

- General nitrogen removal efficiencies of common stormwater treatment technologies.

- Understanding of locations and potential impacts to septic tanks and other on-site wastewater treatment systems.
- Nutrient loads from all licensed discharges, including combined sewer overflows (CBEP staff are well on their way to assembling these data).
- Impact of nonstructural and education approaches, such as YardScaping and Bayscaping.
- Potential reductions in nutrients loads from adoption of nutrient or fertilizer ordinances.
- Impact of pet waste.

This compilation will need to rely heavily on studies of related efforts carried out elsewhere around the nation.

Longer-term, we are likely to need site-specific data, and thus will need to fund a detailed regional assessment of opportunities to reduce nitrogen loads from stormwater. Although we estimate the cost for such a study to be $75,000 to $200,000, we consider it a prudent investment which could prevent spending millions of dollars on wastewater treatment plant upgrades that would not yield as much benefit as other projects. Steps in this direction are likely to be taken as part of Portland's Integrated Planning process, which is now underway.

## **Nutrient Science Recommendation A5:** Apply available hydrodynamic models to shed light on mixing processes near major nutrient sources.

and

## **Nutrient Science Recommendation A6:** Establish a "modeling group" of experts to define the goals and scope of Casco Bay hydrodynamic and ecosystem modeling efforts.

Several hydrodynamic models of Casco Bay exist, but they have not previously been applied to water quality problems derived from nutrient enrichment. Full ecosystem models rest on the same hydrodynamic models, and would provide insight into how ecological processes may shape current and future conditions in the Bay, especially with regards to impacts on anoxia and coastal acidification.

It is becoming clear that a hydrodynamic model (rather than a full ecosystem model) is likely to be sufficient to support near term policy conversations and offer general policy guidance. In the longer term, a full ecosystem-based model may become necessary, especially to address combined effects of climate change and nutrient loads.

The University of Maine at Orono is already conducting hydrodynamic modeling and we expect to be able to run that model with specific, policy-relevant, boundary conditions and outputs. CBEP has set aside limited funds in our 2018-2019 EPA workplan to fund limited hydrodynamic modeling, either in association with other partners, or on our own.

Full ecosystem modeling is expensive and involved, and for the short term, results of a more involved model are unlikely to have as strong an influence on near-term policy deliberations. Longer term, ecosystem-based models could play an important role in helping assess links between anthropogenic nutrient loads and specific ecosystem changes, including coastal acidification and nuisance algal blooms.

Goals for a series of hydrodynamic model runs might include the following:

- Understanding short to medium term (two to four weeks) mixing, dilution and transport processes under policy-relevant conditions (e.g., large storms that produce CSO discharges).
- Developing visualizations and quantitative results based on use of Lagrangian "conservative tracers" to assess mixing, dilution and transport of pollutants from selected sources, including major wastewater treatment facilities, CSOs and stormwater.
- Calculation of "concentrations" at specific locations of regulatory or community concern following discharge events.
- Analysis of "residence times" around the Bay to highlight areas of high and low vulnerability to pollutant loading.
- Assessment of stability of the water column at a few key locations around the Bay, including in the Fore River.

## **Nutrient Science Recommendation A7:** Prepare a schedule of upcoming permits, along with a list of nutrient science information that we want to have before those dates, and develop a plan to gather the information.

Significant progress has been made, and will continue to be made in coming months and years in developing our understanding of nutrients in Casco Bay. It is essential that as we ready for future discharge permits, we gather and organize the information assembled in an open and transparent way, so that all stakeholders have access to similar information in a timely manner. Clean Water Act permits are issued on a five-year schedule, and most major discharge permits have been recently renewed. The current MS4 permit renewal is being finalized this fall. It will be a few years before stormwater and wastewater permits come up again.

## Funding

### **Funding Recommendation B2:** Work with Maine's State Revolving Fund (SRF) administrators to use SRF more effectively for stormwater and point source.

The federal "State Revolving Loan" (SRF) fund is administered by the state to provide funding for water quality infrastructure investments. The program operates under federal guidance that permits both low interest loans, and limited "loan forgiveness" to reduce costs of water infrastructure investments to local communities.

