Marine RESEARCH in focus

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Phytoplankton in the Damariscotta River Estuary

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Background

The Damariscotta River produces more oysters than any other region along the coast of Maine, a result of the river's excellent water quality and ideal temperature conditions. Oyster aquaculture operations on the Damariscotta lease about 100 acres of surface and bottom waters. Increasing production has raised questions about the maximum number of farms that can be supported by the estuary.

Oysters depend on phytoplankton for food; therefore assessing the sustainability of aquaculture in the Damariscotta River estuary requires an understanding of phytoplankton dynamics. Phytoplankton are single-celled photosynthetic organisms, such as microscopic algae, that form the base of the oceanic food web. Often referred to as the "grass of the sea," phytoplankton are the major food source for filter-feeding bivalves, such as oysters and mussels.

This research project examined the distribution of phytoplankton in the Damariscotta River, as well as environmental factors, such as nutrients, light, and physical conditions, in order to assess the estuary's ability to sustain additional farms.

Research Methods

Since 2002, scientists at the Darling Marine Center have analyzed chlorophyll-*a* concentrations and temperature in water samples from the middle of the estuary. Expanding on this program, we included analysis of water samples collected regularly throughout 2005 from the head and mouth of the estuary, transects and profiles during summer, and a two-week deployment of moored instruments (Figure 1).

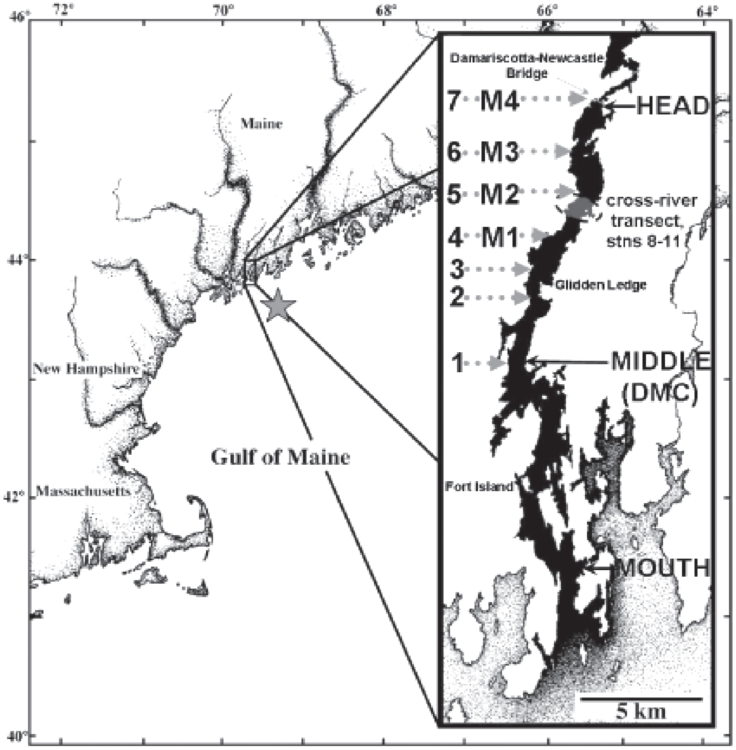

Figure 1. Map of the Damariscotta River Estuary, Maine, USA, with locations of dock sampling stations, hydrographic stations, and moorings. Middle station is located at the Darling Marine Center (DMC). Star denotes location of Gulf of Maine Ocean Observing System (GoMOOS) Buoy E.

From February through December 2005, we collected surface water samples two to five times a week from docks located at the head, middle, and mouth of the estuary and analyzed the samples for chlorophyll-*a* concentrations, temperature, salinity, and dissolved inorganic nutrient concentrations (which can influence phytoplankton growth). We conducted surface transects and vertical

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profiles with Conductivity-Temperature-Depth recorders (CTDs) equipped with portable chlorophyll-*a* fluorometers. Four similarly configured CTDs were moored one to three meters below the surface along the upper estuary during late August and early September 2005.

Results

The late winter phytoplankton bloom occurred approximately one month earlier, and was larger in magnitude and longer in duration in 2003 and 2004, in comparison to the following years, based on chlorophyll-*a* measurements at the middle station (Figure 2).

