Fall 2006 Update: Annual Condition of the Northeast Shelf Ecosystem

Produced by the Ecosystem Dynamics and Assessment Branch

Published by Northeast Fisheries Science Center

October 14, 2006

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Fall 2006 Update: Summary of Spring Conditions of the Northeast Shelf Ecosystem

Summary

This advisory is an examination of satellite remote sensor and in situ survey data related to the plankton of the Northeast U.S. Shelf ecosystem. Specifically, we report on the sea surface temperature (SST), chlorophyll concentration, and zooplankton biomass. These are ecosystem wide environmental measurements. The results can best be interpreted with other physical and biological data to provide a complete description of the ecosystem.

Sea surface temperature and surface chlorophyll data exhibit a large amount of internal variability, but there is an indication in recent years of a cooling trend in shelf-wide SST and a reduction in surface chlorophyll. There was no appreciable trend in SST until the late 1990s, when temperatures began to increase. The data suggest a peak in SST around the year 2000, followed by a decreasing trend through 2005. Estimates of chlorophyll concentration are derived from remotely-sensed measurements made by the SeaWiFS sensor which began operation in September 1997. The available time series in chlorophyll mirrors SST, with a decline evident in recent years.

Data on total zooplankton abundance is available from 1977. There is also substantial inter-annual variability in zooplankton biomass, as represented by a biovolume measurement, yet a long-term trend is apparent. Zooplankton biomass decreased through the late-1970s, remained at relatively constant levels from about 1980-1995, and increased after 1995. Although these data suggest an overall increase in secondary production and a decrease in temperature and phytoplankton biomass, regional and temporal dynamics must be considered in the assessment of the entire ecosystem.

Data Sources

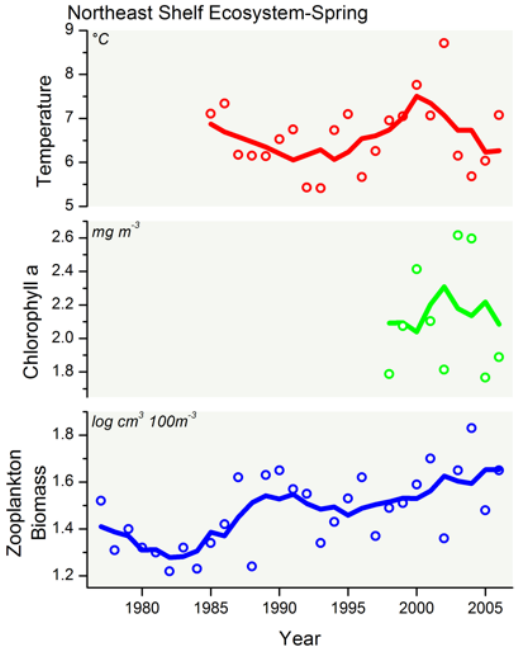
SST is derived from the Advanced Very-High Resolution Radiometer onboard the Polar Orbiting Environmental Satellite (AVHRR-POES) and represents the near-surface ocean temperature, not the temperature of the entire water column.

Daily synoptic views of surface concentrations of chlorophyll a are derived from the Sea-viewing Wide Field of View Sensors (SeaWiFS) ocean color sensor onboard the SeaStar spacecraft. Chlorophyll a is considered to be an index of the amount of phytoplankton biomass present in surface water.

Zooplankton biomass is derived from shipboard surveys of the U.S. Northeast Shelf ecosystem - these small animals link the energy produced through primary production to higher trophic levels. From 1977-1987, the MArine Resources Monitoring, Assessment, & Prediction (MARMAP) program conducted intensive surveys from Cape Hatteras, North Carolina to Nova Scotia. These efforts continued at a reduced level through the 1990s and are ongoing today. Currently, 30 plankton samples are taken 6 times a year in each of the four ecosystem subareas: Mid-Atlantic Bight, Southern New England, Georges Bank, and Gulf of Maine (resulting in approximately 720 measures of zooplankton biomass annually).

