Spring 2013 Update: Annual Condition of the Northeast Shelf Ecosystem

Produced by the Ecosystem Dynamics and Assessment Branch

Published by Northeast Fisheries Science Center

February 14, 2013

Northeast Fisheries Science Center

166 Water Street

Woods Hole MA 02543-1026

Phone: (508) 495-2000

Spring 2013: Summary of Conditions of the Northeast Shelf Ecosystem

Summary

- Sea surface temperatures (SSTs) in the Northeast Shelf Large Marine Ecosystem during 2012 were the highest ever recorded in both long-term observational and short-term remote sensing time series. These exceptionally high SSTs are part of a pattern of elevated temperatures occurring in the Northwest Atlantic, but not seen elsewhere in the ocean basin.
- The fall bloom on the Northeast Shelf was poorly developed with the exception of some bloom activity in the eastern Gulf of Maine; resources dependent on the fall bloom will experience a deficit in energy flow.
- Chlorophyll concentration over the course of the year 2012 remained high compared to recent years despite low fall chlorophyll. The relatively high biomass level can be attributed to the above average 2012 spring bloom.
- Reflecting the large jump in temperature of the ecosystem, Northeast Shelf warm water thermal habitat was at a record high level during 2012, whereas cold water habitat was at a record low level.
- Winter mixing went to extreme depths in 2013, which will impact the spring bloom by redistributing nutrients and affecting the stratification of the water column as the bloom develops.

Data Sources

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

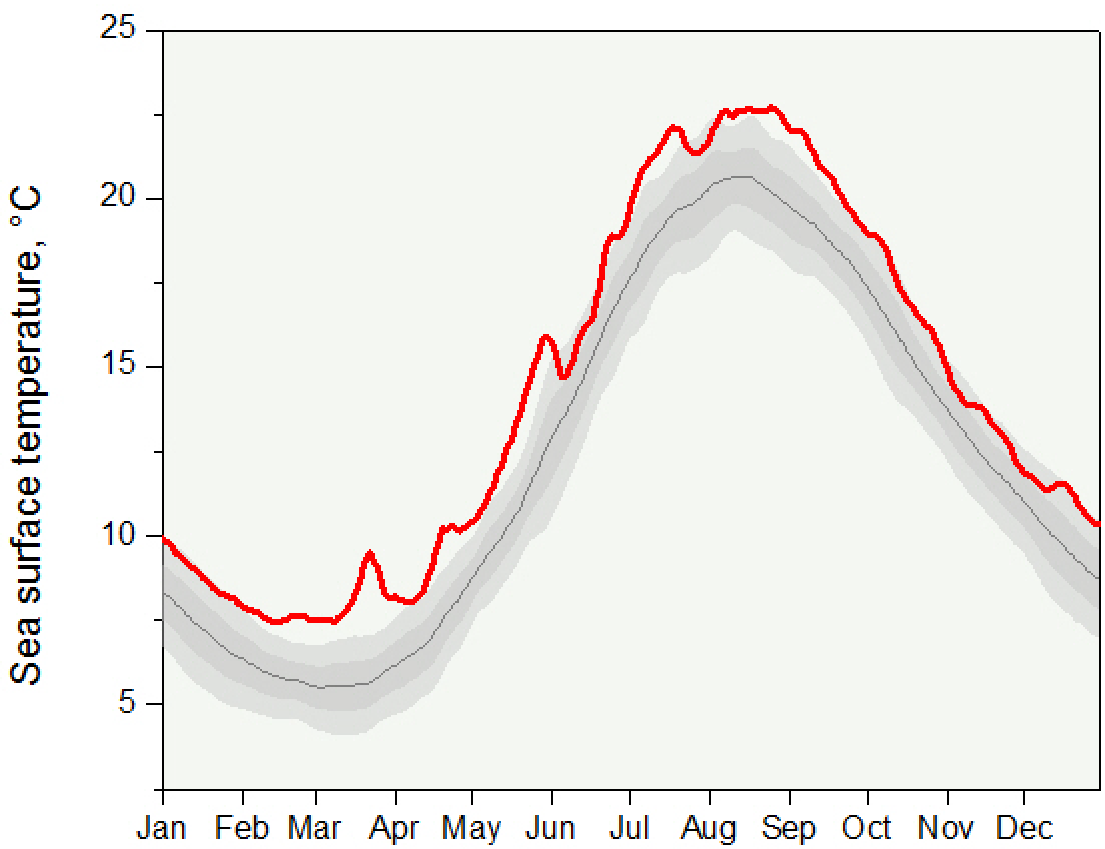
Synoptic views of surface concentrations of chlorophyll a were derived from the Sea-viewing Wide Field of View Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiomater on the Aqua satellite (MODIS-Aqua). Data from these ocean color sensors were obtained from the NASA Ocean Biology Processing Group. Chlorophyll a is considered a proxy of phytoplankton biomass present in the near-surface water.

Zooplankton biomass was derived from shipboard surveys of the U.S. Northeast Shelf ecosystem. Zooplankton provide the link from primary producers 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 four ecosystem subareas: Middle Atlantic Bight, Southern New England, Georges Bank, and the Gulf of Maine (resulting in approximately 720 zooplankton biomass samples annually). Zooplankton are identified to the lowest taxonomic level possible, resulting in taxon specific data on abundance and distribution.

Thermal habitats were computed using the NOAA Optimum Interpolation 1/4 Degree Daily Sea Surface Temperature Analysis.

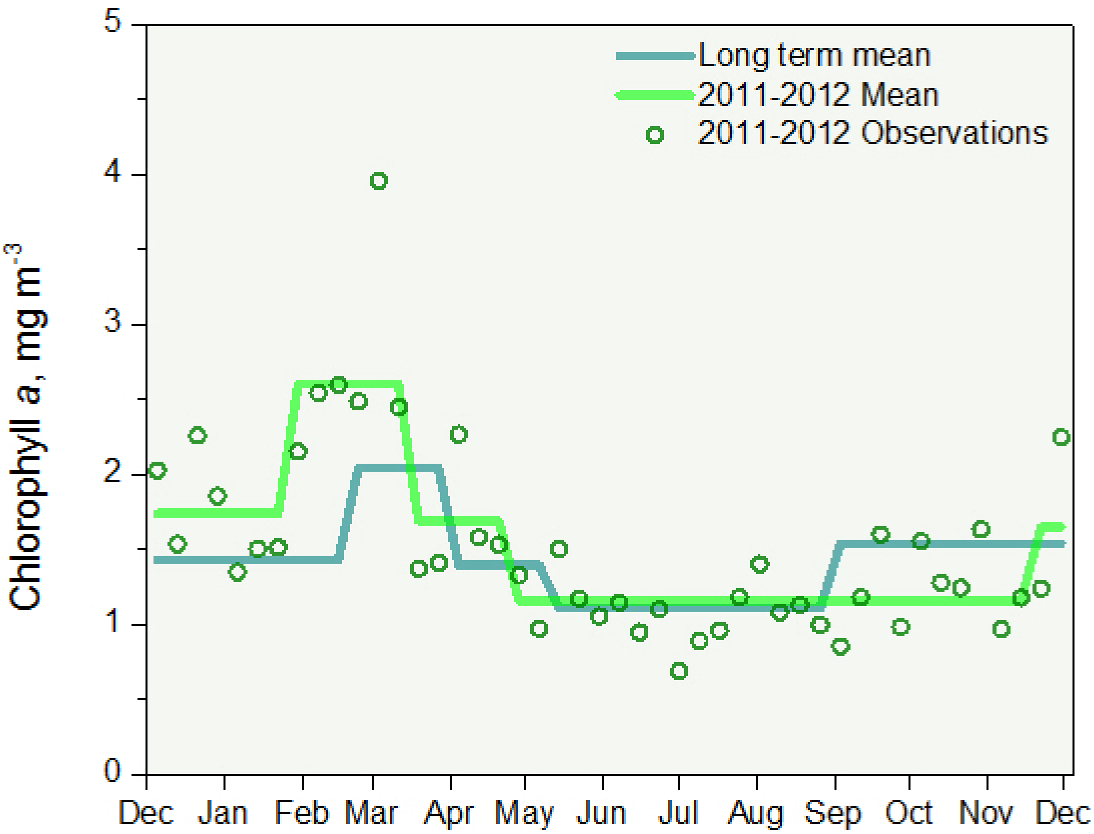
Long term SSTs were extracted from the Extended Reconstructed Sea Surface Temperature (ERSST, version 3b) dataset. This dataset is based on the temperature compilation of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) SST dataset, and contains reconstructed SST fields (obtained by interpolation) in regions with sparse data.

