Reporting on Winter 2007

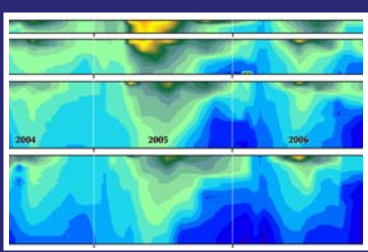
Gulf of Maine MONITOR

Quarterly review of observation and analysis in the Western Gulf of Maine

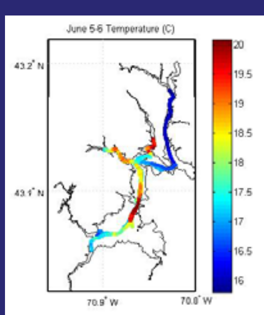
CENTER OF EXCELLENCE IN COASTAL OCEAN OBSERVATION & ANALYSIS
COASTAL OCEAN Observing Center

www.cooa.unh.edu

The Coastal Ocean Observing Center was established at the University of New Hampshire in 2002 as part of NOAA's Coastal Observation Technology System. The Center is working to develop an observing system to monitor the Western Gulf of Maine ecosystem. We seek to understand how the ecosystem is changing seasonally and from year to year, what causes it to change, and ultimately to forecast changes.



Time Series Plots, Page 2-3



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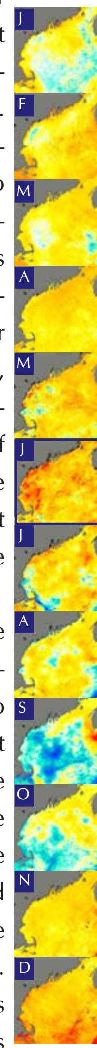
UNIVERSITY of NEW HAMPSHIRE

Is Our Ocean Warming?

Unusually high temperatures raise climate change concerns

If you happened to take a dip in the Gulf of Maine at some point in 2006, you may have noticed how much less painful it was. Sure, it still might have taken a while to get up the courage to totally submerge yourself, but on average the water was one to four degrees warmer than usual. Not enough to make for a relaxing December swim, but significant nonetheless.



With growing concern about climate change, the initial reaction to rising temperature is to suspect global warming. Hightened awareness of the topic leads us to question every unusually warm winter day, or extremely wet or dry month. Indeed, when people learn of our monitoring and research in the Western Gulf of Maine, one inevitable question we hear is, "Have you seen any impact from global warming?" To which the invariable answer is, "Well ..."

We don't know. There may be significant changes in species' abundances or nutrient levels from year to year, but warmer temperature cannot be conclusively singled out as the cause. It's somewhat like assessing the impact of a warm, humid night on the outcome of a baseball game. Would the score have been different if the evening had been colder? Well ... denser air would mean fly balls wouldn't travel as far, and pitches would have more movement. But cold defenders might be too slow to make a critical play, or more likely to make a throwing error. There are so many inherent variables that simply knowing the physical effect of air density on a baseball's flight does not predict the final outcome of the game. For the Gulf of Maine ecosystem, the same is true: the natural variability of the system in any one-year period overwhelms the effect that a one degree rise in average temperature might have ... but there is still an effect.

Teasing out the effect of temperature on any one sample, or any one baseball game, may be impossible. One can better address the effect of temperature on runs scored by utilizing the vast historical records of previous games, to search for correlations between these two variables. This can be done to some extent with the Gulf of Maine, using historical data sources to look for correlations between temperature and other variables to predict how the ecosystem would change in consistently warmer conditions. Increased tem-

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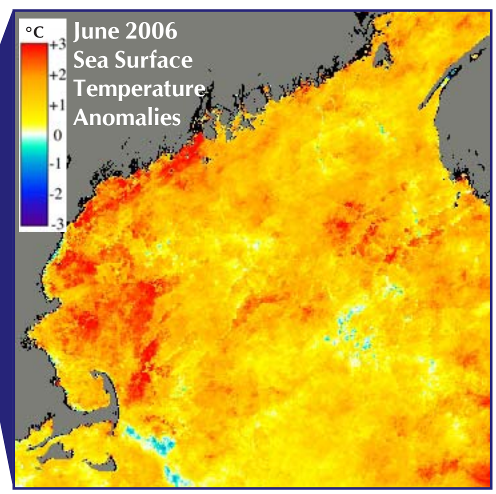


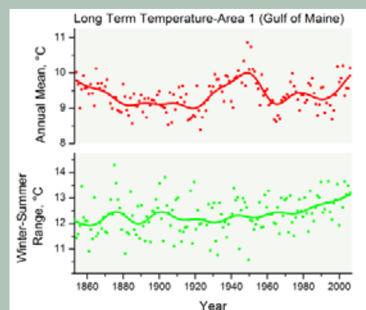
Monthly sea surface temperature anomaly maps show higher than average temperatures in 2006. Colors represent degrees above or below normal, based on satellite data. Consider that satellite sea surface temperature data has only become available relatively recently, during a period of warm temperatures (see page 2).