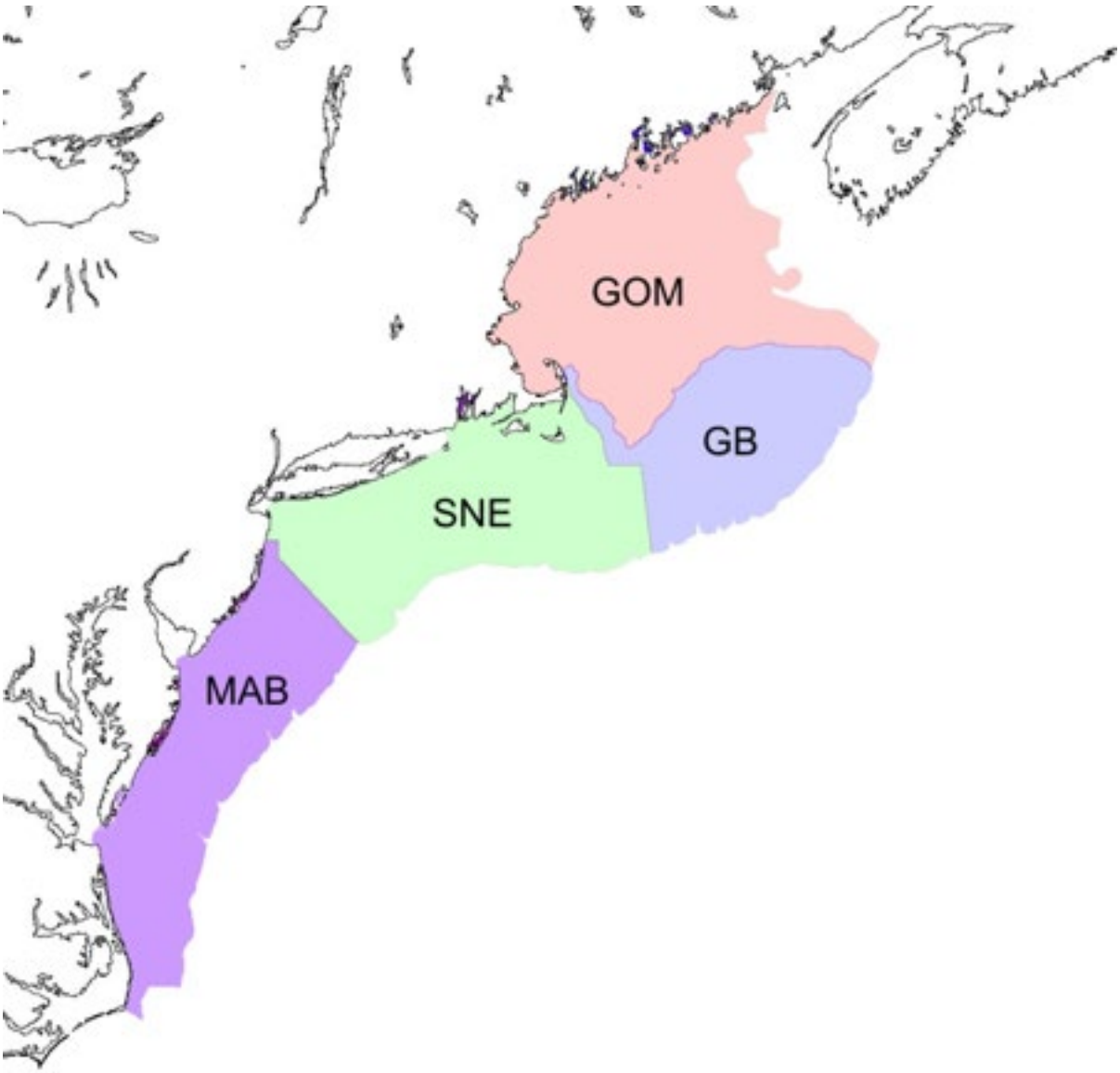
Phytoplankton and zooplankton also are collected on monthly transects across the Gulf of Maine and the Middle Atlantic Bight using Ships of Opportunity. Phytoplankton abundance is quantified based on the color of the sample. Zooplankton abundance is based on counts of individual species and stages. During the spring and summer of 2006, collections were suspended along the Middle Atlantic Bight transect owing to lack of funding.

Spring Conditions on the Northeast Shelf Ecosystem



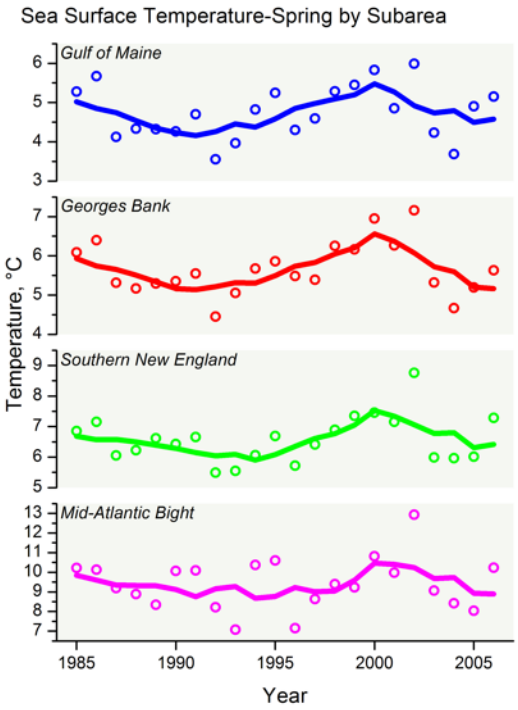
The spring indices for sea surface temperature and zooplankton biomass on the Northeast Shelf exhibit definite trends suggesting decadal and multi-decadal changes in these parameters. The time trend of SST during the spring season follows a pattern similar to the annual trend in SST for the entire shelf system; both indicate surface waters have cooled during the past few years on the order of 1-2°C (**See Spring 2006 Annual Conditions of the Northeast Shelf Ecosystem**). Inter-annual variability in spring levels of chlorophyll has been large, making it difficult to discern a shelf-wide trend. Spring zooplankton biomass is apparently increasing. The lowest biomasses were observed in the early 1980's, and some of the highest biomasses have been observed in recent years. The level of increase in on the order of 30% over the time series minima observed in the early 1980s.

Spring Conditions on the Northeast Shelf by Subarea



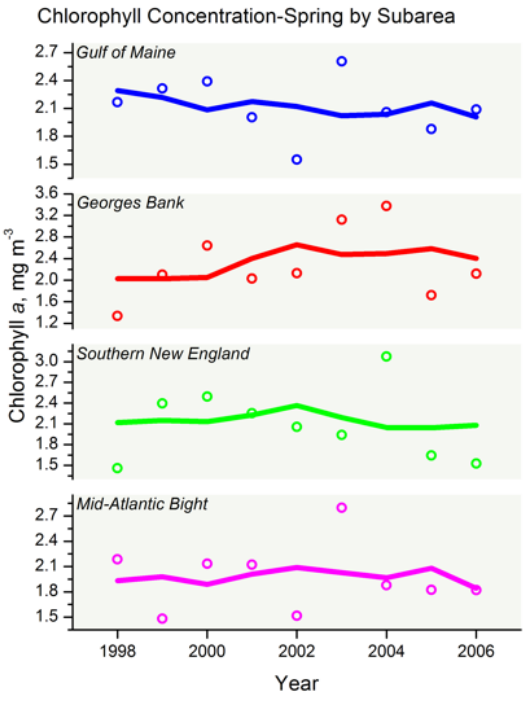
The Northeast Continental Shelf ecosystem can be divided into four major subareas: Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Middle Atlantic Bight (MAB), which reflect different underlying oceanographic conditions and fishery management boundaries. The regional variation in SST, chlorophyll, and zooplankton biomass is evaluated by these subareas.