Sea Surface Temperature



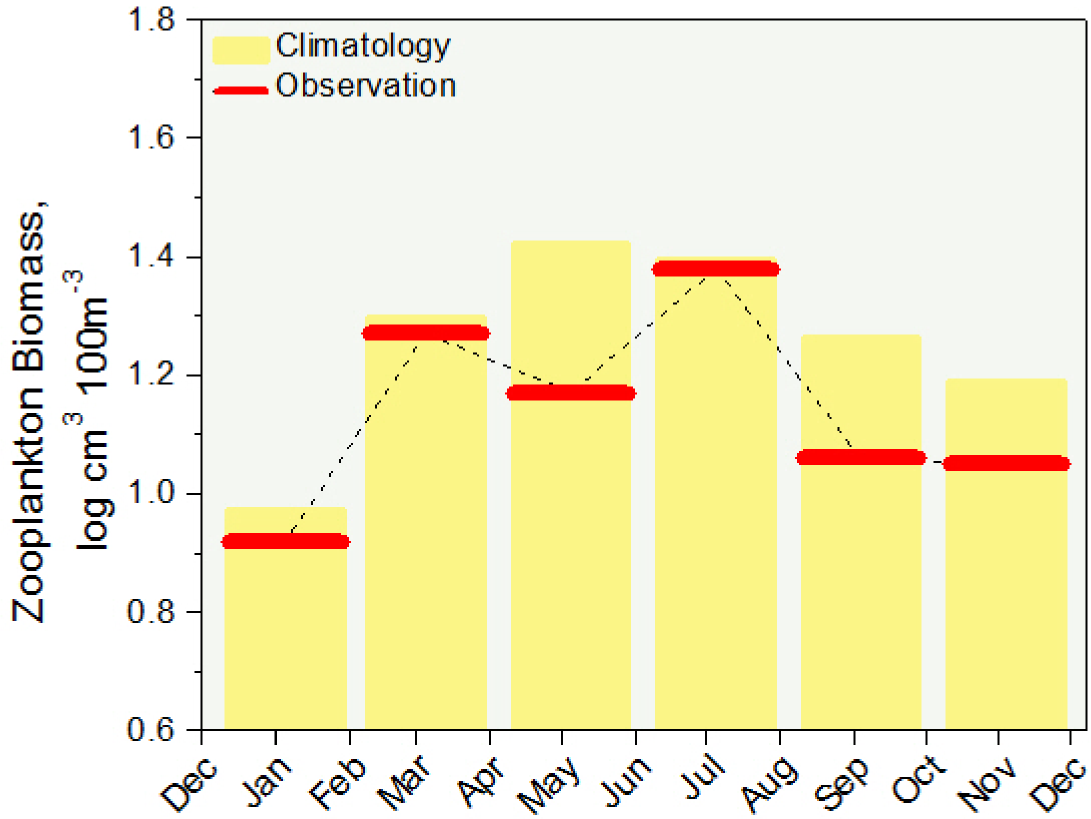
The Northeast Shelf Large Marine Ecosystem experienced above average sea surface temperatures (SSTs) during the fall of 2012, continuing the trend of above average temperatures seen during spring into summer seasons. In the graph, the long term mean SST is shown as a dark gray line with areas representing plus and minus one and two standard deviations of the mean as progressive shades of gray, respectively. In 2012, SSTs were all well above the mean and are shown in red. Some thermal moderation in the fall may have been due to Super Storm Sandy which impacted the NES during late October into November.

Chlorophyll Concentration



Though regions of the Northeast Shelf Large Marine Ecosystem often have fall bloom activity, the ecosystem as a whole does not typically have a fall bloom. The below average chlorophyll concentrations in September through November indicate that many of the areas that often have a fall bloom did not have one in 2012. The low bloom productivity in fall is in contrast to the exceptionally high chlorophyll concentrations observed during the spring bloom.

Zooplankton Biomass

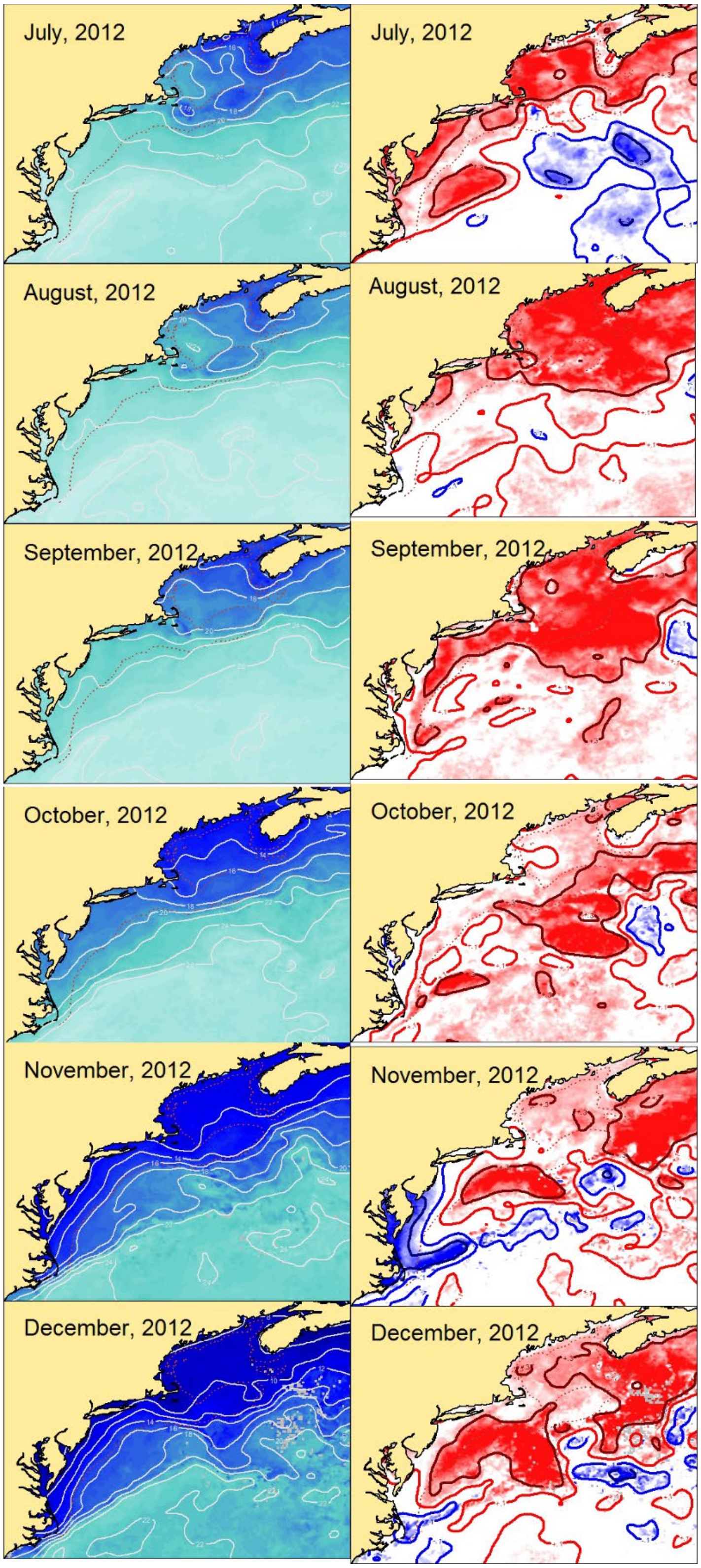


The biomass of zooplankton finished the year at below average levels for ecosystem, which continues the pattern seen in recent years. Spring zooplankton biomass has been at or above the long-term average, possibly a result of the advance in timing of the spring bloom. Fall zooplankton biomass is then below average. The cause of low fall zooplankton is uncertain but may have consequences for a number of species that depend on zooplankton for prey.

Sea Surface Temperature Distribution

Fall Sea Surface Temperature Distribution

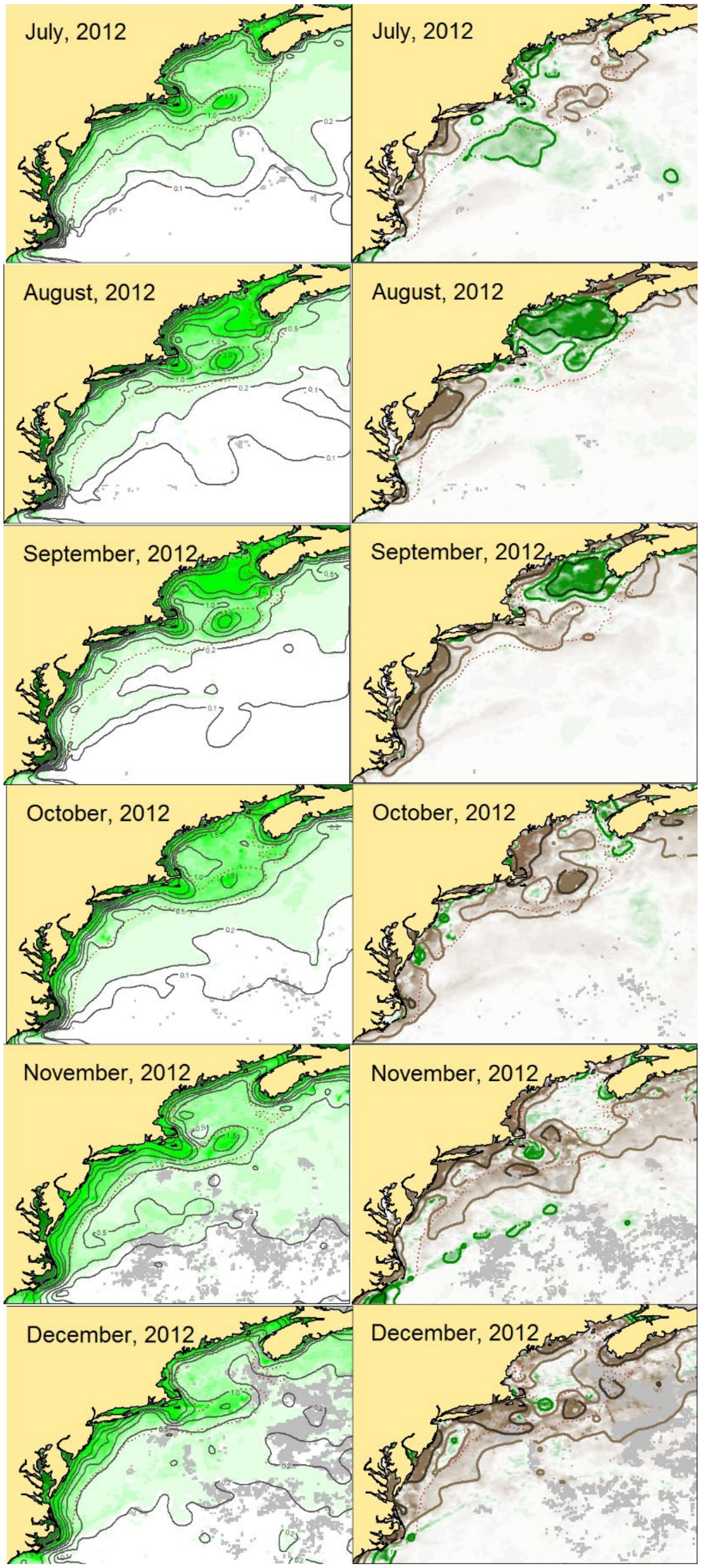
The progression of fall sea surface temperatures for the months of July through December are shown in the interactive figure below. SSTs appear as progressive shades of cyan to blue in the left hand icons. Anomalies of SST, those tending to exceed plus or minus one quarter of a standard deviation of the overall SST for the field, are in the right hand set of icons. This type of anomaly tends to highlight high SSTs in an area, the red shades, and low SSTs in an area, the blue shades. The shelf was generally above average temperature during July through September with the most consistent warming conditions being seen in the Gulf of Maine and on Georges Bank. Temperatures moderated slightly by October and were below average in the Middle Atlantic Bight in November, cooling we attribute to Super Storm Sandy. The cooling signature in the November data may be related to storm runoff. Above average temperature conditions were reestablished by December.


