Fall 2007 Update: Annual Condition of the Northeast Shelf Ecosystem

Produced by the Ecosystem Dynamics and Assessment Branch

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Fall 2007 Update: Summary of Spring Conditions of the Northeast Shelf Ecosystem

Summary

This advisory is an examination of temperature and plankton conditions associated with the Northeast Shelf Ecosystem during the spring of 2007. The spring bloom, and its antecedent winter production period, is pivotal to the recruitment process of many resource species.

- During fall into winter of 2006-2007, sea surface temperature (SST) was warm in the Northeast Shelf Ecosystem, with the exception of Georges Bank where late winter was noticeably cooler. During the spring of 2007, SST tended to be cool in all subregions of the Shelf with the most extreme cooling occurring on Georges Bank.
- The spring bloom was of higher intensity, i.e. with higher chlorophyll concentrations, in all subregions of the Northeast Shelf Ecosystem. The blooms were of average or less than average duration, so bloom magnitude was not particularly high.
- Spring blooms in the Gulf of Maine and on Georges Bank had been occurring later in the spring in recent years; however, both the 2006 and 2007 blooms commenced closer to the average bloom start date in both subregions.
- Zooplankton biomass was at lower levels during the winter of 2006-2007 both for the entire ecosystem and in each of the four subregions. During fall of 2006, ecosystem wide biomass was near average while it was above average in the southern subregions, near average on Georges Bank, and below average in the Gulf of Maine.
- Springtime abundance of larger phytoplankton is at low levels in the Gulf of Maine, based on the Ship of Opportunity Program color index. Similarly, springtime abundance of smaller copepods (e.g., *Oithona* spp) is also at lower levels. Abundance of *Calanus* in the spring, however, remains at or slightly above average.
- Results of climate change modeling done by the Canadian Centre for Climate Modeling and Analysis suggests that sea surface temperature will increase on the Northeast Shelf. The focus of the highest anticipated change is the Gulf of Maine. Under most climate change scenarios, the Gulf of Maine is expected to increase in temperature on the order of 2-4°C. However, under the scenario with the highest greenhouse gas loading, the change in SST could be as high as 7°C.
- There has been an increase in cannibalism in the northern stock of silver hake.

Data Sources

SST is derived from the Advanced Very-High Resolution Radiometer onboard the Polar Orbiting Environmental Satellite (AVHRR-POES) and the MODIS Aqua and Terra sensors. The data 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 subregions: Mid-Atlantic Bight, Southern New England, Georges Bank, and Gulf of Maine (resulting in approximately 720 measures of zooplankton biomass annually).

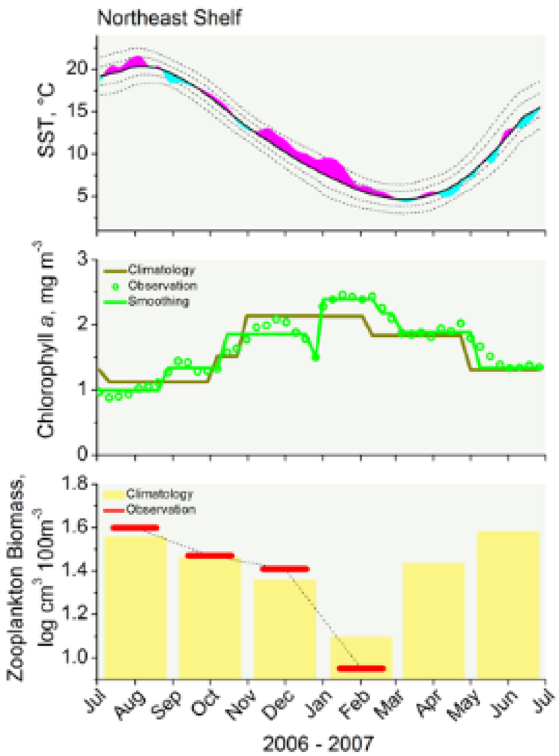
Phytoplankton and zooplankton also are collected on monthly transects across the Gulf of Maine and the Mid-Atlantic Bight using Ships of Opportunity. Phytoplankton abundance is quantified based on the color of the sample. Zooplankton abundance is based on counts of individual species and stages.

The cannibalism index was derived from the Food Habits Database, collected from shipboard fishery independent surveys of the U.S. Northeast Shelf ecosystem.

Long term SST were extracted from the Extended Reconstructed Sea Surface Temperature (ERSST, version 2) dataset. This dataset is based on the temperature compilation of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) SST dataset and represents interpolation procedures that reconstructs SST fields in regions with sparse data.

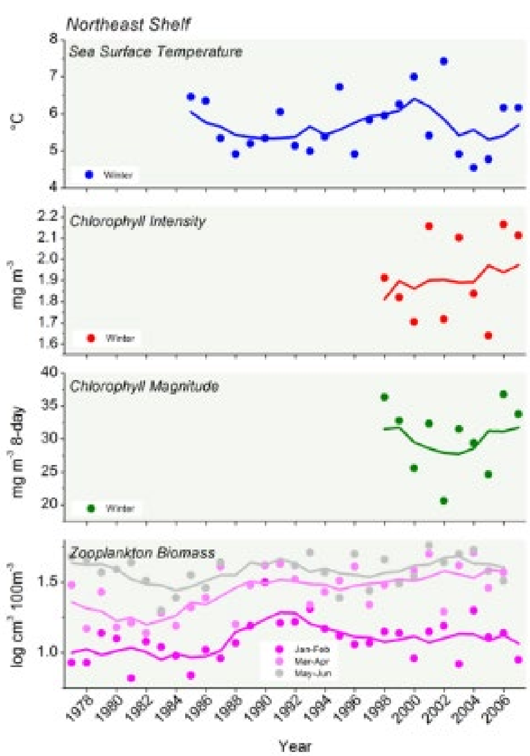
Projections of SST were extracted from the Canadian Centre for Climate Modeling and Analysis (CCCma) third generation coupled general circulation model (CGCM3). All annual means are the average of 5 model realizations provided by the CCCma.

Spring Conditions on the Northeast Shelf Ecosystem



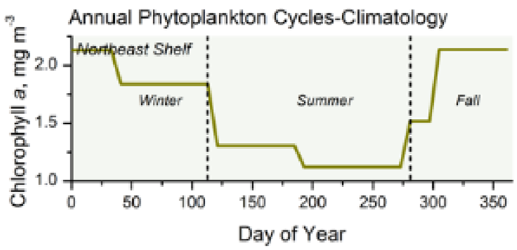
Sea surface temperature conditions on the Northeast Shelf shifted from anomalously warm during late fall and winter of 2006 to cooler than average during spring 2007. This trend persisted through the early summer with June temperatures still below normal. The progression of chlorophyll concentrations suggests winter-spring blooms were above average, with early summer chlorophyll concentrations returning to average levels. Zooplankton biomass levels were above average through the winter months of 2006. Our first estimate of zooplankton biomass for 2007 suggests a dramatic decrease. However, it should be noted that the January-February zooplankton estimate is provisional.

