SECTION THREE

Water Quality

Origamidon

Introduction

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

VLMP

Largemouth bass swims in Casco Bay watershed lake waters.

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

Reference

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

What is the quality of the waters of Casco Bay?

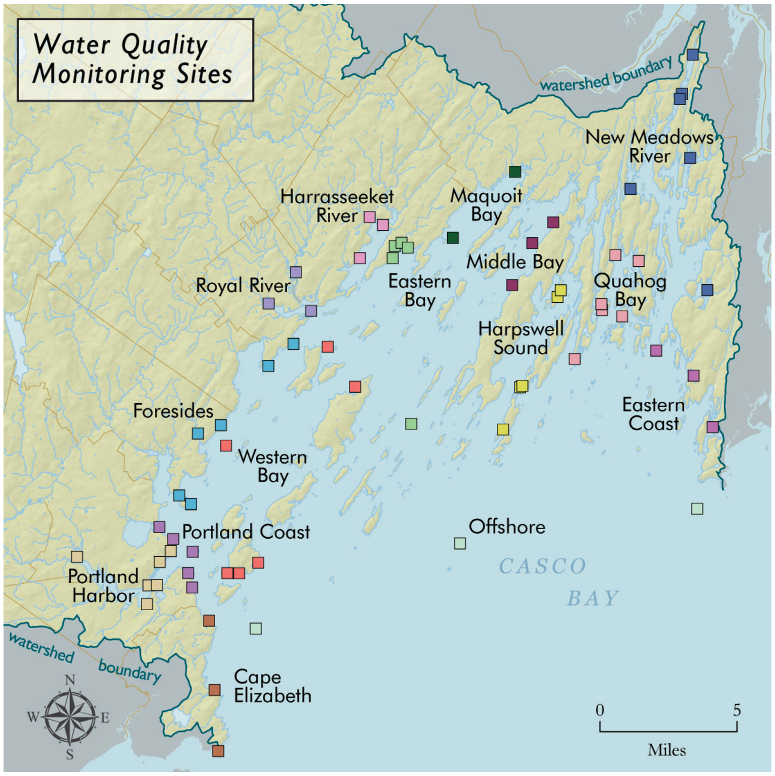
Why Is It Important to Monitor the Water Quality of Casco Bay?

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

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

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

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



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

Status of Water Quality in Casco Bay

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

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

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

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

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

Temporal Trends/Other Issues

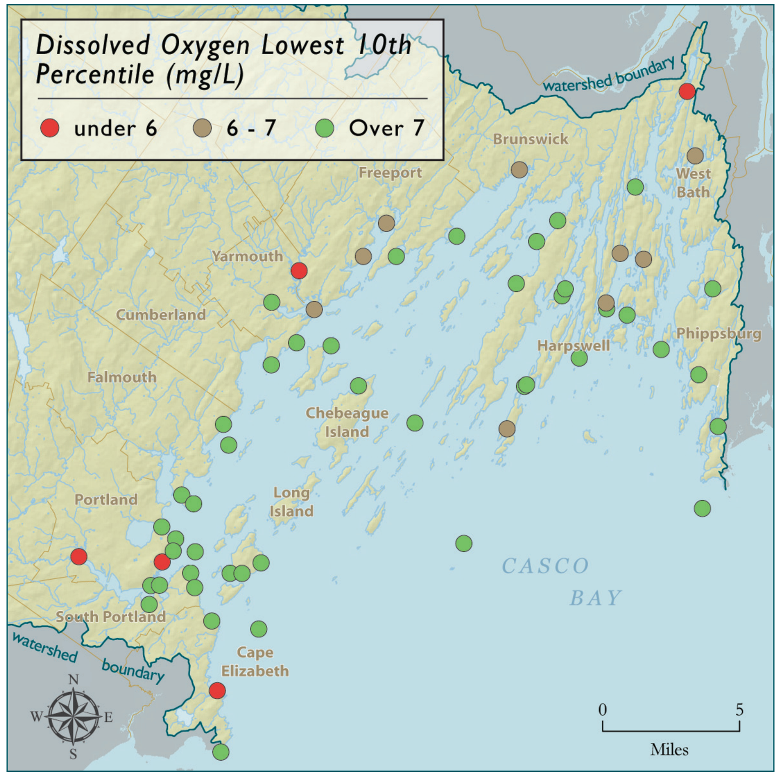
Annual mean surface water temperature (April–October) has been increasing by a tenth of a degree Centigrade annually since 1993 (see graph), while Secchi depth has been decreasing by slightly less than a tenth of a meter each year during that same time period. Both indicators seem to be reflecting reduced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

