# Spring 2016 Update: Annual Condition of the Northeast Shelf Ecosystem

Produced by the Ecosystem Dynamics and Assessment Branch

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# Current Conditions of the Northeast Shelf Ecosystem -- Spring 2016 Update

## Summary


- Sea surface temperatures (SSTs) in the Northeast Shelf Large Marine Ecosystem during 2015 continue to be above average; in some season/area time series, 2015 was the second warmest year on record.
- The fall bloom on the Northeast Shelf was well developed, covering a large area including Georges Bank and much of the Gulf of Maine. There was also a large fall bloom in the Middle Atlantic Bight, which had the earliest start date of the time series.
- Cool water habitats (5-15°C), which form the core thermal habitats of the Northeast Shelf, were reduced in area to their lowest level in the time series during 2015.
- The arrival of the fall thermal transition has gotten progressively later over the past two decades; the 2015 transition in the Middle Atlantic Bight was the latest in the time series.
- The fall distribution of fish and invertebrate species sampled by the NEFSC is portrayed by kernel density plots and the assessments of species distributions using both along-shelf distance and depth. The dominant movement of species has been to the Northeast and into deeper water.
- Summer and winter wind speeds have changed over time, thus impacting the movement of water masses and organisms in the ecosystem.
- The strength of temperature fronts has increased over much of the Northeast Shelf; the 2015 frontal magnitudes for Northeast Shelf ecoregions were the highest in the time series.


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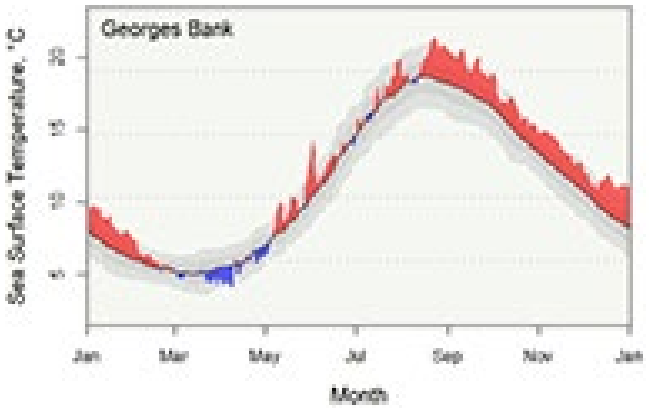
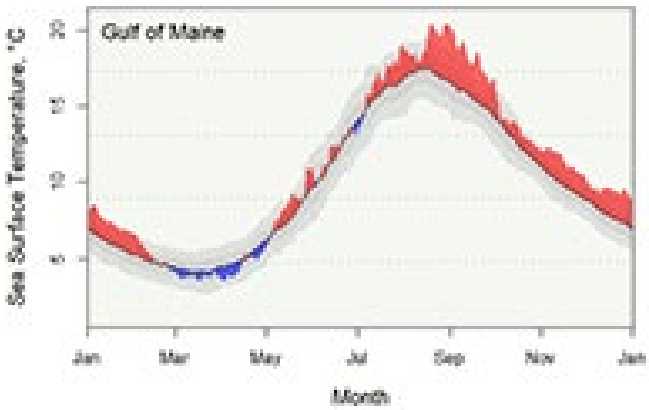
## Fall Sea Surface Temperature - Northeast Shelf Ecosystem

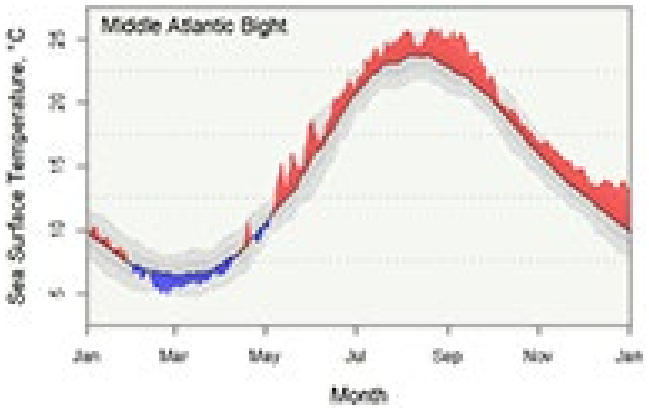
The Northeast Shelf Large Marine Ecosystem experienced above-average sea surface temperatures (SSTs) during the fall of 2015, after a period of below-average temperature during spring. **In each graph** the long-term mean SST is shown as a dark gray line, with areas representing plus and minus 1 and 2 standard deviations of the mean as progressive shades of gray, respectively. SSTs for 2015 above the mean are shown in red and below the mean in blue. Though all areas show above-average summer-into-fall temperatures, SSTs were well above the mean in the northern end of the ecosystem, as seen in the Gulf of Maine, Georges Bank, and Scotian Shelf subareas (see figures). Many days were above the mean by more than 2 standard deviations in these areas. SSTs were at or just above the long-term means during October of last year in the Middle Atlantic Bight and Gulf of Maine, representing the only temperature moderation during the fall season.



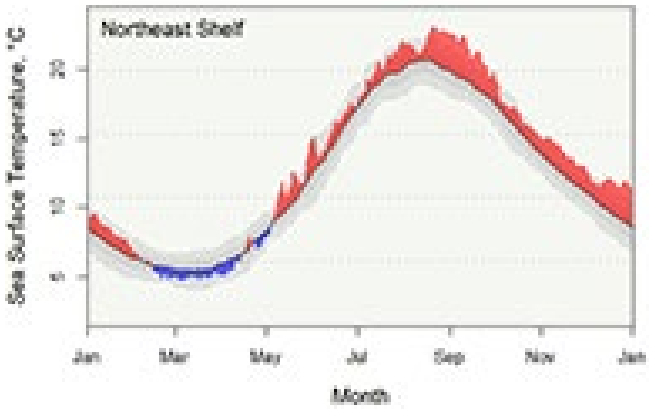

Georges Bank



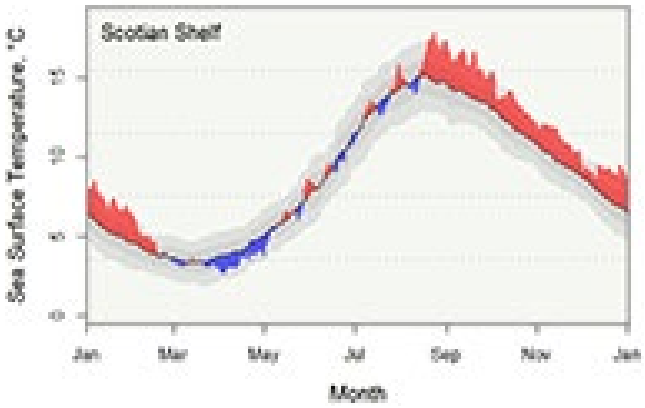

Gulf of Maine




Middle Atlantic Bight




Northeast Shelf




Scotian Shelf

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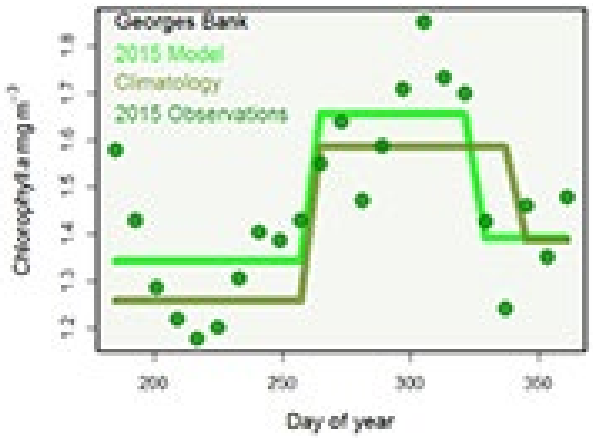
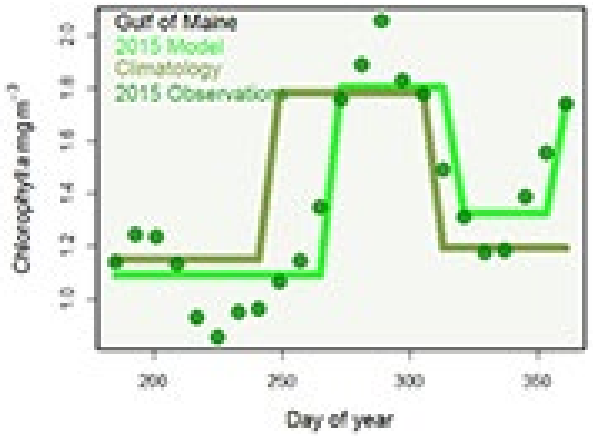
# Fall Bloom Development on the Northeast Shelf

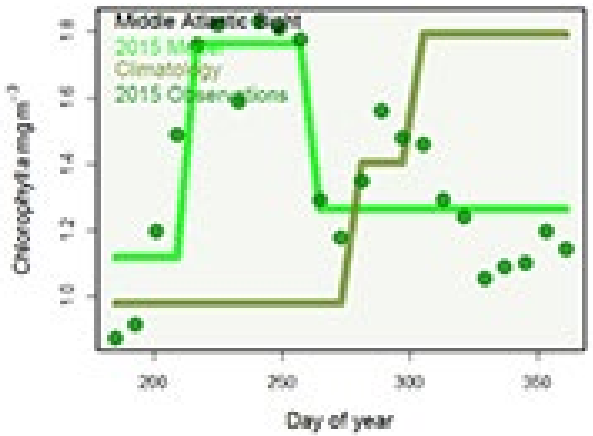
There were well-developed fall blooms detected in the Gulf of Maine and Georges Bank areas, though the bloom in the Gulf of Maine started later in the year than typical (see **figures**). The blooms were of shorter duration than the climatological pattern and had average bloom chlorophyll levels that matched climatological levels of 1.7 - 1.8 mg $m^{-3}$ during the peak of the bloom. The Scotian Shelf subregion, which typically has a fall bloom, had a highly variable pattern of chlorophyll concentrations. A distinct fall bloom is not typical of the Middle Atlantic Bight area, but a bloom developed this year during July, with bloom chlorophyll levels peaking at 1.8 mg $m^{-3}$. The composite depiction of the bloom pattern for the Northeast Shelf reflects the fall blooms in the Gulf of Maine and Georges Bank, but can also be seen to affect the Middle Atlantic Bight.



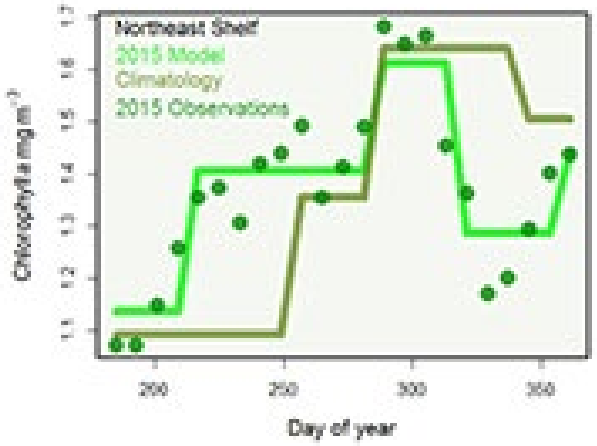

Georges Bank



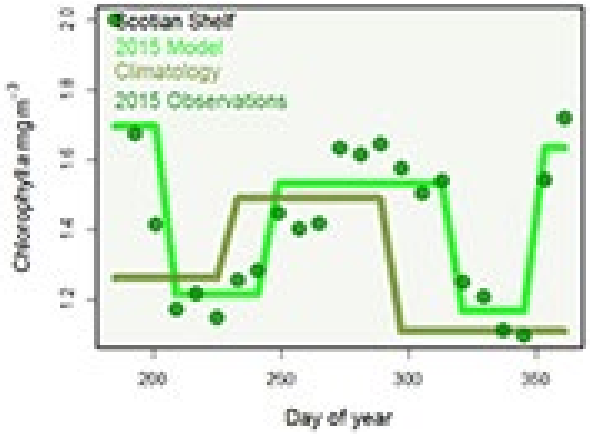

Gulf of Maine




Middle Atlantic Bight




Northeast Shelf




Scotian Shelf

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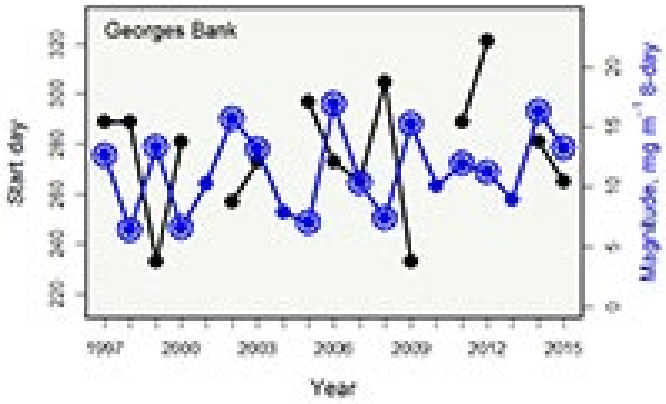
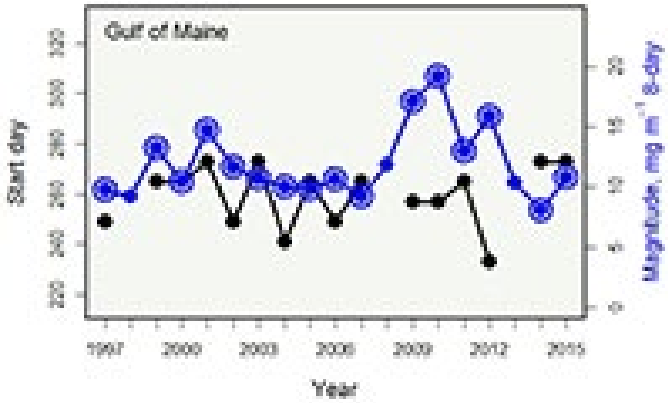
# Fall Bloom Start Day and Magnitude

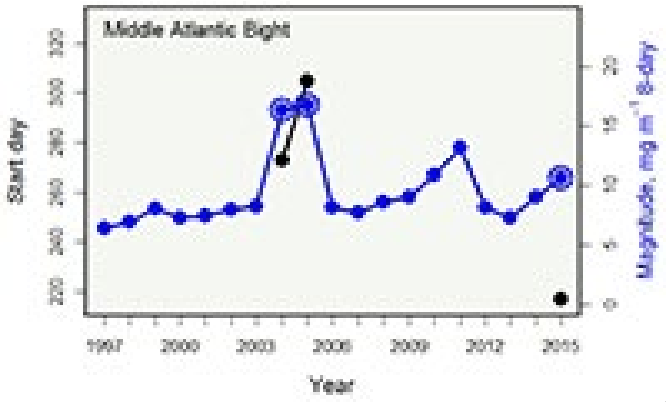
Fall blooms have been most frequently detected in the Georges Bank, Gulf of Maine, and Scotian Shelf regions. In 2015, blooms were detected in all areas of the Northeast Shelf. The **time series figures** for these regions show the start day of detected blooms (black circles) and bloom magnitudes for both detected blooms (large blue circles) and climatological bloom magnitudes for years where a bloom was not detected (small blue circles). The blooms were average size in terms of the bloom magnitude index, in most areas. With the exception of the early bloom in the Middle Atlantic Bight, bloom timing approximated the average in most areas.



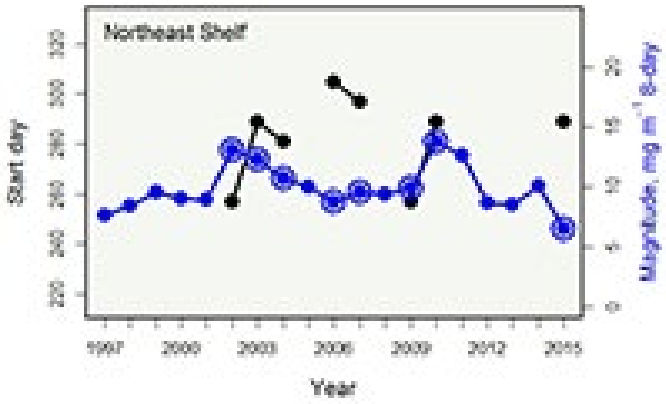

Georges Bank



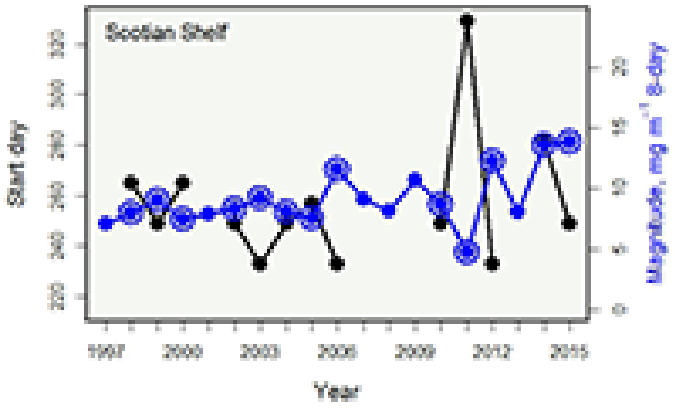

Gulf of Maine




Middle Atlantic Bight




Northeast Shelf




Scotian Shelf

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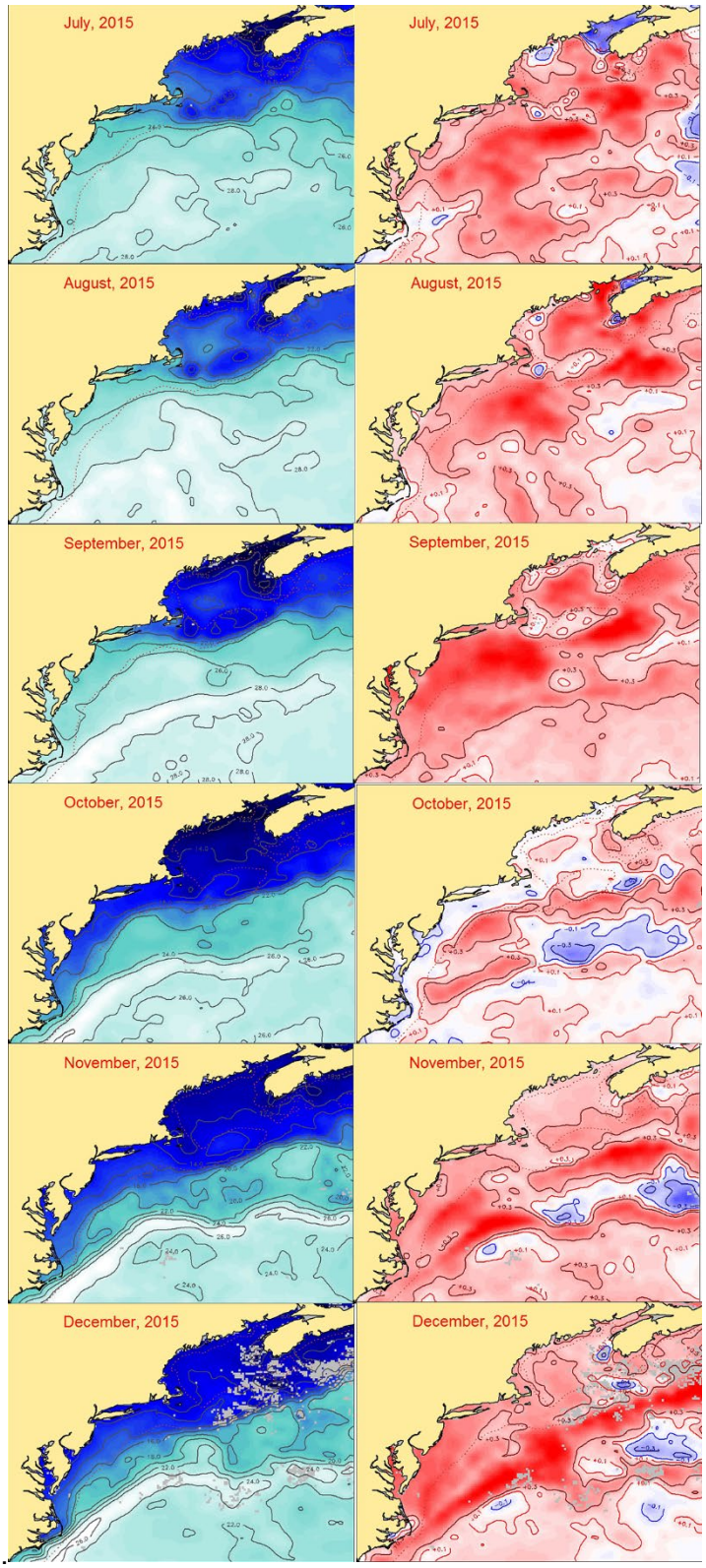
# Fall Sea Surface Temperature Distribution

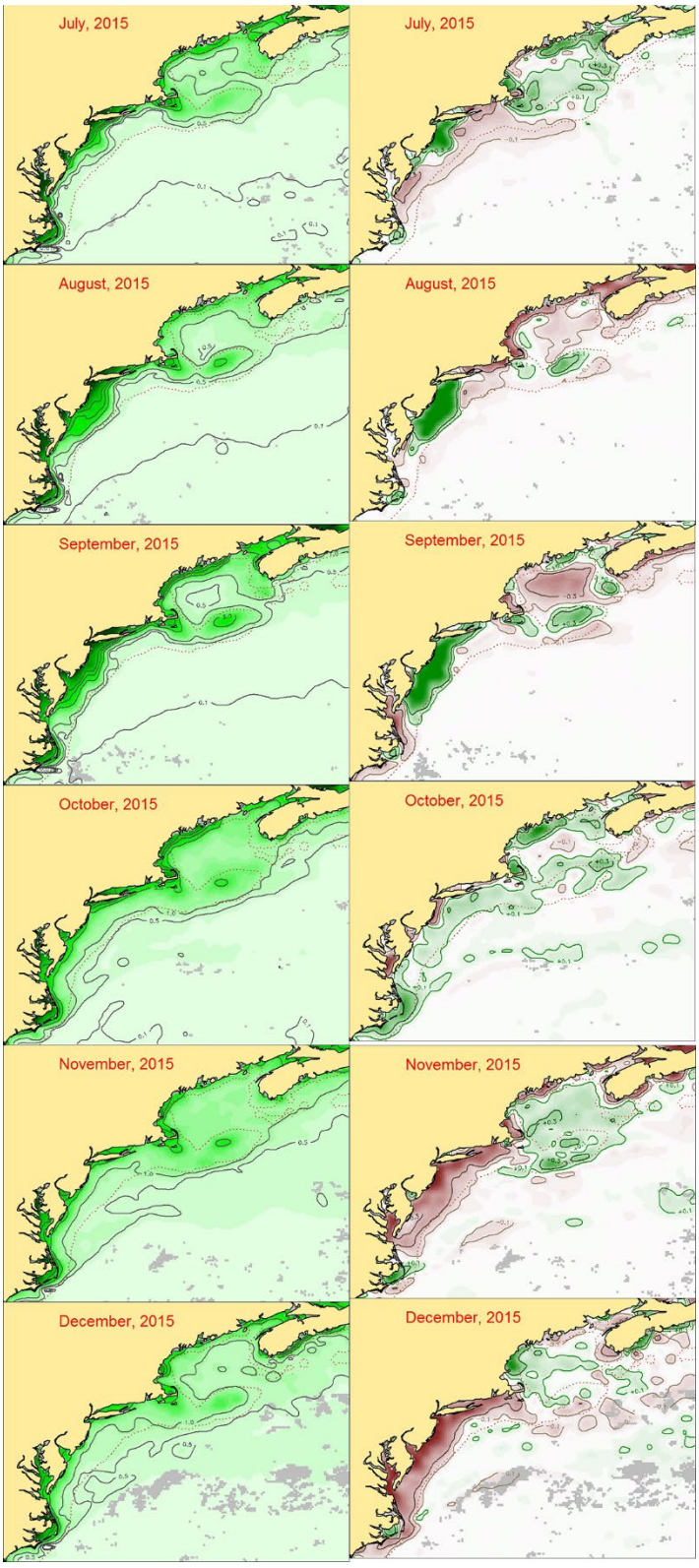
The progression of fall sea surface temperatures for the months of July through December are shown in the interactive figure on this page. SSTs appear as progressive shades of cyan to blue in the top six icons. Anomalies of SST -- those tending to exceed plus or minus one quarter of a standard deviation of the overall SST for the field -- are in the bottom six 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 Northeast Shelf was generally well above average temperature during the months July through December with the exception of October, when most of the shelf SST were




around the long-term mean.

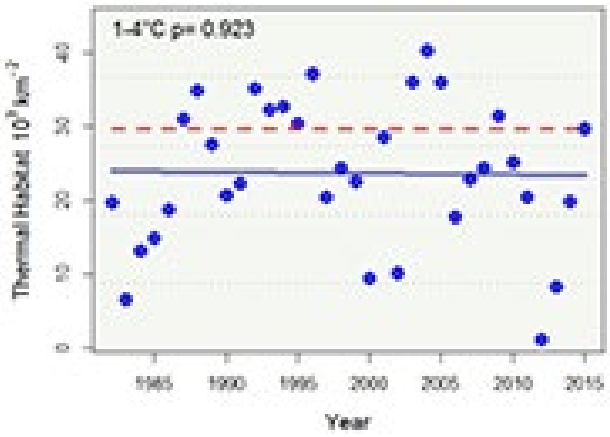
# Fall Chlorophyll Distribution

The progression of fall chlorophyll concentrations for the months of July through December are shown in the interactive figure on this page. Chlorophyll concentrations appear as progressive shades of green in the top six 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 bottom six icons. This type of anomaly tends to highlight strong blooms in an area (green shades) and weak blooms in an area (brown shades). A large fall bloom developed off the coast of New Jersey during July; this bloom continued to enlarge and intensity during August into September. The Gulf of Maine bloom can be seen off the Maine coast in October, with much of the Gulf of Maine and Georges Bank in bloom condition through November.

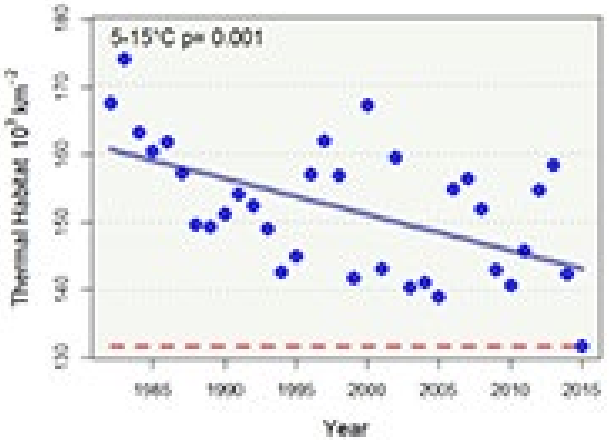



# Ecosystem Shift in Thermal Habitat

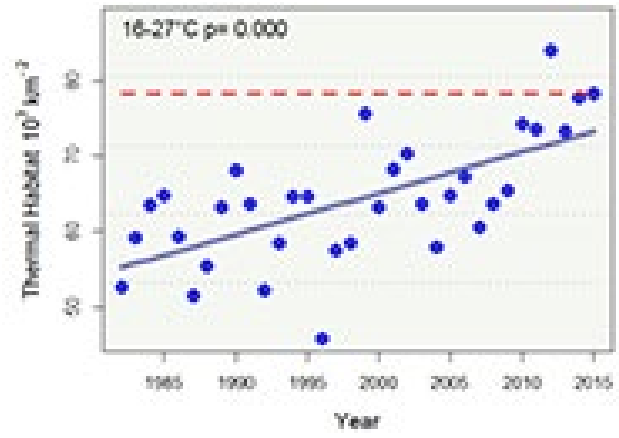
Temperature affects the behavior and physiology of marine organisms; thus it is a key determinant of habitat within the ecosystem. The area of cold water habitats (1-4°C) shows no time series trend despite extremely low values in recent years. **Cold water habitats** in 2015 were approximately 30,000 $km^2$. (2015 value marked over the time series with dashed red line, linear trend shown with blue line, regression model significance shown in upper left.) **Cool water habitats** (5-15°C) show a negative trend over time, declining on the order of 531 $km^2$ $yr^{-1}$, which is matched by a corresponding increase in **warm water habitats** (16-27°C) at a rate of 545 $km^2$ $yr^{-1}$. The cool water habitats were the lowest of the time series at 132,000 $km^2$.




NES cold water habitats




NES cool water habitats




NES warm water habitats

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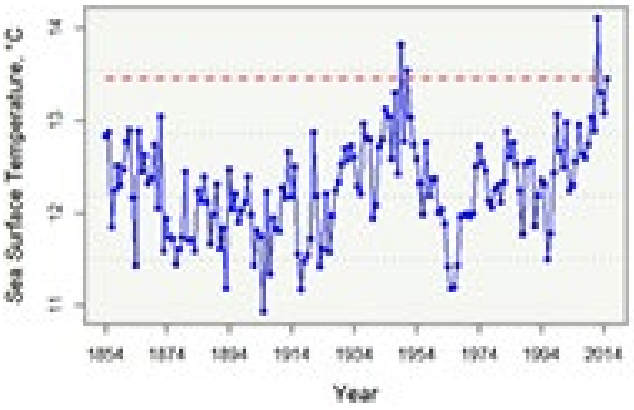
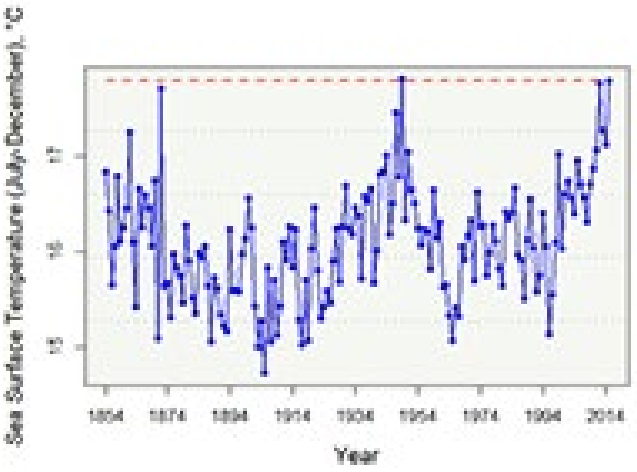
# Long-Term Temperature Trends for the Northeast Shelf Ecosystem

The Northeast Shelf Ecosystem was at a record high SST in 2012. The **2015 annual mean level** (2015 value marked over the time series with dashed red line) was slightly higher than the 2014 value and the fourth highest SST in the time series. The **SST from the second half of the year** (July to December) was the second highest in the time series. The Extended Reconstructed Sea Surface Temperature (ERSST) dataset includes temperature records back to 1854.




ERSST, 1854-2015




ERSST, 2nd half of year

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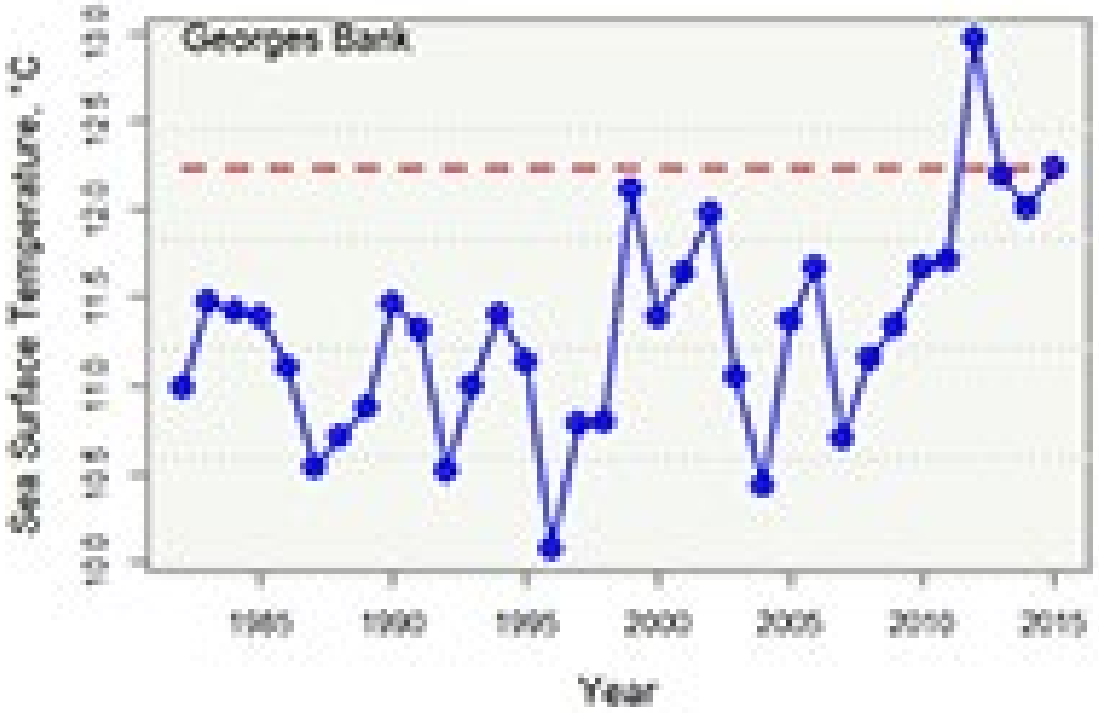
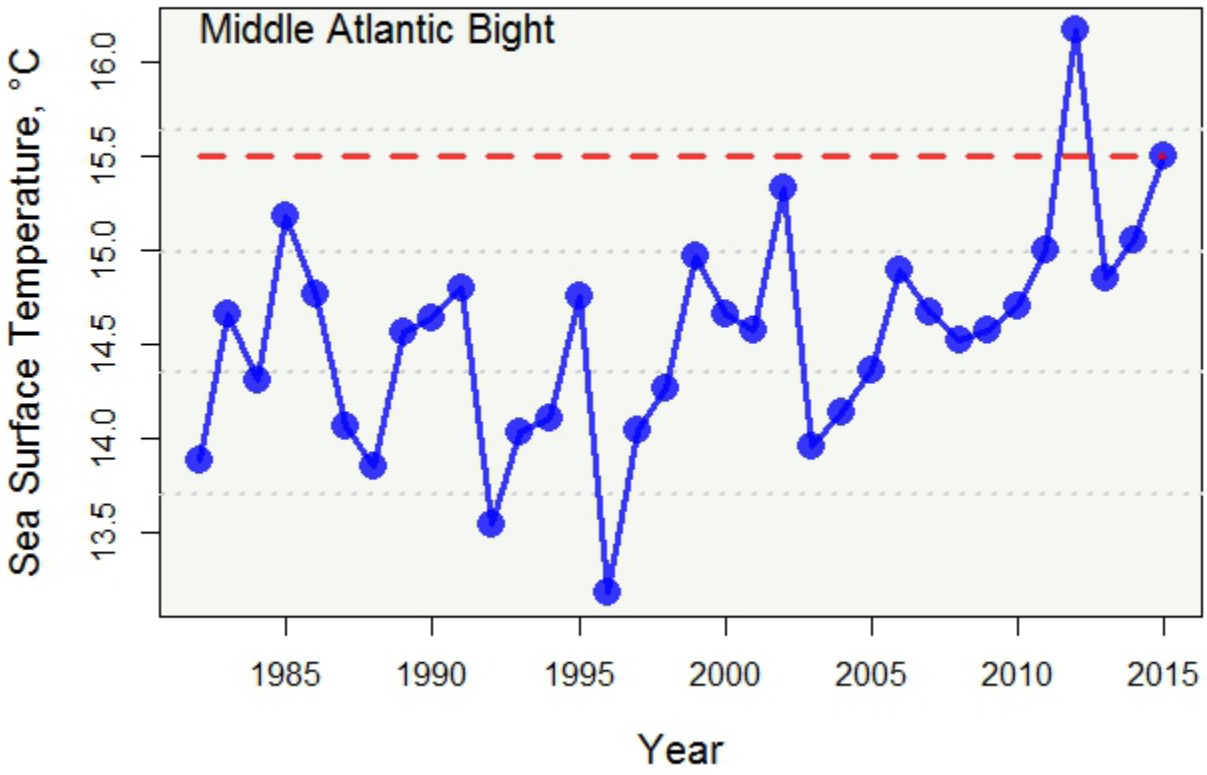
# Satellite SST Trends for the Northeast Shelf Ecosystem

The **SST conditions for 2015** were among the warmest recorded in the satellite remote sensing data series. The NES SST was in excess of 13°C in 2015 (2015 values marked over the time series with dashed red lines), which was less than the record level set in 2012 but well above average for the ecosystem. Temperatures continue to be well above average in the all the subregions of the ecosystem.

