Fall 2008 Update: Annual Condition of the Northeast Shelf Ecosystem

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Fall 2008 Update: Summary of Conditions of the Northeast Shelf Ecosystem

Summary

Sea surface temperature (SST) in the Northeast Shelf Large Marine Ecosystem during the first half of 2008 continued a warming trend in winter and spring temperatures conditions that began five years age. However, these warmer thermal conditions are still lower than levels observed over the past two decades. Problems with the SeaWiFS ocean color sensing satellite make the 2008 chlorophyll data used in this report provisional. Despite the provisional nature of the data, it is clear that there was an exceptional spring phytoplankton bloom in the Massachusetts Bay/Nantucket Shoals area. Zooplankton biomasses began the year at average or above average levels, but spring zooplankton biomass levels were lower than average in the Gulf of Maine and on Georges Bank.

- Sea surface temperature conditions were generally above average during the first half of 2008.
- Provisional chlorophyll data suggests that there was a great deal of spring bloom activity on the Northeast Shelf, in large measure driven by an exceptional bloom that occurred in the Massachusetts Bay/Nantucket Shoals area.
- The dominant zooplankton on Georges Bank exhibited contrasting abundance patterns. *Calanus finmarchicus* has been increasing in abundance in recent years, but *Pseudocalanus*, an important food item of larval cod and haddock, continues a trend of lower than average abundance.
- The 2008 spring blooms on Georges Bank and in the Gulf of Maine began in the same early March time frame as last year. Likewise, the blooms peaked approximately three weeks after initiation of the bloom, also on the same dates as last year. The bloom start and peak dates can vary by two to three weeks and have been indentified as important factors for fish recruitment.

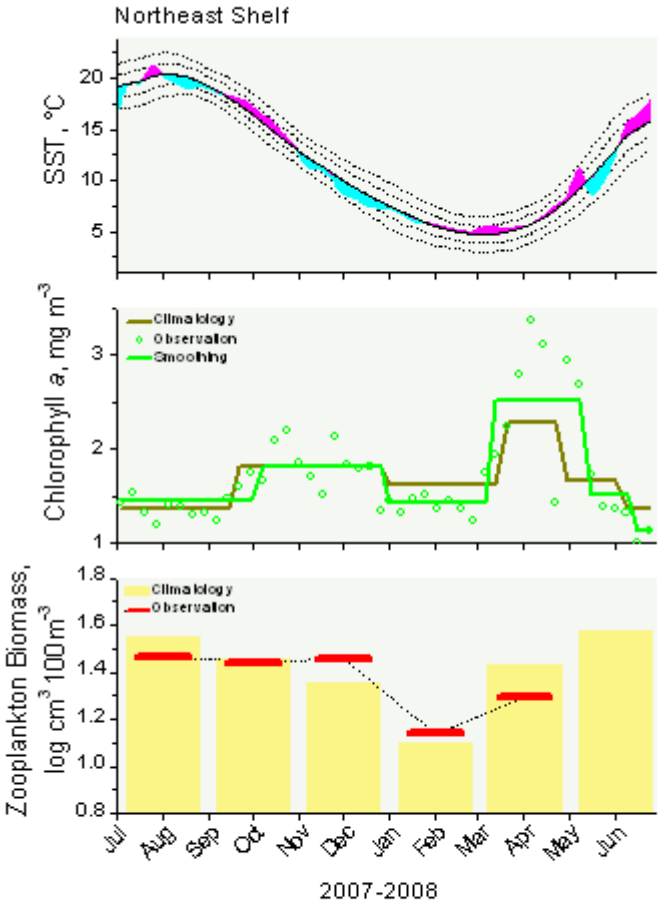
Data Sources

SST is derived by compositing data from three sources: the Advanced Very-High Resolution Radiometer onboard the Polar Orbiting Environmental Satellite (AVHRR-POES); and the MODIS Terra and MODIS Aqua sensors. The data represents the near-surface ocean temperature, not the temperature of the entire water column.

Synoptic views of surface concentrations of chlorophyll *a* are derived from the Sea-viewing Wide Field of View Sensors (SeaWiFS) and MODIS Aqua ocean color sensors.

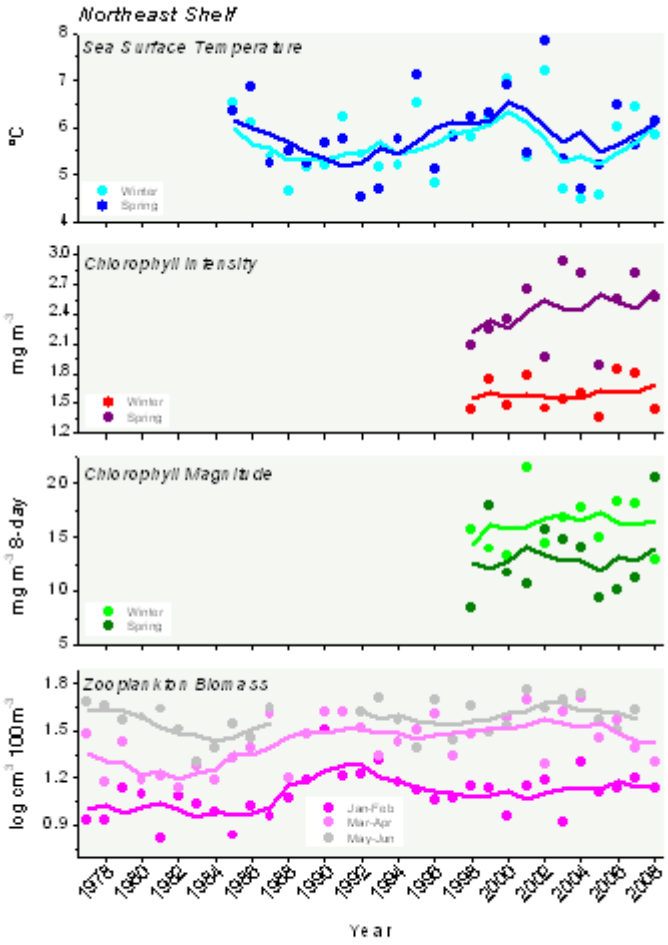
SeaWiFS data was used during the period 1998-2007; the sensor was out of service during most of the first half of 2008. MODIS Aqua data was used to represent trends in chlorophyll during 2008; however, there are known discrepancies between the two sensors. The MODIS data was transformed to reduce the bias between the two sensors, but the data should only be used qualitatively until an upcoming data reprocessing can be completed. 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 provide the link from 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 as the Ecosystem Monitoring program (EcoMon). Currently, 30 plankton samples are taken 6 times a year in each of the four ecosystem subareas: Middle Atlantic Bight, Southern New England, Georges Bank, and Gulf of Maine (resulting in approximately 720 measures of zooplankton biomass annually). Zooplankton are identified to the lowest taxonomic level possible resulting in taxa specific abundances and distributions.