July, 2012
July, 2012
August, 2012
August, 2012
September, 2012
September, 2012
October, 2012
October, 2012
November, 2012
November, 2012
December, 2012
December, 2012

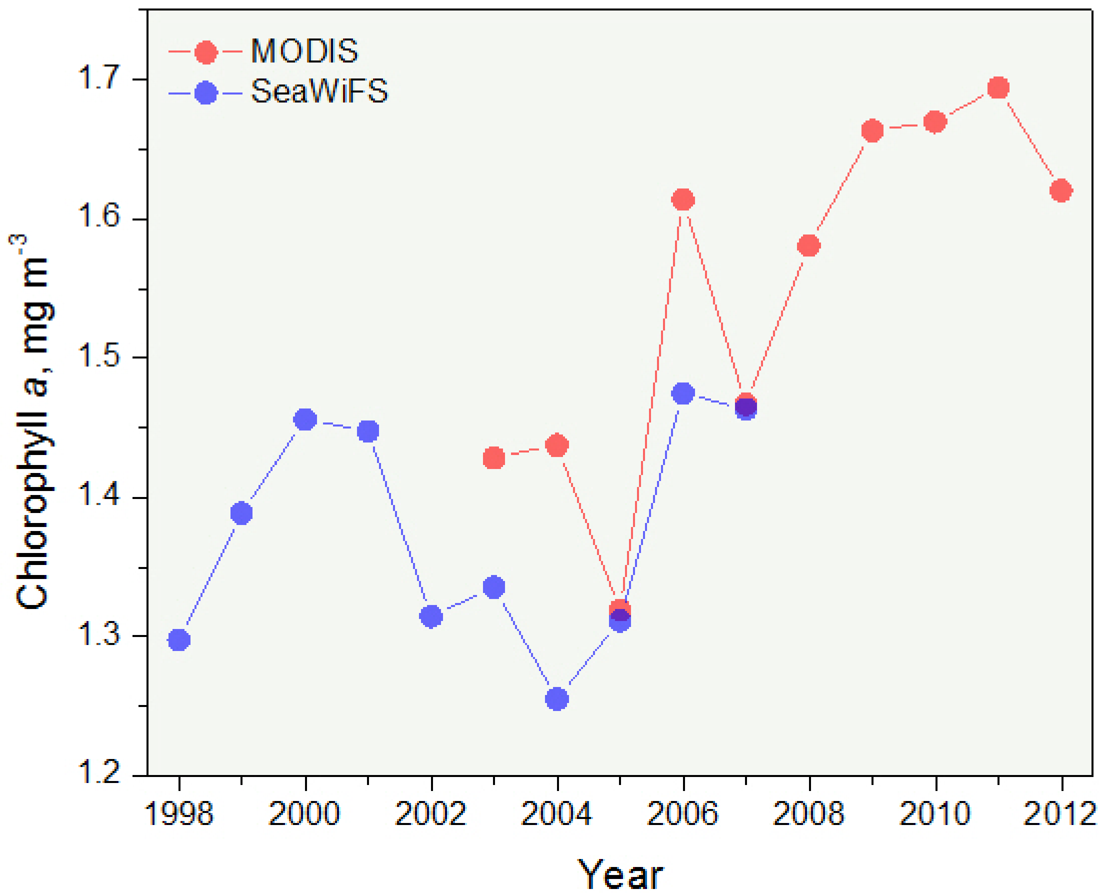
Chlorophyll Distribution

Fall Chlorophyll Distribution

The progression of fall chlorophyll concentrations for the months of July through December are shown in the interactive figure below. Chlorophyll concentrations appear as progressive shades of green in the left hand icons. Anomalies of chlorophyll concentration, those tending to exceed plus or minus one quarter of a standard deviation of the overall concentration for the field, are in the right hand set of icons. This type of anomaly tends to highlight strong blooms in an area, the green shades, and weak blooms in an area, the brown shades. Chlorophyll concentrations were above average during later summer into fall in the Gulf of Maine: however, these above average summer bloom conditions did not persist into fall as can be seen in the October data where there is no evidence of a fall bloom on either Georges Bank or in the Gulf of Maine. In fact, the brown tones indicated below average chlorophyll concentrations.

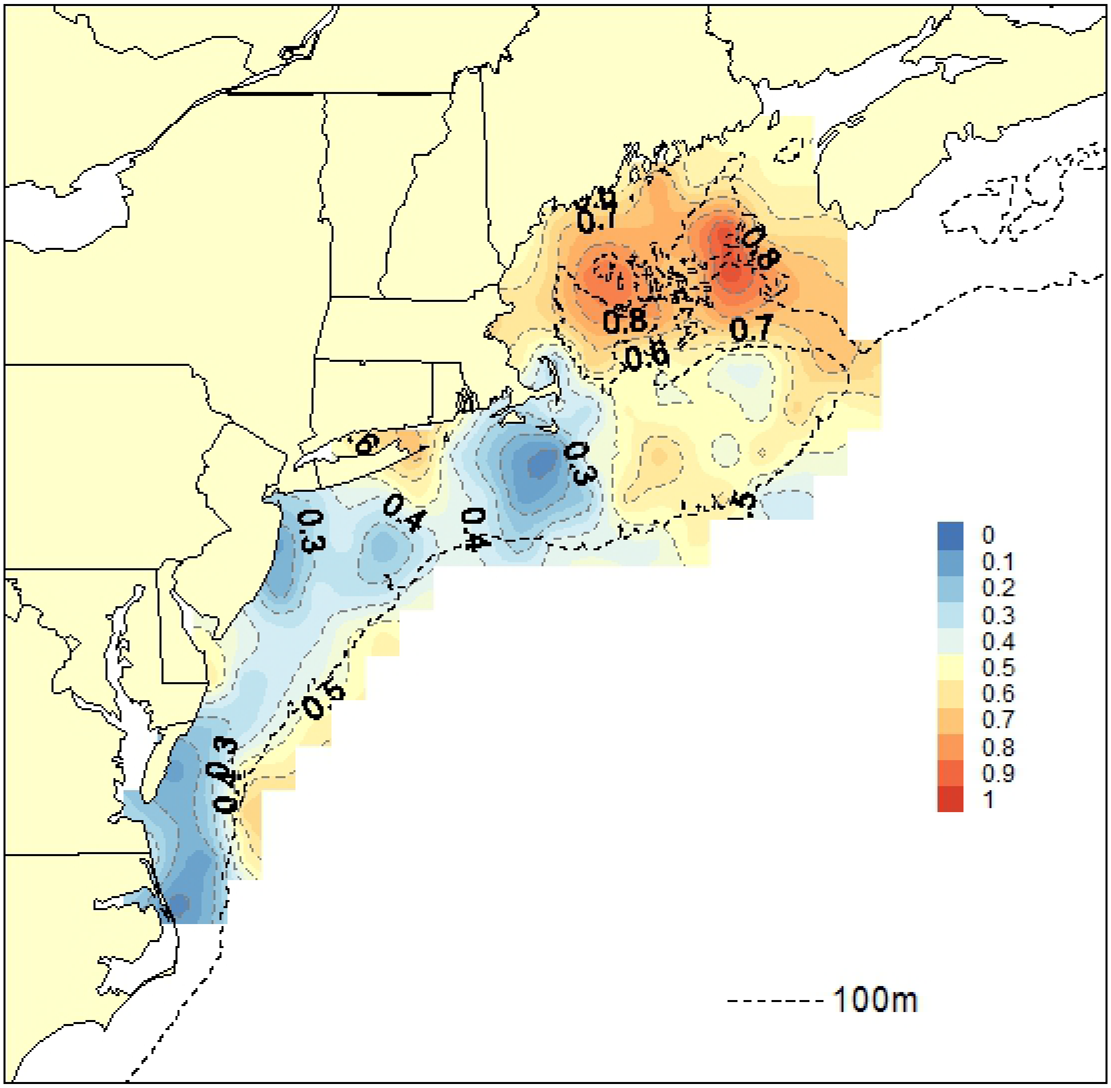

July, 2012
July, 2012
August, 2012
August, 2012
September, 2012
September, 2012
October, 2012
October, 2012
November, 2012
November, 2012
December, 2012
December, 2012

Shelf-wide Chlorophyll Concentration



The integrated mean annual chlorophyll concentration for the Northeast Shelf Ecosystem is represented as separate time series for both the SeaWiFS and MODIS sensors. The estimate of mean annual chlorophyll concentration for 2012 continues the trend of high values that started in 2009, with the caution that MODIS estimates appear to be biased higher than SeaWiFS data. These higher chlorophyll concentrations have been associated with earlier spring blooms, which represents a fundamental change in the timing of the production cycle of the ecosystem. The size of the spring bloom was so large that the annual chlorophyll concentration remained high in 2012 despite low fall bloom activity.