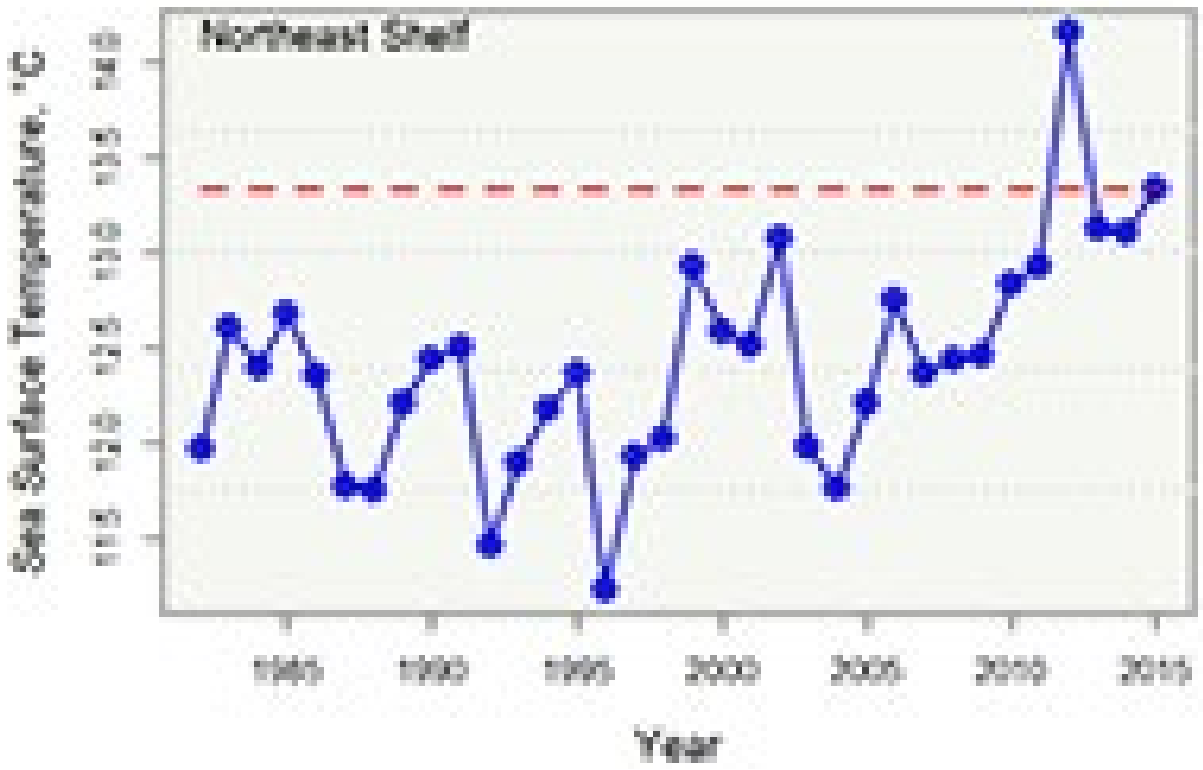



Georges Bank

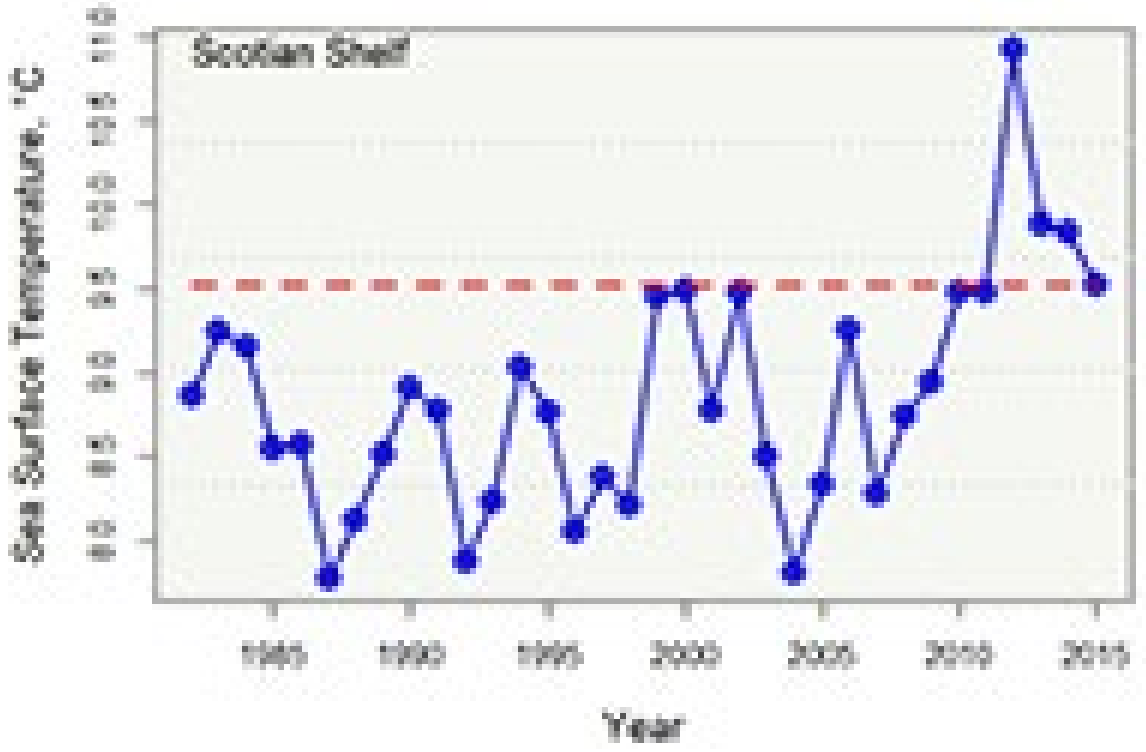

Gulf of Maine




Middle Atlantic Bight




Northeast Shelf




Scotian Shelf

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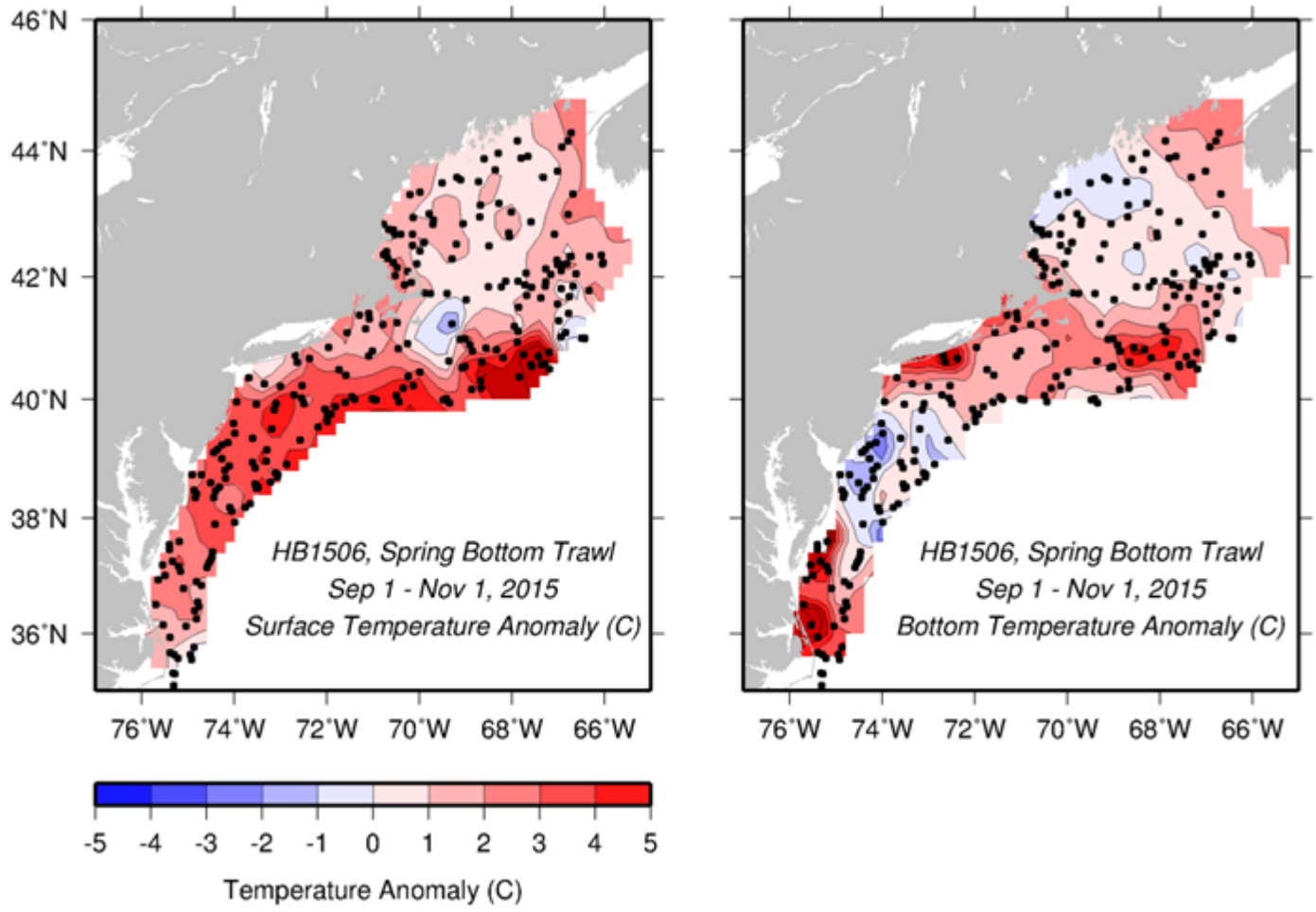
# Fall Temperature from Survey




Fall 2015 temperature anomalies

During spring, ocean temperatures averaged warmer than normal across the northeast U.S. shelf at both surface and bottom (relative to 1977-1987). Warming was enhanced near the surface, with anomalies exceeding 3°C south of Georges Bank and throughout the Middle Atlantic Bight. Warming of bottom waters was regionally enhanced over shallow banks such as Georges Bank, Nantucket Shoals, and near shore along southern New England, suggesting that heat input at the surface has been efficiently distributed vertically. The cold anomalies observed near the bottom in the Middle Atlantic Bight appear to be aligned with the inner edge of the cold pool, a seasonal bottom-trapped feature that is formed when winter-cooled shelf water is isolated from the surface by summer heating. It appears that the core of the cold pool may have been shifted south in 2015. Independent observations preceding this period indicate that cold pool temperatures were anomalously cold in summer 2015.

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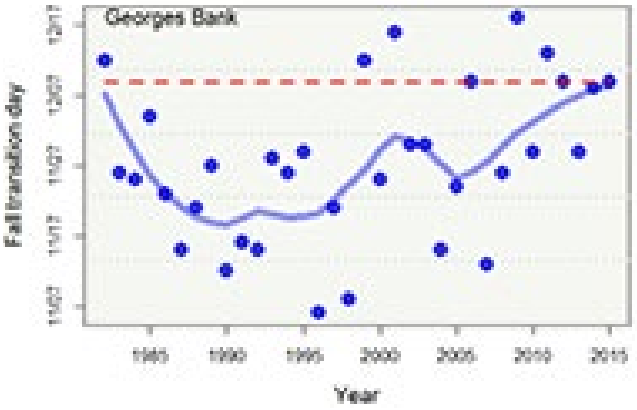
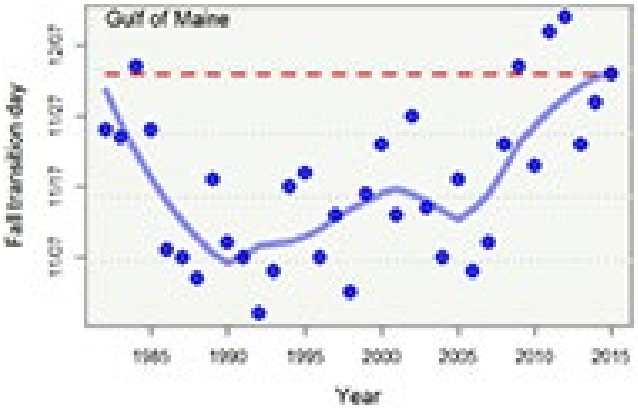
# Fall Thermal Transition Date

Phenology is the climate influence related to the timing between plant and animal production cycles. Many marine organisms time their reproductive cycles to best utilize seasonal

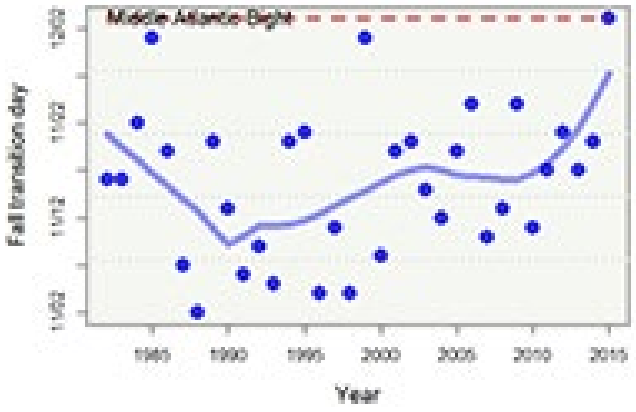
phytoplankton blooms, like the spring and fall blooms, and in turn temperature plays a role in the development of these blooms. One measure to characterize the change in the timing of thermal forcing is the date of arrival of a fall transition temperature, which will vary by region and is meant to mark the occurrence of the average temperature between summer and winter. The date of arrival of the fall thermal transition temperature has reflected progressively later fall seasonal conditions over the past few decades (see **figures**: blue line is time series smoother; red dashed line marks 2014 data). The transition has shifted by nearly a month in the northern part of the ecosystem as seen in the data for the **Scotian Shelf**, where the transition date was around November 20 during the 1980s and is now close to December 20. The shift at the southern end of the ecosystem was not as large. The seasonal shift fall transition in the **Middle Atlantic Bight** was the latest in the time series, occurring in early December. The transition was undetected in **Scotian Shelf** because it did not occur before the end of the year.



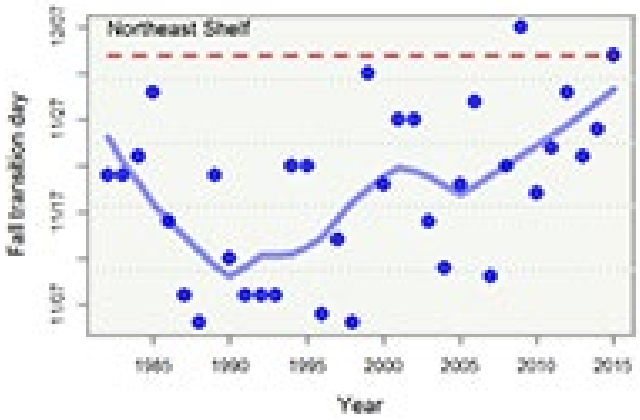

Georges Bank




Gulf of Maine




Middle Atlantic Bight

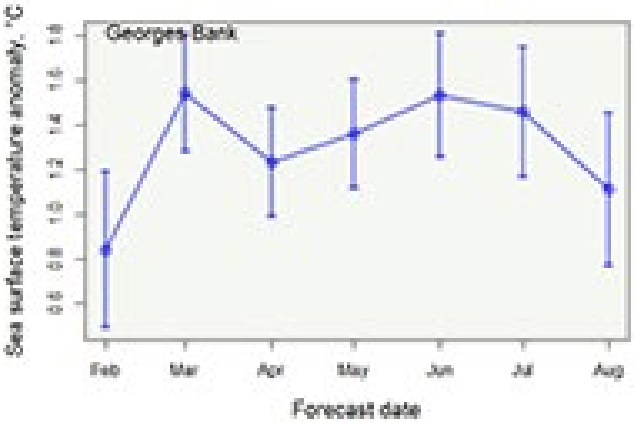



Northeast Shelf

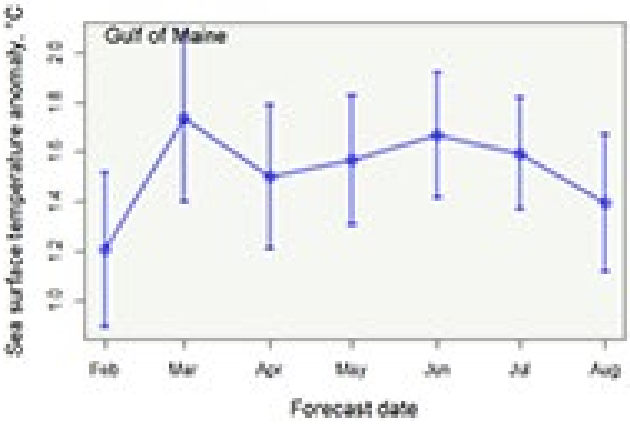

Scotian Shelf

# Ecosystem Forecast - Experimental Data Product

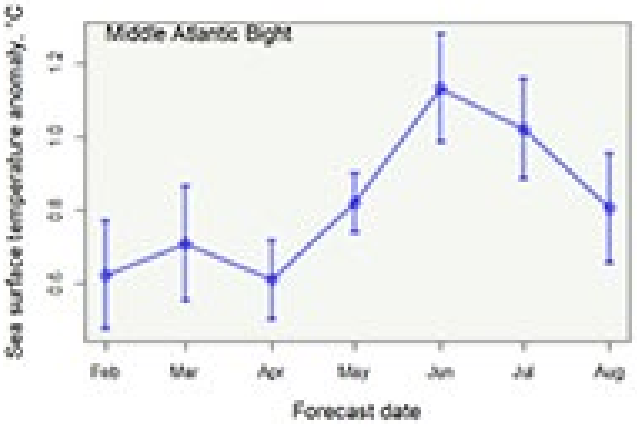
As weather and earth system models have improved, monthly forecasts over seasonal scales ranging up to seven months in advance have improved in quality. For each of the ecoregions of the Northeast Shelf, forecasts from an ensemble of seven forecast models are provided starting with the forecast estimates for February 2016 and ending in August 2016 (see **figures**). There was model agreement in the forecasts for the Middle Atlantic Bight, suggesting that sea surface temperature will rebound in the coming months to an ensemble mean of approximately 1.1°C above average. In the Northern subareas there was less model agreement, as suggested by wider error bands on the ensemble forecast; however, the forecasts suggest SST will be approximately 1.5°C above average in these areas.



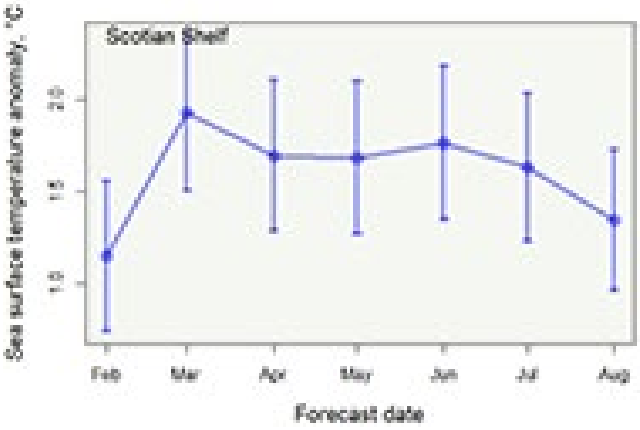

Georges Bank




Gulf of Maine

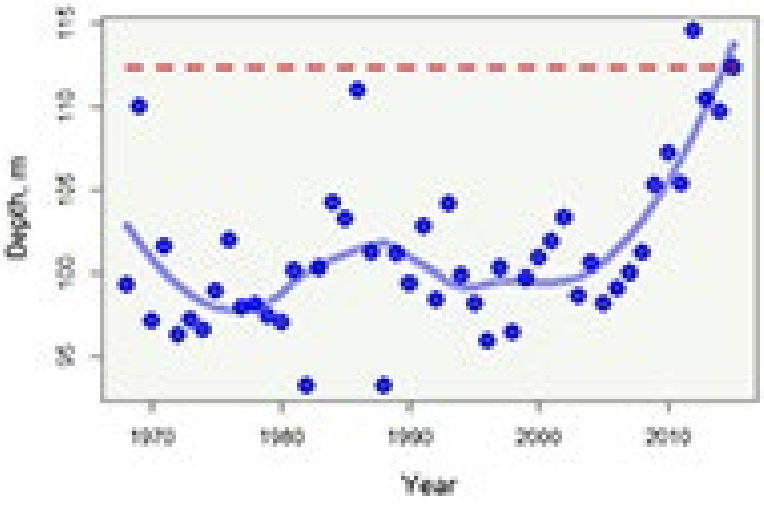



Middle Atlantic Bight

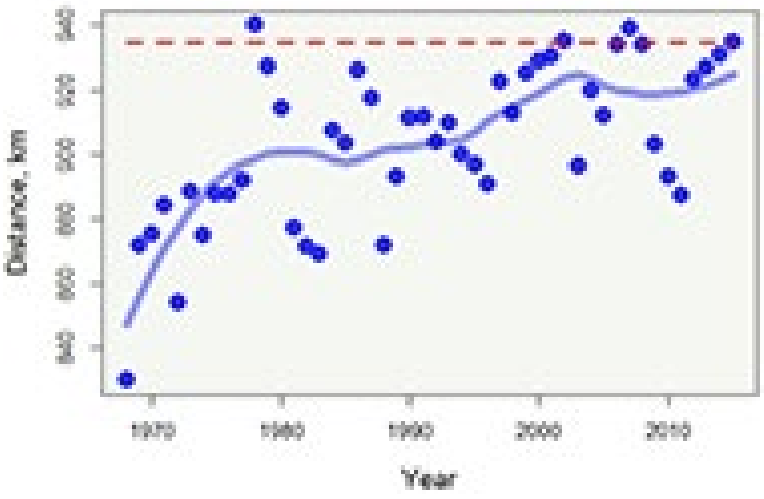



Scotian Shelf

# Trends in Fall Species Distribution




Along-shelf depth trend

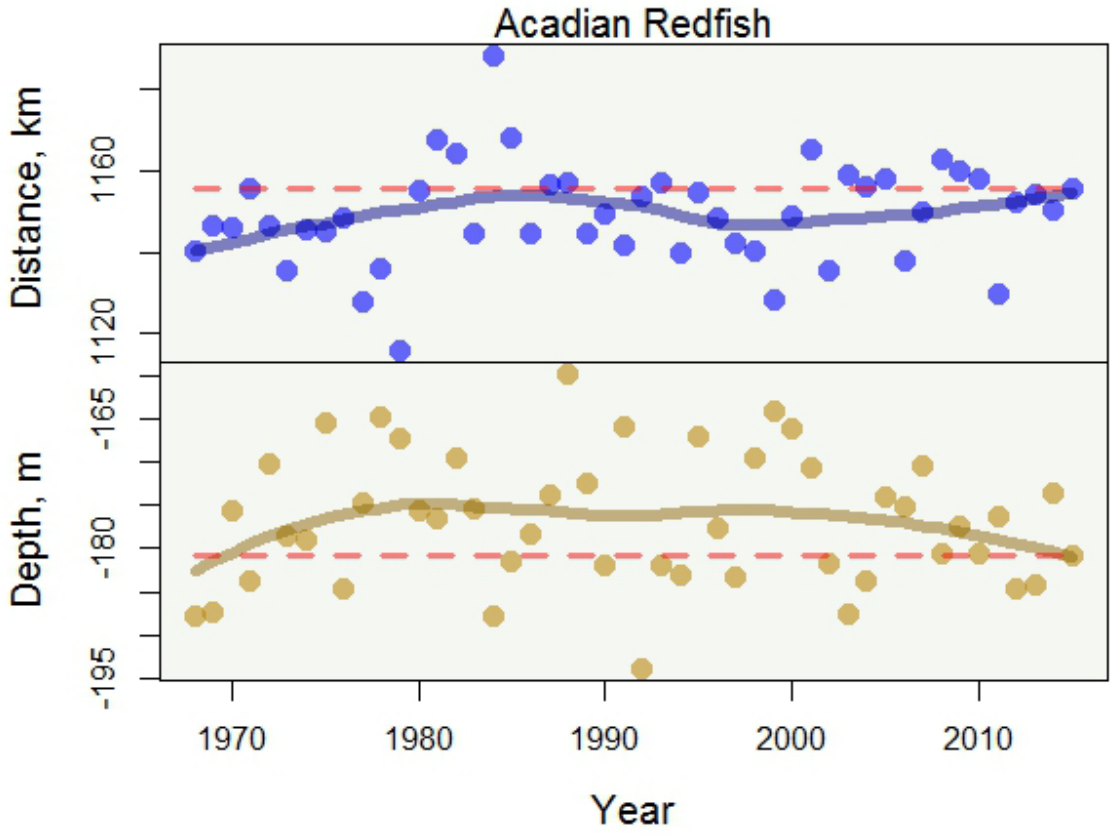



Along-shelf distance trend

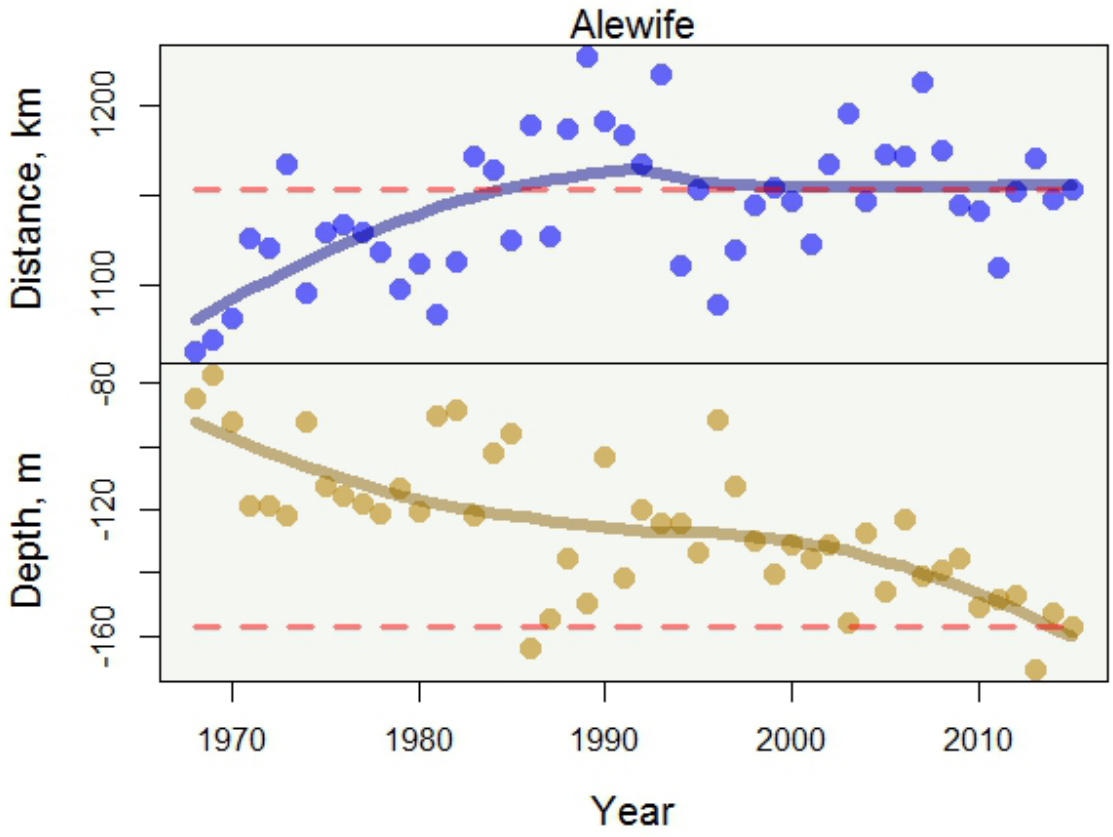
The species of the Northeast Shelf ecosystem have shown changes in distribution over recent decades. Individual species has shifted distribution due to a number of reasons and these shifts can be characterized in a number of different ways. Two metrics that have been used to characterize distribution on the Northeast Shelf include: 1) the position in the ecosystem along an axis oriented from the southwest to the northeast referred to as the **along-shelf distance**; and, 2) the **depth of occurrence**. Along-shelf distances range from 0 to 1360, which relates to positions along the axis from the origin in southwest to northeast in kilometer units. Depth ranges from 0

to -260, which relates to depth of occurrence in meters. The table below shows the species analyzed (click on a species name to see the along and depth distribution trends). The mean along-shelf distance and depth of occurrence for all species by year are shown in the two graphs, with the 2015 values marked with a dashed red line. As a group, these species had an along shelf distance of approximately 870 km, they now have a distance of over 930 km. For most of the time series, the species averaged a depth of 100 m; they now average approximately 113 m.

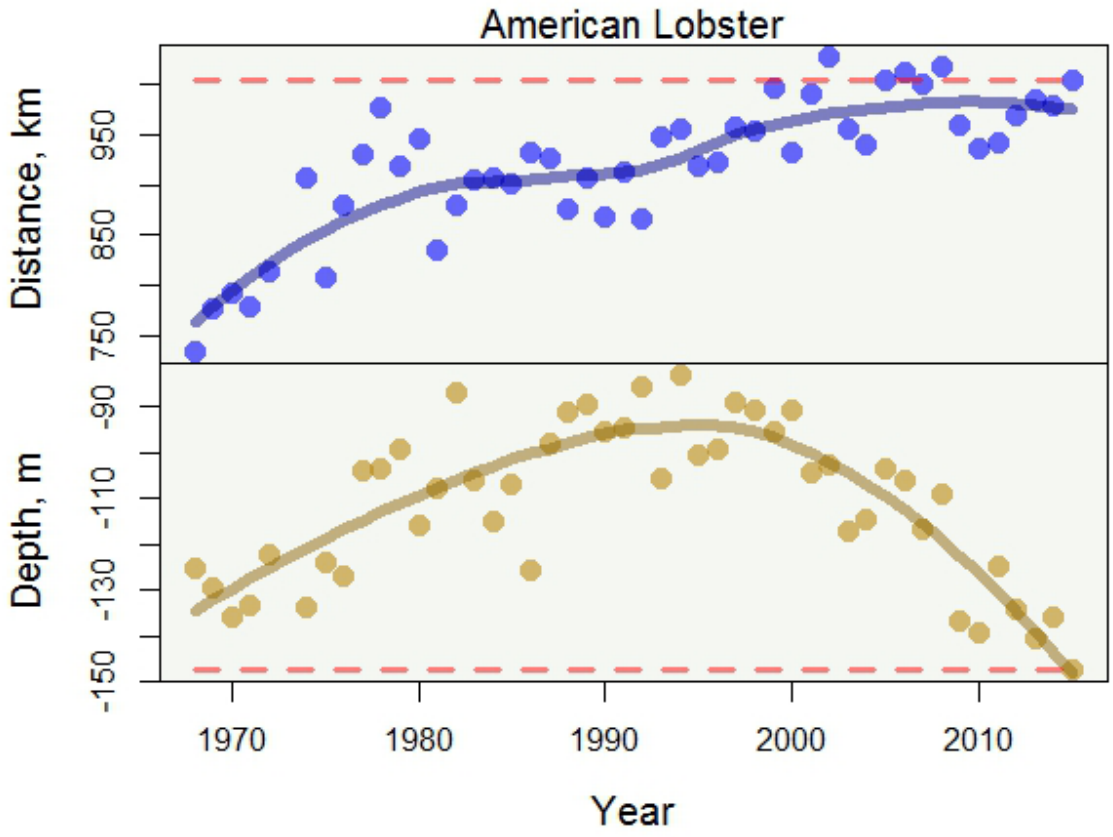
### Acadian redfish



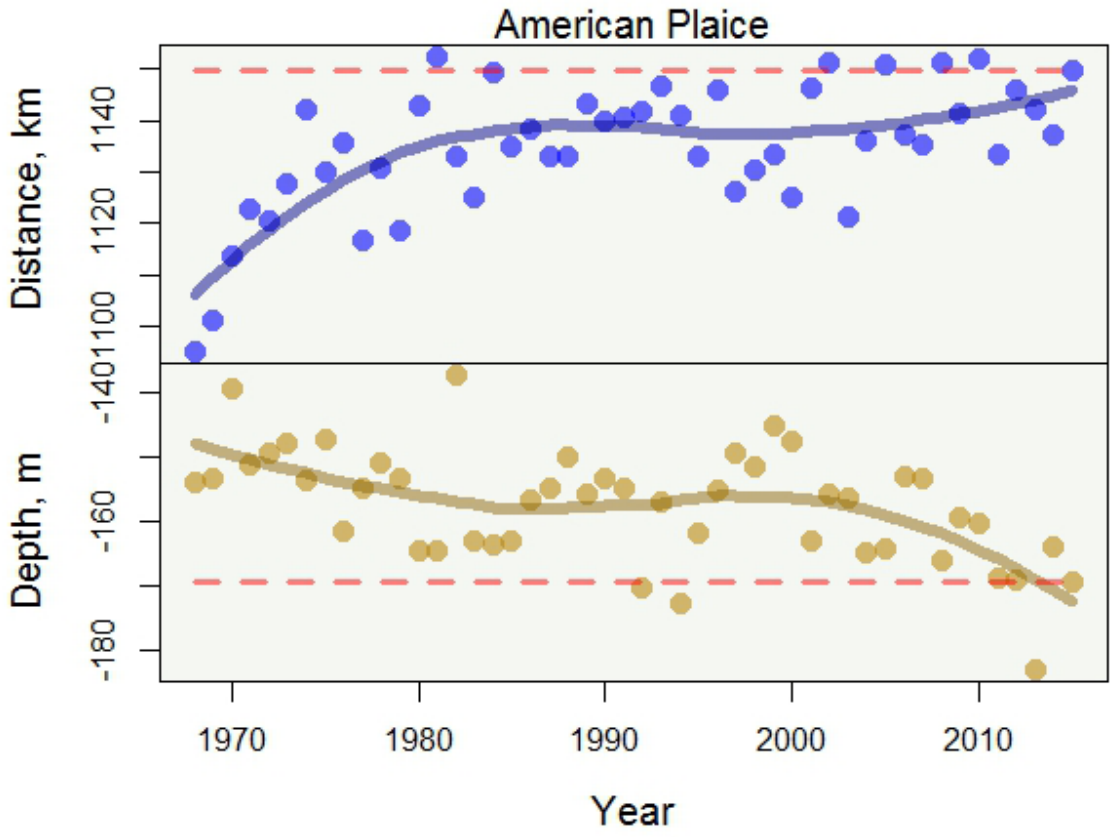
## Alewife


Alewife
Distance, km
1200
1100
Depth, m
-80
-120
-160
1970
1980
1990
2000
2010
Year

