# Spring 2008 Update: Annual Condition of the Northeast Shelf Ecosystem

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# Spring 2008 Update: Summary of Conditions of the Northeast Shelf Ecosystem

## Summary

Sea surface temperature (SST) in the Northeast Shelf Large Marine Ecosystem was cooler in 2007 as compared to the trend in recent years, though SST varied by subregions within the ecosystem. Spring bloom production was well above average; however, summer productivity and the fall bloom were only at average levels. Zooplankton biomass began the year at below average levels, but by summer and fall began to exceed recent trends, perhaps reflecting the added productivity in the system resulting from the robust spring bloom earlier in the year.

- Sea surface temperature in respect to recent term trends (1985-2006) was cooler in all seasons on Georges Bank; in contrast it was warmer in the Middle Atlantic Bight area, especially during winter and fall. The Gulf of Maine was also warmer during those periods, but not to the same extent as in the Bight.
- There was an intense spring bloom on the Northeast Shelf owing to well developed blooms in the Gulf of Maine, Georges Bank and Southern New England areas. A relative weak fall bloom was observed in the Gulf of Maine and despite relatively high chlorophyll concentrations, the George Bank fall bloom never fully developed.
- Zooplankton biomass during fall was at or above historical levels across the ecosystem as a whole. Regionally, zooplankton biomass was near average levels in the Gulf of Maine and Georges Bank while biomass was above average levels in Southern New England and Middle Atlantic Bight.
- The dominant zooplankton on Georges Bank exhibit contrasting patterns. *Calanus finmarchicus* has been increasing in abundance in recent years, but 2006 was lower relative to the previous three years. However, there have been marked decreases in the abundance of *Centropages typicus* and *Temora longicornis* in recent years, but 2006 was higher relative to the previous three years.
- Long term trends (1854-2007) in SST show that the NE Shelf Ecosystem is warming, especially in the Gulf of Maine, Georges Bank and Southern New England subregions. The Middle Atlantic Bight does not show the same overall warming trend largely due to a continuing trend of cool winter conditions.
- Analysis of mean length of finfish captured in the NEFSC trawl survey suggest that average fish size has declined in the Gulf of Maine and Southern New England subregions of the Northeast Shelf; however, despite dramatic changes in the population levels of stocks, fish size has remained remarkably constant on Georges Bank.

# Data Sources

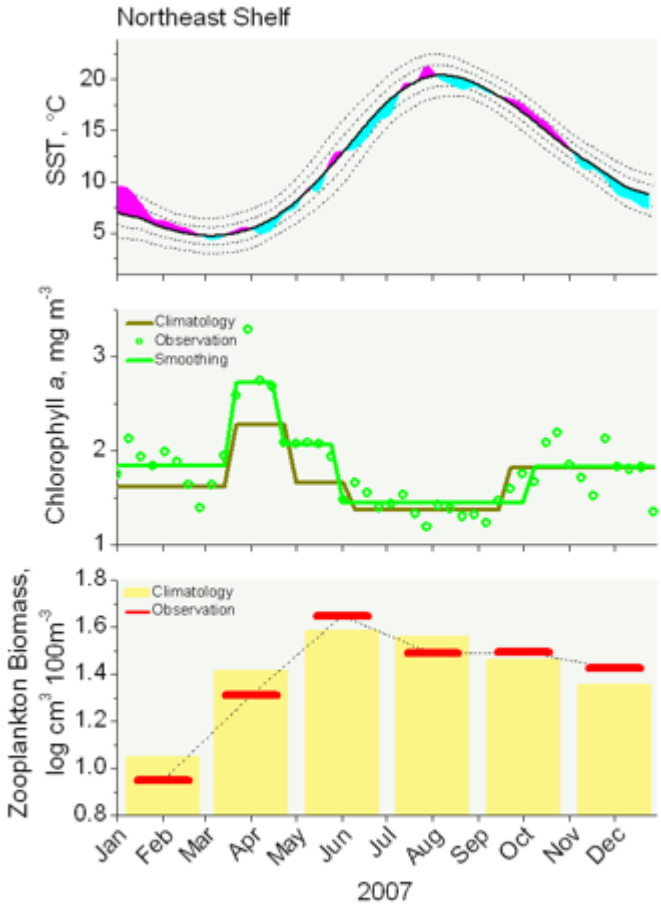
SST is derived by compositing data from three sources, the Advanced Very-High Resolution Radiometer onboard the Polar Orbiting Environmental Satellite (AVHRR-POES), MODIS Terra and MODIS Aqua, and represents the near-surface ocean temperature, not the temperature of the entire water column.

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 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.

Long term SST were extracted from the Extended Reconstructed Sea Surface Temperature (ERSST, version 3) 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.

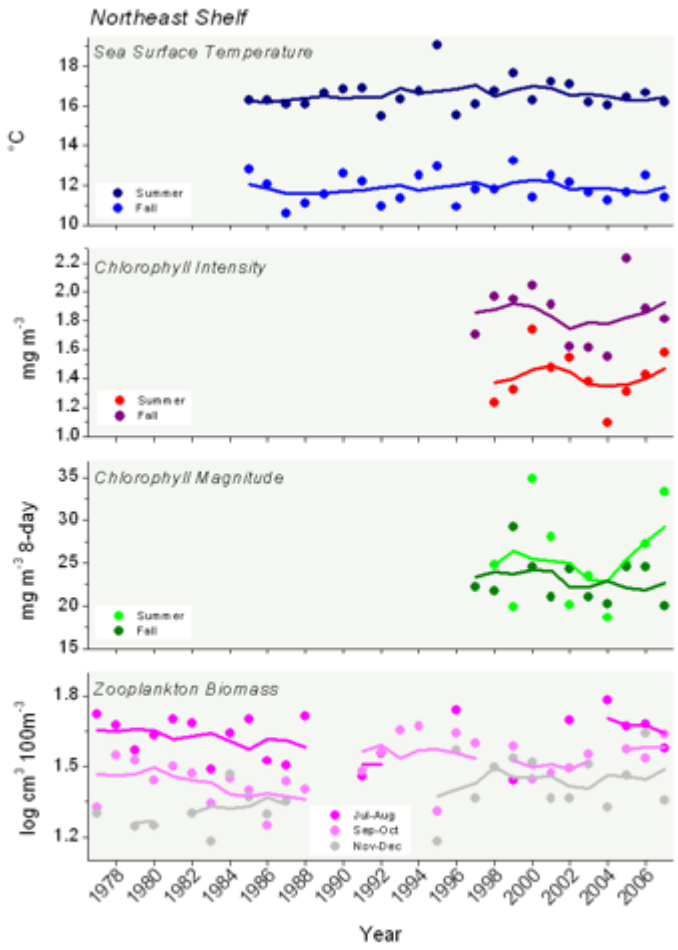
Mean lengths were calculated from the NEFSC bottom trawl survey database. The lengths were averaged across all of the major species we collect and across both seasons to provide an annual snapshot of mean length of the fish community. We executed this calculation for four main ecoregions, Gulf of Maine, Georges Bank, Southern New England, and Middle Atlantic Bight.

# Annual Conditions of the Ecosystem




The Northeast Shelf Large Marine Ecosystem experienced cooler than average sea surface temperatures through much of 2007, with the exception of last winter and part of the fall period. The most dramatic variation from mean conditions occurred last winter when SSTs were in excess of two standard deviations above the recent term mean. Variations in SST since then have been generally within one standard deviation. Winter and spring chlorophyll concentrations were well above the recent trend mean. The spring bloom over the extent of the shelf reached concentrations greater than 3 mg $m^{-3}$, remembering that the progression of the spring bloom develops differently in the different subregions. The balance of the phytoplankton cycle was of average chlorophyll concentration essentially matching the recent trend means through the summer and fall. Large variations in fall chlorophyll concentrations reflect the highly variable fall bloom patterns within the subregions. Zooplankton biomasses were below average in the spring of 2007 and then near or above average for the remainder of the year.

