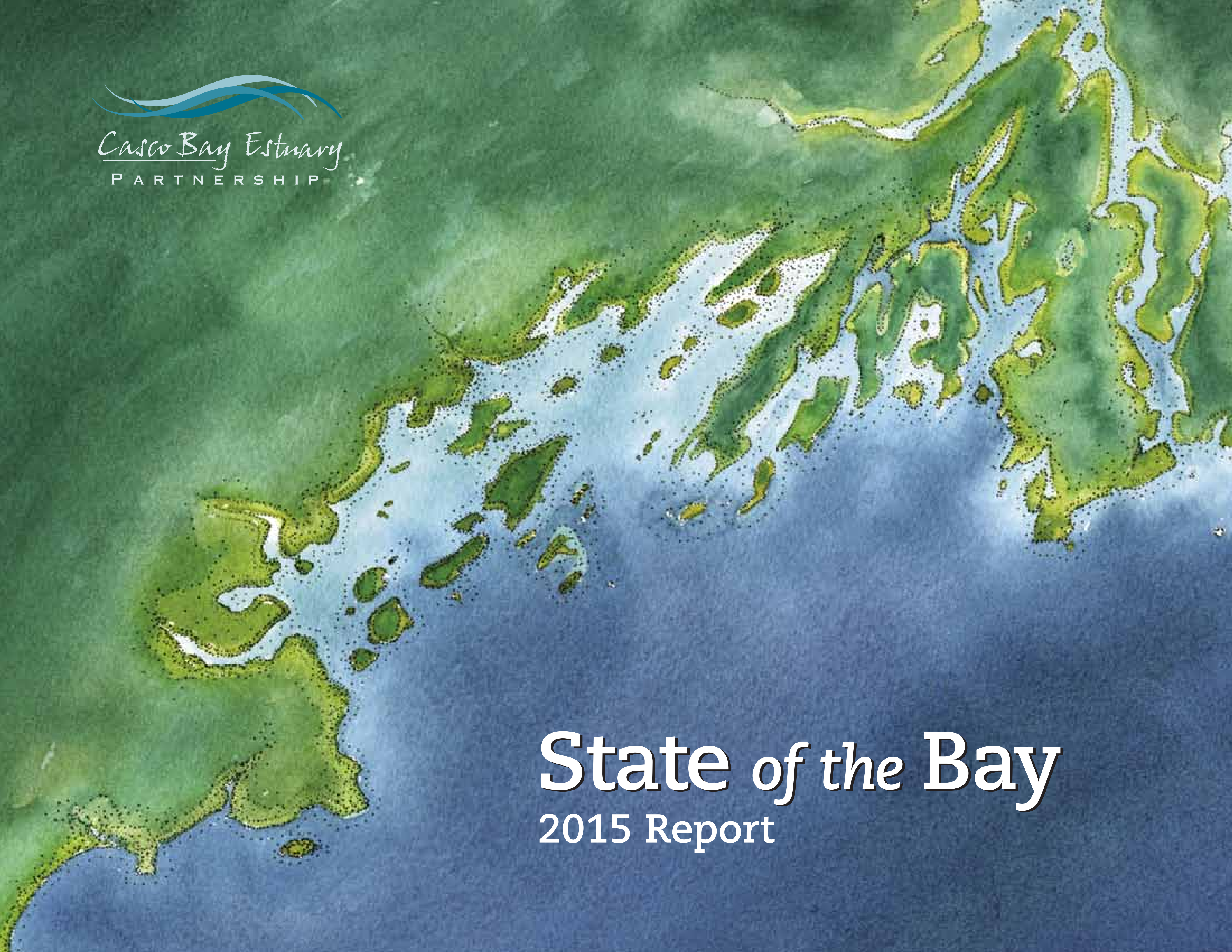

Casco Bay Estuary
PARTNERSHIP

State *of the* Bay
2015 Report

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Editorial Review

Curtis Bohlen, *CBEP Director*
Matthew Craig, *CBEP Program Manager*
Matthew Liebman, *US EPA*

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Don Witherill, *Maine Department of Environmental Protection**
Jed Wright, *U.S. Fish and Wildlife Service Gulf of Maine Coastal Program**

† as of September 2015
* also serves on the Partnership's Executive Committee

Additional Contributors and Reviewers

CBEP acknowledges the following individuals, organizations and agencies for their help compiling and reviewing data in this report:

Alex Abbott, *US Fish & Wildlife Service Gulf of Maine Coastal Program*
Bethany Atkins, *Maine Department of Inland Fisheries and Wildlife, Beginning with Habitat*
Molly Auclair, *Gulf of Maine Research Institute*
Seth Barker, *consultant*
Kari Beaulieu, *University of Southern Maine*
Beth Bisson, *Maine Sea Grant*
Marti Blair, *Casco Bay Estuary Partnership*
Angela Dubois Brewer, *Maine Department of Environmental Protection*
Corey Bryant, *University of Southern Maine*
Mary Cerullo, *Friends of Casco Bay*
Mary-Ellen Dennis, *Maine Department of Environmental Protection*
Deb Debiegum, *Cumberland County Soil and Water Conservation District*
Chris Desorbo, *Biodiversity Research Institute*
Fred Dillon, *City of South Portland Water Resource Protection*
Mike Doan, *Friends of Casco Bay*
Claire Enterline, *Department of Marine Resources*
Jami Fitch, *Cumberland County Soil and Water Conservation District*
Wing Goodale, *Biodiversity Research Institute*
Bill Hancock, *Maine Department of Inland Fisheries and Wildlife, Beginning with Habitat*
Kathy Hoppe, *Maine Department of Environmental Protection*
Keri Kaczor, *Maine Healthy Beaches Program*
Kohl Kanwit, *Maine Department of Marine Resources*
Erin Love, *Island Institute*
Kate McDonald, *Cumberland County Soil and Water Conservation District*
Julia McLeod, *Harpswell Heritage Land Trust*
Jeremy Miller, *Wells National Estuarine Research Reserve*
Slade Moore, *Biological Conservation, LLC*
Lorraine Morris, *Maine Department of Marine Resources*
Hilary Neckles, *US Geological Survey*
Tamara Lee Pinard, *Cumberland County Soil and Water Conservation District*
Sarah Plummer, *Portland Water District*
Charlene Poulin, *Portland Water District*
Brad Roland, *City of Portland*
Rebeccah Schaffner, *Greater Portland Council of Governments*
Alison Sirois, *Department of Marine Resources*
Jason Smith, *University of Southern Maine*
Melissa Smith, *University of Southern Maine*
Jim Stahlnecker, *Maine Department of Environmental Protection*
Jeffrey Tash, *Biodiversity Research Institute*
Ryan Wallace, *USM Center for Business and Economic Research*
John Wensman, *Coastal Studies for Girls*
Theo Willis, *University of Southern Maine*
Karen Wilson, *University of Southern Maine*
Gail Wippelhauser, *Department of Marine Resources*
Erin Witham, *US Fish & Wildlife Service Gulf of Maine Coastal Program*
Jed Wright, *US Fish & Wildlife Service Gulf of Maine Coastal Program*

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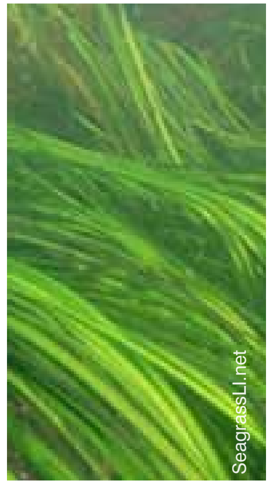
Table of Contents

Indicator	*Page*



Introduction

The Casco Bay Estuary Partnership helps track and report on changing conditions within the Bay and its watershed. Every five years, in its State of the Bay Report, the Partnership portrays how Casco Bay is faring—what trends are evident, what progress is visible, and what new challenges are emerging. By tracking indicators at regular intervals over decades, the Partnership helps identify the collective work needed to sustain the region.

The *State of the Bay 2015* Report reveals a complex array of factors shaping the ecology and economy of the Casco Bay region. There's a mix of encouraging news, interspersed with unsettling trends. The warming climate represents a vast and unpredictable driver of regional change—with hotter ocean and air temperatures, more frequent and extreme precipitation, and rising seas (already evident in flooding at extreme high tides).

Indicators used in the past (and included in the 2015 report) do not fully account for the dynamic interplay of forces currently at work on Casco Bay. Future reports will include new indicators to help gauge the pace and impacts of far-reaching change.

Conserved Lands More Than Double over Two Decades

The total acreage of permanently protected lands in the watershed's lower 16 municipalities has more than doubled, from 3.5 percent (7,300 acres) in 1997 to 9.1 percent (18,960 acres) in 2015.

Suckfish Bog, Falmouth

Conserved Lands Provide Valuable but Often Unquantified Benefits

The Casco Bay watershed includes a mosaic of forest and aquatic habitats that support wildlife, help filter air and water, buffer development impacts and enhance recreational offerings and quality of life. Researchers are now exploring ways to quantify the value of protected land as "green infrastructure," which provides water-quality benefits and other valued services to both human and natural communities.

The Casco Bay watershed is home to at least 25 nonprofit organizations directly involved in land conservation. About half the towns in the watershed have conservation commissions, which are generally volunteer-based municipal commissions that work to improve management of open space. Voters have repeatedly supported bonds to fund land protection through the Land for Maine's Future Fund, which has protected 570,438 acres for conservation and recreation statewide since its inception, with 7,671 of those acres (and an additional 3,512 acres of farmland) falling in Cumberland County (Maine DACF 2015).

Collaborative Work Leads to Steady Gains in Conserved Acreage

Since 1997, U.S. Fish and Wildlife Service's Gulf of Maine Coastal Program, with significant funding from CBEP, has maintained a geographic database of conserved and open space lands in the lower 16 municipalities of the Casco Bay watershed (Cape Elizabeth, South Portland, Portland, Westbrook, Long Island, Chebeague Island, Falmouth, Cumberland, Yarmouth, North Yarmouth, Pownal, Freeport, Brunswick, Harpswell, West Bath, and Phippsburg). It includes lands subject to different levels of protection: (1) conserved lands that are permanently protected; (2) open space lands that lack permanent protection, including lands in agriculture or tree growth programs, lands conserved to protect drinking water, and town forests; and (3) recreational lands that offer some additional conservation or habitat benefits.

> Voters have repeatedly supported bonds to fund land protection.

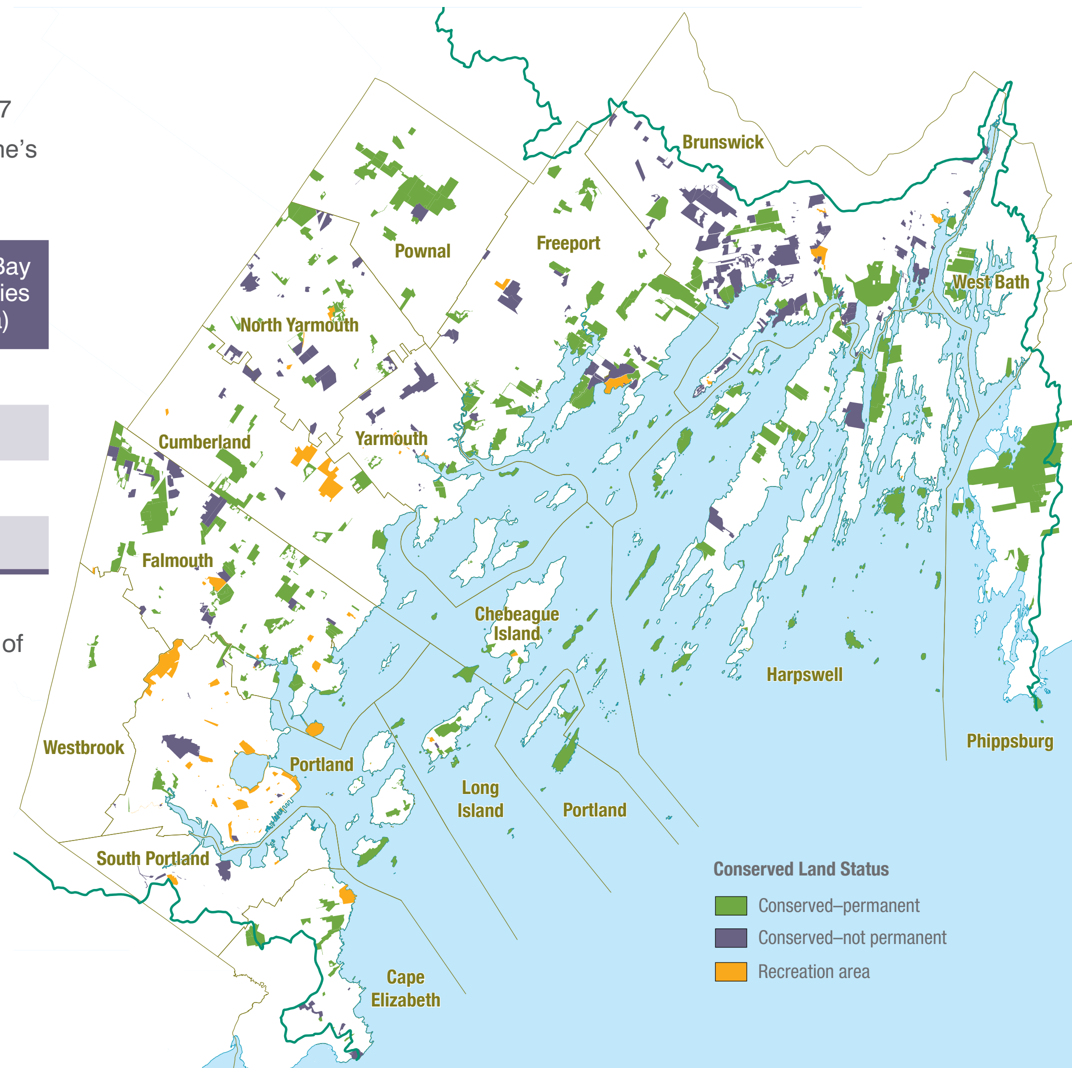
As of 2015, the database includes 956 parcels in the 16 municipalities, with more than 28,990 acres, representing 13.8 percent of the area. A majority of those lands, some 18,960 acres—about 9.1 percent of the area—is considered permanently protected. This compares with 3.7 million acres that have been protected statewide, equivalent to 19 percent of Maine's total land area (Maine Development Foundation, 2014).

Level of Protection	Number of Parcels	Total Acres Protected	Percent of Casco Bay Coastal Communities Area (Study Area)
Conserved-permanent	531	18,959.77	9.1%
Conserved-not permanent	308	8,041.91	3.8%
Recreation area	117	1,988.89	0.9%
TOTAL	956	28,990.57	13.8%

Thanks to the diligence and persistence of many regional organizations, the area of permanently protected land today is 2.6 times greater than it was in 1997.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Year	Number of Sites	Area Permanently Protected	Percent of Casco Bay Coastal Communities Area (Study Area)
1997	246	7,300	3.5%
2005	341	10,900	5.2%
2010	438	15,694	7.5%
2015	531	18,960	9.1%



Bob Travis

Habitat Restoration Efforts Emphasize Stream Connectivity

Results of a two-year survey of stream crossings throughout the Casco Bay watershed are guiding ongoing efforts to improve passage for brook trout and anadromous fish while reducing flooding risks and maintenance costs.


Slade Moore, Biological Conservation LLC

Dams and Culverts around Casco Bay Block Access to Critical Spawning Habitats

For decades, dams, railroads, and roads within the Casco Bay watershed have prevented native fish and other aquatic organisms from reaching critical upstream habitats, limiting their population and distribution (Maine Department of Inland Fisheries and Wildlife 2015). Restoring connectivity between diverse aquatic ecosystems is critical to historically abundant native freshwater and migratory fish, such as Eastern brook trout, shad, blueback herring, alewife, sturgeon, and striped bass.

Undersized, perched and deteriorating culverts can restrict the movement of water, sediments, wood and organisms in riverine systems—diminishing habitat, causing structural failure of road crossings, exacerbating dangerous flooding and requiring costly repairs and maintenance (Gillespie *et al.* 2014). Where roads and other structures cross wetlands, they typically alter local hydrologic conditions, degrading the wetlands.

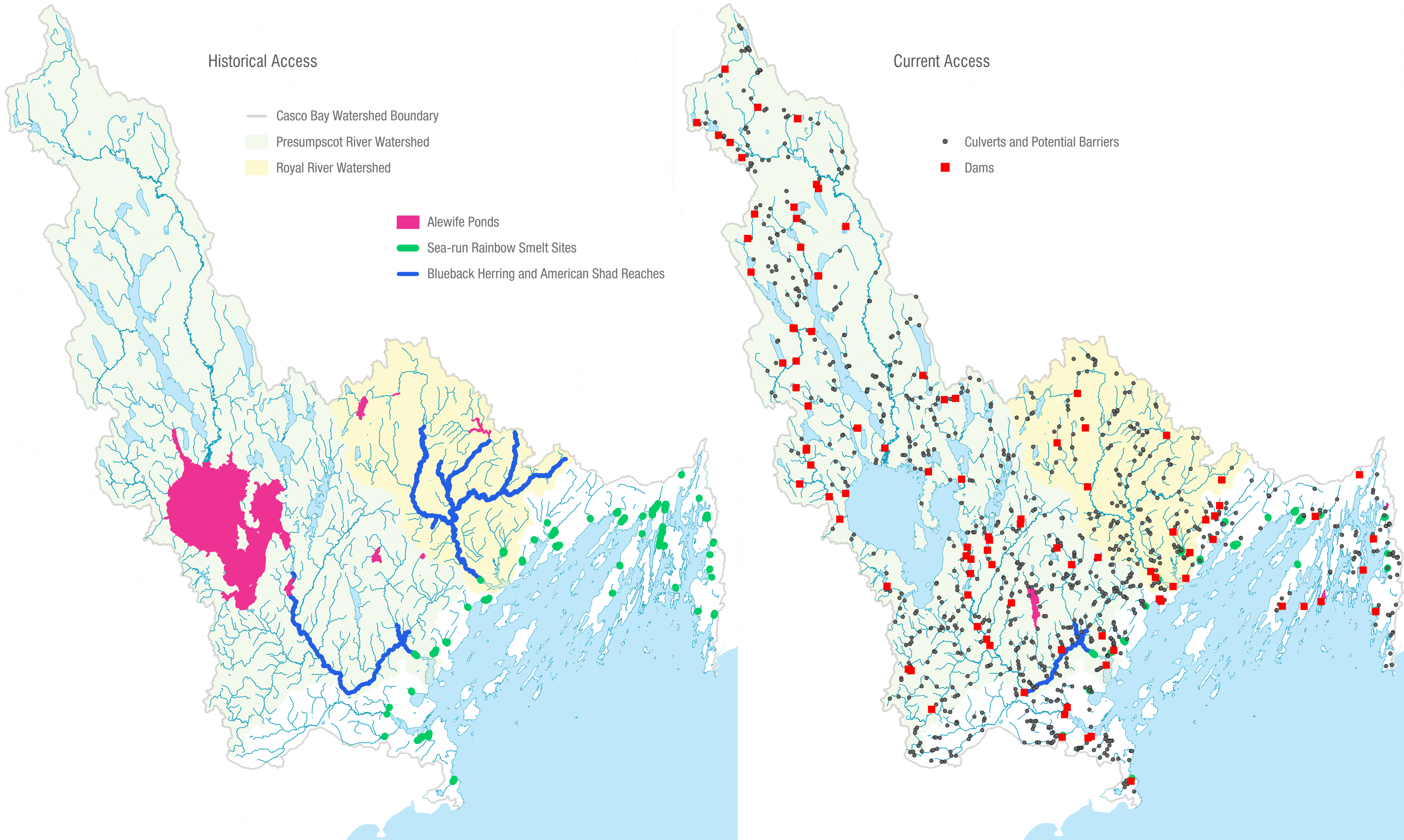
Most Road Crossings within the Watershed Restrict Fish Passage

In 2009–2010, the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program — in cooperation with CBEP and Trout Unlimited volunteers—surveyed fish-passage restoration opportunities throughout the watershed. Among more than 1,400 crossings

CBEP helped facilitate installation in 2011 of a pipe arch culvert in Brunswick, increasing tidal exchange into Thomas Bay Marsh. CBEP has identified more than 70 potential tidal restrictions around Casco Bay, and assessed over 20 of these sites. Since 2011, CBEP has worked with partners to restore tidal flow at three salt marshes and to monitor ecosystem response.