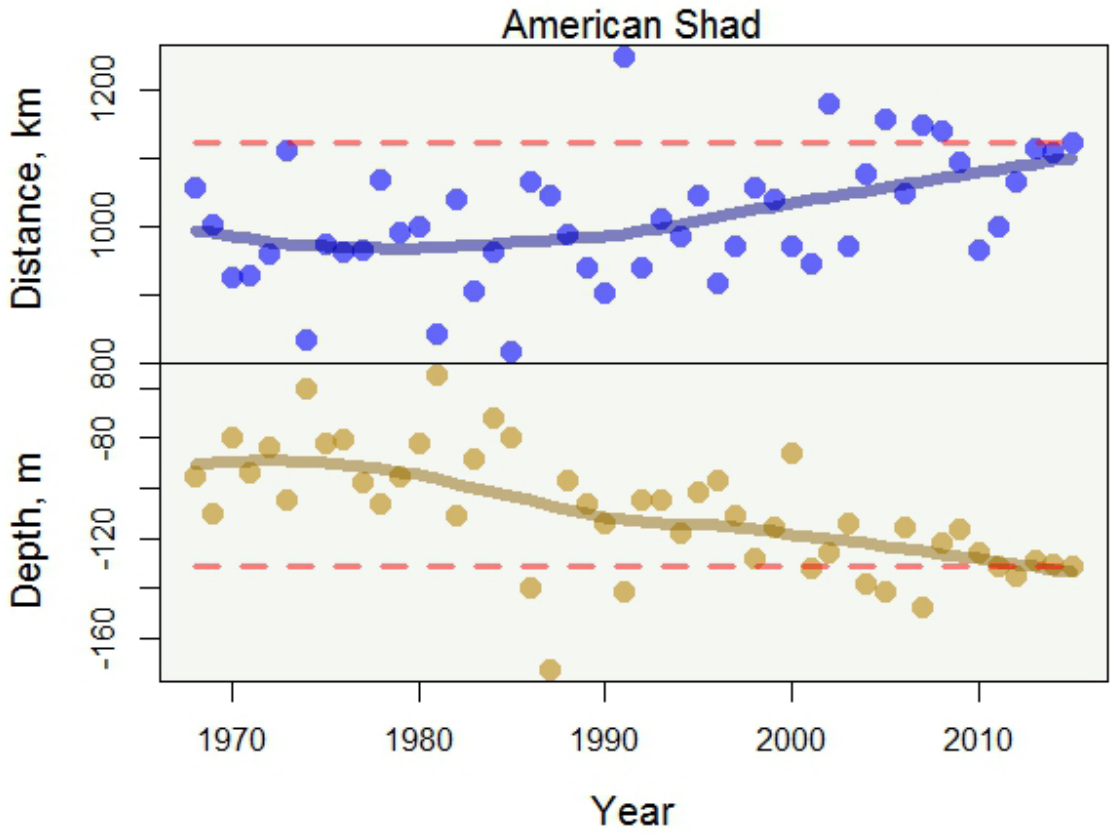
## American Lobster



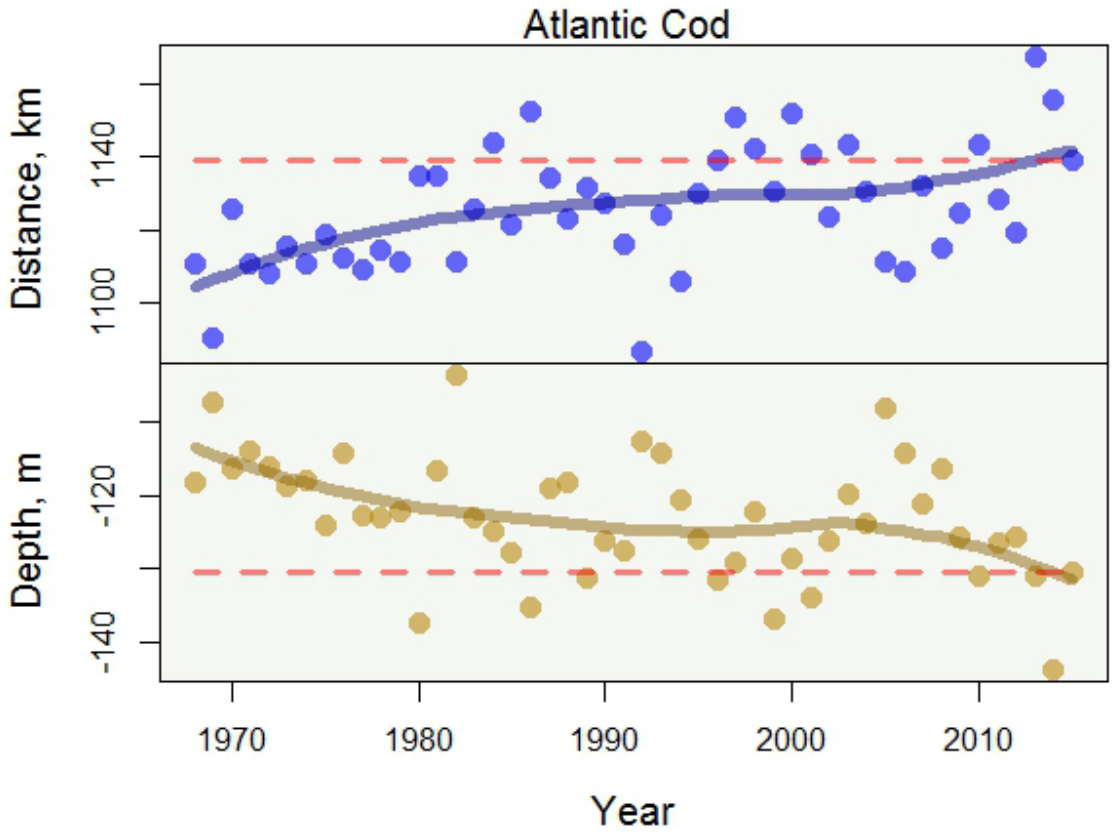
## American Plaice



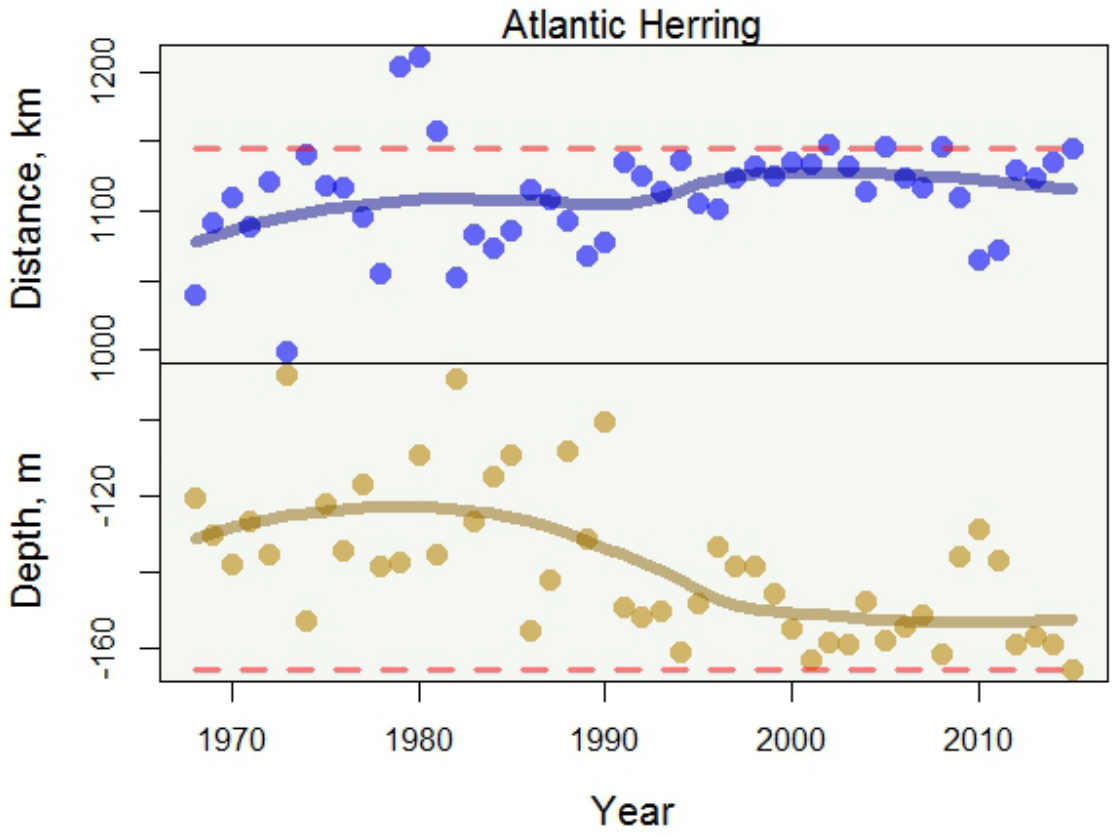
## American shad



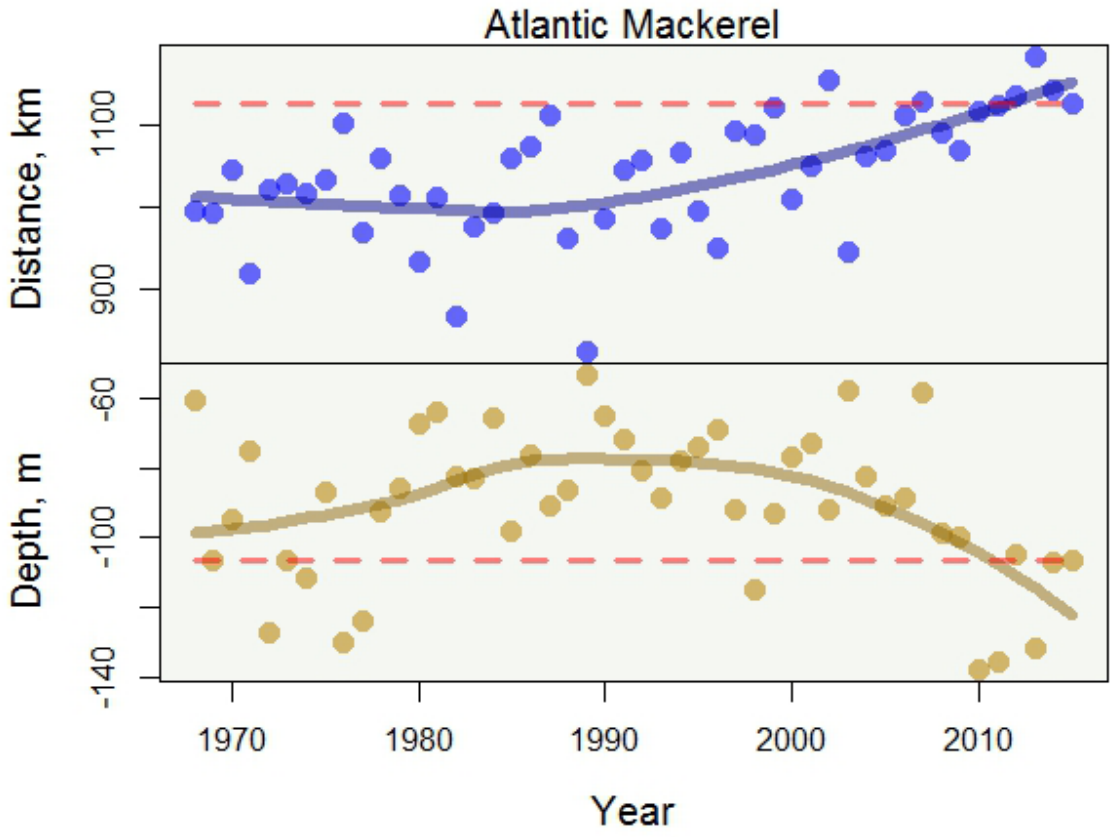
## Atlantic cod



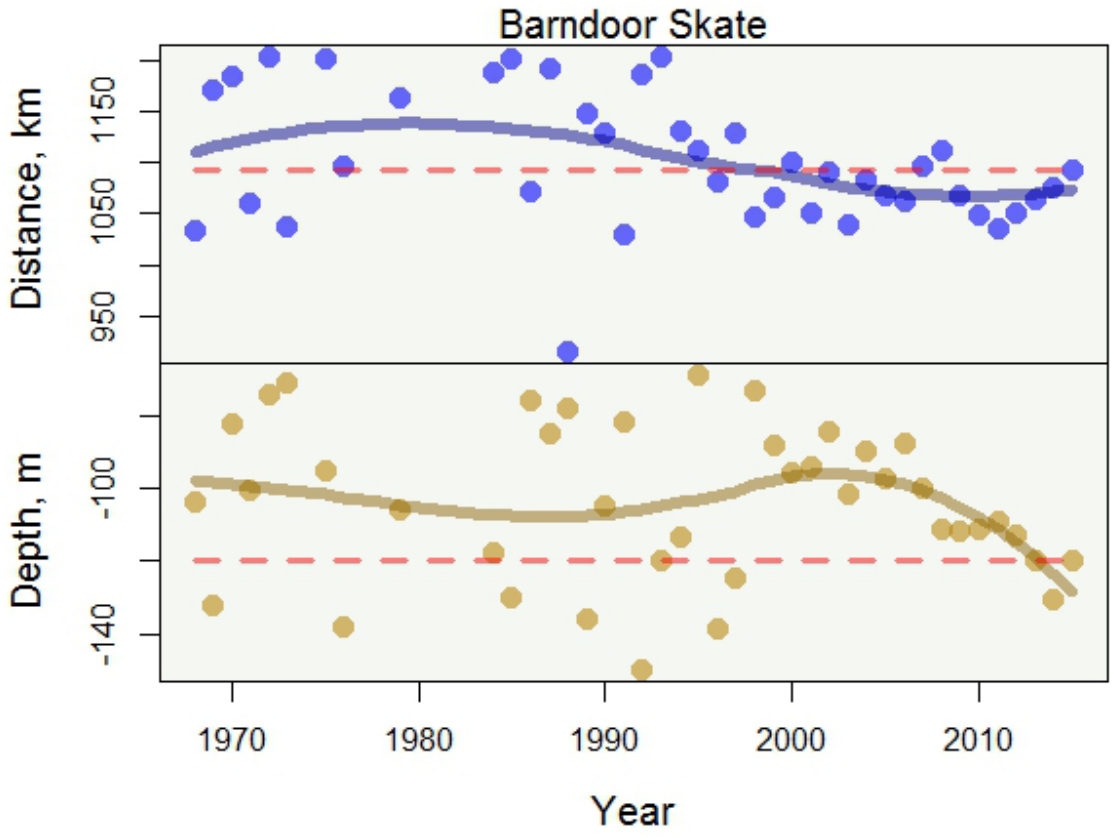
## Atlantic herring



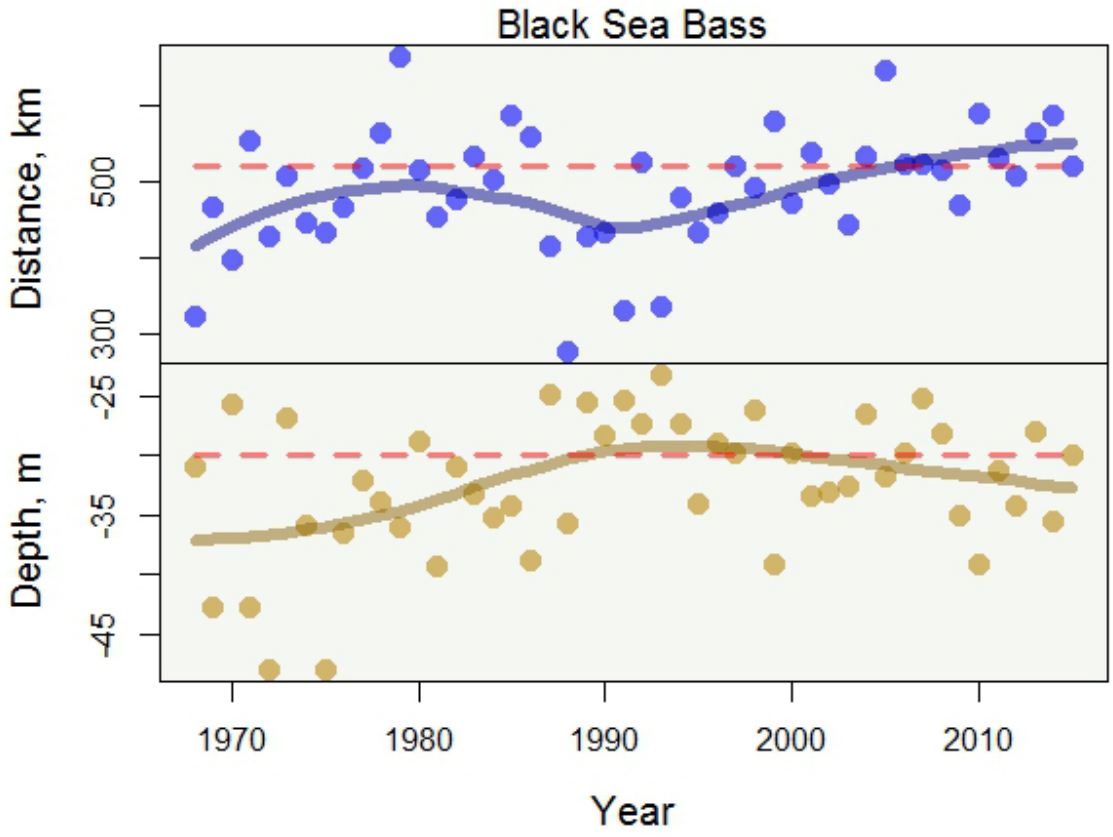
## Atlantic mackerel



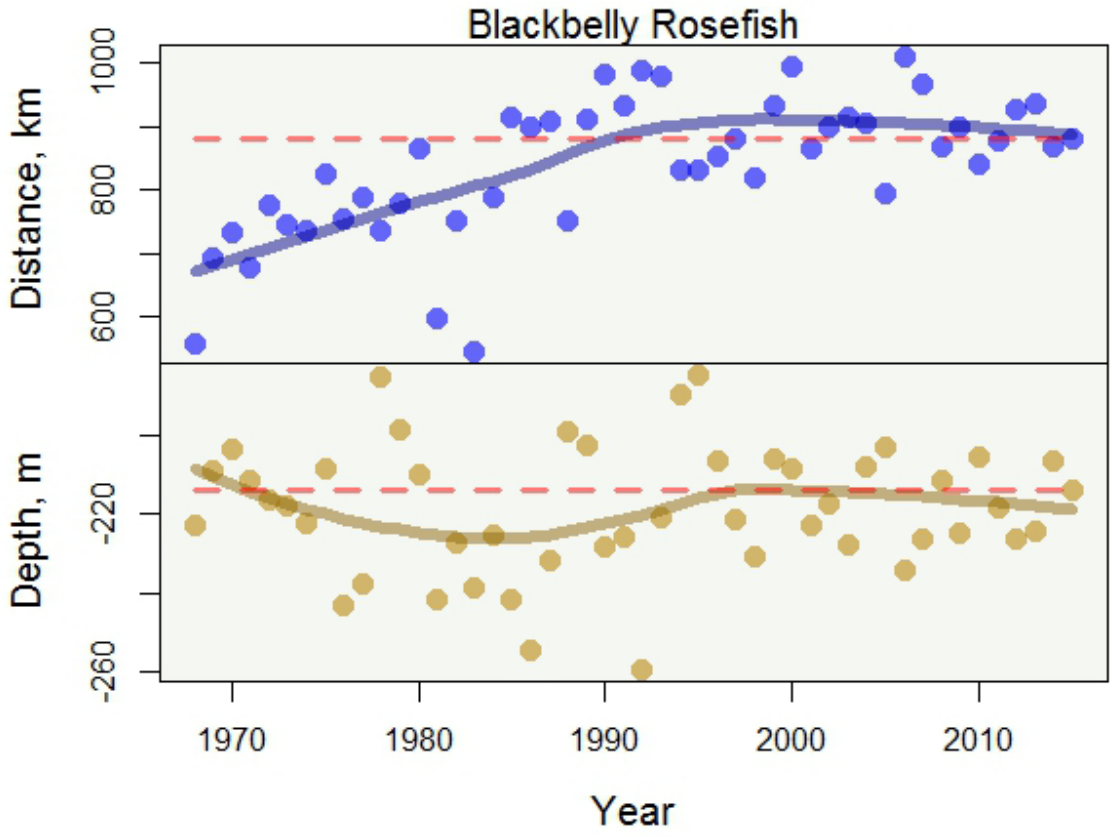
## Barndoor skate



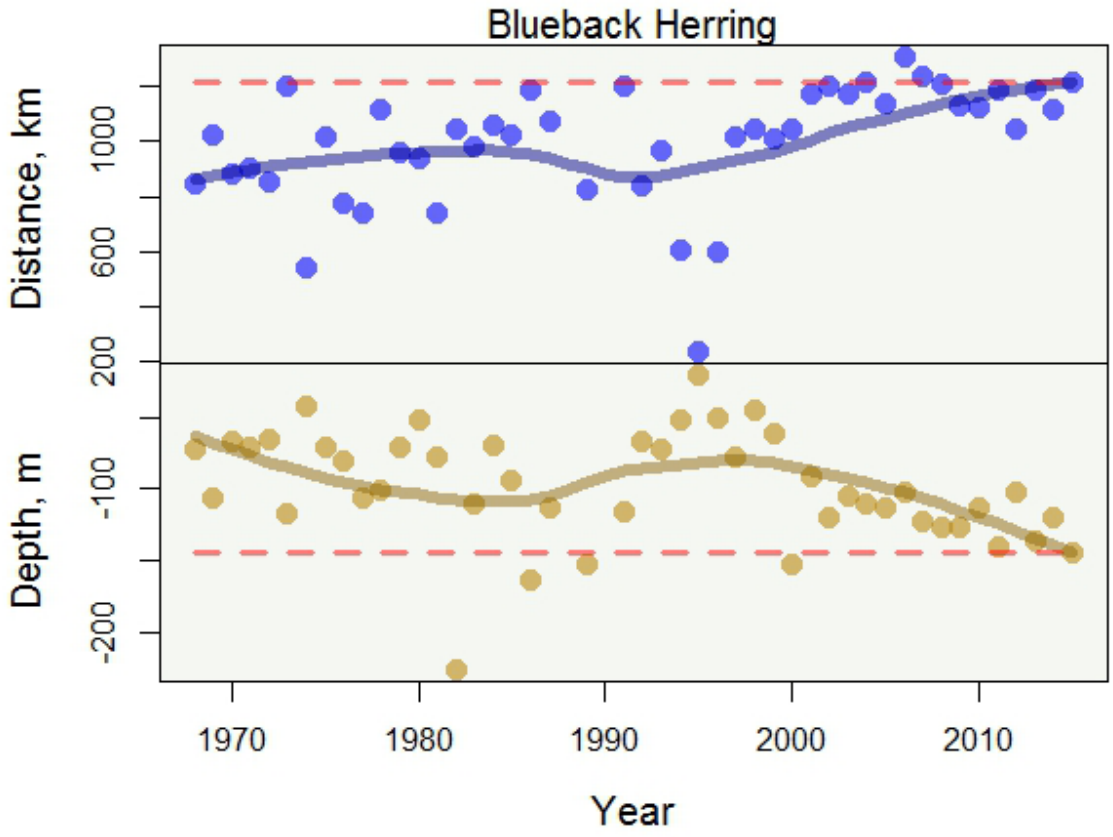
## Black sea bass



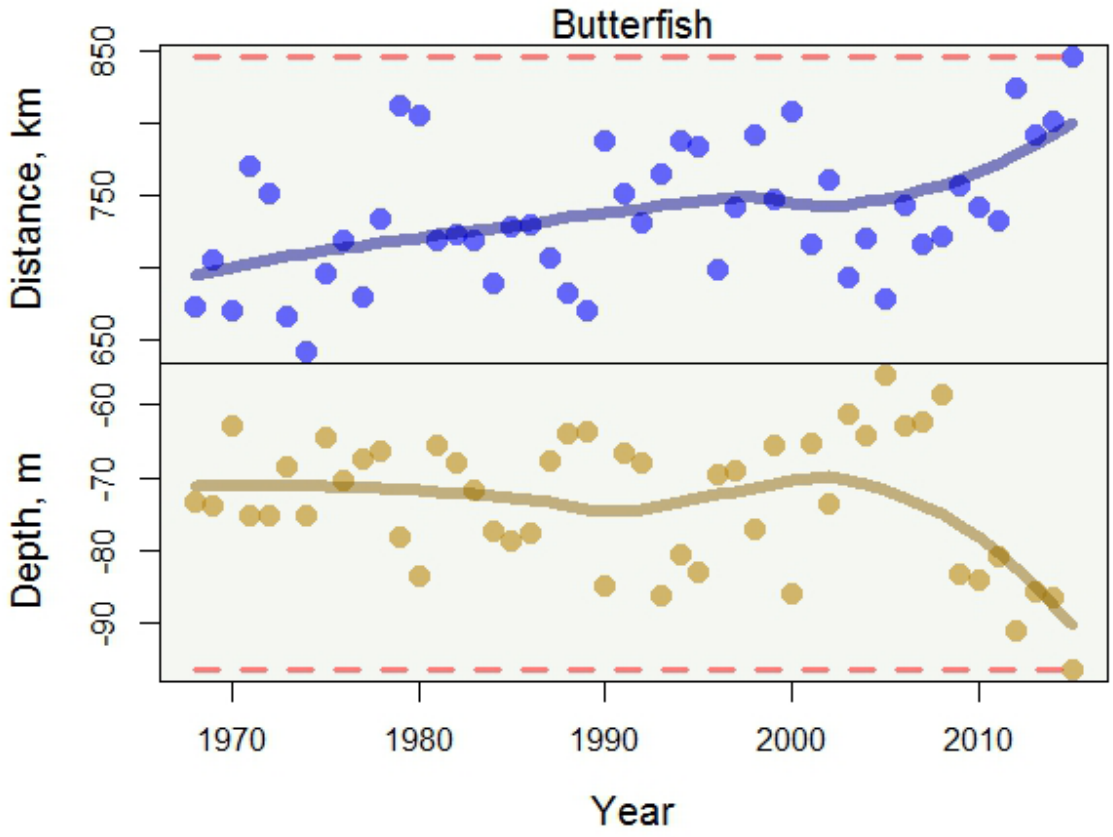
## Blackbelly rosefish



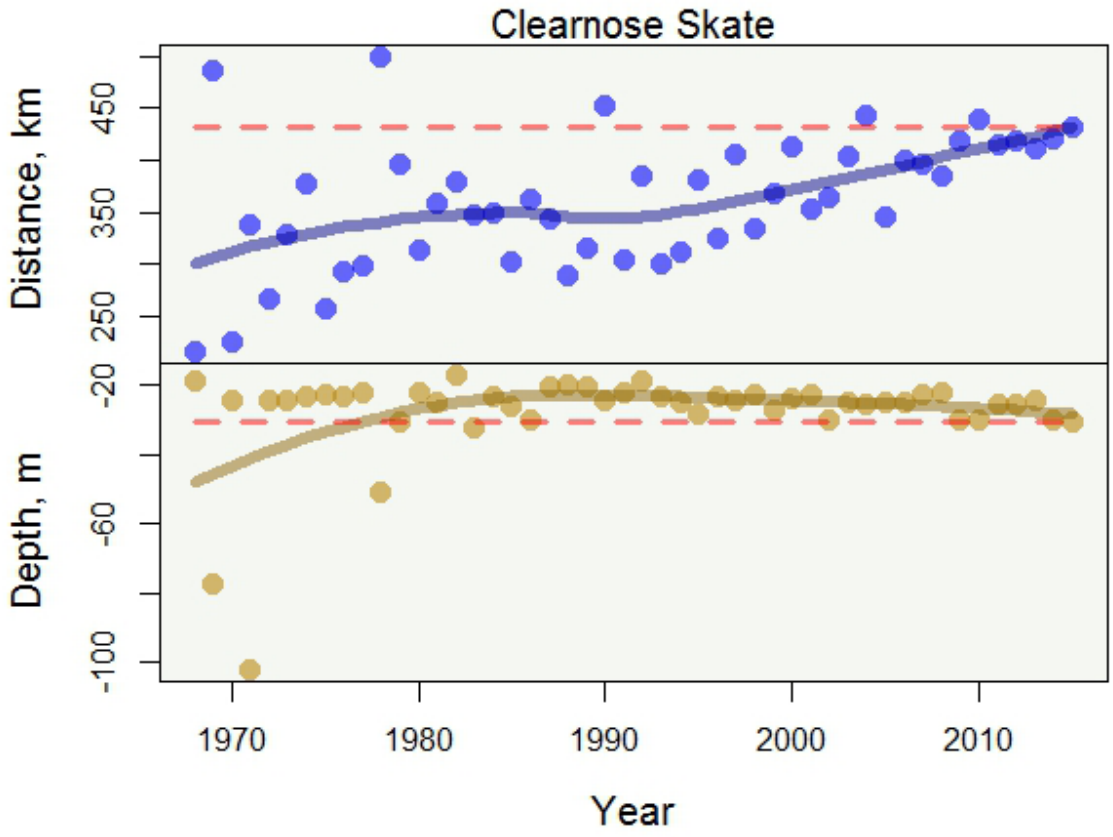
## Blueback herring



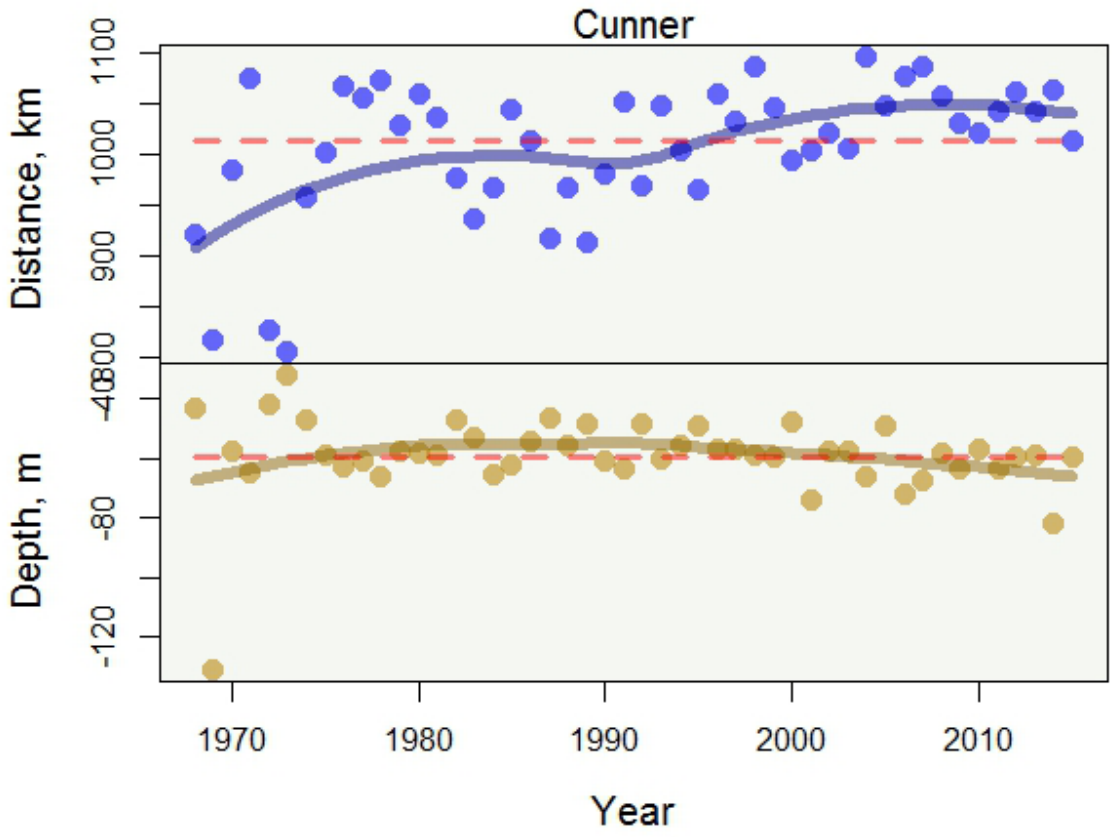
## Butterfish


Butterfish
Distance, km
850
750
650
Depth, m
-60
-70
-80
-90
1970
1980
1990
2000
2010
Year

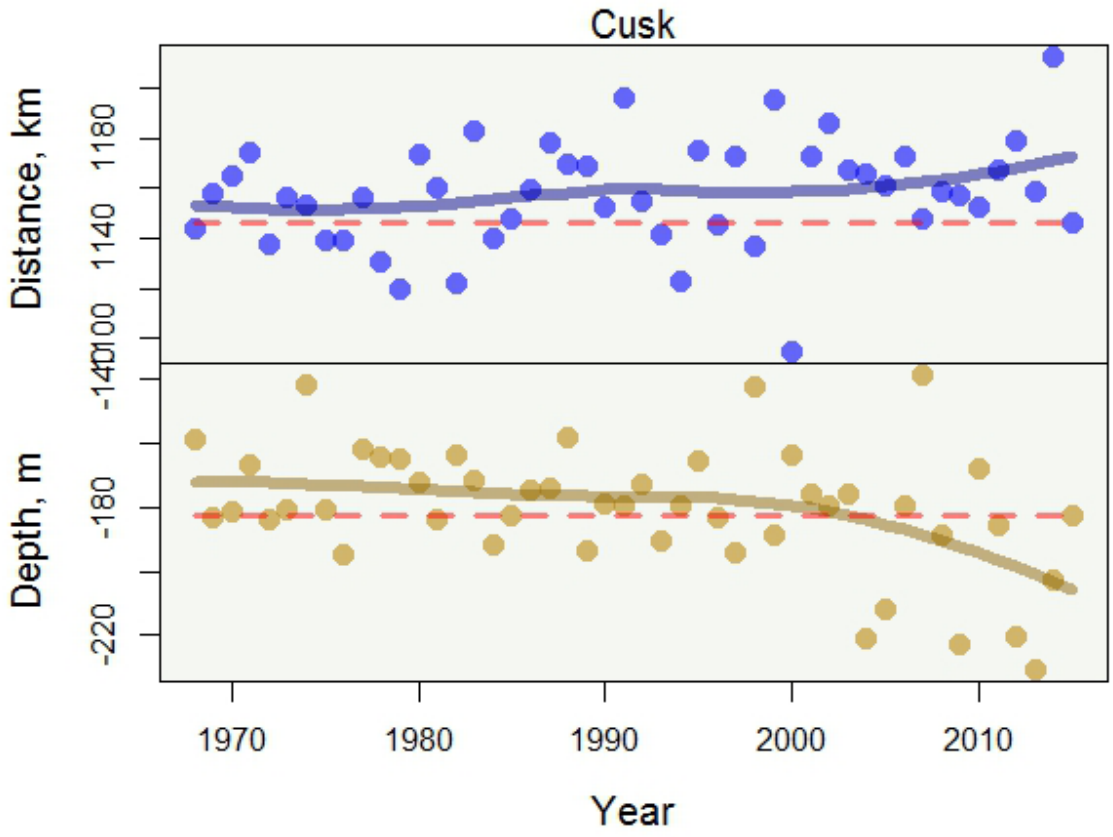
## Clearnose skate



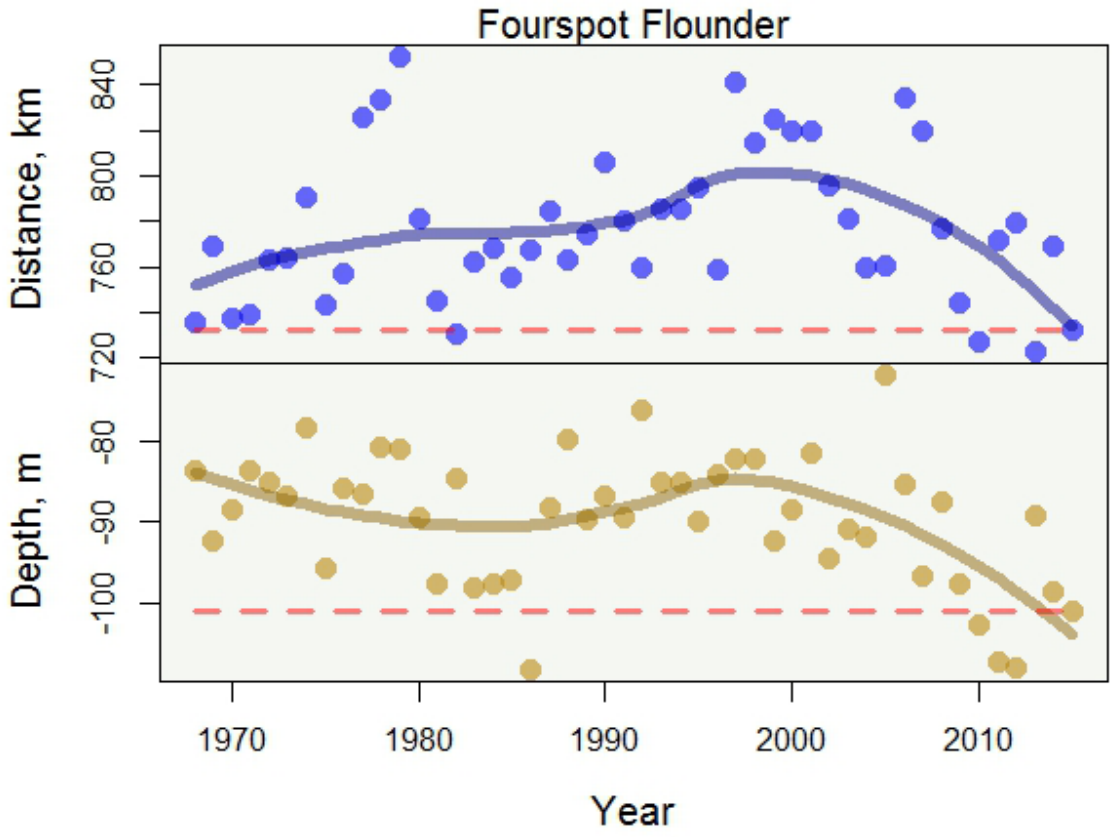
## Cunner


Cunner
Distance, km
1100
1000
900
800
Depth, m
-40
-80
-120
1970
1980
1990
2000
2010
Year

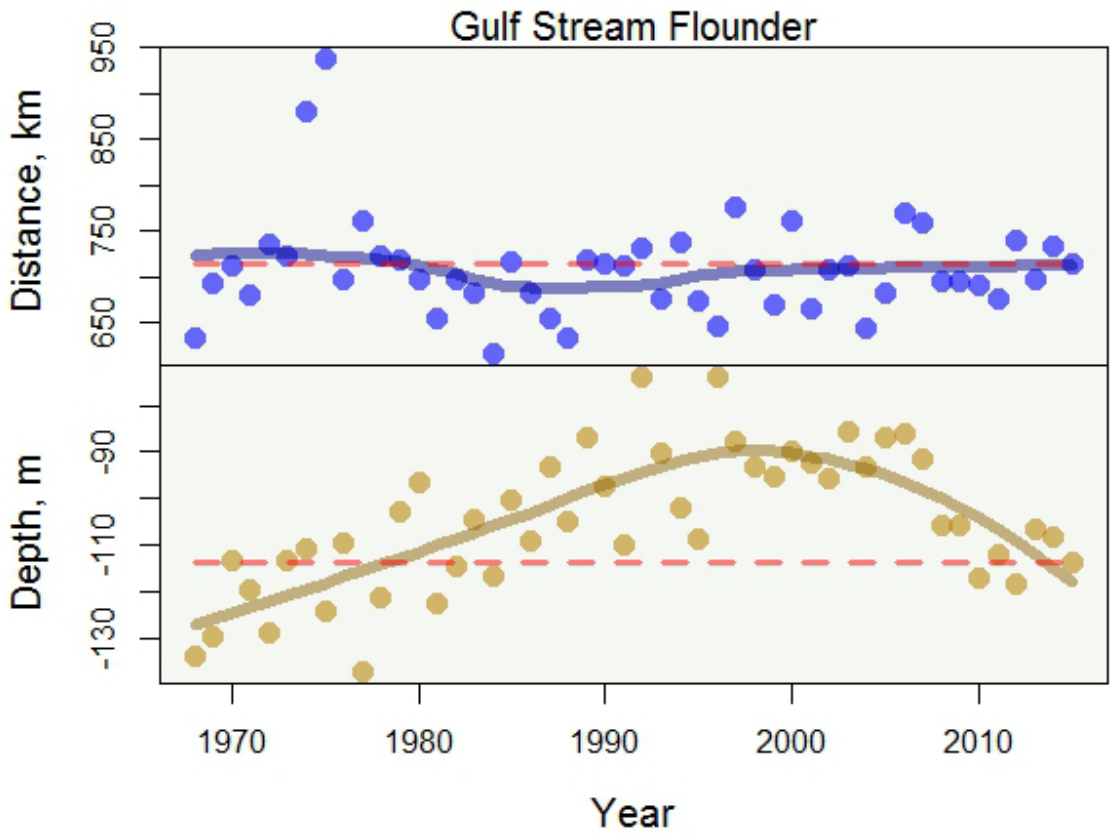
## Cusk


Cusk
Distance, km
1100
1140
1180
Depth, m
-140
-180
-220
1970
1980
1990
2000
2010
Year

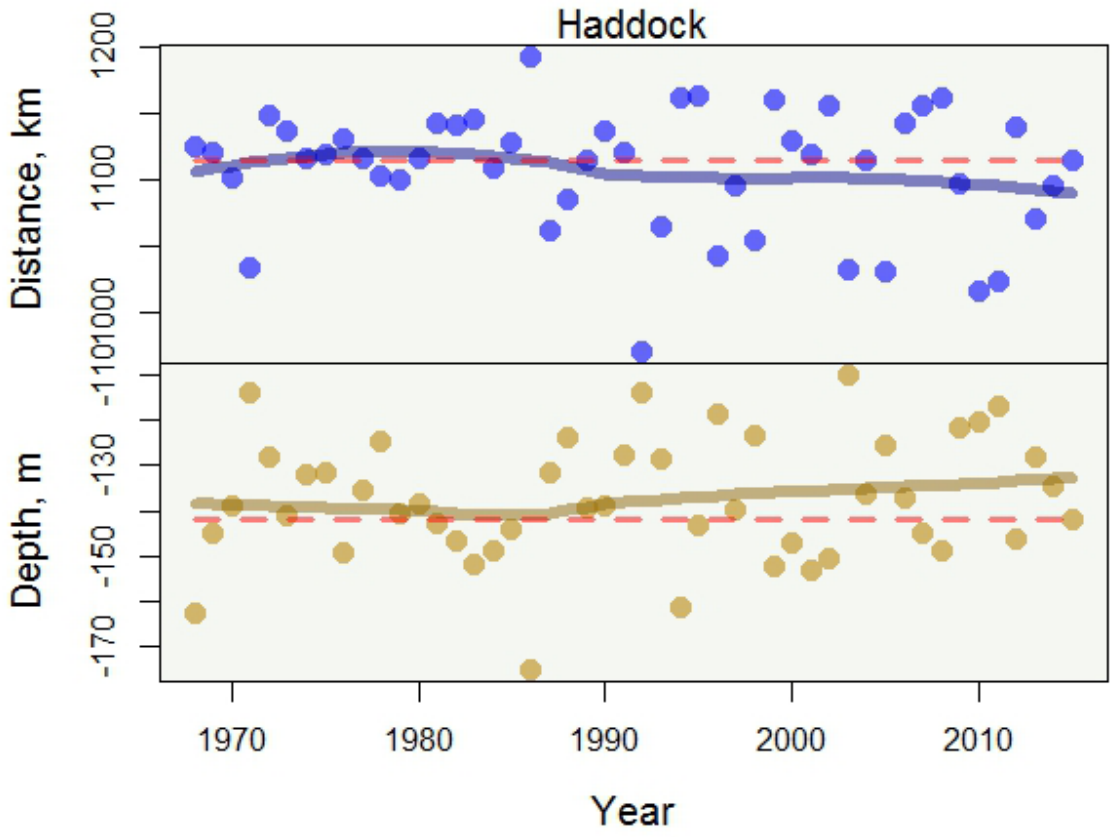
## Fourspot flounder



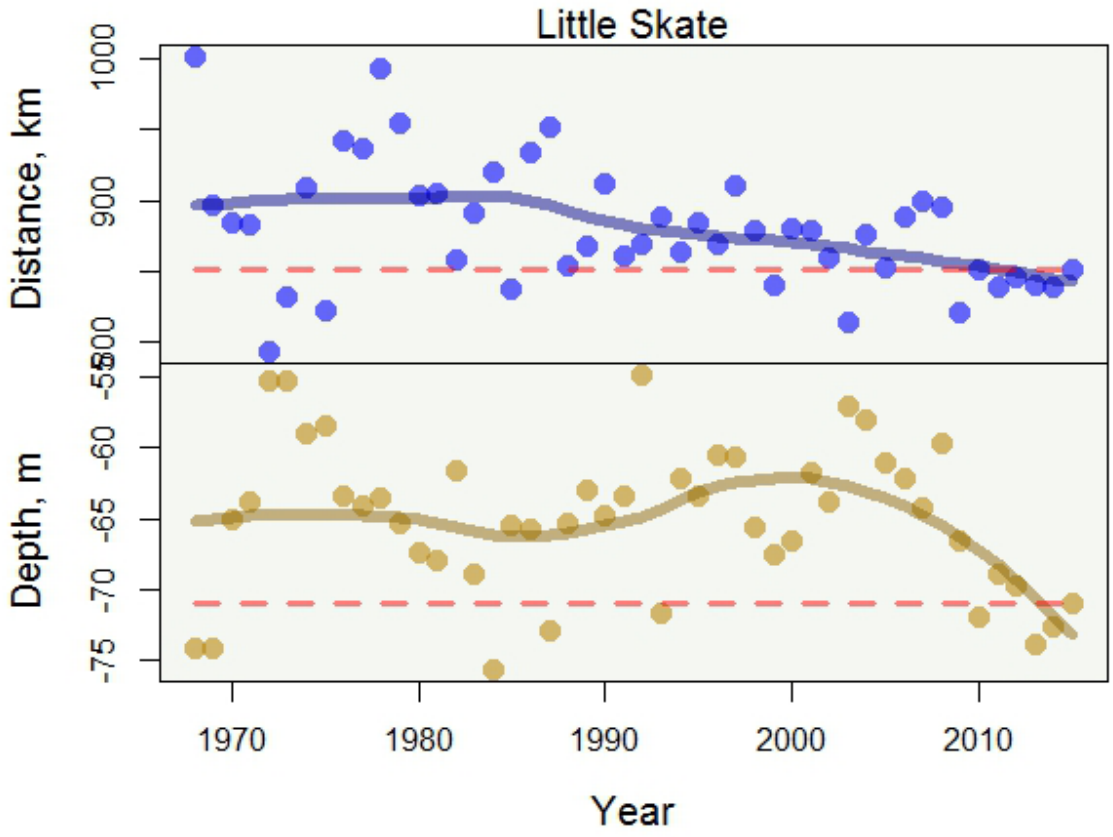
## Glufstream flounder



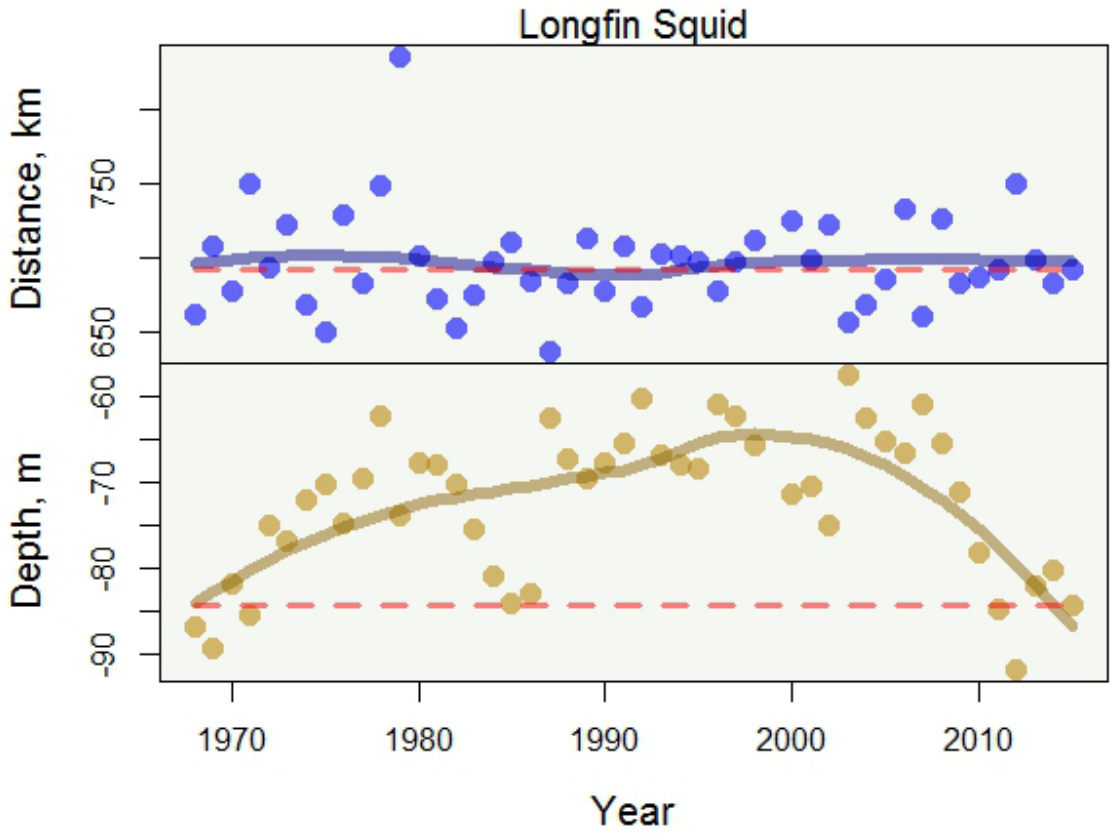
## Haddock


Haddock
Distance, km
1200
1100
1000
Depth, m
-110
-130
-150
-170
1970
1980
1990
2000
2010
Year