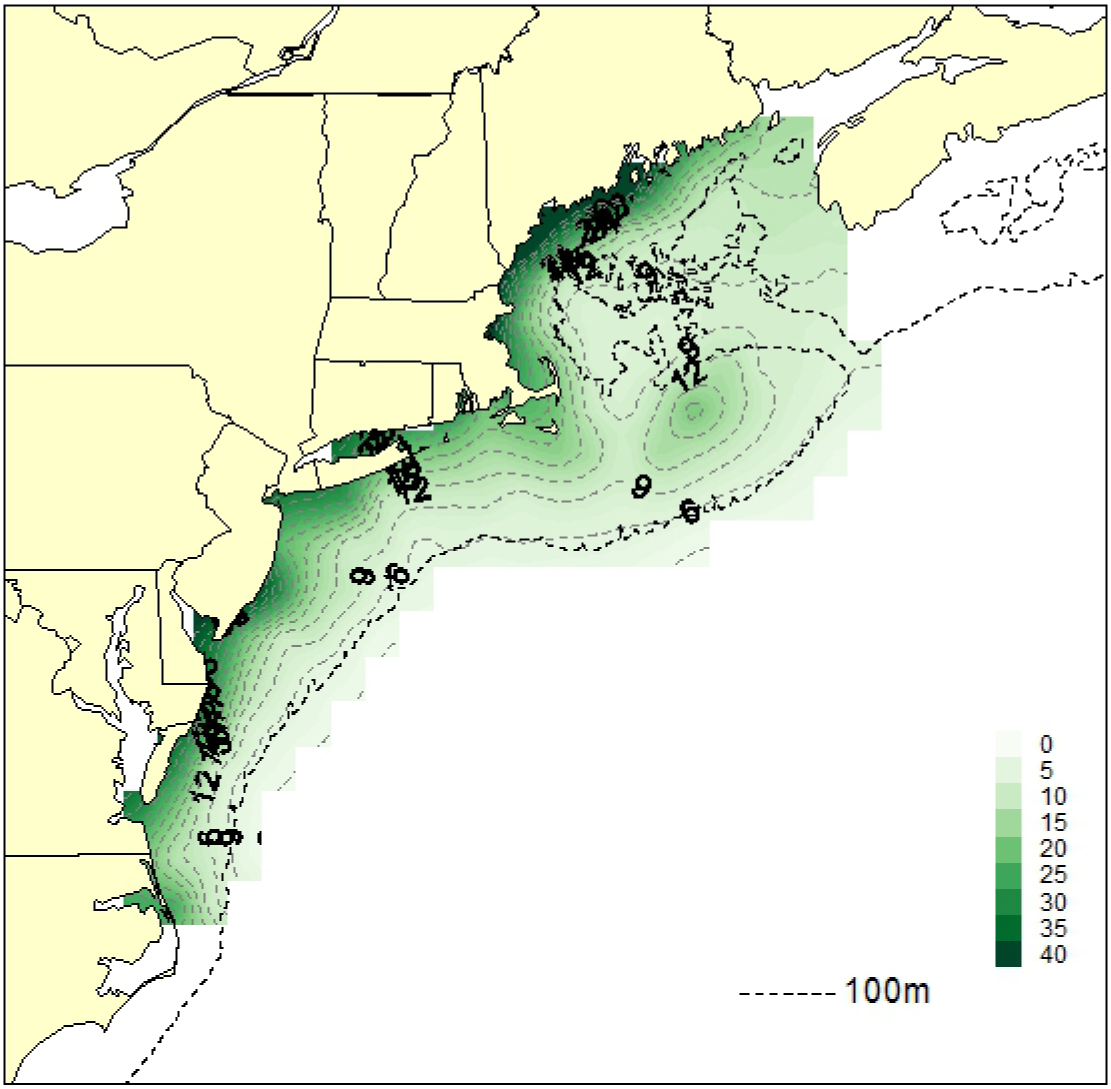
Bloom Frequency

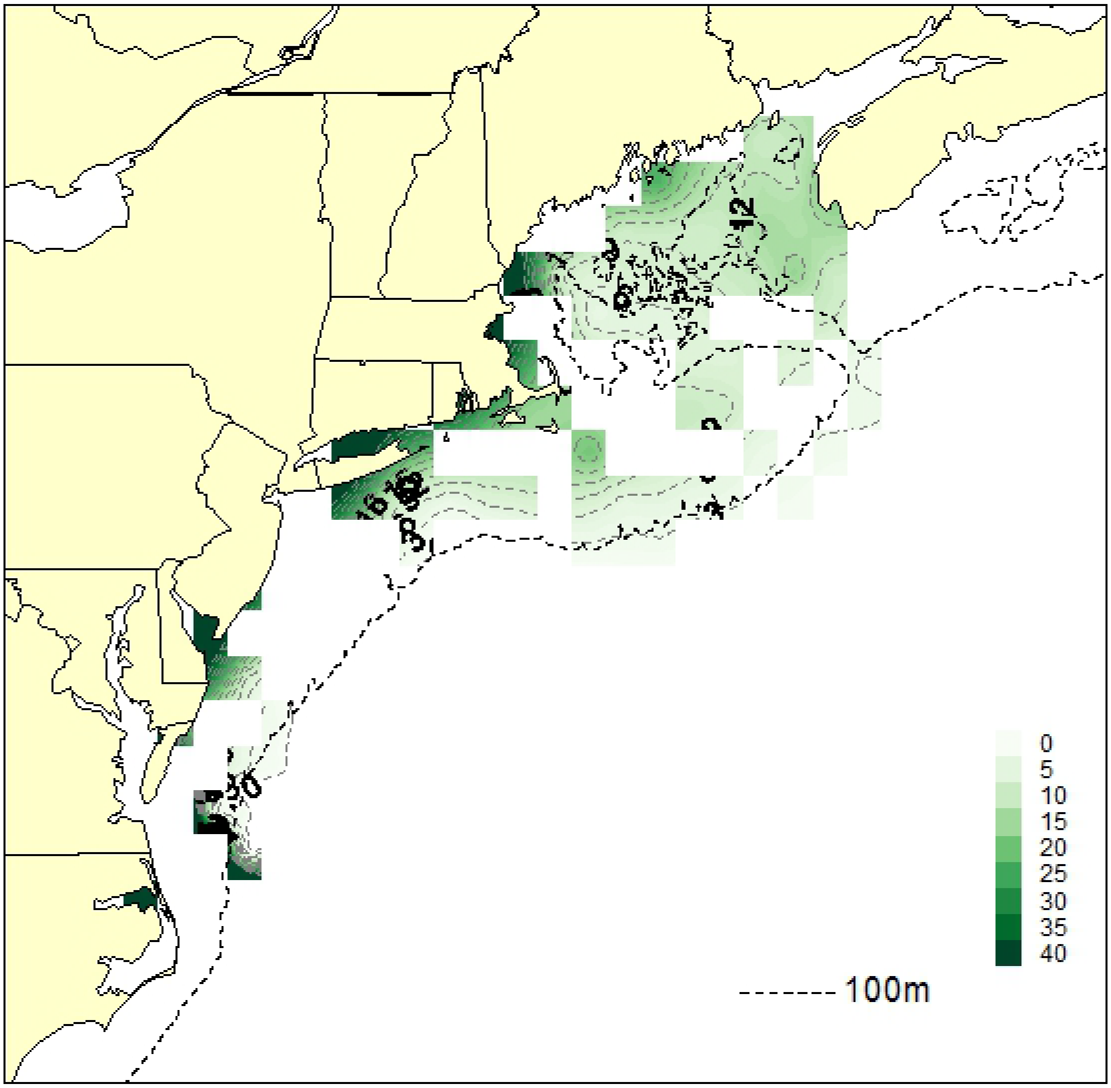


The fall bloom is a production feature that varies in size and frequency in different parts of the ecosystem. A discernible fall bloom develops during most years in the Gulf of Maine. The blue tones in the frequency map indicates that most parts of the Gulf of Maine has a fall bloom frequency in excess of 0.7, indicating that in 7 out of 10 years a fall bloom can be detected. In contrast, the Middle Atlantic Bight has frequencies typically less the 0.3, indicate that a discernible bloom is a rare event. Georges Bank represents an intermediate area with fall blooms having a frequency of occurrence of 0.5, essentially a coin toss. The contrast between years with and without a bloom is emerging as an important ecological driver, which is particularly important on Georges Bank.

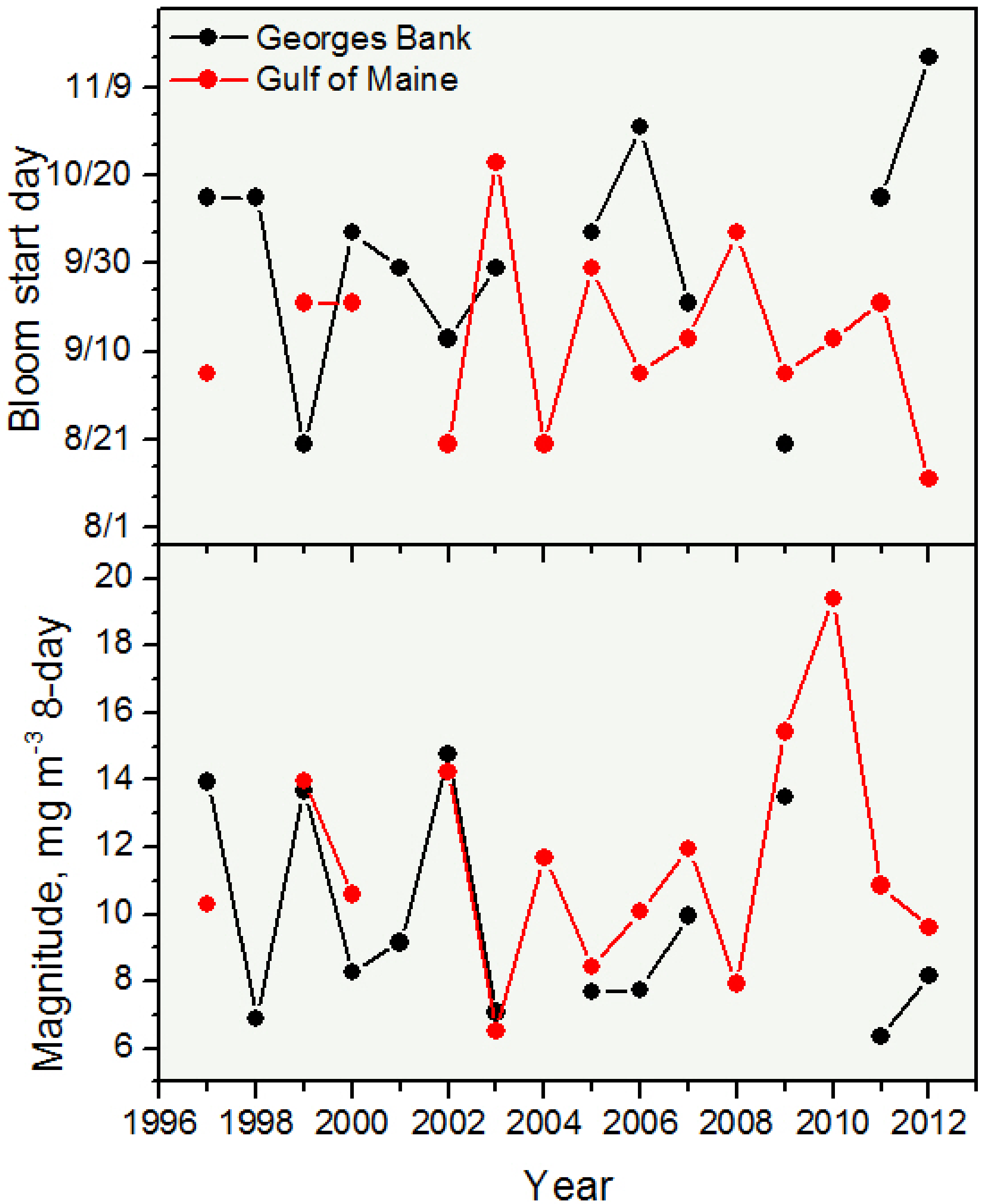
Bloom Magnitude - Climatology and 2012

The dimensions of the fall bloom vary throughout the ecosystem. Here, the fall bloom is characterized as bloom magnitude, or the sum of the chlorophyll concentrations during the bloom period. Bloom magnitudes are highest close to the coastline reflecting the trend of higher chlorophyll concentrations found there (climatology or mean for the years prior to 2012, first panel). However, there tends to be a localized peak in bloom magnitude on the northern flank of Georges Bank. In 2012, fall blooms were detected throughout the eastern Gulf of Maine, but were only found in parts of Georges Bank and Middle Atlantic Bight (2012, second panel). The bloom occurrence in 2012 is a reflections of the fall bloom frequency map found in this Advisory. Resources dependent on the fall bloom in those areas where the bloom did not develop will experience a deficit in food resources.



