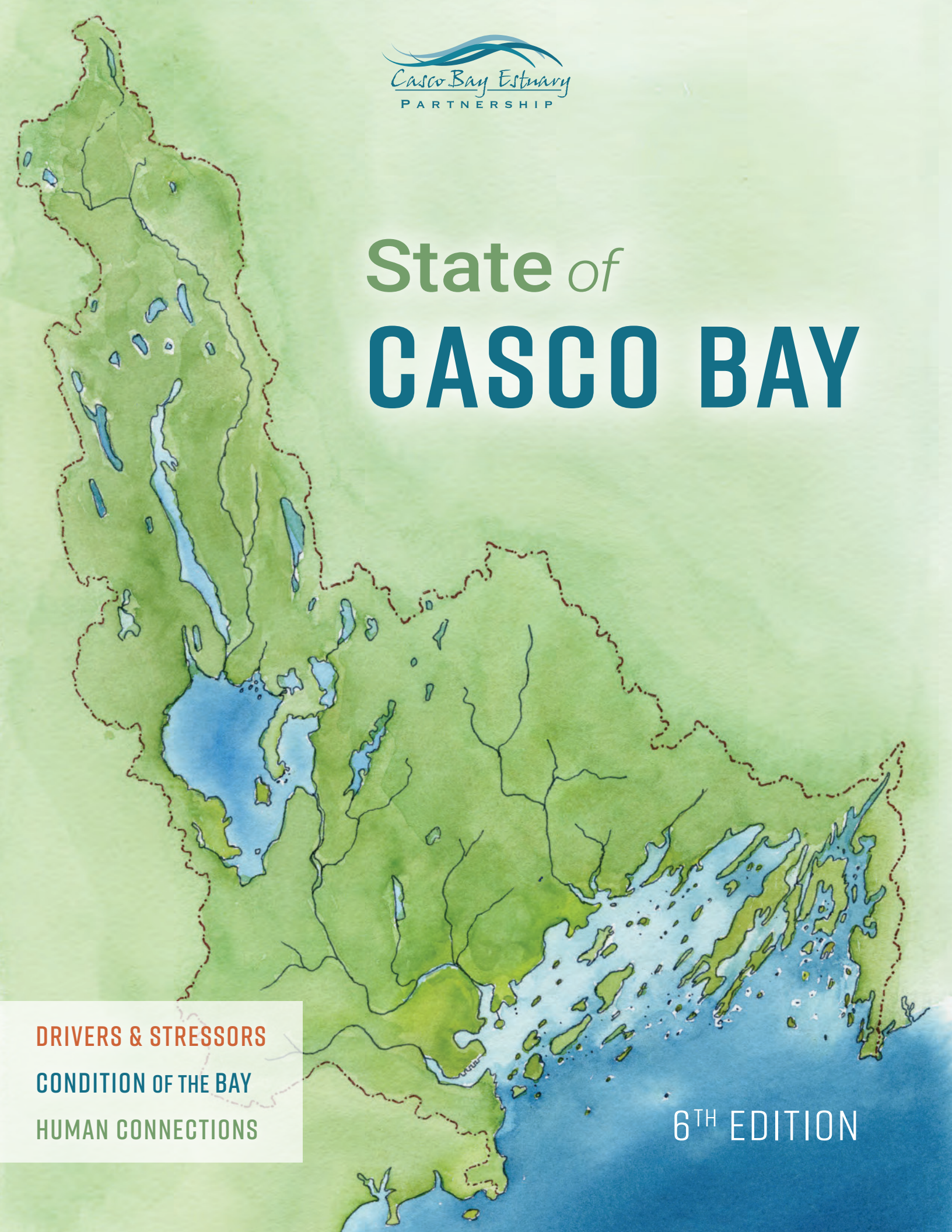
Casco Bay Estuary Partnership

State of CASCO BAY



DRIVERS & STRESSORS

CONDITION OF THE BAY

HUMAN CONNECTIONS

6TH EDITION

Casco Bay Estuary Partnership

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CONTRIBUTORS AND REVIEWERS

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CUTLER INSTITUTE
MUSKIE SCHOOL OF PUBLIC SERVICE

The mission of Casco Bay Estuary Partnership is to help conserve the ecological integrity of Casco Bay and its watershed through science, public stewardship, and effective management.



CASCO BAY

160 square miles of water

575 miles of shoreline

785 islands, islets, and ledges

13 coastal municipalities

Tidally dominated estuary receiving fresh water from Presumpscot River, Royal River, Kennebec River (indirectly), and 31 smaller tributaries

CASCO BAY WATERSHED

985 square miles

Touches **48** municipalities from Bethel to Saco (north to south) and from Lovell to Phippsburg (west to east)

Has **4.4%** of Maine's land area but:
25% of population
32% of employment
39% of GRP

Northward view of Casco Bay from Cape Elizabeth (Shutterstock)

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Casco Bay Generally Healthy—but Experiencing Dramatic Changes

EVERY FIVE YEARS, CASCO BAY ESTUARY PARTNERSHIP gathers and analyzes the best available data on water quality, land use, habitat coverage, and other key indicators to assess the Bay's health. We present the findings in State of the Bay reports that share vital information used by stakeholders and decision-makers to protect and enhance the condition of the Bay.

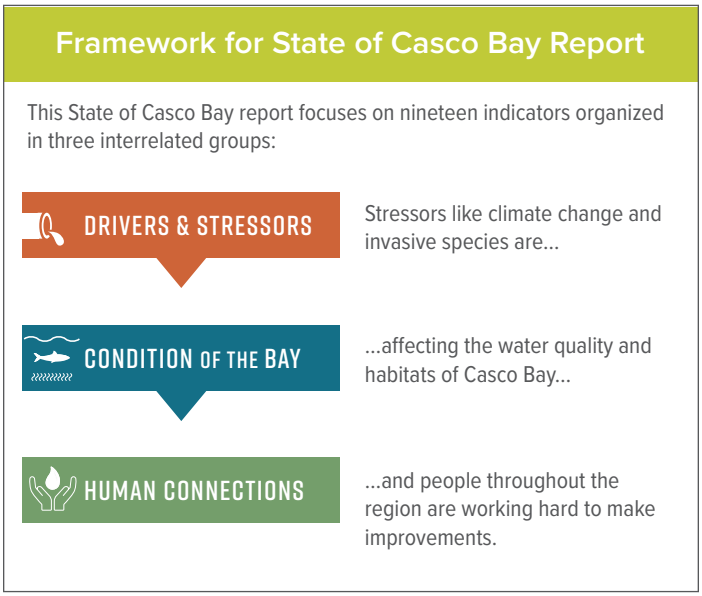
The initial State of the Bay report in 1992 came just one year after Congress designated Casco Bay as an Estuary of National Significance, leading to establishment of the Casco Bay Estuary Project (now Partnership). Like all the reports that followed, it identified critically important resources in Casco Bay and looming challenges to the Bay's health, providing a foundation of information for people to take action.

This report—*State of Casco Bay*, 6th Edition—marks nearly thirty years of science and monitoring efforts that have greatly improved understanding of the Bay and documented three decades of change. It presents findings for nineteen indicators organized in three groups: Drivers & Stressors, Condition of the Bay, and Human Connections. Together, these interrelated indicators provide a framework for understanding the causes and outcomes of change in the Bay and for implementing effective solutions.

State of Casco Bay, 6th Edition contains several indicators that were not included in earlier State of the Bay reports. Over time, these new indicators have grown in importance, demonstrating the need for continual vigilance to detect and understand ecological dynamics in the Bay.

On the whole, Casco Bay continues to be remarkably healthy as it enters the 2020s, compared to many other U.S. estuaries, testament to the dedicated efforts of many individuals and organizations. Yet major changes are under way that warrant a timely response to protect the Bay and the many people whose livelihoods and quality of life depend on it.

We now live in a greatly altered climate that contributes to emerging global challenges such as invasive marine species, warming waters, sea level rise, and coastal acidification. Meanwhile, local issues identified decades ago like stormwater runoff, bacterial contamination of tidal flats, and barriers to migration of anadromous fish still pose major challenges.



The Dashboard of Key Findings on the next page highlights a few of the most noteworthy changes that we found in our data analysis. We encourage you to read the entire report to get a comprehensive sense of the "State of Casco Bay."

The information contained in this report—along with the knowledge, practices, and relationships fostered through the Casco Bay Estuary Partnership over the last thirty years—enables all of us to work toward solutions that will benefit everyone who lives, works, and recreates around the Bay.

In continuing partnership,

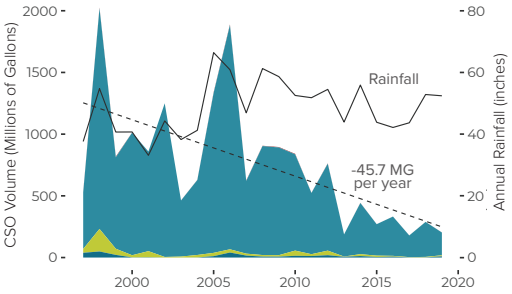


Curtis Bohlen, Executive Director
Casco Bay Estuary Partnership

Dashboard of Key Findings

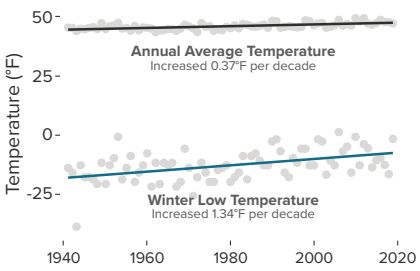
C. Combined Sewer Overflows (p. 7)

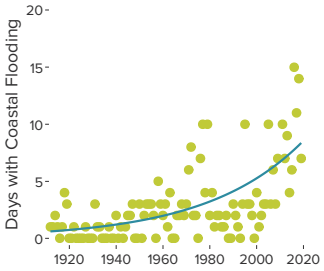
Polluted discharges from CSOs **dropped 80%** over two decades.



E. Climate Change (p. 13)

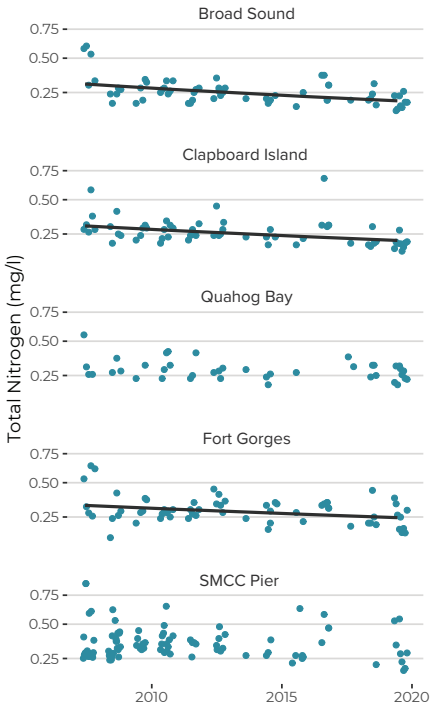
Air temperature **increased** and coastal flooding became **more frequent** during the past century.





H. Nutrients (p. 19)

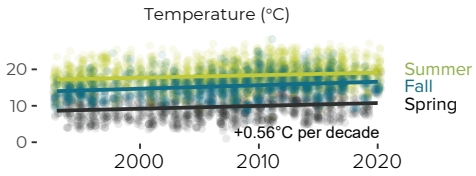
Total nitrogen **declined** at three of five sites with long-term data...



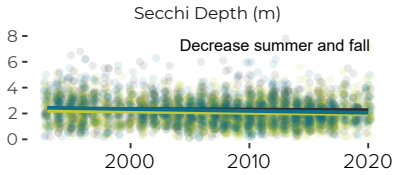
...signaling **improvements** in water quality.

G. Bay Water Quality (p. 17)

Water temperatures **increased** more than 1.6°C (about 3°F) since 1993...

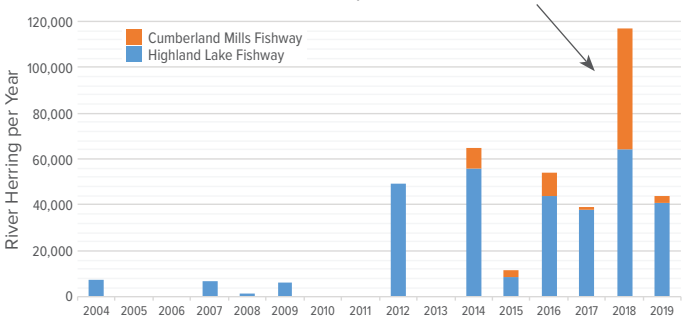


...and water clarity (Secchi depth) **dropped** slightly.

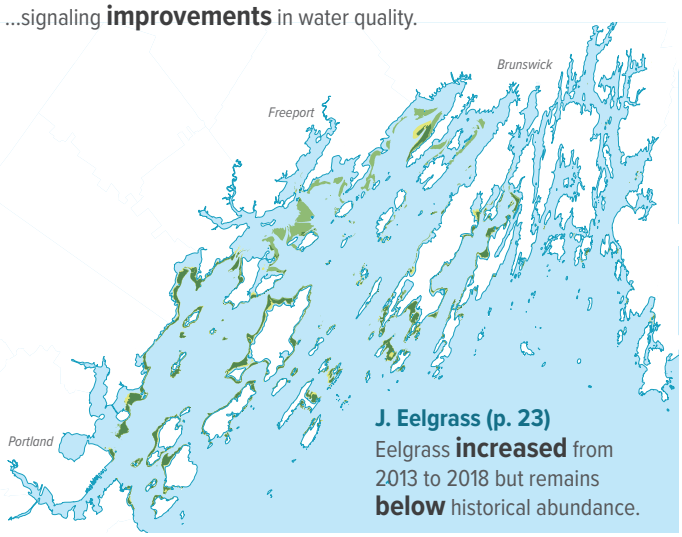


I. Aquatic Connectivity (p. 21)

Sea-run fish are **regaining** access to the Presumpscot River watershed...



...but **relic dams** block fish from swimming up the Royal River, Stroudwater River, and some coastal streams.

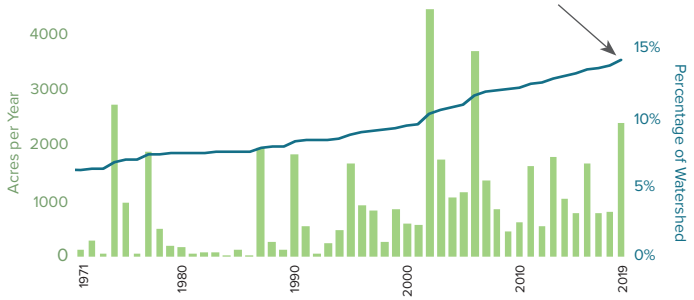


J. Eelgrass (p. 23)

Eelgrass **increased** from 2013 to 2018 but remains **below** historical abundance.

N. Conserved Lands (p. 33)

14.2% of the Casco Bay watershed is permanently conserved.





New Suburban Construction Eats into Forests and Agricultural Lands

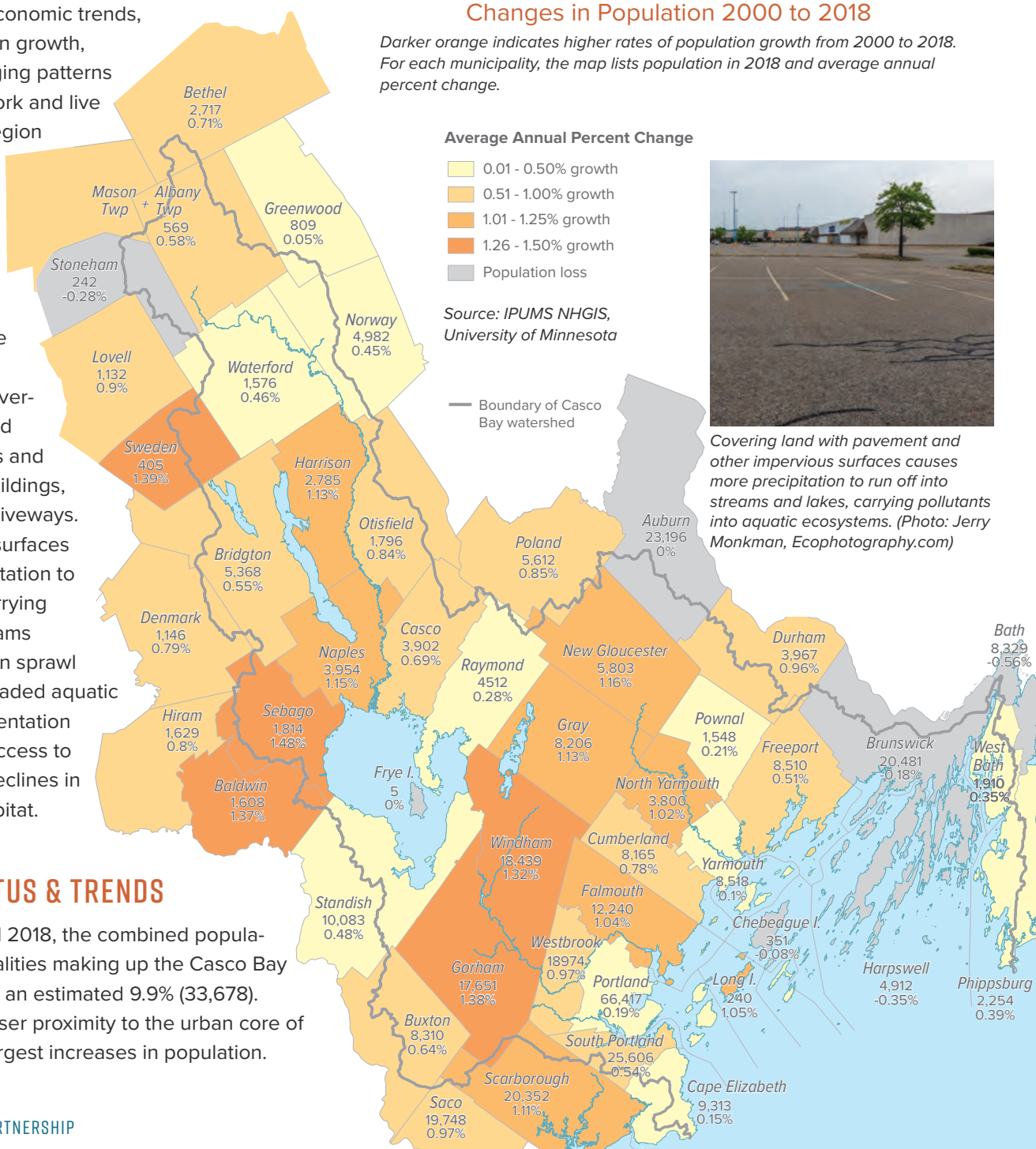
Population of Casco Bay Watershed Grew Nearly 10 Percent in 18 Years

WHY IT MATTERS

Broad social and economic trends, including population growth, contribute to changing patterns in where people work and live in the Casco Bay region and, in turn, the intensity of human impacts. Many environmental stressors affecting the Bay stem from changes in land use in the watershed, particularly the conversion of undeveloped areas such as fields and forests to roads, buildings, parking lots, and driveways. These impervious surfaces cause more precipitation to run off the land, carrying pollutants into streams and lakes. Suburban sprawl contributes to degraded aquatic ecosystems, fragmentation of forests, loss of access to open space, and declines in fish and wildlife habitat.

Changes in Population 2000 to 2018

Darker orange indicates higher rates of population growth from 2000 to 2018. For each municipality, the map lists population in 2018 and average annual percent change.

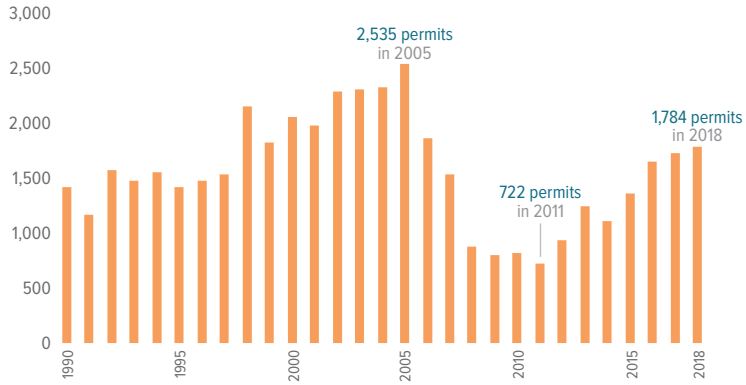


Covering land with pavement and other impervious surfaces causes more precipitation to run off into streams and lakes, carrying pollutants into aquatic ecosystems. (Photo: Jerry Monkman, Ecophotography.com)

STATUS & TRENDS

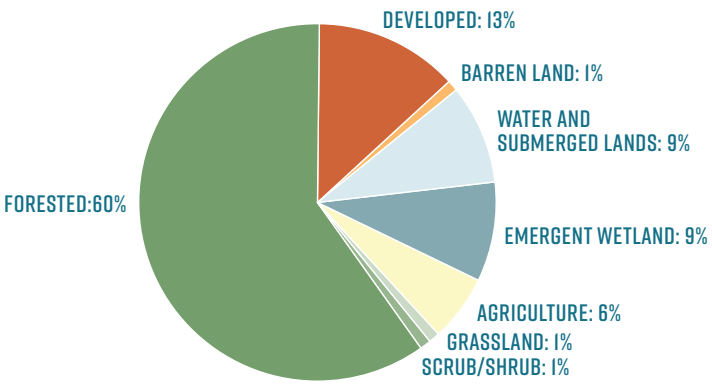
Between 2000 and 2018, the combined population of the municipalities making up the Casco Bay watershed grew by an estimated 9.9% (33,678). Communities in closer proximity to the urban core of Portland had the largest increases in population.

Rebound in Residential Building Permits
(All Watershed Towns and Cities)



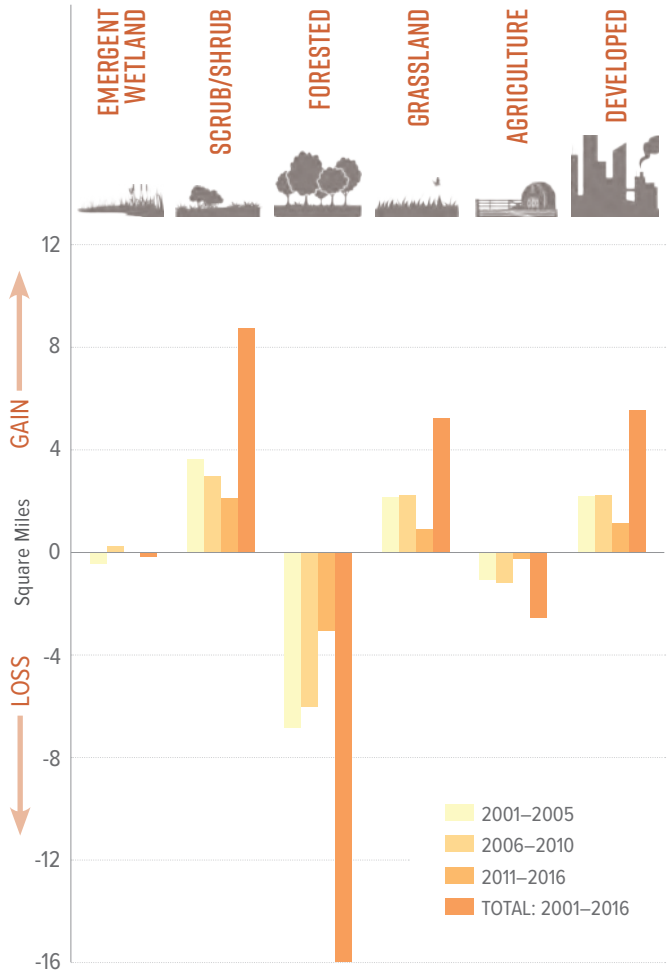
After hitting a low of 722 total units in 2011, residential housing permits rebounded annually from 2011 to 2018, when total units reached 1,784. Source: U.S. Department of Housing and Urban Development, Office of Policy Development and Research, State of the Cities Data Systems.

Land Cover in Casco Bay Watershed: 2016



Land cover classification Casco Bay watershed. Source: National Land Cover Database.

Loss of Forested and Agricultural Land, Increase in Developed Land: 2001–2016



In a continuation of recent trends, the total area of forested and agricultural lands in the watershed declined by 3.35 square miles from 2011 to 2016. The total area of developed lands expanded by 1.13 square miles.

SUCCESSES & CHALLENGES

- Individual towns and cities have been successful in applying Smart Growth approaches to balance economic growth and development with agricultural, forestry, open space, and other community values, but home-rule decision making results in irregular regional growth and development patterns.
- Many land use planning and conservation tools such as comprehensive planning, open space planning, conservation subdivision design, and wetland and shoreland zoning are available to guide local development while protecting water quality and habitat. Casco Bay communities can choose where and how to direct growth through planning and land use ordinances.
- Within the region, ample opportunities exist for redevelopment in growth areas and for allowing increased density to accommodate development that does not expand impervious surfaces. However, regulations aimed at restoring impaired water bodies may create disincentives for doing so.
- Many challenges such as urban sprawl and traffic congestion are regional in nature, but towns handle solutions quite differently. Better support and funding for regional planning is greatly needed to provide technical assistance on a regional level for issues related to transportation and open space planning.