(continued from page 1)

perature also has predictable effects on metabolic rates and behaviors of organisms. These subtle changes could be expected to lead to ecosystem-wide effects.

We cannot know whether the temperature change is indicative of a permanent upward trend without help from a crystal ball. While we can't see the future, we can look back in time, and historical data does help put our current conditions into perspective. From approximately 1930 to 1950, there was a significant warming period, with average temperatures higher than what we have seen to date in this millennium. Were a trend of this magnitude to occur now, it would raise widespread alarm over the effect of global warming on the ocean, when the cause could be a confluence of natural events.

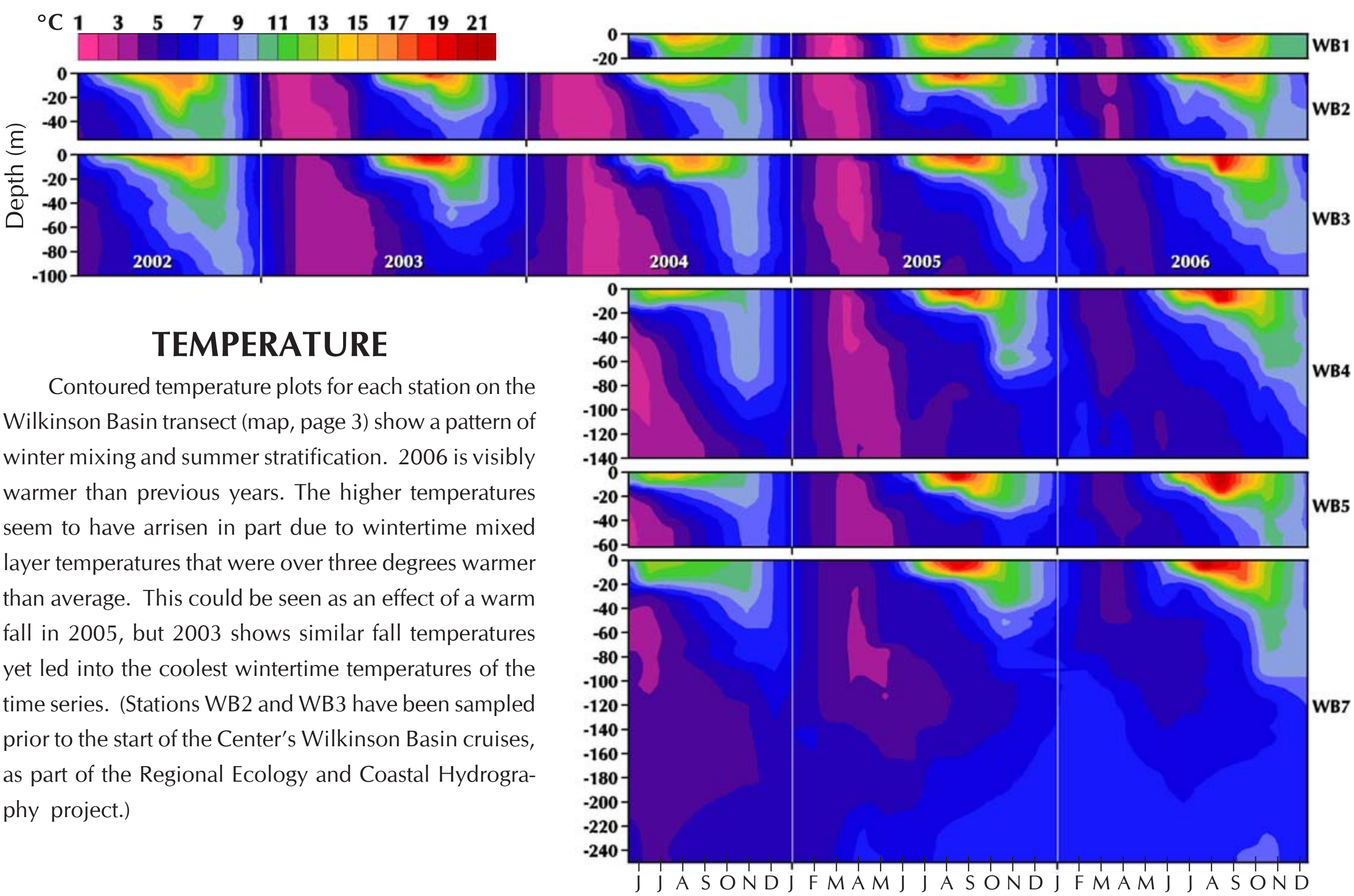
The unusual temperatures seen in 2006 likely had several causes. Above average air temperatures certainly played a role, along with timing and magnitude of wind-driven mixing events. But another significant source of warmth could be the water itself. The Gulf of Maine is filled from the bottom up by water that flows in through the Northeast Channel (south of Nova Scotia). Water that enters the Northeast Channel tends to be from one of two sources: warmer, saltier Atlantic Temperate Slope Water or cooler, fresher Labrador Slope Water. For several years, the water entering the Gulf of Maine has been warm Atlantic slope water. This has a warming effect on the Gulf of Maine, and is independent of the record warm air temperatures recorded in 2006.



