INDICATOR 7

What is the quality of the waters of Casco Bay?

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

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

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

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

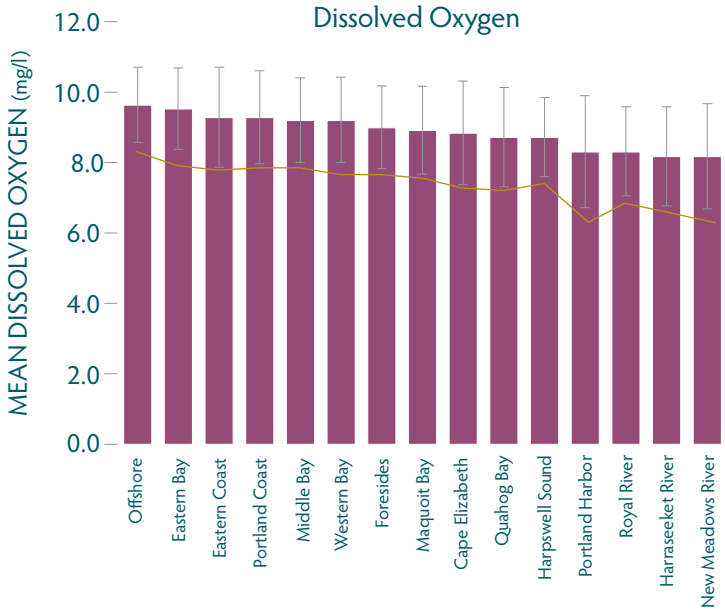
FOCB also monitors Secchi depth, a measure of water clarity. Generally, water with lower organic material, and therefore greater clarity, is considered healthier. The acidity or alkalinity of the water is also measured (as pH). The pH varies with fresh water inputs from rivers or streams or in responses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

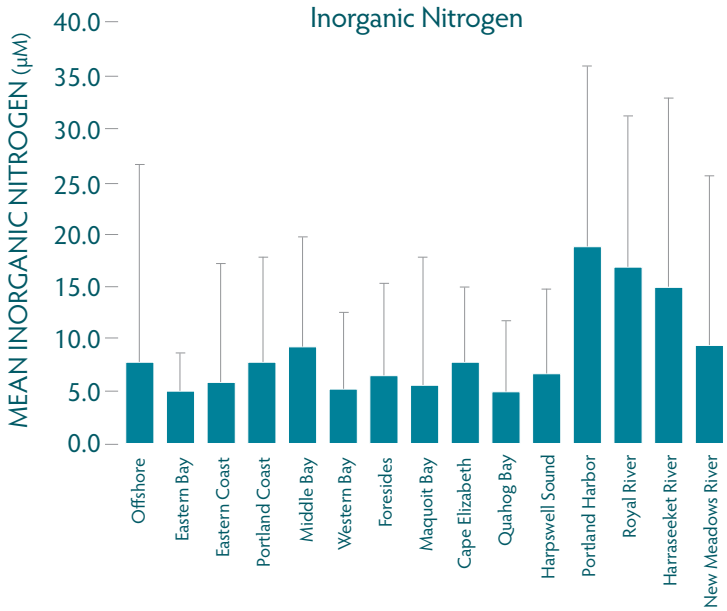
Samples are collected at the surface at more than 45 sites around Casco Bay from April through October. The sites are grouped into the 15 color-coded regions shown (FOCB 2010).