Fish Passage in the Casco Bay Watershed: Historical versus Current

Historical access to the Casco Bay watershed for shad, blueback herring, alewife, and smelt, compared with current access. *Note:* Historical documents confirm that the main stem of the Presumpscot River supported abundant smelt, blueback herring, alewife, and shad, as well as Atlantic salmon. Historical use of many of the Presumpscot's tributaries is presumed likely but is not displayed on the map below due to a lack of written documentation. *Data: USFWS GOMCP 2015*



identified, about one-third of culverts never permit fish to pass upstream, and the majority block access some of the time or to certain species of fish. Only a relative handful of crossings provide complete access for fish and other aquatic organisms (CBEP 2010; Maine Stream Connectivity Working Group 2015).

Assessing Connectivity of Key Tributaries in the Lower Watershed

One way to gauge the extent of fragmentation is the *functional stream network,* a measure of the average length of river and stream segments connected to each other. While the Presumpscot River watershed has 1,270 miles of rivers and streams, the number of existing culverts and dams results in an average functional stream network length of only 3.63 miles. For sea-run fish, the only accessible habitat is in the lowermost Presumpscot, including the newly constructed passage over Cumberland Mills Dam in Westbrook.

The Royal River watershed, with 310 miles of rivers and streams, has an average functional stream network of 4.16 miles (USFWS GOMCP 2015). Above the mainstem dams in Yarmouth, the river has a total connected network of 126 miles. Although fish ladders were retrofitted at the Bridge Street Dam and the Elm Street Dam in the 1970s, these structures have not been maintained and are considered ineffective for upstream passage—leaving just one-third of a mile of the lower mainstem accessible to anadromous fish.

> Where roads cross tidal wetlands, they alter local hydrologic conditions, degrading adjacent wetlands.


Matt Craig, CBEP

In 2013, Trout Unlimited, working closely with private landowners and Caribou Springs, LLC, removed Randall Mill Dam on Chandler Brook (a tributary to the Royal River), with support from CBEP, USFWS Gulf of Maine Coastal Program, Maine Rivers, Royal River Conservation Trust and others. A dam had been on the site since 1796.


Landis Hudson, Maine Rivers

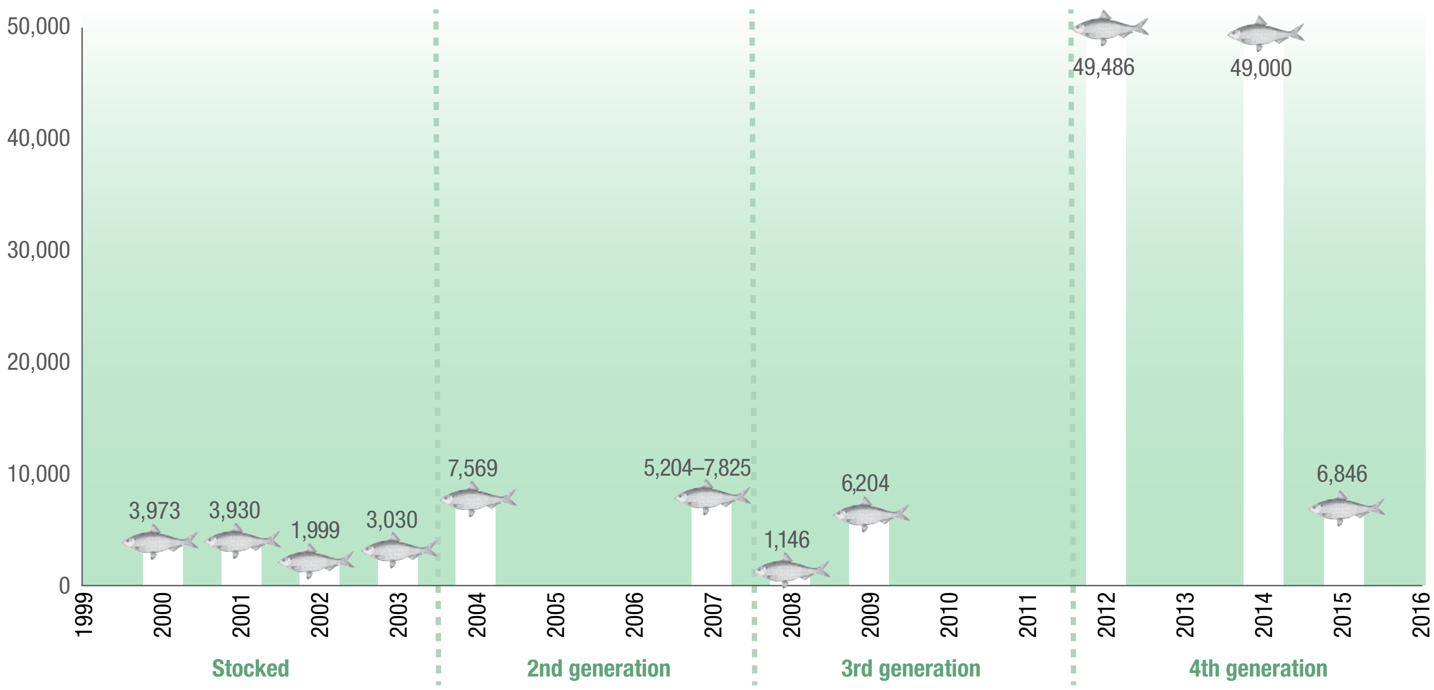
Bridge Street Dam in Yarmouth, one of two dams that span the lower main stem of the Royal River, sits just one-third of a mile upstream from head of tide, disconnecting the Royal River watershed from Casco Bay.

Alewives Return in Force to Highland Lake

Alewives (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) help support the Bay's food web—being prey to recreationally and commercially valued fish species and many birds. They also represent the preferred bait of the spring lobster fishery (Maine DMR).

In recent years, as many as 50,000 adult alewives have migrated annually from the Gulf of Maine into the Presumpscot River, up Mill Brook, and into Highland Lake to access critical spawning and nursery habitat. The return of alewives into Highland Lake was made possible through collaboration and pooled resources spanning 15 years. The run was "seeded" with alewives from other Maine streams between 2000 and 2003, and four subsequent generations of alewives have now returned to Highland Lake.

Meanwhile, on the Presumpscot River, an estimated 9,300 river herring passed over Cumberland Mills Dam in downtown Westbrook in 2014, accessing parts of the river that have been blocked from anadromous fish for hundreds of years (S.D. Warren 2014).



Total number of alewives entering Highland Lake, 2000–2015.

Sources: Wippelhauser and Bartlett 2012; Enterline 2015; Wippelhauser 2015

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Henry T. McLin

Water Bird Data Focus on Shorebirds and Ospreys

Late-summer surveys of wading birds on six tidal flats showed an average (over four years) of more than 13,000 birds feeding (mostly small sandpipers); Casco Bay's osprey populations are robust, but current reproductive measures are lower than they were in the early 1980s.

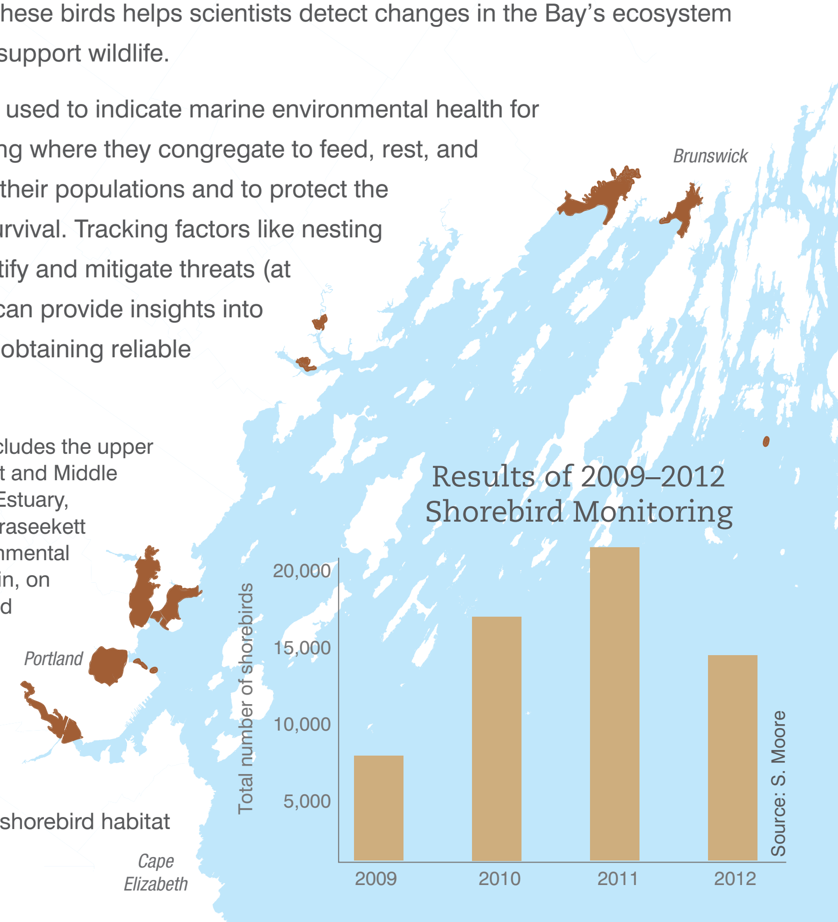
Chris DeSorbo, BRI

Water Bird Populations Can Signal Ecosystem Health

Water birds (such as seabirds, wading birds, waterfowl and shorebirds) are vulnerable to human disturbance, pollution and the effects of a changing ecosystem. Most of the region's water birds are migratory but depend on food and habitat in Casco Bay for part of their lives. Monitoring these birds helps scientists detect changes in the Bay's ecosystem that affect its ability to support wildlife.

Water birds have been used to indicate marine environmental health for decades. Understanding where they congregate to feed, rest, and breed helps to assess their populations and to protect the habitats vital to their survival. Tracking factors like nesting success can help identify and mitigate threats (at least local ones), and can provide insights into ecosystem health, but obtaining reliable

Prime shorebird habitat in Casco Bay includes the upper Fore River and upper reaches of Maquoit and Middle Bays, Back Cove and the Presumpscot Estuary, along with portions of the Royal and Harraseekett Rivers. The Maine Department of Environmental Protection currently regulates activities "in, on or over" 3,927 acres of these habitats and the surrounding buffer zones.



Data: Maine Office of GIS. 2013. www.maine.gov/megis/catalog/indexaz.shtml information is resource-intensive. Field methods vary greatly, and some recent methods use high-resolution aerial imagery (Allen *et al.* 2012).

Shorebird Numbers Fluctuate

Historically, human impact on water bird populations has been severe. Many seabirds were harvested for food, bait, and feathers, and combined with development of nesting islands, several species were extirpated from New England (Allen *et al.* 2012).

During the summers of 2009–2012, with funding from CBEP, the Maine Coastal Program, Maine Department of Inland Fisheries and Wildlife (MDIFW) and the U.S. Fish and Wildlife Service, Biological Conservation LLC conducted a ground-based shorebird monitoring program focused on several state-designated habitat areas (see map). Total shorebird observations rose from 6,724 in 2009 to 20,054 in 2011 before dropping to 13,246 in 2012. The decline from 2011 to 2012 was due to lower counts of “peeps” (the five smallest North American sandpipers). Within Casco Bay, the Presumpscot Estuary consistently had the Bay’s highest total shorebird counts over the four years.

Ospreys Experience Declines in Nest Success, Productivity and Brood Size

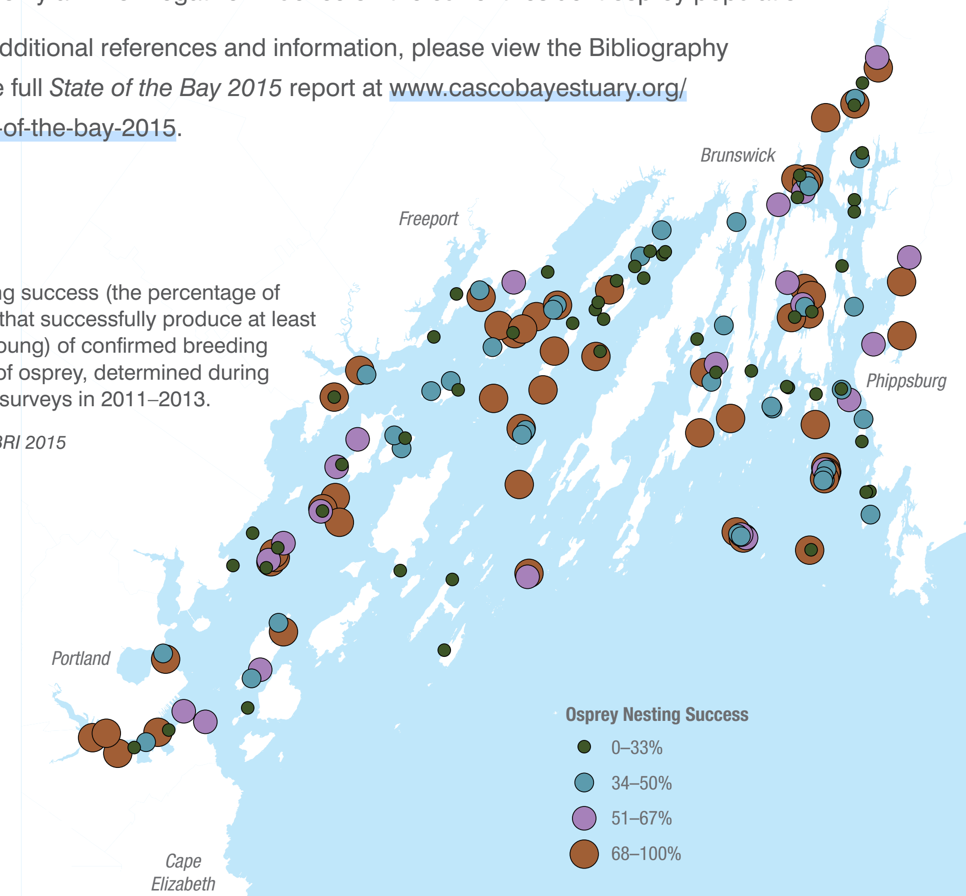
Due to their long lifespan, fish-based diet, fidelity to nesting sites, and sensitivity to environmental contaminants, osprey (*Pandion haliaetus*) populations are monitored worldwide as an indicator of ecosystem health. With funding from CBEP, the Biodiversity Research Institute and MDIFW worked jointly between 2011 and 2013 to determine the abundance, distribution and reproductive status of Casco Bay’s ospreys.

Through annual surveys checking up to 185 nest sites, researchers found that ospreys are still broadly distributed throughout the Bay, but that nest success, productivity, and brood size varied widely and were generally lower compared to osprey populations elsewhere in Maine. Although researchers believe the osprey population is stable, productivity (a reproductive measure of young fledged per occupied nest) reached the level associated with population stability during only one of the three years surveyed.

Researchers also found evidence of a long-term decline in osprey productivity. Between 2011 and 2013, Casco Bay’s osprey population generated an average of 0.73 young per breeding pair annually, while the population surveyed in 1982-1983 by MDIFW produced an average of 1.10 young per breeding pair annually. Researchers suspect this difference is largely attributable to changes in food availability (the number of young produced are known to fluctuate in response to changes in food supply).

While bald eagles (*Haliaeetus leucocephalus*)—a known adversary of osprey–may be affecting osprey populations in areas such as Penobscot Bay, eagle populations are still in the early stages of recovery in Casco Bay and so likely have only a minor negative influence on the current resident osprey population.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.



Nesting success (the percentage of nests that successfully produce at least one young) of confirmed breeding pairs of osprey, determined during aerial surveys in 2011–2013.

Data: BRI 2015

Judith Pederson, MIT Sea Grant

Tracking the Spread of Invasive Species

The aggressive spread of non-native species like European green crabs and colonial tunicates is disrupting Casco Bay's ecosystems and fishery resources.

Michael Barriault, *The Forecaster*

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

◀ Dr. Larry Harris of the University of New Hampshire identifies introduced, cryptogenic, and native species at the Spring Point Marina in South Portland during a summer 2013 rapid assessment.

The Importance of Identifying New Arrivals

Non-native species enter Casco Bay through a variety of pathways or vectors, and many become established—having a detrimental effect on marine habitats, economies and even public health (Pappal 2010). These species can outcompete and displace native species, becoming invasive and difficult to contain or eradicate. Identifying the vectors by which these species arrive can help anticipate future invasions, and early detection of new invaders can help shape effective management responses.

Twenty Introduced Species Found in Recent Casco Bay Assessment

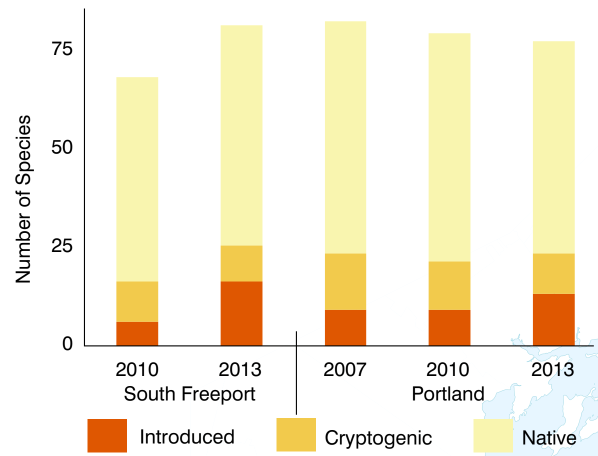
Compiling findings from several studies, the *2010 State of the Gulf of Maine Report* lists 64 non-native species that have been observed in the Gulf of Maine (not counting the numerous cryptogenic species whose origins are unclear; Pappal 2010). Within Casco Bay, there's limited information about the distribution and abundance of many of these introduced species, although there's been intensive monitoring in recent years of the European green crab (*Carcinus maenus*) due to its potential impact on vital marine habitats. A 2013 rapid assessment of fouling organisms on docks and piers, led by the Massachusetts Office of Coastal Zone Management and Massachusetts Institute of Technology Sea Grant, identified 20 introduced species, 11 cryptogenic species, and 84

Established in 2004, the Maine Marine Invasive Species Collaborative (MMISCo) brings together staff from state and federal agencies, research institutions, and public, private, and industry organizations to collectively address marine invasive species issues and related impacts. The group collaborates to conduct research and outreach activities that generate, collect and disseminate information. It also helps inform marine and coastal resource management decisions at local, state, and regional levels.

native species at two Casco Bay sites (Spring Point Marina in South Portland and Brewer South Freeport Marine in Freeport). The introduced species included one red alga, seven arthropods, three bryozoans, six tunicates, one anemone and two mollusks (Wells *et al.* 2014)

Numbers of Introduced Species Increasing Regionally

Bottom-dwelling (benthic) communities in the Gulf of Maine have been going through major shifts in species composition since the 1970s, and the introduction of non-native species has been a factor in these shifts (Harris 2009; Harris and Tyrell 2001).