Long term temperature trends in the Gulf of Maine (top) and the difference between winter and summer temperatures (bottom). Figure generated by the Northeast Fisheries Science Center; for more information see http://www.nefsc.noaa.gov/omes/OMES/spring2007/advisory.html.

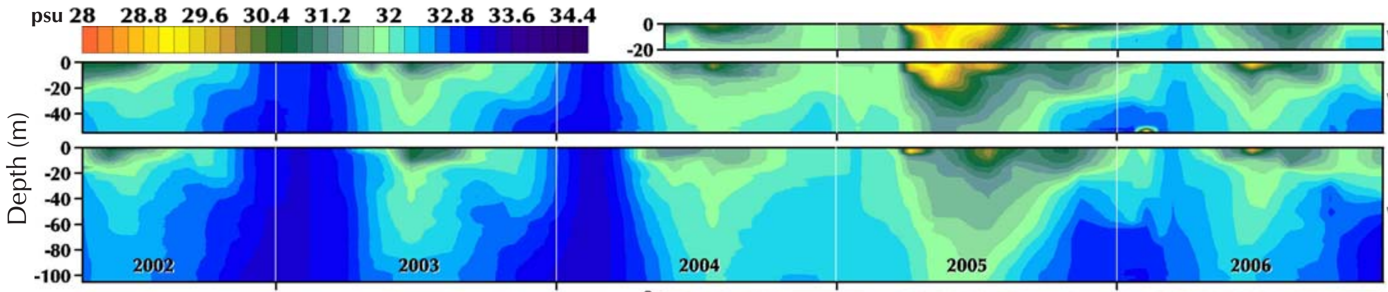
This justification is not intended to suggest that global climate change will not impact the Gulf of Maine, but rather to illustrate that natural variation exists even in the age of human-induced climate shifts. We hope that data we are collecting now may eventually be used as an historical archive of pelagic conditions. And speaking of historical archives, someone has already done the math: based on historical April data, higher temperatures do correlate with higher scoring baseball games.[1]

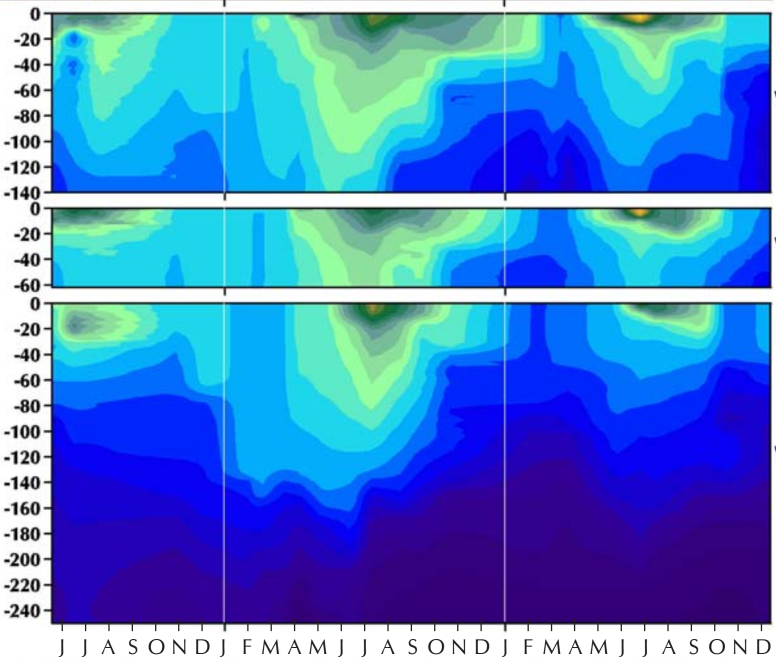
[1] http://www.nytimes.com/2006/05/14/sports/baseball/14score.html



TEMPERATURE

Contoured temperature plots for each station on the Wilkinson Basin transect (map, page 3) show a pattern of winter mixing and summer stratification. 2006 is visibly warmer than previous years. The higher temperatures seem to have arrisen in part due to wintertime mixed layer temperatures that were over three degrees warmer than average. This could be seen as an effect of a warm fall in 2005, but 2003 shows similar fall temperatures yet led into the coolest wintertime temperatures of the time series. (Stations WB2 and WB3 have been sampled prior to the start of the Center's Wilkinson Basin cruises, as part of the Regional Ecology and Coastal Hydrography project.)