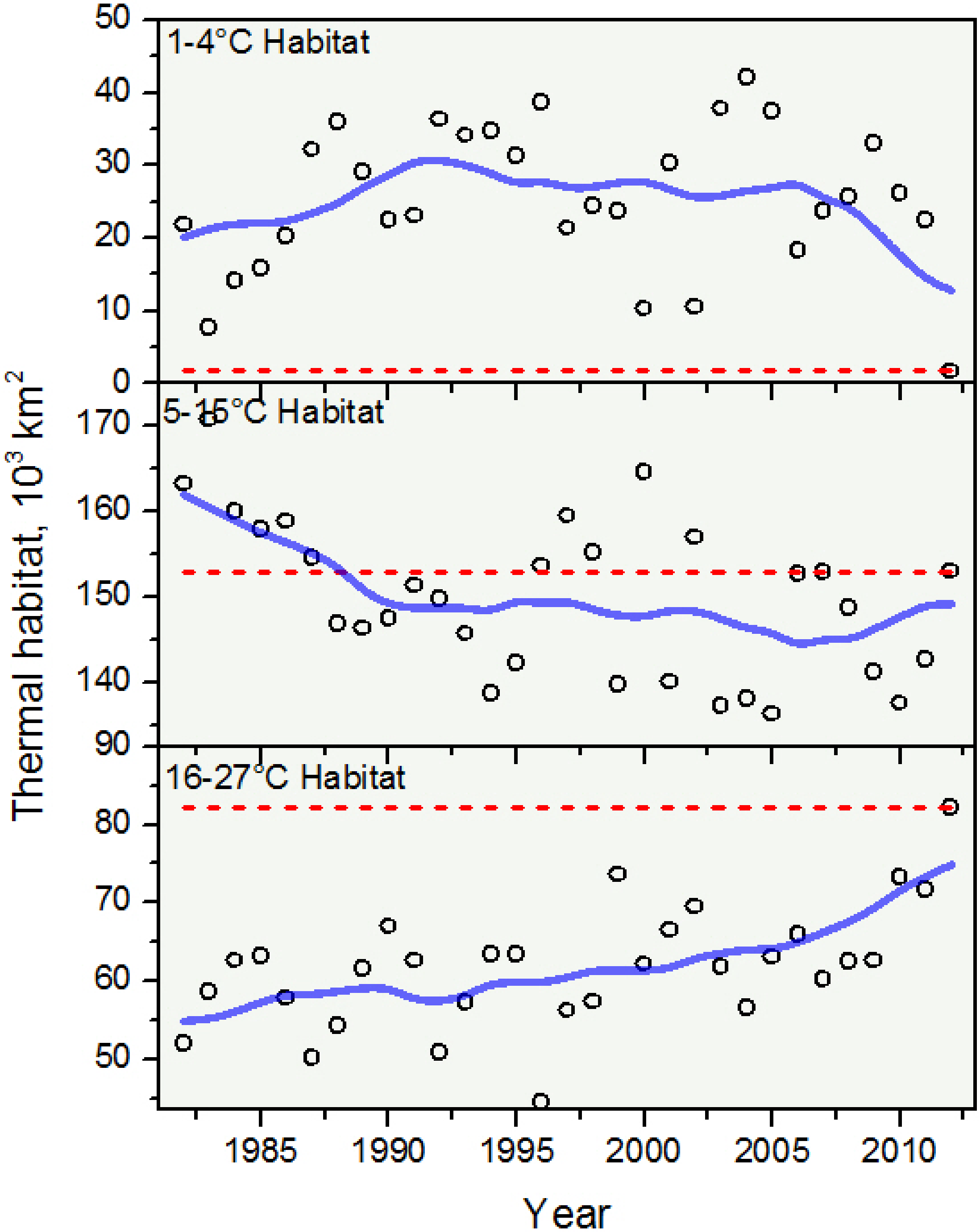


Bloom Start Date and Magnitude



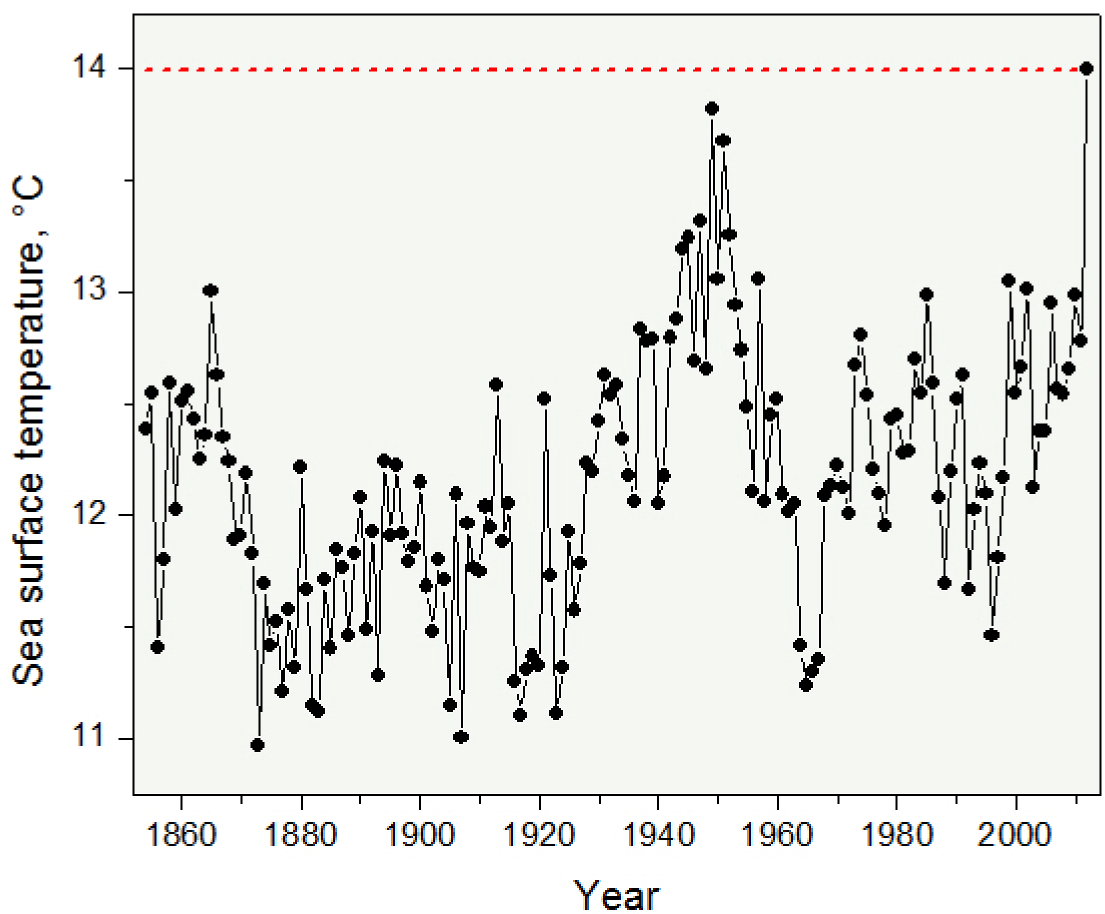
Fall bloom start day and magnitude on Georges Bank and in the Gulf of Maine are characterized by highly variable time series, however, there are no obvious trend to these data. Start day for the fall bloom on Georges Bank ranges from mid-August to mid-November, with three years where no bloom was detected in the ecoregion (see upper panel). The fall bloom in the Gulf of Maine tends to start two weeks earlier than on Georges Bank, during mid-September versus early October, respectively. In 2012, the time series extremes of late and early fall booms were observed in the Gulf of Maine and on Georges Bank, respectively. Fall bloom magnitude is similar in the two areas averaging around 10 over the time series (see lower panel). The 2012 magnitudes were approximately 9 in the two areas.

