3 Figures

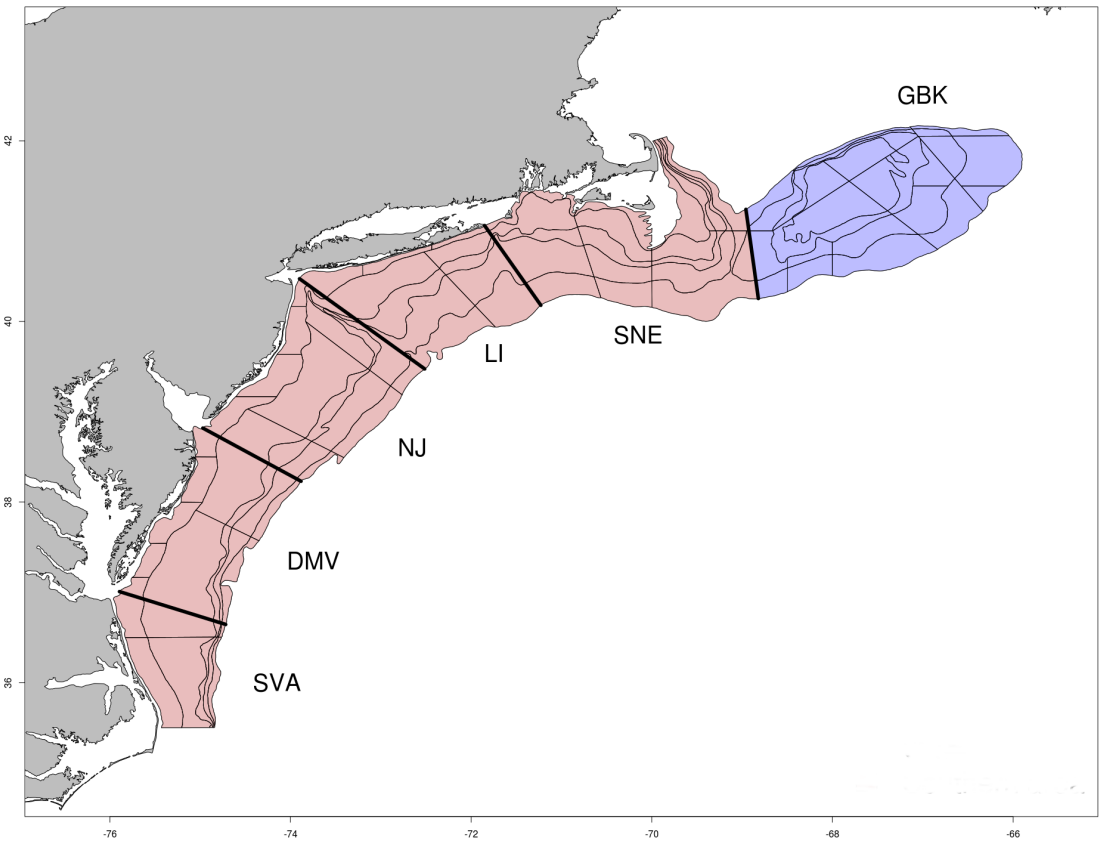


Figure 6: The Atlantic surfclam regions divided, for assessment modeling, into two areas. The northern area is blue and the southern area is pink.

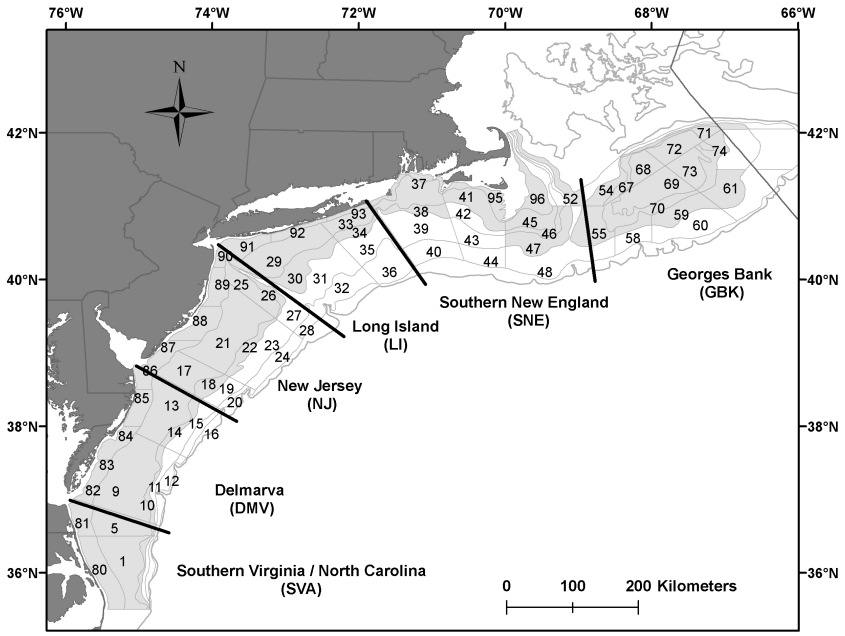


Figure 7: Surfclam stock assessment regions and NEFSC shellfish survey strata. The shaded strata are the surfclam strata that have been used in past assessments.

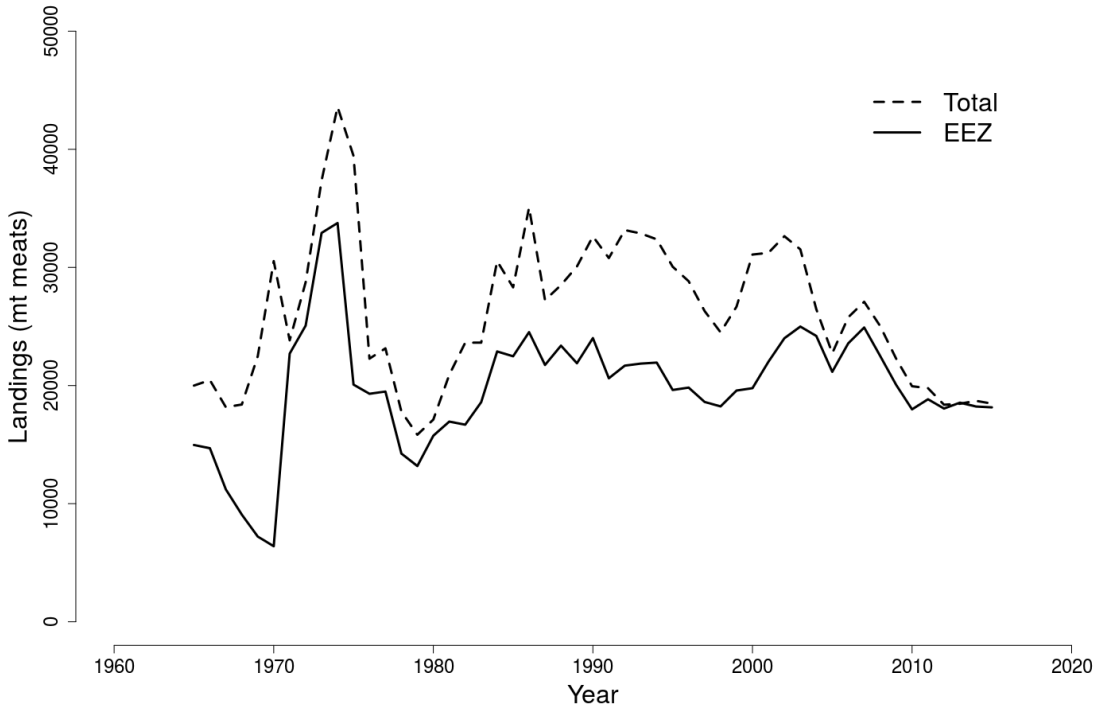


Figure 8: Atlantic surfclam landings (total and EEZ) during 1965-2015.

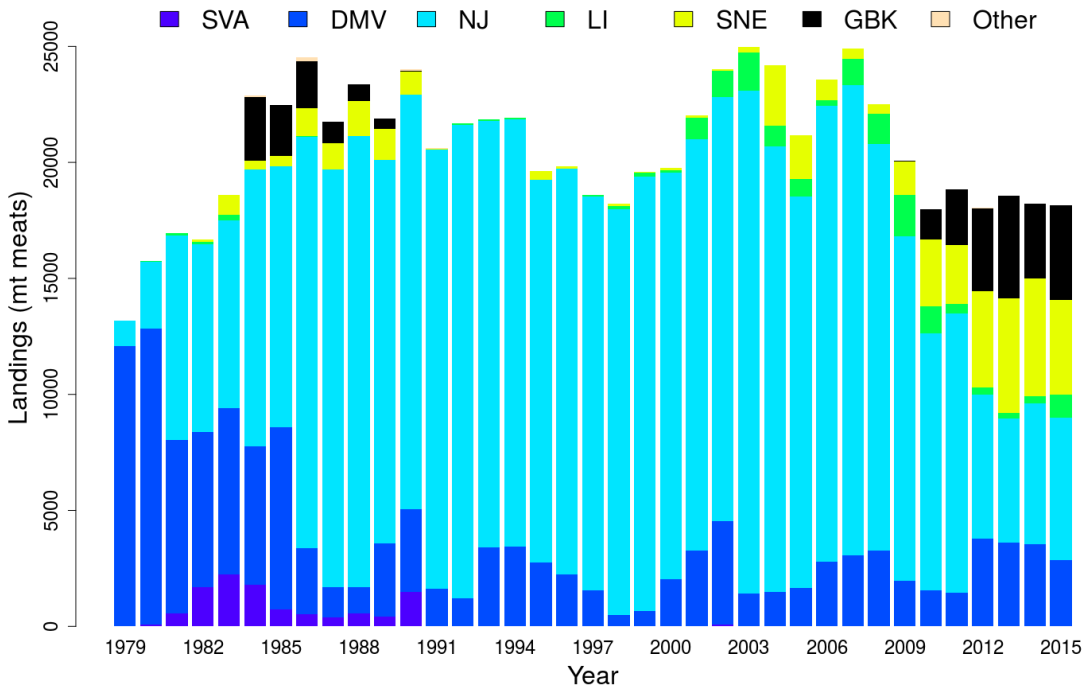


Figure 9: Surfclam landings from the US EEZ during 1979-2015, by stock assessment region.

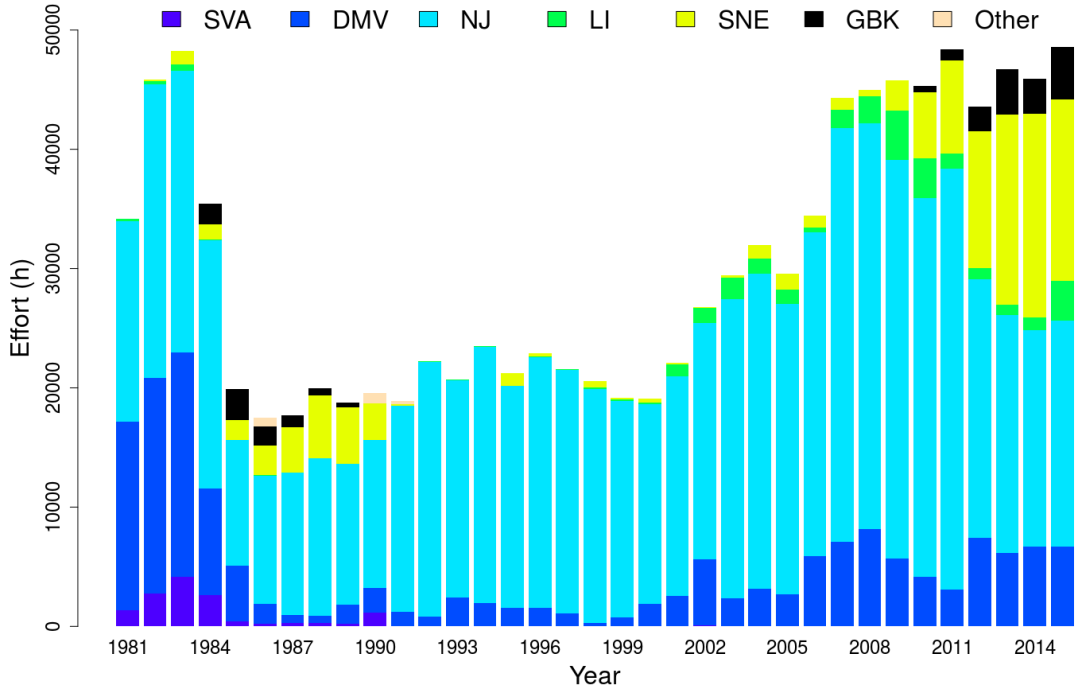


Figure 10: Surfclam hours fished from the US EEZ during 1981-2015, by stock assessment region.

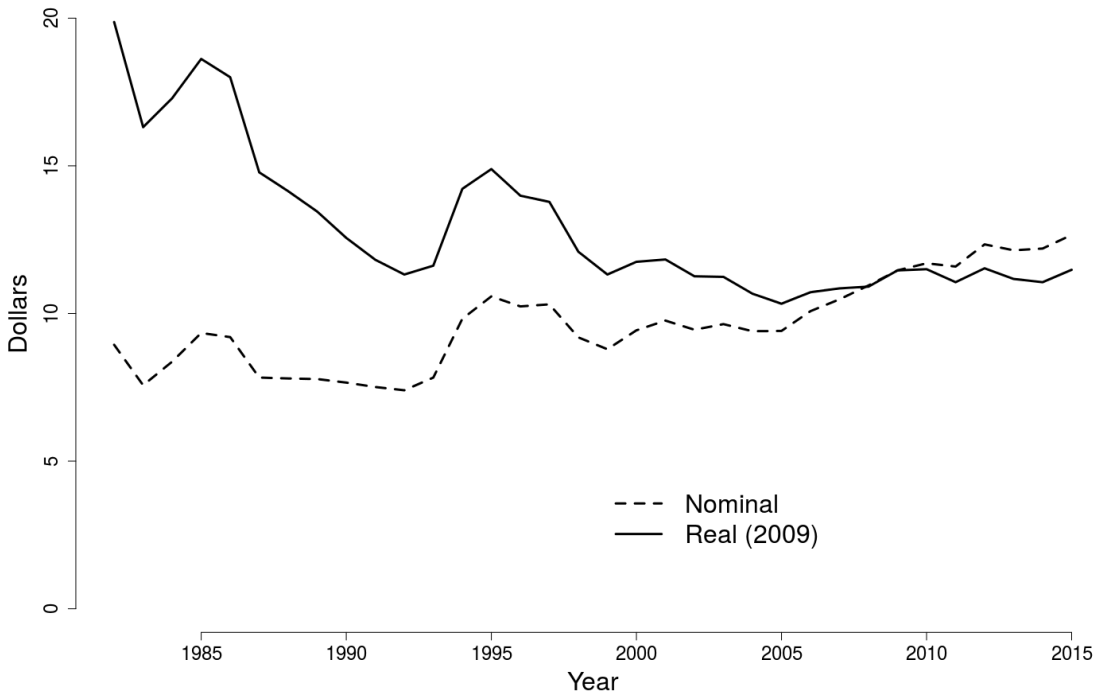


Figure 11: Nominal and 2009 dollar equivalent prices for surfclam 1981-2015.

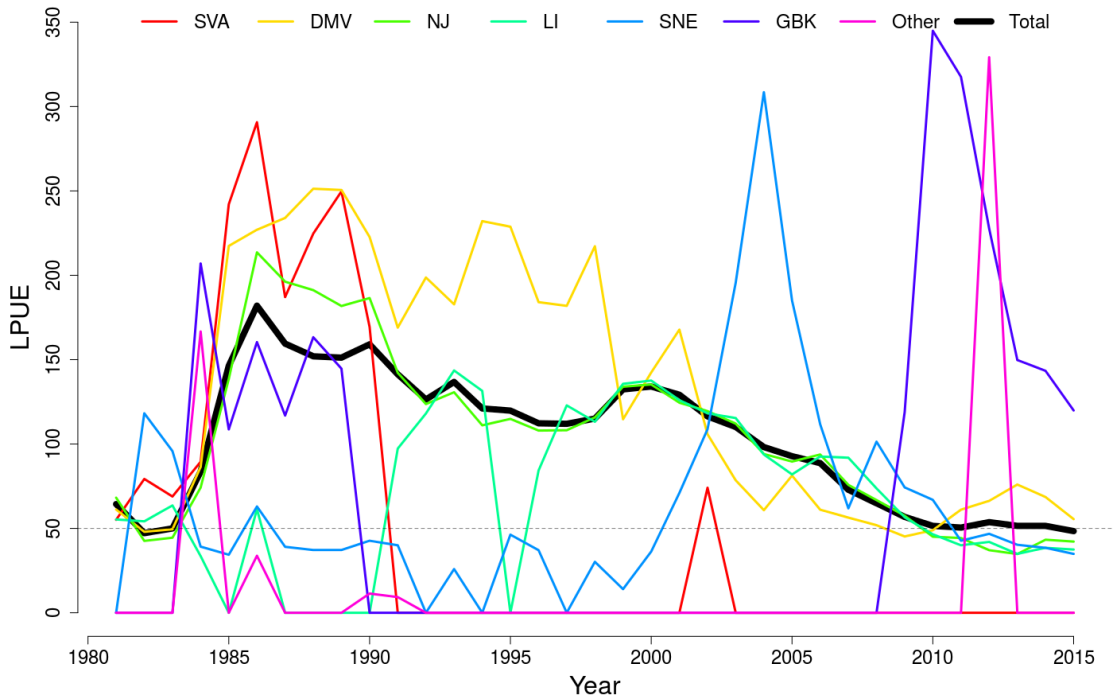


Figure 12: Nominal landings per unit effort (LPUE in bushels landed per hour fished) for surfclam, by region and overall. LPUE is total landings in bushels divided by total fishing effort. A dashed line has been added at LPUE=50 for reference.

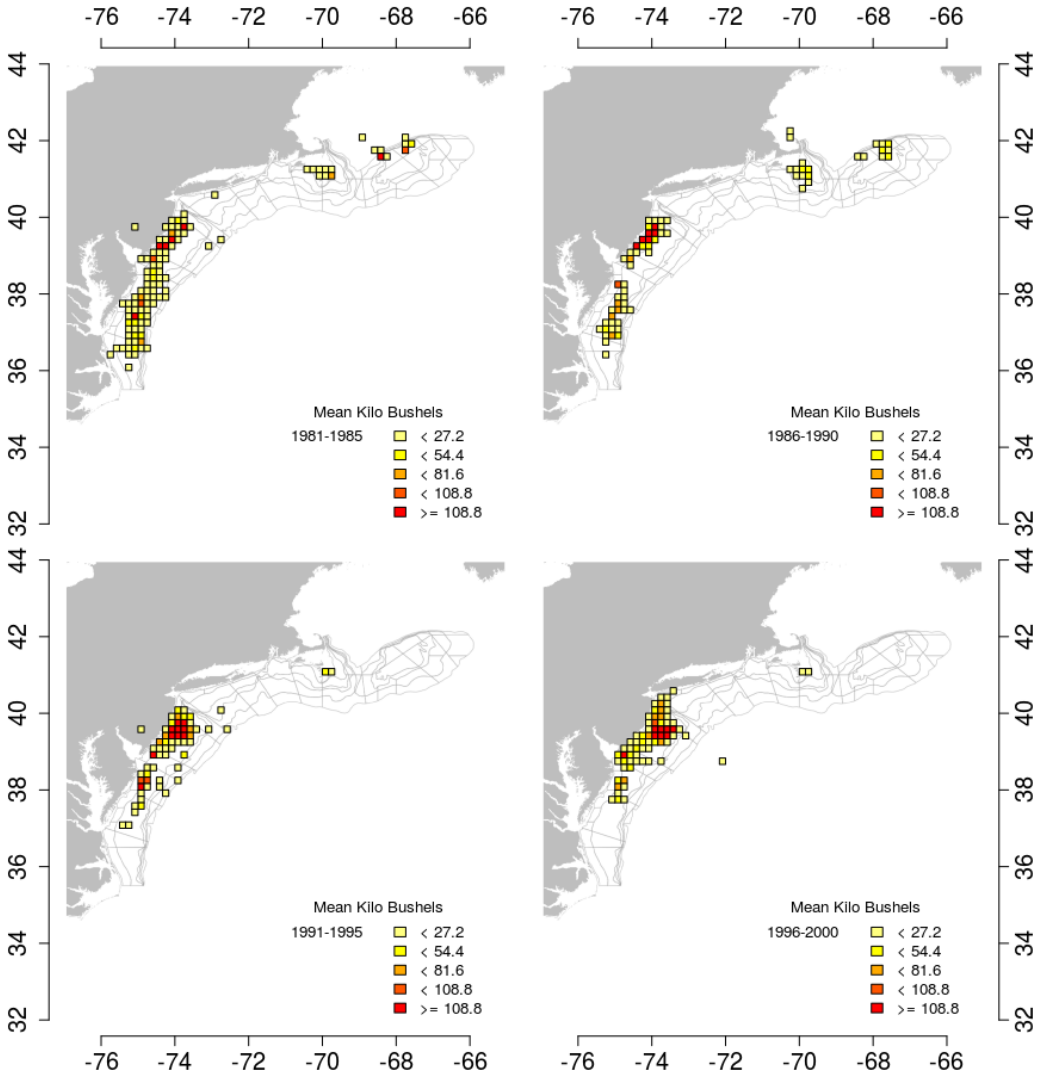


Figure 13: Average surfclam landings by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

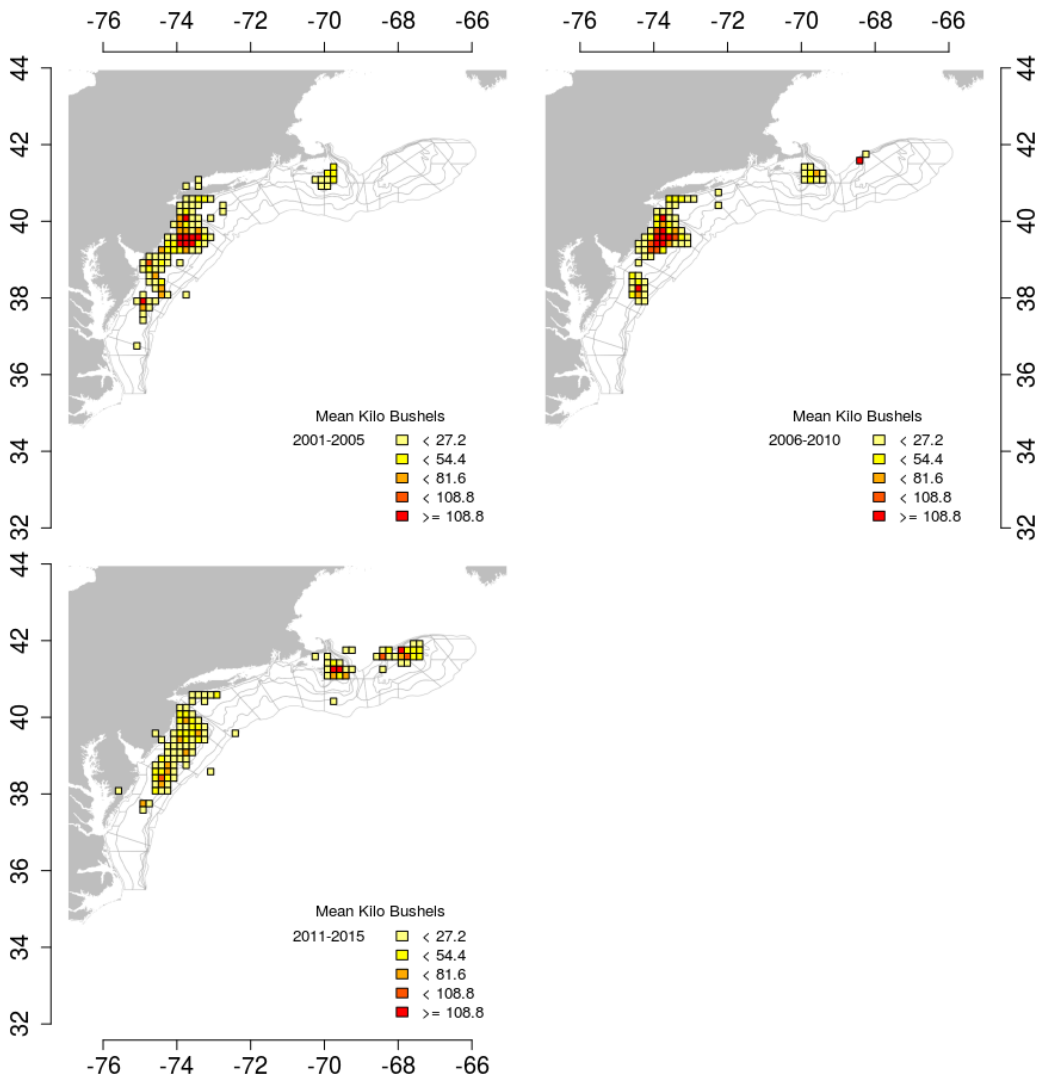


Figure 14: Average surfclam landings by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