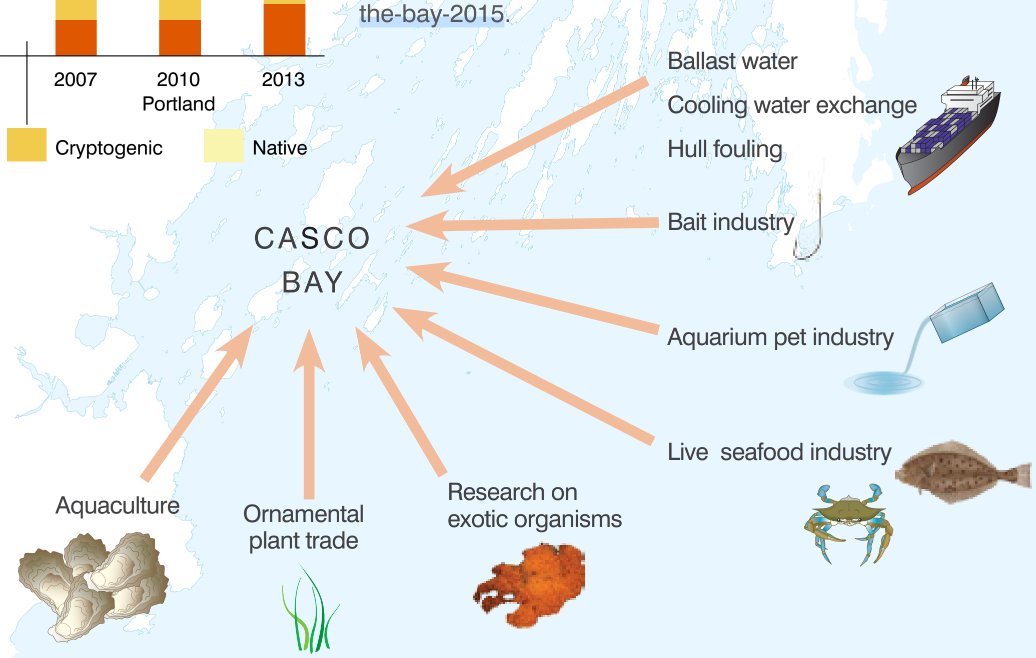
Since 2000, scientists have conducted regional rapid assessment surveys throughout the Northeast roughly every three years. The graph at right compares results from the rapid assessments of fouling organisms conducted at the same two Casco Bay sites in 2007, 2010, and 2013 (site-by-site data from earlier surveys are unavailable). The data at both sites show increased numbers of invasive species found. Some of the apparent increase may reflect sampling variability, but also represents the arrival of several new invaders to the Bay, such as the Asian shore crab and the European rock shrimp.

Ongoing Monitoring Helps Detect Marine Invaders

The Marine Invader Monitoring and Information Collaborative (MIMIC), a network of New England scientists, natural resource managers, and more than 100 trained volunteers, has monitored marine invasive species at the Southern Maine Community College in South Portland since 2008. This program seeks to provide an "early detection system" for marine invaders, and to educate local communities about the issue. In 2014, scientists at the Wells National Estuarine Research Reserve teamed up with CBEP and local volunteers to establish two new MIMIC sites on Peaks Island and Chebeague Island, and plans are underway to add more MIMIC sites around Casco Bay in the next few years.

The Vital Signs program, established and managed by the Gulf of Maine Research Institute, works with citizen scientist volunteers (including students and teachers) to collect information on terrestrial, marine and freshwater aquatic invasives. A participating class from South Portland was the first in the state to positively identify *Heterosiphonia japonica* on mainland sites in 2012, according to Maine Sea Grant.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.



Invasive species enter Casco Bay waters through multiple pathways or vectors. Shipping is considered the most significant source (through ballast water exchange, exchange of cooling water and transport of organisms on ship hulls). Other vectors include accidental release of research organisms, release of exotic aquatic plants and animals, aquaculture of non-native species and release of non-native bait organisms.

Eelgrass Beds Decline as Green Crab Numbers Explode

Eelgrass beds are facing serious declines, prompting CBEP and partners to monitor their status and assess restoration potential.


SeagrassLI.net

A Valuable and Vulnerable Resource

A seagrass that forms extensive intertidal and subtidal beds in Casco Bay, eelgrass (*Zostera marina*) provides food for migratory winter waterfowl and critical nursery habitat for fish and shellfish. It also helps sustain water quality by stabilizing sediments and filtering nutrients and suspended particles.

Eelgrass thrives in clean water where adequate light can reach its slender leaves. Beds become stressed when water quality declines due to increased suspended sediments and excess nitrogen, which fuels algal growth and reduces light availability. Eelgrass can also be lost or damaged due to dredging, boat propellers, moorings, anchors, docks, and shellfish dragging. In addition, the invasive European green crab (*Carcinus maenas*) can decimate eelgrass beds by clipping and uprooting vegetation, and fouling of leaves by invasive colonial tunicates can reduce eelgrass growth and production.

Local Beds Experience Dramatic Losses

The *State of the Bay 2005* report cited eelgrass bed coverage as 7,056 acres in 1993-1994, and 8,248 acres in 2001-2002. In 2013, CBEP and the Maine Department of Environmental Protection (DEP) facilitated mapping of eelgrass beds using high-resolution aerial photographs and underwater videography. That survey quantified eelgrass bed coverage as 3,650 acres, representing a loss of more than 55 percent

Because Casco Bay's green crab population is not well understood, predicting its future impact on the remaining eelgrass beds is difficult.

from 2001–2002 acreage. Eelgrass distribution can also be characterized by the relative density, or percent cover, of eelgrass within a bed. Casco Bay's highest density eelgrass beds (between 70 and 100 percent cover) declined by 4,392 acres between the 2001-2002 survey, and the 2013 survey.

Much of the eelgrass decline occurred between 2012 and 2013, coinciding with a population explosion of European green crabs— which are known to disturb sediments and uproot and clip eelgrass when foraging. This loss was disproportionally concentrated in areas that historically supported extensive and dense eelgrass beds, particularly Maquoit and Middle Bays. Research by Dr. Hilary Neckles of the USGS Patuxent Wildlife Research Center suggests that disturbance by green crabs was a leading cause of eelgrass loss (Neckles 2015).

> Much of the decline appears to have occurred between 2012 and 2013, coinciding with a population explosion of European green crabs.

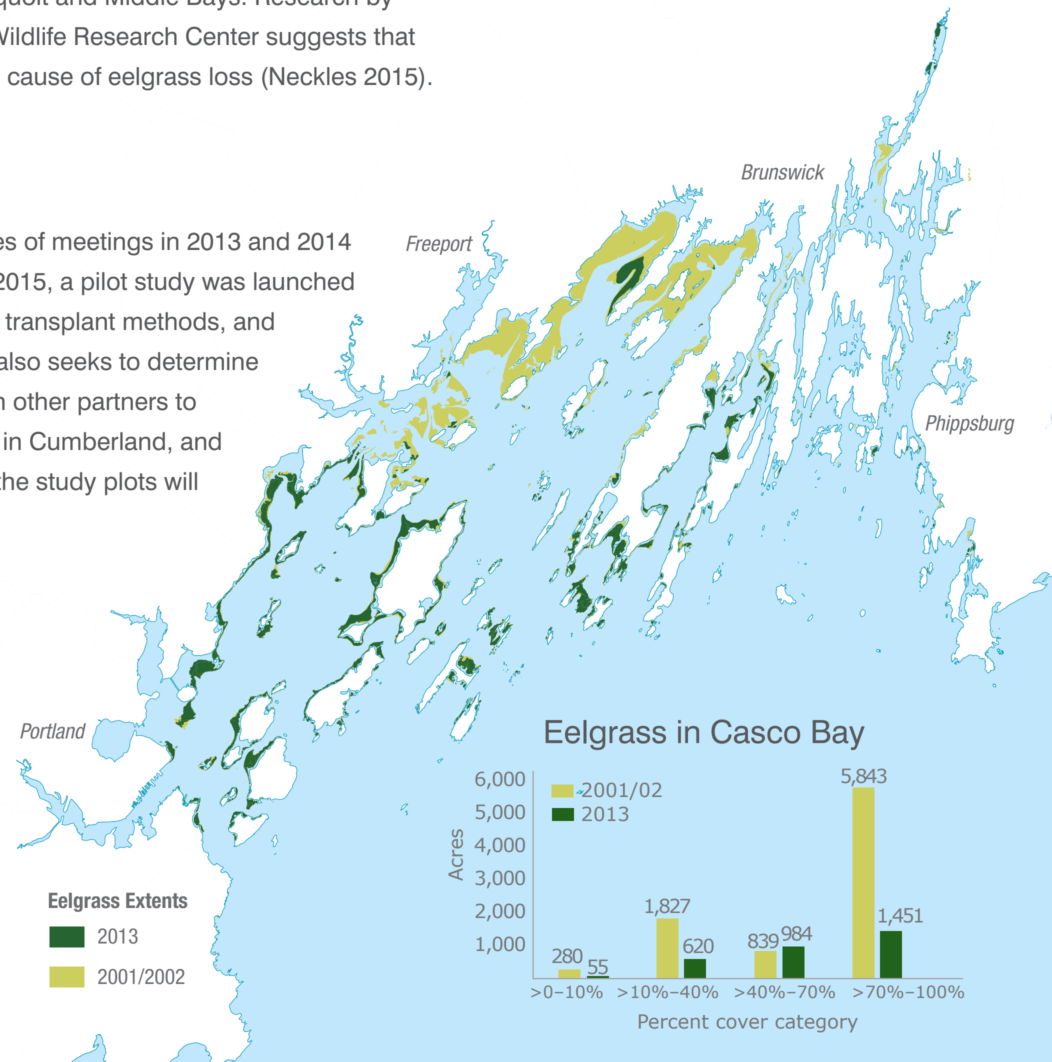
Partners Explore Restoration Sites

Recognizing the need for a rapid and coordinated response, CBEP convened a series of meetings in 2013 and 2014 that sparked formation of a broad partnership focused on eelgrass conservation. In 2015, a pilot study was launched to identify suitable sites for large-scale eelgrass restoration, gauge effective eelgrass transplant methods, and determine which environmental factors contribute to restoration success. The study also seeks to determine whether green crab control is necessary to restore eelgrass beds. CBEP worked with other partners to build local capacity for eelgrass restoration. Plants were harvested from Broad Cove in Cumberland, and planted at two upper Casco Bay locations in Freeport and Brunswick. Monitoring of the study plots will continue through 2016.

PARTNERS WORKING FOR CASCO BAY EELGRASS CONSERVATION

CBEP, US Geological Survey Patuxent Wildlife Research Center, Maine Department of Environmental Protection, The Nature Conservancy in Maine, Friends of Casco Bay, Bowdoin College, Town of Brunswick, US Fish and Wildlife Service–Gulf of Maine Coastal Program, local citizens in Cumberland and Freeport, Southern Maine Community College, Mount Desert Island Biological Laboratory, Maine Coastal Program, University of New Hampshire Jackson Estuarine Lab, Resource Access International

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.




John Howell

Population Grows Slowly, but Dispersed Development Intensifies Impact

Casco Bay Estuary PARTNERSHIP

The region's population grew over the past decade at a slow but steady pace. Between 1996 and 2010, the watershed's forested cover decreased by 16.2 square miles (declining to 65 percent of the watershed's land area) and developed areas increased by 8.53 square miles (reaching 10 percent of the watershed's land area).


Peter Taylor/Waterview Consulting

Even Slow Growth Can Transform Rural Landscapes

The Casco Bay watershed is among the most densely developed in Maine, representing just 3 percent of the state's total land mass but holding nearly 18 percent of its population. As urbanization pushes outward into formerly rural areas, it fragments the landscape, leading to habitat loss and water-quality degradation as well as increased impervious surfaces. The watershed acts like a funnel, channeling water and waterborne pollution downstream into rivers, streams, lakes, and the Bay—causing potential long-term health effects on these waters.

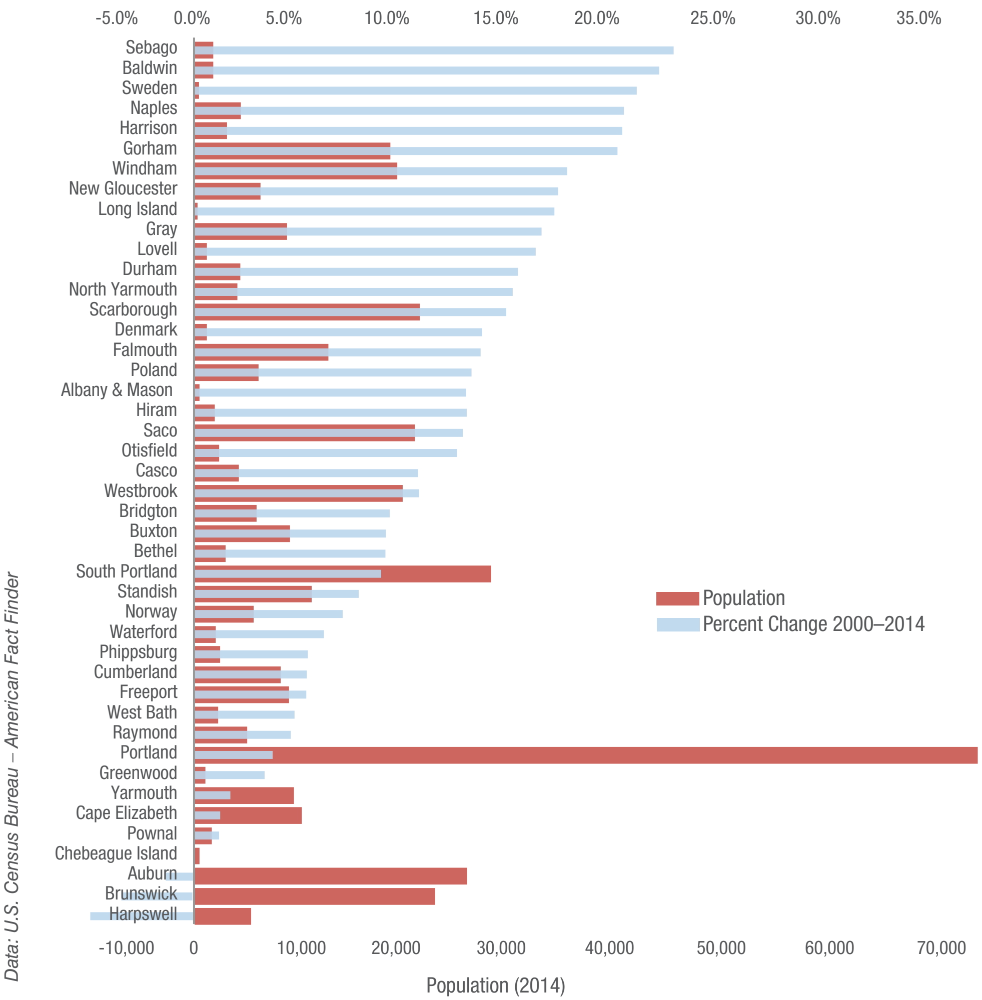
Some Communities See Significant Growth

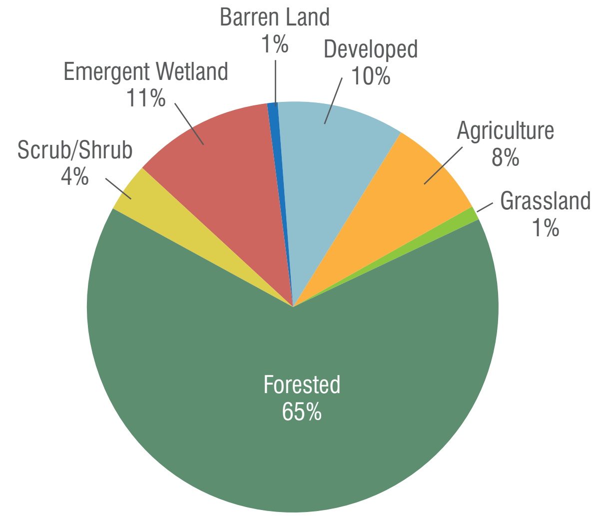
The region's population continues to grow at a slow but steady pace, according to the most recent U.S. Census data. (U.S. Census methodology does not allow for deriving accurate population counts by watershed boundaries so statistics cited here reflect populations for entire municipalities, even though some of the 48 communities have very little acreage within the watershed.)

Between 2000 and 2010, the total population of communities that contribute to the watershed grew by 20,871, representing a 6.1 percent increase (from 340,574 in 2000 to 361,445 in 2010). Municipalities that contribute to the (federally designated) Urbanized Area saw 67.6 percent of that growth (14,117 people), urban core communities (Portland, South Portland, Westbrook, and Auburn) saw 23.1 percent of the population increase (except Auburn, which lost population), while 44.5 percent of growth occurred in suburbanized communities. Rural towns accounted for a larger share of total growth (32.4 percent) than might be expected based on their share of the population.

By 2014, the 48 watershed municipalities had an estimated population of 367,969, a 1.8 percent increase in four years. The population growth rate within watershed communities exceeds that of the State as a whole. In 2000, these communities held 26.7 percent of Maine's population. By 2014, that figure had grown to an estimated 27.7 percent.

Large suburban communities close to Portland (*e.g.,* Gorham, Windham, Scarborough, and South Portland) are seeing robust population increases, with population increases exceeding 10 percent from 2000 to 2014. Portland's population also began to increase again, with an estimated 3.8 percent increase between 2010 and 2014.





2010 Casco Bay Watershed Land Cover

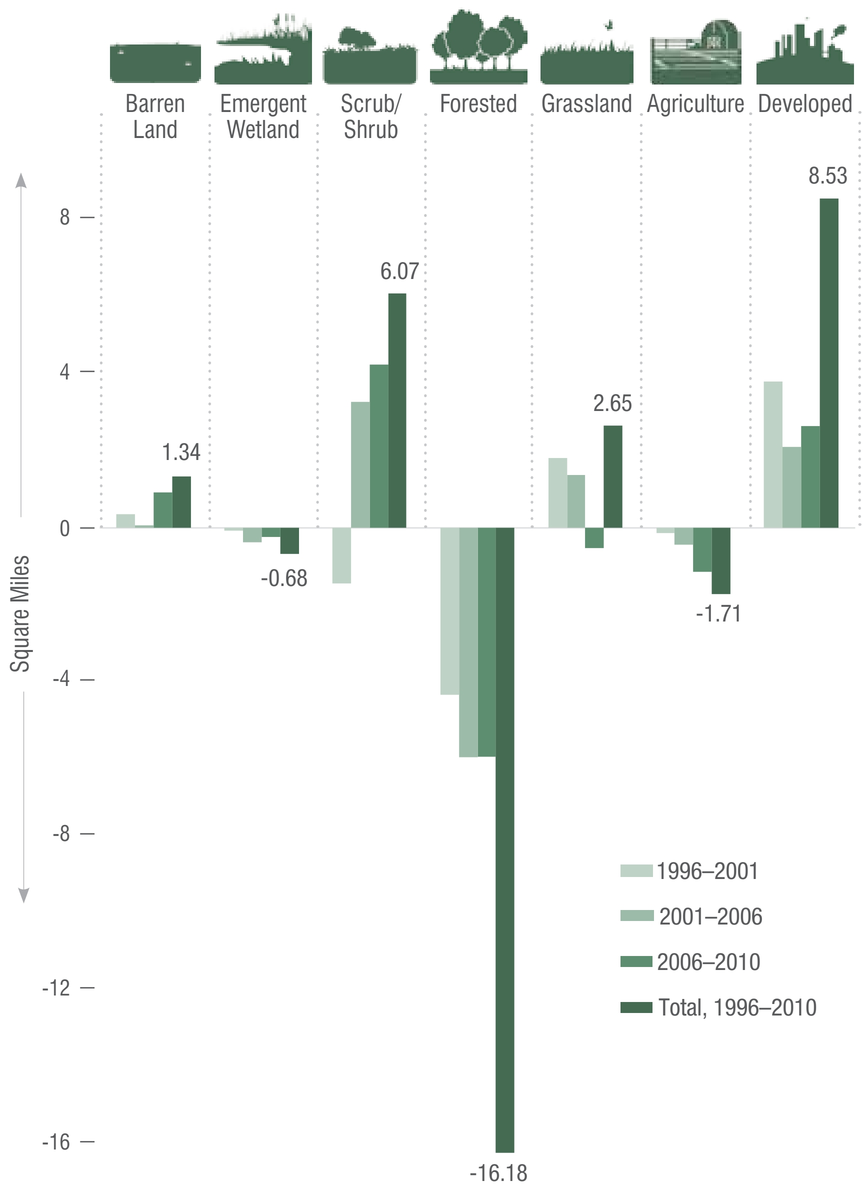
Modest Declines in Forests and Farmlands

National Oceanic and Atmospheric Administration (NOAA) launched the Coastal Change Analysis Program (C-CAP) in 1995 to develop a standardized database on land cover and habitat change along the nation's coast. C-CAP has analyzed satellite imagery to classify land cover at 30-meter pixels in 1996, 2001, 2006, and 2010.