Ecosystem Shift in Thermal Habitat



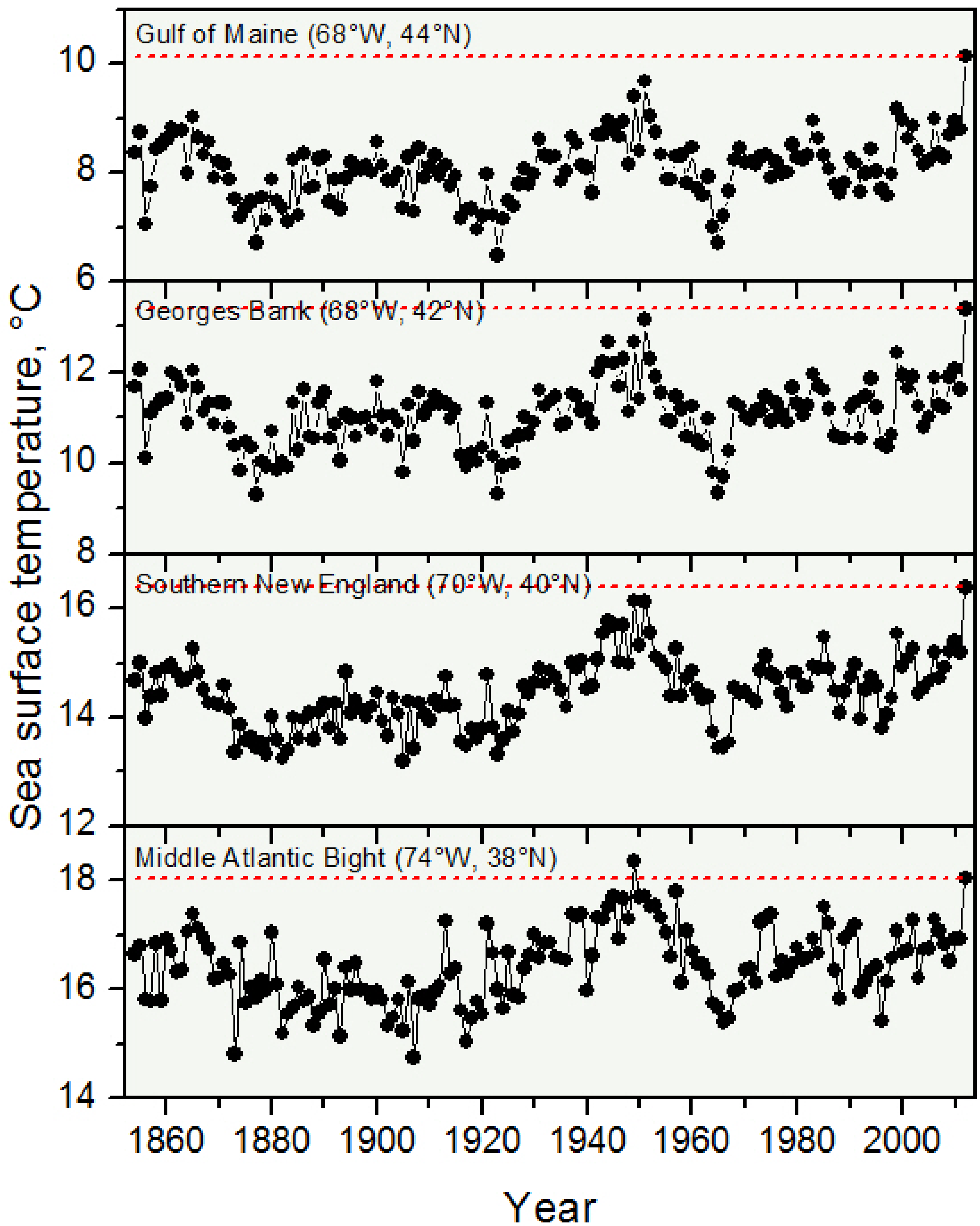
Temperature affects the behavior and physiology of marine organisms, thus it is a key determinant of habitat within the ecosystem. The year 2012 represented a dramatic departure in the quantities of thermal habitat on the Northeast Shelf. Cold water habitats had remained relatively stable over time despite an overall trend of warming in the ecosystem. With 2012 (2012 value marked over the time series with dashed red line), cold water habitats (1-4°C) have virtually disappeared during the course of the year. Cool water habitats (5-15°C) moderated in 2012 to just over 150,000 km^2, an increase that in part reflects the loss of cold water habitats. Warm water habitats (16-27°C) increased to record levels to well over 80,000 km^2 in 2012. The simultaneously cooling and warming affecting the ecosystem in recent decades, actuated by Labrador Current, ended abruptly in 2012 signaling the potential start of a new environmental regime.

Long-Term Temperature Trends



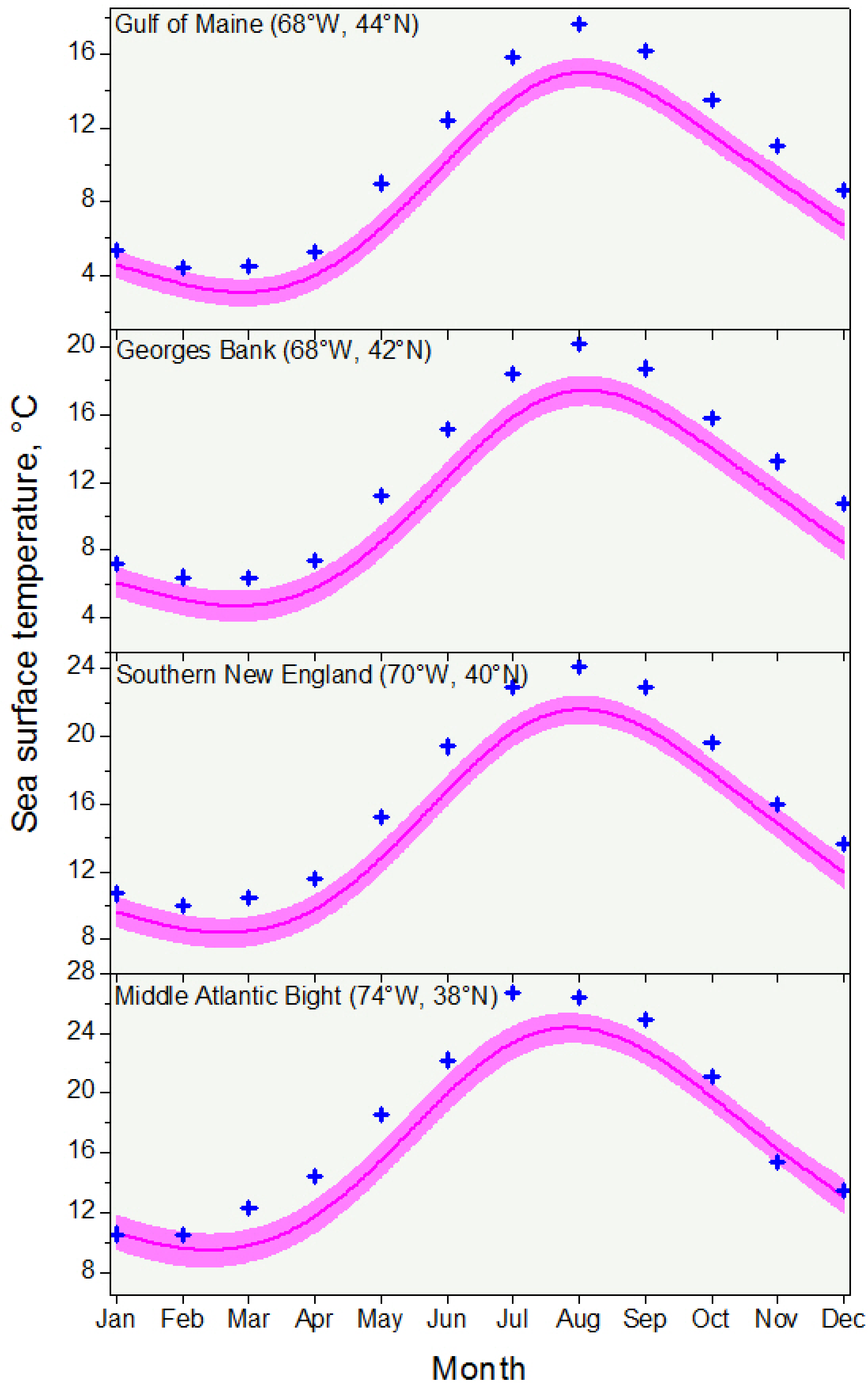
The Northeast Shelf Ecosystem was at a record high SST in 2012 (2012 value marked over the time series with dashed red line) now exceeding the previous record high levels the ecosystem experienced during the 1940s and 1950s. The Extended Reconstructed Sea Surface Temperature (ERSST) dataset includes temperature records back to 1854. The temperature increase in 2012 was the highest absolute jump in temperature seen in the time series and among only five times temperature has changed by more than 1°C.

Long-Term Temperature Trends by Subregion



Sea surface temperatures in three of the four subregion index areas of the Northeast Shelf Ecosystem were at a record highs in 2012 (2012 values marked over the time series with dashed red lines), with the exception of the index area associated with the Middle Atlantic Bight. In all likelihood, the Middle Atlantic Bight temperatures were moderated by the effects of Super Storm Sandy.

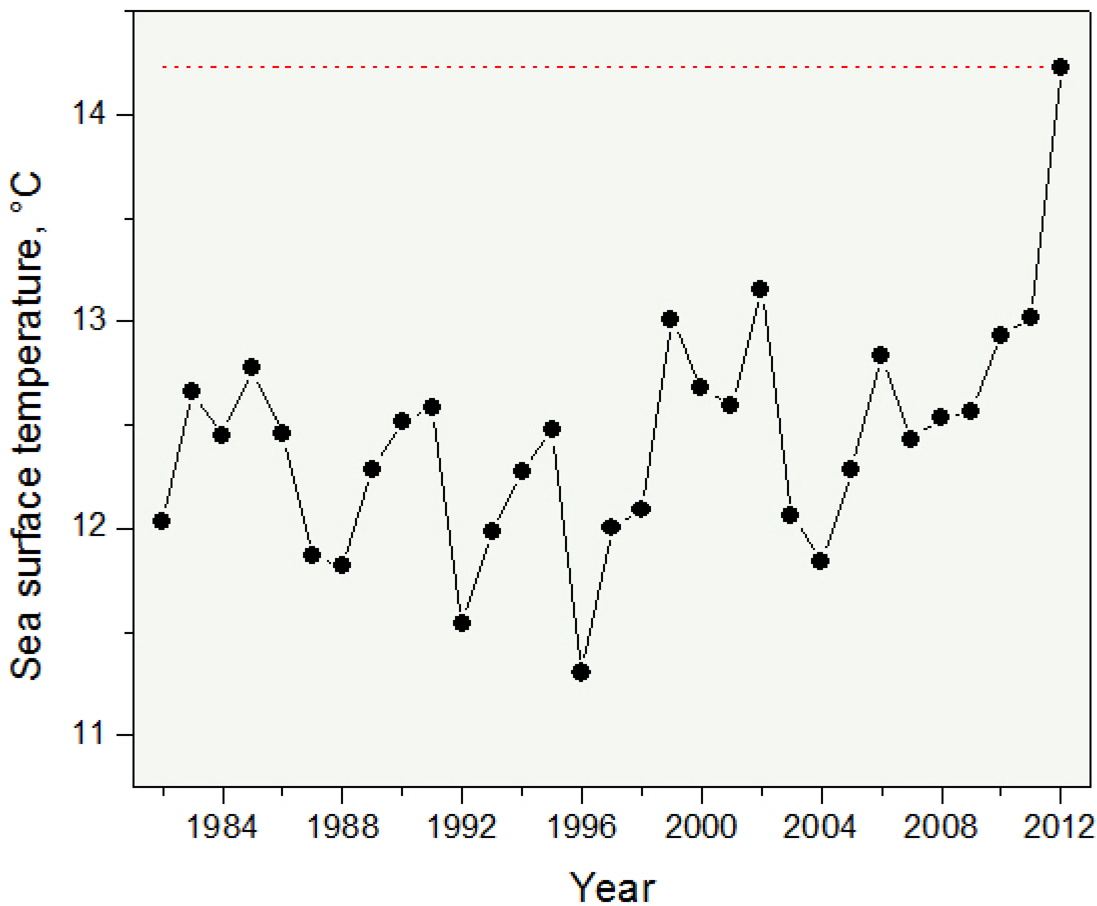
Long-Term Monthly Temperature Trends by Subregion