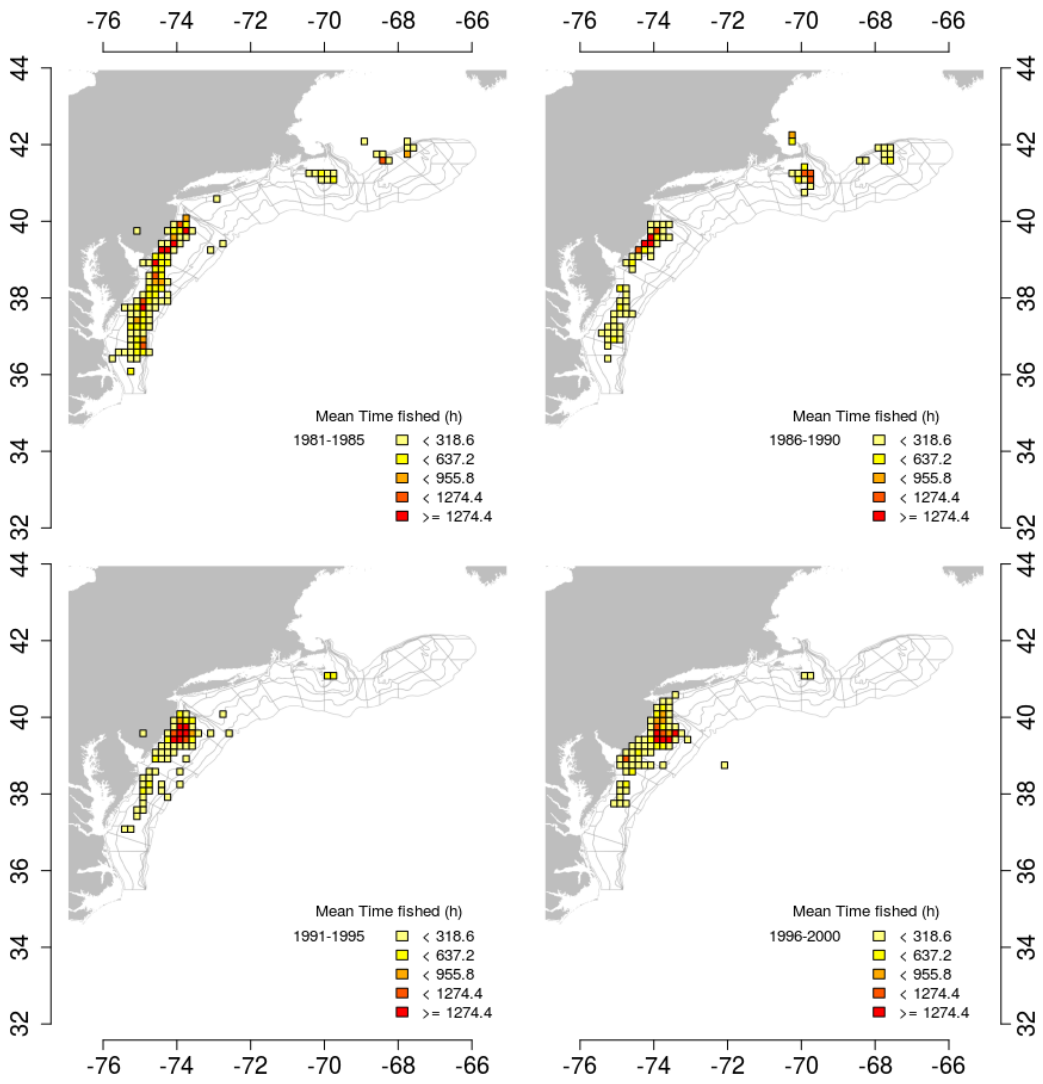


Figure 15: Average surfclam effort by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

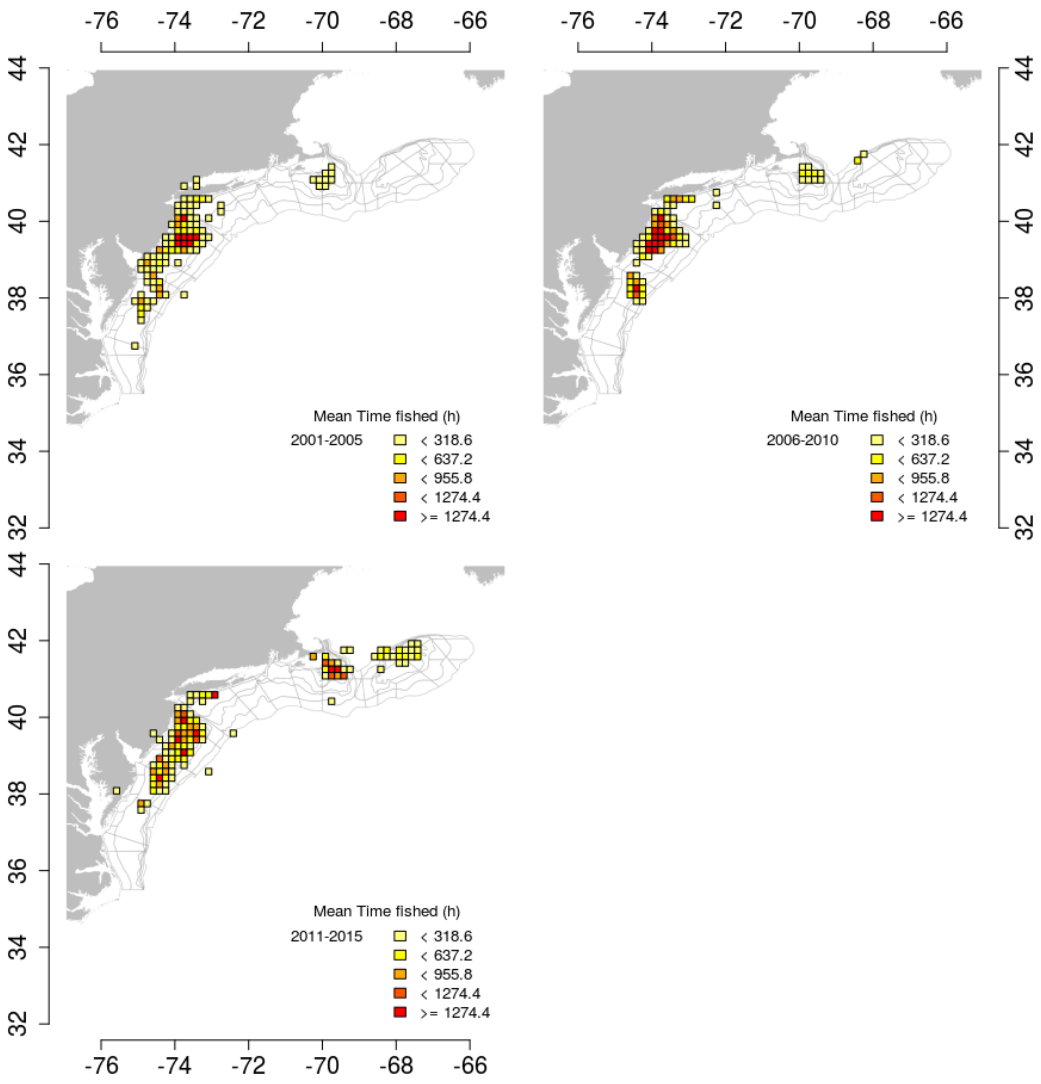


Figure 16: Average surfclam effort by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

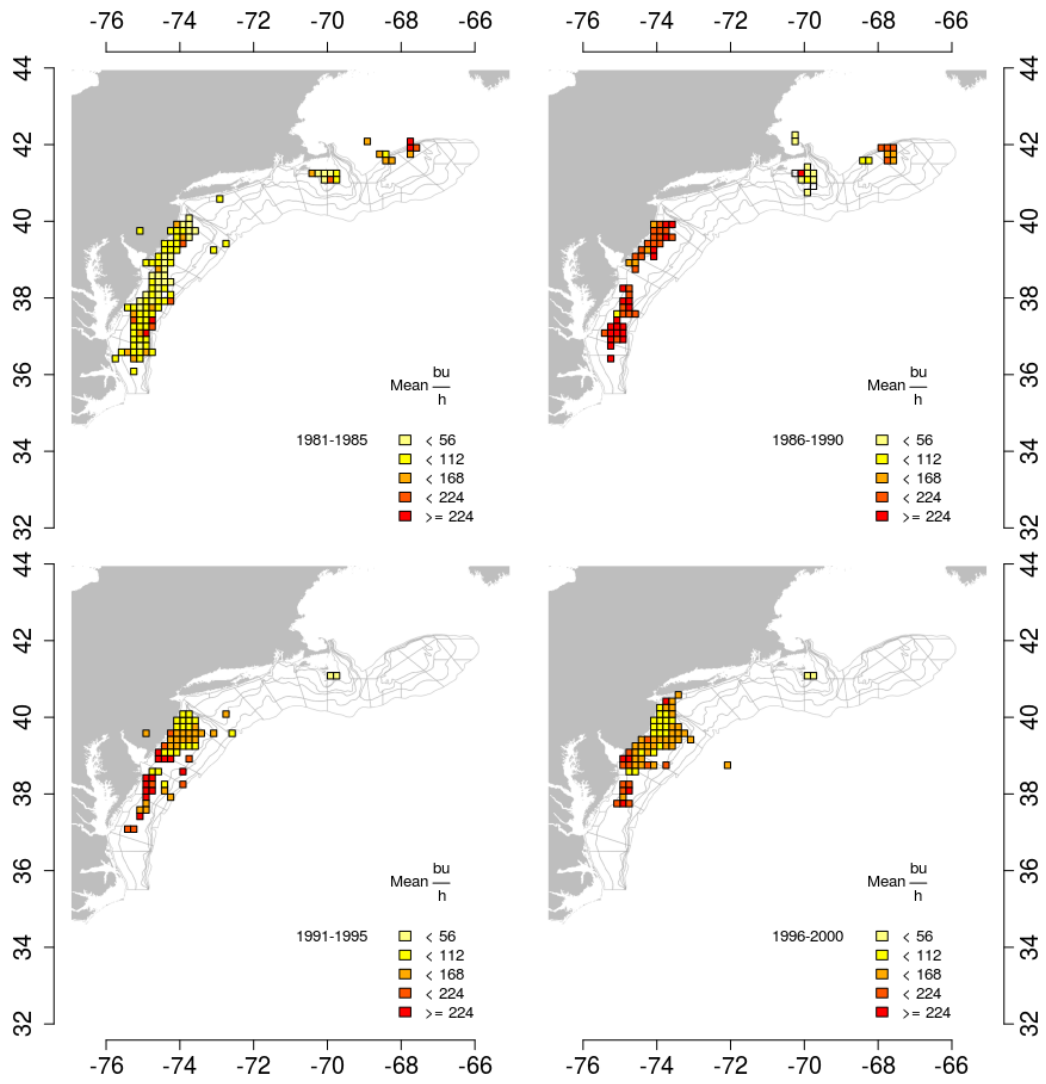


Figure 17: Average surfclam LPUE (bu. h^{-1}) by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

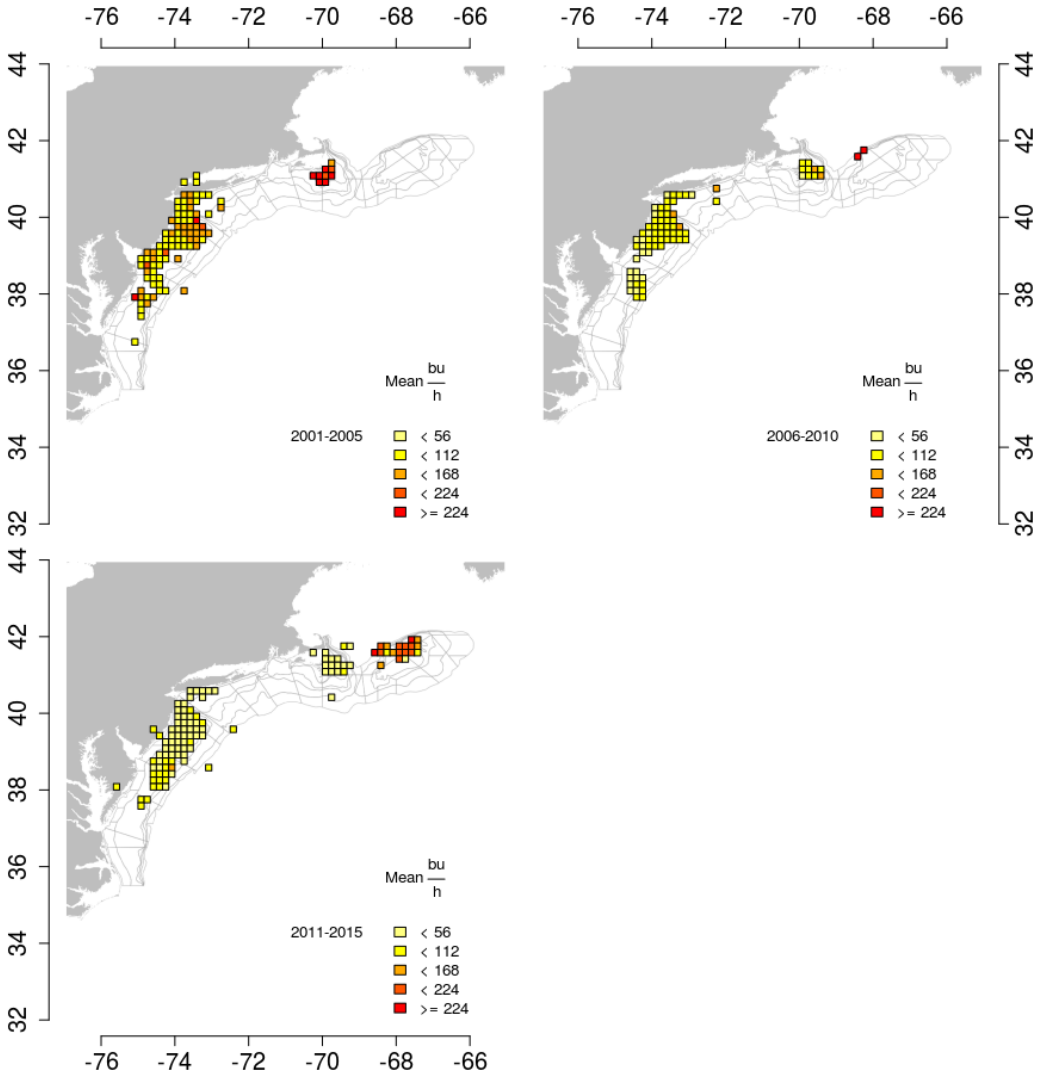


Figure 18: Average surfclam LPUE (bu. h^{-1}) by ten-minute squares over time. Only squares where more the 10 kilo bushels were caught are shown.

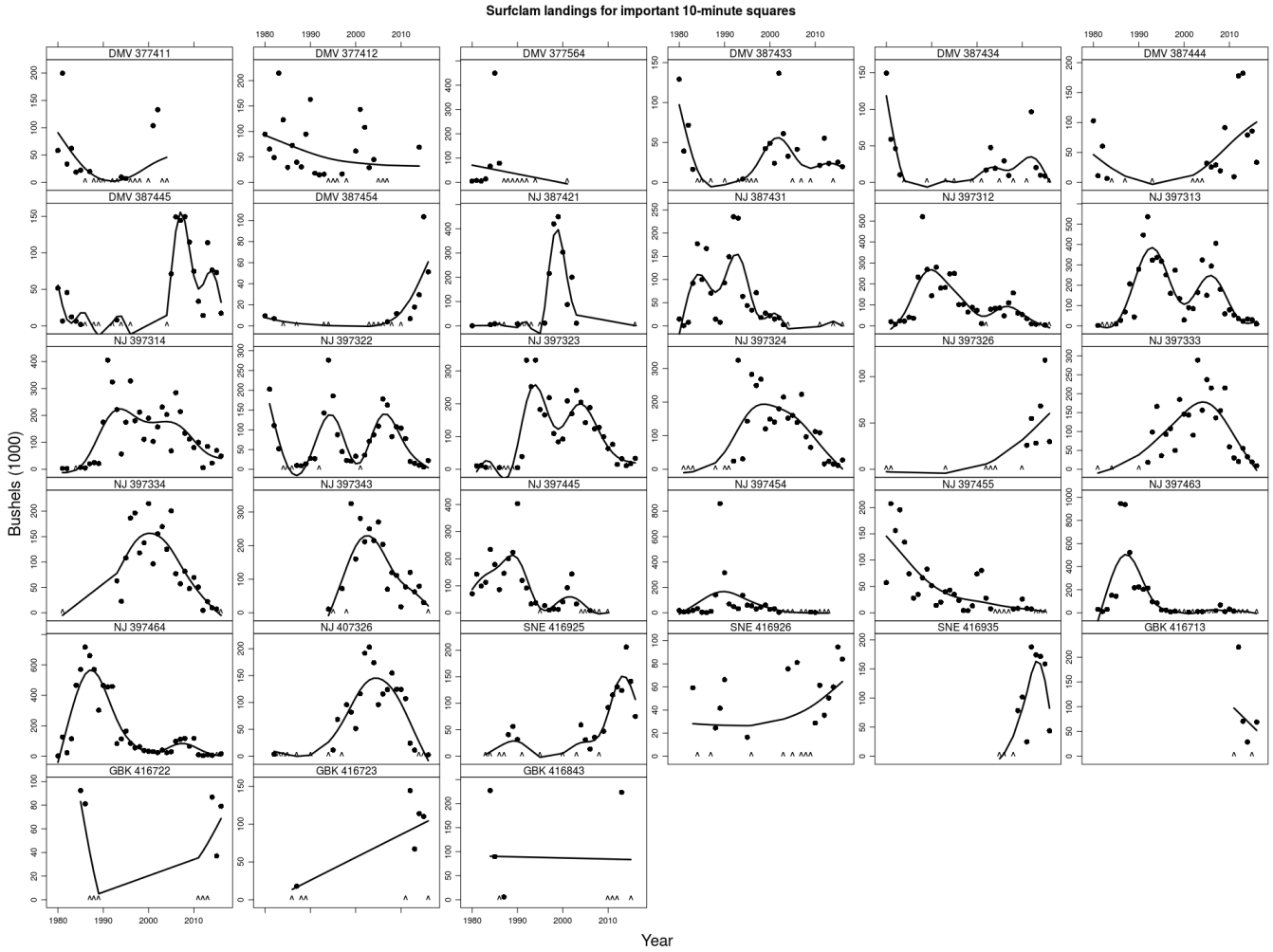


Figure 19: Annual surfclam landings in "important" ten minute squares (TNMS) during 1980-2015 based on logbook data. Important means that a square ranked in the top 10 TNMS for total landings during any five-year period (1980-1984, 1985-1989, ..., 2000-2004, 2005-2009, 2010-2015). To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 3. Instead, a "$\wedge$" is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

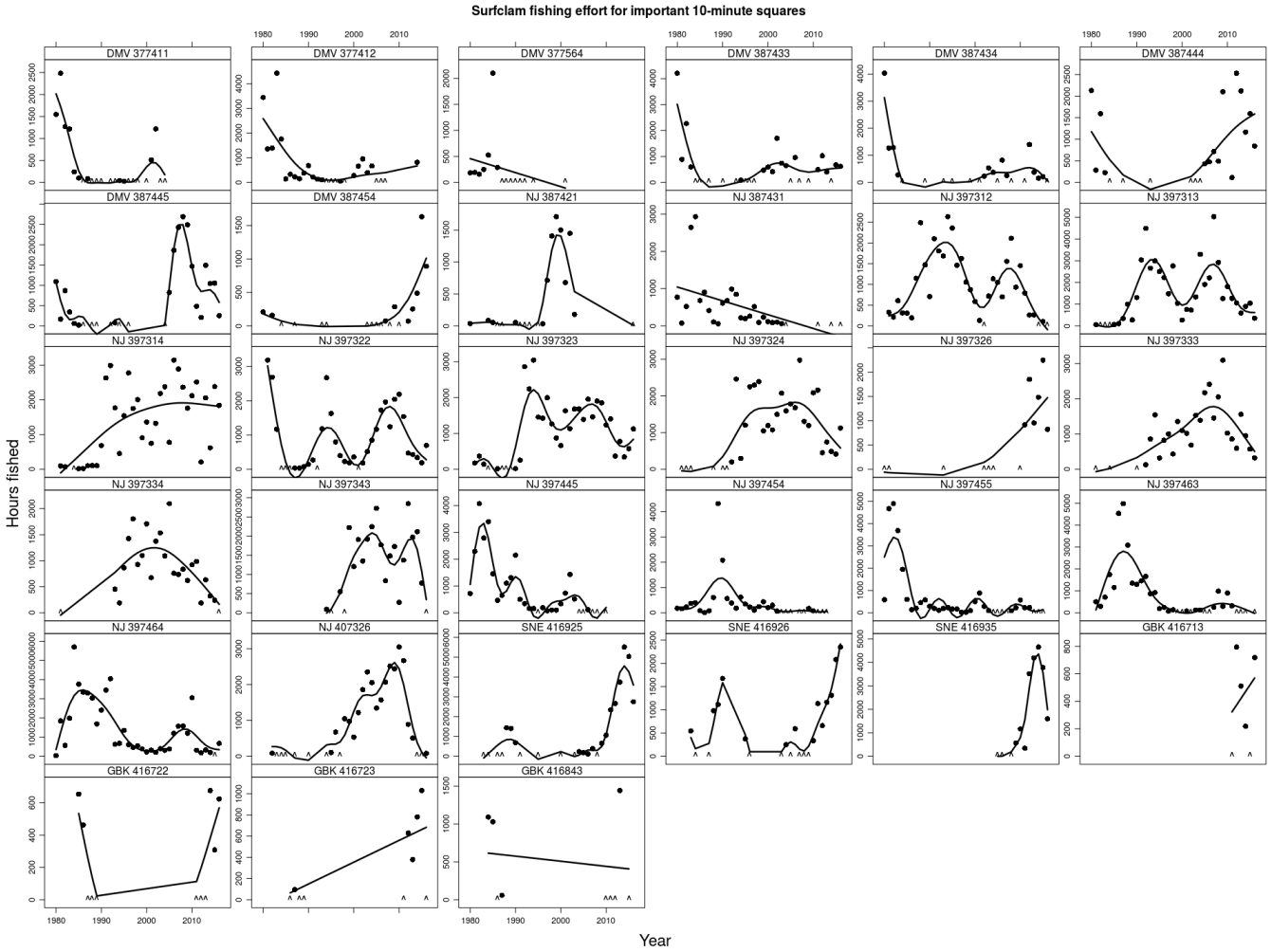


Figure 20: Annual surfclam effort (hours y^{-1}) in "important" ten minute squares (TNMS) during 1980-2015 based on logbook data. Important means that a square ranked in the top 10 TNMS for total landings during any five-year period (1980-1984, 1985-1989, ..., 2000-2004, 2005-2009, 2010-2015). To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 3. Instead, a "$\wedge$" is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