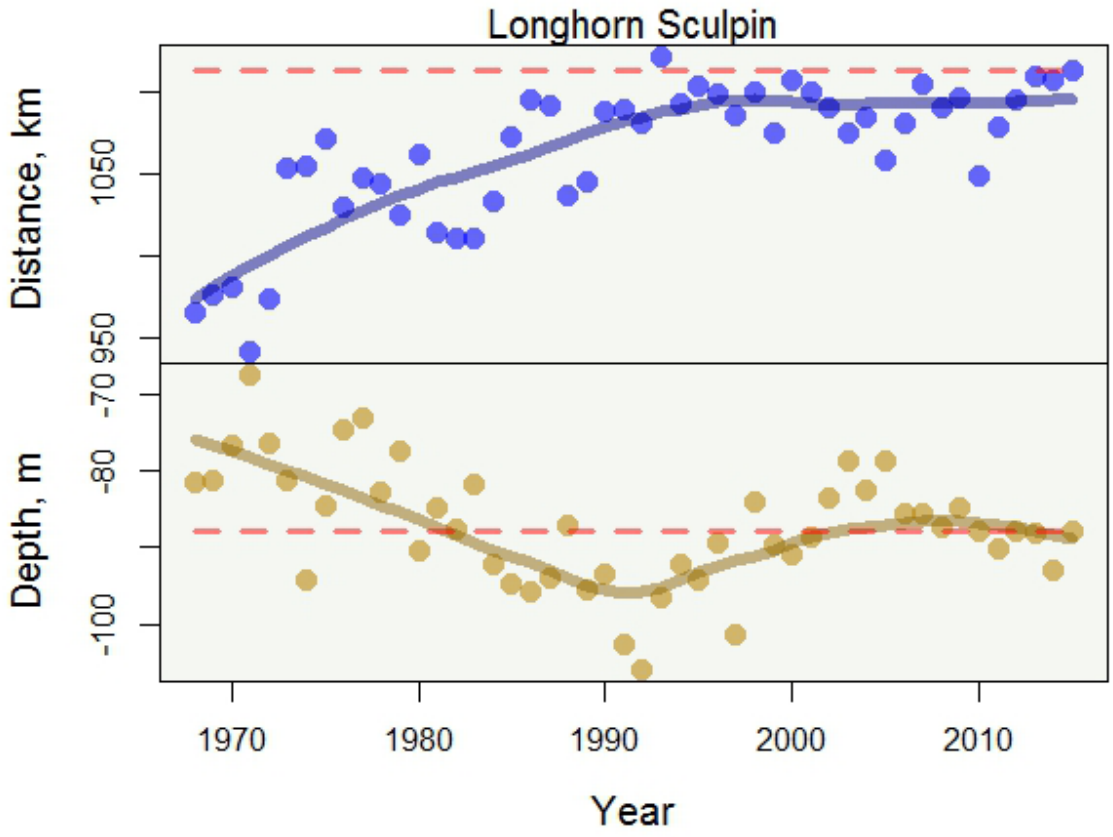
## Little Skate



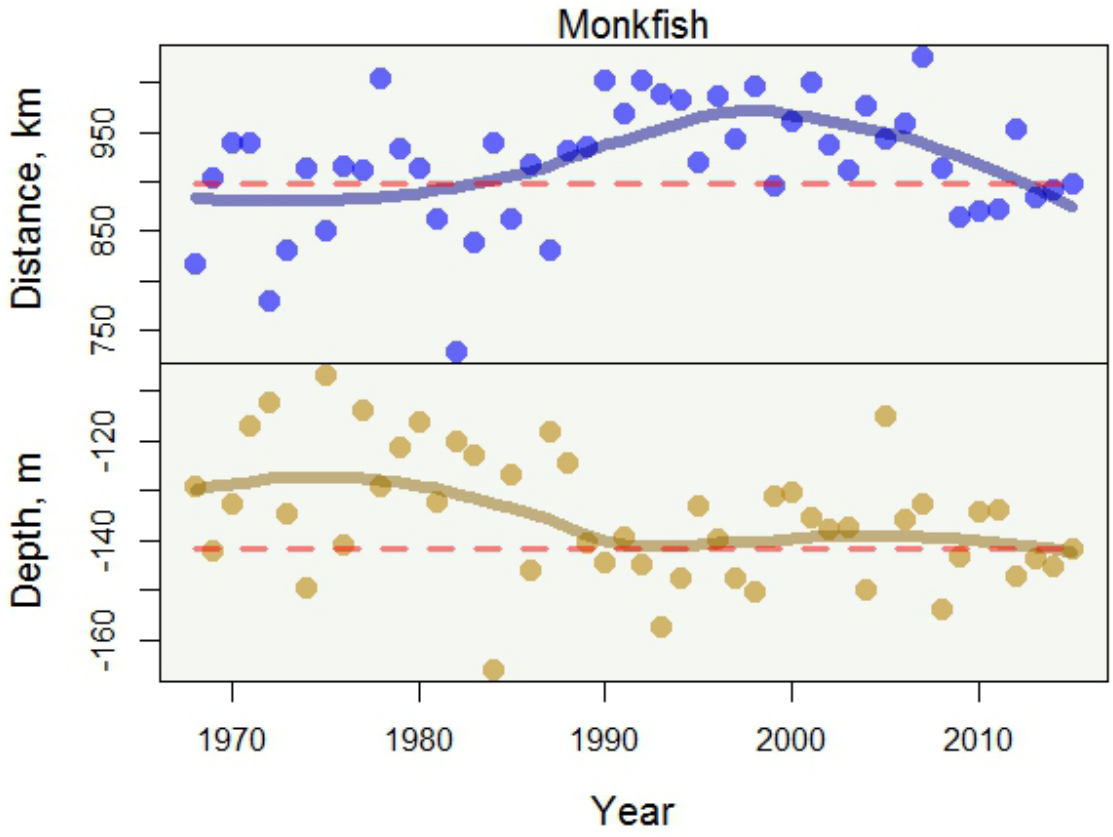
## Longfin squid



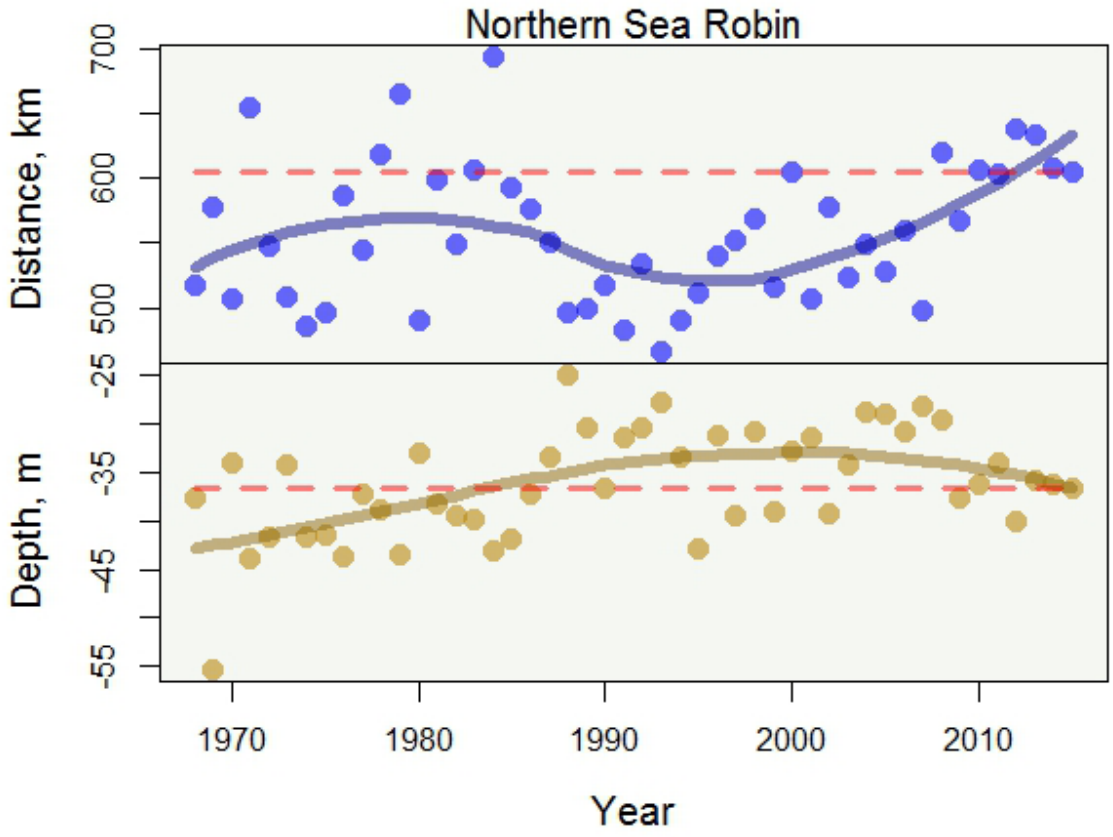
## Longhorn sculpin



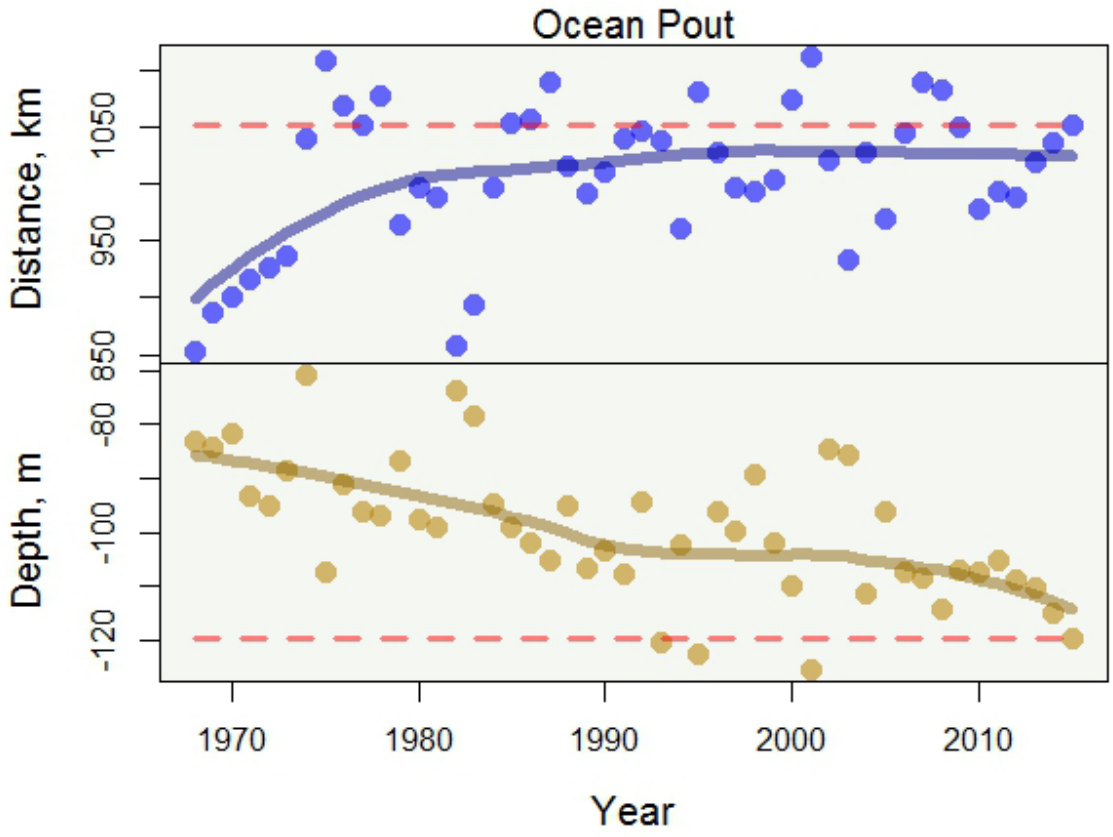
## Monkfish


Monkfish
Distance, km
750
850
950
Depth, m
-160
-140
-120
1970
1980
1990
2000
2010
Year

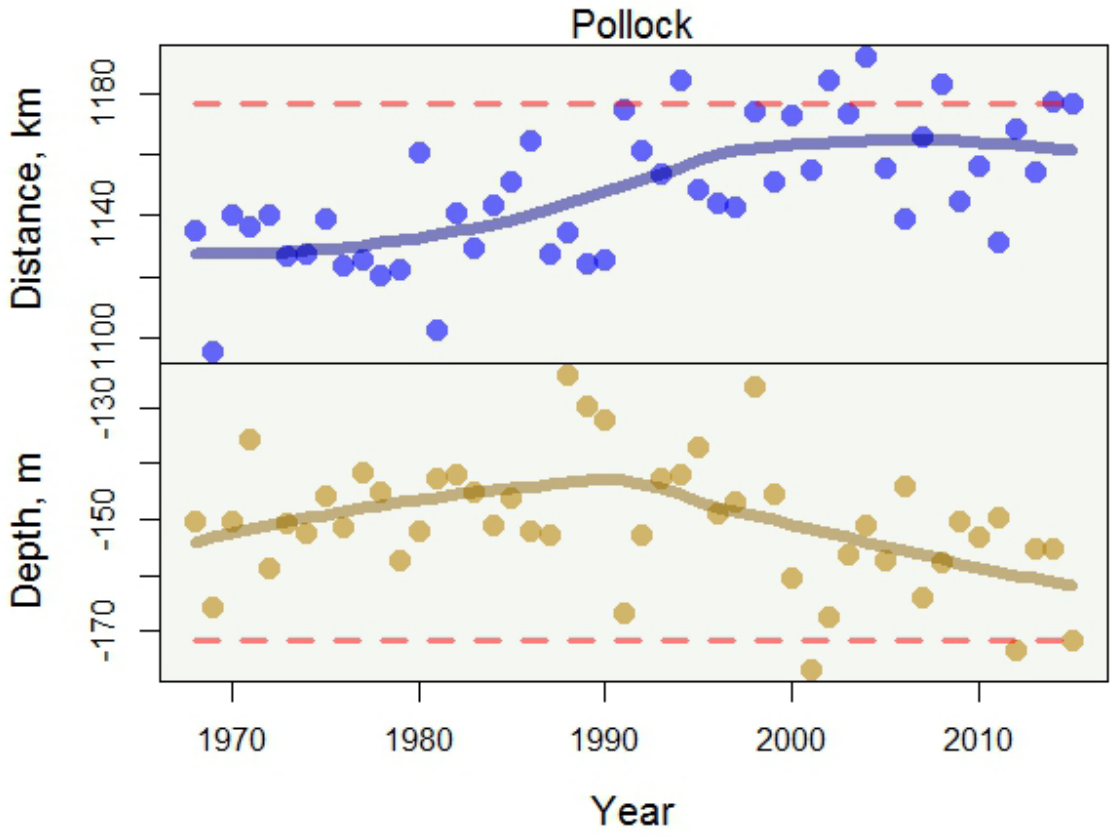
## Northern sea robin



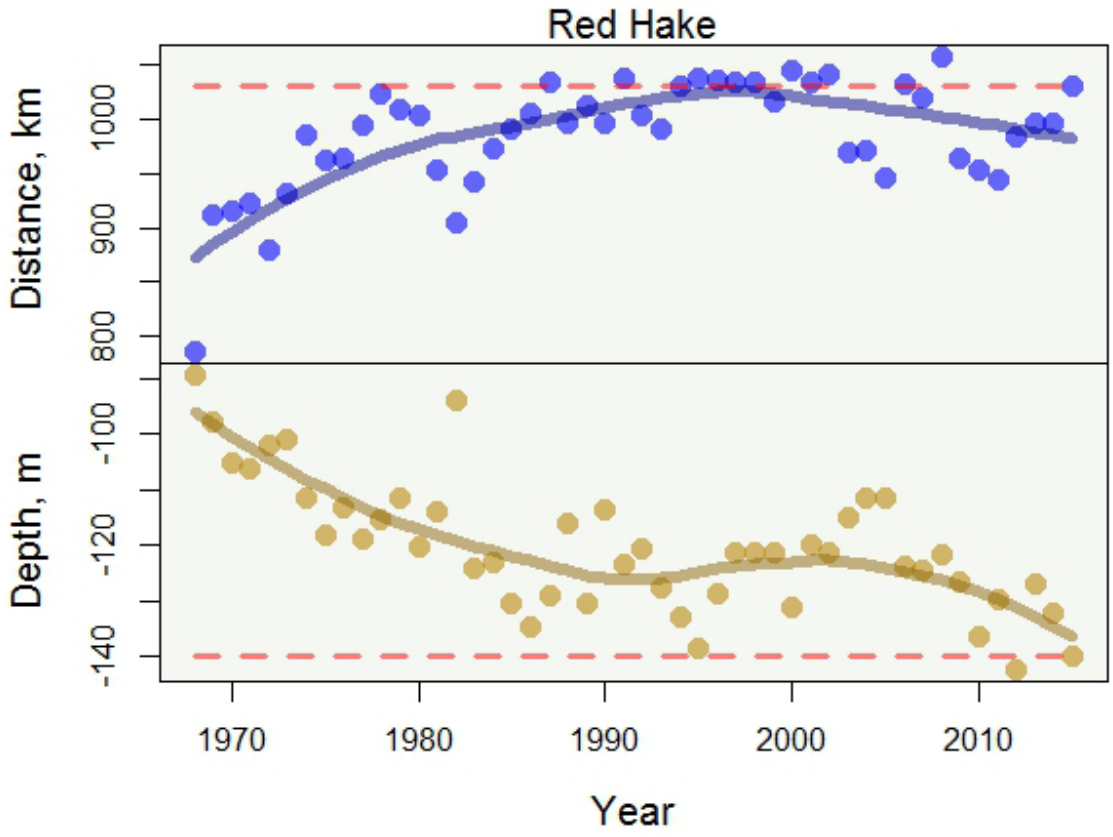
## Ocean pout


Ocean Pout
Distance, km
1050
950
850
Depth, m
-80
-100
-120
1970
1980
1990
2000
2010
Year

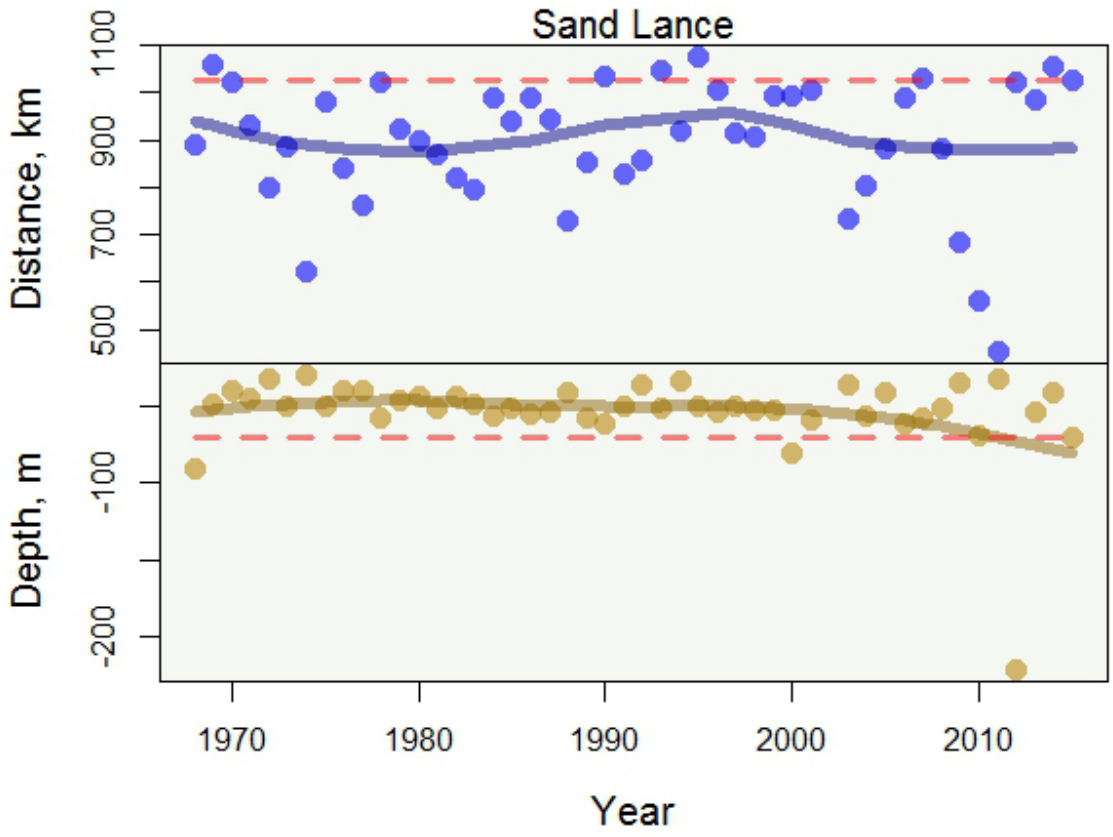
## Pollock


Pollock
Distance, km
1180
1140
1100
Depth, m
-130
-150
-170
1970
1980
1990
2000
2010
Year

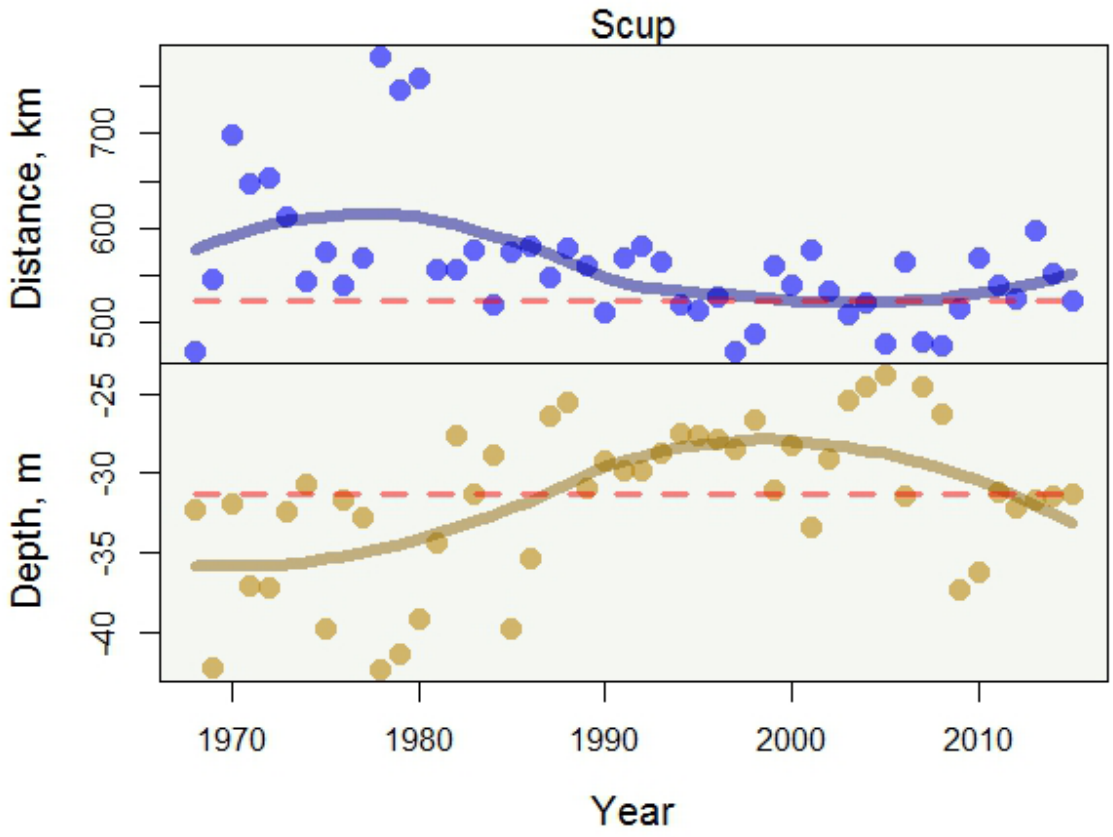
## Red Hake


Red Hake
Distance, km
800
900
1000
Depth, m
-140
-120
-100
1970
1980
1990
2000
2010
Year

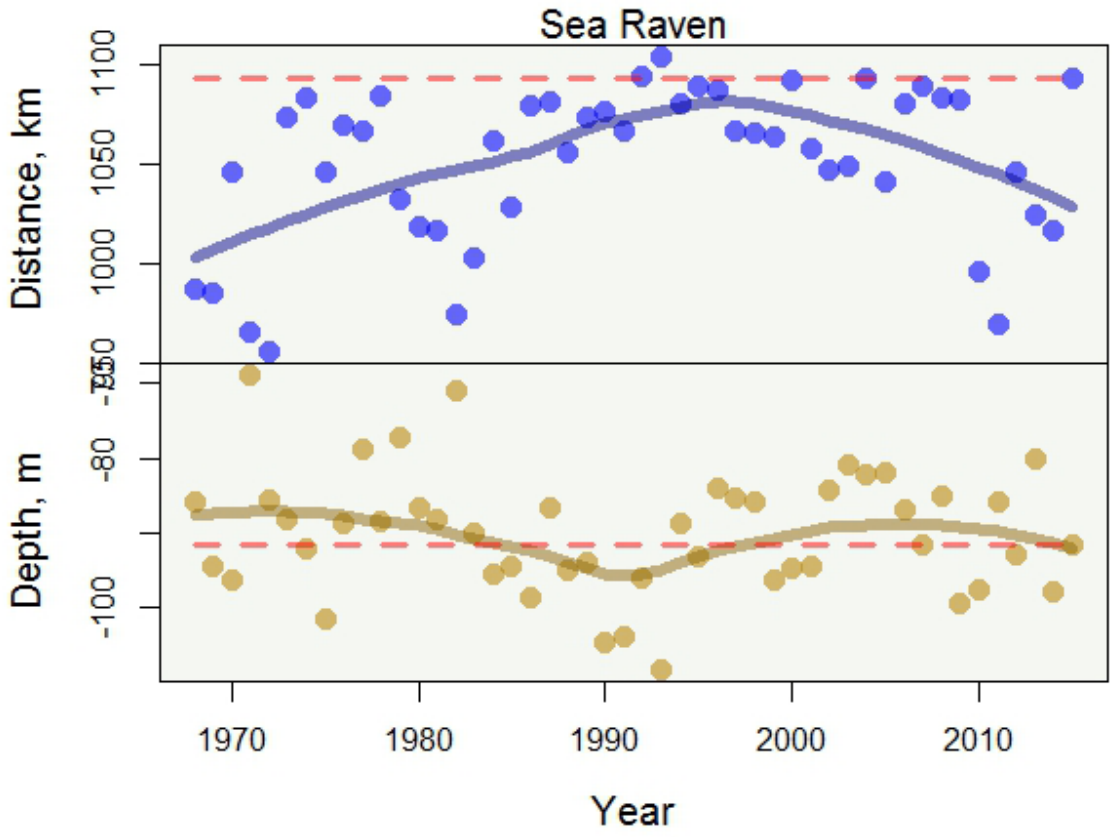
## Sand lance


Sand Lance
Distance, km
1100
900
700
500
Depth, m
-100
-200
1970
1980
1990
2000
2010
Year

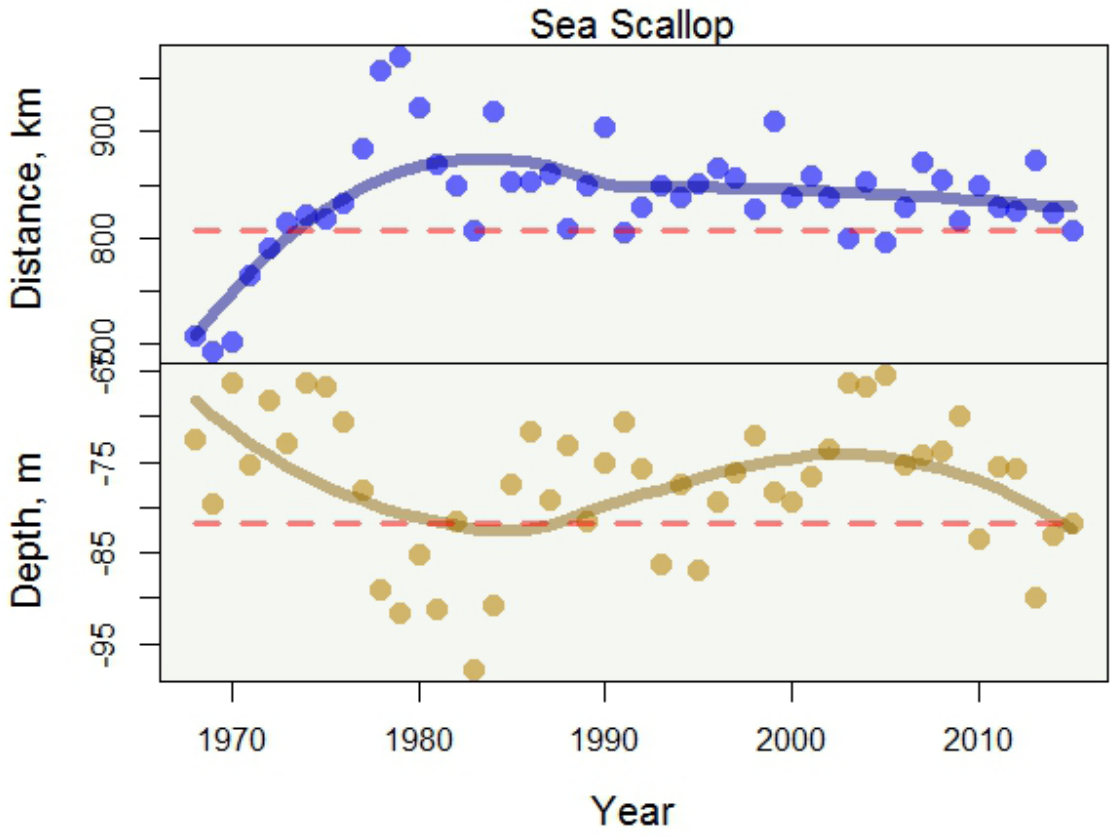
## Scup


Scup
Distance, km
500
600
700
Depth, m
-40
-35
-30
-25
1970
1980
1990
2000
2010
Year

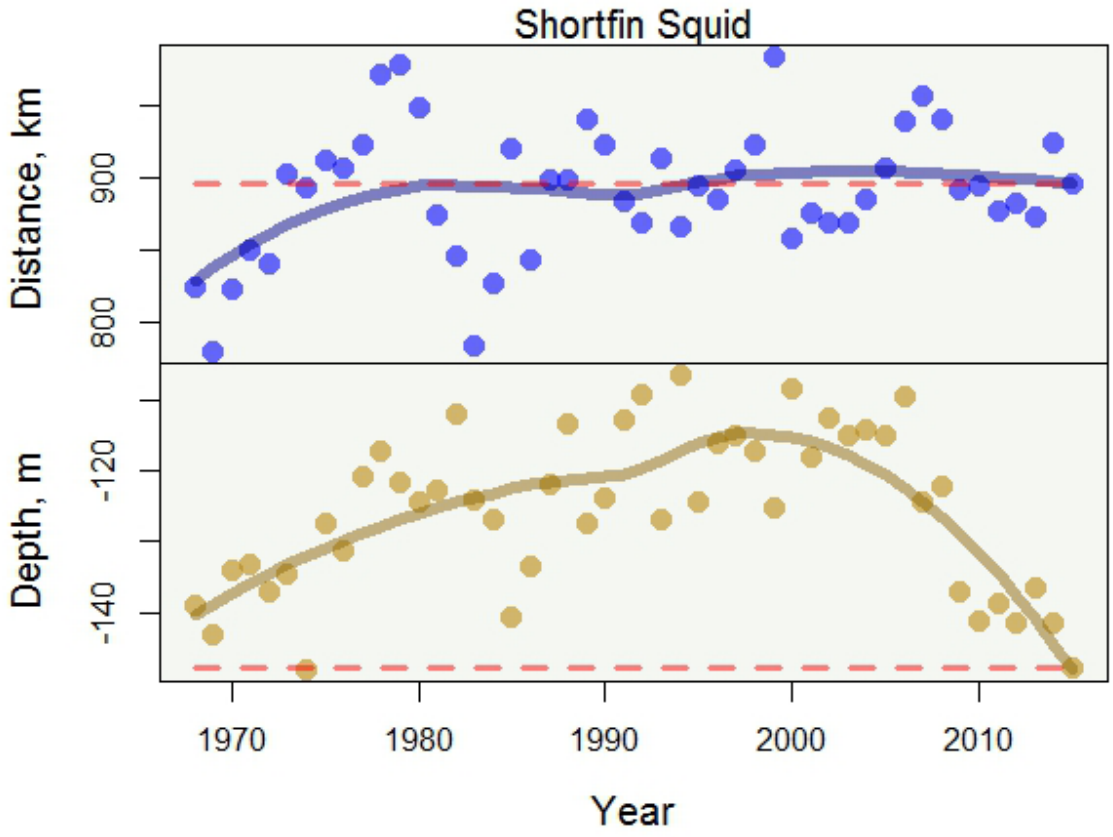
## Sea raven


Sea Raven
Distance, km
1100
1050
1000
Depth, m
-80
-100
1970
1980
1990
2000
2010
Year

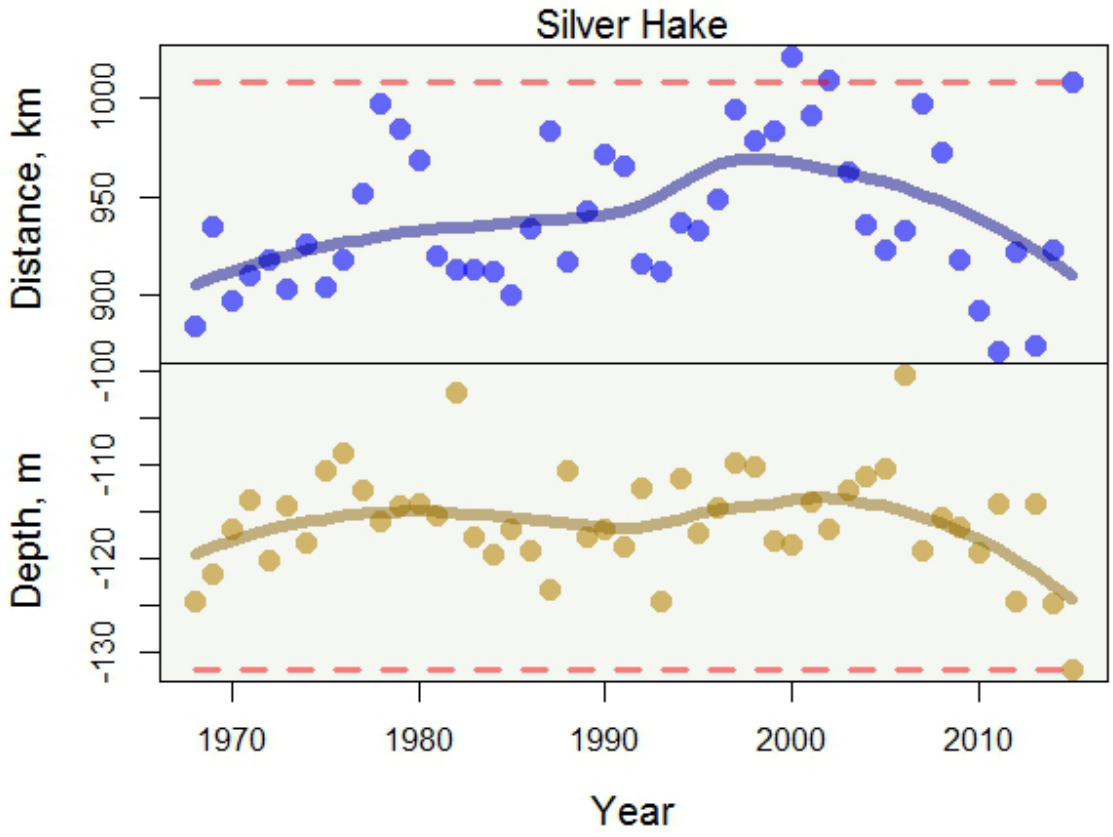
## Sea Scallop


Sea Scallop
Distance, km
900
800
700
Depth, m
-75
-85
-95
1970
1980
1990
2000
2010
Year