Stormwater Runoff Degrades Water Quality in Urban Streams

Salt from Winter Deicing Products Poses a Threat to Urban and Suburban Waters

Jerry Monkman, Ecophotography.com

WHY IT MATTERS

"Stormwater" refers to runoff that occurs during and soon after rain or during snow melt events. Runoff from roads, parking areas, lawns, and other urban areas carries contaminants, including sediments, petroleum products, toxic metals, winter deicing products, pesticides, fertilizers, human and animal waste, bacteria, and pathogens. In addition, stormwater running off hot pavement in the summer increases temperatures in nearby streams, leading to lower dissolved oxygen levels. In urban or developed areas, stormwater not only adds pollutants, but changes runoff amount and timing. Because rain cannot soak into the ground through roads, parking areas, or roofs (known collectively as "impervious surfaces"), runoff comes fast, increasing risk of flooding, eroding stream channels, and damaging aquatic habitat. Between storms, urban streams are often starved of water, and can even dry completely. The combination of pollutants, warmer water, and disruption of flow adversely affects fish and other aquatic organisms.

STATUS & TRENDS

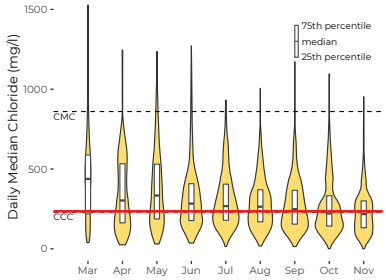
As shown in the Inland Waters section of this report, many Casco Bay streams that do not meet water quality standards are found in urban areas. Long-term data on water quality in urban streams, however, is limited.

The Long Creek watershed includes about three and a half square miles in Portland, South Portland, Westbrook, and Scarborough. It encompasses the Maine Mall and many other businesses, such as hotels, medical facilities, restaurants, and retail stores. Approximately thirty percent of the watershed is impervious surfaces. Less than three percent of subwatersheds in the Casco Bay region have a higher level of imperviousness.

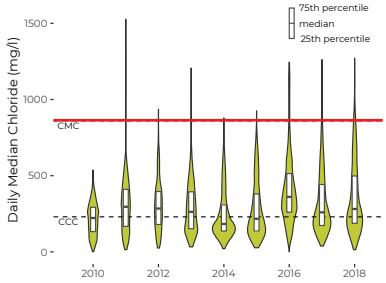
The Long Creek Watershed Management District (LCWMD) has been monitoring water quality in Long Creek for a decade. LCWMD's data provides the most complete record of urban water quality in our region. It documents pollutants in Long Creek such as metals, nutrients, and chlorides, as well as changes in temperature, dissolved oxygen, and flow. Conditions in other urban streams are likely to be similar.

Winter Salt Runoff Affects Freshwater Streams

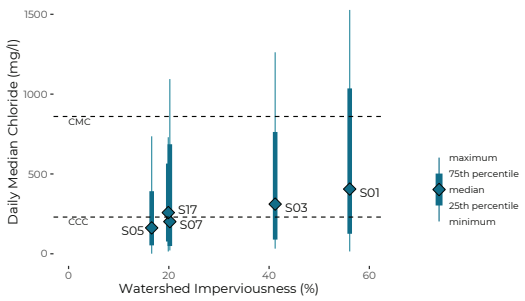
Salt used to remove ice and snow from roads and parking areas eventually enters streams, where it can be toxic to freshwater organisms. In the graphs below, salts are measured as chlorides.



Daily median chloride concentration in Long Creek from 2010 through 2018 exceeded chronic exposure limits (CCC) over half the time. Conditions are generally at their worst in the spring, or under low-flow conditions. (Width indicates number of observations.)



Chlorides above acute thresholds (CMC) occurred nearly every year. Although some recent years, such as 2016, have been especially bad, no long-term trend is evident. Year-to-year variability is likely caused by variation in rainfall and stream flow.



Impervious surfaces contribute to high chlorides. Even within the Long Creek Watershed, monitoring locations with more impervious surfaces upstream (draining subwatersheds with relatively more roads and parking) tended to have higher chloride concentrations over the period of record (2010-2018).

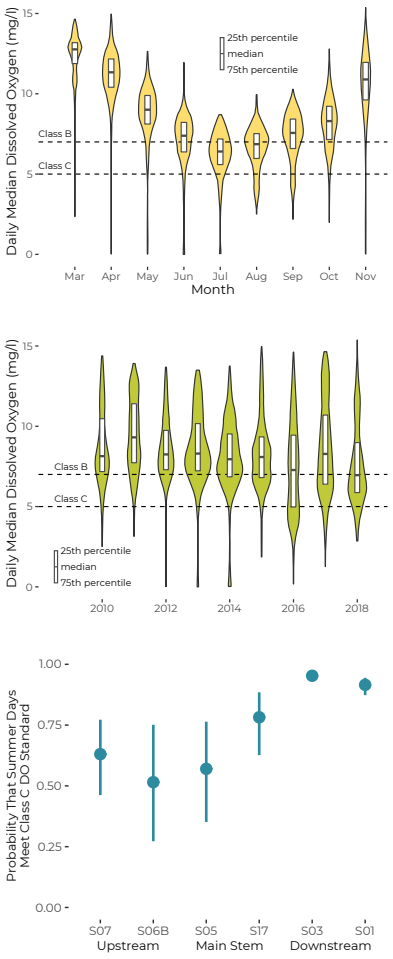
Declining Dissolved Oxygen Levels

Fish and other aquatic organisms require adequate levels of dissolved oxygen in order to thrive. Low levels cause stress, and at very low levels aquatic organisms may suffocate.

Top: From 2010 through 2018, Long Creek had low dissolved oxygen conditions most commonly during the summer months. While low oxygen conditions (below Maine's Class C water quality standard) are uncommon, even brief periods of low or no dissolved oxygen can be devastating to aquatic organisms.

Middle: Dissolved oxygen levels in Long Creek have declined slightly over the last ten years, and the probability of violating the Class C standard during the summer increased. Both trends are statistically robust despite high year-to-year variability. Low oxygen is especially likely under low flow conditions and during hot weather, but variation in weather alone does not explain the trend.

Bottom: Downstream sites were more likely to pass the Class C oxygen standard during the summer from 2010 to 2018. Conditions at the upstream sites, where the stream is small, have been especially bad in years with low stream flow, like 2016. Where the stream is small, the water warms fast on hot days, especially when flow is limited. Under very warm conditions, lower oxygen solubility and higher rates of respiration and decomposition reduce oxygen levels. (Graphic shows modeled daily probability and 95% confidence intervals, adjusted for sampling history.)



SUCCESSES & CHALLENGES

- Reducing the thousands of tons of salt put on roads and parking areas in Maine each winter could save money and protect streams. Public expectations for winter travel and concern about accidents and injuries provide incentives for continued high use. Solutions have proven elusive.
- Much of our region's urban and suburban landscape lacks modern stormwater infrastructure because it was constructed before standards to minimize risks to water quality. High cost of "retrofitting" stormwater treatment in urbanized areas slows efforts to address water quality problems. Better practices are now required at the state and local level for new construction and redevelopment, but widespread implementation will only happen over a long period of time.
- "Low Impact Development" for new construction, which uses practices that mimic or preserve natural drainage processes to manage stormwater, can reduce flooding and improve water quality. This approach can also provide community amenities like playing fields, recreational trails, and landscaping. Although some municipal ordinances encourage the practice, adoption in the Casco Bay region has been slow.
- The City of Portland in 2016 established a "Stormwater Service Charge" to help defray costs of managing stormwater and combined sewer overflows. The City bases service fees on a property's impervious cover, which correlates to the amount of runoff generated from each property. Funds cover both costs of running stormwater programs and capital investments in infrastructure to reduce water pollution.

MUNICIPAL STORMWATER: MS4 PERMIT PROGRAMS

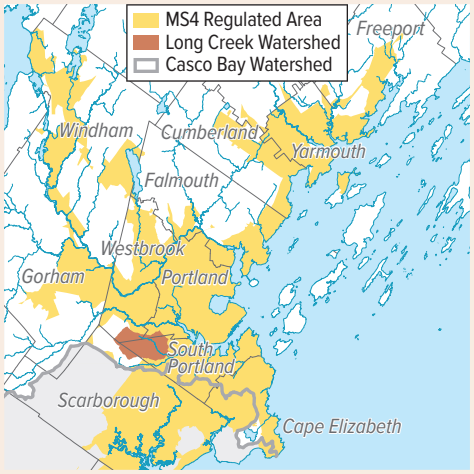
Stormwater finds its way to streams through a system of catch basins, storm sewers, drains, swales, chambers, ditches, ponds, and other conveyances. This oft-forgotten infrastructure–if up to date, and properly designed and constructed–can reduce flooding and protect water quality. While some of this system is privately owned, most is the responsibility of cities and towns.

The Clean Water Act regulates discharge of stormwater, addressing Municipal Separated Storm Sewer Systems (MS4s). Under the MS4 program, municipalities take steps to reduce water quality impacts of stormwater, including public education, reducing stormwater pollution from municipal operations, and passing ordinances to reduce runoff from construction sites. MS4 programs play a significant role in protecting water quality. In the Casco Bay region, the Interlocal Stormwater Working Group coordinates implementation, reducing community costs and helping improve water quality.

Currently, eleven Casco Bay watershed communities have MS4 programs. Requirements are tied not to municipal boundaries or to intensity of land use, but to designation by the U.S. Census of an "urbanized area". Following the 2020 census, additional towns in the region may fall within official urban areas, and thus be required to implement an MS4 program.

MS4 Programs in Casco Bay Watershed

Cape Elizabeth, Cumberland, Falmouth, Freeport, Gorham, Portland, Scarborough, South Portland, Westbrook, Windham, Yarmouth



Orange indicates MS4 regulated areas. Some municipalities have elected to apply similar policies to reduce stormwater pollution town-wide rather than only within regulated areas.



Community Investments Have Reduced Pollution from Combined Sewer Overflows (CSOs)

Discharges from CSOs Dropped by Eighty Percent Over Two Decades

WHY IT MATTERS

The term "combined sewer overflows" refers to discharges of untreated or partially treated mixtures of sewage and stormwater into rivers or the Bay after rainstorms, imperiling water quality and public health.

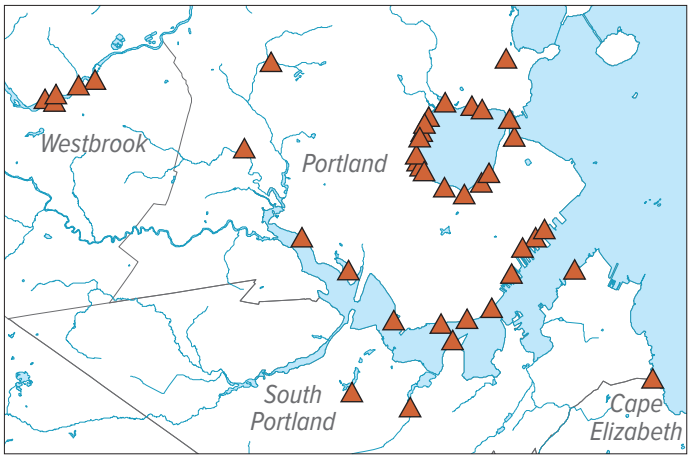
When sewer systems were built in the Casco Bay watershed, even as late as the mid-twentieth century, it was common to install pipes that collected a combination of sewage and rainwater, and discharged the mixture into nearby waters. Today, those pipes (if they have not been replaced) normally carry the combined sewage and rainwater to a wastewater treatment plant instead. Heavy rainfall, however, can overwhelm the capacity of the sewer system or the wastewater plant, leading the overflow to be discharged—pollution and all—directly into a waterbody. Combined sewer overflows (CSOs) are therefore regulated, and municipalities are required to make progress reducing discharges.

Fixing this problem is challenging and expensive. Communities must build parallel stormwater and sanitary sewer systems (known as “sewer separation”), redesign combined sewers, or build underground tanks to store large volumes of combined waters after storms, which are then released gradually to wastewater treatment facilities.

STATUS & TRENDS

CSO volumes have, on average, declined 7.5 percent each year across the Casco Bay watershed over the past two decades. Portland, South Portland, Westbrook, and Cape Elizabeth had permitted CSOs in 2019. Portland accounted for most CSOs, by volume, events, and locations. All four communities and Portland Water District are working to reduce CSO discharges.

CSO Outfall Locations



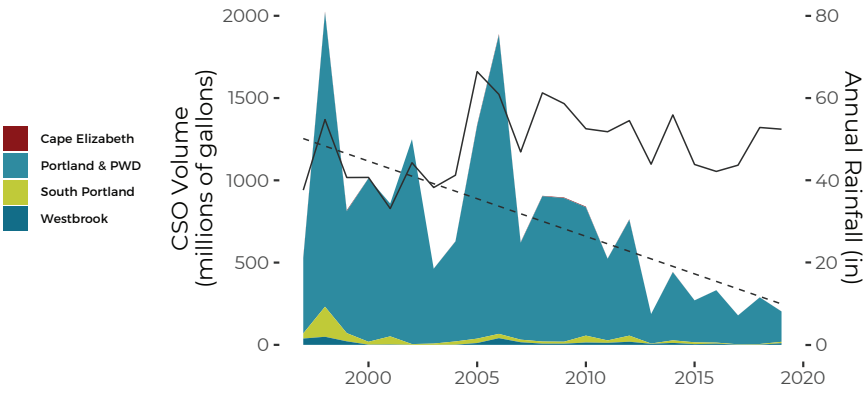
In 2019, 40 CSO outfalls were classified with an "active" permit status. Some of these active outfalls, however, have been remediated or eliminated and have not discharged CSO effluent in several years.

Number, Volume, and Reductions of Combined Sewer Overflows (CSOs)

COMMUNITY	STORMS WITH MEASURABLE CSO DISCHARGES 2019	PERMITTED OUTFALLS 2019	CSO VOLUME 2019 (MILLIONS OF GALLONS)	PERCENT REDUCTION 1997-1999 VS 2017-2019
Cape Elizabeth	2	1	0.4	93%
Portland and Portland Water District	46	30	184.5†	78%
South Portland	3	4	8.7	95%
Westbrook	4	5	9.8	88%
TOTAL	N/A‡	**40**	**203.4**	**80%**

†This value does not include “bypass” wet weather flows at the East End Wastewater Treatment Facility, which receive primary treatment and disinfection.
‡ A total is not applicable in this column because the same storm may cause CSO discharges in multiple communities.

Decrease in CSO Volumes in Casco Bay Watershed

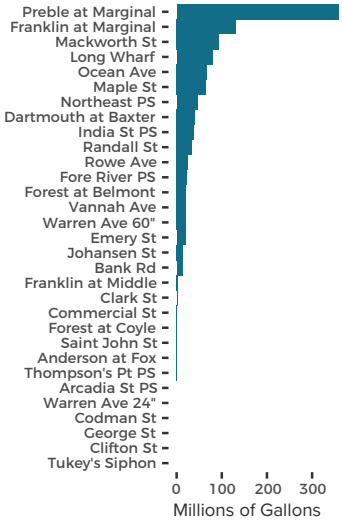


Above: Annual CSO volumes in the Casco Bay watershed have declined approximately 80 percent over a period of two decades. The improvement reflects long-term investments by communities with CSOs. Years with high CSO volumes tend to correspond to years with high rainfall as measured at the Portland Jetport. Yarmouth had permitted discharges until 2002, but they were too small to be visible on this graph.

Right: Over the past five years, 44 percent of Portland's CSO discharge volume has passed through the two most significant CSO outfalls at Preble Street and Franklin Street. The city's Back Cove South CSO Storage facility, under construction in 2021, is designed to catch and store up to 3.5 million gallons of CSO effluent, principally from those two outfalls.

Source: PWD

Portland CSO Volumes by Site



SUCCESSES & CHALLENGES

- Portland Water District (PWD) has a sophisticated monitoring system that tracks CSO volumes in real time at many outfalls. PWD staff use the data to identify emerging problems and improve operations of the sewer systems.
- Despite the rising costs of remediation and some delays in implementing State-mandated Long-Term Control Plans, Casco Bay communities have made substantial progress over the past twenty years in reducing CSOs, and progress looks likely to continue.
- Current plans call for continued investment of tens of millions of dollars in CSO abatement but not closure of all CSOs. Costs to eliminate the last few climb rapidly, and greater water quality benefit may be achievable by investing in other water quality solutions.
- A primary goal of the CSO abatement effort has been to remove CSO discharges from small streams. Portland accomplished that for Fall Brook but still has CSO outfalls in Capisic and Nasons Brooks. South Portland still has a CSO outfall to Barberry Creek and one to Calvary Pond. Elimination of CSO outfalls to these vulnerable waters remains a priority.
- In 2019, wet weather bypass flows at Portland's East End Wastewater Treatment Facility—which receive partial treatment, including disinfection, and so pose a lower human health risk—were nearly 1.3 times the CSO volumes. For comparison, the facility's total permitted discharges of treated wastes are twenty-five times greater.

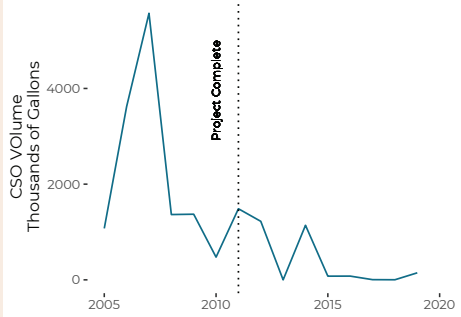
WESTBROOK PROJECTS REDUCE DISCHARGES TO PRESUMPSCOT RIVER

Two projects completed in 2011 by the Portland Water District (PWD) in Westbrook reduced CSO volumes with good engineering. The projects took place at the Warren Avenue and Dunn Street CSO regulators. Both of those CSOs discharge to the Presumpscot River and ultimately to Casco Bay.

The Warren Avenue project replaced an eight-inch combined sewer with an eighteen-inch alternative able to handle larger flows. Since completion of the project, the site has experienced a 77 percent decrease in CSO volumes, with no overflow events recorded since 2013.

The Dunn Street project replaced an eight-inch pipe with a sixteen-inch pipe. A related structure, known as a weir, was elevated by two feet. The weir prevents sewage or runoff from entering the Presumpscot River under normal flow conditions and allows flow to be conveyed to the treatment facility.

Dunn Street CSO Discharges



Discharges from the Dunn Street CSO dropped 85 percent after a larger pipe was installed and the weir modified.



Weir inside a large Portland CSO. Weirs prevent CSO discharges under low-flow conditions. (Photo: PWD)



Most Lakes and Streams Meet Water Quality Standards

Urban Waters More Likely to Have Poor Water Quality

Jerry Monkman, Ecophotography.com

WHY IT MATTERS

The Casco Bay watershed includes all lands and waters that drain to Casco Bay. The watershed is linked hydrologically and ecologically, from headwaters to the Bay. Flowing waters transport wood, sediment, and other materials downstream, carving the valleys and shaping the stream channels that provide habitat for aquatic organisms. If rivers and streams are healthy (and unblocked by dams or other barriers) they allow fish, aquatic insects, and other animals to move from bay to river to lake and back again.

If water quality is poor, however, not only can pollutants be transported downstream to the Bay, but those long-distance ecological linkages can be disrupted, lessening the ecological integrity of our waters, including the Bay. Both direct and indirect effects of poor water quality in the watershed make our lakes, rivers, and the Bay more vulnerable to other stressors, including climate change.

The fresh waters of the Casco Bay watershed are a major economic asset. Our lakes, rivers and streams support boating and recreational fisheries. Our region's healthy waters underpin a robust tourism economy. Sebago Lake provides drinking water to more than 200,000 people in Portland and the surrounding region.

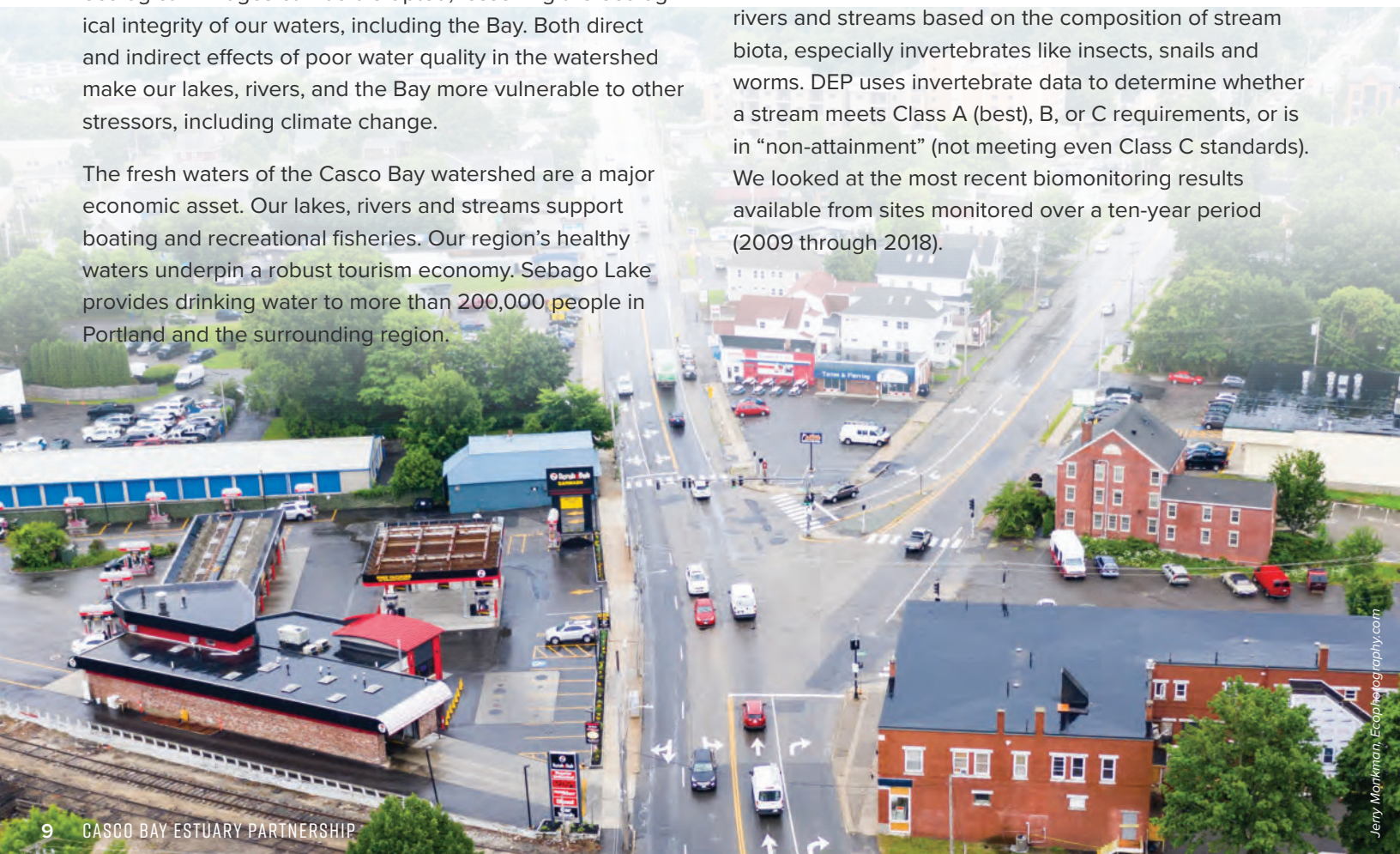
STATUS & TRENDS

Lakes, Rivers, and Streams

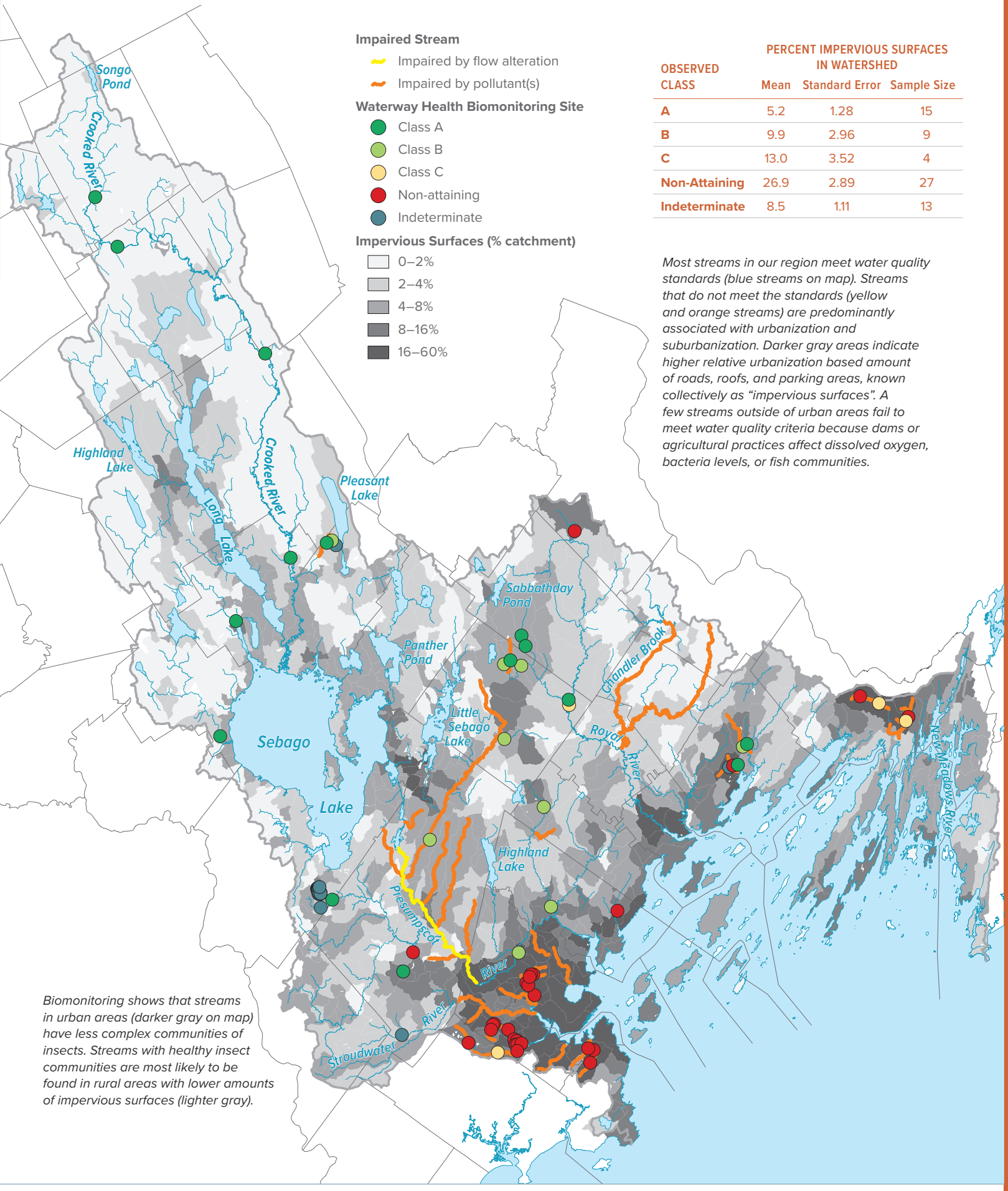
Under Maine law, every body of water must meet water quality criteria, specific to the "designated uses" associated with the waterbody's assigned water quality class. For example, lakes, rivers, and streams must have sufficient dissolved oxygen to support healthy insect and fish communities. Waters that do not meet related standards are labelled as "impaired".

