2010

2010 State of the Bay Report

Casco Bay Estuary Partnership

STATE OF THE BAY 2010







Casco Bay Estuary
PARTNERSHIP

Casco Bay Estuary Partnership

These are logos of organizations represented on the CBEP Board of Directors and a sampling of partners that work on behalf of Casco Bay.

STATE OF THE BAY 2010

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Residential development in the Casco Bay watershed (Maine Office of GIS)
Presumpscot River Youth Conservation Corps (Casco Bay Estuary Partnership)
Osprey (Chris DeSorbo, BRI)
Brook trout (USFWS)
Harvesting clams in Casco Bay (Mike Timberlake)
View of ferry, ship, and downtown Portland from Peaks Island (Origamidon)
Seagrass bed (www.SeagrassLI.org)

Back Cover Photograph:
Workers pose with thick blocks of ice on Sebago Lake circa 1920 (Maine Historical Society)

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OF THE BAY

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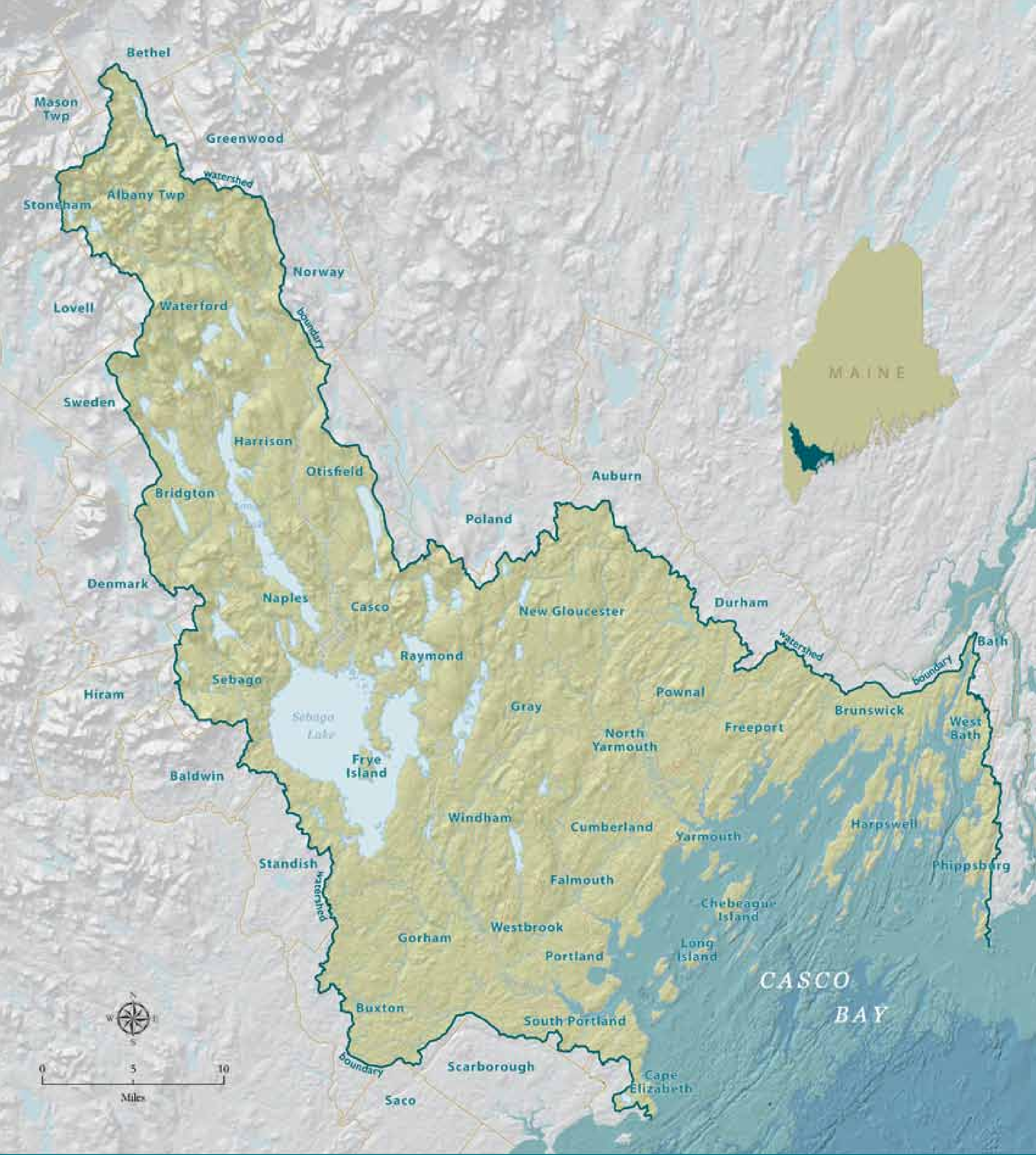


Casco Bay and Its Watershed

The watershed of Casco Bay is some 986 square miles in area (about 899 square miles of land and 87 square miles of inland waters). It comprises approximately three percent of Maine's land area, but in 2000 it was home to about 17 percent of Maine's population, a proportion expected to have increased for the 2010 Census. Forty-two municipalities and four counties are partly or wholly within the watershed, including some of the state's largest and fastest growing towns. The area contains major lakes, including Sebago Lake, which is the state's second largest and the source of drinking water for many area residents. The watershed also contains several significant river systems, including the Presumpscot, Stroudwater, and Royal.

SEPTEMBER 2010

Letter from the Director

How Is Casco Bay Doing?

That is probably the most common question I hear when someone learns where I work. I am never quite certain how to respond. While it is a simple question, there is no simple answer – certainly none that can be conveyed in a few seconds of polite conversation.

This report is an extended reply to that question. The answers here – as with most scientific answers – are limited and contingent. Limited because available information is always limited. Contingent because a reader's answers will depend on his or her interests (Migratory birds? Clam harvests?) and the baseline against which an individual compares current conditions (The 1600s? The 1960s?). Nonetheless, the 2010 *State of the Bay* report provides the most complete analysis we could assemble of the condition of Casco Bay and its watershed. The report is based on eighteen environmental indicators adopted by the Casco Bay Estuary Partnership to assess the environmental condition of Casco Bay and its watershed.

In the following pages, good news coexists with less positive trends: evidence for the continued health of the Bay alternates with hints of problems ahead. The watershed is still largely forested. Developed lands and impervious surfaces, both of which are hard on aquatic ecosystems, still represent a relatively small proportion of the watershed. Thus the region's lakes, rivers and coastal waters remain generally healthy and support robust tourism, recreation, and resource-based industries.

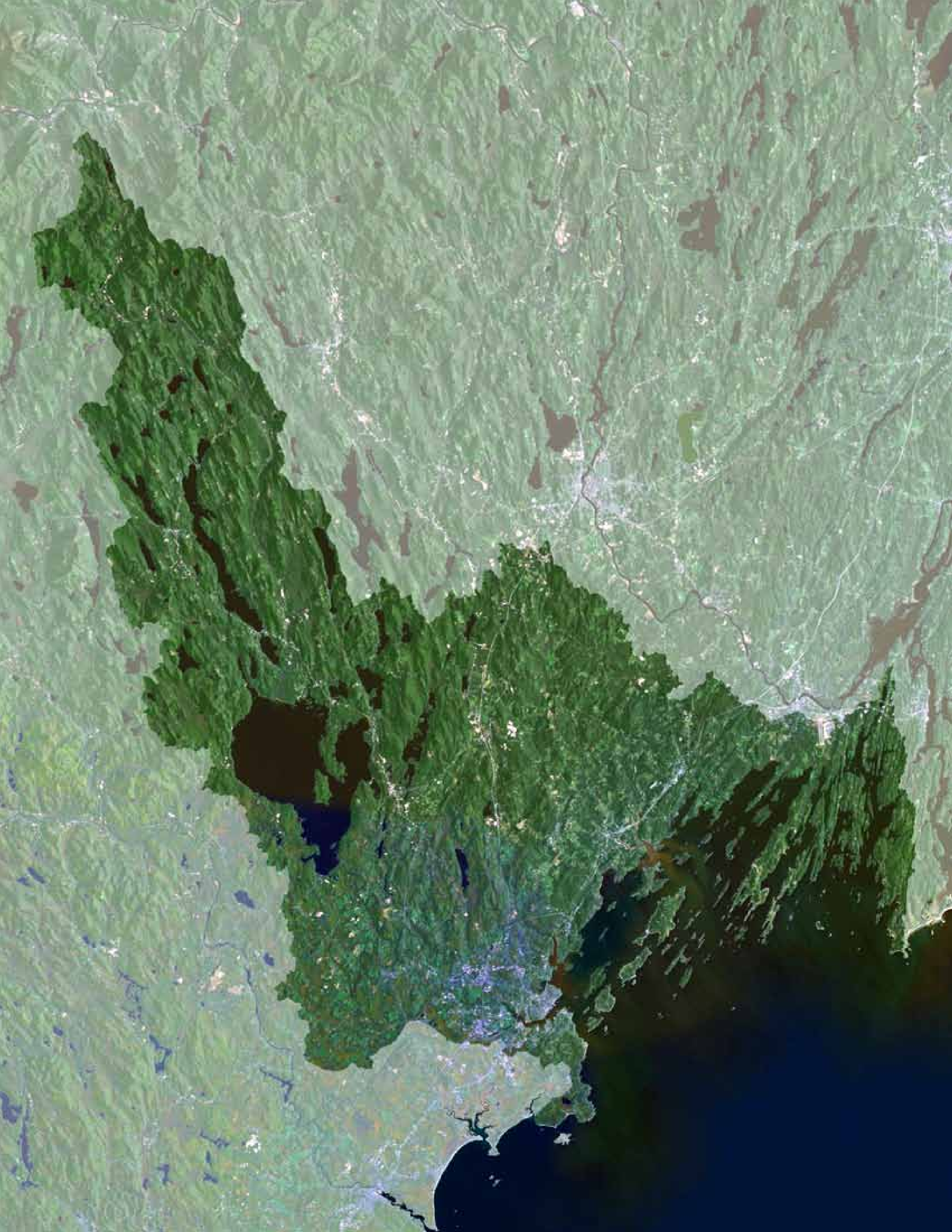
But the population of the region continues to grow, and that growth is concentrated in peripheral communities that were sparsely populated and rural a generation ago. That pattern of settlement changes the character of rural communities, and strains municipal and state budgets. It also risks degrading many of the natural characteristics – abundant wildlife, clean waters, and beautiful scenery – that attracted many residents to the watershed in the first place.

Some ongoing problems – urban runoff, combined sewer overflows, clam flat closures – have been central to the mission of the Casco Bay Estuary Partnership since its inception. Over the last decade, new issues have emerged. To address those, we have added new indicators to the fourteen addressed in the 2005 *State of the Bay* report: Contaminants of Emerging Concern; Invasive Species; and Climate Change. We have also added an indicator focused on Stormwater.

All of us at the Casco Bay Estuary Partnership look forward to your reactions to this report, as well as to new and continued collaboration with our partners on behalf of Casco Bay. Our collective challenge is to understand, strengthen, and protect the myriad ways that a healthy Casco Bay watershed contributes to the special sense of place that binds all those who live and work in this wonderful part of the world.

Sincerely yours,

Curtis C. Bohlen



SECTION ONE

Population, Land Use, and Watershed Impacts

Maine Office of GIS

Introduction

Many environmental stressors affecting the Bay and its watershed stem from gradual changes in population and land use. Even slowly growing populations require new housing, schools and other infrastructure. Under current development patterns, providing for those needs stresses aquatic ecosystems, forests, and rural landscapes. Expansion of road networks, for example, can decrease commuting times and improve commerce, but it also increases impervious surfaces, generates stormwater that can degrade streams, and creates new corridors for suburban sprawl. Without thoughtful planning, deterioration of water quality and fragmentation of rural landscapes can result.

The Casco Bay watershed is among the most densely developed in Maine. Although the watershed area represents only three percent of the state's total land mass, it holds nearly 20 percent of its population. As in many coastal areas around the United States, planners project that the region's population will continue to grow in the coming decades. The subsequent development will generate additional paved surfaces, roof tops, compacted soils, and other impervious surfaces. As urbanization pushes outward into formerly rural areas, it transforms and fragments the landscape, leading to habitat loss and water quality degradation.

It is difficult to measure how urbanization of the watershed affects Casco Bay, since many of the impacts from development occur as a result of nonpoint sources of pollution transported by stormwater. Although our population is distributed in varying densities across the region, the watershed acts like a funnel, channeling water and pollution and directing it downstream into rivers, streams, lakes, and bays that become the repository for stormwater and its contents. In some places in the watershed, the impact of stormwater is magnified because stormwater and sewage are mixed in combined sewers, and rainfall can cause untreated human waste to be discharged to rivers or the Bay.

Assessing how much the region has grown has limited value without also understanding how the region has grown. Where we grow, and how we grow, will have long lasting effects on the health of Casco Bay. Thus the four indicators in this section – population, impervious surface cover, stormwater and CSOs – provide a proxy of our current understanding of the impact that urbanization and stormwater are having on the health of Casco Bay. Together, the four are "drivers" behind many of the ecosystem indicators discussed in later sections.

USFWS Gulf of Maine Coastal Program/Bob Houston

INDICATOR 1

How has the population of the Casco Bay watershed changed over time, and how is it distributed?

Why Is Understanding Population Change Important?

Concern about impacts of the building boom of the 1980s was a primary factor in Casco Bay's designation as an estuary of national significance in 1990. Since then, the coast of southern Maine has continued to attract new residents. That phenomenon is not new: for much of the nation's history, more than half its population has resided along its coasts (Beach 2002). Many of us live in this region because we value the natural communities of Casco Bay and the landscapes and waterways which together form the Casco Bay watershed. The coast is a cornerstone of Maine's economy, providing jobs, food, and ecosystem services.

Reviewing how the region's population has changed over time and projecting how it will grow in the future helps to illustrate a fundamental driving force behind the expansion of transportation, housing, stormwater, sewer, and other built infrastructure throughout Casco Bay's watershed. Tracking population change helps planners and government officials understand how communities have changed over time, as well as to forecast how they will change in the future. Such information enables more carefully planned development.

Status and Trends

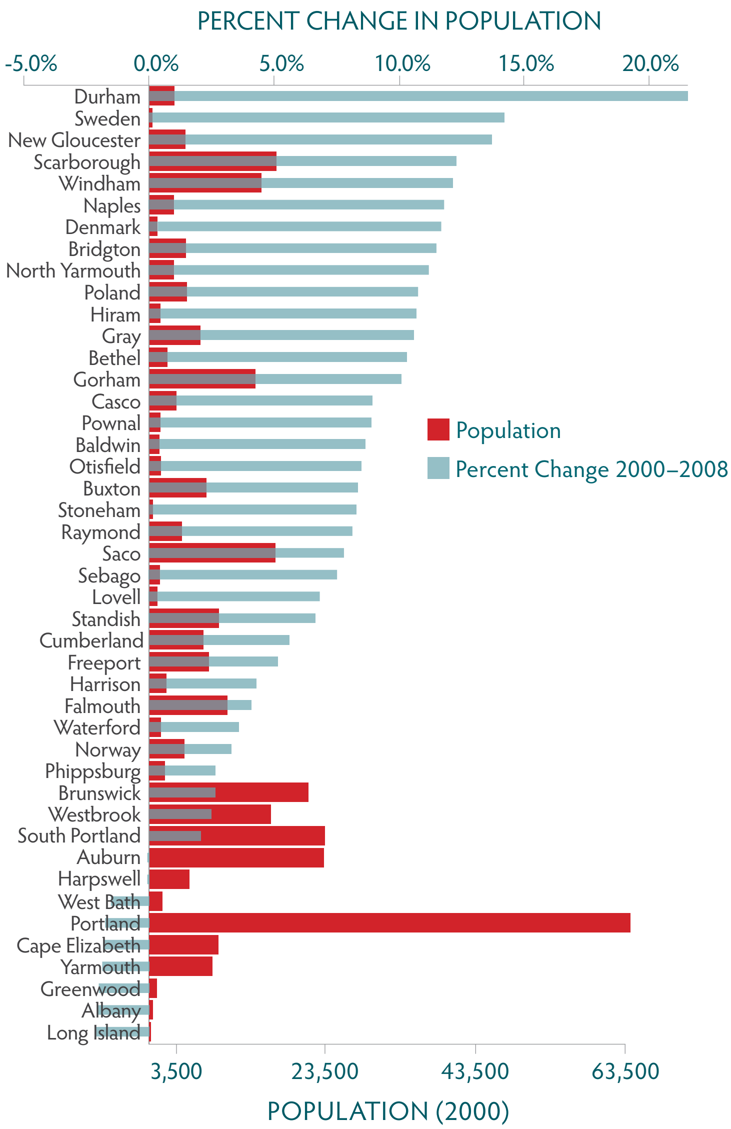
The National Oceanic and Atmospheric Administration (NOAA) estimates that over 50 percent of the nation's population lives in coastal areas that represent just 17 percent of the total land area of the lower 48 states, resulting in higher population density within coastal areas. That density often results in urban sprawl, which typically means an increase in the amount of impervious surfaces, as well as a greater dependence on personal automobiles.

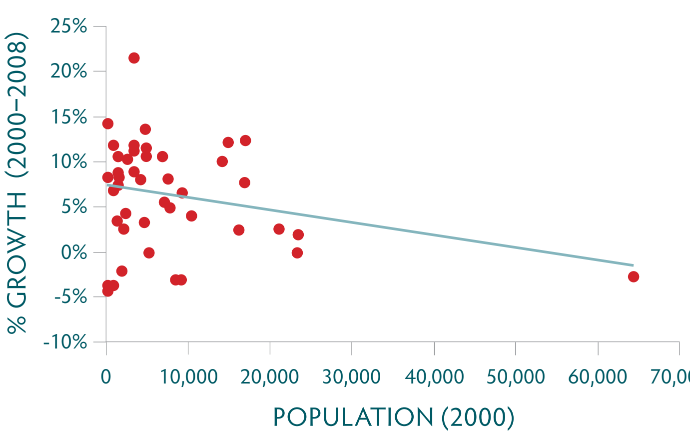
In Maine, the decennial U.S. Census is the fundamental source of data about population growth and density. The Maine State Planning Office (SPO) and regional planning commissions supplement those data with information on building permits and other data to project future population change.[1]

New and longtime residents alike value the coast of southern Maine, yet population growth and intensive use of land can have a direct impact on Casco Bay and its watershed.

The land around Casco Bay, like much of Maine's coast, continues to attract new residents. Planning entities, including the Greater Portland Council of Governments (GPCOG) and Maine SPO, project that the region's population will continue its recent growth trend, particularly in suburban and rural areas. According to SPO population estimates, Bethel, Bridgton, Denmark, Durham, Gorham, Gray, Hiram, Naples, New Gloucester, North Yarmouth, Poland, Scarborough, Sweden, and Windham were estimated to have population growth rates above 10 percent between 2000 and 2008, equal to an average growth rate of over one percent per year. In 2000, Cumberland County had an estimated 109,822 housing units. By 2008, the total was estimated to have increased to 118,553 units, a jump of eight percent in eight years. Conversely, over the same time period, the regional hubs of Portland, South Portland, and Brunswick were estimated to experience low to no population growth, consistent with local longer term trends. For example, in 1950, the population of the Portland peninsula was 43,433, one third of the county's population. In 2010, 23,168 people lived there (GPCOG 2010). Although the peninsula remains densely developed compared with nearby communities, fewer people now live in each housing unit. Low growth rates in urban areas are being offset by increases in neighboring bedroom municipalities, expanding the footprint of development into former farm and forest lands in the watershed.

[1] 2010 Census data were not available at the time this report went to press, therefore all the population projections and estimates are based on data from 2000. Neither do any of the reports referenced in this section address recent declines in the state or national economies.



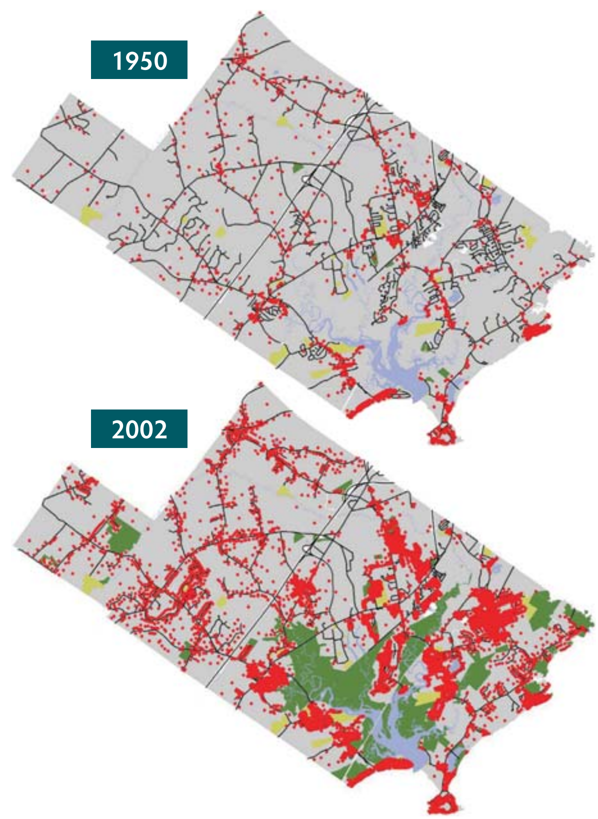


Data for both graphs: Maine State Planning Office population projections; 2000 US Census.

Regional planners estimate that by 2025, Cumberland County will require an additional 26,625 housing units to accommodate projected population growth.

As such growth transpires, careful planning will be extremely important. Scarborough's 2006 Comprehensive Plan update compared the town's residential housing units in 1950 with those in 2002, and illustrated a typical pattern of how unplanned suburban growth can transform rural communities. According to the study, Scarborough's rapid development did not incorporate village areas historically used as town centers, leaving "...little relationship to traditional patterns, spreading whenever tracts of land were available in the marketplace." Many of the region's rural communities will face those same development pressures in coming decades.

The 2006 *Charting Maine's Future* report by The Brookings Institution puts local trends into a broad context. Brookings found that between 2000 and 2005, about 60 percent of all new housing units built in Cumberland County were located outside of the traditional population centers of Portland, South Portland, Westbrook, Scarborough, Freeport, Brunswick, and Bridgton. The study reports that suburbs and rural areas are the primary locations of growth, and that as a whole, southern Maine's regional hubs no longer contain the majority of the region's residents.



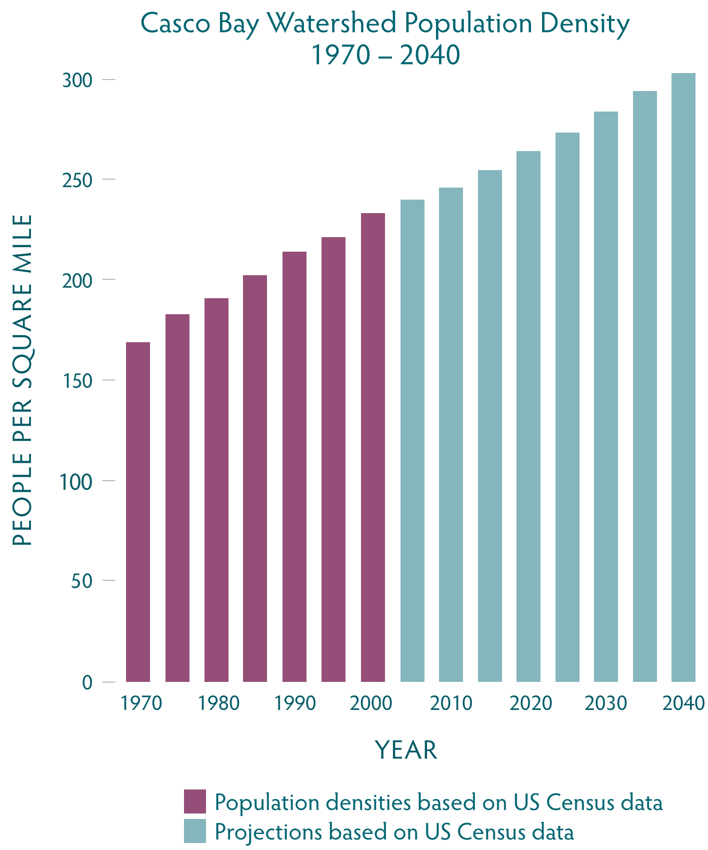
These maps of Scarborough's housing units (red) in 1950 and 2002 illustrate how quickly and extensively suburbanization has transformed some communities.

Source: *2006 Update of the Comprehensive Plan*

Brookings also found that the population of southern Maine is growing at a faster rate than the nation as a whole.

In a related 2006 background study, GrowSmart Maine, working with GPCOG and other regional planning commissions, conducted a build-out analysis of the Portland Metropolitan Statistical Area "service center" communities of Portland, South Portland, and Westbrook, to determine whether there is sufficient inventory of land and properties to absorb the employment and residential growth projected for the Portland Labor Market by 2025. GPCOG concluded that, with few exceptions, there is enough land available in those communities to accommodate projected growth. In an accompanying statewide analysis of development capacity, GrowSmart Maine reported that Portland, South Portland, and Westbrook will experience only a small increase in total housing units, while surrounding communities could show 15 percent to 20 percent increases. Although regional service center communities could accommodate future growth, under existing development patterns, they won't. Planners and municipal officials will need to implement newer, smarter growth strategies to meet development challenges.

Another way to look at regional population change is to consider the watershed boundaries, rather than municipal and county lines. Although neither the Census nor the state tracks population data at the watershed scale, NOAA has developed a tool to analyze population in the watersheds of estuaries of national significance. Using a modeling



Source: Woods & Poole via NOAA Spatial Trends in Coastal Socioeconomics (STICS) Population Data. Population projections based on 2000 US Census data.

Vehicles and Population

The watershed's increasing population means more vehicles as well, which increases the use of – and need for – transportation infrastructure. Vehicles are a source of greenhouse gas (carbon dioxide) emissions and toxic pollutants (see Section 4, Toxics, and Section 7, Climate Change). However, not only are new residents of the watershed bringing in new vehicles, resulting in a net increase in the number of vehicles registered and in use, the actual number of vehicles per capita has also increased, consistent with national trends. A review of Maine Bureau of Motor Vehicle data for Cumberland County between 2000 and 2009 shows that the overall number of registered vehicles per capita (not including trailers) was .87 vehicles per person in 2000, and .90 vehicles per person in 2009, an increase of more than three percent. Although the population of Cumberland County was estimated to have grown by 12,531 people – an increase of .47 percent a year – over that span, the number of registered vehicles increased by 17,681, an average increase of .76 percent per year. Over the last decade, increase in vehicle registrations in Cumberland County outpaced population by 41 percent.

Transfer of Development Rights can be a tool to protect rural landscapes, which face constant development pressure as the region's population continues to expand outward from regional hubs.

technique to interpret 2000 Census data, NOAA estimates that the Casco Bay watershed's current population is approximately 240,000 people, with an equivalent population density of 245 people per square mile. Between 2000 and 2009, NOAA estimates that the watershed has added about 10,000 people, an increase of 4.3 percent. NOAA forecasts that the population density of the watershed will approach 300 people per square mile by 2040.

Solution and Actions

As the region grows, planning tools such as smart growth and Low Impact Development will continue to play important roles in helping communities to absorb new development. One promising innovation is the concept of Transfer of Development Rights (TDRs), a market-based planning tool with the potential to affect regional development patterns. TDRs work to purchase land in rural "sending" areas and transfer development rights to targeted "receiving" areas at a higher density than would typically be permitted under standard zoning ordinances. Nationwide, support for the concept is growing (Beginning with Habitat 2010).

To date, only a few Maine municipalities use TDRs, but the Town of Gorham began to employ the idea when it updated its land use ordinances in 2006. Gorham's Development Transfer Overlay District is designed to concentrate development in the Village and Little Falls areas at the town's core, and preserve outlying rural areas. By encouraging density where public water and sewer infrastructure is already present, officials and planners believe they can maintain the town's rural character.

Particularly if applied at a regional scale, TDRs have the potential to be effective tools for accommodating development that allows for continued growth while maintaining quality of place.

References

Beach, Dana. 2002. *Coastal Sprawl: The Effects of Urban Design on Aquatic Ecosystems in the United States.* Pew Oceans Commission. http://www.pewtrusts.org/our_work_report_detail.aspx?id=30037.

Beginning with Habitat. 2010. Land Use Ordinance Tools. http://www.beginningwithhabitat.org/toolbox/land_tdr.html (Sept. 8, 2010).

Brookings Institution Metropolitan Planning Program. 2006. *Charting Maine's Future: An Action Plan for Promoting Sustainable Prosperity and Quality Places.* http://www.brookings.edu/reports/2006/~/media/26ECCD724E67440DA027B12C0230715D.ashx

The Brookings Institution. 2006. *Charting Maine's Future: An Action Plan for Promoting Sustainable Prosperity and Quality Places – A Profile of Southern Maine: Cumberland and York Counties.* http://www.brookings.edu/metro/pubs/maine/southern.pdf

Greater Portland Council of Governments. Unpublished housing start data, C. Paras. March 2010.

Greater Portland Council of Governments. 2006. *Portland-South Portland-Westbrook Build-Out Analysis.* Unpublished background report.

GrowSmart Maine. 2006. *State of Maine Selected Service Center Development Capacity Analyses.* http://www.brookings.edu/~/media/Files/rc/reports/2006/10cities/capacity.ashx

Maine Bureau of Motor Vehicles. http://www.maine.gov/sos/bmv/stats/statistics09.htm (May 26, 2010).

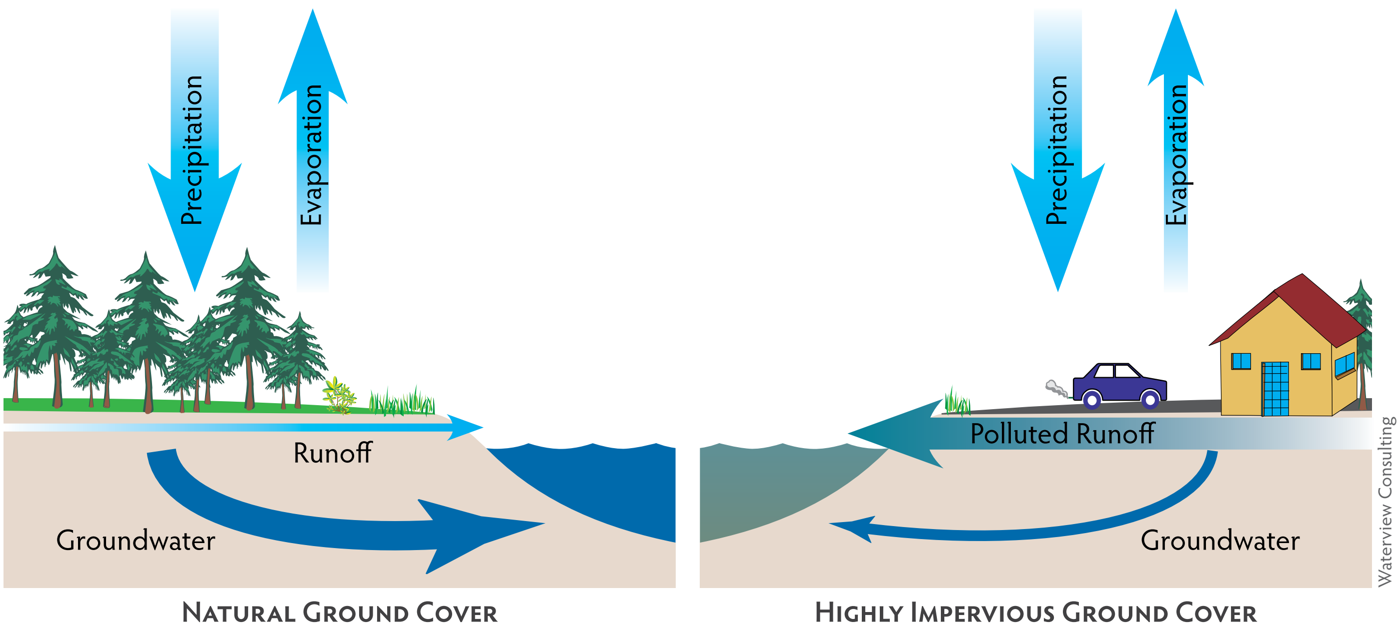
Maine Development Foundation. February 2010. *Measures of Growth in Focus: Performance Measures and Benchmarks to Achieve a Vibrant and Sustainable Economy for Maine.* Maine Economic Growth Council.

National Oceanic and Atmospheric Administration. Spatial Trends in Coastal Socioeconomics. http://marineeconomics.noaa.gov/socioeconomics/tools.html (May 7, 2010).

Town of Scarborough. July 2006. *2006 Update of the Comprehensive Plan.* http://www.scarborough.me.us/planning/documents/2006_update_comp_plan.pdf

INDICATOR 2

How much of the Casco Bay watershed is covered by impervious surfaces?



The effects of impervious cover on the water cycle include reduced infiltration to groundwater, increased runoff, and less evaporation.

Why Is It Important to Monitor Impervious Cover?

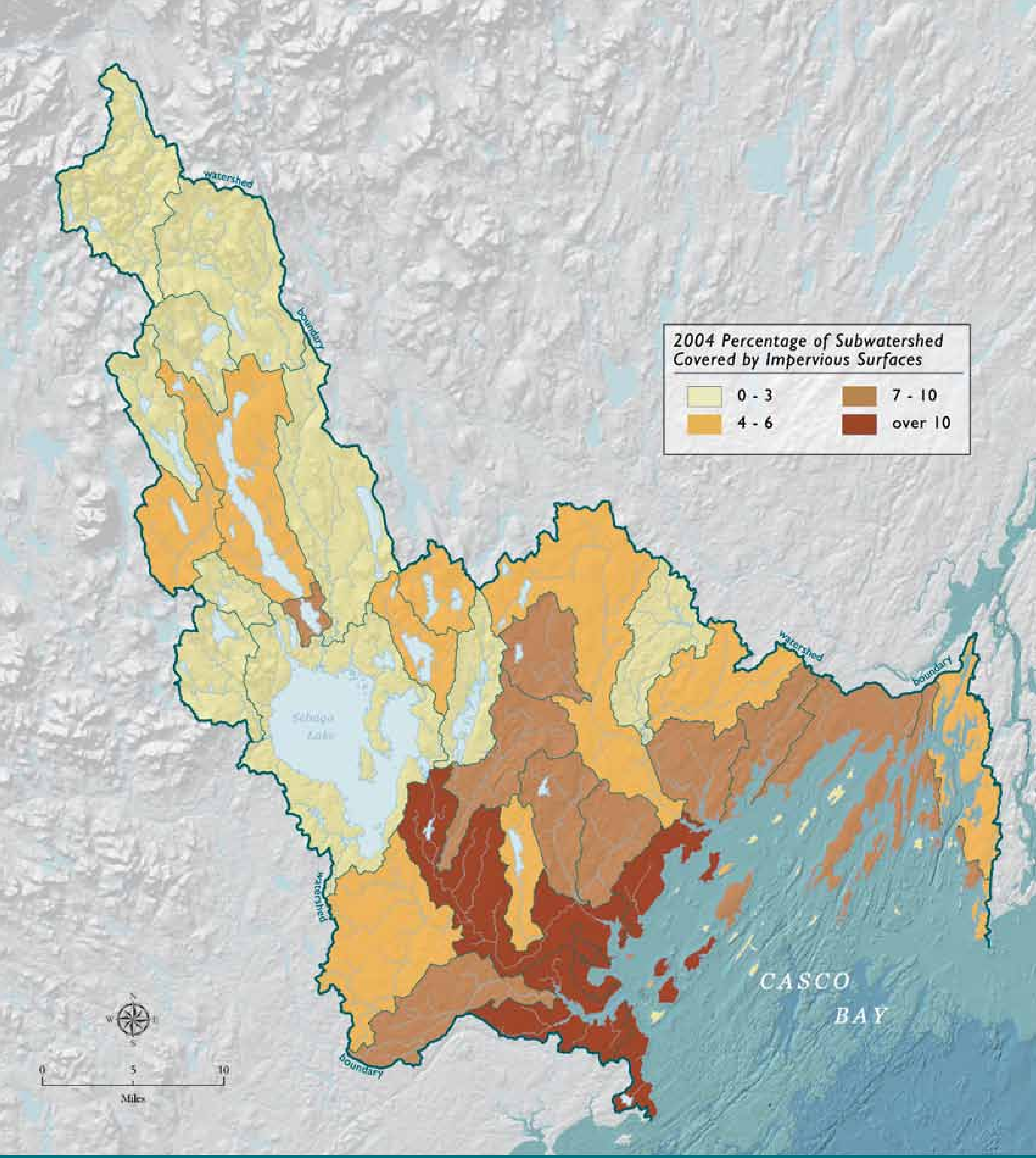
As population densities increase around Casco Bay, formally rural areas become increasingly urbanized, resulting in extensive impervious surface cover. Impervious surfaces - any material or structure on or above the ground that prevents water from infiltrating through the underlying soil – include paved parking lots, sidewalks, roof tops, driveways, patios, and paved, gravel and compacted dirt surfaced roads (Horsley Witten 2007). Rainwater and snow melt that falls onto an impervious surface collects contaminants, sediments, and debris before entering stormwater drainage systems and discharging to downstream waters, including Casco Bay. Impervious surfaces increase pollutant loads, exacerbate erosion and sedimentation, and increase both the volume and the velocity of stormwater runoff into rivers and streams. The *Casco Bay Plan* points to stormwater as being the single greatest contributor of contaminants to Casco Bay.

The Maine Department of Environmental Protection (DEP) has determined, based on research in Maine as well as other parts of the country, that there is a relationship between the percent impervious area of a watershed, and the water quality of the water body to which the watershed drains. Detrimental impacts to stream communities occur where impervious surfaces cover more than about 10 percent of a watershed's area. Therefore, percent impervious cover within a watershed is increasingly used as an indicator of the intensity of development and the degree to which development is impacting water quality.

Status and Trends

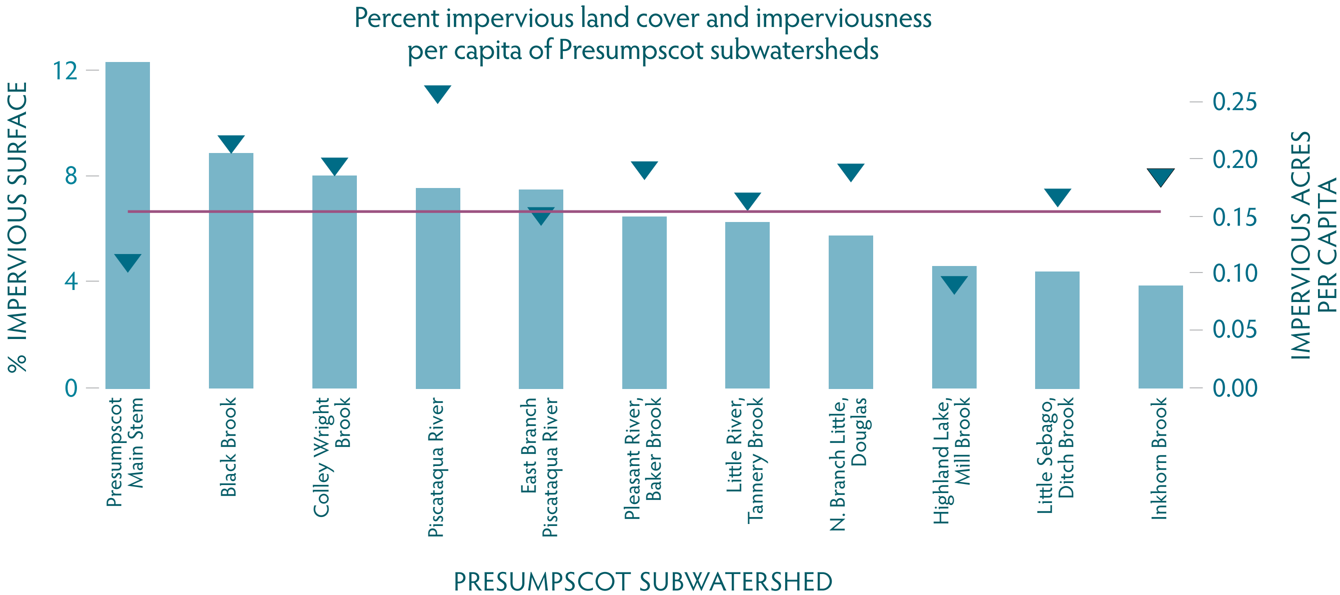
The best and most recent high resolution assessment of impervious surface cover was developed in 2004 by Maine DEP based on five-square-meter resolution SPOT satellite imagery. The dataset was previously used to present impervious surface area in the 2005 *State of the Bay* report. At that time, the impervious surface area of the Casco Bay watershed was calculated to be about six percent, the equivalent of 57.9 square miles.