While SRF has been tapped in Maine to provide funds for stormwater programs, significant barriers remain to more widespread use for that purpose. Because the program is principally a loan program, it is most readily accessible to entities like water utilities that have access to a predictable long-term flow of income from taxpayers or rate payers. This has made the program less accessible to the local, often not-for-profit organizations that have taken the lead on watershed management in the past. In addition, SRF funds generally cannot be used to pay for investments on private property, which blocks use of these funds for collaborative, public-private partnerships that install supplemental water quality treatments on private property (although a partial exception exists for projects in National Estuary Program watersheds).

### **Funding Recommendation B3:** Develop a catalog of existing public and private stormwater treatment infrastructure in key watersheds, to identify opportunities for cost-effective investments in stormwater treatments, and highlight BMPs that work well for nitrogen and phosphorus reduction.

Specifically:

- Gather data on local municipal examples of "Green Infrastructure" and other innovative stormwater control technologies.

- Create a Google Earth map (or use other online mapping technologies) to create a clickable map with pushpins at X, Y coordinates, showing locations of installed devices. Add a photograph, a brief description of each project or device, and information on key contacts.
- In watersheds where data is already available, or where watershed planning induces data collection, add private systems to the online tool as well.

The challenge with this task is gathering examples in a systematic manner. We suggest working through municipal stormwater managers to access existing information on stormwater infrastructure, and working with students or interns to organize the geographic data.

## **Funding Recommendation B4:** Facilitate use of public funds to construct stormwater treatment on private property.

When water quality issues were seen as principally about getting major polluters to invest in treatment systems to solve water quality problems they had induced, use of federal or state funds to address water quality on private property was seen as an unfair subsidy to polluting businesses. One consequence was that most federal and state funding mechanisms, including the State Revolving Funds (SRF), and Section 319 of the Clean Water Act, have restrictions on use of government funds on private property[8]. However, the issues we face today are of a different scale and character. Treating runoff and restoring streams involves addressing runoff from multiple properties. Private property will often offer the only, the most effective, or the most cost-effective places to install treatment systems. Existing regulatory regimes do not include rules to address individually minor, but cumulatively important, discharges on already-developed land, making voluntary programs and supplemental funding all the more important.

## **Funding Recommendation B6:** Pursue applications to the WIFIA program to facilitate public-private partnerships such as stormwater retrofit projects.

[8] Federal law allows greater flexibility for use of SRF funds to assist any public, private, or nonprofit entity to implement activities identified in the Comprehensive Conservation and Management Plan of a National Estuary Program, including the Casco Bay Plan (See 40 CFR § 35.311 2011).

The Water Infrastructure Finance and Innovation Act (WIFIA) which was passed in March of 2018, provides long-term, low-cost supplemental loans for "regionally and nationally significant" projects. A primary focus of the act is to provide funds that are more flexible than SRF funds with respect to making investments in water quality investments on private property. Grants are substantial, and thus the program encourages small communities to come together to take advantage of the program.

The New England Environmental Finance Center also has relevant expertise on public – private partnerships.

### **Funding Recommendation B8:** Start a conversation about establishing alternative funding sources for water infrastructure.

In many cases it seems that governments and the public are not getting the message about, or do not have the means to invest in, maintenance, replacement of failing water infrastructure, monitoring, or water quality science.

Examples might include:

- Private sponsorship of monitoring buoys;
- Costs borne by the private sector during redevelopment;
- A watershed approach based on incentives, in which the costs of small BMPs are covered by the need for continual improvements to roads, sidewalks, and other existing infrastructure into which BMPs can be integrated.

## Education and Outreach

### **Education & Outreach Recommendation C1:** Define clear nutrient education and outreach goals.

While the Council is in agreement that outreach and education are likely to play a significant role in any strategy to reduce nutrient pollution, the goals for outreach are not yet well defined. Behavior-change goals, such as encouraging dog owners to pick up after their pets, or reducing use of nitrogen-containing fertilizers, call for different communications strategies than do longer-term educational goals, such as increasing awareness of impacts of stormwater or the connection between land use and water quality.