Biomonitoring

The Maine Department of Environmental Protection (DEP) has developed statistical tools to evaluate the health of rivers and streams based on the composition of stream biota, especially invertebrates like insects, snails and worms. DEP uses invertebrate data to determine whether a stream meets Class A (best), B, or C requirements, or is in "non-attainment" (not meeting even Class C standards). We looked at the most recent biomonitoring results available from sites monitored over a ten-year period (2009 through 2018).



Jerry Monkman, Ecophotography.com



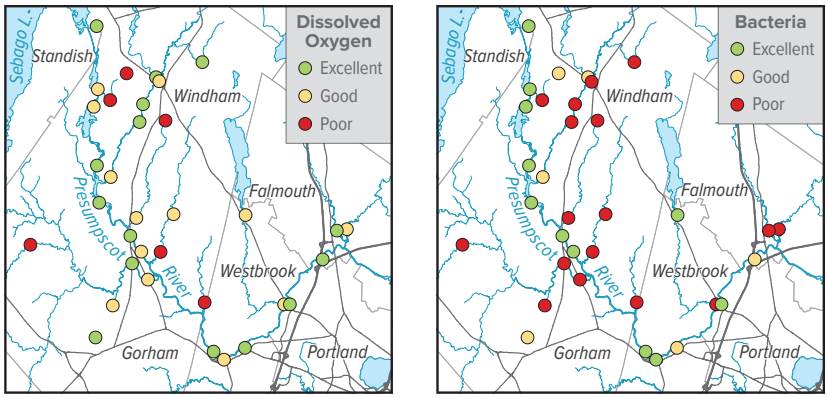
OBSERVED CLASS	PERCENT IMPERVIOUS SURFACES IN WATERSHED		
	Mean	Standard Error	Sample Size
A	5.2	1.28	15
B	9.9	2.96	9
C	13.0	3.52	4
Non-Attaining	26.9	2.89	27
Indeterminate	8.5	1.11	13

Most streams in our region meet water quality standards (blue streams on map). Streams that do not meet the standards (yellow and orange streams) are predominantly associated with urbanization and suburbanization. Darker gray areas indicate higher relative urbanization based amount of roads, roofs, and parking areas, known collectively as "impervious surfaces". A few streams outside of urban areas fail to meet water quality criteria because dams or agricultural practices affect dissolved oxygen, bacteria levels, or fish communities.

Biomonitoring shows that streams in urban areas (darker gray on map) have less complex communities of insects. Streams with healthy insect communities are most likely to be found in rural areas with lower amounts of impervious surfaces (lighter gray).

Presumpscot Region River Monitoring

A dedicated group of volunteers, led by Presumpcot Regional Land Trust (PRLT), monitors water quality in the Presumpscot River and its tributaries. Data on dissolved oxygen and bacteria levels were collected regularly from over thirty sites from 2015 to 2019.

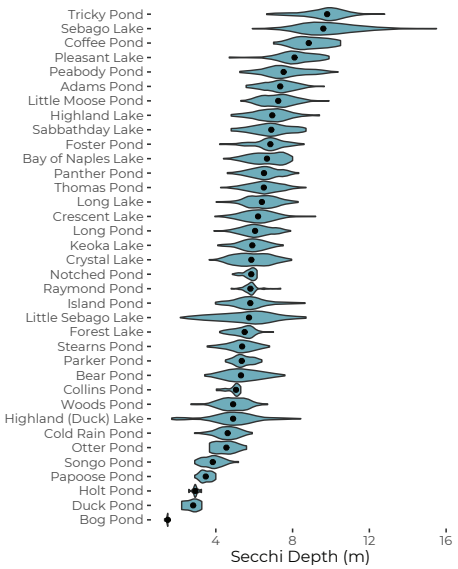


The PRLT data shows that instances of poor levels of dissolved oxygen (left map) are uncommon, but elevated bacteria levels (right map) are widespread. When compared to State water quality criteria, conditions at most sites along the main stem of the Presumpscot and Pleasant Rivers usually have acceptable levels of dissolved oxygen and meet bacteria criteria. Several tributaries have persistent problems with low dissolved oxygen, and most show elevated levels of E. coli *bacteria. Elevated bacteria levels pose a potential health risk, especially to swimmers. (Excellent: Meets class A/B standards almost always. Good: Meets Class C standards almost always).*

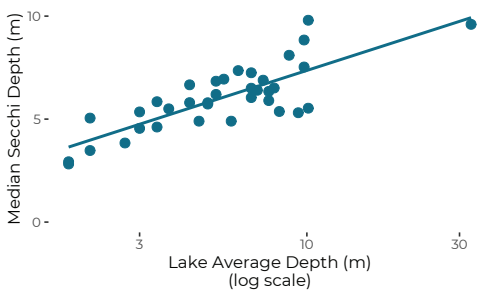
Lakes and Ponds

Maine has a long history of monitoring lake water quality, with data for some lakes extending more than 40 years. Much of the data has been collected by volunteers working with lake associations or regional monitoring networks. DEP aggregates and curates lake data, releasing it to the public. (Data on recent conditions in Sebago Lake were provided directly by Portland Water District.)

Monitoring practices vary from lake to lake, and have changed over time, so not all water quality indicators are available for all lakes, or for long enough to evaluate trends. Most monitoring programs, however, have long collected Secchi depth data. Secchi depth measures relative water clarity based on how deep an observer can see a dinner plate-sized disk—the greater the Secchi depth, the more transparent the water. Tens of thousands of observations have been collected from waterbodies in the region. The length of the record varies for each lake, with only a few recent samples for Duck and Bog Ponds, and thousands collected over decades from our most heavily studied lakes.



Lakes and ponds in the Casco Bay watershed generally have clear waters. Over the past ten years, median Secchi depths for all but four lakes in the region for which data are available were over four meters (about 13 feet). (Blue shapes show relative amount of observations at different Secchi depths for each lake.)



Above: Water clarity is related to lake size, especially depth. Deeper lakes tend to have clearer water. The larger volume of deep lakes can absorb a greater load of nutrients, without showing water quality problems, making the lake more resistant to pollution. Larger lakes also tend to have larger watersheds with a high percentage of intact forest, which naturally filters water as it flows to the lakes, thus reducing nutrient inputs to the lake.

Right: Water clarity in most lakes in our region has been stable or improving slowly. Secchi depths in more than half the lakes in our region have improved over the past ten years. Longer-term (more than fifteen years) conditions have improved in just under half. Only five lakes show evidence of declining water clarity.

	WATER QUALITY TREND	
LAKE	Short Term (<10 year)	Long Term (>15 year)
Adams Pond	Improving	No Change
Bay of Naples Lake	No Change	No Change
Bear Pond	Improving	No Change
Bog Pond	No Change	No Data
Coffee Pond	No Change	Improving
Cold Rain Pond	No Change	No Change
Collins Pond	Improving	No Change
Crescent Lake	No Change	No Change
Crystal Lake	Improving	Improving
Crystal Lake	Improving	No Change
Duck Pond	No Change	No Data
Forest Lake	No Change	Improving
Foster Pond	Declining	No Change
Highland (Duck) Lake	Improving	Declining
Highland Lake	Improving	Improving
Holt Pond	No Change	No Change
Island Pond	Improving	No Change
Keoka Lake	Improving	Improving
Little Moose Pond	No Change	No Change
Little Sebago Lake	Improving	Improving
Long Lake	Improving	Improving
Long Pond	Improving	Improving
Notched Pond	Improving	Improving
Otter Pond	No Change	Improving
Panther Pond	Improving	No Change
Papoose Pond	No Change	Improving
Parker Pond	Declining	No Change
Peabody Pond	Improving	No Change
Pleasant Lake	Improving	No Change
Raymond Pond	No Change	Declining
Sabbathday Lake	Improving	Improving
Sebago Lake	Improving	No Change
Songo Pond	Improving	Improving
Stearns Pond	Improving	Improving
Thomas Pond	Improving	Improving
Tricky Pond	No Change	Declining
Woods Pond	Improving	Improving

A LAKE VULNERABILITY INDEX

Portland Water District (PWD) provides drinking water to over 200,000 people in the Portland region. Sebago Lake's excellent water quality requires less treatment than other lakes, which reduces the cost of distributing safe drinking water to PWD's customers. If Sebago Lake's water quality were degraded, PWD would have to invest tens of millions of dollars in additional treatment facilities, causing higher water rates.

Like other drinking water providers that rely on surface water, PWD works to protect water quality by addressing upstream threats. But the Sebago Lake watershed is about 440 square miles in area. Thus PWD partners with many other organizations (including Casco Bay Estuary Partnership) to combine watershed protection efforts.

If each subwatershed above Sebago Lake is protected, then Sebago Lake itself is likely to remain healthy. One way to prioritize watershed protection, therefore, is to look at each lake in the region and prioritize projects that can benefit lakes that are most vulnerable. But how do we know which lakes are most vulnerable?

Several years ago, PWD (working with University of Southern Maine, the Maine Department of Environmental Protection, and the Cumberland County Soil and Water Conservation District) developed an index of lake condition and vulnerability. The index is based on evaluation of water quality and land use, considering both existing conditions and long-term trends.

PWD's Lake Index shows clearly that conditions for some lakes are more concerning than for others. Each lake is ranked from 1 (worst) to 5 (best) in each of four categories, with 20 being the highest overall score or index. (Blanks show where indexes could not be calculated because of insufficient data; assumed equal to 3 for calculating totals). The eight lakes with the lowest index are seeing rapid conversion of forests, which help protect water quality, to other land uses.

	Existing WQ	WQ Trend	Existing Land Cover	Land Cover Trend	Total Score
Peabody Pond	5	3	5	5	18
Little Moose Pond	5	3	5	5	18
Raymond Pond	4		5	5	17
Thomas Pond	4	5	4	3	16
Stearns Pond	3	4	5	4	16
Sebago Lake	5	3	4	3	15
Foster Pond	4	2	4	5	15
Pleasant Lake	5		4	2	14
Highland Lake	4	4	4	2	14
Crescent Lake	4		4	3	14
Cold Rain Pond	2		5	4	14
Bear Pond	3	2	4	5	14
Keoka Lake	4	3	3	3	13
Trickey Pond	5	1	4	2	12
Songo Pond	1	3	5		12
Panther Pond	4	1	4	3	12
Mcwain Pond	3	3	3	3	12
Woods Pond	2	4	4	1	11
Papoose Pond	1		5	2	11
Long Lake	4	3	3	1	11
Island Pond	3	3	3	1	10
Crystal Lake	3	3	3	1	10
Brandy Pond	4	3	2	1	10
Adams Pond	5	1	3	1	10
Otter Pond	1		4	1	9

SUCCESSES & CHALLENGES

- Our region has a large, diverse constituency for clean water, which supports efforts by organizations and state agencies to protect water quality. Lakes are safeguarded by lake or watershed associations and regional lake organizations. Boaters, anglers, hunters, hikers, and residents recognize the importance of our lakes, rivers, and streams. Businesses from tackle shops to hotels and real estate agencies benefit from clean water.
- All of Maine's fresh waters are polluted by trace levels of mercury, principally transported from coal-fired power plants in the Midwest. A national transition away from fossil fuels as our economy's primary energy source would not only reduce greenhouse gas emissions, but also mercury pollution in Maine.
- Forests and wetlands protect water quality. Close to two-thirds of the Casco Bay watershed remains forested, and the proportion of forested area inland is even higher. Water quality in many of our inland waters remains excellent.
- Replacement of forest with suburban and urban land degrades water quality. Thus expansion of Portland's suburban and exurban communities threatens water quality in our lakes and streams. That is true even if local communities follow regulations and policies designed to reduce the impact of suburbanization. Investing in forest conservation can help safeguard water quality for future generations.
- Natural wetlands and floodplains reduce flooding, protect water quality, and support stream ecosystems. Native floodplain trees and shrubs shade streams, cool the water and ensure a healthy supply of dissolved oxygen. They slow flood waters, protect the structural integrity of stream channels, and build stream habitat. Floodplain vegetation supports aquatic food webs by contributing food for aquatic insects, and also protects habitat for the terrestrial adult forms of many aquatic insects.


Jerry Monkman, Ecophotography.com



Maine's Climate Has Been Changing for Decades

Winters Have Become Warmer, and Rainfall More Intense, as Sea Level Has Risen and High Tide Flooding Increased

WHY IT MATTERS

As our climate changes, it will continue to shape the Bay, its people, communities, and natural landscape. Climate change will also exacerbate other ongoing issues such as water quality and habitat degradation. As storms become more severe, river towns and coastal communities are at greater risk of flooding. Increased rainfall delivers not only more fresh water but also more pollutants to the Bay, and warmer waters mean our lakes and the Bay are more vulnerable to those pollutants. Warming climate on land brings health risks, while a warming ocean shifts the range and abundance of marine organisms, changing fisheries and altering coastal economies. Gradually rising seas mean that monthly extreme high tides inundate waterfront infrastructure such as piers and coastal roads more frequently. Rising seas also threaten salt marshes, eelgrass beds, tidal flats, and other coastal habitats.

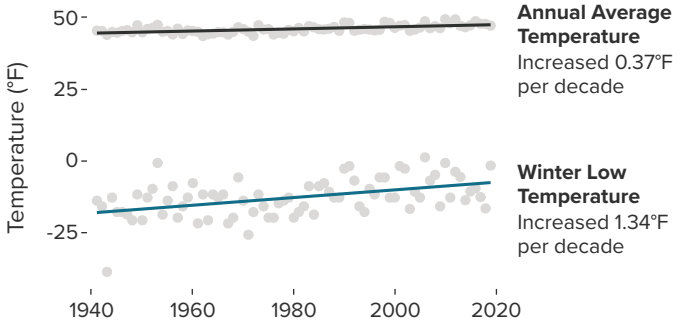
STATUS & TRENDS

A NOAA weather monitoring station set up eighty years ago at what is today the Portland International Jetport is still in operation, providing a decades-long record. While the record shows substantial year-to-year variability, long-term trends are clear. Overall, conditions are warmer, especially in the winter, and wetter than in the past. Ocean data collected over the past century at Portland Harbor show a rising sea level.



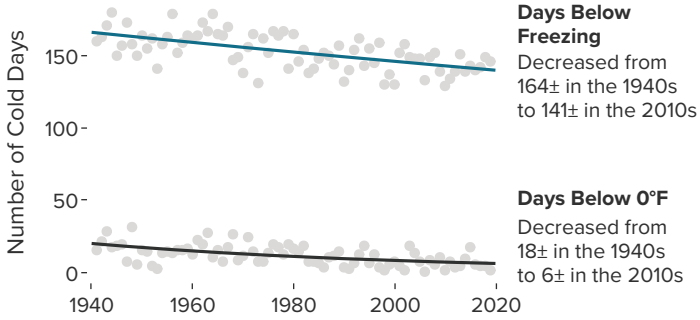
Sea level rise is making tidal flooding of coastal infrastructure much more frequent. Flooding is about three times more likely today than in the recent past. With only one more foot of sea level rise, it may become ten to fifteen times more common. (Photo: CBEP)

Warmer Years and Winters



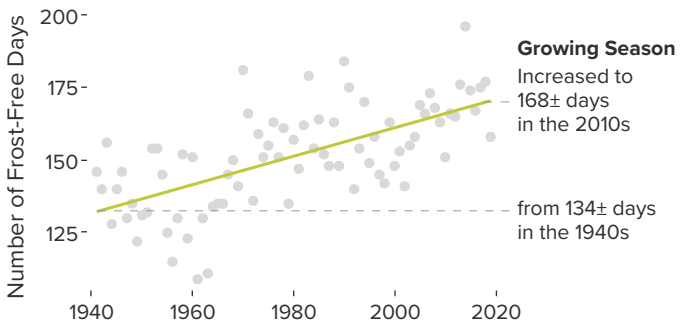
Annual average temperatures and coldest winter temperatures have become warmer over the last eighty years. Data on summer high temperatures indicated no change (not shown on graph).

Fewer Cold Days



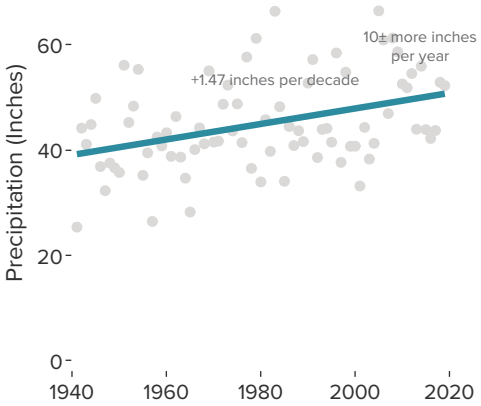
Days with cold temperatures are less common than in the past. Data on hot days (above 90°F) indicated no change (not shown on graph).

Longer Growing Season



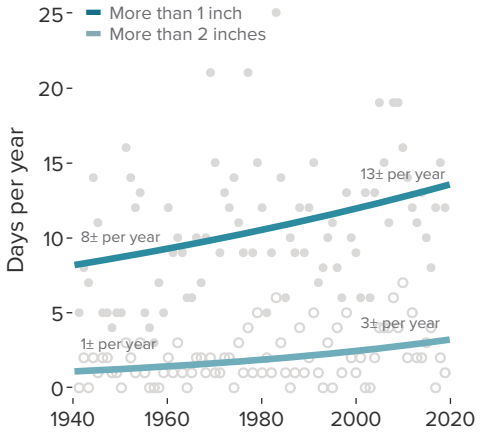
Our growing season (contiguous days that stay above freezing) has lengthened by about a month in eighty years.

More Annual Precipitation



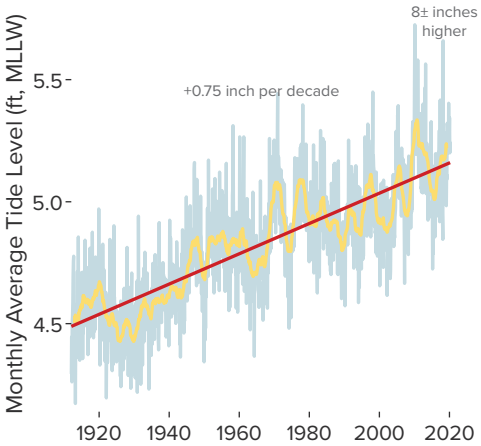
Total annual precipitation has increased gradually. A typical year gets about ten inches more rainfall now than in the middle of the twentieth century.

More Days of Heavy Precipitation



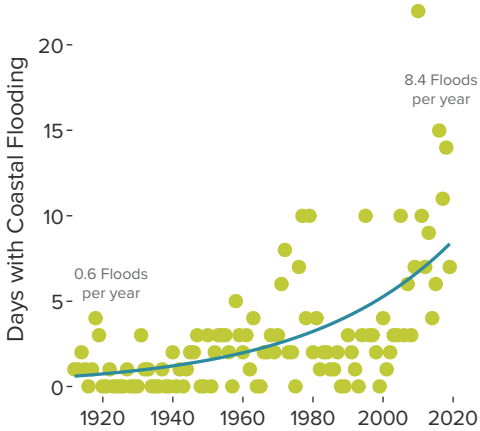
Big storms are more common now. Days with more than 1 inch (solid circles) or 2 inches (open circles) of precipitation happen more often. Extreme storms can occur even in years of average total rainfall.

Rising Sea Level



At Portland, sea level has risen about eight inches over a century, in line with global averages. Sea level rise has not been steady, with periods of increase interrupted by declines lasting several years. Scientists predict the rate of sea level rise will increase in coming decades.

More Days with Coastal Flooding



A century of moderate sea level rise has greatly increased the frequency of coastal flooding. Analysis suggests coastal flooding could be eight times more frequent still under an additional foot of sea level rise—meaning some sixty days of coastal flooding each year.

EFFECTS OF SEA LEVEL RISE ON COASTAL HABITATS

Coastal habitats occur in a narrow range of elevations. Eelgrass grows only in shallow water. Tidal flats form principally in the lower intertidal zone. Tidal marshes develop in the upper intertidal zone.

Sea level rise, therefore, will shift the location and size of coastal habitats; just how is an area of active research. Impacts of sea level rise depend on many factors, especially intertidal elevations and the rates of sea level rise and sediment accumulation.

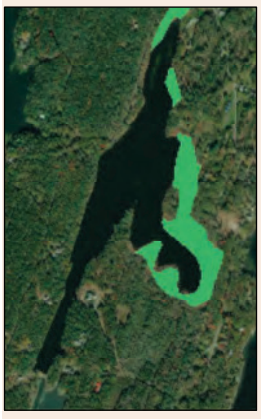
Researchers have looked carefully at the likely impacts of sea level rise on tidal marshes, yet studies of the effects on other coastal habitats lag.

Models suggest that, for most of this century, many of Casco Bay's larger tidal wetlands will “migrate” into adjacent freshwater wetlands and forests. Losses of tidal marsh to submergence and erosion at their seaward margins are likely to be more than balanced by expansion into adjacent low-lying areas. Elsewhere, rising seas will squeeze tidal marshes against steep slopes or developed areas, leading to losses.

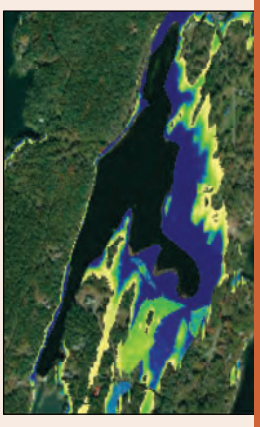
The net effect is difficult to predict and may depend on actions and polices that facilitate marsh migration. In particular, by protecting low-lying areas adjacent to tidal wetlands today, we can ensure that tidal wetlands have somewhere to expand into decades from now.

SUCCESSES & CHALLENGES

- Changes in Maine’s climate will continue for many decades and become more disruptive, particularly if global greenhouse gas emissions do not decrease. Under some scenarios, Maine’s climate at the end of the century may resemble the present-day climate of Maryland.
- The state, through the Maine Climate Council, is developing plans to reduce greenhouse gas emissions and to help Maine communities, businesses, and residents adapt to climate change.
- The cities of Portland and South Portland are leading local efforts to advance energy efficiency, alternative energy development, and adaptation to climate change through the One Climate Future initiative.
- Many costs of climate adaptation, such as emergency response, and repairing or upgrading infrastructure, will fall on municipalities, often already strapped for cash.



Existing Tidal Marsh (2015)



Probability of Tidal Marsh in 2100

Tidal marshes around Dan’s Ice Pond, in Harpswell, are likely to expand with sea level rise, potentially improving habitat, but putting infrastructure at risk.



Invasive Species Persist in a Warming Casco Bay

Tunicates Are Especially Abundant and May Displace Other Species

Wells NERR

WHY IT MATTERS

Invasive species are animals, algae, and other organisms that are not native to a region but arrive there through human activity and become self-sustaining. They may harm ecosystem processes, the economy, and public health.