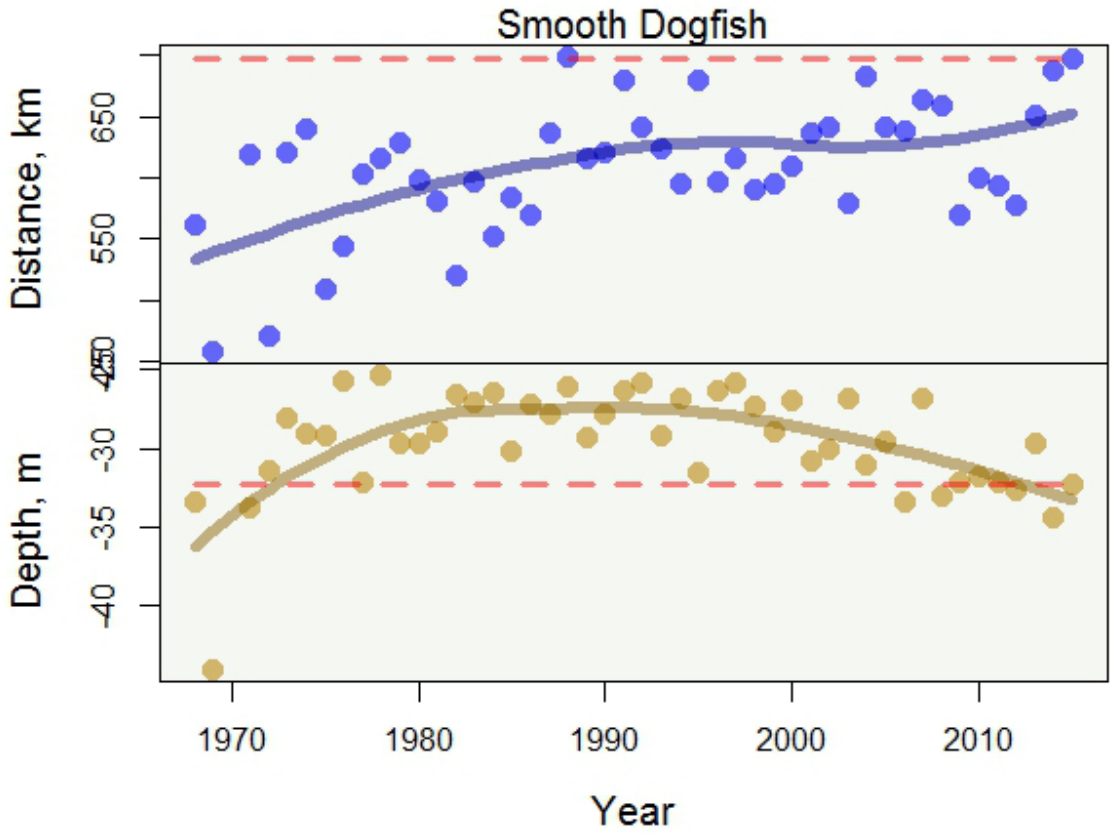
## Shortfin squid



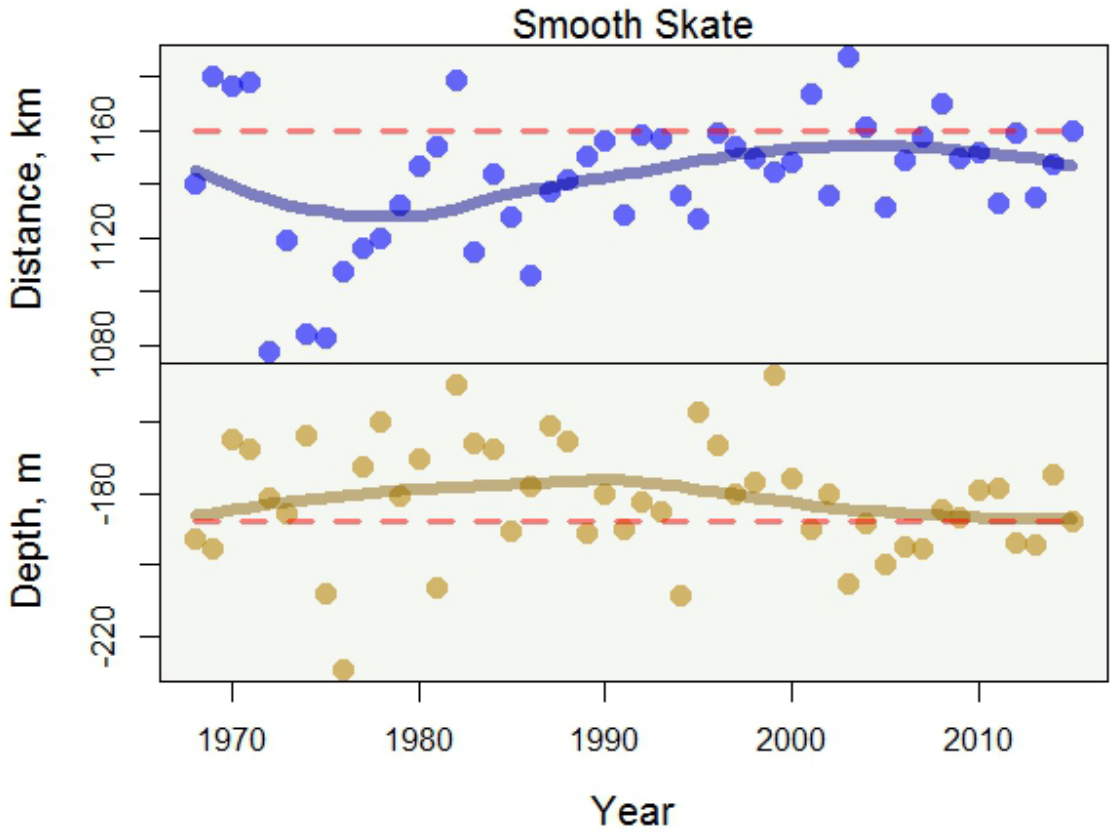
## Silver hake


Silver Hake
Distance, km
1000
950
900
-100
Depth, m
-110
-120
-130
1970
1980
1990
2000
2010
Year

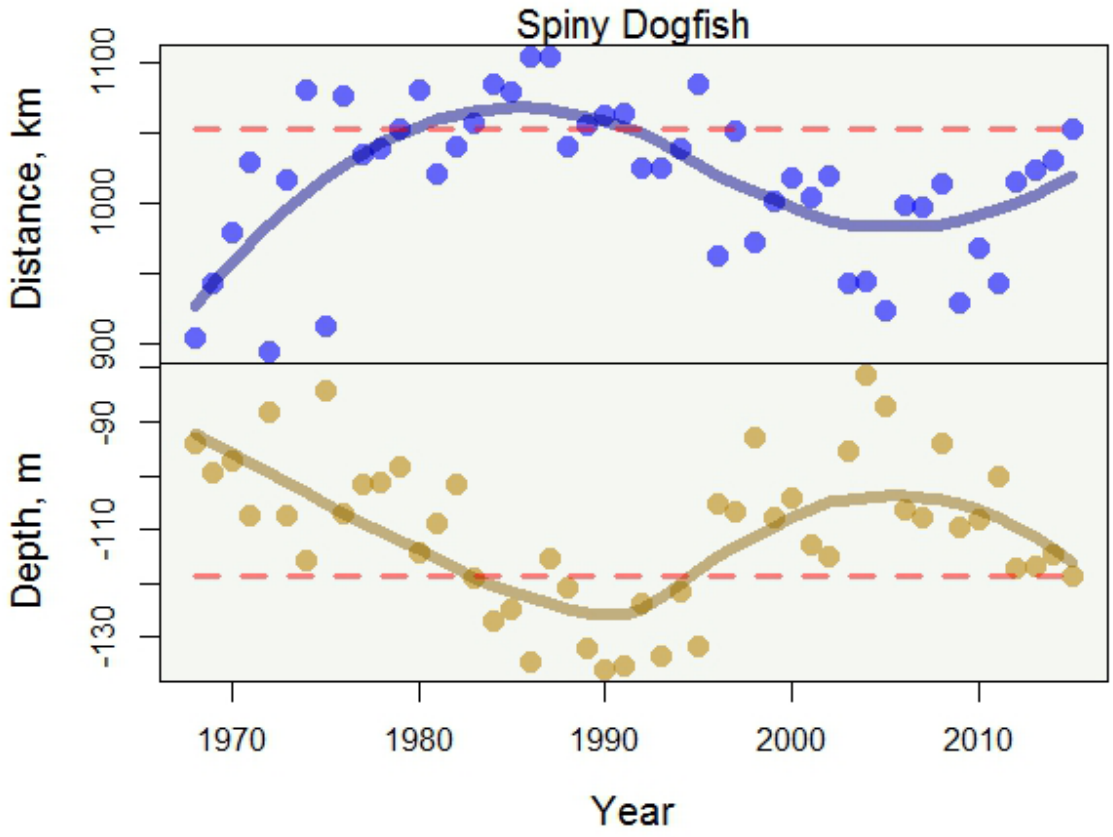
## Smooth dogfish



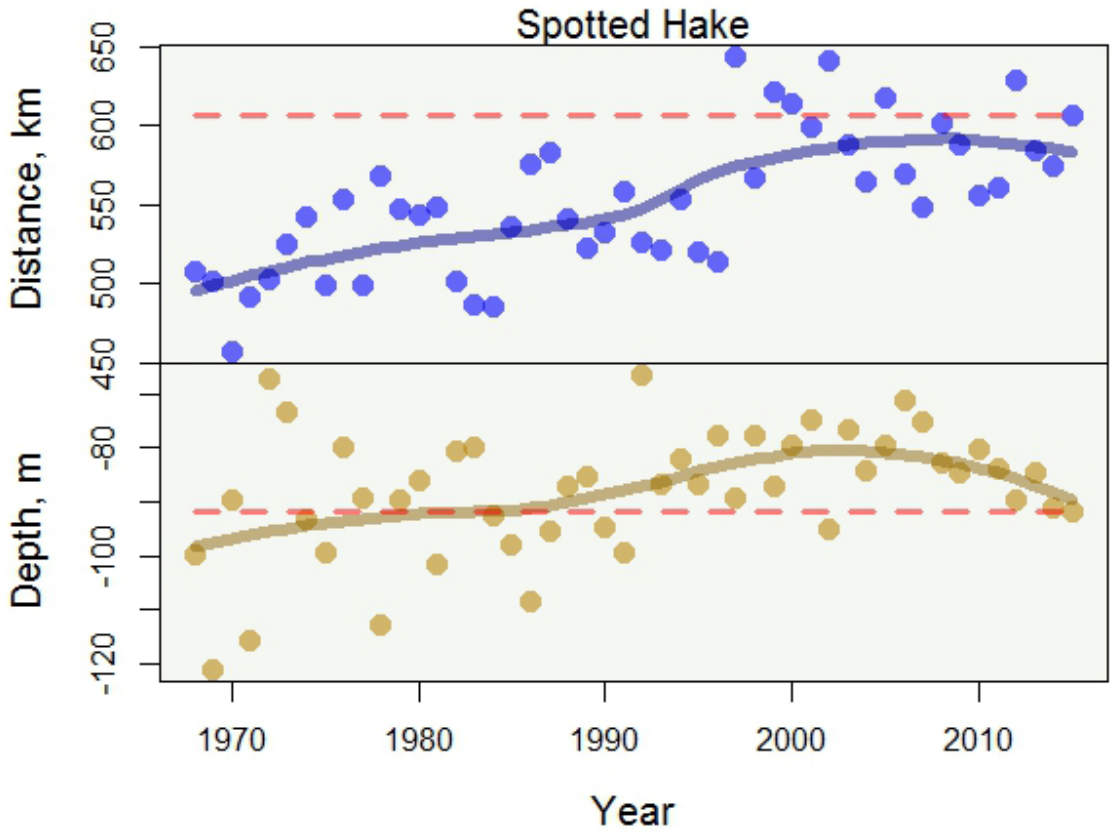
## Smooth skate



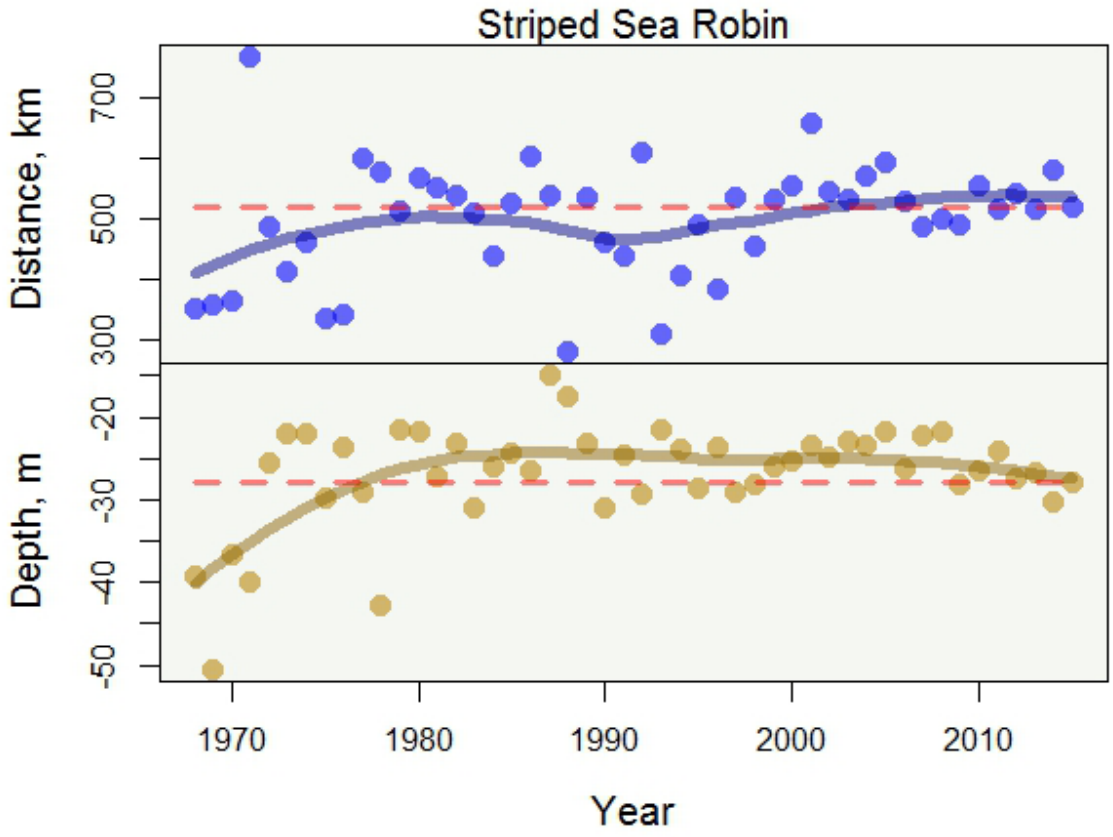
## Spiny dogfish



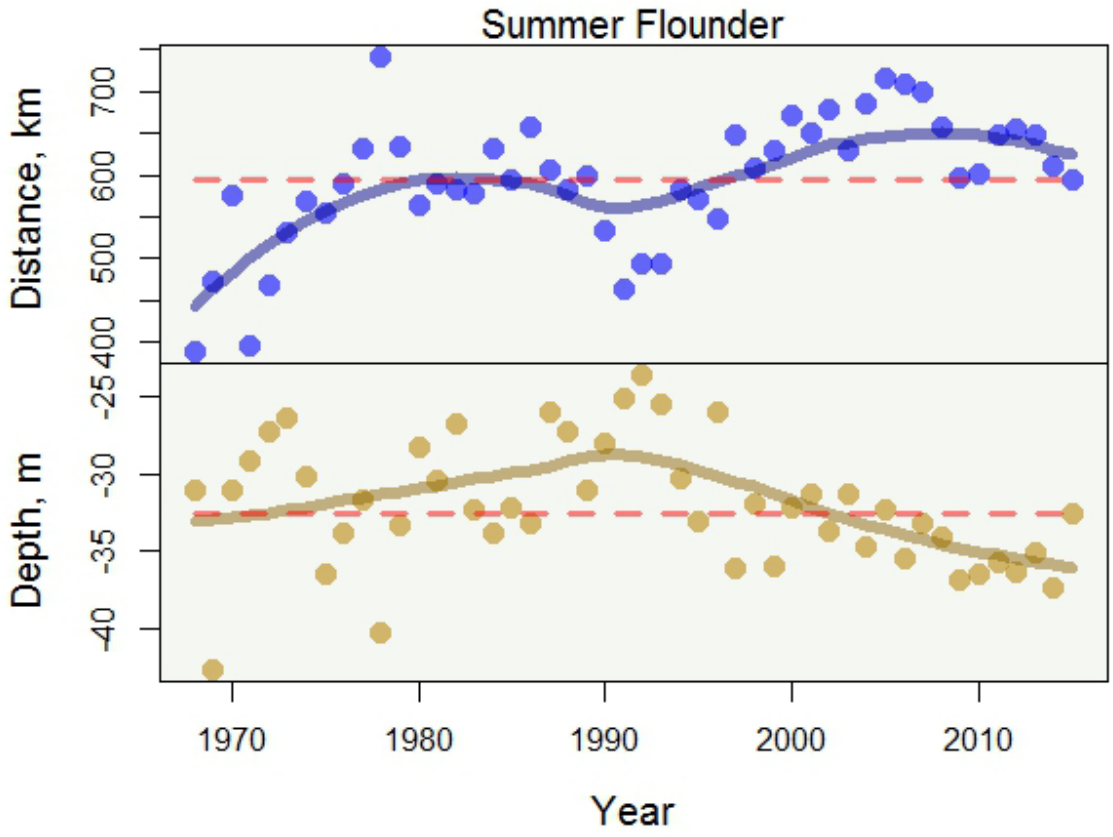
## Spotted hake



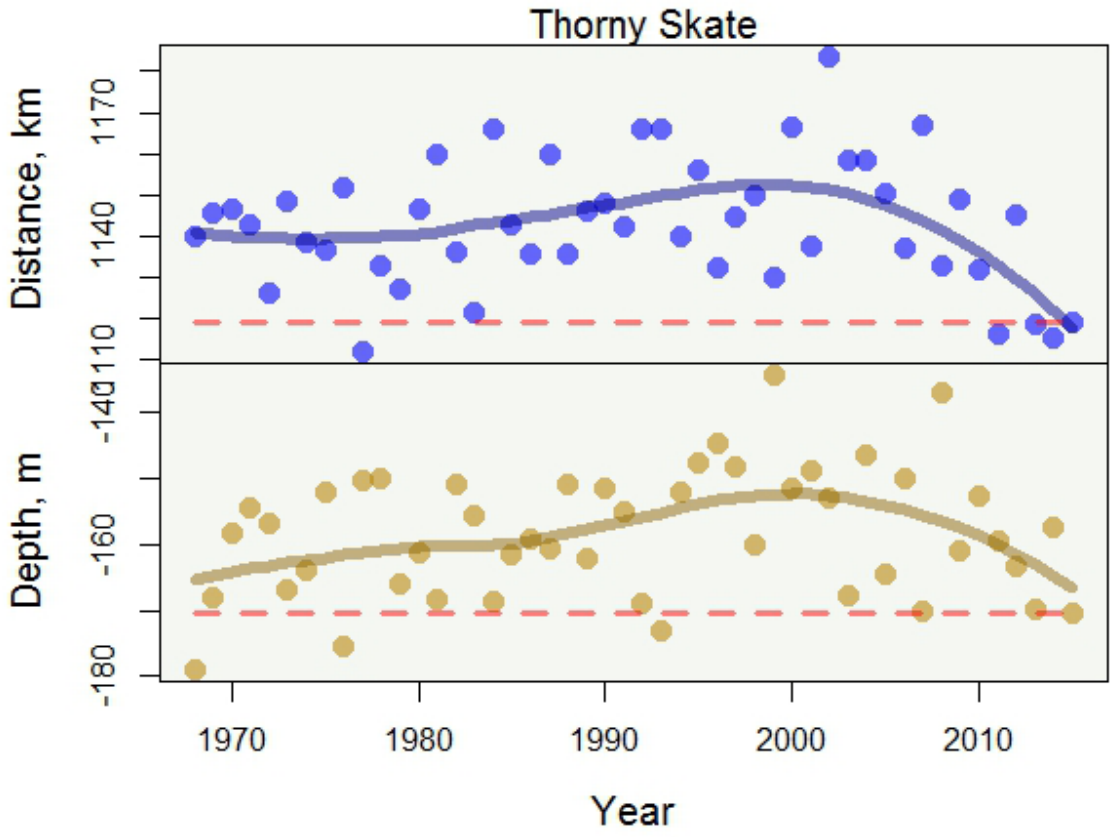
## Striped sea robin



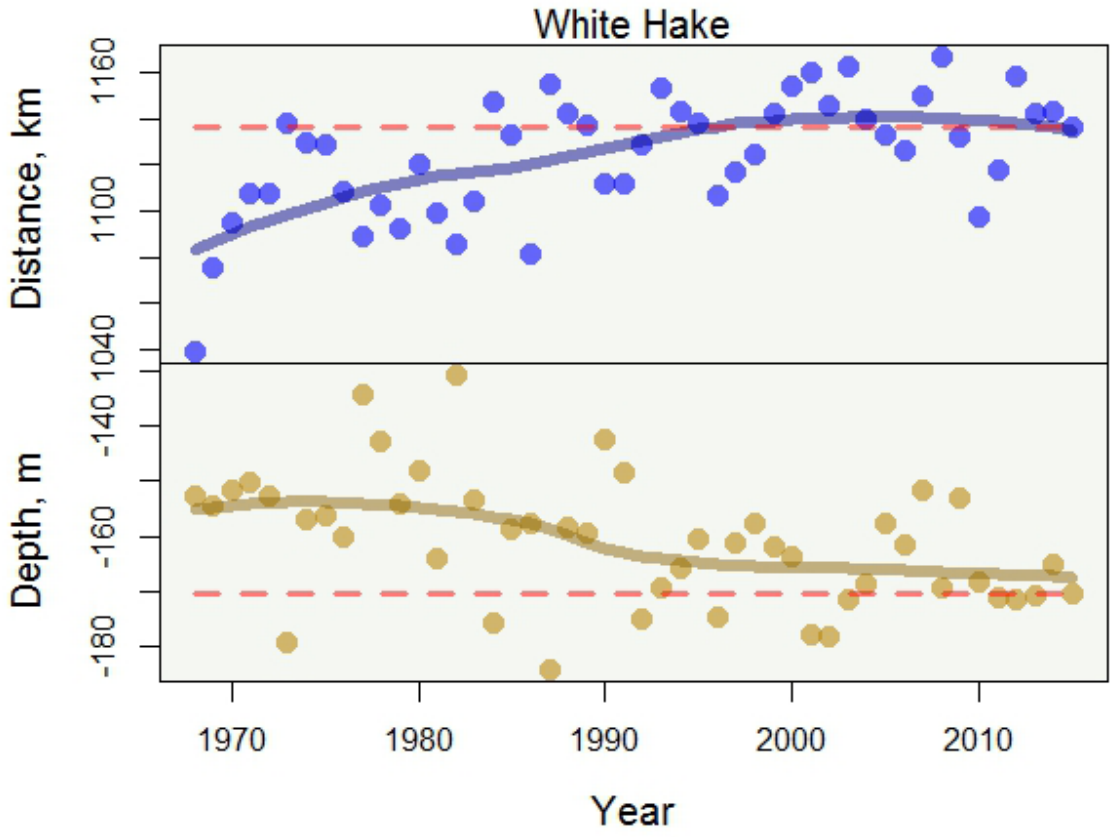
## Summer flounder



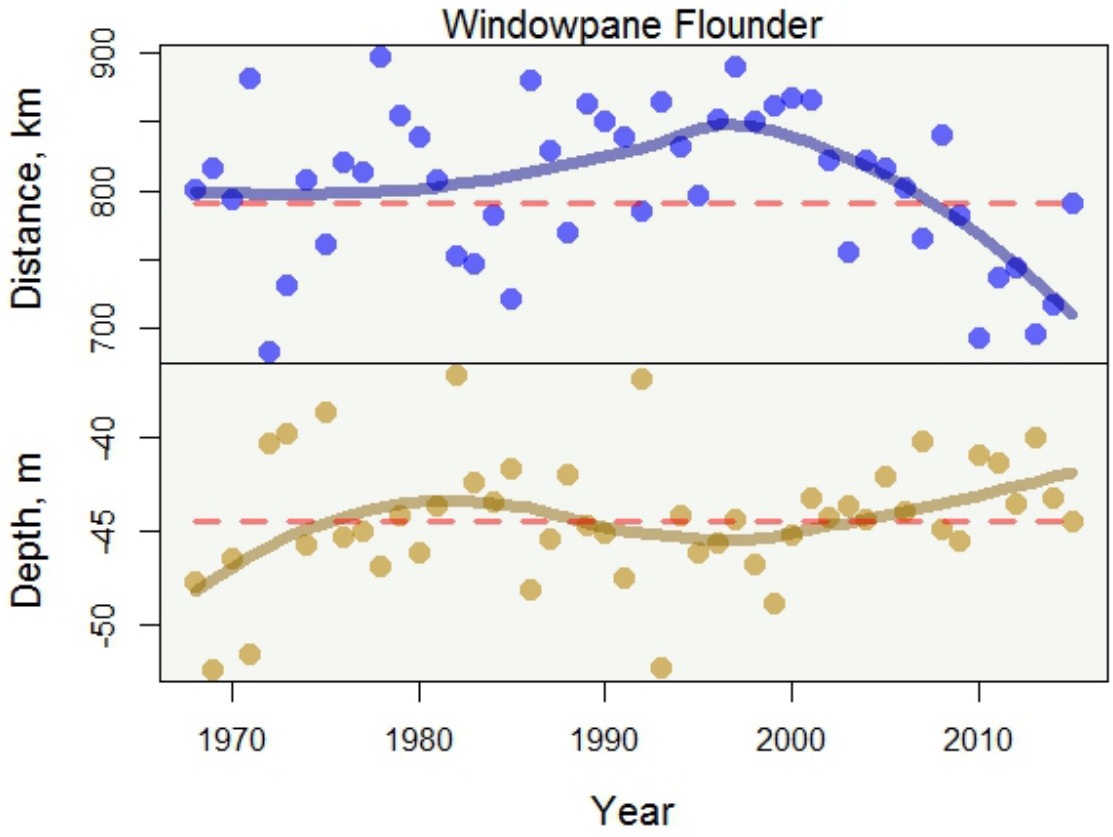
## Thorny skate



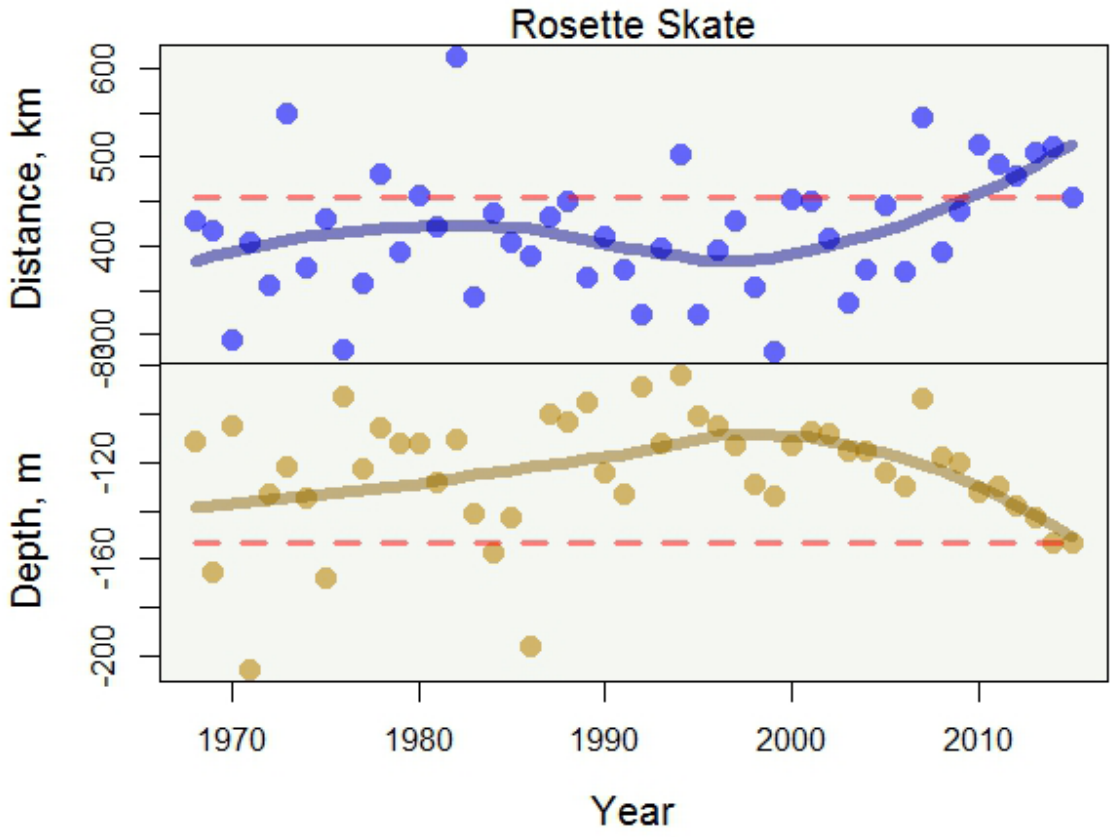
## White Hake


White Hake
Distance, km
1160
1100
1040
Depth, m
-140
-160
-180
1970
1980
1990
2000
2010
Year

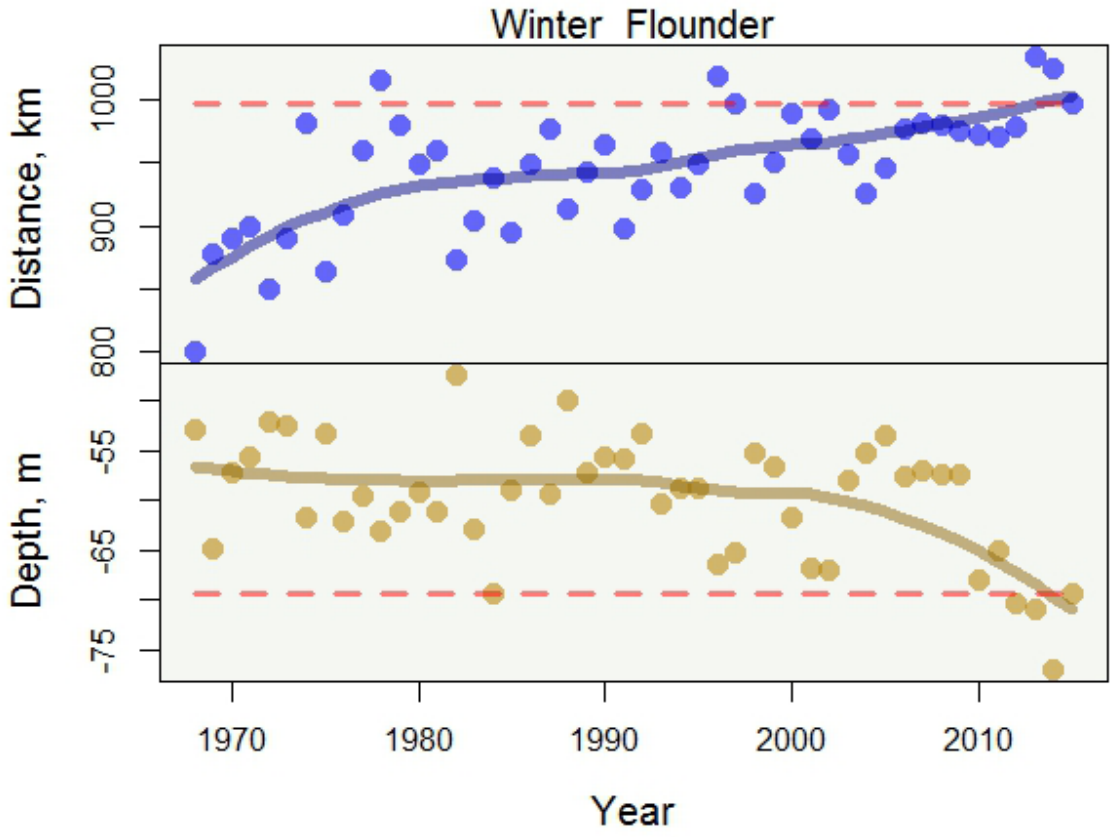
## Windowpane flounder



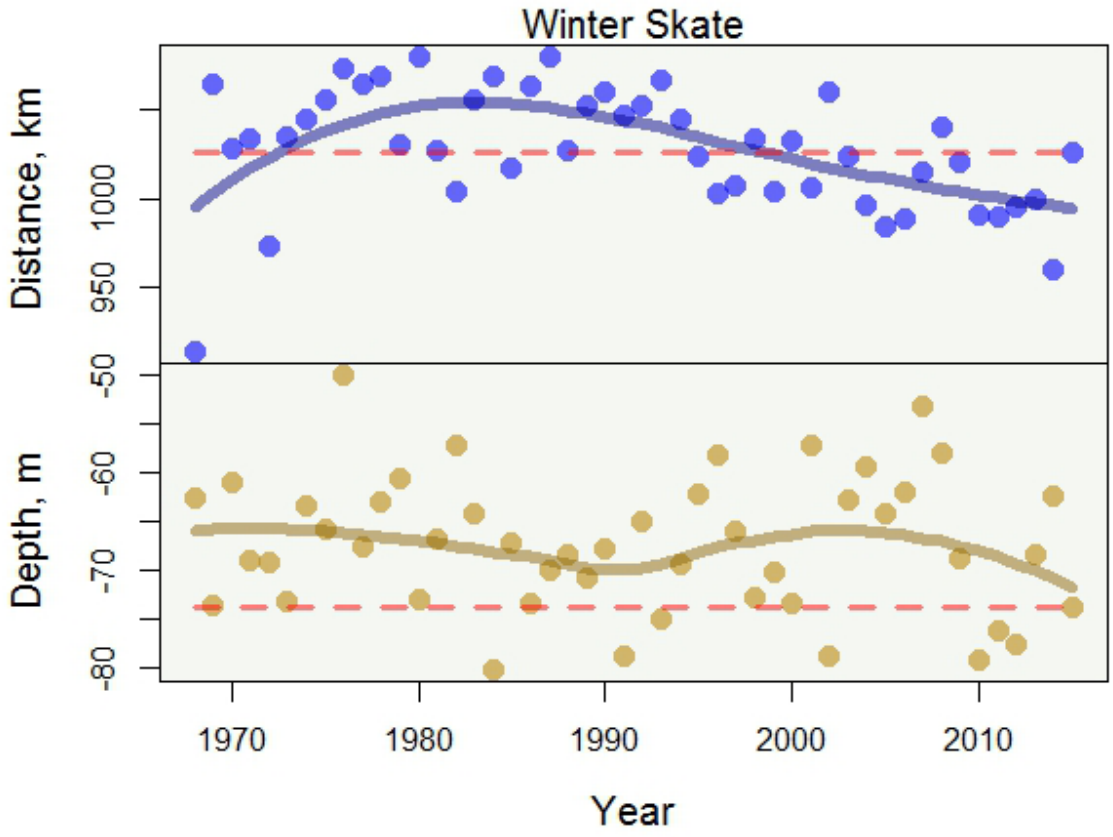
## Rosette skate



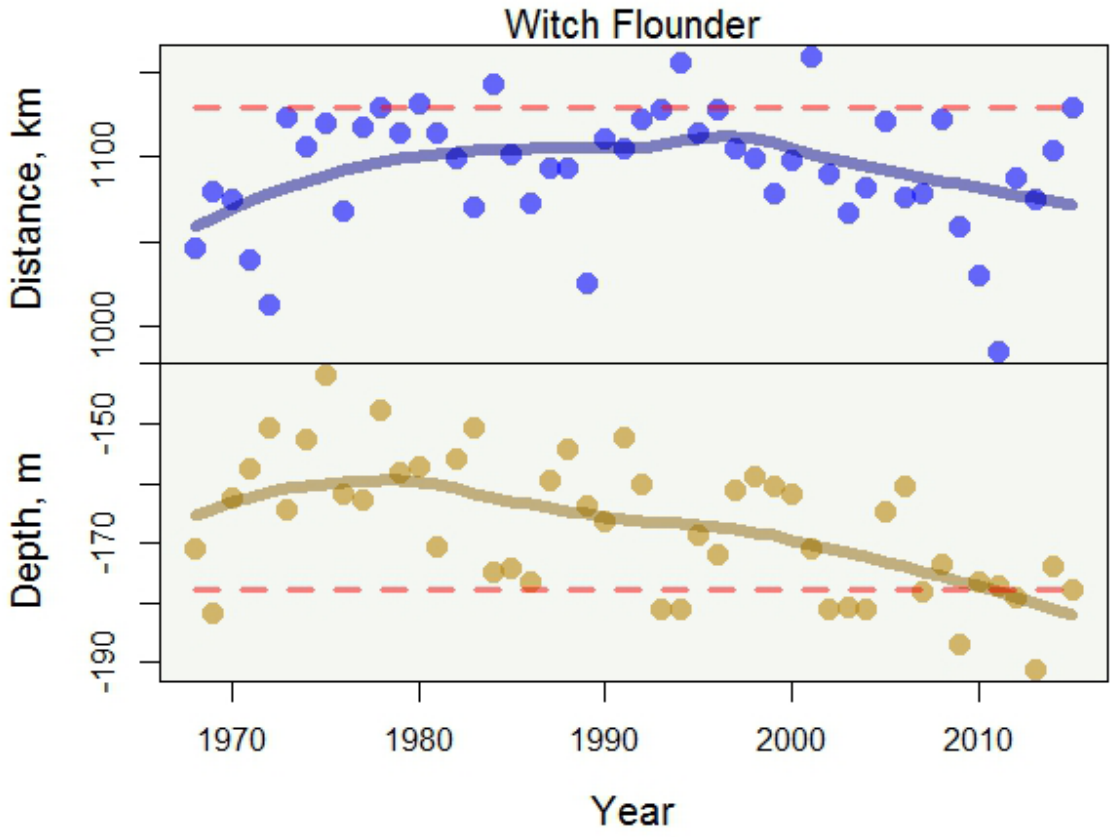
## Winter flounder



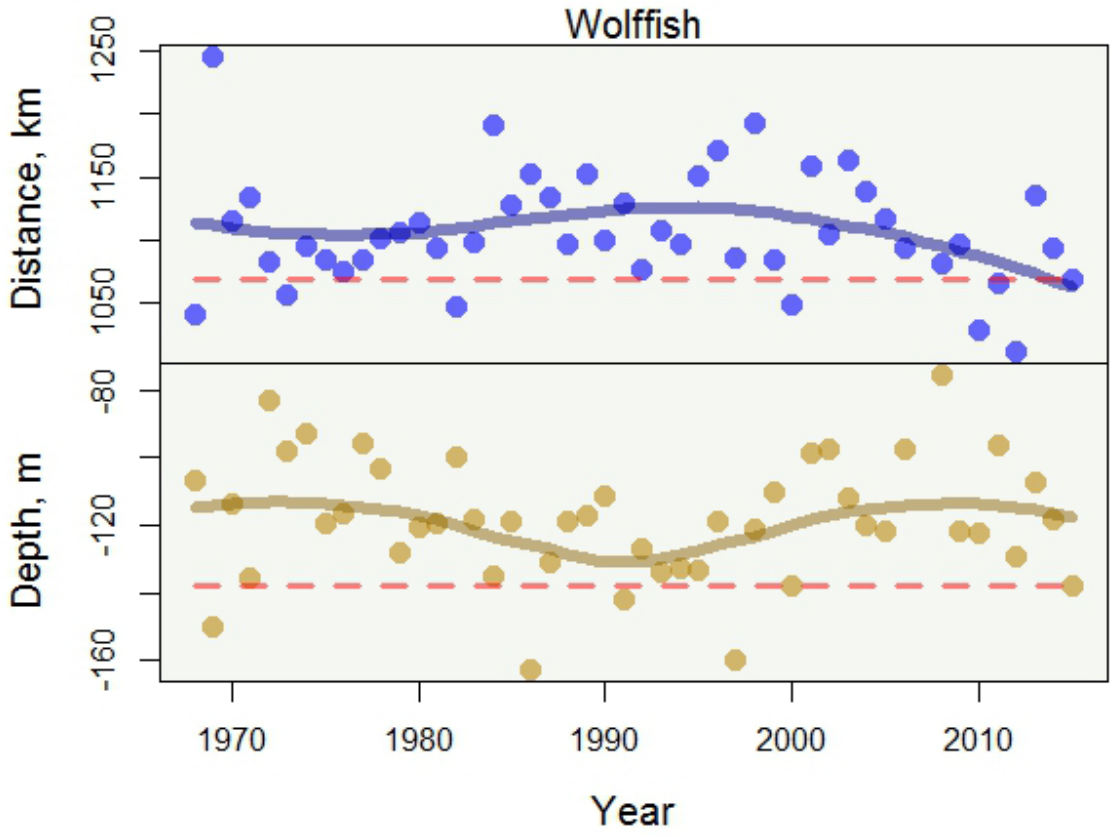
### Winter skate



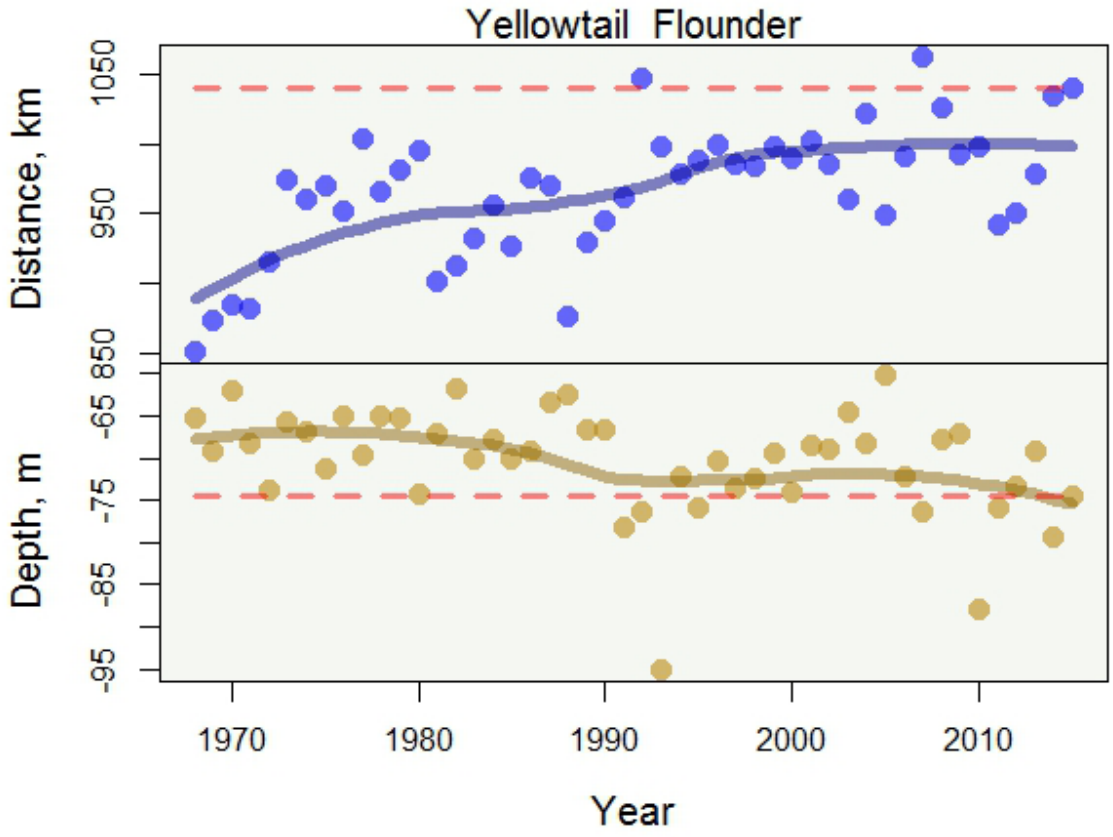
## Witch flounder



## Wolffish


Wolffish
Distance, km
1250
1150
1050
Depth, m
-80
-120
-160
1970
1980
1990
2000
2010
Year