## Trends in Fall Conditions




Summer and fall SSTs do not appear to be trending over the time period analyzed. There has been an upturn in chlorophyll concentration or chlorophyll intensity during summer and fall. Summer chlorophyll intensity remains approximately 75% of the fall bloom level. The variation in the duration of the summer inter-bloom period resulted in a higher magnitude summer period and a lower magnitude fall bloom. Summer (Jul/Aug) zooplankton biomass appears to be decreasing and is below the long-term mean. The late summer (Sep/Oct) and fall (Nov/Dec) zooplankton biomasses appear to be stable and above the long-term mean.

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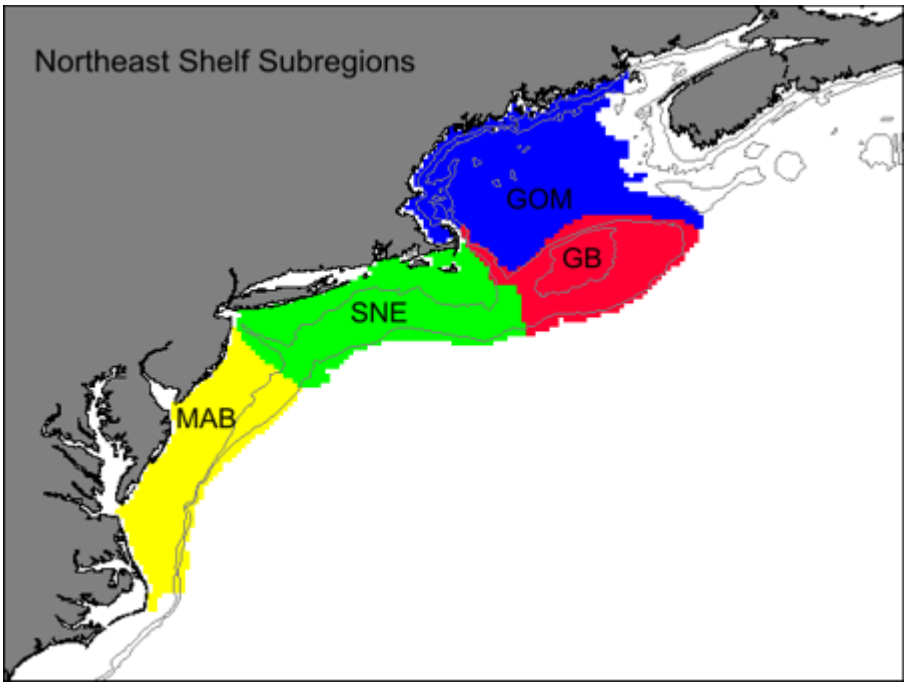
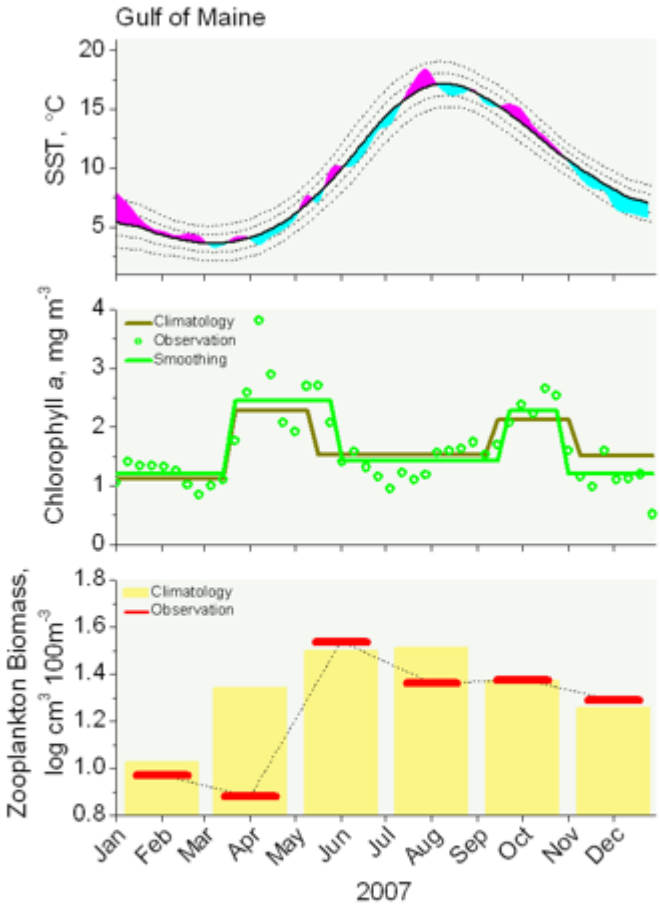
# Fall Conditions Subregion



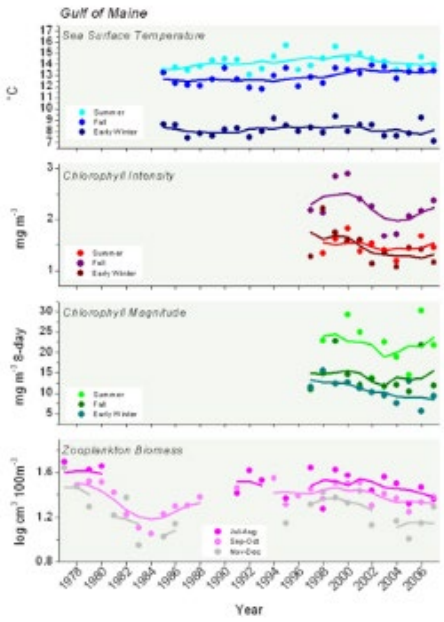

The Northeast Continental Shelf ecosystem can be divided into four major subareas: Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Middle Atlantic Bight (MAB), which reflect different underlying oceanographic conditions and fishery management boundaries. The regional variation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

## Gulf of Maine Subregion



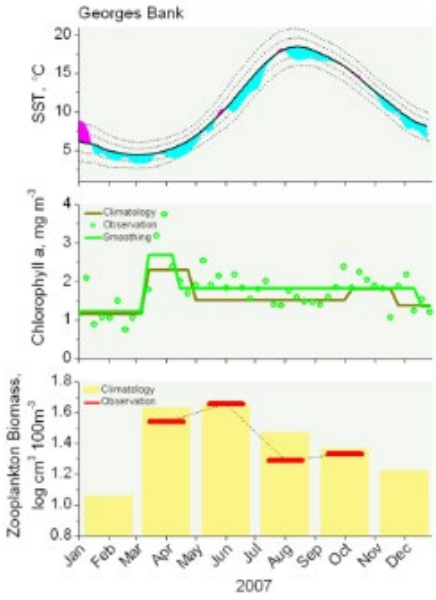

The Gulf of Maine subregion experienced warm conditions at the beginning of the year and during two short periods during summer and fall. Spring and fall tended to be cooler than average. The spring bloom in the Gulf of Maine began at about the same time as the recent term data suggests, but was of longer duration lasting well into May. The fall bloom was of short duration beginning and ending after and before the climatological starting and end dates, respectively. Spring zooplankton abundances were very low and summer and fall abundances were below or at the long-term means.