In 2010, CBEP staff recalculated impervious area to include the Bay's largest islands, and there was no significant change to the overall impervious surface cover. Casco Bay's coastal subwatersheds were broken into separate drainages to reflect the geography of the coastline, so that watersheds of distinct features such as bays were distinguishable. The Back Cove watershed in Portland (52 percent), and the Fore River watershed in Portland and



Impervious Surfaces by Subwatershed

Data: Maine DEP 2004 LandSat imagery.



Bars: Percent impervious cover. Triangles: Impervious acres per capita. Line: Impervious acres per capita for Casco Bay watershed as a whole. Sources: MEGIS; Per capita data are estimates based on analysis of US Census data by R. Mosher.

South Portland (34 percent), contain the highest percent impervious covers of any Casco Bay's HUC 12 subwatersheds. With the exception of the Cousins River and the New Meadows River watersheds, Casco Bay's coastal watersheds, as well as the Stroudwater River watershed, are at or above eight percent impervious surface cover.

Casco Bay's major freshwater watersheds remain slightly less impervious than coastal areas. The Royal River watershed, and those of its tributaries, remains below eight percent. However, the watershed for the main stem of the Presumpscot River exceeds 12 percent, and the Presumpscot's tributaries are close behind, with both Black Brook and Wright Brook watersheds at more than eight percent. A comparison of impervious surface area per capita with impervious surface area within the Presumpscot subwatersheds shows that the two are distinct measurements. Along the main stem of the Presumpscot River, where population density is greater than in surrounding rural areas, and impervious surface coverage is highest (in part due to the presence of Westbrook along the main stem), the estimated effective impervious surface per capita is actually lower (.11 impervious acres per person) than that of Inkhorn Brook's subwatershed (.18 impervious acres per person), despite the fact that impervious surfaces cover only 3.9 percent of the land area there. For sake of comparison, estimated impervious surface cover per capita for the entire Casco Bay watershed is .154 acres per person. Although that analysis of impervious surface per capita is based on population estimates only, the results provide insight into how land consumption patterns differ across the landscape, and can be traced to the types of development (*e.g.*, residential, commercial, industrial).

Solution and Actions

Maine NEMO

Maine NEMO (Nonpoint Education for Municipal Officials) works closely with municipal planning boards and other groups to provide information about the impacts of development and land use change on water quality. NEMO also provides tools for local officials to protect water by addressing stormwater pollution through planning, site design, and treatment strategies. (For information about NEMO presentations, see www.mainenemo.org.)

Interlocal Stormwater Working Group

As part of national and state mandated stormwater permitting requirements, the Interlocal Stormwater Working Group (ISWG), comprising14 municipalities within Cumberland County and the Casco Bay watershed, is working collaboratively to address stormwater pollution. Six programmatic areas are addressed: public education and outreach on stormwater impacts; public participation; illicit discharge detection and elimination; runoff from construction sites; post-construction management; and pollution prevention/good housekeeping. (Additional information about ISWG is available online at www.cumberlandswcd.org/stormwater.)

Low Impact Development

Low Impact Development (LID) approaches to managing stormwater are increasingly being recommended by state and federal agencies for use in new developments. The goal of LID is to reduce the volume of stormwater runoff from a developed site in a way that mimics the way water flowed through the site before it was developed. LID techniques can take the shape of best management practices

(*e.g.*, shared driveways to minimize impervious surfaces) or physical structures that are designed to maintain pre-development hydrology, primarily by directing stormwater back into the ground through infiltration. Examples of physical LID design elements include rain gardens, pervious pavement, green roofs, rain barrels, tree box filters, and gravel wetlands. By approximating the "natural" hydrology of a site, LID helps to reduce the impacts that stormwater has on receiving water bodies, both in terms of water quality (reducing pollution), and water quantity (flooding).

Tree box filters. In certain soil and site conditions, tree box filters, which direct stormwater runoff from impervious surfaces for uptake by trees or shrubs, can be useful as aesthetically pleasing tools to infiltrate, treat, and take up stormwater runoff. With partial funding provided by CBEP, the Town of Brunswick installed tree box filters to help absorb and filter stormwater runoff at curb cuts along Maine Street.


Green roof at the East End School in Portland.

Green Roofs. Demonstration sites for green roof technology have been constructed in several places around Casco Bay, although information about their performance and maintenance needs is limited. A small green roof was installed on top of the University of Southern Maine's new LEED – Gold certified Wishcamper Center. In addition to its aesthetic benefits, the Wishcamper green roof drains water into a cistern that provides water for toilets throughout the facility. A similar modular green roof was built on Portland's East End School.

Subsurface Gravel Wetland. The University of New Hampshire Stormwater Center tests new and existing stormwater mitigation structures and practices, including several LID approaches, and studies their effectiveness at mitigating stormwater runoff. The center has provided information about the performance and maintenance of different structures year round, with particularly valuable insights about cold climate performance. One of the LID structures evaluated at UNH, subsurface gravel wetlands, was found to be particularly effective at removing pollutants and reducing peak flows (quantity) of stormwater following rain or snow melt. A combination of crushed rock, wetland soils, piping, and vegetation, subsurface gravel wetlands, and other bioretention systems, are recommended in the Maine Coastal Program's LID Guidance Manual for Maine Communities. (Additional information about the UNH Stormwater Center can be found at www.unh.edu/erg/cstev.)

Following a heavy downpour, stormwater runs off conventional pavement (at right), while the porous pavement sidewalk (at left) has no standing water.

Porous pavement. Porous pavement is a LID design that mimics the performance of standard asphalt for transportation purposes, while infiltrating stormwater runoff to protect water quality. Porous pavement applications are in place in several locations around Casco Bay, including Maine Mall Road in South Portland, at the Wishcamper Center, and at the Freeport Community Center.

References

Casco Bay Estuary Partnership. 1996, update 2005. *The Casco Bay Plan.* http://www.cascobay.usm.maine.edu/cbplan96.html

Center for Watershed Protection. 2003. *Impacts of Impervious Cover on Aquatic Systems.*

Horsley Witten Group. 2007. *LID Manual for Maine Communities: Approaches for implementation of Low Impact Development practices at the local level.* http://www.maine.gov/dep/blwq/docwatershed/materials/LID_guidance/manual.pdf

Maine Department of Environmental Protection. *Imperviousness of a watershed.* http://www.maine.gov/dep/blwq/docstand/stormwater/impervious.htm

Maine NEMO Program. *Fact Sheet #3: Impacts of Development on Waterways.* http://www.mainenemo.org/publication/NEMOfact3.pdf

Morse, C. and S. Kahl. 2003. *Measuring the Impact of Development on Maine Surface Waters.* http://www.umaine.edu/waterresearch/outreach/pdfs/Stream%20Digest.pdf

INDICATOR 3

What is the quality of stormwater entering Casco Bay and its watershed?

CBEP Goal: Minimize the loading of pathogens, toxics, nutrients, and sediments from stormwater and combined sewer overflows to Casco Bay.

Why Is It Important to Monitor Stormwater?

It is sometimes difficult to accept that stormwater runoff could degrade local streams and transport pollutants to Casco Bay. Rainfall has an only partially deserved reputation for purity. Indeed, when rain falls on urban or suburban lands, it can cause water quality problems downstream.

"Stormwater" is a term of art used to refer to surface water and water in drainage systems that flows during and soon after rain events. It washes pollutants from urban and suburban lands, and transports them to streams, lakes, and the Bay.

Automobiles are a significant source of those pollutants, which are often concentrated in runoff from roads and parking lots. Metals are released into the environment as brakes wear out. Oil leaks from engines, transmissions, and hydraulic systems. Exhaust adds a complex mix of pollutants, especially rich in toxic polycyclic aromatic hydrocarbons (PAHs). Newly paved roads are another source of PAHs.

CDOT

Oil entering a storm drain.

Compared with runoff from forests and wetlands, urban stormwater tends to accumulate toxics, nutrients, sediments, and pathogens. Toxic compounds can come from: use of pesticides or lawn chemicals; spills or improper disposal of industrial chemicals; and material washed out of dumpsters, among other sources. Nutrients that can fuel growth of aquatic algae can come from eroding soils, misuse of fertilizer, or failing septic tanks. Bacteria and pathogens stem from failing or poorly maintained private waste treatment systems (*e.g.*, septic tanks, overboard discharges), from combined sewer overflows, and from pet and livestock waste.

Status and Trends

While the presence of a variety of pollutants in stormwater has been well documented in studies nationwide, two recent studies offer data about toxic chemicals in stormwater in the Casco Bay region.

EPA Study

A 2008 US EPA report revealed the prevalence of heavy metals and PAHs in stormwater from 21 sites in Portland and South Portland, which were sampled in 2006.

Metals. Metals of potential concern were observed at all sites. Comparison with federal water quality criteria (US EPA 2009) shows that the concentrations of most metals observed in Portland and South Portland stormwater were generally below federally suggested standards for protecting both drinking water and freshwater ecosystems. Several samples showed concentrations of zinc and copper above state guidelines for protection of aquatic ecosystems. Zinc is widely used as a coating (*e.g.*, "galvanized" fasteners), or for sacrificial anodes to protect steel from corrosion. Copper is used in automotive components, and is released into the urban environment primarily due to wear.

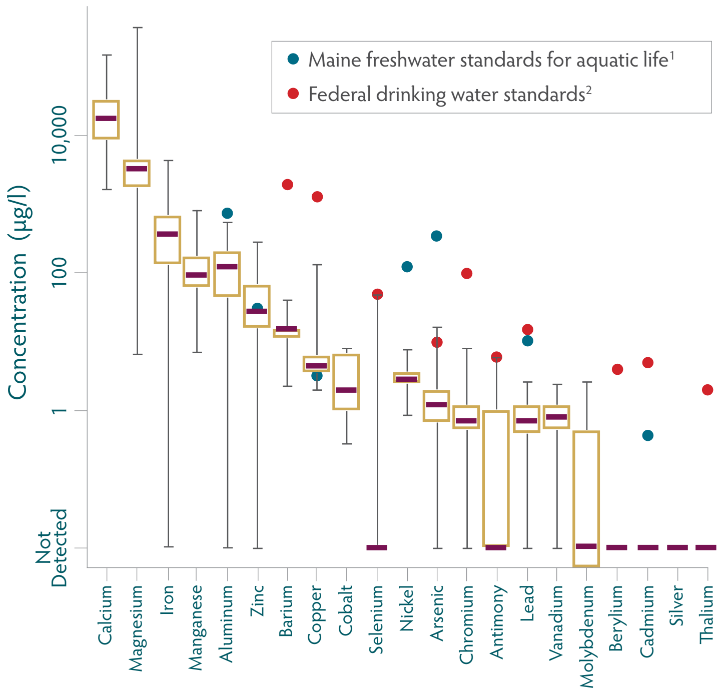
Polycyclic Aromatic Hydrocarbons. PAHs were detected at about one half of all sites tested. A characteristic group of PAHs was often found together, at about a quarter of all sites tested. That consistent PAH "fingerprint" suggests a common source of detectable levels of PAHs, possibly derived from recent paving operations, or application of pavement sealers. No relevant aquatic life criteria for PAHs are available, but when PAHs were present, levels were generally well above drinking water standards.

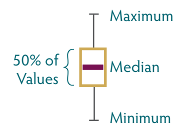
Pesticide Surveys

The Maine Board of Pesticides Control (BPC), working in association with Friends of Casco Bay, has been sampling surface waters in the Portland area since 2001 looking for a variety of pesticide residues. Pesticides have been found in area streams, sometimes at concentrations above federal aquatic life criteria. Detected pesticides include compounds commonly used in lawn care and on golf courses.

Most of the compounds found are not thought to persist for long periods in the environment, so detection probably reflects application somewhere upstream a few days to weeks before sampling. If that is the case, elevated levels may occur sporadically throughout the growing season. It is difficult to know just how frequently streams face elevated levels of pesticides without much more extensive sampling.

Metals in Stormwater in Portland and South Portland





"Box and Whisker Plots" of concentrations of various metals observed in 21 stormwater samples collected in Portland and South Portland during spring of 2006. The vertical axis is a logarithmic scale. Many stormwater samples exceeded aquatic life criteria for zinc, copper, or both. Copper and zinc are commonly found at elevated levels in stormwater nationwide.

Pesticides in Surface Water of Casco Bay

Pesticide	Primary Use	Maximum Concentration Observed (ppb)	Maximum Exceeds Aquatic Life Criteria
Diazinon	Organophosphate insecticide	2.6	✓
2,4-D	Herbicide	36.4	✓
Dicamba	Herbicide	4.1	
MCPP	Herbicide	26.0	✓
MCPA	Herbicide	0.45	
Clopyralid	Herbicide	0.91	
Propiconazole	Fungicide	0.07	
Chlorothalonil	Fungicide	0.22	

Pesticide residues detected in surface water samples from the Casco Bay region 2001-2008 (only highest concentration shown). Pesticide residues have sometimes been found at concentrations of concern. (See also sidebar in Indicator 10.)

[1] Maine's ambient water quality standards from Maine DEP 2005. Some standards depend on water hardness; values were calculated assuming a hardness of 20 mg/l.

[2] Federal drinking water standards from US EPA 2008.

Solution and Actions

The best approach to reducing pollutants in stormwater is to address them at their source by releasing fewer toxic compounds into the environment, or by removing them before they enter the water. Toxic chemicals and other pollutants enter stormwater because they are present in the urban environment as a result of human activity. Use of lawn chemicals, for example, brings with it the potential for those chemicals to find their way into surface waters. Many PAHs find their way into the environment because of a heavy reliance on automobiles for transportation.

Several public education campaigns encourage area businesses and residents to make choices that can reduce releases of pollutants into stormwater. Those include Friends of Casco Bay's Bayscaping program, the Board of Pesticides Control's Yardscaping Partnership and the statewide "Think Blue" media campaign, which has many partners, including CBEP, Maine DEP, and the Cumberland County Soil and Water Conservation District. Think Blue is funded largely by municipalities. Such programs emphasize actions that can be taken by individuals to reduce pollutants in stormwater.

Federal and state permit programs under the Clean Water Act require many industrial enterprises, large municipalities, and a few commercial businesses to take steps to reduce pollution in stormwater. Those include practices such as spill prevention, and response plans for organizations handling toxic materials. Another important strategy is placing sources of pollutants such as dumpsters or automobile maintenance areas out of the weather, or in areas where spills can readily be contained. In some cases, vacuum sweeping of road and parking lot surfaces can remove pollutants before they find their way into streams. Finally, a variety of engineered and structural solutions (discussed in more detail under Indicator 2) can help trap pollutants before they reach the waterways.

References

United States Environmental Protection Agency. 2008. *Wet Weather Water Quality Study, Portland and South Portland, Maine.* Project Report, December 2008. Region I, New England. Office of Environmental Measurement and Evaluation, Ecosystem Assessment Unit.

Maine Department of Environmental Protection. 2005. Chapter 584: Surface Water Quality Criteria for Toxic Pollutants. 06-096 *Code of Maine Rules* Chapter 584. http://www.maine.gov/sos/cec/rules/06/096/096c584.doc

United States Environmental Protection Agency. 2009. *National Recommended Water Quality Criteria.* United States Environmental Protection Agency, Office of Water, Office of Science and Technology. http://www.epa.gov/ost/criteria/wqctable

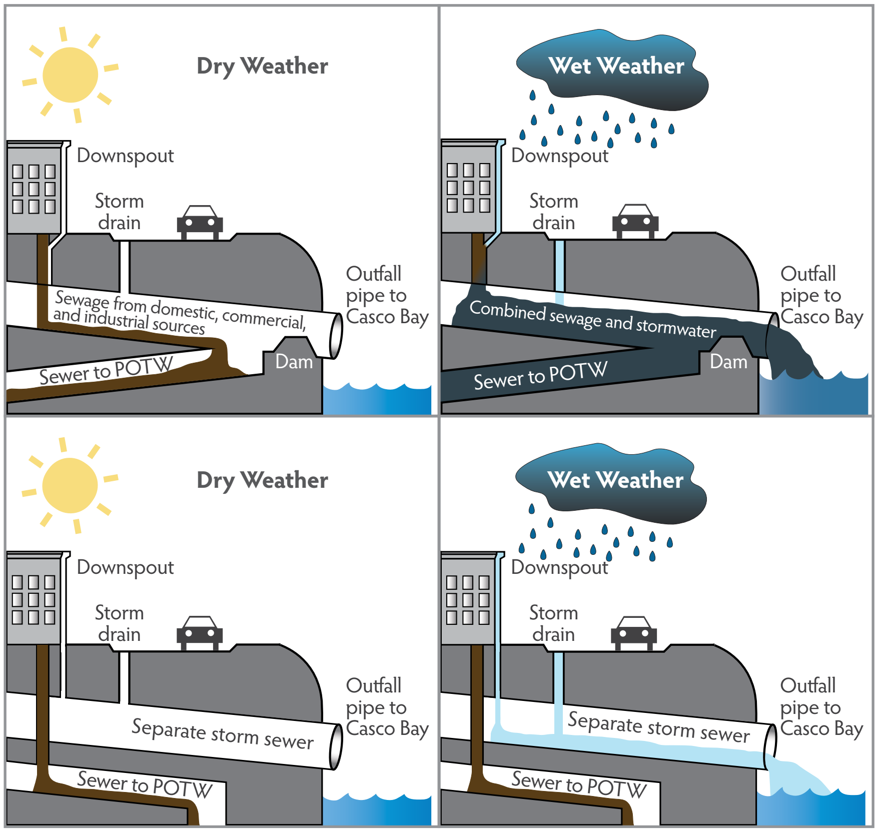
Are combined sewer overflow discharges in Casco Bay declining?

CBEP Goal: Minimize the loading of pathogens, toxics, nutrients, and sediments from stormwater and combined sewer overflows to Casco Bay.

Why Is It Important to Monitor Combined Sewer Overflow Discharges?

When a community's sanitary waste and stormwater runoff flow in the same underground pipes, the system is called a combined sewer. During rainfall events, stormwater can overwhelm the capacity of such sewers or sewage treatment plants, causing direct discharge of untreated sewage mixed with stormwater into Casco Bay waters. Such discharges are called combined sewer overflows (CSOs), a term that refers both to the locations at which such events occur, and to the events themselves.

Typical of older cities nationwide, Portland and some surrounding communities laid only a single set of pipes when their wastewater infrastructures were established more than a century ago. Those pipes serve two purposes: carrying human waste – sewage– away from individual homes; and transporting stormwater runoff away from communities. While combined sewers reduced the initial costs of establishing urban water infrastructure, the resulting plumbing system has distinct disadvantages. When wastewater treatment plants or underground pipes lack the capacity to handle the volume of water from a storm, wastes such as pathogens, nutrients, toxic chemicals, and pharmaceuticals are discharged directly to coastal waters. However, a combined sewer system does provide limited treatment for the pollutants in stormwater from small volume storms, which would otherwise flow untreated to the stormwater system and into the receiving waters (see diagram).

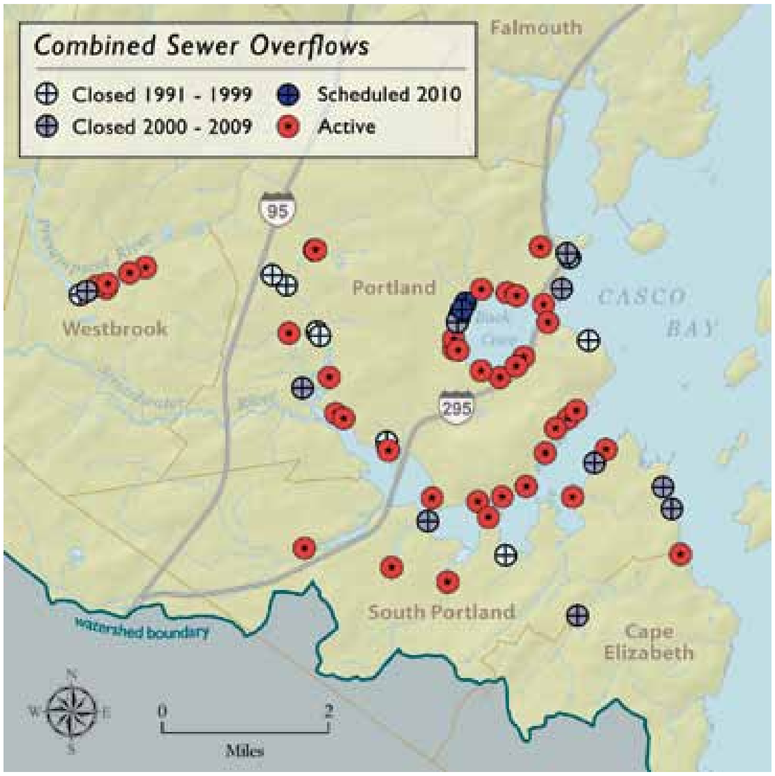


How Combined Sewer Systems Work. During rain events, stormwater in combined sewer systems (upper panels) is mixed with runoff, which can generate enough water to overwhelm sewer systems or sewage treatment systems, leading to discharges to surface waters. In separated systems (lower panels), runoff and sewage are never mixed, eliminating the problem. "POTW" is publicly owned treatment works.
Illustration by Waterview Consulting adapted from EPA

Unfortunately, traditional solutions to the CSO problem, while conceptually straightforward, don't come cheap. The prospect of re-plumbing an entire city to provide separate pipes for stormwater and human waste is daunting, and such fully separated systems typically provide no treatment for stormwater pollutants. Less comprehensive solutions separate sanitary and stormwater systems in certain neighborhoods, or take steps to reduce the frequency or severity of CSO events.

Status

National, state, and local efforts at CSO abatement are having an effect in Casco Bay. Portland is in the midst of "Phase II" of a three-part CSO abatement effort, for which it is receiving funding under the American Reinvestment



Casco Bay CSO Discharges by Municipality (2009)

Community	2009 Discharges (Millions of gallons)	Percentage
Cape Elizabeth	3.5	0.4%
Portland	872.8	97.5%
South Portland	12.2	1.4%
Westbrook	7.1	0.8%
TOTAL	895.6	100.10%

In 2009, an estimated 895.6 million gallons of combined stormwater and sewage were discharged from 45 different outfalls in the region. Despite the city's efforts, Portland's discharges have accounted for more than 95 percent of all CSO discharges in the watershed over the last decade, dwarfing those from other Casco Bay communities. (Percentages do not sum to 100 because of rounding.)

and Recovery Act. The city has invested more than $29 million in Phase II over the past several years, and has permanently eliminated seven CSO outfalls, while reducing expected discharges at others. Overall, the city has spent over $47 million on the CSO program since abatement efforts began in 1993, the majority of which has been borne directly by the city's sewer ratepayers (see sidebar). While the total number of active CSO discharge points in the Casco Bay watershed has declined by about one third in the past 15 years, Portland, South Portland, Westbrook and Cape Elizabeth still have active CSOs. The Portland Water District plays a major role in addressing CSO challenges throughout the region.

Trends

Over the last two decades, the number of CSO outfalls across the watershed has dropped from 80 in 1990 to 45 at the end of 2009. South Portland eliminated half of its CSO locations by the mid 2000s and Yarmouth eliminated its single outfall in the mid 2000s. Portland and Westbrook have been making progress at their CSO outfalls as well. Several of Portland's CSOs are slated to be eliminated in 2010 based on construction work the city has recently undertaken. Once that occurs, the

Portland's CSO Abatement Program

Portland and PWD are currently in the process of updating their long-term control plan (LTCP). The update will investigate the effectiveness of the city's efforts to date in reducing CSOs, and will develop a "Tier III" plan that will guide further efforts to eliminate CSO outfalls, and significantly reduce system-wide overflows. As part of that effort, Portland and PWD are updating the model of the city's stormwater and sanitary waste collection system to better simulate existing conditions. That model update is based on extensive flow monitoring data (see sidebar p. 17) and will help select strategies for further CSO abatement. The current model suggests that to date, Portland has reduced CSO volumes by approximately 28 percent on an average annual basis since 1997, primarily by applying extensive sewer separation efforts throughout the city (CDM 2010). The Tier III LTCP update will investigate additional technologies to further reduce CSO frequency and volumes. Those technologies may include storage facilities to capture excess wet weather flows before they become overflows, and then return those captured flows to the collection system for secondary treatment at the wastewater treatment plant. Other possible strategies under consideration are high rate clarification, and application of LID strategies. LID techniques not only control wet weather flows but can also improve property values while reducing flooding. The LTCP update is scheduled for completion by June 2011.

total number of CSO discharge points in the watershed should stand at 38.

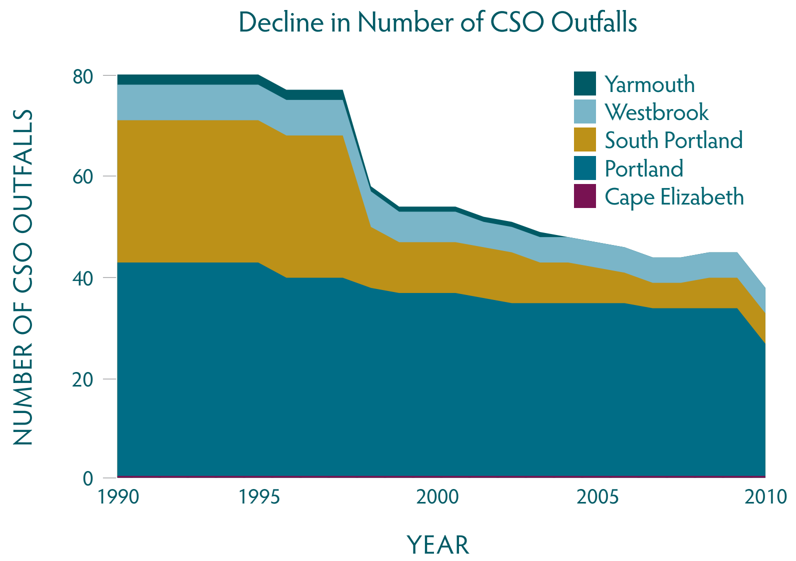
The number of CSO discharge points does not tell the whole story, however. The volume of CSO discharges is of primary importance to downstream aquatic ecosystems, including the Presumpscot River, Portland Harbor, and Back Cove. Despite community efforts at CSO reduction, total CSO discharges have not dropped consistently over the past decade. CSO discharge volumes are strongly influenced by precipitation. During wet years, significantly more overflow is discharged into Casco Bay than in dry years. Recent years have been especially wet, increasing discharges. Year to year variation in precipitation thus partially masks the beneficial effects of efforts by Portland, South Portland, Westbrook, and Yarmouth to reduce CSO volumes.

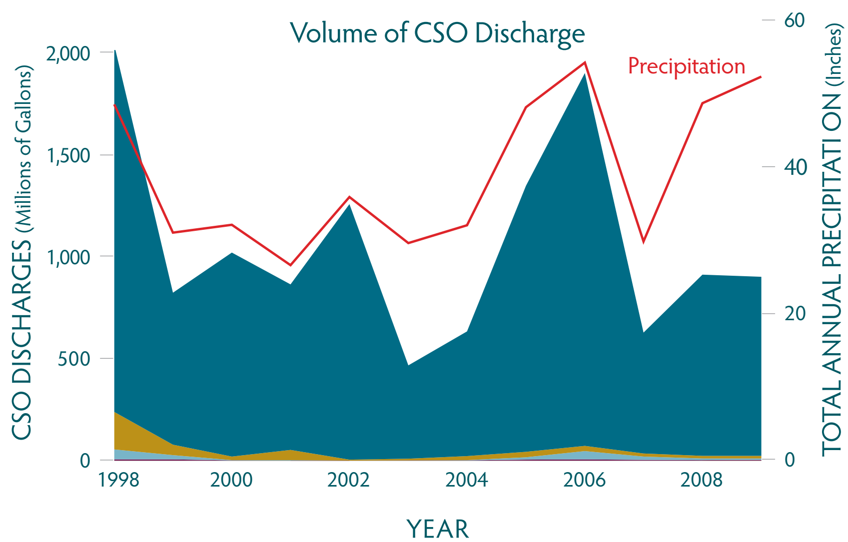
Just how beneficial have local efforts been to reducing CSO volumes? Casco Bay currently receives about 16 or 17 million gallons of CSO discharge for each inch of rain that falls over the course of a year. A decade ago, each inch of rain brought a discharge of closer to 30 million gallons. Thus local efforts do appear to be reducing discharges, despite the high rainfall the region has experienced in recent years. While the decline is uneven, varying with the volume, type, and timing of storms over the course of a year, the downward trend is statistically significant, and amounts to a decline in discharges of about 1.36 million gallons each year per inch of annual rainfall as measured at the Portland Jetport.

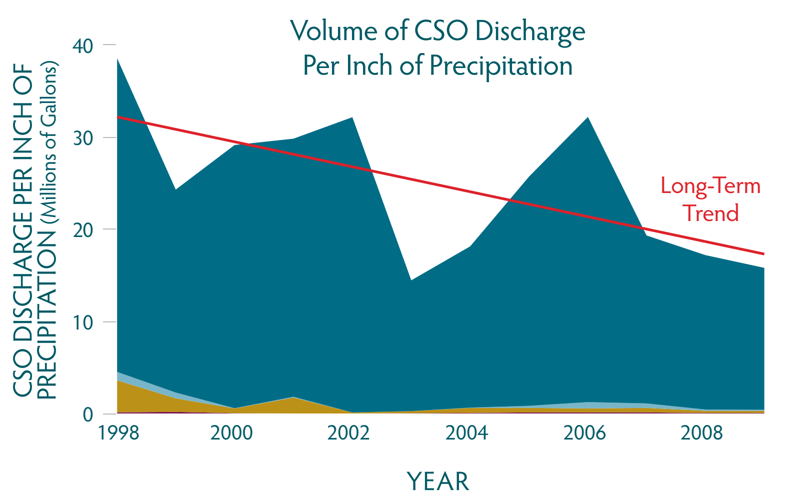
Solution and Actions

Casco Bay communities continue to work on reducing CSO volumes through a combination of better monitoring, engineering improvements, and better stormwater management practices. For example, in the last few years, Portland's CSO program has separated stormwater systems and sanitary sewers in a number of neighborhoods to reduce combined sewer overflows and eliminate CSO outfalls. Portland is also in the process of updating its long-term control plan (see sidebars) to assess the accomplishments of CSO elimination efforts to date, and to identify actions necessary to significantly reduce remaining CSOs.

CSO discharges are directly related to stormwater management efforts as well. Since CSOs occur when urban runoff exceeds the capacity of sewer pipes or sewage treatment systems, reducing the volume of urban runoff in areas served by combined sewer systems translates directly into fewer CSO events, and lower total CSO discharges. Reducing







stormwater volumes in areas served by combined sewers is likely to require applying Low Impact Development technologies, reducing the area of impervious surfaces, and installing stormwater control devices.

It is difficult to overstate the importance of coupling CSO remediation with improved stormwater management. Separation of storm and sanitary sewers – the focus of many CSO abatement efforts – helps alleviate CSOs, but doing so may exacerbate the negative effects of stormwater runoff. In combined sewer systems, polluted runoff from small storms, and from the "first flush" of larger storms, gets routed to a sewage treatment plant, where it receives at least some treatment to remove pollutants. As CSOs are eliminated by separating sewers, more polluted stormwater will find its way to local streams, rivers, and the Bay. While urban stormwater is on a per unit volume basis generally less harmful to the Bay than CSO discharges, it is not benign. So as CSO separation progresses, work should continue simultaneously to reduce stormwater pollution.

Reference

CDM. 2010. *Baseline Report to City of Portland/Portland Water District.* April 7, 2010.

Combined sewer overflow at Capisic Brook in Portland.

Portland Water District CSO Monitoring

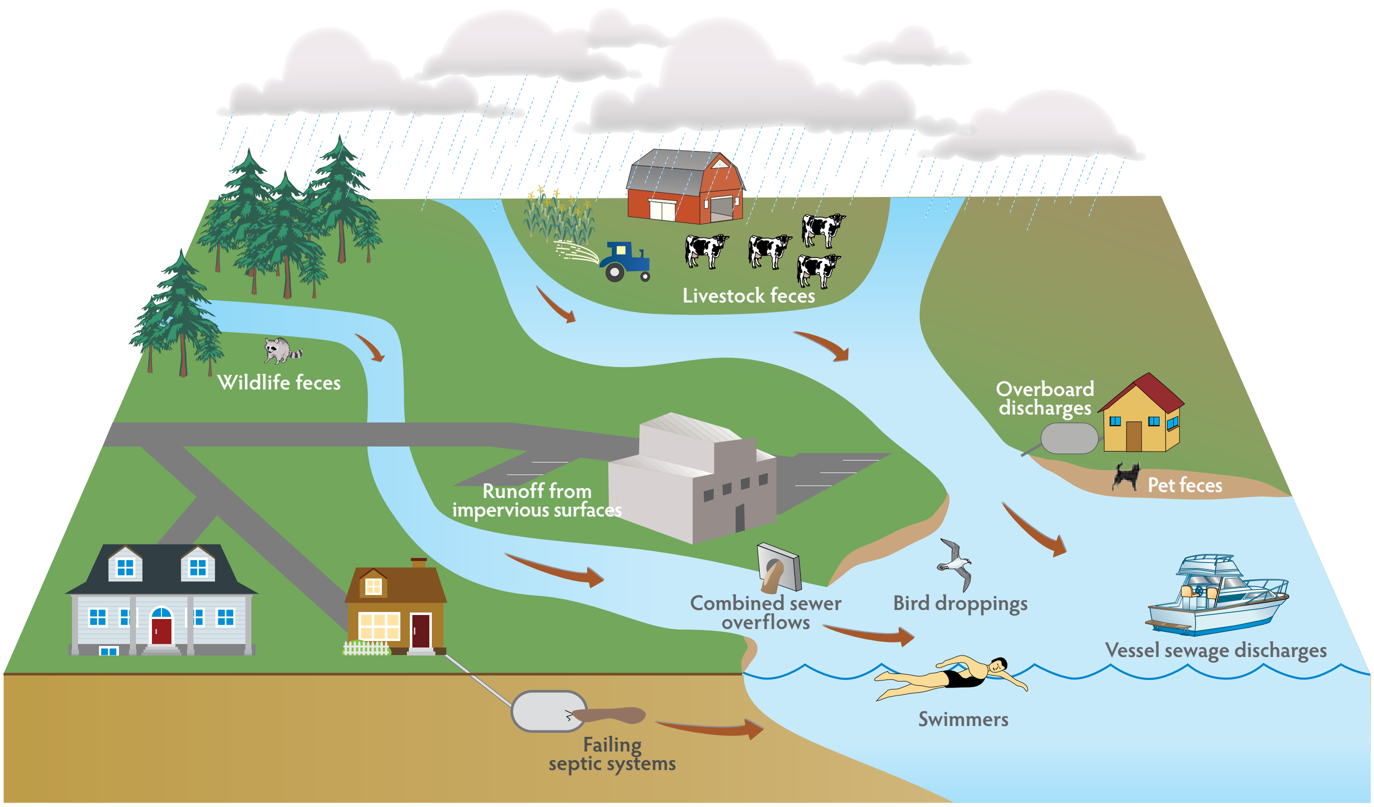
PWD has been monitoring flows in the collection system and at CSO outfalls since 2007. The goal is to monitor each CSO: to date PWD is monitoring 88 percent of CSOs in Portland. PWD is also monitoring rainfall to supplement rainfall data collected at the Portland Jetport. The resulting data have allowed PWD to substantially increase the accuracy of CSO estimates, which are reported to Maine DEP each year. The monitoring data have also been critical to Portland's LTCP update modeling effort: PWD data were used to calibrate the city's stormwater models, substantially improving their accuracy.

The monitoring data also allow PWD to take a look at what is happening in combined sewer pipes in real, or near-real, time. Flow data are collected remotely through cellular technology so staff can review them even as rain events are occurring. The in-pipe data have proven valuable for improving maintenance of sewer pipes. The system can display flow changes at any time, and send alarms to PWD staff if flows reach an unusually high level. Thus crews can respond to a potential problem before any dry-weather overflow events can occur.

Example monitoring data from the monitored CSO at Mackworth Street. Vertical axis shows inches of water in the pipe, a measure which is directly related to flow. The site alerts PWD staff when the water reaches slightly less than five inches (green line), even though an actual CSO would occur only when the water depth rises to nearly eight inches (red line). (The data are from March 2010.)

SECTION TWO

Pathogen Pollution



Disease-causing pathogens can enter Casco Bay coastal waters from multiple sources, leading to potential public health risks.
Illustration by Waterview Consulting including symbols adapted from the Integration and Application Network, University of Maryland Center for Environmental Science.

Introduction

Pathogens, which include disease-causing bacteria, viruses, and parasites, can be found in fecal material from humans and warm-blooded animals. They can enter coastal waters through sewage effluent, agricultural and stormwater runoff, or malfunctioning septic tanks. They also find their way into our waters via pets, wildlife, swimmers, and boaters.

Exposure to pathogens through ingestion of contaminated shellfish, or contact with polluted waters, can present a public health risk. Managing that risk requires monitoring for the presence of indicator organisms. The ideal indicator is one associated with fecal contamination, easy to measure, relatively harmless to humans, and found in greater numbers than pathogens. Under federal and state rules, fecal coliform bacteria are the indicator used to assess water quality in shellfish harvesting areas, while *Enterococci* bacteria are measured at beaches and swimming areas.

Monitoring provides resource managers with the information they need to decide when to protect public health by posting an advisory at public beaches, or closing shellfish beds to harvesting. CBEP's two pathogen pollution-related indicators (Indicators 5 and 6) are discussed on the following pages.

What is the status of swimming beach monitoring in Casco Bay?

CBEP Goal: Open and protect swimming areas impacted by water quality.

Why Is Beach Monitoring Important?

Monitoring the water at recreational beaches regularly is necessary because the risk of exposure to pathogens changes with weather conditions and source inputs. For example, a rainstorm can wash pathogens from land and carry them into recreational waters, temporarily degrading the water quality, and increasing the risk of eye and ear infections, sore throats, and gastric illness. By monitoring for the indicator bacterium *Enterococcus* during the summer beach season, managers can identify periods when the risk of illness exceeds acceptable levels. Beach monitoring is a voluntary activity in Maine, and the decision to monitor or to issue swimming beach advisories or closures based on monitoring results is left to the discretion of local and municipal beach managers, or to state park officials.

Status of Casco Bay's Beach Monitoring Program

The Maine Healthy Beaches (MHB) Program is a US EPA-funded partnership started in 2003 to ensure that local beaches are safe and clean. Municipalities, the University of Maine Cooperative Extension/ Sea Grant, state agencies, and nonprofits participate in beach monitoring, data analysis and public outreach.

MHB Program signs notify swimmers of beach status using color coding. An orange overlay indicates swimming is not advised and red indicates the beach is closed to swimming.