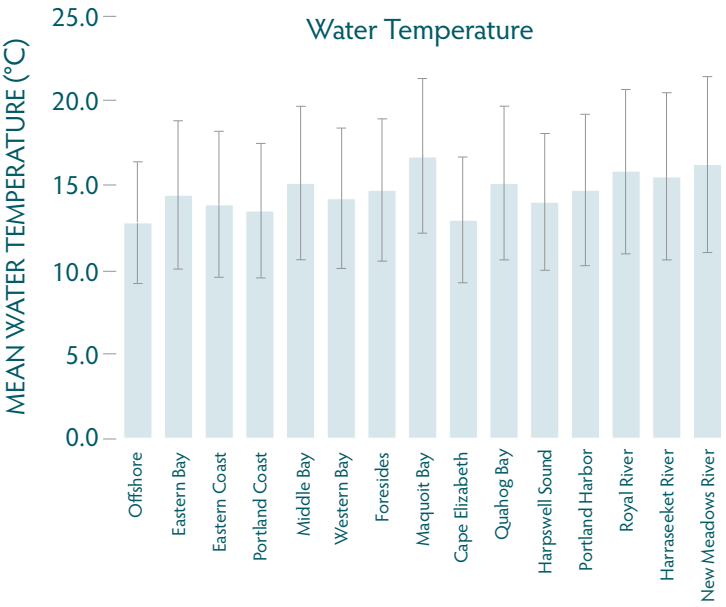
Status of Water Quality in Casco Bay

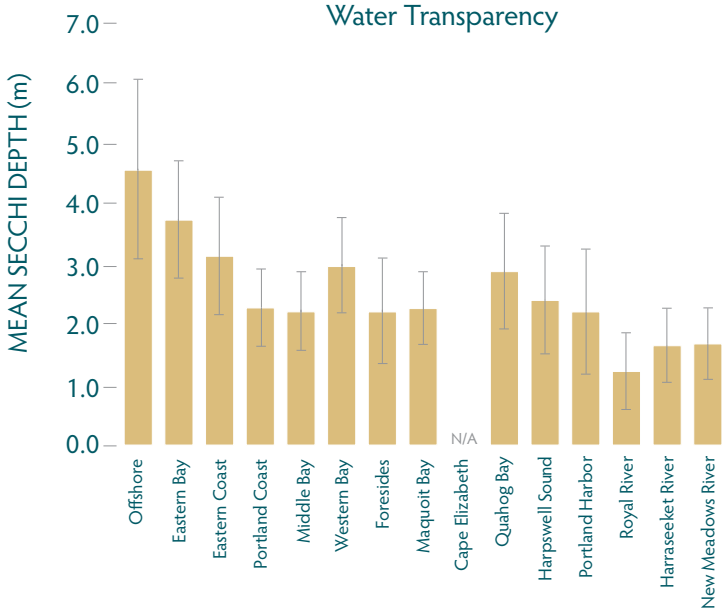
Dissolved oxygen, water temperature, Secchi depth and pH levels have been measured in the Bay since 1993. Measurements of dissolved inorganic nitrogen (DIN), which is the sum of nitrate, nitrite and ammonium, were added in 2001 through collaboration with the University of Maine School of Marine Sciences.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

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









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

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

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

Temporal Trends/Other Issues

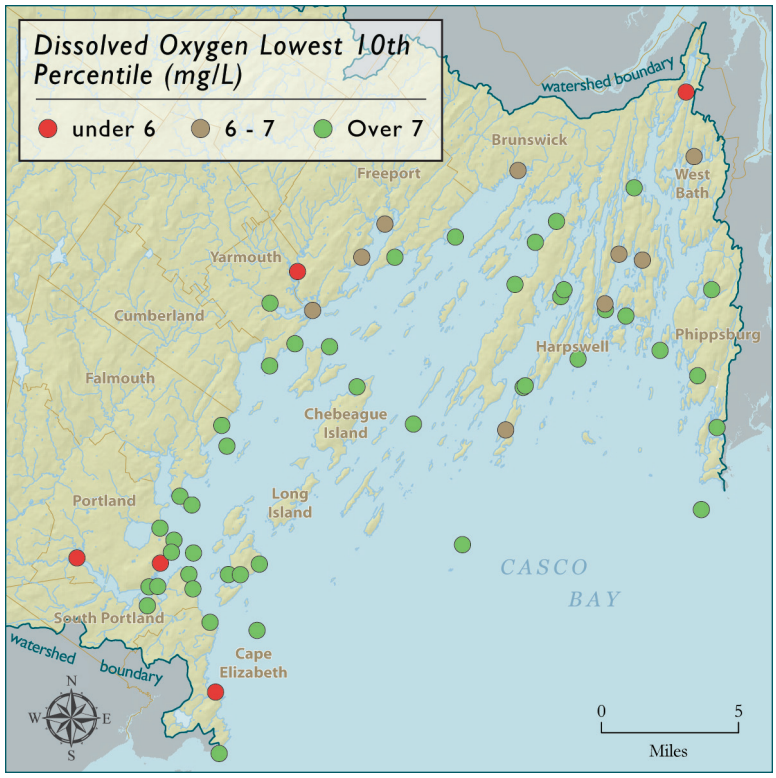
Annual mean surface water temperature (April–October) has been increasing by a tenth of a degree Centigrade annually since 1993 (see graph), while Secchi depth has been decreasing by slightly less than a tenth of a meter each year during that same time period. Both indicators seem to be reflecting reduced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