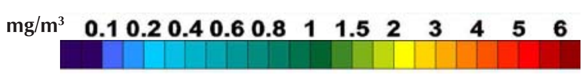


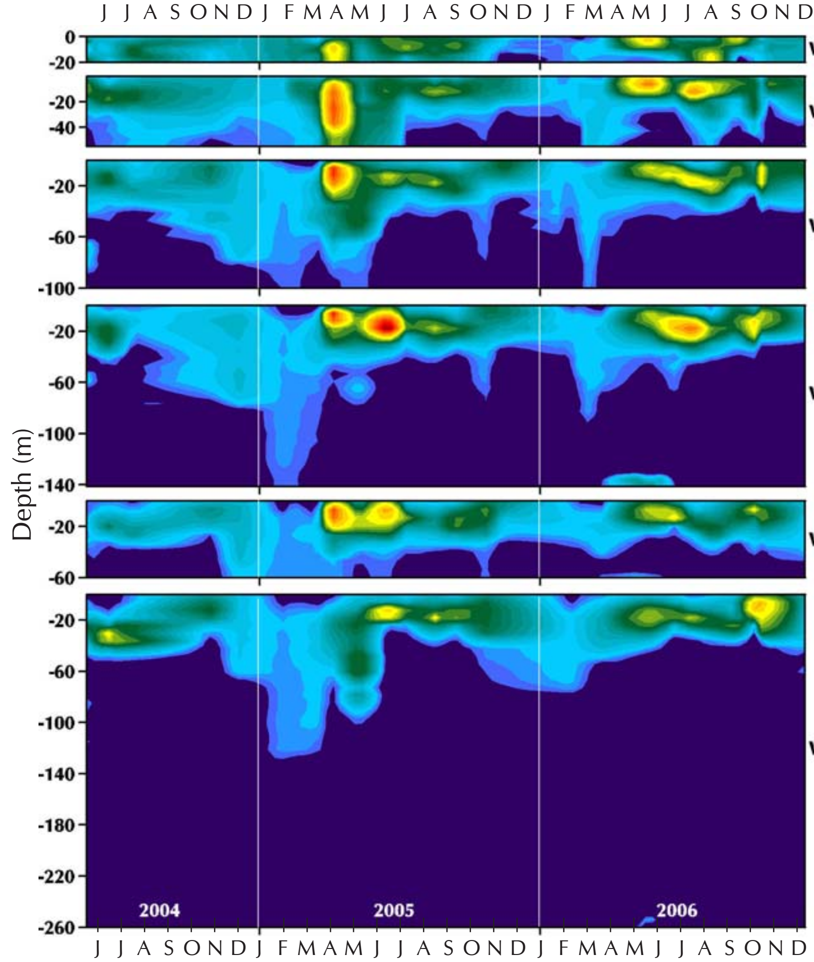


SALINITY

The Wilkinson Basin Transect covers a wide range of salinities, as stations range from 6 km to over 60 km offshore. These figures show contoured monthly salinity records for each station along the transect. Stations WB2 and WB3 have been sampled since April 2002; other stations have been sampled since June 2004. Inshore stations have noticably lower salinity due to riverine influence of the near-shore waters. Also notice the high salinity water in the deep basin at WB7.

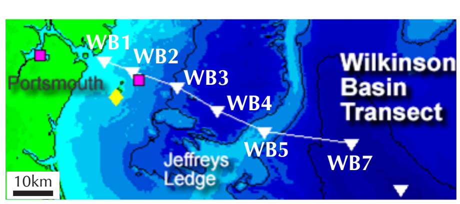
Though May 2006 saw record flooding along parts of the New England coast, this surge of fresh water did not noticably impact the Gulf of Maine. The heavy rainfall events of 2005 had a much larger effect, especially in conjunction with how much lower salinities were to start 2005.





CHLOROPHYLL

Contoured plots of fluorometric chlorophyll illustrate the times of greatest primary production levels in the Gulf of Maine: the spring and fall blooms. Chlorophyll concentrations are highest in the surface water, since phytoplankton cannot survive at depths where light levels are too low for photosynthesis to occur. Yet maximum chlorophyll values are not found in the top few meters, where the light is brightest. Instead, a subsurface chlorophyll maximum forms at around 20 meters where there is the greatest trade off between available sunlight and available nutrients, and sinking rates are slowed due to increasing water density at the thermocline.



Bathymetric map of the Wilkinson Basin Transect run by the Coastal Ocean Observing Center. The transect begins just offshore from Portsmouth, NH.

New Hampshire's Great Bay

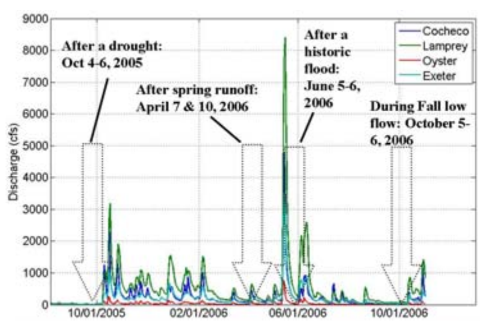
A small estuary system reveals large differences in ecosystem metabolism

Located at the meeting places of land and sea, estuaries are the zones where fresh water and sea water mix. This mixing produces amazing and complicated changes in chemistry and biology, as well as vibrant animal and plant life. We know that different rivers carry different types and amount of particles, chemicals, plants and animals to the sea. But do these different rivers mix with the ocean in different ways, and if they do, what does this mean for the estuary ecosystem?