MHB currently monitors 60 coastal beach management areas, including three beaches in Casco Bay considered high-priority due to volume of use and potential risk of contamination. (Many swimming spots around Casco Bay are not monitored.) Local beach managers take water samples and record weather conditions from Memorial Day to Labor Day three times a week at Portland's East End Beach, twice weekly at South Portland's Willard Beach and, since 2008, once a week at Winslow Park in Freeport, tides permitting. Using *Enterococcus* bacteria counts, the beach's history, bather numbers, and recent rainfall to assess health risks, the managers post beach status online. They also use color-coded signs and flags at the beaches themselves. (For more information, see www.mainehealthybeaches.org.)

Selfnoise

Trends

When seawater samples collected by the MHB Program contain 104 MPN (Most Probable Number) or more *Enterococci* per 100 milliliters of beach water, water quality is considered degraded. High levels of those indicator bacteria are often observed on Willard and East End beaches during and immediately following heavy rainfall, suggesting that stormwater runoff is a key contributor to beach water quality at those urban beaches.

Total Beach Action Days* per Year at Casco Bay Beaches

	Willard Beach, South Portland	East End Beach, Portland	Winslow Park, Freeport
2003	0	0	
2004	7	6	
2005	11	1	
2006	11	0	
2007	3	4	
2008	3	6	0
2009	23	24	0

The high number of advisories and closures in 2009 can be attributed to the 24.79 inches of rain reported in Portland during the beach season (approximately 2.5 times above average).

Source: Keri Lindberg, Maine Healthy Beaches, personal communication.

*The numbers are based on data provided by the Maine Healthy Beaches Program. An Action Day refers to the number of days a beach is posted with an advisory against swimming or a closure where 1 day ≤ 24hrs; 2 days > 24hrs but ≤ 48hrs; 3 days > 48hrs but ≤ 72hrs.

Casco Bay No Discharge Area and Pumpout Facilities

Sewage discharge from boats can be a significant source of pathogen pollution to coastal waters. With strong state and local support, the US EPA designated Casco Bay as Maine's first No Discharge Area (NDA) in 2006. In Casco Bay, discharge of both treated and untreated vessel sewage is prohibited in all waters between Two Lights in Cape Elizabeth and Small Point in Phippsburg, including the navigable reaches of the Fore, Presumpscot, Royal, Cousins, Haraseeket and New Meadows Rivers. Maine has also enacted legislation that controls the discharges of combined sewage and gray water (sink and shower water) from large commercial passenger vessels. That legislation is unique to Maine and, in combination with the NDA, results in coastal waters that receive the highest regulatory protection from vessel discharges in the United States (Maine DEP 2010).

FOCB

Federal NDA designation under the Clean Water Act requires that boaters have access to an adequate number of pumpout facilities. In Casco Bay there are 21 commercial shoreside facilities, and one mobile pumpout, the Friends of Casco Bay Vessel Pumpout Boat. That mobile pump-out service offers boaters a convenient, legal way to empty their vessel's holding tanks, by pumping out the tanks at docks or moorings. FOCB's Pumpout staff also helps boat owners locate and operate shoreside facilities. Since 1995, the services of the pumpout boat have prevented more than 100,000 gallons of raw sewage from entering Casco Bay's waters. (For more information, see http://friendsofcascobay.org/pumpoutprogram.aspx)

Solutions and Actions

The MHB Program is working with communities statewide on public education campaigns, special monitoring and circulation studies, mapping and "hot spot" analysis, and sanitary shoreline surveys to identify pollution sources.

For example, a 2006 sanitary shoreline survey at Willard Beach in South Portland identified five storm drain outfalls discharging directly into the water. Those outfalls could be moved into deeper water to reduce their near-shore impacts (Mosley 2006). Littering (which attracts gulls), poor sanitary practices by bathers, and failure to remove dog waste also increase pathogen loading to the beach. Continuing public education is helping to address those human impacts. In addition, discharge of wastes from boats anchored at a mooring field offshore of Willard Beach has been illegal since the 2006 Casco Bay No Discharge designation (see sidebar). The Maine Healthy Beaches' boater education program has further reduced illicit and accidental discharges.

The *Maine Statewide Bacterial Total Maximum Daily Load* (TMDL) report, completed in 2009, should also help to reduce pathogen inputs. The TMDL sets targets for allowable levels of bacteria in state waters. The maximum levels provide pollutant targets under the federal Clean Water Act, constraining permitting, funding and other actions. The report provides documentation and maps of impaired areas, and information on pollutant sources. It also offers tools to help communities and other stakeholders implement bacterial control strategies. One of the case studies in the report is a shoreline survey training program for municipal employees in Casco Bay communities, which CBEP helped to sponsor in partnership with the Maine Department of Marine Resources and the Maine Department of Environmental Protection.

References

Maine Department of Environmental Protection. 2009. *Statewide Bacterial Total Maximum Daily Load.* (http://www.maine.gov/dep/blwq/docmonitoring/TMDL/2009/report.pdf)

Maine Department of Environmental Protection. 2010. *No Discharge Areas* (http://maine.gov/dep/blwq/topic/vessel/nda)

Mosley, Sarah. 2006. *Willard Beach Sanitary Shoreline Survey.* Maine Healthy Beaches Program.

INDICATOR 6

Has the acreage of open shellfish beds in Casco Bay changed over time?

CBEP Goal: Open and protect shellfish areas impacted by water quality.

Why Is Open Shellfish Bed Acreage Important?

For many residents and commercial diggers around Casco Bay, shellfish harvesting is both an important tradition and livelihood. Soft-shell clams (*Mya arenaria*), blue mussels (*Mytilus edulis*), quahogs (*Mercenaria mercenaria*), and other species provide significant economic benefits to the region. Some sheltered coves also present optimal conditions for shellfish aquaculture. In most parts of the Bay, determination of whether mudflats and other shellfish areas are open to harvest depends on the degree and extent of fecal pollution, which is assessed by monitoring representative fecal coliform bacteria levels. Tracking changes to shellfish management area classifications leads to knowledge of the levels of fecal bacteria in the Bay, which adds to an understanding about the Bay's current water quality.

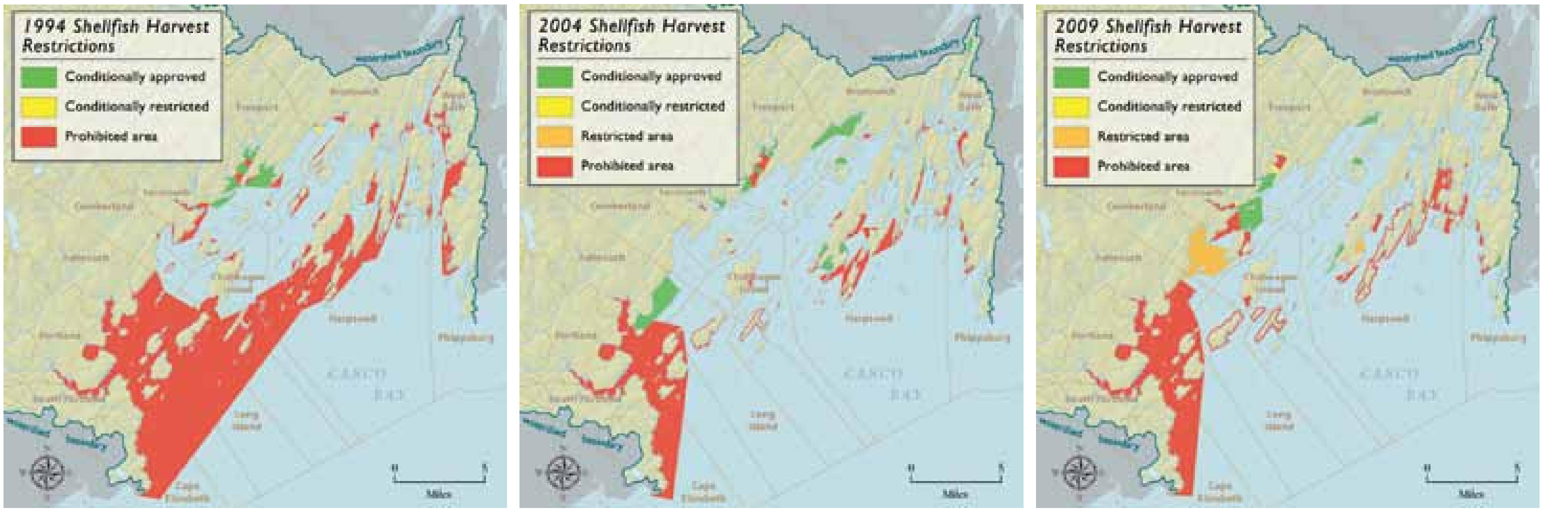
Mike Timberlake

Status and Trends

The National Shellfish Sanitation Program (NSSP), directed by the U.S. Food and Drug Administration and administered locally by the Public Health Division of the Maine Department of Marine Resources (DMR), determines the water quality standards that shellfish areas must meet to ensure that shellfish product falls within public health thresholds for human consumption. Under the NSSP, DMR classifies shellfish areas as prohibited, restricted, conditionally restricted, conditionally approved, or approved based on an assessment of the risks of illness. Each management area's status is determined by several criterion such as proximity to private or municipal wastewater treatment facilities; recent heavy rains (which can wash pathogens and other pollutants into the Bay); the presence of high levels of fecal bacteria; dangerous red tide levels; toxic substances in sediments; or a combination of the above. In Casco Bay, most shellfish bed closures occur due to the presence of anthropogenic sources of fecal bacteria carried in stormwater runoff, and fecal bacteria associated with human waste from malfunctioning septic systems, release of treated and untreated sewage from boats, combined sewer overflows, and overboard discharges.

Brad Lauster

Local, state, and federal agencies have taken important steps to reduce fecal pollution inputs to Casco Bay by removing overboard discharges, eliminating combined sewer overflows, and designating Casco Bay as a No Discharge Zone. Nonetheless, fecal bacteria counts persist at elevated levels in many areas, resulting in widespread restrictions on harvesting shellfish. In 2009, shellfish harvesting remained prohibited throughout much of southern Casco Bay, including but not limited to, the Fore River/Portland Harbor, Back Cove, the Presumpscot Estuary, Peaks Island, Great Diamond Island, Mussel Cove, and the Royal River estuary. Much of Broad Cove, along with most of the

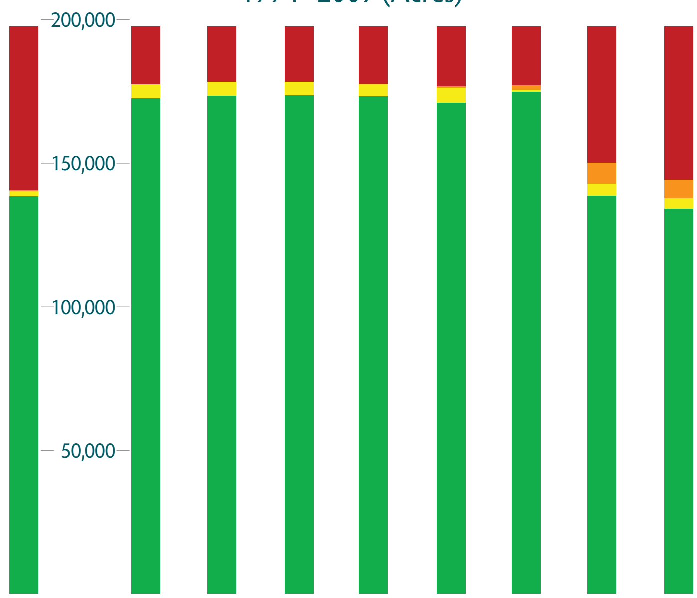


Shellfish Management Area classification status in 1994, 2004, and 2009. The 1994 and 2004 data were presented in the 2005 *State of the Bay* report. Although the maps show a dramatic reduction in prohibited area from 1994 to 2004, much of the change is attributed to closure lines being re-drawn to fit the shoreline of affected islands. Note: DMR did not use 'restricted' as a classification until 2000–2002. Data: Maine DMR

waters around Cousins Island, was classified as either restricted or prohibited in 2009. In eastern Casco Bay, Quahog Bay and Ridley Cove were classified as prohibited, along with sections of Sebasco Harbor and Small Point Harbor. Notable classification improvements between 2004 and 2009 occurred in the upper and lower New Meadows, and in sections of Maquoit Bay.

From 2007 to 2008, a shift in the proportion of open to closed shellfishing areas took place. The total area classified as prohibited more than doubled from 20,441 acres to 47,421 acres, while the total area classified as approved or conditionally approved area fell from 174,761 acres to 138,575 acres. Between 2004 and 2009, the total area classified as restricted increased sharply from 57 acres to 6,416 acres. Those shifts represent administrative changes in NSSP guidance, as well as in actual water quality changes. The increase in prohibited area can be attributed to a number of factors including: expanded closures around sewage treatment plant outfalls to ensure adequate dilution of effluent; the expiration of required sanitary surveys along the shoreline; and prioritization of commercial digging sites. The increase in restricted area reflects changes to NSSP standards. Areas that are affected by nonpoint source pollution, and which do not meet approved standards, are now classified as restricted, reflecting the fact that nonpoint source pollution is having a bigger impact on shellfish areas than in past years. Although the increase can be partially attributed to high rainfalls in 2008 and 2009, intensive development of coastlines and subwatersheds is a contributing factor.

Change in Casco Bay Shellfish Management Area Status 1994–2009 (Acres)



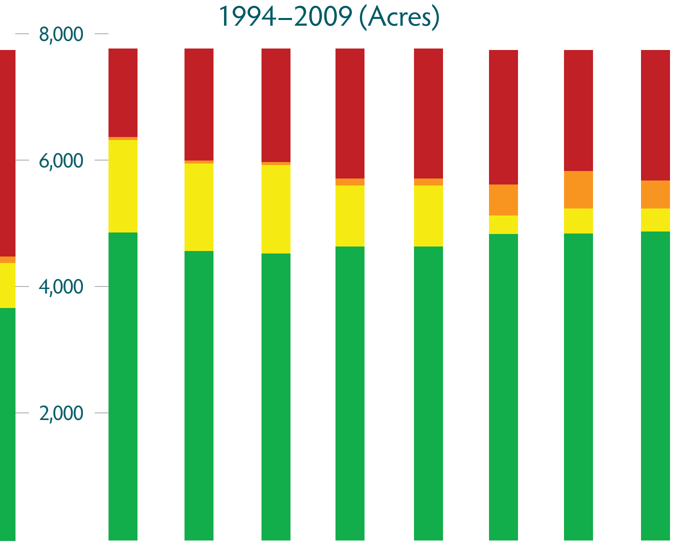
Status of Shellfish Flats	1994	2002	2003	2004	2005	2006	2007	2008	2009
Prohibited	57,020	20,014	19,260	19,174	19,908	20,845	20,441	47,421	53,356
Restricted	224	57	57	57	170	489	1,619	7,272	6,416
Conditionally Restricted	1,865	4,893	4,796	4,732	4,236	5,202	538	4,091	3,668
Approved or Conditionally Approved	138,250	172,395	173,245	173,395	173,045	170,823	174,761	138,575	133,919

Data: Maine DMR

Shellfish management areas are much larger than actual harvestable digging sites. Although tracking changes in the classification of entire management areas is a useful way to illustrate the extent of fecal pollution in Casco Bay, the scale does not accurately convey the specific impact that

classification changes have on where harvesters can dig for shellfish. To understand how classification has affected Casco Bay's most important shellfish industry, it is useful to review classification changes as they pertain specifically to mapped softshell clam digging areas. At that scale, classification trends are less pronounced. Although clam flats classified as prohibited increased from 1,774 acres in 2004 to 2,040 acres in 2009, an increase of 15 percent, there was a simultaneous increase in combined open (approved) and conditionally approved acreage from 4,504 acres in 2004 to 4,843 acres in 2009, a 7.5 percent increase. The area of clam flats classified as restricted increased from 49 acres in 2004 to 442 acres in 2009. Again, the impact of increased nonpoint source pollution on shellfish harvesting is evident. Consequently, nonpoint source pollution adjacent to shellfish harvesting areas is a topic of growing concern among state and local shellfish managers.

Change in Casco Bay Softshell Clam Bed Status 1994–2009 (Acres)



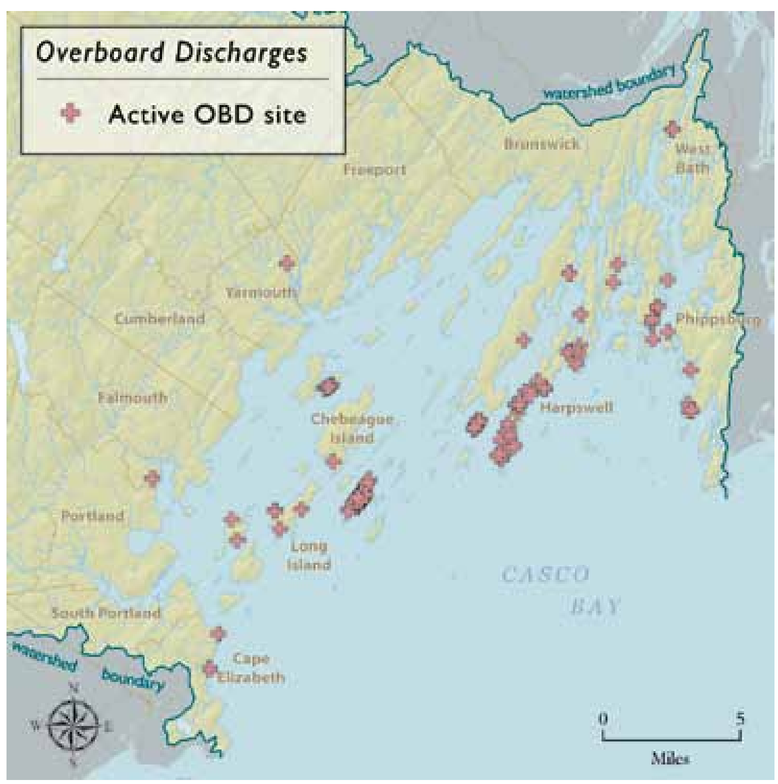
Status of Softshell Clam Beds	1994	2002	2003	2004	2005	2006	2007	2008	2009
Prohibited	3,233	1,376	1,749	1,774	2,033	2,301	2,107	1,897	2,040
Restricted	105	49	49	49	103	218	480	581	442
Conditionally Restricted	704	1,450	1,368	1,382	965	1,005	298	392	364
Approved or Conditionally Approved	3,644	4,832	4,542	4,504	4,607	4,186	4,805	4,819	4,843

Data: Maine DMR

Solution and Actions

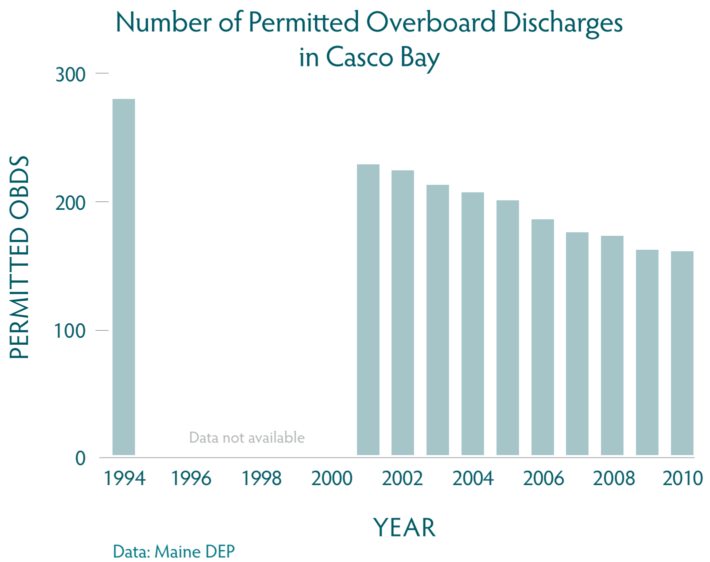
Overboard Discharge System Elimination

Between 1974 and 1987, Maine DEP regulations allowed treated, chlorinated overboard discharge systems (OBDs) to be built as a replacement for "straight pipes" or as an alternative to conventional inground septic systems. By 1987, nearly 400 OBDs had been installed in towns surrounding Casco Bay. Coastal buildings without access to publicly owned treatment facilities, or the ability to install septic systems due to poor soil conditions or small lot sizes, often had no other choice, because underlying ledge leaves little room for proper function and operation of leach fields. Since OBDs require consistent maintenance, they are considered by state and federal regulators to be a source of fecal bacteria, leading to mandatory prohibition of shellfish harvesting in adjacent areas. OBDs constitute a major cause of Casco Bay's shellfish management area closures.



Data: Maine DEP

To address that ongoing cause of shellfish closures, towns are working closely with DEP and DMR and continue to seek ways to remove and replace OBDs, particularly those located near productive shellfish resource areas. As a result, the number of permitted OBDs has declined by about half since 1995. Since 2004, despite a shortage of low-interest state loans to assist with removal and replacement costs, the

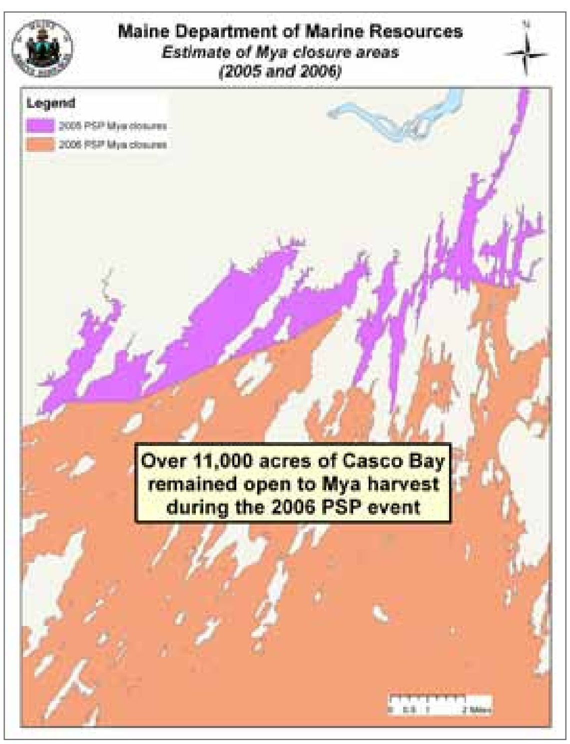


Harvesting clams in Harpswell.

Town of Harpswell has been successful in securing and utilizing Community Development Block Grant funds to replace OBDs by making a strong case for the economic development benefits of opening shellfish areas that have long been closed to harvest. Between 2001 and 2009, Harpswell eliminated 37 OBDs along its 150 mile coastline.

Red Tide

Harmful algal blooms of *Alexandrium fundyense*, also known as red tide, produce a biotoxin that accumulates in clams and other shellfish, and can lead to paralytic shellfish poisoning (PSP) if consumed. PSP-related closings have had a severe impact on Casco Bay's shellfish harvest since 2005, when an intense and prolonged red tide closed shellfish areas to harvest for weeks at a time, producing record levels of toxicity, and resulting in a disaster declaration for affected areas.



Since red tide was expected to continue for several years following the 2005 event, the Casco Bay Clam Team worked closely with Maine DMR to better understand red tide, and to enable finer-scale management of shellfish areas during red tide events. The 2006 pilot program created 43 new sampling stations which – along with the three DMR already had in place – provided comprehensive information about the extent and severity of red tide in Casco Bay. The additional data enabled continuation of shellfish harvesting in some near-shore flats, despite ongoing red tide blooms off shore. As a result of the pilot program, more than 11,000 acres of shellfish management area that had been ordered closed in 2005 remained open during the entire red tide event in 2006. Based on the success of the pilot program, DMR has maintained the new monitoring protocol in Casco Bay, and applied the approach to other areas of the state. (For additional information about red tide, see Section 3: Water Quality.)

References

Casco Bay Estuary Partnership. 2005. *State of the Bay.* http://www.cascobay.usm.maine.edu/sotb05.html

Maine Department of Environmental Protection. 2004. *DEP Fact Sheet – Summary of Laws Pertaining to Overboard Discharges.* http://www.maine.gov/dep/blwq/docstand/OBD/obdlaw.pdf

Maine Department of Environmental Protection. 2010. *DEP Google Earth Interactive Maps - Overboard Discharges.* http://www.maine.gov/dep/gis/datamaps/LAWB_OBD/LAWB_OBD.kmz (June 2010)

Maine Department of Environmental Protection. 2010. Unpublished data.

Maine Department of Marine Resources. 2010. Unpublished data.

U.S. Food and Drug Administration. 2007. *Guide for the Control of Molluscan Shellfish.* http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/NationalShellfishSanitationProgram/ucm046353.htm

SECTION THREE

Water Quality


Origamidon

Introduction

The Casco Bay region relies upon good water quality to support the fisheries and water-dependent recreational uses that are an important part of the local economy. For example, Maine tourism alone generates approximately $13 billion in annual economic activity, employing 140,000 people (Maine Office of Tourism 2010). Many of those tourists visit Casco Bay to fish and swim in its coastal and inland waters. The quality of the waters of Casco Bay and its watershed is also an important indicator of the overall health of the ecosystem. Levels of dissolved oxygen and nutrients, for example, affect the health of the biological community – from the microscopic plants at the base of the food chain to top-level predatory fish like largemouth bass and stripers. Pathogen pollution affects water quality and limits the availability of shellfish resources and the safety of our beaches to swimmers. Finally, toxic contaminants can move up through the food chain to contaminate seafood as well as birds, mammals and humans.


VLMP

Largemouth bass swims in Casco Bay watershed lake waters.

The following two water quality indicators are based on monitoring programs conducted by the State of Maine, Friends of Casco Bay, and other CBEP partners and collaborators. (To learn more about programs that monitor for toxic contaminants and pathogens, see Sections Two and Four.)

Reference

Maine Office of Tourism. 2010. Governor's Conference on Tourism. http://www.mainetourismconference.com/sponsorship.php

INDICATOR 7

What is the quality of the waters of Casco Bay?

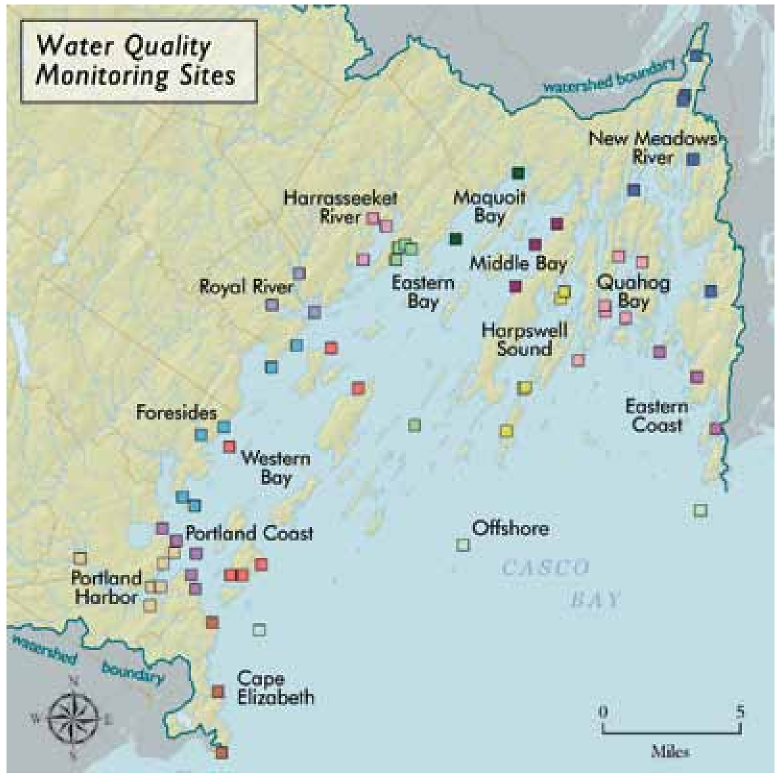
Why Is It Important to Monitor the Water Quality of Casco Bay?

The structure and function of the Bay depend on good water quality. Healthy waters are essential for a productive and diverse population of marine organisms, from phytoplankton to fish, shellfish and lobsters. Good water quality is also vital to a region where economic fortunes are tied to marine-related tourism and fisheries. For example, the value of the fisheries industry to Casco Bay has been estimated in the past at $120 million annually (Colgan and Lake 1990), with softshell clams alone contributing over $11 million per year (Heinig *et al.* 1995).

Friends of Casco Bay (FOCB) is a non-profit marine advocacy organization dedicated to the health of the Bay. With funding support from CBEP, FOCB has been monitoring water quality in Casco Bay for over 15 years by tracking several key indicators.

Dissolved oxygen (DO) and water temperature are especially important indicators. In water with low concentrations of DO (below 5.0 mg/l), fish and other marine organisms may become stressed or suffocate. The amount of oxygen that water can hold decreases as water becomes warmer. In addition, warmer temperatures increase the rate of microbial activity and decomposition of organic matter that can further depress DO levels. Seasonal effects due in part to temperature result in maximum DO values in the winter and minimum DO values in the summer.

FOCB also monitors Secchi depth, a measure of water clarity. Generally, water with lower organic material, and therefore greater clarity, is considered healthier. The acidity or alkalinity of the water is also measured (as pH). The pH varies with fresh water inputs from rivers or streams or in responses to changes in photosynthesis and respiration. Nitrogen , a major plant nutrient, is also measured. Too much nitrogen can stimulate excessive growth of algae or other organic matter, which can lower DO, reduce water clarity and potentially prolong red tides (see p. 30). Nitrogen is delivered to the Bay from natural as well as anthropogenic processes. Manmade sources include combustion of fossil fuels, use of fertilizers, failing septic systems and discharges from sewage treatment plants.



Samples are collected at the surface at more than 45 sites around Casco Bay from April through October. The sites are grouped into the 15 color-coded regions shown (FOCB 2010).

Status of Water Quality in Casco Bay

Dissolved oxygen, water temperature, Secchi depth and pH levels have been measured in the Bay since 1993. Measurements of dissolved inorganic nitrogen (DIN), which is the sum of nitrate, nitrite and ammonium, were added in 2001 through collaboration with the University of Maine School of Marine Sciences. Total nitrogen (TN, which incorporates both DIN and the nitrogen tied up in organisms and organic matter) was added in 2007. In 2010, FOCB analyzed the data collected from 1993 to 2008.

The distribution of all of the DO data – including more than 7,600 measurements – shows that 90 percent of the DO values in Casco Bay were above 7.2 mg/l. Only 0.5 percent fell below 5.0 mg/l. On the whole, those values are typical of well oxygenated, healthy coastal waters. Low dissolved oxygen levels that may be of significant management concern are still rare in Casco Bay. Not surprisingly, urban

Water quality conditions in Casco Bay by region. Regions are sorted the same way in all panels (in order of average DO levels, from highest to lowest) so that comparisons can be made among parameters. Portland Harbor, the Royal River, the New Meadows River, and the Harraseeket River experience the lowest DO. Sites offshore and in the Eastern Bay region have the highest DO. For each region, 90 percent of observations had DO above the level shown by the orange line. Sites in the offshore region and the coast along Cape Elizabeth have the coldest mean water temperatures, while Maquoit Bay, the New Meadows, and Royal and Harraseeket Rivers are the warmest regions. The relationship between colder water and higher dissolved oxygen levels is evident. Deeper offshore sites showed the greatest water clarity, while the Royal River, Harraseeket River and New Meadows regions had the lowest mean Secchi depths. A link is apparent between higher DO and greater Secchi depths, both of which correlate with colder water temperatures. The mean values for DIN show increased levels near freshwater sources and/or urban areas, and lower levels offshore. The regional means for DIN generally track well with the previous three parameters: higher DIN levels are found in regions with lower DO, warmer water, and lower Secchi depths (FOCB 2010). (The error bars show +/- one standard deviation among measurements taken in a region to show the magnitude of local, seasonal and annual variability.)

areas exhibited some of the lowest minimum DO concentrations, perhaps due to nutrient loading from point sources, combined sewer overflows, and polluted runoff. However, low DO concentrations were also observed in less developed areas, such as the New Meadows River, where restricted circulation is to blame (FOCB 2010).

Key water quality parameters vary in different parts of Casco Bay (see graphs on p. 27). As might be expected, areas with high dissolved oxygen tend to have lower water temperatures, and to be located offshore. Simultaneously, areas with high nutrient levels or low water clarity tend to be located inshore. Those patterns are reminiscent of the strong inshore-offshore water quality gradient observed in the Casco Bay Water Quality index reported in the 2005 *State of the Bay* report.

Temporal Trends/Other Issues

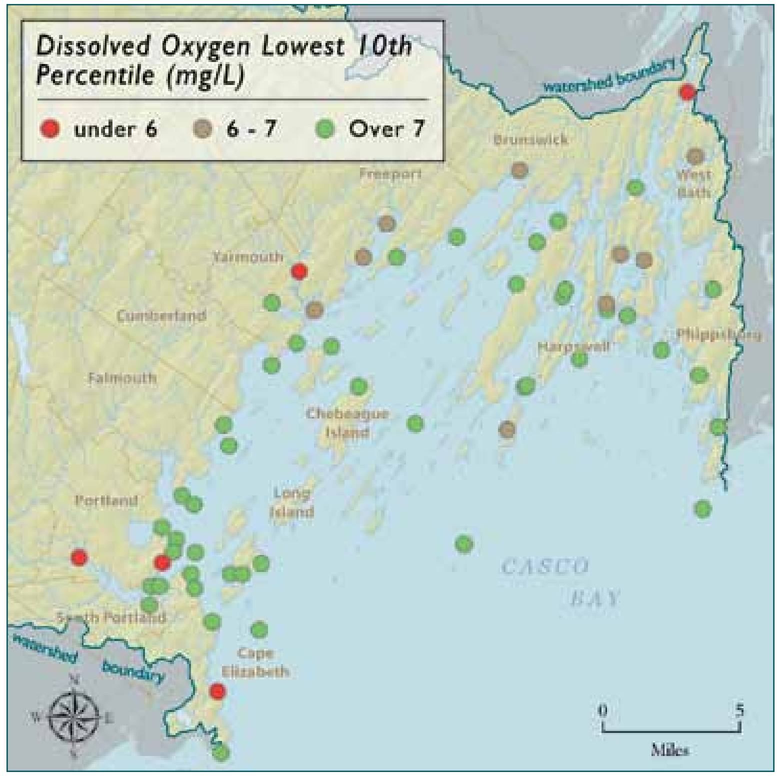
Annual mean surface water temperature (April–October) has been increasing by a tenth of a degree Centigrade annually since 1993 (see graph), while Secchi depth has been decreasing by slightly less than a tenth of a meter each year during that same time period. Both indicators seem to be reflecting reduced water quality over time (FOCB 2010). The observed increase in water temperature may have a connection to increased carbon dioxide in the atmosphere. The reduction in water clarity may mean that there is an increase in the amount of organic matter in Casco Bay, or may be due to an increase in sediment load from runoff.

There is also a very slight decrease in pH values Bay-wide since 1993, although much more analysis is required before any conclusions can be made. Recent global evidence suggests that carbon dioxide is becoming available in large enough quantities to measurably lower marine pH (see Indicator 17).

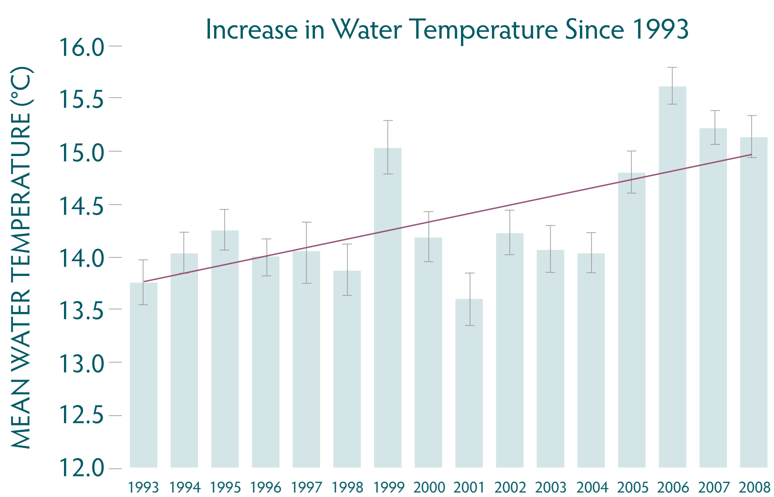
The DIN results show a relatively high ratio of ammonium to DIN. That is somewhat surprising since nitrate tends to be the dominant fraction of DIN in coastal waters. Further study is needed to interpret that ratio (FOCB 2010).

Conclusions and Future Directions

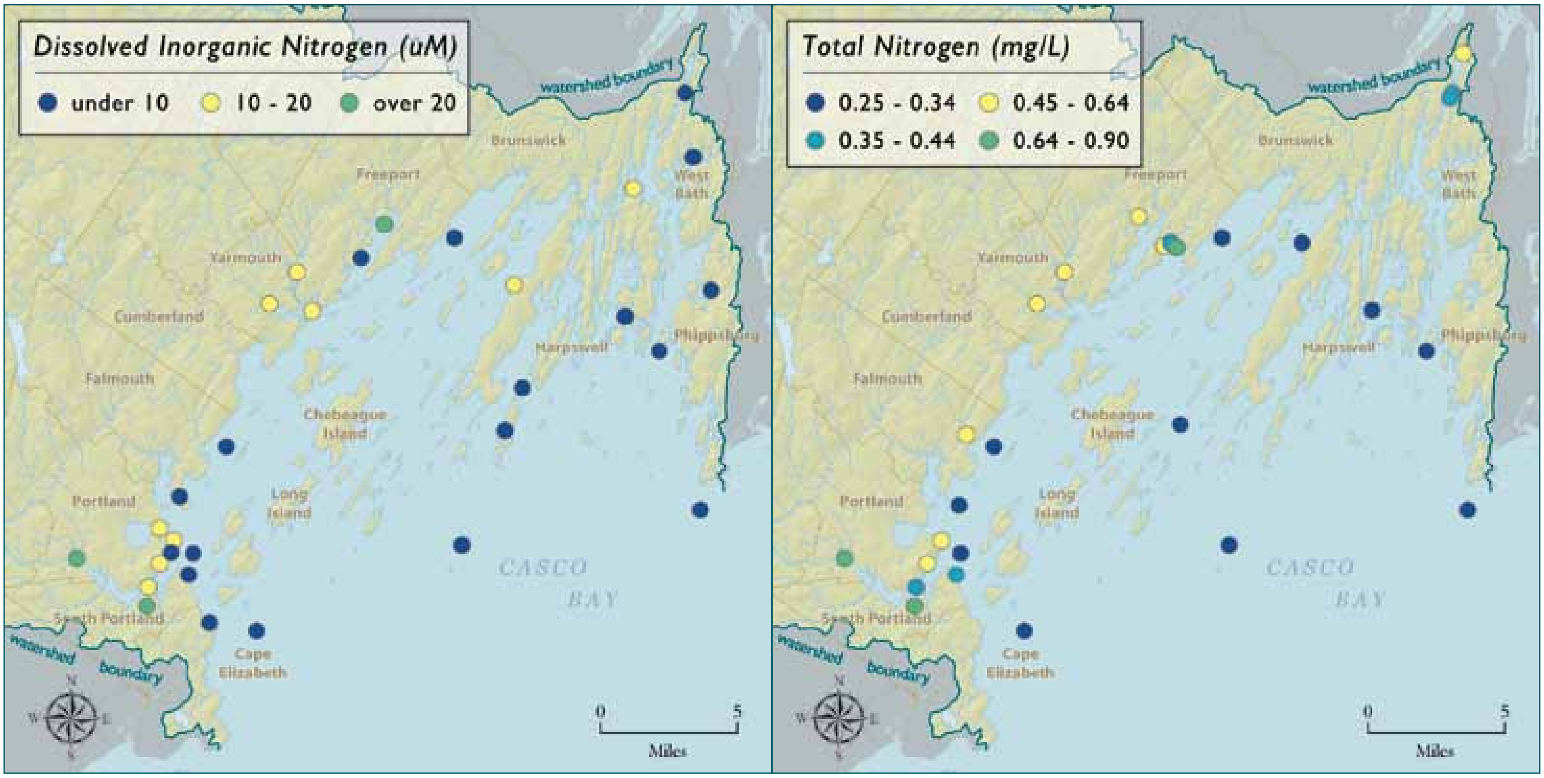
The overall water quality of Casco Bay is good, although there are a few sites where indicators have been measured at levels of concern. Low DO near urban areas suggests that the Bay is



The lowest 10th percentile values for DO show where issues with dissolved oxygen may be occurring. There is a strong inshore to offshore trend of improving DO conditions. Sites that exhibit more frequent low levels of DO include Stroudwater Creek and Custom House Wharf in Portland Harbor, the Cousins River and the upper New Meadows River. The Peabbles Cove site in Cape Elizabeth occasionally experiences low levels of DO, probably as a result of decomposing storm-cast seaweed (FOCB 2010).