The most recent C-CAP data show that if open water and submerged lands are excluded, the watershed remains primarily covered by forest (65 percent) with wetlands representing 11 percent and agricultural land 8 percent. The footprint of developed areas rose from 77.1 square miles in 1996 to 85.6 square miles in 2010, an increase of 8.5 square miles (11 percent growth), while the forested area in that time period decreased by 16.2 square miles. Agricultural land cover also declined, by 1.7 square miles, with the loss appearing to accelerate between 2006 and 2010. Areas of scrub/shrub, barren land, and grassland all increased over that time.

The rapid loss of forest cover was noted by a U.S. Forest Service report that ranked the Casco Bay watershed (using a different watershed boundary than used in this report) first among 33 Eastern and Midwestern watersheds studied for risk of development to private forests near drinking water supply areas (Barnes *et al*., 2009).

Changes in Land Cover of Casco Bay Watershed (1996–2010)



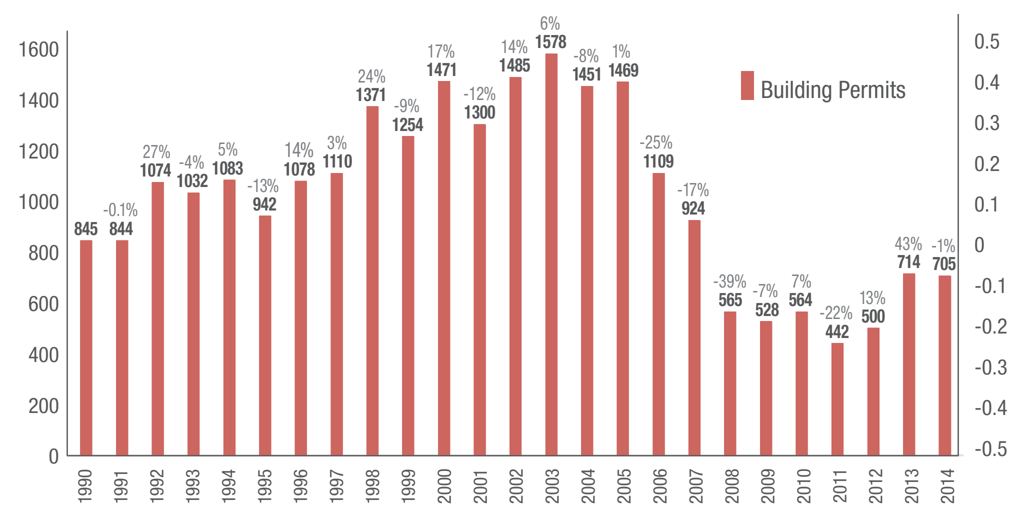
Data: 30-meter pixel land cover analysis by NOAA C-CAP (2010)
This graph does not include open water and submerged tidal lands data.

> The population growth rate within watershed communities exceeds that of the State as a whole.

Residential building permits can be used as a proximate indicator of development. Although the number of building permit applications dropped sharply beginning in 2006, reaching a low in 2011 following the Great Recession, permit applications are increasing again.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Total Residential Building Permits, Cumberland County

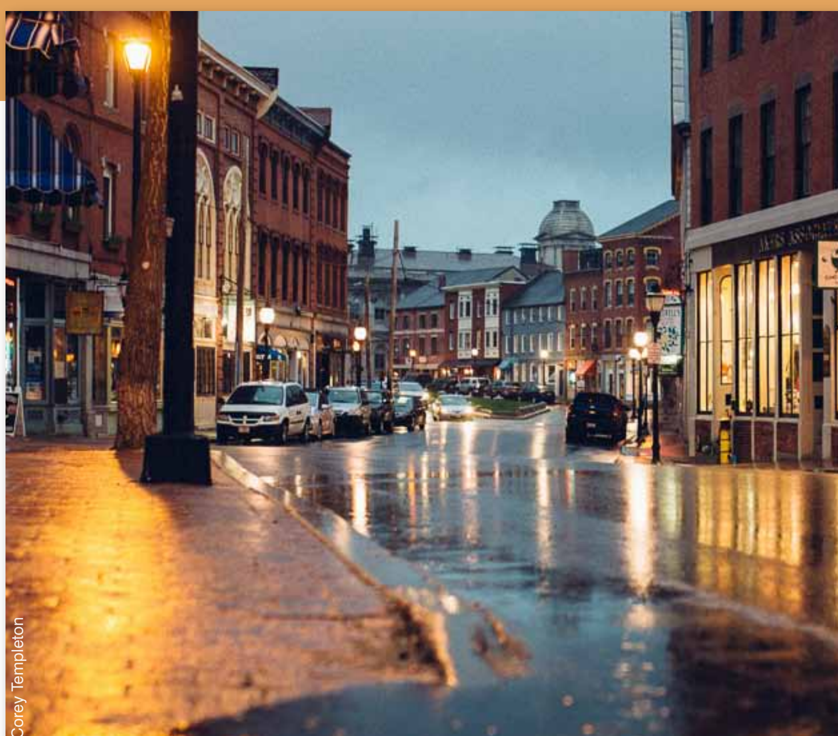


Data: U.S. Census Bureau

As Impervious Surfaces Expand, Runoff Increases

designm.ag

In the few parts of Casco Bay's watershed that have extensive impervious cover, even moderate increases in pavement and built infrastructure can degrade the Bay's most urban waters.



Corey Templeton

Runoff from Impervious Surfaces Linked to Declines in Aquatic Habitats

Impervious surfaces that do not absorb rain or allow it to infiltrate into the ground—such as pavement, sidewalks and rooftops—can aggravate erosion and hasten transport of sediments and pollution into aquatic habitats. Studies confirm that areas with a high percentage of impervious surfaces (10 percent or more) have diminished water quality and degraded aquatic habitat.

Runoff Impacts Are Highest in Urban Areas

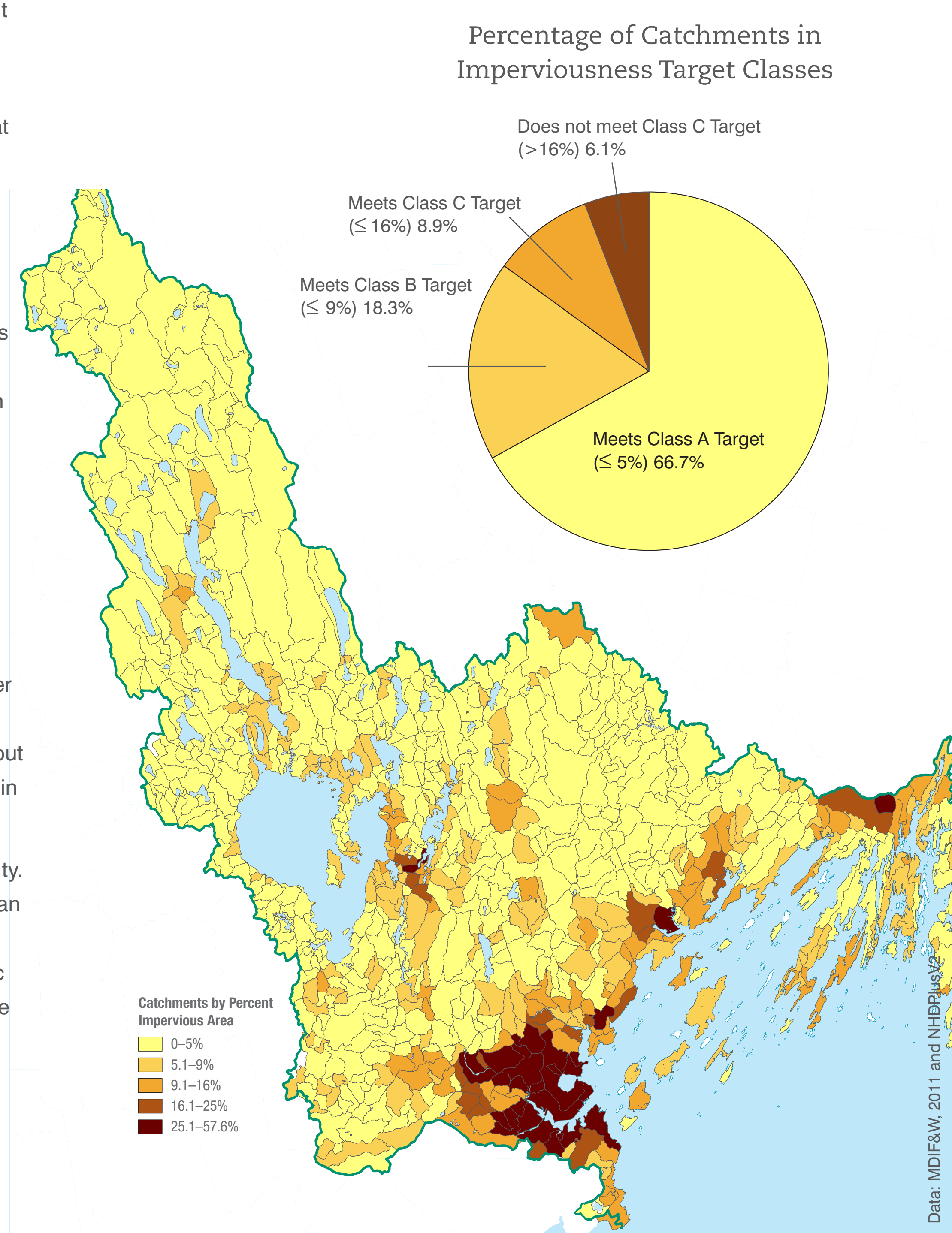
The extent of impervious surfaces in the Casco Bay watershed, mapped most recently by the Maine Department of Inland Fisheries and Wildlife in 2011 (based on 2007 aerial photographs), was 5.1 percent overall. The highest levels are found in urban areas, commercial districts and downtown areas.

The watershed has localized areas with impervious surfaces greater than 50 percent on the Portland peninsula and in parts of the Long Creek watershed, which houses the Maine Mall and adjacent commercial development.

Maine's water-quality classification system establishes goals for each river and stream in the state. Class AA waters must meet the most stringent conditions. Class A, B and C waters must meet progressively less stringent standards. A 2012 State plan identifies target levels for imperviousness that can guide efforts to restore water quality in urban streams to meet these standards. For Class AA and Class A streams, standards generally require that impervious surfaces cover no more than 5 percent of watershed area. The threshold increases to 9 percent for Class B streams and to 16 percent for Class C streams.

To assess local conditions, the Casco Bay watershed can be divided into smaller areas called catchments that reflect the way water flows across the landscape. As of 2007, two-thirds of the Casco Bay watershed was in catchments that met the recommended Class A threshold. Only 6 percent of the watershed was in urbanized areas with such high levels of imperviousness (more than 16 percent) that streams are unlikely to meet even Class C standards without significant investments to improve water quality.

> Increases in impervious surfaces can degrade urban waters.



Impervious Surfaces Grow as Construction Rebounds

The *State of the Bay 2010* report cited a slightly higher estimate of impervious cover levels than reported here, due to changes in methods and data sets rather than a real reduction in impervious area. No data are available that allow for a quantitative comparison of impervious surface levels between 2010 and 2015, but some evidence suggests that levels of impervious cover have increased slowly in recent years.

Creation of new impervious surfaces is closely coupled with construction activity. Regional construction slowed following the economic downturn, and only began to rise again in 2014. Thus for most of the past five years, the rate at which new roads, parking areas, and buildings were created fell below recent historic trends. Increasing construction activity in the coming years is apt to expand the coverage of impervious surfaces.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Salt in Stormwater Degrades Urban Streams

Ongoing monitoring by the Long Creek Watershed Management District sheds light on how winter salt degrades the health of urban streams, and demonstrates that focused stormwater management can improve urban streams.

Urbanization Diminishes Water Quality of Local Streams

As urbanization increases, surface water quality in local streams typically declines. This “urban stream syndrome” results from a complex mix of factors that includes pollutants from the developed landscape, changing stream flow conditions, increased channel erosion, habitat destruction, clearing of riparian vegetation, and increasing water temperature.

The Long Creek Watershed Management District (LCWMD) works to improve water quality in the Long Creek watershed on behalf of 130 participating landowners that each face permit obligations under the Clean Water Act to address stormwater pollution.

A key part of LCWMD’s work involves monitoring the conditions in Long Creek. This effort has become one of the most comprehensive urban stream-monitoring programs in the Northeast. Issues observed in Long Creek hold lessons for other urban watersheds in the Casco Bay watershed.

Winter Salt Poses Challenges, but Impacts Vary

Tons of de-icing products (“road salt”) of various formulations are applied each winter to roads and parking areas within the Long Creek watershed. Until recently, little was known about the impact these products might be having. Nearly continuous water-quality monitoring in Long Creek has provided insight into how and when salt washes into the stream, and what impacts it may have on organisms there.

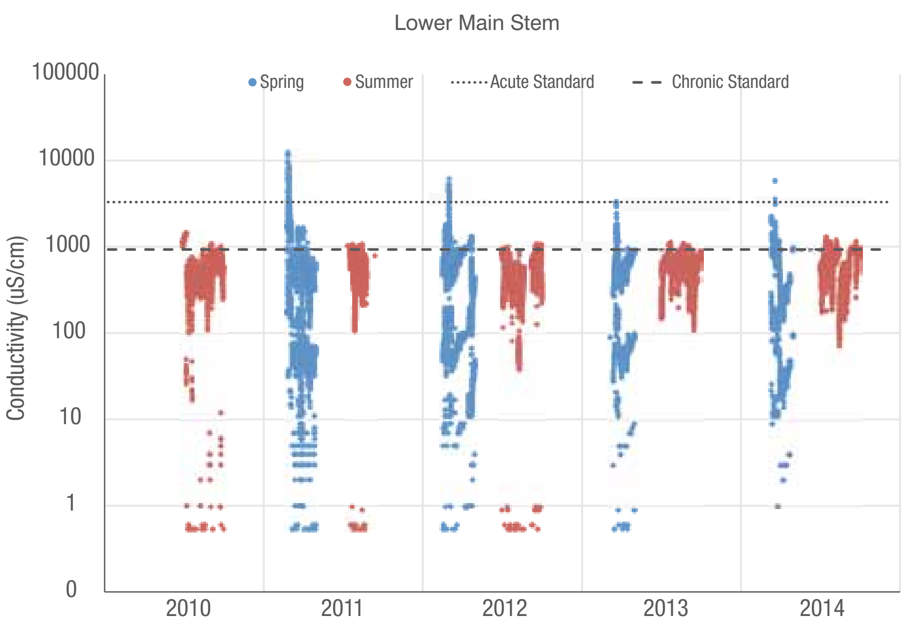
The monitoring station that LCWMD manages on the Creek's lower main stem receives runoff and stream flow from 62 percent of the Long Creek Watershed. Overall, 18.7 percent of the area that drains to this point is impervious, with 4.8 percent in roads and 10.2 percent in parking areas (with the remainder attributable to buildings, pathways, and access areas).

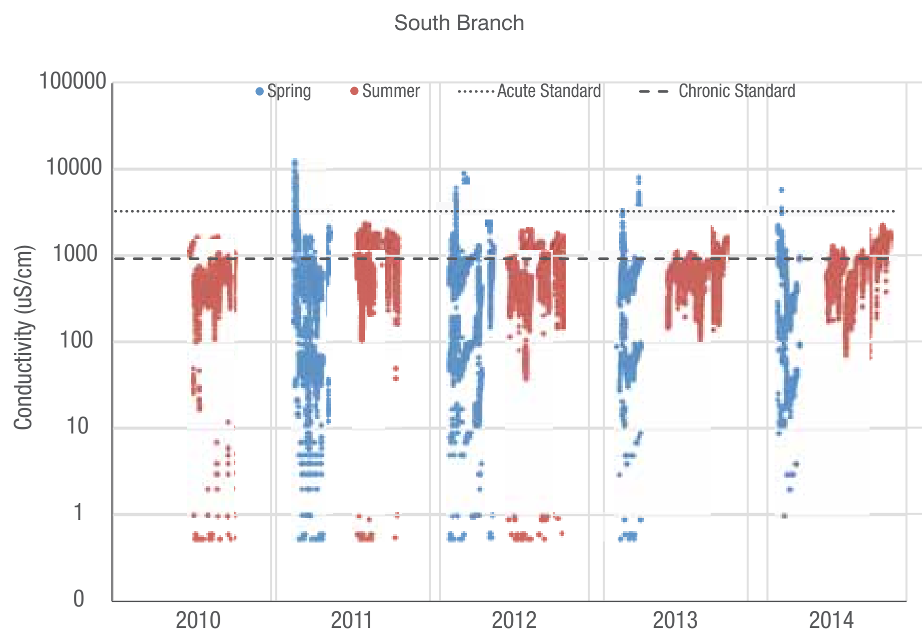
A second monitoring station, only a few hundred yards away, lies on the South Branch of Long Creek. The smaller area draining to that monitoring station, which includes parking lots near the Maine Mall, contains 54.9 percent impervious cover, of which 8.7 percent is in roads, and 30.5 percent in parking area. Equally important, the area includes some highly permeable, sandy soils that allow stormwater to readily enter the groundwater.

Federal and state water-quality standards restrict the level of chloride in freshwater streams, with standards both for short-term (acute) and long-term (chronic) exposure. Aquatic organisms may succumb to salt concentrations when exposed over a period of days even though they might survive shorter periods of exposure.

At both monitoring stations, the highest salt concentrations are observed during snow melt in the winter and spring. Levels then often exceed acute toxicity levels for freshwater organisms (although many aquatic insects are still dormant then, which may reduce the impact of short-lived spikes in salt).