Trends in Spring Conditions for the Northeast Shelf



The SST and chlorophyll data for the Northeast Shelf Ecosystem were partitioned into time period/seasonal indices following the scheme described in the **Spring 2007 Ecosystem Advisory**. The annual cycle of the parameters for the Northeast Shelf was divided into three seasonal time periods, the details of this division can be found in the link below. For this advisory, which summaries spring conditions, the only time period with complete data is winter. The time series of the Northeast Shelf winter sea surface temperatures shows that the 2006 and 2007 values reverse the cooling trend of the past five years. The 2007 winter SST index was slightly above average. Winter chlorophyll intensity and magnitude remained at high levels similar to levels observed in 2006. The January-February zooplankton biomass estimate suggests a large, but not unprecedented, decrease in zooplankton during the winter of 2007. Zooplankton data from March-April and May-June 2007 is not yet available.

Partitioning the Year on the Northeast Shelf



The overall chlorophyll concentration cycle for the Northeast Shelf Ecosystem suggests that the year be partitioned into three time periods/seasons similar to the partitioning done for the southern subregions, Southern New England and Mid-Atlantic Bight, which also lack a consistent spring or fall bloom.

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 suggests 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.

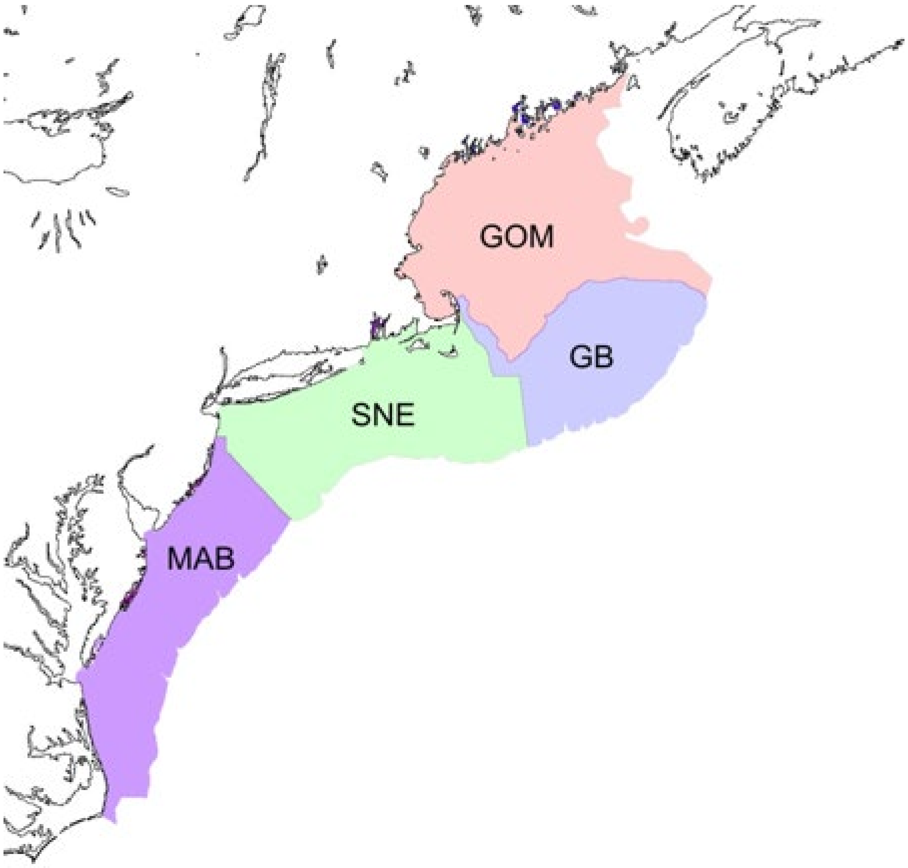
Spring Sea Surface Temperature Distribution

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. The departures of SSTs during April 2005 from the long-term April mean are shown as a temperature-anomaly map. 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

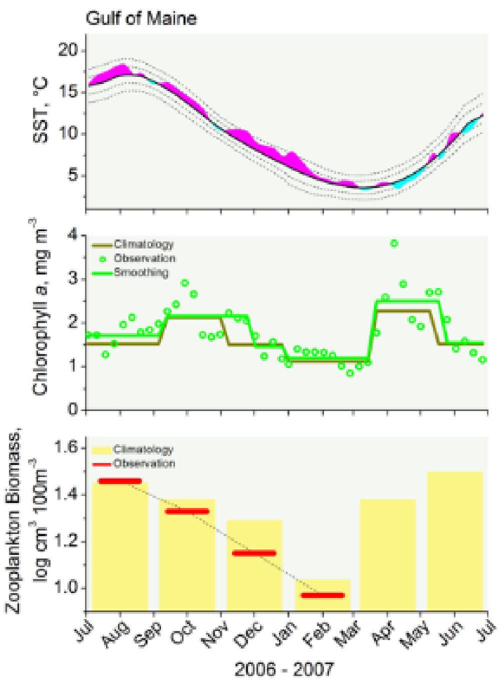
A general pattern is evident where chlorophyll concentration is greatest in continental shelf waters, intermediate over the deeper slope water, and lowest in the vicinity of the Gulf Stream and Sargasso Sea. High levels of chlorophyll during spring occur in the tidally mixed central areas of Georges 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. 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).