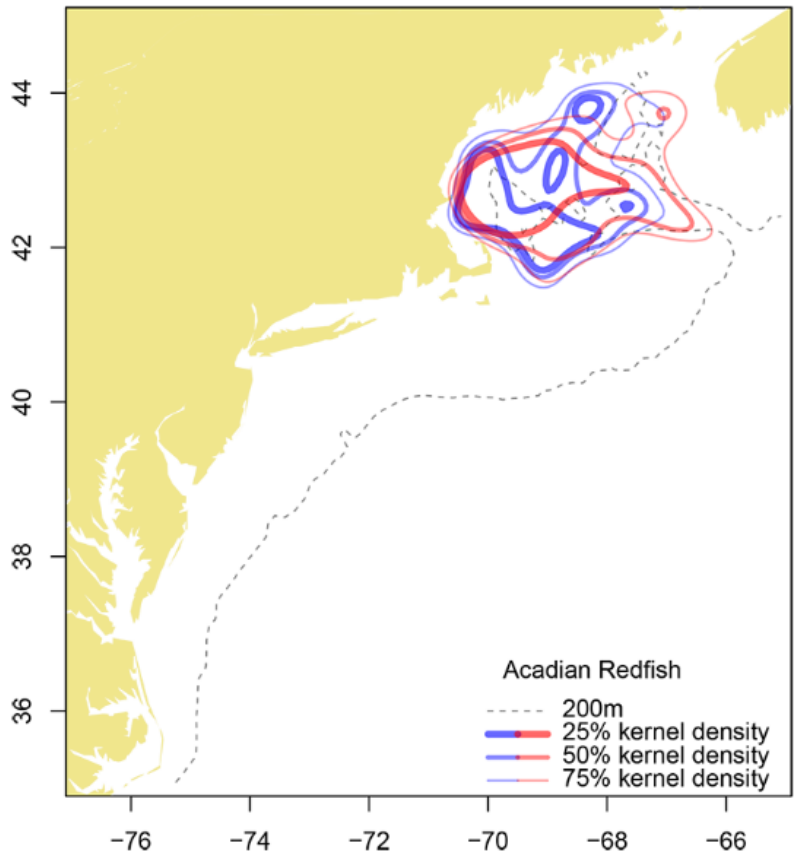
### Yellowtail flounder



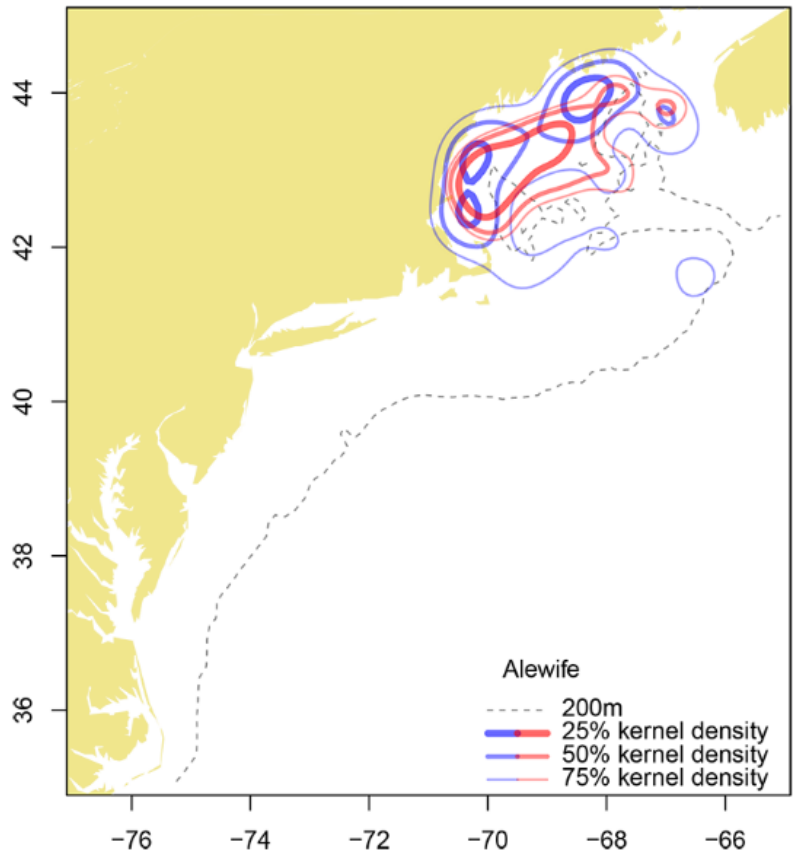

# Kernel Density Plots of Fall Species Distribution

The habitats used by species of the Northeast Shelf ecosystem have changed over recent decades. Species have moved in response to a complex set of factors, resulting in changes in distribution in respect to latitude and depth among a number of other habitat indicators. Kernel density plots provide a way of characterizing where a species is distributed by defining an area with an associated probability that a species will be found there. We compared the kernel densities for three probability levels between two time periods. The three probability levels were 25%, 50%, and 75% kernel densities. The 25% kernel defines the core area of the distribution, whereas the 75% defines the broader use of the ecosystem. The two time periods were a base distribution period based on species distribution during the 1970s (shown as blue kernel densities) and a contemporary distribution period based on the last three years (2013-2015) for the fall survey (shown as red kernel densities). The table below shows the species analyzed.

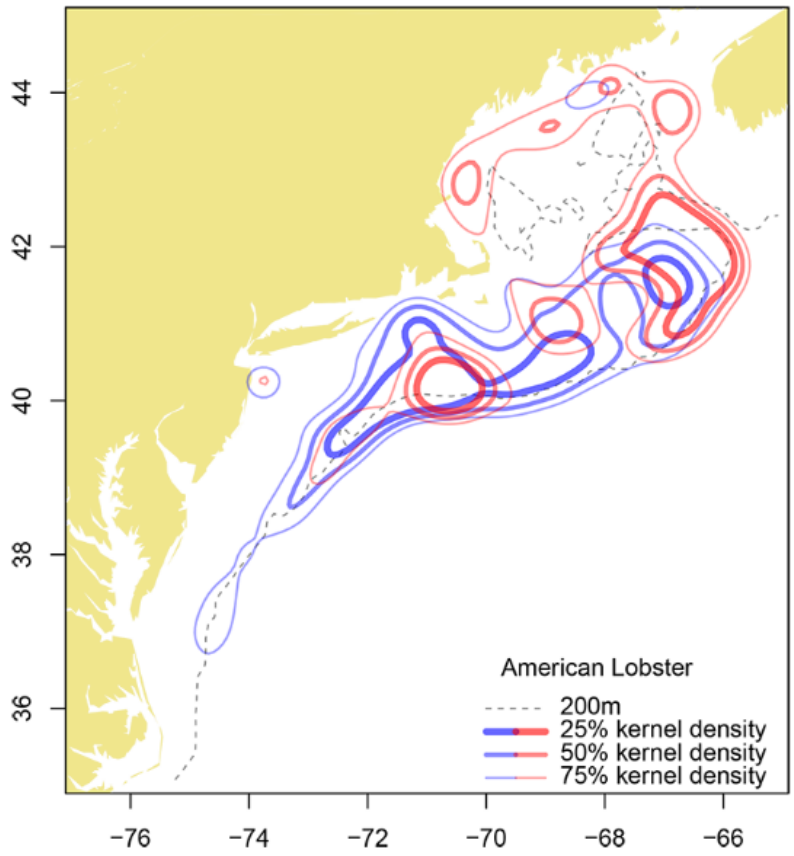
## Acadian redfish



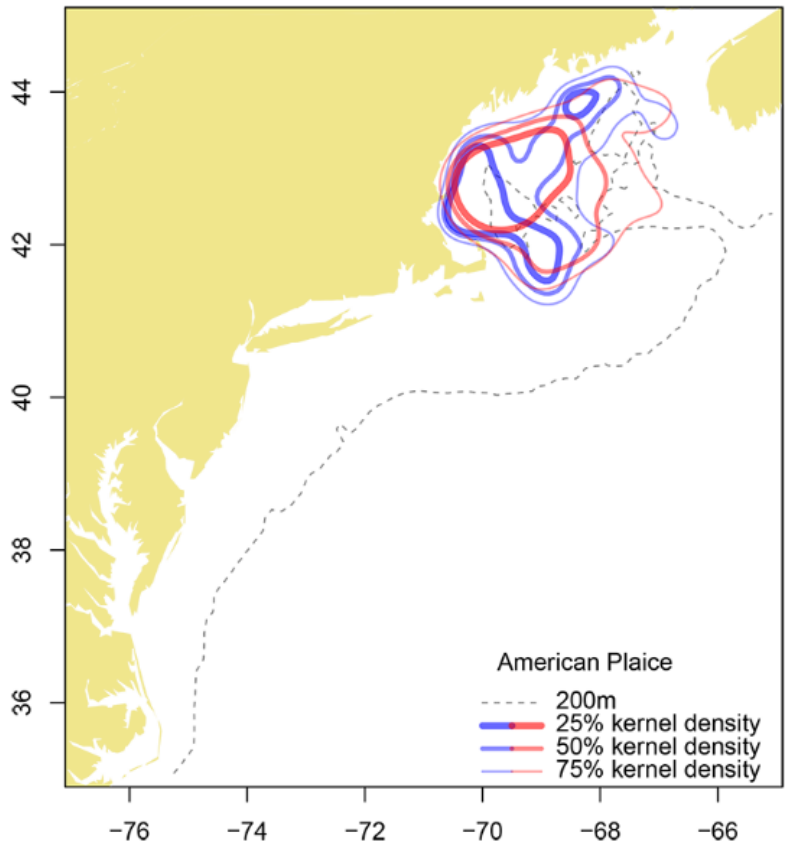
## Alewife


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Alewife
200m
25% kernel density
50% kernel density
75% kernel density

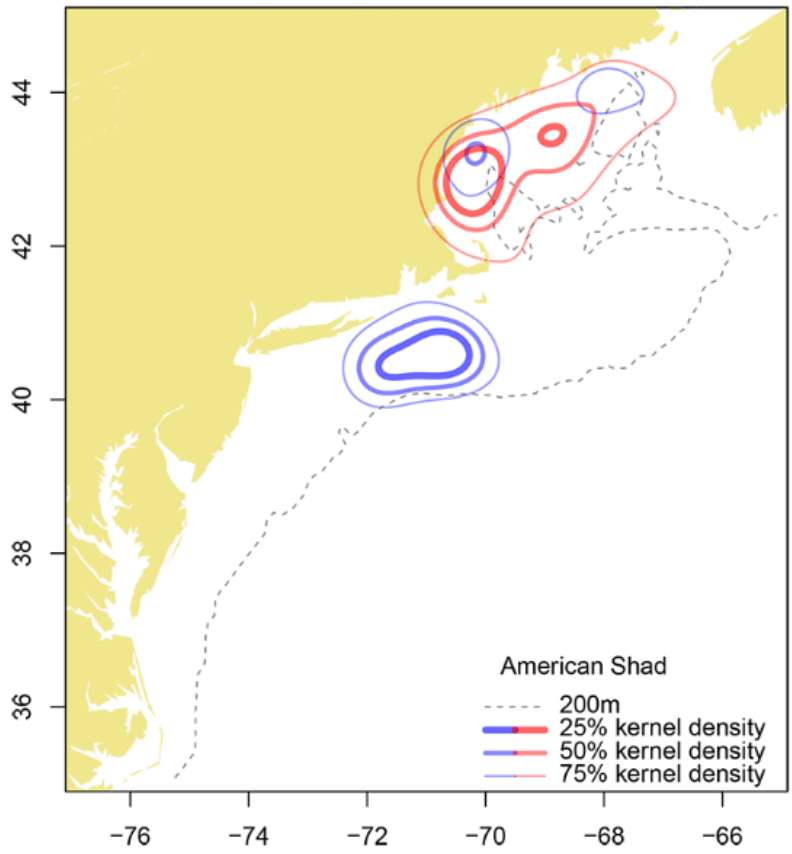
## American Lobster



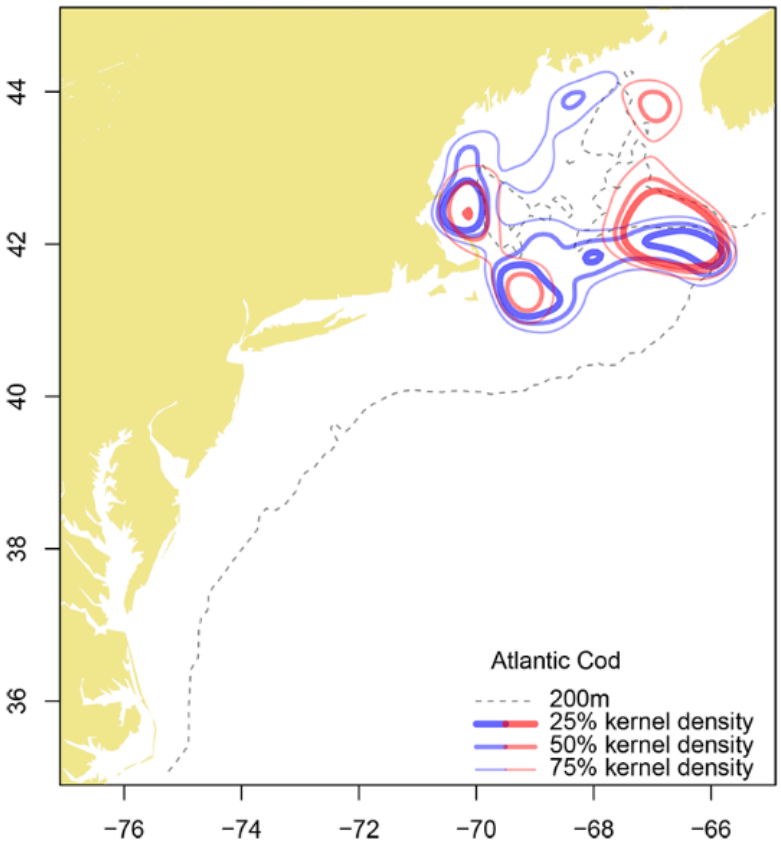
## American Plaice



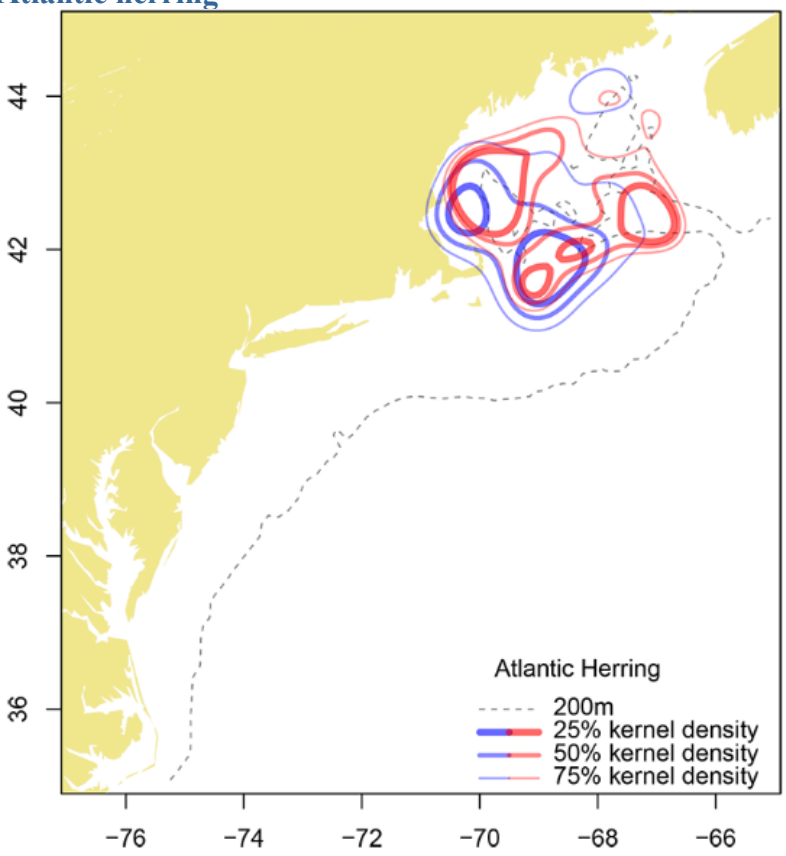
## American shad



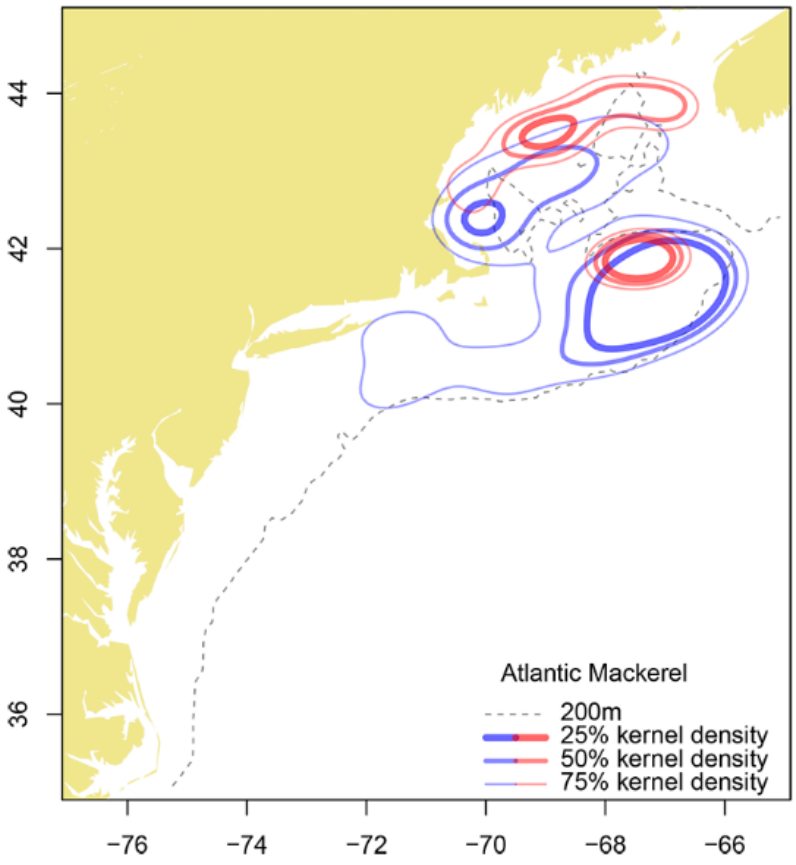
## Atlantic cod



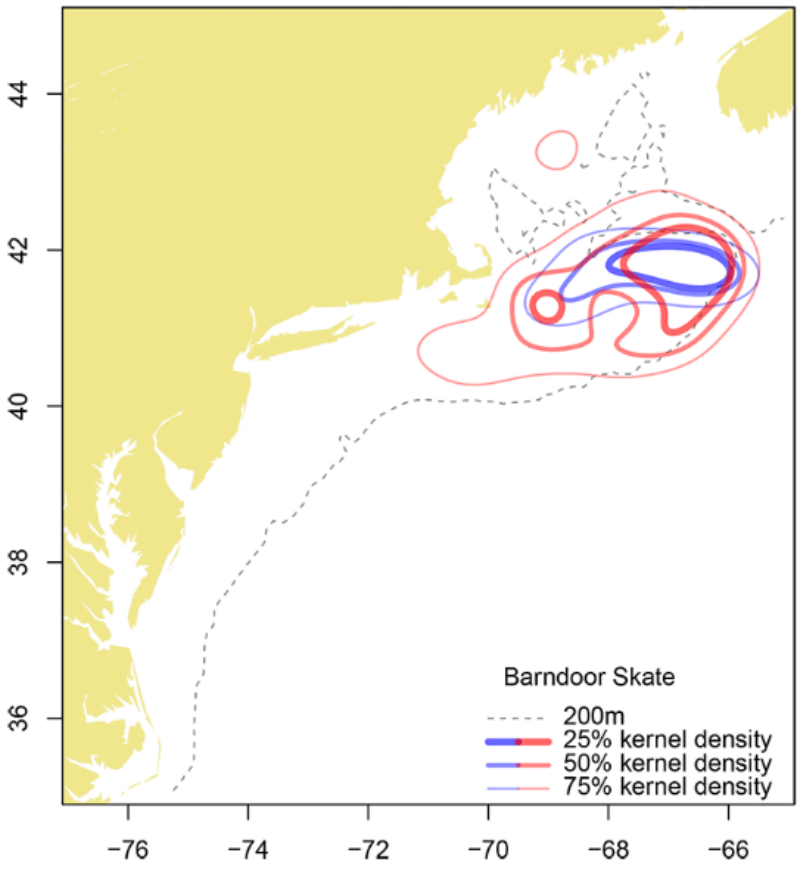
## Atlantic herring



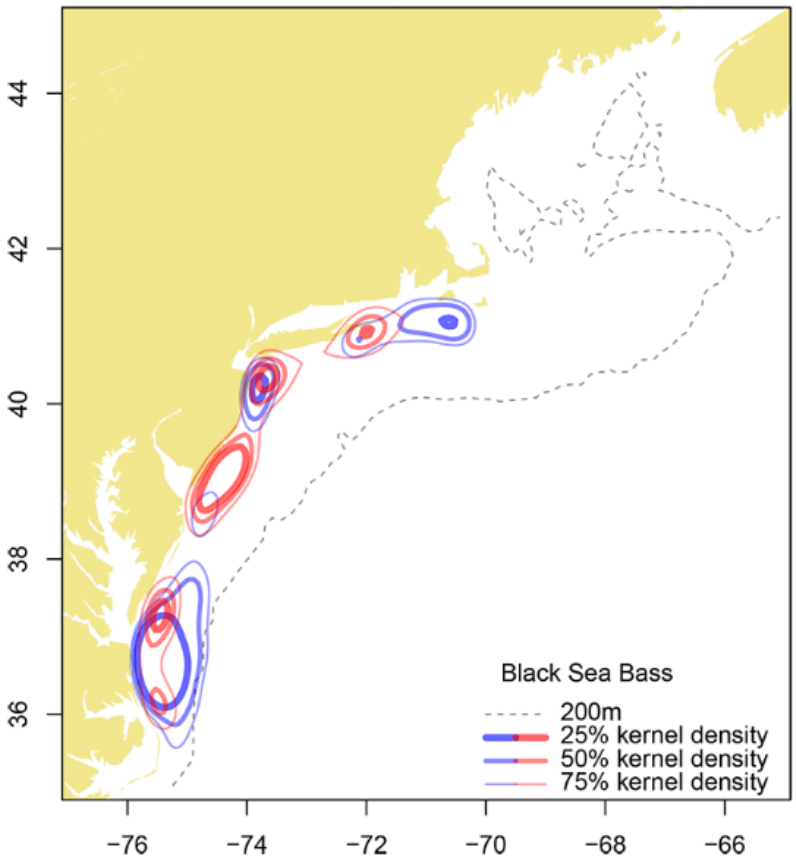
## Atlantic mackerel



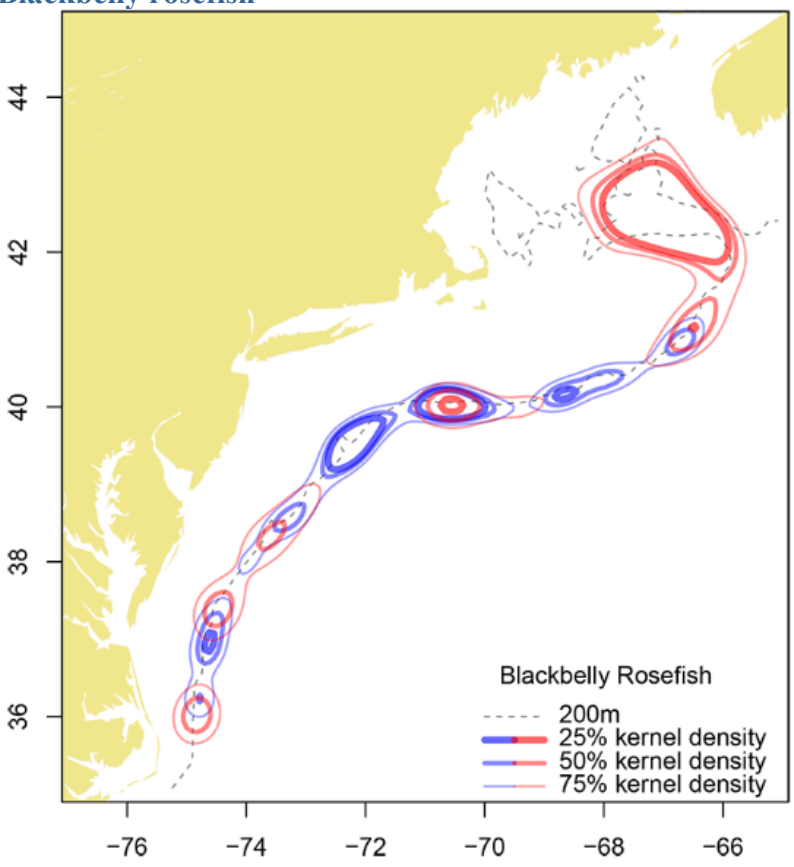
## Barndoor skate



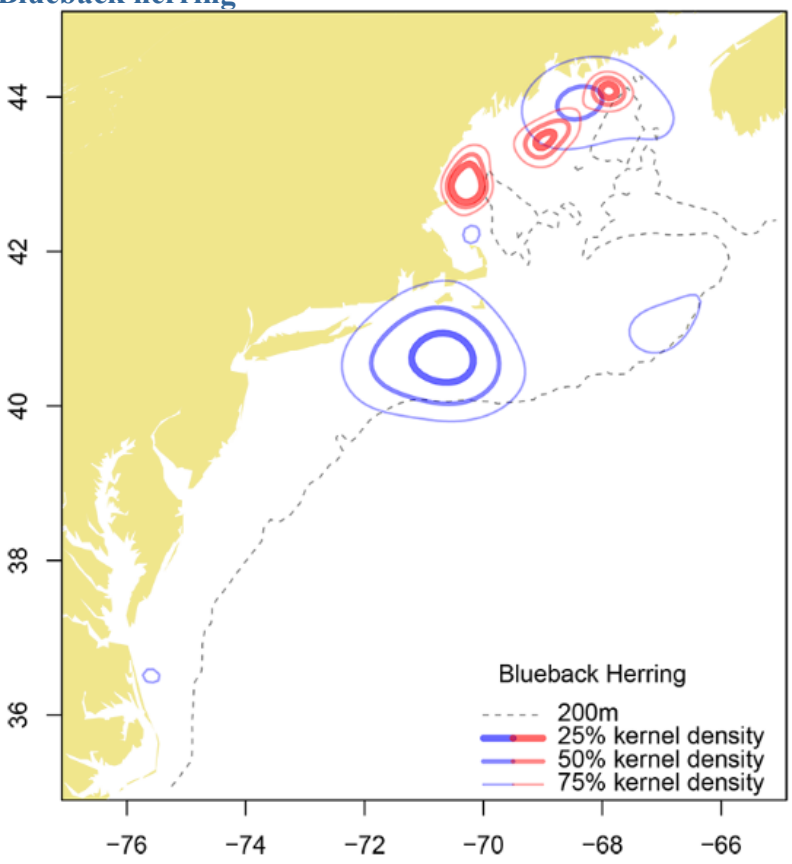
## Black sea bass



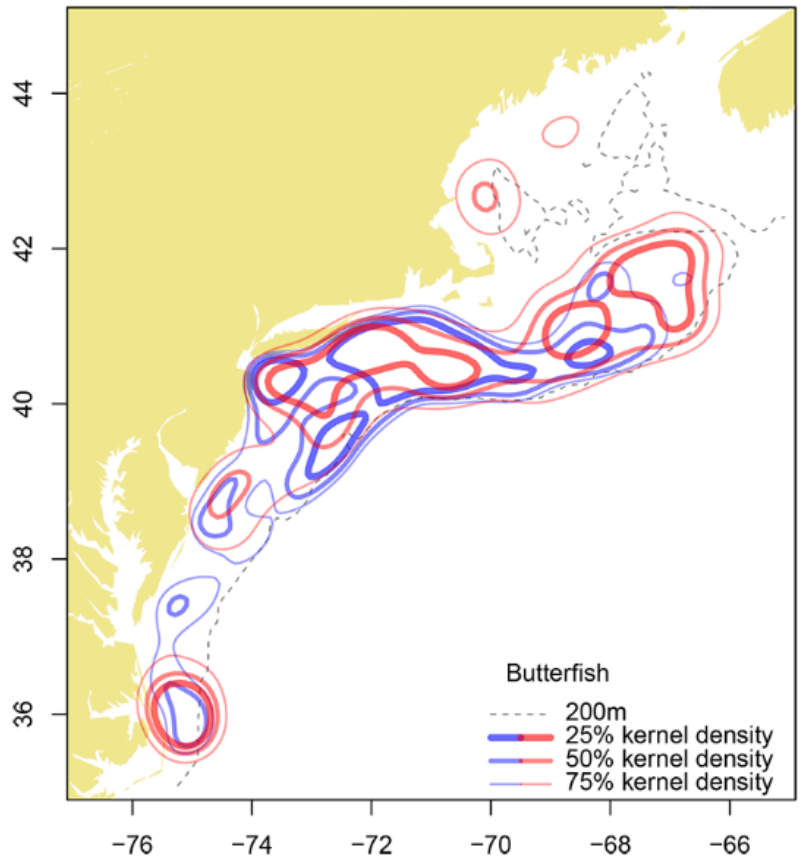
## Blackbelly rosefish



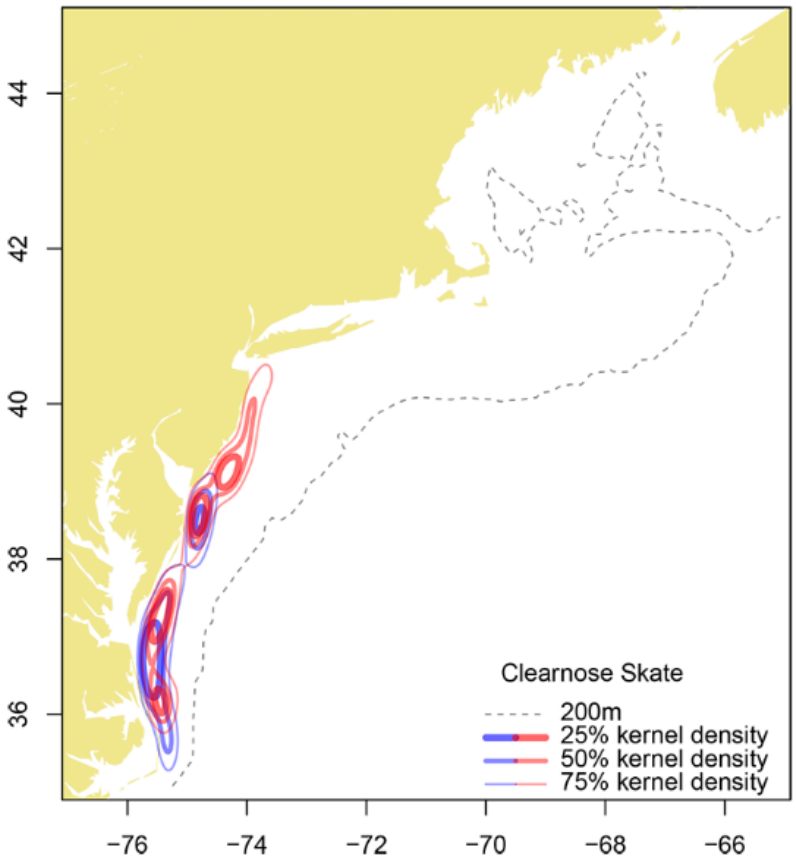
## Blueback herring



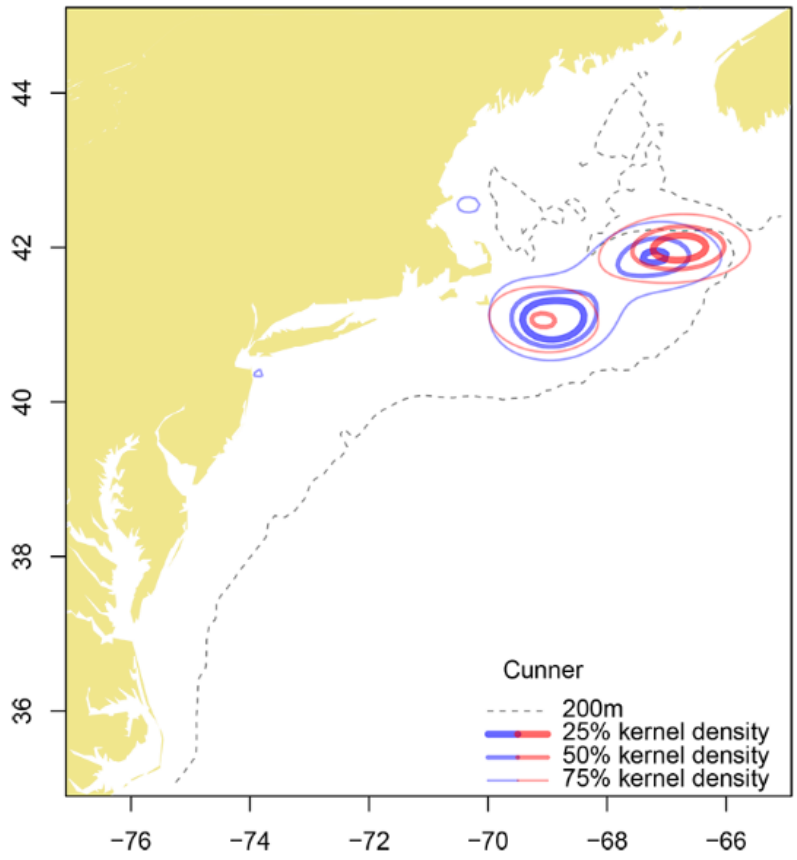
## Butterfish


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Butterfish
200m
25% kernel density
50% kernel density
75% kernel density

