Spring 2011 Update: Annual Condition of the Northeast Shelf Ecosystem

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Northeast Fisheries Science Center

166 Water Street

Woods Hole MA 02543-1026

Phone: (508) 495-2000

Spring 2011 Update: Summary of Conditions of the Northeast Shelf Ecosystem

Summary

- Sea surface temperature (SST) in the Northeast Shelf Large Marine Ecosystem moderated to cool conditions during the second half of 2010 after the exceptionally warm conditions found during the first half of the year.
- There were exceptionally robust spring phytoplankton blooms on the Northeast Shelf; however, the fall bloom was below average. As a result, 2010 had below average chlorophyll *a* concentrations in contrast to the record level set last year.
- Zooplankton biomass levels were below average for the first half of the years (values are not available for the second half of the year).
- Key climate drivers related to thermal conditions on Northeast Shelf were at extreme index levels, which were associated with the warm conditions observed on the Shelf in both short and long time series.
- Core thermal habitats were at a low level in 2010 caused by warming conditions that were not uniform across the ecosystem.
- Dietary breath has been found to vary for key resource species such as cod and haddock; change in this indicator may reflect the impact of habitat and climate change.

Data Sources

SST was derived by combining 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. The data sources were combined to represent trends in chlorophyll *a* during 2009. Chlorophyll *a* is considered a proxy of phytoplankton biomass present in the near-surface water

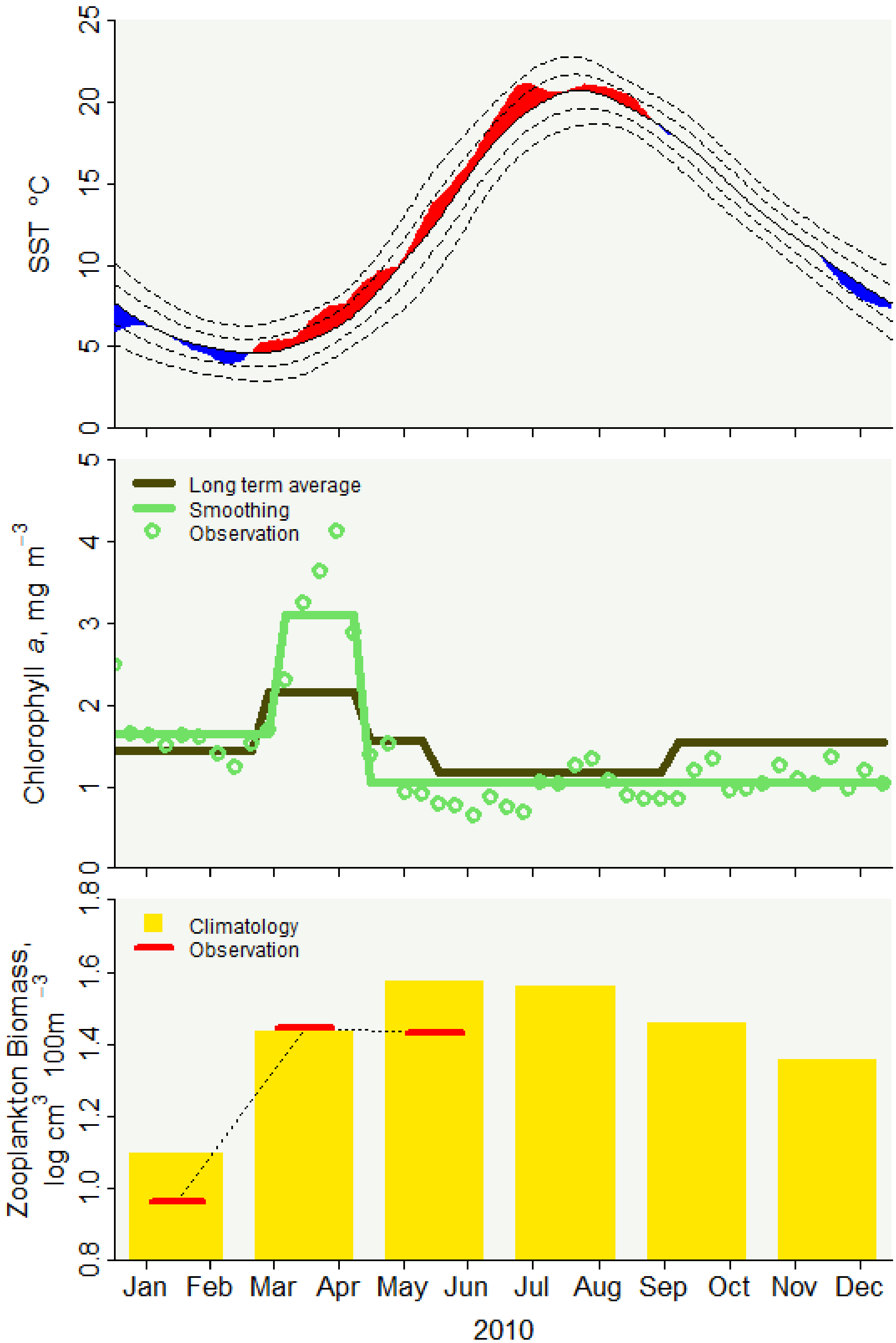
Zooplankton biomass was derived from shipboard surveys of the U.S. Northeast Shelf ecosystem. Zooplankton provide the link from primary producers to higher trophic levels. From 1977-1987, the MArine Resources Monitoring, Assessment, & Prediction (MARMAP) program conducted intensive surveys from Cape 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 3) 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.