Spring Condition by Shelf Subregions

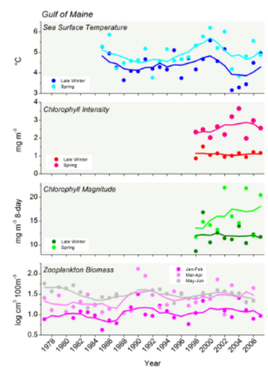


The Northeast Continental Shelf ecosystem can be divided into four major subregions: Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Mid-Atlantic Bight (MAB), which reflect different underlying oceanographic conditions and fishery management boundaries. The regional variation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

Gulf of Maine Subregion



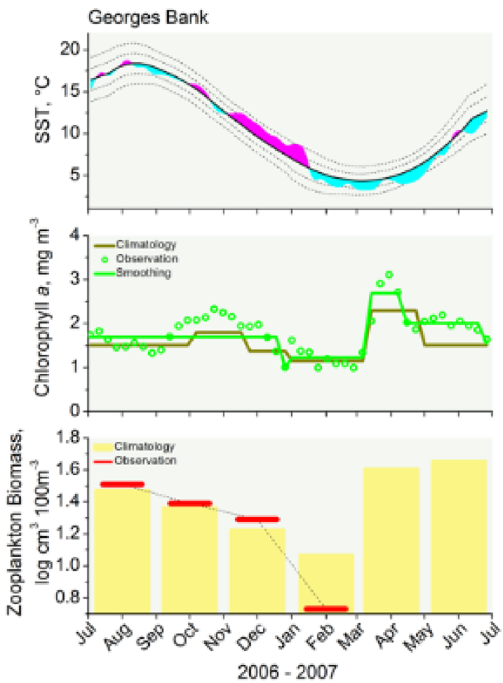
SST conditions were warm in the Gulf of Maine subregion during the fall of 2006 into the winter of 2007. The spring 2007 temperatures were both above and below the long term mean. The 2007 spring bloom was above the climatological mean in both its intensity and magnitude. The bloom started at a date typical of the spring bloom in that subregion, but lasted slightly longer than usual. Early summer chlorophyll concentrations were at an average level. The winter 2007 zooplankton biomass for the Gulf of Maine continues a trend that began in fall 2006 of lower than average zooplankton biomass. The January-February zooplankton estimate is provisional.



Trends in Spring Conditions for the Gulf of Maine Subregion

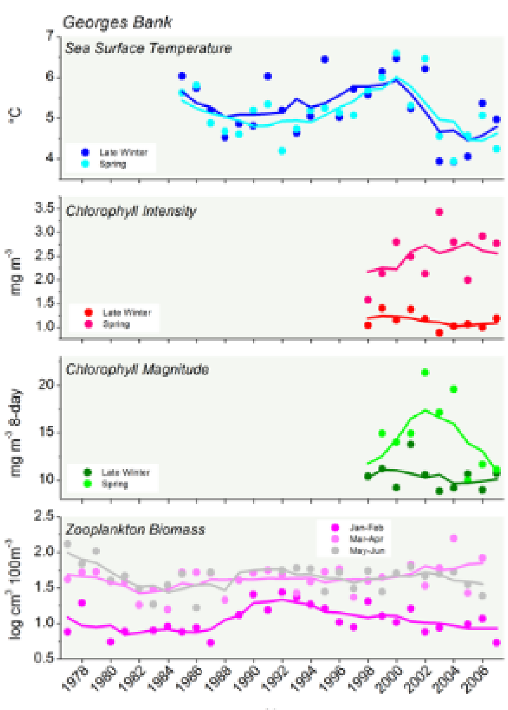
The SST and chlorophyll data for the Gulf of Maine were partitioned into time period/seasonal indices following the scheme described in the **Spring 2007 Ecosystem Advisory**. The SST time series for the Gulf of Maine shows that the 2006 and 2007 values reverse the cooling trend of the past five years. The 2007 winter SST index was above the time series trend whereas the spring index approximated the trend. Winter chlorophyll intensity and magnitude remained at levels similar to those observed in 2006. Spring chlorophyll intensity in 2007 was at the time series trend level, but the 2007 spring bloom magnitude was well above the trend reflecting the highly variable bloom magnitudes seen in this subregion. The January-February zooplankton biomass estimate suggests a modest decrease in zooplankton during the winter of 2007. Zooplankton data from March-April and May-June 2007 is not yet available.

Georges Bank Subregion



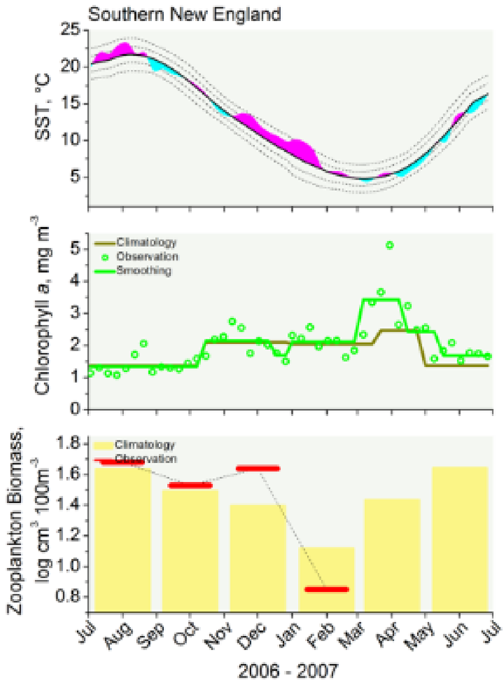
SST conditions were warm on Georges Bank during the fall of 2006, but quickly become cool with onset of winter, and continued to be cool into the spring of 2007. These cool conditions persisted into early summer. The 2007 spring bloom was above the climatological mean in terms of intensity, but the bloom was of low magnitude since it only lasted 3-4 weeks. The bloom started at a date typical of the spring bloom in that subregion, but it was over by the end of April. Early summer chlorophyll levels were well above average. The winter 2007 zooplankton biomass for Georges Bank was extremely low, well below the long-term mean for the subregion. Since the January-February zooplankton estimate is provisional, caution should used in interpreting this trend.

Trends in Spring Conditions for the Georges Bank Subregion



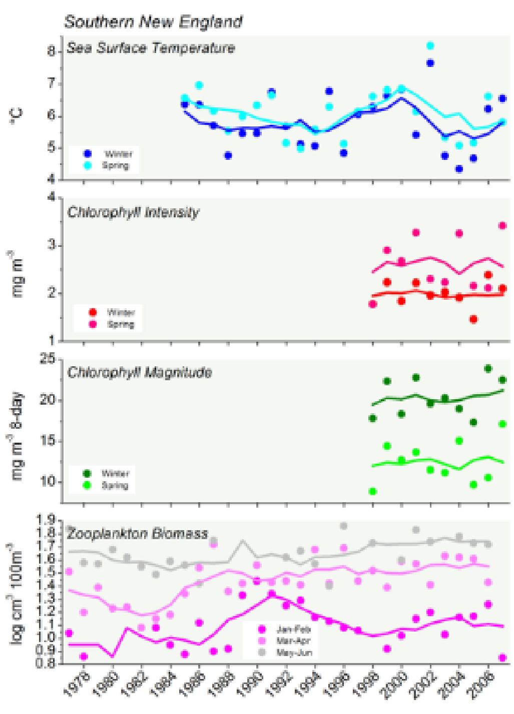
The SST and chlorophyll data for Georges Bank were partitioned into time period/seasonal indices following the scheme described in the **Spring 2007 Ecosystem Advisory**. The SST time series for Georges Bank shows that the 2007 values continue the cooling trend of the past five years. The 2007 winter SST index was above the time series trend whereas the spring index was below the trend. Winter chlorophyll intensity and magnitude remained at levels similar to those observed in 2006. Spring chlorophyll intensity in 2007 was at the time series trend level, but 2007 spring bloom magnitude was very low reflecting a poorly developed spring bloom. The January-February zooplankton biomass estimate suggests a decrease in zooplankton during the winter of 2007. Zooplankton data from March-April and May-June 2007 is not yet available.