The highly invasive European green crab, *Carcinus maenas*, was first observed in Casco Bay in 1905. It has become the dominant species of shore crab along the Maine coast, preying on soft-shell clams, uprooting eelgrass, and causing erosion in tidal marshes.

But other invasives are less noticeable. For example, small colonial tunicates and bryozoans grow abundantly as part of the "fouling communities" of organisms found on hard surfaces such as rocks, pilings, docks, and floats. While native species remain, many of the most abundant, colorful, and visible species are non-native arrivals. Some invasives grow on blades of eelgrass and kelp, impairing their growth.

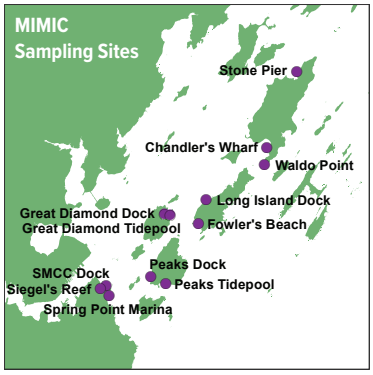


The European rock shrimp, Palaemon elegans*, is an infrequently observed but distinctive member of fouling communities in Casco Bay. Note blue color on appendages. (Photo: Wells NERR)*

Invasive species are often indicators of changing marine ecosystems. While many of the most harmful ones are native to Europe or Asia, other species turning up in our waters are from closer to home and are properly termed "range-shifters". For example, mid-Atlantic species such as the fiddler crab are expanding their ranges and may displace native species.

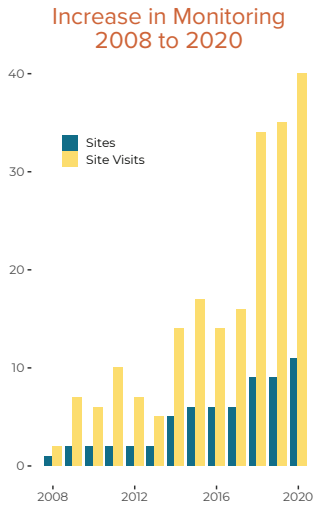
STATUS & TRENDS

The Marine Invader Monitoring and Information Collaborative (MIMIC) in Casco Bay is a partnership between CBEP and the Wells National Estuarine Research Reserve (Wells NERR). Wells NERR trains community scientists to identify 23 species of invasives, including tunicates, bryozoans, algae, and crustaceans.



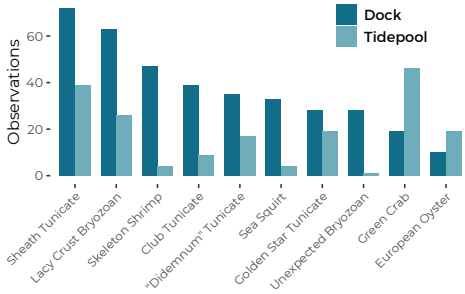
Community scientists visit floating docks at piers or marinas, and tidepools each month between May and October and document presence (and approximate abundance) of these species. The program began with two sites in Casco Bay in 2008 and has expanded to include twelve mainland and island locations (see map). Sampling on the islands began in 2014, when four volunteers sampled just two sites. In 2020, twenty-one volunteers sampled nine sites on four islands.

Among the most abundant non-native species are colonial or solitary tunicates (pictured at top of page), which are found more frequently on docks than in tidepools. Two species—*Didemnum vexillum* (present in Maine since approximately 1978) and *Diplosoma listerianum* (a recent arrival)—can grow over many other species and may become dominant at some sites.



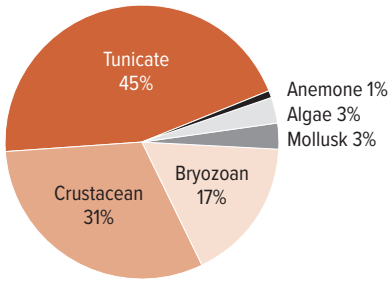
Monitoring sites and site visits have risen steadily since 2008.

Number of Observations by Major Taxon



Green crabs were found mostly in tidepools, where they are the most frequently observed non-native species. Docks and piers were dominated by tunicates and bryozoans. Data based on observations from 2016 to 2020 at all Casco Bay sites.

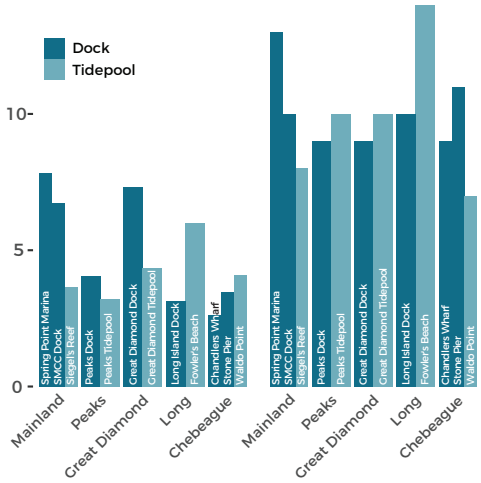
Percentage of Observations by Major Taxon



Of the 23 invasive species targeted by the MIMIC program, tunicates, which here includes six different species, are the most frequently observed invasives. This graph is based on 1,500 observations from 2016 to 2020.

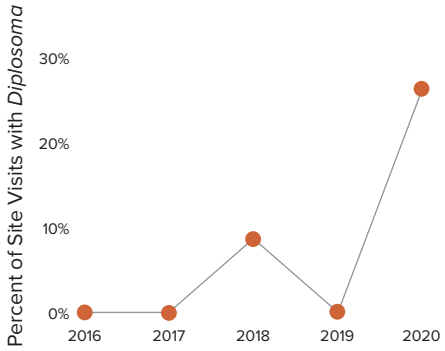
Average Invasives per Site Visit

Total Invasives Observed at Sites



Almost every site visit identified at least one invasive species. From 2016 through 2020, typically two to eight invasive species were observed on each site visit. Between seven and fourteen different invasive species were observed at each location.

Colonial Tunicate Now Firmly Established



Although rarely seen in the past, Diplosoma listerianum, *a colonial tunicate, increased dramatically in 2020. Before 2016,* Diplosoma *had only been observed once, in 2014. It was observed three times in 2018 and then eleven times in 2020. Observed in rocky intertidal communities since 2010 (MA CZM 2013), it now appears to be firmly established in the fouling community in our region.*

SUCCESSES & CHALLENGES

- The MIMIC program provides an "early detection system" for marine invaders in Casco Bay. MIMIC provides a network of organizations and trained volunteers to track marine invaders on the mainland and now on the islands. The data collected by MIMIC are shared with state agencies and others to provide insights into what species are present and alerts for new arrivals.
- Controlling or managing invasive species in the marine environment is difficult because of their diversity and complex life histories. Because few strategies exist for restricting the spread of invasive species once they become established, education to prevent new arrivals is paramount.
- Continued monitoring and collaborative efforts with local coastal stakeholders continue to be our best approach to understanding and mitigating the effects of these invaders. There are actions taking place to mitigate impacts from, and finding uses for, some of these species. For example, the Wells NERR and others are working with local fishermen in southern Maine to improve the market for green crabs.

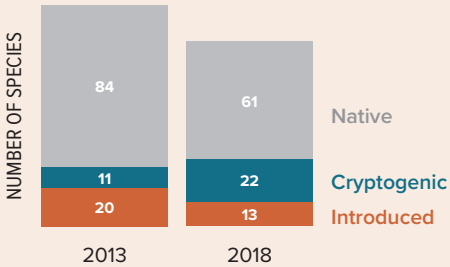
RAPID ASSESSMENT SURVEY (RAS)

The Gulf of Maine Rapid Assessment Survey (RAS) is a regional survey of invasive species conducted every three to five years and led by the Massachusetts Office of Coastal Zone Management and MIT Sea Grant College Program. Since 2000, scientists have sampled dozens of sites from Maine to New York in July or August. Taxonomic experts identify native and non-native macroalgae and invertebrates on floating docks and related structures, such as pilings, ropes, and boat fenders.

From Massachusetts to Maine, the teams found that the percentage of invasive species has remained relatively stable, with less than a quarter of all species observed in both 2013 and 2018 known to be invasive.

Several species, however, have expanded their range. For example, the colonial tunicate *Didemnum vexillum* and the bryozoan *Tricellaria inopinata* were observed more frequently in Maine, and the ranges for the algae *Colpomenia peregrina* (moving southward) and *Grateloupia turuturu* (moving northward) expanded. *Dasysiphonia japonica*, a red alga, was observed for the first time in 2018 at both sites surveyed in Casco Bay—Port Harbor Marine (Portland) and Brewer South Freeport Marine (South Freeport)—continuing its northward expansion. At Casco Bay sites, the total number of species declined from 2013 to 2018, and more cryptogenic species were observed.

Species at Two RAS Sites in Casco Bay



Less than one quarter of species observed during recent Rapid Assessment Surveys in Casco Bay are known to be introduced. Cryptogenic species are ones whose origins are unknown and may have been introduced (Kennedy et al. 2020).



Bay Water Temperatures Increased 1.6°C (3°F) in Three Decades

Inshore Waters May Be More Vulnerable to Water Quality Problems

Jerry Monkman, Ecophotography.com

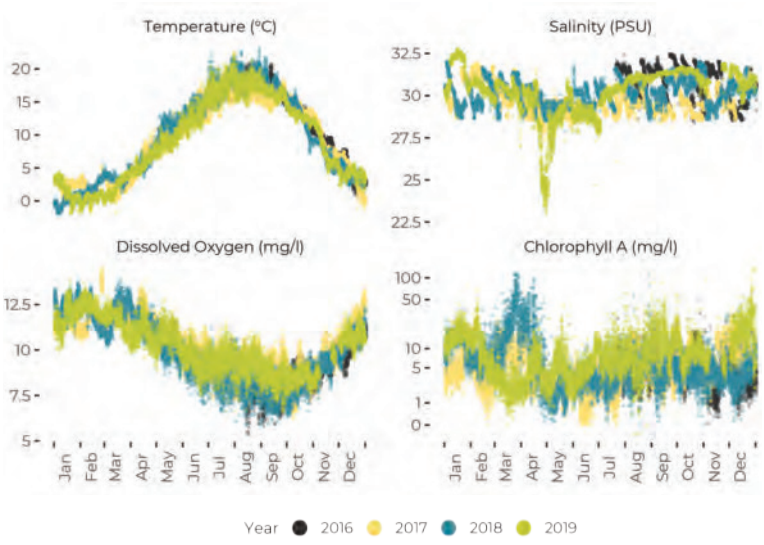
WHY IT MATTERS

Water quality refers to physical, chemical, and biological properties of the waters in an aquatic ecosystem. This chapter focuses on six measures of water quality in the Bay: temperature, salinity, dissolved oxygen, water clarity, pH, and chlorophyll. These measures provide insight into how the biology of the Bay interacts with physical mixing processes to produce clean waters that support healthy fisheries and coastal ecosystems. The chapters on Nutrients, Shellfish and Swimming Beaches, and Coastal Acidification present closely related information on the Bay's water quality.

Friends of Casco Bay (FOCB) staff and volunteers have monitored water quality at dozens of sites since the early 1990s, making it possible to develop an understanding of how the Bay is changing and how conditions vary among regions of the Bay. Recent adoption of new continuous monitoring technologies by FOCB, University of Maine, and Maine Department of Environmental Protection is further expanding our understanding of water quality.

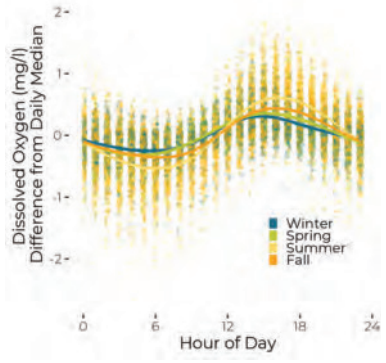
STATUS & TRENDS

Continuous Monitoring Reveals Seasonal Changes



"Continuous" monitoring uses automated equipment to collect water quality data at regular intervals (often hourly), providing new insight into site-specific changes over time. These graphs show data from FOCB's continuous monitoring station at Cousins Island. Temperature and dissolved oxygen display strong seasonal patterns. Late summer's elevated water temperatures are associated with the lowest dissolved oxygen of the year. For salinity and chlorophyll, seasonal patterns are less consistent, driven by spring runoff and late winter algae blooms, respectively, which vary in intensity year by year. Salinity is measured in Practical Salinity Units (PSU).

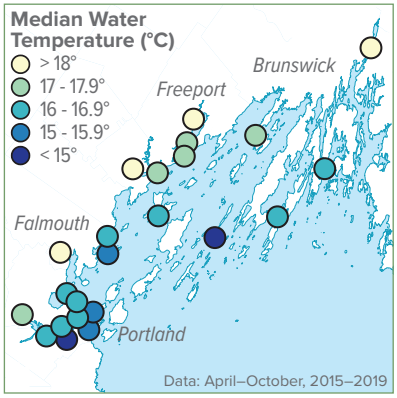
Dissolved Oxygen Daily Cycle



Dissolved oxygen varies over a daily cycle, with lowest levels in the early morning. At FOCB's Cousins Island monitoring station, the daily rise and fall in oxygen levels is greatest in summer, when the water is warmest, and daylight lasts longer.

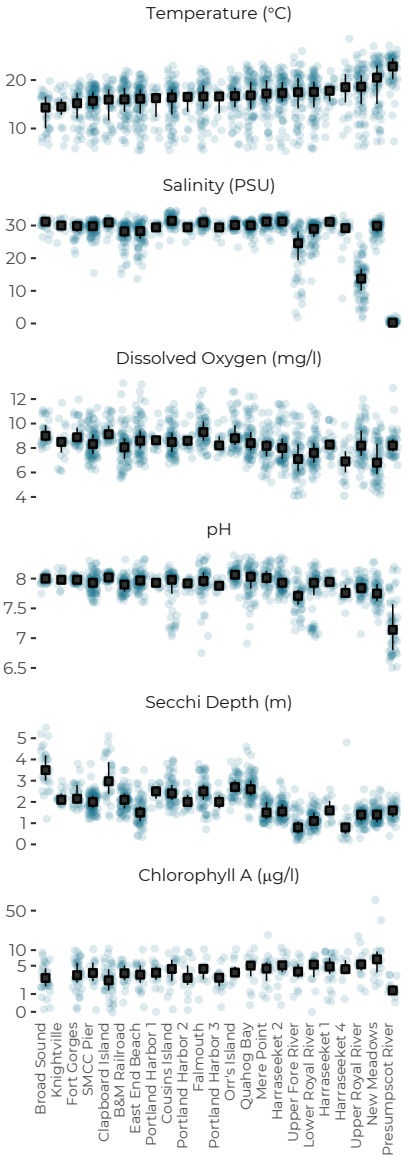
Data: 2016–2019

Temperature Hints at Vulnerability to Pollution



In Casco Bay, FOCB water temperature data can be used as an indicator of vulnerability of different sites to water quality problems. Offshore waters, which carry less pollution, are cooler. Therefore, sites characterized by higher median water temperatures have less mixing with offshore waters.

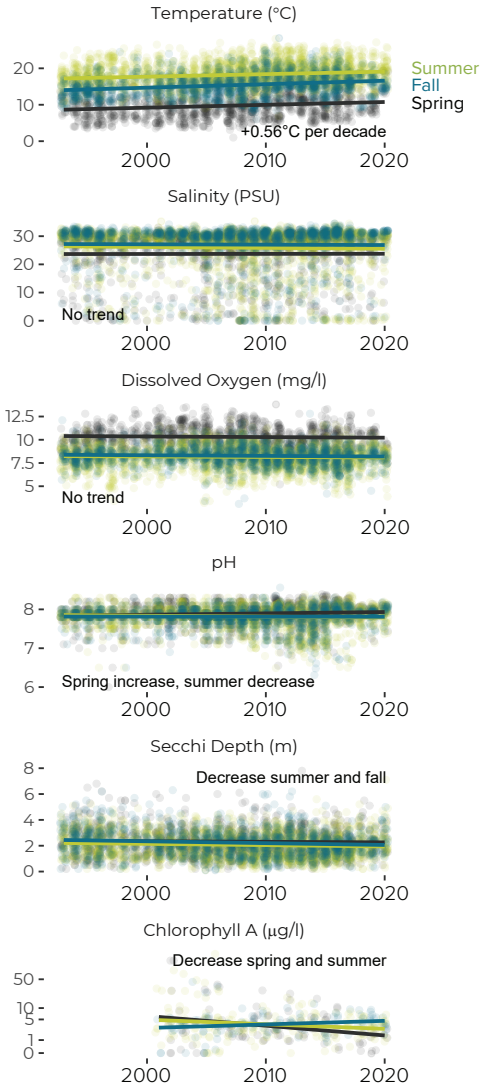
Water Quality by Location



Inshore sites tend to have warmer water, which is associated with lower dissolved oxygen, lower pH, lower water clarity (Secchi depth), and higher chlorophyll. Lower salinity sites are influenced by the Presumpscot, Stroudwater, and Royal Rivers and other tributaries.

Surface observations from FOCB discrete monitoring sites, April to October, 2015 through 2019. Squares: Medians. Error bars cover the middle 50% of observations. Sites sorted by increasing median temperatures.

Long-term Bay-wide Trends



Water temperatures increased more than 1.6°C (about 3° F) since 1993. Water clarity (Secchi depth) dropped slightly. Chlorophyll levels declined in spring and summer but not in fall.

Spring: April, May. **Summer**: June, July, August. **Fall**: September, October. Consistent long-term chlorophyll data are only available from three sites. Apparent recent changes in variability of pH and salinity reflect changes in monitoring methods.

MEASURES OF WATER QUALITY

Temperature and Salinity: Water temperature and salinity reflect and influence patterns of water mixing. In Casco Bay, summer water temperatures provide a rough indication of the degree to which conditions are dominated by offshore waters. Salinity values show the effects of river and stream discharge, especially the Presumpscot and Kennebec rivers. Cooler or saltier water is denser than warmer or fresher water. Thus differences in temperature or salinity can reduce water mixing in estuaries, shaping spatial water quality patterns.

Dissolved Oxygen: Low dissolved oxygen conditions can stress marine organisms, but oxygen is also an indicator of biological activity. Oxygen levels reflect the balance between photosynthesis and respiration as mediated by physical processes like the mixing of surface and bottom waters. Diurnal fluctuations, for example, can reveal the interplay of respiration (which consumes oxygen throughout the day and night) and photosynthesis (which releases oxygen in daylight). Oxygen is more soluble in cold water, so low dissolved oxygen—a hazard for marine organisms—is most likely in early morning during summer months, when waters are warm.

pH: pH is a measure of the concentration of hydrogen ions in solution. Ocean waters tend to have pH near 8. Maine rivers generally have pH below 7. Site-to-site differences in pH reflect relative contributions of marine versus fresh water. Carbon dioxide from biological activity also affects pH in the Bay.

Secchi Depth: Secchi depth measures water clarity based on how deep an observer can see a dinner plate-sized disk – the greater the Secchi depth, the more transparent the water. Water clarity principally reflects the abundance of algae and suspended sediments in the Bay, but it is also influenced by colored dissolved materials. Poor or declining water clarity can be an indicator of water quality problems, especially if accompanied by other signs of excess phytoplankton abundance.

Chlorophyll *a*: Chlorophyll is the dominant photosynthetic pigment in phytoplankton. It is commonly used as a measure of the abundance of phytoplankton in coastal waters. Excess nutrients, especially nitrogen, may increase phytoplankton abundance or help trigger blooms.

SUCCESSES & CHALLENGES

- Conditions in much of Casco Bay remain good, because Maine's large tides bring in cooler, salty, offshore waters, thus helping to protect the Bay from water quality problems.
- Inshore waters have limited tidal mixing, shallow depths and naturally warmer water, making them more vulnerable to many water quality problems. They are also more directly influenced by runoff, discharges, and other human activity.
- Rising water temperatures are a reminder that climate change already affects conditions in the Bay. Warmer waters are expected to lead to changes in organisms found in the Bay, affecting fisheries, tourism and recreation.
- Water quality monitoring is transitioning towards more automated sensors, more continuous data, and fewer locations. This improves understanding of daily, tidal, and seasonal changes in water quality at those locations. Discrete monitoring at other locations remains essential for understanding conditions around the Bay.



Nutrient Pollution Puts Bay Water Quality at Risk

Community Efforts to Protect Water Quality and the Bay's Natural Resilience Have Prevented Widespread Impacts

WHY IT MATTERS

Nutrients like nitrogen and phosphorus are essential to all life, but high levels in aquatic ecosystems can sometimes fertilize excessive growth of phytoplankton and other algae. The consequences can be profound: harmful algae blooms, low dissolved oxygen, disappearance of eelgrass and kelp, loss of marine habitat, declines in marine harvests, coastal acidification, even fish kills. While phosphorus is often the nutrient of primary concern in Maine lakes, nitrogen is more likely to be a primary concern in Casco Bay.

Nutrients entering Casco Bay come predominately from three sources: wastewater treatment facilities, direct atmospheric deposition, and runoff (including stormwater, combined sewer overflows, and river discharges).

Recent data provide good estimates of atmospheric, wastewater, and tributary loads, but the size of the runoff component is not as well understood.

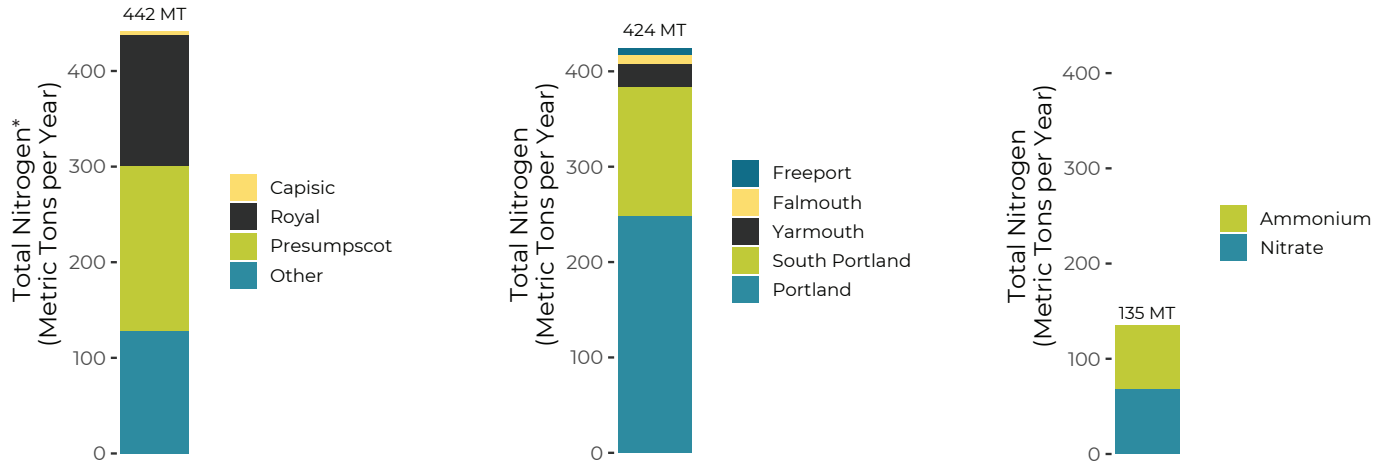
Several nutrient sources of potential importance to Casco Bay are not well characterized because of lack of recent, reliable data, notably:

- **combined sewer overflow (CSO)**,
- **direct runoff from urban areas**, and
- **septic systems**.

Data from the 1990s and early 2000s indicated that Casco Bay's overall nitrogen load was low compared to most other large estuaries in the northeastern U.S. However, the nitrogen loading is concentrated near Portland, raising local concerns.

STATUS & TRENDS

Documented Nitrogen Loads from Three Sources



Tributaries

Estimated nitrogen loads from rivers and streams entering the Bay are about 440 metric tons per year. About two thirds of that nitrogen enters the Bay from the Royal and Presumpscot Rivers. Tributaries carry nitrogen from all upstream sources, including agriculture, runoff, and wastewater.

Wastewater

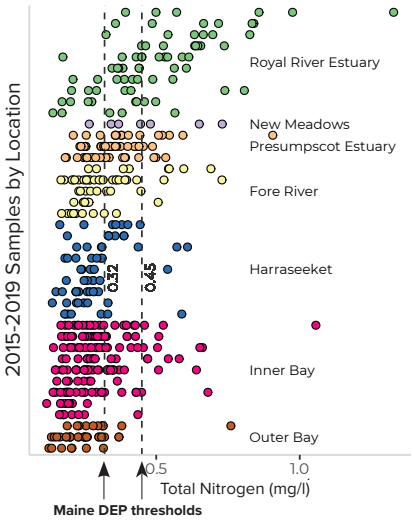
Compared to tributaries, direct wastewater discharges of nitrogen to Casco Bay are slightly lower, on the order of 425 metric tons per year. Well over three quarters of those discharges occur in Portland and South Portland.