Conditions on the Northeast Shelf Ecosystem



The Northeast Shelf Large Marine Ecosystem experienced minor fluctuations in sea surface temperatures during the spring of 2008. SST was above average during the winter and cooled during May in some parts of the ecosystem. Considered in context of SST change for the last half of 2007, there have been only relative low amplitude changes in seasonal SST. There appears to have been a well developed spring bloom on Northeast Shelf as evidenced by the bloom period which appears to have begun earlier than average and ended well after the climatological bloom period. However, as mentioned in Data Sources section the bloom level may not be in calibration to the time series data and we must hold judgment as to whether the bloom was truly above climatological levels. Zooplankton biomasses were at or above average through the summer and fall of 2007 and the winter of 2007/2008. Biomass decreased to below average in the spring of 2008.

Trends in Spring Conditions



Winter and spring SSTs continued warming trend that appears to have begun in 2003. SSTs for season were approximately 6°C during 2008 and are near the mean of the SST time series. The chlorophyll intensity for the winter period and the spring bloom were below and at the trend suggest by the time series, respectively. There is an upward trend to spring bloom intensity, the dynamics of which is not completely understood. The magnitude of the winter period and the spring bloom do not appear to be showing any trends and as cautioned in the Data Sources section, we must be cautious in our interpretation of the 2008 spring bloom magnitude datum, which is the highest in the time series, but derived from data that will likely be revised in future assessments. Winter (Jan/Feb) zooplankton biomass is near the long-term mean, but spring (Mar/Apr) zooplankton biomass appears to be decreasing over the last 5 years. There were no early-summer (May/Jun) collections made in 2008.

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 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.

Sea Surface Temperature Distribution

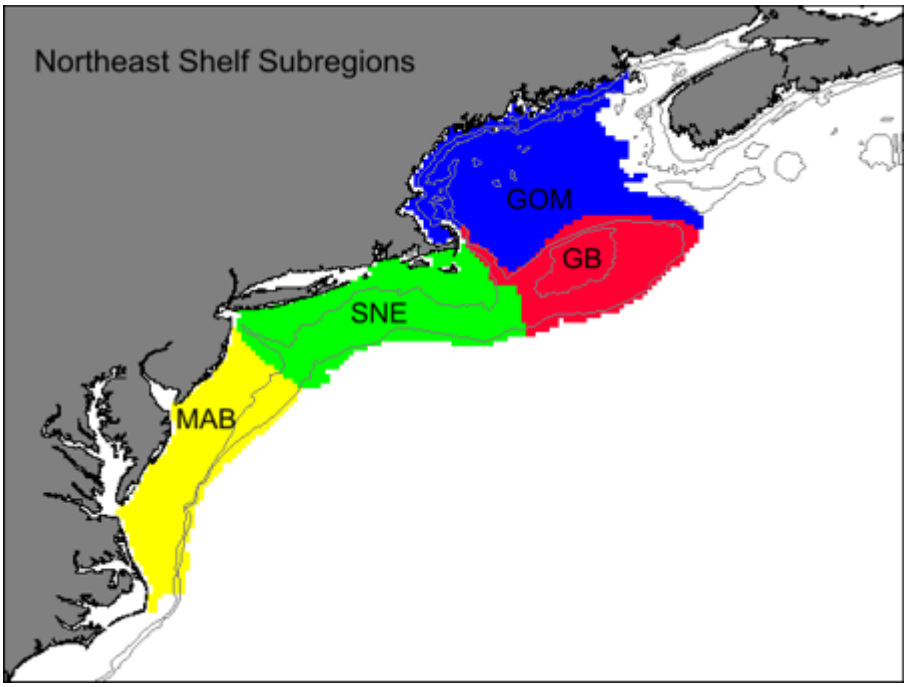
The distribution of sea surface temperature (SST) throughout the Northeast Shelf ecosystem during April 2006 shows the expected gradient of decreasing SST with increasing latitude. A sharp contrast is evident between the cool shelf water and the relatively warmer water along the shelf break from southern GB to Cape Hatteras. **(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.

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**

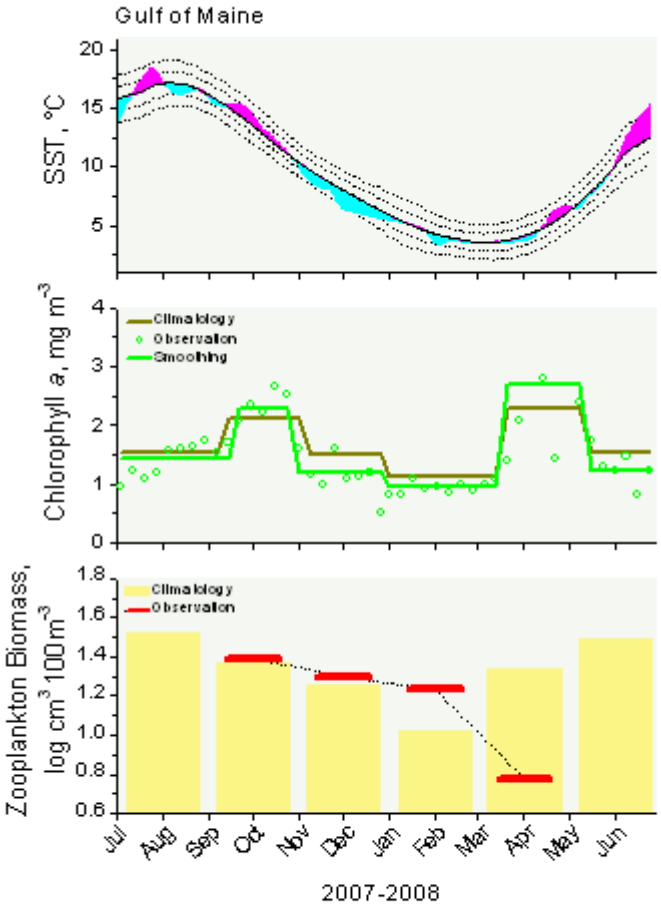
chlorophyll during April 2006 from Cape Hatteras to Nova Scotia). High levels of chlorophyll during spring occur in the tidally mixed central areas of Georges Bank and Nantucket Shoals, and in the Middle Atlantic Bight estuaries and coastal waters enriched by estuarine plumes. The high chlorophyll values (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).