Spring Sea Surface Temperature



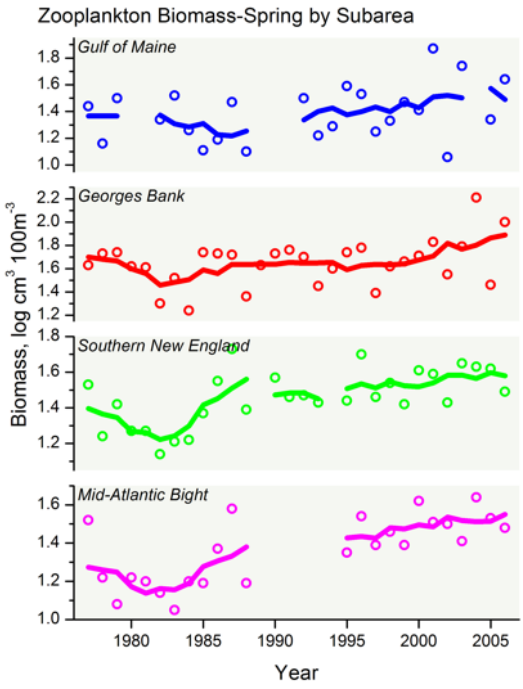
Average sea surface temperature during spring, as represented by data for April, is illustrated for the four major shelf regions. These regional indices present a coherent depiction of SST in the ecosystem. The time series minima in spring SST occurred during 1992 and the maxima occurred during 2000. Since then, there has been a general trend of decreasing spring SSTs in all four regions. The variability in spring indices decreases with latitude with the range in mean SST being nearly 6°C in the Mid-Atlantic Bight and decreasing to less than 2.5°C in the Gulf of Maine.

Spring Chlorophyll



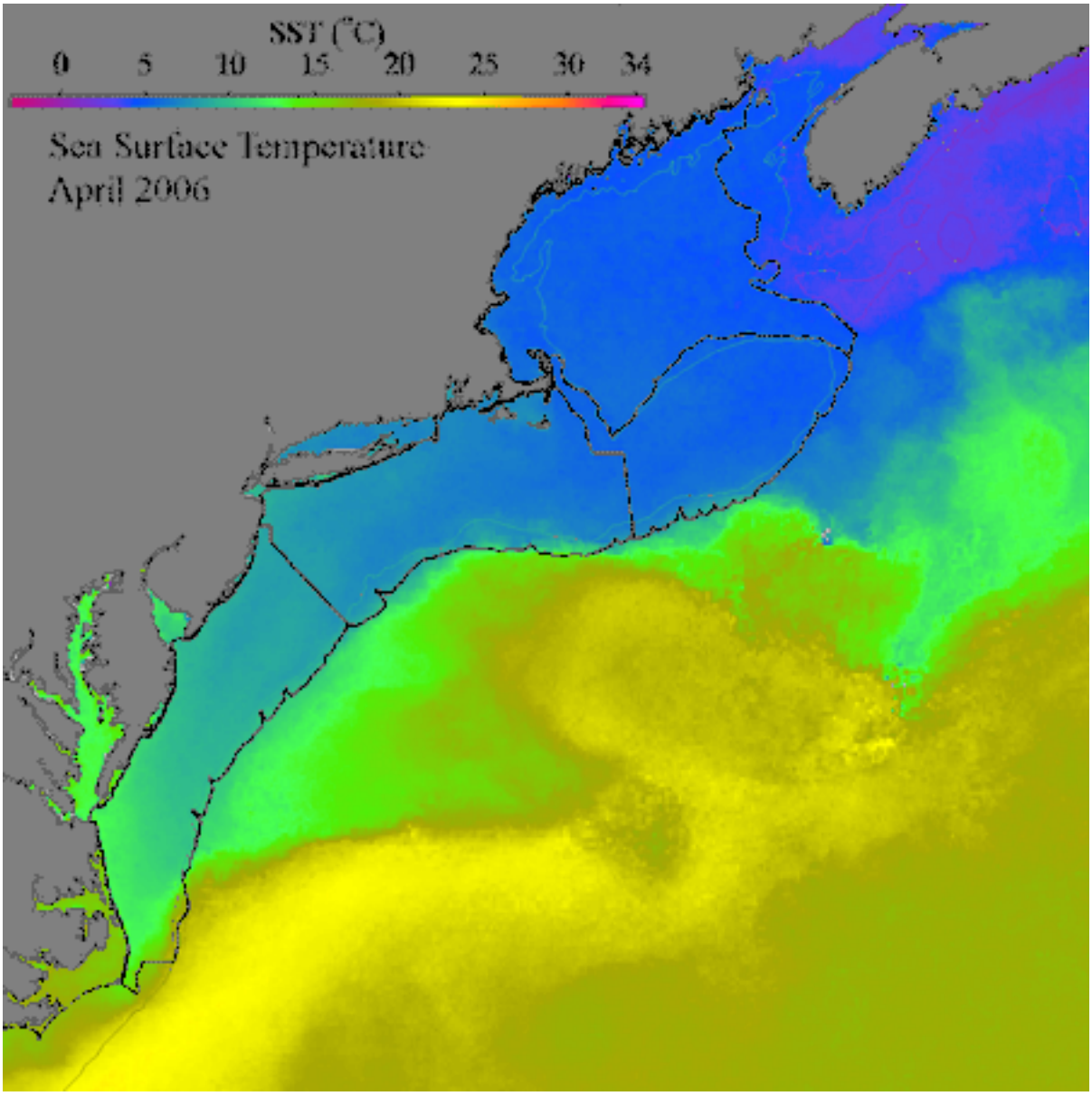
Average spring chlorophyll concentrations in surface waters, as represented by data for April, are illustrated for the four major shelf regions. The most striking feature of these data is the high degree of inter-annual variability in the time series; any perceived trends should be viewed with caution. The trend analysis suggest that chlorophyll concentration may be declining in the Gulf of Maine and may be increasing on Georges Bank, but these trends are not well developed and will have to be monitored. The data for Southern New England and the Mid-Atlantic Bight suggest that the spring bloom has maintained levels without significant trend. Individual yearly data suggest important bloom events may have occurred in the Gulf of Maine and Mid-Atlantic Bight in 2003 and in Southern New England and on Georges Bank in 2004.