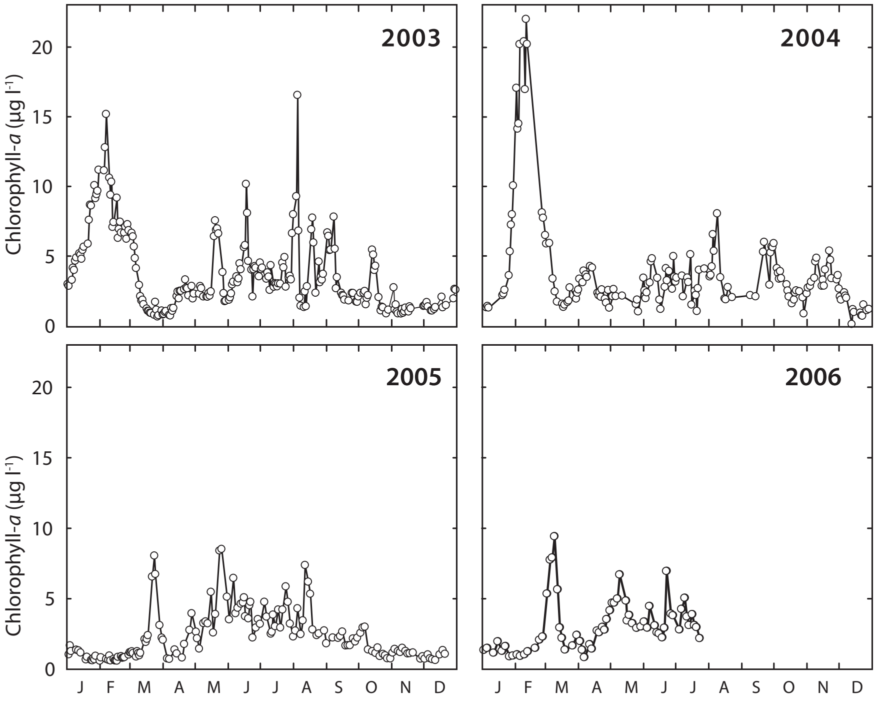


Figure 2. Chlorophyll-*a* concentrations (µg l^{-1}) at the middle station from January 2003 through July 2006.

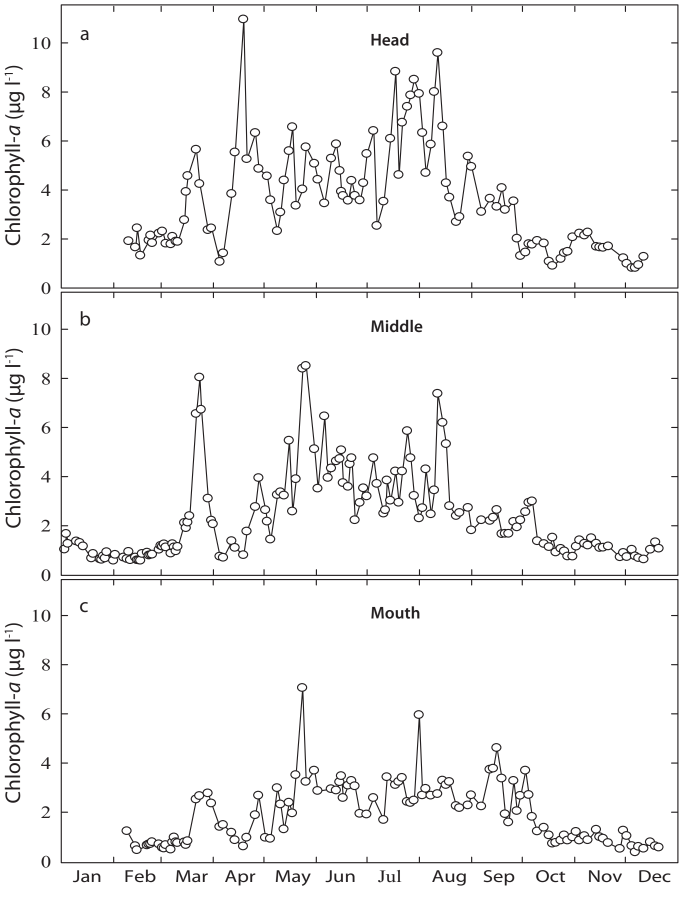
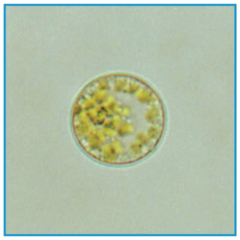


Figure 3. Time series of extracted chlorophyll-*a* concentrations (µg l^{-1}) sampled at three dock stations in 2005.

Chlorophyll-*a* concentrations in water samples collected at the head, middle, and mouth of the estuary were low during the winter, increased during the late winter/early spring phytoplankton bloom, and remained high but variable through spring to early autumn (Figure 3). Concentrations were typically highest at the head of the estuary.