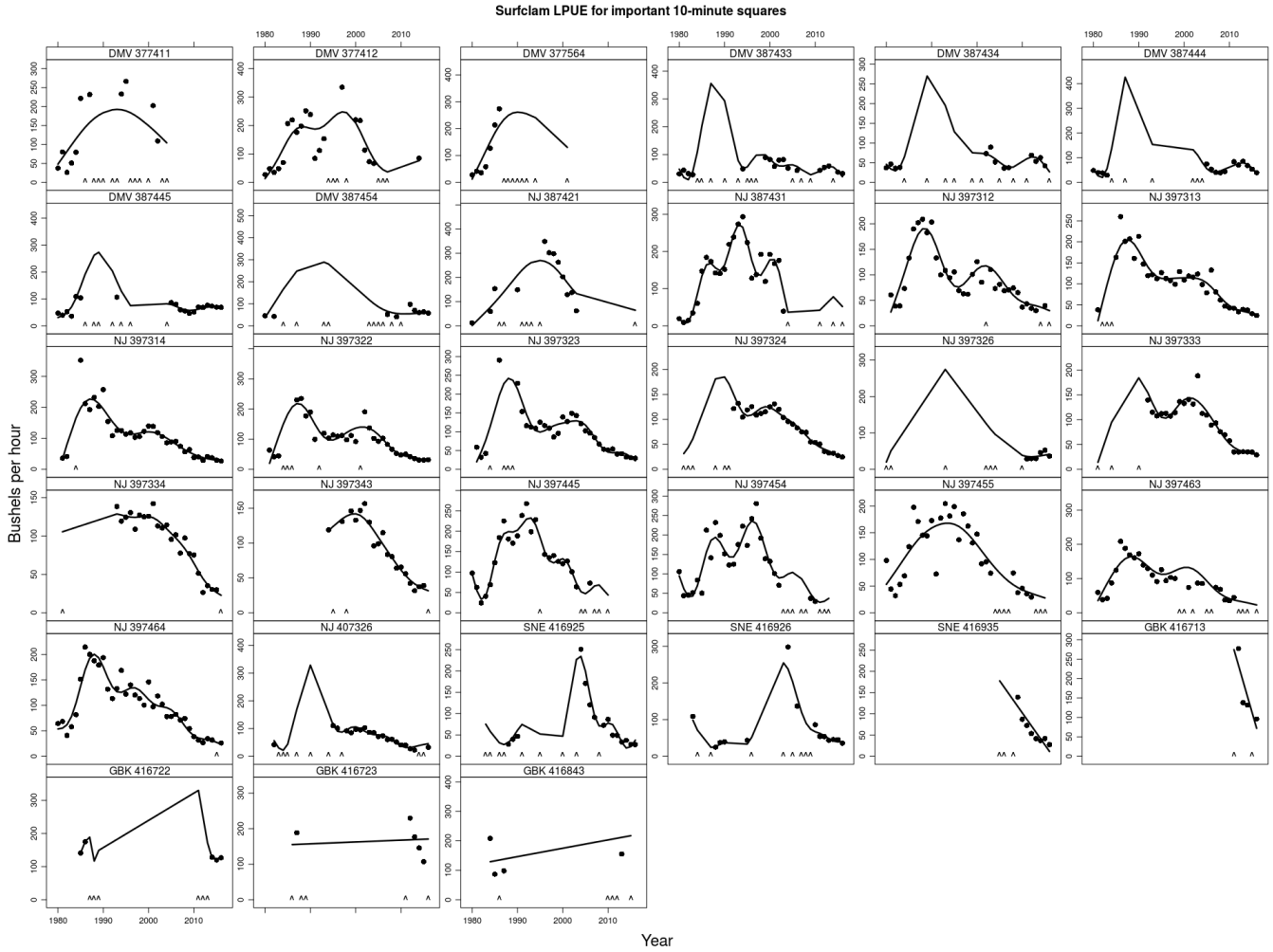


Figure 21: Annual surfclam LPUE (bu h^{-1}) in "important" ten minute squares (TNMS) during 1980-2015 based on logbook data. Important means that a square ranked in the top 10 TNMS for total landings during any five-year period (1980-1984, 1985-1989, ..., 2000-2004, 2005-2009, 2010-2015). To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 3. Instead, a "$\wedge$" is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

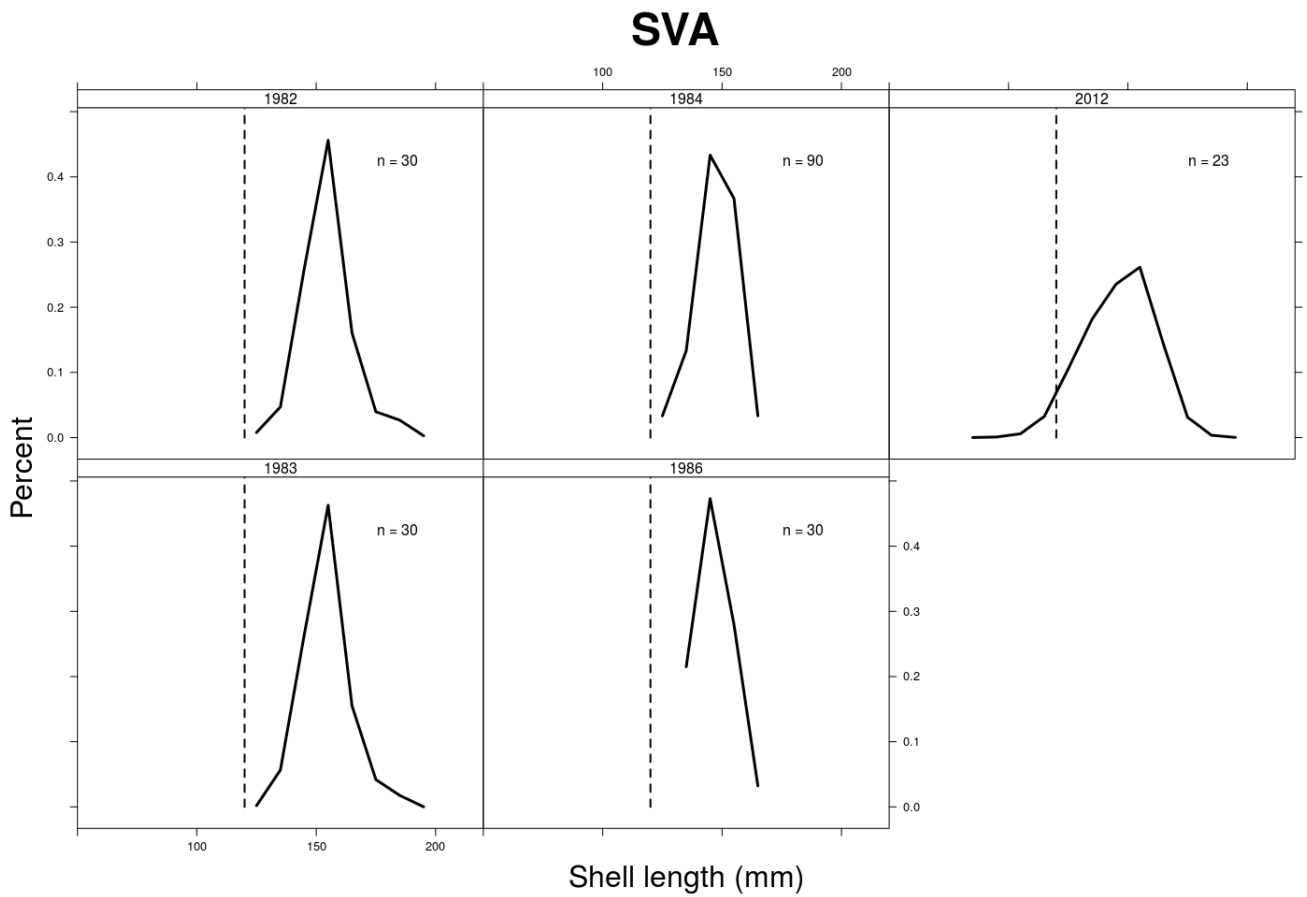


Figure 22: Length compositions for Atlantic surfclam from port samples of landings from the SVA region. Sample sizes are the number of clams measured in each year.

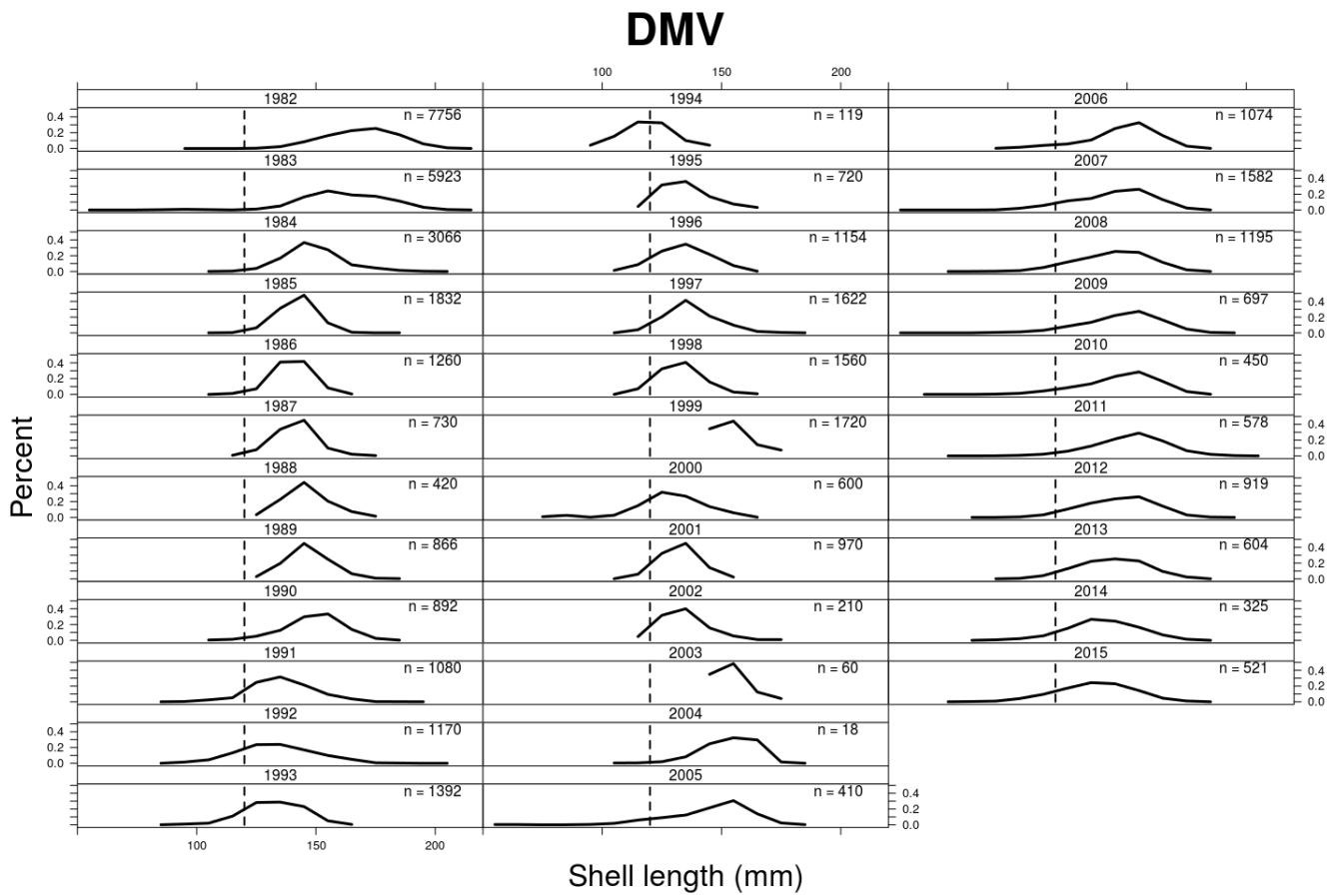


Figure 23: Length compositions for Atlantic surfclam from port samples of landings from the DMV region. Sample sizes are the number of clams measured in each year.

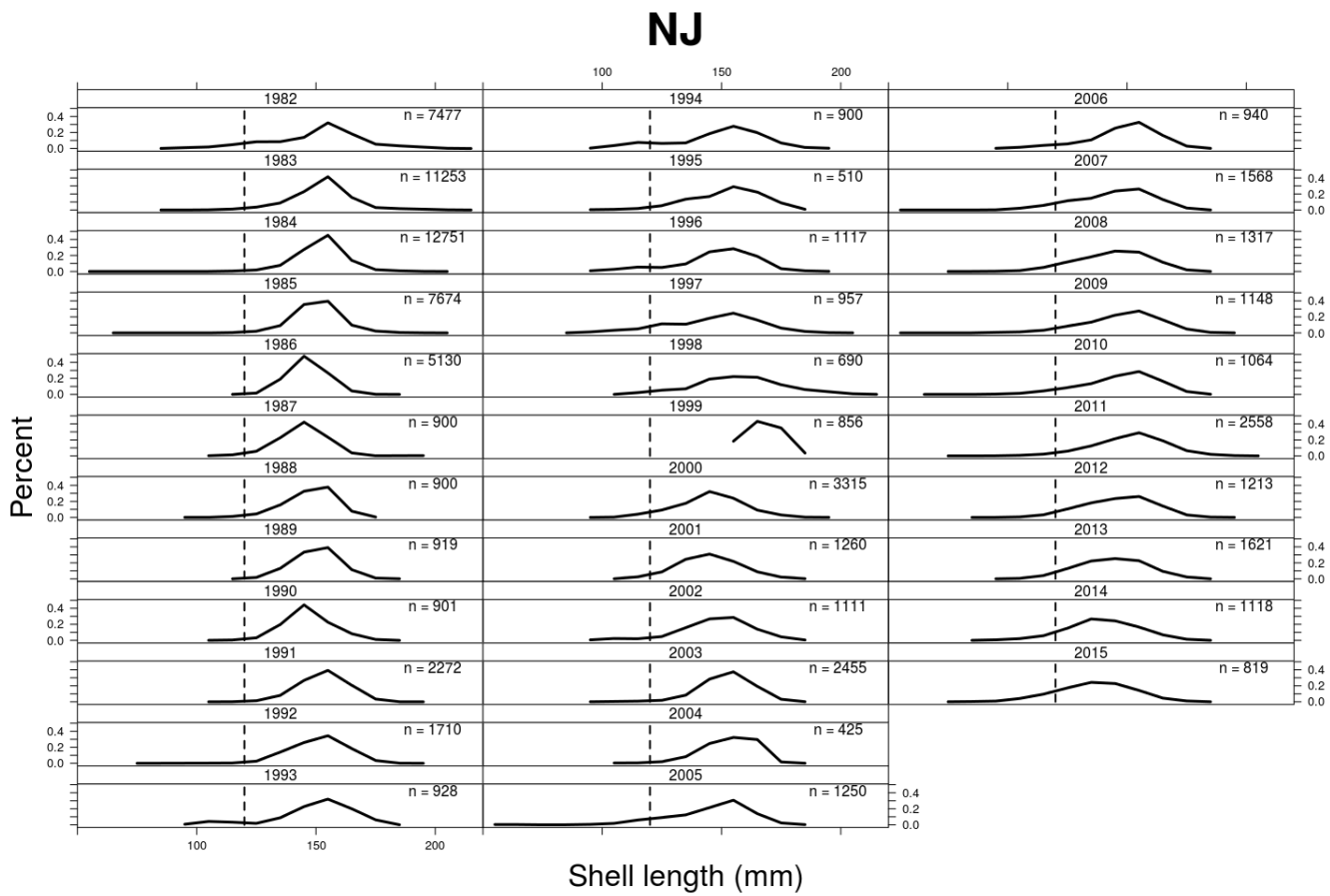


Figure 24: Length compositions for Atlantic surfclam from port samples of landings from the NJ region. Sample sizes are the number of clams measured in each year.

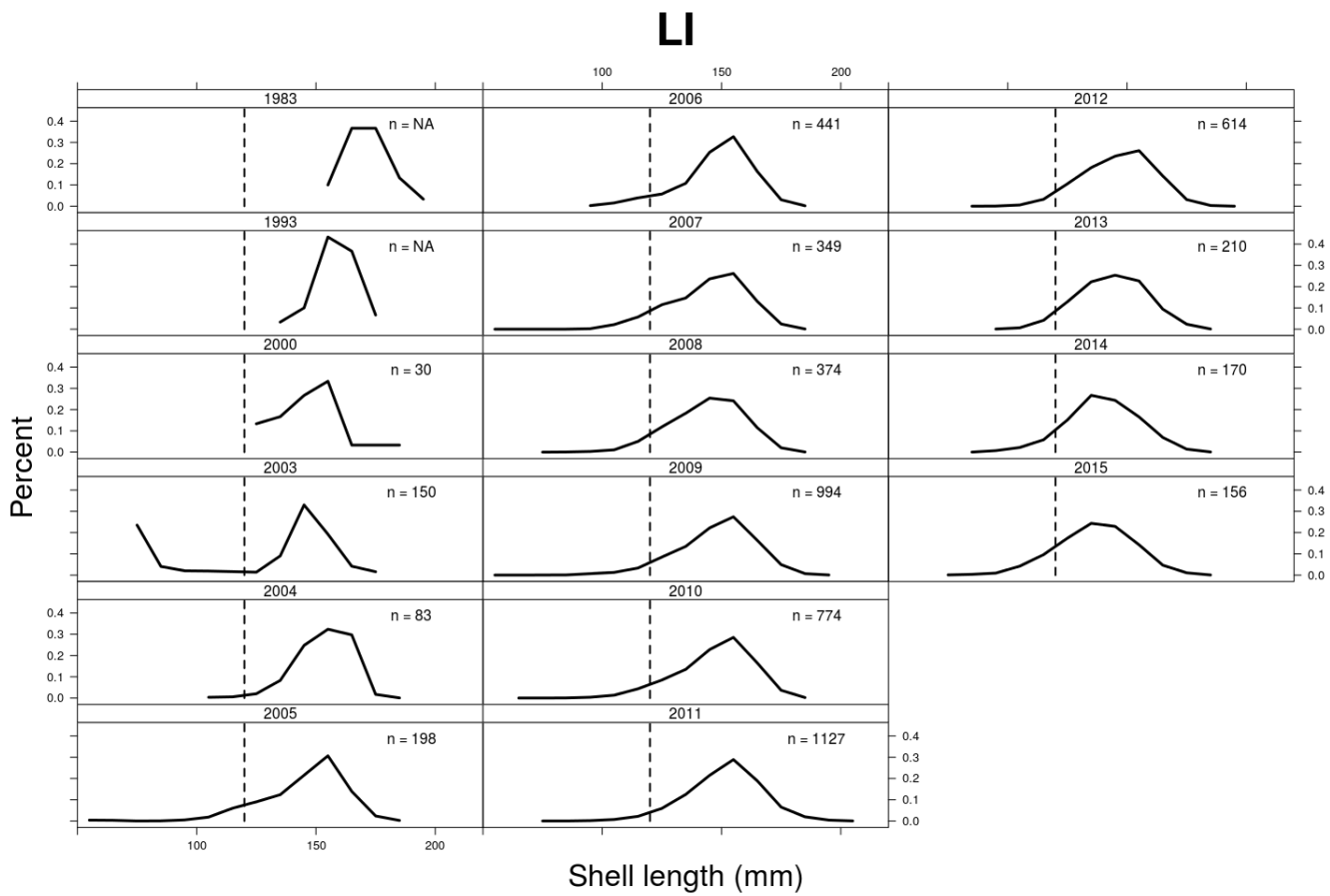


Figure 25: Length compositions for Atlantic surfclam from port samples of landings from the LI region. Sample sizes are the number of clams measured in each year.

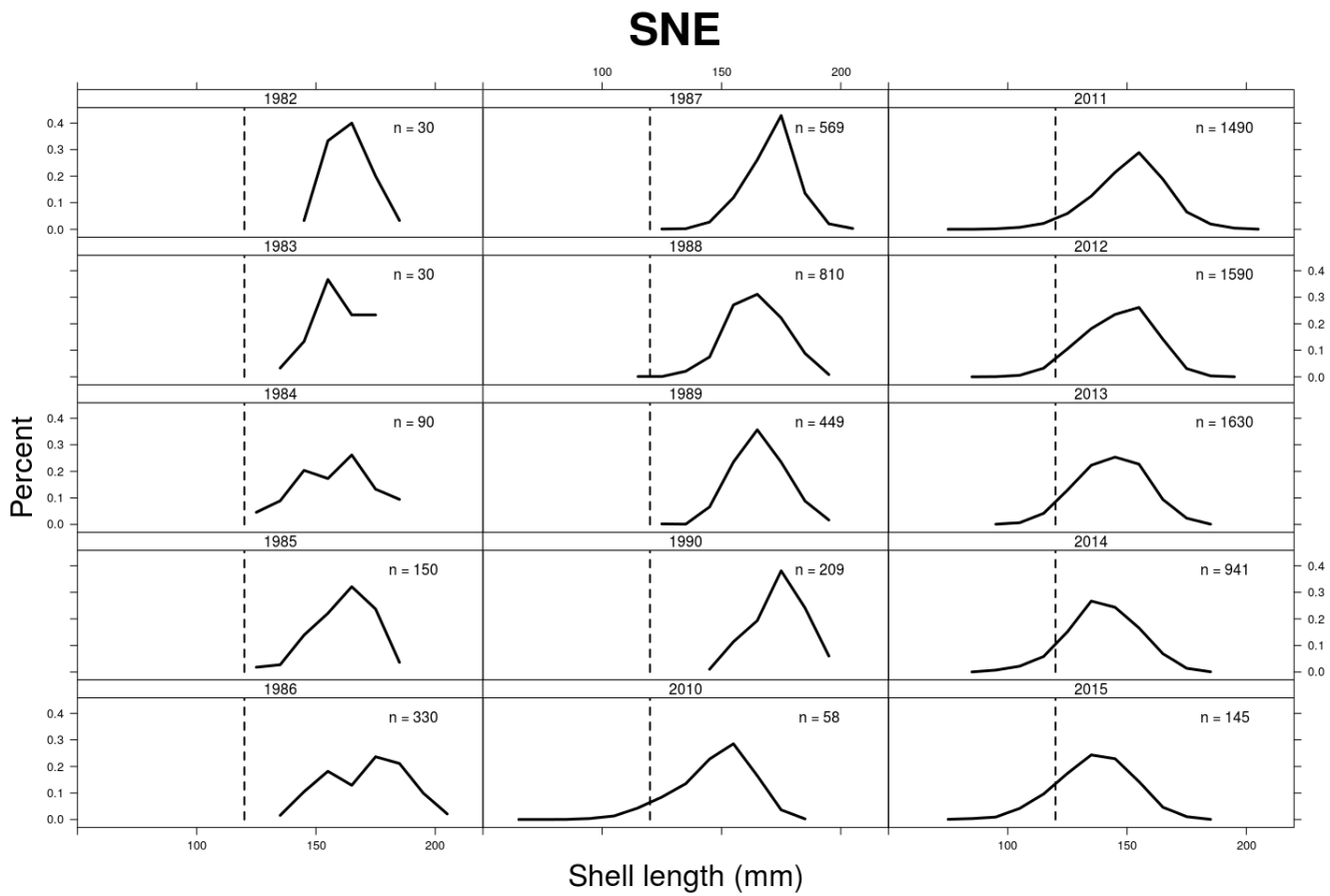


Figure 26: Length compositions for Atlantic surfclam from port samples of landings from the SNE region. Sample sizes are the number of clams measured in each year.