Spring Conditions by Subregion



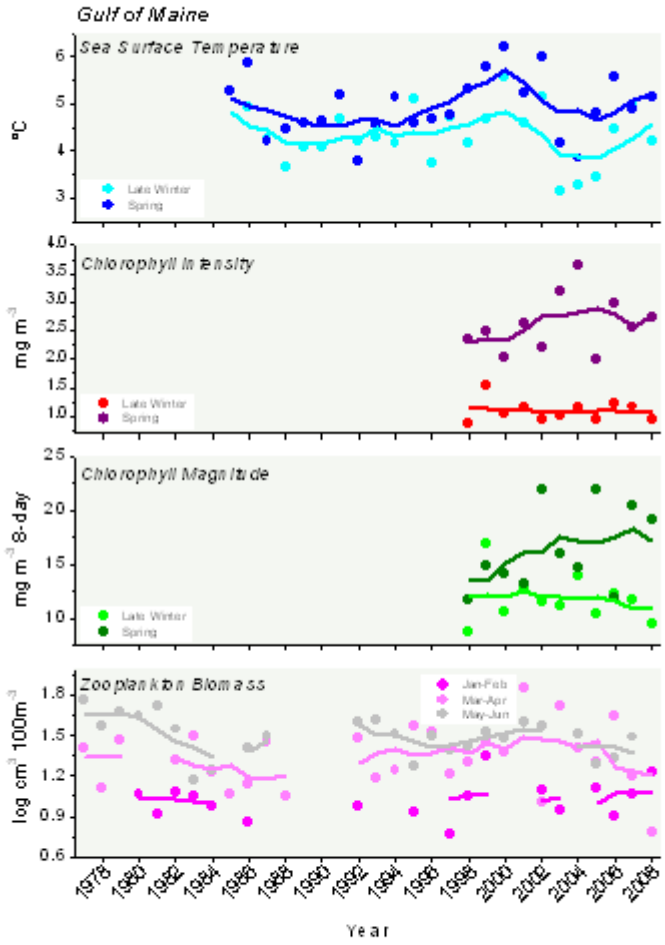
The Northeast Continental Shelf ecosystem can be divided into four major subareas: Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Middle Atlantic Bight (MAB), which reflect different underlying oceanographic conditions and fishery management boundaries. The regional variation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

Gulf of Maine Subregion



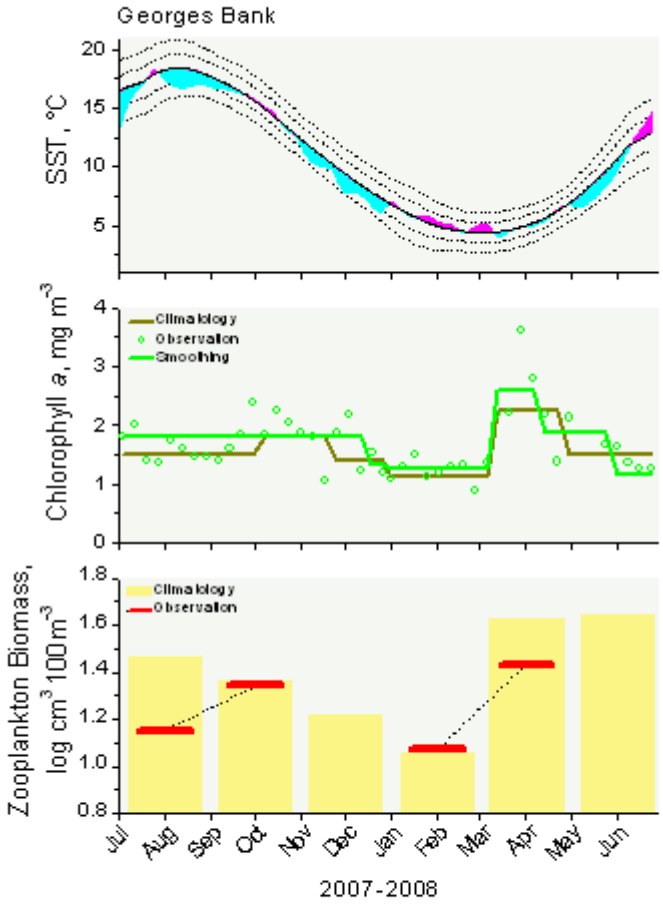
The Gulf of Maine subregion experienced mostly average SST conditions during winter into spring, with the suggestion of rapidly warming conditions developing for the summer of 2008. The spring bloom was of average duration with the bloom starting and ending during the same 8-day periods as the climatological data. Judgment on the level of the Gulf of Maine spring bloom will have to be delayed until the MODIS data are reprocessed. Fall 2007 and winter 2007/2008 zooplankton abundances were at or above average but spring abundances were well below average

Trends in Spring Conditions for the Gulf of Maine Subregion



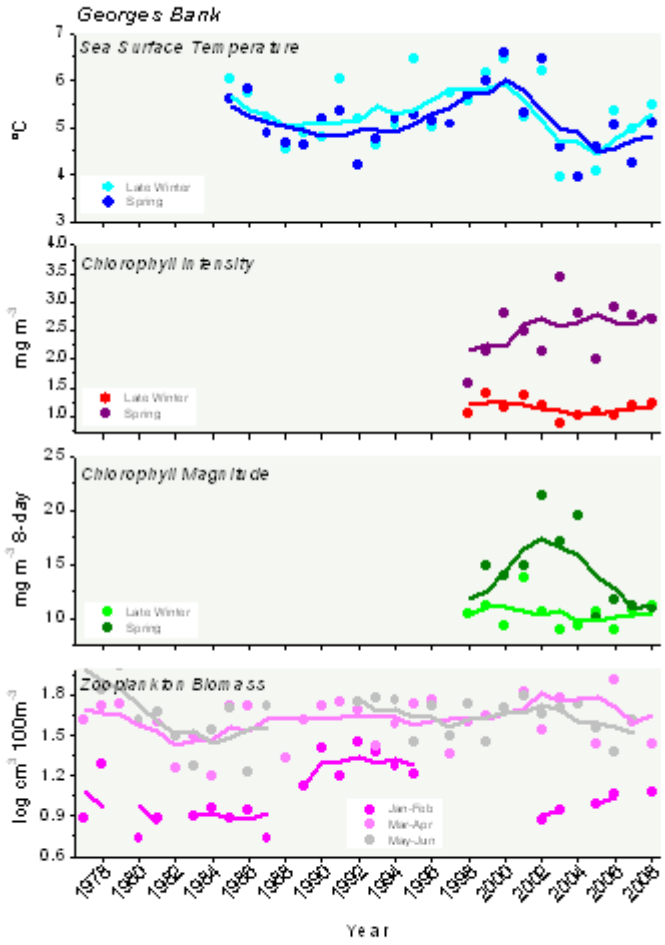
Gulf of Maine winter and spring SSTs have been trending upward over the past five years, but remain lower than the SSTs observed during the late 1990s. Chlorophyll intensity associated with the spring bloom has increased over recent years as has the bloom magnitude; however, the provisional status of the 2008 data does not allow inference on whether the trend is continuing. The winter period continues to be characterized by low chlorophyll concentration with no perceivable trend. Winter 2008 (Jan/Feb) zooplankton abundances were high, but spring (Mar/Apr) zooplankton abundances were the lowest observed over the time series. There were no collections in early summer (May/Jun) of 2008.