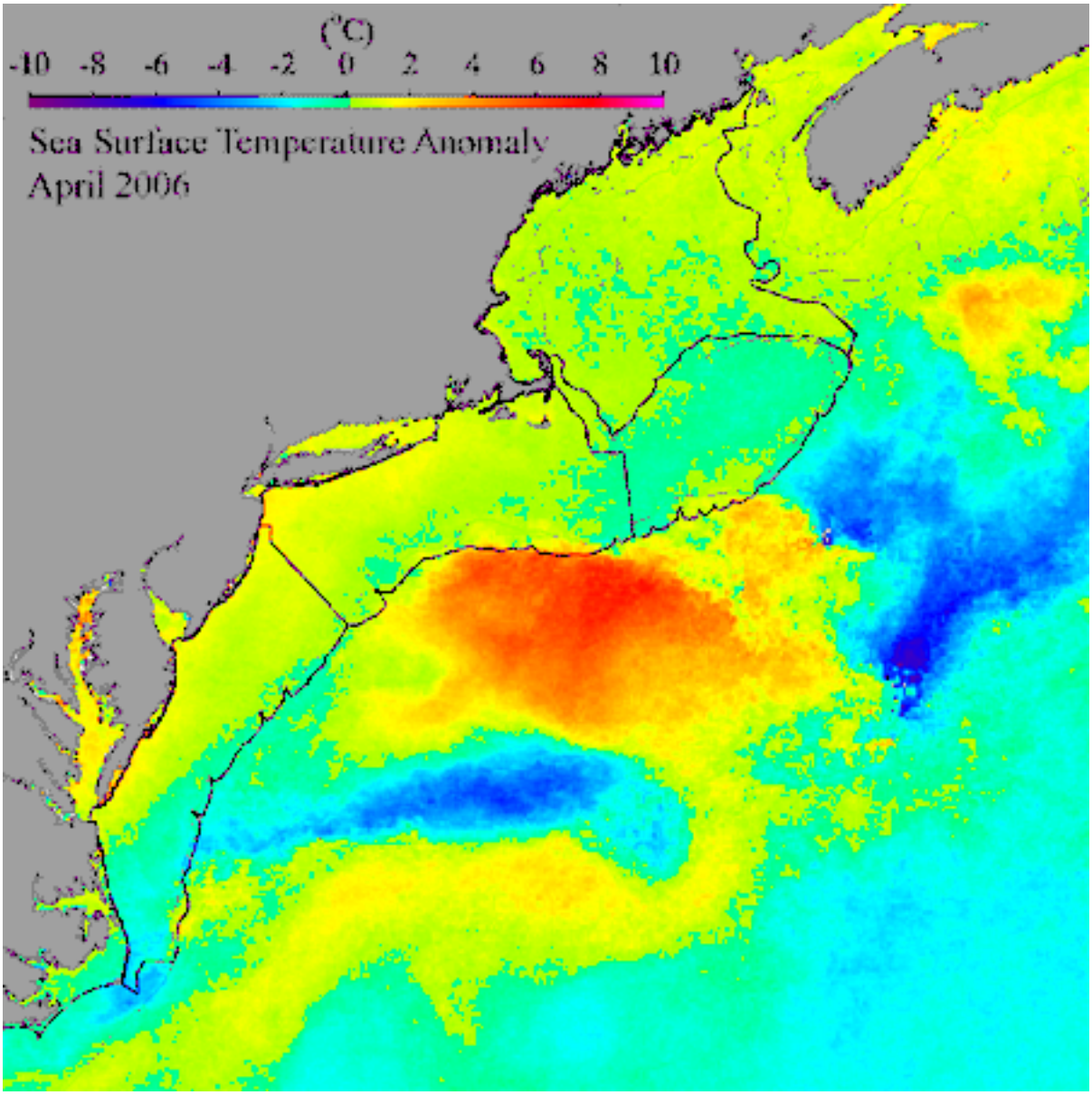
Spring Zooplankton



Mean zooplankton biomass, as measured by bio-volume, is shown for the four subregions during March and April. Zooplankton biomass is greatest on GB and least in the MAB. Spring increases in zooplankton biomass are observed in all four regions with the most pronounced increases in the MAB.