Beginning in the fall of 2005, the UNH Coastal Ocean Observing Center team, led by our Coastal Carbon project, began to ask these questions about the Great Bay estuary system, located right in our own backyard. Six major rivers drain into Great Bay and mix with some of the world's strongest tidal currents before flowing on to the New Hampshire seacoast and the Gulf of Maine. Four surveys of Great Bay allowed us to map out the system during very different conditions: spring snowmelt, a historic flood, and fall low flow. With the same flow-through system we use on our Wilkinson Basin and Coastal Transects, we made continuous maps of physical and chemical measurements, such as salinity, temperature, oxygen and in-water carbon dioxide (pCO2). We also collected samples of the plant and animal plankton throughout Great Bay, and water samples to examine chemical and optical properties. These surveys represent the first time the whole Great Bay system has ever been examined at once, all the way from fresh water to seawater.

The results from these four surveys were surprising, to say the least. The Great Bay system is fairly small, only about 44 square kilometers, but there were obvious differences between the estuaries of the different rivers. Some rivers, such as the Cocheco and Lamprey Rivers, appeared to produce more carbon dioxide than we expected. Carbon dioxide is an important greenhouse gas, as well as an indicator of biologic activity. Others, such as the Bellamy and Oyster Rivers, seemed to sometimes produce more carbon dioxide than expected, and other times produce less than expected.

These patterns of carbon dioxide are quite unusual, since the land around all these rivers is very similar. One reason for the differences might lie in the number of people living along these rivers, and how waste from these people gets into the rivers. The Cocheco and Lamprey Rivers each have wastewater treatment plants, while the Bellamy River does not. Wastewater treatment plants are sources of nutrients- the chemical substances that allow plants to grow. The carbon dioxide patterns in the Cocheco and



Top: Joe Salisbury pilots the Camden Belle *up the Lamprey River as Megan Hiedenreich processes phytoplankton samples. The Lamprey is one of six rivers that discharge into the Great Bay estuary.*

Above left: The four sampling trips in Great Bay have encompassed a wide range of conditions, from drought to record floods.

Above: Joe Salisbury and Chris Hunt prepare to take alkalinity samples from the Cocheco River.

Lamprey Rivers show these rivers have much more active plant growth than other Great Bay rivers.

The amount of river discharge into Great Bay greatly affected the chemical and biological makeup, especially in June 2006, after a major storm event sent huge amounts of fresh water, particles and dissolved material into Great Bay. Scientists are beginning to determine how significant a role storms play in the chemical and biological cycles of rivers, estuaries and the ocean, and these data from Great Bay provide a glimpse into the effects of a major storm.

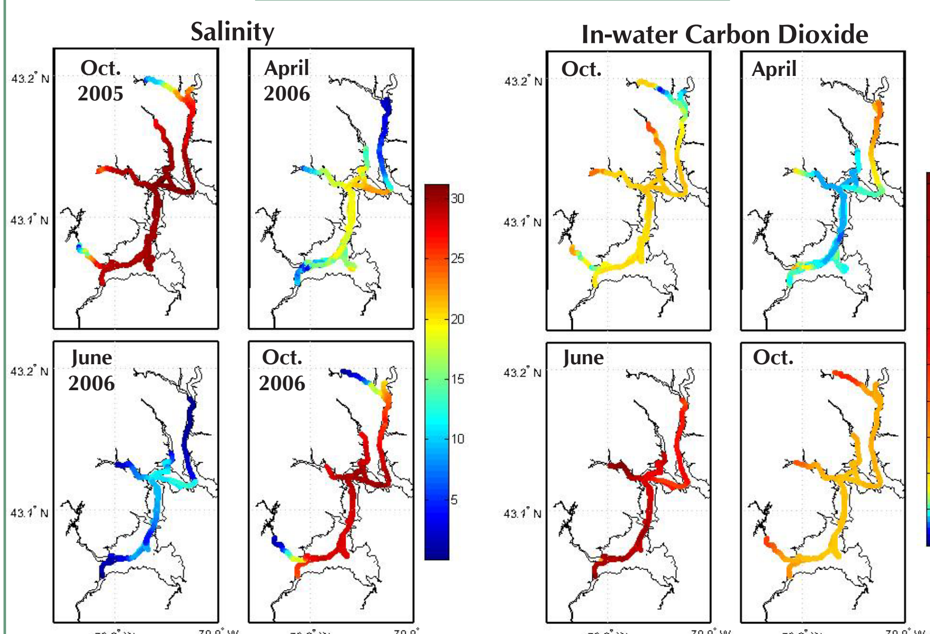
The phytoplankton, or microscopic plants living in the water, varied both spatially and seasonally in the bay. Diatoms were dominant during the spring, which is typical for this area. The flagellates particularly the Chlorophytes characterized summer months, while the fall saw a slight increase in Dinoflagellates with one large bloom of *Akashiwo sanguine* in the Cocheco River in October of 2005. Dinoflagellates never dominated the phytoplankton community save for the one bloom event in the fall of 2005. The Mothers Day flood of 2006 resulted in a flushing of the bay possibly changing the phytoplankton community. Freshwater species of algae that had not been observed before the flood event were seen in small numbers.