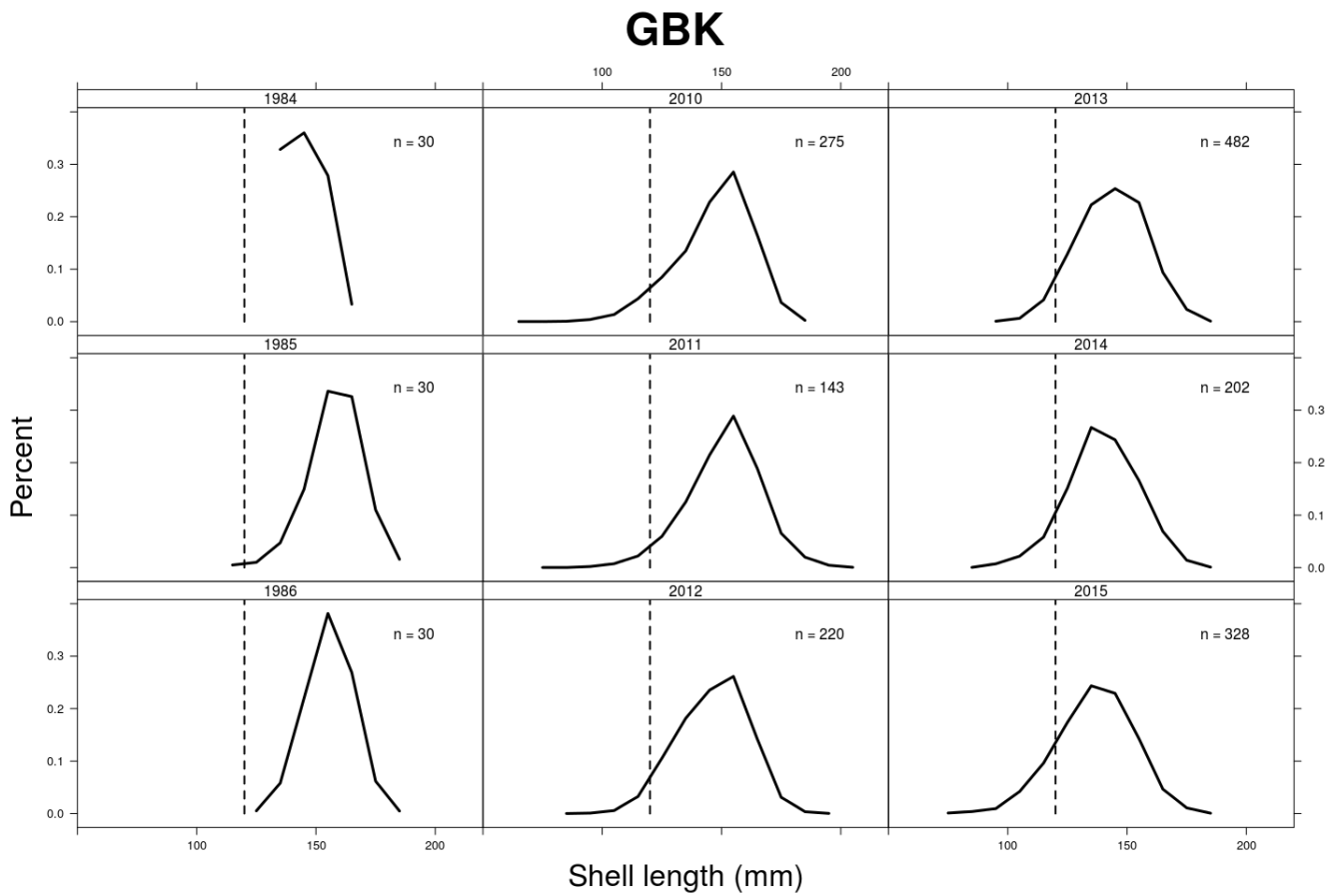


Figure 27: Length compositions for Atlantic surfclam from port samples of landings from the GBK region. Sample sizes are the number of clams measured in each year.

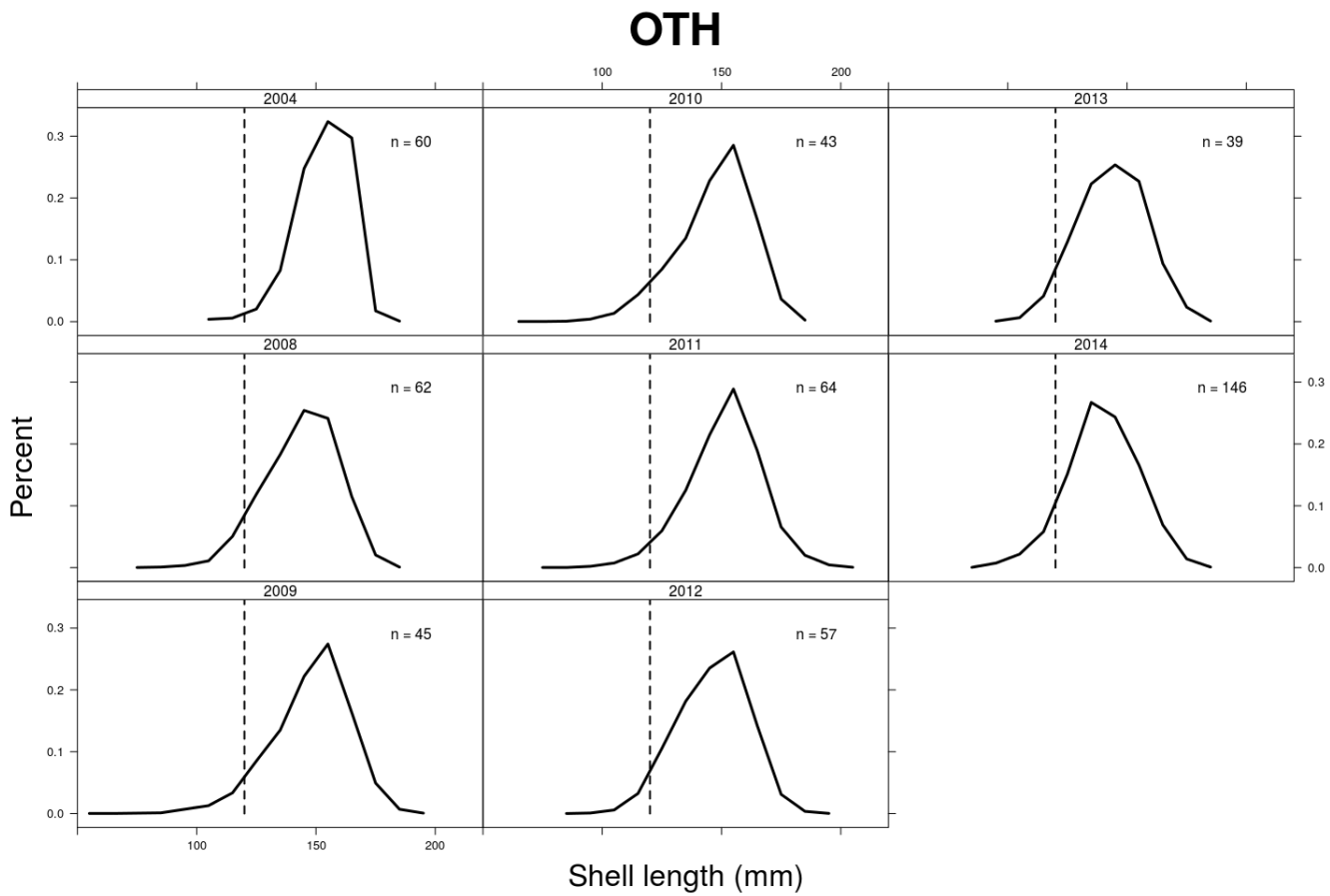


Figure 28: Length compositions for Atlantic surfclam for which no area was recorded (OTH). Sample sizes are the number of clams measured in each year.