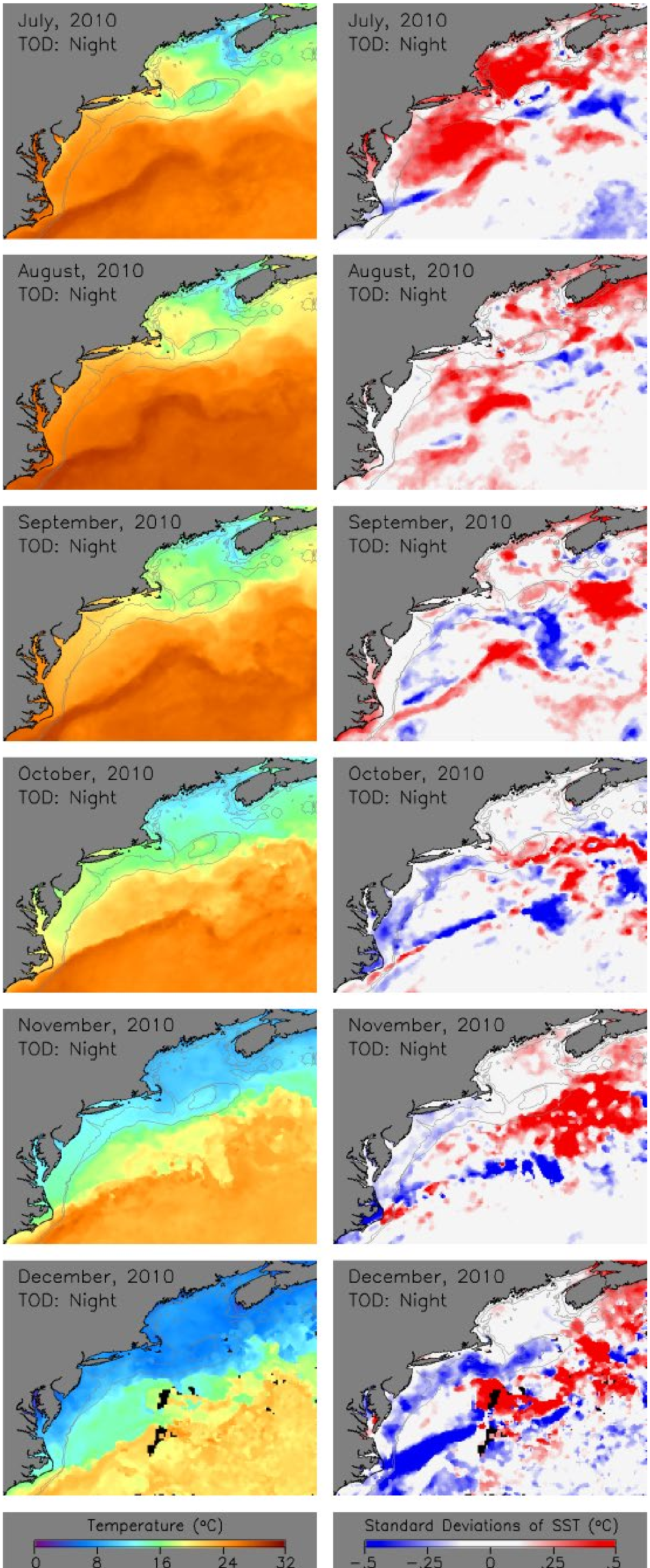
Estimates of dietary breadth were derived from the NEFSC Food Habits Database, collected from shipboard fishery-independent surveys of the northeast U.S. shelf ecosystem.