Georges Bank Subregion



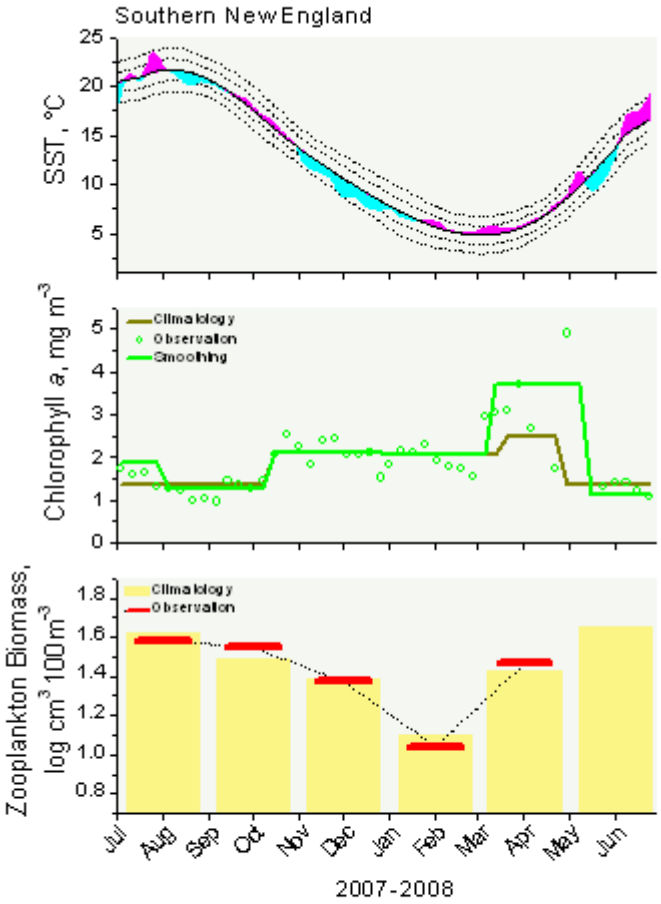
Following cooler than average summer and fall SSTs during 2007, the Georges Bank subregion moderated during the winter 2008. Cooler conditions were established by late spring followed by a warming trend into summer. The spring bloom was of short duration though the data is not clear on when exactly the bloom ended. The data associated with the spring bloom was highly variable and there were missing values associated with the latter portion of the bloom. Zooplankton biomass has been at or below the long-term average on Georges Bank through the summer of 2007 to the spring of 2008. There were not enough samples in the region during the winter of 2007 (Nov/Dec) to derive a reliable estimate of regional biomass and there were no samples in the early summer (May/Jun).

Trends in Spring Conditions for the Georges Bank Subregion



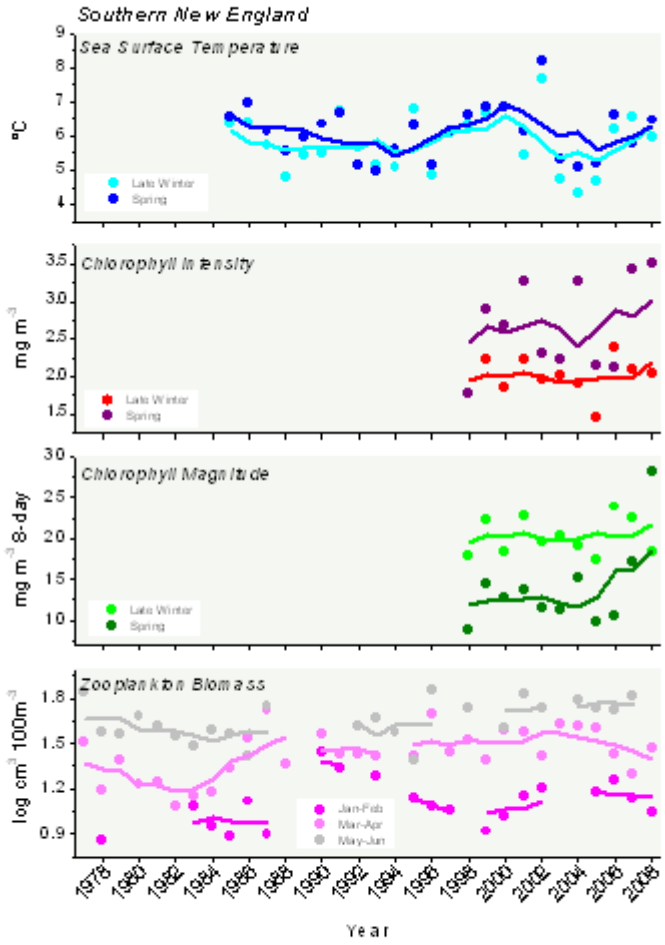
The thermal conditions on Georges Bank during the winter and spring seasons of 2008 continued a decade long trend of relatively low temperatures. In many years during the 1980s and 1990s SSTs during both seasons exceeded 6°C, whereas in recent years SSTs were around 5°C. Despite the issues in interpreting trends in the provisional chlorophyll concentration data, the duration of the spring bloom was very short resulting in a low magnitude spring bloom on the Bank. Winter, early spring, and spring zooplankton biomasses have been at intermediate levels during the past several years. There is some evidence for increasing zooplankton in the winter (Jan/Feb) but decreasing zooplankton in the spring (Mar/Apr).

Southern New England Subregion



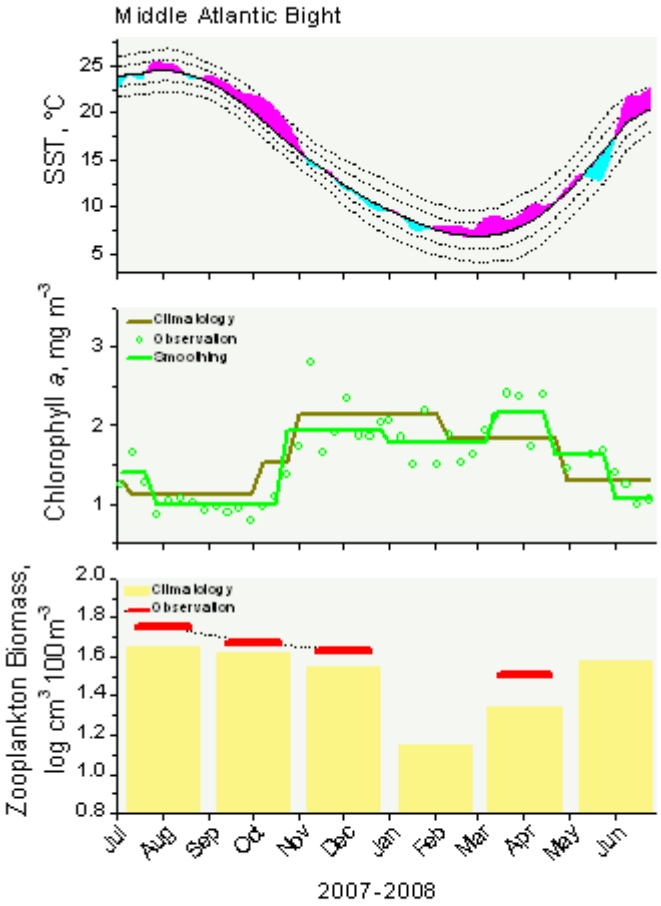
The Southern New England subregion tended to be warmer than average during the first half of 2008 with the exception of a cool period during May. The chlorophyll concentration data for the Southern New England subregion suggests that the area experienced an intense and long duration spring bloom. Much of this bloom activity can be attributed to the chlorophyll concentrations in the contiguous area of Massachusetts Bay and Nantucket Shoals. The provisional nature of chlorophyll data suggests caution should be applied in respect to the true dimensions of this bloom. Zooplankton abundances were near the long-term average from the summer of 2007 (Jul/Aug) through the spring of 2008 (Mar/Apr).