Southern New England Subregion



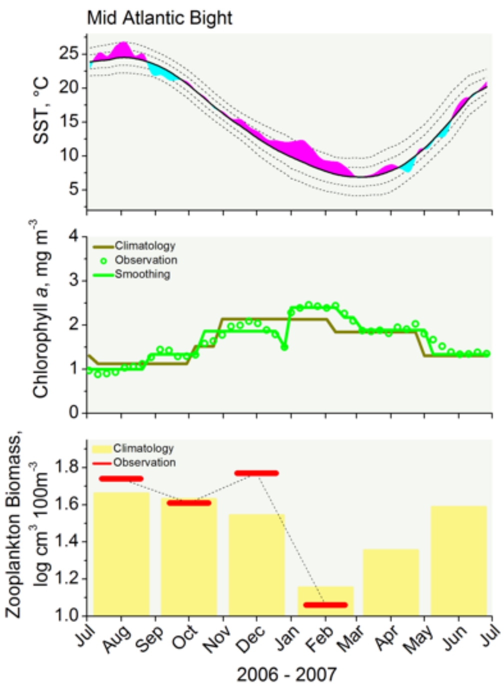
SST conditions were warm in the Southern New England subregion beginning in fall and lasting well into winter. Spring SST conditions were closer to the long-term mean or only slighter cooler than average. The 2007 spring bloom was relatively early and was very intense with chlorophyll concentrations around 5 mg m-^{3}. The winter 2007 zooplankton biomass for Southern New England was extremely low, well below the long-term mean for the subregion. Since the January-February zooplankton estimate is provisional, caution should used in interpreting this trend.

Trends in Spring Conditions for the Southern New England Subregion



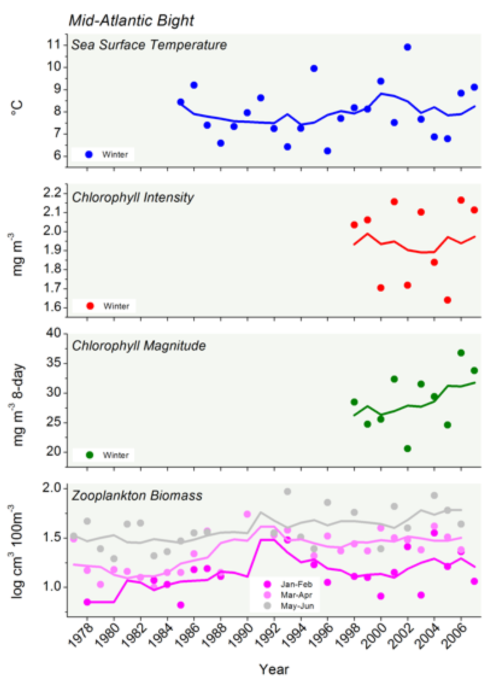
The SST and chlorophyll data for the Southern New England subregion were partitioned into time period/seasonal indices following the scheme described in the **Spring 2007 Ecosystem Advisory**. The SST time series for Southern New England shows that the 2007 values continue the reversal of inshore cooling of the past five years. The 2007 winter SST index was above the time series trend whereas the spring index approximated the trend. Winter chlorophyll intensity and magnitude were slightly above the time series trend in this subregion. The 2007 spring bloom was the largest recorded in the time series in terms of both intensity and magnitude. The January-February zooplankton biomass estimate suggests a dramatic decline in zooplankton during the winter of 2007. Zooplankton data from March-April and May-June 2007 is not yet available.

Mid-Atlantic Bight Subregion



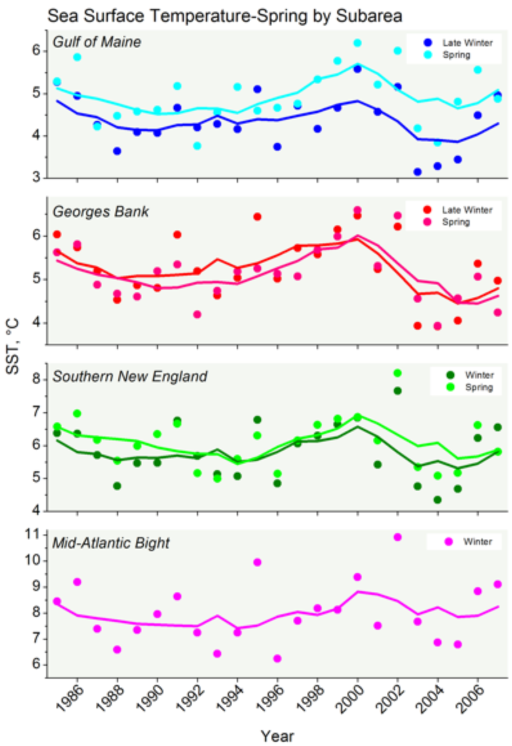
SST conditions in the Mid-Atlantic Bight subregion were warm in fall through spring, with the only evidence of the cooling seen in other parts of the ecosystem occurring in April. January SST exceeded two standard deviations above the long-term mean for a short period of time. The 2007 winter period bloom was above the climatological mean in terms of intensity, but chlorophyll levels returned to average values during the spring and early summer time periods. The dramatic decline in winter 2007 zooplankton biomass seen in other subregions was also seen in the Mid-Atlantic Bight, but biomass declines of this magnitude are not without precedent in this subregion.