Fall Conditions



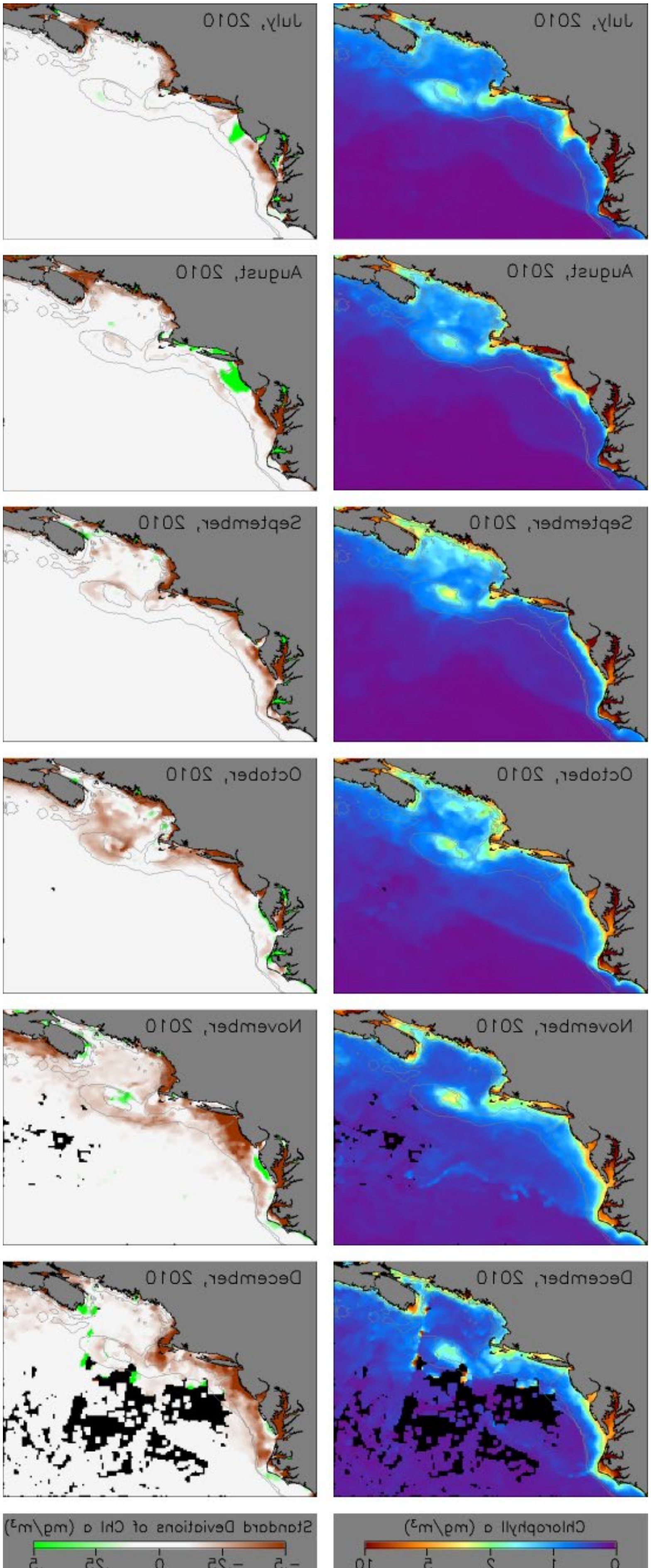
The Northeast Shelf Large Marine Ecosystem experienced moderating sea surface temperatures (SSTs) during the fall of 2010 after the exceptionally warm conditions found on the shelf during spring and summer. SSTs during the second half of the year were generally below average during July and August and declined to below average levels during November into December. The high level of phytoplankton biomass (represented by the high chlorophyll a concentrations in the adjacent figure) observed in the first half of 2010 and associated with the spring bloom was not sustained into the second half of the year. Integrated estimates of chlorophyll concentration were below average level during summer into fall suggesting that fall blooms were poorly developed on the shelf. Zooplankton biomasses are not yet available for the summer and fall of 2010. Samples were collected but owing to the NEFSC participation in the response to the Deepwater Horizon Incident, sample processing from the northeast U.S. continental shelf ecosystem have been delayed.

Sea Surface Temperature Distribution


July, 2010
TOD: Night
July, 2010
TOD: Night
August, 2010
TOD: Night
August, 2010
TOD: Night
September, 2010
TOD: Night
September, 2010
TOD: Night
October, 2010
TOD: Night
October, 2010
TOD: Night
November, 2010
TOD: Night
November, 2010
TOD: Night
December, 2010
TOD: Night
December, 2010
TOD: Night
Temperature (°C)
0 8 16 24 32
Standard Deviations of SST (°C)
-.5 -.25 0 .25 .5

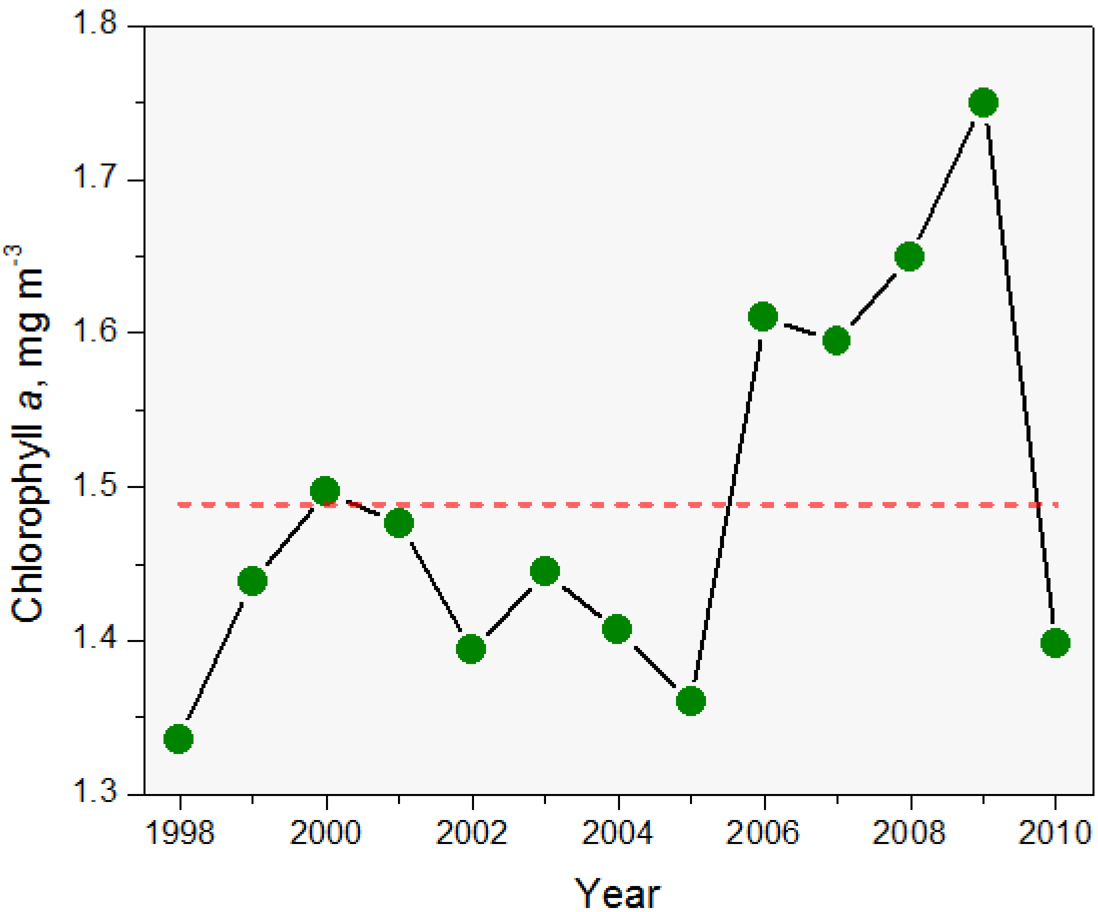
The progression of fall sea surface temperatures (SSTs) during the months of July through December are shown in the left hand set of panels. Higher SSTs appear as warm shades whereas low SSTs appear as cool shades. The right hand set of panels show SST anomalies, those tending to exceed plus or minus one quarter of a standard deviation of the overall SST for the field. The anomaly figures highlight above (red shades) and below (blue shades) average SSTs in a given area. Above average SSTs were observed during the months of July and August reflecting the warm condition found throughout the shelf during spring and the first part of the summer. During September, most of the shelf was at or near average conditions and by October, much of the area south of Cape Cod was below average. By early winter, Georges Bank and the Middle Atlantic Bight were at significantly below average temperatures. Offshore patches of warming and cooling are typically due warm and cold core rings associated with the Gulf Stream. The Scotian Shelf, which is a source of water for the Northeast Shelf, was relatively warm this past fall.