Spring Sea Surface Temperature Distribution

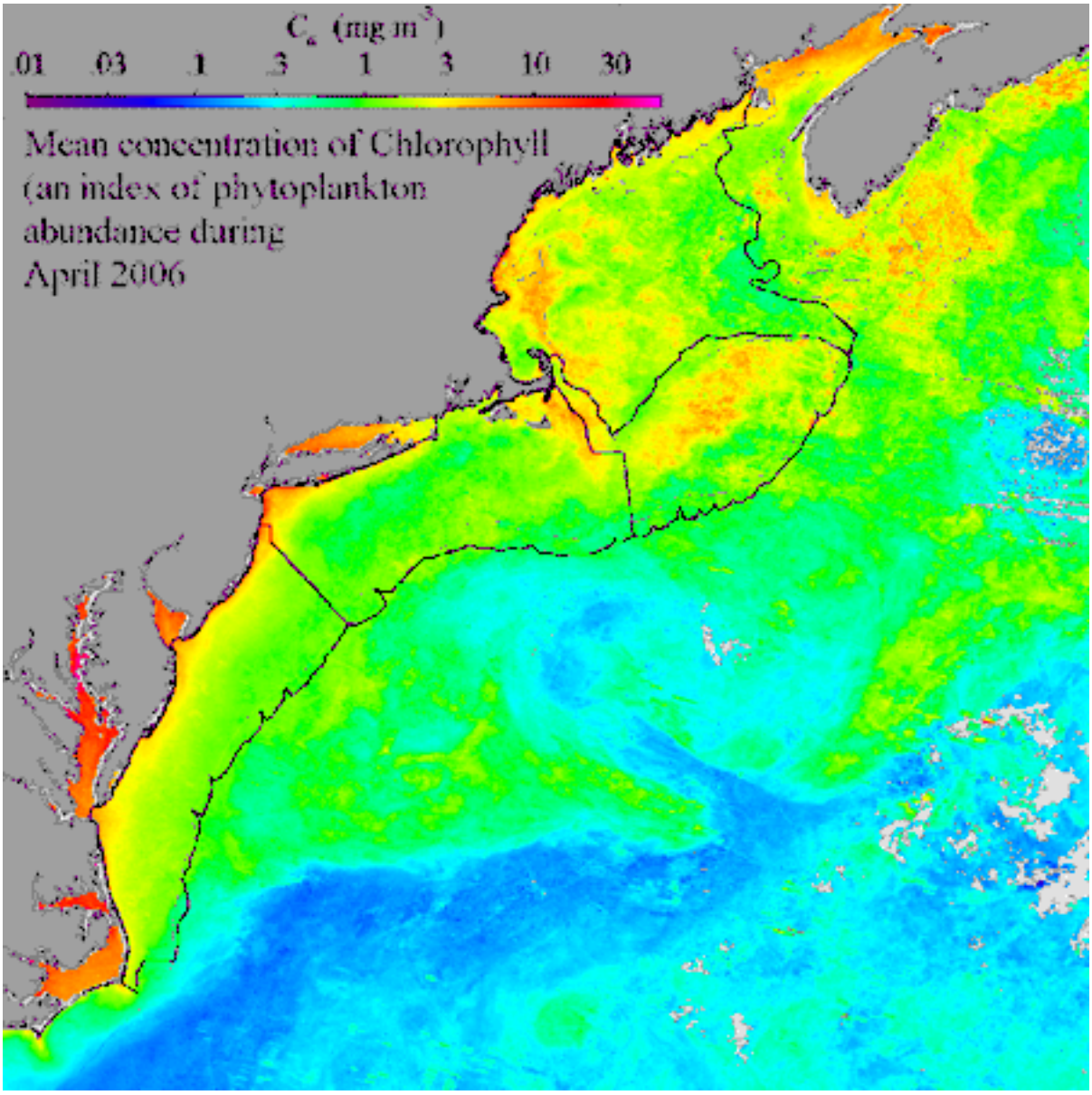

SST (°C)
0 5 10 15 20 25 30 34
Sea Surface Temperature
April 2006

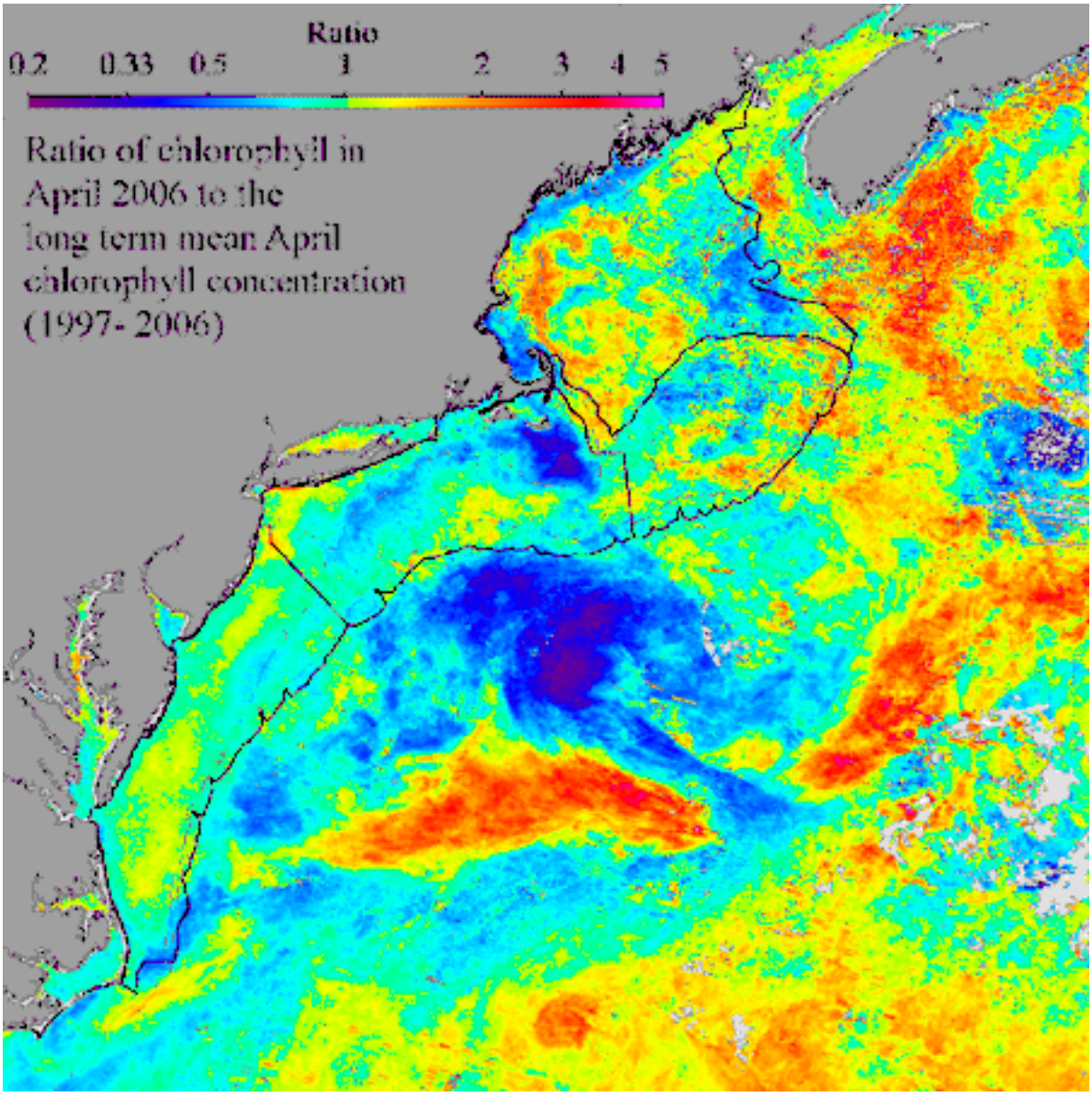


The distribution of sea surface temperature (SST) throughout the Northeast Shelf ecosystem during April 2006 shows the expected gradient of decreasing SST with increasing latitude. A sharp contrast is evident between the cool shelf water and the relatively warmer water along the shelf break from southern GB to Cape Hatteras. **(see upper map figure showing the distribution of sea surface temperature in degrees Celsius).** The departures of SSTs during April 2005 from the long-term April mean are shown as a temperature-anomaly map **(see lower anomaly map, also in units of degrees Celsius).** Surface waters in the northern portions of the GOM, and a large portion of the nearshore MAB, were slightly warmer than usual whereas SSTs on Georges Bank were normal to slightly cooler. Noteworthy is the unusually warm SSTs in the Slope Sea adjacent to the SNE shelf break. These anomalously warm SSTs are the result of a strong landward meander of the Gulf Stream during April. The presence of the Gulf Stream and a large warm-core ring off the Southern New England shelf may

result in the transport of warm-temperate and tropical zooplankton and fish larvae into the region.