Gulf of Maine (68°W, 44°N)
Georges Bank (68°W, 42°N)
Southern New England (70°W, 40°N)
Middle Atlantic Bight (74°W, 38°N)
Sea surface temperature, °C
Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

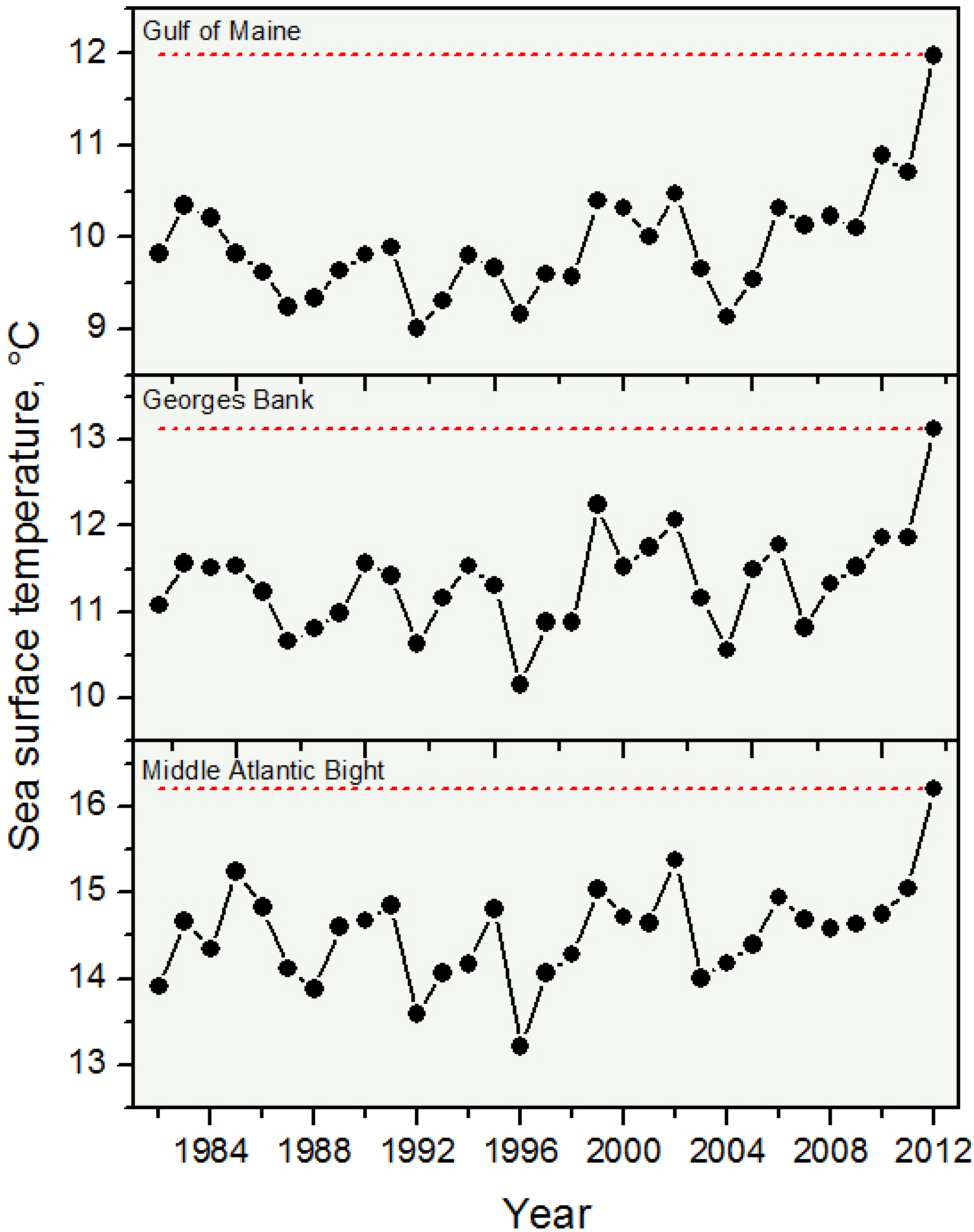
Monthly SSTs during 2012 were well above average in all four Northeast Shelf subregions with the only below average conditions observed in the Middle Atlantic Bight during November. This analysis is based on the full time series of the Extended Reconstructed Sea Surface Temperature (ERSST) dataset, which includes temperature records back to 1854. Monthly mean SSTs in 2012 in four subregions were compared to long term means bounded by confidence bands (magenta line in light magenta region, respectively). The exceptionally low temperatures in November can be attributed to Super Storm Sandy.

Satellite SST Trends



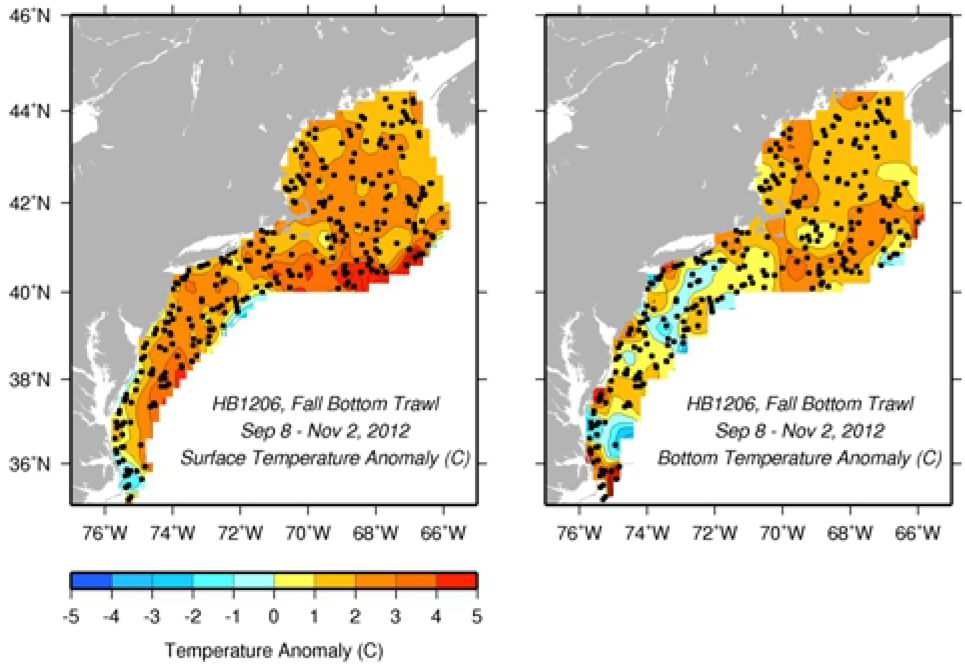
The SST conditions for 2012 were the warmest recorded in the satellite remote sensing data series. The NES SST was in excess of 14°C in 2012 (2012 values marked over the time series with dashed red lines), whereas it has been typically less than 13°C over the past three decades. The annual deviation between 2011 and 2012 was over 1.2°C, which was the highest annual deviation in the time series and only one of four deviations to exceed 1°C.

Ecoregion Satellite SST Trends



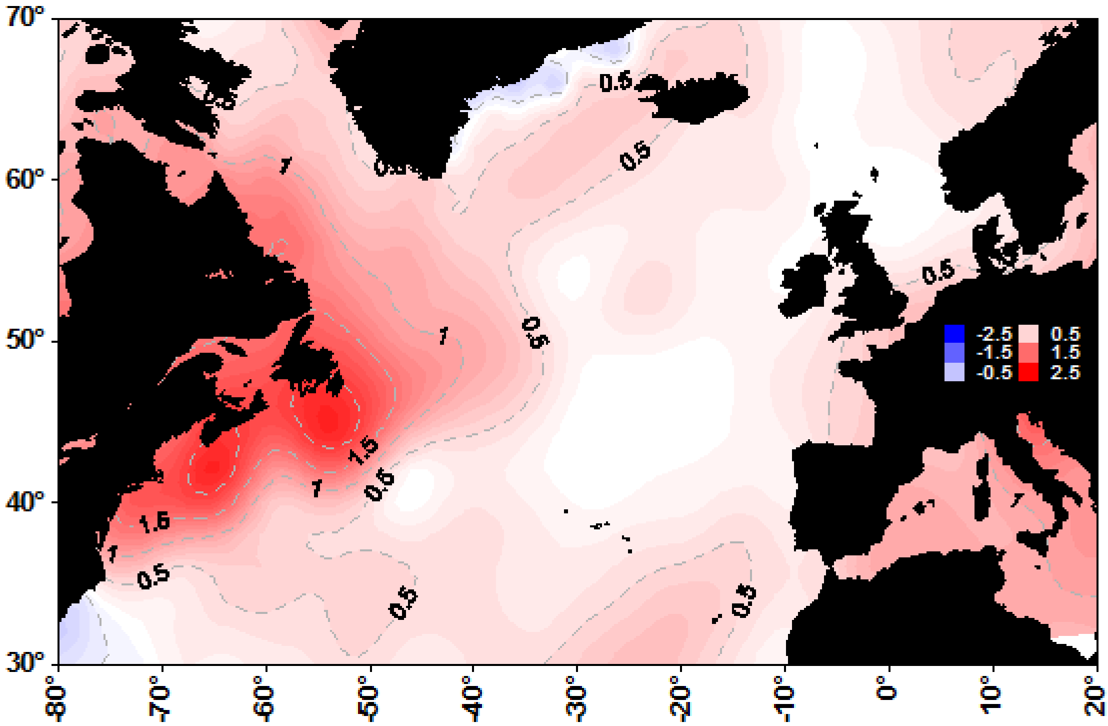
The SST conditions in the three Northeast Shelf ecoregions for 2012 were the warmest recorded in the satellite remote sensing data series. The relative increase in temperature was highest in the Gulf of Maine where the 2012 SST was over 2°C higher (2012 values marked over the time series with dashed red lines) than the baseline means of the previous three decades. The relative increases in the Georges Bank and Middle Atlantic Bight areas were on the order of 1.8°C above the baseline mean.