Chlorophyll Distribution


July, 2010
August, 2010
September, 2010
October, 2010
November, 2010
December, 2010
Standard Deviations of Chl a (mg/m^3)
.5
.25
0
-.25
-.5
Chlorophyll a (mg/m^3)
10
5
2
1
0

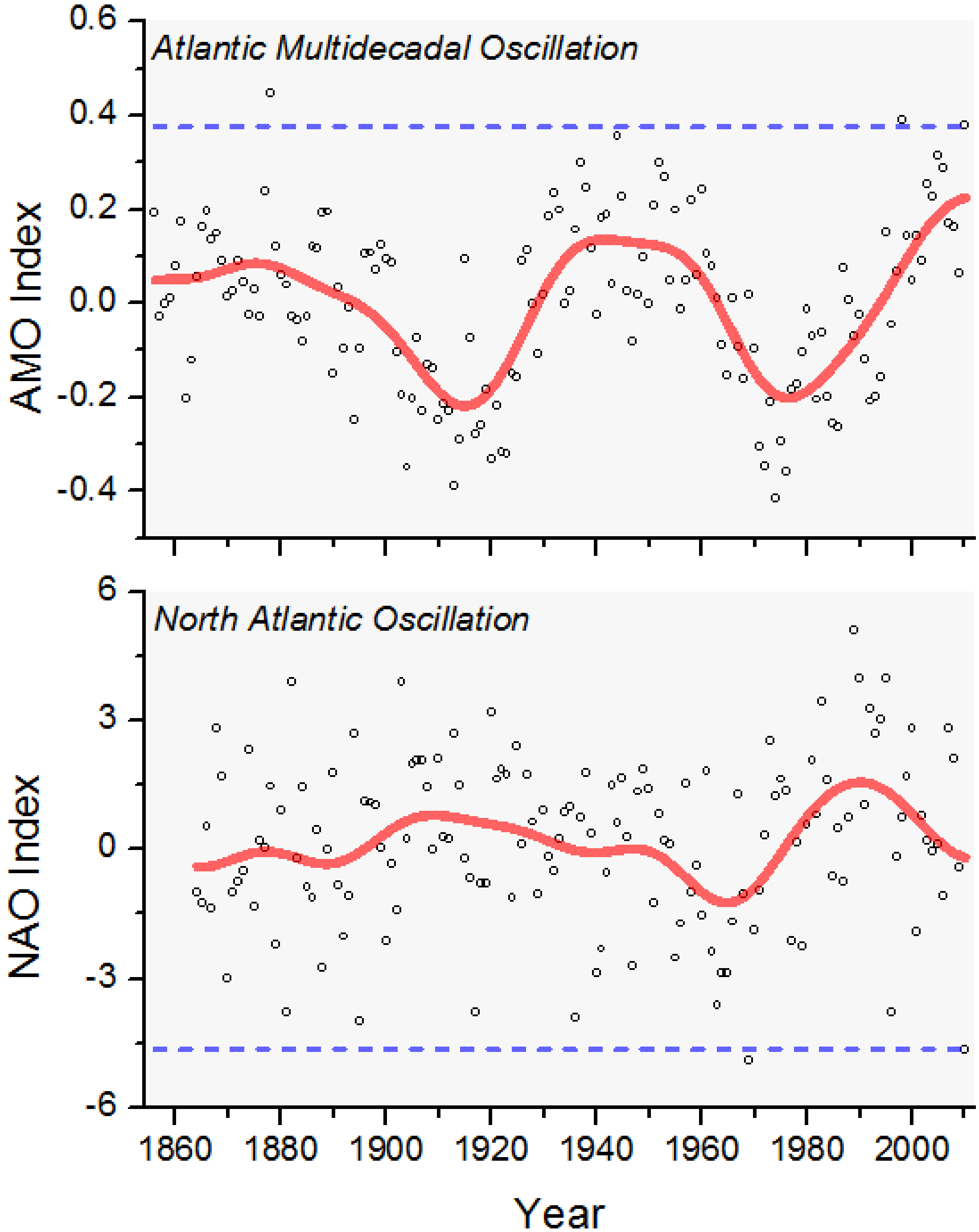
The progression of fall chlorophyll a concentrations during the months of July through December are shown in the left hand set of panels. Higher chlorophyll a concentrations appear as warm shades whereas low concentrations appear as cool shades. The right hand set of panels show exceptional anomalies of chlorophyll concentration, those tending to exceed plus or minus one quarter of a standard deviation of the overall concentration for the field. The anomalies highlight strong blooms in an area (i.e., the green shades) as well as significantly below-average concentrations (i.e., the brown shades). Chlorophyll concentrations were at or below average levels over most of the shelf during summer, with the exception of an August bloom off the New Jersey coast. Fall chlorophyll conditions were generally below average with the exception of some November measurements associated with some parts of Georges Bank and along the Delmarva Peninsula.