Centric diatom

Diatom chain

Pennate diatom

Daitom chain

Dinoflagellate

From early May through late September, mean water temperature was highest and mean salinity was lowest at the head; there was much less variation in temperature and salinity between the middle and mouth of the estuary (Figure 4).

Nitrate concentrations at all three sites were elevated in winter, with higher concentrations at the middle and mouth of the estuary (Figure 5). A strong seasonal drawdown of nitrate began in mid-winter, well before the accumulation of chlorophyll-*a* associated with the late winter/early spring bloom; however, an increase in the rate of nitrate drawdown did coincide with the bloom. The pattern of silicate concentrations also reflected a drawdown associated with the beginning of the phytoplankton growing season and the onset of the late winter/early spring bloom (Figure 5).

During CTD transects and vertical profiles of the estuary, we again observed strong spatial gradients in temperature and salinity, with chlorophyll-*a* concentrations consistently highest in the upper estuary, specifically above a major constriction at Glidden Ledge.

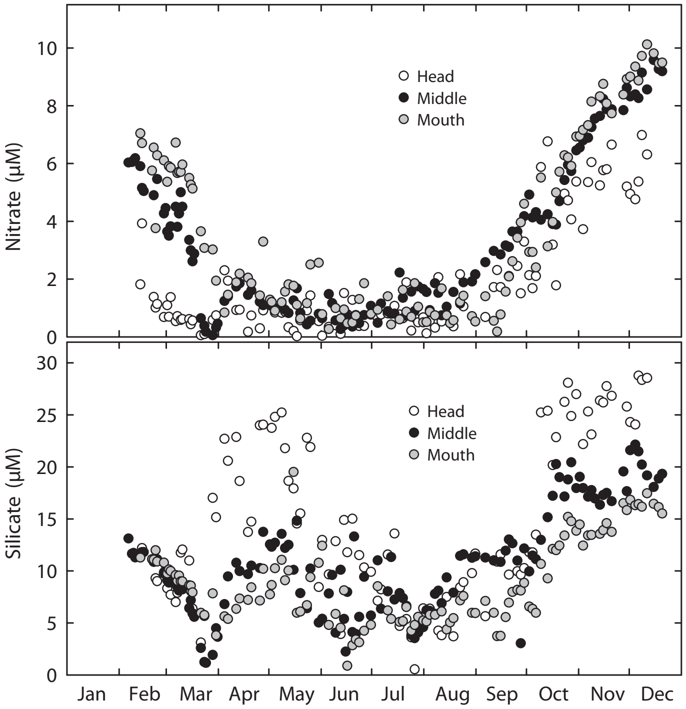


Figure 5. Nitrate and silicate concentration at the three dock stations in 2005.

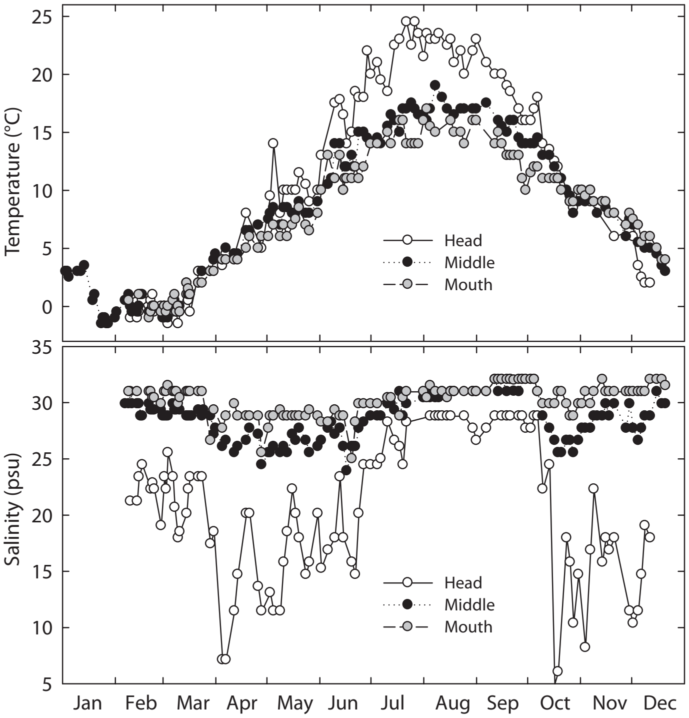


Figure 4. Temperature (°C) and salinity (psu) at the three dock stations in 2005.