### Trends in Spring Conditions for the Gulf of Maine Subregion



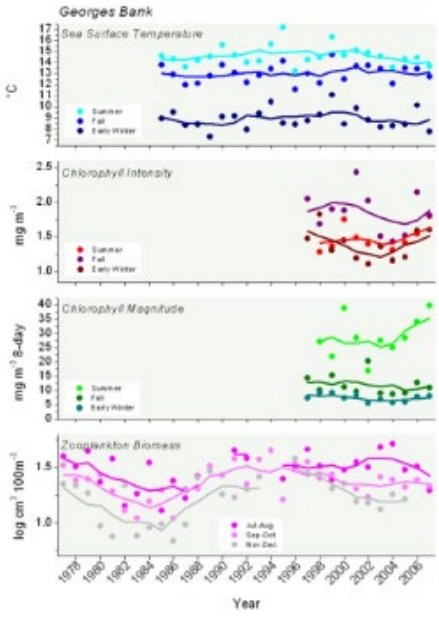

Summer SSTs have been trending lower over the past decade in the Gulf of Maine, whereas fall temperatures have been increasing. Chlorophyll intensity remains low and shows little inter-annual contrast as compared to the changes in intensity associated with the fall bloom. Fall bloom intensity and magnitude have increased slightly over a recent multiyear period when the bloom was poorly developed. Summer, early fall, and fall zooplankton biomasses have been decreasing in the Gulf of Maine. These trends continued into 2007 for summer and early fall, but the 2007 late fall estimate was near the long-term average, suggesting that the long-term decrease in late fall zooplankton may be ending.

## Georges Bank Subregion



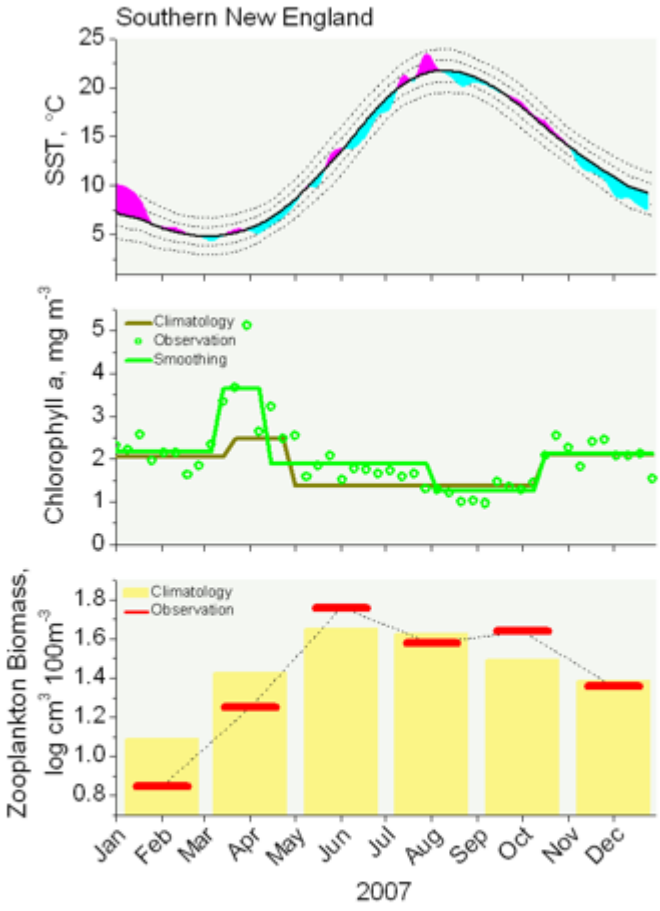

The Georges Bank subregion was cooler than average through most of the year. During many periods, SSTs were in excess of 1 standard deviation below the recent term mean. The spring bloom was of short duration and though there were some higher than average chlorophyll concentrations associated with the fall bloom period, the sequential t-test algorithm could not distinguish a specific fall bloom period. Spring zooplankton abundances were low and summer and early fall abundances were below or at the long-term means. There were not enough samples from the region in winter and late fall to derive a reliable estimate of regional biomass.

### Trends in Spring Conditions for the Georges Bank Subregion



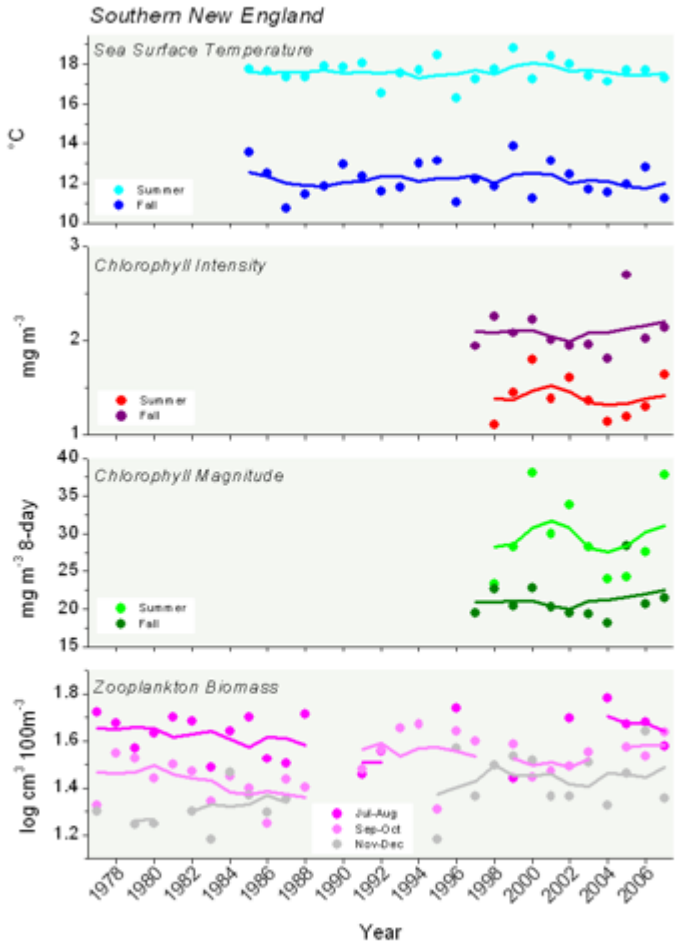

The SST during summer of 2007 continued a decade long trend of declining temperatures on the Bank, whereas fall and early winter temperatures do not show the same declines. The intensity of the fall bloom was at an average level after a series of years showing wide swings in this bloom indicator. The intensity of summer and early winter chlorophyll concentrations have both been increasing over the past five years. The magnitude of the summer production period has increased in part because of the poorly developed fall bloom in recent years; this is due to the reciprocal nature of the calculations, with a short fall bloom the summer production period lasts longer. The 2007 fall bloom was of average to low magnitude. Summer, early fall, and fall zooplankton biomasses have been at intermediate levels during the past several years. There is evidence for decreasing zooplankton biomasses in the summer, but relatively stable biomass in the early fall. Coverage has not been adequate on Georges Bank in recent years to estimate reliable zooplankton biomasses during late winter.

