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

Introduction

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

Portland Water District

Ice house on Sebago Lake circa 1927.

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

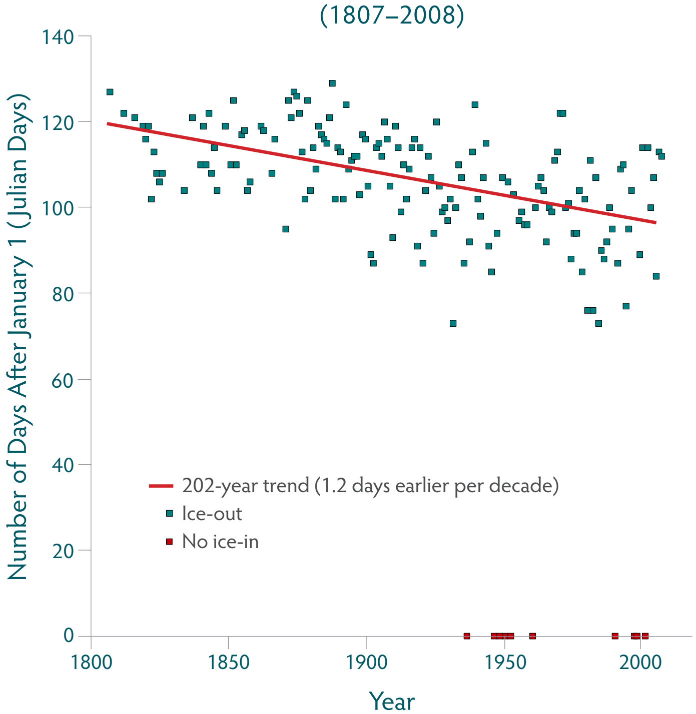
Whether they realize it or not, Maine's farmers, fishers, and naturalists have long used phenology – the study of how seasonal changes influence plant and animal life cycles – to plant their crops and plan their harvests. In doing so, they are following centuries of tradition. Written records of European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

Status and Trends

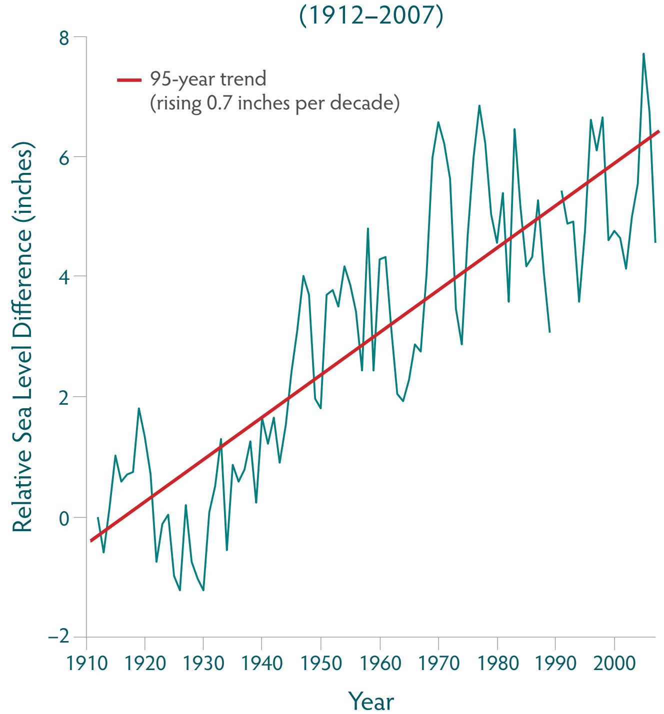
Sebago Lake Ice Out

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

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



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



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

Sea Level Rise

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

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

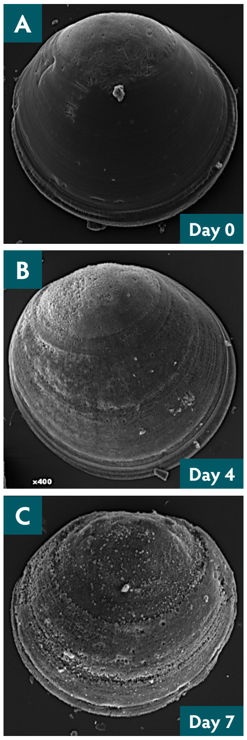
The Wake *et al.* (2009) report makes a preliminary estimate of future sea level changes in the Portland area. The city is projected to have increases in ocean elevations of between two and five feet by the end of this century. Those changes would require rates of sea level rise significantly above the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

Estimates of Future Sea Level Rise at Portland Harbor

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

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

[1] Feet above NAVD 1988.



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

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

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

C. Image of a clam after seven days exposure.

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

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

Ocean Acidification

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

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

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

Future Direction / Next Steps

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

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

References

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