Estimating Phytoplankton Biomass by Measuring Chlorophyll-*a* Fluorescence

One of the most effective ways to quantify phytoplankton biomass in a water sample is to measure the amount of photosynthetic pigment, or chlorophyll-*a,* using a laboratory instrument called a fluorometer. While this is one of the most accurate ways to measure chlorophyll-*a* concentrations, it is also a relatively tedious process. A smaller, waterproof fluorometer can be used to make high resolution, real-time measurements of chlorophyll-*a* in the field; however, it is less accurate than the highly sensitive laboratory fluorometer. These instruments are often best used in combination, as was done for this study.

The moored instruments showed strong temporal variation in chlorophyll-*a*, temperature, and salinity that correlated with the tides (Figure 6).

While tidal oscillations were responsible for movement of the peak phytoplankton biomass up and downstream in the upper estuary, the variation in phytoplankton biomass was also linked to daily insolation. Chlorophyll-*a* fluorescence exhibited two peaks per day at three of the moorings, but when tidal influence was eliminated from the data set, maximal values of chlorophyll-*a* occurred in the early evening and minimal values in early morning for all four moorings.

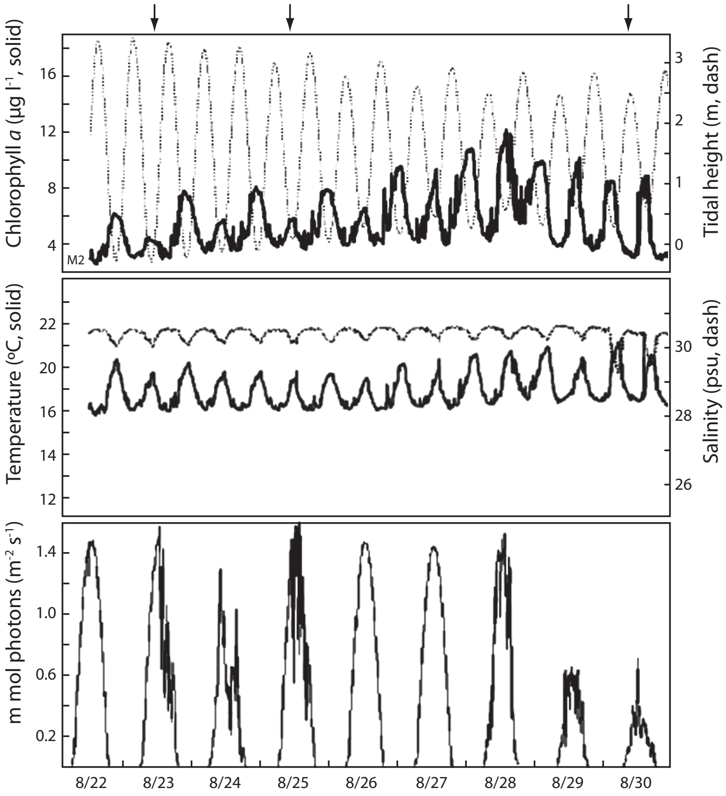


Figure 6. Mooring 2, located 4.0 km from head. Data for first week of deployment for chlorophyll-*a* concentration, local tidal height, temperature, and salinity at 3 m; 10-min average PAR was measured above water at middle station dock. Arrows indicate times when a CTD profile was taken adjacent to the mooring.

Discussion

Concentrations of phytoplankton biomass in the upper estuary may be higher than that of the lower estuary due to local environmental conditions that favor production, and a higher residence time for water north of Glidden Ledge. The seasonal period of elevated chlorophyll-*a* concentrations continued through the summer, the time of year when oysters have been observed to grow most rapidly. Future research might perform an intensive survey of near-bottom and bottom chlorophyll-*a* concentrations to better assess the phytoplankton carrying capacity and the availability of phytoplankton to bottom culture. Continued monitoring of phytoplankton variability could help farmers decide when to sow, maintain, and harvest their oysters and mussels.

For more information, please visit the Darling Marine Center Phytoplankton and Optics Laboratory Web page at http://optics.dmc.maine.edu/, or contact:

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Monitoring Phytoplankton Makes a Difference

"I was able to use your data to immediately advise a mussel aquaculturist of the increase in chlorophyll in February and March that might enhance meat growth of his mussels in the next few weeks. I urged him to postpone his harvest during this critical time, even though I was not sure of the chlorophyll providers for this year (sometimes the qualitative data is very important due to dietary preferences). Preliminary samples show that his mussels are actively growing now, with increase in meat weight."

—Elin Haugen, 2006

Phytoplankton in the Damariscotta River Estuary

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