De-icer residues appear to have different effects at the two stations despite their proximity. On the Lower Main Stem, conductivity levels that exceed chronic exposure limits are rare and short-lived. Levels that exceeded chronic exposure limits at least once occurred on 16 percent of summer days from 2010 through



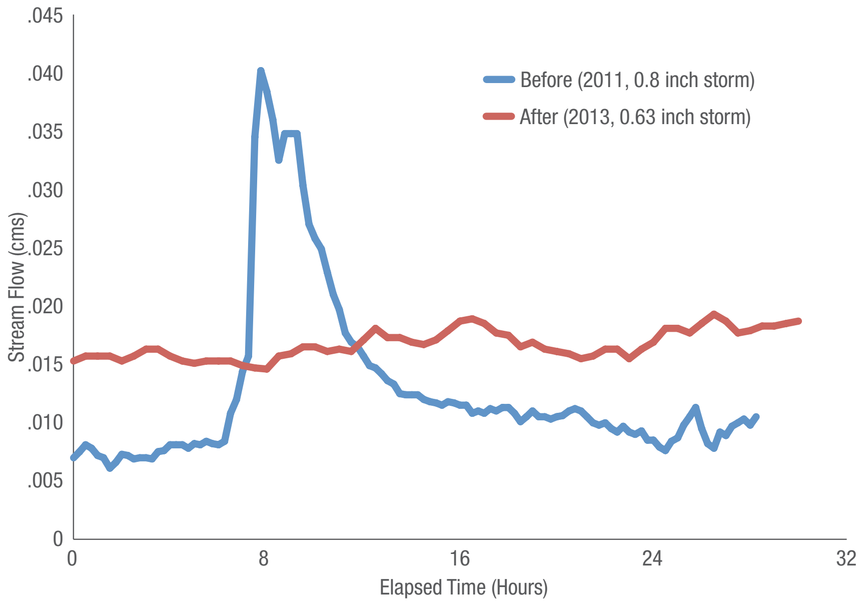


Spring (February-April) and summer (July-September) conductivity measurements from continuous monitoring. Conductivity is an indirect measure of salinity and chloride concentration.

2013, but lasted all day for only 5.6 percent of days. At the South Branch station, high conductivity days are the rule, with elevated levels seen on 81 percent of summer days. High levels last all day 56 percent of days.

Elevated levels in the South Branch are caused in part by the high proportion of parking and road areas upstream, but local soils may exacerbate problems. The area contains lenses of sandy soils interbedded with less permeable silt and clay layers. The sandy soils allow snow melt to enter the groundwater while the silt and clay layers slow the water's travel. As a result, relatively salty water may take months to reach the stream.

Freshwater organisms living in the South Branch are thus exposed to high levels of salt for long periods of time, exacerbating potential toxic effects. Such high salt levels alone could prevent recovery of stream health.



Flow Data, North Branch of Blanchette Brook

Effort to Address Stormwater Provides Benefits

Blanchette Brook, a headwater stream of Long Creek, has become a focus of restoration efforts. The area draining to its monitoring station (just above where the Brook meets Long Creek) totals 431 acres, 17.7 percent classified as impervious. Despite a moderate level of imperviousness (compared to the rest of Long Creek), the brook had serious water-quality problems in 2010. Water temperatures were high, dissolved oxygen levels were low, the stream was often choked with algae, and the aquatic insect community was degraded.

In 2011 and 2012, LCWMD installed stormwater control facilities—creating a "gravel wetland," planting riparian vegetation, and completing a stream restoration project that addressed habitat deficiencies in the stream. The stream responded well to these cumulative measures.

In 2010, before the restoration began, minimum dissolved oxygen levels recorded from April through September fell below 5 mg/l (the state "Class C" standard) on 33 percent of days. The comparable figure for 2013 was just 5.7 percent. In 2010, the average daily dissolved oxygen level over the six-month period was only 5.5 mg/l; by 2013, that level climbed to 6.7 mg/l, well above levels of concern for most aquatic organisms.

The Blanchette Brook restoration was also highly successful in slowing stream flows following precipitation while increasing flow at other times. Comparison of flows following a storm in 2011 and 2013 showed a clear change in how the stream responds to storms. In 2011, stream flow spiked within a few hours of a storm's beginning. No similar increase was evident in a similar storm two years later.

These physical and chemical changes have benefited the organisms living in Blanchette Brook. Maine DEP uses data on the composition of stream invertebrates (primarily insects) to evaluate stream health (see the Inland Water Quality Indicator). In both the 1999 and 2010 storms, the invertebrate community at a site on Blanchette Brook was so poor that the stream was judged to be in "Non-Attainment" of water-quality standards. By 2013, following the restoration effort, the invertebrate community had recovered to the point that it met "Class C" criteria, a significant improvement.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Less Untreated Sewage Is Entering Casco Bay after Heavy Rains

Casco Bay Estuary
PARTNERSHIP

Communities bordering the Bay have made significant progress reducing Combined Sewer Overflow discharges, and additional improvements are planned.

CSO discharge point on the Portland waterfront, adjacent to the Casco Bay Ferry Terminal.

The More Rain that Falls in a Given Year, the More Untreated Sewage Enters Casco Bay

When sewer systems were built more than a century ago, many cities laid only one set of pipes to carry both human waste and runoff. Since passage of the Clean Water Act, communities have built wastewater treatment plants, and diverted the flow from these combined sewers to the plants for treatment. But heavy rain events can overload the system, discharging untreated human waste into Casco Bay via what are known as “Combined Sewer Overflows” (CSOs).

While Portland, South Portland, Westbrook, and Cape Elizabeth continue to operate CSOs, they have made significant progress in recent years reducing CSO discharges. Both the volume and frequency of discharges are weather-dependent, but even in recent high-rainfall years, discharges have been declining.

Active Combined Sewer Overflows (2014)

Town	Locations	Events	Volume†
Portland (DPW and PWD)	31	75	414.42
South Portland	6	9	15.53
Westbrook	5	70	11.93
Cape Elizabeth	1	12	1.44
Total	43	166	443.32

† Millions of gallons

Baxter Boulevard CSO storage conduit during installation.

Formally, 43 active (*i.e.,* permitted by DEP) CSO locations remain in our region, but not all these sites have been discharging in recent years. Several locations are being decommissioned but are still considered active, while others discharge only during the largest of storms. In 2014, total CSO discharges directly to Casco Bay or to its tributaries totaled about 187.5 million gallons. Casco Bay's CSOs had 166 overflow "events" that year (Breau 2015).

Over the last 15 years, annual CSO discharges around Casco Bay have been declining on average by about 35.9 million gallons per year. For well over a decade, discharges have declined by one million gallons per inch of rainfall annually, thanks to continuing efforts to address CSOs. Whereas 24.9 million gallons of untreated CSO wastes discharged per inch of rainfall in 2000, only 7.9 million gallons discharged per inch of rainfall in 2014.

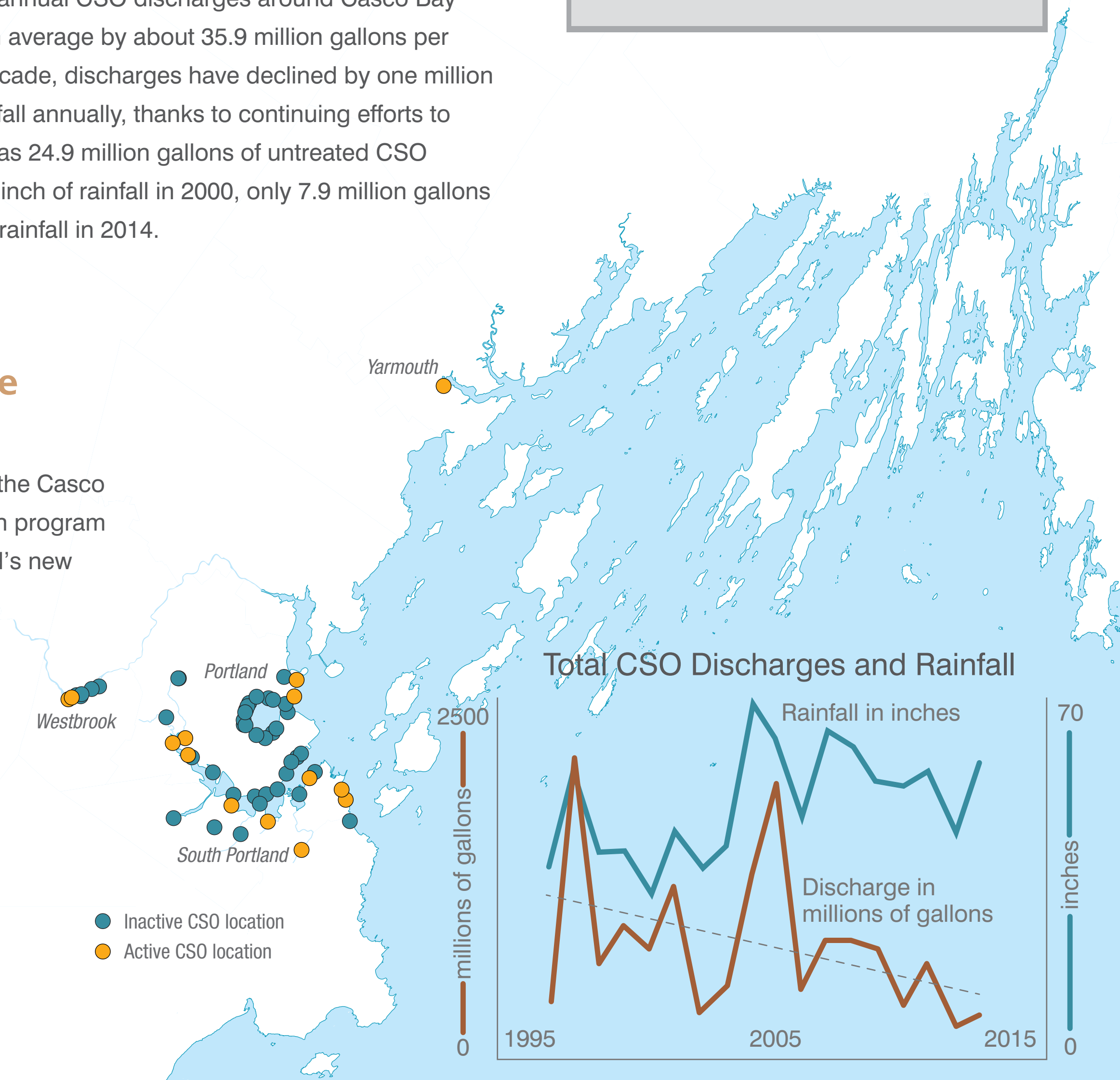
In Portland, new facilities hold combined stormwater and wastewater for treatment, instead of discharging it into the Bay.

Underground Storage Conduits Help Reduce CSO Discharges to Casco Bay

Portland, which has the vast majority of CSO discharges (not only within the Casco Bay watershed, but statewide), has begun work on a 15-year, $170 million program to further reduce CSO discharges. Half the funds to be raised by Portland's new stormwater service charge are slated to be spent on CSO remediation.

In 2013, as part of an ongoing effort to reduce CSO discharges, Portland constructed two large (one million gallon) underground storage conduits under Baxter Boulevard and Payson Park, on the north side of Back Cove. These facilities trap and hold combined stormwater and wastewater (in all but the largest storms) long enough to allow the waste to be pumped to the sewage treatment plant without discharges to the Bay. Additional storage conduits are planned south of Back Cove and along the Fore River.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.



Lakes and Streams Typically Have Good Water Quality

Brad Knabel

Water quality in most of the Casco Bay watershed remains good, with cause for concern in selected lakes and streams. Problems with stream health are especially common in urban and suburban areas.

Lee Dassler

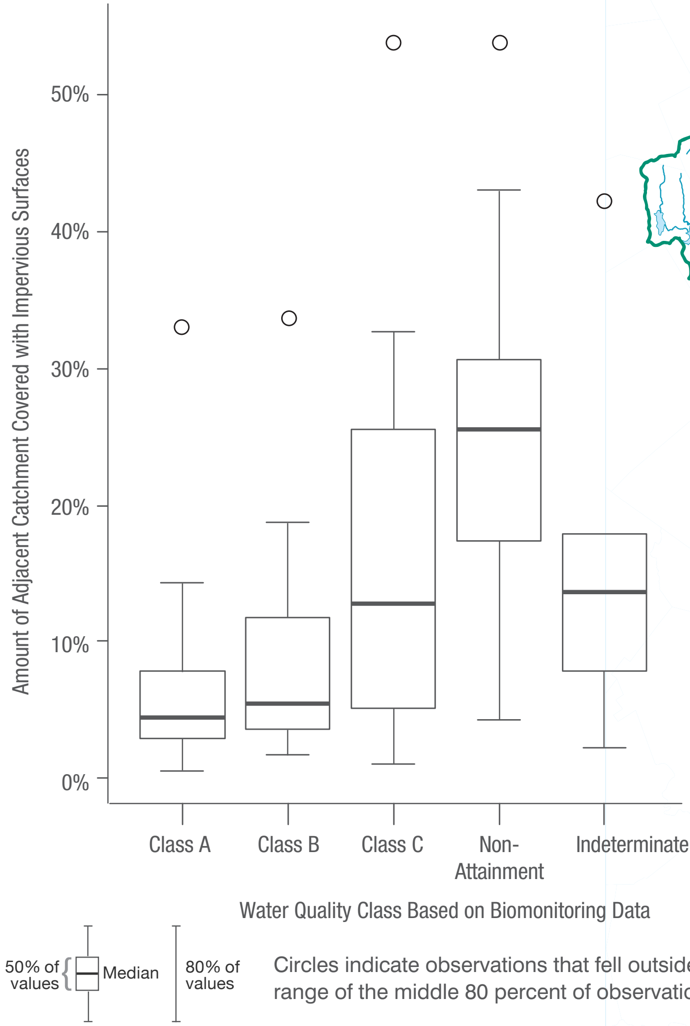
Bay's Health Depends on Tributaries' Well-being

Rivers, estuaries and bay form an ecological continuum: pollution in inland waters is transported to the Bay and degrades its water quality. Living organisms from ospreys to alewives migrate between fresh water and saltwater environments with the turn of the seasons, and even with changes in weather.

More than 10 Percent of Rivers and Streams Fail to Meet Water-Quality Goals

The Maine Department of Environmental Protection (DEP) is charged with evaluating the health of the state's waters every two years. Technically, all of Maine's fresh waters fail to fully meet water-quality standards because mercury contamination is prevalent enough that the State posts a fish consumption advisory to limit or avoid eating freshwater fish. Because that restriction applies statewide, it is useful to look at other forces that locally degrade water quality.

The Casco Bay watershed contains approximately 1,228 miles of mapped rivers and perennial streams. As of 2012, 141 miles (11.5 percent)—falling within 28 streams—failed to meet applicable water-quality standards (other than the mercury standard). The most common problems include low dissolved oxygen and stream insect communities indicative of poor conditions. Most of the main stem of the Presumpscot River fails to meet water-quality standards because of low dissolved oxygen that can occur in the river's many impoundments when water levels are low.

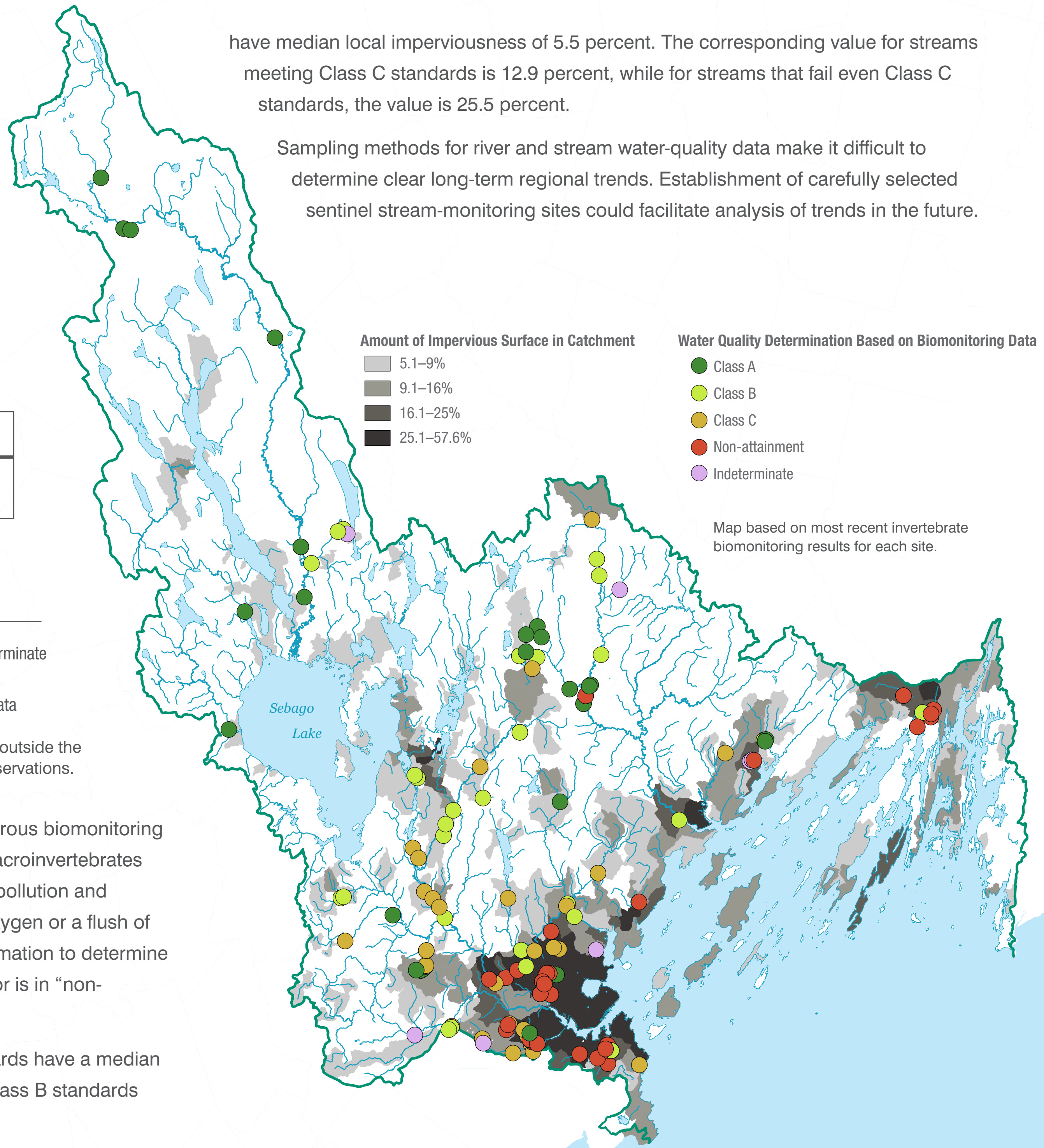


Circles indicate observations that fell outside the range of the middle 80 percent of observations.

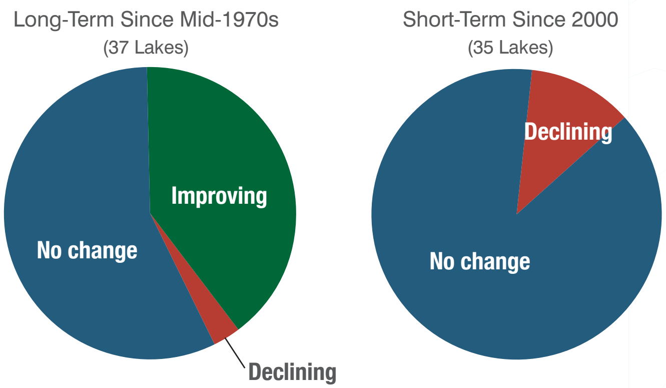
To gauge water quality, Maine DEP has developed a rigorous biomonitoring method that assesses what aquatic insects and other macroinvertebrates live in a stream. Their composition reflects both chronic pollution and more severe, short-term challenges like low dissolved oxygen or a flush of contaminants from flooding. DEP uses invertebrate information to determine whether a stream meets Class A, B, or C requirements; or is in "non-attainment" (not meeting even Class C requirements).