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

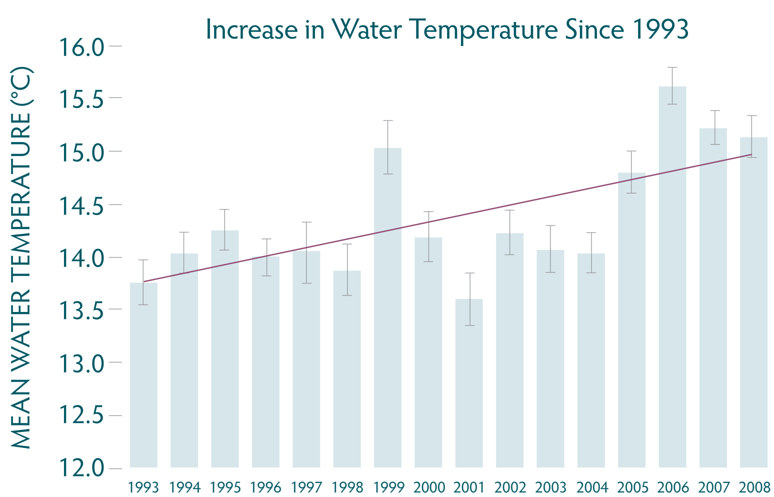
The DIN results show a relatively high ratio of ammonium to DIN. That is somewhat surprising since nitrate tends to be the dominant fraction of DIN in coastal waters. Further study is needed to interpret that ratio (FOCB 2010).

Conclusions and Future Directions

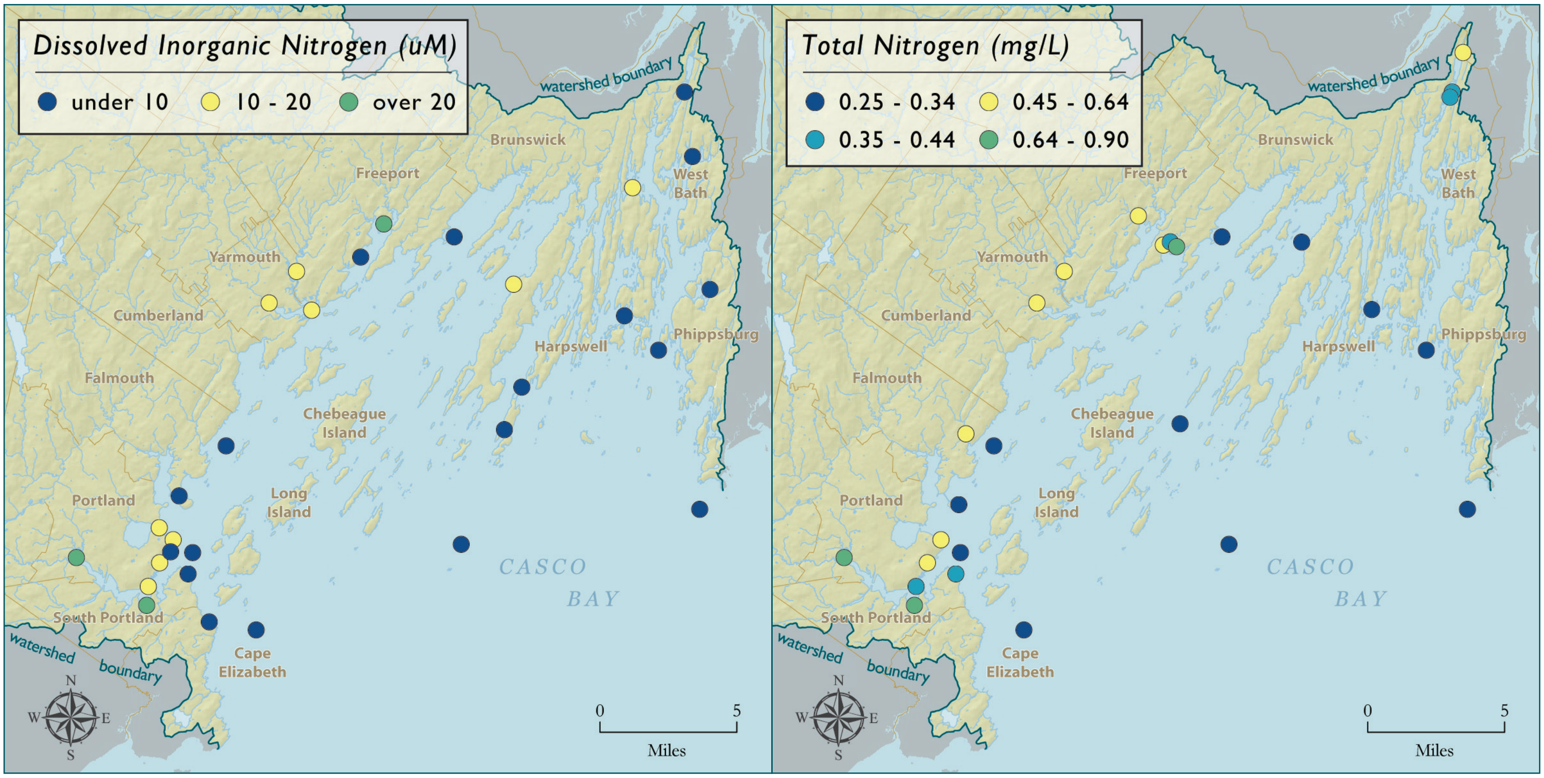
The overall water quality of Casco Bay is good, although there are a few sites where indicators have been measured at levels of concern. Low DO near urban areas suggests that the Bay is