Shelfwide Chlorophyll Concentration



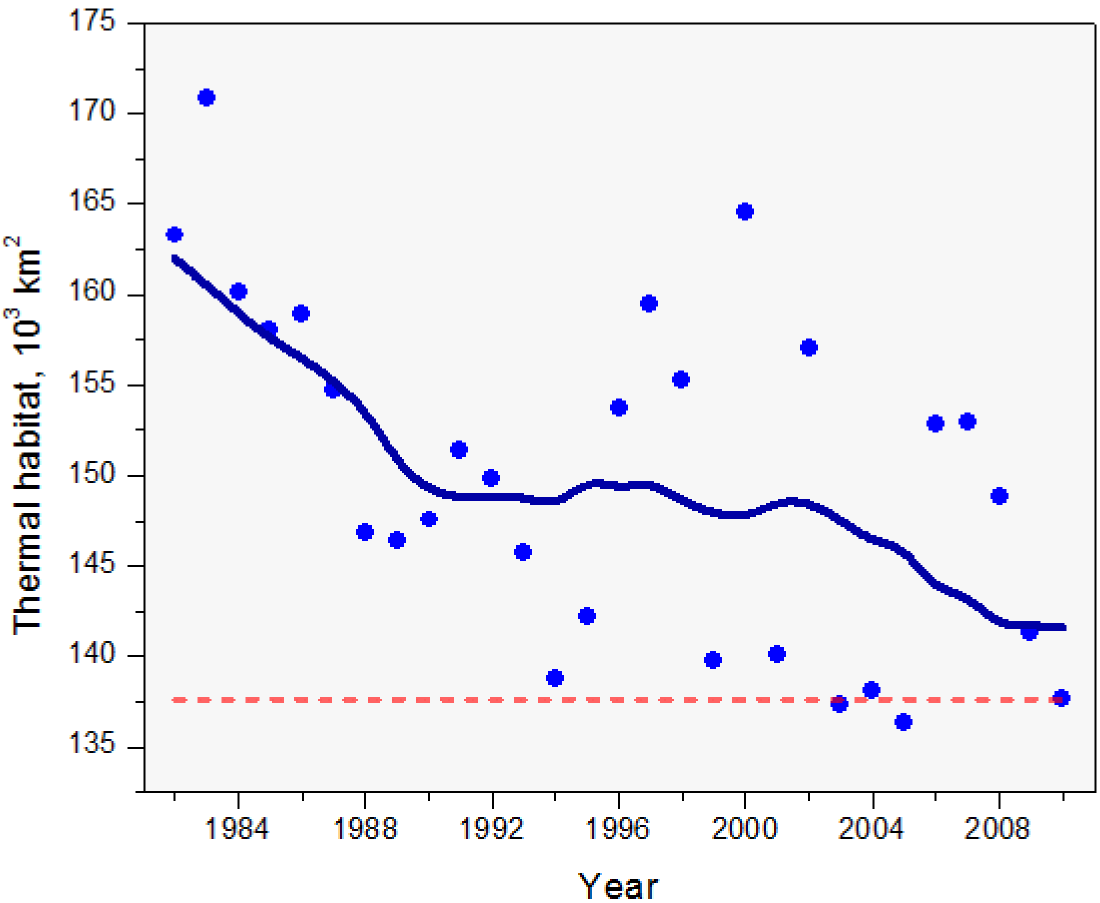
The integrated mean annual chlorophyll concentration for the Northeast Shelf Ecosystem declined dramatically from the time series high set in 2009. The 2010 estimate is well below the time series mean marked by the dashed red line. Despite an above average spring bloom during the first half of the year, chlorophyll concentrations were below average for the second half of the year. This pattern of variation in chlorophyll concentration has the potential of affecting higher trophic levels by providing lower energy inputs than previous years, depending on the type of phytoplankton species comprising the bloom – not all contribute equally to energy transfer to upper trophic levels.