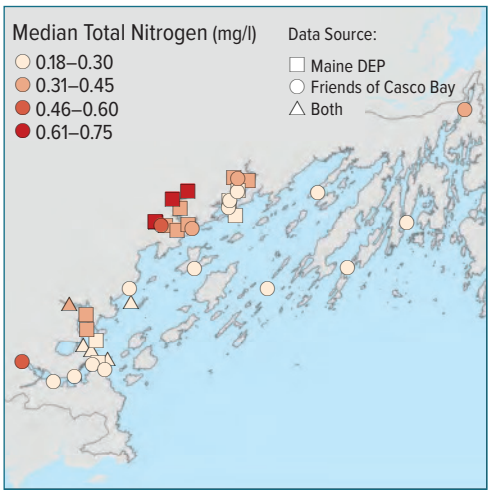
Atmospheric Deposition

Direct atmospheric deposition of nitrogen is a relatively small, and declining, share of nitrogen entering the Bay. "Atmospheric deposition" transfers airborne pollutants, including ammonium and nitrate, to the surface of Casco Bay, via rainfall and dust.

*Total Nitrogen (TN) includes the sum of nitrogen from ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), and organic nitrogen in water. Source: University of Maine, Maine Department of Environmental Protection (DEP), and National Atmospheric Deposition Program. CBEP estimates of annual loads based on most recent available data.

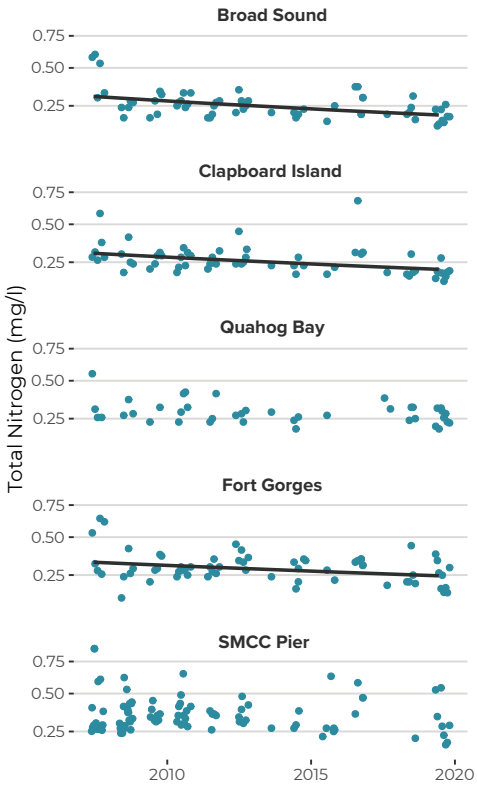
Total Nitrogen Regularly Exceeds Water Quality Thresholds





Elevated nitrogen levels have been observed regularly in portions of Casco Bay, especially in the tidal estuaries of the Royal, Presumpscot and Fore Rivers. Above left: Data collected from 2015 through 2019 by Friends of Casco Bay and Maine Department of Environmental Protection show that levels above DEP's advisory thresholds (0.32 mg/l TN to protect eelgrass; 0.45 mg/l TN to reduce risk of low dissolved oxygen) occurred in most areas. Above right: Typical nitrogen concentrations are higher in Casco Bay's restricted bays and tidal tributaries than in the Bay's open waters, where tidal currents facilitate waters mixing.

Nitrogen Decreasing Over Time



Long-term data on total nitrogen show declines at three of five locations that have been monitored regularly by Friends of Casco Bay for more than ten years. Downward trends at the other sites are not strong enough to distinguish clearly from seasonal, year to year, and other sources of variation.

Long-Term Decline in Atmospheric Deposition of Nitrogen



The rate of atmospheric deposition of nitrogen at a DEP monitoring station in Freeport, Maine is declining. Total atmospheric loads to Casco Bay have dropped roughly a third in recent decades, mirroring regional trends. In recent years (2015 through 2019), the annual rate of atmospheric nitrogen deposition at the monitoring station in Freeport has been about 2.5 kg nitrogen per hectare. The elevated level in 2012 was caused by an unknown, but apparently short-term, local source.



Collecting nutrient data in Casco Bay. (Photo: CBEP)

SUCCESSES & CHALLENGES

- Portland Water District updated the aeration system at the East End Wastewater Treatment Facility in 2016 and 2017. Summer discharges of nitrogen to the Bay have dropped by nearly three quarters.
- Atmospheric deposition of nitrogen has been declining for several decades, likely as a result of adoption of emission control technologies on power plants and automobiles; improved automobile fuel efficiency; and reduced reliance on coal for electrical generation. Further reductions in nitrogen deposition are likely with increasing adoption of electric vehicles and reduction in fossil fuel use.
- Over the last five years, understanding of nitrogen in Casco Bay has improved thanks to focused efforts by Maine's Department of Environmental Protection, the University of Maine, Friends of Casco Bay, and Casco Bay Estuary Partnership. More research is needed to characterize terrestrial sources, understand how water movement affects nutrients in the Bay, and learn how recycling of nutrients from the Bay's sediments affects water quality.
- Controlling nitrogen delivery in runoff from urban areas can be difficult. Most stormwater control structures are more effective at trapping phosphorus than nitrogen. "Green infrastructure," which relies on living organisms for nitrogen control, can be more effective than traditional structures, but adoption has been slow.

Sea-Run Fish Regaining Access to the Presumpscot Watershed

Relic Dams Block Fish from Swimming Up Royal River, Stroudwater River, and Some Coastal Streams



WHY IT MATTERS

Being able to move freely among different types of habitats is essential for many aquatic species. Anadromous fish such as river herring, shad, and rainbow smelt, which are prey for commercially important saltwater fish like cod and haddock, must be able to migrate upstream from estuaries to fresh water each spring to reach spawning habitat. Eastern brook trout and other fish that require cold, oxygen-rich water move seasonally among spring-fed streams, mainstem rivers, and estuaries in order to reproduce and feed. Terrestrial animals often travel and feed along rivers and streams.

Construction of dams, roads, and railways in Casco Bay's watershed severed many of these vital linkages and caused severe declines in anadromous fish populations. Dams block passage between upstream and downstream habitats, and interrupt the natural movement of sediment, wood, nutrients, and floodwaters. Where roads and railways cross waterways, inadequate culverts often impede fish passage. Cold-water species cannot thrive in the warm, oxygen-impaired waters behind dams and perched culverts.

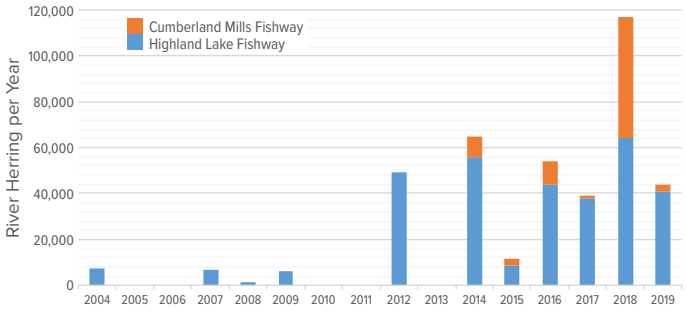


This perched, slip-lined round culvert obstructs movement of fish and other aquatic organisms. (Photo: Maine Stream Habitat Viewer)

STATUS & TRENDS

Connectivity between aquatic habitats in Casco Bay and the Presumpscot River watershed has steadily expanded since the 1990s as a result of concerted efforts by NGOs, state and federal agencies, and businesses to remove dams, construct technical fishways, and replace inadequate culverts. These efforts have facilitated restoration of alewife, blueback herring, and shad runs into some historical spawning habitats in the Presumpscot River watershed. These efforts have also benefited sea-run brook trout.

Fish Returning to Spawn in Presumpscot River



Total annual returns of river herring (alewife, blueback herring, and shad) at two counting stations in the Presumpscot River watershed. The number of returning fish remains variable, peaking in 2018 with over 117,000 observations, but there is potential for continued growth now that fishway construction is complete at Saccarappa Falls in Westbrook.

Source: University of Southern Maine; Maine Department of Marine Resources

Current and Historical Amounts of Sea-Run Fish Habitat

		PRESUMPSCOT RIVER		ROYAL RIVER		COASTAL/OTHER		TOTAL	
SPECIES	Units	CURRENT	HISTORICAL	CURRENT	HISTORICAL	CURRENT	HISTORICAL	CURRENT	HISTORICAL
Alewife	Acres	640	31,597	0	460	85	85	**725**	**32,142**
Blueback Herring	Miles	11.7	24.2*	0.3	60.0	0	0	**12.0**	**84.2**
American Shad	Miles	11.7	24.2*	0.3	60.0	0	0	**12.0**	**84.2**
Sea-Run Rainbow Smelt	Sites	2	2	2	2	19	37	**23**	**41**

* Minimum mileage only. May be substantially higher if additional tributaries were shown to be historical habitat.
Note that habitat for other sea-run species such as American eel, sea-run brook trout, and sea lamprey exists in Casco Bay streams, but data for those habitats is either not available or not reflected here to focus on the species above. Source: U.S. Fish and Wildlife Service (2015)

Many Fish Spawning Habitats Remain Blocked by Dams and Substandard Culverts

Orange indicates historical spawning habitats for blueback herring, American shad, and alewife that the fish currently cannot access because of dams and culverts. A survey of the Casco Bay watershed in 2008-2010 found 573 severe (or assumed severe) barriers and 551 potential barriers to fish passage.



Alewives encountering a barrier in Mill Brook, Westbrook. (Photo: Jerry Monkman, Ecophotography.com)

SUCCESSES & CHALLENGES

- Maine is a national leader in restoration of stream connectivity. Maine's Stream Smart training program guides the process of designing and replacing culverts, and the Maine Department of Environmental Protection provides grant funds for addressing derelict municipal culverts. Despite many successes, much work remains, as over 80 percent of culverts pose a barrier to passage of aquatic organisms.
- The pace of dam removal remains slow even though most dams in the Casco Bay watershed are decades, if not centuries, old and no longer serve their original purpose. Despite the compelling ecological and resilience benefits of dam removal, some people are reluctant to embrace the necessary changes in river recreation (e.g., flatwater paddling, fishing, and ice skating) and scenery.



Eelgrass Increased from 2013 to 2018 But Remains Below Historical Abundance

Beds in Freeport and Brunswick Rebounded Through Natural Propagation

WHY IT MATTERS

Eelgrass (*Zostera marina*) is a seagrass that forms extensive subtidal beds in sheltered areas where sunlight penetrates to its slender leaves. Eelgrass plays many vital roles in the Casco Bay ecosystem. Its beds serve as nursery habitat for young fish, while providing food for fish, shellfish, and migratory birds. Eelgrass helps to remove sediments and excess nutrients from the water, and its roots stabilize sediments. Abundant eelgrass indicates a healthy ecosystem, as eelgrass both contributes to and depends on good water quality.

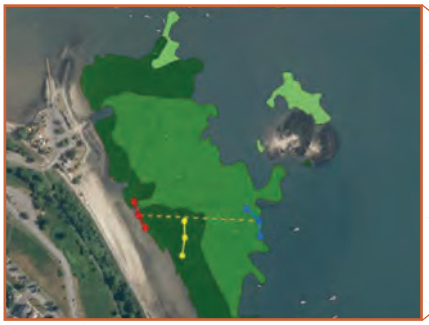
Eelgrass beds contribute to climate resilience in important ways. They buffer ocean and coastal acidification by absorbing carbon dioxide and raising pH levels in the water. They provide "blue carbon" benefits by storing organic carbon in their underground biomass and sediments. They dampen wave energy near shorelines, reducing storm damage and erosion.



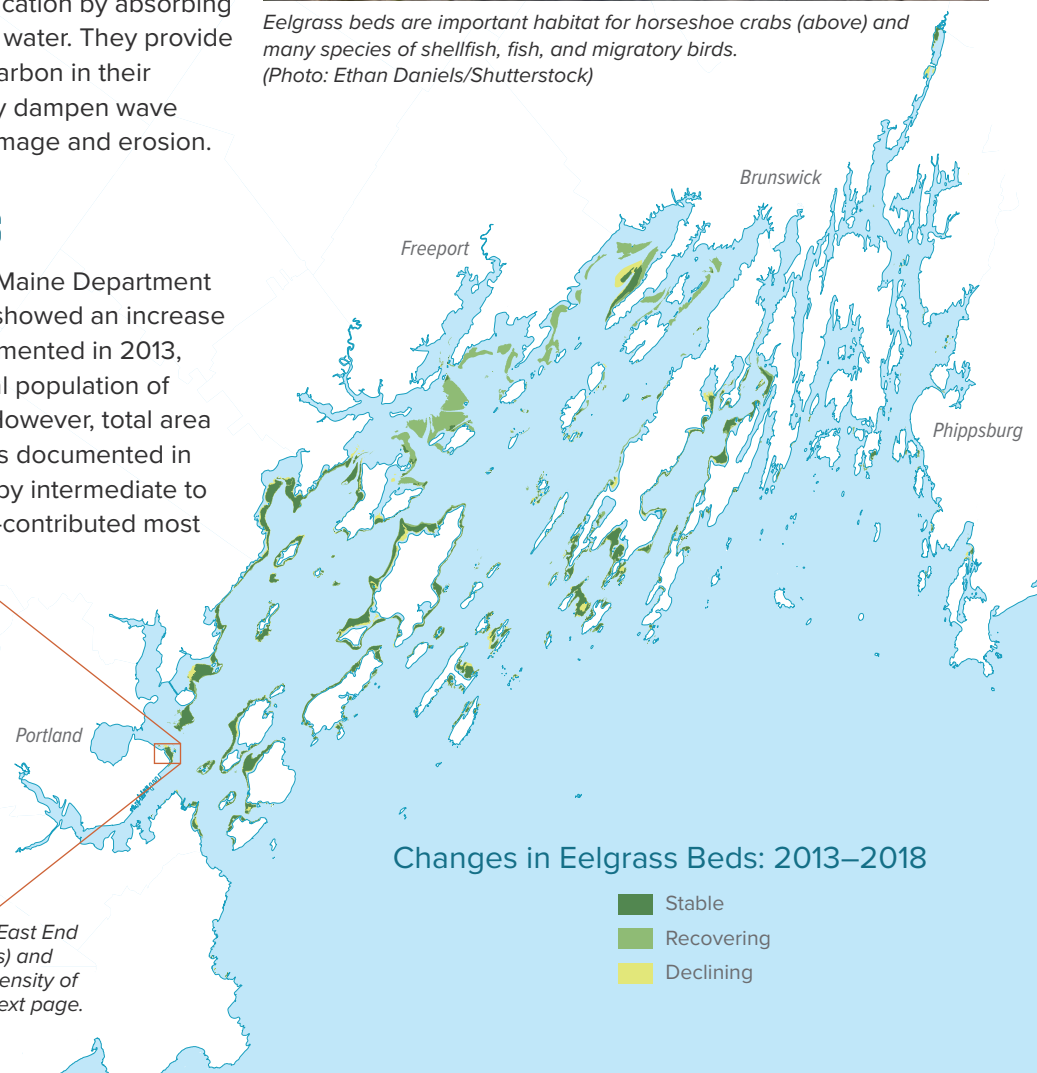
Eelgrass beds are important habitat for horseshoe crabs (above) and many species of shellfish, fish, and migratory birds. (Photo: Ethan Daniels/Shutterstock)

STATUS & TRENDS

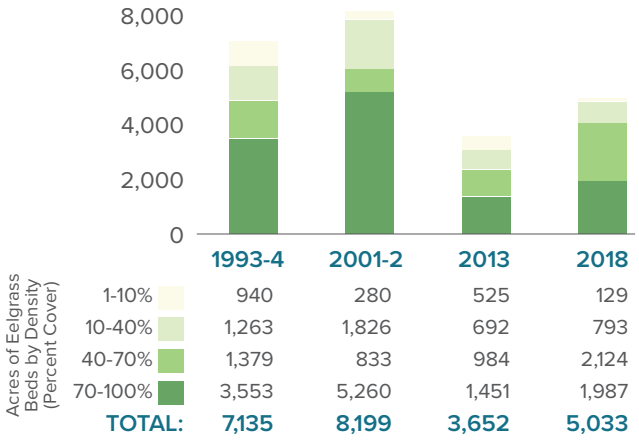
Mapping of Casco Bay's eelgrass beds by Maine Department of Environmental Protection (DEP) in 2018 showed an increase in total area since widespread losses documented in 2013, associated with a rapid increase in the local population of European green crab (*Carcinus maenas*). However, total area remained over 30 percent lower than levels documented in 1993-94 and 2001-02. Beds characterized by intermediate to dense eelgrass—40 to 100 percent cover—contributed most of the expansion.



The image above shows eelgrass beds at Portland's East End Beach mapped based on dive transects (colored lines) and aerial photo analysis. The green colors indicate the density of eelgrass coverage, corresponding to categories on next page.



Changes in Acres of Eelgrass Beds



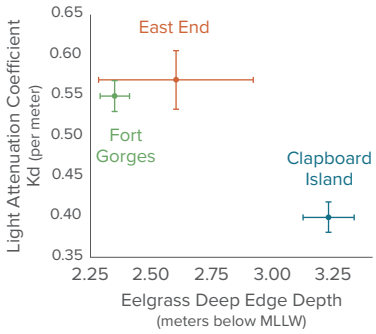
Acres of Eelgrass Beds by Density (Percent Cover)	1993-4	2001-2	2013	2018
1-10%	940	280	525	129
10-40%	1,263	1,826	692	793
40-70%	1,379	833	984	2,124
70-100%	3,553	5,260	1,451	1,987
TOTAL:	**7,135**	**8,199**	**3,652**	**5,033**

Acres of eelgrass beds mapped in Casco Bay. Colors represent density of eelgrass coverage from low-density (1-10% cover) beds to high-density (70-100% cover) beds. Source: DEP; Maine Department of Marine Resources

Comparison of Depth of Eelgrass Bed Deep Edge and Light Attenuation at Three Sites

Site	Year	Depth*	Light Attenuation**
East End	2018	2.4	0.58
East End	2019	2.7	0.57
Fort Gorges	2018	2.3	0.55
Fort Gorges	2019	2.4	0.55
Clapboard Island	2018	3.2	0.37
Clapboard Island	2019	3.2	0.43

* Eelgrass deep edge depth (meters below Mean Lower Low Water, MLLW)
** Light attenuation coefficient: Kd (per meter)
Figures provided by DEP



Site seasonal mean per year of the depth of the bed deep edge (meters below MLLW) and the water column light attenuation coefficient (Kd per meter). Larger Kd values indicate less available light for eelgrass growth at the deep edge of each bed.

Site seasonal means (2018, 2019) with standard error of the water column light attenuation coefficient (Kd per meter) vs. eelgrass bed deep edge depth (meters below MLLW).

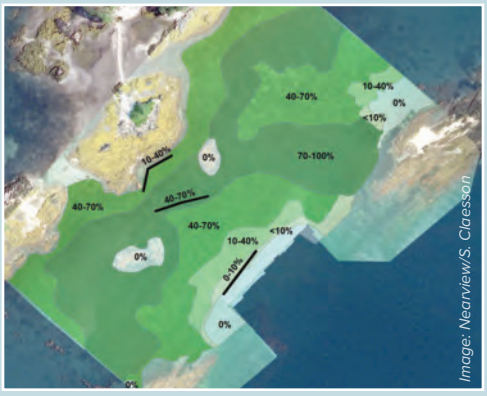
THREATS

- Eelgrass is vulnerable to small changes in light penetration through the water. Poor water clarity results from suspended sediments and algal blooms, which are caused by excess nitrogen, dredging projects, and other human activities. Aerial and dive surveys in Casco Bay are designed to document any changes in eelgrass quantity and health in response to nitrogen load reductions over time.
- Invasive European green crabs often clip or dig up eelgrass as they hunt for shellfish. Invasive colonial tunicates also pose a threat. When growing on eelgrass, the tunicates cover photosynthetic tissues and weigh down eelgrass blades, reducing access to light.
- Mooring chains, anchors, boat propellers, and bottom-dragging fishing gear can cause severe damage to eelgrass beds.



DIVE SURVEYS BY MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION

Twice each year beginning in 2018, the Maine Department of Environmental Protection (Maine DEP) Marine Dive Team has assessed the health of eelgrass beds at Fort Gorges, Clapboard Island, and Portland's East End Beach. Along fixed transects that run parallel to shore and are located from the bed's shallow edge to its deep edge, the divers monitor shoot density, percent cover, canopy height, and other parameters. The purpose of the monitoring is to document bed condition and trends, and to correlate those findings with water quality measurements to understand whether efforts to reduce nitrogen discharges at nearby wastewater treatment facilities are resulting in improvements to eelgrass health.



NEW METHODS FOR MAPPING EELGRASS

Drone imagery is increasingly being used for eelgrass monitoring and mapping. New drone sensors and technologies are expected to allow better detection of eelgrass deep edges and development of algorithms to assess important health metrics, such as epiphyte load.



Coastal Acidification Varies Seasonally, Daily, and Among Locations in Casco Bay

Scientists Are Investigating Local Patterns and Causes of Acidification

Jerry Monkman, Ecophotography.com

WHY IT MATTERS

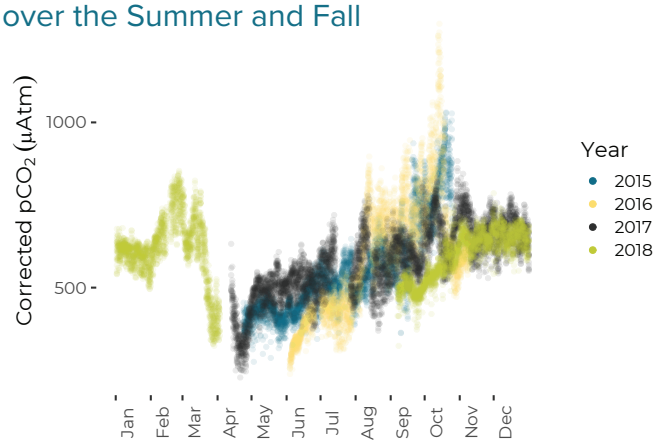
Lobsters, clams, and many other marine species build their shells out of carbonate minerals that they extract from seawater. Acidification of the water can make it more difficult for them to build their shells, or even cause shells to dissolve. Four out of every five dollars in Maine fisheries comes from shell-building species. Lobster represents about 75 percent of the fisheries' total value, and clams, oysters, urchin, and scallops account for another five or six percent.

In offshore waters, the primary cause of acidification is carbon dioxide (CO_2) from the atmosphere dissolving into the water. One quarter of the carbon dioxide released to the atmosphere by human activity annually is absorbed by the ocean, making ocean acidification a global concern. Near the coast, however, other localized sources such as rivers and nutrient pollution are major contributors to acidification, which refers to changes in not only pH but also availability of carbonate ions. Coastal acidification interacts with other environmental stressors like climate change, invasive species, and poor water quality to affect the ecosystem.

STATUS & TRENDS

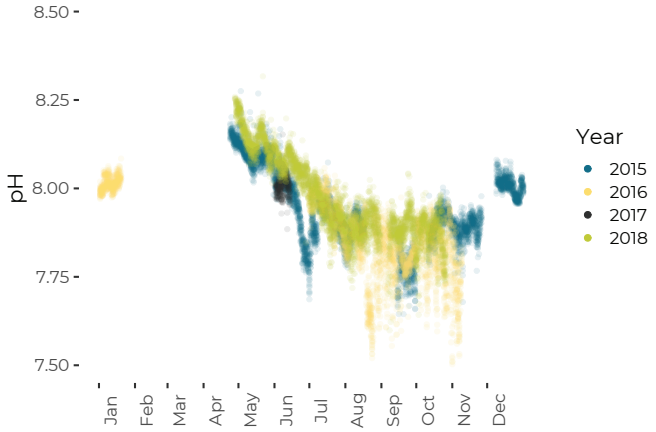
Data are limited, especially for the winter months, but about ten percent of all observations in Casco Bay show conditions corrosive enough to dissolve carbonate minerals like clam shells. Scientists from the University of New Hampshire, with funding through Casco Bay Estuary Partnership, have monitored coastal acidification near Southern Maine Community College (SMCC) in South Portland for five years. The monitoring reveals seasonal and daily variations reflecting biological activity in the ecosystem. Carbon dioxide levels fluctuate seasonally and daily, in synchrony with cycles of photosynthesis, respiration, and decomposition. In late summer and fall, levels of carbon dioxide hit their peak, pH drops, and acidification reaches levels of concern. For most of the year, levels of carbon dioxide dissolved in the Bay's waters are higher than atmospheric levels, meaning the Bay seldom absorbs carbon dioxide from the atmosphere.

Dissolved Carbon Dioxide Rises over the Summer and Fall



Carbon dioxide levels in the Bay (temperature-corrected) are at their lowest in the spring, and climb steadily through the fall. Levels are above atmospheric concentrations (~ 400 µAtm) most of the year.

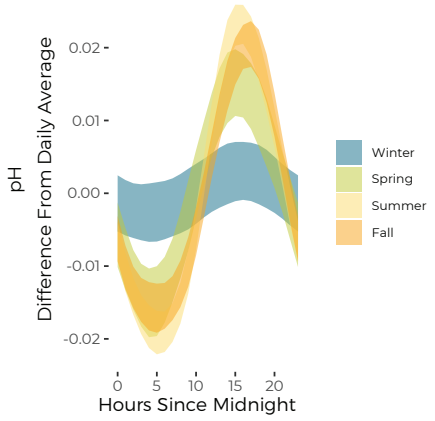
pH Decreases from Summer to Fall



At SMCC, pH shows a clear seasonal pattern, dropping over the course of the year by as much as a half of a pH point. pH is measured on a logarithmic scale, so that difference in pH represents a change in acidity by a factor of 3.