Waters that biomonitoring indicates meet Class A standards have a median local imperviousness of 4.4 percent. Streams meeting Class B standards have median local imperviousness of 5.5 percent. The corresponding value for streams meeting Class C standards is 12.9 percent, while for streams that fail even Class C standards, the value is 25.5 percent.

Sampling methods for river and stream water-quality data make it difficult to determine clear long-term regional trends. Establishment of carefully selected sentinel stream-monitoring sites could facilitate analysis of trends in the future.



Changes in Lake Water Clarity



Lake Water Clarity a Concern

As of 2012, no lakes in the Casco Bay watershed were reported to be failing water-quality standards, but there is significant variability and emerging concerns such as the growing abundance of the blue-green algae *Gloeotrichia*.

Several lakes have locally developed and formally approved watershed-based plans that guide water-quality protection efforts and facilitate access to federal funding: Crescent Lake (Raymond); both Highland Lakes (Windham/Falmouth and Bridgton); Little Sebago Lake (Windham); Panther Pond (Windham); Sebago Lake (many townships); and Woods Pond (Bridgton). Long Lake and the two Highland Lakes also have legal water-quality improvement plans called "Total Maximum Daily Load" studies (TMDLs) to help control phosphorus (a nutrient that fertilizes algae growth and degrades water quality).

> Several lakes have developed watershed-based plans that provide direction for protection efforts.

Water-clarity data from Casco Bay watershed lakes shows a slight but statistically significant improvement since the mid-1970s (with 37 lakes being monitored during at least five years over that period). Of those lakes, 40 percent show statistically meaningful increases in water clarity, while only one shows real declines.

Since 2000, though, water clarity has been steady or declining. Of the 35 lakes sampled at least five times since then, four (11 percent) show statistically significant declines in water clarity and none show meaningful improvement. The lakes with recent declines in water clarity include Panther Pond, Crescent Lake, Long Lake and Sebago Lake.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Data: Maine DEP, 2012 Integrated Water Quality Monitoring and Assessment Report and www.maine.gov/dep/gis/datamaps/index.html. Accessed June 2015.

Trends in Bay Water Quality Signal Need for Further Research

While water quality can encompass many different environmental measurements, this indicator combines 23 years of data on basic parameters such as dissolved oxygen, water clarity, nutrient concentrations, and pH—offering unparalleled insight into the changing condition of Casco Bay.

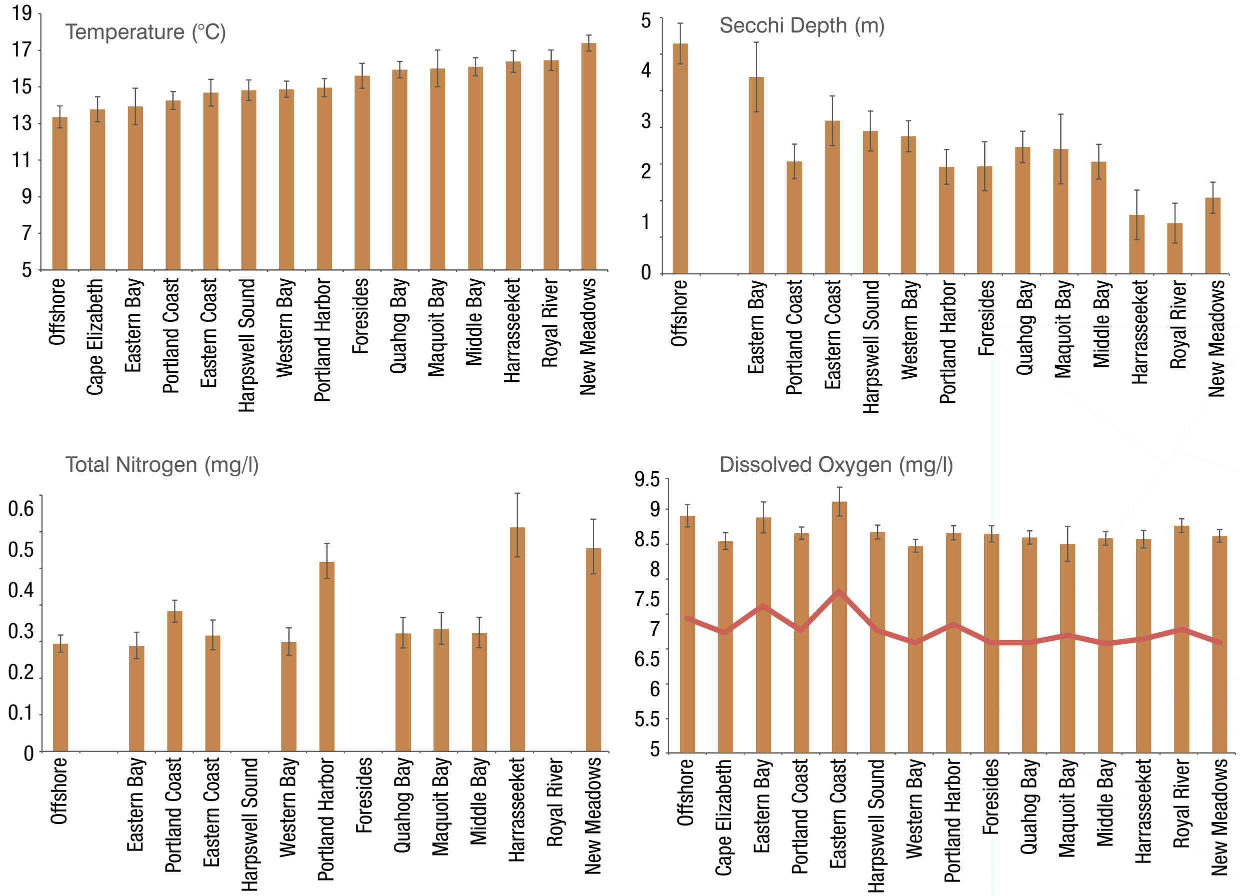
Tracking Conditions for Two Decades

For more than 20 years, Friends of Casco Bay (FOCB) has worked with volunteers to collect standard water-quality parameters including salinity, dissolved oxygen, pH (a measure of acidity), Secchi Depth (a measure of water clarity), and temperature around the Bay (at 36 sites in 2014). In recent years, measurements have been taken twice a day every other week for seven months each year. Each month, FOCB staff visit by boat 10 “profile” sites to characterize conditions further from shore. Since sampling locations have changed over time, data cited here include measurements collected since 1993 at 63 sites. FOCB also has collected data on Total Nitrogen (TN) concentrations in the Bay, providing data from 17 sites (between 2007 and 2014). Results are based on statistical methods that account for sampling history (as data collection methods changed over time).

Water Quality Varies Significantly between Sites

Water quality in Casco Bay, while generally good, varies markedly between inshore (where runoff from the land, shallow depth and restricted water movement influence conditions) and offshore (where waters are typically colder, more clear, less acidic, lower in TN and higher in dissolved oxygen).

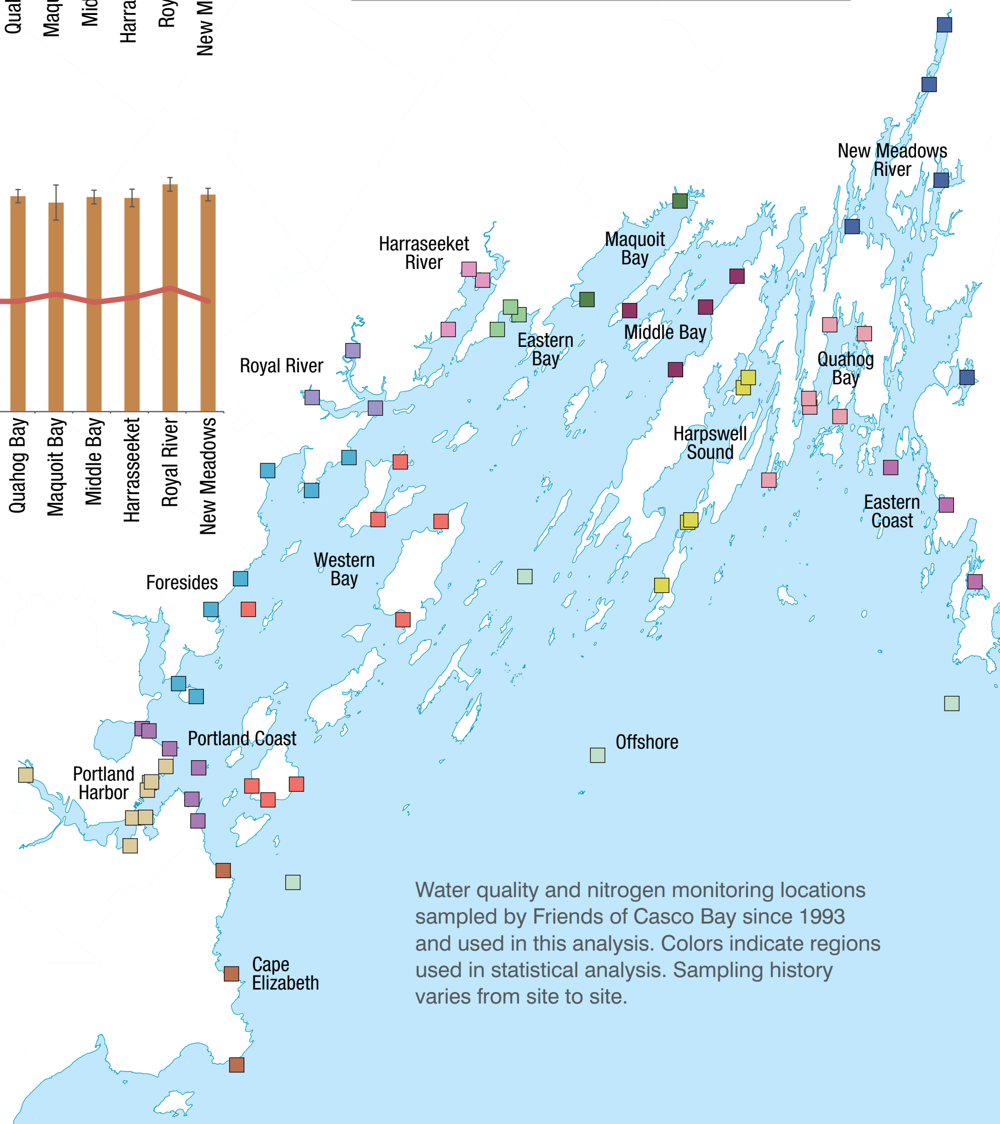
Dissolved oxygen levels throughout the Bay are generally at or above 8.5 mg/l. More than 90 percent of FOCB’s dissolved oxygen observations in each region have been above 6.5 mg/l in recent years (a level high enough not to affect aquatic biota).



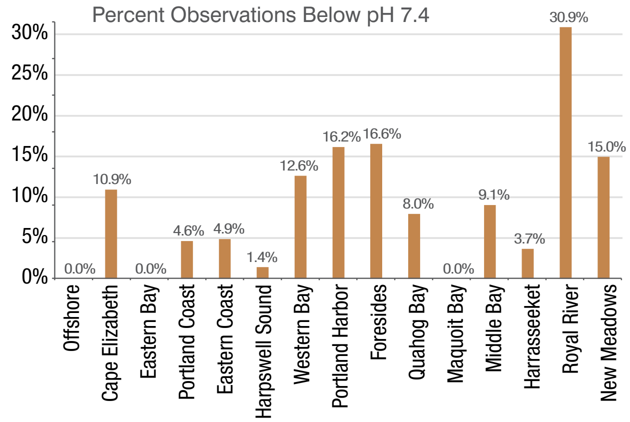
Average water-quality conditions by region for the period 2010-2014, adjusted for sampling history. Results for Temperature, Secchi depth and Dissolved Oxygen are based on data from 2010 through 2014. Data on Total Nitrogen shows estimated geometric mean since 2008. Ninety percent of all dissolved oxygen observations in the last five years fall above the red line.

> Coastal acidification is driven both by rising atmospheric CO_2 and by local water-quality conditions.

In contrast, nitrogen levels in parts of Casco Bay are high. According to 2009 report prepared for Maine Department of Environmental Protection, 90 percent of measurements statewide were below 0.42 mg/l. (Cadmus Group 2009). Average conditions (geometric means) for three Casco Bay sub-embayments (Portland Harbor, Harraseeket River and New Meadows River) exceed those values, suggesting that these areas consistently have among the highest nitrogen levels observed in Maine coastal waters.



Water quality and nitrogen monitoring locations sampled by Friends of Casco Bay since 1993 and used in this analysis. Colors indicate regions used in statistical analysis. Sampling history varies from site to site.



Over the past five years, average pH observed by FOCB staff and volunteers was 7.84, with 11.1 percent of measured values Bay-wide showing acidified conditions (pH below 7.4). Few offshore areas had acidified conditions, while nearly a third of all pH measurements in the Royal River were below that threshold. Coastal acidification is driven both by rising atmospheric $C0_2$ and by local water-quality conditions. Elevated nutrient levels, as seen in some inshore areas of Casco Bay, have been associated with higher primary productivity and increased risk of acidification.

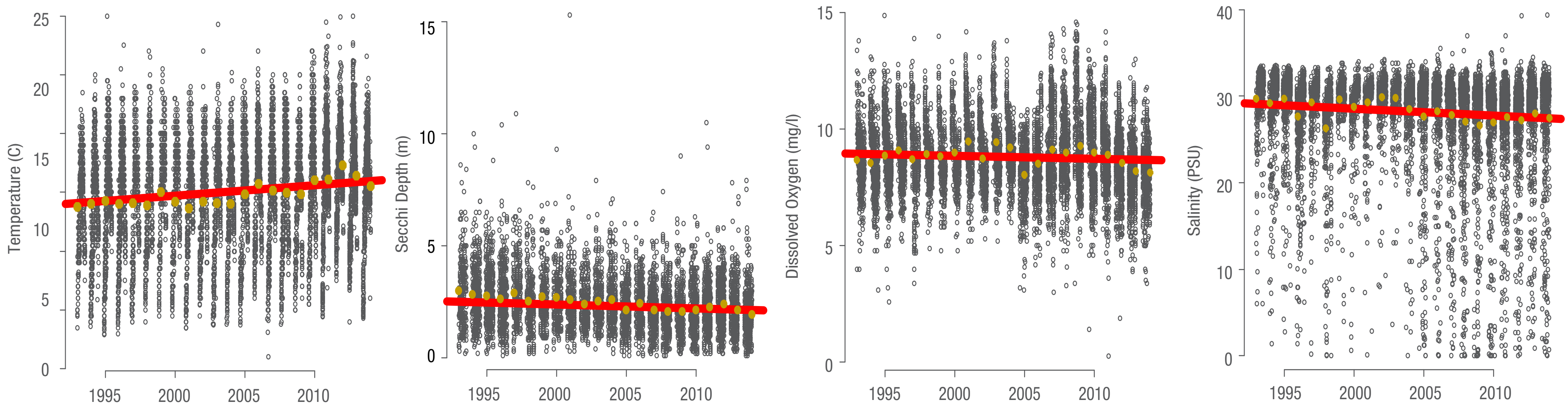
Water Quality Reveals Some Troubling Trends

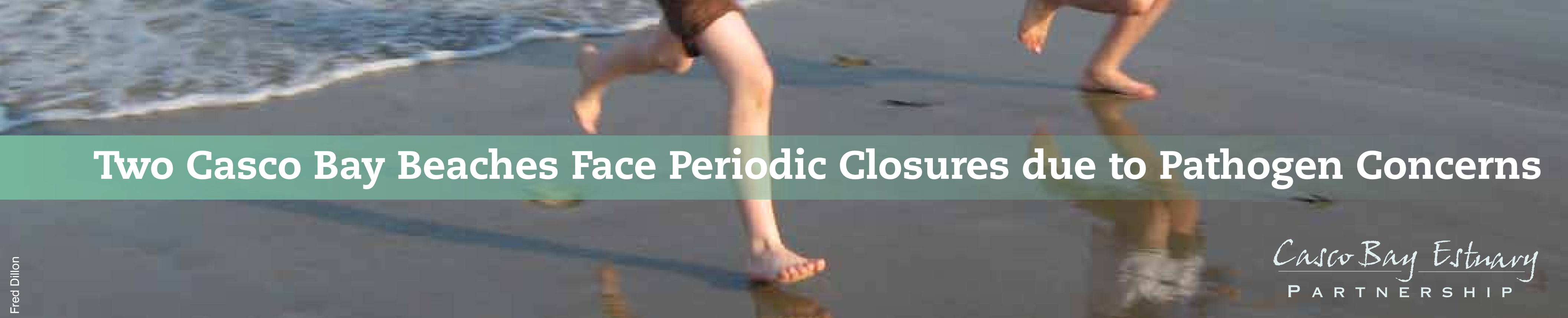
With more than 11,000 observations over a long period of record (23 years), even relatively weak trends can reach statistical significance. FOCB's data suggest that Casco Bay water temperatures have climbed 3.6°F on an average, seasonally adjusted basis since monitoring began in 1993. Average dissolved oxygen levels have declined slightly (0.30 mg/l over 13 years), probably due to warmer waters. Water clarity, as measured by the Secchi Depth, has also declined (0.39 meters; 1.28 feet) over the same period.

While long-term trends in pH (data not shown) are statistically significant, the change is small (0.04 pH units over 23 years), and measurement techniques have changed, making the practical importance of the finding unclear.

Surprisingly, Casco Bay's salinity appears to be changing slightly (declining ~ 1.8 PSU over the period of record). While salinity is dropping or unchanged in most of the Bay (including offshore), it has increased in the Royal River and Portland Harbor, both areas influenced by river discharge (data not shown).

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.





Fred Dillon

Two Casco Bay Beaches Face Periodic Closures due to Pathogen Concerns

Routine water-quality monitoring done by Maine Healthy Beaches program volunteers reveals recurrent challenges at two Casco Bay Beaches—East End Beach in Portland and Willard Beach in South Portland—which consistently rank among the top beaches statewide for advisories posted.

Jim Pennucci

Volunteers Monitor Water Quality

Beaches represent an important recreational and economic asset for coastal communities as long as their waters are "swimmable." To protect the health of swimmers (particularly vulnerable populations like children), municipalities or parks post advisories or closures if water-quality monitoring reveals potentially dangerous levels of pathogens (based on risk-based thresholds set by the US Environmental Protection Agency). Pathogens of concern (bacteria, viruses and parasites that can prompt gastric illnesses, eye and ear infections and other health issues) often are due to fecal contamination that enters coastal waters through sewage effluent, malfunctioning septic tanks, illegal boat discharges, and agricultural or stormwater runoff.

Monitoring, coordinated by the University of Maine Cooperative Extension and Maine Department of Environmental Protection through the Maine Healthy Beaches program, occurs three times each week between Memorial Day and Labor Day at East End Beach in Portland, twice a week at Willard Beach in South Portland and twice per month at Winslow Park in Freeport. Advisories are issued based on recent bacterial samples, but can also be precautionary, such as when elevated bacteria counts are anticipated due to heavy rainfall conditions. Maine DEP requires that more populous communities identify and correct any human sources of pollution in their municipal stormwater system.

Don Shall

Willard Beach and East End Beach Face Recurrent Closures

Of the three beaches routinely monitored in Casco Bay, Willard Beach and East End Beach have extensively developed watersheds, and are issued recurrent swimming advisories by the Maine Healthy Beaches Program and local beach managers. In 2014, Willard Beach was one of only seven beaches in Maine where more than 20 percent of samples exceeded the allowable fecal bacteria threshold. Statewide, about 10 percent of samples exceeded the threshold.