Trends in Spring Conditions for the Southern New England Subregion



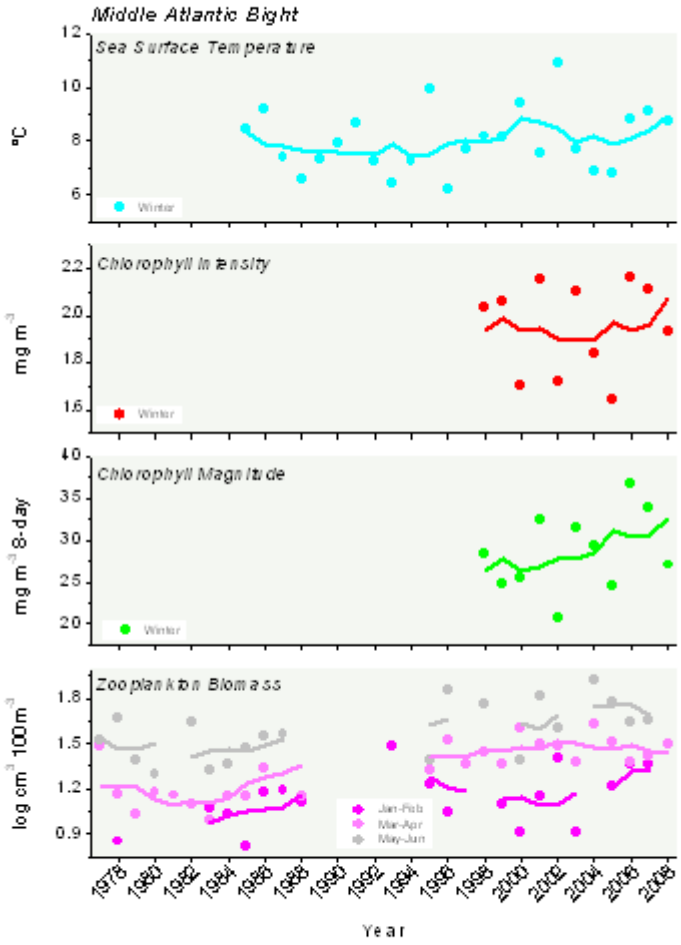
Winter and spring SSTs in the Southern New England area continued an upward trend that began in 2005. With the exception of 2002 when SSTs were around 8°C, 2008 SSTs were at the upper end of the range of temperatures during these seasons. The provisional chlorophyll intensity levels for 2008 were similar to what has been observed for the area in the time series data, but chlorophyll magnitude for the spring bloom was two fold higher than any previous estimate. This exceptional value was caused by a bloom that developed in the Massachusetts Bay/Nantucket Shoals area that was in part included in the Southern New England area. Winter and spring zooplankton biomasses have been relatively stable and high through the last several years.

Mid-Atlantic Bight Subregion



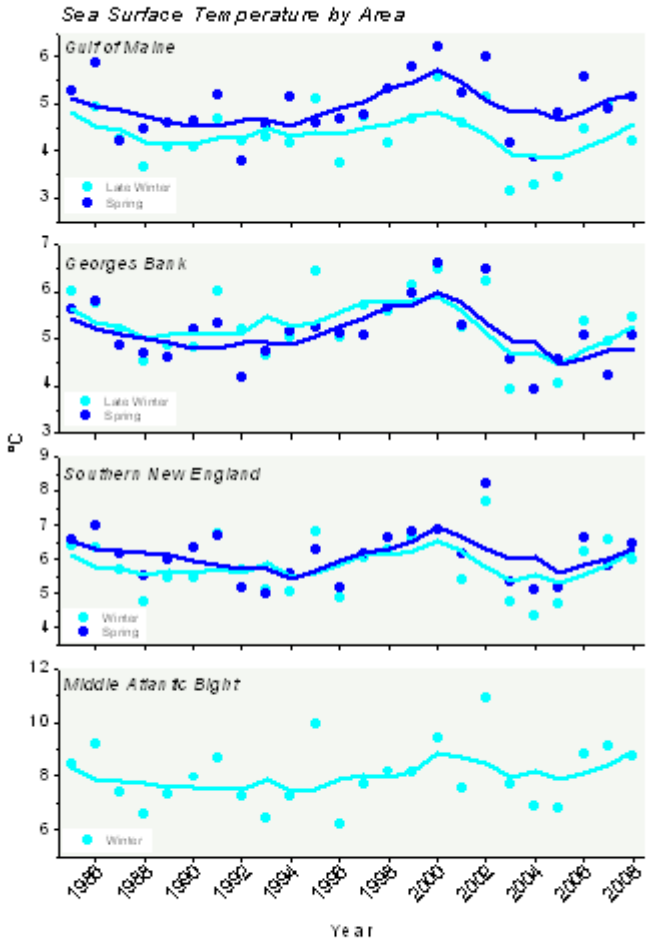
Unlike other subregions of the shelf, the Middle Atlantic Bight experienced warm SST conditions during the late winter and spring of 2008. The warming associated with the beginning of the summer was statistically above the recent term mean of SSTs for the area. The provisional chlorophyll concentrations were generally above average levels during the winter into spring period. Typically the Bight area does not have a well develop spring bloom, but in 2008 a spring bloom appeared to develop in March into April. Zooplankton abundances were consistently above average in the MAB from the summer of 2007 through the spring of 2008.

Trends in Spring Conditions for the Mid-Atlantic Bight Subregion



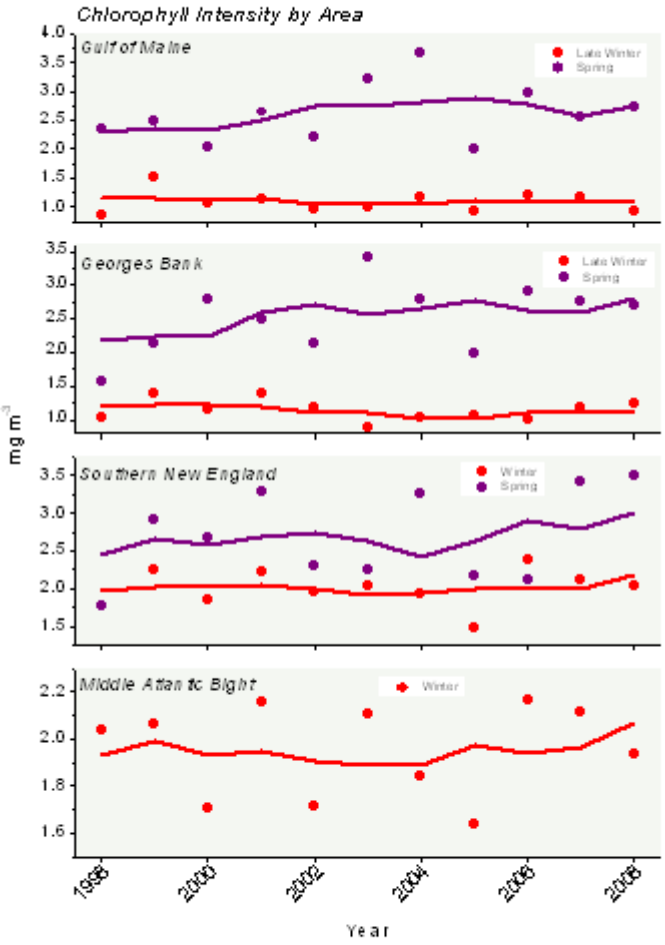
There is little to suggest a trend in winter SSTs over the recent term and only a weakly developed increasing trend in winter conditions over the long term. The SST indices are partitioned to match the major periods of the chlorophyll production cycle, thus they are averaged over a number of months each year and tend to dampen elevated SST conditions that may only last a month or two. Winter production chlorophyll intensity and magnitude have been increasing in recent years, with the provisional 2008 values slightly below the average of the trend. Zooplankton abundances were near all-time highs in the winter (Jan/Feb) and spring (Mar/Apr). There were no samples from the early summer (May/Jun).