It is interesting that both the rivers (The Cocheco and Lamprey Rivers) with higher productivity, as indicated by their CO2 levels also had the greatest number of Dinoflagllates. These rivers also appeared to have a greater amount of all species of algae than the Oyster River. This could be due to multiple factors including the presence of Sea Lettuce competing for nutrients in the Oyster River.

The dominant planktonic animals in Great Bay changed from season to season. Barnacle larvae peaked in April, comprising over 95% of the zooplankton in each sample. In June the copepod *Acartia tonsa* was the most abundant species in saltier portions of Great Bay, while cladocerans dominated brackish river water. The October samples, taken during the same week in 2005 and 2006, offered an interesting window into the variability of this system. *Acartia hudsonica* was the dominant copepod in 2005, but the lower salinity portions of the bay were teeming with jellyfish, a leptomedusae in the genus *Clytia*. In 2006, *Acartia tonsa* vastly outnumbered other zooplanton,

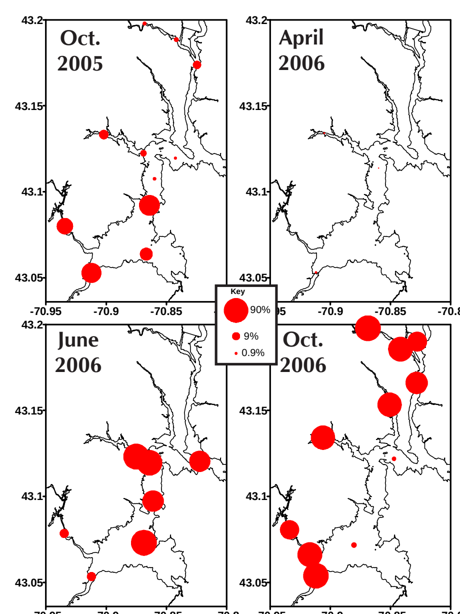
and the jelly bloom was back – but this time they were anthomedusae in the genus *Bougainvilla* (pictured at left). The factors that govern which species of plankton dominates the system are likely as complex as the factors that determine the amount of riverine input from year to year. Using this cooperative, comprehensive sampling approach, scientists can begin to determine how variability in physical characteristics corresponds to variability in the biological ecosystem.

Flow-Through Data



Data collected by continuous flow-through sampling system highlights dramatic differences in the Great Bay system throughout the year. Salinity is highest in October, after dry summertime conditions. Snowmelt and spring rains lower April salinity levels. June was unusually fresh due to the record flooding that occurred in May. The differences in carbon dioxide from river to river are striking, especially in October 2005.

Acartia tonsa



The relative abundance of Acartia tonsa, *a common estuarine copepod. Relative abundance measures the percentage that the species comprises in the sampled community. Despite similar salinity conditions,* A. tonsa *was much more dominant in October 2006 than it was in 2005.*

Ingredients for Photosynthesis

Nutrient sampling provides insight into biological and physical realms

The pelagic ecosystem in the Gulf of Maine, as in oceans world wide, is built on a phytoplankton foundation. The success of almost all other organisms at higher trophic levels - higher in the "food chain" - depends directly or indirectly on the presence and abundance of phytoplankton. These unicellular organisms are photosynthetic, using only sunlight to create the complex molecules necessary for growth and survival. Well, this isn't quite true. Phytoplankton cannot generate these molecules out of thin air (thin water, really). They need to have the proper nutrients available to use as building blocks.