Trends in Spring Conditions for the Mid-Atlantic Bight Subregion



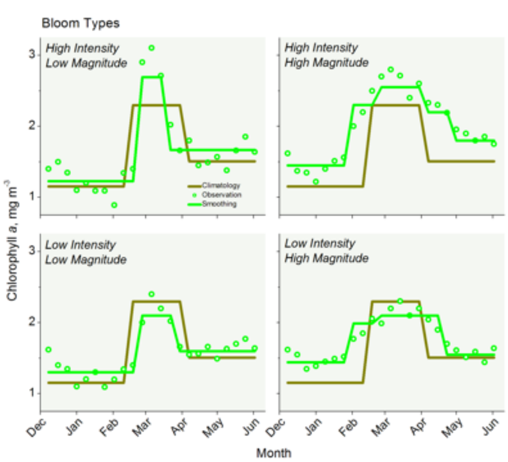
The SST and chlorophyll data for the Mid-Atlantic Bight were partitioned into time period/seasonal indices following the scheme described in the **Spring 2007 Ecosystem Advisory**. The SST time series for the Mid-Atlantic Bight shows that the 2007 winter period value continues the warming trend suggested by the value for 2006. Winter chlorophyll intensity and magnitude were both above the time series trends suggesting the winter bloom was robust. The January-February zooplankton biomass estimate suggests a decrease in zooplankton during the winter of 2007. Zooplankton data from March-April and May-June 2007 is not yet available.

Subregion Comparison of Sea Surface Temperature



Gulf of Maine SST during both late winter and spring time periods increased after a short multi-year run of cool conditions. Warming around the year 2000 resulted in SSTs in excess of 5°C during both time periods, changing to SST levels less than 4°C in the year 2004. A pattern coherent to the Gulf of Maine data is seen in the Georges Bank time series, but the pattern of SST change in the Southern New England and Mid-Atlantic Bight subregions is markedly different. There is an absence of a trend in the Mid-Atlantic Bight data suggesting that thermal patterns for the winter and spring periods may be distinct between the northern and southern segments of the ecosystem.

Subregion Comparison of Chlorophyll

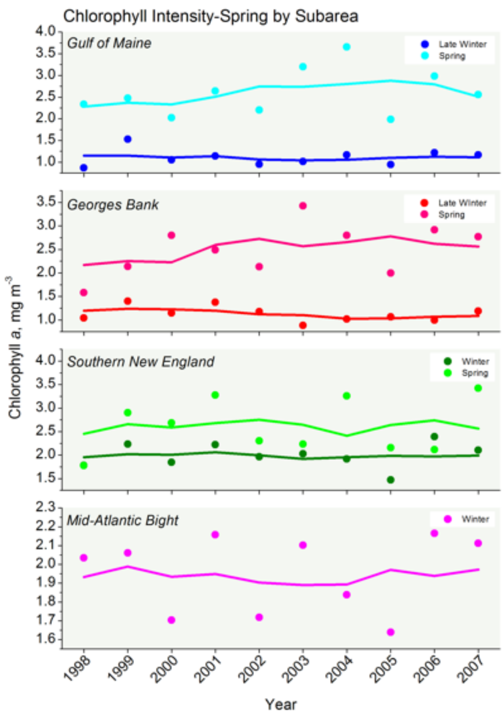


Plankton blooms can be quite variable which affects the way pelagic and benthic resources utilize the primary production associated with the bloom. In an attempt to quantify these characteristics, two measures of bloom size are reported, chlorophyll intensity and chlorophyll magnitude, which are a reflection of the concentration and duration of the bloom, respectively:

Intensity: is the mean chlorophyll concentration for the seasonal time period in a region.

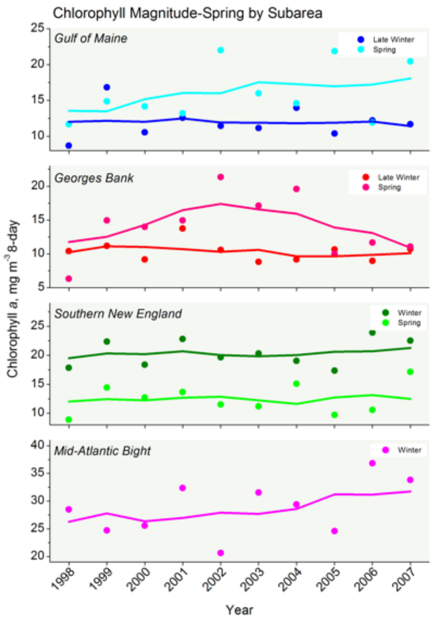
Magnitude: is the mean chlorophyll concentration for a seasonal time period multiplied by the length of the time period. In some years, the time period start or stop dates were not obvious from the annual data, in these cases the climatological time period was used instead.
This figure illustrates the differences between high and low intensity versus high and low magnitude blooms.

Subregion Comparison of Chlorophyll Intensity



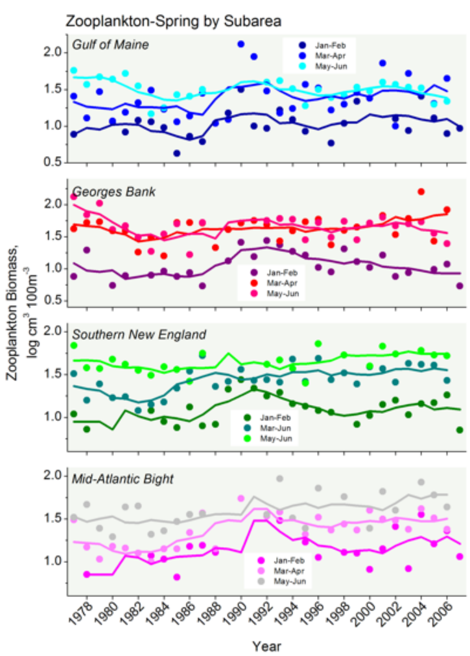
Chlorophyll intensity increases on the order of three fold during the spring time period compared to the late winter period in the Gulf of Maine and on Georges Bank, which reflects the increase in chlorophyll concentration associated with the spring bloom. There is no obvious trend in the winter data; however, it would appear that the spring bloom intensity in the Gulf of Maine and on Georges Bank has increased over the decadal period of SeaWiFS observations. A spring bloom is differentiated in the Southern New England subregion, but it only represents a two fold increase over winter chlorophyll intensities, which tend to be higher than observed in the northern subregions. There does not appear to be any time series trend in the Southern New England bloom intensity data. Bloom intensity of the winter bloom in the Mid-Atlantic Bight is variable and without trend.