The annual mean water temperature has increased since 1993, with four of the five warmest years occurring in the last four years analyzed (2005 – 2008). Statistical analysis suggests that this is a meaningful trend, not simply a result of year to year fluctuations. Early morning data (collected prior to 10:00 AM) shows a similar statistically significant trend (FOCB 2010).



Average DIN and TN values by site. A clear decreasing trend from inshore to offshore can be seen for both parameters. This pattern of more nitrogen in areas with lower salinity, most likely from runoff, suggests that there is a significant contribution of nitrogen to Casco Bay from terrestrial sources (FOCB 2010).

experiencing localized pollution problems, most likely due to over-enrichment with nitrogen. This hypothesis is further supported by the presence of patches of "green slime" (principally *Ulva intestinalis*) along the Casco Bay coast. Often an indicator of nutrient enrichment, *U. intestinalis* has been increasingly apparent along the Maine coast in the past few years (Doggett 2010).

FOCB

If temperatures, sunlight levels and nutrient levels are high enough, green slime proliferates, especially in more protected areas such as mudflats, around piers and docks, and in sheltered harbors.

FOCB's water quality monitoring program, already among the most sophisticated volunteer-based programs in the country, continues to grow and evolve. The 18-year history of the program shows the program taking on new water quality monitoring challenges and increasing in sophistication. For example, FOCB's ongoing collection of TN data began only in 2007, and yet may be used to help establish reference conditions for the Bay. Since 2005, sampling has been conducted twice a day, in the morning and in the afternoon, providing a way to assess daily productivity (phytoplankton growth). Future monitoring might include more sophisticated pH measurement to track the impact of increasing concentrations of carbon dioxide in the atmosphere, or quantitative chlorophyll measurements to assess how the phytoplankton of Casco Bay is responding to nitrogen loading.

References

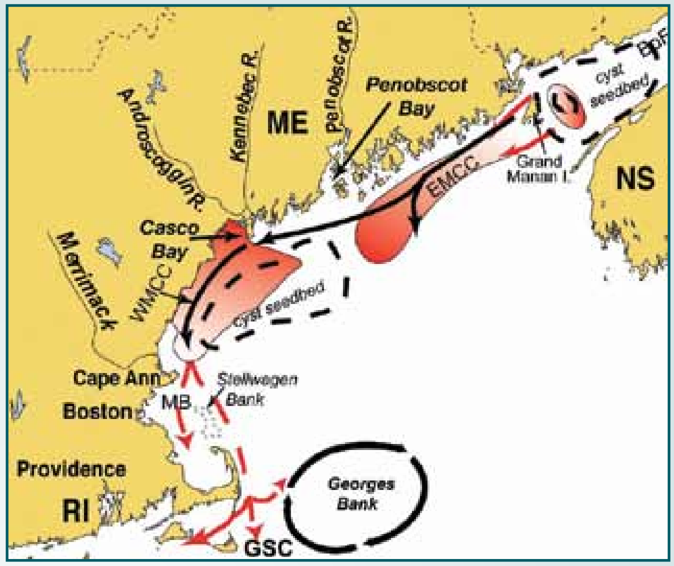
Colgan, C. and F. Lake. 1990. *The Economic Value of Casco Bay.* Maine Coastal Program/Maine State Planning Office.

Doggett, L. 2010. Personal Communication. February 26, 2010.

Friends of Casco Bay. 2010. *Draft Water Quality Data Analysis, 1993-2008.* Casco Bay Estuary Partnership.

Heinig, C. S., P. Moore, D. W. Newburg and L. R. Moore. 1995. *Economic Analysis of the Soft-Shell Clam (*Mya arenaria*) Industry in Casco Bay.* Casco Bay Estuary Partnership.

The Causes of Red Tides in Casco Bay: Does Local Water Quality Have an Impact?



Conceptual model of red tide propagation in the Gulf of Maine.
Modified by Libby and Anderson (2010) from Anderson *et al.* (2005)

Red tides, or "harmful algal blooms" of the toxic microorganism *Alexandrium fundyense*, have become common in the Gulf of Maine and Casco Bay in recent decades. Spring 2005 brought the most intense outbreak in New England since 1972. Shellfish beds from Canada to Cape Cod were closed to protect human consumers from paralytic shellfish poisoning (PSP).

CBEP and Maine DMR together began an intensive red tide monitoring program in 2006. From April to July, data on PSP toxicity in mussels, *A. fundyense* cell counts, water depth, temperature, salinity, and nutrient concentrations (including nitrogen as nitrate + nitrite and ammonium) were collected at 43 stations throughout the coast of Casco Bay on weekly two-day surveys.

The project had two goals: to improve DMR's ability to make localized decisions on closing shellfish growing/harvesting areas during the red tide season; and to understand the local and regional factors that drive red tide blooms, particularly whether anthropogenic sources of nutrients were worsening local bloom events.

DMR has continued the monitoring program into the summer of 2010, and has been able to use the resulting data annually to keep some shellfish areas open that otherwise would have been closed (see Indicator 6). A CBEP-funded analysis of data from the first three years of monitoring (2006–2008), along with data on precipitation, river flows, and red tide from the Gulf of Maine, explored the causes of Casco Bay red tides.

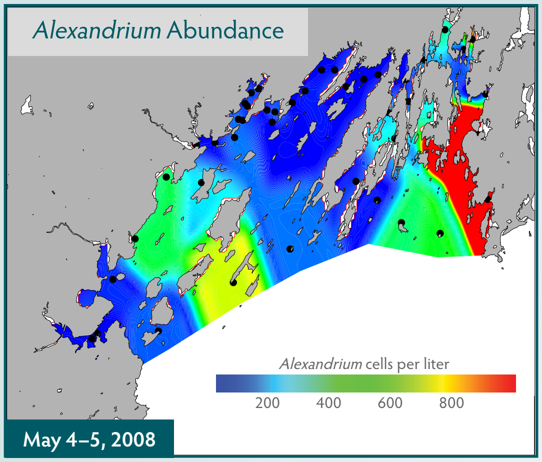
External Sources of Red Tide Organisms to Casco Bay

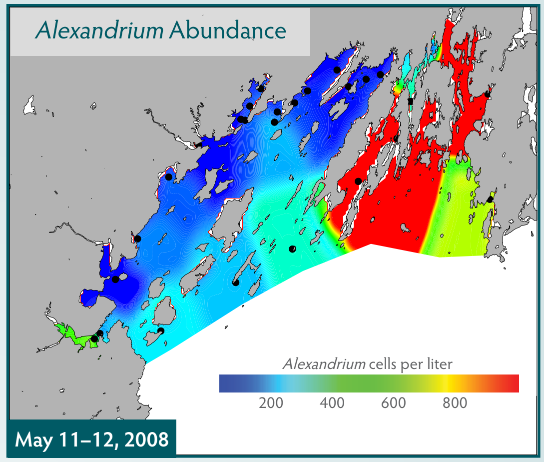
Red tides in the Gulf of Maine originate from dormant cysts (a resting stage of *A. fundyense*) that accumulate in localized "seed beds." As shown in the conceptual model, cysts in the Bay of Fundy germinate and cause recurrent blooms that are carried south and west by the Eastern Maine Coastal Current (EMCC). The flow sometimes continues alongshore where it joins the outflow of the Kennebec and Androscoggin Rivers to form a buoyant plume called the Western Maine Coastal Current (WMCC), which is also seeded by germination of cysts from the mid-coast Maine seedbed (Anderson 2005). The WMCC can carry cells into Casco Bay and further south. During persistent downwelling-favorable conditions (winds from the north and east), the red tide cells are brought close to the coast, while upwelling-favorable conditions move all cells, including those from the eastern Maine cyst beds, further offshore (Keafer *et al.* 2005).

Solid black lines in the figure denote the eastern and western segments of the Maine Coastal Current system (EMCC and WMCC, respectively). Long, solid black lines also depict the circulation around Georges Bank. Short, dashed black lines delimit the cyst seedbeds in the Bay of Fundy and mid-coast Maine. The red-shaded areas represent portions of the EMCC and WMCC where *A. fundyense* blooms tend to occur with the highest color intensity, denoting areas with higher cell concentrations. Dashed red lines show the transport pathways of the water masses and their associated cells.

Internal Sources of Red Tide Organisms to Casco Bay

There is also a local source of red tide cells in Casco Bay. Small embayments and kettle holes such as Lumbos (a.k.a Lombos) Hole in Harpswell are "point sources" of cells within the Bay itself (Bean *et al.* 2005). (Lumbos Hole has historically been the first site along the coast of Maine to show *A. fundyense* cells and become toxic in spring.) Local red tide cysts have been detected in the sediments in those areas, and in such shallow, warm areas, cells may grow faster than in the deep, colder waters offshore. Thus, for Casco Bay, there are apparently two distinct sources of *A. fundyense* cells: cyst populations that reside within the Bay (especially





Alexandrium abundance during selected 2008 surveys in the Casco Bay region.

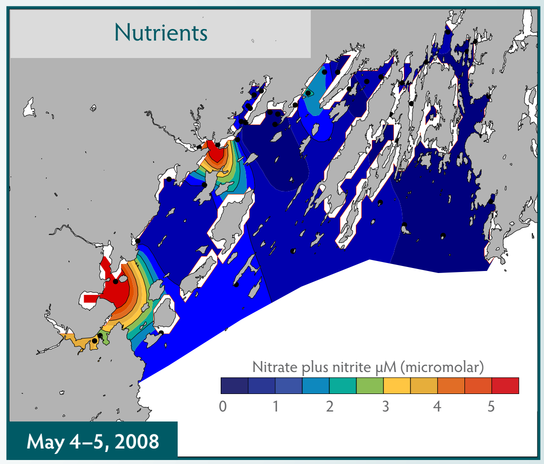
the distal portions of the New Meadows River and other sounds like Lumbos Hole) and the WMCC, which brings cells that originated in the Bay of Fundy and mid-coast Maine into Casco Bay (Libby and Anderson 2010).

Nutrients and Red Tides in Casco Bay

Analysis of the 2006–2008 monitoring data indicated clear differences between the stations in eastern and western Casco Bay. Eastern Casco Bay stations were deeper, and warmer (the stations were located in sheltered embayments), had higher salinity, lower nutrient levels, higher PSP toxicity, and higher *A. fundyense* cell counts than the western Casco Bay stations. Stations in western Casco Bay, at the mouths of rivers, typically had the highest concentrations of nutrients. There was no apparent correlation between the magnitude of red tide blooms (either as cell counts or PSP toxicity levels) and nutrient concentrations (or nutrient loading).

Conclusions

While it has been suggested that anthropogenic nutrients can worsen or spur on localized bloom events (Anderson *et al.* 2008), analysis of the available 2006–2008 data showed no apparent indication that landside contribution of nutrients plays a role in the intensity of local blooms in Casco Bay. The analysis showed a clear spatial separation between areas with the highest nutrient concentrations and areas with the greatest abundance of *A. fundyense*. While there is evidence of early inshore-initiated local blooms in Casco Bay, trends in the data and statistical analyses both point to the large regional offshore blooms as the source of the major red tide events in Casco Bay (Libby and Anderson 2010).



Surface concentrations of nitrate plus nitrite during May 4–5, 2008 survey. Note that there is no apparent correlation between concentrations of these nutrients and *A. fundyense* abundance (Libby and Anderson 2010).

References

Anderson, D.M., C.A. Stock, B.A. Keafer, A. Bronzino Nelson, B. Thompson, D.J. McGillicuddy Jr., M. Keller, P.A. Matrai, J. Martin, 2005b. *Alexandrium fundyense* cyst dynamics in the Gulf of Maine. *Deep-Sea Research II* 52: 2521-2542.

Anderson, D.M., J.M. Burkholder, W.P. Cochlan, P.M. Glibert, C.J. Gobler, C.A. Heil, R. Kudela, M.L. Parsons, J.E. Rensel, D.W. Townsend, V.L. Trainer, and G.A. Vargo. 2008. Harmful algal blooms and eutrophication: Examining linkages from selected coastal regions of the United States. *Harmful Algae* 8: 39-53.

Bean, L.L., J. D. McGowan, and J. W. Hurst. 2005. Annual variations of paralytic shellfish poisoning in Maine, USA 1997–2001. *Deep-Sea Research II* 52:2834-2842.

Keafer, B.A., J.H. Churchill, D.J. McGillicuddy, and D.M. Anderson. 2005. Bloom development and transport of toxic *Alexandrium fundyense* populations within a coastal plume in the Gulf of Maine. *Deep-Sea Research II* 52: 2674-2697.

Libby, S. and D. M. Anderson. 2010. *Red Tides in Inshore and Offshore Casco Bay and Their Relationship to Local and Gulf of Maine Physical and Biological Conditions.* Casco Bay Estuary Partnership.

INDICATOR 8

Do the rivers, streams and estuaries in the Casco Bay watershed meet state water quality standards?

What Are State Water Quality Standards and Why Are They Important?

To manage the water quality in its rivers, streams and estuaries, Maine has enacted laws in compliance with the Federal Clean Water Act of 1972. The four water quality classes established for rivers and streams are AA, A, B and C. Marine waters have three classes - SA, SB and SC - while lakes have the single class GPA. For each class, certain "designated uses" are specified such as swimming, fishing, boating, habitat for aquatic life, drinking water supply, navigation, agriculture, hydropower, industrial process and cooling water. Assigning a water body to a water quality class thus sets both numeric and narrative (descriptive) water quality goals or standards. The standards are different for the different classes, with AA and SA standards being most protective, B and SB aiming to maintain general high quality water and C and SC providing a lower level of protection. Regardless of the water quality classification, the standards for all Maine waters include the goal that they be both fishable and swimmable (Maine DEP 2010). See the table on p. 33 for more detail on classification standards for Maine's waters. Maine's Water Quality Classification law is detailed at http://janus.state.me.us/legis/statutes/38/title38sec464.html

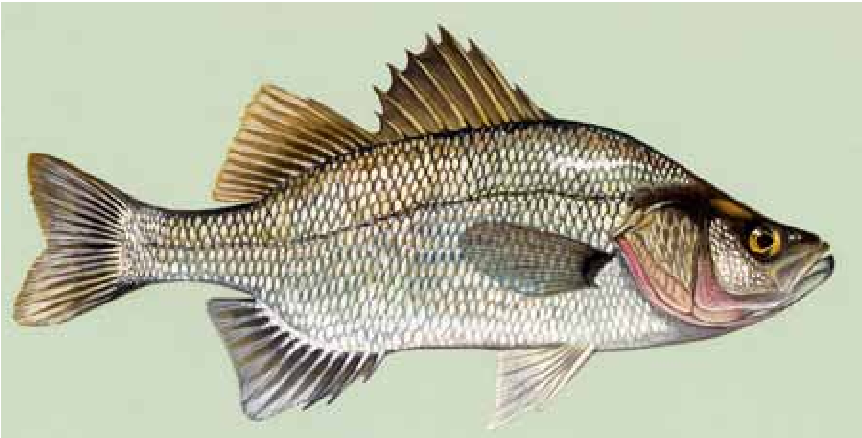
Every two years the Maine Department of Environmental Protection (DEP) assesses the status of its waters and produces an Integrated Water Quality Monitoring and Assessment Report ("305b") report. This report, most recently released in 2010, describes whether waters of the state (where monitoring data are available) meet or fail to meet the water quality standards applicable to their designated uses. The assessment helps the state focus its management efforts in order to maintain the designated uses of Maine's surface waters. For example, the state develops Total Maximum Daily Load (TMDL) plans to improve water quality in waters that fail to meet one or more water quality criteria.

Status: Pollutants and Impacts

Toxics (such as PCBs, dioxins, heavy metals, and pesticides) are by far the greatest cause of impairments to Maine waters. Several statewide "advisories" suggest people limit consumption of certain fish and shellfish from all Maine waters because of possible presence of toxic compounds. Citizens are advised not to eat lobster tomalley due to the potential presence of PCBs and dioxin (which can be concentrated in the tomalley) in Maine's coastal waters. A fish consumption advisory applies to striped bass and bluefish caught in the state. (Bluefish and striped bass, however, are migratory, so contamination may not come from Maine's waters). In addition, consumers are advised to limit consumption of freshwater fish from Maine because of the presence of mercury. The primary source of mercury is atmospheric deposition from power plants and other sources outside of the region. Additional fish consumption advisories apply to some segments of Maine's largest rivers as a result of "legacy pollutants" like PCBs from past industrial activities (Maine DEP 2010).

Some estuarine areas like Portland Harbor also have local toxic pollution problems due primarily to "legacy pollutants" from past activities such as papermaking, gasworks, tanning and metal working. In addition, PAHs and heavy metals (such as lead, copper and zinc) continue to enter the coastal environment due to urban development and boat-related activities.

Pathogen pollution affects many Casco Bay water bodies (see Section Two).



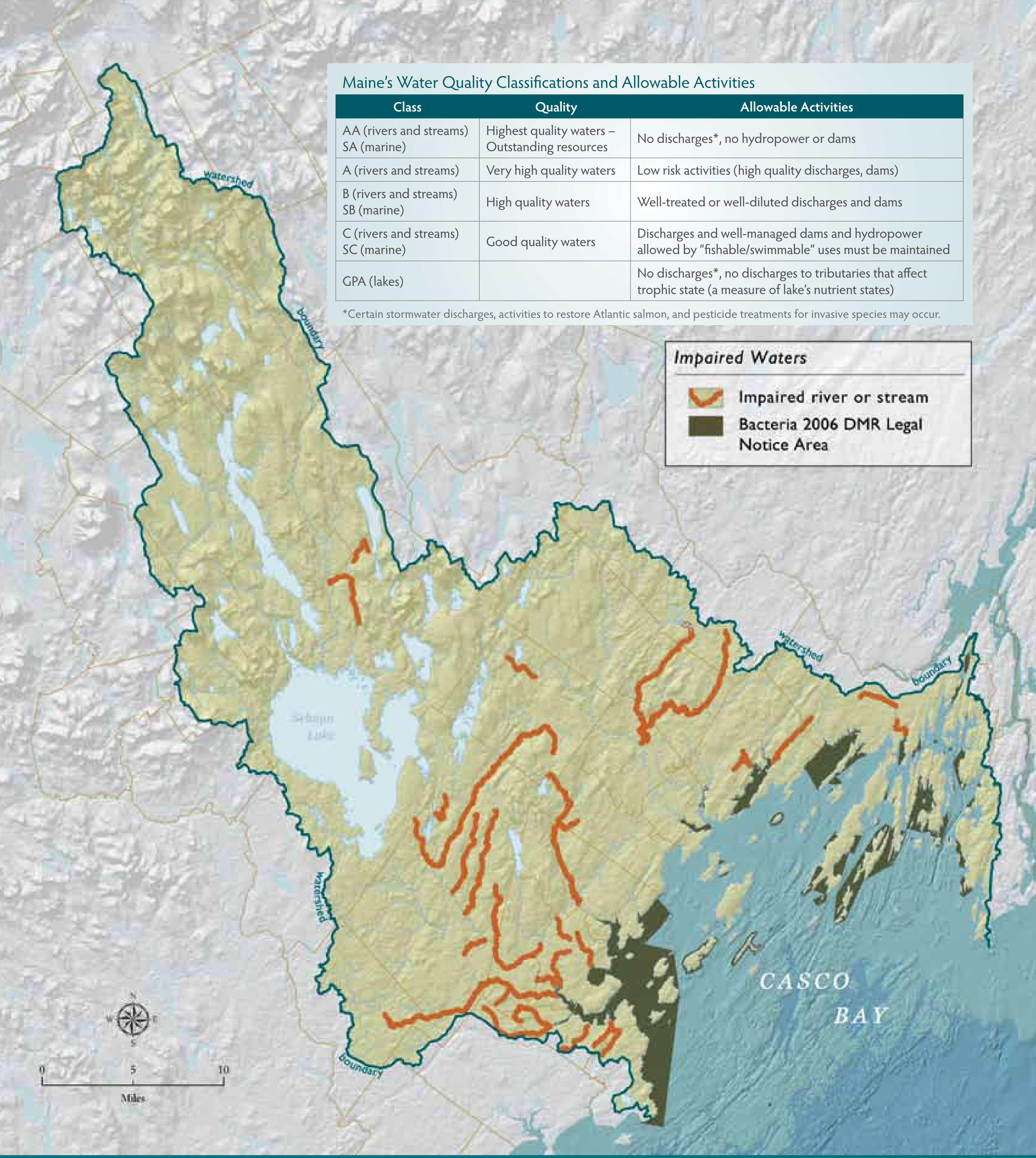
Duane Raver

Consumption advisories and consumer guidance have been issued by Maine Center for Disease Control (CDC) for all fish caught in Maine fresh waters, including white perch, pictured above, because of mercury pollution.

Maine's Water Quality Classifications and Allowable Activities

Class	Quality	Allowable Activities
AA (rivers and streams) SA (marine)	Highest quality waters – Outstanding resources	No discharges*, no hydropower or dams
A (rivers and streams)	Very high quality waters	Low risk activities (high quality discharges, dams)
B (rivers and streams) SB (marine)	High quality waters	Well-treated or well-diluted discharges and dams
C (rivers and streams) SC (marine)	Good quality waters	Discharges and well-managed dams and hydropower allowed by "fishable/swimmable" uses must be maintained
GPA (lakes)		No discharges*, no discharges to tributaries that affect trophic state (a measure of lake's nutrient states)

*Certain stormwater discharges, activities to restore Atlantic salmon, and pesticide treatments for invasive species may occur.



Impaired Waters in the Casco Bay Watershed

Marine waters of Casco Bay and streams and rivers of the Casco Bay watershed that do not meet water quality standards are called "impaired waters." All streams in Maine are impaired because of elevated levels of mercury, derived primarily from sources outside the state. All marine waters are impaired because the possible presence of toxic chemicals has led to recommendations that people limit consumption of certain fish and of lobster tomalley. Waters shown on the map have additional water quality problems. Marine waters impaired because of bacteria are displayed as DMR's 2006 Legal Notice Areas; in some cases only a portion of the legal notice area is impaired. (For details, see text and supplemental information at www.cascobayestuary.org/sotb2010.html)

Nutrients (nitrogen and phosphorus) may also become pollutants when present in excess, leading to excessive phytoplankton growth or intertidal mats of "green slime" (*e.g.*, *Ulva intestinalis*) along the coast. Nutrients also trigger decreased levels of dissolved oxygen and impacts to aquatic life (Maine DEP 2010).

Toxic chemicals, low dissolved oxygen and other stressors have an impact on the suitability of habitat for fish, invertebrates and other aquatic life. One way Maine DEP assesses whether rivers, streams and wetlands are meeting aquatic life standards is by monitoring the aquatic macroinvertebrate community. Those aquatic organisms – primarily insects – can serve as indicators of water quality because species vary with respect to their sensitivity to pollution and disturbance. For example, the larvae of stoneflies, mayflies and caddisflies are highly sensitive to pollution. Of intermediate tolerance to pollution are the larvae of dragonflies, damselflies, dobsonflies and blackflies. More severely polluted or disturbed habitats may contain only tolerant organisms like midge larvae, snails and/or leeches (Maine DEP 1999, 2008).


Friedrich Böhringer

Stonefly larvae are sensitive to pollution and are one of the organisms that disappear from polluted streams.

The water bodies in Casco Bay and its watershed that are impaired are shown on p. 33.

What Are the Trends?

Overall, water quality in the watershed is good and has remained so over time. There has been little change in the number of water bodies impaired by pollution in the Casco Bay watershed since the 2005 *State of the Bay* report. More urbanization in the lower watershed may increase nonpoint source loads and lead to decreased water quality in the future unless new impervious surface is minimized or its impacts are mitigated. Urban streams are especially vulnerable to development pressure (see Indicator 3).

Solutions and Actions to Help Meet Water Quality Standards

CBEP and its partners are working to assess and reduce the loading of pollutants to Casco Bay and its watershed. For example, Maine DEP has developed TMDL water quality improvement plans for many of the impaired waters in Casco Bay. Most recently, US EPA approved a Maine TMDL that includes bacterial loading reduction strategies for both freshwater and marine waters (DEP 2009). A regional mercury improvement plan (a TMDL) was approved by US EPA in 2007. The state of Maine is also working to reduce local mercury sources. To address nitrogen impacts in the state's coastal waters, Maine is working with US EPA to establish coastal nutrient water quality criteria.

In addition to monitoring and assessment activities, Maine DEP manages the National Pollutant Discharge Elimination System (NPDES) program, which regulates permitted point source discharges into the state's waters. Casco Bay communities in the federally mandated Municipal Separate Storm Sewer System (MS4) program are working collaboratively to reduce pollution from stormwater (see Indicator 3). Both Portland and South Portland are working to reduce the frequency and volume of combined sewer overflows (see Indicator 4).

Nonpoint source pollution reduction is being addressed, for example, by educational outreach through the state and the Nonpoint Source Education for Municipal Officials (NEMO) program. Federal Section 319 grants are awarded by the state to reduce nonpoint source pollution through development of management plans and on the ground source reduction. The Long Creek Restoration Project is an innovative state and local partnership focused on reduction of nonpoint source pollution to a major urban stream. CBEP's Urban Stream Initiative is working with local partners to assess and address pollution impacts to those vulnerable water bodies.

Throughout the Casco Bay watershed, citizen steward programs like those of Friends of Casco Bay, Presumpscot River Watch, Maine Volunteer Lake Monitoring Program and Lakes Environmental Association continue to collect monitoring data to assess the health of our waters and to support Maine DEP's efforts to manage water quality. CBEP has provided financial support to each of those groups.

References

Casco Bay Estuary Partnership. 2005. *State of the Bay*. http://www.cascobay.usm.maine.edu/sotb05.html

Maine Department of Environmental Protection. 1999. *Biomonitoring Retrospective: Fifteen Year Summary for Maine Rivers and Streams.* http://www.maine.gov/dep/blwq/docmonitoring/biomonitoring/romans.pdf

Maine Department of Environmental Protection. 2006. Chapter 500, Stormwater Management, and Chapter 502, Direct Watersheds of Lakes Most at Risk from Development, and Urban Impaired Streams, effective December 27, 2006. http://www.maine.gov/dep/blwq/docstand/stormwater/rule500and502/502appA.pdf

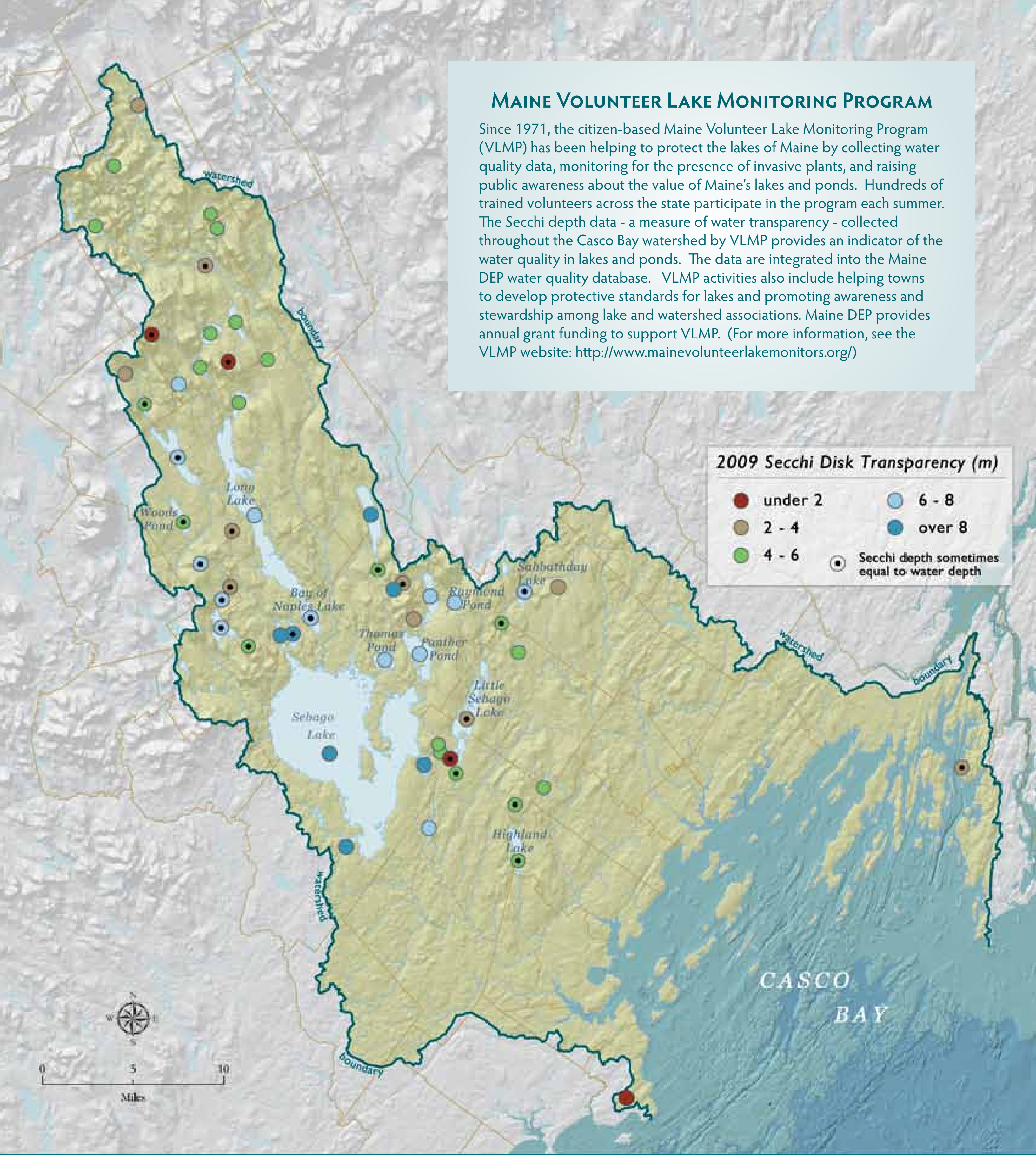
Maine Department of Environmental Protection. 2008. *Common Aquatic Macroinvertebrates in Maine Streams and Wetlands* (Fact Sheet). http://www.maine.gov/dep/blwq/docmonitoring/biomonitoring/material.htm

Maine Department of Environmental Protection. 2009. *Statewide Bacterial Total Maximum Daily Load.* http://www.maine.gov/dep/blwq/docmonitoring/TMDL/2009/report.pdf

Maine Department of Environmental Protection. 2010. *Integrated Water Quality and Assessment Report.*

Maine Volunteer Lake Monitoring Program

Since 1971, the citizen-based Maine Volunteer Lake Monitoring Program (VLMP) has been helping to protect the lakes of Maine by collecting water quality data, monitoring for the presence of invasive plants, and raising public awareness about the value of Maine's lakes and ponds. Hundreds of trained volunteers across the state participate in the program each summer. The Secchi depth data - a measure of water transparency - collected throughout the Casco Bay watershed by VLMP provides an indicator of the water quality in lakes and ponds. The data are integrated into the Maine DEP water quality database. VLMP activities also include helping towns to develop protective standards for lakes and promoting awareness and stewardship among lake and watershed associations. Maine DEP provides annual grant funding to support VLMP. (For more information, see the VLMP website: http://www.mainevolunteerlakemonitors.org/)

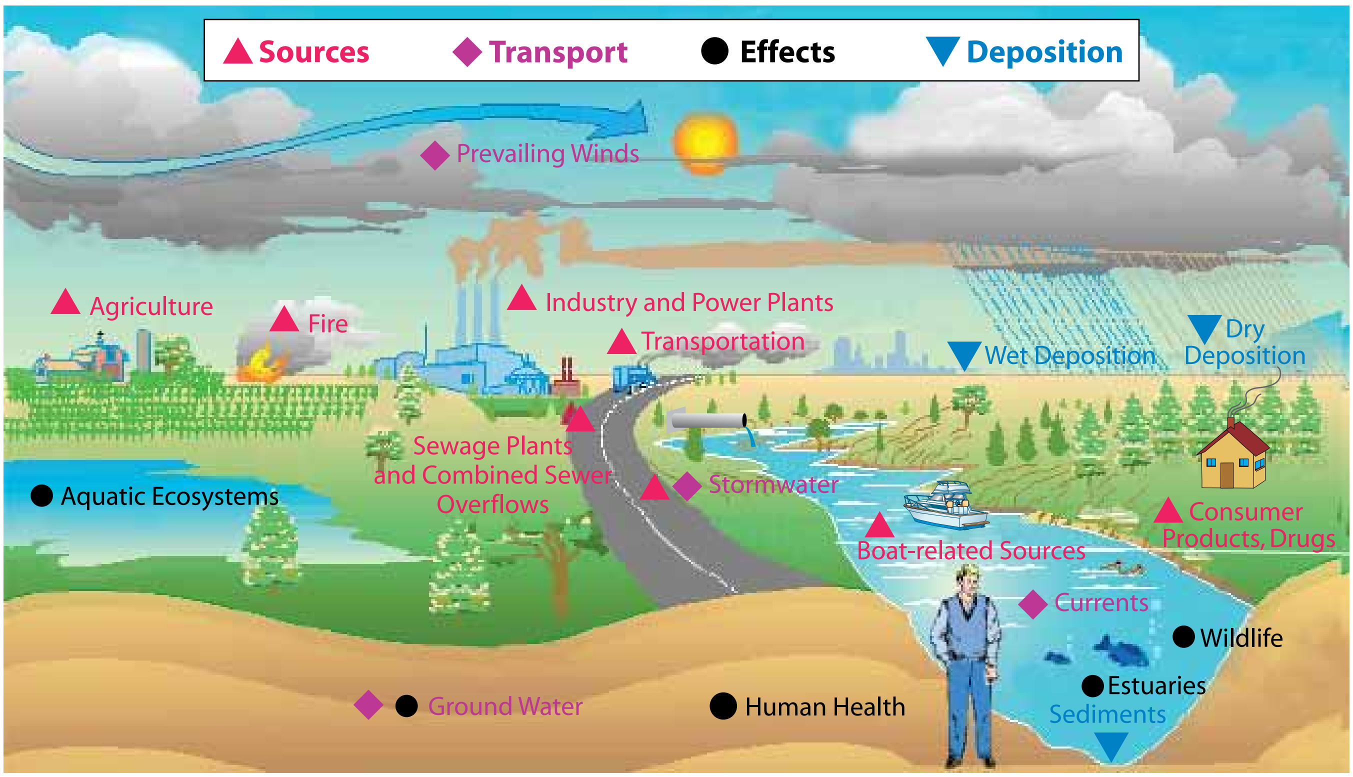


Lake Water Transparency

Average Lake Transparency in Casco Bay Watershed, 2009. The map illustrates the average transparency of lakes in the Casco Bay watershed monitored by VLMP. Among the larger monitored lakes and ponds that Maine DEP considers to be at risk of future impairment by development in the watershed are Bay of Naples Lake, Highland Lake, Little Sebago Lake, Thomas Pond, Sabbathday Lake, Woods Pond, Panther Pond, Long Lake, Raymond Pond and Sebago Lake (Maine DEP 2006).

SECTION FOUR

Toxic Pollution



Toxic Chemical Pathways. Major toxic chemical pathways including sources, transport mechanisms, deposition, and effects are illustrated. Whether the toxics enter the watershed from point sources such as pipes, smokestacks, and internal combustion engines, or are transported and deposited by rain (wet deposition), wind (dry deposition) and stormwater runoff, toxic chemicals are finding their way into freshwater and marine aquatic ecosystems.

Adapted from National Science and Technology Council Committee on Environment and Natural Resources, Air Quality Research Subcommittee, 1999.

Introduction

Toxic chemicals are the major stressor impairing Maine's marine and estuarine waters (DEP 2008). The toxic chemicals addressed by CBEP's indicators include two primary types of pollutants: (1) heavy metals and (2) organic chemicals like polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and dioxins and furans – bonded forms of carbon, hydrogen and other atoms. Those organic chemicals break down slowly into their component parts, but as they do, they and their metabolites (breakdown products) can be toxic to living organisms. Since the 2005 *State of the Bay* report and the 2007 report *Toxic Pollution in Casco Bay*, CBEP has added a new class of contaminant chemicals to the indicators it monitors: "contaminants of emerging concern," chemicals that have not traditionally been monitored or regulated. Those include persistent organic chemicals like polybrominated diphenyl ethers (PBDEs) and perflourinated chemicals (PFCs) as well as pharmaceuticals and personal care products (PPCPs). Such contaminates are being found worldwide in aquatic environments, including Casco Bay.

Major pathways by which toxic chemicals enter the environment are illustrated in the diagram above. Sources of the toxic chemicals found in Casco Bay include the following:

- **PAHs**, the most common toxic contaminants in the Bay, come primarily from combustion of fossil fuels and wood, but oil, fuel spills, and asphalt are also sources.

- **PCBs** are potent carcinogens formerly used in electric transformers and other industrial applications. While they were banned in the 1970s, they are still found in old landfills and dumps, and are present at high levels in the Fore River.
- **Planar PCBs** are the most toxic form of PCBs, and commercial PCB mixtures are their source (Tanabe *et al.* 1987).
- **Pesticides** are largely carried from lawns and fields to water bodies through stormwater runoff. Although banned since 1972, the pesticide DDT and its toxic breakdown products still persist in the environment.
- **Dioxins and furans** are formed when organic material is burned in the presence of chlorine. Incineration, pulp paper manufacturing, coal-fired utilities, diesel vehicles and metal smelting are all sources of dioxin in the environment. Although the pulp mill discharging waste into the Presumpscot River stopped doing so in 2000, dioxins and furans still reach the Bay through atmospheric deposition.
- **PBDEs** are organic contaminants used as flame retardants in a variety of consumer products. They enter the environment through runoff, municipal waste incineration and sewage outflows, as well as by leaching from consumer products, sewage sludge applied to land as bio-solids, and industrial discharges (Kimbrough *et al.* 2009).
- **PFCs** are heat-resistant, slippery industrial chemicals that are used, for example, as water, stain and grease repellants (*e.g.*, Teflon). They are released into the environment through manufacturing processes, as well as through industrial and consumer use.
- **PPCPs** include over-the-counter and prescription drugs, as well as personal hygiene and beauty products like soaps, hairspray and sunscreen. When consumers wash off, excrete, or discard such products down drains, they can pass through septic systems and wastewater treatment plants into the environment.
- **Butyltins** are toxic organometallic compounds, molecules in which metal is bonded to a carbon atom in an organic molecule. Butyltins enter the Bay's sediments primarily from marine anti-fouling paints.
- **Heavy metals** are dense metallic elements such as lead, mercury, arsenic, cadmium, silver, nickel, selenium, chromium, zinc and copper. Because they do not break down over time, metals delivered from point sources, stormwater runoff, or atmospheric deposition can accumulate in the environment. In addition, metals can bind with organic chemicals forming organometallic compounds such as methyl mercury and butyltin, which can be highly toxic. Sources of heavy metals include vehicle emissions, industrial processes, coal combustion, weathering of metal pipes, and incineration (CBEP 1996).