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



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



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

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

FOCB

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

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

References

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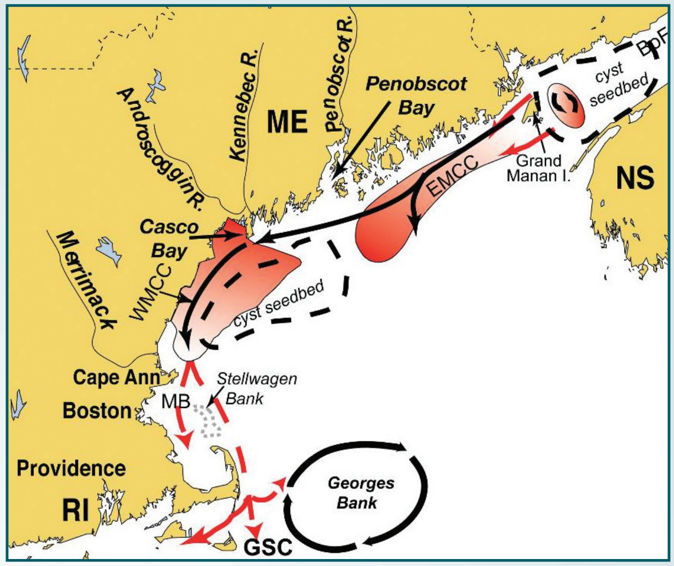
The Causes of Red Tides in Casco Bay: Does Local Water Quality Have an Impact?

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

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



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

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

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

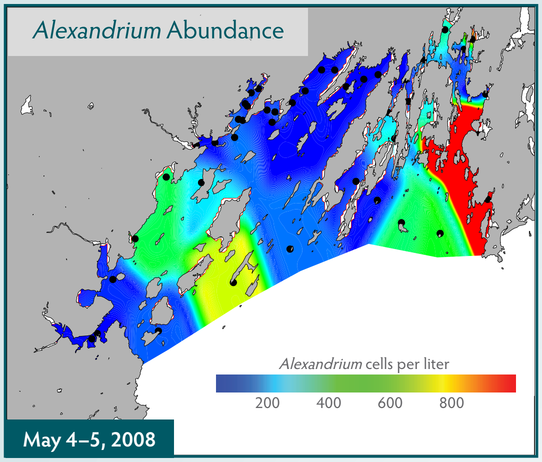
External Sources of Red Tide Organisms to Casco Bay