## Southern New England Subregion



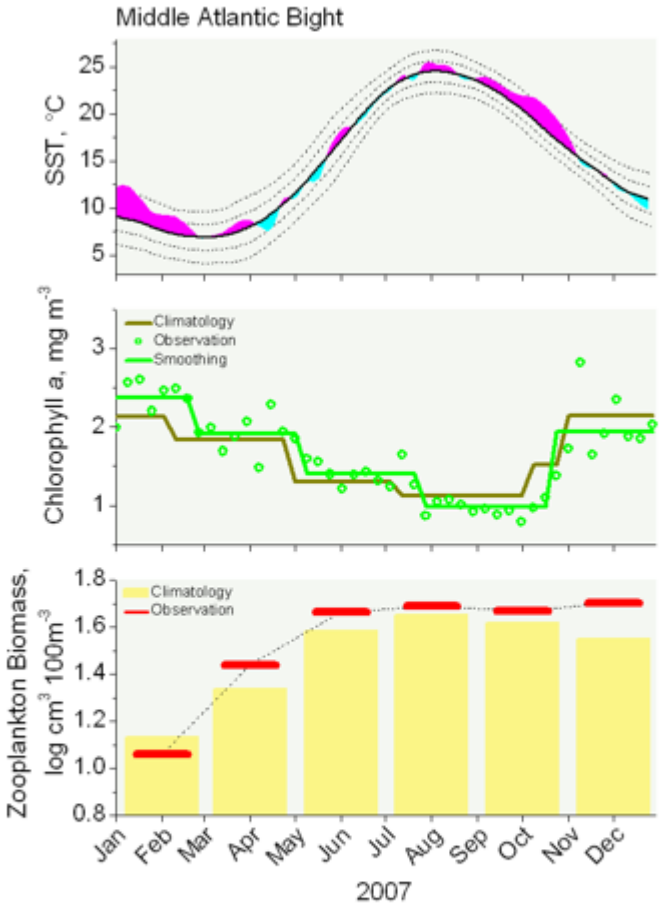

The Southern New England subregion was cooler than the trend in SST for recent years with the exception of a short period during mid summer and at the very beginning of the year. The spring bloom began early and was very intense with chlorophyll concentrations for one 8-day period reaching 5 mg m-3. Chlorophyll concentrations were above average at the beginning of the summer period whereas during the late summer and the fall periods they were at average levels. Spring zooplankton abundances were low but summer and early fall abundances at or above the long-term means.

## Trends in Spring Conditions for the Southern New England Subregion



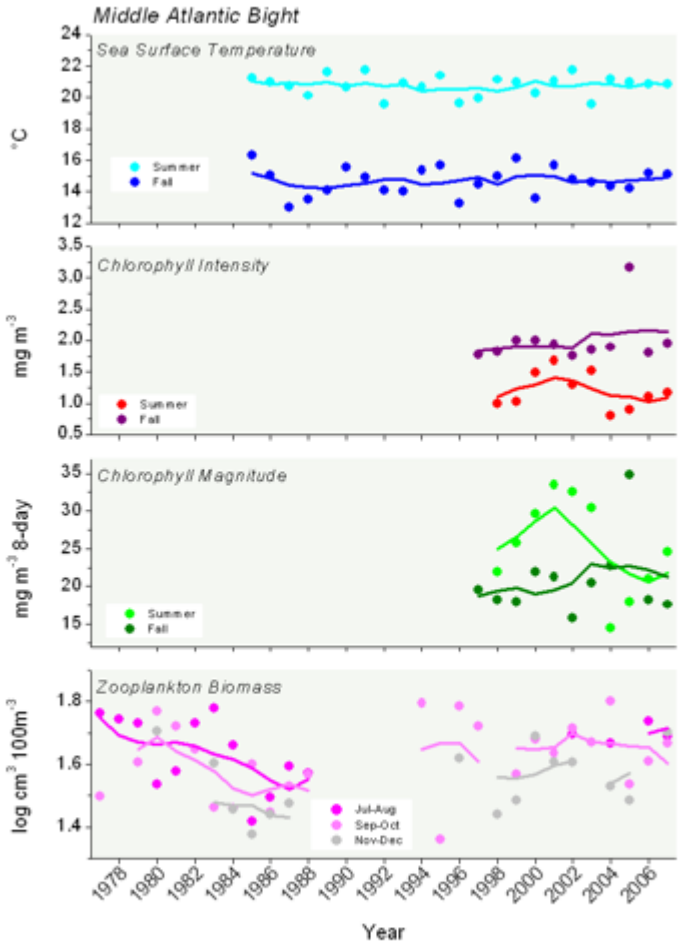

The SSTs during summer and fall in the Southern New England subregion have declined slightly over recent years, with the 2007 values below the trend line. Summer chlorophyll intensity increased in 2007 whereas fall intensity was on the trend line suggesting average conditions. The increase in summer chlorophyll in the Southern New England region resulted in the second highest magnitude summer production period observed for the area. Fall production magnitude was on the trend line. Summer, early fall, and fall zooplankton biomasses have been relatively stable and high through the last several years. There is evidence for decreasing zooplankton biomasses in the summer, but relatively stable biomass in the early and late fall.

## Middle Atlantic Bight Subregion



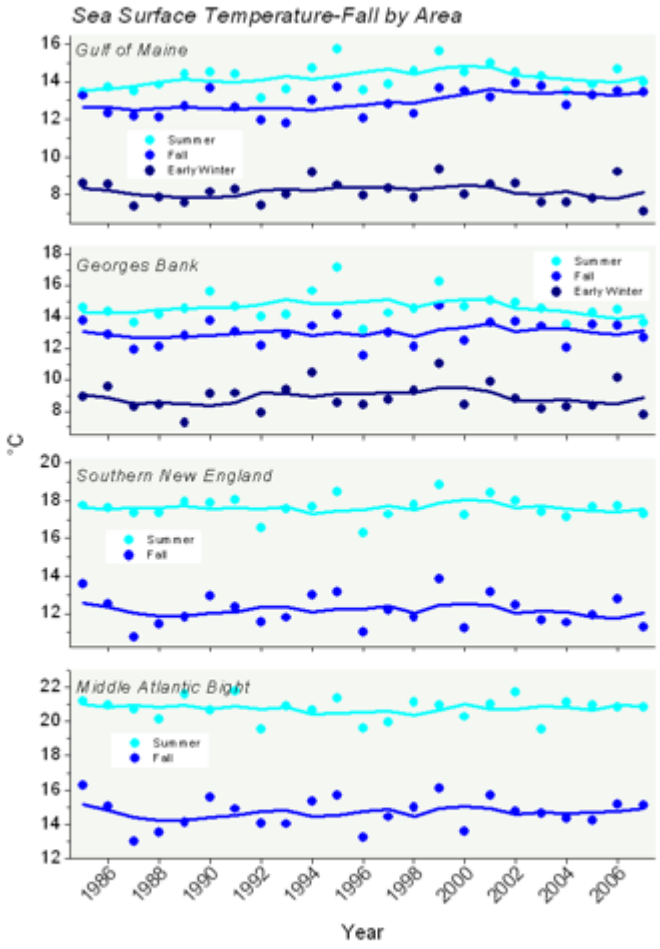

Unlike other subregions of the shelf, the Middle Atlantic Bight experienced extremely warm SST conditions during late winter and the fall of 2007. These warm periods exceeded two standard deviations above the recent term mean of SSTs for the area. Chlorophyll concentrations were generally above average levels during the first half of the year and below average during the later half. As is typical of the Bight area, no distinct spring bloom developed, instead the production cycle was dominated by activity during the winter. Winter zooplankton abundances were low but spring, summer and fall abundances were above the long-term means.

## Trends in Spring Conditions for the Mid-Atlantic Bight Subregion



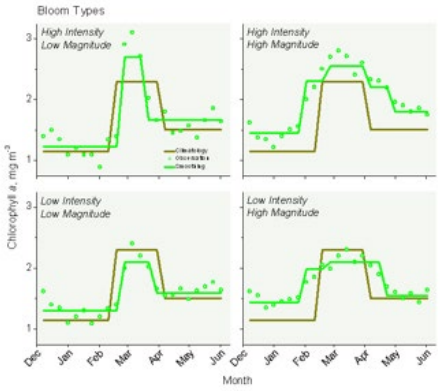

There is little to suggest a trend in summer SSTs over the recent term and only a weakly developed increasing trend in fall conditions. The SST indices are partitioned to match the major periods of the chlorophyll production cycle, thus they are averaged over a number of months each year and tend to dampen elevated SST conditions that may only last a month or two. Summer production chlorophyll intensity and magnitude have been low in recent years, with the 2007 points reflecting the average of the trend. The fall bloom time series is still dominated by the event that took place in 2005 when the Bight experienced an intense near shore bloom. Summer, early fall, and fall zooplankton biomasses have been relatively stable and high through the last several years. The coverage, however, has been spotty in recent years, making it difficult to discern trends.