The following three indicators report on toxic chemical monitoring programs that CBEP and its partners and collaborators are undertaking in Casco Bay.

References

Casco Bay Estuary Partnership. 1996. rev. 2006. *Casco Bay Plan.* http://www.cascobay.usm.maine.edu/cbplan96.html

Kimbrough, K. L., W. E. Johnson, G. G. Lauenstein, J. D. Christensen and D. A. Apeti. 2009. *An Assessment of Polybrominated Diphenyl Ethers (PBDEs) in Sediments and Bivalves of the U.S. Coastal Zone.* Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 94. 87 pp. http://ccma.nos.noaa.gov/PBDEreport.pdf

Maine Department of Environmental Protection. *2008 Integrated Water Quality Monitoring and Assessment Report* . http://www.maine.gov/dep/blwq/docmonitoring/305b/2008/report.pdf

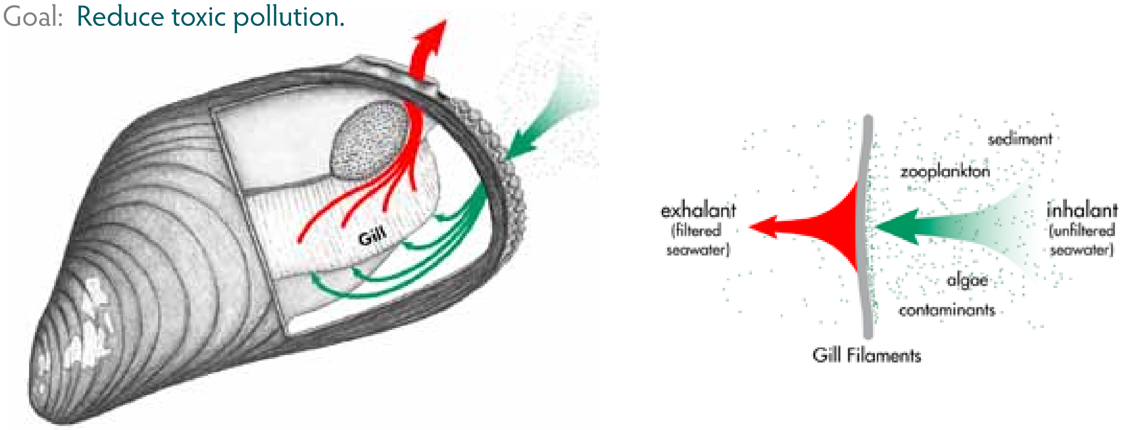
National Science and Technology Council Committee on Environment and Natural Resources. Air Quality Research Subcommittee. 1999. *The Role of Monitoring Networks in the Management of the Nation's Air Quality.* http://nature.nps.gov/air/Monitoring/docs/role-aqmonit.pdf

Tanabe S., N. Kannan, A. N. Subramanian, S. Watanabe, and R. Tatsukawa. 1987. Highly toxic coplanar PCBs: occurrence, source, persistency and toxic implications to wildlife and humans. *Environmental Pollution* 47 (2): 147-163.

INDICATOR 9

Are there toxic chemicals in the tissues of Casco Bay blue mussels?

CBEP Goal: Reduce toxic pollution.



Ethan Nedeau

The common blue mussel is an excellent indicator of environmental contamination. As a mussel breathes and feeds, its gill filters out and retains small particles, including biologically available contaminants, which can be ingested and assimilated into its tissues.

Why Is It Important to Monitor the Levels of Toxic Chemicals in Blue Mussels in Casco Bay?

The common blue mussel, *Mytilus edulis*, is long lived and sedentary as an adult, accumulating local contaminants through feeding and surface contact. It is common throughout Gulf of Maine coastal areas where it is found in densely populated beds in the intertidal zone—the area between low and high tides. Casco Bay is one of the most productive areas in Maine for wild mussels. The blue mussel is thus a useful “sentinel” species for the Bay. Because many toxic compounds biomagnify (become more concentrated in organisms higher up the food chain), elevated levels of contaminants in the tissues of blue mussels—which are near the base of the food chain—suggest that top-level consumers, including fish and humans, may be at risk from contaminants in the ecosystem.

Andreas Trepte

Data on toxic compounds in mussels from Casco Bay come primarily from statewide and regional monitoring programs. Maine DEP began using *Mytilus edulis* as an indicator species of toxic exposure in 1987, and has analyzed their soft tissues from approximately 65 sites along the Maine coast over the past 23 years. CBEP has periodically provided funding to add additional sites in Casco Bay to the program. Gulfwatch, a joint US/Canada blue mussel monitoring program, began sampling US and Canadian waters in 1991.

Status of Casco Bay Mussels

DEP SWAT Program 2007–2009 Sample Collection

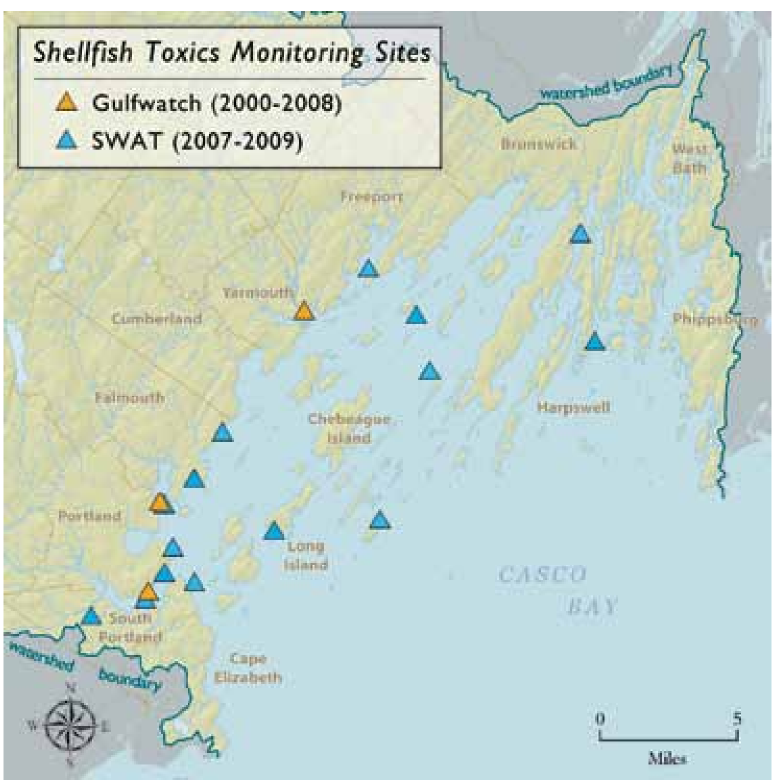
Samples were collected by DEP from sites in Casco Bay in 2007, 2008 and 2009 (see map on p. 39). Sampling was done from mid-October to mid-December each year, at four sites along the shoreline at each of the sampling locales. Mussels selected for analysis were in the 50 - 60 mm size range (DEP 2010). All samples were analyzed for aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), zinc (Zn), silver (Ag) and mercury (Hg), PAHs, PCBs pesticides, dioxins and furans. Samples with elevated levels are noted in the table. Note that elevation of Al and Fe (which are common and relatively non-toxic constituents of clay and soil minerals) often corresponds to high intake of suspended sediment and may relate to gut contents rather than tissue levels.

Pesticides sampled include the sum of DDTs (dichloro-diphenyl-trichloroethylene) and breakdown products. While the highest DDT levels were seen in Long Island, all Maine samples were considered to be in the low range nationally, based on National Status and Trends Mussel Watch data (NOAA 2008). Dieldrins and chlordanes were also in the low range in Maine samples. Elevated levels for the sum of organochlorine pesticides as compared to

Toxics Elevated[1,2] in Mussels Collected from Sampling Sites in Casco Bay 2007 – 2009
(Note that only East End Beach was sampled twice during this period)(DEP 2010)

Year Sampled	Sampling Location	Al	Fe	Cr	Cu	Ni	Pb	Zn	Hg	PCBs[3]	PAHs[4]	Organo-chlorine Pesticides[5]
2007	Spring Point, S. Portland				X[2]		X[2]					X[2]
	Middle Fore River, S. Portland				X[2]		X[2]	X[1,2]		X[2]	X[2]	X[2]
	East End Beach, Portland				X[2]		X[2]					X[2]
	Jewell Island, Punch Bowl											
	Falmouth Anchorage				X[2]							
	Harraseeket River, Freeport				X[2]							
	Mare Brook, Harpswell Cove				X[2]							
2008	Presumspcot River, Falmouth				X[2]		X[1,2]		X[2]			X[2]
	Middle Bay, Harpswell											
2009	Inner Fore River, Portland	X[1,2]	X[2]	X[1,2]	X[2]	X[2]				X[2]	X[2]	X[2]
	East End Beach, Portland	X[1,2]	X[2]	X[1,2]		X[2]	X[2]			X[2]		X[2]
	Mill Creek, Falmouth											
	Long Island											X[2]
	Maquoit Bay Freeport											
	Quahog Bay, Harpswell					X[2]						

1 Elevated based on Maine Reference Conditions, mean + 2 standard deviations (DEP 2005)
2 Elevated based on Gulf of Maine-wide Gulfwatch 85th percentile value, *i.e.*, 85% of samples fall below the 85th percentile value (GOMC 2009)
3 Sum of 19 PAHs
4 Sum of 35 PCB congeners
5 Sum of Organochlorine pesticides



other data from the Gulf of Maine are noted in the table. In 2009, samples were also collected for additional pesticides: organophosphates, triazines, pyrethroids and organonitrogens. Those pesticides were not at detectable levels in the Maine samples tested (DEP 2010).

Temporal Trends in Casco Bay

Where data from the same sites are taken over time, it may be possible to compare the levels of pollutants, and observe whether there is any apparent temporal trend. Maine DEP undertook an analysis of temporal trends for selected metals in mussel samples collected from 1987 to 2008 (DEP 2009). Three Casco Bay sites were included: East End Beach in Portland, and Spring Point and Middle Fore River, both in South Portland. The results indicated that:

- Cadmium showed a stable or decreasing trend.
- Copper was relatively stable through time.
- Zinc was relatively stable through time (DEP 2009).

Changes in Lead Concentration in Mussels from Casco Bay Sampling Sites Over Time

DEP SWAT sampling over time at several Casco Bay sites suggests that while there was an initial increase in lead levels from 1988 to 2001/2002, there has been a decline in lead levels in more recent samples. Units are micrograms per gram dry weight. The Gulfwatch mussel sampling program (see table below) has observed a regional decline in lead levels over the past decade.

Comparison of lead levels in past and recent samples suggests that for some sites in Casco Bay, lead levels have declined over time. (See the bar graph above.)

Trends in Mussel Toxics Across the Gulf of Maine: Gulfwatch Data

Gulfwatch is a joint US/Canada blue mussel monitoring program funded through the Gulf of Maine Council on the Maine Environment. Since 1991, the program has monitored mussels to help identify temporal and spatial trends in ecosystem exposure to toxic compounds throughout the Gulf. Three sites sampled from 2000-2009 lie within the Casco Bay watershed: Portland Harbor (sampled five times in that period), Presumpscot River (sampled three times) and Royal River (sampled twice).

Metals

Concentrations for most metals appear to have decreased over time in the Gulf. In addition, concentrations are generally higher to the south and west, and lower heading downeast. At the Portland Harbor site, most metal concentrations, including lead, decreased from 2000 to 2008 (see the table below). To the extent comparisons can be made, metals at the other sites (data not shown) showed either no change or a decline over time.

PAHs

PAHs in the region (based on the sum of 24 PAHs) were highest for the two sites located in Boston Harbor and Long Island-Boston Harbor. For the most part, sample locations for the remainder of the Gulf of Maine contained relatively low levels of PAHs. However, the fourth highest total PAHs in the Gulf of Maine were observed at Portland Harbor (see the graph on p. 41). Similar high levels of PAHs were noted in the 1993–2001 data analysis (GOMC 2006).

Chlorinated Pesticides and PCBs

With respect to chlorinated pesticides, values were quite high in Massachusetts, with the largest concentrations observed in Boston's Inner Harbor. Casco Bay samples ranged from a low at the Royal River site to a high at Portland Harbor. In general, concentrations of pesticides decrease with increases in latitude. Similarly, the concentrations of all PCBs summed together decrease with increases in latitude. Highest values were observed in Massachusetts at Neponset River and Boston's Inner Harbor. Casco Bay samples ranged from a low at the Royal River to a high at Portland Harbor.

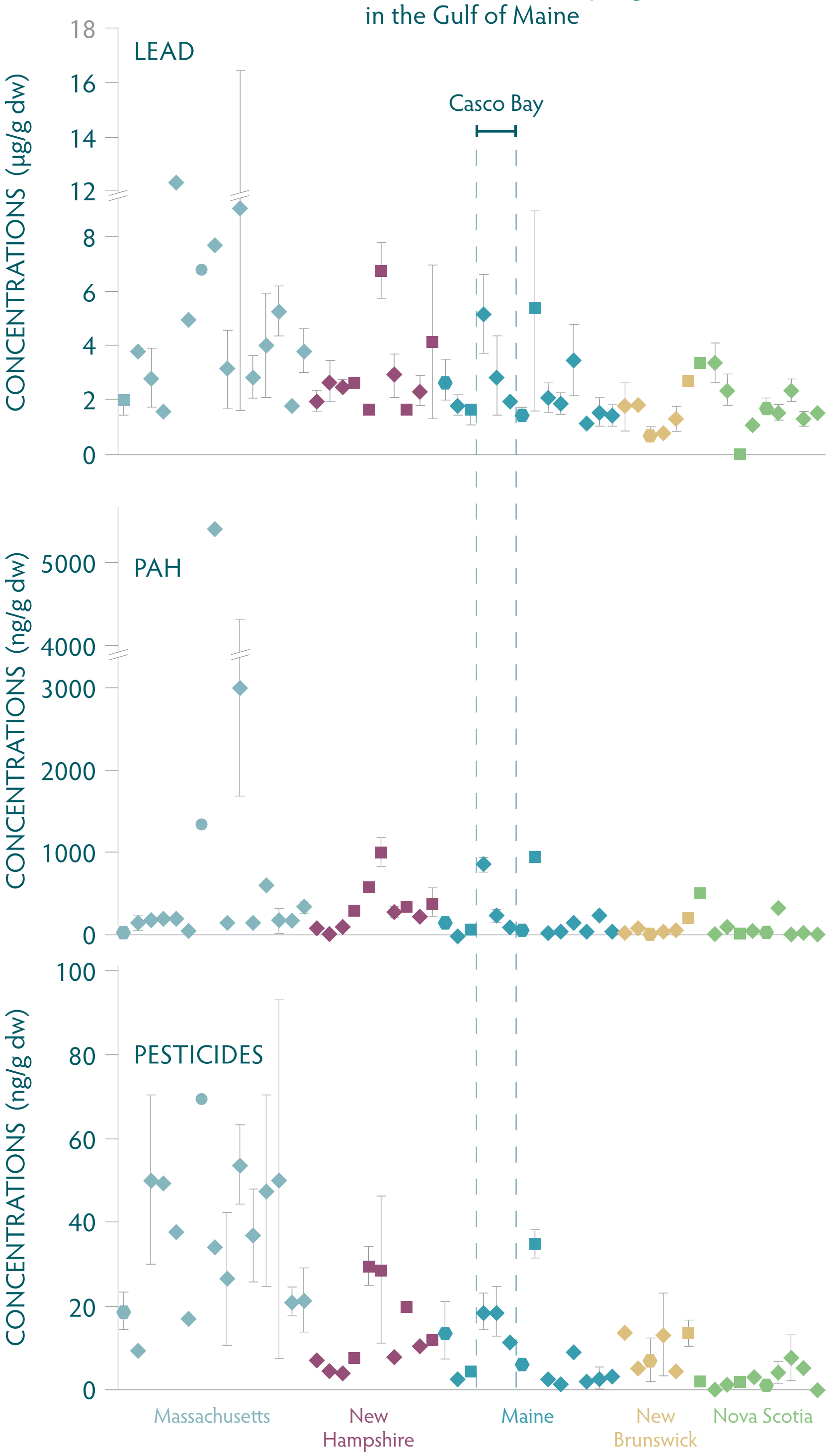
Gulfwatch Data for Metals in Portland Harbor

Year	Hg	Ag	Cd	Pb	Ni	Zn	Al	Cr	Fe	Cu
2000		0.1	1.78	11.5	2.45	357.5	370	2.3	737.5	12.3
2003	0.30	0.09	1.48	2.33	7.62	107.8	467		668.8	
2005	0.29	0.05	1.89	6.58	1.39	159.5	464	1.8	761.3	8.6
2007	0.2	0.02	1.39	4.34	0.95	146	250	1.7	444	7.6
2008	0.2	0.02	1.48	5.16	1.06	139	483	1.4	606	8.08

Most metals have decreased over time (units are µg/g dry weight).

Corey Templeton

Concentrations of Toxics at Sampling Sites in the Gulf of Maine



Eight-year (2000-2008) median and median absolute deviations[1] in concentrations in mussel tissues at all Gulfwatch sites, in geographic order (south to north along the x axis from Massachusetts to Nova Scotia).

- Benchmark site (sampled every year)
- Multi-year sites (sampled every 3 years)
- Sampled every 6 years
- Occasionally sampled sites

[1] In statistics, the median absolute deviation (MAD) is defined as the median of the absolute deviations from the data's median: $MAD = \text{median}_i (|X_i - \text{median}_i(X_i)|)$ In words, 50% of observations lie within the range defined by the MAD.

Conclusions

Most areas of Casco Bay and the Maine coastline that are located away from human activity have measurable but not elevated levels of toxic chemicals (based on Maine reference conditions and Gulfwatch 85th-percentile values). Elevated levels tend to occur where past manufacturing has left a legacy of pollutants in the sediment; in harbors and commercial port areas; at the mouths of rivers; and in developed areas where runoff is carried into coastal waters from impervious surfaces (see Indicator 2). In the polluted Inner Fore River, for example, historical upstream industry, inflow from the Stroudwater River, and runoff from the Portland Jetport and the Maine Mall all contribute to the toxic body burden of resident mussels. At East End Beach, another affected area, urban runoff, leachate from a dump, riverine inputs from the Presumpscot, and nearby dense residential development all contribute to pollution levels.

The human activity-related pattern of mussel contamination seen by Maine DEP's mussel sampling efforts and by the Gulfwatch regional sampling program is also observed in the distribution of sediment contamination in the Bay (see Indicator 10). There is some positive news. The Gulfwatch data suggest that metal levels in mussels (and in the ecosystem) are declining across the Gulf of Maine, including Casco Bay. The Maine DEP data also support the conclusion that lead levels have dropped at several Casco Bay sites over time.

References

Casco Bay Estuary Partnership. 2005. *State of the Bay.* http://www.cascobay.usm.maine.edu/sotb05.html

Gulf of Maine Council. 2006. *The Nine-Year Gulfwatch Program 1993-2001: A Review of the Results and Program Design.* L. White, S. Jones, P. Wells, G. Brun, G. Harding, P. Hennigar, C. Krahforst, D. Page, J. Schwartz, S. Shaw, D. Taylor, P. Trowbridge.

Gulf of Maine Council on the Marine Environment. 2009. *Gulfwatch 2008 Data Report: Eighteenth Year of the Gulf of Maine Environmental Monitoring Program.* http://www.gulfofmaine.org/gulfwatch/data/files.php

Maine Department of Environmental Protection. 2005. *A Decade of Toxics Monitoring.* John Sowles.

Maine Department of Environmental Protection. 2009. *2008 Surface Water Ambient Toxic Monitoring Program.*

Maine Department of Environmental Protection. 2010. *2009 Surface Water Ambient Toxic Monitoring Program, Draft.*

National Oceanic and Atmospheric Administration. 2008. *An Assessment of Two Decades of Contaminant Monitoring in the Nation's Coastal Zone.* Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 74. 105 pp. http://nsandt.noaa.gov

Are the levels of toxic chemicals in Casco Bay sediments changing over time?

CBEP Goal: Reduce toxic pollution.

Why Is It Important to Measure the Levels of Toxic Chemicals in Casco Bay Sediments?

When the sediments of Casco Bay were first analyzed in 1980, scientists were surprised to learn that contamination by heavy metals and organic contaminants was widespread. Toxic chemicals enter the Bay through multiple pathways (see the diagram on p. 36), often becoming attached to sediment particles. Once in the sediments, toxics can either break down over time or become buried under newer layers of sediment, where burrowing or deposit-feeding organisms, or dredging by humans, can return them to the surface. Pollution exposure adversely affects the benthic (bottom) community, making organisms sick, reducing the number of species present, and increasing the predominance of hardy, pollution-tolerant organisms.

Organisms that inhabit the benthic sediments play an important role in the marine food chain, recycling organic matter and serving as a food source to groundfish, lobsters, and crabs. By ingesting smaller organisms that have accumulated toxic chemicals from the sediments, fish and larger crustaceans may experience inhibited growth and reproduction, increased vulnerability to disease, and even death (US EPA 2006). Humans who consume seafood contaminated by toxic chemicals can be at risk as well. For example, the dioxins present in Casco Bay, a legacy of the pulp and paper industry, have resulted in elevated levels in the livers – the tomalley – of lobsters. A public health advisory against eating tomalley has been in effect in Maine since 1992 (DEP 2004). Monitoring sediments for pollutant concentrations, toxicity, and benthic community structure over time allows us to assess the extent and impacts of pollution contamination, and to measure the success of management strategies to reduce pollutant loads.

Steve Karpiak

Bottom-dwelling organisms like lobsters are exposed to toxic chemicals in the sediments. DEP advises consumers not to eat lobster tomalley.

Status

Contaminants

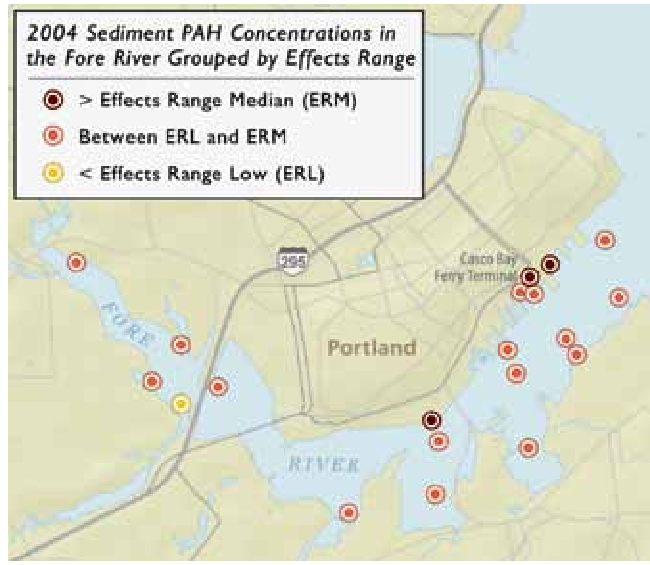
CBEP began monitoring the sediments in the Bay in 1991, conducting a baseline assessment at 65 sites. The site selection process took into consideration good areal coverage of the Bay, different sediment types and bottom communities, water depth, circulation patterns, and areas known to be historically affected by pollution. Surface sediments were analyzed for heavy metals, PAHs, PCBs and pesticides (Kennicutt *et al.* 1992). In 1994, 28 of the original sites and five new sites were analyzed for butyltins, doxins/furans, and coplanar PCBs (Wade *et al.* 1995). In 2000 and 2001, in partnership with EPA's National Coastal Assessment (NCA), CBEP resampled the sediments at the original locations for toxic pollutants, as well as for sediment toxicity and community structure. The results indicated that, in general, the most widespread contaminants in the Bay are petroleum and its byproducts, particularly high molecular weight PAHs derived from high-temperature combustion of petroleum products (*e.g*, vehicle exhaust). The sampling also indicated that PCBs were highly elevated in the inner Bay near Portland; and that none of the pesticides measured was highly elevated in the Bay. Trace metals were generally highest in the Inner Bay but few samples were much elevated above background levels. Butyltins, dioxins/furans, and planar PCBs were found throughout the Bay, with the highest levels in the Inner Bay.

Toxicity

Based on CBEP and NCA sampling, the concentrations of metals, PCBs (at almost all sites), pesticides, butyltins, doxins/furans and planar PCBs are lower in Casco Bay than levels known to cause harmful effects to organisms. PAH concentrations in the inner part of the Bay were between the levels identified by the National Status and Trends Program (NST) as Effects Range Low (possible biological

Sampling was conducted in 2004 in the Fore River by Friends of Casco Bay, supported by a Natural Resource Damage Assessment grant and funds from CBEP. Low and high molecular weight PAHs come from different sources, and their ratio can be used to help identify the likely source of the PAHs. For example, at the Casco Bay Ferry Terminal the primarily high molecular weight PAH signature indicates post-combustion sources such as vehicle exhaust and industrial combustion, rather than the low molecular weight signature of oil spills and urban runoff. The PAHs are likely carried via the CSO at the site (FOCB 2005).

effects) and Effects Range Median (probable biological effects) (Wade *et al.* 1995). The toxicity of additional PAH samples collected in the Fore River in 2004 is described in the map at right.



Trends

Scientists from Texas A & M University compared the pollutant concentration data from the 1991/1994 Casco Bay sediment sampling to the 2000/2001 data. They concluded that most toxic chemicals decreased or stayed the same during that time period, indicating that pollution control strategies are working in Casco Bay (see the summary table to the right and the TBT maps; Wade and Sweet 2005). Since many toxic compounds decay very slowly – or not at all – in the sediments, it is assumed that the declining levels observed primarily reflect the burial of toxics by cleaner, more recent sediments. The NCA program and CBEP collected sediment samples again in summer 2010. When the results of the 2010 sampling are available, CBEP will fund an analysis of spatial and temporal trends from 1991 to 2010.

Change in Concentration of Toxic Chemicals from 1991/1994 to 2000/2001 in Casco Bay Sediments

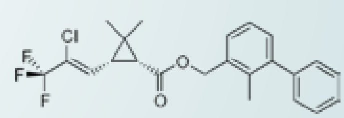
Decreased	No Overall Change	Increased
Cadmium	Arsenic	Silver
Chromium	Copper	
Mercury	Lead	
Nickel	Zinc	
Selenium		
Total pesticides, 4,4-DDE, 4-4DDD and total DDTs		
Tributyl tin and total butyl tin		
Total PCBs		
Planar PCB 126	Planar PCB 77	
	Dioxins/Furans	
Low molecular weight PAHs	Total PAHs	High molecular weight PAHs

Source: Wade and Sweet 2005

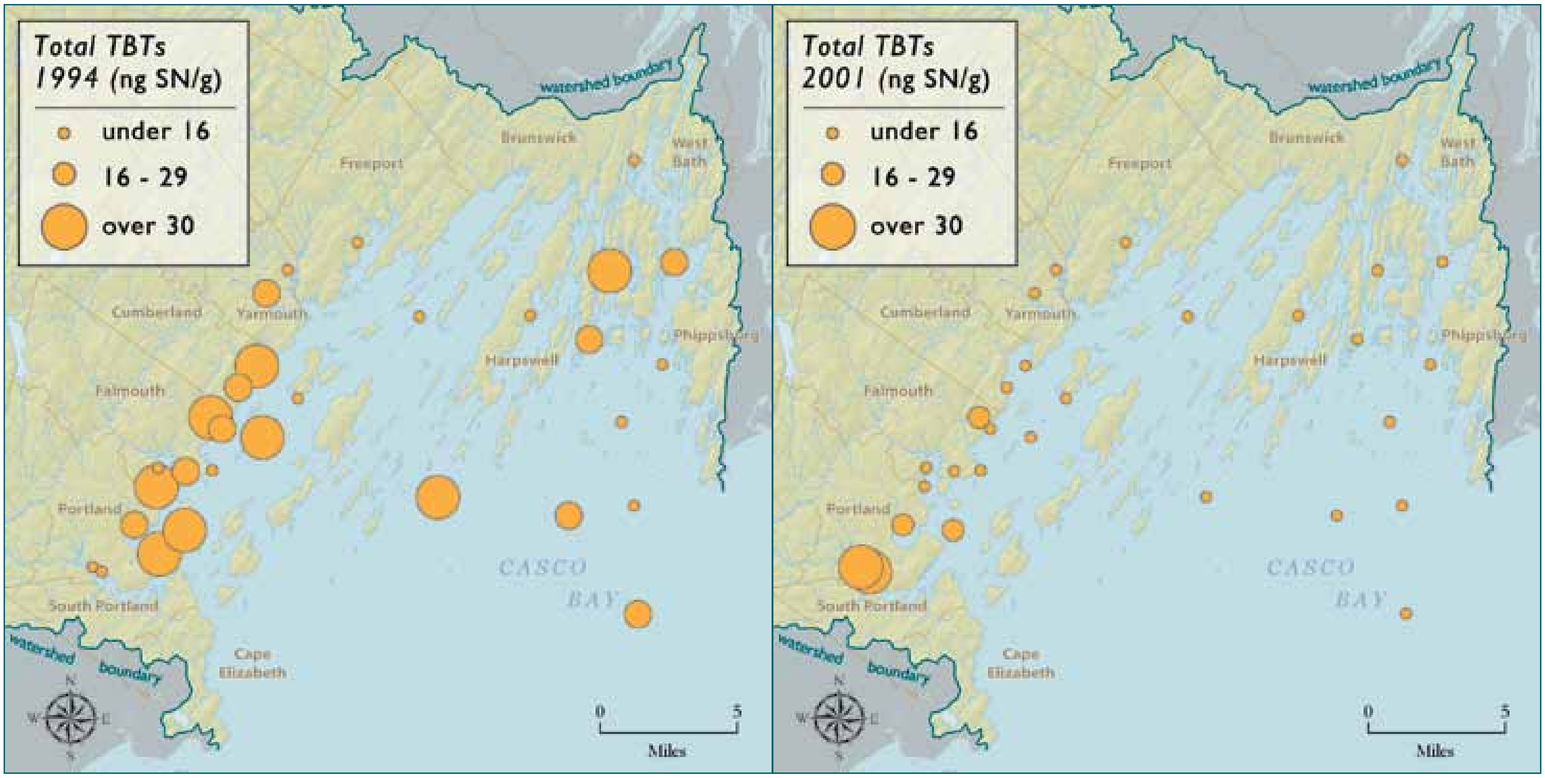
Pesticide Runoff from Urban Areas

Maine Bureau of Pesticides Control (BPC) has been concerned about pesticides running off the land surface of urban watersheds into coastal sediments. In 2008 BPC analyzed sediment samples from Mussel Cove in Falmouth and Back Cove in Portland for pyrethroid pesticides, including bifenthrin. Pyrethroids are used in common household insecticides and are toxic to aquatic fish and invertebrates. (Commercially available products that include bifenthrin include Talstar, Capture, Brigade, Bifenthrine, Ortho Home Defense Max, and Scotts LawnPro Step 3.) Mussel Cove's intertidal mud flats are commercially harvested for soft-shell clams. Land use in the 5.4 square mile drainage area of Mill Creek, which empties into Mussel Cove, is both residential .and commercial, especially along Route 1, where there are large areas of impervious surface. Land use in areas adjacent to Back Cove is heavily residential and stormwater continues to discharge to the Cove. Back Cove, an important migratory waterfowl wintering and stopover area, also serves an important marine worm habitat (DEP 2005).

The results indicated that bifenthrin was present at detectable levels in samples from both sites, with the highest levels found at Payson Park (Back Cove) (BPC 2008). More extensive sampling will be needed to confirm the concentrations present and their potential for impacts to organisms. Pyrethroids were not found at detectable levels in mussels sampled by Maine DEP in the Mill Creek/Mussel Cove area in 2009 (see Indicator 9).



Bifenthrin molecule



Tributyl tin (TBT) is an ingredient in marine anti-fouling paints. Federal and state laws now ban the use of paints with TBT for all uses except for vessels longer than 25 meters, or those having aluminum hulls (Maine DEP 1999). The overall decline of TBT concentrations in the Bay's sediments reflects the effectiveness of those laws at reducing toxic chemicals in the marine environment. The continued use of TBT paints on large commercial vessels may explain the continued presence of elevated TBT in the sediments of inner Casco Bay sites (Wade and Sweet 2005).

The results of the 1991/1994 and the 2001/2002 sampling were reported in more detail in both the 2005 *State of the Bay* report and the 2007 report *Toxic Pollution in Casco Bay*. The figure above illustrates an interesting pollutant management success story.

Conclusions and Future Directions

Management strategies for reduction of pollution inputs in the Bay are having a positive impact. In addition to the observed declines in metals, PCBs and pesticides, the overall decline in low molecular weight PAHs in the Bay suggests that management strategies to reduce PAH inputs from spills and stormwater are working. The increase in high molecular weight PAHs, which are primarily a byproduct of combustion, is likely due to increased use of fossil fuels throughout the region.

CBEP will report on the long-term spatial and temporal trends in the concentration of toxic contaminants in the Bay's sediments based on sampling in 1991/1994 , 2001/2002 and 2010, as soon as that analysis is ready. The results will be included in the 2015 *State of the Bay* report. In addition, data from the 2001/2002 and 2010 NCA samples of benthic community structure will be analyzed to determine how pollutants are impacting the Bay's benthic organisms.

References

Friends of Casco Bay. 2005. *Sediment PAH Concentration from the 2004 Study of Portland Harbor.*

Kennicutt, II, M.C., T.L. Wade, and B.J. Presley. 1992. Texas A & M University. *Assessment of Sediment Contamination in Casco Bay*. Casco Bay Estuary Project.

Maine Bureau of Pesticides Control. 2008. *Pyrethroid Analysis for Maine Board of Pesticide Control.*

Maine Department of Environmental Protection. 2004. *Maine Integrated Water Quality and Assessment Report.*

Maine Department of Environmental Protection. 2005. *A Decade of Toxics Monitoring*. John Sowles. http://maine.gov/dep/blwq/docmonitoring/toxics/index.htm

United States Environmental Protection Agency. 2006. *Ecological Toxicity Information*. May 19, 2008 http://www.epa.gov/R5Super/ecology/html/toxprofiles.htm

Wade, T.L., T.J. Jackson, L. Chambers, and P. Gardinali. 1995. Texas A & M University. *Assessment of Contaminants in Sediments from Casco Bay*. Casco Bay Estuary Project.

Wade, T. L. and S.T. Sweet. 2005. Texas A & M University. *Assessment of Sediment Contamination in Casco Bay*. Casco Bay Estuary Project. http://www.cascobay.usm.maine.edu/pdfs/GERG_sediment_report_2005.pdf

INDICATOR 11

How prevalent are selected contaminants of emerging concern in the Casco Bay ecosystem?

CBEP Goal: Reduce toxic pollution in Casco Bay; minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Why Is It Important to Monitor Contaminants of Emerging Concern?

Many common synthetic chemicals, which were not recognized as pollutants in the past, are now being detected in aquatic ecosystems throughout the world, where they are accumulating in the tissues of wildlife and humans. Those "contaminants of emerging concern" persist in the environment along with the more traditionally monitored persistent pollutants like polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs) and heavy metals. They are typically introduced into the air and water through municipal, agricultural, and industrial wastewater sources, and are transported by wind and water currents.

Among that new class of contaminants are polybrominated diphenyl ethers (PBDEs), used as flame retardants in commercial and residential textiles, furniture foam, and electronics since the 1970s. The primary forms are penta, octa- and deca-PBDE. Those lipophilic (fat-loving) molecules can accumulate in the fatty tissues of organisms, leading to negative health effects. Another important class of emerging contaminants is perflorinated chemicals (PFCs), industrial chemicals whose common uses include stain repellents, Teflon coatings, cleaning agents, and fire-fighting foam. They are highly resistant to degradation, and persist in the environment. Two forms, perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) are most common in the environment and in organisms (Goodale 2008).

Despite some recent restrictions on their use, those chemicals have been used in a variety of consumer and household products for over four decades. They cause cancers, endocrine disruption, reproductive and neurodevelopmental effects in animals, and are associated with reproductive and endocrine-disrupting effects in people (Birnbaum and Staskal 2004, Jensen and Leffers 2008).

The recent monitoring studies described below indicate that those contaminants are found in seal and bird populations in Maine.

MERI

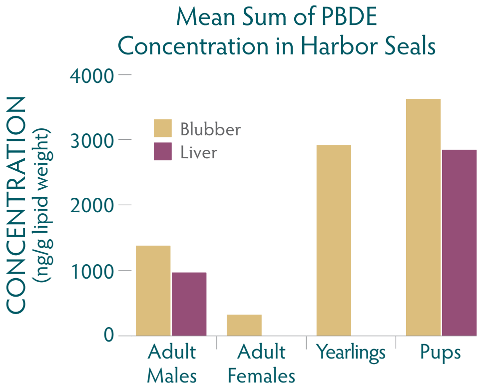
The *Seals as Sentinels* project indicated that seal pups had higher levels of PBDEs and PFCs than adults, reflecting their high exposure to the compounds from their mothers' milk.

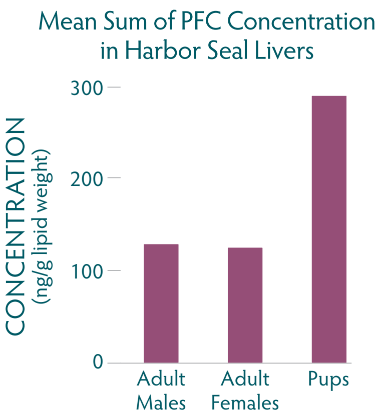
Status and Trends

Contaminants of Emerging Concern in Seals from Casco Bay and the Gulf of Maine

Since 2001, Dr. Susan Shaw and her co-workers at the Marine Environmental Research Institute (MERI) in Blue Hill, Maine, have been conducting a long-term investigation, *Seals as Sentinels*, that analyzes the levels and effects of environmental pollutants in harbor seals (*Phoca vitulina concolor*) along the northwest Atlantic coast. To date, the study has measured 395 compounds in 487 tissue samples from 181 stranded and live seals from Canada to Long Island, New York, including Casco Bay.

As top predators, seals accumulate persistent organic pollutants (POPs) from the fish they consume, and pass them on to their pups in their milk. High concentrations of chemicals such as PCBs can weaken the immune system of seals and increase their susceptibility to disease (Shaw 2007). In recent years, Gulf of Maine seals have been plagued by disease outbreaks, including a die-off in 2006 that claimed the lives of 800 animals (Shaw *et al.* 2005, 2007). Similar mass mortalities and reoccurring epidemics linked with contaminant stress are common among harbor seals worldwide. Recently, the *Seals as Sentinels* study found





high levels of contaminants of emerging concern, including PBDEs and PFCs, in harbor seal tissues. (Shaw *et al.* 2008, 2009a,b; see graphs). It was the first study to reveal that PBDEs and PFCs have permeated the northwest Atlantic Ocean environment.

- PBDEs were detected in 42 harbor seal blubber samples and 56 liver samples at levels among the highest reported worldwide for the species, reflecting the heavy usage of these compounds in North America.
- PBDEs are rapidly working their way up the food web. Biomagnification rates calculated for persistent PBDEs show they are readily transferred from fish to seal tissues, and become highly concentrated in top predators. People eat many of these fish: flounder, hake, and herring, for example.
- PFCs are also widespread in the Gulf of Maine; they were detected at substantial levels in liver tissues of 68 harbor seals.
- Unlike the pattern for PCBs, which are higher in seals near densely populated urban centers, there was no clear urban to rural trend in the distribution of PBDEs and PFCs. (Those compounds originate from multiple urban and rural sources, *e.g.*, wastewater treatment plants, farmland sludge, landfills, and airports.)
- Seal pups had higher levels of PBDEs and PFCs than adults, reflecting their high exposure to the compounds in their mothers' milk. The highest level of PBDEs was found in a female pup from mid-coast Maine (25700 ng/g lw). A male pup from Massachusetts Bay had the highest level of PFCs (1430 ng/g ww).