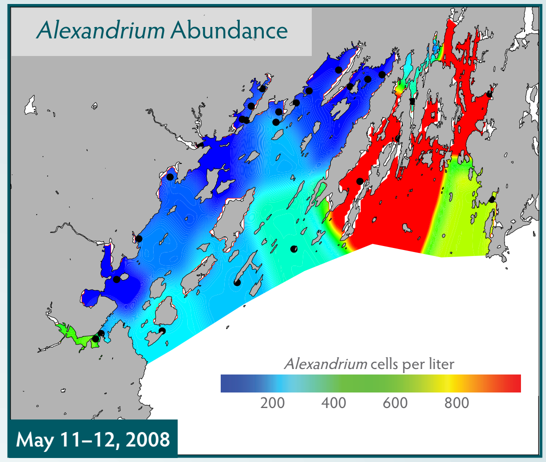
Red tides in the Gulf of Maine originate from dormant cysts (a resting stage of *A. fundyense*) that accumulate in localized "seed beds." As shown in the conceptual model, cysts in the Bay of Fundy germinate and cause recurrent blooms that are carried south and west by the Eastern Maine Coastal Current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

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

Internal Sources of Red Tide Organisms to Casco Bay

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





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

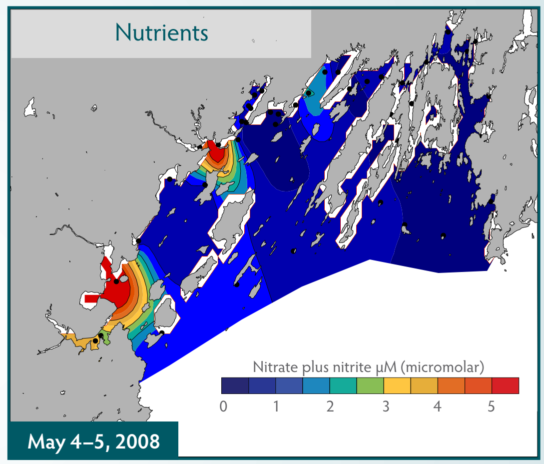
the distal portions of the New Meadows River and other sounds like Lumbos Hole) and the WMCC, which brings cells that originated in the Bay of Fundy and mid-coast Maine into Casco Bay (Libby and Anderson 2010).

Nutrients and Red Tides in Casco Bay

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

Conclusions

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



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

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INDICATOR 8

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

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

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

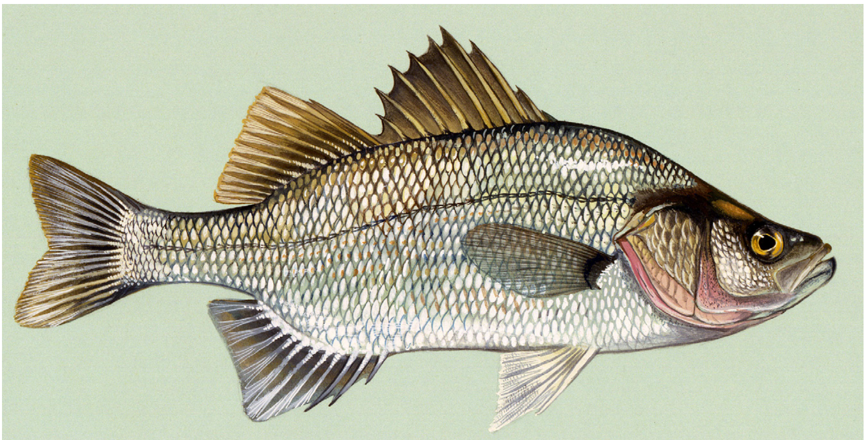
Every two years the Maine Department of Environmental Protection (DEP) assesses the status of its waters and produces an Integrated Water Quality Monitoring and Assessment Report ("305b") report. This report, most recently released in 2010, describes whether waters of the state (where monitoring data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