Spring Chlorophyll Distribution

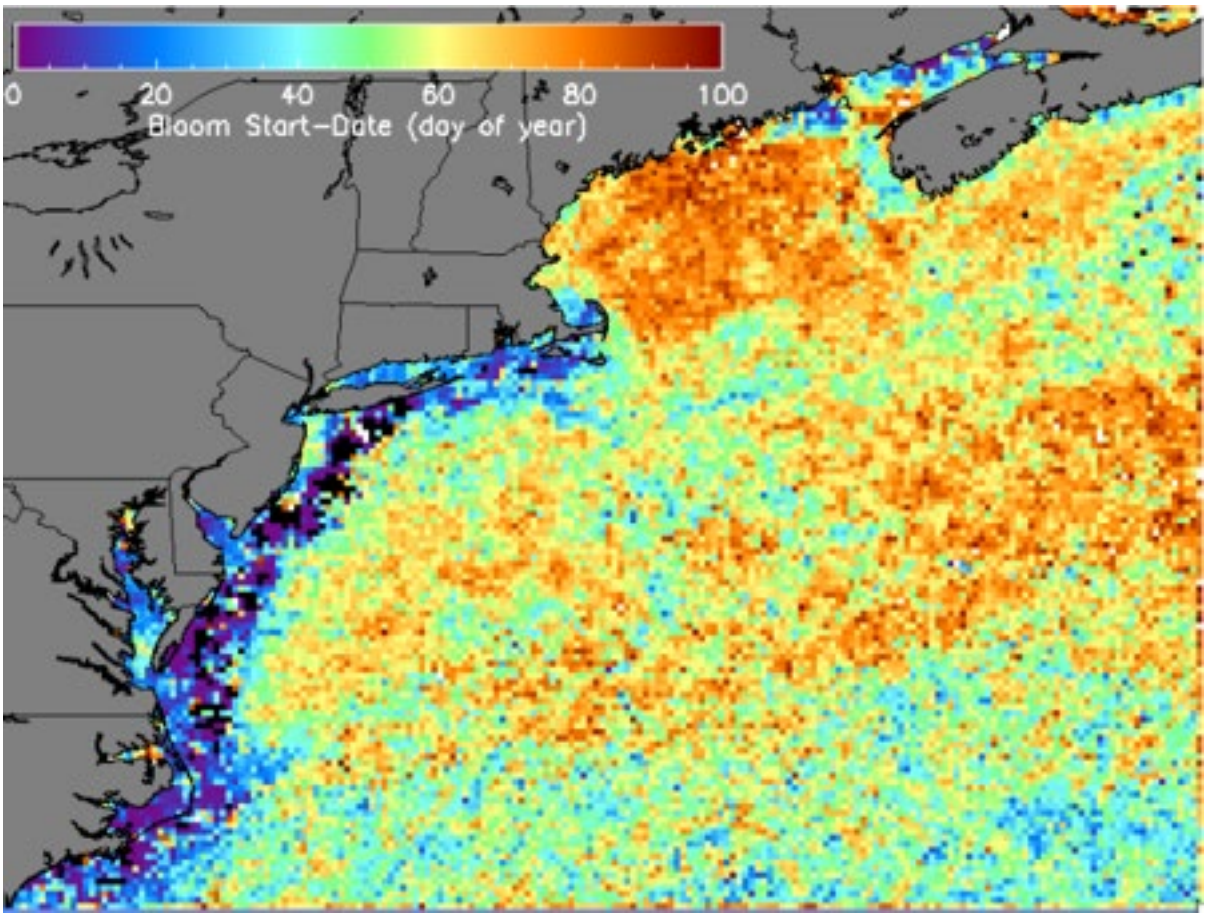


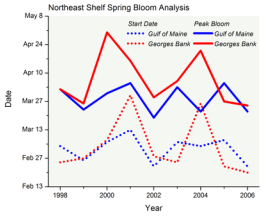


A general pattern is evident where chlorophyll concentration is greatest in continental shelf waters, intermediate over the deeper slope water, and lowest in the vicinity of the Gulf Stream and Sargasso Sea **(see upper map figure showing concentration of chlorophyll during April 2006 from Cape Hatteras to Nova Scotia)**. High levels of chlorophyll during spring occur in the tidally mixed central areas of Georges Bank and Nantucket Shoals, and in the Middle Atlantic Bight estuaries and coastal waters enriched by estuarine plumes. The high chlorophyll values (3-8 mg m-3) in the western Gulf of Maine indicate that spring bloom is underway during April. The same geographic range is used to illustrate how chlorophyll conditions during April 2006 compare with the average values for this month, where the average is computed from April data from 1997 through 2006 **(see lower map figure showing ratio of chlorophyll concentration)**. The ratio of April 2006 chlorophyll to the 9-year April mean chlorophyll indicates that levels in the western Gulf of Maine were above normal whereas levels