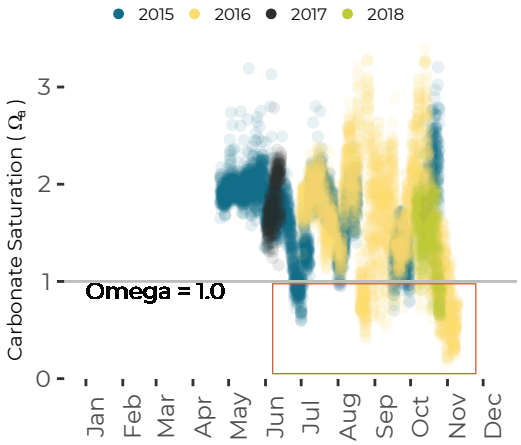
pH Fluctuates Through Day and Night Reflecting Biological Activity

Biological activity in the Casco Bay ecosystem drives small but detectable daily fluctuations in pH (shown on graph) and dissolved carbon dioxide (not shown). Colored bands on the graph represent the daily fluctuations by season. Fluctuations peak in the late summer (yellow) and fall (orange), when the waters are warmest and the ecosystem most active. Photosynthesis removes carbon dioxide during the day, increasing pH. At night, respiration and decomposition release carbon dioxide, causing a decline in pH overnight. In winter (blue), when daylight is shorter, waters are cold, and fewer data are available, the effect appears weaker.



Potential for Shell Corrosion in Late Summer and Fall

Although familiar, pH is not the only indicator of acidification's potential impacts on marine organisms. Scientists also use a measurement called omega (Ω_a) to determine how corrosive the water is to the carbonate mineral aragonite, a constituent of shells of many marine organisms. When omega falls below 1.0, shells tend to dissolve (although slowly). As indicated by the orange box, periods of low omega (below 1.0) tend to occur in Casco Bay each year, during late summer and fall.

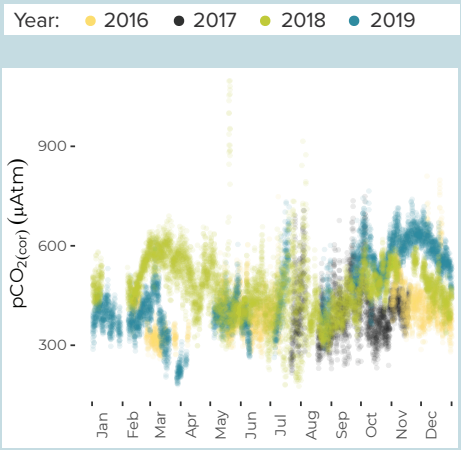


SUCCESSES AND CHALLENGES

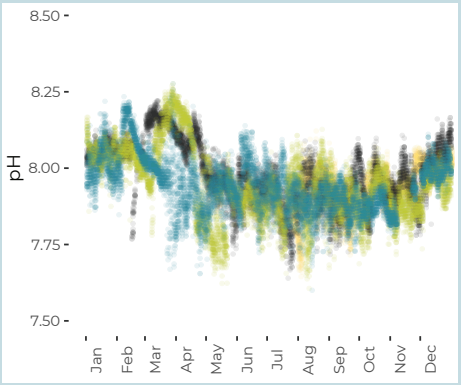
- The Gulf of Maine, including Casco Bay, is especially vulnerable to acidification because of its cooler waters and the low alkalinity of the region's freshwater inputs.
- Coastal acidification is already affecting shellfish aquaculture in Maine, especially in the Damariscotta River, where freshwater inflows make the system vulnerable.
- Monitoring of acidification in Casco Bay and other estuaries is revealing how local conditions affect acidification. In Casco Bay, data suggest that acidification may be affected by tides and by river discharge, but the science remains inconclusive for now.
- Laboratory experiments have demonstrated that levels of acidification that are observed from time to time in Casco Bay can affect behavior and reproduction of softshell clams and quahogs. However, it is not yet known whether present-day conditions affect shellfish living in the wild.
- Monitoring in other estuaries with more nutrient pollution than Casco Bay has revealed high levels of dissolved carbon dioxide and more dramatic daily and seasonal fluctuations. Reducing nutrient pollution could help protect coastal ecosystems from acidification.

MONITORING BY FRIENDS OF CASCO BAY

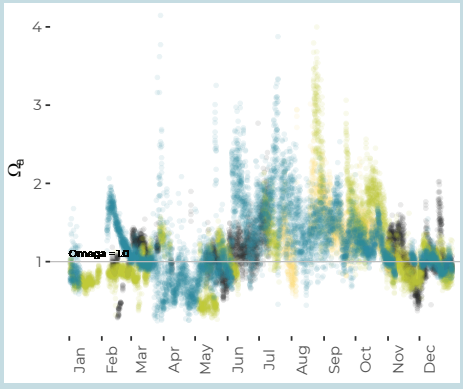
Since 2016, Friends of Casco Bay (FOCB) has monitored acidification parameters from a location on Cousins Island in Yarmouth. Results are similar, but not identical, to findings from SMCC.



The Cousins Island data do not show the strong seasonal pattern of carbon dioxide observed at SMCC. It is not clear whether that reflects location, or the additional years of winter and spring data collected by FOCB.



While the total range of pH at Cousins Island is similar to what was observed at SMCC, pH at Cousins Island tends to be somewhat lower and the seasonal pattern less pronounced.



Conditions at Cousins Island are more corrosive (shells are more likely to dissolve) than at SMCC. More than one third of all observations fell below levels of concern. In contrast to what was observed at SMCC, corrosive conditions were most common during winter and spring.



Elevated Bacteria Levels Occur at Some Monitored Locations

High Bacteria Numbers More Common Downstream of Urban and Suburban Areas

Carlos Castro / Creative Commons

WHY IT MATTERS

Polluted waters can expose people to pathogens. The Maine Healthy Beaches Program collects water samples at public swimming beaches to monitor for concentrations of fecal indicator bacteria, while the Department of Marine Resources (DMR) tracks bacteria in shellfish harvesting areas to assess risks to human health.

Individuals swimming or wading in marine waters can be exposed to pathogens in polluted water, risking gastrointestinal, upper respiratory and eye infections. People who eat bivalve shellfish grown in polluted areas are also at risk, especially for gastrointestinal disease. Bivalves like clams, mussels, and oysters are filter feeders. They can concentrate some pathogens (and algae-derived toxins, not discussed here) in their bodies, posing a risk to anyone consuming contaminated shellfish.

While most infections acquired this way are mild, they can be dangerous for immunocompromised individuals, and serious diseases like hepatitis can also be transmitted.

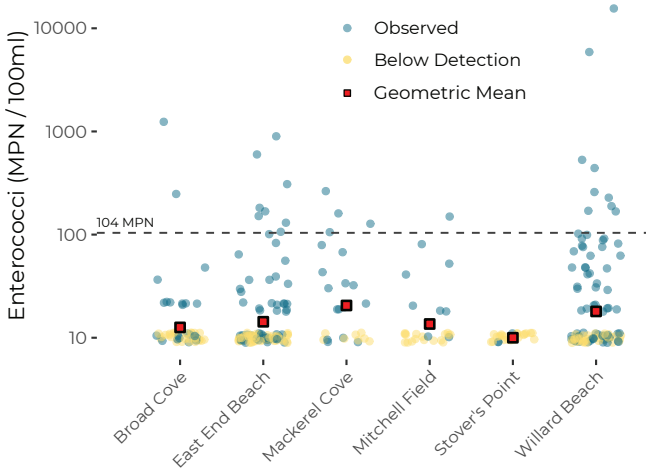
STATUS & TRENDS

Because methods used by the two agencies to track bacteria levels differ, the numbers they report are not directly comparable. The Beaches program collects data on “enterococci” bacteria (which is a better indicator of risk to swimmers), and DMR tracks “fecal coliform” bacteria.

SWIMMING BEACHES

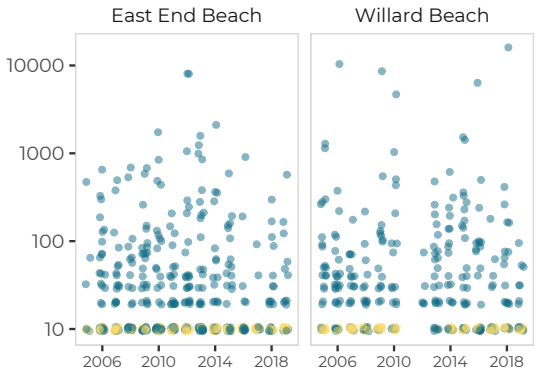
The Maine Healthy Beaches Program works with participating towns and state parks to track bacteria levels at public marine beaches. Volunteers collect water samples to be analyzed for bacteria concentration. Bacteria levels above the “Beach Action Value” of 104 MPN/100ml (most probable number of enterococci bacteria per 100 milliliters of sample water) may lead to posted advisories or beach closures. Samples are typically collected once a week between Memorial Day and Labor Day, when people are most likely to go swimming.

Differences in Bacteria Levels Among Beaches



Six beaches in Casco Bay are monitored from Memorial Day to Labor Day for enterococci bacteria, an indicator of potential health risk to swimmers. Bacteria levels above the single sample safety threshold (104 enterococci MPN/100ml) occurred in about 7% of samples from 2016 through 2019. (Note: The y-axis is on a log scale.) In 2018, 6.6% of samples statewide exceeded that threshold. Elevated bacteria levels are often associated with rain events, freshwater inputs, or point sources of pollution. Stover's Point Beach (in Harpswell) has consistently low bacteria levels. Mackerel Cove (Harpswell) and Willard Beach (South Portland) have the highest average levels.

No Changes Over 15 Years at Two Beaches



Bacteria levels at two urban beaches in Portland and South Portland show no trend over the past 15 years. (Note: The y-axis is on a log scale.) Long-term data is only available from East End Beach and Willard Beach. Neither absolute levels nor probability of exceeding the safety threshold have changed.

SHELLFISH HARVESTING LOCATIONS

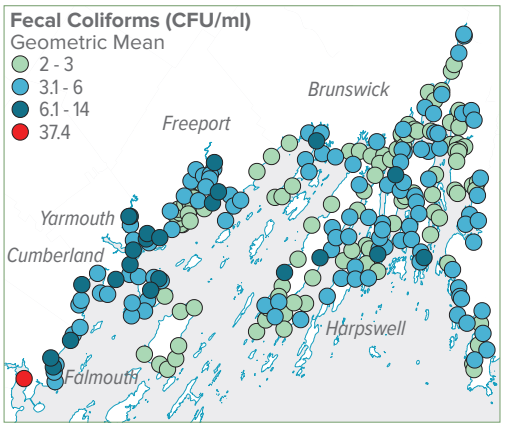
Maine Department of Marine Resources monitors bacteria levels at more than 235 shellfish harvesting areas around Casco Bay. Samples are collected several times a year. The data are used to manage shellfish harvests to protect public health. Harvest areas may be classified as "Approved" for harvest if geometric mean fecal coliform levels are below 14 colony forming units (CFU) per 100 ml, and if no more than the top 10% of samples exceed 31 CFU/100ml (the 90th percentile, or "P90" threshold).

Almost all monitored locations in Casco Bay met the geometric mean standard and most met the P90 threshold as of 2019. However, some areas of the Bay, including most of the waters in the southern Bay near Portland, are permanently closed because of proximity to possible sources of pollution like wastewater treatment facilities and combined sewer overflows. DMR does not collect bacteria data from such areas on a regular basis.

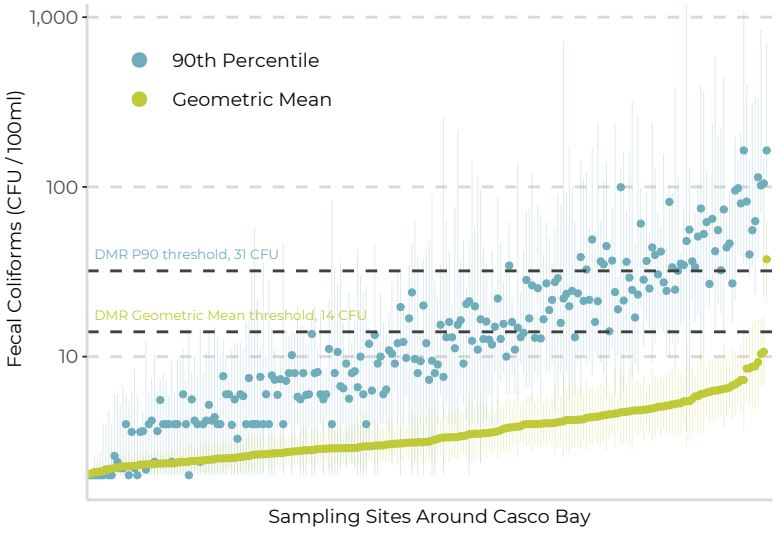
*Typical levels of bacteria at all but one sampled shellfish bed remain below the **14 CFU/100 ml** geometric mean threshold as of 2019. Only a single site (in the Presumpscot Estuary) failed to meet that condition. But infrequent elevated bacteria levels occur at more monitored locations. Forty seven sites had ten percent or more of recent samples above the 90th percentile threshold of **31 CFU/100 ml**. In addition to location, rainfall and time of year affect bacteria levels, with high levels more likely after rain, or during the warmest months of year.*

Average Bacteria Levels at Sites Around Casco Bay

Waters adjacent to Falmouth, Cumberland and Yarmouth tend to have higher bacteria levels than waters of the Eastern Bay. Site-to-site differences are large, pointing to possible opportunities to address water quality at a local scale. Data are not available from the most urbanized shores in the southern Bay or from around several islands.



Bacteria Levels Usually Stay Below Thresholds



SUCCESSES & CHALLENGES

- Bacteria levels in the parts of Casco Bay for which data are available tend to be below the beach notification threshold or shellfish area classification thresholds most of the time. Exceptions are usually associated with rain or other events that transport bacteria to coastal waters.
- Beaches and shellfish beds may be closed preemptively due to heavy rainfall, even in the absence of a sample showing high bacteria levels. Since beach samples are typically collected once a week, and shellfish samples only a few times a year, this precautionary approach protects public health.
- Urban and suburban waters are most at risk. Human activity increases the risk of bacteria levels via stormwater runoff, pet waste, combined sewer overflows, or inadequate sanitation systems. In the Eastern Bay and the islands, aging or failing on-site wastewater treatment systems can be a source of problems.
- DMR generally does not collect bacteria data in areas permanently closed to shellfish harvesting. As a result, limited data are available on bacteria levels precisely where those levels are expected to be highest—adjacent to heavily settled areas and near known sources of possible pathogens like combined sewer overflows or overboard discharges (OBDs).
- OBDs were allowed by Maine Department of Environmental Protection (DEP) as recently as 1987. OBDs discharge filtered and chlorinated human waste to state waters. Because they are not always properly maintained, they sometimes pose a risk of bacterial contamination. Decades of work by DEP and others have reduced active OBDs in Casco Bay from nearly 400 in 1987 to only 95 as of 2020.



Persistent Toxics Have Declined Over Past 30 Years

Uncertainties Remain about Impact of Novel Contaminants

Kevin Cole / Creative Commons

WHY IT MATTERS

Our society releases thousands of biologically active chemicals into the environment. These compounds include medications, pesticides, industrial chemicals, and byproducts of combustion, corrosion and wear, among others. Such compounds are called toxic when they have negative impacts on human health or the environment, especially if they have negative effects at low environmental concentrations.

By definition, toxic chemicals can harm living organisms, including humans, animals, plants, and microorganisms. Contaminants can have both severe short-term and subtle long-term effects. Effects include mortality, neurological impairment, developmental effects, impacts to metabolic processes, increased risk of genetic mutations and cancer, disruption of hormonal systems, and changes in behavior. Toxic contaminants in the environment can affect success of individuals and species, thus altering composition of ecological communities and ecosystem processes.

Many organisms can concentrate persistent contaminants in their bodies, increasing contaminant exposure to organisms who eat them. In marine food webs, that process can occur repeatedly as predator becomes prey, in a process called "biomagnification". Biomagnification means that even low environmental levels of persistent contaminants can pose health risks to organisms (from osprey and seals, to humans) who eat large, predatory fish.

Industrial uses of many persistent contaminants (like DDT and PCBs – See the sidebar for information on persistent toxic compounds) were phased out in the 1970s and 1980s, leading to reductions in environmental concentrations. We see the effects of those bans in long-term trends in levels of persistent contaminants in Casco Bay. Yet use of less-persistent toxic chemicals (including novel industrial chemicals, modern pesticides, pharmaceuticals and personal care products) has expanded. For many bioactive compounds, relatively little is known about their persistence or impacts in the marine environment.

PERSISTENT ORGANIC CONTAMINANTS

PAHs
Polycyclic aromatic hydrocarbons are principally derived from petroleum products or combustion of petroleum or other organic materials. Transportation and industrial activity are major sources.

PCBs
Polychlorinated biphenyls are chlorinated hydrocarbons that found a variety of industrial uses 50 years ago. Because of their toxicity, their use was phased out in 1979. Today, PCBs may be released when older products are improperly disposed of, or as a byproduct of poorly controlled burning of plastics.

Dioxins and furans
Dioxins and furans are not industrial products in their own right, but byproducts of incomplete combustion of organic matter and some industrial processes such as chemical manufacturing and chlorine bleaching of pulp and paper.

Butyltins
Tributyltin is a metal-organic molecule used in anti-fouling paint on large ships. Because of its toxicity and persistence in the marine environment, its use on smaller boats has been phased out. In the marine environment, it breaks down into related mono- and di-butyltins, so the group of related compounds are often studied together.

DDT Residues
DDT is well known as one of the more troublesome members of a class of pesticides known as organochlorines. Other members of this class include chlordane and lindane. Most organochlorine pesticides were banned decades ago because of their persistence in the environment. Like many organochlorines, DDT breaks down into closely related chemicals in the environment.

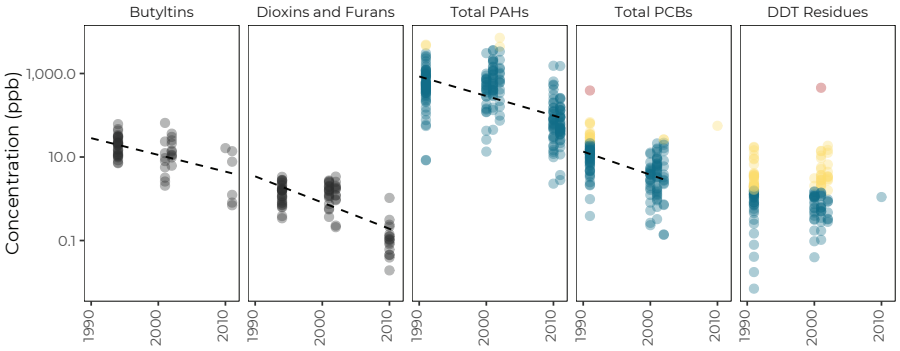
BENCHMARKS FOR RISK ASSESSMENT

A common way to evaluate risks associated with contaminants in sediments is to compare concentrations to published risk benchmarks, such as ERL and ERM:

- **Effects Range Low (ERL)** – A concentration below which negative effects on marine organisms are seldom observed.
- **Effects Range Median (ERM)** – A concentration at which negative effects are about as likely as not.

STATUS & TRENDS

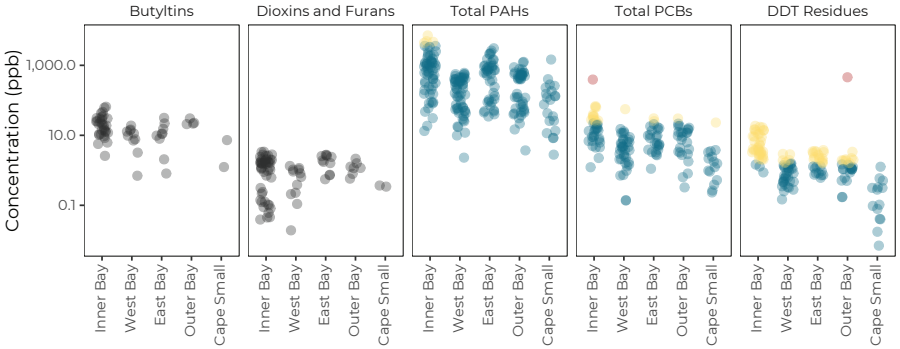
Persistent Organic Contaminants on the Decline in Casco Bay's Sediments

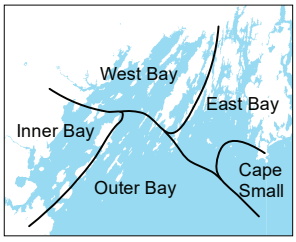


In 2016, CBEP released analysis of twenty years of sediment data from dozens of sites around Casco Bay. From 1990 to 2010, concentrations of many groups of toxic organic contaminants in the Bay's sediments declined. (Note: The y-axis is on a log scale.) More recent sediments are less contaminated than older sediments, which are now buried. Changes in analytic methods made it impossible to detect low levels of PCBs and pesticides in 2010, so recent trends are uncertain, but continued declines are likely.

Above ERM
Between ERL and ERM
Below ERL
No Reference Defined

Sediment Contamination Tends to Be Highest Near Portland





Since 1990, contaminant levels have varied across regions of the Bay. (Note: The y-axis is on a log scale.) Several contaminants tend to be highest in the Inner Bay (near the Portland metropolitan area) or lowest in the Outer Bay and off of Cape Small (in Phippsburg). However, levels of PAHs are high in the East Bay, perhaps because of historic discharges of contaminants from industries along the Kennebec and Androscoggin Rivers.

Almost All Metals Decreasing in Sediments

Many metals are toxic and all are persistent in the environment. As each poses different risks, they need to be assessed separately. Almost all metals are decreasing in Casco Bay's sediments. None were observed at levels above the ERM threshold, and thus levels are thought to pose limited risks to marine organisms. Persistent elevated levels of arsenic reflect presence of natural sources in the Casco Bay watershed. Elevated mercury bay-wide reflects atmospheric deposition.

	ABOVE ERL*					TREND**		
METAL	FREQUENT	COMMON	UNCOMMON	RARE	NEVER	INCREASING	DECREASING	DIFFERENCES AMONG REGIONS OF CASCO BAY
Arsenic	✓						*No trend*	Cape Small < Other regions
Nickel	✓						↓	Cape Small < Other regions
Chromium		✓					↓	Cape Small < East Bay and West Bay
Mercury		✓					*No trend*	Cape Small < Outer Bay and West Bay < East Bay < Inner Bay
Cadmium				✓		↑		Cape Small < Outer Bay < Other regions
Copper				✓			*No trend*	Cape Small < Outer Bay < Other regions
Lead				✓			↓	Cape Small < Other regions < Inner Bay
Silver					✓		*No trend*	Cape Small < Other regions < Inner Bay
Zinc					✓		↓	Cape Small < Other regions; Outer Bay < Inner Bay
Iron* **			*N/A (No ERL)*				*No trend*	Cape Small < East Bay and West Bay
Selenium			*N/A (No ERL)*				↓	No differences.

* Rare: < 10%; Uncommon: < 25%; Common: <50%, Frequent > 50%. No metals were above ERM.
** Trend analysis based on robust regression, including non-detects.
*** Iron is widespread in soil and sediments and is functionally non-toxic.

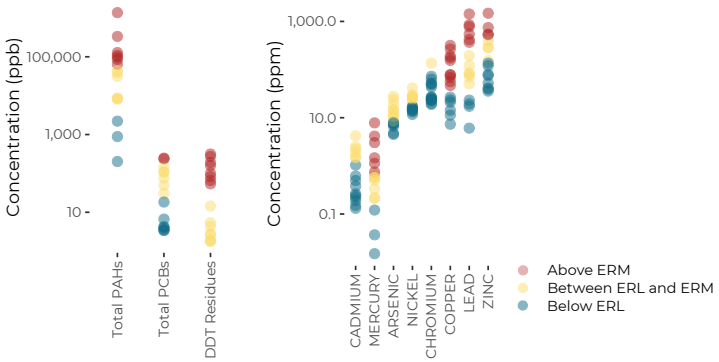
Results from Casco Bay Sediment Sampling (1991-2011)

CHEMICAL GROUP	MOST RECENT CONDITIONS (2010-2011)	TRENDS SINCE 1991
Metals	Generally below concentrations likely to be harmful*	Mostly declining/stable**
PAHs	Below concentrations likely to be harmful	Decline since 2000-2002
PCBs	Rarely detected	Decline 1991 to 2002; likely continued through 2010***
Dioxins and Furans	Low concentrations****	Decline since 2000-2002
Organochlorine Pesticides	Rarely detected	Decline 1991 to 2002; likely continued through 2010
Butyltins	Low concentrations, often not detected	Declining

*For those metals where sediment screening values are available. **Cadmium and silver show increases, but result could be due to differences in laboratory methods between sampling events. ***Because of changes in laboratory methods, detection limits in 2010 and 2011 were relatively high, obscuring trends. ****ERL and ERM levels are not available for dioxins and furans.