## Subregion Comparison of Sea Surface Temperature




The range in summer SST is on the order of 7°C with northern segments of the ecosystem averaging 14°C in summer versus 21°C in the Middle Atlantic Bight. The Gulf of Maine, Georges Bank and Southern New England area have experienced a slight cooling trend in recent years, a trend not evidenced in the Middle Atlantic Bight. Fall period SSTs have increased slightly in the Gulf of Maine and on Georges Bank, whereas there is no obvious trend in the southern subregions. The early winter period, which is partitioned in the Gulf of Maine and Georges Bank, was cooler than average in 2007.

## Subregion Comparison of Chlorophyll



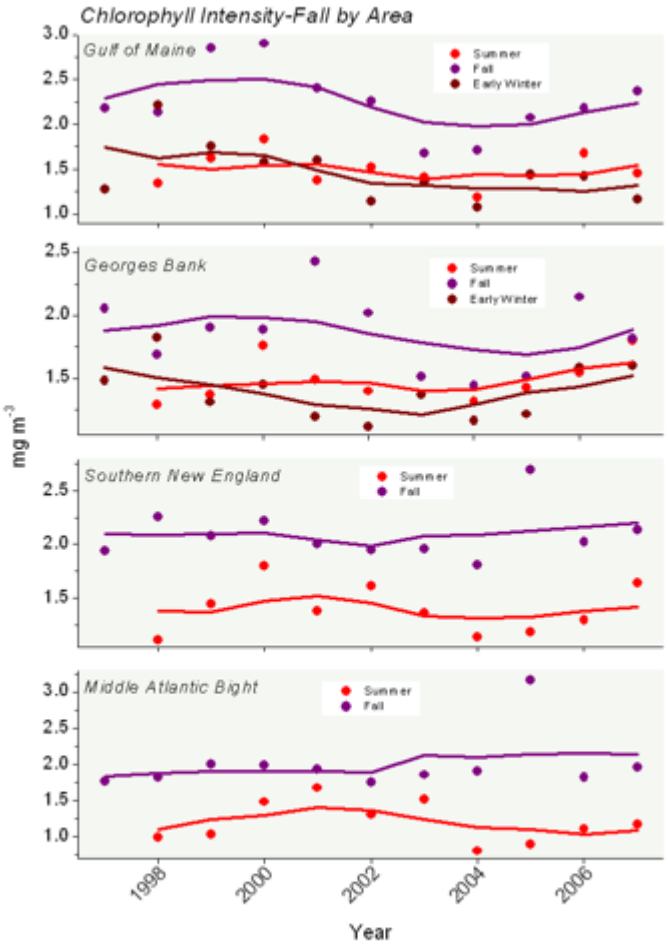

Plankton blooms can be quite variable which affects the way pelagic and benthic resources utilize the primary production associated with the bloom. In an attempt to quantify these characteristics, two measures of bloom size are reported, chlorophyll intensity and chlorophyll magnitude, which are a reflection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

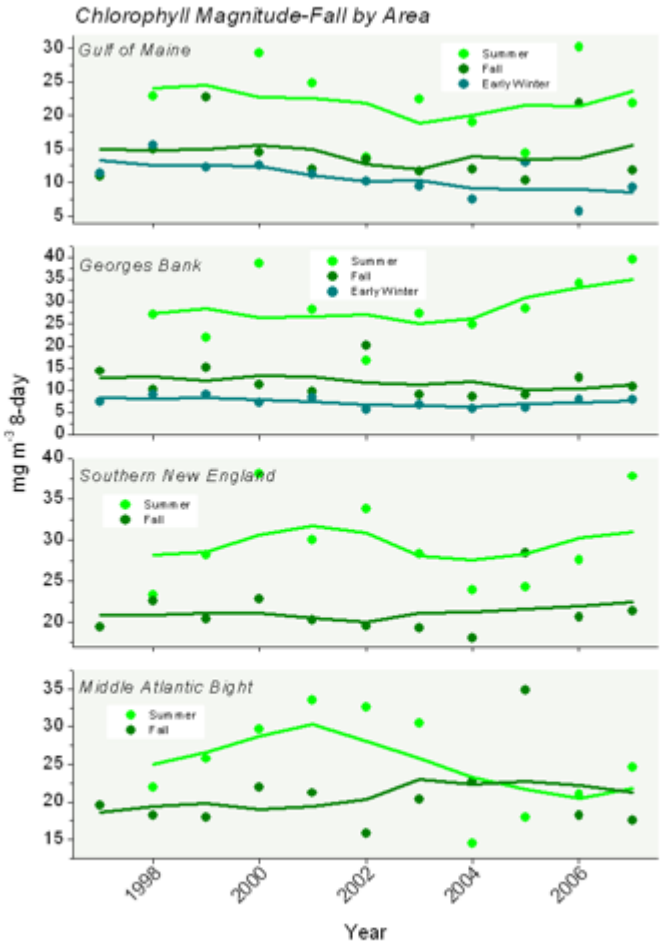
This figure illustrates the differences between high and low intensity versus high and low magnitude blooms.

## Subregion Comparison of Chlorophyll Intensity



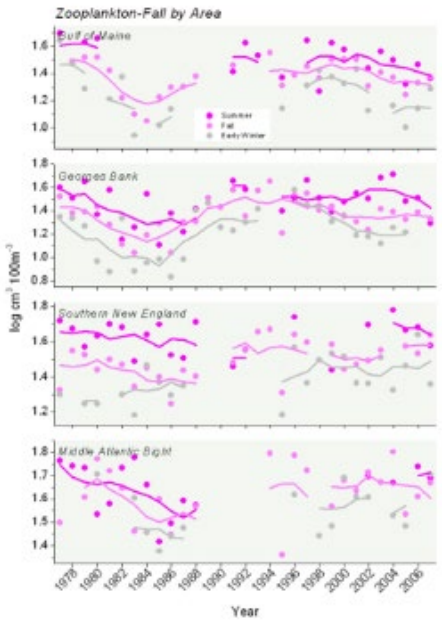

The intensity of summer blooms has increased in the three northern subregions, Gulf of Maine, Georges Bank and Southern New England, during recent years. The opposite trend is evident for the Middle Atlantic Bight where the summer bloom remains at low levels, a trend that began in 2004. The fall bloom intensity in all areas is characterized by the occurrence of a few exceptional blooms exceeding the overall time series trend. In the Gulf Maine, exceptionally intense fall blooms occurred in 1999 and 2000 whereas the exceptional blooms on Georges Bank occurred in 2001 and 2006. The 2005 fall bloom was an exceptional event in both the Southern New England and Middle Atlantic Bight areas. The early winter blooms in the Gulf of Maine and Georges Bank were low intensity blooms and do not have an apparent trend.