Status: Pollutants and Impacts

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

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

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



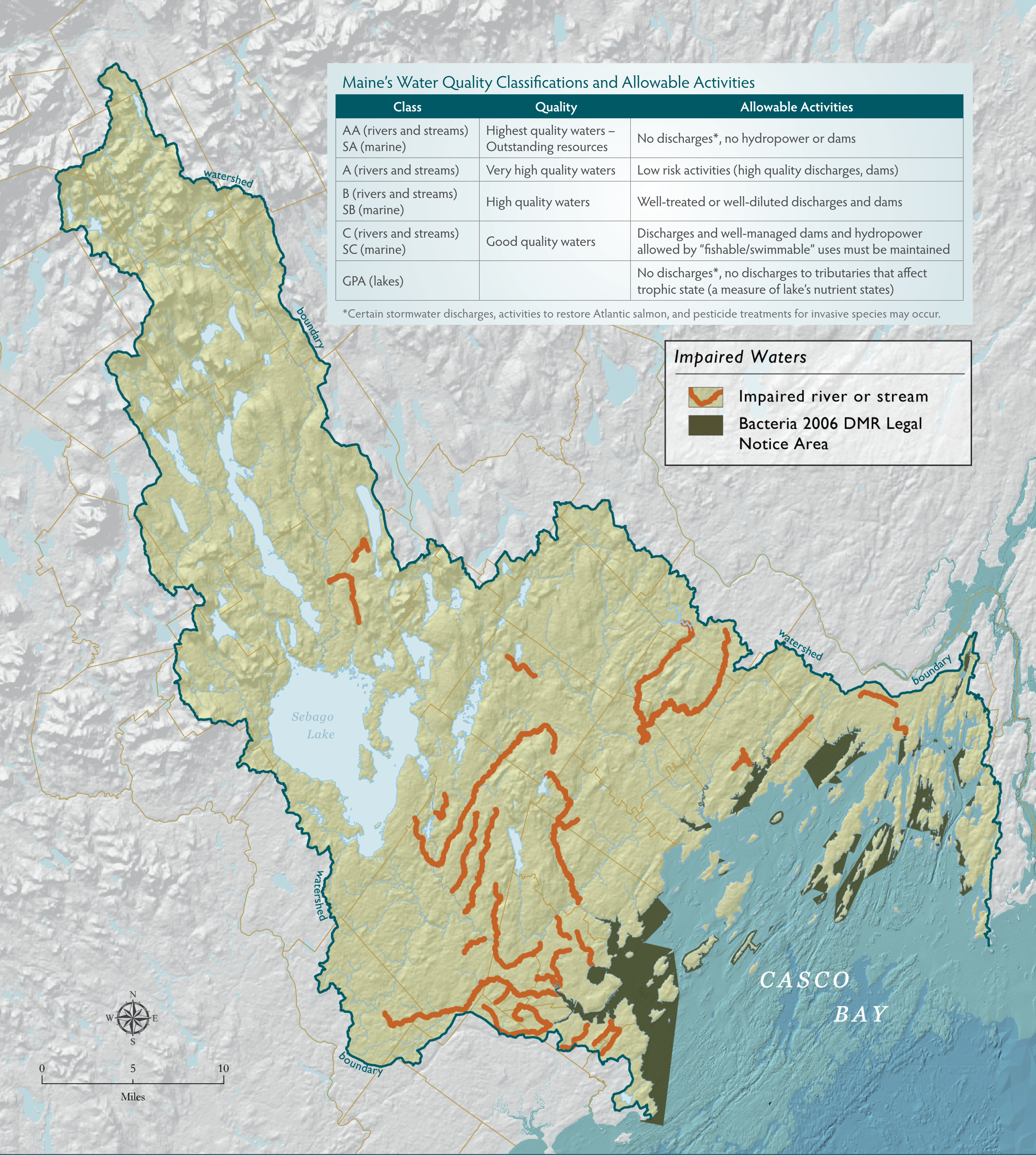
Duane Raver

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

Maine's Water Quality Classifications and Allowable Activities

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

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



Impaired Waters in the Casco Bay Watershed

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

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

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


Friedrich Böhringer

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

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

What Are the Trends?