Contaminants of Emerging Concern in Birds of Casco Bay

With support from CBEP and other partners, in 2007, BioDiversity Research Institute (BRI) began the first study to measure PBDEs, PFCs, PCBs, OCs and mercury in eggs from 23 species of birds in Maine from marine, estuary, river, lake and terrestrial habitats. The suite of chemicals studied was found in all the species sampled across all types of ecosystems, with the highest contaminant loadings in southern coastal Maine. That pattern suggests that while atmospheric deposition is an important transport pathway, local point sources near the urban and industrial areas of the southern coast are also important. For PCBs, PBDEs, PFCs, and OCs, birds with a high level of one chemical tended to also have elevated levels of the others.

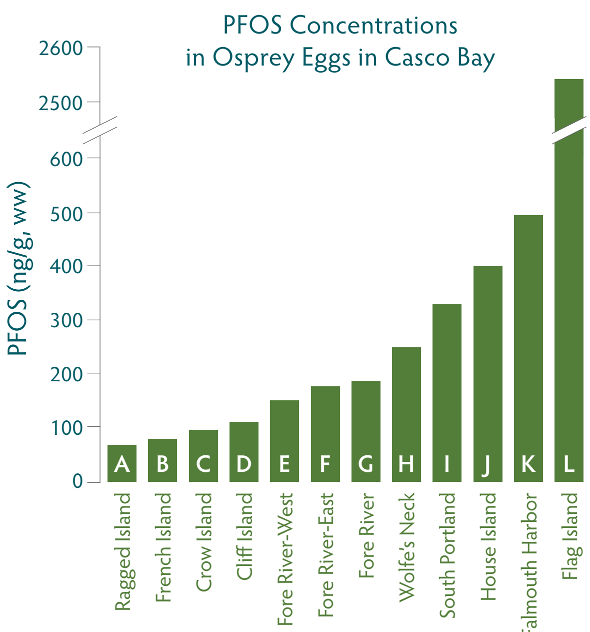
Collecting osprey eggs in Casco Bay for analysis of contaminants, including PBDEs and PFCs.

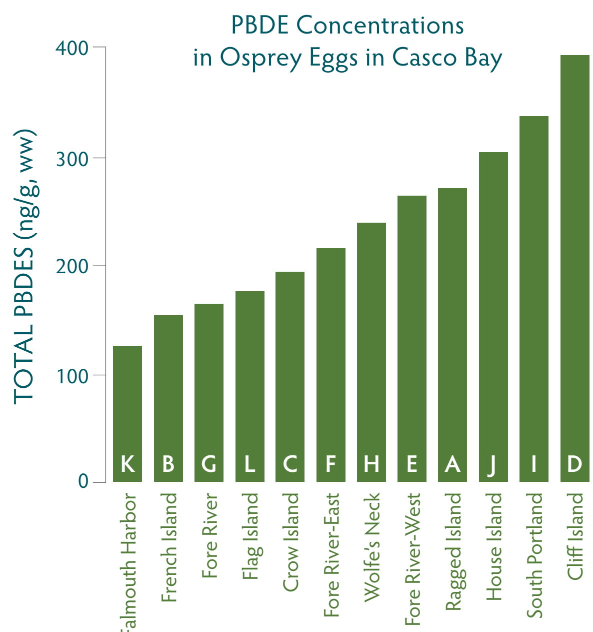
The study indicated that osprey (*Pandion haliaetus*) in the greater Portland area had some of the highest levels of PCBs, PBDEs, and PFOs seen in 14 species sampled there. As foraging predators, osprey accumulate contaminants and pass them to their offspring. Of six osprey samples collected along the Maine coast, the sample from the Portland Breakwater Light (Bug Light) had the highest total contaminant load, and levels of PFOs three times greater than the threshold for adverse effects (Goodale 2008). A follow-up study of osprey from Casco Bay was funded by CBEP to determine if the high PFOS levels observed in the Bug Light sample were found elsewhere in Casco Bay (Goodale 2010).

Starting in May of 2009, ten additional eggs were collected at Casco Bay sites and analyzed for PCBs, PBDEs, PFCs (including PFOs), and OCs. The combined results of osprey egg studies in 2007 and 2009 are summarized in the figures on the opposite page.

Kevin Cole

Wayne Boardman





Results of 2007 and 2009 osprey egg sampling in Casco Bay. PCBs, PBDEs, PFCs and OCs were found in all of the eggs sampled. Deca-PBDE was detected in 10 of 12 eggs collected in Casco Bay during the two sampling seasons. PFOS in an egg collected from Flag Island were the highest ever seen in Maine wildlife, and among the highest ever observed in a bird egg. Fully 75 percent of osprey eggs had PFOS concentrations exceeding the threshold for negative health effects established for chickens (100 ng/g, wet weight). No spatial trend was detectable among the samples, suggesting that point sources, watershed characteristics and food web dynamics may all play a role in exposure to contaminants (Goodale 2010). While osprey are highly mobile and there is no certainty about where birds are exposed to contaminants, research indicates that the toxic contaminants in eggs come from food consumed in the bird's local breeding territory (Hobson *et al.* 1997, Elliott *et al.* 2007).

Solution and Actions

The studies raise concerns about the long-term health of marine mammals and birds in the region and, more critically, the overall health of the food web and the ecosystem. Data from *Seals as Sentinels* have influenced policy decisions, including two recent Maine laws: LD 1658 (2007) which bans the neurotoxic flame retardant deca-PBDE from furniture, foam mattresses and electronics, and LD 2048 (2008) which requires manufacturers to disclose the toxic chemicals they add to baby products and children's toys, and authorizes the state to require safer alternatives whenever available. Data from the BRI bird egg study were provided as testimony during the development of LD 2048.

Penta- and octa-PBDE mixtures have been banned in Maine since 2006 and are no longer in production in the United States (DEP 2007a). PFOS, formerly an ingredient in Scotchguard brand stain repellent, was phased out by its primary US manufacturer in 2000. Nevertheless, large reservoirs of BFRs and PFCs, like PFOS, still exist in consumer products, ensuring ongoing inputs to the environment for decades to come (Shaw and Kannan 2009).

PPCPs (pharmaceuticals and personal care products) are also important contaminants of emerging concern. A cocktail of painkillers, hormones, antibiotics, beta-blockers and other drugs, along with household products like soaps, hairspray and sunscreens, enters the waste stream when washed off, excreted or discarded. Research suggests that some PPCPs can result in impacts to biota, although their cumulative and synergistic effects in aquatic systems are still unknown. The complexity of the possible mixtures and their limited biological degradability make removal from municipal wastewater a major challenge (Ternes *et al*. 2004). Addressing PPCPs at the source is an important control strategy. In 2007, Maine became the first state to pass legislation authorizing a mail-in program for unused and unwanted medicines. Maine DEP is also working with communities on one-day collection events. (To learn more about the Safe Medicine Disposal for ME program visit http://www.safemeddisposal.com.)

Given the vulnerability of Gulf of Maine and Casco Bay wildlife, as well as concerns for human health, monitoring for the presence of emerging contaminants and their effects in Casco Bay and the larger Gulf of Maine ecosystem will continue to be an important challenge.

ME DEP

Researchers from the Maine Department of Environmental Protection (DEP) collect white suckers for Cumulative Effects Assessment.

Endocrine Disruptors: Maine DEP Cumulative Effects Assessment

Endocrine disruptors are contaminants of emerging concern that disrupt the normal functioning of hormonal systems. They include man-made chemicals such as pesticides and plasticizers, pharmaceuticals, or hormones that are excreted in animal or human waste (EPA 2009). Since 2000, Maine DEP has been conducting Cumulative Effects Assessments (CEA) of fish populations in Maine rivers, measuring the effects of exposure to endocrine disruptors on survival, growth and reproduction. Studies have examined fish collected upstream and downstream of major discharges. Between 2007 and 2009, DEP conducted CEA studies in the Presumspcot River. Male and female white suckers (*Catostomus commersoni*) were caught in overnight gill net sets at stations in Windham and Gorham above the Westbrook wastewater treatment plant and the SAPPI mill – sites of the major discharges into the Presumpscot River – and at a station below the discharges.

Although there were individual metabolic or physiological responses for one or both sexes, indicating endocrine disruption below Westbrook compared to stations upstream, there is no consistent evidence of endocrine disruption in white suckers at the population level in the river below Westbrook. Growth rates and abundance appear to be lower below Westbrook. Those data are consistent with a 2006-2007 study of fish communities in the Presumpscot River that found reduced species richness, abundance, and biomass downstream of Westbrook (Yoder and Hersha 2009). The causes may be natural differences in habitat exacerbated by past or present discharges of sediments or other pollutants from municipal and industrial activities and urban runoff from Westbrook (DEP 2008, 2010).

Cynthia Stroud

References

Birnbaum, L.S., Staskal, D.F. 2004. Brominated flame retardants: Cause for concern? *Environ. Health Perspect.* 112, 9-17.

Elliott, J.E., C.A. Morrissey, C.J. Henny, E.R. Inzunza, and P. Shaw. Satellite telemetry and prey sampling reveal contaminant sources to Pacific Northwest ospreys. *Ecological Applications.* 17(4), 1223-1233.

Goodale, W., 2008. *Preliminary findings of contaminant screening of Maine bird eggs: 2007 Field Season.* BioDiversity Research Institute, Gorham, Maine. http://www.briloon.org/pub/doc/2008Contaminant.pdf (March 29, 2010)

Goodale, W. 2010. *Contaminant screening of osprey eggs in Casco Bay, Maine: 2009 Field Season.* BRI Report # 2010-09. BioDiversity Research Institute, Gorham, Maine. http://www.briloon.org/contaminants/Goodale2010.pdf

Hobson, K.A., K.D. Hughes, and P. J. Ewens. 1997. Using stable isotope analysis to identify endogenous and exogenous sources of nutrients in eggs of migratory birds: Applications to Great Lakes contaminant research. *The Auk* 114, 467-478.

Jensen, A.A., Leffers, H., 2008. Emerging endocrine disrupters: Perfluoroalkylated substances. *Int. J. Androl.* 31, 161-169.

LD 1658. http://www.ncel.net/news_uploads/175/ME-LD%201658%20-%20as%20amended%20in%20Committee.rtf

LD 2048. http://www.mainelegislature.org/ros/LOM/LOM123rd/123S1/PUBLIC643.asp

Maine Department of Environmental Protection. 2007a. *Brominated Flame Retardants: Third Report to the Maine Legislature.* http://maine.gov/dep/rwm/publications/legislativereports/pdf/finalrptjan07.pdf

Maine Department of Environmental Protection. 2008. *Surface Water Ambient Toxic Monitoring Program 2007 Report.* http://www.maine.gov/dep/blwq/docmonitoring/swat/2008_SWAT_report.pdf

Maine Department of Environmental Protection. 2010. *Surface Water Ambient Toxic Monitoring Program 2009 Report.*

Shaw, S.D., Brenner, D., Bourakovsky, A., Mahaffey, C.A., Perkins, C.R., 2005. Polychlorinated biphenyls and chlorinated pesticides in harbor seals (*Phoca vitulina concolor*) from the northwestern Atlantic coast. *Mar. Pollut. Bull.* 50, 1069-1084.

Shaw, S.D., Brenner, D., Bourakovsky, A., Mahaffey, C.A., Perkins, C.R. 2005. Polychlorinated biphenyls and chlorinated pesticides in harbor seals (*Phoca vitulina concolor*) from the northwestern Atlantic coast. *Mar. Pollut. Bull.* 50, 1069-1084.

Shaw, S.D. 2007. Chapter 7. How are seals, as top predators, impacted by toxic contaminants in Casco Bay and the Gulf of Maine? In: *Toxic Pollution in Casco Bay: Sources and Impacts.* Casco Bay Estuary Partnership. http://www.cascobay.usm.maine.edu/pdfs/toxics Chapter 7.pdf

Shaw, S.D., Kannan, K. 2009. Polybrominated diphenyl ethers in marine ecosystems of the American continents: Foresight from current knowledge. *Rev. Environ. Health* 24, 157-229.

Shaw, S.D., Brenner, D., Berger, M.L., Dwyer, M., Fang, F., Hong, C.-S., Storm, R., O'Keefe, P. 2007. Patterns and trends of PCBs and PCDD/Fs in NW Atlantic harbor seals: Revisiting toxic threshold levels using the new TEFS. *Organohalogen Compounds* 69, 1752-1756.

Shaw, S.D., Brenner, D., Berger, M.L., Fang, F., Hong, C.-S., Addink, R., Hilker, D. 2008. Bioaccumulation of polybrominated diphenyl ethers in harbor seals from the northwest Atlantic. *Chemosphere* 73, 1773-1780.

Shaw, S.D., Berger, M.L., Brenner, D., Tao, L., Wu, Q., Kannan, K. 2009a. Specific accumulation of perfluorochemicals in harbor seals (*Phoca vitulina concolor*) from the northwest Atlantic. *Chemosphere* 74, 1037–1043.

Shaw, S.D., Berger, M.L., Weijs, L., Roosens, L., Covaci, A. 2009b. Specific accumulation of polybrominated diphenyl ethers including deca-BDE in tissues of harbor seals from the Northwest Atlantic. *Organohalogen Compounds* 71, 2547-2552.

Shaw, Susan. 2010. Personal communication. (April 25, 2010).

Ternes, T. A., A. Joss and H. Siegrist. 2004. Scrutinizing pharmaceuticals and personal care products in wastewater treatment. *Environ. Sci. Technol.* 38, 392A-399A.

United States Environmental Protection Agency. 2009. *Endocrine Disruptor Research.* http://www.epa.gov/endocrine/

Yoder, C. and Hersha. 2009. *Fish Assemblage and Habitat Assessment of the Presumpscot River.* Midwest Biodiversity Institute Technical Report 2008-12-6. http://www.cascobay.usm.maine.edu/pdfs/presumpscot%20_final_revised_report_20090731.pdf

SECTION FIVE

Habitats

Peter Taylor/Waterview Consulting

Introduction

The quality and quantity of habitat available for fish, birds, mammals and other organisms provides one of the most direct measures available of the cumulative impact of development on environmental quality. Yet high-quality habitat can also be tricky to track, since what is good habitat for one species is not necessarily good for others. It is easy to see how development on coastal islands could harm populations of eiders and gulls that nest there. It may be less obvious why the conversion of forest to a suburban landscape in the (still largely forested) Casco Bay watershed would harm wildlife.

Maine has been a largely forested state with abundant rivers, lakes and wetlands for over 10,000 years. Many of Maine's native fish and wildlife, from fisher to moose, migratory birds to brook trout, are dependent on forest, or a mosaic of forest and aquatic habitats, to survive. Moose are denizens of forest, lake and wetland; beaver of forest and river; Atlantic salmon of forested streams and ocean waters.

Loss of wetlands, destruction of forests and damage to riparian areas produce direct effects on populations of birds, mammals, amphibians, fish, and invertebrates that depend on such areas for all or part of their lifecycle. But urban and suburban development not only reduces the amount of habitat available for Maine's forest species, it also alters how habitats are connected to one another. Roads, lawns and shopping malls slice intact forests into small, often isolated patches. While a road or lawn may not be much of a barrier to a deer, it can be an uncrossable chasm for species from warblers to ground beetles that prefer the shelter of trees. Where roads cross streams, culverts can create barriers to movement of aquatic organisms, preventing fish from reaching spawning areas, or denying them shelter in smaller streams from spring floods or hot summer afternoons. Such habitat fragmentation can lead to declines in wildlife populations and local loss of species. Fragmented habitats are also thought to be less resilient to environmental change.

Tracking changes in habitat quality and quantity provides direct information to guide land use policy and to suggest priorities for land conservation. It also helps identify local and regional drivers for changes in abundance of species of concern. A look at habitat change shows the extent of landscape alteration and helps to make clear the types of landscapes that public policies, market forces, and individual choices are building.

INDICATOR 12

How are urbanization and development affecting the availability of habitats for fish, wildlife and birds that depend on interior forest areas?

CBEP Goal: Minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Status

Forests provide essential habitat to many of Maine's native birds, fish, and mammals. Certain species, including large herbivores and predators such as fishers, hawks and owls, roam over large areas of forest and thus cannot survive in the small forests found in suburban areas. Many species of migrant songbirds, including many warblers, are forest specialists, nesting successfully only in large blocks of forest. While the Casco Bay watershed is still largely forested, forest interior habitat may be in short supply.

While to most humans there may appear to be little difference between the edge and the interior of a forest, there can be profound differences from the perspective of the animals and plants that live there. The edges of forests have a different microclimate from the interior. They often are sunnier, windier, and drier than the depths of the woods. Proximity to other habitats, such as lawns or agricultural fields, brings its own challenges. For example, invasive species like Eurasian bittersweet and house sparrows are far more abundant. Many predators, from raccoons to house cats, are less common in deep woods than near open habitats. The brown-headed cowbird, which lays its eggs in the nests of other birds, favors open habitats as well. Certain wildlife species are sensitive to human disturbance, and thus are most common in the deep woods where people are less active.

Forest interior wildlife includes songbirds such as the wood thrush, scarlet tanager, and many warblers; larger birds, including woodpeckers, hawks, and owls; and forest interior mammals such as fisher, lynx, and bear. Even some small rodents and insects have been shown to be much more abundant in interior forest.

Maine's Beginning with Habitat Program recently analyzed land cover data derived from satellite imagery from 1999-2001 to shed light on the availability of deep forest habitats throughout Maine (Beginning With Habitat 2010). The resulting geographic dataset represents large – more than 500 acre – contiguous areas of forest that are at least 300 feet away from other habitats. Such areas are most likely to provide significant interior forest habitat.

Clockwise from top left: Scarlet tanager, wood thrush (with young cowbird, a nest parasite), brook trout, and lynx are among the species in Maine that need interior forest habitat.

Even in a largely forested watershed such as Casco Bay, suitable habitat for forest specialists may be uncommon. Their ideal habitat occurs only in large areas of forest that are compact in shape and are located far from most human activity. Almost 69 percent (676.0 square miles) of the 986 square mile Casco Bay watershed is forested (Maine Office of GIS 2004). In contrast, only 172.6 square miles (17.5 percent) of the watershed consists of interior forest habitat, the majority of which is located in the upper portions of the watershed. Interior forest is far less abundant in the more highly developed coastal communities, where suburban lands, abundant roads, powerlines, and other linear infrastructure cut the forest into smaller areas that provide little true interior forest habitat.

Trends

Most of New England, including Maine, has been gaining forest area for much of the last 150 years. That long-term trend reflects shifts in the rural economy: the agricultural production that fed eastern cities first moved to the Midwest and then overseas. Today, abandoned agricultural lands are a major component of the landscape of the Casco Bay watershed. Their presence is revealed by the presence of stone walls, old apple trees, and other, more subtle evidence of past agriculture in the midst of large areas of forest.

Only in recent decades, as development patterns have converted more and more forest to suburb (The Brookings Institution 2006), has that long-term trend been reversed. Where characteristic exurban development patterns are most intense – along the route 95 and 295 corridors and near Portland, Brunswick, and the other regional service center communities – interior forest habitat has undoubtedly declined in recent decades. The extent and speed of those declines, however, is poorly known.

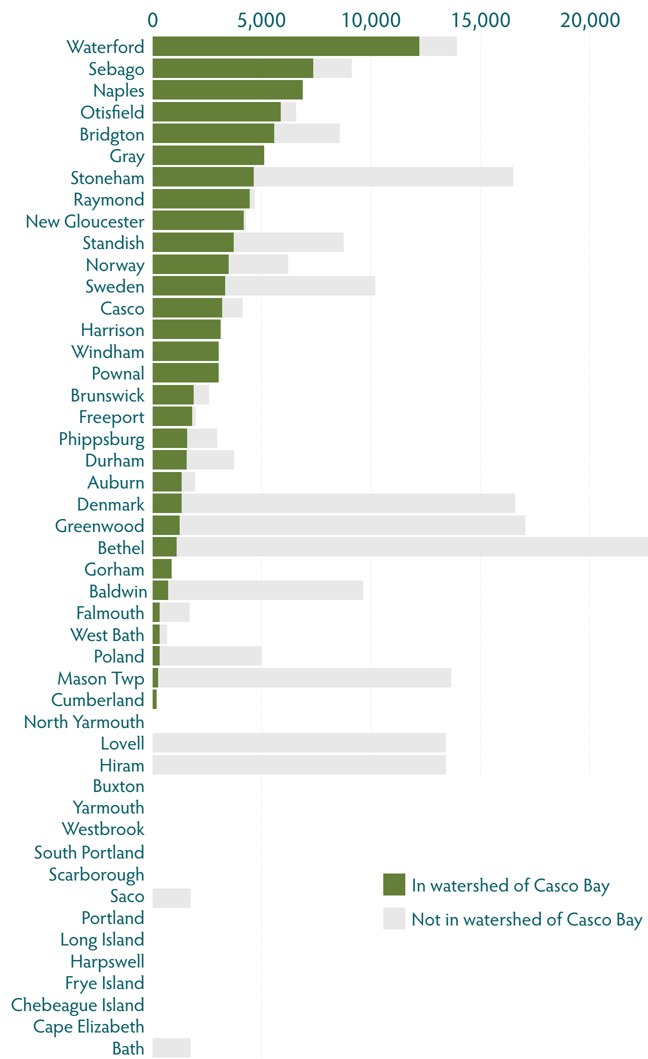
The Beginning with Habitat program has only recently begun explicitly mapping interior forest habitat. Its analysis was first made available in 2009, but the underlying satellite data on which it is based dates back a decade. Rigorous, geographically defined trend analysis will require generation of new geographic data from historic sources and acquisition of new imagery. (Note: In the 2005 *State of the Bay* report, CBEP reported on "Undeveloped Blocks of Land," a related metric that sheds light on similar issues. That metric was based on the same land use data, harking back to the same satellite imagery as the interior forest metric.)

Actions/Solutions

The Beginning with Habitat program was founded to help educate towns about the value of protecting wildlife habitat. Its habitat maps, land use analysis, and related products together provide a important planning toolkit to help local communities achieve this goal.

Other approaches may prove important for the long-term protection of interior forest habitat. Land trusts, towns, and state agencies are finding creative ways to support conservation of forest area for a host of reasons. Protection of forests not only provides habitat for forest interior wildlife, but can also support forest-dependent jobs, and protects the character of our communities. The forests of the Casco Bay watershed also provide important ecosystem services of direct benefit to our society, such as carbon sequestration and provision of clean water. Acquisition of land or conservation easements provides direct habitat conservation (see Indicator 13), and support the economic viability of forest-dependent land uses, from traditional forestry, to carbon sequestration markets and markets for ecosystem services.

Interior Forest Habitat in Casco Bay Townships



The majority of the interior forest habitat in the Casco Bay watershed lies within the northern and western towns at the headwaters of the Sebago Lake / Presumpscot River watershed. The more developed coastal communities contain little or no interior forest habitat.

References

Beginning with Habitat 2010. Beginning with Habitat: Primary Map 3. Undeveloped Habitat Blocks. http://www.beginningwithhabitat.org/the_maps/map3-undev_habitat.html

The Brookings Institution. 2006. *Charting Maine's Future: An Action Plan for Promoting Sustainable Prosperity and Quality Places*. Brookings Institution Metropolitan Policy Program.

Casco Bay Estuary Partnership. 2005. *State of the Bay*. http://www.cascobay.usm.maine.edu/sotb05.html

Maine Office of GIS. 2006. MECLD dataset. Maine Office of Geographic Information Systems. http://megis.maine.gov/catalog

Interior Forest Habitat

While forest land is still abundant in the Casco Bay watershed, much of it offers little suitable habitat to wildlife that depends on deep forest habitat. While forests are widespread except in the heart of the Portland metropolitan area, interior forest habitat is much more concentrated away from the coast. Roads and developed lands near the coast divide forest into patches too small to provide secure habitat for forest interior specialists. Data: Beginning with Habitat and Maine Office of GIS

Riparian Buffers in the Casco Bay Watershed

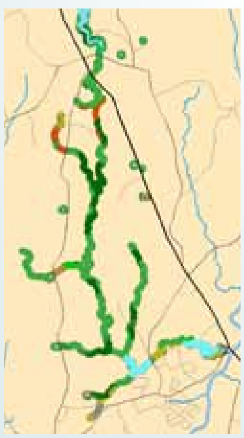
Introduction

Riparian buffers are the narrow strips of land adjacent to streams, rivers, lakes and the coast. Well-vegetated buffers, especially forested and wetland buffers, are important to supporting good water quality, and to improving fish and wildlife populations.

Vegetated buffers slow water, help shorelines resist erosion, and filter runoff, which limits the delivery of sediment and associated pollutants to streams. Buffers, especially wetland buffers, are also excellent at absorbing macronutrients like nitrogen and phosphorus, further protecting water quality.

Forested buffers shade the water, reducing temperatures and increasing dissolved oxygen levels. They also provide dead leaves, which, by providing food directly or indirectly to aquatic organism, are a major energy source for stream ecosystems. Logs and woody debris derived from riparian trees provide shelter for aquatic organisms along the shore. Woody debris influences stream channel development, and contributes to development of pools, backwaters and other stream features that make for good fish habitat. In some of the watershed's sandy or clay-lined coastal streams, rocks are rare, making woody debris one of the few places where aquatic insects can attach to hard surfaces, and avoid being washed downstream.

Riparian forests also provide important sheltered corridors for wildlife reluctant to cross open land. In agricultural and suburban landscapes, the long, sinuous strips of forest remnants that often lie along streams can link together patches of forest that would otherwise be isolated, supporting robust populations of woodland wildlife, and facilitating annual migration of forest birds and animals (see Indicator 12).


Land use in the 50-meter riparian zone of Mill Brook.

Status

GIS technology can be used to combine information on land cover (Maine Office of GIS 2006) with data on the locations of aquatic areas like streams, lakes, and the ocean (Maine Office of GIS 2004). The result characterizes land use in areas close to aquatic habitats, as shown in the example above.

The majority of the Casco Bay watershed and a majority of the riparian areas within it remain forested. 70.7 percent of the watershed is forest or wetland. The 50-meter riparian buffer zone adjacent to Casco Bay itself (65.9 percent) is slightly less forested than the landscape as a whole, presumably because people like to live and work along the shore. The buffer areas along the watershed's lakes and ponds (75.3 percent) and especially along streams and rivers (83.1 percent), in contrast, are more likely to be forested than is typical for the watershed as whole.

The proportion of buffers within each subwatershed – the HUC 12 subwatersheds – of the Casco Bay watershed that remains in forest or wetland varies from a low of 27 percent in the highly urbanized Fore River subwatershed to 98 percent along the Northwest River. The percentage of riparian buffers that remains in forest and wetland is correlated with the proportion of each subwatershed that is either forest or wetland. Thus the abundance of riparian forest and wetland is lowest near the coast, and greatest in the largely forested upper watershed.

Trends

Riparian buffer analysis has not previously been carried out throughout the watershed, and available historic land cover data used slightly different methods for determining what constituted forest or wetland. Accordingly, we do not have rigorous information on trends in riparian buffer condition.

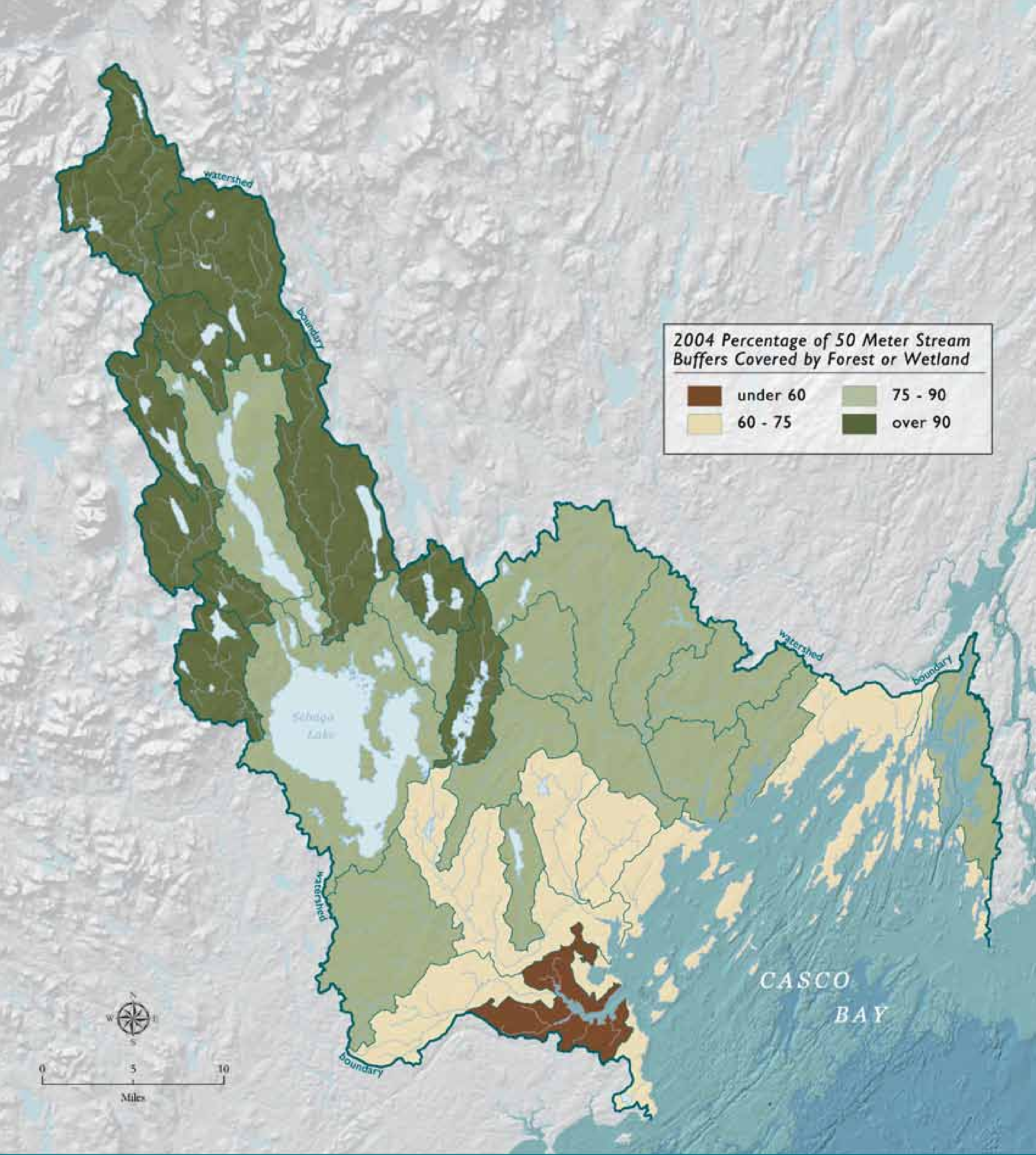
As with the other Casco Bay watershed habitat indicators, however, the driving force behind long-term trends in the condition of riparian vegetation is land use change, along with the economic choices, policy decisions, and social forces that shape land use decisions.

Maine has several laws that protect shorelines and riparian areas. Its Shoreland Zoning Act, for example, requires towns to adopt land use regulations that apply within the "shoreland zone" – areas within 250 feet of pond and lakes, rivers, tidal waters and wetland, as well as those within 75 feet of streams. Rules generally include restrictions on construction and clearing of vegetation. The Natural Resources Protection Act offers additional protection for lands adjacent to coastal wetlands, some freshwater wetlands, great ponds, rivers and streams.

References

Maine Office of GIS. 2006. MECLD dataset. Maine Office of Geographic Information Systems. http://megis.maine.gov/catalog/

Maine Office of GIS. 2004. WQPONDS, WQSTREAMS, WQRIVERS, and WQCOAST datasets. Geographic data available through Maine Office of Geographic Information Systems. http://megis.maine.gov/catalog/



Condition of Riparian Buffers by Subwatershed

Fish Passage Survey

While habitat fragmentation has been studied extensively in upland forests, it is also a significant problem in rivers and streams. Flowing waters are often crossed by many roads and are blocked by large and small dams. Without proper design, construction, and maintenance, dams and culverts can block the movement of fishes and other aquatic organisms. The effects of such fish passage barriers on long distance migratory fish species like Atlantic salmon and alewives are significant. The effects on resident species are less well understood.

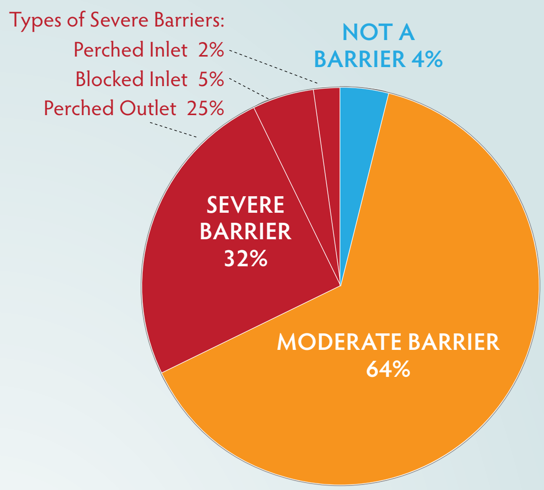
In 2009, CBEP seasonal staff, working with volunteers from Trout Unlimited and personnel from the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program Office, visited over 700 potential fish passage barriers in the Royal River and lower Presumpscot River watersheds. They collected detailed data from over 480 culverts and approximately 30 dams. The survey was the first in the state to be carried out in a region that is largely urban and suburban; previous Maine surveys were focused on more rural landscapes, especially forested watersheds.

About one-third of culverts in the region never permit fish to pass. The majority of culverts are partial barriers to fish movement – blocking access some of the time, or to certain species of fish. Only a handful of crossings never restrict movement of fishes.

U.S. Fish and Wildlife staff analyzed the data to identify priority restoration opportunities in the study area, both for restoring access of anadromous fishes to stream habitat and for restoring access to lake habitat – which is particularly important to alewives, one of the most abundant anadromous species in the region. The results of those analyses provide CBEP and its partners with a "to do" list for fish passage restoration.

CBEP staff have also developed a tool – based in part on methods pioneered by the Piscataqua Region Estuaries Partnership under their Climate Ready Estuaries project – that provides a rough estimate of the relative flood risk at each culvert. Using the geometric data about each culvert collected during the field survey, along with the geographic information derived from GIS analysis, CBEP compared culvert flow capacity with expected storm flows.

Analysis of the results showed significant overlap between culverts that block fish migration and culverts that may pose higher than average flood risk. That insight has led to conversations with local communities, the Maine Department of Transportation, and the Cumberland County Emergency Management Agency to identify sites where culvert replacement would simultaneously serve environmental, infrastructure and public safety goals.



Results of 2009 field survey. Most culverts are fish passage barriers. A quarter of all culverts are impassable to fish because their outlet is perched significantly above the elevation of the stream. Since most of Maine's anadromous fishes don't jump, these culverts effectively block upstream movement of many anadromous fishes.

INDICATOR 13

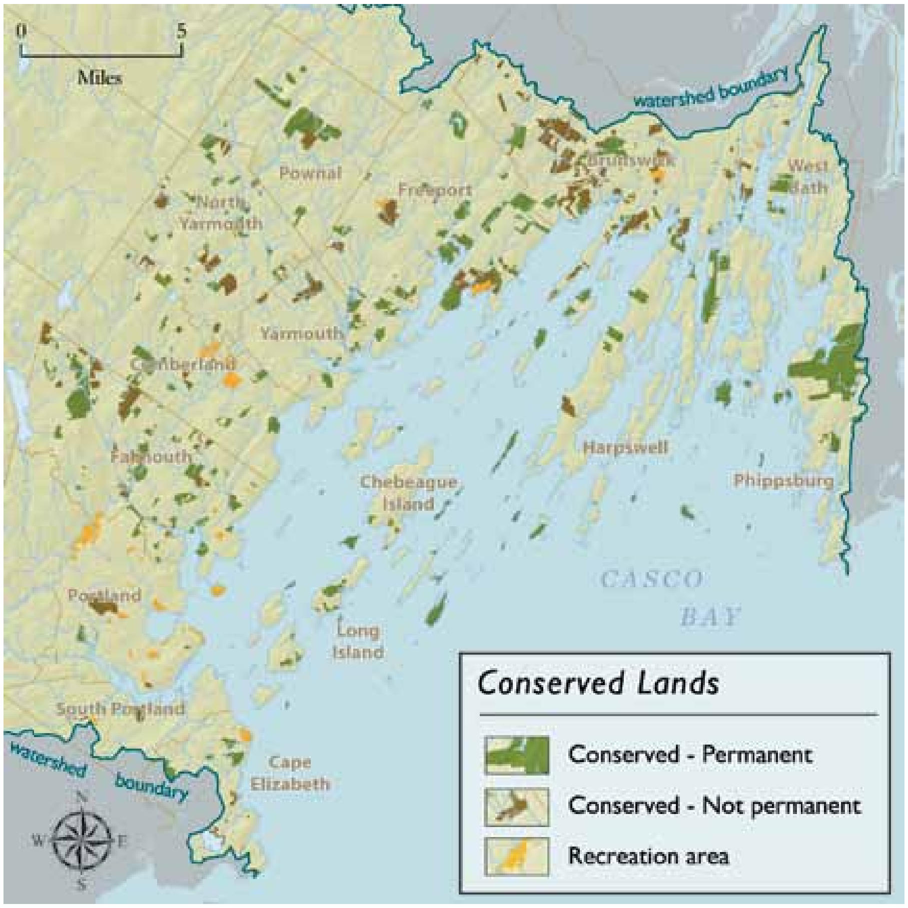
Is the area of protected habitat increasing in the Casco Bay watershed?

CBEP Goal: Minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Status

The Casco Bay watershed continues to provide valuable habitat for a range of fish and wildlife species. Available habitat, however, can be lost or degraded by human activity, especially urban and suburban development. Constructing homes or shopping malls converts field and forest wildlife habitats to lawns, roads, and remnant forest plots that support a less abundant and less diverse animal community.

While land conversion in the Casco Bay watershed may have slowed slightly due to the recent economic downturn, the population of the Greater Portland area is growing, and the use of land for homes and businesses has been growing still more rapidly. Development today consumes more land per person than it did a generation ago, and much more than it did in the mid-twentieth century. Much of the regions' recent growth has been centered not in existing urban areas, but in peripheral communities that, until recently, were largely rural.



Conserved lands in the lower 16 municipalities around Casco Bay. Many conserved lands remain in private ownership, and do not allow public access. Always check with the landowner before visiting any protected area.

Such land use trends reduce both habitat quantity and quality; pose challenges for industries based on natural resources; and block access to wild lands for traditional pursuits like hunting and hiking. Land conservation efforts play an essential role in ameliorating such unintended consequences of land use choices.

Maine has a vibrant tradition of locally led conservation. As of June 2010, the Maine Land Trust Network listed 100 land trusts and other organizations dedicated to conserving land around the state (MLTN 2010). Those groups are involved not only with protecting habitat, but also with preserving farmland, protecting working forests, and developing recreational trails. Several times, Maine's voters have supported bonds to fund land protection through the Land for Maine's Future Fund, which has protected nearly half a million acres in Maine since its inception (Maine State Planning Office 2010). State and federal agencies also undertake conservation initiatives, and facilitate local efforts by providing technical assistance, leadership, funds, and other support.

The Casco Bay watershed itself is home to at least 25 nonprofit organizations directly involved in land conservation. About half the towns in the watershed have



Examples of properties protected with support from the CBEP Habitat Protection Fund in Scarborough, Bridgton, and Pettingill Island (clockwise from top left).

Casco Bay Habitat Protection Fund

CBEP's Habitat Protection Fund supports local conservation by providing seed funding in support of habitat protection efforts by land trusts, towns and state agencies. Between 2006 and 2010, CBEP invested more than $250,000 through the fund to support a dozen conservation projects. While not all projects are complete – and thus permanent protection is not yet assured – the projects involve over 4,500 acres of land. They have resulted in protection of a Casco Bay island and purchase of land for a park in Bridgton, Maine, and they include several projects to protect wetlands, mudflats, riparian areas, and forests. The projects provide significant opportunities for recreation, while two included efforts to support local agriculture.