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

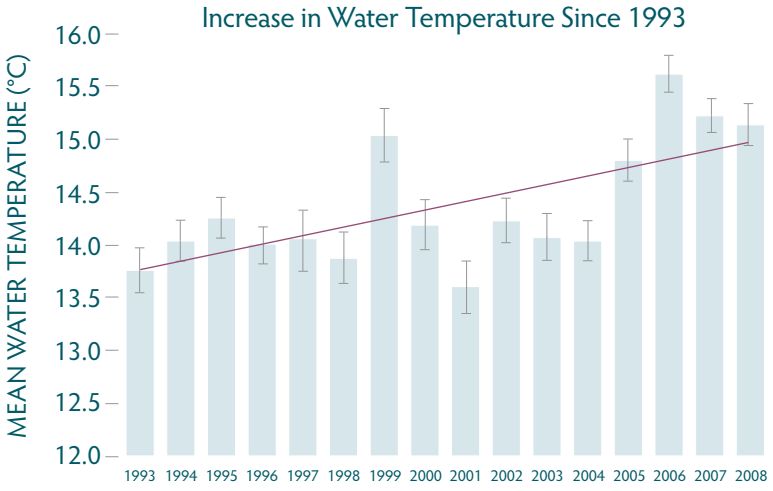
The DIN results show a relatively high ratio of ammonium to DIN. That is somewhat surprising since nitrate tends to be the dominant fraction of DIN in coastal waters. Further study is needed to interpret that ratio (FOCB 2010).

Conclusions and Future Directions

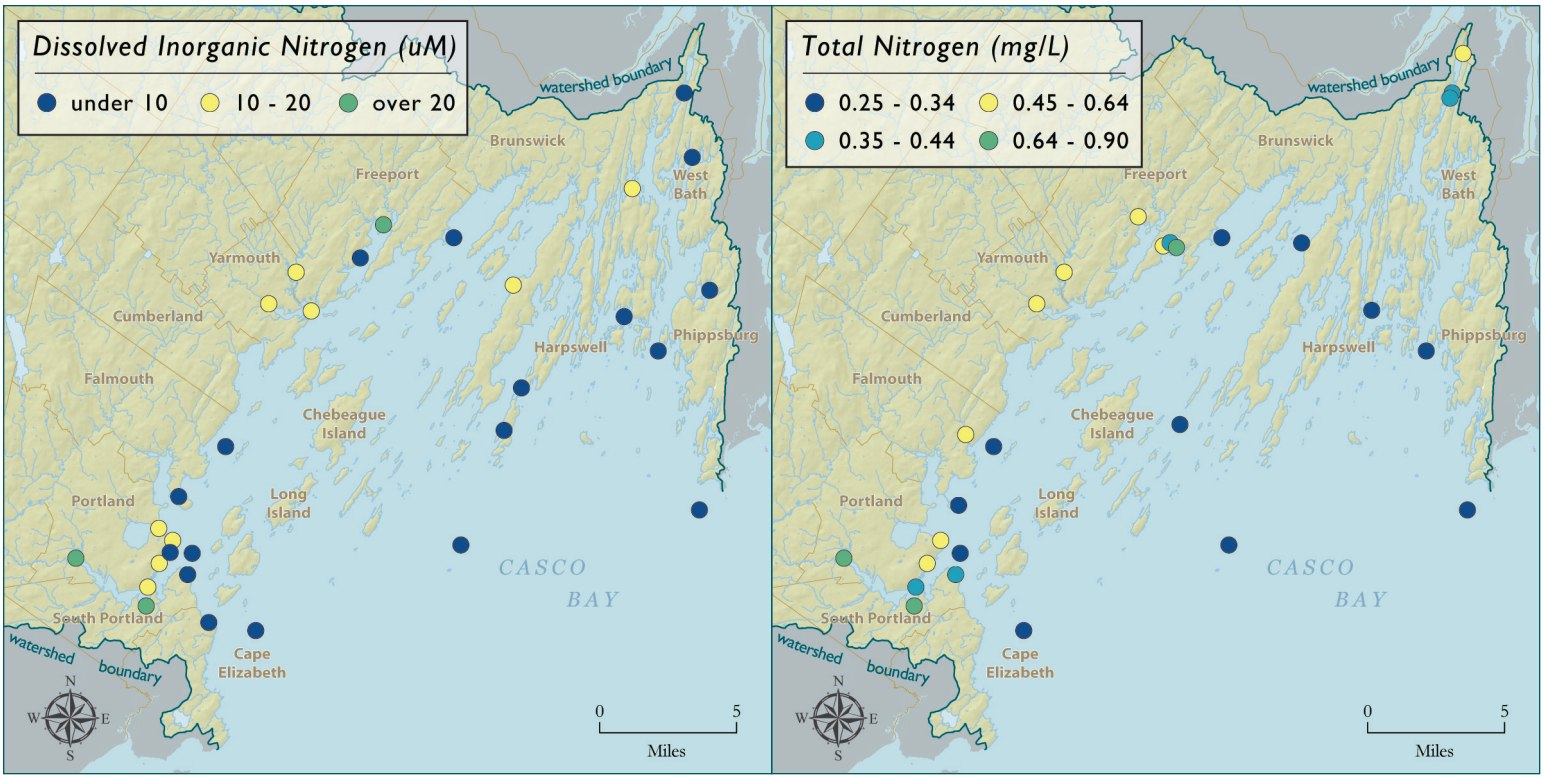
The overall water quality of Casco Bay is good, although there are a few sites where indicators have been measured at levels of concern. Low DO near urban areas suggests that the Bay is