Subregion Comparison of Chlorophyll Magnitude



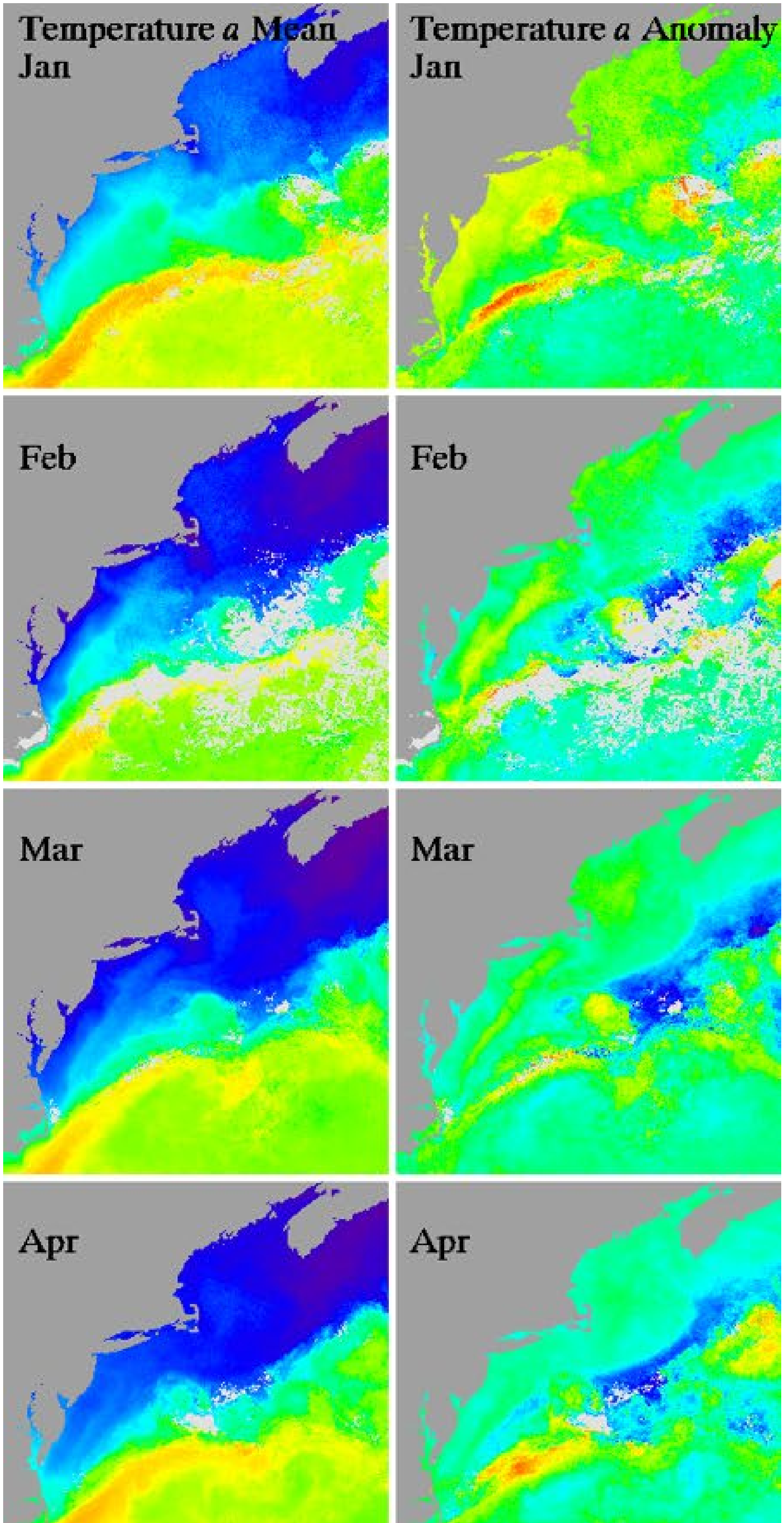
Bloom magnitude has increased for Gulf of Maine spring blooms over the ten year time series, reflecting a similar trend seen in the bloom intensity data for this subregion. The magnitude of Georges Banks spring blooms increased during the period 2001-2004; however, in recent years bloom magnitude has declined suggesting that the spring blooms on the Bank have been short duration and high intensity blooms, which can result in low magnitude blooms. There are no discernable trends in the winter blooms occurring in the Gulf of Maine, on Georges Bank or in the Southern New England subregions. The winter bloom in the Mid-Atlantic Bight has increased in magnitude over the time series.

Subregion Comparison of Zooplankton



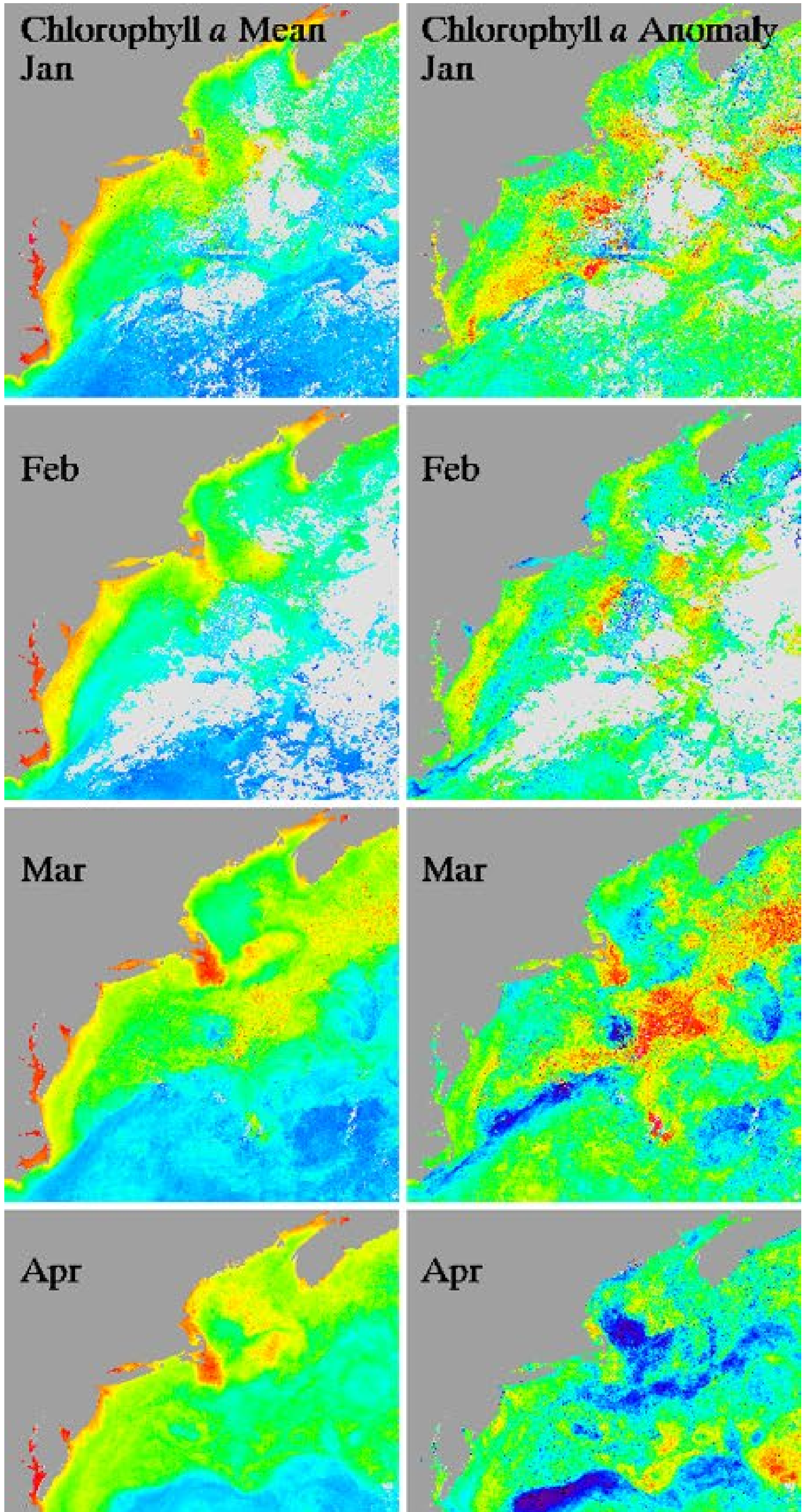
Mean zooplankton biomass, as measured by bio-volume, is shown for the four subregions during the first three standard bi-monthly time periods of the year. Zooplankton biomass during the first half of the year shows some common features between subregions. Zooplankton populations increased during spring in all subregions. There also appears to have been a shift in first half of the year zooplankton populations from the 1980s into the 1990s, with biomass increasing slightly in all subregions.