The frequency of advisories, however, is not a precise indicator of conditions as policies for issuing advisories have changed in an effort to better protect public health. Following changing federal guidance, the Maine Healthy Beaches program began recommending in 2012 that communities issue beach advisories based on rainfall (because risk exposure is typically greatest following significant rain due to pathogens in stormwater runoff). Since then, many advisory days have been triggered by rainfall, not water quality testing, making the numbers hard to compare with earlier values.

Elevated Bacteria Levels Likely More Common

Changing conditions can also be assessed by looking at Maine Healthy Beaches historical data (www.mainehealthybeaches.org). By a long-used federal and state standard (issuing an advisory if the number of bacteria exceeded 104 *Enterococci* per 100 ml of water), samples collected at Willard Beach are more likely to be elevated today than in the past. A similar trend is possible at East End Beach, but the data are not conclusive. No trend is apparent at Winslow Park.

> Municipalities post advisories or closures if water-quality monitoring reveals dangerous levels of pathogens.

Total Beach Action Days per Year at Casco Bay Beaches

Year	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
2010	11	11	3
2011	N/A[1]	9	0
2012	1[1]	37	2
2013	18	28	0
2014	19	19	0

[1] Willard Beach did not conduct monitoring in 2011, and began sampling in 2012 in mid-August. Starting in 2012, South Portland reduced the number of sampling stations at Willard Beach from 3 to 1.

Changing probabilities should be interpreted with caution, since sampling practices may have changed.

Source: State of the Bay 2010; Keri Kaczor, Maine Healthy Beaches Program. An "action day" refers to the number of days a beach is posted with an advisory against swimming or closed. Updated conditions can be found at www.MaineHealthyBeaches.org.

South Portland Works to Address Challenges at Willard Beach

Willard Beach, a sandy beach with intact dunes in a densely populated part of South Portland, is a highly popular destination on hot summer days, not only for those in the neighborhood but residents throughout Greater Portland. While it offers beautiful vistas, the beach faces ongoing water-quality challenges—with more than 100 advisories posted in the past five years. Six stormwater outfall pipes lie along the 4-acre beach, and 40 percent of the immediate watershed is paved.

To identify human sources of bacteria, the Maine Healthy Beaches program and the City of South Portland have employed several tools. First, researchers sampled stormwater catch basins and other locations for both indicator

Changing probability that a water sample submitted to the Maine Healthy Beaches showed elevated bacteria levels (*Enterococci* > 104 CFU/100ml) for three Casco Bay beaches.

bacteria and optical brighteners (chemicals added to detergent that are typically found in sewage but not in stormwater). Specially trained dogs were brought in to sniff out human sources of sewage.

Using this information, the City honed in on specific locations within the underground stormwater system and, using dye-testing and cameras, identified settings where sewage was leaking into the storm drain system. Through the process, the City was able in 2014 to identify and remove an illicit cross-connection between sewer and stormwater infrastructure (Sims 2015). The City also launched a pet waste and water-quality campaign. To date in 2015, the beach is still experiencing stormwater-related advisories so more research and collaborative work is needed. South Portland's experience illustrates the ongoing challenge of tracking and addressing nonpoint source pollution.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Andrew Malone

Most Shellfish Areas in Casco Bay Meet State's Approved Classification

Casco Bay Estuary PARTNERSHIP

The majority of Casco Bay's waters are open for shellfish harvesting, but harvesting restrictions affect about half of the Bay's soft-shell clam habitat. To see further improvements, communities will need to further reduce sources of fecal contamination, and the State will need to fund adequate water sampling, biotoxin monitoring and sanitary surveys.

Andrew Malone

Shellfish Bed Status Signals Water Quality

In the last decade, the Public Health Division of the Maine Department of Marine Resources (DMR) has reassessed how shellfish beds are managed to more accurately account for potential sources of pollution. Casco Bay has a mosaic of management areas designed to protect the health of consumers eating soft-shell clams, mussels, oysters and quahogs—whether dug from mudflats or harvested from aquaculture.

The State classifies shellfish growing areas based on several factors: the presence of fecal indicator bacteria, proximity to sewage treatment plant outfalls, and temporary events such as heavy rainfall or a wastewater treatment plant malfunction. These rules are mandated under the US Food and Drug Administration's National Shellfish Sanitation Program (NSSP). Waters are classified based on a "sanitary survey," which involves water testing, a shoreline survey looking for potential pollution sources, and an analysis of other potential risks. Only when a sanitary survey has determined little risk of pathogen pollution are waters harvestable year-round. Many coastal waters are managed on a conditional basis, depending on rainfall, time of year, or episodic events like malfunctions in sewage treatment plants.

Mike Timberlake

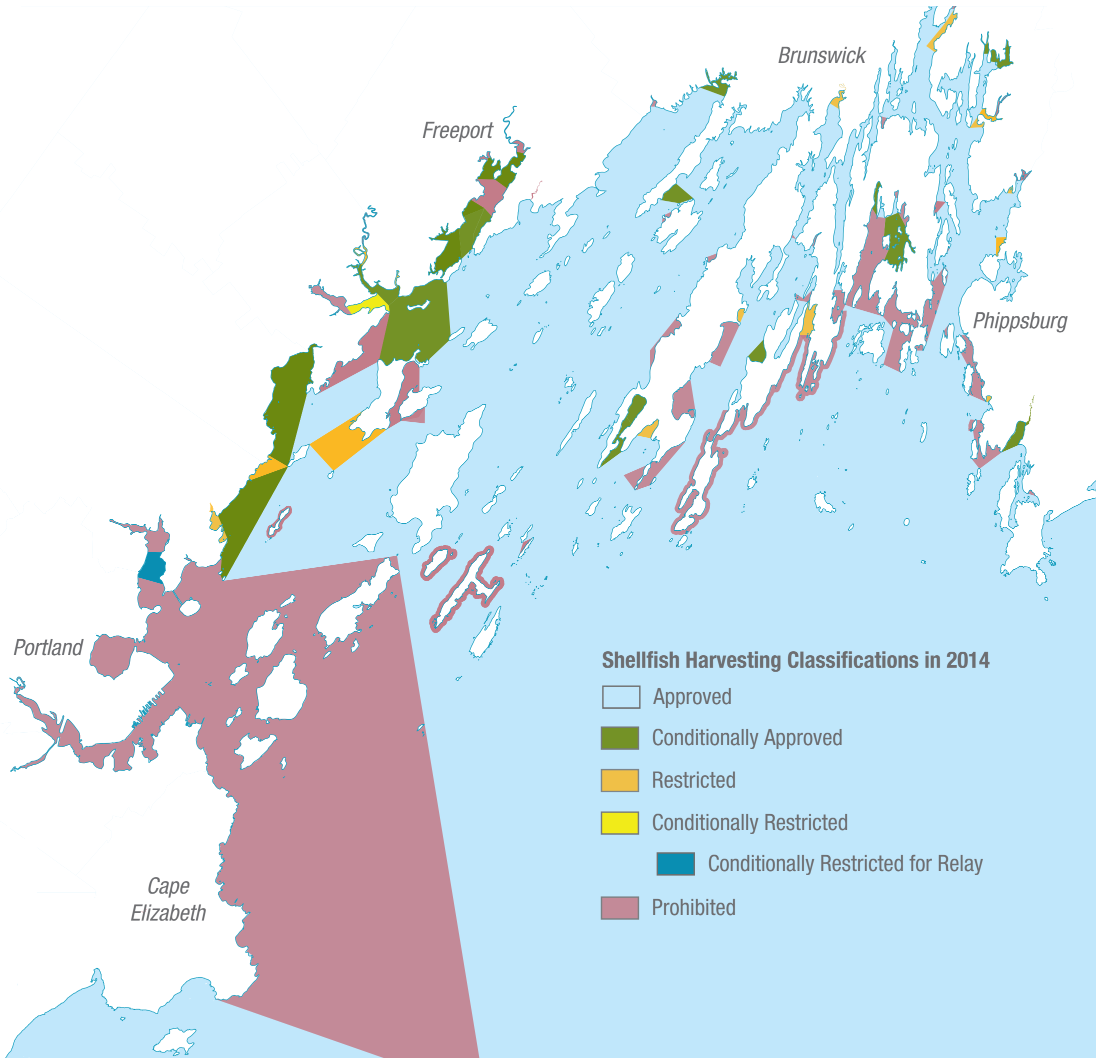
	Shellfish Growing Areas		Soft-shell Clam Habitat	
Classification	Acres	Percent	Acres	Percent
Approved	97,542.9	67.1	4,868.1	48.4
Conditionally Approved	8,314.8	5.7	1,999.4	19.9
Restricted	2031.4	1.4	331.8	3.3
Conditionally Restricted	327.8	0.2	194.2	1.9
Prohibited	37,154.0	25.6	2,654.6	26.4
TOTAL	145,371		10,048.2	

Classification of shellfish growing areas (all waters of Casco Bay) and soft-shell clam habitat areas in 2014 by Maine Department of Marine Resources Public Health Division. *Data: DMR*

The Maine DMR has five shellfish classification categories, reflecting a gradient in water quality. Approved represents the best water quality, and Prohibited represents the worst.

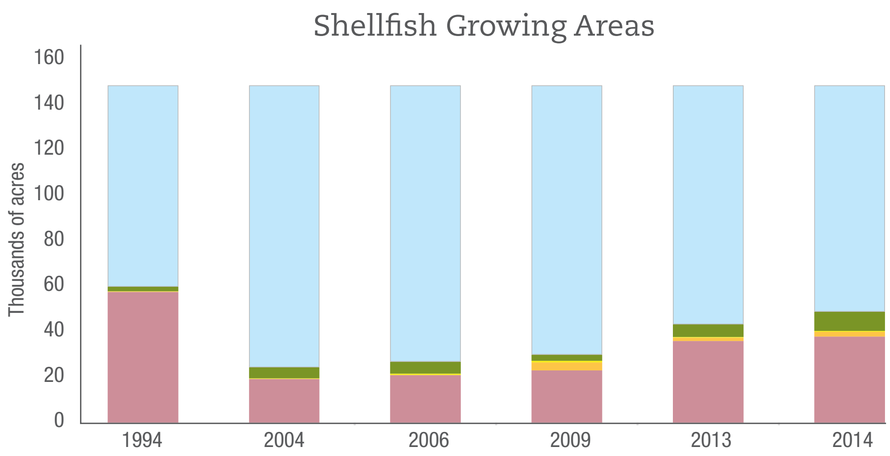
- An Approved classification authorizes shellfish harvest for direct marketing.
- Conditionally Approved areas have good water quality, but may be temporarily closed under certain conditions such as a significant rainfall event or a sewage treatment plant malfunction.
- Restricted areas do not meet all water-quality standards for an Approved classification, and the sanitary survey indicates a limited degree of pollution. Shellfish harvested from Restricted areas cannot be marketed directly; they must be "relayed" to Approved areas or cleansed at a depuration facility.
- Conditionally Restricted areas meet conditions for restricted classification, but may also be temporarily closed to harvest after adverse events. In 2014, a portion of the Presumpscot Estuary was classified as "Conditionally Restricted for Relay."
- Prohibited areas are closed to harvest at all times, when water testing shows elevated levels of fecal bacteria, or when areas are near sewage treatment plant outfalls or other potential sources of pathogens.

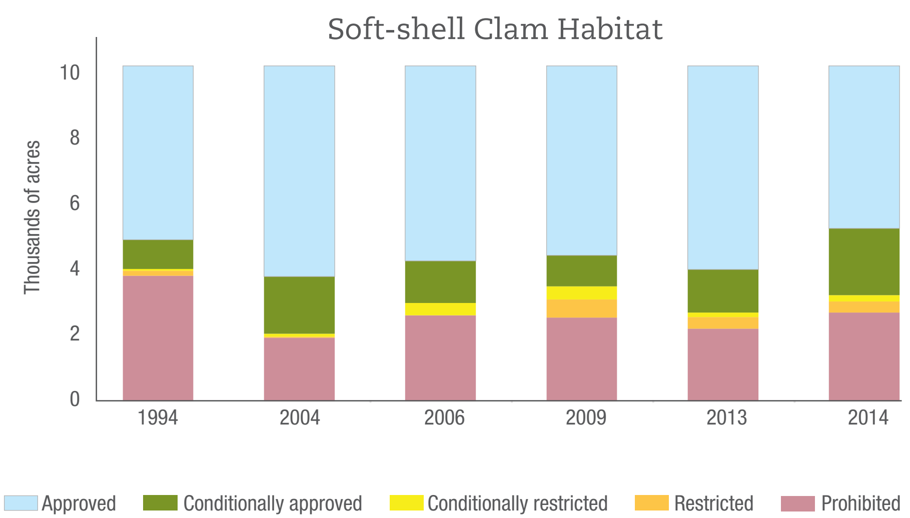
In 2014, harvesting was unrestricted in the majority (67 percent) of Casco Bay's waters. However, more than 37,000 acres of waters (25.6 percent) were classified as Prohibited. Many of these waters are nearshore and close to pollution sources such as wastewater treatment plants and Combined Sewer Overflows. Thousands of the prohibited acres adjoin islands (where residential licensed "overboard discharges" can raise pathogen risks if not well maintained).



Policy Changes Affect Closure Areas

Over the years, changes in classification have occurred due to new information from shoreline surveys or water-quality testing, boundary changes to facilitate management or enforcement, reopening of cleaned-up areas, and changed NSSP recommendations.





Data: Maine DMR

While Prohibited and Conditionally Approved acreage has increased in recent years, these changes do not signal lower Bay water quality but changes in NSSP guidance. Most of the increase represents growth in the "Conditionally Approved" category (*i.e.*, areas open to harvest except under specific circumstances such as heavy rains).

Shellfish aquaculture is not yet widespread in Casco Bay, but interest in aquaculture and other forms of intensive shellfish management is growing. Many aquaculture facilities may be sited in locations that do not provide natural shellfish habitat so the impact of closure areas on them is hard to anticipate.

Improving State Testing for Red Tide

Harmful blooms of the alga *Alexandrium fundyense*, known locally as red tide, produce a biotoxin that accumulates in mussels and other shellfish and can lead to paralytic shellfish poisoning (PSP) in humans who consume the shellfish. Since 2005, when an intense and prolonged red tide closed shellfish areas in Casco Bay and throughout the Gulf of Maine, Maine DMR has more actively managed shellfish areas to protect public health. In 2006, DMR began to sample more intensively to pinpoint locations of toxicity.

DMR has changed the assay used to measure biotoxin levels in wild-caught mussels, employing High Performance Liquid Chromatography, which is considered more accurate and eliminates the need for animal testing (DMR estimates that in 2014 more than 40,000 mice were spared).

Monitoring Shellfish Beds Requires Resources

Maine DMR has lost resources for shellfish bed monitoring due to governmental cutbacks, leaving insufficient staff to conduct sampling and compile data. Some of these deficits may be filled by the New England Sustainability Consortium, which has received funding through National Science Foundation Experimental Program to Stimulate Competitive Research grants to the University of Maine and University of New Hampshire.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Annmarie

Elevated Lead and PAHs Found in a Few Localized Shellfish Beds

Periodic monitoring of shellfish tissues indicates that most Casco Bay shellfish are safe for human consumption, with some samples from the most industrialized parts of the Bay showing elevated levels of contaminants.


Dave Roberts

Historic Sources Account for Some of Toxic Chemicals Found in Bay Shellfish

The presence of toxic chemicals in filter feeders like blue mussels (*Mytilus edulis*) and soft-shell clams (*Mya arenaria*) can indicate contaminants within the larger marine ecosystem, revealing how chemicals released from human sources appear in the food chain—potentially harming fish, wildlife and humans.

The Maine Department of Environmental Protection's SWAT (Surface Water Ambient Toxics) monitoring program collects and analyzes blue mussels and soft-shell clams for toxic chemicals. Maine DEP compares concentrations of mussels collected from Casco Bay with those collected elsewhere in the Gulf of Maine using a standard based on the Gulfwatch program, a joint US/Canada blue mussel monitoring program that has sampled mussels throughout the Gulf. Concentrations are described as elevated when they exceed the 85th percentile value based on over two decades of sampling (GOMC 2009).

Shellfish sampled in the last five years from more urban areas of Casco Bay have higher levels of some toxic chemicals compared to less developed areas of Casco Bay. Centuries of pollution from industry and waste dumps, as well as urban runoff from residential and commercial development explain this finding (CBEP 2007).

In 2010 and 2012, for example, mussels collected from Spring Point in South Portland exhibited elevated levels of polycyclic aromatic hydrocarbons (PAHs), toxic compounds released from combustion of fossil fuels and wood and from fuel spills and asphalt. This location, downstream of the Fore River, is near a marina and an oil terminal.

Toxics Elevated[1] in Mussels Collected at Casco Bay Sampling Sites from 2011 to 2014

Year Sampled	Sampling Location	Al	Fe	Cr	Cu	Ni	Pb	Zn	Hg	PCBs[2]	PAHs[3]	Organochlorine Pesticides[4]
2010	Spring Point, South Portland	✔	✔	✔	✔	✔	✔	✔			✔	✔
2011	East End Beach, Portland				✔		✔					✔
	Mill Creek, Falmouth											
2012	Spring Point, South Portland				✔		✔				✔	✔
2013	East End Beach, Portland				✔		✔					Not measured
2014	Mill Creek, Falmouth			N/A[5]		✔						Not measured
	Navy Pier, Harpswell			N/A[5]		✔						Not measured
	Mare Brook, Brunswick		✔	N/A[5]		✔						Not measured

Al: Aluminum   Fe: Iron   Cr: Chromium   Cu: Copper   Ni: Nickel   Pb: Lead   Zn: Zinc   Hg: Mercury   PCBs: Polychlorinated biphenyls   PAHs: Polycyclic aromatic hydrocarbons

[1] Elevated based on Gulf of Maine-wide Gulfwatch 85th percentile value, i.e., 85% of samples fall below the 85th percentile value (GOMC 2009)

[2] Sum of 35 PCB congeners

[3] Sum of 19 PAHs

[4] Sum of organochlorine pesticides

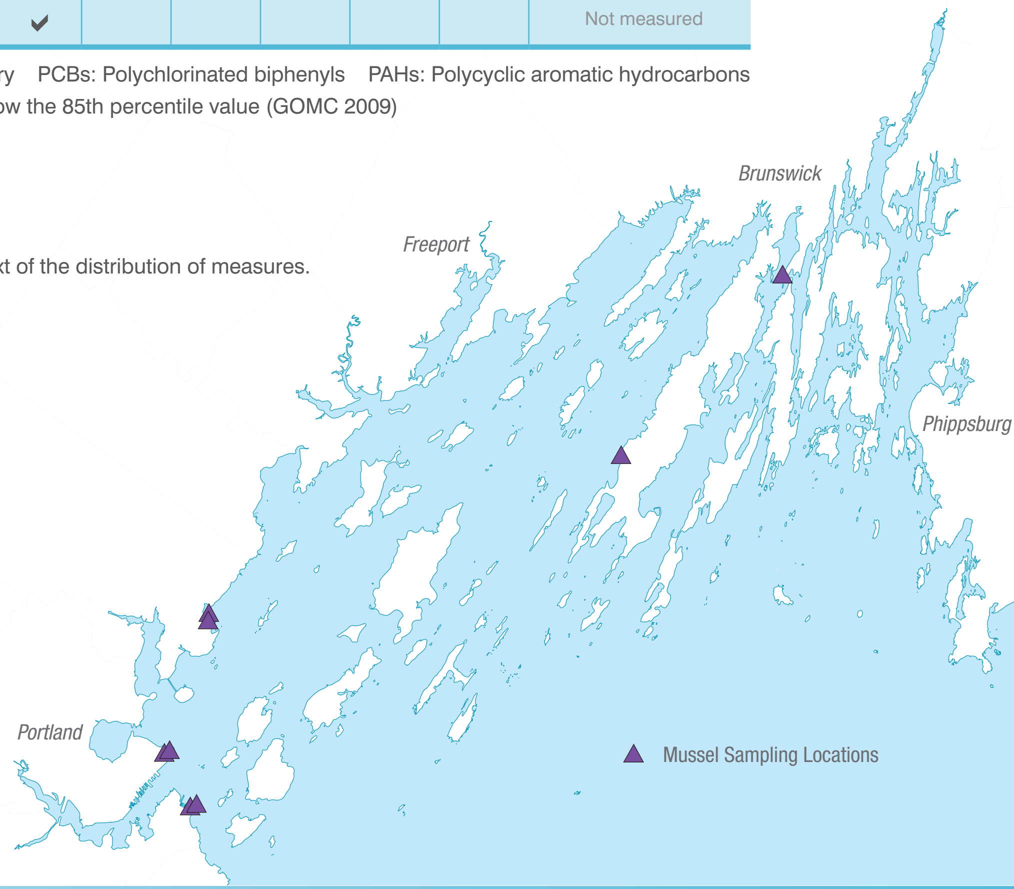
[5] Data not available pending additional data-quality checks.