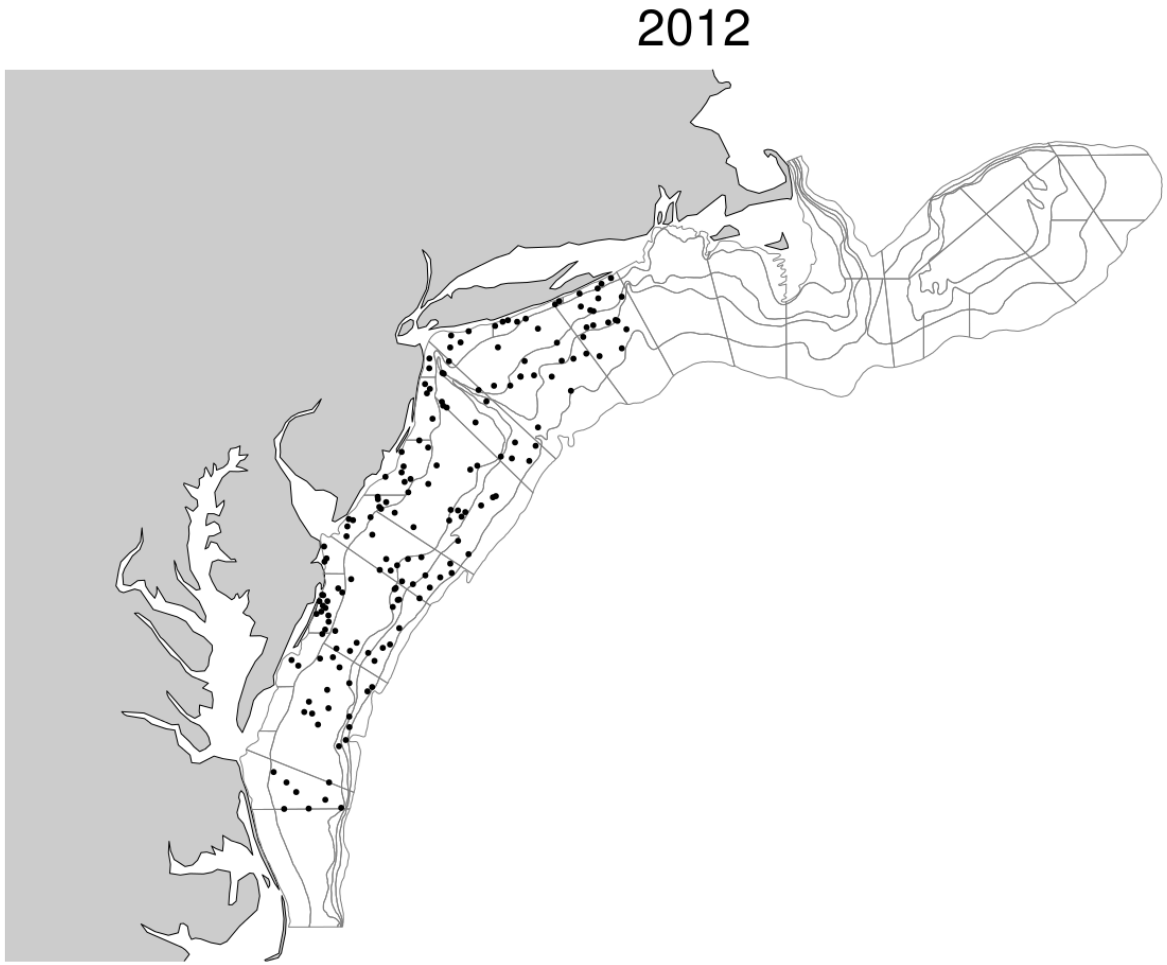


Figure 29: Station locations from the 2012 survey

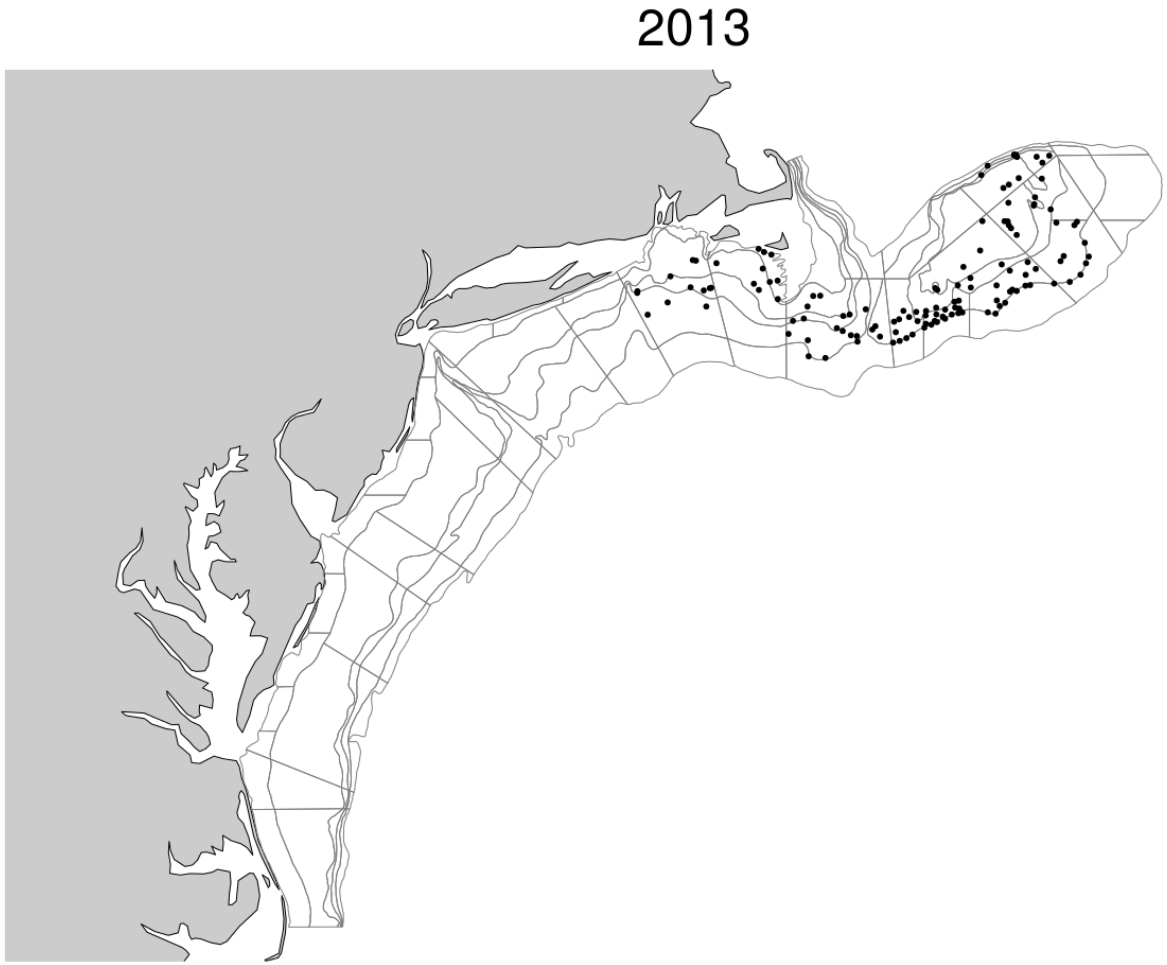


Figure 30: Station locations from the 2013 survey

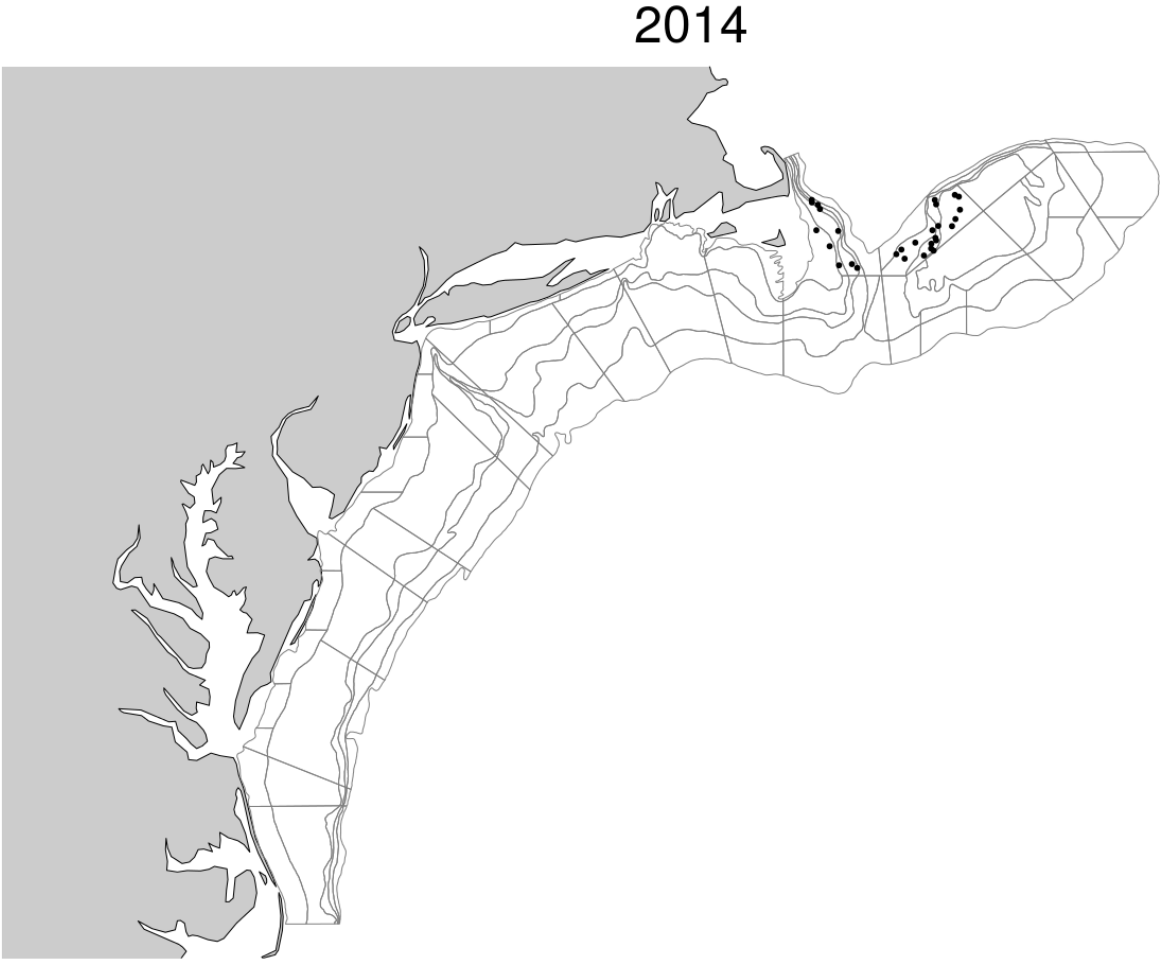


Figure 31: Station locations from the 2014 survey

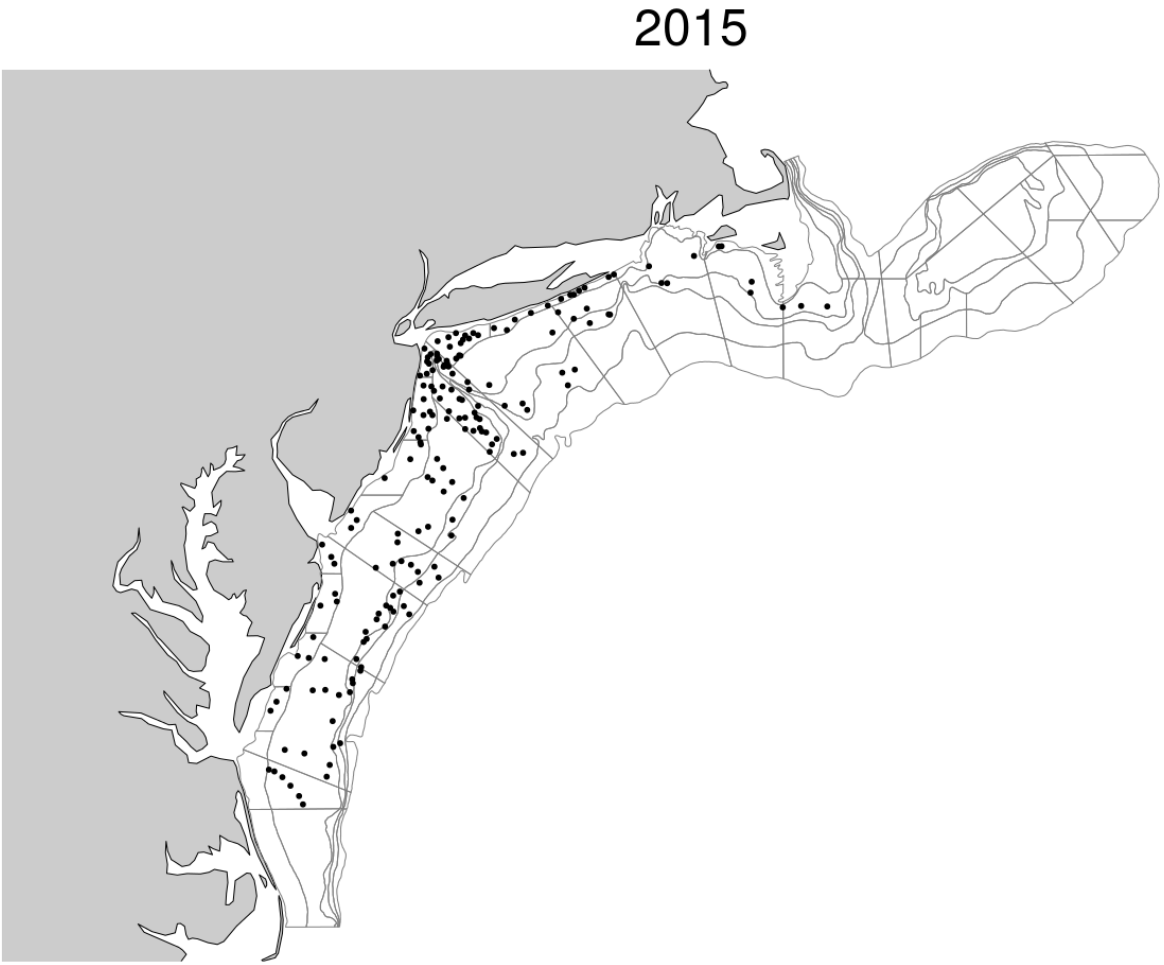


Figure 32: Station locations from the 2015 survey

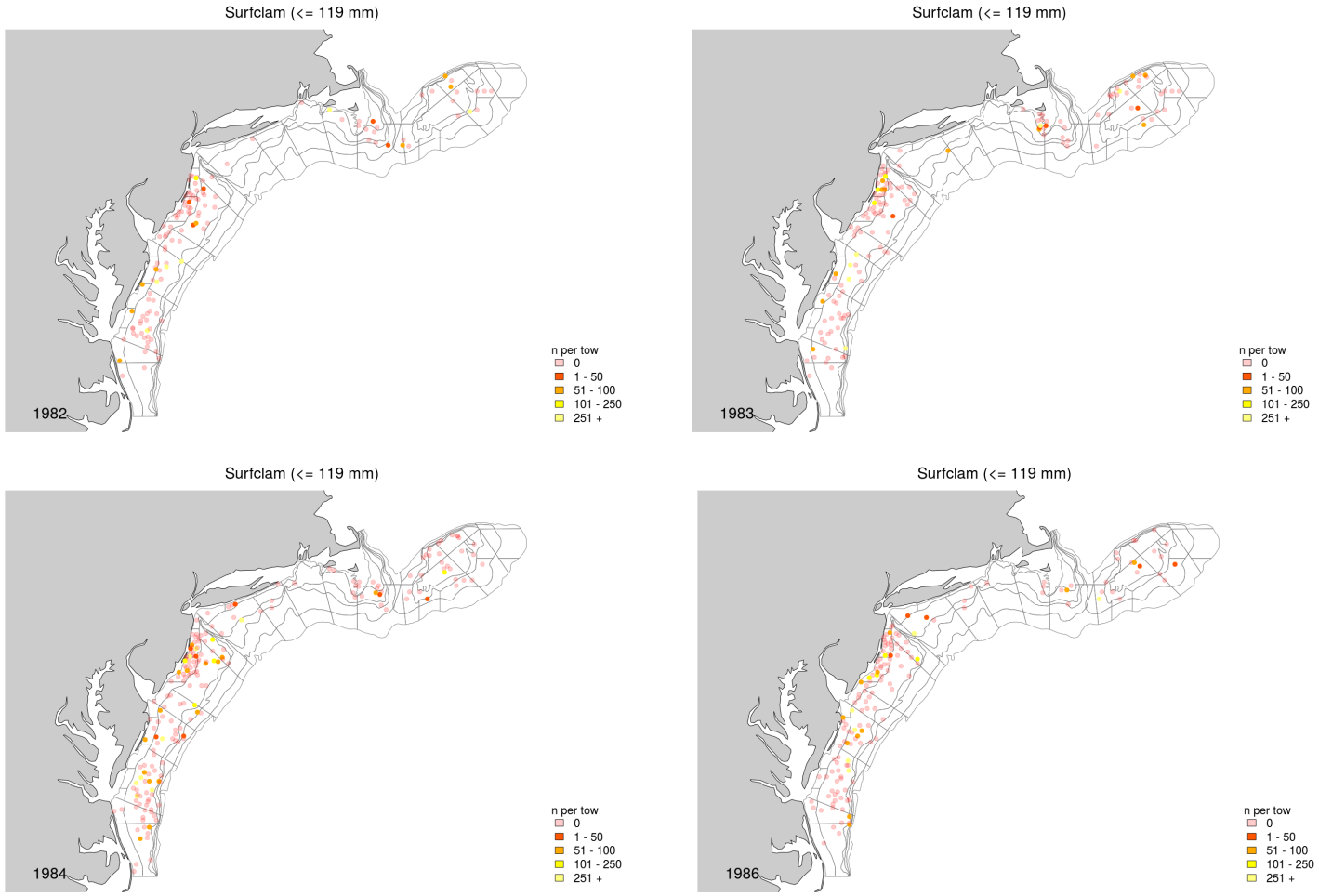
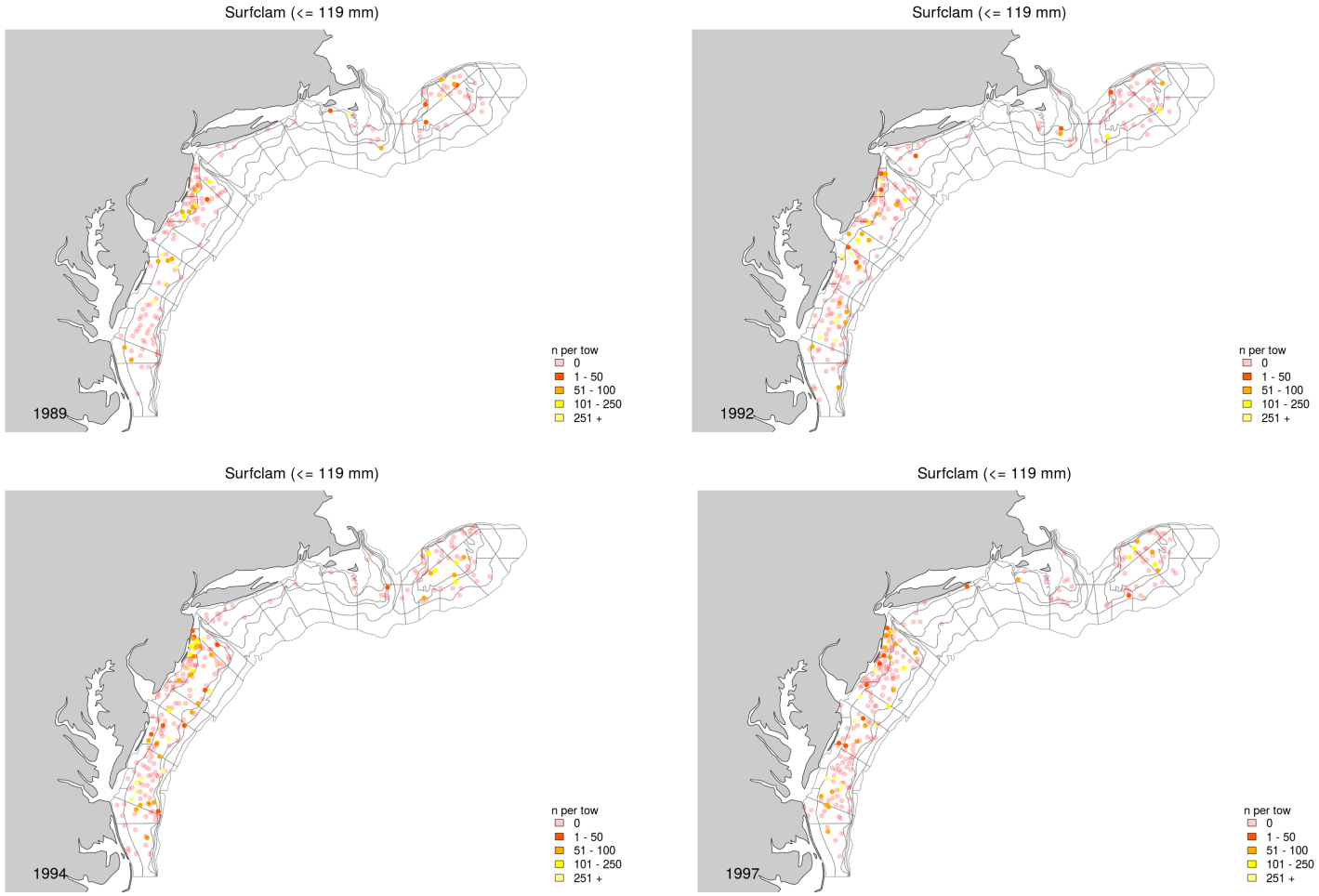


Figure 33: Survey stations where small ($<= 119\ mm$) surfclam were caught, by year.



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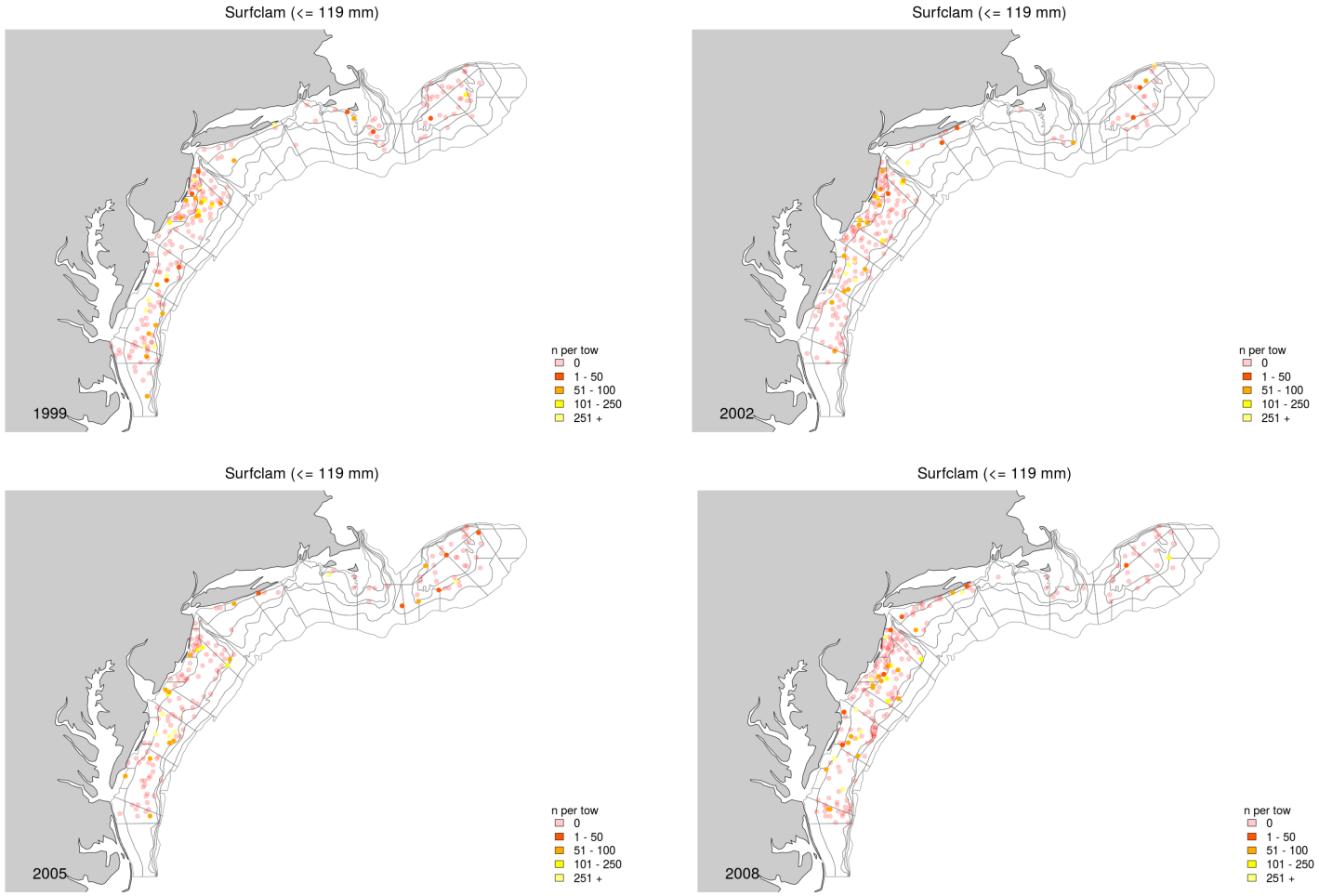

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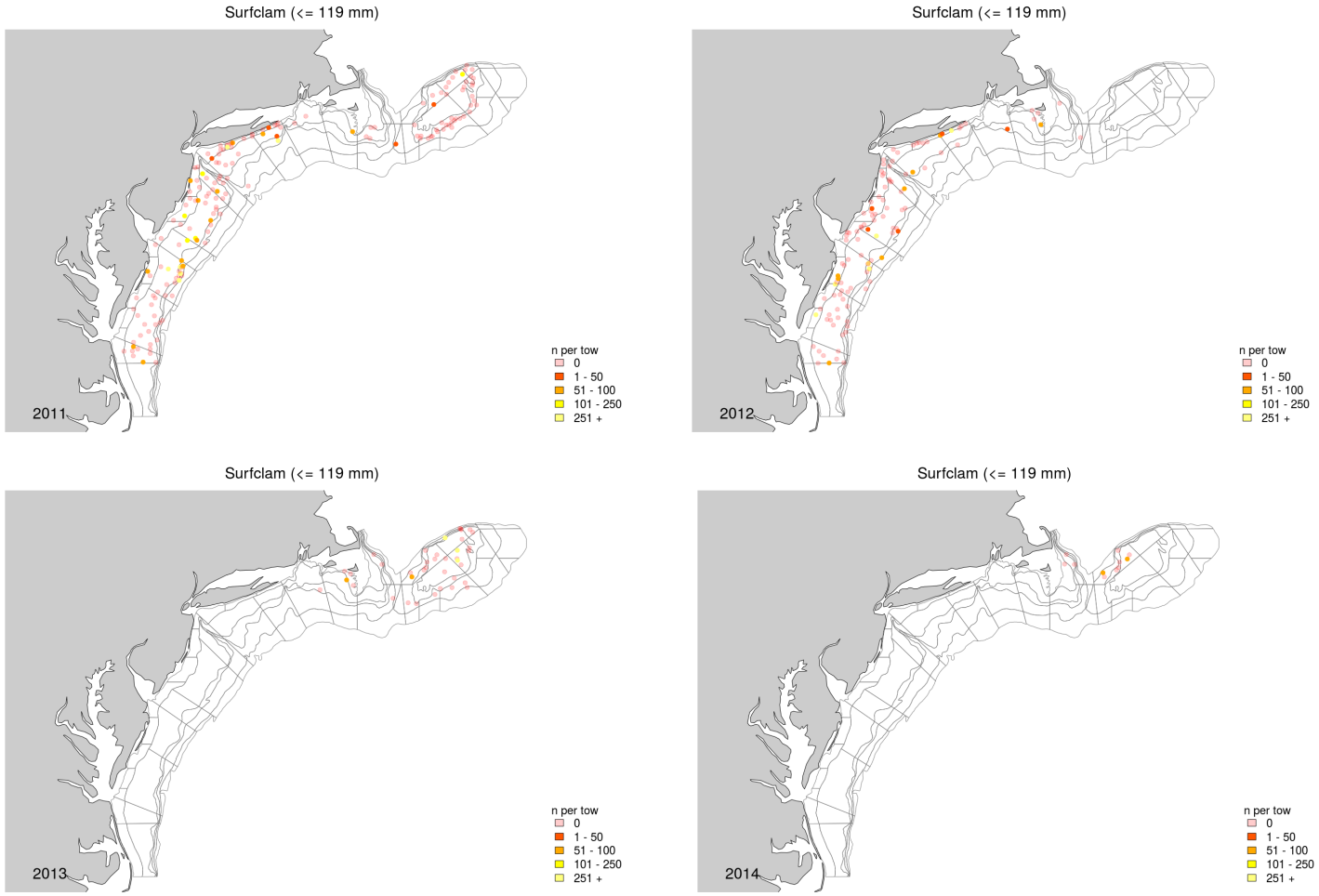

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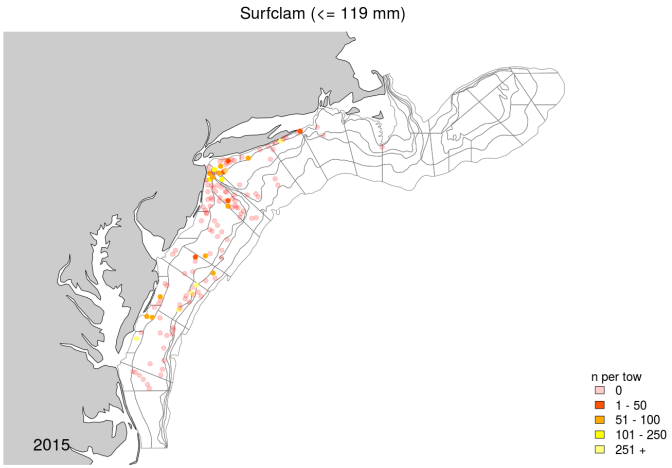

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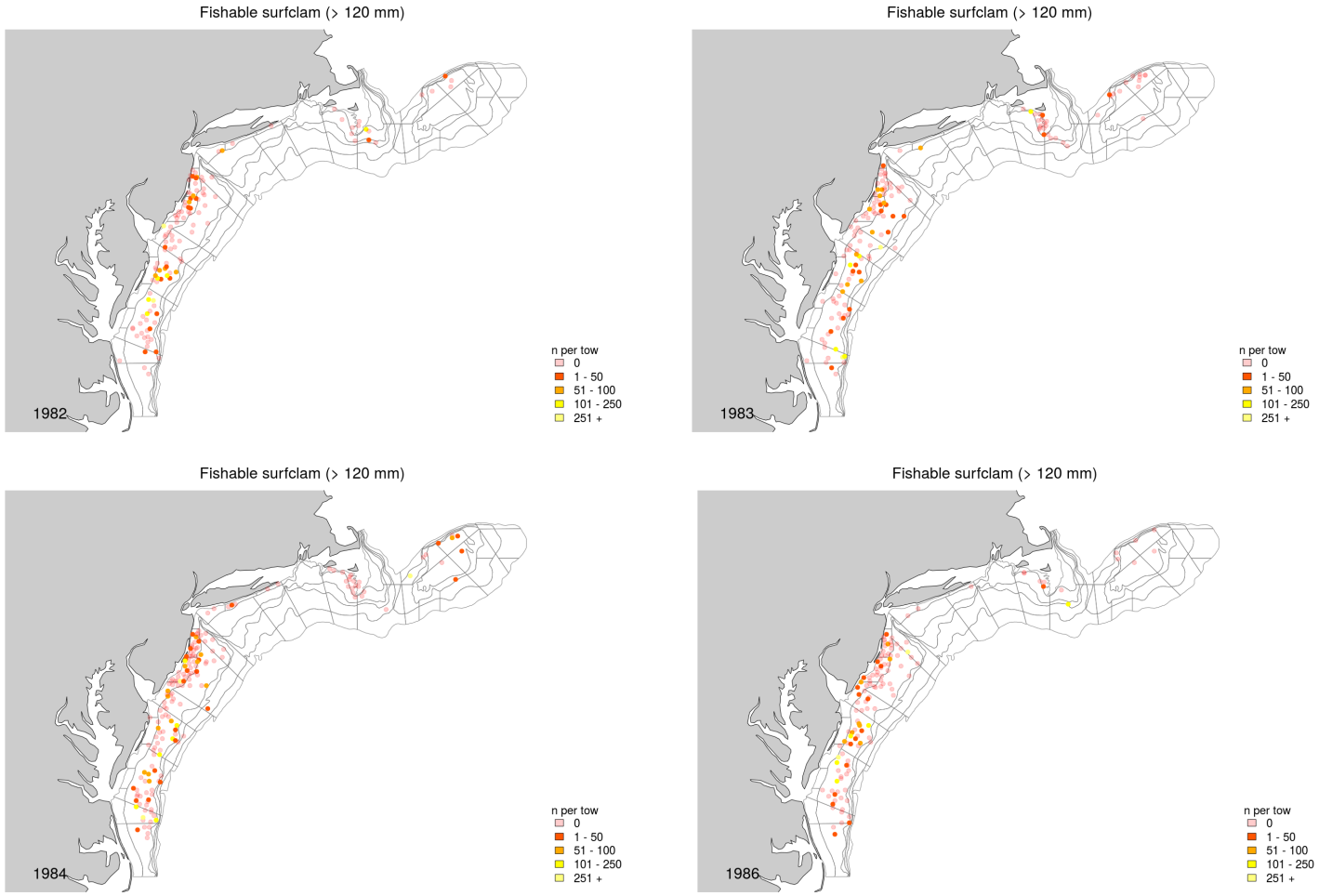
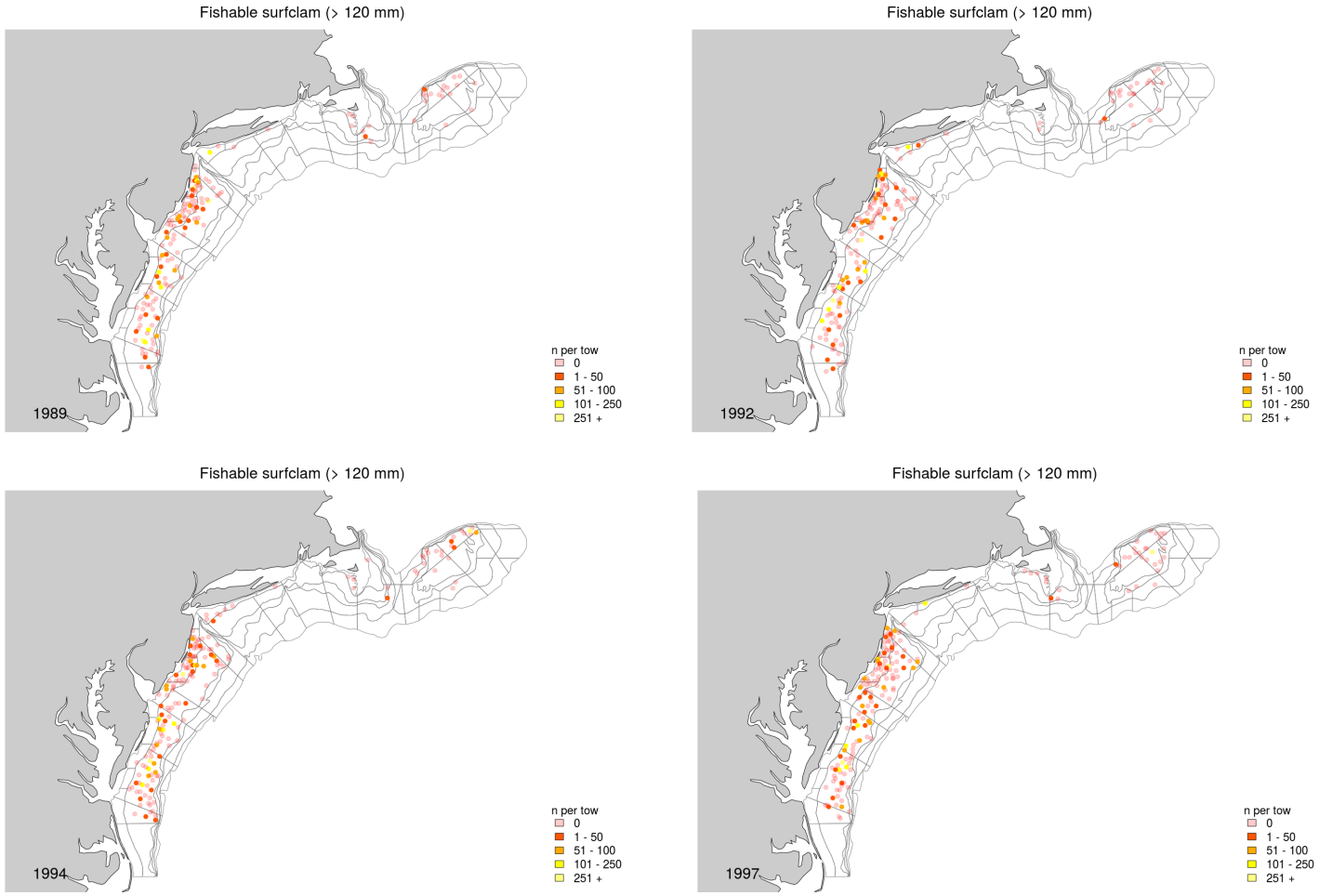


Figure 34: Survey stations where large ($> 120\ mm$) surfclam were caught, by year.