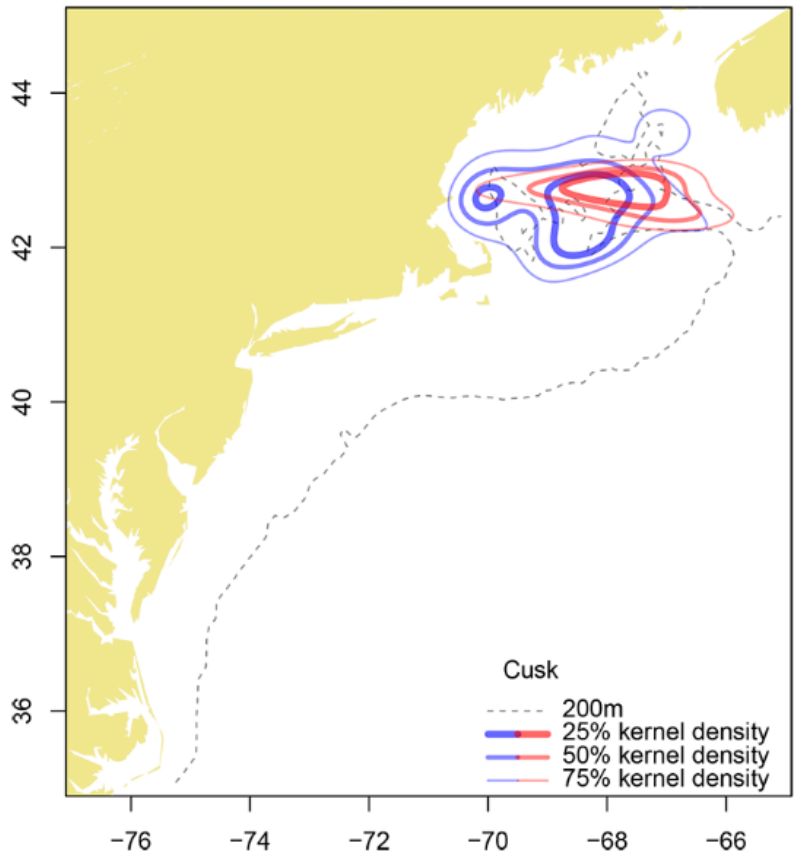
## Clearnose skate



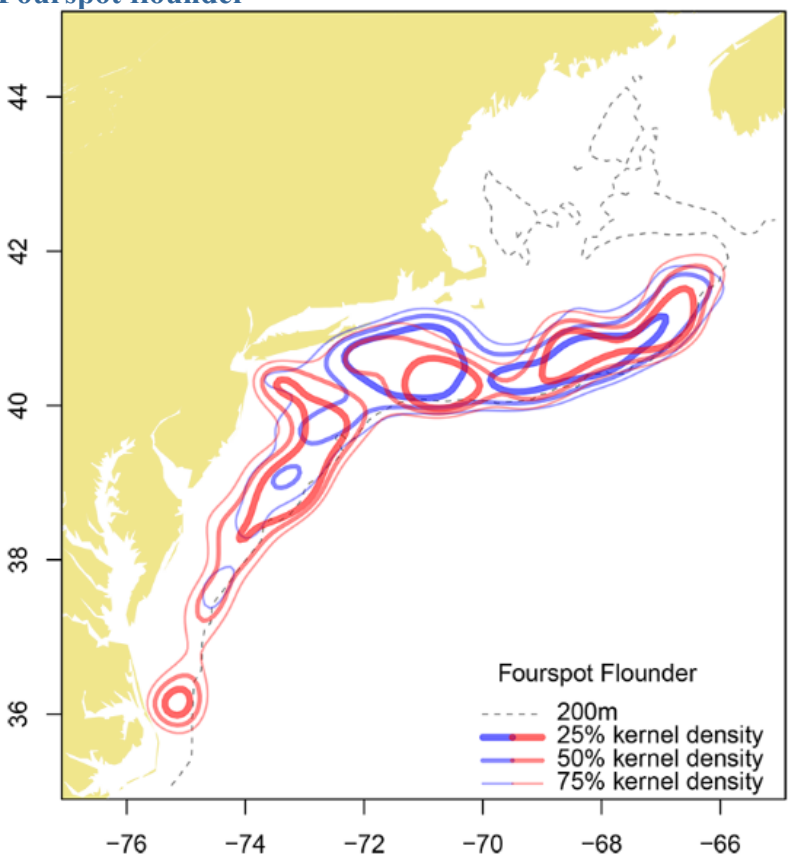
## Cunner


Cunner
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

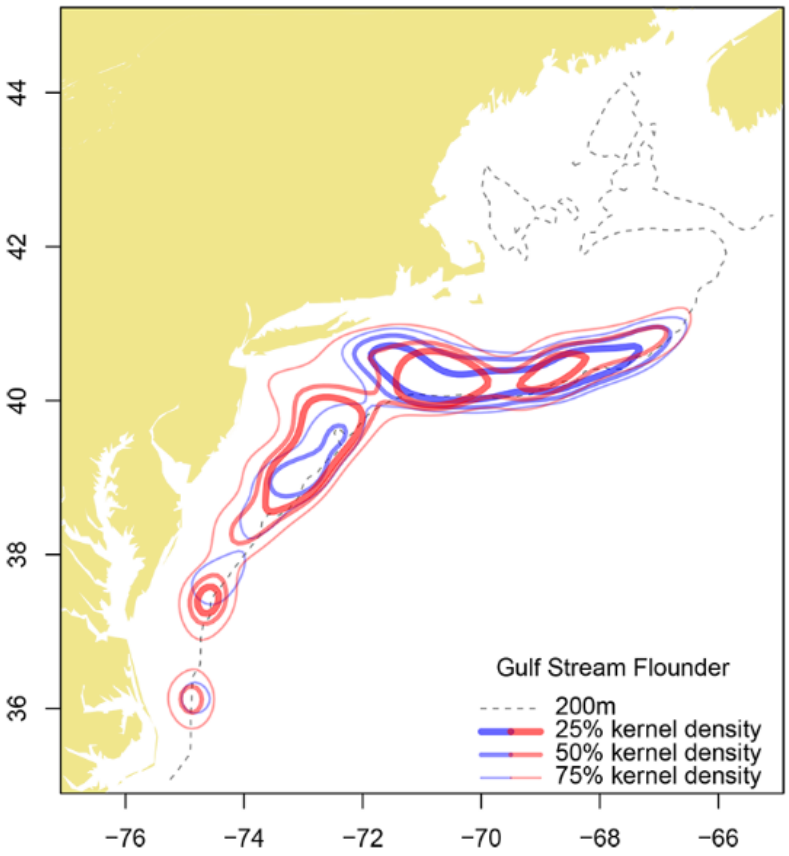
## Cusk


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Cusk
200m
25% kernel density
50% kernel density
75% kernel density

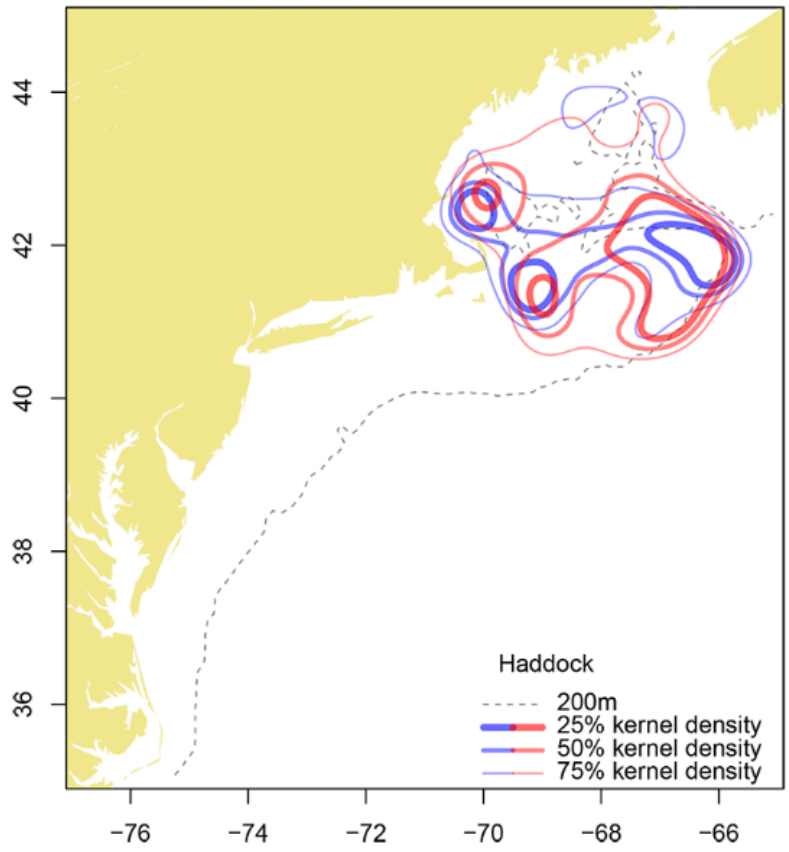
## Fourspot flounder



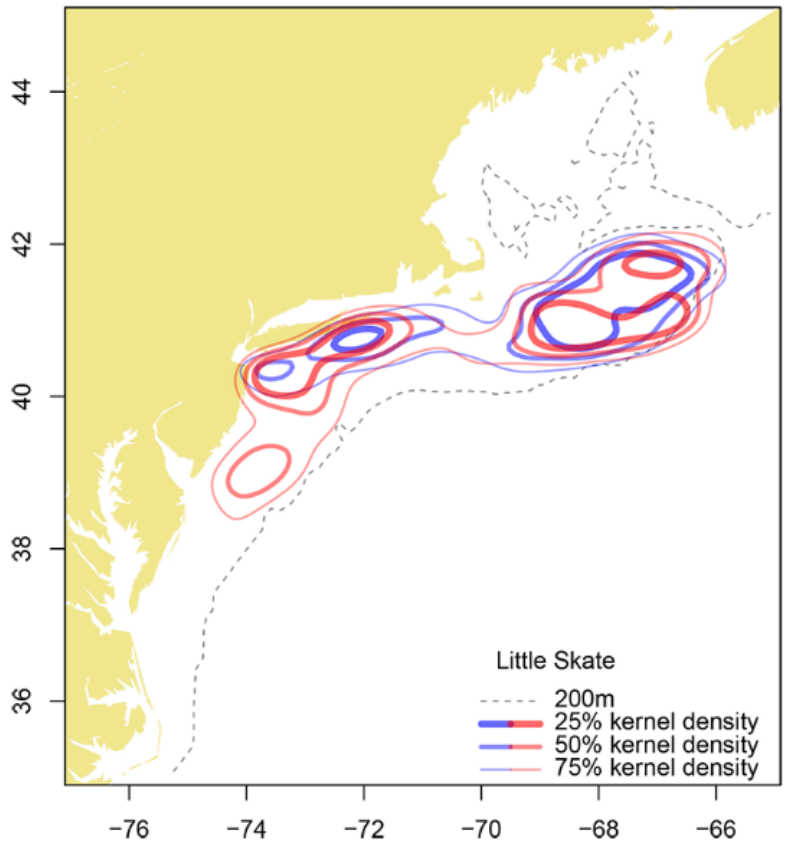
## Gulf stream flounder



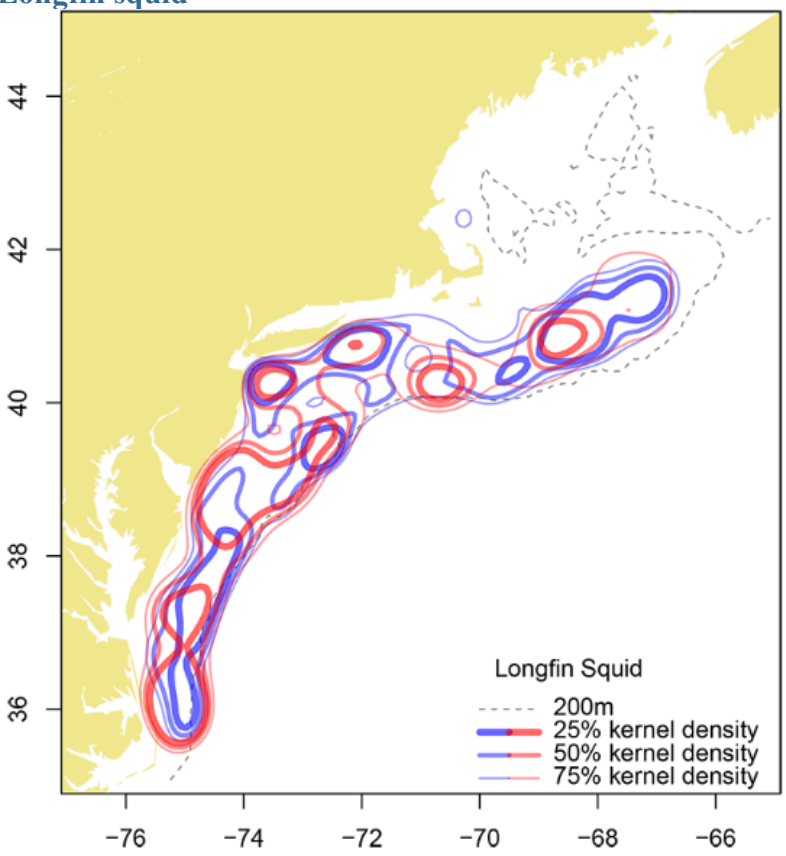
## Haddock


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Haddock
200m
25% kernel density
50% kernel density
75% kernel density

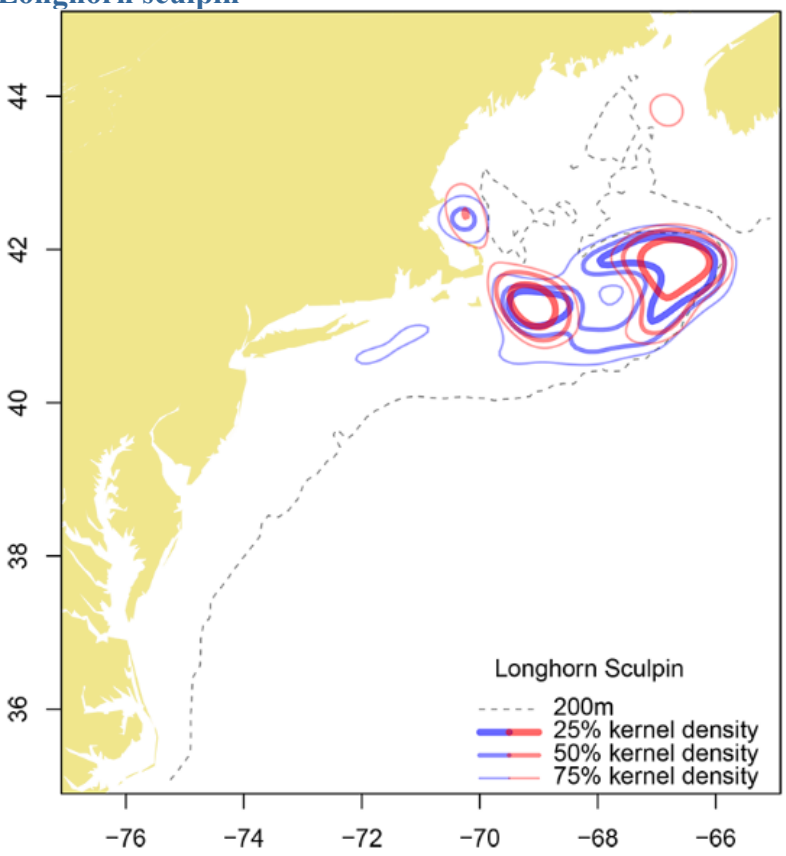
## Little Skate



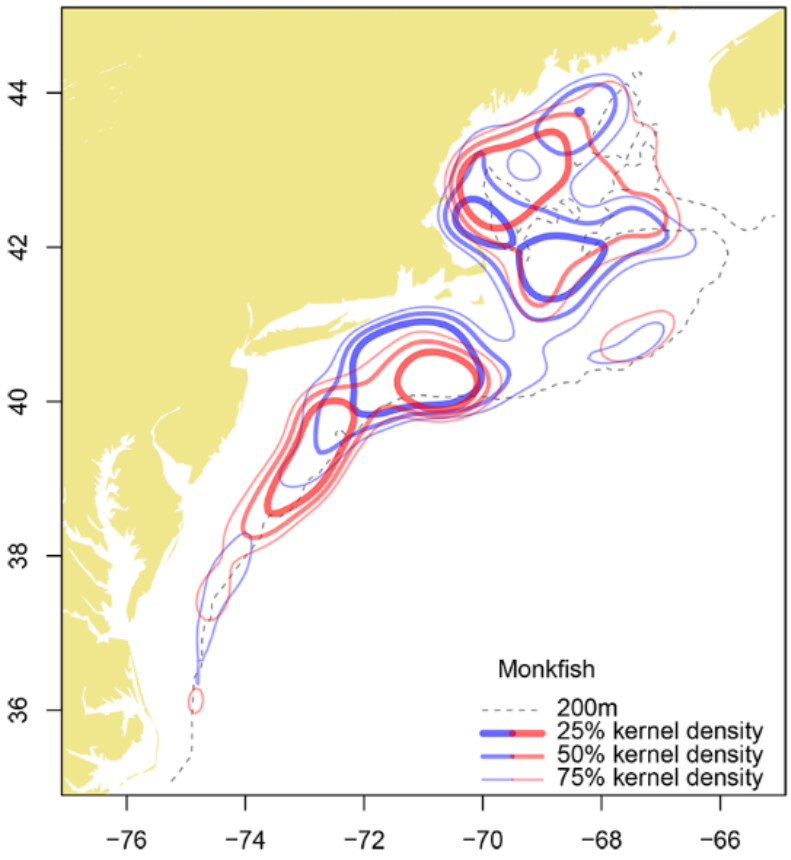
## Longfin squid



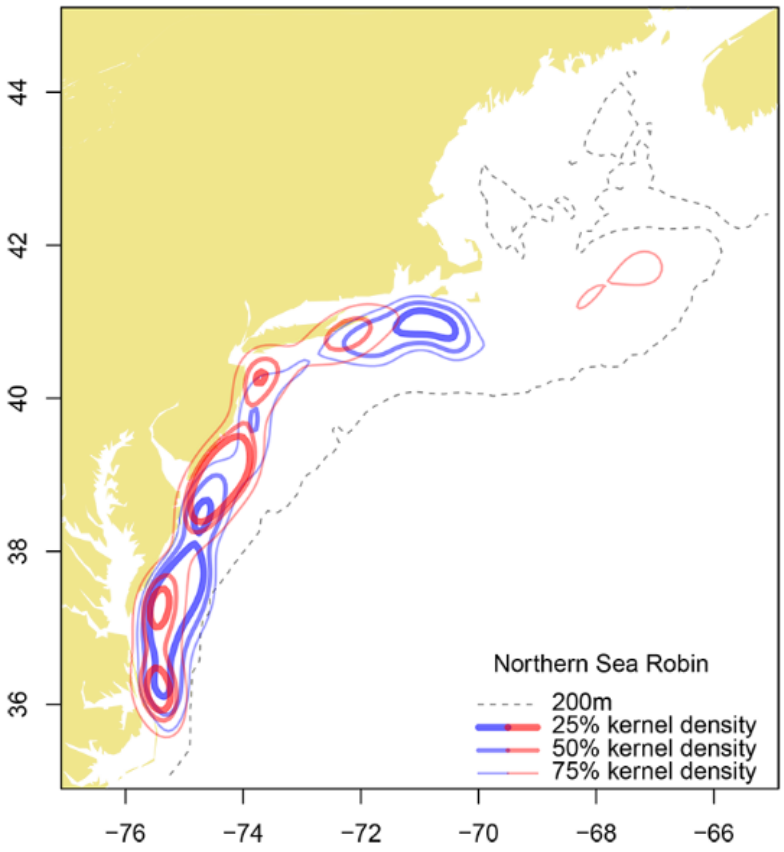
## Longhorn sculpin



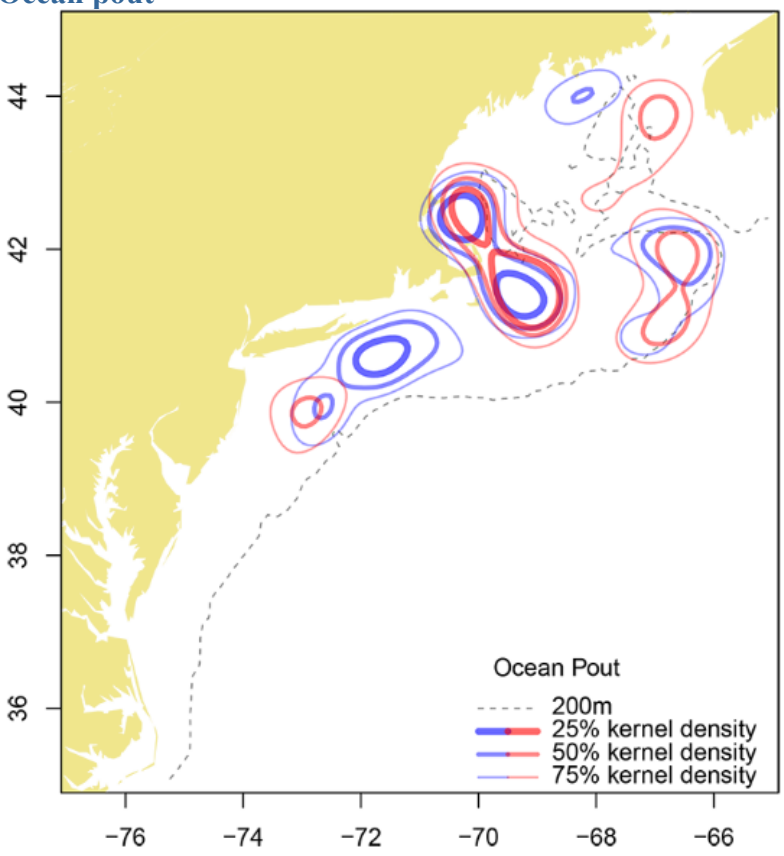
## Monkfish


Monkfish
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

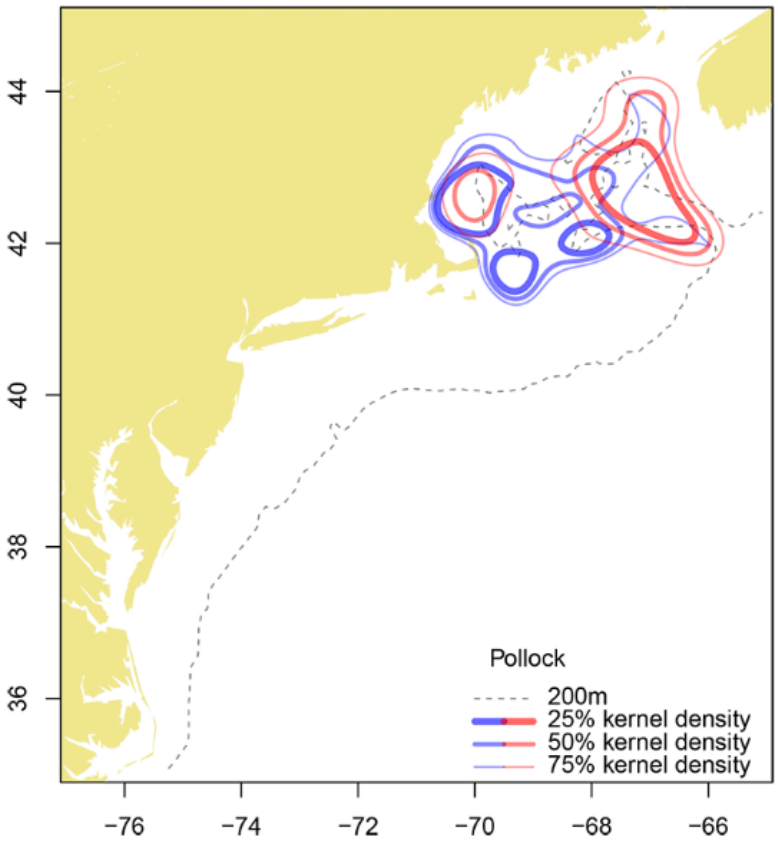
## Northern sea robin



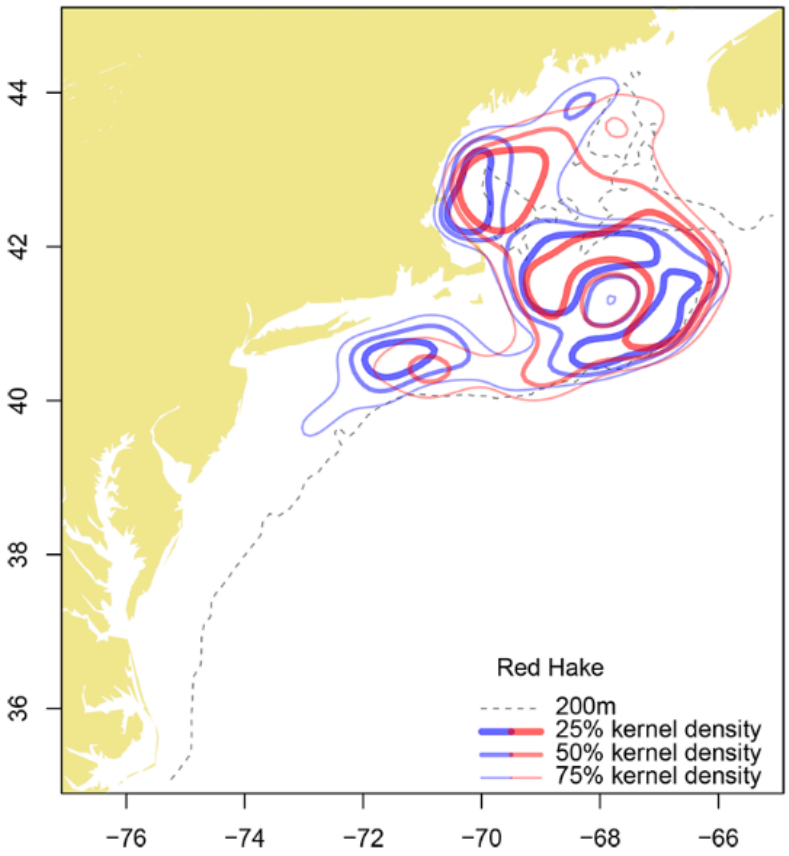
## Ocean pout


Ocean Pout
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

## Pollock


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Pollock
200m
25% kernel density
50% kernel density
75% kernel density

## Red Hake


44
42
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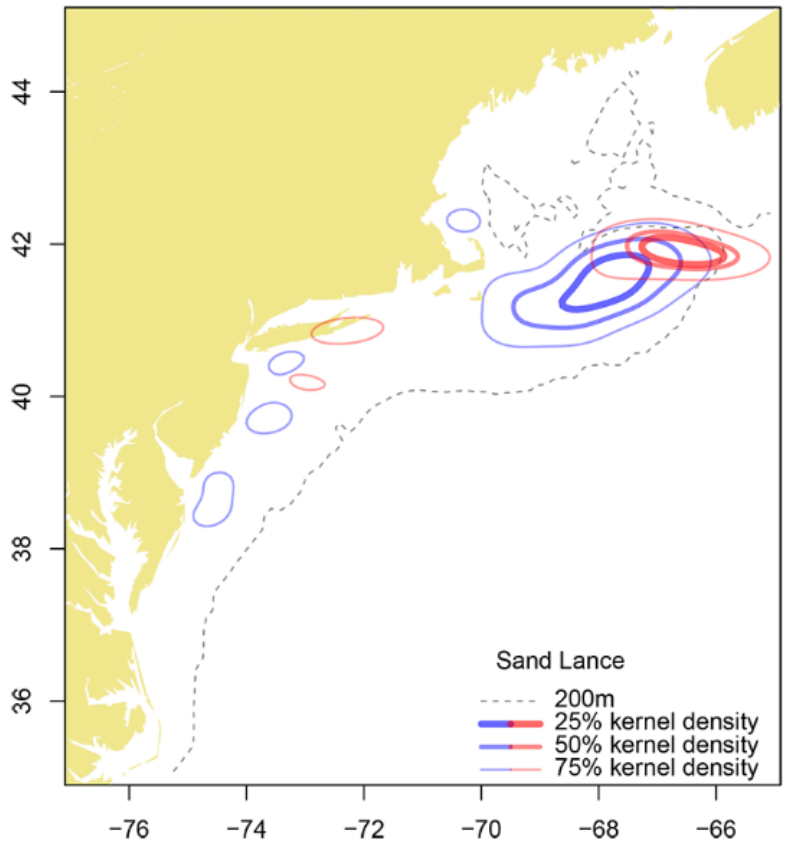
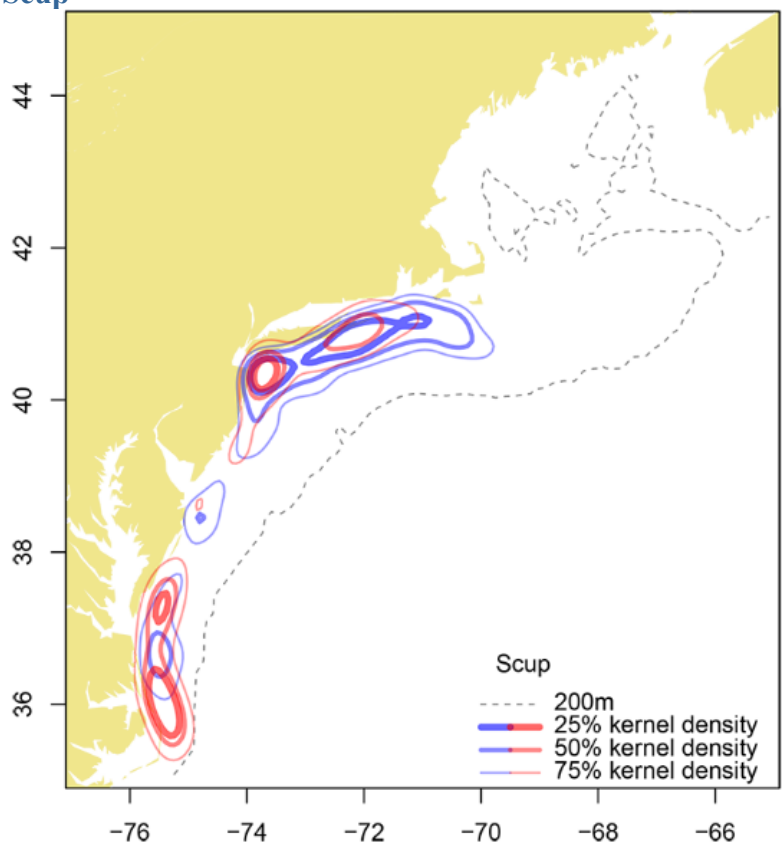
38
36
−76
−74
−72
−70
−68
−66
Red Hake
200m
25% kernel density
50% kernel density
75% kernel density

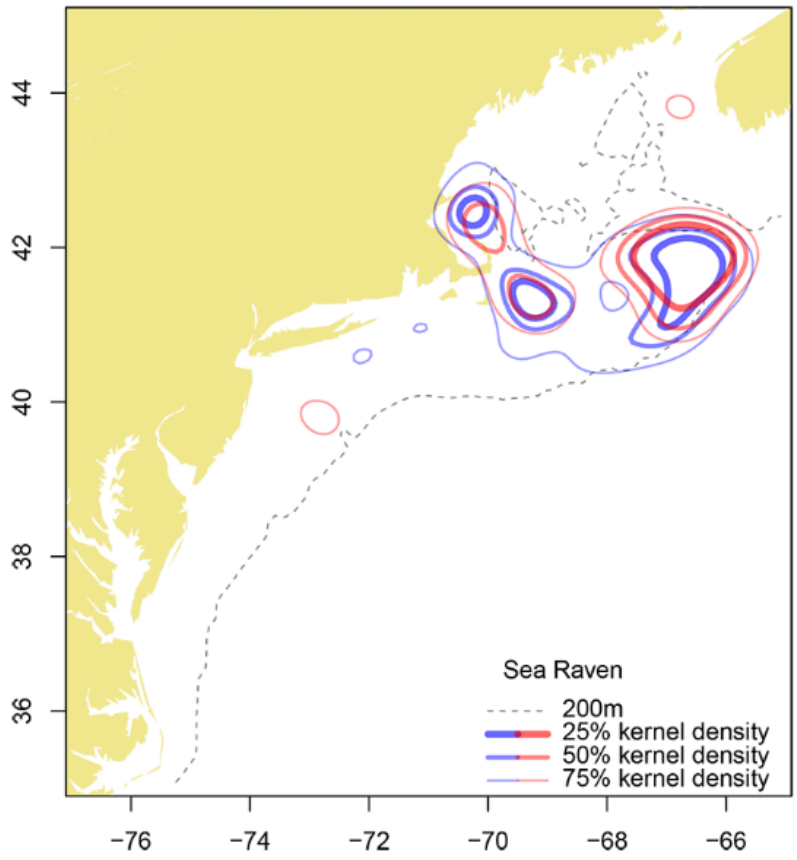
## Sand lance


Sand Lance
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

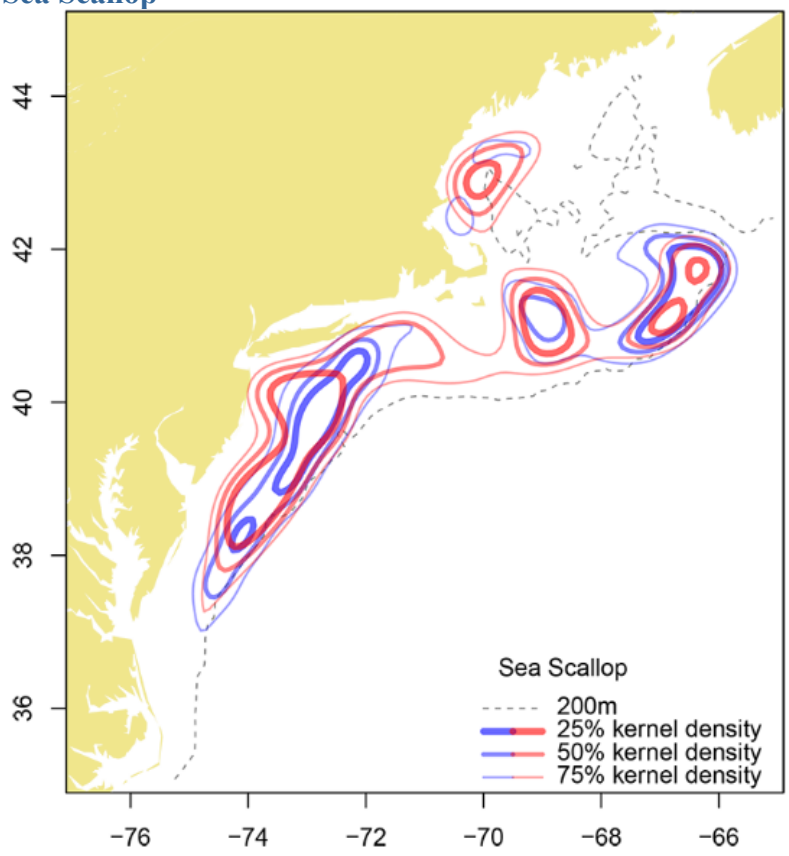
## Scup


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Scup
200m
25% kernel density
50% kernel density
75% kernel density

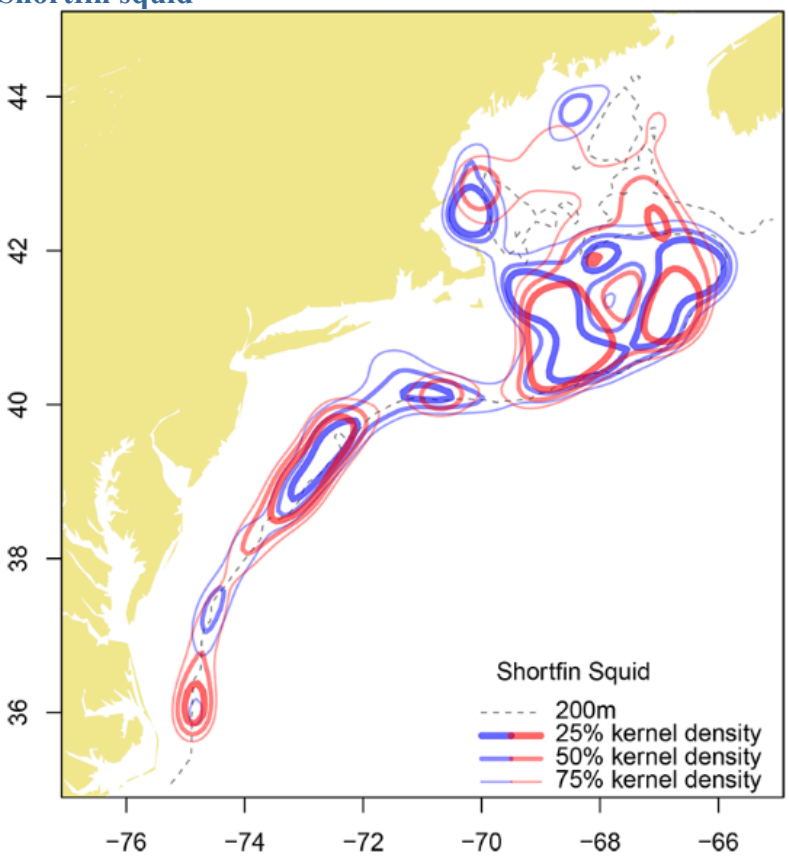
## Sea raven


Sea Raven
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

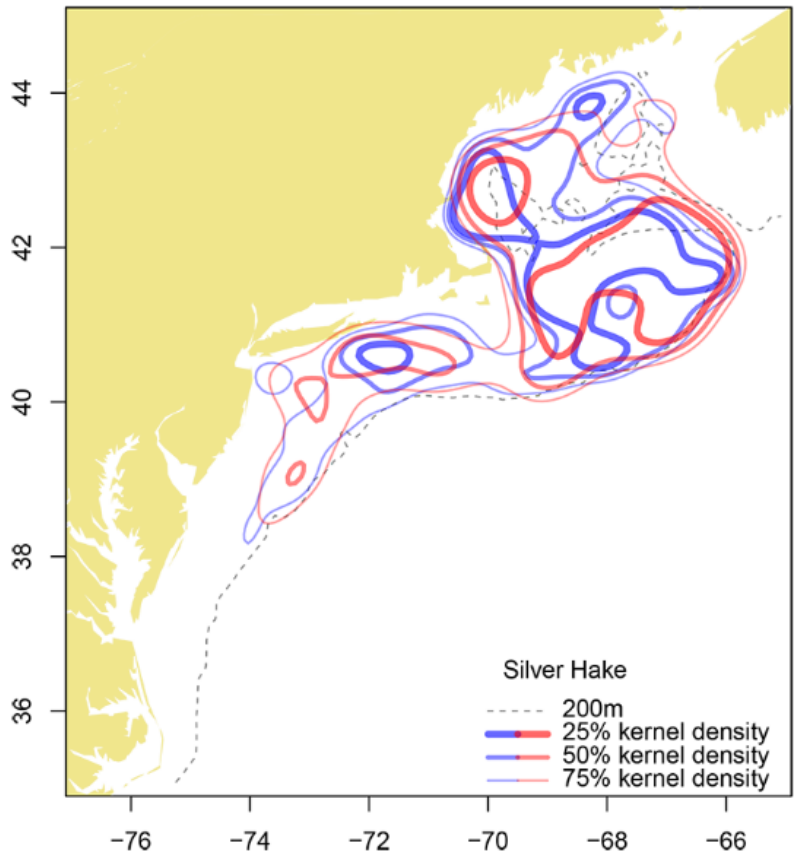
## Sea Scallop


Sea Scallop
200m
25% kernel density
50% kernel density
75% kernel density
44
42
40
38
36
−76
−74
−72
−70
−68
−66