## Subregion Comparison of Chlorophyll Magnitude



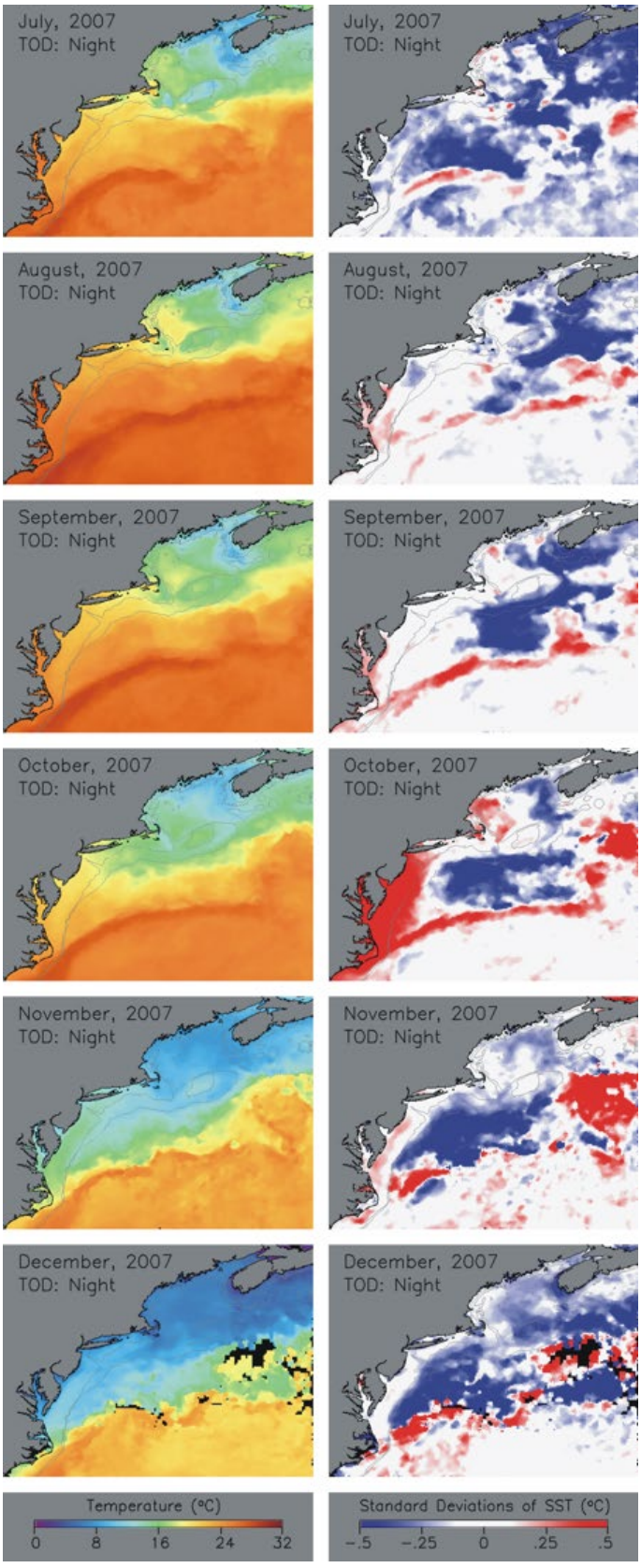

The magnitude of summer blooms has increased in the three northern subregions, Gulf of Maine, Georges Bank and Southern New England, during recent years. The opposite trend is evident for the Middle Atlantic Bight where the summer bloom remains at low levels, a trend that began in 2004. The fall bloom magnitude in all areas is characterized by the occurrence of a few exceptional blooms exceeding the overall time series trend. In the Gulf Maine, exceptional fall blooms occurred in 1999 and 2006 whereas the exceptional blooms on Georges Bank occurred in 1999 and 2002. The 2005 fall bloom was an exceptional event in both the Southern New England and Middle Atlantic Bight areas. The early winter blooms in the Gulf of Maine and Georges Bank are low magnitude blooms and do not have an apparent trend.

## Subregion Comparison of Zooplankton




Summer, fall, and early winter zooplankton biomasses have been decreasing in the Gulf of Maine. These trends continued into 2007 for summer and fall, but the 2007 early winter estimate was near the long-term average, suggesting that the long-term decrease in early winter zooplankton may be ending. On Georges Bank, zooplankton biomasses have been at intermediate levels during the past several years. There is evidence for decreasing zooplankton biomasses in the summer, but relatively stable biomass in the fall. Coverage has not been adequate on Georges Bank in recent years to estimate reliable zooplankton biomasses during early winter. On the Southern New England shelf, summer, fall, and early winter zooplankton biomasses have been relatively stable and high through the last several years. There is evidence for decreasing zooplankton biomasses in the summer, but relatively stable biomass in the fall and early winter. In the Middle Atlantic Bight, summer, fall, and early winter zooplankton biomasses have been relatively stable and high through the last several years. The coverage, however, has been spotty in recent years, making it difficult to discern trends

# Sea Surface Temperature Distribution


July, 2007
TOD: Night
July, 2007
TOD: Night
August, 2007
TOD: Night
August, 2007
TOD: Night
September, 2007
TOD: Night
September, 2007
TOD: Night
October, 2007
TOD: Night
October, 2007
TOD: Night
November, 2007
TOD: Night
November, 2007
TOD: Night
December, 2007
TOD: Night
December, 2007
TOD: Night
Temperature (°C)
0
8
16
24
32
Standard Deviations of SST (°C)
−.5
−.25
0
.25
.5

The progression of fall sea surface temperatures for the months of July through December 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 fall cooling was advanced compared to most years, thus, with the exception of the distribution of SST in October along the Middle Atlantic Bight, cool anomalies dominate the Northeast Shelf. The exception to this was the warm conditions that persisted in the Middle Atlantic Bight area during October. Georges Bank was either near the climatological mean or below average temperature during the six month period. The Gulf Maine only saw above average temperatures in October, and those warm conditions were limited to the eastern portion of the Gulf.

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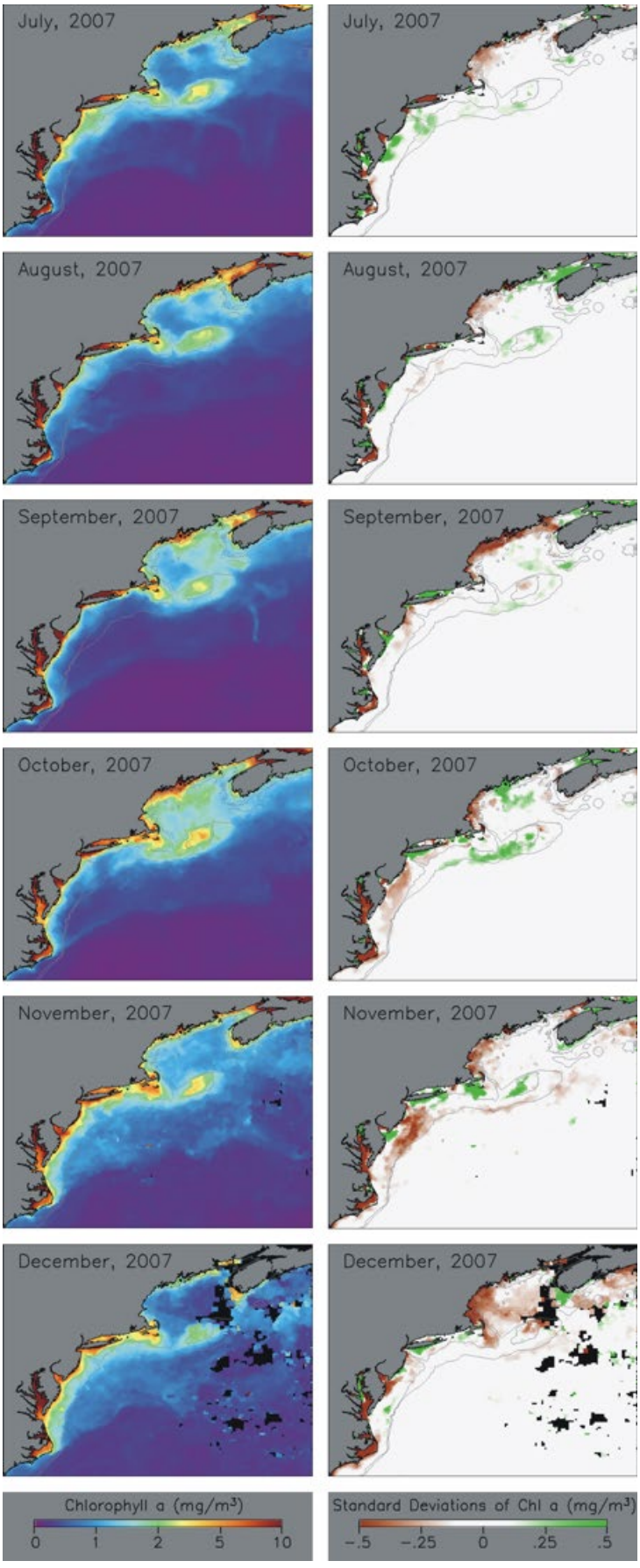
# Chlorophyll Distribution