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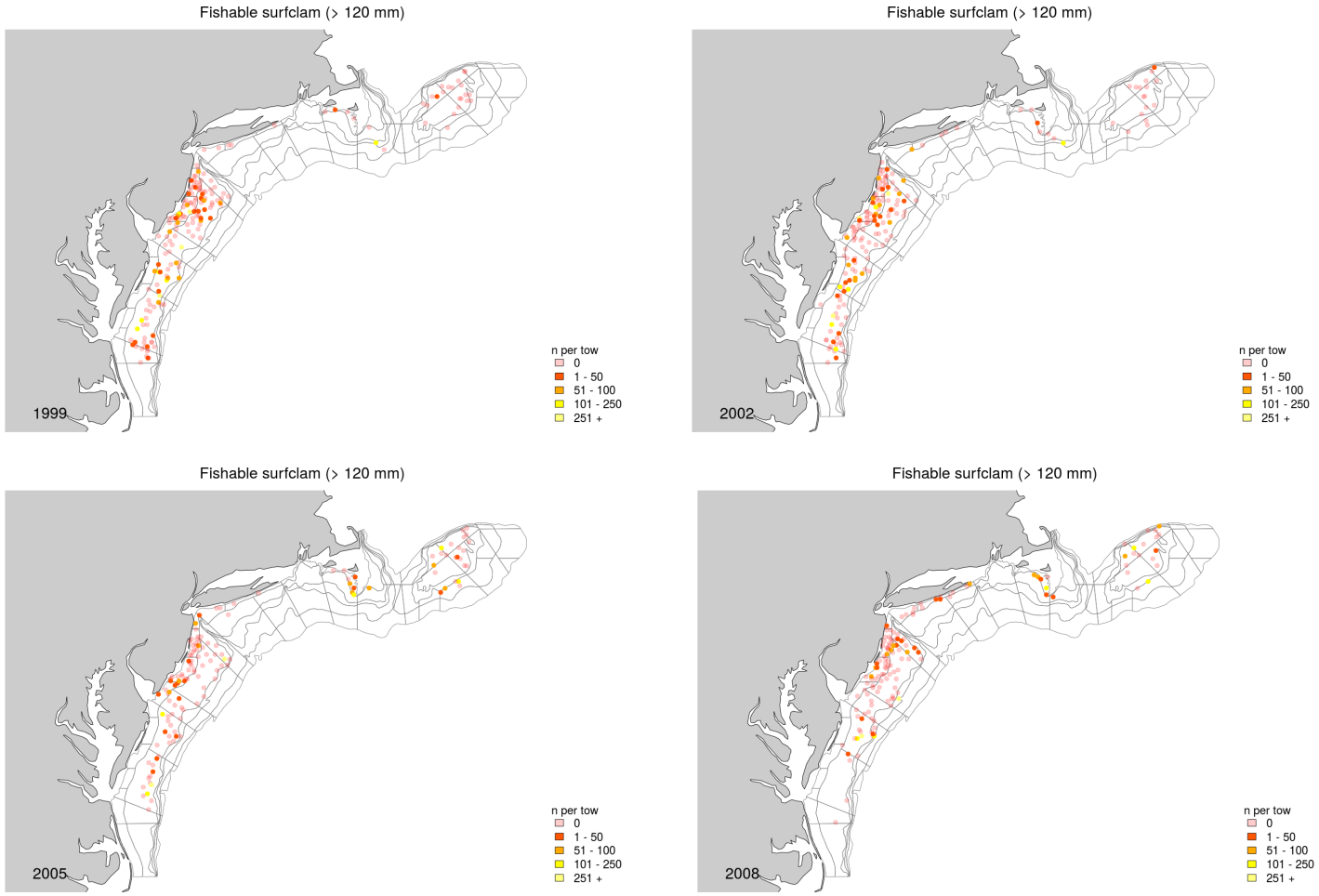

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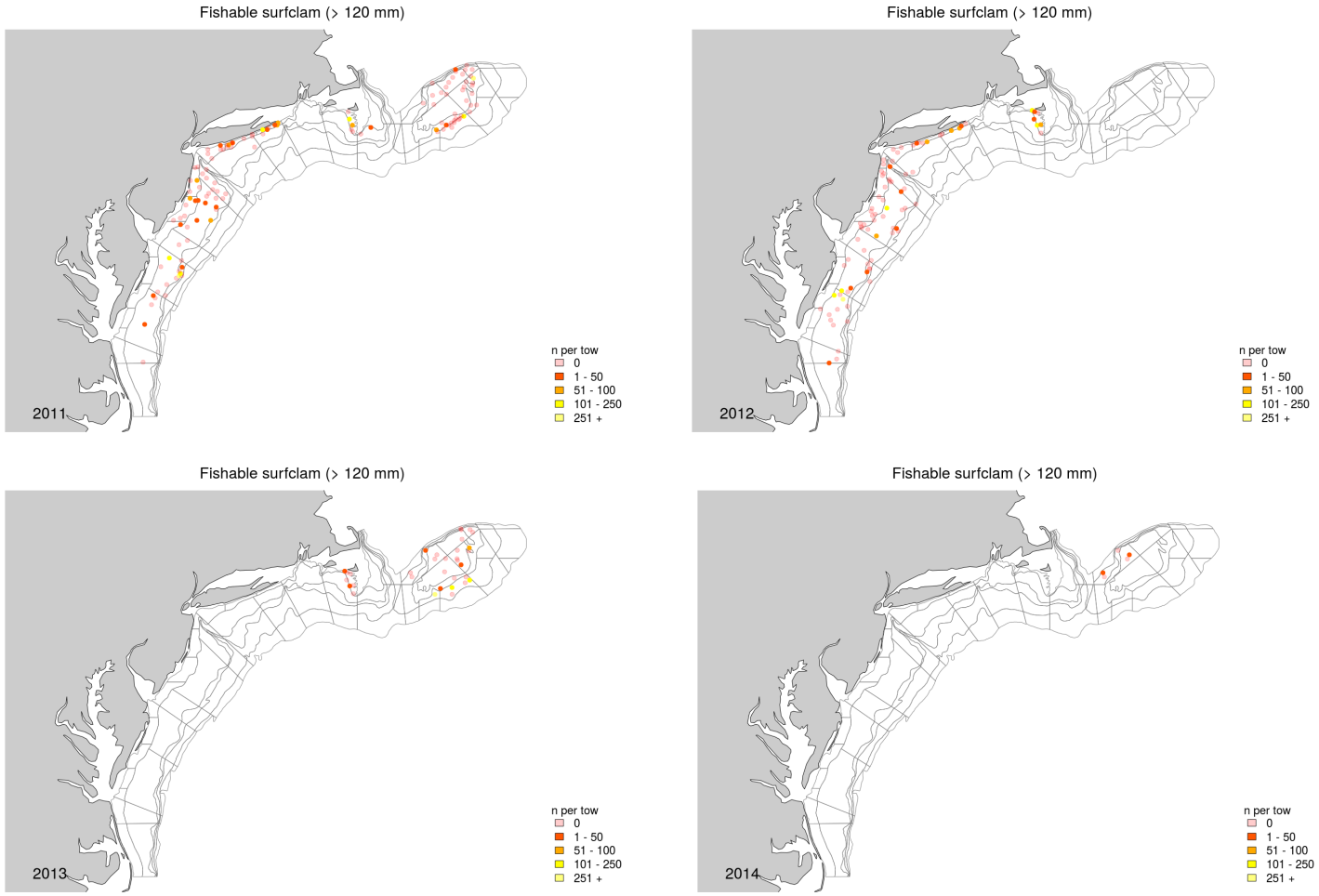

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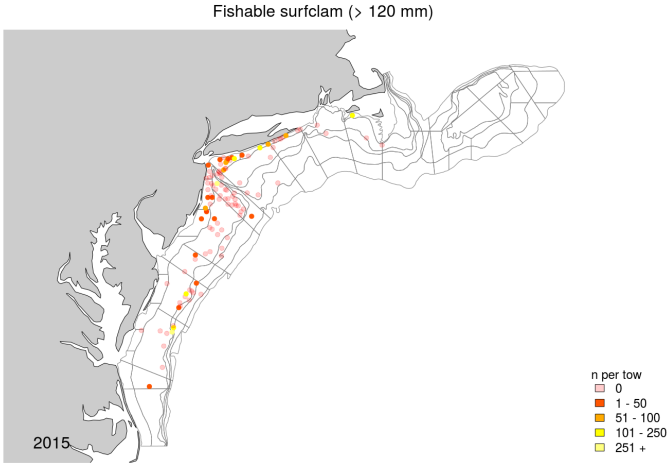

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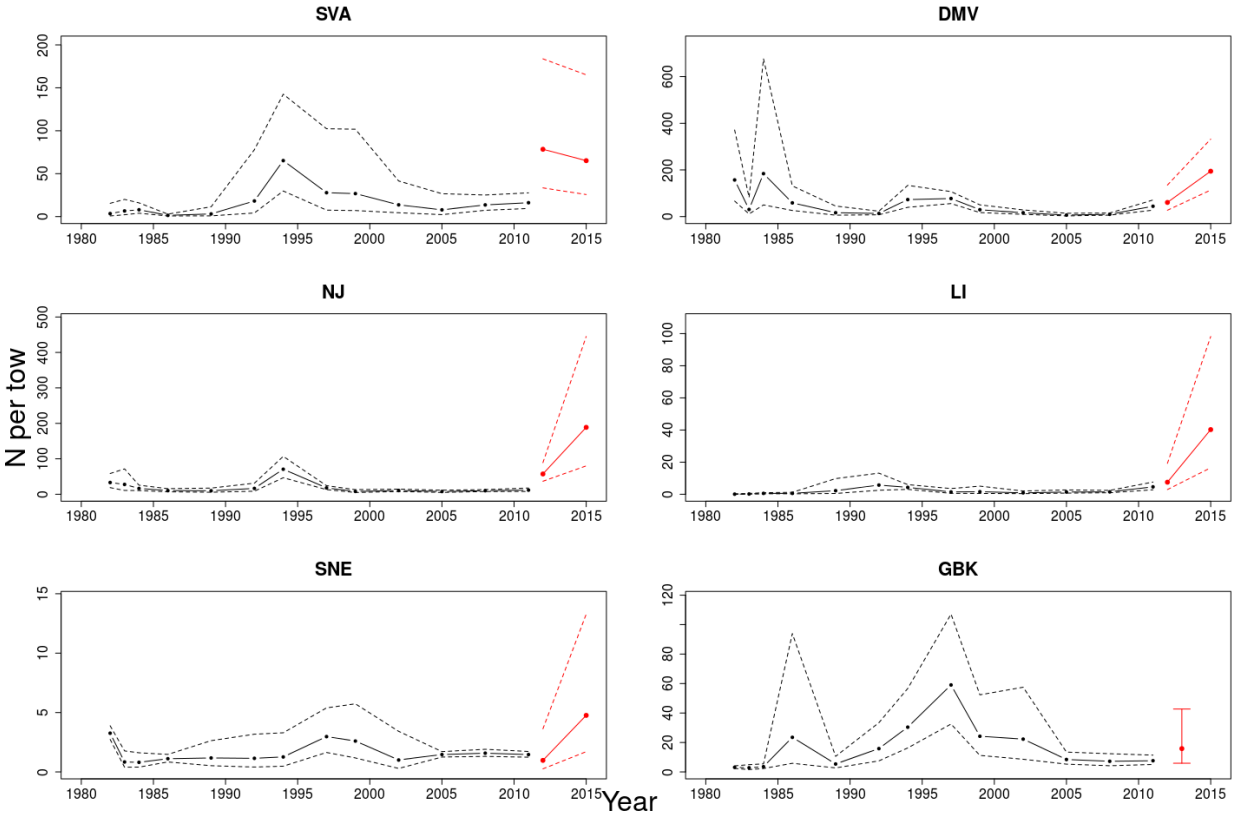

Figure 35: Surfclam 50 – 119 mm from NEFSC surveys adjusted for selectivity, but not efficiency, with approximate 95% asymmetric confidence intervals, by region. Beginning in 2012, the survey was conducted from a commercial platform using a dredge with higher capture efficiency. Results from the new survey platform are shown as a separate series in red. GBK and SNE were not sampled in 2012 and SVA, DMV, NJ and LI were not sampled in 2013 or 2014.

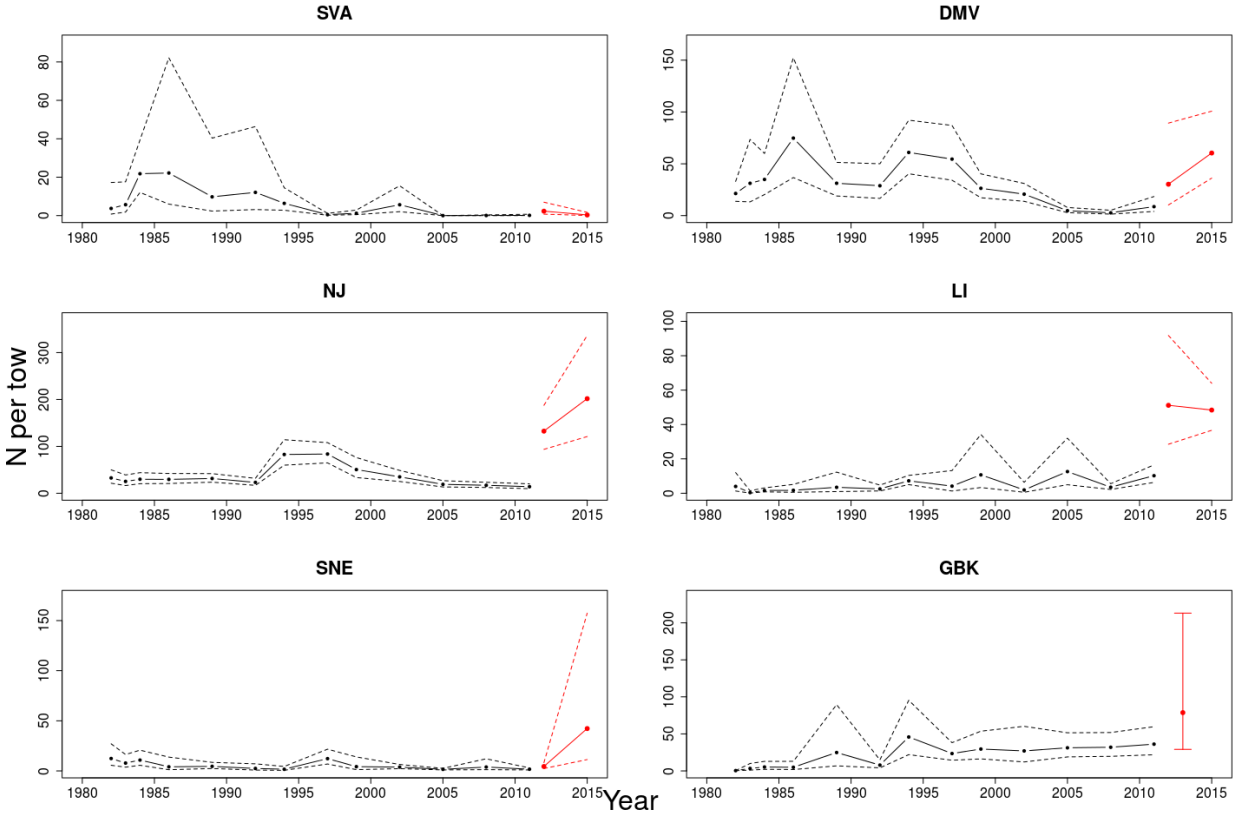

Figure 36: Surfclam > 119 mm from NEFSC surveys adjusted for selectivity, but not efficiency, with approximate 95% asymmetric confidence intervals, by region. Beginning in 2012, the survey was conducted from a commercial platform using a dredge with higher capture efficiency. Results from the new survey platform are shown as a separate series in red. GBK and SNE were not sampled in 2012 and SVA, DMV, NJ and LI were not sampled in 2013 or 2014.

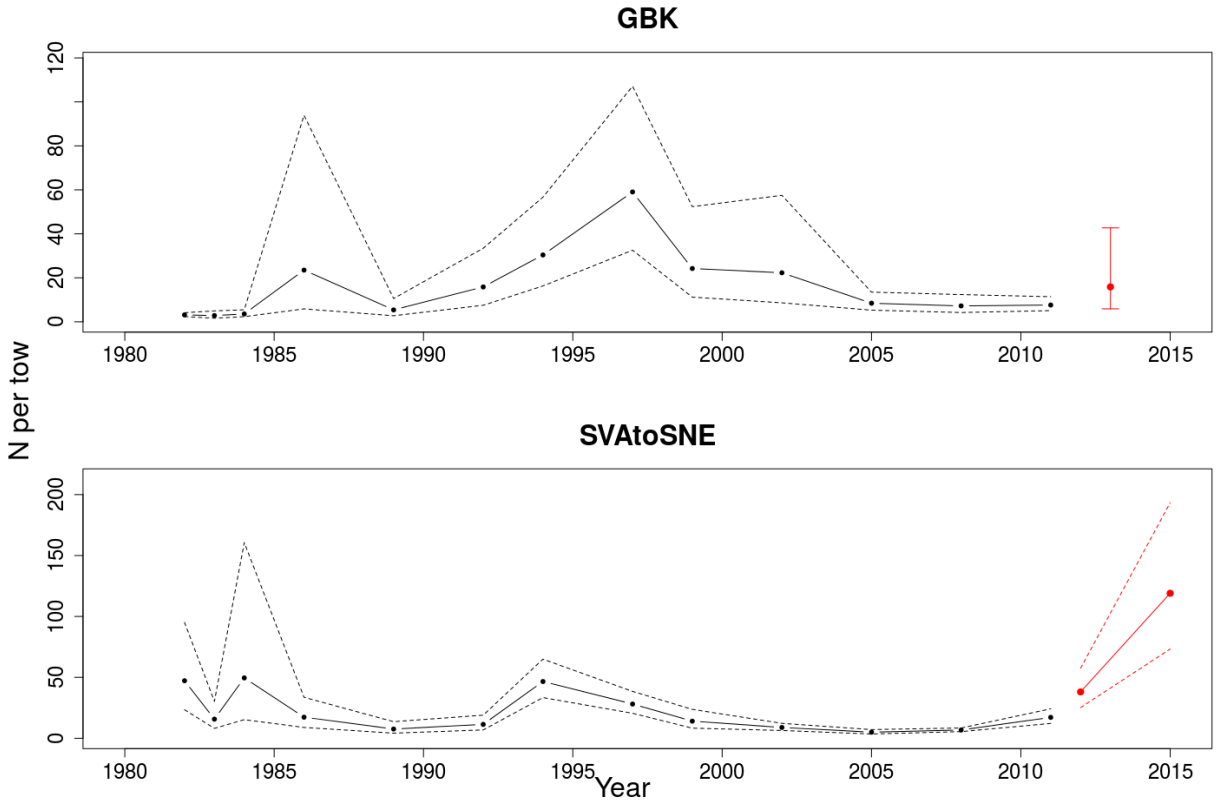

Figure 37: Surfclam 50 – 119 mm from NEFSC surveys adjusted for selectivity, but not efficiency, with approximate 95% asymmetric confidence intervals, by area. Beginning in 2012, the survey was conducted from a commercial platform using a dredge with higher capture efficiency. Results from the new survey platform are shown as a separate series in red. GBK and SNE were not sampled in 2012 and SVA, DMV, NJ and LI were not sampled in 2013 or 2014.

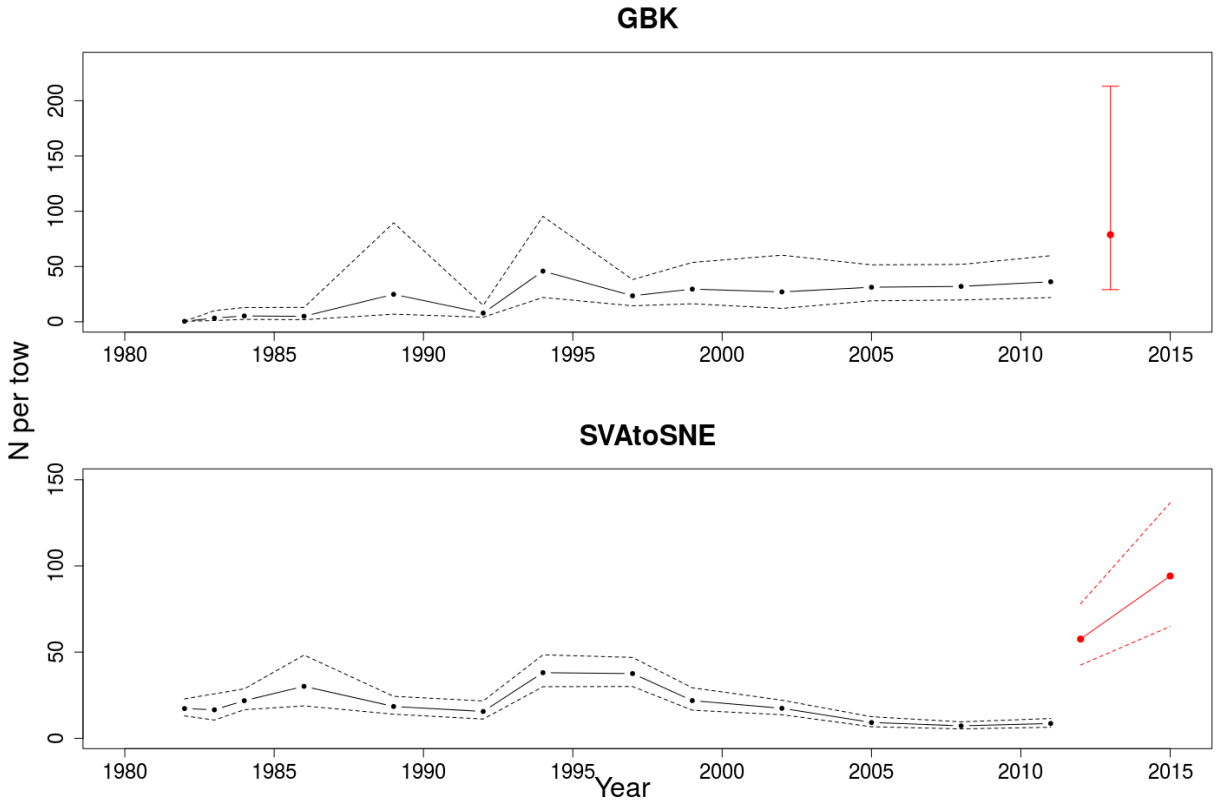

Figure 38: Surfclam > 119 mm from NEFSC surveys adjusted for selectivity, but not efficiency, with approximate 95% asymmetric confidence intervals, by area. Beginning in 2012, the survey was conducted from a commercial platform using a dredge with higher capture efficiency. Results from the new survey platform are shown as a separate series in red. GBK and SNE were not sampled in 2012 and SVA, DMV, NJ and LI were not sampled in 2013 or 2014.