CBEP funding typically represents only a small fraction of a project's total cost: sponsors must raise the bulk of necessary monies from other sources. But CBEP funding is often available early in project development, and can be used to support the cost of surveys or appraisals, without which project negotiations often cannot begin. And by clearly demonstrating local support, CBEP funds can also boost the chances of receiving funding from state, regional, or national sources.

conservation commissions, which are generally volunteer-based municipal commissions that work to improve management of open space in our communities. Local organizations garner support for conservation efforts from a variety of sources, including private donors, foundations, local community members, municipal budgets, the Land for Maine's Future program, and federal grants, as well as from CBEP's own Habitat Protection Fund.

Counting Protected Lands

Land protection takes many forms, and some areas that local residents think of as "protected" may in fact be more vulnerable than is generally known. Town forests, for example, are often considered permanently protected. Yet most are community assets that could be tapped at any time to address community needs. In the absence of other restrictions, town forests could become the location of a new school or town building, or even be sold to raise revenue for cash-strapped municipalities.

Conservation easements are an important tool for land conservation. Under an easement, certain rights associated with land ownership – the right to subdivide the property, construct a house, or log an area of forest, for example – are donated or sold by the land owner to a conservation organization. Such restrictions are binding not only on the current land owner, but on future owners as well. Easements thus provide a legal mechanism for permanent protection.

Conservation easements, however, are drafted on a case by case basis. Each one reflects the particular landowner's wishes, the conservation goals being addressed, and legal and practical constraints. Some easements allow agriculture, logging, or even limited residential or commercial development. It is thus sometimes difficult to decide exactly what constitutes "protected lands."

Acres and Parcels

Since 1997, The Gulf of Maine Coastal Program Office of the U.S. Fish and Wildlife Service, with significant funding from CBEP, has maintained a geographic database of conserved and open space lands in the lower 16 municipalities[1] of the Casco Bay watershed. Several different levels of protection are tracked: (1) conserved lands that are permanently protected; (2) open space lands that lack permanent protection, including unofficial conservation lands; and (3) recreational lands, which include areas that are used primarily for recreation, but may provide some conservation or habitat benefits. Open space lands that are not permanently protected comprise a variety of lands: areas in agricultural or tree growth programs; those owned in common by homeowners associations; areas conserved to protect drinking water; town forests for which there exists no legal barrier (such as a conservation easement) to block conversion to another use; and similar areas.

[1] The 16 municipalities are Cape Elizabeth, South Portland, Portland, Westbrook, Long Island, Chebeague Island, Falmouth, Cumberland, Yarmouth, North Yarmouth, Pownal, Freeport, Brunswick, Harpswell, West Bath, and Phippsburg.

Protected Lands in Lower 16 Casco Bay Watershed Towns, 2010.

Level of Protection	Number of Parcels	Total Acres Protected	Percent of Casco Bay Watershed
Conservation Land	438	15,694	7.5%
Open Space (no protection)	306	7,494	3.6%
Recreational Land	110	1,917	0.9%
TOTAL	854	25,105	12.0%

As of 2010, 854 parcels in the lower 16 municipalities of the Casco Bay watershed, amounting to more than 25,000 acres and 12 percent of the area of the watershed, are being tracked in the database. A majority of those lands, some 15,694 acres – about 7.5 percent of the area of the towns examined – is considered permanently protected.

Trends and Conclusions

The amount of permanently protected land in the lower 16 municipalities of the Casco Bay watershed has more than doubled since 1997. That truly remarkable achievement reflects the diligence and hard work of many individuals and organizations throughout the region.

Year	Number of Sites	Area Permanently Protected (acres)	Percent of Study Area
1997	246	7,300	3.5%
2005	341	10,900	5.2%
2010	438	15,694	7.5%

Collectively, those efforts are of great significance to local communities. No location in any of these 16 towns is more than three miles from permanently protected conservation lands: the typical distance is less than two-thirds of a mile. There is little doubt that conservation efforts are playing an important role in protecting the character of the landscape in the watershed.

References

Maine Land Trust Network. 2010. MLTN: Alphabetical List of Land Trusts. http://www.mltn.org/view_trusts-alphabetical.php

Maine State Planning Office. 2009. *Land for Maine's Future Program: Protecting Maine's natural heritage and future economic health. The 2009 Biennial Report to the Joint Standing Committee on Agriculture, Conservation & Forestry.* Augusta. February 2009. http://www.maine.gov/spo/lmf/docs/ACF%20Biennial%20Report%202-09%20WEB.pdf

SECTION SIX

Living Resources/ Indicator Species

Michelle Kinsey Bruns

Introduction

Protecting the quality and quantity of habitat is necessary to maintain biological diversity in and around Casco Bay. It is individual species, however, that often capture our attention and provide daily reminders that natural communities are in balance. Certain species, due to their unique habitat requirements or role within ecological communities, serve as broader indicators of the health of natural systems. Section Six addresses the following indicator species assemblages:

- **Eelgrass.** Eelgrass beds provide critical habitat for several commercially important fisheries. Eelgrass is a key biological indicator of the Bay's water quality because it both contributes to and depends upon good water quality. Monitoring eelgrass status provides information about physical/chemical conditions and ecological health in Casco Bay.
- **Waterbirds.** Estuaries are important seasonal stopovers in the Atlantic Flyway for migratory birds and provide essential habitat for several migratory and resident species. Waterbirds are among our most observable and charismatic fauna, and monitoring their status in Casco Bay serves as an important and visible indicator of estuarine and watershed health.
- **Marine invasive species.** Marine invasive species threaten to irreversibly change the structure of marine communities in Casco Bay and the Gulf of Maine, with significant implications for marine-based industry. Tracking the status and trends of these exotic species provides information about threats to the marine ecosystem.

Has eelgrass habitat in Casco Bay changed over time?

CBEP Goal: Minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Why Is Eelgrass Habitat Important?

Eelgrass (*Zostera marina*) is a flowering seagrass that lives in low intertidal and subtidal marine environments. It forms extensive beds that provide critical habitat for fish, shellfish and other marine organisms throughout Casco Bay. Eelgrass leaves filter nutrients and suspended particles from the water column, and its root system stabilizes sediments. As a primary producer, eelgrass forms part of the base of estuarine food webs, and provides nursery habitat for a variety of commercially important species, as well as food for migratory winter waterfowl and fish.

In addition to their habitat values, eelgrass beds are an important indicator of the health of an estuarine ecosystem because they both contribute to – and depend upon – good water quality. Eelgrass flourishes where water quality conditions permit adequate light to penetrate to its slender leaves. Excess nutrient levels (nitrogen), along with suspended sediments from natural sources, or associated with coastal development, can lead to decreased water clarity, and increase epiphytic macroalgae growth, both of which stress individual plants.

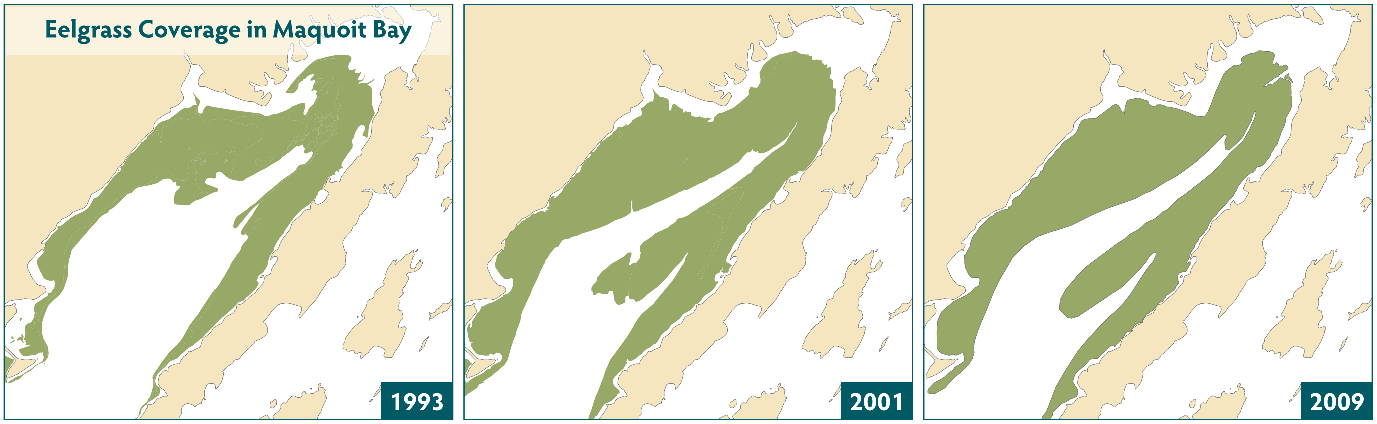
Portland Harbor is a local example of how turbidity, and subsequent poor light penetration through the water column, can lead to the decline and loss of eelgrass beds (Tyrell 2005). Damage from dredging, boat propellers, moorings and mooring chains, anchors, docks, and shellfish dragging are additional anthropogenic causes of eelgrass decline and loss. Eelgrass beds are also susceptible to periodic infestation by slime molds, sometimes referred to as eelgrass wasting disease. Concerns are also emerging in southeastern New England about threats to eelgrass by invasive marine tunicates, which have been documented in eelgrass beds off Martha's Vineyard by scientists at the Woods Hole Oceanographic Institution (Carmen and Grunden 2010).

www.SeagrassLI.org

Beds of eelgrass serve as an important habitat for fish and source of food for waterfowl.

John Sowles

Healthy eelgrass beds like those off Little Flying Point in Maquoit Bay depend on good light penetration through the water column. Excess sediments create turbid water conditions and reduce water clarity, causing stressed eelgrass plants to grow long and thin, stretching toward the surface to reach adequate sunlight.



Data: 1993/2001 - Maine DMR; 2009 - J. Sowles. 2009 photointerpretation by S. Barker, Maine DMR.

Status and Trends

Maquoit Bay

Resource managers have not conducted a Casco Bay-wide assessment of eelgrass coverage since the 2005 *State of the Bay* report, but aerial photographs of Maquoit Bay in November 2009 provide a snapshot of coverage in one of Casco Bay's most significant eelgrass beds. Although it is not possible to fully characterize the density or percentage of cover using those photographs – which encompass the southernmost tip of Little Flying Pont across to the southernmost tip of Mere Point – there appears to be little overall change in distribution of eelgrass in Maquoit Bay since the previous analysis in 2001 (Barker 2010).

In 2009, a collaborative team, comprising Friends of Casco Bay, the Casco Bay Estuary Partnership, the US Geological Survey, and Bates College, began to develop a baseline of boat-based rapid assessment eelgrass data at randomly selected monitoring stations within Maquoit Bay and off Mackworth Island. Initial analysis of the 2009 data provided valuable information to help guide future eelgrass surveys in Casco Bay, and generally suggested that eelgrass is present and healthy where expected, based on previous macro-scale assessments and habitat modeling. Additional boat-based data collection should expand understanding of eelgrass conditions within Casco Bay.

Hillary Neckles, of USGS Patuxent Wildlife Research Center, deploys an underwater video camera to measure eelgrass cover.

Solution and Actions

Eelgrass is vulnerable to a number of human activities, including boating. In Casco Bay, sheltered coves and bays that provide excellent mooring conditions often also support eelgrass beds. As chains drift during tide cycles, however, scour can leave a circular scar on eelgrass beds. That scouring effect can also increase turbidity in the water column, decreasing available light to adjacent plants.

Although individual mooring impacts to eelgrass beds may seem insignificant, the cumulative impact of a mooring field can be locally damaging.

At the annual "Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States" workshop held in Portland in February 2009, attendees learned about new conservation mooring technologies that hold promise for reducing the impacts of moorings on eelgrass. Incorporating flexible rods, the moorings suspend mooring chains off the bottom to reduce scour. Under the Cooperative Habitat Protection Partnership, an initiative of the National Marine Fisheries Service, state and federal agencies are working with Massachusetts communities to promote use of the moorings, while studying their effectiveness at reducing the impacts of mooring fields on eelgrass beds. Researchers hope to determine whether the conservation moorings can indeed protect eelgrass, and whether resource managers should promote their use.

References

Barker, S., Maine Department of Marine Resources. Personal communication. May 19, 2010.

Carman, M.R. and D.W. Grunden. 2010. First occurrence of the invasive tunicate *Didemnum vexillum* in eelgrass habitat. *Aquatic Invasions* 5(1): 23-29. http://www.aquaticinvasions.net/2010/AI_2010_5_1_Carman_Grunden.pdf

Casco Bay Estuary Partnership. 2005. *State of the Bay.*

Neckles, H. A., A. R. Hanson, P. Colarusso, R. N. Buchsbaum, and F. T. Short (eds.). 2009. *Status, Trends, and Conservation of Eelgrass in Atlantic Canada and the Northeastern United States.* Report of a Workshop Held February 24-25, 2009, Portland, Maine. Available at www.gulfofmaine.org

Tyrrell, M.C. 2005. *Gulf of Maine Marine Habitat Primer.* Gulf of Maine Council on the Marine Environment. www.gulfofmaine.org/habitatprimer

What is the status of the waterbird populations of Casco Bay?

CBEP Goal: Minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Why Is It Important to Monitor Waterbird Populations in Casco Bay?

Waterbirds are vulnerable to human disturbance, pollution, and the effects of a changing climate. Collecting data on the locations where waterbirds congregate to feed, rest, and reproduce improves our ability to protect those vital habitat areas from the effects of human actions. Studying population numbers, as well as how birds use the spots they return to yearly for wintering and breeding, helps us to assess environmental impacts on the birds. Comparing the waterbird populations of Casco Bay to those in other parts of Maine and New England can help to determine whether habitat threats are of local origin – such as oil spills or loss of key habitat – or originate in other parts of the birds' range.

In 2000, aerial surveys of Casco Bay waterbirds were conducted during the spring migration, nesting period, and

Tim Bowman

Semipalmated sandpiper (*Calidris pusilla*) ranked highest among shorebirds identified to species during a 2009 survey in Casco Bay (Biological Conservation 2009). The bird needs to double its body weight in Maine before it migrates south. One of the birds banded in Eastport, Maine was observed only 48 hours later in Suriname, South America (Maine Audubon 2009).

State Protection of Significant Bird Habitats

MDIFW has identified and mapped Significant Wildlife Habitats including shorebird feeding and roosting areas; and inland and tidal waterfowl and wading bird habitat. In 2006, with modifications added in 2007, the DEP began regulating activities "in, on or over" those habitat areas, as well as in surrounding buffer zones

For example, more than 4,078 acres of shorebird feeding and roosting areas in the Casco Bay watershed now receive some protection from human disturbance (DEP 2007). The types of activities that require a permit within those habitats include residential and commercial development, road construction, the building of new wharves, and bridge construction. The permit may allow such activities if they are done in a way that minimizes harm to the birds and their habitat. Those protection measures support the survival and resilience of Casco Bay's waterbird populations.

Data source: DEP 2010b

fall migration. The results of those surveys are discussed in the 2005 *State of the Bay* report. Since then, CBEP and others have continued to study and monitor Casco Bay waterbirds including shorebirds (birds that feed in the intertidal such as plovers and sandpipers), island-nesting terns, and common eiders. This section focuses on those studies.

Status and Trends

Shorebird Surveys

In summer 2009, with funding from CBEP and Maine Coastal Program, Maine Inland Fish and Wildlife (MDIFW), US Fish and Wildlife Service (USFWS), Biological Conservation began a ground-based shorebird monitoring program focusing on a subset of state-designated habitat areas (see sidebar). The multiyear study will help to characterize habitat functions and identify trends in habitat usage. The data can be used to develop management strategies to promote the resilience of Casco Bay's shorebird populations as they respond to ecological stresses, including habitat loss and climate change.

The 2009 monitoring focused on areas designated by MDIFW as shorebird staging areas (areas where birds feed and rest during migration periods). In addition, the program examined sites on 15 Casco Bay islands and ledges to identify important roosting areas – where birds rest during high tide.

The results are indicated in the table. A total of 35 non-shorebird taxa were also identified during the shorebird surveys, including gulls, waterfowl and cormorants. Shorebirds were not common at island roosting sites, perhaps because the island roosting survey took place on just a single day. Data collected during that initial sampling season suggest that 2009 was not a typical year. Birds arrived in Maine late, and heavy rainfall caused high water conditions in early summer. Analysis of long term trends in shorebird abundance is likely to require many years of data collection, so that year to year variation can be taken into account. In 2010, scientists will both increase monitoring of state-designated roosting areas, and increase frequency of monitoring at selected sites.

Shorebirds observed at Casco Bay sites during July 23 – October 14, 2009 surveys of state-identified feeding areas. Each site was surveyed on six separate days at least one week apart, with the exception of Mackworth Flats, which was surveyed four times. The Presumpscot, Stroudwater and Mackworth areas had the greatest number of shorebirds observed at each site. ("Peeps" refers to small sandpipers not identified to species.) (Biological Conservation 2009).

	Upper New Meadows	Maquoit Bay	Royal River	Presumpscot River	Mackworth Flats	Back Cove	Stroudwater River	Upper Fore River	TOTAL
Black-bellied plover	0	155	17	118	0	83	0	21	**394**
Semipalmated plover	0	53	74	9	259	90	27	1	**513**
Killdeer	0	0	0	0	0	2	0	0	**2**
Greater yellowlegs	7	85	14	7	0	96	1	6	**216**
Lesser yellowlegs	0	33	6	3	1	2	3	2	**50**
Yellowlegs spp.	0	9	0	0	0	0	0	0	**9**
Solitary sandpiper	0	0	0	0	0	0	0	0	**0**
Willet	0	7	0	0	0	0	0	0	**7**
Spotted sandpiper	1	1	1	1	0	1	0	0	**5**
Ruddy turnstone	0	0	0	0	0	1	0	0	**1**
Semipalmated sandpiper	2	130	237	308	47	656	259	0	**1639**
Western sandpiper	0	0	1	0	0	0	0	0	**1**
Least sandpiper	25	60	29	1	1	18	13	0	**147**
White-rumped sandpiper	0	0	1	0	0	0	1	0	**2**
Baird's sandpiper	0	0	0	0	0	1	0	0	**1**
Pectoral sandpiper	1	0	0	0	0	0	0	0	**1**
Peeps	0	0	307	2665	0	0	719	2	**3693**
Dunlin	0	18	0	0	0	0	0	0	**18**
Short-bill. dowitcher	0	76	0	13	2	1	0	1	**93**
Dowitcher spp.	0	0	1	0	0	0	0	0	**1**
TOTAL	**36**	**627**	**688**	**3125**	**310**	**951**	**1023**	**33**	**6793**

Phyllis Cooper

Common tern (*Sterna hirundo*).

Restoring Island Nesting Terns

Common terns (*Sterna hirundo*), the most abundant tern species found in Casco Bay, breed on coastal islands and often return to the same site year after year. Once abundant, tern populations had fallen sharply by the late 1990s, largely due to gulls and other predators. Terns are now classified as a "species of special concern" by MDIFW. Colonies on Outer Green Island and Jenny Island are monitored and managed by National Audubon's Seabird Restoration Program headed by Dr. Steve Kress. CBEP has contributed funding to the effort. Those Casco Bay islands are among the few islands in Maine that still support hundreds of nesting pairs, making them especially important common tern nesting sites (MDIFW 2006).

In 2009, despite 26 inches of rain, 837 nesting pairs of common terns at Outer Green Island achieved the third-highest productivity (hatchlings fledged per nest) in the Gulf of Maine. The field crew is now using vegetation management to ensure bare-ground habitat remains available for nesting. On Jenny Island in 2009, the 578 nesting pairs of common terns had the highest productivity seen there since 1997, largely due to the absence of predators and abundant herring in the diet of chicks (National Audubon Seabird Restoration Program 2009).

Common Eiders on Flag Island, Casco Bay

Flag Island in Harpswell is one of the most significant seabird nesting islands in Casco Bay, a premier coastal nesting site for common eiders (*Somateria mollissima dresseri*). The island was permanently protected in 2002 by the cooperative efforts of a federal, state and private partnership that included CBEP and the US Fish and Wildlife Service Gulf of Maine Coastal Program. The Rhode Island North Cape Oil Spill settlement provided major funding for the effort.

A survival and productivity study conducted on the island from 2003-2008 revealed that Flag Island eiders rely on important brood-rearing habitats in eastern Casco Bay, including Sebasco Harbor in Phippsburg and Cundy's Harbor. The nesting eider population on the island during the study period was fairly stable except for 2006, when only 200 pairs nested, perhaps related to a virus that affected eiders overwintering in Massachusetts. In 2008, 500 pairs were nesting (Allen *et al.* 2008). Pond Island and Ragged Island are also sizeable eider nesting islands in East Casco Bay.

Tim Bowman

Common eider (*Somateria mollissima dresseri*).

Solutions and Actions

Protecting the habitat of Casco Bay's waterbirds is key to improving the birds' ability to survive human and environmental stresses. CBEP plans to continue the shorebird monitoring surveys over the next several years. The results of those surveys will help MDIFW evaluate the accuracy of their maps of Significant Wildlife Habitat, and will aid DEP in implementing regulatory protections under the National Resources Protection Act.

Oil spills are one of most dramatic impacts that waterbird populations periodically confront, causing short-term damage from the oil itself and long-term health effects related to toxic PAHs (polycyclic aromatic hydrocarbons) that can linger in the environment. DEP has developed Environmental Vulnerability Index Maps that identify coastal resources at risk from marine oil spills, including Significant Wildlife Habitat areas for waterbirds. The maps provide first responders with a tool for prioritizing and targeting protection of vulnerable habitat during the event of an oil spill (DEP 2010a).

Ongoing programs such as the monitoring, restoration and protection efforts described above are helping to ensure that the waterbird populations of Casco Bay and the larger Gulf of Maine will have the resilience to survive and remain healthy well into the 21st century.

References

Allen *et al.* 2008. *Survival, nest success and productivity of female common eiders* (Somateria mollissima dresseri) *on Flag Island, Harpswell, Casco Bay, Maine*. http://www.cerc.usgs.gov/nrdar/Document%20Center%20Files/Rhode%20Island/NC_Eider_FlagIslandFinalReport07-08.pdf

Biological Conservation, LLC. 2009. *Casco Bay Shorebird Monitoring Project 2009 Report*. http://www.cascobay.usm.maine.edu/pdfs/casco_bay_shorebird_monitoring_report_2009.pdf

Casco Bay Estuary Partnership. 2005. *State of the Bay*. http://www.cascobay.usm.maine.edu/sotb05.html

Maine Audubon. Spring 2009. *Conserving Maine's Significant Wildlife Habitat: Shorebirds*. http://www.maineaudubon.org/resource/documents/SHOREBIRDS.8.5x11.pdf

Maine Department of Environmental Protection. 2007. Amy Lemelin, Personal Communication.

Maine Department of Environmental Protection. 2010a. Maine Environmental Vulnerability Index Maps. http://maine.gov/dep/rwm/emergspillresp/evi/intro.htm

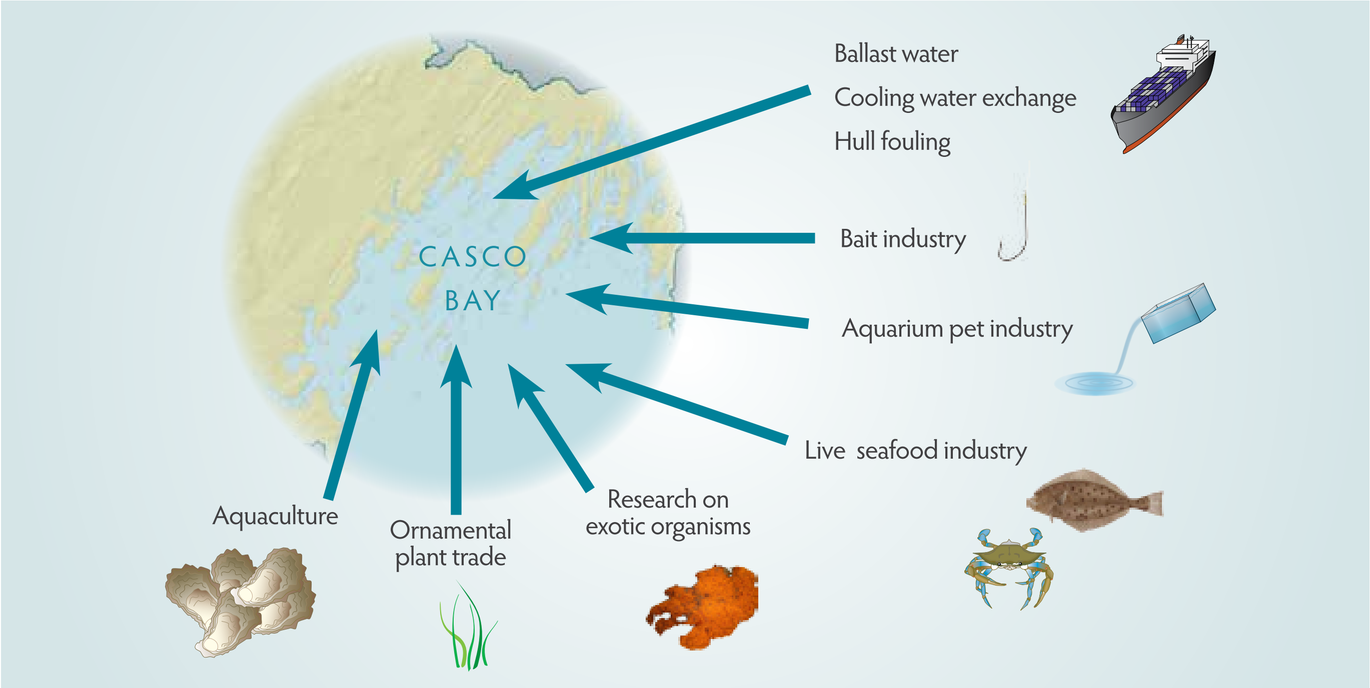
Maine Department of Environmental Protection. 2010b. Maps - High and Moderate Value Waterfowl & Wading Bird Habitat and Shorebird Habitats. http://www.maine.gov/dep/blwq/docstand/nrpa/birdhabitat/maps/index.htm

Maine Department of Inland Fish and Wildlife. 2006. *Island-Nesting Terns Assessment*. http://maine.gov/ifw/wildlife/species/plans/birds/islandnestingterns/ternassessment06.pdf

National Audubon Seabird Restoration Program. 2009. *Egg Rock Update*. http://www.projectpuffin.org/nsarchive/ERUpdate_2009.pdf

Are marine invasive species present in Casco Bay, and are they increasing?

CBEP Goal: Minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.



Invasive species enter Casco Bay's waters through multiple vectors – methods and mechanisms of transport. Shipping is considered the most significant source of invasive species, through ballast water exchange, exchange of cooling water, and transport of fouling organisms on the hulls of ships. Other vectors include accidental release of research organisms, release of exotic aquatic plants and animals, aquaculture of non-native species and related introduction of non-native fouling organisms, and release of non-native bait organisms.

Why Is It Important to Monitor Marine Invasive Species?

The bottom-dwelling (benthic) communities of the Gulf of Maine have been going through major shifts in species composition since the 1970s (Harris 2009). The factors influencing those shifts include the introduction of non-native species (see the vector diagram above). When a non-native species succeeds in establishing a reproducing population – and has a negative impact on the native plant and animal community or habitat – it is called "invasive."

Disturbance of the natural community can lead to successful invasion by non-native species. For example, overfishing of predatory groundfish in the Gulf of Maine led to a boom in green sea urchins around 1980, replacing many of the kelp beds that had dominated hard bottom habitats with urchin barrens (areas grazed bare by the urchins). When the urchins were intensively fished starting in 1987, a shift occurred in the bottom community towards previously rare species. The new community was dominated by introduced species such as the green alga *Codium fragile*, colonial tunicates like *Didemnum vexillum* and *Botrylloides violaceous,* and the encrusting bryozoan *Membranipora membranacea* (Harris 2009). Those organisms are now considered to be invasive in Maine (Maine DMR 2006).

Marine communities face multiple stressors. Already affected by overfishing and introduced species, they now also experience warming waters due to climate change (see Section 7). Those elements may act together to allow non-native organisms to spread into new habitats (Harris and Tyrell 2001; Harris 2009). Once introduced species become well established, containment or eradication can become difficult or impossible because wind and currents and other vectors can quickly transport larvae and organisms over a wide range. Programs that regularly monitor the abundance and geographic extent of introduced and invasive species are key to successful management (Maine DMR 2006).

Status of Invasive Species in Casco Bay

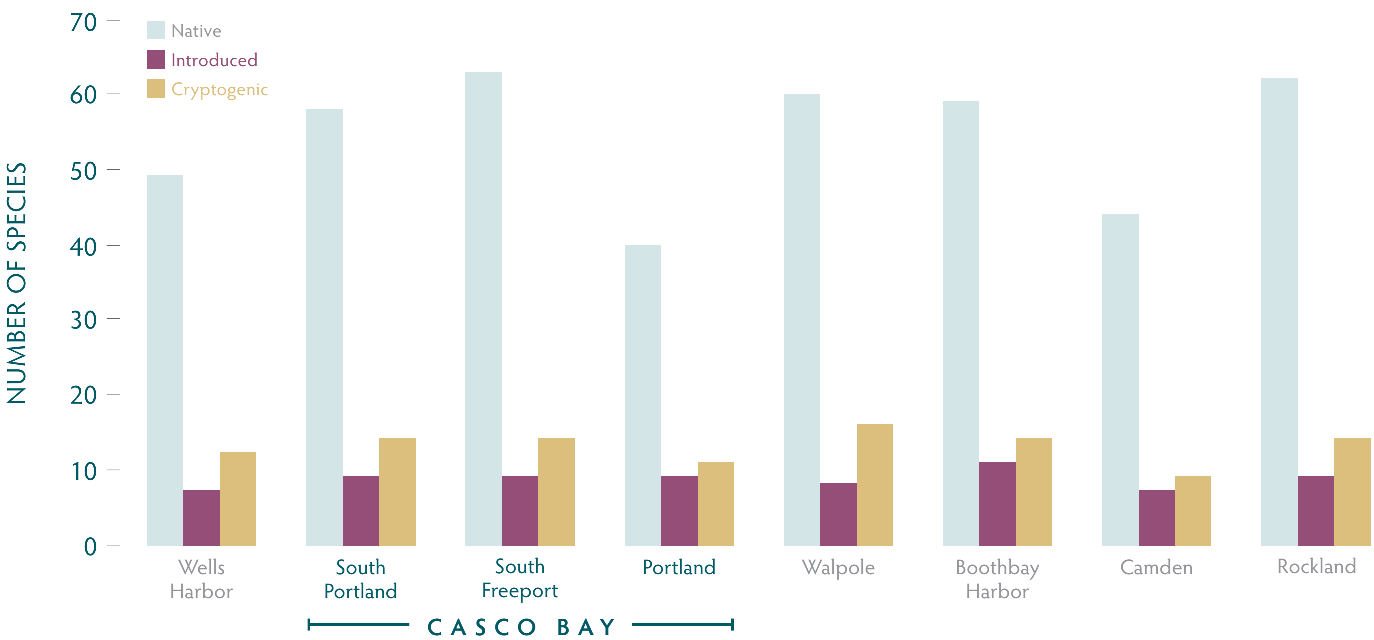
Invasive species can have significant economic and environmental impacts on fishery resources, ecosystem functions and human welfare in Casco Bay. The European green crab (*Carcinus maenus*), for example, is perhaps the most destructive established invader, responsible for reducing populations of soft-shell clams. The crab arrived in the 1800s in ballast water from the Baltic and North Seas and has become well-established in Casco Bay and throughout Maine. The invasive Asian shore crab (*Hemigrapsus sanguineus*), first reported in Casco Bay in 2001, is slowly spreading through Maine waters, and replacing native species (Maine DMR 2006). Tunicates like *D. vexillum* are spreading on bottom areas, and competing with juvenile fish and scallops for habitat and food. *Styela clava*, a clubbed tunicate from the western Pacific, fouls gear and moorings, and smothers shellfish. The spongy alga *Codium fragile* or deadman's fingers, likely introduced from Asia, is another invader that can smother shellfish beds. The bryozoan *M. membranacea* can damage kelp beds, which provide a valuable source of food and habitat, allowing *Codium* to recruit and replace the kelp (Maine DMR 2006).

In 2003 and 2007, MIT Sea Grant and the northeastern National Estuary Programs organized a weeklong "rapid assessment survey" (RAS) to examine the fouling organisms on floating docks and piers in areas with likely exposure to invaders, such as those near shipping ports. The August 2003 Casco Bay sites were Port Harbor Marine in South Portland, Portland Yacht Services, and Brewer South Freeport Marine. Of 29 introduced species identified in 2003 from across the region, 14 were present at the Casco Bay sampling sites (Pederson *et al.* 2005). In July 2007, the RAS revisited Port Harbor Marine and Brewer South Freeport Marine and added the Maine Yacht Center in Portland. The results of the 2007 RAS in coastal Maine are summarized in the following table. There was another RAS at Casco Bay sites in summer 2010, but the data are not yet available.

Gretchen Lambert

Botrylloides violaceus, an invasive colonial tunicate or "sea squirt" found in Casco Bay.

Results of the 2007 Rapid Assessment Survey in Maine. Scientists with expertise in native, introduced, and cryptogenic (not demonstrably native or introduced) species monitored the abundance of all three types of organisms at several sites (Pederson 2010). The most common non-native species in 2007 were two colonial tunicates, *Botryllus schlosseri* and *Botrylloides violaceus* and the bryozoan, *M. membranacea* , which appeared in all the stations. Other common non-native species included the club tunicate, *Styela clava*, and the European green crab. A total of 200 species were identified in the eight Maine sites, with an average of two fewer non-native species in Maine than in Massachusetts and New Hampshire sites (Pederson 2010).



The Vital Signs Program

Students and the Public Collect and Share Data on Invasive Species and Vulnerable Habitats

In partnership with scientists, resource managers and classroom educators, the Gulf of Maine Research Institute (GMRI) developed Vital Signs, a science learning environment investigating invasive species. Vital Signs challenges middle school students to ask questions about their local habitats, find and document both native and non-native species, and share their findings with one another and with professional scientists on the program website, www.vitalsignsme.org. Vital Signs focuses on contributing to statewide efforts to document invasive species and vulnerable native species and habitats, including lakes, forests, trout streams, wetlands, fields, salt marshes, and rocky intertidal zones. Program outcomes include increased research capacity for scientists and an opportunity for students and the public to learn and to participate in scientific research.

More than 2,000 students, 15 scientists, 47 educators, and many local citizens have taken part: downloading data sheets and taxonomic resources from the website; collecting written observations and water quality measurements; documenting species with digital cameras; and referencing their data with GPS positions. Scientists, educators, and others provide feedback on their findings, and experts check the species identifications (Thus far, the participants have an 84 percent accuracy rate.) All data and resources, scientific and educational, are publicly available online. The Maine DEP and the Invasive Plant Atlas of New England, based at the University of Connecticut, are two of Vital Signs' early partners, recognizing the program's potential to focus efforts of motivated citizens and ultimately to help scientists address the diverse challenges of invasive species monitoring and research.

Trends/Indicator Development

Maine Marine Invasive Species Working Group (MMISWG), a stakeholder committee comprising government, non-profit and academic members, has been exploring development of an indicator for the invasive tunicate *Didemnum vexillum*. As part of the state's annual May/June sea urchin dive surveys along the Maine coast, Maine Department of Marine Resources (DMR) has been collecting spring data on invasive *Didemnum* abundance since 2007. *Didemnum* typically reaches its maximum density in the fall and dies out over the winter. CBEP and Maine Department of Environmental Protection (DEP) provided funding to test the capacity of the spring data to predict fall abundance and distribution of *Didemnum* by repeating the survey in September, 2009 at twelve sites in Casco Bay and Boothbay Harbor. The data suggest that while there is a significant correlation between spring and fall abundance, there were many sampling sites where *Didemnum* was absent in the spring, but had appeared by September. In Casco Bay, *Didemnum* was not as abundant as some other areas of the coast. Additional studies will be required to establish local spring/fall abundance relationships to determine whether spring data can serve as an indicator for the extent and biomass of *Didemnum*.

Woods Hole Science Center, USGS

Didemnum vexillum, a harmful colonial tunicate that has invaded Casco Bay waters.

Solution and Actions

The most effective ways to minimize problems with invasive species rely on source prevention strategies such as ballast water and fouling organism management programs. Ballast water management is now addressed in US Coast Guard (USCG) regulations requiring mid-ocean ballast water exchange and in the Vessel General Permit (VGP) issued to commercial vessels under the federal Clean Water Act. The VGP requires, for example, that vessels avoid discharging into sensitive areas (such as shellfish beds); clean tanks in mid-ocean or in dry dock; and discharge the minimum amount required for operation. The permit also requires disposal of fouling organisms from anchor chains and seawater

The US Coast Guard has proposed strict regulation of ballast water discharges based on treatment to meet numeric standards.

piping, and management of hull-cleaning away from sensitive areas (VGP 2009). USCG (2009) has proposed new national regulations requiring treatment of ballast water to reach strict numeric standards for organisms discharged and is currently working on both treatment and testing protocols. (While the majority of ships coming into Casco Bay do not discharge ballast water in port, there are some discharges every year.)

The Northeast Aquatic Nuisance Species Panel (NEANS), consisting of state and federal representatives from throughout the northeast region, is addressing non-shipping vectors through educational programs and materials for industries that import non-local marine organisms such as the hatchery, fish-farming, and bait industries; the exotic pet industry; and aquatic pet owners (Weigle 2007). Public education programs in Casco Bay include the Gulf of Maine Research Institute's Vital Signs program (see sidebar). Maine Sea Grant, working with the MMISWG and others, has distributed a brochure (2008) and a poster (2009) encouraging fishermen and others to report invasive species, including two that have not yet made it to New England: the Chinese mitten crab (see photo) and the Rapa whelk (*Rapana venosa*), which preys voraciously on several commercially important shellfish species. Early detection and reporting may make control of those invaders possible.

Actions under the State of Maine 2002 *Action Plan for Managing Aquatic Invasive Species* (DEP 2002) have been focused on managing the introduction of freshwater plants. To address marine species, the state is participating in the regional NEANS panel as well as the MMISWG. The members of MMISWG, including CBEP, are continuing to work together on invasive species indicators, as well as on the tools and strategies needed for early detection and rapid response.

Christian Fischer

The Chinese mitten crab, *Eriocheir sinensis*, is found in both estuarine and fresh waters (but not yet in Maine!). This dinner-plate sized crab burrows into muddy banks and can accelerate shoreline erosion. To report sightings, call Maine DMR 207-633-9539.

Educational poster from Maine Sea Grant.

References

Harris, L. G. and M. C. Tyrell. 2001. Changing community states in the Gulf of Maine: synergism between invaders, overfishing and climate change. *Biological Invasions* 3: 9-21.

Harris, Larry G. 2009. Shifts in Benthic Community Composition in the Gulf of Maine: Increasing Roles of Invasive Species. Abstract. *Gulf of Maine Symposium 09: Advancing Ecosystem Research for the Future of the Gulf.* St Andrews, New Brunswick, Canada.