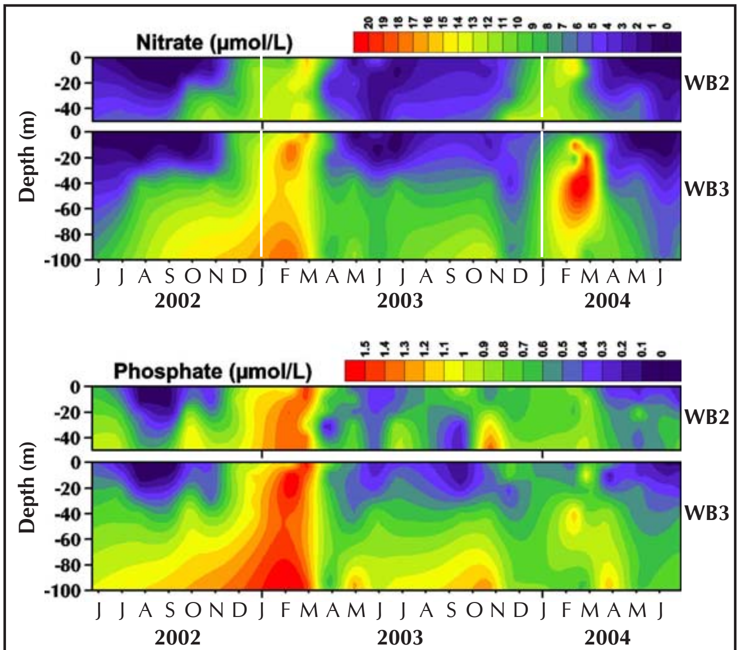
Measuring the levels of nutrients in the water can help scientists determine how quickly phytoplankton may be growing, or how their growth may be limited by low levels of a key nutrient. Nutrients can also act as tracers, indicating differences between deep ocean and coastal waters.

Nitrogen and phosphorous are two atoms which are critical for the growth of phytoplankton. Silica is an important nutrient for diatoms, which use the molecule to create ornate cell walls. If insufficient amounts of necessary nutrients are available in the water, phytoplankton are unable to grow. The Gulf of Maine is generally nitrogen limited, meaning phytoplankton tend to use up available nitrogen and stop growing, though there may be sufficient quantities of phosphorous available. This is typical of the ocean in general, and contrasts with freshwater systems which are often phosphorous-limited. It is also a good example of how the biological realm can significantly impact the physical characteristics of a water mass. The resulting signal can be measured and used to infer the timing or rate of biological activities.

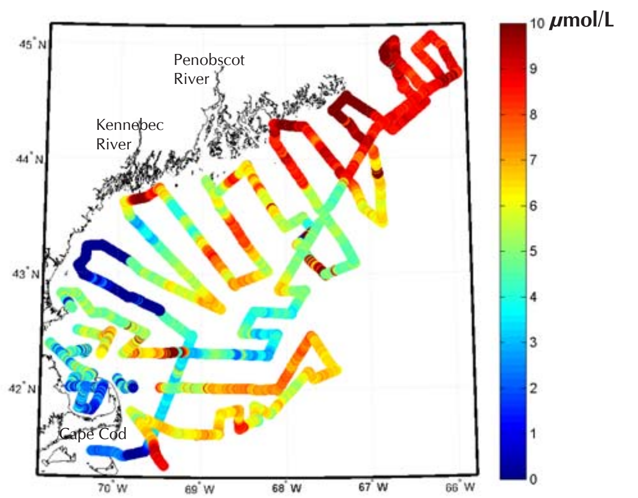
As part of our monitoring project, we analyze water samples for levels of nitrate, nitrite, ammonia, phosphate, and silica. These samples are taken from discrete depths at all of our transect stations. We also measure nitrate using instruments attached to our flow-through system, providing continuous records of nitrate levels from surface water along our cruise tracks. And our buoy in Great Bay has instruments to measure both nitrate and phosphate, sending the data back in real time for web-based access.[1] The phosphate sensor is a new instrument, which we are developing in cooperation with WET Labs.

Nutrient data may also be used to solve an ongoing question regarding the nitrogen budget of the Gulf of Maine. It is unclear how much nitrate is delivered by deep water flowing into the gulf, versus riverine input or regeneration of nitrate at depth by bacterial action. Using our combination of deep basin nutrient samples, river samples, and many others in between, we may gain some clarity in an otherwise fuzzy picture.

[1] See data at http://www.cooa.unh.edu/buoydata/buoy.jsp



Nitrate (top) and phosphate levels over a two year period at stations WB2 and WB3. Higher levels of both nutrients accumulate in the winter months, when low sunlight prevents high growth rates of phytoplankton. The spring bloom and stratification of the water column lead to depletion of nutrients in the surface layers during warmer months. Note that nitrate is limiting in this system, and is drawn down to consistently low levels while phosphate fluctuates more widely.