Key Climate Drivers



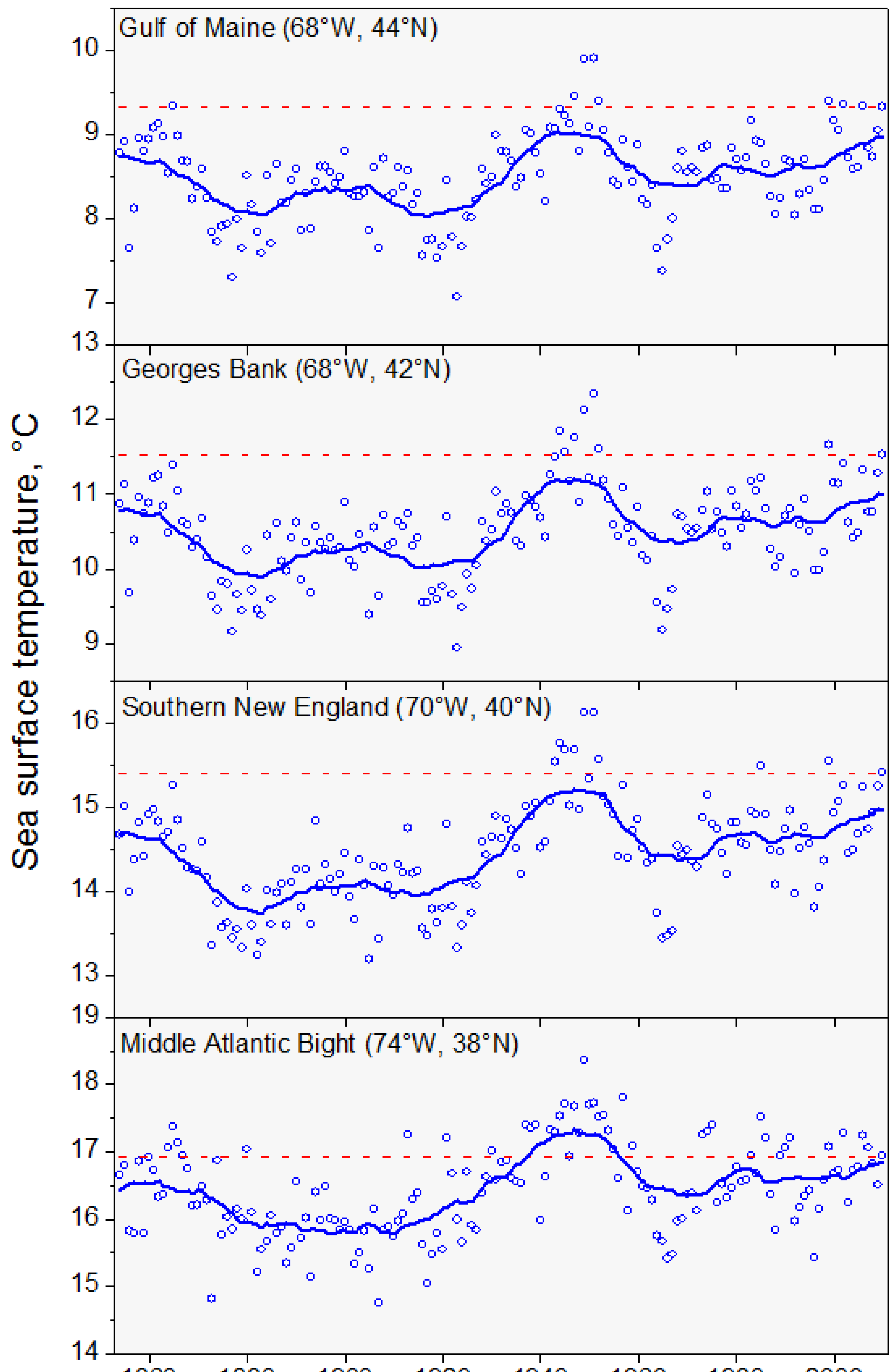
Two key climate drivers affecting the oceanography of the Northeast Shelf Ecosystem are the Atlantic Multidecadal Oscillation (AMO) and the North Atlantic Oscillation (NAO). Multidecadal patterns in sea surface temperature SST) in the North Atlantic are represented by the Atlantic Multidecadal Oscillation (AMO) index, which has been linked to the poleward shifts of fish distributions on the northeast U.S. shelf. The AMO has been in a warm phase (positive) since 1997, a trend that continues with the 2010 level (marked in the time series with the dashed blue line) which was the third highest in the time series. The warm phase is expected to continue for the next 10-20 years. This (NAO) index has been related to key oceanographic and ecological processes in the Northern hemisphere and is associated with alternate states of wind and weather in regions associated with the North Atlantic Basin. Since 1972, the NAO has primarily been in a positive state, although one-year reversals to a negative state have occurred. Changes in the NAO have been linked to changes in plankton community composition in the North Atlantic, reflecting changes in both the distribution and abundance of warm and cold-temperate species. In 2010, the winter NAO index was strongly negative (marked in the time series with the dashed blue line); this was the second lowest value of the index time series.