over Nantucket Shoals and the SNE mid-shelf area were below normal values for April. Surface chlorophyll levels are also low just seaward of the Southern New England shelf break (100m isobath), reflecting the influence of the warm Gulf Stream meander on phytoplankton production in this region (see April temperature map above).

Timing of the Spring Bloom

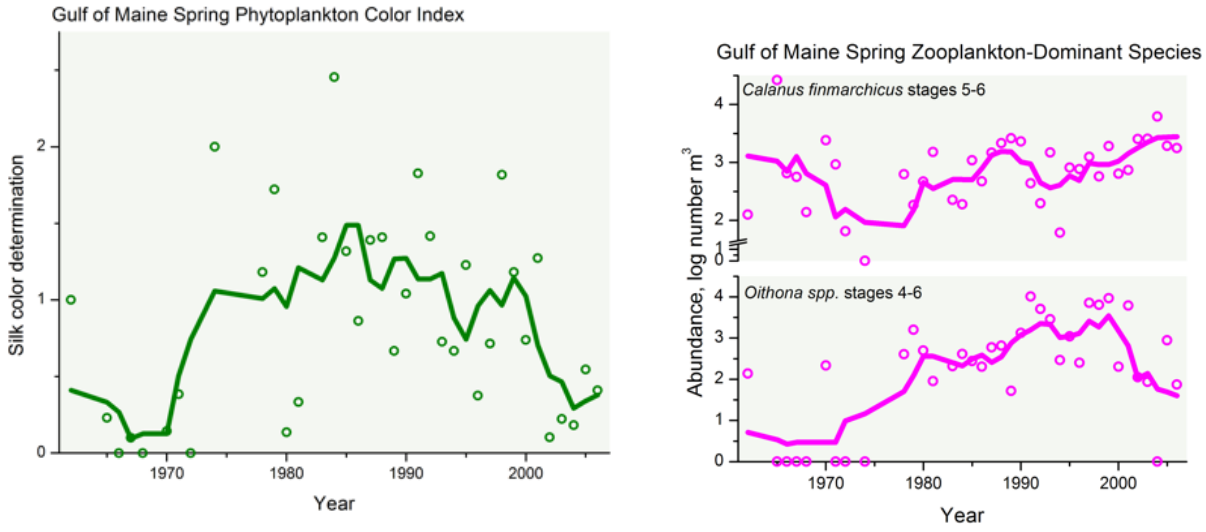




The timing of the spring bloom can be of importance to the recruitment of fish stocks and the production realized by various components of the food chain. Bloom start and peak date was estimated for 9km squares on the Northeast Shelf **(see map showing bloom start date for all locations)**. Many locations in Southern New England and the Middle Atlantic Bight were poorly estimated and appear black in the map indicating no value could be estimated with the regression procedure. In part, this was likely due to the fact the fall bloom is the dominant feature in these areas. Mean start and peak bloom date were calculated for the Gulf of Maine and Georges Bank areas **(see figure).** Bloom start data was typically in early March in both areas, with Georges Bank showing evidence of a more variable

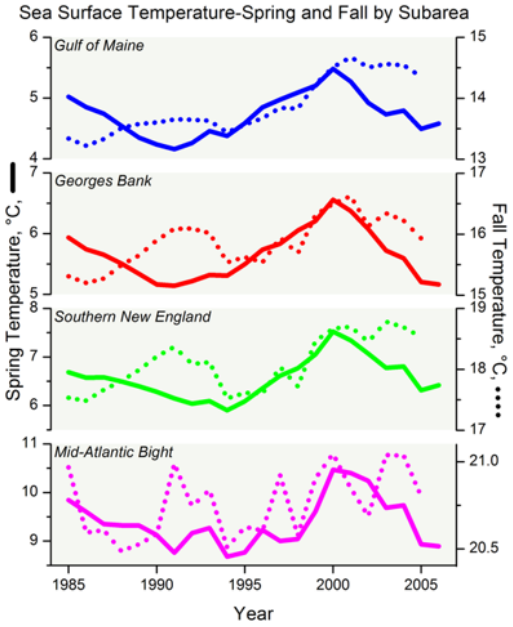
start timing of the bloom. Peak bloom date was typically in early April, and again the peak bloom date associated with Georges Bank was more variable, with some years not showing a peak in bloom development until the end of April.