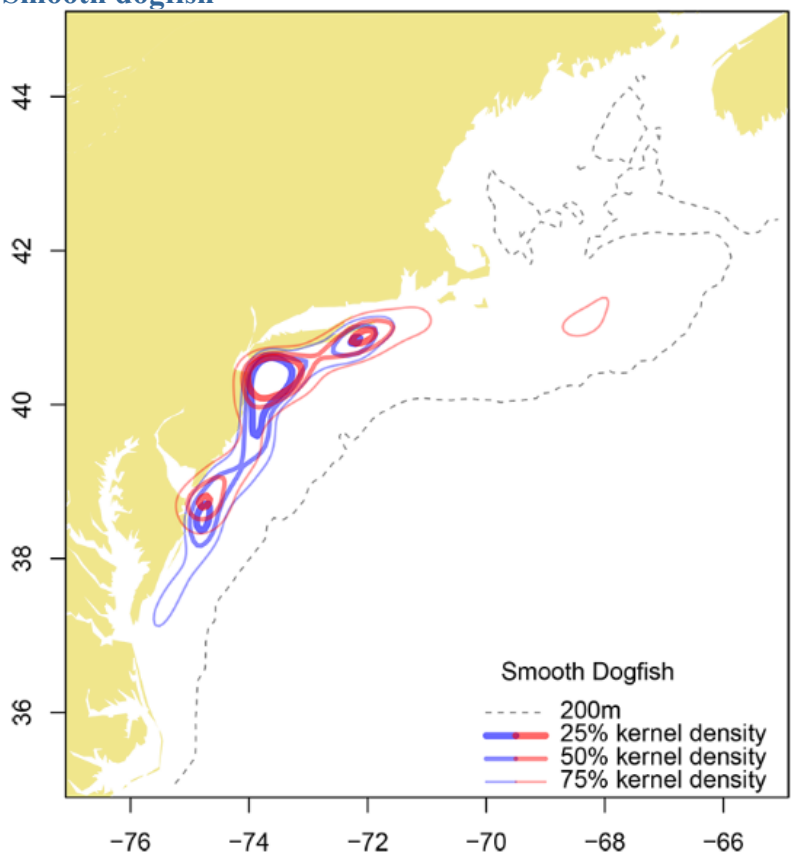
## Shortfin squid



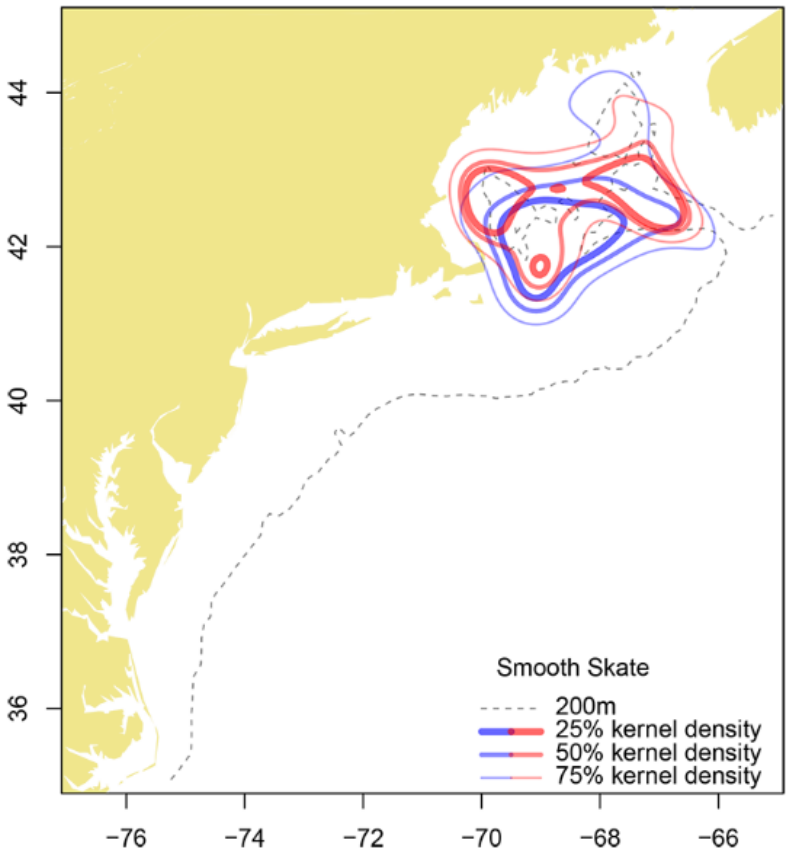
## Silver hake


44
42
40
38
36
−76
−74
−72
−70
−68
−66
Silver Hake
200m
25% kernel density
50% kernel density
75% kernel density

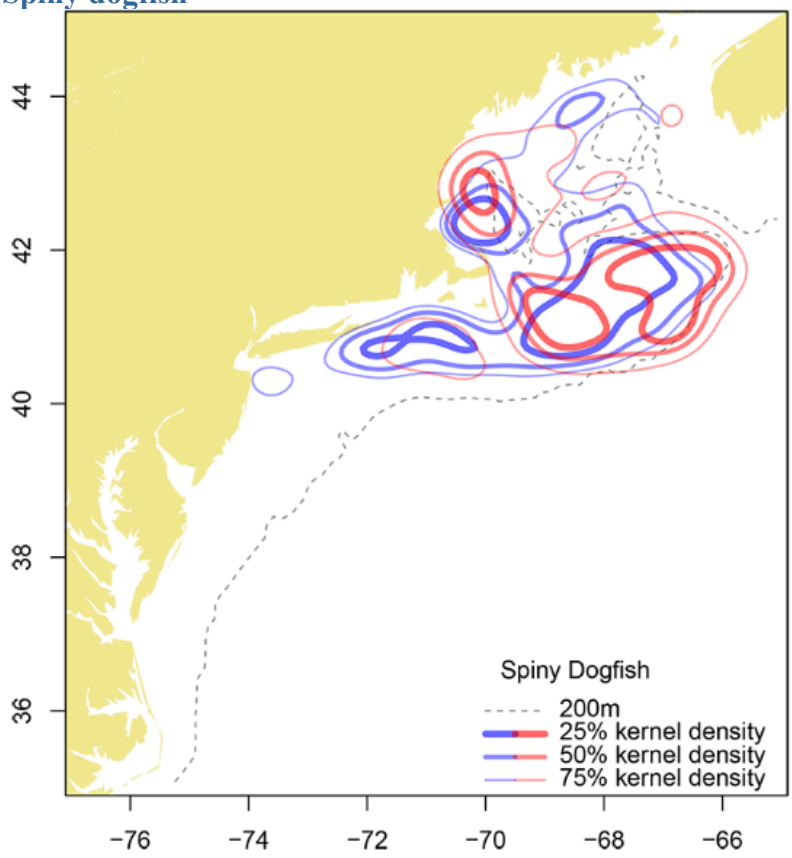
## Smooth dogfish



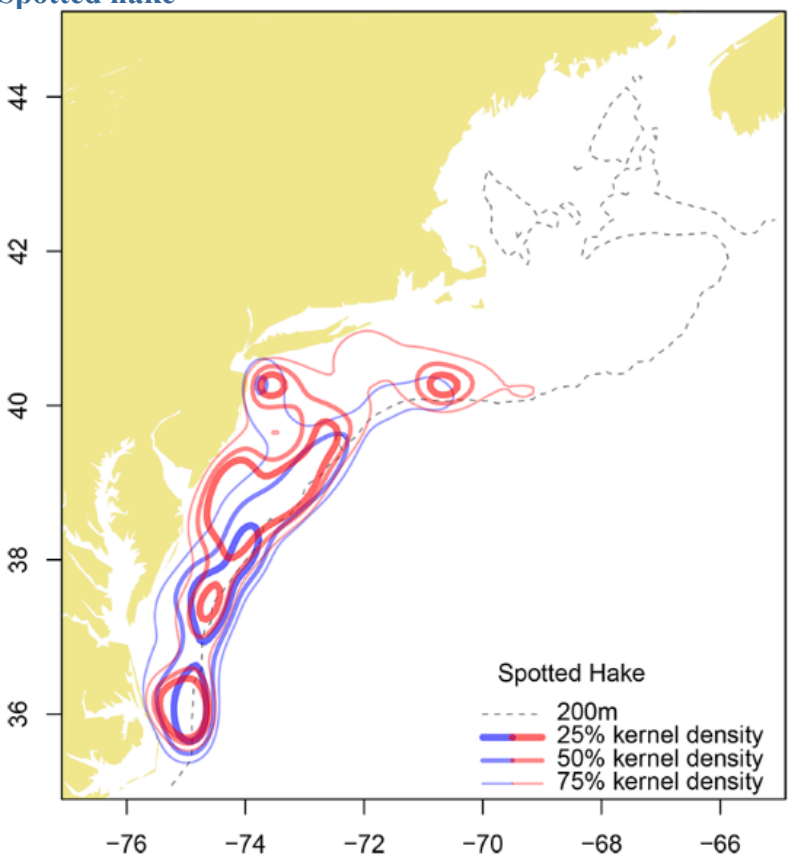
## Smooth skate



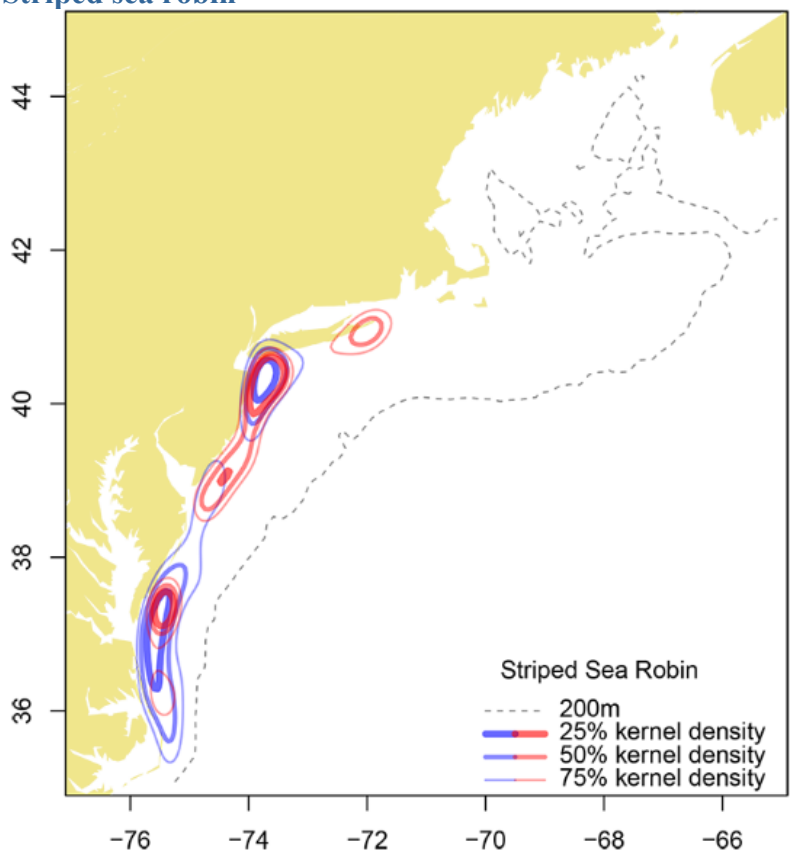
## Spiny dogfish



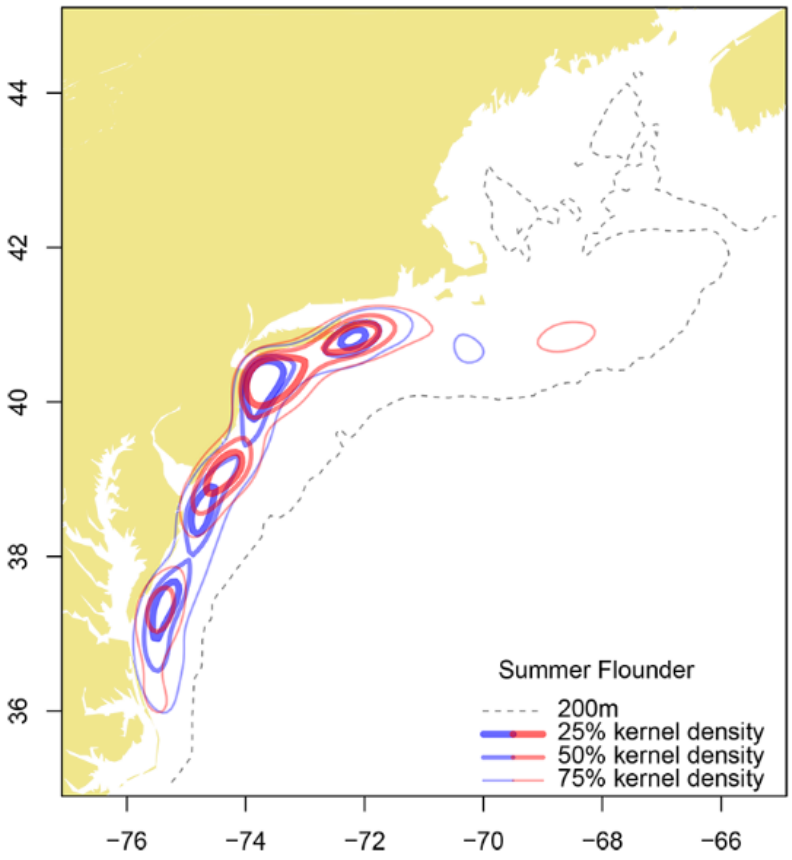
## Spotted hake



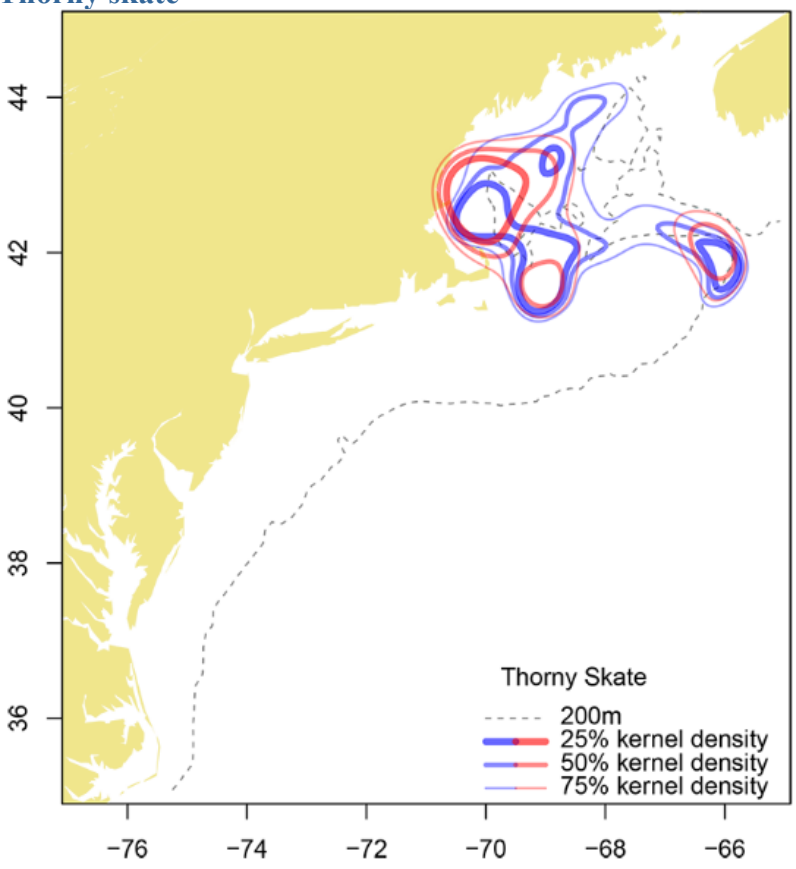
## Striped sea robin



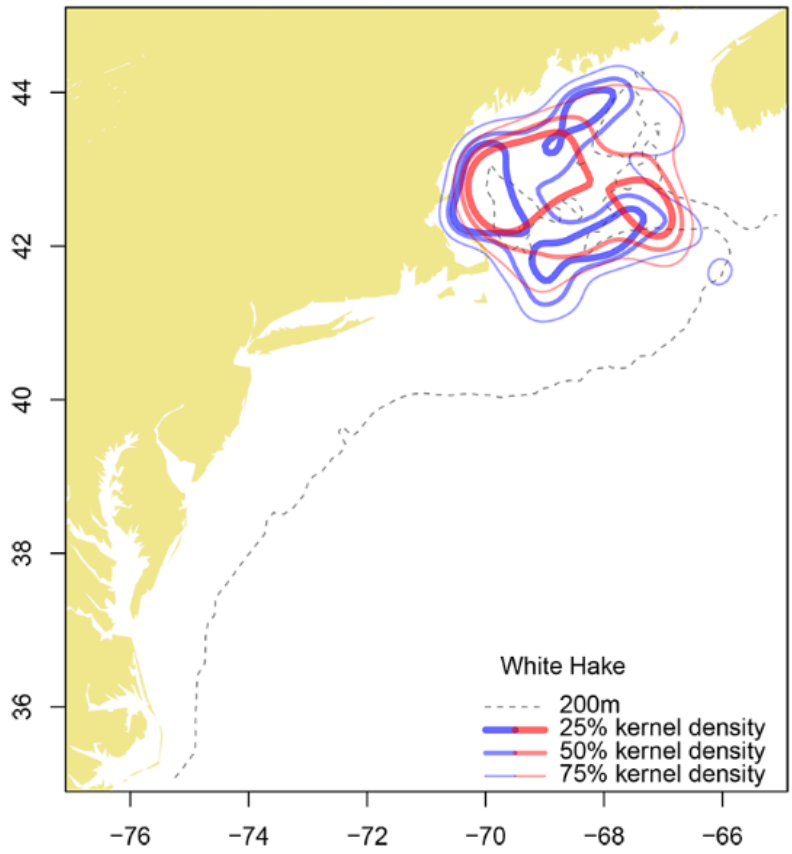
## Summer flounder



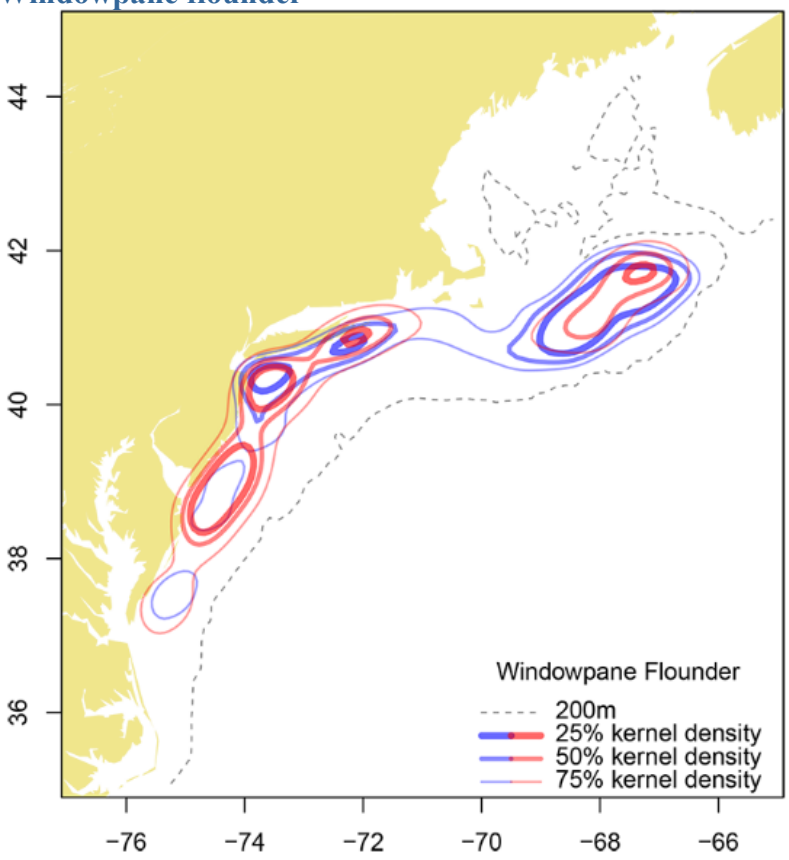
## Thorny skate



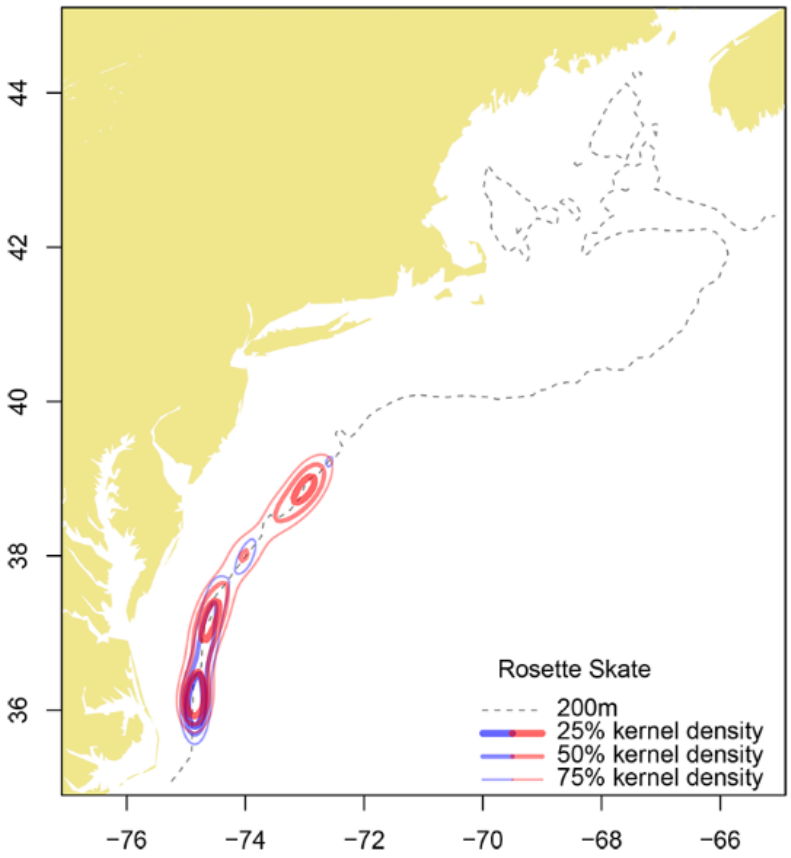
## White Hake


44
42
40
38
36
−76
−74
−72
−70
−68
−66
White Hake
200m
25% kernel density
50% kernel density
75% kernel density

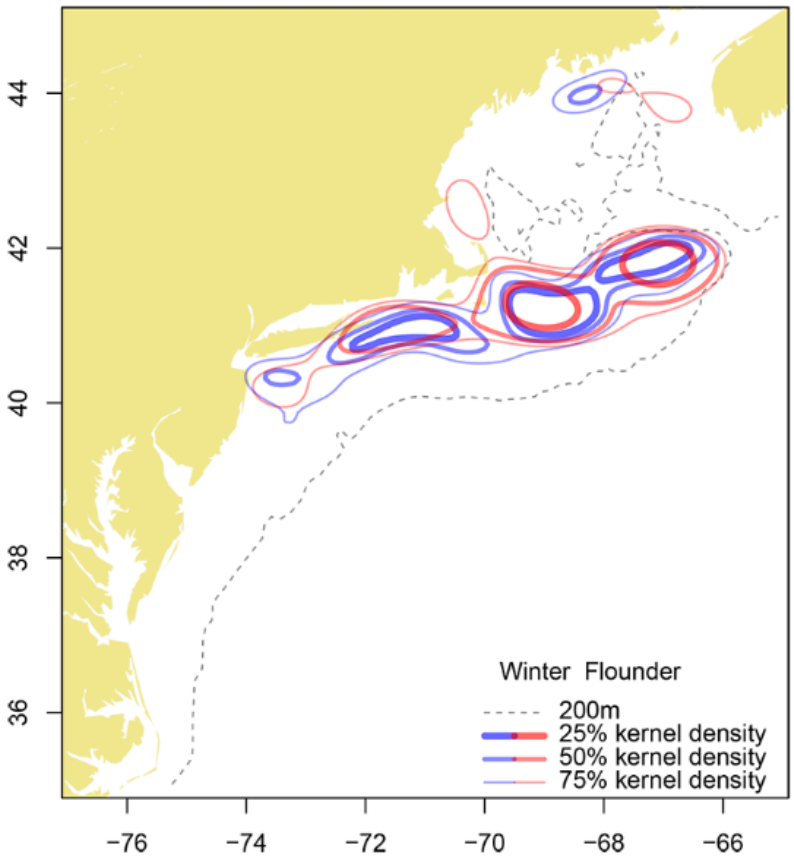
## Windowpane flounder



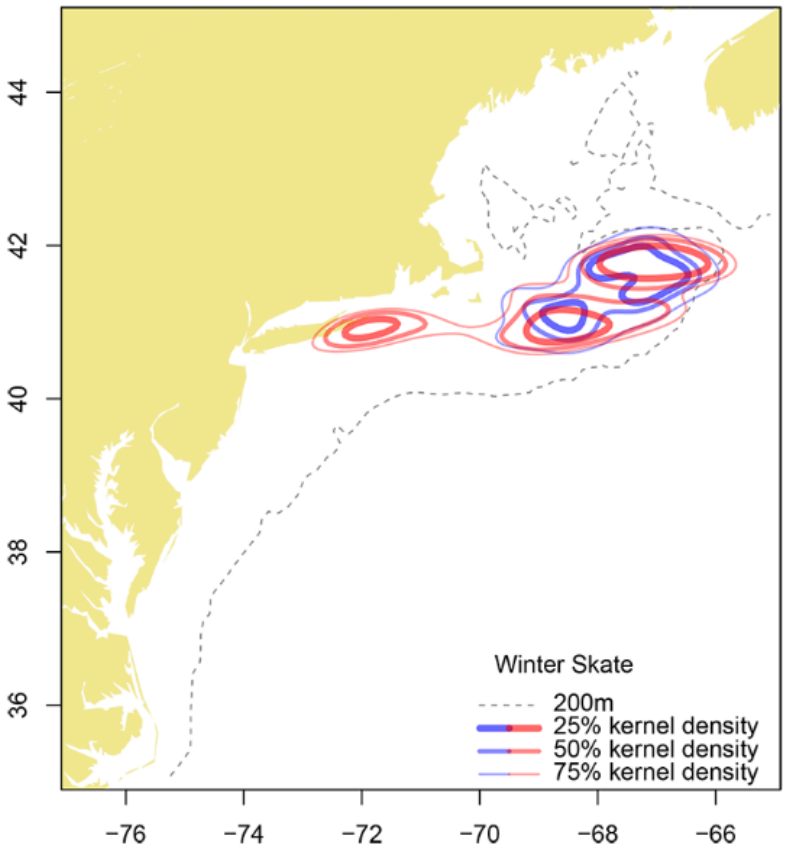
## Rosette skate



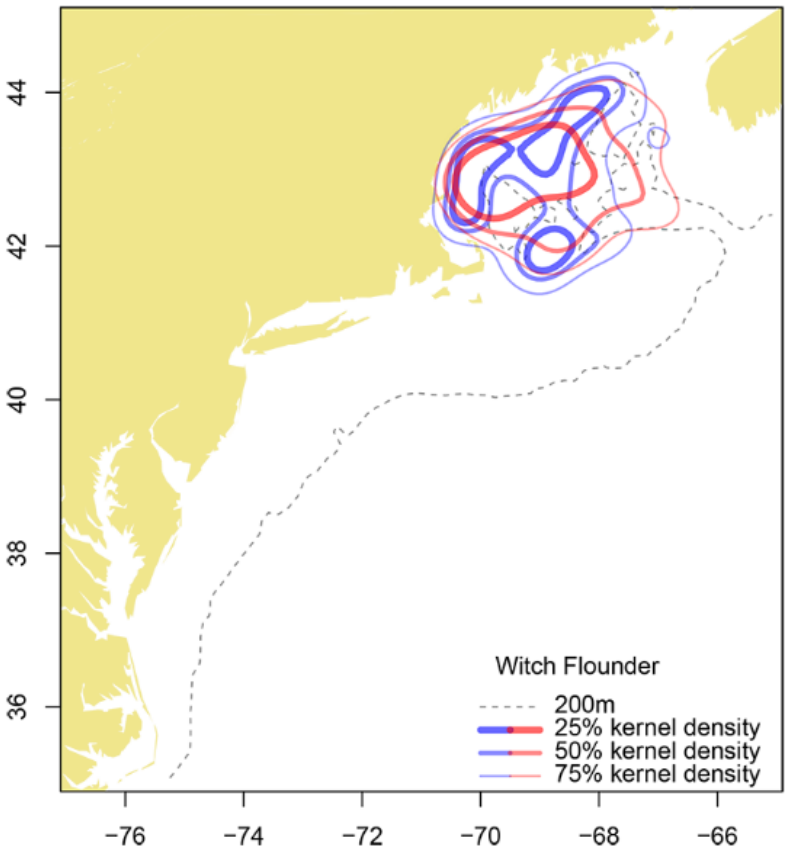
## Winter flounder



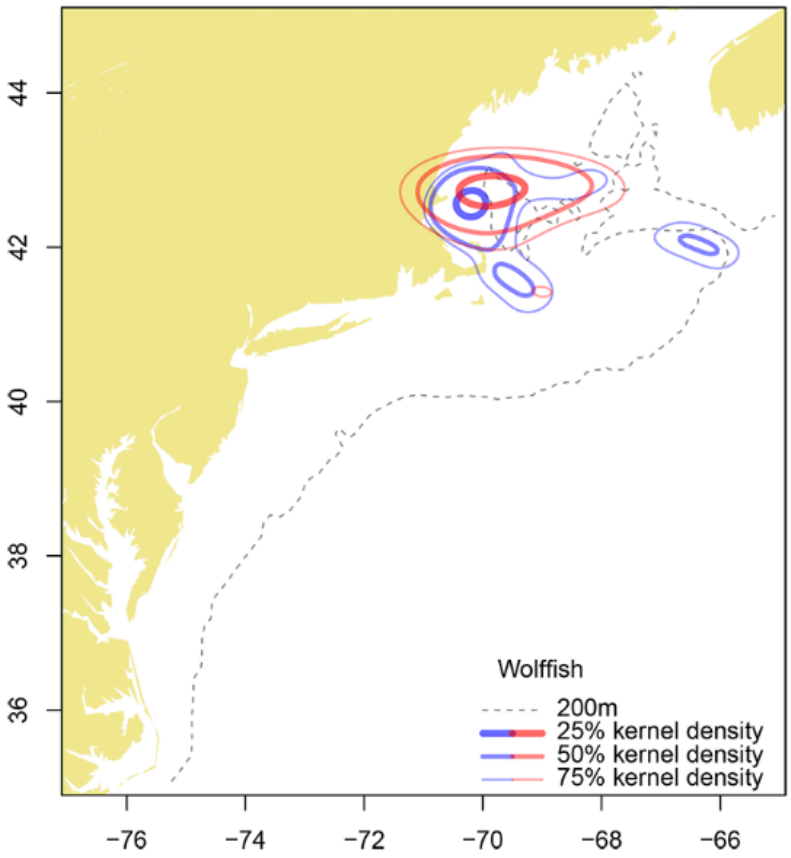
## Winter skate



## Witch flounder



## Wolffish


44
42
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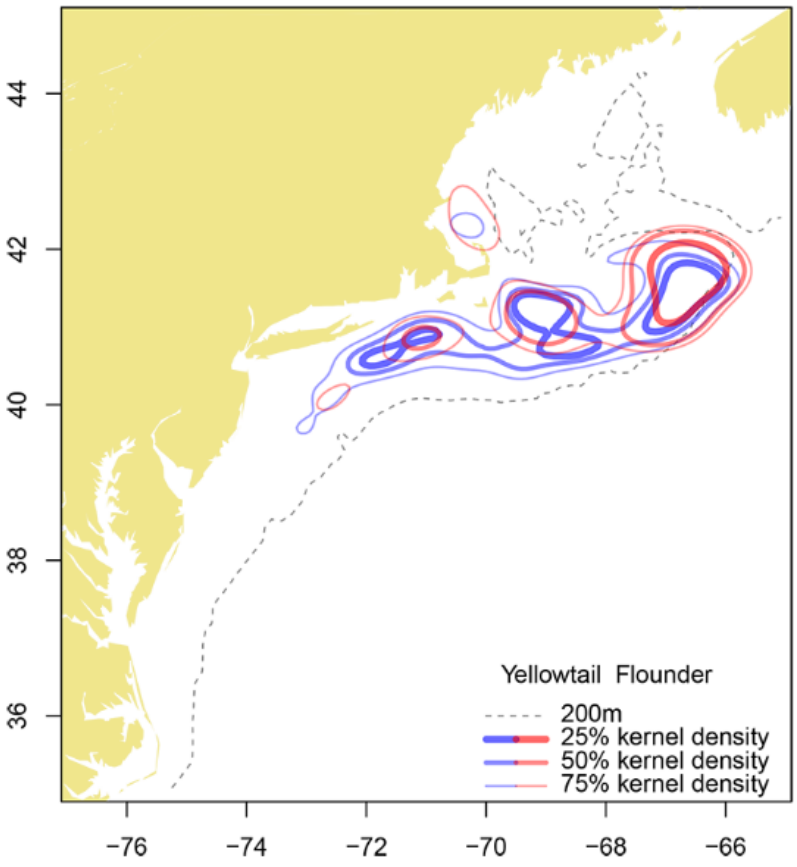
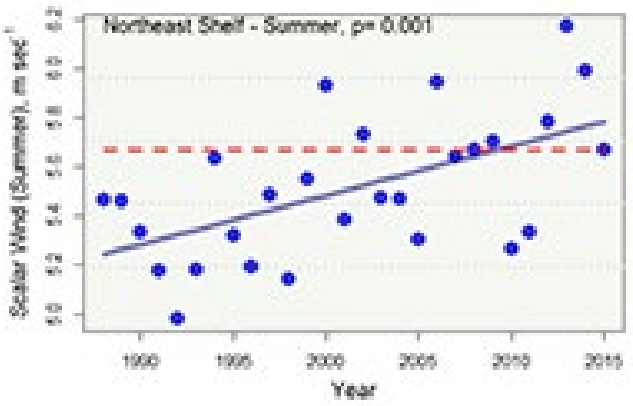
38
36
−76
−74
−72
−70
−68
−66
Wolffish
200m
25% kernel density
50% kernel density
75% kernel density

**Yellowtail flounder**

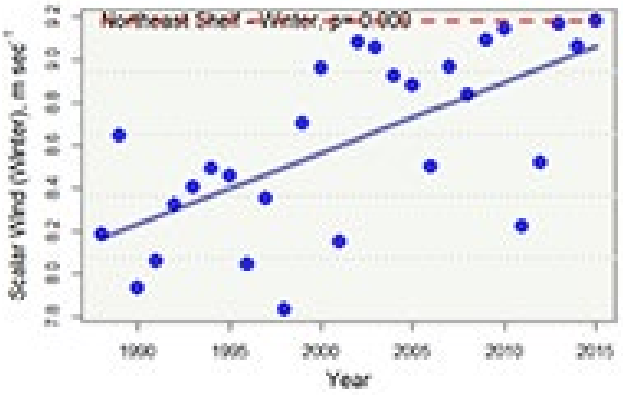



# Scalar Wind Speed

Wind speed affects a number of biological processes associated with resource species. Wind speed can affect the transport of early life history stages between spawning and rearing habitats and can also affect water column turbulence, which is a factor governing the encounter rates between plankton predators and prey. The Blended Sea Winds for the Northeast Shelf show distinct seasonal trends over time. **Summer wind speeds** have increased in recent decades from approximately 5.2 m $sec^{-1}$ to more recently averaging over 6.0 m $sec^{-1}$. **Winter wind speeds** have also increased by approximately 1.0 m $sec^{-1}$ over the time series; the winter wind speed in 2015 was the highest in the time series.




Summer wind speed




Winter wind speed

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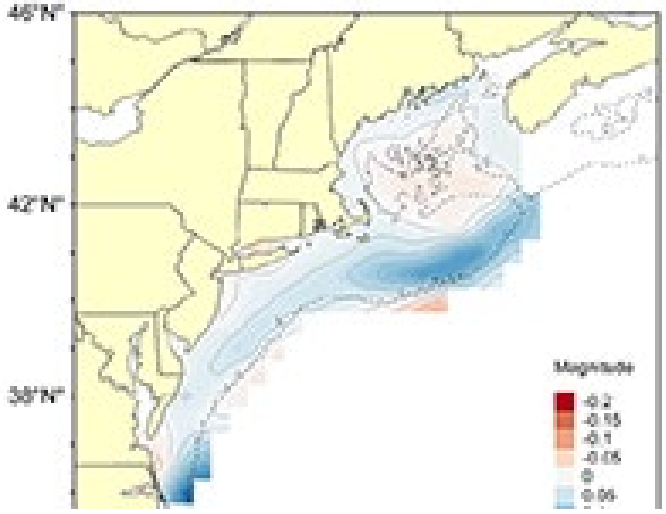
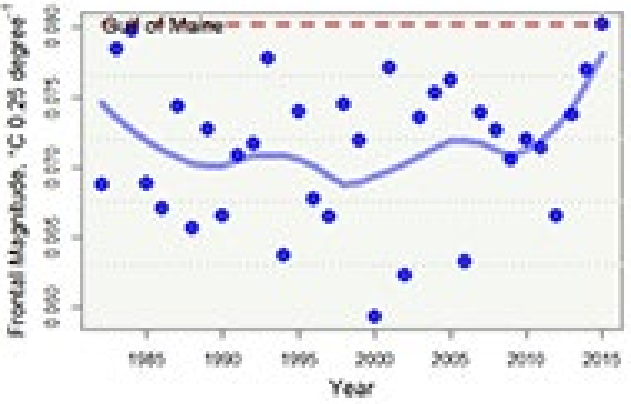
# Change in Frontal Strength

Temperature fronts form at the interface between differing water masses, often marking the boundary of an ocean current within the ecosystem. Fronts are of biological significance because they tend to concentrate organisms at both lower and upper trophic levels. A measure of fronts is the gradient magnitude, which relates the change in SST per unit distance across a frontal feature. The **map** shows the linear trend in gradient magnitude over the time period 1982-2015. Frontal gradient magnitude has increased on Georges Bank and in much of the Middle Atlantic Bight, suggesting that stronger frontal features can be found in these areas over time. Frontal magnitude has decreased in much of the Gulf of Maine, suggesting an opposite trend of less well developed fronts. **Time series of frontal magnitude** is summarized for the four Northeast Shelf ecoregions. Magnitude has increased dramatically during the most recent decade of the time series in the Middle Atlantic Bight, Georges Bank and Scotian Shelf areas (blue line is time series smoother, dashed red line marks 2015 data). Magnitude in the Gulf of Maine does not have a well-developed trend. In all areas, frontal magnitude in 2015 was the highest in the time series.



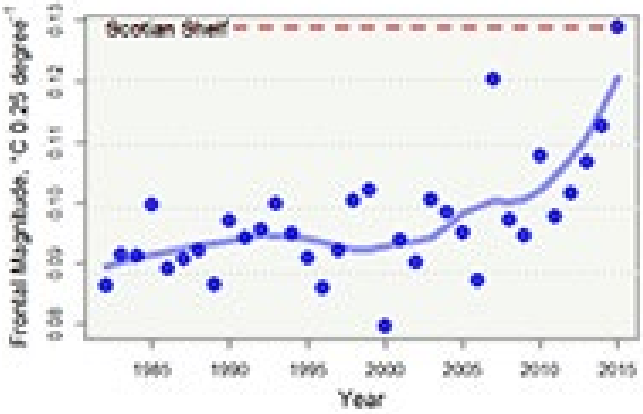

Frontal magnitude map


Georges Bank




Gulf of Maine


Middle Atlantic Bight




Scotian Shelf