July, 2007
July, 2007
August, 2007
August, 2007
September, 2007
September, 2007
October, 2007
October, 2007
November, 2007
November, 2007
December, 2007
December, 2007
Chlorophyll a (mg/m³)
0
1
2
5
10
Standard Deviations of Chl a (mg/m³)
−.5
−.25
0
.25
.5

The progression of fall chlorophyll concentrations for the months of July through December 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.  The fall bloom appears most intense in the Gulf of Maine during October, especially in the area of the Maine Coast around and south of Penobscot Bay. Some level of bloom activity can be seen on Georges Bank for all months except December, perhaps providing a reason why it was difficult to demarcate the Georges Bank fall boom. Exceptionally high chlorophyll levels are associated with areas of the eastern Gulf of Maine and the southern flank of Georges Bank during October and Nantucket Shoals during November. Exceptionally low chlorophyll concentrations appear in the western Gulf of Maine during December and along the Middle Atlantic Bight in November.

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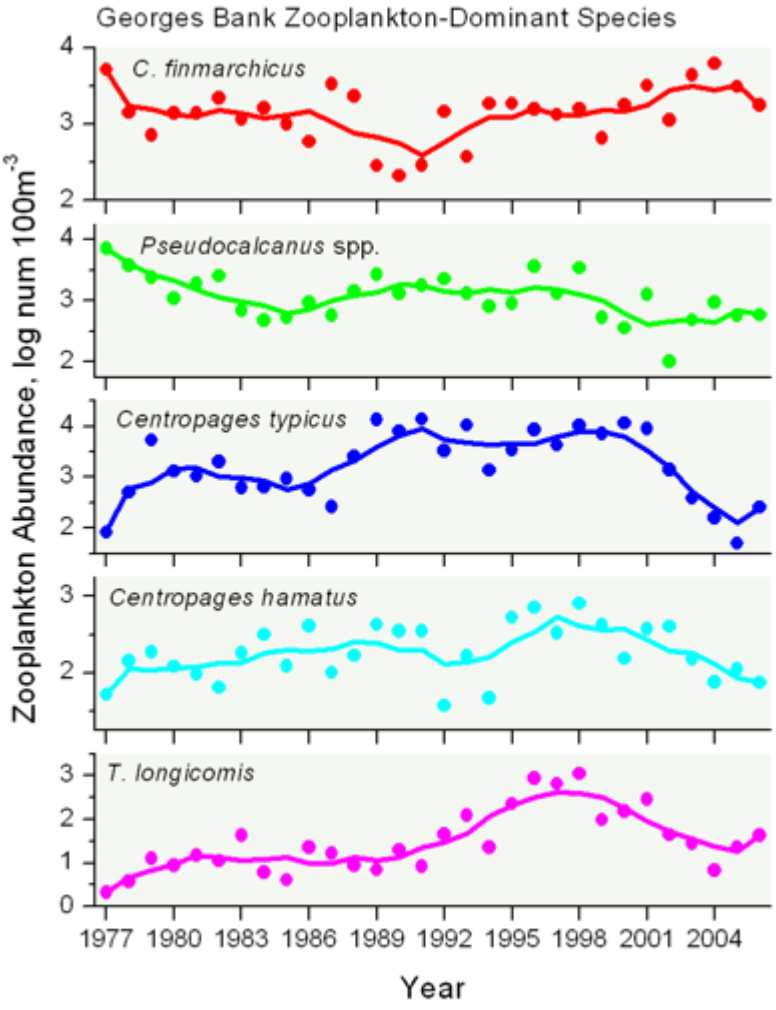
# ECOMON-Dominant Zooplankton Species




*Pseudocalanus*, and 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, but 2006 was lower relative to the previous three years. There have been marked decreases in the abundance of *Centropages* and *Temora* in recent years. The most recent year's data (2006) is higher than the lowest observed in the past 5 years, indicating that this decreasing trend may be reversing.

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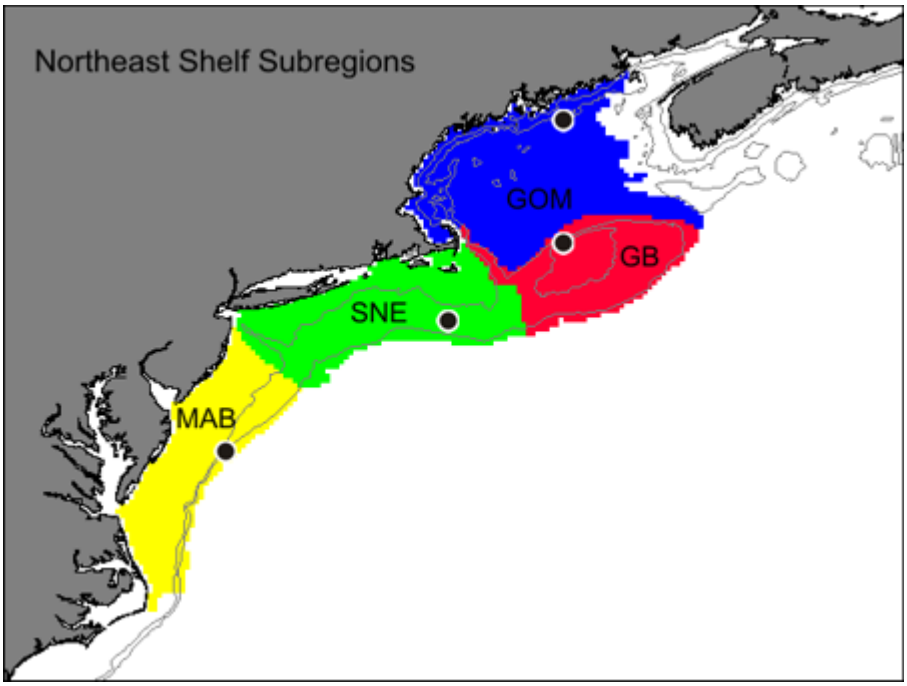
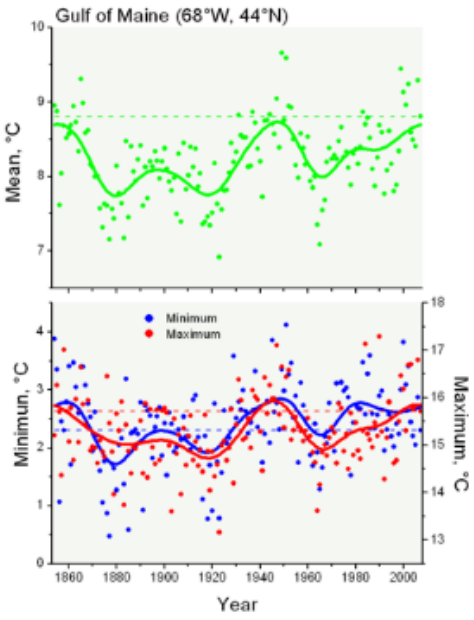
# Long-Term Temperature Trends




The Extended Reconstructed Sea Surface Temperature (ERSST) dataset is organized by 2° square longitude by latitude bins; thus, it is too coarse grain to exactly represent NE Shelf subregions (Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Middle Atlantic Bight (MAB)). However, individual data bins are highly correlated with the shorter time series of satellite SST data for each subregion. Four of these data bins have been selected to serve as a long term SST indices for their respective subregions. The center of the ERSST data bin used to represent a subregion is shown on the map as a block dot.