Subregion Comparison of Sea Surface Temperature



The recent trend of increasing winter and spring SSTs can be seen as a coherent trend in all four Northeast Shelf subregions, and it is also clear that the subregions experienced warmer conditions a decade ago. The winter and spring partitioning is based on the individual patterns of primary productivity in each subregion, so strictly speaking they are not directly comparable across regions. There appears to be a trend of increasing differences between the winter and spring SST in the Gulf of Maine, which is reflective of an increasing rate of warming occurring during spring. This reflects the earlier arrival of SST conditions which may affect the timing of migrations and biological interactions of predators and prey. There is little difference between the winter and spring SSTs on Georges Bank or in Southern New England.

Subregion Comparison of Chlorophyll



The intensity of winter blooms show little time series trend. These bloom periods are associated with low chlorophyll levels in the northern subregions, but they are important periods of primary productivity in the Southern New England and Middle Atlantic Bight areas. Spring bloom chlorophyll intensity shows a slight trend of increasing levels in the Gulf of Maine and Georges Bank over the past decade. The provisional 2008 chlorophyll intensity data is largely in line with levels that have been observed in past years.

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

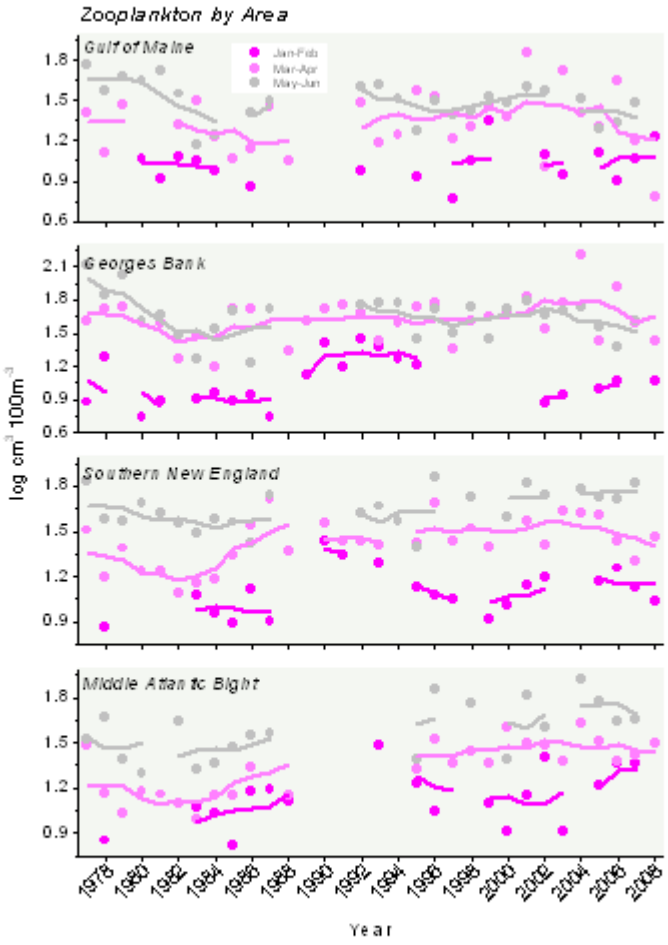
decadal period of SeaWiFS observations. A spring bloom is differentiated in the Southern New England subregion, but it only represents a two fold increase over winter chlorophyll intensities, which tend to be higher than observed in the northern subregions. There does not appear to be any time series 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 eleven 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 of short duration, which results in low magnitude blooms. The dramatic increase in the Southern New England spring bloom magnitude

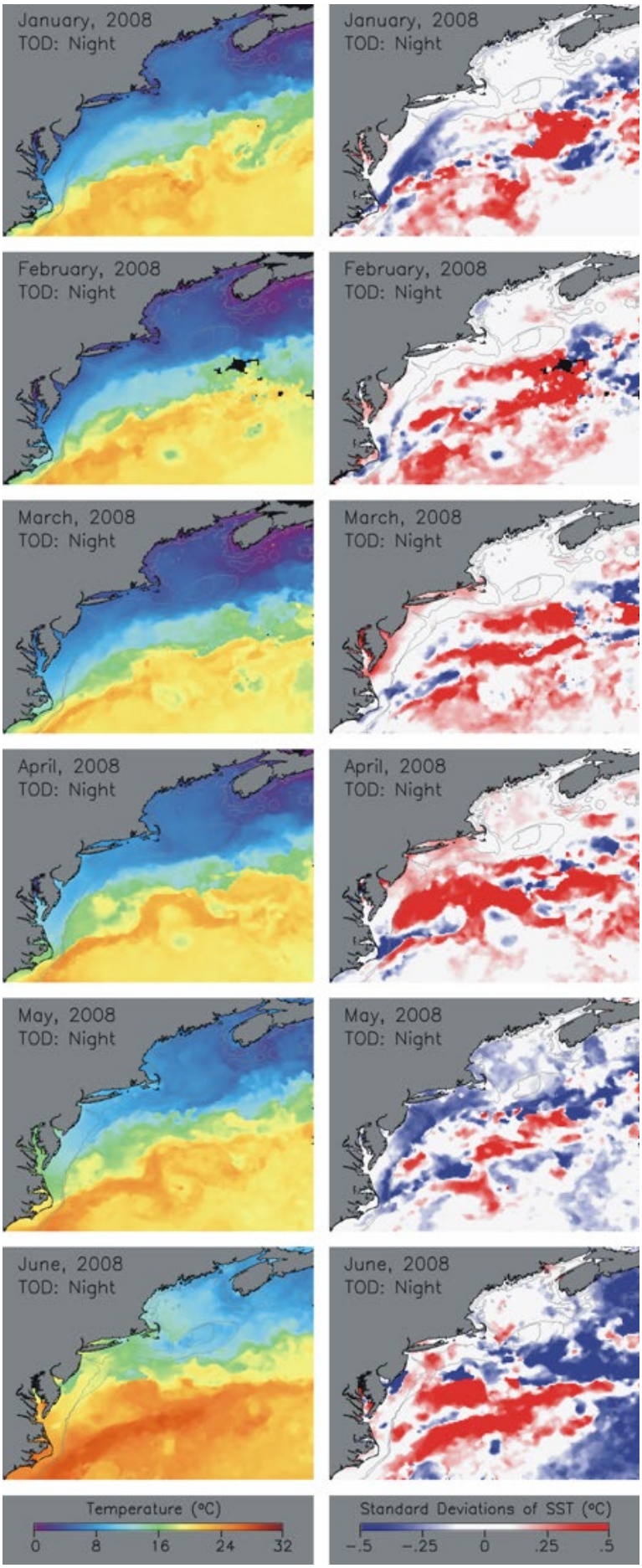
may be an artifact of the provisional data used in the 2008 assessment, or may reflect the bloom that occurred in the Massachusetts Bay/Nantucket Shoals area. These data will need to be re-evaluated after the chlorophyll data are reprocessed. There are no discernable trends in the winter blooms occurring 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