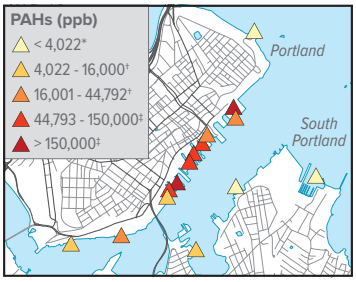
Deep Sediments of Portland Harbor Are More Contaminated

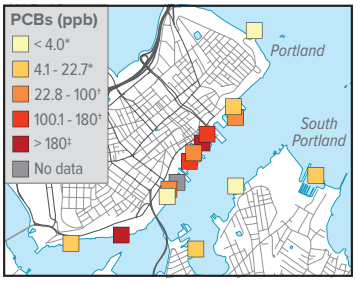
In 2018, the Portland Harbor Commission commissioned a study of contaminants in sediments of Portland Harbor. The study was undertaken as part of designing a "Confined Aquatic Disposal" facility to safely dispose of potentially contaminated dredged material from the Harbor. The results provide a window into historic levels of contaminants in the Harbor, because samples were collected from material buried under several feet of sediment, which has accumulated over many decades. The deep sediments of the Harbor act as a time capsule, revealing levels of contamination that were commonplace in the harbor 50 years ago, before passage of major environmental laws.

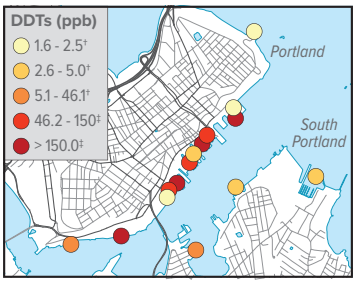


Right: The highest levels of contaminants were generally found along the Portland waterfront. That partially reflects the waterfront's industrial heritage but also decades of runoff from the City and uncontrolled wastes discharged directly to the Bay before construction of wastewater treatment plants.

* Below ERL (effects range low)
† Between ERL and ERM
‡ Above ERM (effects range median)







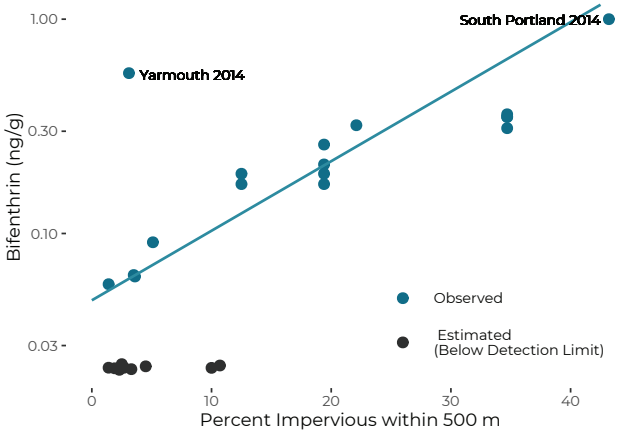
Above: *Levels of organic contaminants (left graph) were substantially higher than elsewhere in Casco Bay, and also higher than in shallow sediments from Portland Harbor. (Note: The y-axis is on a log scale.) Over half the samples had concentrations of PAHs at or above levels of concern. Levels of PCBs are less extreme, although still higher than elsewhere in Casco Bay. DDT residues are consistently at levels of concern, an especially striking result, as the pesticide has been banned for decades, probably because of DDT's long environmental persistence and low mobility in the Harbor's sediments. Levels of metals (right graph) in Portland Harbor deep sediments regularly exceeded screening levels. Concentrations are often several times higher than seen in Casco Bay's shallow sediments. Levels for mercury, copper, lead, and zinc, regularly exceeded levels of concern.*

Urbanized Shores Have Higher Levels of the Pesticide Bifenthrin

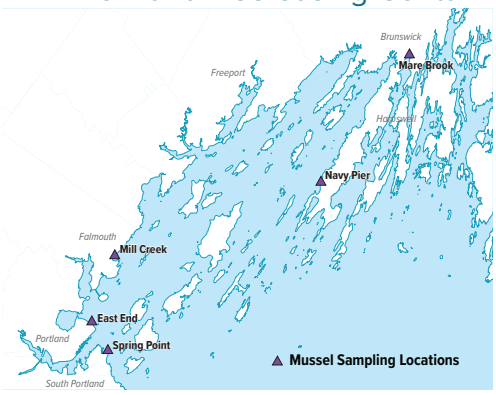
Many persistent toxic chemicals, including DDT and most other organochlorine pesticides, were restricted or outlawed in the later part of the twentieth century. As a consequence, levels of such persistent toxics have declined in the environment. Novel compounds, such as less persistent pesticides, have come to replace outlawed or restricted chemicals in many uses. Replacement chemicals can pose lower environmental risk, but they are not risk-free, and many are less studied.

Because lobsters and other crustaceans may be vulnerable to certain pesticides, Maine's Board of Pesticides Control conducted studies of fourteen "pyrethroid" pesticides, in Maine's intertidal marine sediments in 2014 and 2015, including 18 locations around Casco Bay. Only bifenthrin, which is relatively easy to detect at low concentrations, was detected regularly. Bifenthrin (first approved for use in the U.S. in 1985) was detected in most samples, although at levels well below levels of concern.

As shown in this graph, the levels of bifenthrin are related to urbanization. Higher levels were observed when impervious surfaces like roads and parking lots were common within 500 meters of the sampling location. The relatively high sample from Yarmouth from 2014 is unexplained.

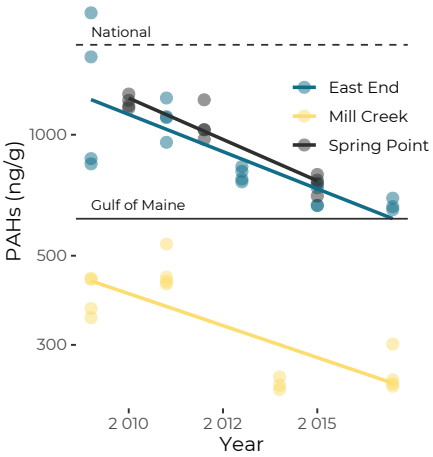


Low and Decreasing Contaminant Levels in Casco Bay Blue Mussels

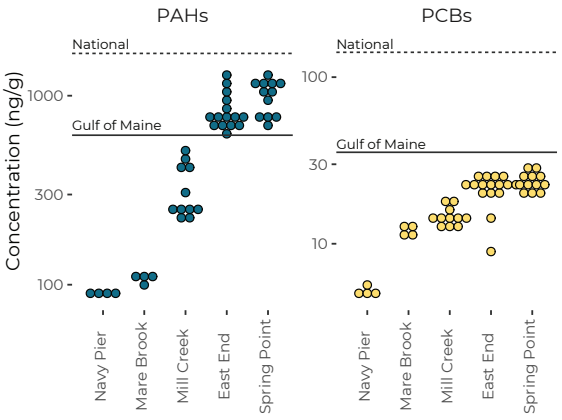


From 2010 to 2019, data on toxic contaminants in mussels were collected from five locations in Casco Bay. Data has been collected multiple times since 2006 at Mill Creek, East End, and Spring Point.

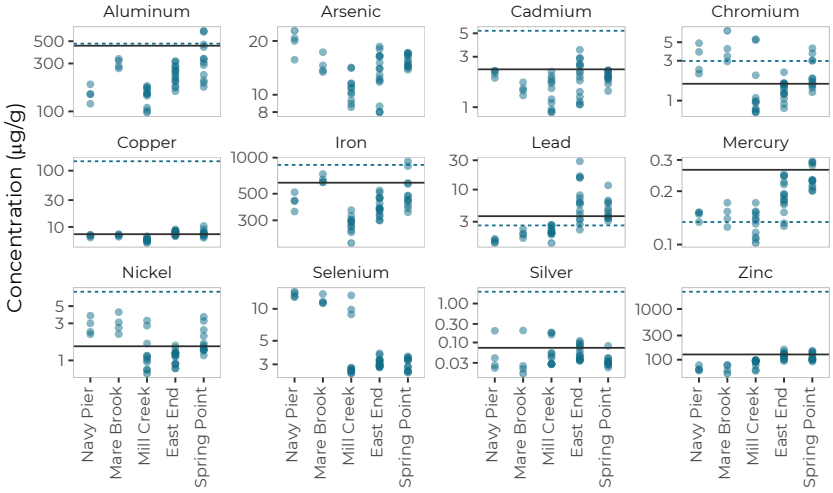
Contaminants in the ocean can pose human health risks if they find their way into seafood. Maine's Surface Water Ambient Toxics (SWAT) program collects data on persistent contaminants in several marine species, including blue mussels. Mussels are filter feeders, and can concentrate contaminants from their surroundings. National and regional programs have tracked contaminants in mussels and oysters for many years. CBEP analyzed Casco Bay mussel data in relation to Gulf of Maine (Gulfwatch) and National (NOAA) benchmarks. Benchmarks used here (85th percentiles) show levels exceeded by 15% of observations from regional and national studies.



PAHs in blue mussels from all three long-term monitoring sites have declined over the past 15 years. PCBs (not shown) have shown no significant trends.



PAHs in Casco Bay mussels near Portland are elevated compared to regional, but not national benchmarks. PCBs are consistently below benchmarks. Published benchmarks compare the sum of a subset of PAHs and PCBs to levels of similar totals from national and regional samples. Health-based comparison levels are not available for PAHs. DEP reports that levels of PCBs were below health action levels. Recent data on pesticides and dioxins are unavailable.



Most metals in Casco Bay mussel tissue are well below benchmarks, with only lead and chromium showing frequent levels above the national benchmark. Most metals show scattered values above regional benchmarks, with only nickel frequently above regional but not national benchmarks. Lead and mercury are highest near Portland, while selenium is highest at Navy Pier and Mare Brook. Few metals show clear long-term trends, but arsenic is increasing, while iron is decreasing Bay-wide, and chromium is decreasing at East End and Spring Point (data not shown).

SUCCESSES & CHALLENGES

- Concentrations of most toxic chemicals that have been studied in Casco Bay are below established levels of concern. Exceptions tend to occur principally, but not exclusively, in our more urban waters. Most persistent contaminants are less abundant today than in prior decades.
- Many persistent toxic chemicals, like PCBs and certain pesticides, were phased out in the late 20th century. Those policies led to reductions in concentrations in the Bay. Reductions of other toxic chemicals may reflect better stormwater management or reductions in tailpipe emissions from more fuel efficient, cleaner automobiles.
- Mercury still occurs at levels of potential concern for marine organisms in sediments across much of the Bay. A primary source of mercury entering the Bay is atmospheric deposition, associated with discharges from power plants to our west. Conditions may improve as coal-fired power plants are retired and replaced by natural gas and renewables.
- Historically, data collection on toxic contaminants in the marine environment has focused on persistent compounds which were identified as problematic in the 1960s and 1970s. Data on modern contaminants of concern, from flame retardants to microplastics, pharmaceuticals to personal care products, remains scarce.



Fourteen Percent of Land in Casco Bay's Watershed Has Been Permanently Conserved

In Coastal Communities, Conservation Land Approaches Ten Percent

WHY IT MATTERS

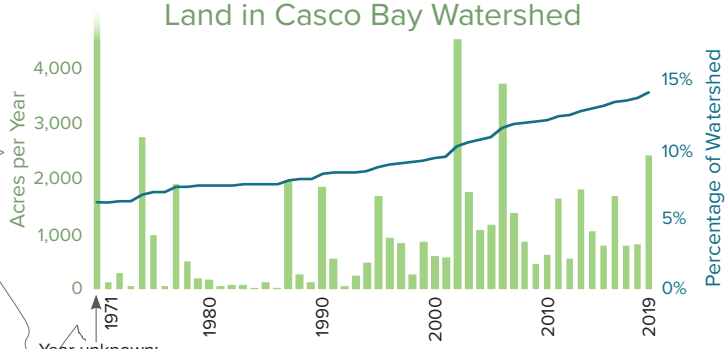
Conservation land is land that is permanently protected from development and generally remains in a natural state for fish, wildlife, and their habitat, or provides protection for other land values such as agriculture and forestry. Typically it allows for low-impact recreation but does not include land that is predominantly recreational such as ball fields or playgrounds. Keeping track of conservation lands over time helps illustrate the level of success conservation partners have had in protecting land. The actual rate of protection may reflect the availability of funding sources and the pace of residential and commercial development.

Throughout Casco Bay's watershed, and particularly in proximity to Portland, land is being developed in response to demand for residential housing and commercial or industrial property, fueled by changing patterns in where people work and live. Setting aside a network of natural areas in perpetuity is important to protect clean water, conserve ecological communities, enhance climate resilience, sustain working forests and farms, and provide current and future generations with access to open space and outdoor recreation.

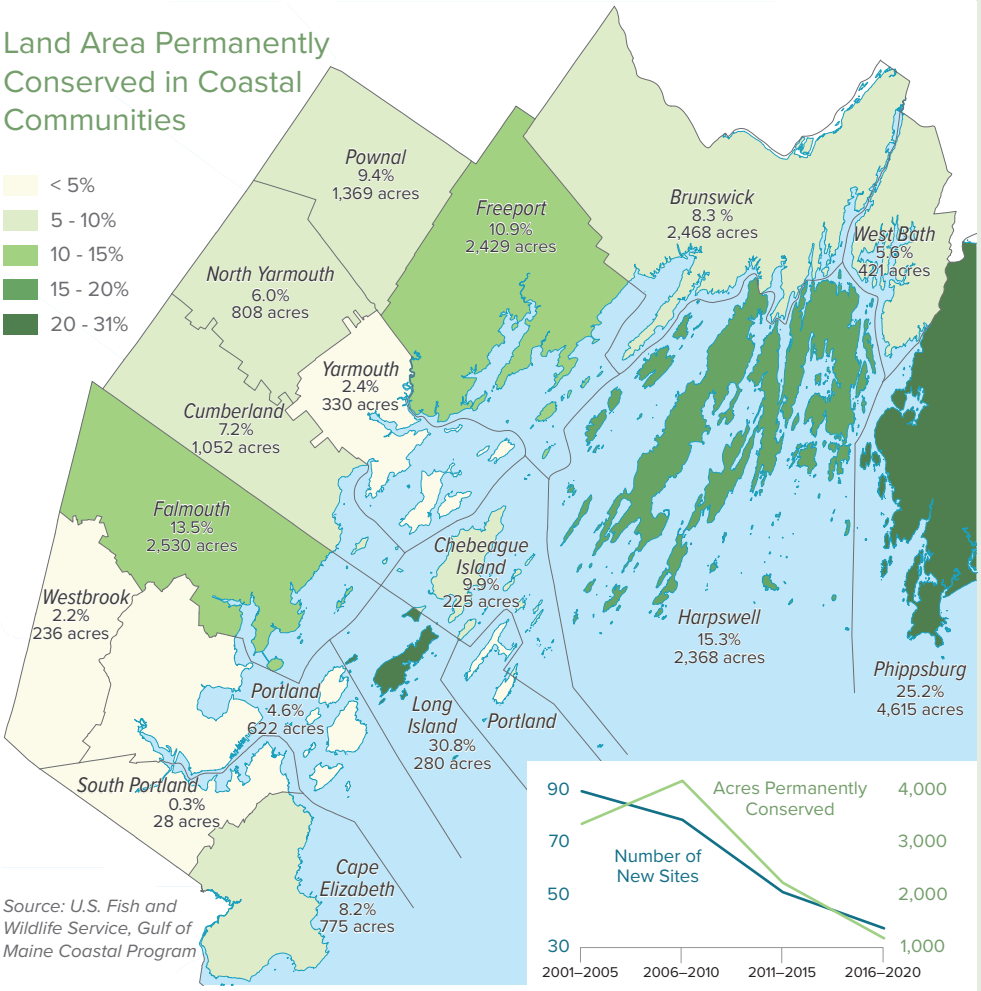
STATUS & TRENDS

In the Casco Bay watershed, 81,621 acres of land had been permanently protected as of December 2019. This amounts to 14.2 percent of the total watershed land area and represents an additional 6,480 acres since 2014. The impressive increase reflects the tireless work of land trusts and other conservation partners.

Increase in Permanent Conservation Land in Casco Bay Watershed



Source: State of Maine Department of Conservation, Agriculture and Forestry and U.S. Fish and Wildlife Service, Gulf of Maine Coastal Program



Within coastal communities, which were the focus of previous CBEP State of the Bay summaries for conserved lands, a total of 20,556 acres were protected through the end of 2019, an increase of 1,596 acres from the 2015 State of the Bay report. In terms of area conserved, the pace of land protection in coastal communities has steadily declined in recent years, while substantial new conservation projects have occurred in the upper watershed.

THREATS / CHALLENGES

- The forces that are driving development are fundamentally regional in nature. And yet, the primary entities that work to protect land are operating at smaller scales—at either a local or multi-town level. As a result, regional development, land use, and transportation planning can be disconnected from land protection needs.
- The Casco Bay region lacks a set of shared, regional priorities for land protection, as well as regional conservation funding mechanisms to help address the higher cost of conservation work in this part of the state.
- There are challenges with tracking and mapping conservation land at a regional scale. For example, municipally owned properties may not be defined as protected, despite long-term management practices.
- The pace of land conservation is limited by costs, particularly during periods with strong real estate markets. Long-term stewardship obligations can also constrain the pace of conservation.



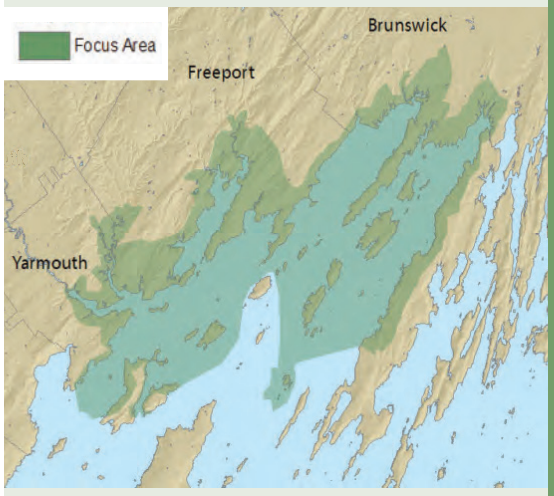
MAQUOIT AND MIDDLE BAY CONSERVATION FOCUS AREA

The sheltered coves and peninsulas between the Royal River estuary and Harpswell Neck provide an “extraordinary array of ecological values," according to the State of Maine Beginning with Habitat program. This area of Casco Bay includes salt marshes, mudflats, eelgrass beds, and over a dozen islands.

The interconnected landscape supports numerous “rare animals as well as fish, invertebrates, waterfowl, wading birds, and other wildlife, including commercially valuable species,” providing ecological and economic benefits to the Bay and its communities.

The State's designation of this area as a Conservation Focus Area has helped to concentrate collaborative efforts to protect this special place and build regional awareness of its importance.

Maquoit and Middle Bay Conservation Focus Area. (Map: Beginning with Habitat)





Casco Bay Has 16,655 Acres of Tidal Habitats

Over a Hundred Acres of Tidal Marshes Restored Through Culvert Replacement

Jerry Monkman, Ecophotography.com

WHY IT MATTERS

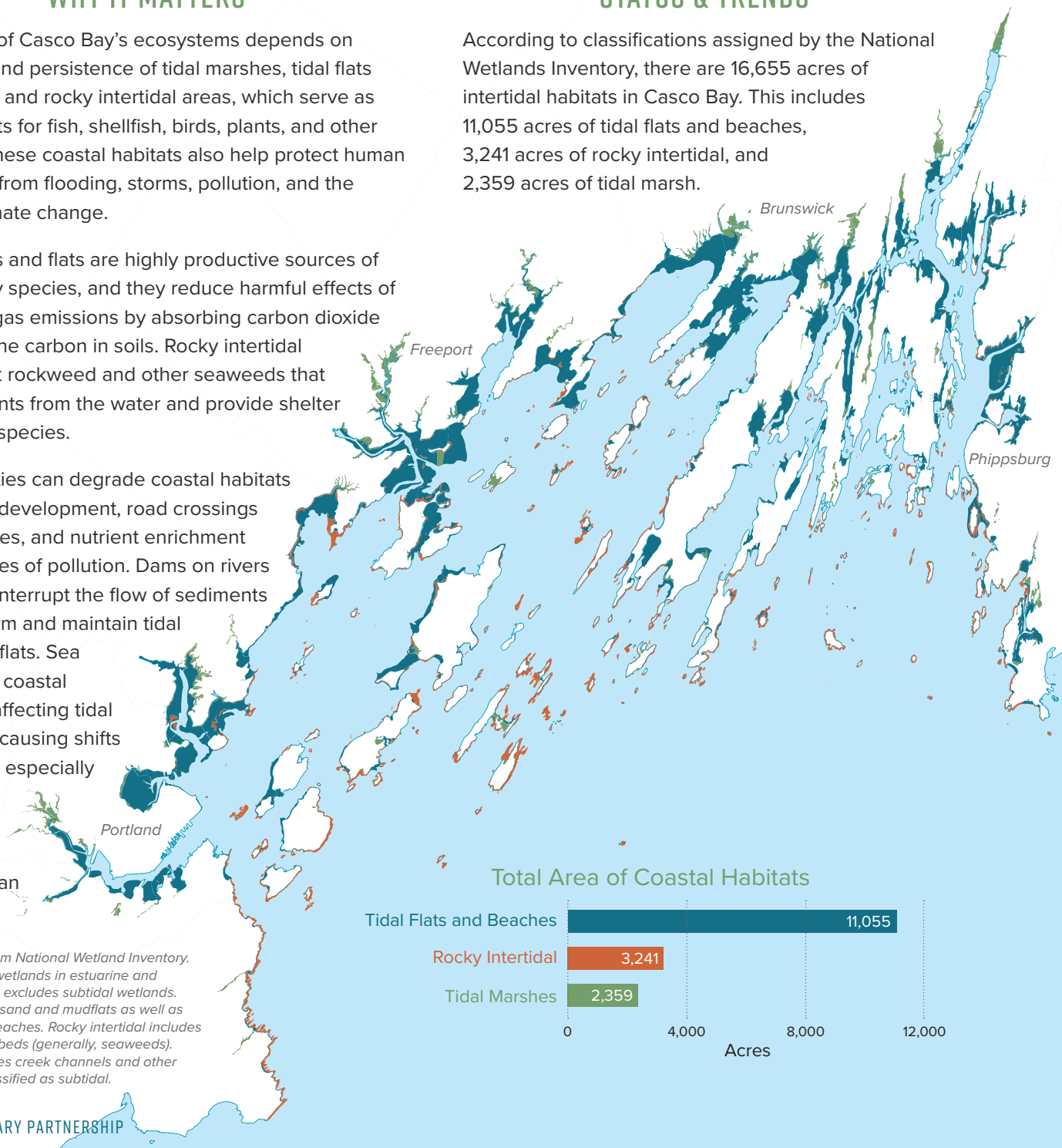
The integrity of Casco Bay's ecosystems depends on the function and persistence of tidal marshes, tidal flats and beaches, and rocky intertidal areas, which serve as critical habitats for fish, shellfish, birds, plants, and other organisms. These coastal habitats also help protect human communities from flooding, storms, pollution, and the effects of climate change.

Tidal marshes and flats are highly productive sources of food for many species, and they reduce harmful effects of greenhouse gas emissions by absorbing carbon dioxide and burying the carbon in soils. Rocky intertidal areas support rockweed and other seaweeds that absorb nutrients from the water and provide shelter to numerous species.

Human activities can degrade coastal habitats through land development, road crossings of tidal marshes, and nutrient enrichment and other types of pollution. Dams on rivers and streams interrupt the flow of sediments needed to form and maintain tidal marshes and flats. Sea level rise and coastal flooding are affecting tidal marshes and causing shifts in vegetation, especially in marshes already degraded by other human activities.

STATUS & TRENDS

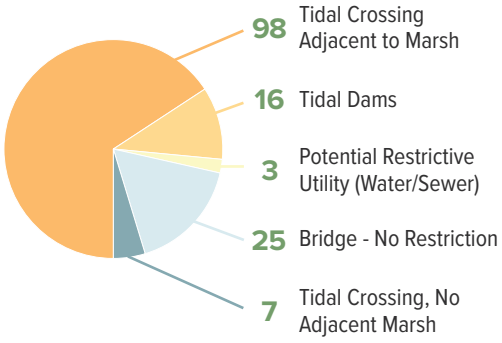
According to classifications assigned by the National Wetlands Inventory, there are 16,655 acres of intertidal habitats in Casco Bay. This includes 11,055 acres of tidal flats and beaches, 3,241 acres of rocky intertidal, and 2,359 acres of tidal marsh.



Source: Derived from National Wetland Inventory. Includes intertidal wetlands in estuarine and marine waters, and excludes subtidal wetlands. Tidal flats includes sand and mudflats as well as rocky and sandy beaches. Rocky intertidal includes aquatic vegetated beds (generally, seaweeds). Tidal marsh excludes creek channels and other marsh features classified as subtidal.