Maine Department of Environmental Protection. 2002. *State of Maine Action Plan for Managing Invasive Aquatic Species.* http://www.maine.gov/dep/blwq/topic/invasives/invplan02.pdf

Maine Department of Marine Resources and Maine Department of Environmental Protection. 2006. *Non-Native Invasive Species in Maine: A Report to the Maine State Legislature, Maine Resources Committee and Natural Resources Committee.* http://www.maine.gov/dep/blwq/report/marine_invasive2006.pdf

Maine Sea Grant. 2008. *Maine's Marine Invasion.* (brochure). http://www.seagrant.umaine.edu/files/pdf-global/08MMI.pdf

Maine Sea Grant. 2009. *New England's Marine Invasion.* (poster). http://www.seagrant.umaine.edu/files/pdf-global/Marine%20Invasion%20Poster042209_LowerRes.pdf

Pederson, J. R. Bullock, J. Carlton, J. Dijkstra, N. Dobroski, P. Dyrynda, R. Fisher, L. Harris, N. Hobbs, G. Lambert, E. Lazo-Wasem, A. Mathieson, M.-P. Miglietta, J. Smith, J. Smith III, and M. Tyrrell. 2005. *Marine Invaders in the Northeast: Rapid Assessment Survey of Non-Native and Native Marine Species of Floating Dock Communities, August 2003.* Massachusetts Institute of Technology Sea Grant College Program. Publication No. 05-3. http://www.mass.gov/envir/massbays/pdf/ras2003.pdf

Pederson, J. February 23, 2010. Massachusetts Institute of Technology Sea Grant College Program. Personal Communication.

United States Coast Guard. September 15, 2009. White Paper: Proposed Ballast Water Discharge Standard Rulemaking. http://www.uscg.mil/hq/cg5/cg522/cg5224/docs/White%20Paper%20-%20Ballast%20Water%20Discharge%20Standard%20v3B.pdf

VGP Clean Water Act (CWA), as amended (33 U.S.C. 1251 et seq.) 2/5/2009. http://www.epa.gov/npdes/pubs/vessel_vgp_permit.pdf

Weigle, S. 2007. *Non-Shipping Pathways for Marine Invasive Species in Maine.* http://www.cascobay.usm.maine.edu/pdfs/non-shipping_vectors_report.pdf

SECTION SEVEN

Climate Change

Maine Historical Society

Three workers pose with thick blocks of ice on Sebago Lake circa 1920.

Introduction

Climate is always changing, a fact that is hard for anyone living in the glaciated landscape of Maine to forget. Eighteen thousand years ago, the Casco Bay watershed lay below a mile or more of ice. Ten thousand years ago, most of it was under hundreds of feet of water. But current information suggests that recent climate change is more rapid, and more consistent – more directional – than anything seen in human history (*e.g.*, Solomon *et al.* 2007)

Human societies are adaptable, but there will be costs related to adapting to a novel climate. The tendency of people to organize their lives and economic activities around climate means that a shifting climate is likely to generate more costs than benefits. For many in Maine, the idea of warmer winters may sound like a blessing. Yet warmer winters would reduce the viability of the ski industry, allow northward migration of forest pests, and produce major changes in marine life found in coastal waters. (Indeed, many of those effects are already occurring in response to changes in climate during the 20th and early 21st centuries.) Mainers will adapt over time, but the costs of that adaptation may be significant. Work done now can reduce those costs.

A recent CBEP report (Wake *et al.* 2009) shows that climate in the Casco Bay region is warmer and wetter than it was a century ago. Projections suggest those trends are likely to continue for decades, even if human societies sharply curtail greenhouse gas emissions. Both drought and flooding are likely to be more common than in the past. Sea level in Casco Bay will increase more rapidly than it has in millennia. Changes are even likely in the chemistry of our coastal waters.

CBEP, with support through EPA's Climate Ready Estuaries Program, has been working to both gather information on climate change in the Casco Bay region, and to make that information available to regional communities. The goal is to help Mainers better understand past, present, and future climate, so that residents, businesses, local organizations, and municipal governments can consider climate information in their decisions.

INDICATOR 17

How will climate change, sea level rise, and ocean acidification affect Casco Bay?

Introduction

Climate underlies nearly everything we do. Both public and private investment decisions are based on expectations – often implicit – of future weather. When climate changes rapidly or persistently, some of those expectations may be frustrated, affecting our communities in many ways.

Portland Water District

Ice house on Sebago Lake circa 1927.

Mainers have certain agricultural, economic and recreational experiences and expectations based on the state's climate. Those expectations drive much of the state's economy. Potatoes are grown in northern Maine and blueberries downeast because they are suited to the seasons and the soil. Fish, clams and lobsters thrive in the cool waters of our rivers and bays. Hunters, fishers, snow lovers, summer visitors and leaf peepers contribute millions to Maine's economy; what draws them is Maine's natural wealth, scenic beauty – and climate.

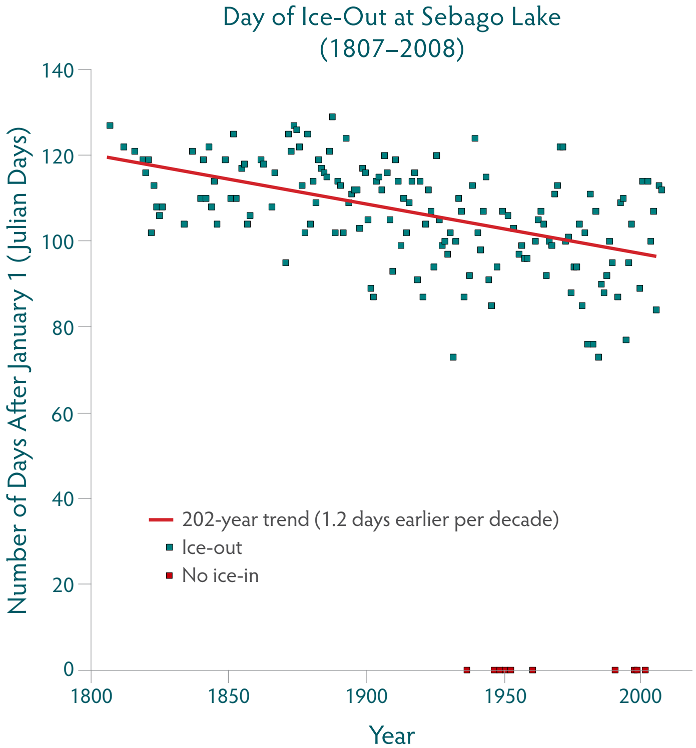
Whether they realize it or not, Maine's farmers, fishers, and naturalists have long used phenology – the study of how seasonal changes influence plant and animal life cycles – to plant their crops and plan their harvests. In doing so, they are following centuries of tradition. Written records of European grape harvests, along with information on weather and growing conditions, go back more than 500 years. Similar long-term records have become of great interest as people try to understand the effects of climate change. For example, the owners of Jordan's Store in East Sebago can provide more than a century of information on ice-out dates for Sebago Lake. Maine's seasonal markers also include the first lilac blooms of the spring, the arrival of migratory birds, the timing of lobster shedding, and the dates that the fall leaves turn.

Status and Trends

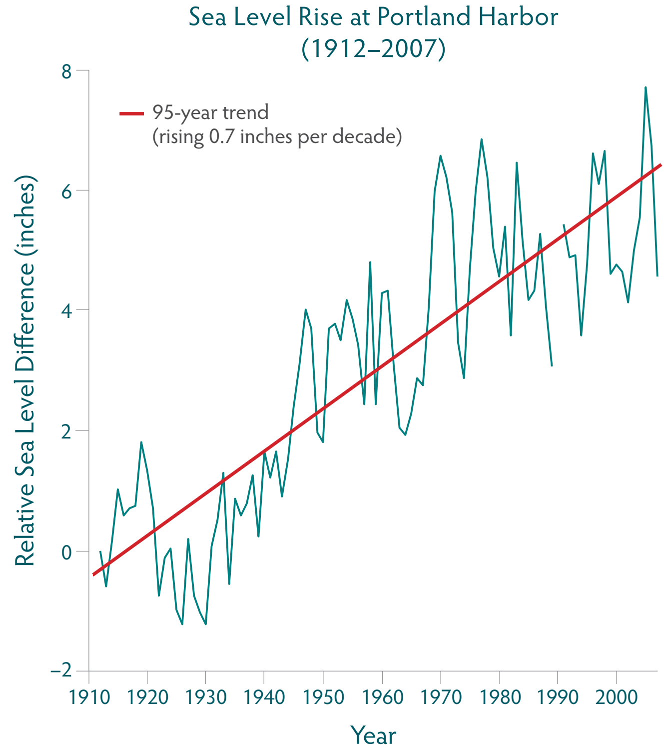
Sebago Lake Ice Out

Local evidence for past climate change or its effects is surprisingly common. Yet because many of the changes documented in long-term records occurred over a period of decades, most people are not consciously aware of them.

A recent report commissioned by CBEP (Wake *et al.* 2009) reviewed historical sources of data on weather and climate from the Casco Bay region, and documented historical changes in temperature, precipitation, stream flow, and the number of days with snow on the ground. Perhaps the most compelling example of historic changes in climate, however, stems from the 200-year tradition of betting on "ice-out dates" on Sebago Lake. Average ice-out dates are about three weeks earlier now than they were in the mid-1800s. While ice-out dates in May were fairly common before 1800, they have occurred only three times since 1900.



Day of ice-out at Sebago Lake from 1807 to 2008. The day of ice-out is defined as the number of days past January 1st until the lake is considered ice-free. Red squares indicate years in which the lake did not freeze over (Wake *et al.* 2009).



Relative sea level (inches) measured at the Portland Harbor tidal gauge, 1912 to 2007. The 1912 value has been subtracted from annual values to illustrate the change in sea level relative to the start of the record. The red line is the linear regression applied to the time series, and is used to calculate the rate of change: about 0.7 inches/decade (Wake *et al.* 2009).

Sea Level Rise

A warming climate directly influences sea level. The most direct cause of that effect at a global scale is the thermal expansion of the oceans. As ocean waters warm, they expand, taking up more volume, and leading to sea level rise. Additional increases in sea level are possible if significant melting of the Antarctic and Greenland ice sheets occur. Changes in ocean circulation patterns, should they occur, may also produce regional changes in sea level.

Sea level has been rising along the coast of Maine for some 4,000 years. Over the past century, data on water level have been recorded nearly continuously at the tide gauge in Portland Harbor. Evaluation of historic data reveals that sea level has been rising in Portland at a rate of 0.7 inches (just less than three quarters of an inch) each decade. A majority of that rise can be accounted for based on estimates of eustatic (global) sea level rise (Wake *et al.* 2009), some of which is likely to be anthropogenic in origin.

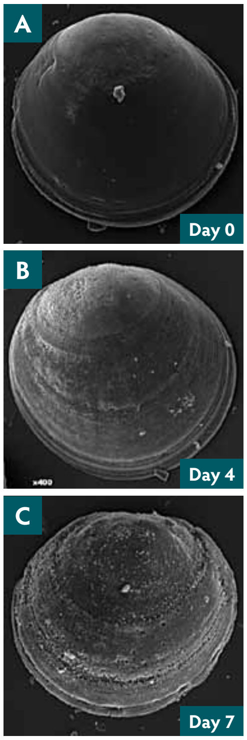
The Wake *et al.* (2009) report makes a preliminary estimate of future sea level changes in the Portland area. The city is projected to have increases in ocean elevations of between two and five feet by the end of this century. Those changes would require rates of sea level rise significantly above the rates seen in Portland in the past century.

Estimates of Future Sea Level Rise at Portland Harbor

Emissions Scenario	Lower		Higher	
Year	2050	2100	2050	2100
1998 stillwater elevation (ft)	8.9	8.9	8.9	8.9
Subsidence of coastline	0.024	0.043	0.024	0.043
Changes in ocean circulation	NE	0.52	NE	0.79
Global average sea level	0.66	1.6	1.4	4.6
Total stillwater elevation[1] (ft)	9.5	11.1	10.3	14.3

Estimates of changes in tidal elevation at the Portland tide gauge under lower and higher greenhouse gas emissions scenarios. Changes in elevation will reflect (1) subsidence of the Maine coastline; (2) dynamic changes due to changes in ocean currents, and (3) eustatic (global) changes in sea level due principally to changes in the volume of ocean water. Elevations do not consider effects of storm surge or waves. (Wake *et al.* 2009)

[1] Feet above NAVD 1988.



Damage to shells of juvenile quahogs (*Mercenaria mercenaria*) caused by exposure to acidified conditions in the laboratory.

A. Scanning electron micrograph of a juvenile clam at start of experiment.

B. Image of a clam after four days exposure to acidified conditions.

C. Image of a clam after seven days exposure.

After a period of a week, significant damage to the shell is clearly evident. Exposure to acidified conditions has been hypothesized to contribute to poor recruitment of softshell clams in mudflats in Casco Bay.

From Green *et al.* 2009. Used with permission of the author.

Ocean Acidification

Mainers have been aware for decades that emissions of greenhouse gasses, especially carbon dioxide, may influence climate. But the significant effects that carbon dioxide may also have on water chemistry and marine ecosystems are less commonly understood.

Atmospheric carbon dioxide, which has been increasing for more than 100 years due primarily to combustion of fossil fuels, does not simply accumulate in the atmosphere. A significant portion dissolves in the ocean, where it generates carbonic acid which changes the acidity of the ocean, and shifts the abundance of bicarbonate and carbonate ions. Many marine organisms – from corals to phytoplankton to shellfish – build shells or structural supports out of carbonate minerals. These organisms include commercially important species such as softshell clams and lobsters.

Already, ocean acidification may contribute to what Mark Green, of St. Joseph's College, calls "death by dissolution:" the wasting away of the shells of juvenile clams. Green has been investigating the high mortality of softshell clams (*Mya arenaria*) seeded onto clam flats in eastern Casco Bay. He hypothesizes that many of the tiny clams die as a result of shell dissolution. Laboratory experiments confirm that quahog (*Mercenaria mercenaria*) shells dissolve in conditions similar to those found on some mud flats. In the field, softshell clam mortality was reduced in plots where crushed clam shell was added. Crushed shell helps reduce acidity in the mud and ameliorates its effects (Green *et al*. 2009). Acidified conditions in the near shore mud flat environment cannot be attributed solely to ocean acidification, but Green's studies illustrate how sensitive important commercial species may be to changes in water chemistry.

Future Direction / Next Steps

In 2009, the Maine Legislature requested that the Department of Environmental Protection undertake studies on adaptation to climate change in Maine. The resulting report was issued in 2010. It includes a preliminary evaluation of vulnerabilities of human and natural systems to climate change, and lays out strategies to improve how local communities, natural lands, and marine systems adapt to changing conditions. For instance, it advocates the development of accurate high-tide and flood-plain maps – some of which are now fifty years out of date. The report also stresses the importance of collaboration and planning in responding constructively to climate change. Related vulnerability assessments and adaptation planning efforts are now occurring at the national, regional, state, and local levels.

As detailed in this section, we are already seeing local consequences of climate change, such as earlier ice out on Sebago Lake, increased precipitation, and changes in river flows. Because of the significant momentum built into the global climate system, additional – even accelerating – changes lie ahead. The degree to which we take projections of future climate conditions seriously, and work to minimize potential harm, will determine the consequences for human societies and natural systems.

References

Green, M. A., G. G. Waldbusser, S. L. Reilly, K. Emerson, and S. O'Donnell. 2009. Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves. *Limn. and Oceanogr.* 54(4): 1037-1047.

Department of Environmental Protection. 2010. *People and Nature Adapting to a Changing Climate: Charting Maine's Course*, a report presented to the Joint Standing Committee on Natural Resources of the 124th Maine Legislature.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). 2007. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Wake, C., E. Burakowski, K. Hayhoe, C. Watson, E. Douglas, J. VanDorn, V. Naik, and C. Keating. 2009. *Climate change in the Casco Bay watershed: Past, present, and future.* Casco Bay Estuary Partnership. Portland Maine. http://www.cascobay.usm.maine.edu/pdfs/Climate_Change_in_Casco_Bay.pdf

SECTION EIGHT

Stewardship

Above: The Presumpscot River Youth Conservation Corps restores a streambank. Below: Students participate in the Maps for Schools program.

Introduction

Calls to improve human relationships with the landscapes we inhabit trace back many generations and have been voiced by numerous environmental leaders, perhaps most prominently by Aldo Leopold in his land ethic.

The 1996 *Casco Bay Plan* made stewardship a cornerstone of CBEP programmatic activities, and recognized the vital importance of stewardship by setting a primary goal that, "All members of the Casco Bay community act as responsible stewards to protect Casco Bay and its watershed." The plan notes that stewardship depends on cultivation of an awareness among individuals, volunteer groups, local business and industry, municipal officials, regional entities, and state and federal governments to ensure that stewardship pervades everyday decisions and activities.

Since then, CBEP and its partners have continuously supported and advanced activities to promote stewardship of Casco Bay. Tracking stewardship activities provides important information about our broader relationships with the natural communities that we depend upon and enjoy.

References

Casco Bay Estuary Project. 1996. *Casco Bay Plan.*

Leopold, A. 1949. *A Sand County Almanac.* New York: Oxford University Press.

INDICATOR 18

How are CBEP and our partners promoting stewardship and community engagement in the Casco Bay watershed?

CBEP Goal: All members of the Casco Bay community act as responsible stewards to protect Casco Bay and its watershed.

Why Is It Important to Promote Stewardship of the Casco Bay Watershed?

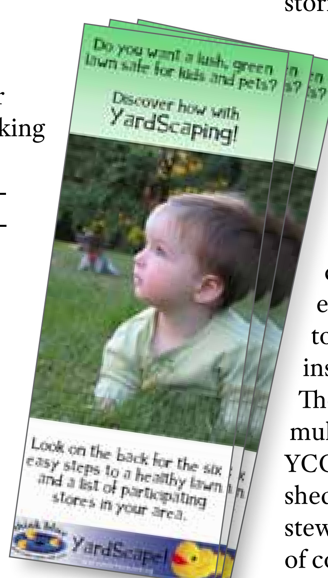
The US EPA defines environmental stewardship as a responsibility shared by all those whose actions affect the environment. Thus all 240,000 residents of the Casco Bay watershed have an obligation to help protect their environment, regardless of the nature or frequency of their use of the Bay and the rivers and streams that feed it. On any given day, each citizen of the watershed makes decisions that cumulatively affect its health over time. CBEP believes that by helping those citizens understand the effects of those decisions, and engaging them in collective action, it is protecting and maintaining the health of the estuary for future generations.

What Are Some of the Stewardship Activities Taking Place in the Casco Bay Watershed?

Numerous stewardship activities take place around the watershed every day, ranging from volunteers collecting water quality samples to land trusts stewarding individual properties, to watershed groups like the New Meadows Watershed Partnership promoting the health of a water body. Space limitations prevent a comprehensive compilation of all these activities. Below is a sampling of recent stewardship-related programs undertaken by CBEP and its partners.

YardScape!

The Cumberland County Soil and Water Conservation District (CCSWCD), working directly with the Interlocal Stormwater Working Group municipalities, horticulturists, lawn care professionals and nurseries, has been successfully promoting the YardScape! program for low-impact yard care to residential homeowners. YardScape! aims to reduce the use of pesticides and fertilizers that can enter stormwater and degrade water quality.



This door hanger is part of the YardScape! outreach campaign.

CCSWD began the program by surveying homeowners in the watershed to determine residential needs and interests in lawn care. Using those results, CCSWD developed a series of fact sheets – "Mow Better," "Aerate," "Water Wisely," and "Grubs," among others. They provide yard care recommendations that save money, result in lovely outdoor areas, and reduce health risks associated with pesticide use.

Casco Bay Youth Conservation Corps Collaborative

For several years, the watershed has benefited from the stewardship and leadership of local youth conservation corps (YCCs): teams of five high school students, a crew leader, and a technical director. YCCs work with private landowners, lake associations, municipalities, state and federal agencies, and others to implement water quality improvement projects in the watershed. The participants excel at projects such as constructing low-impact development structures, planting riparian buffers and rain gardens, and stenciling storm drains. As just one example: over three summers, the Presumpscot River YCC completed 50 projects, installing 82 infiltration steps, painting 442 storm drains, and building 12 water diverters.

Jeff Varrichione

Volunteers plant trees and shrubs on an eroded riverbank.

YCCs' greatest benefits may be in cultivating environmental stewardship among youth, who develop leadership skills while working in their local communities to protect water quality. In Maine and elsewhere, the YCC model has proven to be an effective tool for raising awareness, energizing communities, and inspiring local youth to become environmental leaders. The Casco Bay YCC Collaborative, which brings together multiple crews for large projects, further expands the YCCs' contributions to their communities and their watershed. When participants become the Bay's environmental stewards in the future, they will be aware of the importance of collaborative action.

In-School Education Programs

The Cumberland County Soil and Water Conservation District, Portland Water District, and other organizations are bringing watershed-based education programs directly into area schools through hands on lessons and field-based experiential learning activities.

Maps For Schools

Maps For Schools is a collaborative effort of CCSWCD, CBEP, the University of Southern Maine (USM), and Orbis LLC. With funding from the Presumpscot Watershed Initiative, the program was launched in 2006 to help youth reconnect with their "sense of place" in the Presumpscot watershed. The multidisciplinary program incorporates environmental science, social studies, history, and geography while addressing Maine Learning Results standards. Using maps and data, students investigate historical and present day human relationships with waterways by learning about how villages, canals, sewers, mills, and archaeological sites relate spatially to the Presumpscot River and its tributaries. CCSWCD and USM environmental studies faculty developed a series of lessons and activities that incorporates digital maps, and provided a compact disc/CD (available upon request from CCSWCD) to distribute curriculum and mapping materials.

So far, more than 1,000 first- through eighth- graders have participated in Maps for Schools in the watershed communities of Falmouth, Gorham, Portland, Westbrook, Windham, and Yarmouth, for a collective total of 3,135 contact hours of education.

ISWG Stormwater Education Activities

The Interlocal Stormwater Working Group provides funding to CCSWCD to offer stormwater education to schools. Between 2004 and 2009, 3,850 students in the watershed received 10,539 contact hours of lessons thorough the program. Those children represented 11 municipalities, and 27 elementary, middle, and high schools in the watershed.

Portland Water District Education Programs

The Portland Water District runs multiple education programs that are active in many areas of the Casco Bay watershed. Programs include Hydrologics, TroutKids, and Drop in the Bucket. Taking advantage of students' innate curiosity by basing lessons on the water cycle, watershed, groundwater, wastewater treatment, lakes, and salmon, PWD's educators actively seek to help children become stewards of their water resources. In Hydrologics, eight lessons on nonpoint source pollution, human impacts, watershed characteristics, stormwater, low impact development, and behavior change are given once a month. Students design and then implement environmental projects in their communities. In TroutKids, students visit hatcheries and deliver eggs, maintain tanks, record data, and learn about fish anatomy and habitat. Drop in the Bucket programs are shorter or one-time presentations, workshops, and events at schools. Over the span of the 2009-2010 school year, PWD educators reached more than 4,500 students through more than 22,319 contact hours.

Fifth-graders from the Reiche School in Portland at the 2010 Southern Maine Children's Water Festival.

Youth also have opportunities to learn about Casco Bay and the Casco Bay watershed at local libraries. PWD educators participate in summer reading and activity programs to help students learn what they can do to protect the watershed, while Friends of Casco Bay introduces the watershed and its history to young audiences.

Southern Maine Children's Water Festival

CBEP and several of its partners contribute financially, programmatically, and administratively to the Southern Maine Children's Water Festival, held each spring on USM's Portland campus. The festival is a collaboration of several state and local agencies and is dedicated to providing nearly 700 fifth-graders a full day of hands-on, interactive, and fun educational experiences. From games like Dripial Pursuit and Eel of Fortune, to hands-on activities such as touch tanks, bug identification, and fly-tying, the festival staff and volunteers work diligently to incorporate an awareness of the watershed's importance to its marine and human occupants. Teachers receive supplementary materials to help them incorporate the lessons of the day into their long-term curricula.

The festival has grown significantly in recent years: in 2010, the committee received twice as many applications as it could accept. Judging from the enthusiastic reviews of teachers and students, the Southern Maine Children's Water Festival is laying excellent groundwork for the future of the watershed.

Reference

Casco Bay Estuary Partnership. 2010. *Presumpscot Watershed Initiative - Final Report.*

Presumpscot Watershed Initiative

In February 2006, CBEP, in partnership with the Presumpscot River Watershed Coalition (PRWC), Cumberland County Soil and Water Conservation District, Friends of Casco Bay, and Presumpscot River Watch, was awarded a $740,000 EPA Targeted Watershed Grant to implement a number of environmental improvement projects. That collaboration, the Presumpscot Watershed Initiative (PWI) took the lead on installing 116 projects throughout the watershed, while engaging area farms, golf courses, schools, and homeowners to foster improved stewardship of water resources and adjacent lands (CBEP 2010). Representative highlights from the three-year effort follow.

At Walnut Crest Farm in Gorham, owner Dale Rines fenced off four acres of pasture along the Presumpscot River, some of which was severely eroded from heavy livestock use, and provided cattle with an alternate source of drinking water. Over the course of multiple planting events, Mr. Rines and a dozen volunteers then planted more than 4,000 trees and shrubs to stabilize loose soils and restore the riparian buffer.

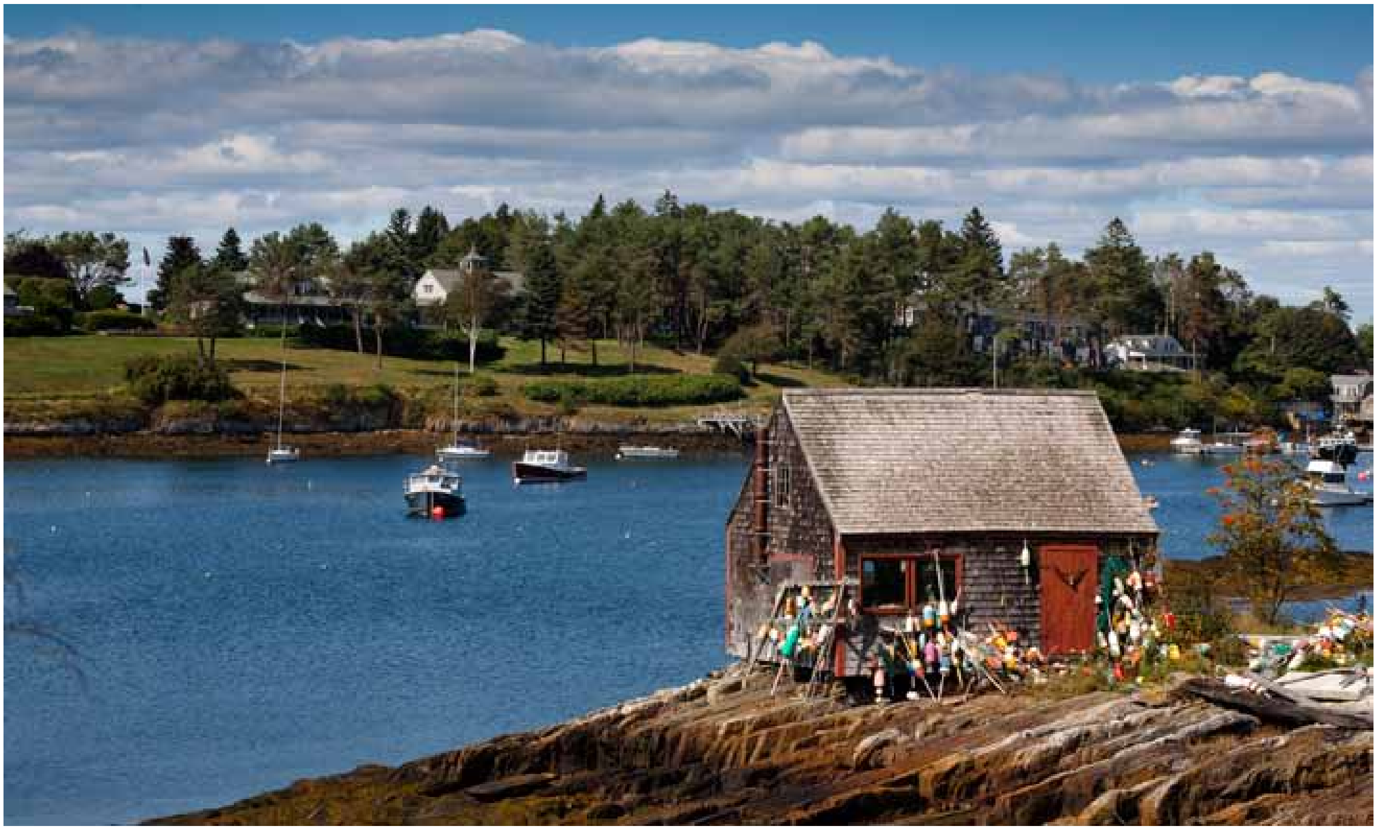
Municipal public works crews, in collaboration with CCSWCD staff, addressed faulty culverts, eroding road banks, and other problems identified at 47 stream-road crossing sites throughout the watershed. In addition to preventing an estimated 455 tons of sediments from eroding into adjacent water bodies, 13 new culverts were installed. A bottomless arch culvert was installed at the crossing of Totten Road over Thayer Brook in Gray, where two small culverts caused periodic flooding, and presented a moderate barrier to fish and other aquatic organisms. Among the first such stream/road crossing in the Casco Bay region, the bottomless arch culvert eliminates erosion issues associated with the previous structure, and provides unhindered passage to fish and other aquatic life while demonstrating recommended practices for installing new and replacement culverts.

In response to local demand for low-impact golf courses, several Presumpscot-area golf courses initiated the process of becoming certified as Audubon International Cooperative Sanctuaries. To qualify, they must follow program recommendations for improving habitat, reducing pollution, and protecting water quality. All recommendations are designed to allow courses to maintain high-quality fairways and greens. In response, course superintendents are expanding vegetated buffers, establishing no-mow zones, and timing watering to minimize runoff, among other strategies. Falmouth Country Club, for example, is now brewing compost tea (pictured above) to reduce the amount of fungicides it uses.

In 2008, hundreds of people joined PRWC and other organizations in the first Presumpscot River Fest, a celebration held at Riverbank Park in Westbrook. Visitors learned about ongoing efforts by PRWC and its partners to preserve open space, mitigate cumulative impacts, and restore native fisheries. Local musicians performed, children participated in environmental education activities, and all participants learned about ways they might become involved in activities to protect and maintain the Presumpscot River.

To learn more, or to get involved in these and other stewardship activities, visit the Casco Bay Estuary Partnership web site at www.cascobayestuary.org.

Afterword: The State of the Bay



Dieter Weinelt

Putting together a comprehensive picture of the condition of Casco Bay is a difficult project: one CBEP tackles every five years.

One purpose of that periodic effort is simply to gather available information on the condition of Casco Bay, and provide it readily to the watershed's community at large. Another goal is to provide insight to guide future efforts to benefit Casco Bay, its watershed, and the region's human and natural communities. The *State of the Bay* reports also provide the opportunity to highlight successes of CBEP and its many partners.

Several themes emerged from the exercise in 2010.

First, Casco Bay remains largely healthy. The Bay supports a remarkable abundance of fish, birds, and wildlife. The Bay's submerged aquatic vegetation, principally eelgrass (*Zostera marina*), is widespread, and it appears to be flourishing in areas of suitable habitat throughout most of the Bay. The Bay's lobstermen and clammers continue to ply their trades, generating millions of dollars in economic value to the harvesters, and millions more to associated businesses. The unparalleled beauty of the Bay, and its coastlines and islands support both historic summer communities and robust tourism-based industries. Simply put: the region is a wonderful place to live, and the Bay is a big part of why that is so.

Casco Bay remains one of the healthiest estuaries in the National Estuary Program. Its watershed continues to be predominately forested. Each of its subwatersheds – with the exception of the heavily urbanized Fore River subwatershed, in the heart of the Portland metropolitan area – is more than half forest. Many streams continue to support native fish and invertebrates. The waters of the

upper watershed provide excellent fishing for trout and landlocked salmon. And the forests of the upper watershed protect water quality in Sebago Lake, annually saving the Portland Water District and its rate payers millions in water treatment expenses.

In some ways, the Bay is healthier than it was a generation ago: the Clean Water Act has been beneficial for the watershed. Concentrations of many toxic compounds in the Bay's surface sediments have been declining, largely because environmental regulations have resulted in sharp declines in environmental releases of persistent toxins, from DDT to PCBs to lead. Less untreated, or only minimally treated, human waste is entering the Bay. Hundreds of discharges from shorefront houses have been eliminated. It is (finally) illegal to discharge waste from boats into the Bay. And the region's cities and towns have reduced the volume and number of combined sewer overflows.


Dieter Weinelt

But there are problems on the horizon. In June and July, 2010, much of the cove at the mouth of Anthoine Creek, visible from the deck of the Route 88 bridge across the Fore River between Portland and South Portland, was bright green because of an extensive overgrowth of filamentous green algae (principally species of the genus *Ulva*). While quantitative data is lacking, such "green slime" events may be increasing in frequency. If so, they may be an early sign of nutrient over-enrichment within the Bay. Anadromous fish are still blocked from the majority of their historic habit within the watershed, and solutions, where they are even possible, are expensive. Sometimes alarming levels of "toxics of emerging concern" are appearing in the biota of the region. Invasive species in both freshwater and marine environments are increasing. Climate change and associated sea level rise pose significant threats not only to people living around the Bay, but also to the region's natural resources, in ways yet to be completely understood.

While the upper watershed remains largely forested and undeveloped, that is not the case in the lower watershed. There, especially in the areas along the Interstates 295 and 95 corridors, development has already reached levels likely to reduce water quality, and to have negative effects on ecosystem services. Continued population growth and associated changes in land use – perhaps exacerbated by changes in climate that will make Maine an even more attractive place to live – is likely to increase consumption of natural lands, further reducing availability of ecosystem services, and increasing stresses on Casco Bay. A critical challenge for the coming decade will be accommodating increasing population without degrading ecosystem services that have been taken for granted by generations of Mainers.

Luckily, the community working in ways large and small on behalf of Casco Bay is growing. Dozens of organizations, hundreds of volunteers, and thousands of individuals are engaged with the meaningful work of improving the quality of our environment. Engineers design and install structures to treat stormwater. Citizens collect data on the water quality and aquatic life of Casco Bay. Kids pick up after their dogs. Volunteers search for invasive aquatic plants in area lakes and streams. Towns hold festivals to celebrate and help preserve their aquatic heritage. Teachers incorporate watershed-based education into their curricula. Lobstermen continue to notch the tails of lobsters bearing eggs. Fishing enthusiasts survey culverts and dams to see whether they allow for passage of fish. Locally led conservation efforts have better than doubled the area of permanently protected land in the lower watershed – to more than 15,690 acres. Farmers fence their livestock away from streams. And clammers seed local clam flats with spat.

Efforts such as those demonstrate that all residents of the watershed – those whose roots go back generations and those who arrived from away – hold the future of the Bay and its watershed in their actions and choices. In the words of Wendell Berry: "The care of the Earth is our most ancient, and most worthy, and, after all, our most pleasing responsibility."

Glossary

Ag: silver
Al: aluminum
ambient water quality: the natural concentration of water quality constituents prior to the mixing of either point- or nonpoint source loads of contaminants
anthropogenic: the influence of human activities
atmospheric deposition: the process by which airborne pollutants fall to the ground in raindrops, in dust, or due to gravity
background or baseline reference condition: an environmental condition that is relatively free of industrial and anthropogenic influences
Beginning with Habitat: a Maine DEP program to preserve and improve wildlife habitats
benthic: referring to the bottom of a body of water
bioaccumulation: the sequestering of toxic chemicals in the tissues of an organism at a higher concentration than those of the source
bioindicator/biosentinel: a resident organism that serves as an indicator of environmental contamination
biomagnification: the increasing concentration of toxics in organisms with each step up the food chain from the lowest to the highest links
biomarker: an indicator that can be used to measure a biological process
biota: the animal and plant life of a given region
butyltins: toxic organometallic compounds, *i.e.*, molecules in which metal is bonded to a carbon atom in an organic molecule
CBEP: Casco Bay Estuary Partnership
CCSWCD: Cumberland County Soil and Water Conservation District
Cd: cadmium
Cr: chromium
CSO: a combined sewer overflow that discharges untreated wastewater directly to a body of water; refers to both the location and the event
Cu: copper
CWA: the federal Clean Water Act
DBT: dibutyl tin
DEP: Maine Department of Environmental Protection
dioxins and furans: toxic organic chemicals formed when organic material is burned in the presence of chlorine
DO: dissolved oxygen
EMCC: Eastern Maine Coastal Current
estuary: a semi-enclosed coastal water body with a free connection to an open sea, and within which seawater is measurably diluted with fresh water
eustatic: referring to a uniform global rise in sea level
FOCB: Friends of Casco Bay
Fe: iron
green slime: *Ulva intestinalis*, a green alga that is used as an indicator of nutrient enrichment
Gulfwatch: a joint United States/Canada blue-mussel monitoring program
HAPs: Hazardous air pollutants
heavy metals: dense metallic elements such as lead, mercury, arsenic, cadmium, silver, nickel, selenium, chromium, zinc, and copper
Hg: mercury
HUC: hydrologic unit codes that designate the size of a hydrologic unit or watershed
hydrophobic: chemicals that do not readily dissolve in water
intertidal zone: areas between high tide and low tide that are alternately exposed to seawater and air
ISWG: Interlocal Stormwater Working Group
LEED: Leadership in Energy and Environmental Design
LID: Low Impact Development - an approach to site planning, design, and development that aims to maintain pre-development hydrology of a site in order to manage stormwater
LiDAR: (light detecting and ranging) an optical remote sensing technology that measures properties of scattered light
load, loading: the total amount of a material (pollutant) entering a system from one or multiple sources.
Maine DEP: Maine Department of Environmental Protection
Maine DMR: Maine Department of Marine Resources
MDN: Mercury Deposition Network
MERI: Marine Environmental Research Institute
MHB: Maine Healthy Beaches Program
NADP: National Atmospheric Deposition Program
NATA: National Air Toxics Assessment
NCA: National Coastal Assessment
NDA: No Discharge Area
NEMO: Nonpoint Source Education for Municipal Officials
neurotoxin: a substance that causes damage to the tissues of the nervous system
Ni: nickel
NOAA: National Oceanic and Atmospheric Administration
nonpoint source: an indirect discharge – not from a pipe or other specific source – such as stormwater runoff
NPDES: National Pollutant Discharge Elimination System
NSSP: National Shellfish Sanitation Program
PAHs: polycyclic aromatic hydrocarbons; toxic organic chemicals primarily from the combustion of fossil fuels and wood, as well as fuel spills and asphalt
Pb: lead
PBDEs: polybrominated diphenyl ethers, widely used as flame retardants
PCBs: polychlorinated biphenyls; persistent, toxic organic chemicals that were once used to insulate transformers and capacitors, and to lubricate gas pipelines
pelagic: relating to or living in the open sea (*i.e.*, offshore not coastal).
PFCs: heat resistant, slippery industrial chemicals such as Teflon
PFOA: perfluorooctanoate, a form of PFC
PFOS: perfluorooctanesulfonate, a form of PFC
planar PCBs: the most toxic conformation of PCBs, based on health effects; also called "dioxin-like" compounds
point source: any confined or discrete conveyance (*e.g.*, a pipe) from which pollutants are or may be discharged into a watershed
POPs: persistent organic pollutants, *e.g.*, PCBs, dioxins, and DDT
PPCPs: pharmaceuticals and personal care products
PRWC: Presumpscot River Watershed Coalition
red tide: harmful algae blooms of *Alexandrium fundyense*
Secchi depth: measure of water clarity
SEM: scanning electron microscope
sentinel or indicator organisms: resident organisms that serve as indicators of environmental contamination.
smart growth: a planning strategy that promotes integration of compact, centralized downtown development patterns with land conservation and alternative transportation
TBT: tributyltin
TDR: transfer development rights; a market-based planning tool
TMDL: total maximum daily load; a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources; also refers to the report that establishes a TMDL
trophic level: the position of an organism in the food chain.
US EPA: United States Environmental Protection Agency
USCG: United States Coast Guard
USFWS: United States Fish and Wildlife Service
USGS: United States Geological Survey
VOCs: volatile organic compounds (*e.g.*, gasoline and benzene) that produce vapors readily
WMCC: Western Maine Coastal Current
Zn: zinc

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