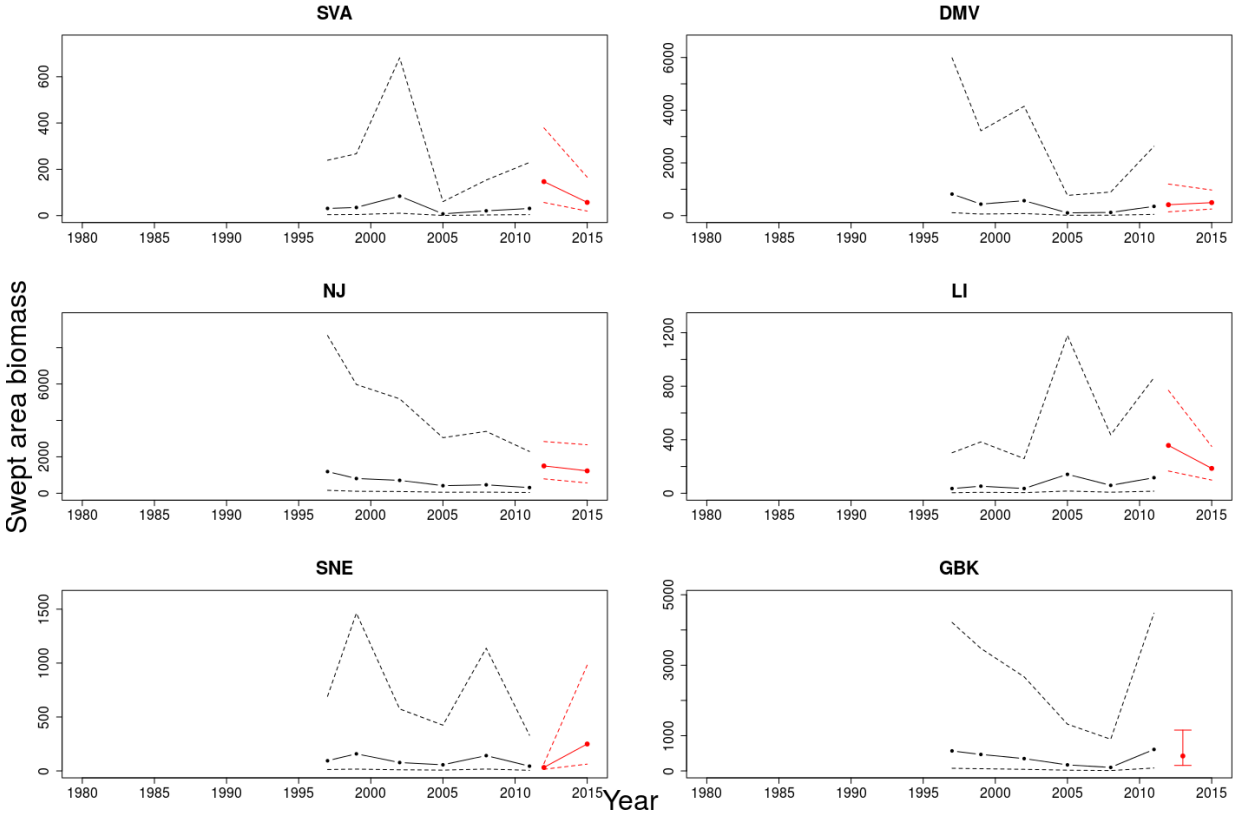

Figure 39: Surfclam swept area biomass from NEFSC surveys adjusted for selectivity and efficiency, with approximate 95% asymmetric confidence intervals, by area. Beginning in 2012, the survey was conducted from a commercial platform using a dredge with higher capture efficiency. Results from the new survey platform are shown as a separate series in red. GBK and SNE were not sampled in 2012 and SVA, DMV, NJ and LI were not sampled in 2013 or 2014.

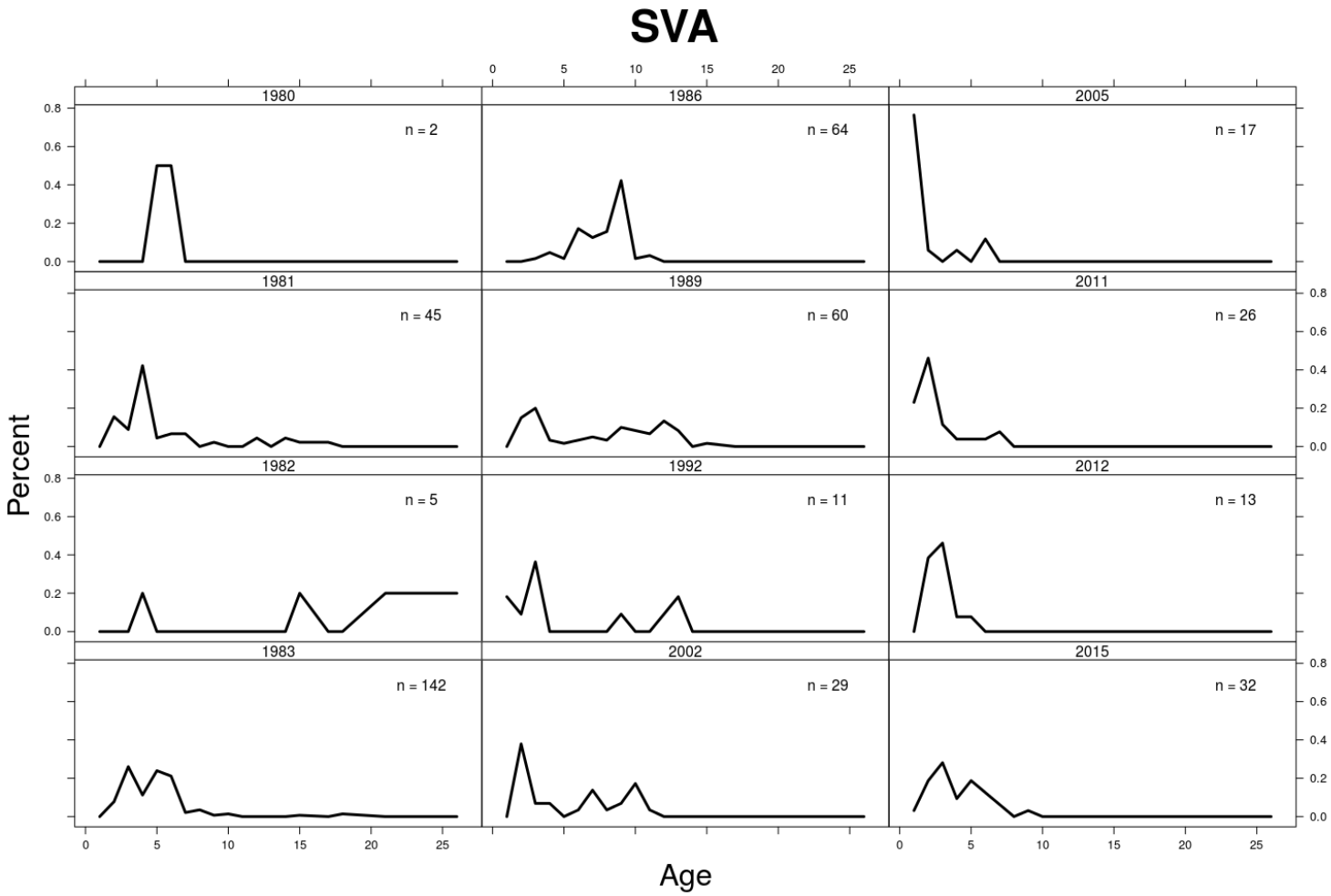

Figure 40: Age composition of Atlantic surfclam in NEFSC surveys in SVA, including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

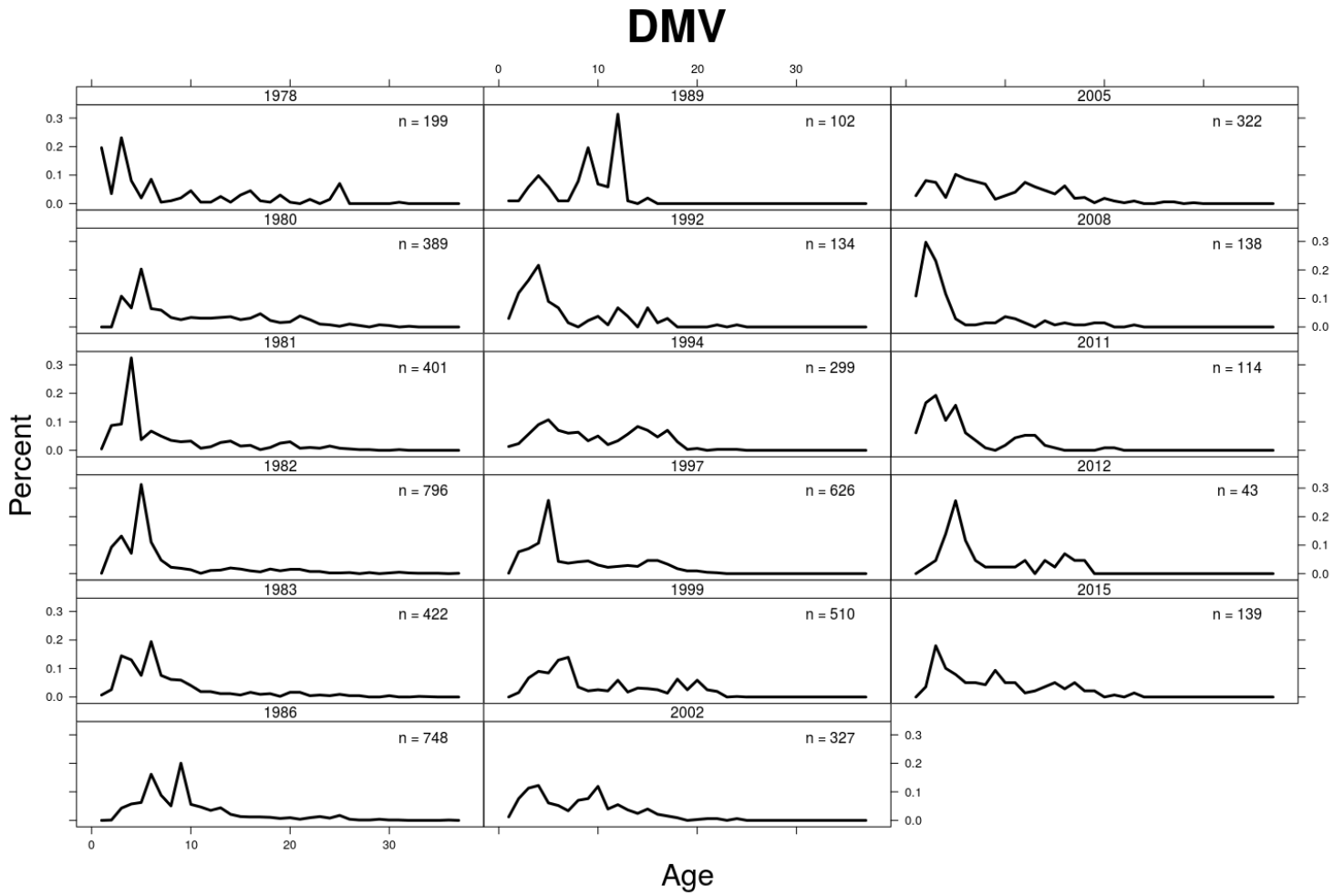

Figure 41: Age composition of Atlantic surfclam in NEFSC surveys in DMV, including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

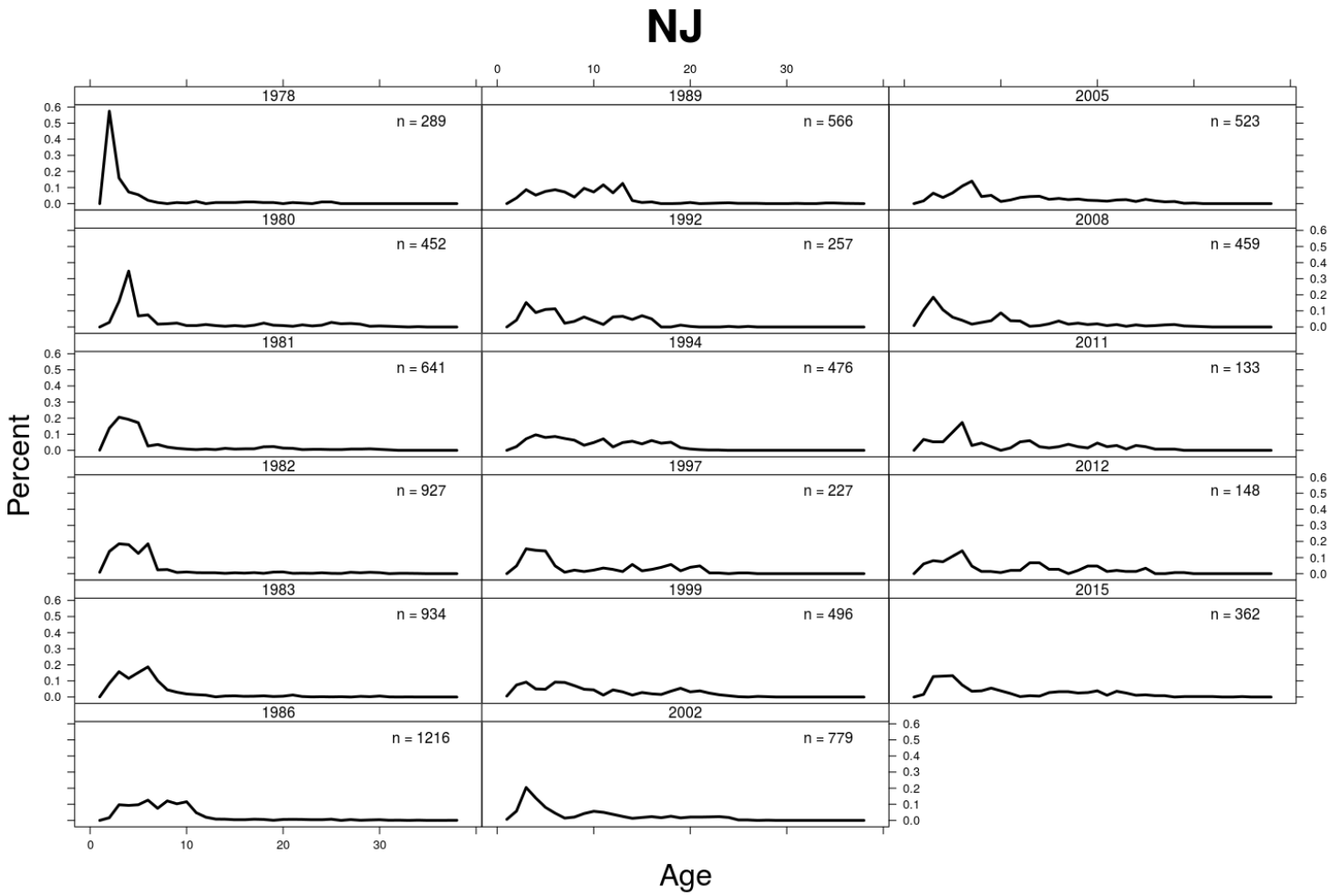

Figure 42: Age composition of Atlantic surfclam in NEFSC surveys in NJ, including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

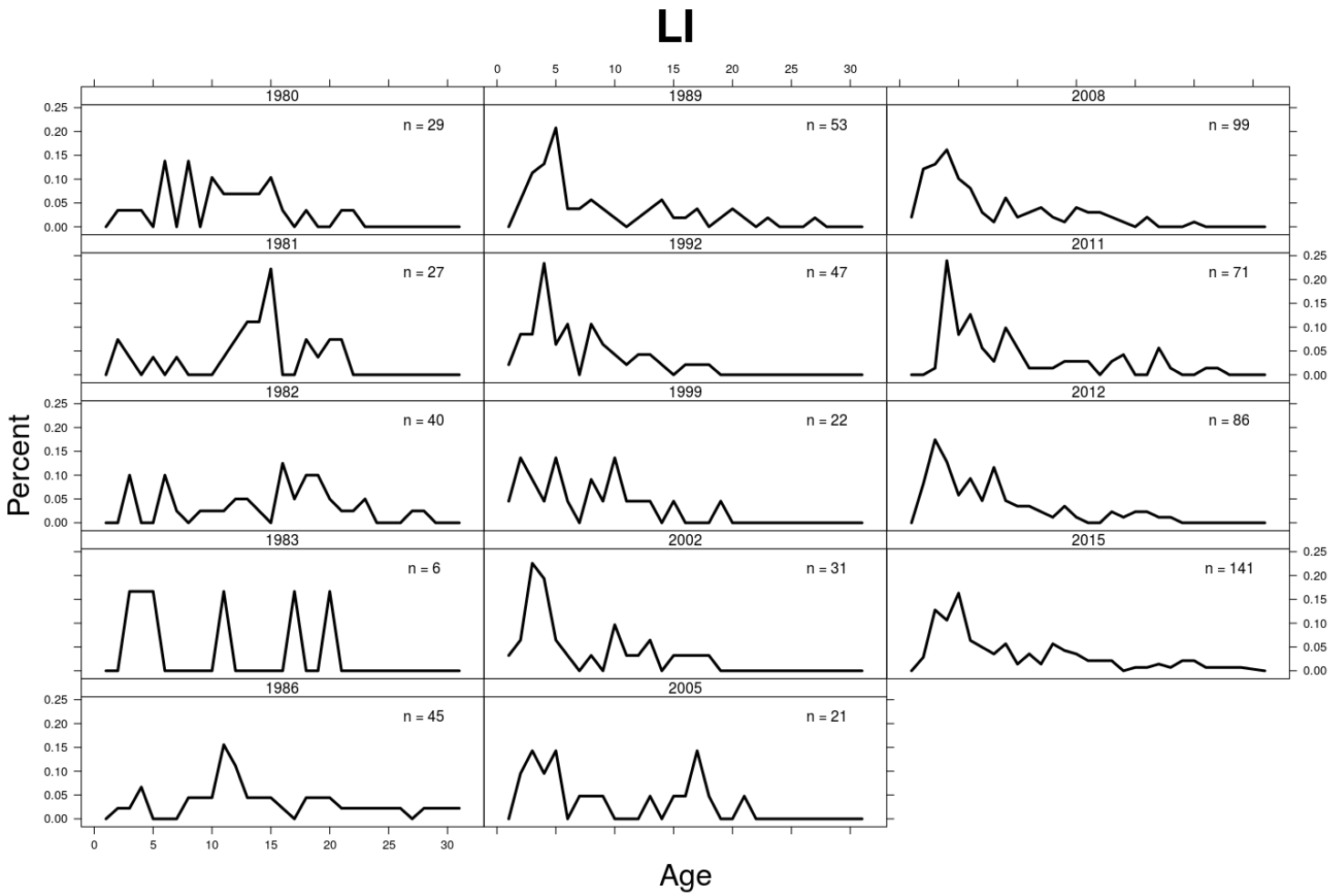

Figure 43: Age composition of Atlantic surfclam in NEFSC surveys in LI, including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

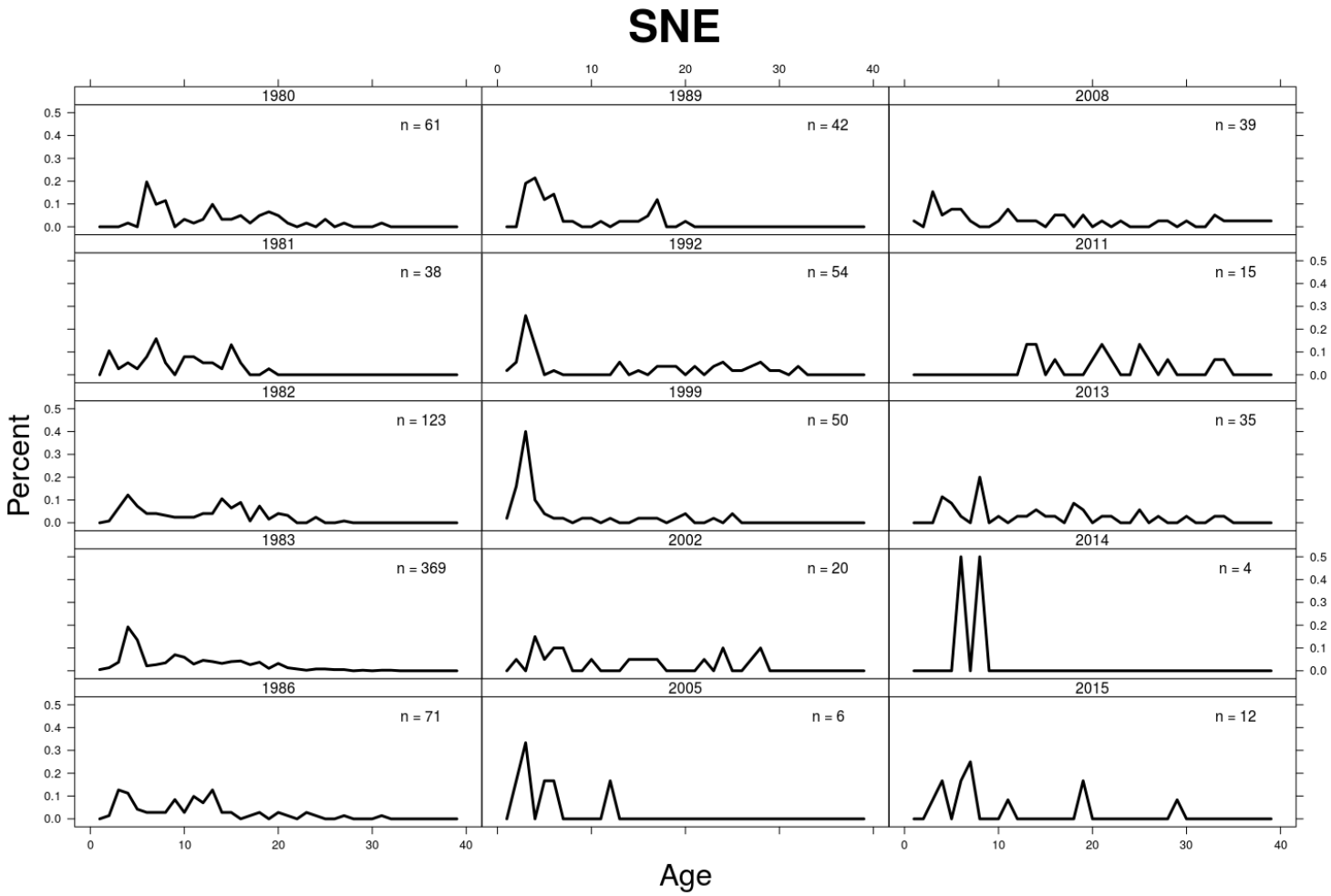

Figure 44: Age composition of Atlantic surfclam in NEFSC surveys in SNE, including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