Tidal Marshes Impaired by Over 100 Road Crossings and Dams

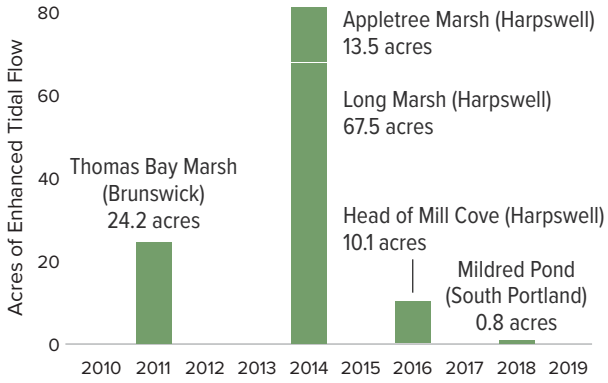
Tidal marshes support 36 Species of Greatest Conservation Need according to Maine's Wildlife Action Plan. Spartina *salt marshes are considered a rare natural community type. However, many of Casco Bay's tidal marshes have been degraded or converted to freshwater wetlands by hydrological modifications following the construction of roads, railways, dams, and dikes, resulting in the loss of* Spartina *salt marsh. CBEP estimates that there are 149 tidal crossings around Casco Bay, of which about 114 may be restricting tidal flow into adjacent wetlands.*



Source: CBEP and Maine Coastal Program

Replacing Undersized Culverts Restores 116 Acres of Tidal Marsh

Five proactive tidal culvert replacement projects since 2010 have resulted in enhanced tidal exchange into 116 acres of marsh, equal to 6.9% of the Bay's total marsh area.



Source: National Wetlands Inventory and Maine Natural Areas Program

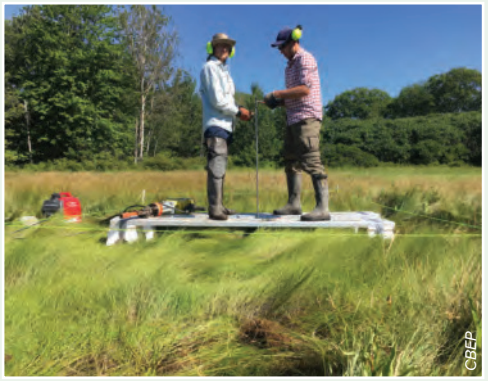
SUCCESSES AND CHALLENGES

- Tidal flats and marshes are vulnerable to accelerating sea level rise, which may alter sediment deposition processes and cause erosion. As tidal marsh erodes, it typically converts to mudflats, but both habitats depend on delivery of sediment to maintain elevations within the tidal range. It is unclear whether sediment delivery will be adequate to maintain marshes and mudflats in Casco Bay. Protection of low-lying uplands adjacent to tidal marshes accommodates expansion of new marsh inland as the seaward edge erodes, while safeguarding water quality and activities such as shellfish harvesting and aquaculture that depend on it.
- Where roads and other structures restrict tidal flow to marshes, and where conditions permit, restoration of tidal exchange can enhance resilience to sea level rise and other stressors. Brunswick, Harpswell, Phippsburg, and South Portland have recently implemented marsh restoration efforts, resulting in enhanced tidal exchange into 116 acres of marsh, or 6.9% of the Bay's total marsh area.
- Establishment and expansion of non-native species such as European green crab and the common reed, *Phragmites australis*, can result in sudden ecological shifts that may be difficult to reverse. Healthy marsh ecosystems are better able to withstand these and other threats.



COASTWISE ROAD CROSSINGS

Maine Coastal Program and collaborating partners, including CBEP, are developing a voluntary set of science-based, field-tested best practices for designing climate-resilient tidal road crossings. CoastWise aims to reverse centuries of impacts to marshes and other tidal habitats by designing safe, low-maintenance crossings scaled to accommodate sea level rise and restore natural tidal flow. Training sessions will also encourage municipalities to utilize a definitive statewide atlas of tidal crossings recently developed by Maine Coastal Program.



MONITORING COASTAL HABITATS

Scientists agree on the need to establish long-term sentinel monitoring stations aimed at tracking changes to coastal habitats. One example is Maine Coastal Program's statewide network of salt marsh monitoring sites, including one in Maquoit Bay. Using Rod Surface Elevation Tables (rSETs), precise annual measurements of sediment elevations are collected annually. Researchers hope that eventually these data will provide insights into the rates of marsh elevation change relative to sea level rise, as well as an improved understanding of the processes driving these changes.



Bay Has $700 Million Economic Impact

Tourism and Marine Resources Are Key Sectors of Coastal Economy

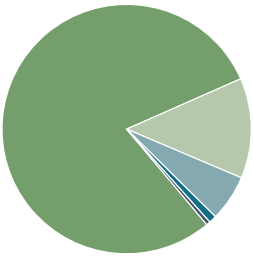
Jerry Monkman, Ecophotography.com

WHY IT MATTERS

The Casco Bay region is home to one quarter of Maine's population and one third of total jobs statewide, despite containing just 4.4 percent of the state's land area. Tourism and recreation make up 80 percent of the jobs in Casco Bay's coastal economy. The living resources sector makes up a smaller share but is central to the Bay's identity. The fishing industry's cherished cultural traditions are a way of life for many Maine families and represent the coastal identity that brings so many visitors to Maine.

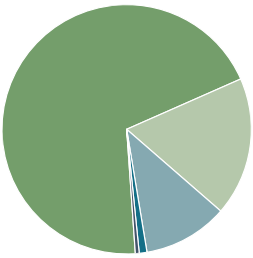
STATUS & TRENDS

Eighty Percent of Bay-Related Jobs Are in Tourism and Recreation



JOBS: 18,493

Tourism & Recreation	14,797	80%
Marine Transportation	2,433	13%
Living Resources	1,139	6%
Marine Construction	94	1%
Ship and Boat Building	30	<1%



GROSS REGIONAL PRODUCT: $703 MILLION

Tourism & Recreation	$491.6 M	70%
Marine Transportation	$126 M	18%
Living Resources	$76 M	11%
Marine Construction	$7.8 M	1%
Ship and Boat Building	$2.5 M	<1%

Note: Boat building excludes Bath Iron Works. Source: The Economic Contribution of Casco Bay (CBEP 2017). Report produced by Maine Center for Business and Economic Research.







Top and top right: Lobstering and clamming are important traditions and livelihoods, and the fishing industry supports tourism.

Middle right: The marine aquaculture industry in Casco Bay is growing rapidly. Long-term leases have increased by 75 percent from 21 to 37 since early 2017, and Limited Purpose Aquaculture leases rose from 152 to 165.

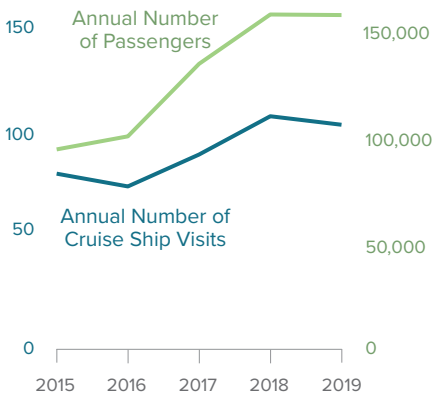
Bottom right: Icelandic shipping company Eimskip's North American headquarters is located at Portland's International Marine Terminal.

(Photos: Top and bottom, Jerry Monkman, Ecophotography.com; Middle, Quahog Bay Conservancy)

Cruise Ship Visits and Passengers

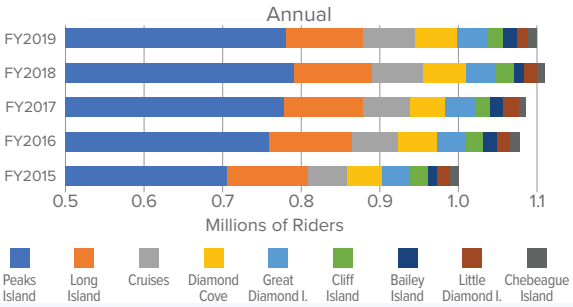


Cruise ship visits to Portland increased from 2015 to 2019, with passenger numbers rising even faster, reflecting larger ships. (Photo: Corey Templeton)

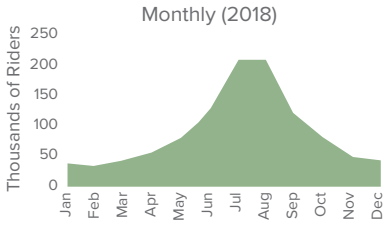


Source: City of Portland

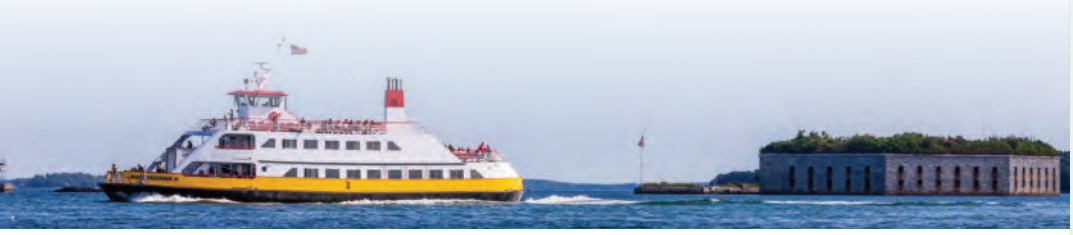
Casco Bay Ferry Ridership



Ferry ridership increased from 2015 to 2019, with more than a million riders annually. Source: Casco Bay Lines



Ferry ridership follows a seasonal trend, peaking in summer months.



SUCCESSES & CHALLENGES

- Marine ecosystems are expected to be affected by climate change in numerous ways, and the health of the regional economy is highly dependent upon the health of Casco Bay.
- People visiting Casco Bay may not always make the connection between the importance of clean water, protected habitat, and ample access, to the quality of their recreational experiences. How do we help them make that connection?
- How do people without extensive resources and access to the Bay experience it? Providing adequate access to recreational opportunities for all is important for nurturing personal connections to the Bay and building public support for its protection.
- Impacts from the COVID-19 crisis illuminate how dependent the local economy is on the tourism industry.

RECREATION ON THE WATER

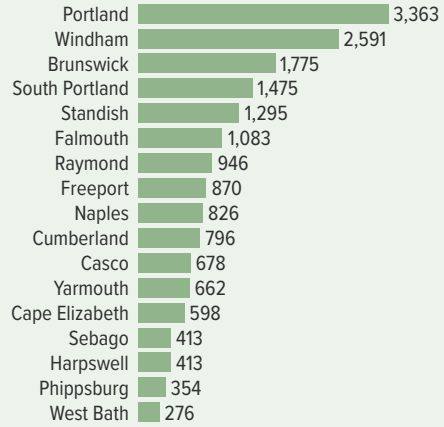


For local residents and visitors alike, Casco Bay is renowned for its sailing, sport fishing, motorboating, paddling, island hopping, birding, beachgoing, and many other recreational activities. (Photos: Jerry Monkman, Ecophotography.com)



The Casco Bay region has approximately fifty marinas and numerous launch points for motorized and non-motorized boats.

Recreational Fishing Licenses (2018)



Source: Maine Department of Inland Fisheries and Wildlife



(Photo: Royal River Conservation Trust)



Place-Based Education Engages Thousands of K-12 Students Around Casco Bay

Schools and Nonprofits Collaborate to Provide Environmental Education

Harpswell Heritage Land Trust

WHY IT MATTERS

Thousands of K-12 students in the Casco Bay region participate in community-based environmental learning programs run by schools, nonprofits, and government agencies. These in-school or field-based programs educate youth about the environment while connecting them to their communities. Community-based learning has many positive impacts, from enhancing critical thinking skills and increasing environmental literacy, to providing youth with a much-needed connection to nature and to real-world issues in their communities. These education programs foster a greater understanding of local environmental impacts and can lead to volunteer stewardship efforts that have a positive effect on the Casco Bay ecosystem.

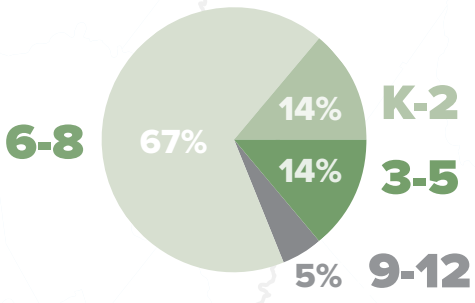
STATUS & TRENDS

In 2020, CBEP canvassed partner nonprofits and land trusts that provide K-12 environmental education programs. Their responses showed that place-based education is reaching more than 7,900 students in most of the watershed's communities.



Cumberland County Soil and Water Conservation District's CONNECT program focuses on clean water education with lessons, field trips, and service learning. In 2019, they reached 1,525 students in eleven Bay communities. (Photo: CCSWCD)

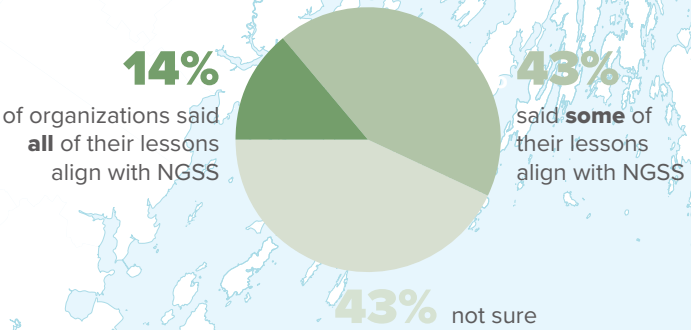
Participating Students by Grade Level



Most place-based education programs are aimed at grades 6-8, followed by grades K-2 and 3-5; fewer programs are geared to grades 9-12.

Source: CBEP canvassing of partner organizations

Alignment with Next Generation Science Standards



Fifty-seven percent of organizations said that some or all of their lessons align with Next Generation Science Standards (NGSS). Most lessons are focused on water quality, water cycle, watershed, and habitat themes.



Through the TroutKids Program coordinated by the Portland Water District, students raise brook trout and release them into water bodies each spring. The students learn about water quality and have hands-on science and stewardship opportunities. (Photo: Portland Water District)

SUCCESSES AND CHALLENGES

- Some of the challenges organizations face in carrying out K-12 educational programs include staff capacity issues, funding, scheduling, and the "constant shuffling of science curriculum" that one organization says puts them at risk of program cancellation if they "can't adapt quickly to content and standards."
- Many local organizations recognize the importance of instilling an appreciation for the natural world at an early age, and to that end, are creating early childhood place-based learning programs.
- Partner organizations need support and training in science standards, to increase linkages between these organizations and school systems. Schools also need support and training on incorporating place-based learning into their existing curricula.
- The most successful education programs seem to be those with long-standing connections with the schools in their area, where teachers reach out regularly and the provider organizations share resources.

One nonprofit noted that their biggest success is "working with teachers who are eager to bring real, local issues and collaborative problem solving to their students."



In Brunswick Junior High School's community-based expeditionary learning unit, students survey Thomas Bay Marsh. (Photo: CBEP)

EXPEDITIONARY LEARNING

Several schools around Casco Bay have long-standing expeditionary learning programs, including Casco Bay High School and King Middle School in Portland; Brunswick Junior High School; and West Bath Elementary School. Harpswell Coastal Academy has a project-based learning approach to education that offers similar, real-world experiences beyond the classroom. Schools that employ expeditionary learning choose a topic for their "learning expedition" and integrate the topic into all subjects, as opposed to students learning unrelated content in each class.

A CHANGING EDUCATION LANDSCAPE

The COVID-19 pandemic created new educational challenges as schools shifted to a combination of in-person, virtual, and hybrid learning. In response, environmental organizations and state agencies active around Casco Bay moved quickly and nimbly to provide resources and creative curricula for students. The organizations received funding from the Maine Mathematics and Science Alliance Teach ME Outside Initiative and Community Learning for ME, a virtual space to support teachers and families during the pandemic.



(Photo: Maine Mathematics and Science Alliance)



Volunteers Donate More than 17,000 Hours to Stewardship of Casco Bay

Organizations Engage Volunteers in Wide Range of Roles

Jerry Monkman, Ecophotography.com

WHY IT MATTERS

Volunteers for nonprofit and state government environmental organizations engage in important work. Their efforts contribute to the health and resilience of their communities. They may also develop personal connections with the Bay's ecosystem and become more deeply involved in the Bay's protection and restoration. The number of hours donated by volunteers for environmental stewardship is one measure of how connected people are to Casco Bay and how committed they are to protecting it.

STATUS & TRENDS

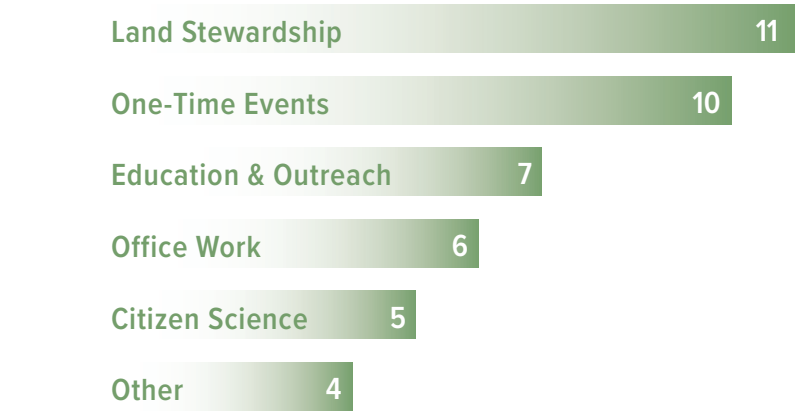
CBEP in 2020 canvassed 26 nonprofit and state government environmental organizations active in Casco Bay and its watershed about volunteer stewardship and heard back from 13 organizations, 9 of which were land trusts.



Land trusts in the Casco Bay region rely heavily on volunteers. This volunteer for the Presumpscot Regional Land Trust is collecting water in Mill Brook to be analyzed for E. coli. *(Photo: PRLT)*



Volunteers from Idexx help Maine Island Trail Association dismantle a derelict float on Little Chebeague Island. The lumber was repurposed to build a boardwalk on the island. (Photo: Chris Wall)



The most common volunteer roles according to 13 nonprofit and state government environmental organizations that provided data to CBEP.

SUCCESSES AND CHALLENGES

- CBEP's canvassing of nonprofit and state government environmental organizations asked respondents to describe successes and challenges related to engaging volunteers in stewardship. The following quotations are representative of the range of responses:

  "We've learned that on the whole, working with volunteers does not save us time or money. However, it's an extremely rewarding and important way of engaging our communities with land conservation."

  "Couldn't live without them."

- Several organizations cited long-term retention of volunteers and multi-year engagement as their greatest volunteer program successes.

- Leading nature walks, monitoring water quality, and participating in citizen science projects provide unique opportunities for volunteers. Popular public events can also be built around these topics.



Volunteers particpate in a Portland Trails work day on the Stroudwater River Trail. (Photo: Garrick Hoffman)

Volunteer recruitment generally is not a challenge, but staff capacity to execute projects and manage volunteers is.



A member of Phippsburg Conservation Commission recording water quality data. (Photos: CBEP)

CONSERVATION COMMISSIONS: KEY PARTNERS FOR CASCO BAY

Conservation commissions are municipal advisory boards established by towns and cities through their legislative bodies such as town meetings or municipal councils. Members of conservation commissions are volunteers.

According to the Maine Association of Conservation Commissions, the most active commissions educate community members about local environmental issues; advise elected officials regarding environmental policies and practices; and organize and implement initiatives that address community environmental concerns. They often work in concert with local land trusts and nonprofits.

Commissions in the Casco Bay watershed are engaged in sea level rise monitoring, trail improvement, comprehensive plan guidance, pollution best management practices and education, and many other projects.



Conservation Commission members reading site plans in a CBEP Coastal Academy workshop.

Municipal and Community Leaders Take Action Toward Climate Resilience

Many Paths to Community Resilience and Adaptation in Casco Bay

CBEP

WHY IT MATTERS

Maine's warming climate brings increased intensity, frequency, and variability to precipitation events, snowmelt, coastal flooding, and sea level rise. These climate-related events are already threatening Casco Bay's coastal ecosystems, community infrastructure, social fabric, and marine and tourism economy. Casco Bay coastal communities are diverse but share a common goal of protecting our natural resources to remain socially, economically, and environmentally resilient. There are many different metrics to assess resilience and steps communities can take to adapt to a changing climate, such as strengthening land use ordinances. All communities need increased and ongoing coordinated support and technical assistance to adapt to our changing climate.



In a pilot project to test the use of natural elements to protect against shoreline erosion, a team led by Maine Geological Survey installed "living shorelines" at three sites around Casco Bay. (Photo: Maine Geological Survey)

STATUS & TRENDS

8+
Communities have completed climate change vulnerability assessments

12
Communities are covered by their region's Hazard Mitigation Plan

11
Communities have consistent comprehensive plans; only a few integrate climate resilience planning

2-3
Communities are in the process of developing adaptation plans and vulnerability assessments

Corey Templeton / Creative Commons

Flood Insurance Policies and Community Rating System Participation

COMMUNITY	NUMBER OF FLOOD INSURANCE POLICIES	CRS CLASS
Brunswick	49	NP
Cape Elizabeth	64	8
Chebeague Island	1	NP
Cumberland	32	NP
Falmouth	35	NP
Freeport	26	NP
Harpswell	146	NP
Long Island	6	NP
Phippsburg	48	NP
Portland	240	8
South Portland	125	NP
West Bath	8	NP
Yarmouth	63	NP

Source: FEMA NFIP Insurance Report; Maine Emergency Management Agency

As of July 2020, about 96% of Maine communities participated in the Federal Emergency Management Agency's National Flood Insurance Program (NFIP). As of October 1, 2019, there were 17 Maine communities participating in the Community Rating System (CRS). The CRS provides flood insurance discounts for communities that invest in flood mitigation measures such as reducing flood damage to existing buildings, preserving and restoring natural functions of floodplains, and other activities.

SUCCESSES & CHALLENGES

- Lack of municipal resources and capacity, competing community and political priorities, and little regional coordination pose challenges, particularly for small municipalities.
- Community awareness and support, increased education and assistance from state agencies and nonprofits, and the presence of community champions all greatly increase the likelihood of implementing programs and policies.
- Continuing to share information, success stories, and existing resources between communities and partners will help improve community planning for resilience.
- Underserved and vulnerable populations are often those most impacted by environmental pollution and climate change. Furthermore, there are often barriers to and inertia in engaging these residents.
- The Governor's Office of Policy Innovation and the Future, in partnership with state agencies, is following up on the Maine Climate Council report with more and stronger state and regional programs that offer technical assistance and coordinated funding sources.

COMMUNITY ACTIONS



The cities of Portland and South Portland adopted a joint climate action and adaptation plan called One Climate Future. This model of regional collaboration is one that other communities could adopt.



The Town of Harpswell has been planning for the impacts of sea level rise and coastal flooding events on both public and private roads (above). A local climate resilience task force completed a climate resilience vulnerability assessment in 2020 and is actively seeking funding to implement adaptation projects and engage the community. Below: Wallace Shore Road in Harpswell overtopping during a nor'easter in January 2018. (Photos: Top, CBEP; Bottom, Harpswell Conservation Commission)



Casco Bay and Its Watershed



Casco Bay Estuary Partnership

CASCO BAY ESTUARY PARTNERSHIP MANAGEMENT COMMITTEE

Gretchen Anderson
Town of Windham

Erno Bonebakker
Casco Bay Islands Alliance

Damian Brady
University of Maine-Orono

Jacki Cohen
Citizen

Andrew Coughlin
Mast Landing Brewing Company

Dan Devereaux
Town of Brunswick

Fred Dillon
City of South Portland

Michael Feldman
Coldwell Banker

Ivy Frignoca
Friends of Casco Bay

Nancy Gallinaro
City of Portland

Wendy Garland
Maine Department of Environmental Protection

Howard Gray
Acadia Center

Charles Hebson
Maine Department of Transportation

Heather Huntt
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Rachel Lasley-Rasher
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Regina Lyons
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Christopher Meaney
U.S. Fish & Wildlife Service

Sara Mills-Knapp
Greater Portland Council of Governments

Charlene Poulin
Portland Water District

Tamara Risser
Standard Biocarbon

Tom Shyka
NERACOOS

Karen Wilson
University of Southern Maine

Indicators Reported in *State of Casco Bay*, 6th Edition







DRIVERS & STRESSORS

What's Affecting the Bay?

A. POPULATION & LAND USE
B. STORMWATER
C. COMBINED SEWER OVERFLOWS
D. INLAND WATER QUALITY
E. CLIMATE CHANGE
F. INVASIVE SPECIES

CONDITION OF THE BAY

How Is the Bay Doing?

G. BAY WATER QUALITY
H. NUTRIENTS
I. AQUATIC CONNECTIVITY
J. EELGRASS
K. COASTAL ACIDIFICATION
L. SWIMMING BEACHES & SHELLFISH BEDS
M. TOXICS

HUMAN CONNECTIONS

What's Being Done?

N. CONSERVED LANDS
O. COASTAL HABITATS
P. ECONOMICS
Q. EDUCATION
R. STEWARDSHIP
S. CLIMATE PREPAREDNESS

Casco Bay Estuary PARTNERSHIP

www.cascobayestuary.org/state-of-casco-bay

Front cover map: MollyMaps. Back cover photos (L to R): CBEP; Jerry Monkman, Ecophotography.com; Cumberland County Soil and Water Conservation District.