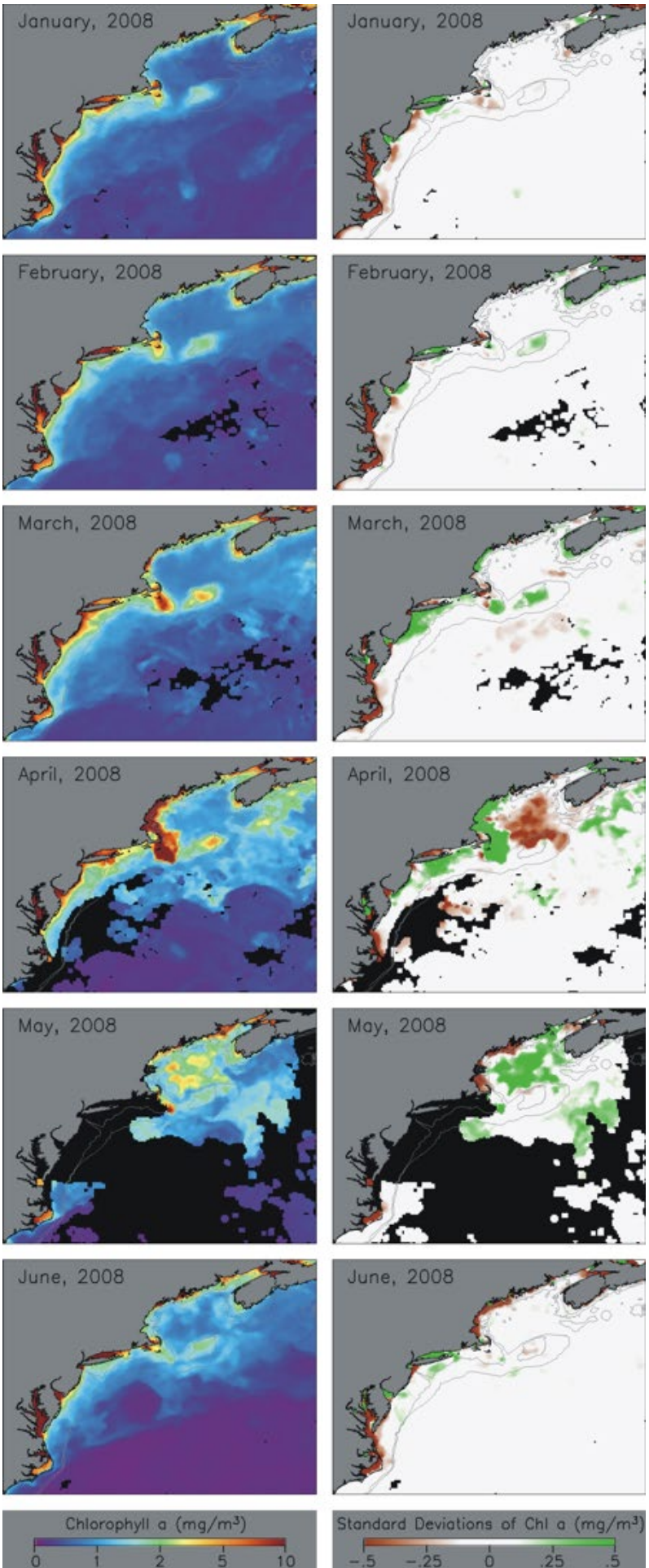
Winter (Jan/Feb) zooplankton biomasses have been remaining steady or increasing through the ecosystem. In contrast, early spring (Mar/Apr) zooplankton biomass is declining in the Gulf of Maine and on Georges Bank but are remaining steady in Southern New England and the Middle Atlantic Bight. Spring zooplankton biomasses in the Gulf of Maine were the lowest observed in the 30 year record. Unfortunately, there is no data from the early summer of 2008.

Spring Sea Surface Temperature Distribution


January, 2008
TOD: Night
January, 2008
TOD: Night
February, 2008
TOD: Night
February, 2008
TOD: Night
March, 2008
TOD: Night
March, 2008
TOD: Night
April, 2008
TOD: Night
April, 2008
TOD: Night
May, 2008
TOD: Night
May, 2008
TOD: Night
June, 2008
TOD: Night
June, 2008
TOD: Night
Temperature (°C)
0
8
16
24
32
Standard Deviations of SST (°C)
−.5
−.25
0
.25
.5