### **Education & Outreach Recommendation C2:** Create a clearly articulated nutrient outreach plan that fully considers existing water quality outreach and education programs.

It is hard to educate people about nutrient-related problems quickly and succinctly. A plan, which should specify details like goals, target audiences, desired outcomes, and messages, is essential for progress. An outreach strategy also needs to honestly assess levels of investment needed for success and be clear that success is likely to require investment over a period approaching a decade.

Resources for such long-term outreach will not be easy to find, and so coordination with (and support for) related water quality outreach is essential. Without clearly articulated goals, is not yet clear whether touching on nutrients though existing outreach efforts or separating out nutrients into a separate marketing and education campaign will prove to be the best strategy.

### **Education & Outreach Recommendation C3:** Consider a new campaign focused on nutrients entering the Bay, and develop common branding as well as shared marketing materials, such as infographics, "conceptual models," fact sheets, and a regional outreach framework.

and

### **Education & Outreach Recommendation C4:** Target some effort at informing the general public regarding water quality investments. Engage the public and non-traditional allies to explain the costs and trade-offs of different actions (or non-actions).

Research has shown that people absorb information only after repeated exposure to the same ideas. Transfer of information can be enhanced by delivery of similar information thorough multiple outlets. Moreover, for educational and outreach messages in general, it helps to be blunt, catchy, and short. Nutrient issues are often complex, and it will take work to develop materials that are appealing and memorable. Materials that link nutrient pollution to wallet (costs, economic activity), health (pathogens or harmful algal blooms), food (fish and shellfish), or fun (fishing and boating), are likely to be most effective.

A collective effort to develop materials and use them across multiple platforms can make everyone's outreach and education programs more effective.

### **Education & Outreach Recommendation C5:** Increase education and outreach, through existing and expanded programs, about nutrient pollution, its effects, and actions that can be taken in response.

Most water quality-related education efforts we have identified in the region share some information with their target audiences about nutrients or nutrient-related topics. For example, YardScaping and Bayscaping programs encourage reduced use of lawn chemicals, including fertilizer. Portland Water District's education programs discuss the impact of nutrients on Sebago Lake. But nutrients are not a central message for most programs, which have broader, often more general goals. Historically there has been more education done in this region about freshwater quality issues (for example, stormwater and lakes) than there has about Bay-specific or marine water quality issues. For freshwater education, it may be enough to enhance existing nutrient pollution messages. But to effectively communicate the importance of nutrients – especially nitrogen – for the Bay, we may need to develop new programs or materials.

Successful water education programs led by the Portland Water District and the Cumberland County Soil and Water Conservation District have demonstrated the value of age appropriate, class-room ready materials. Educational institutions, especially public schools, must ensure that students reach specific age-appropriate educational milestones. Many schools and teachers are interested in incorporating environmental themes into the classroom but lack the time and other resources to develop age appropriate curricula. This is especially true for schools and teachers facing mandates to meet specific learning standards or to advance STEM education.

Potential actions:

- Share best available nutrient science and solutions with educational organizations to assist them in incorporating nutrient education.
- Define clear nutrient outreach goals, articulating both education/knowledge and behavior change goals.
- Encourage the expansion of existing freshwater quality education programs to incorporate more of a focus on nutrients.
- Encourage incorporation of nutrient messages as part of existing outreach and education programs.

- Encourage or facilitate nutrient-related outreach and education under existing regulatory programs (chiefly, the MS4 permit programs).
- Identify relationship of nutrients education to current educational standards.
- Identify / make available / develop curriculum materials for classroom use.
- Develop resources to support STEM–related programs and student projects directly related to nutrients, especially at the high school and college levels. Offer more general education about wastewater plants.

## Policy and Regulation

### **Policy & Regulation Recommendation D1:** Adopt a policy statement, such as: "The Casco Bay Nutrient Council recommends policies be established to prevent the net increase in anthropogenic nutrient loads entering Casco Bay."

The Nutrient Council endorses the following policy statement (Note: here are two alternatives for statements. Final wording will need to be clarified.)

- "The Casco Bay Nutrient Council recommends policies be established to prevent a net increase in nutrient loads resulting from human activity entering Casco Bay."