Ecosystem Shift in Thermal Habitat



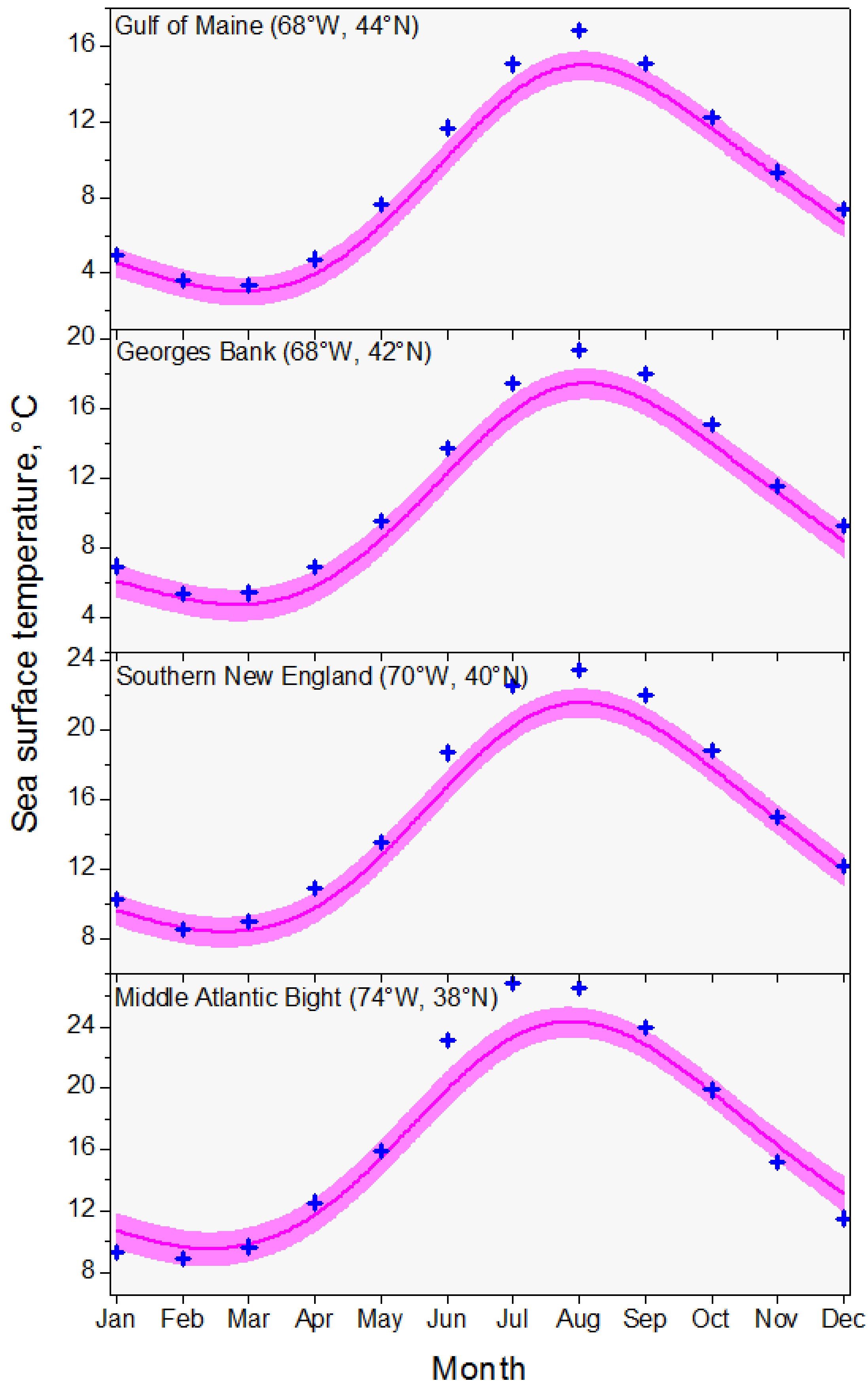
Temperature is one of the most important factors defining the habitat of marine organisms. Thermal conditions affect the growth and development of fish and shellfish, and differentially affect the survival of different life stages. Recent analyses of the amount of surface thermal habitat on the Northeast Shelf over the past 29 years reveal a trend of constriction of the core thermal habitats of the Northeast Shelf ecosystem. Core thermal habitats represent year round habitats ranging from 5 to 15°C, whereas peripheral thermal habitats are only available during parts of the years, i.e. the winter and summer. Core thermal habitats have been declining over time (see figure), with the 2010 estimate of approximate 138,000 km2 being one of the lower values in the time series (marked by red dashed line). The ecosystem appears to have been affected simultaneously by both cooling and warming effects; cooling was most likely actuated by inputs from the Labrador Current and warming by increased temperatures observed in the Middle Atlantic Bight.

Long Term Temperature Trends


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
10
9
8
7
13
12
11
10
9
16
15
14
13
19
18
17
16
15
14
1860
1880
1900
1920
1940
1960
1980
2000

The Northeast Shelf Ecosystem continues its warming trend and in many areas is approaching the record high levels the system experienced during the 1940s and 1950s. The Extended Reconstructed Sea Surface Temperature (ERSST) dataset includes temperature records back to 1854. Monthly mean SSTs in 2010 in four subregions of the ecosystem (Gulf of Maine, Georges Bank, Southern New England, and the Middle Atlantic Bight) were compared to long term trends in SST (dashed magenta line marks 2010, blue line is smoothed trend). The northern subareas of the ecosystem were well above the recent trends in the data and amongst the highest values in the time series, whereas the annual mean 2010 SST for the Middle Atlantic Bight was essentially equal to the trend.