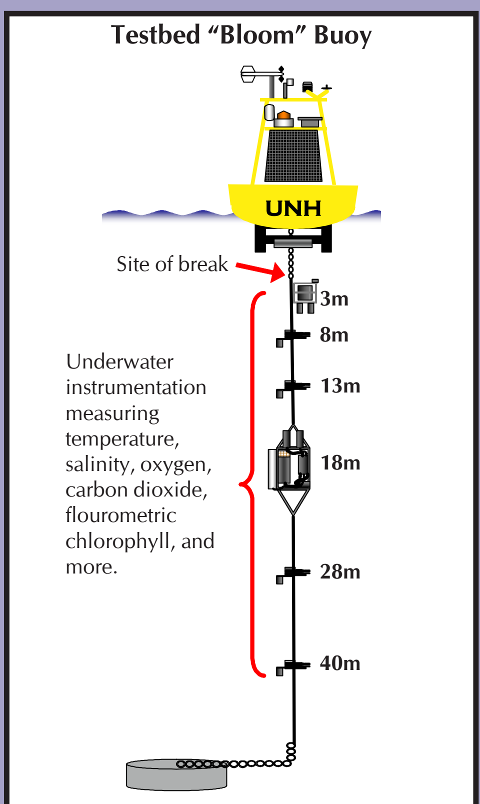


Continuous measurementes of nitrate made aboard the R/V Oceanus by Coastal Observing Center scientists. The cruise track covers a two-week period in November 2006. Strong influx of nitrate can be seen along the Maine coastline near the Kennebec and Penobscot River mouths. High nitrate is also seen in the Bay of Fundy, due to tidal mixing.

A tale of science, lost and found

For scientists at the Coastal Ocean Observing Center at the University of New Hampshire, a small area in the Gulf of Maine recently earned a bad reputation. This wasn't due to a scientific discovery, or unusually high seas, or vicious tidal currents. The nondescript patch of water northeast of the Isles of Shoals suddenly became a dangerous place for oceanographic equipment. It's the colder, New England equivalent of the Bermuda Triangle, with one critical difference: so far, everything that has gone in has eventually come out.

To the Coastal Ocean Observing Center, this area is known as WB2 – it is the second station along a transect stretching from Portsmouth, NH to the 260 m deep waters of Wilkinson Basin some 40 miles offshore. Once a month, scientists from the Center take measurements along this transect, stopping at each station to gather more detailed information about the water below. Station WB2 was also the location for two fixed monitoring buoys operated by the Coastal Ocean Observing Center. These buoys were equipped with instruments that measured many properties of the seawater as it flowed past. One of the buoys is still there.



This otherwise unremarkable location became a mariner's nightmare on October 28th. Stormy weather that caused widespread power outages and local flooding on land created waves over 20 feet tall at sea. At some point during this storm, one of the monitoring buoys at WB2 disappeared. Ironically, its absence was noticed two days later when a crew from UNH came out to retrieve the buoy for the winter. It was unclear if the buoy had sunk in the seas, or broken free of its moorings. Neither option seemed likely, given that the metal frame of the buoy floats on a gigantic foam base which should be almost unsinkable, and is connected to the seabed by a chain with a rated breaking strength of 11,000 lbs. Despite the improbability, the fact remained that the buoy was no longer where it should have been.

Taking the assumption that the buoy had broken free and was adrift, researchers at the Coastal Ocean Observing Center spread the word through regional fishing communities to be on the lookout for a lose buoy. Amazingly, after 21 days adrift, a lobsterman spotted the buoy near Acadia National Park, Maine. The good news spread to scientists from the Center as they were heading out to sea, back to WB2, to another equipment disaster.

At each station during the research cruises, one of the most critical measurements the researchers take is a complete profile of the water – recording temperature, salinity, oxygen, and other properties from the surface to the bottom – with an instrument known as a profiler. The profiler is attached to a winch and lowered almost to the bottom, along with several sampling bottles specially designed to collect water from discrete depths. Though this has been done thousands of times without incident, during this cruise the line was somehow pulled under the boat into the propeller, severing it and sending the sampling equipment plummeting to the bottom. Fortunately, the vessel is equipped with a GPS system; unfortunately, knowing where the equipment is and recovering it from 200ft of water are two different things. Researchers and vessel crew returned the day after the loss with a grapple hook and plans for a long day of fishing for instruments. Fortunately, the three lobstermen with nearby traps volunteered to move any gear that was in the way. Without this help, it would not have been possible to attempt recovery as the grapple would have been continuously snagging trap lines. Amazingly, after six hours of towing, the hook caught hold of the lost equipment and it was brought on board. All scientists and crew purchased lottery tickets upon their return to shore.

Chris Manning and Mike Novak pull the lost profiler aboard as one of the helpful lobstermen waits to provide assistance if needed.

The story was not over, though. When the missing buoy was recovered in Maine, the scientists discovered that it had broken free close to the surface. This meant several instruments that were attached to the cable and measured deeper water conditions had sunk to the bottom when the buoy broke free. A recovery effort was made with the help of a local fisherman. Amazingly, the gear was grappled up from the bottom after a full day of towing across the area. The name of the fishing boat that participated in the recovery was, ironically, the F/V *Stormy Weather*.

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It may be warmer, but the Gulf of Maine in winter is still a cold place to do research. Top: Frozen sea spray encrusts regulators on tanks of carbon dioxide and nitrogen used to calibrate the flow-through system. Bottom: The R/V Gulf Challenger *breaking through ice on the Kennebec River during a Coastal Transect cruise.*

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