- "The Casco Bay Nutrient Council recommends policies be established to prevent negative impacts from nutrients in Casco Bay."

### **Policy & Regulation Recommendation D4:** Encourage action on the part of our region.

Nutrient problems are inherently regional, and thus we must work collaboratively as a region both to address nutrient pollution and facilitate effective and cost-effective solutions. Multiple regional structures exist that can facilitate regional programs, including Cumberland County, our regional planning bodies (GPCOG and MCED), CCSWCD, CBEP, and ISWG. These issues are not confined only to Cumberland County or even to the Casco Bay watershed, so opportunities should be sought to address these issues across southern Maine, by working with allied organizations to our south.

Possibilities on what to do include:

- Develop model ordinances and other tools to encourage local policies that reduce nutrient delivery to coastal waters.
- Develop model ordinances and policies to address key areas, such as stormwater management, green infrastructure, shoreland zoning and wetland protection.
- Evaluate whether a funded "water circuit rider" tasked with assisting towns with development of water friendly local policies would be effective.
- Work with towns to identify areas where state policies sometimes complicate identification of innovative solutions.
- Encourage regulatory consistency across municipalities. Cost effective solutions for addressing nutrients can be hampered by the patchwork of regulatory mechanisms that protect clean water. An important public policy goal is to facilitate efforts to identify solutions across institutional, legal, geographic boundaries, including:
    - Levels of government (local, state, and federal);
    - Regulatory silos (clean water vs. land use; wastewater permits vs. stormwater permits);
    - Municipal borders;
    - Public vs. private investment.

Possibilities on how to do it include:

- Work through regional groups like GPCOG, CCSWCD, and CBEP to bring together town managers and elected officials to discuss opportunities and challenges of managing water at the local scale and to identify solutions for improving water quality and addressing regulatory mandates.
- Increase Nutrient Council and/or Casco Bay Estuary Partnership work with the Maine Municipal Association.
- Learn from GPCOG research and examples.
- Employ lessons learned at Long Creek to inform how Impervious Cover and Non-Point Source TMDLs are addressed. (They are expected to be incorporated for the first time in the 2018 MS4 permits.)

## Private Actions

### **Private Actions Recommendation E2:** Consider creating and promoting awards and certification programs.

Awards and certification programs can be an effective recognition and motivational tool.

For instance:

- Encourage adoption of "SITES" certification by developers seeking to market "green" buildings to prospective tenants.
- Work with SITES program to provide additional points for projects that incorporate nutrient pollution reduction or nutrient retention strategies.
- Educate consumers and business leaders that LEED certification does little to protect the Bay, and that other certification programs exist.
- Establish a local "Bay-friendly" award or certification program that extends or complements SITES certification to specifically consider the effects of development on nitrogen.
- Publicize and thank businesses that go beyond regulatory minimums to address water quality.

## Integrated Planning and Collaboration

### **Integrated Planning & Collaboration Recommendation F2:** Representatives of the Nutrient Council should participate in Portland's Integrated Planning effort, and we should ensure that findings are shared with all Council members.

Many of the questions discussed by the Nutrient Council will be front and center while the City of Portland completes its Integrated Planning Process (IPP). While Portland's process is shaped by the City's permit obligations, the premise of integrated water resources planning is to identify cost effective strategies for achieving water quality and other community goals. The overlap with the Nutrient Council's work should be obvious. Portland has committed significant resources to the IPP, and it behooves us to pay attention.

## Metrics and Evaluation

### **Metrics & Evaluation Recommendation G3:** Establish a regional nutrient reduction actions database to track costs and anticipated benefits of nutrient reduction efforts.

We need to gather and make sense of available data on costs and performance (or at least anticipated performance) of different nutrient reduction strategies, as actually implemented in our region. Maintaining data on costs and benefits as we continue to invest in water quality will enable us to evaluate future proposed investments against actual experience in our region.

## **Metrics & Evaluation Recommendation G4:** Establish agreed-upon metrics to track efforts to reduce nutrient pollution.