Spring Sea Surface Temperature Distribution


Temperature *a* Mean
Jan
Temperature *a* Anomaly
Jan
Feb
Feb
Mar
Mar
Apr
Apr

Monthly sea surface temperature mean and anomaly maps of the Northeast Shelf for the first half of 2007 show the expected progression of seasonal cooling and warming throughout the shelf. The conventional gradient of increasing SST with decreasing latitude is clearly evident, as well as the sharp contrast between the cool shelf water and the relatively warmer water along the shelf break from Georges Bank to Cape Hatteras. Monthly anomalies are shown as the departure of the monthly mean from the long-term mean for the given month. The above average conditions in the Southern New England subregion in January are possible remnants of warm core rings from the Gulf Stream. Negative anomalies were consistently present from February through May in the waters east and south of Georges Bank. The temperature departures in June were weak, indicating that the regional SST patterns were in-line with the ten year mean.

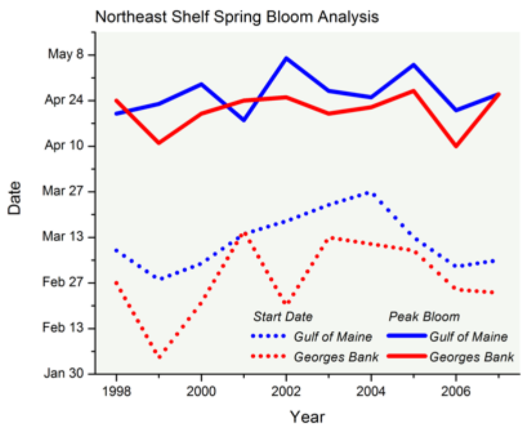
Spring Chlorophyll Distribution



Chlorophyll a Mean
Jan
Chlorophyll a Anomaly
Jan
Feb
Feb
Mar
Mar
Apr
Apr

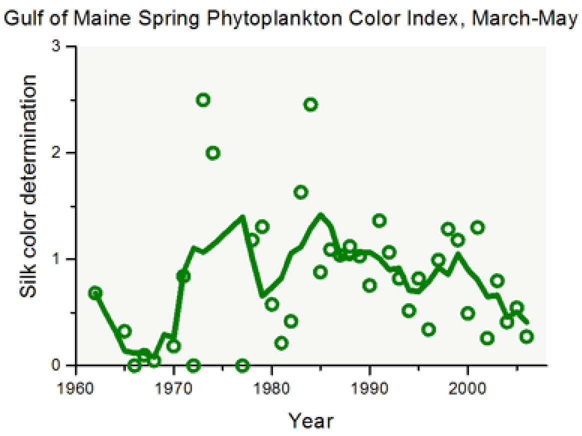
The distribution of chlorophyll concentration during the first half of 2007 is shown as a progression of monthly maps with a parallel set of monthly anomaly maps. Chlorophyll anomalies are the ratio of the monthly mean to the long-term mean for the given month (1997-2007). There is a general onshore to offshore gradient where chlorophyll concentrations are greatest in the continental shelf waters, intermediate over the deeper slope water, and lowest in the vicinity of the Gulf Stream and Sargasso Sea. High levels of chlorophyll during the spring occur in the Mid-Atlantic Bight estuaries and enriched coastal waters, and in the tidally mixed central subregions of Nantucket Shoals and Georges Bank. The spring bloom first appears along the coastal regions and in the subregion of Nantucket Shoals during March, but never extends offshore into the Gulf of Maine as indicated by the below average conditions present in April. The bloom, however, persists on Georges Bank through June.

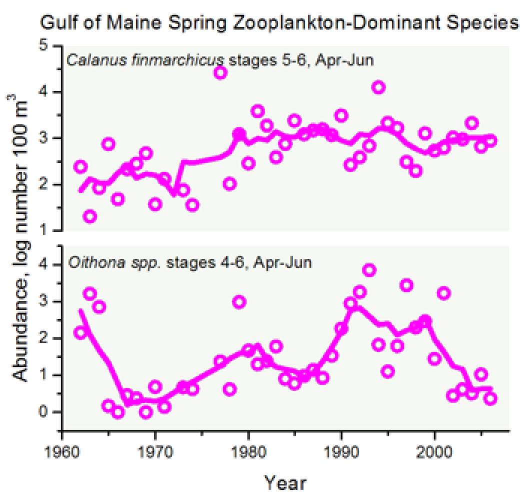
Timing of the Spring Bloom



The timing of the spring bloom can be important to the recruitment of fish stocks and the production realized by various components of the food web. Bloom start and peak dates were estimated for 9km squares on the Northeast Shelf. Many locations in Southern New England and the Mid-Atlantic Bight were poorly estimated, in part due to the fact the spring bloom is not a dominant feature in these subregions. Mean start and peak bloom dates were calculated for the Gulf of Maine and Georges Bank subregions. Bloom start dates were typically in early March in both subregions, with Georges Bank showing evidence of a more variable start time of the bloom. The 2007 spring bloom was estimated to have started around February 24 and March 6 on Georges Bank and in the Gulf of Maine, respectively. Peak bloom date is typically in early April in both subregions and appears to have coincided in 2007 with both the Georges Bank and Gulf of Maine blooms peaking around April 26.