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



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



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

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

FOCB

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

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

References

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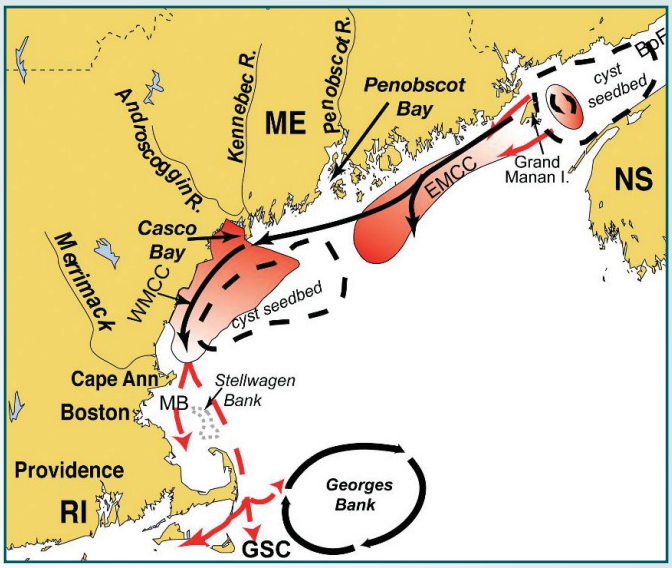
The Causes of Red Tides in Casco Bay: Does Local Water Quality Have an Impact?

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.

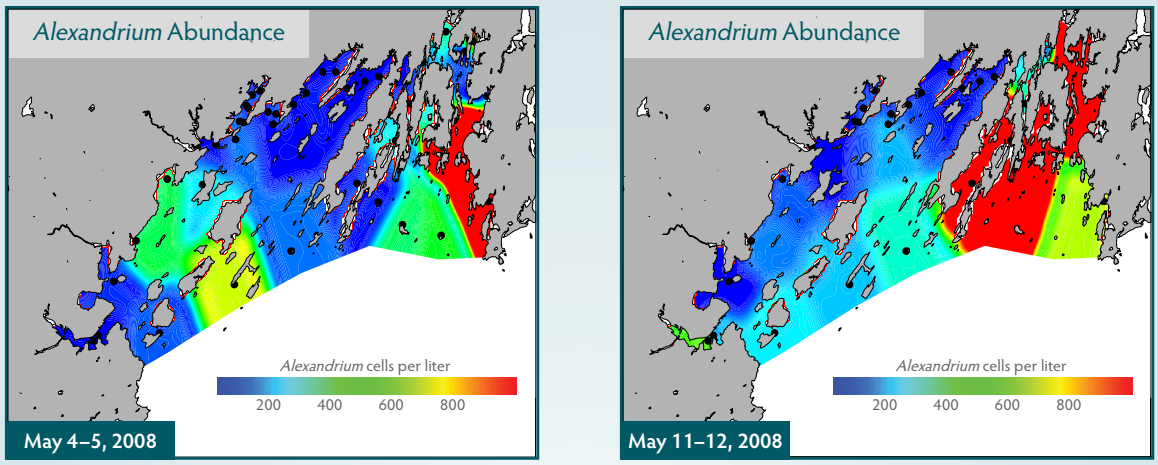
External Sources of Red Tide Organisms to Casco Bay

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.

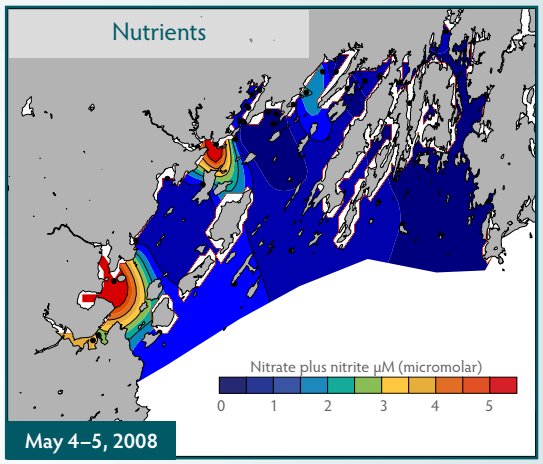
the distal portions of the New Meadows River and other sounds like Lumbos Hole) and the WMCC, which brings cells that originated in the Bay of Fundy and mid-coast Maine into Casco Bay (Libby and Anderson 2010).

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).

References

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