It is a truism that that which gets measured gets done. Thus if we wish to address nutrients on a region-wide basis, we should develop regionally consistent ways of assessing performance. Performance metrics should range from tracking of project-level inputs (already done for many water quality–related activities under existing permitting authorities), to measuring water quality.

## **Metrics & Evaluation Recommendation G5:** Create data visualizations to help in communications with policymakers.

Opportunities for those of us working on water quality issues to communicate with key local and state decision makers are relatively uncommon. We need to be able to convey information about the state of Casco Bay (and other local waters), and about efforts at nutrients reduction, concisely to policy makers. We can support efficient communication if we prepare in advance (automatically or on a regular schedule) graphs and charts based on up-to-date data that facilitate understanding of these issues by policymakers and the general public.

Visualizations could include “static” products such as fact sheets and annual data summaries, but also “live” online graphics with links to “live” or regularly updated data sources. Visualizations should be based on careful graphical design intended to communicate principal findings to a diverse audience. Additional effort could involve investment in telemetered data collection or processes to facilitate regular updates of online data with the latest results.

## **Metrics & Evaluation Recommendation G6:** Establish clear, measurable metrics for evaluating the success of marketing, outreach, and education programs.

Evaluation of marketing and educational programs is notoriously difficult and expensive. This is especially true if you wish to evaluate changes in attitude, understanding or behavior in the general public. Evaluation may need to focus on intermediate metrics like number of students served, number of impressions, number of hits to a webpage, or be based on interviews with key policy makers or water quality professionals.

# Appendix E: Background on the Nutrient Council and this Report

## About the Casco Bay Nutrient Council

In 2017, Casco Bay Estuary Partnership (CBEP) convened the Casco Bay Nutrient Council (the Council) to provide a forum for examining the impact of nutrient pollution on Casco Bay, and identifying effective and cost-effective strategies to address nutrient pollution in the Bay. The Council consists of a core group of 12 members, representing municipal government, wastewater treatment plant operators, stormwater engineers, regulatory agencies, advocacy organizations, and academics. A broader “Advisory Network” of more than 30 individuals are regularly informed of meetings, and invited to attend. Meetings of the Council have been professionally facilitated by Craig Freshley of Good Group Decisions.

### 1. Purpose

The purpose of the Casco Bay Nutrient Council is to develop recommendations to policy makers, regulators, and funders on how best to assess, understand, convey and reduce the negative impacts of excess nutrients on Casco Bay.

### 2. Process

The Council held seven meetings between April 2017 and May 2019:

- At the kickoff meeting on April 26, 2017, we established the Council’s purpose (see above) and framed the problems. As a result, we determined the following:
    - First the Council will try to define the current state and the nature of the problem including specific negative impacts at various levels of nutrient loading and including leading causes of nutrient loading and their relative impacts. We will also take stock of current efforts to address nutrients in Casco Bay. Needs for further information will be considered.

    - Second, the Council will develop a variety of potential actions with estimated costs and benefits for each, including different actions for different regions and how to react to potential future scenarios.
- At the second meeting on November 13, 2017, the Council heard and discussed presentations from:
    - Ivy Frignoca, Casco Baykeeper, Friends of Casco Bay;
    - Angie Brewer, Biologist and Marine Unit Section Leader, Maine Department of Environmental Protection;
    - Rob Roseen, Former Director of the University of New Hampshire Stormwater Center;
    - Scott Firmin, Director of Wastewater Services, Portland Water District;
    - Damian Brady, Professor, University of Maine (presented by Curtis Bohlen in Damian's absence).
- At the third meeting on February 20, 2018, the Council heard and discussed updated nutrient monitoring data from Angie Brewer, brainstormed solutions, and identified short-term priorities for CBEP staff to support the work of the Council.
- At the fourth meeting on June 21, 2018, the Council reviewed and discussed a draft Preliminary Findings Report prepared by Curtis Bohlen. The EPA Regional Administrator attended this meeting.
- Between the fourth and fifth Council meetings, three work groups were established to address specific areas of the Draft Report: Policy, Education, and Science. Results from the work groups were incorporated into the Draft Report.
- At the fifth Council meeting on October 25, 2018, the Council reviewed and discussed a near-final Draft Report, and began narrowing down a list of recommendations to include in the report.
- At the sixth Council meeting on November 29, 2018, the Council reviewed the final Draft Report, finalized the list of recommendations, and made plans for the next phase of related work.
- At the seventh and final Council meeting on May 17, 2019, the Council took stock of progress made so far, identified lead responsibilities for the recommendations going forward, made an adjustment to one recommendation, and provided input for finalization of this report's Executive Summary.