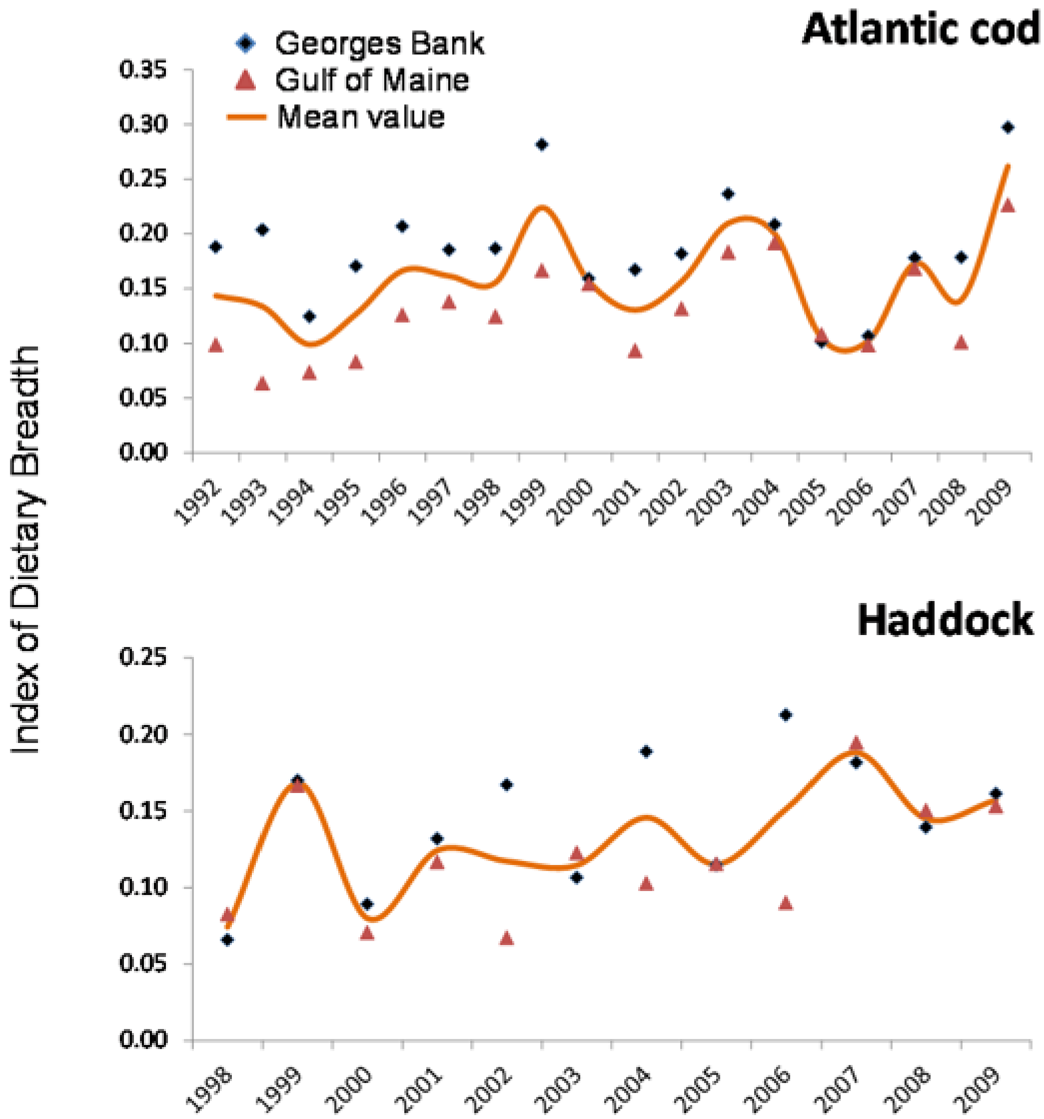
Long Term Monthly Temperature Trends



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
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

All subregions of the shelf ecosystem showed warmer than average summer temperatures and generally average winter temperatures. The Extended Reconstructed Sea Surface Temperature (ERSST) dataset includes temperature records back to 1854. Monthly mean SSTs in 2010 in four subregions (Gulf of Maine, Georges Bank, Southern New England, and the Middle Atlantic Bight) were compared to long term means bounded by confidence bands (magenta line in light magenta region, respectively). In 2010, monthly SSTs for the Gulf of Maine were close to the long-term average early in the year, but were well above average during the spring and summer months. A similar pattern can be seen in the monthly temperature data for Georges Bank and Southern New England. In the Middle Atlantic Bight subregion, winter temperatures were below average while summer temperature, in particular the temperature for June and July, were significantly above the long term mean. These data underscore how thermal properties within the ecosystem are not uniform.

Dietary Breadth of Cod and Haddock



Annual estimates of dietary breadth were evaluated to detect trends in groundfish foraging patterns on Georges Bank and the Gulf of Maine of the northeast U.S. continental shelf. This preliminary analysis examined two economically-important gadid species: Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) during the period 1992-2009. Here, diet diversity or breath was quantified with a diet index (Levin's index) where high values equate to a more generalist diet (wider prey field) and low values equate to specialist feeders. As expected, Atlantic cod was a more opportunistic feeder than haddock (Levin's index = 0.26 vs. 0.16 in 2009). Cod fed on a broad range of benthic and pelagic invertebrates and fishes, whereas haddock ate primarily benthic invertebrates, consuming ophiuroids, polychaetes, gammarids, and other small benthic items. Interestingly, the dietary breadth of both species was generally lower in the Gulf of Maine. This was due to a dominance of certain prey taxa (Atlantic cod: Atlantic herring [*Clupea harengus*] and unidentified fish remains; haddock: ophiuroids) seen in the Gulf of Maine. Levin's index also varied 2-3 fold throughout the time series, and mean values over the continental shelf may be increasing for haddock since 1998. Continued monitoring of dietary breadth can determine whether these trends in fish feeding are temporary or long-term events. Additionally, the use of this index as an ecological indicator of changes in prey availability due to a host of variables (e.g. climate forcing and anthropogenic disturbance) holds merit for select species and warrants further investigation.