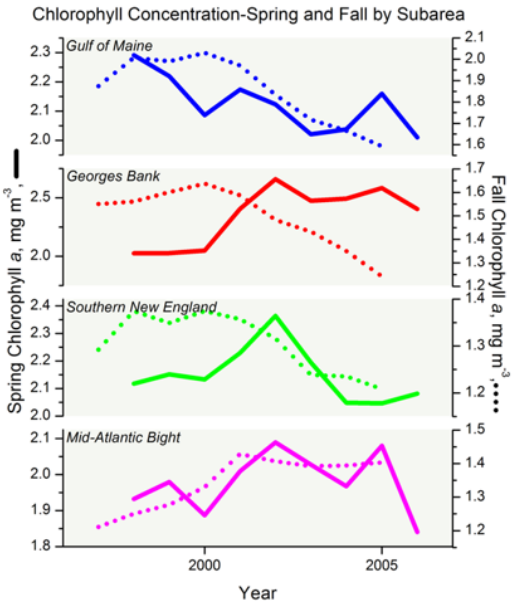
Ship of Opportunity Data - Dominant Zooplankton Species

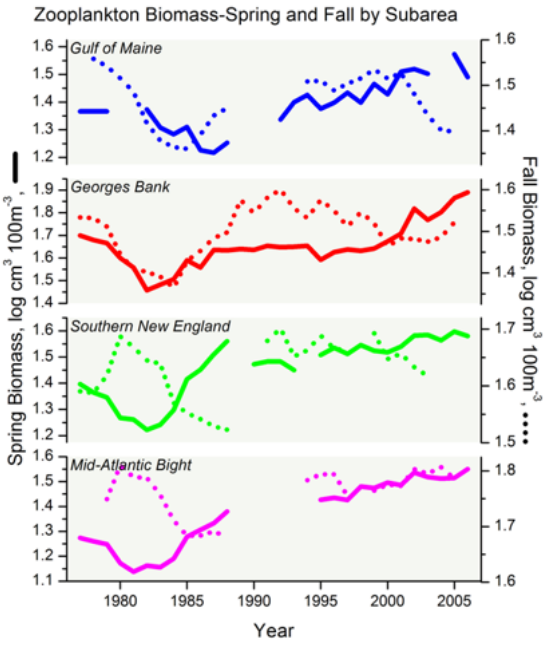


Phytoplankton color index from the Continuous Plankton Recorder transect across the Gulf of Maine is shown in the top panel. The decrease in spring chlorophyll concentration observed from satellites is also evident in the in situ data. Extremely low color indices were observed in the 1960s and early 1970s. There was then a rapid increase until about 1985 when a gradual decrease started. The decrease in color index seemed to accelerate in 2000 and low levels have been observed since. Abundances of two species of copepods from the Gulf of Maine Continuous Plankton Recorder transect are shown. Adult *Calanus finmarchicus*, which is a key indicator species for ecosystem status in the Gulf of Maine, has recently increases after a period of lower values in the 1990's. Smaller zooplankton, as exemplified by *Oithona*, have decreased after a period of higher values in the 1990's. These changes are indicators of shifts in community structure from larger bodied copepods, including *Calanus* in the 1980's, to smaller bodied copepods in the 1990's, including *Oithonia*, back to larger bodied copepods in the 2000's. The increase in larger-bodied copepods coincides with an increase in total zooplankton biomass during the fall

Comparison of Spring and Fall Conditions







For most regions, seasonal production can be partitioned into to spring and fall blooms, thus making the contrast in conditions during these two periods important. As described previously, spring surface water temperatures have declined in recent years from a peak in temperature around the year 2000. In contrast, fall temperatures appear to be continuing to increase or maintain higher levels in the Gulf of Maine, Southern New England, and Mid-Atlantic Bight **(see figure)**. Despite being represented by a shorter

time series, chlorophyll concentrations have some well developed trends as seen in the fall data where chlorophyll has declined in recent years with exception of fall bloom in the Mid-Atlantic Bight area. Spring bloom trends are less well developed, but the data do suggest that most areas are either maintaining bloom levels or increasing in chlorophyll concentration, with the exception of the Gulf of Maine, where the spring bloom appears to be trending downward over the past decade **(see figure)**. The importance of seasonal dynamics is seen in the comparison of fall and spring zooplankton biomasses. In our prior advisory we stated that 'Regional declines in fall zooplankton coupled with regional increases in annual zooplankton indicate important regional dynamics affect the shelf-wide annual patterns.' The observed increases in spring zooplankton are apparently large enough in magnitude to cancel the decreases in fall zooplankton and result in modest regional increases in the annual zooplankton biomasses **(see figure)**. The obvious implication is that the decline in fall primary production is affecting zooplankton populations. The continued increase in spring zooplankton populations is not supported by a direct relationship with chlorophyll concentration, but may be attributed to a shift in zooplankton community structure.