# 3. Members

## Members of the Council

1. Betty McInnes, Cumberland County Soil and Water Conservation District (joined by Aubrey Strause)
2. Ivy Frignoca, Friends of Casco Bay
3. Jessa Berna, Greater Portland Council of Governments
4. Susie Arnold, Island Institute
5. Don Witherill, Maine Department of Environmental Protection
6. Kristie Rabasca, Maine Water Environment Association
7. Bill Najpauer, Midcoast Economic Development District
8. Nancy Gallinaro, Portland
9. Scott Firmin, Portland Water District
10. Paul Collins, South Portland
11. Damian Brady, University of Maine (joined by Aaron Strong)
12. Steve Johnson, Yarmouth

Supported by:

- Curtis Bohlen, Casco Bay Estuary Partnership
- Matt Liebman, U.S. Environmental Protection Agency
- Marti Blair, Casco Bay Estuary Partnership
- Craig Freshley, Facilitator, Good Group Decisions
- Kerri Sands, Associate, Good Group Decisions

## Members of the Advisory Network

1. Nichole Price, Bigelow Laboratory for Ocean Sciences
2. Jared Woolston, Brunswick
3. Matt Craig, Casco Bay Estuary Partnership
4. Marjorie Stratton, Chebeague Island
5. Sean Mahoney, Conservation Law Foundation
6. Ralph Oulton, Cumberland
7. Bill Shane, Cumberland
8. Travis Kennedy, Cumberland County

9. Damon Yakovleff, Cumberland County Soil and Water Conservation District
10. Theo Holtwijk, Falmouth
11. Adam Bliss, Freeport
12. Mike Doan, Friends of Casco Bay
13. Michael Shaughnessy, Friends of the Presumpscot River
14. Steph Carver, Greater Portland Council of Governments
15. Andy Pershing, Gulf of Maine Research Institute
16. Mary Ann Nahf, Harpswell Conservation Commission
17. Nick Battista, Island Institute
18. Angie Brewer, Maine Department of Environmental Protection
19. Brian Kavanah, Maine Department of Environmental Protection
20. Rob Mohlar, Maine Department of Environmental Protection
21. Gregg Wood, Maine Department of Environmental Protection
22. Carl Wilson, Maine Department of Marine Resources
23. Beth Turner, National Oceanic and Atmospheric Administration
24. Esperanza Stancioff, Northeast Coastal Acidification Network
25. Amber Jones, Phippsburg
26. Doug Roncarati, Portland
27. Carrie Lewis, Portland Water District
28. Mark Green, Saint Joseph's College
29. Patrick Cloutier, South Portland
30. Fred Dillon, South Portland
31. Sean Smith, University of Maine
32. Susan Farady, University of New England
33. Joe Salisbury, University of New Hampshire
34. Jerre Bryant, Westbrook
35. Gretchen Anderson, Windham
36. Zach Henderson, Woodard and Curran
37. Barry Sheff, Woodard and Curran
38. Tom Connolly, Yarmouth

## About this Report

This report was prepared by CBEP staff for the Nutrient Council. Its purpose is to record the findings of the Nutrient Council; namely, what we know and agree on, what we still need to learn, and our recommendations for both near term and long-range actions to address nutrient pollution.

The structure of this report was designed by Curtis Bohlen with support from facilitator Craig Freshley. Work Groups made up of Council and Advisory Network members and others were formed in the areas of Science, Education, and Public Policy, and provided input for the report. Craig Freshley and Kerri Sands of Good Group Decisions helped Curtis Bohlen and Marti Blair prepare and finalize subsequent drafts of the report. Victoria Boundy and Jessica Stumper of CBEP assisted with information collection and presentation.