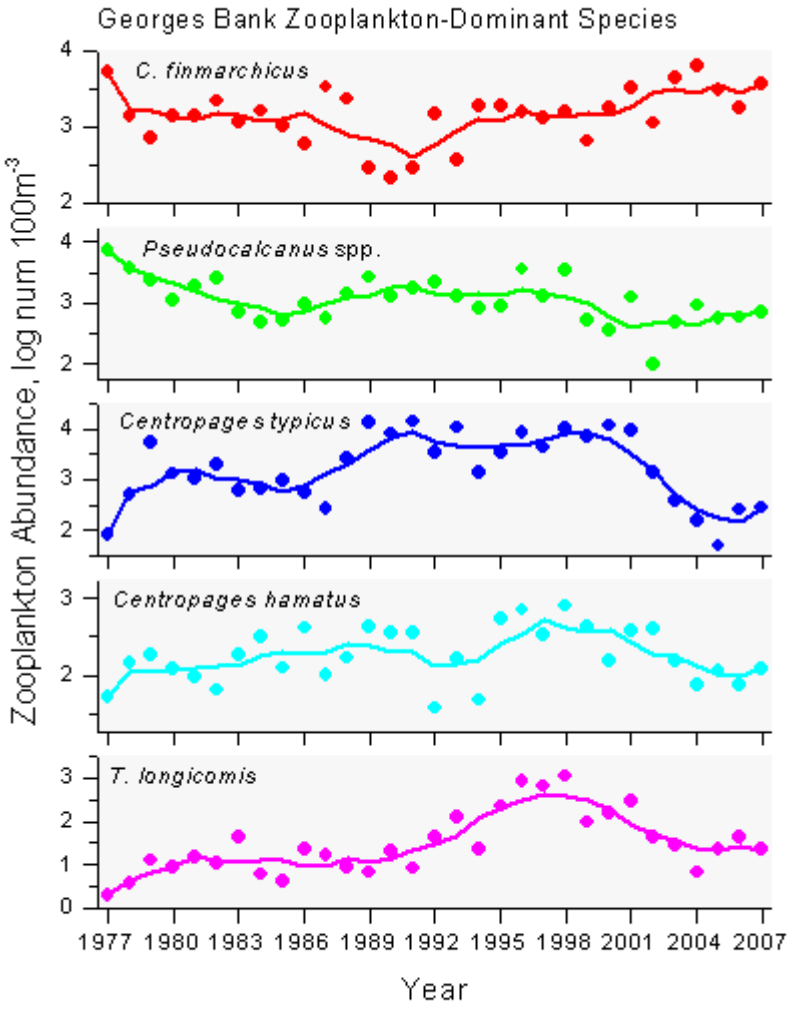
The progression of spring sea surface temperatures for the months of January through June are shown in the left hand set of panels. Higher SSTs appear as warm shades whereas low SSTs appear as cool shades. The right hand set of panels show exceptional anomalies of SST, those tending to exceed plus or minus one quarter of a standard deviation of the overall SST for the field. This type of anomaly tends to highlight high SSTs in an area, the red shades, and SSTs well below the average in an area, the blue shades. The progression of spring warming was generally at average levels for most of the Northeast Shelf with the exception of cool conditions that were established during May. The variation in thermal conditions was greater in the southern subregions of the shelf including the Middle Atlantic Bight and Southern New England. In most months, the Gulf of Maine and Georges Bank subregions experienced average SST conditions. When cool SST conditions were observed in these areas, often only parts of the subregion were affected.

Spring Chlorophyll Distribution


January, 2008
January, 2008
February, 2008
February, 2008
March, 2008
March, 2008
April, 2008
April, 2008
May, 2008
May, 2008
June, 2008
June, 2008
Chlorophyll a (mg/m3)
0
1
2
5
10
Standard Deviations of Chl a (mg/m3)
-.5
-.25
0
.25
.5

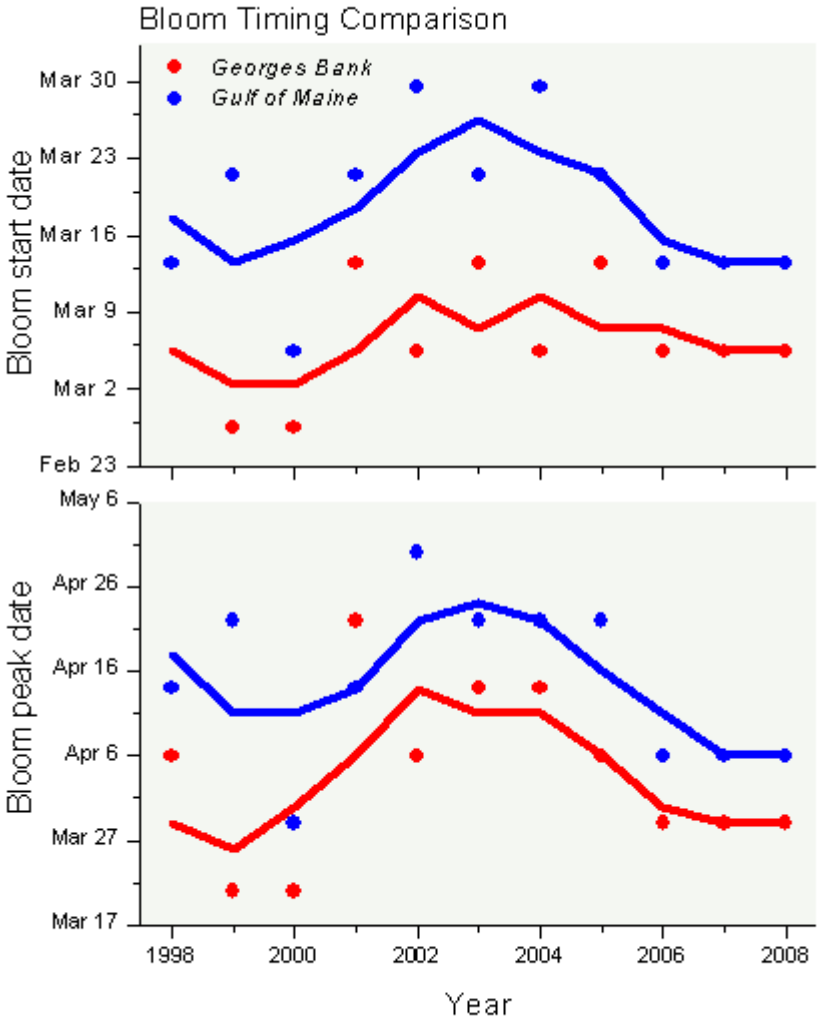
The progression of spring chlorophyll concentrations for the months of January through June are shown in the left hand set of panels. Higher chlorophyll concentrations appear as warm shades whereas low concentrations appear as cool shades. The right hand set of panels show exceptional anomalies of chlorophyll concentration, those tending to exceed plus or minus one quarter of a standard deviation of the overall concentration for the field. This type of anomaly tends to highlight strong blooms in an area, the green shades, and concentrations well below the average in an area, the brown shades. With the provisional nature of these data, it would be impudent to make definitive inferences on the intensity of regional bloom activity on the shelf. However, some features are of interest in efforts to understand the relationship between primary and secondary production in the ecosystem. One feature in the chlorophyll spatial distribution data is the exceptional nature of phytoplankton bloom in the contiguous region of Massachusetts Bay and Nantucket Shoals. This region often blooms in advance of the other northern subregions of the Northeast Shelf and often with greater intensity. Traditionally, this area has not been separated as a distinct subregion, but its role as a distinct production area should be investigated.

ECOMON-Dominant Zooplankton Species



Pseudocalanus, an important food item of larval cod and haddock, has been at low levels since about 2001. *Calanus finmarchicus* has been increasing in abundance in recent years. The decreases in the abundance of *Centropages* and *Temora* in recent years seem to have stabilized.

Spring Bloom Timing



In prior assessments, spring bloom start and peak dates for the Gulf of Maine and George Bank areas were computed using a computer algorithm that analyzed daily chlorophyll data at fine spatial resolution. The problems with ocean color sensors this past year has made the necessary data unavailable to repeat the assessment. Instead, bloom start and peak were estimated using the time series methods used to partition production cycle based in the 8-day chlorophyll data. This approach yields comparable data to the previous assessment and in some cases appears to provide more accurate results. The bloom on Georges Bank precedes the bloom in the Gulf of Maine by approximately a week in most years. The 2008 spring bloom began around March 6 on Georges Bank and around March 14 in the Gulf of Maine. The bloom peaked around March 26 and April 6 for Georges Bank and the Gulf of Maine, respectively. After a period of five years during which the spring bloom started later during in the spring, the bloom is occurring during an earlier time frame that typified the beginning of the time series.

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.