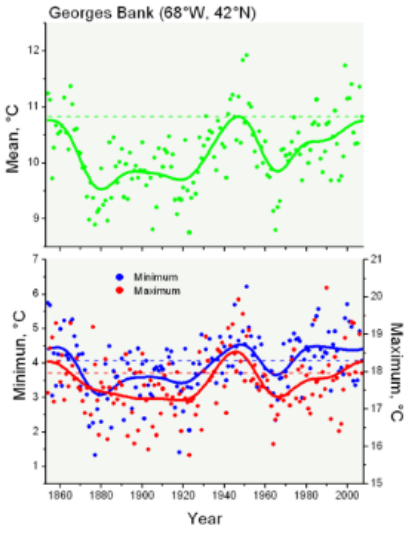



## Gulf of Maine

The Gulf Maine subregion is represented by SST data for the ERSST bin centered on 68°W, 44°N. SSTs have been increasing in the Gulf of Maine over the past few decades as indicated by the solid green trend line. This trend suggests SSTs are approaching the warmest conditions observed in the Gulf Maine, which occurred around 1860 and 1950. However, the 2007 SST data point, which is marked by the green dashed line, though in line with the trend line, is below many of the SST values observed in recent years indicating it was a relatively cool year. The 2007 SST minimum for the area, marked by the dashed blue line, was approximately 2.3°C, which is lower then the recent trend for the

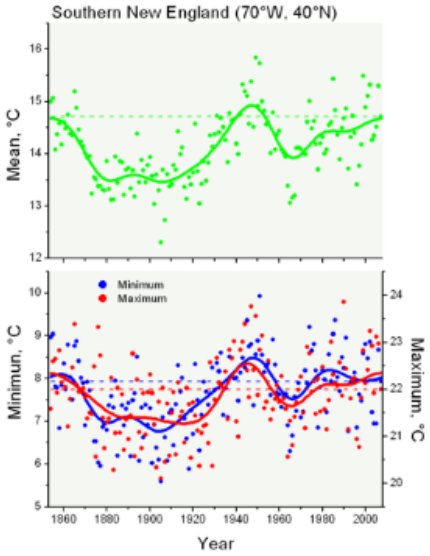
minima by nearly a half degree. The subregion maximum, marked by the red dashed line, was approximately 15.7°C and was in line with the recent trend for these data.

## Georges Bank



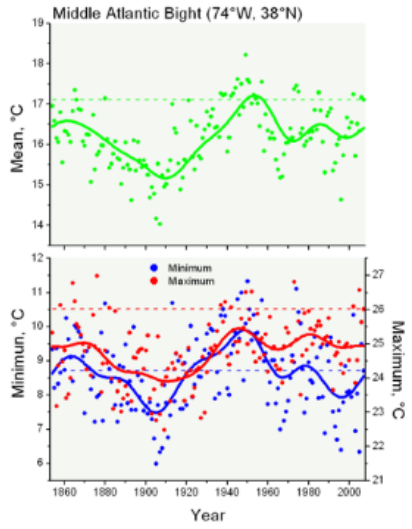

The Georges Bank subregion is represented by SST data for the ERSST bin centered on 68°W, 42°N. SSTs have been increasing on Georges Bank over the past few decades as indicated by the solid green trend line. This trend suggests SSTs are approaching the warmest conditions observed on the Bank that occurred around 1860 and 1950. However, the 2007 SST point, which is marked by the green dashed line, though in line with the trend line, is below many of the SST values observed over the past few decades suggesting it was a relatively cool year. The 2007 SST minimum for the area, marked by the blue dashed line, was approximately 4.1°C, which was lower then the recent trend for minima by approximate a quarter degree. The subregion maximum, marked by the red dashed line, of approximately 18.0°C was also cooler than the recent trend in these data.

## Southern New England




The Southern New England subregion is represented by SST data for the ERSST bin centered on 70°W, 40°N. SSTs have been increasing in the Southern New England area over the past few decades as indicated by the solid green trend line. This trend suggests SSTs are approaching the warmest conditions observed in Southern New England that occurred around 1860 and 1950. However, the 2007 SST point, which is marked by the green dashed line, though in line with the trend line, is below many of the SST values observed over the past few decades indicating the year was relatively cool. The 2007 SST minimum for the area, marked by a blue dashed line, was approximately 7.9°C, which is in line with the recent trend for minima. The subregion maximum, which is marked by a red dashed line, was approximately 22.0°C and was cooler than the recent trend in these data.

## Middle Atlantic Bight




The Middle Atlantic Bight subregion is represented by SST data for the ERSST bin centered on 74°W, 38°N. Unlike the northern subregions of the NE Shelf, SSTs have not been increasing in the Middle Atlantic Bight area over the past few decades as indicated by the solid green trend line. However, the 2007 SST point, which is marked by the green dashed line, is well above this trend line along with a number of other recent observations suggesting SST may be starting to increase in this subregion as well. The 2007 SST minimum for the area, which is marked by the blue dashed line, was approximately 8.7°C, which is in line with the recent trend for minima. The subregion maximum, which is marked by a red dashed line, was approximately 26.0°C and was nearly a degree warmer then the trend for the maximum.

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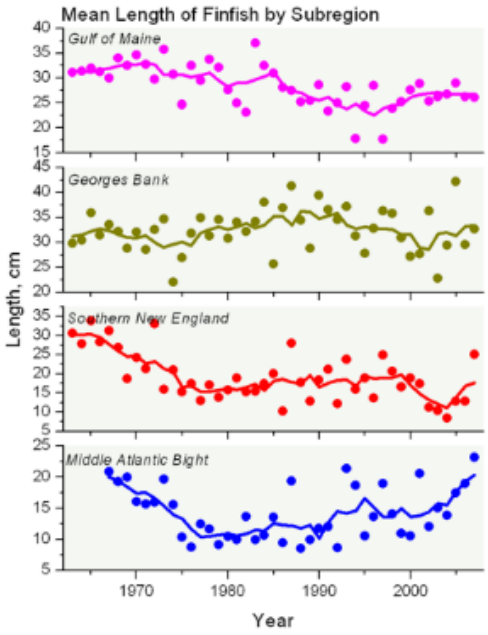
# Trends in Fish Size




The mean lengths of all finfish for each of the subregions, along with the smoothed average, exhibit minimal change for Georges Bank, ranging without trend from 25 to 35 cm. However, mean length of fish in the Gulf of Maine and Southern New England are, respectively on average, currently 5 and 10 cm less than in the 1970s and 1980s. Evidence for the Middle Atlantic Bight suggests a recent increasing trend, with mean length of fish ~ 5cm larger than in the 1980s or 1990s, similar to what was observed in earlier time periods. Overall this indicator suggests the fish community has undergone notable changes from an aggregate perspective in most of these regions.

## 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.