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

Solutions and Actions to Help Meet Water Quality Standards

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

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

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

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

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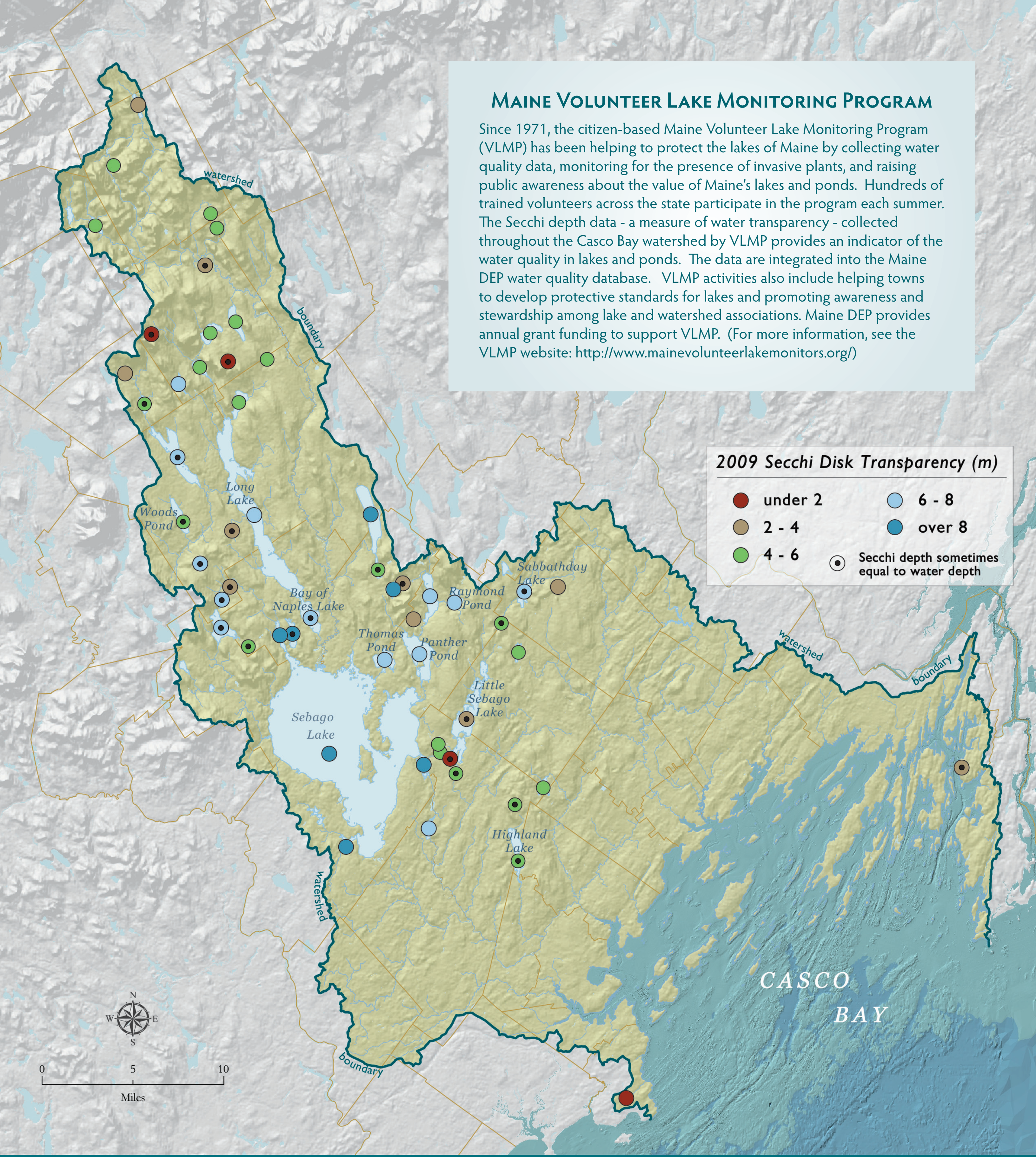
Maine Volunteer Lake Monitoring Program

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



Lake Water Transparency

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