Temperature from Fall Survey



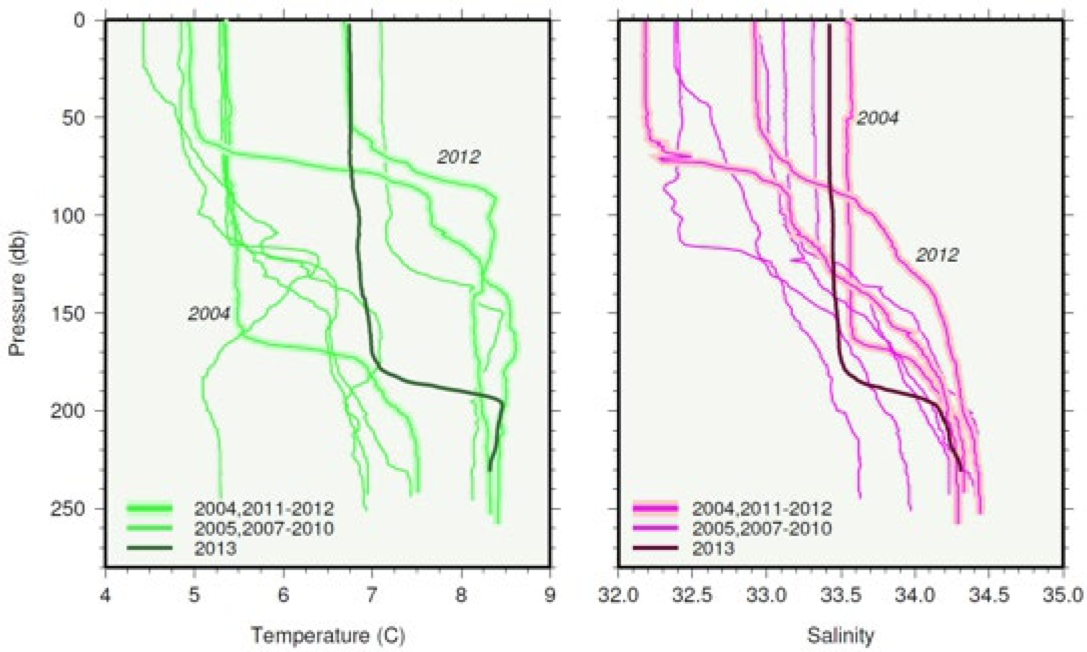
Warming continues to dominate surface ocean temperatures across the northeast U.S. shelf relative to average values (1977-1987), although the magnitude of warming is weaker than was observed during spring 2012. Surface temperature anomalies remained high, exceeding average values by more than 4°C at the surface, but with the greatest warming observed over the mid- to outer-shelf. This surface-warming pattern did not penetrate to the bottom everywhere in the Middle Atlantic Bight, a markedly different pattern than the top-to-bottom warming that was observed during spring 2012. Instead, cooler conditions were observed near the bottom along the mid-shelf offshore of New Jersey and near the mouth of Chesapeake Bay. The mid-shelf cooling is aligned with the so-called “cold pool” in the Middle Atlantic Bight, a seasonal bottom-trapped feature that is formed when winter-cooled shelf water is isolated from the surface by summer heating. The near-bottom cooling patterns observed in fall 2012 suggest that temperatures in the cold pool were lower than average values. Both surface and bottom temperatures in the Gulf of Maine region were warmer than average values, with anomalies exceeding 1°C everywhere. Bottom waters in the Gulf of Maine are largely insulated from surface forcing, so that temperature trends typically reflect changes in the composition of slope waters entering through Northeast Channel.

Northeast Shelf SST in Context to the North Atlantic



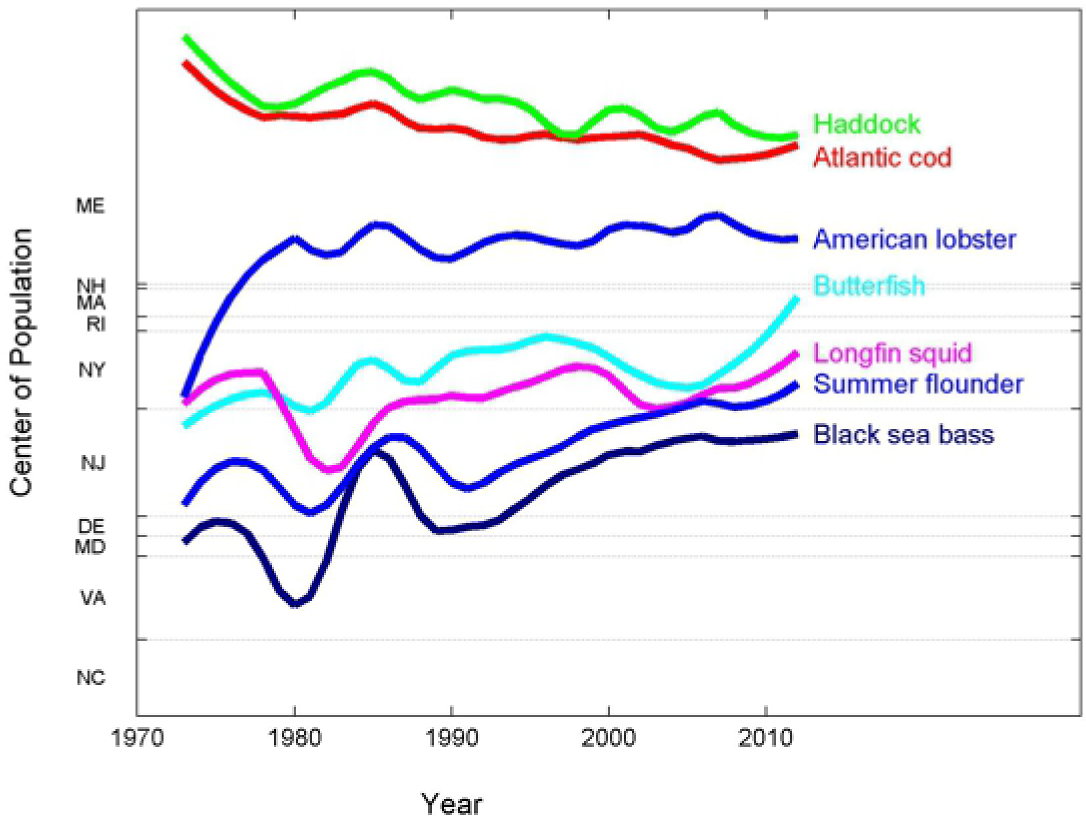
The dramatic increase in sea surface temperature observed for the Northeast Shelf ecosystem is part of a trend seen in Northwest Atlantic temperature conditions. The map figure shows the 2012 SST anomaly compared to the mean of the last 100 years across the North Atlantic basin. SSTs in the Gulf of Maine were on the order of 2°C above the long-term mean, as was the case for the Scotian Shelf and Grand Banks in Atlantic Canada. In contrast, the North and Norwegian seas in the Northeast Atlantic were at or just above the long-term means for those areas. This contrast in SST distribution is in part a reflection of the dependency of the Northeast Shelf and associated shelf seas on the Labrador Current to moderate temperature conditions.

Water Column Structure and Winter Mixing



Seasonal cooling over the Gulf of Maine leads to the formation of homogenous water mass layers extending from the surface to varying depths. The lower limit of these mixed layers, where profiles of temperature and salinity change abruptly from uniformly low to higher values, corresponds with the depth to which vertical mixing penetrates during a given winter. This is an important mechanism for the upward delivery of deep nutrients and for setting the vertical stratification at the start of the spring season. During 2013, winter mixed layers in Wilkinson Basin were historically deep, where temperature and salinity were uniformly mixed to 180 m during February. Historically, winter mixed layer depth in the Gulf of Maine has been highly variable, ranging from 20-180 meters since 2004. Similarly deep mixed layers were last observed in 2004, when surface layers were homogenized to 160 m. Compared with recent years (2011-2012), a significant amount of heat was lost at intermediate depths in 2013, although mixed layer temperatures did not cool to 2004 values. In contrast, near-bottom water masses have remained warm and salty since 2011, suggesting that slope waters continue to be dominated by more nutrient-rich southern sources. While the cause of this year's deep mixing remain unknown, the stratification of the water column at the beginning of winter and the intensity of atmospheric cooling will both be important factors. The deeper vertical mixing has greater potential to tap into nutrient rich slope water at depth and should result in a thicker intermediate layer this spring. However, it is unclear whether either of these factors will have an impact on the timing or intensity of spring phytoplankton blooms.

Along Shelf Position of Some Key Species



Several recent studies have demonstrated that distributions of fish and shellfish are changing on the Northeast U.S. shelf. Using presence/absence data from the NEFSC trawl survey data, we calculated the average along-shelf position of seven fishery species. Along-shelf position is used rather than latitude because of the complex shape of the shelf. The four southern species all showed an upshelf (northeastward) progression over time. To put these shifts in distribution in context, the center of mass of black sea bass shifted from Maryland to northern New Jersey and the center of mass of butterfish shifted from southern New Jersey to Massachusetts. Lobster has also shifted upshelf over time, but at a slower rate than the southern species. In contrast, Atlantic cod and haddock have shifted downshelf. Temperature is generally related to these changes in distribution, but there are likely multiple factors involved including temperature, population size, prey distributions, and predator distributions.