Ship of Opportunity Data-Dominant Zooplankton Species



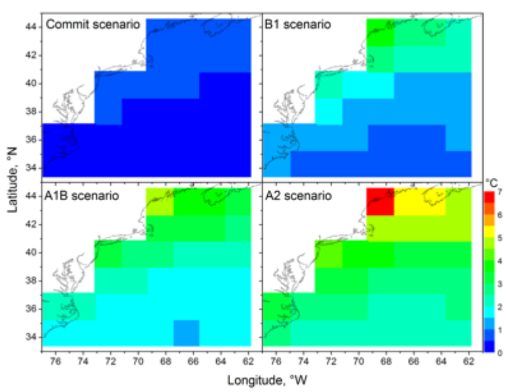


Phytoplankton color index from the Continuous Plankton Recorder transect across the Gulf of Maine is shown in the top panel. The color index reflects the relative abundance of larger phytoplankton retained by the silk filter. The index indicates that the abundance of large phytoplankton continues to decline in the Gulf of Maine as compared to high values observed in the 1970s and 1980s. Abundances of two species of copepods from the Gulf of Maine Continuous Plankton Recorder transect are shown in the lower graph. Adult *Calanus finmarchicus*, which is a key indicator species for ecosystem status in the Gulf of Maine, has recently increased after a period of lower values in the 1990's. Smaller zooplankton, as exemplified by *Oithonia* spp., 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.

Potential Changes in Northeast Shelf Climate

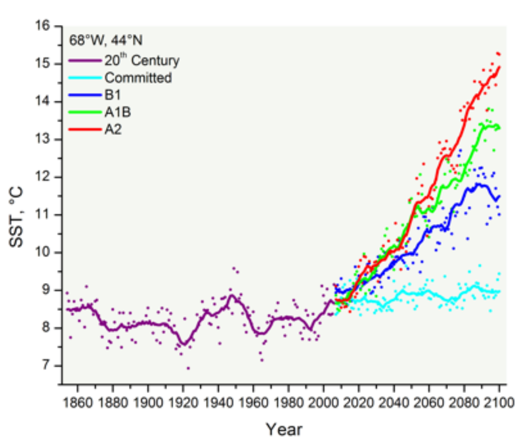
There are a number of climate models that forecast changes in ocean parameters over the next century. One class of model used for this purpose is the coupled general circulation model. The Canadian Centre for Climate Modeling and Analysis (CCCma) runs such a model, the Centre's most recent version is its third generation coupled general circulation model (CGCM3). The Centre runs the model with a series of scenarios or storylines suggesting varying degrees of population and economic growth and conservation (note that these are internationally agreed scenarios used by other modeling centers). The primary anthropogenic drivers of climate change are greenhouse gases such as CO_2, thus the different scenarios can be represented by the expected CO_2 concentrations in the atmosphere over the next century. The change in CO_2 levels can be judged by the benchmark levels associated with those observed during the 20th century. In the committed scenario, CO_2 levels are kept at current concentrations, which would require the immediate cessation of fossil fuel use. Scenarios B1, A1B and A2 represent different conservation strategies and socio-economic responses to changes in energy use and delivery. The most pessimistic scenario is A2 which suggests little will be done to stem the deposition of CO_2 into the atmosphere.

Range of Potential SST Change on the Northeast Shelf



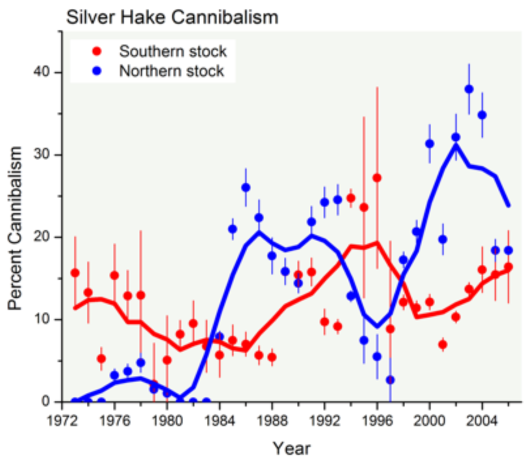
The maps show the range of potential SST change by the end of the 21st century under the four scenarios used to drive the climate model. The committed scenario suggests SST will change on the order of 0.5-1.0°C without an increase in anthropogenic forcing. Scenarios B1 and A1B suggest that shelf subregions like the Gulf of Maine and Southern New England will likely see increases of SST on the order of 2-4°C. The most dramatic changes are suggested by the model output for scenario A2, which suggests that the Northeast Shelf in general will increase on the order of 4°C, and that the Gulf of Maine could see increases in SST as high as 7°C.

Comparison of Potential SST Change to Historical SST



To put the potential change in SST through the 21st century into perspective, we compared the CCCma model output for a selected location to the historical time series of SST using the ERSST dataset. The observed SST and model output overlap, so this period was used to develop a calibration between the two datasets. The model output was corrected to scale properly to the observed historical SST. Global scale circulation models often have trouble with SST estimates in the Northeast Shelf area owing to its proximity to the Gulf Stream. The location we selected is representative of the Gulf of Maine and also represents an area where the climate model predicts the greatest impact on SST. With the exception of the committed scenario, all other scenarios suggest SST will increase well above the levels we have experienced in this region of the ocean over the past 150 years.

Silver Hake Cannibalism



The percent diet composition of silver hake eaten by silver hake, i.e. cannibalized, has changed over time. This index of cannibalism denotes three things: 1) changes in the amount of other prey items eaten by silver hake, with an increase in cannibalism suggestive of less suitable food available; 2) changes in the abundance of pre-recruits of silver hake, with 0 and 1 age-groups comprising the bulk of cannibalistic prey eaten by silver hake, with implications for stock-recruitment relationships for these notoriously difficult-to-assess stocks; and 3) potential environmental factors influencing these stock dynamics. The southern stock has had a percent incidence of cannibalism between 10-18% for most of the time series, with only slight increases in recent years. Conversely, the northern stock has exhibited notable increases in cannibalism, with up to 35-40% of the diet cannibalistic in recent years. As silver hake is an important predator of and prey for other species in this ecosystem, it will continue to be important to monitor it's incidence of cannibalism and stock dynamics.