All data are compared to the Gulfwatch 85th percentile (GOMC 2009) to provide a geographic context of the distribution of measures.

Most Shellfish Sampled Appear Safe for Human Consumption

The SWAT monitoring program's recent tests reveal that most of the shellfish sampled from Casco Bay are generally safe for human consumption. This statement is based on levels of mercury and PCBs compared to a risk-based standard for human health (based on shellfish consumption)† and not on levels of indicator bacteria, which is governed by the National Shellfish Sanitation Program (NSSP).

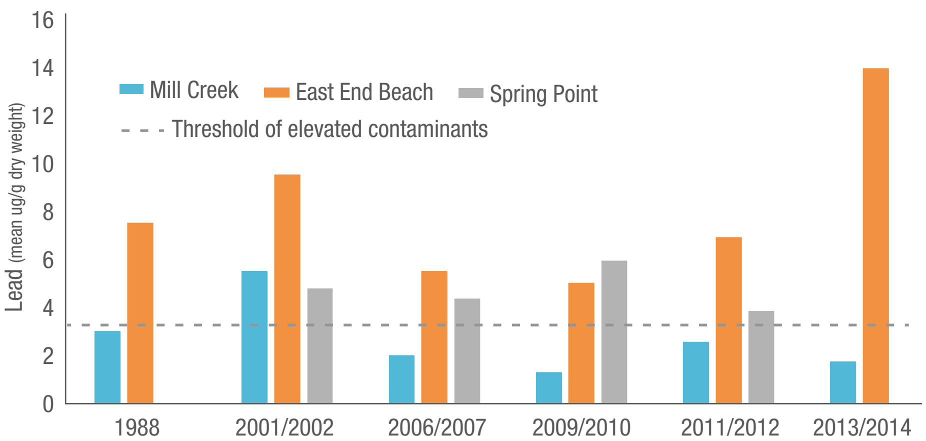
† This standard set by the Maine Center for Disease Control and Prevention was recently rescinded. It is used here because the SWAT program continues to use it in reporting (since no alternative standard has been adopted).



Mussels at Three Sites Reveal Consistently Elevated Lead Concentrations

Contaminant levels of Casco Bay mussels have been tracked for more than two decades at three sites: Mill Creek in Falmouth, East End Beach in Portland, and Spring Point in South Portland.

For lead, values fluctuate but both East End Beach and Spring Point consistently exceed the Gulf of Maine 85th percentile value.



Lead concentration in mussels at three sites in Casco Bay

Concentrations of lead in mussel tissue are also compared to the health-based threshold called the Fish Tissue Advisory Level (FTAL; 0.6 ug/g wet weight) set by the Maine Center for Disease Control and Prevention. Mussels from East End Beach (near both the Portland Wastewater Treatment Facility outfall and the outlets of the Presumpscot River and Back Cove) have consistently exceeded the FTAL (range 0.8 to 2.1 in 2007, 2009, 2011 and 2013); mussels from Spring Point in South Portland equaled or barely exceeded the FTAL (range 0.6 to 0.7 in 2007, 2010 and 2012); and mussels from Mill Creek in Falmouth (a smaller estuary with less surrounding development) have not exceeded the FTAL.

State Begins Testing for PFCs

In 2013, the Maine Department of Environmental Protection replaced testing for organochlorines with perfluorinated compounds (PFCs), a class of organofluorines that are considered "emerging contaminants of concern." These compounds, used in industrial and commercial products such as Scotchguard and Teflon, are highly persistent, mobile and distributed worldwide. Some of them are associated with cancer and endocrine disruption in humans and wildlife. At the one site sampled in 2013 (East End Beach), measurements of 11 out of 12 individual PFCs were below detection limits. In 2014, 11 out of 13 individual PFCs were below detection at two of the blue mussel sites sampled. PFCs were not detected in any clam samples in 2013.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Researchers Anticipate Increased Climate Stressors

Casco Bay Estuary
PARTNERSHIP

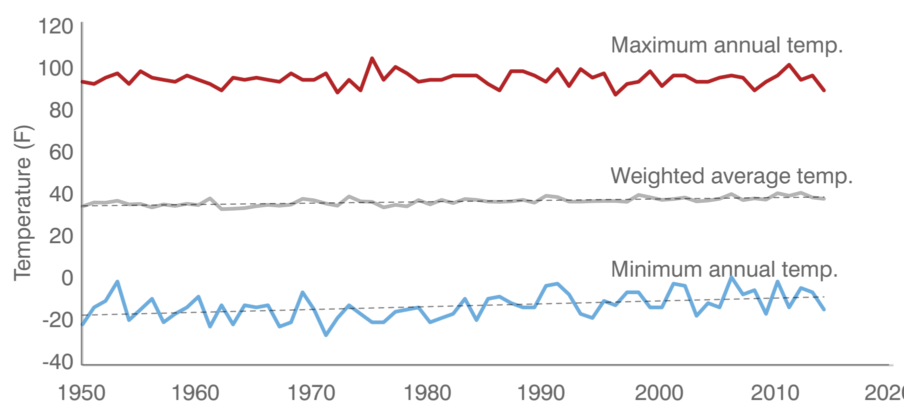
Increasingly, climate change is the inescapable backdrop for all other forces affecting the health of Casco Bay. Warming waters increase vulnerability to water-quality problems and invasive species, intensifying storms exacerbate stormwater runoff pollution, and rising seas transform the shoreline.

Air and Water Temperatures Increase

Regional air temperatures are predicted to rise between 2° and 6°F by mid-century, and according to a *Science* article in press, the Gulf of Maine warmed faster between 2004 and 2013 than 99 percent of the global ocean (Pershing 2015). Water temperatures in Casco Bay have increased about 3°F since the mid-1990s.

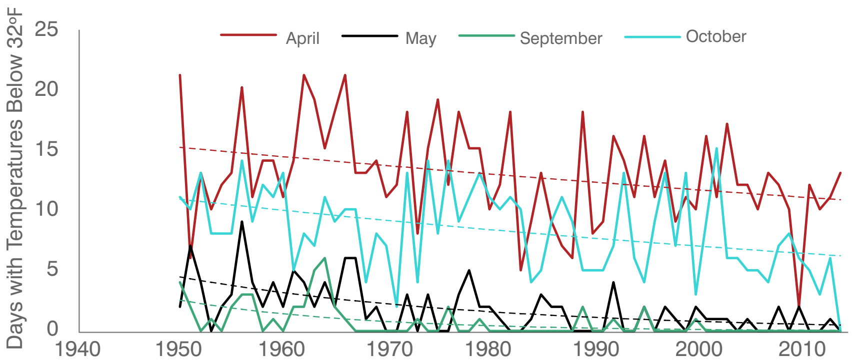
Historical data for the Portland Jetport from the National Centers for Environmental Information (NCEI 2015) confirm that air temperatures have been increasing gradually for decades. The greatest change appears in cold temperatures, with weaker effects on warmer weather. By almost any measure, the region's winters are warmer than they were a generation ago.

Annual average temperatures have climbed slowly, at a rate of about 0.65°F each decade over the past 65 years. Annual minimums have climbed more than twice as fast, rising 1.3°F every ten years. Over the same period, maximum temperatures show no consistent trend.



Annual minimum, average, and maximum temperatures at Portland Jetport

Rising minimum temperatures have reduced the number of freezing days and very cold days, especially in spring and fall. Overall, the number of very cold days (with temperatures below zero) has also declined (data not shown).

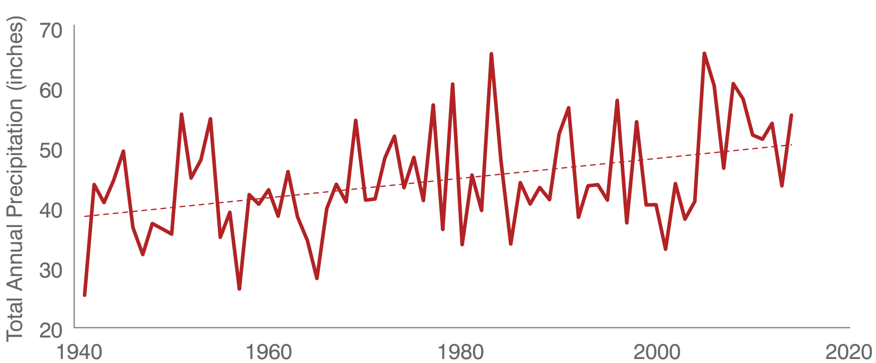


Fewer freezes in spring and fall

More Frequent and Intense Precipitation

Data from the Portland Jetport (confirmed by the *2015 Update of Maine's Climate Future*) show that Maine is experiencing increases in both annual precipitation and extreme precipitation events. These increases raise concerns about flooding, damage to infrastructure such as culverts, increased discharges from Combined Sewer Overflows, and greater stormwater runoff impacts.

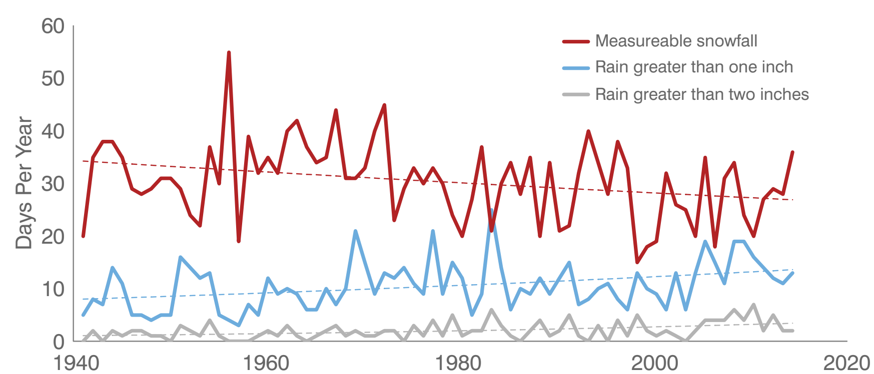
Historical weather data show a long-term trend toward increasing total annual precipitation, with an average increase (including both rain and the water equivalent of snowfall) of about one inch every six years.



Total annual predipitation, Portland Jetport 1941–2014

NASA

Intense storms are becoming more frequent: the expected number of days with more than 1 inch of rainfall increased from 8 in the early 1940s to 13 in the 2010s (and a similar increase is evident in number of days with more than 2 inches of rain). Intense rain events typically occurred about once a year in the early 1940s, but are now occurring in Portland about three times a year. Snowstorms (days with measurable snowfall) have declined about 20 percent in the past 65 years as more winter precipitation arrives as rain.



Storms and snowfall

Corey Templeton

Substantial increases in sea level will cause increased coastal flooding, erosion, and infrastructure damage. While Casco Bay's steep, mostly rocky shoreline could moderate some of the more severe effects of moderate sea level rise, key community assets are still at risk.

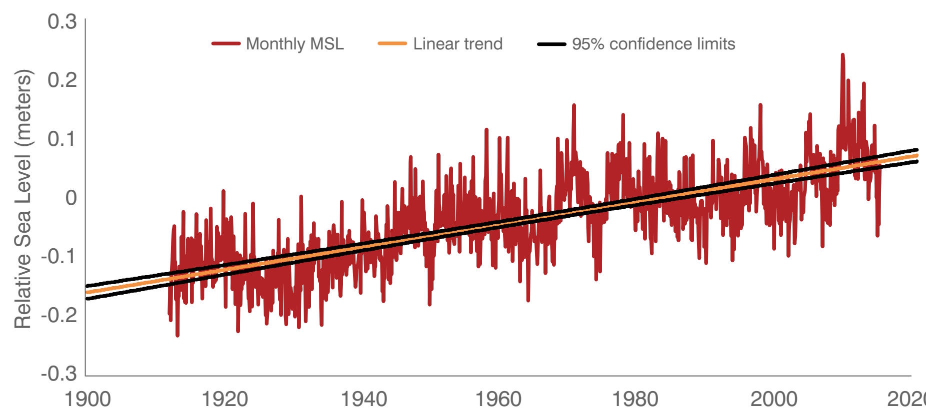
CBEP commissioned a study of flood risk in the Back Cove neighborhood of Portland (Merrill *et al*. 2012), which projected that flooding would cause hundreds of millions of dollars in cumulative damages by mid-century if no protective actions are undertaken. Significant portions of the Portland and South Portland waterfronts are similarly vulnerable. Even in the absence of sea-level rise, much of that damage remains likely due to storm surge—making short-term actions to protect infrastructure cost-effective.

Another CBEP study examined the vulnerability of Casco Bay's tidal wetlands to sea-level rise, finding that many wetlands could migrate into adjacent freshwater wetlands if faced with moderate increases in sea level.

Rising Sea Level Exacerbates Flooding Risks

Over the past century, Portland's tide gauge has shown an average annual increase in sea level of 1.9 mm per year (7.5 inches per century), close to global averages. The Maine Geological Survey currently estimates that Casco Bay will experience a 2- to 4-foot rise in sea level by the end of this century, implying rates that are more than three times higher. The U.S. Global Change Research Program makes similar projections for the northeastern US as a whole (Horton *et al.* 2014). While considered unlikely by many, the risk of a substantially faster rise in sea-level cannot be ruled out (Hanson *et al.* 2015).

A 2012 study found that flooding would cause hundreds of millions of dollars in cumulative damages by mid-century in Portland if no protective actions are undertaken.



Sea Level Trend, Portland Maine, 1912–2015. (Data show seasonally corrected average Mean Sea Level, MSL, from 1912 through 2015. Linear prediction and confidence limits based on NOAA analysis.)

Data: NOAA Center for Operational Oceanographic Products and Services 2015

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

Educational and Stewardship Initiatives Engage Citizens with Casco Bay

Melissa Smith, CBEP

Thousands of students within the Casco Bay watershed participate in marine and environmental education programs run by schools, nonprofits and agencies that seek to increase environmental literacy and promote sound stewardship.

Erin Love

A Spectrum of Bay-Related Educational Programs

Throughout the watershed, school-based, nonprofit and government-sponsored programs work to help residents understand Casco Bay, its significance to communities, and how human activities affect its health. These programs seek to increase environmental literacy; provide training in science, engineering, technology and math (STEM); connect learning across multiple disciplines; and enable students to engage in self-directed inquiry. Education programs can prompt behavioral changes and encourage volunteer stewardship efforts that have a positive impact on the Bay.

A sampling of current efforts suggests the breadth and variety of environmental education programs occurring in the Casco Bay region:

- Students from eleven area schools participate in Vital Signs, a Gulf of Maine Research Institute program that educates students and teachers on field research and data collection—helping them learn to document the presence of invasive species such as non-native plants or marine organisms. Student sightings are reviewed by volunteer taxonomic experts to confirm species identification.
- Portland Water District's Hydrologics program offers school visits and special programs such as TroutKids Program, in which students raise native brook trout in the classroom. PWD programs reach more than 2,500 students annually, many of whom visit the Sebago Lake Ecology Center.
- Cumberland County Soil and Water Conservation District offers a varied menu of classroom programs, funded by the District, CBEP and the Interlocal Stormwater Working Group. In the 2014–15 school year, its CONNECT program worked with 48 teachers to deliver lessons to 96 different classes, reaching 1,900 students in grades 3–12.

- Working with many partners, the City of South Portland has integrated educational programs into efforts to restore Trout Brook. High-school students, participating in a Youth Conservation Corps program, implemented a riparian planting project to improve water quality through two successive summers. Students at South Portland schools raise trout in the classroom and release them into the Brook.
- Coastal Studies for Girls provides a semester-long immersion program for sophomore girls from around the country focused on environmental research and leadership education.
- Harpswell Heritage Land Trust runs family outings, a weekly "rain or shine" hiking group for families, after-school programs, summer camps and community seminars.
- Maine Audubon runs preschool programs, summer camps, and vacation day camps at Gilsland Farm in Falmouth.
- Rippleffect provides a wide range of experiential education programs at Cow Island in Casco Bay and on the mainland.
- Friends of Casco Bay has created a curriculum, *Casco Bay through Time*, to help students from middle school through high school and beyond understand local impacts of climate change—such as warming ocean temperatures, sea-level rise and ocean acidification.
- In 2014–2015, CBEP sponsored an Island Institute AmeriCorps Fellow to promote environmental education in Casco Bay island schools. In addition, CBEP hired an intern through the Island Institute Island Scholars Program to lead a summer nature camp in which children on Long Island explored different habitats and learned about ecological principles.

No such listing of programs can ever be complete as new programs and projects continually evolve. The Casco Bay region is home to many educational institutions that support active, engaged learning—whether expeditionary learning (*e.g.,* Casco Bay High School and King Middle School), experiential learning (*e.g.,* Coastal Studies for Girls), or service learning (*e.g.*, the seventeen Maine college campuses working together as the Maine Campus Compact).

Stewardship

It is even more difficult to track Bay-related volunteer and stewardship opportunities although these abound and appear more common than in the past. Numerous land trusts, conservation commissions and nonprofit organizations now encourage their members to give back to their communities and to the Bay through events such as beach cleanups and work days, or through long-term monitoring commitments.

Volunteer monitors not only collect data to help examine long-term changes (see the Bay Water Quality indicator), they get to know local waters, see changes first-hand, and advocate on behalf of the Bay. Friends of Casco Bay has run an exceptional volunteer water-quality monitoring program for more than 20 years, collecting data from 35 sites or more each year. Presumpscot River Watch has successfully coordinated volunteer water-quality monitoring for more than a decade.

Recognizing that stewardship often stems from recreational enjoyment, CBEP recently helped the Presumpscot River Watershed Coalition compile and publish a fold-up waterproof *Presumpscot River Paddling Map & Guide* that celebrates the river's ongoing recovery and showcases its cultural and natural assets. This collaborative project involved the City of Westbrook, Town of Falmouth, SAPPI, Friends of the Presumpscot River, Presumpscot Regional Land Trust, Portland Trails, Presumpscot River Watch and others, with grant support from the Maine Outdoor Heritage Fund.

CBEP is working with area residents and the Wells National Estuarine Research Reserve to expand volunteer-based monitoring of invasive marine organisms through the Marine Invader Monitoring and Information Collaborative (MIMIC), which has recently begun monitoring efforts on Peaks, Long and Chebeague Islands. It also helped establish the Casco Bay Invasive Species Network (CBISN), a regional network of conservationists, land managers, and others dedicated to awareness and management of non-native invasive species in and around Casco Bay. CBISN hosted a Field Academy in the summers of 2014 and 2015 to expand the number of environmental managers knowledgeable about invasive species.

For additional references and information, please view the Bibliography of the full *State of the Bay 2015* report at www.cascobayestuary.org/state-of-the-bay-2015.

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