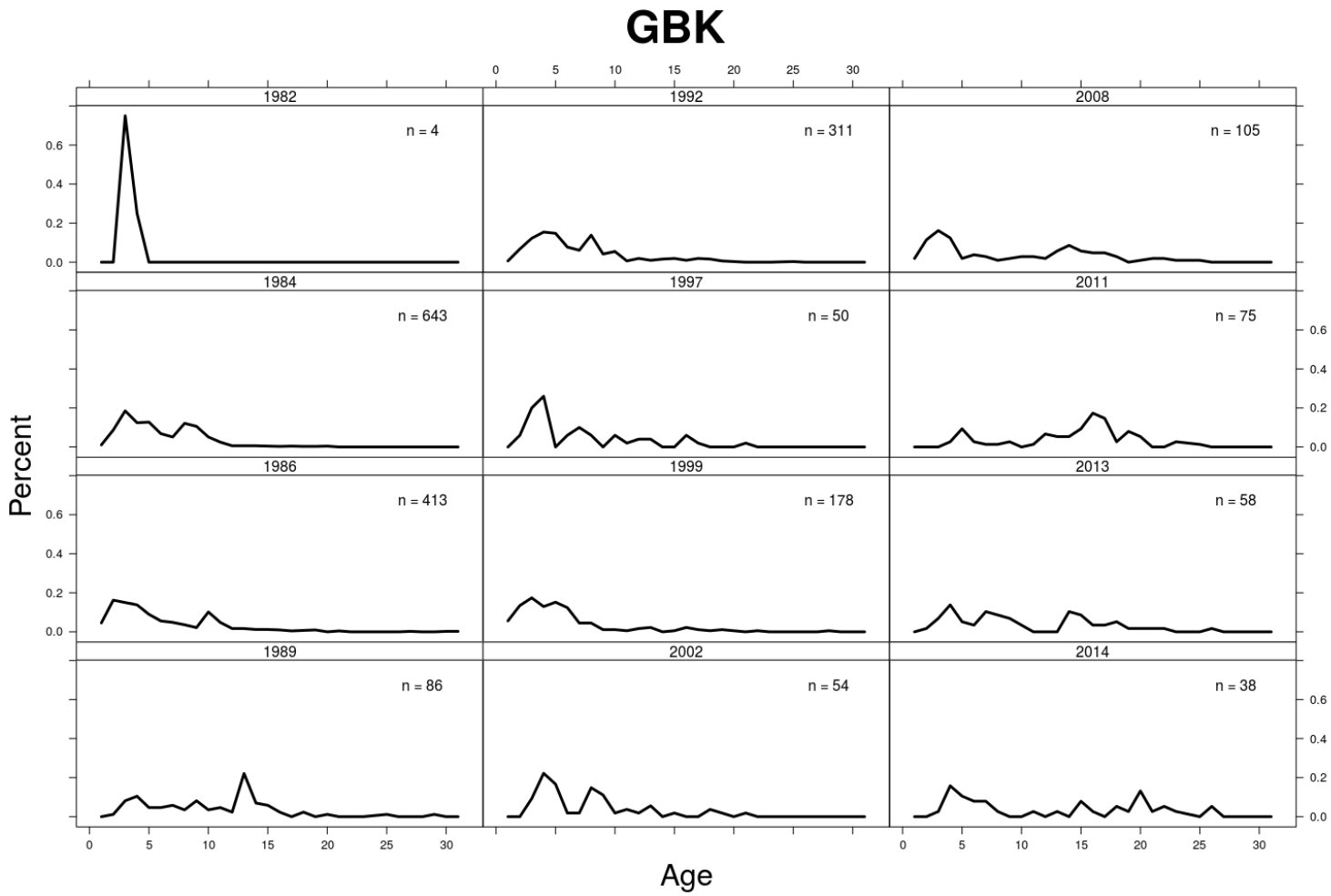

Figure 45: Age composition of Atlantic surfclam in NEFSC surveys in the northern area (GBK), including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

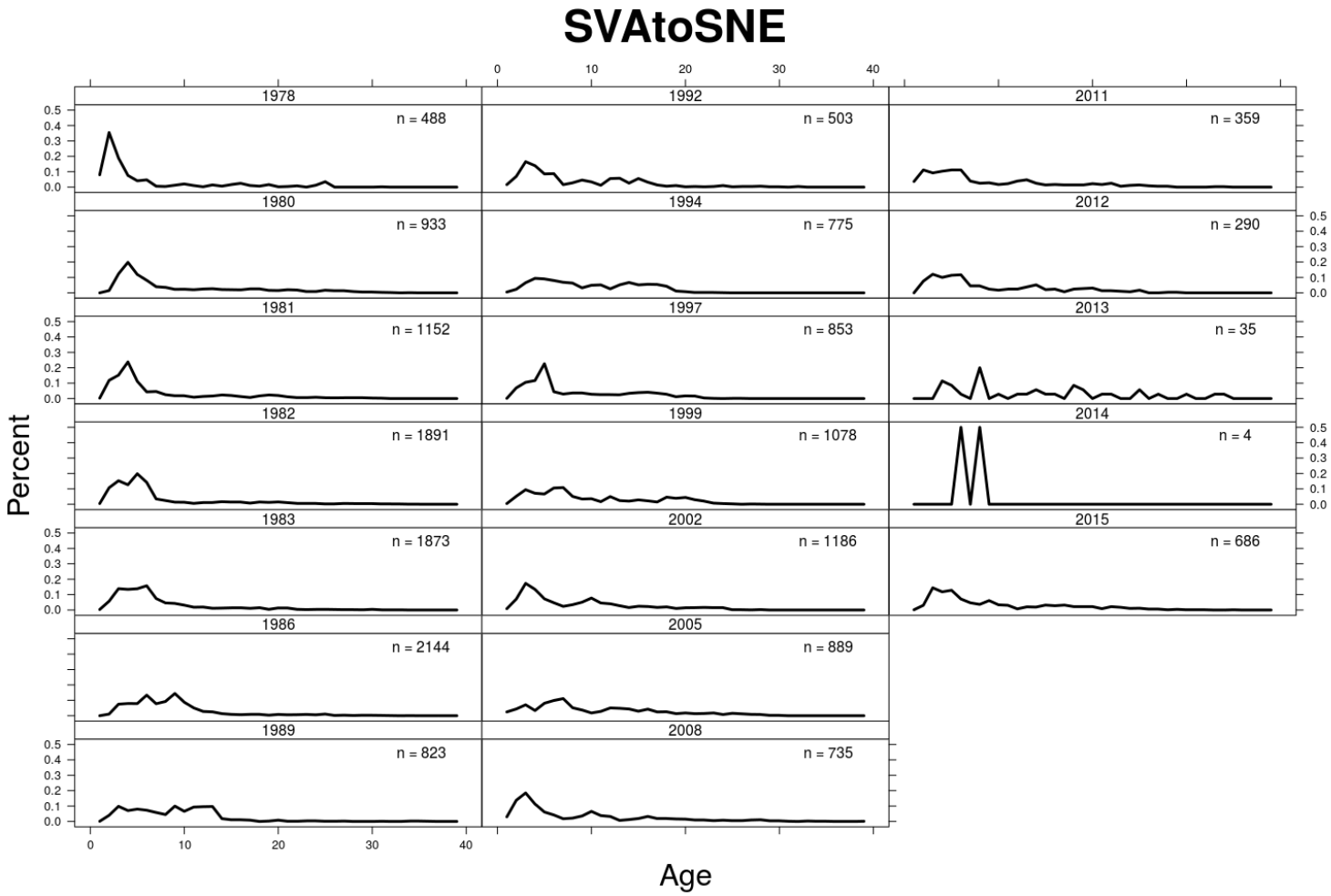

Figure 46: Age composition of Atlantic surfclam in NEFSC surveys in the southern area (SVAtoSNE), including the number of Atlantic surfclam aged in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

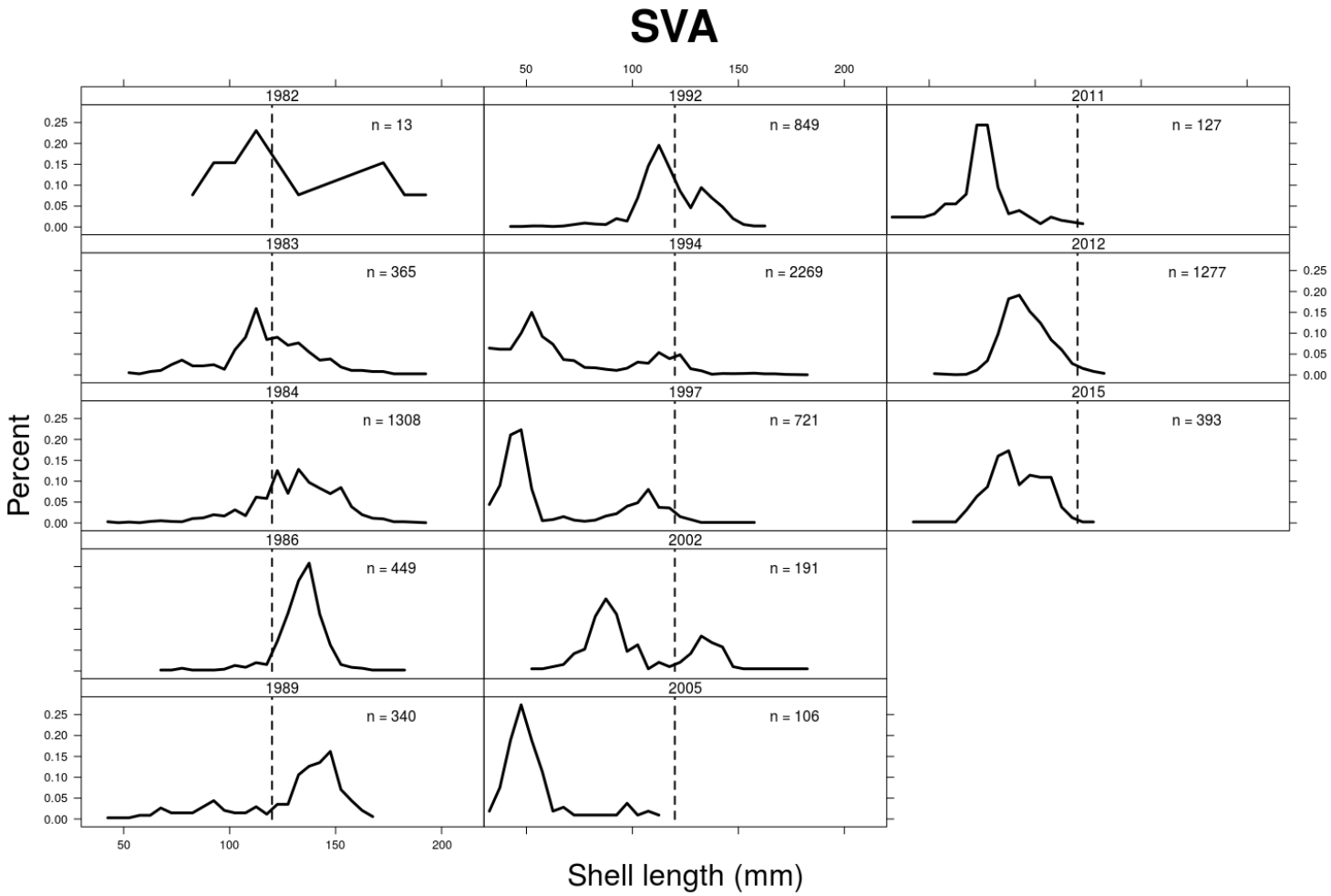

Figure 47: Length composition of Atlantic surfclam in NEFSC surveys in SVA, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

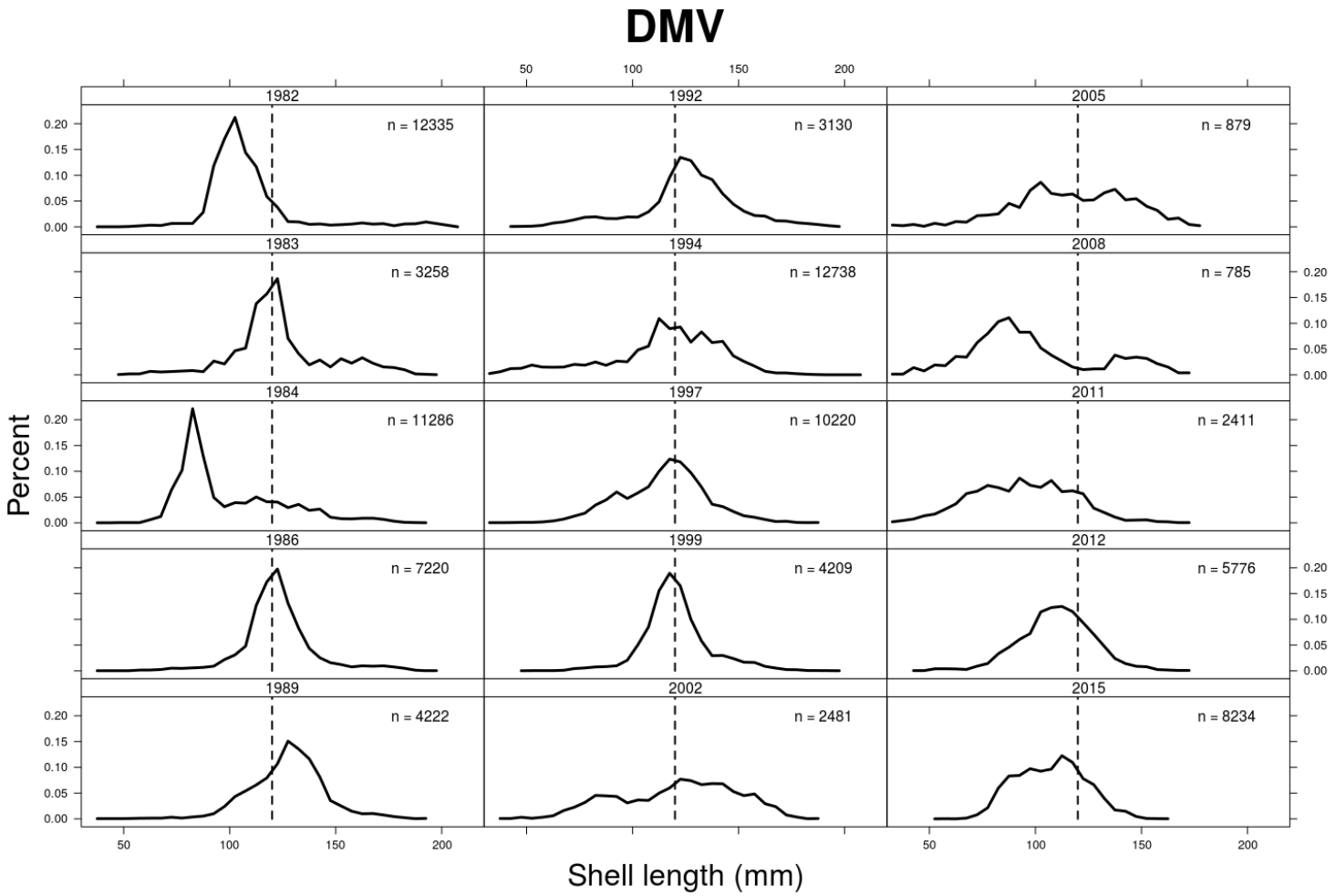

Figure 48: Length composition of Atlantic surfclam in NEFSC surveys in DMV, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

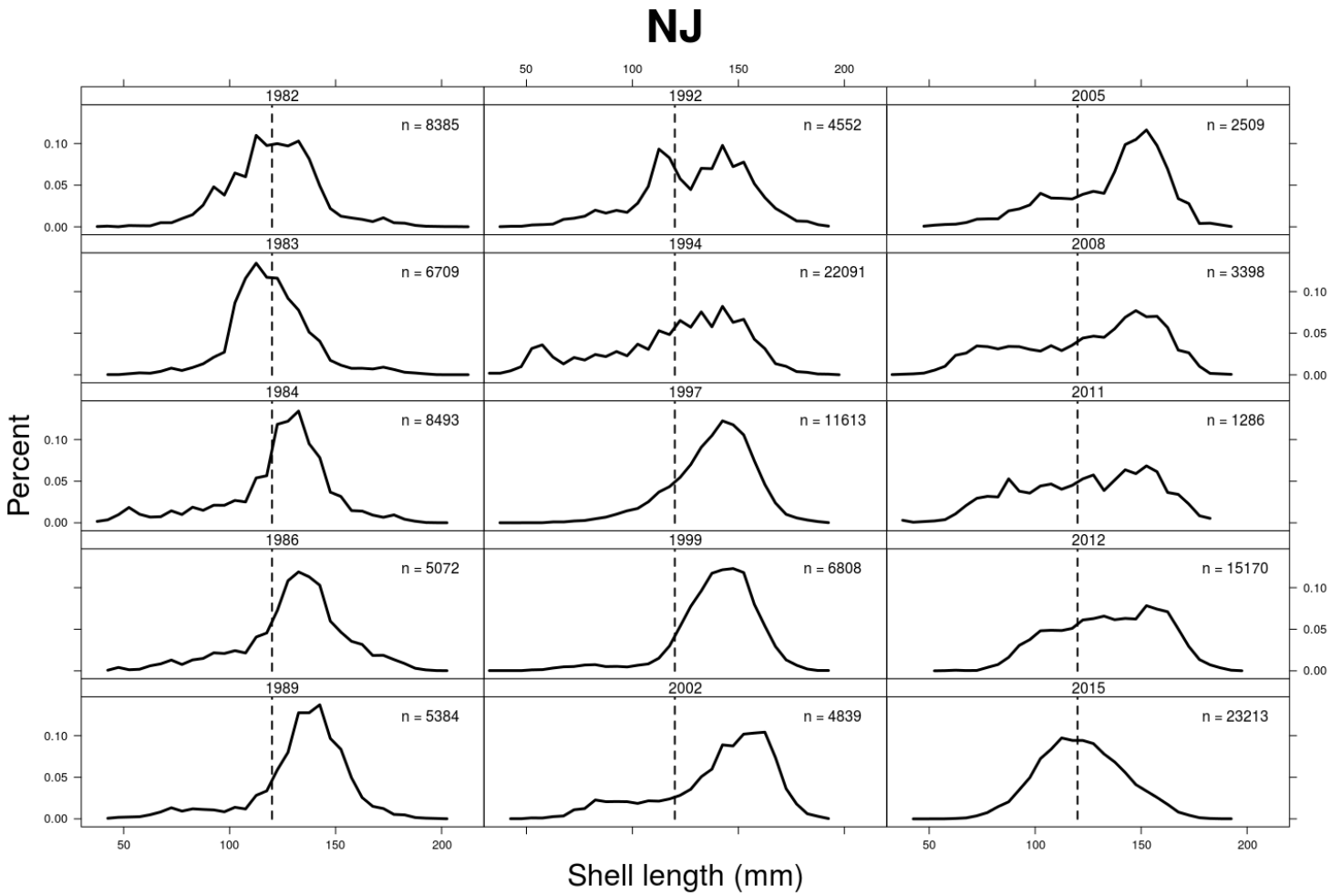

Figure 49: Length composition of Atlantic surfclam in NEFSC surveys in NJ, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

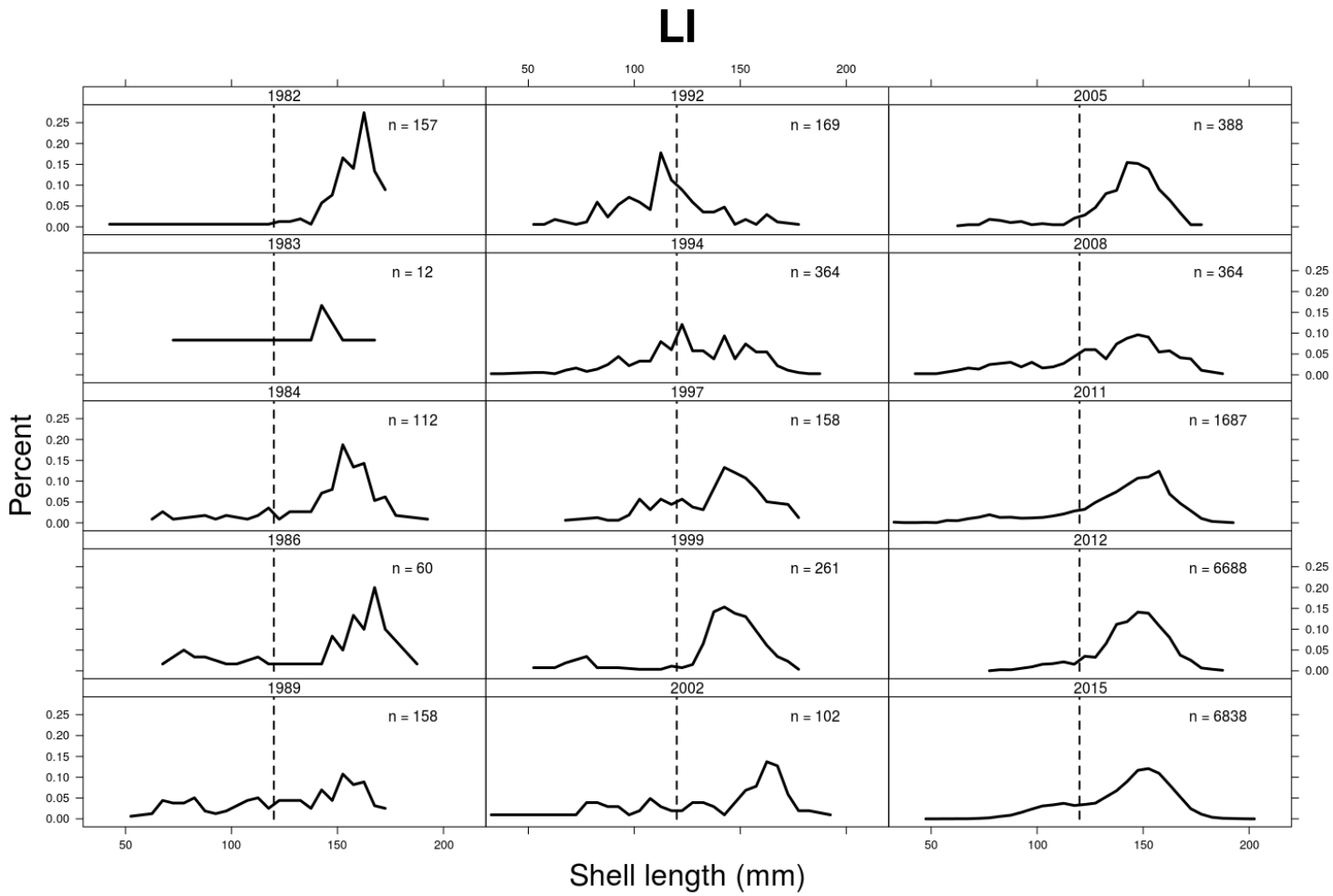

Figure 50: Length composition of Atlantic surfclam in NEFSC surveys in LI, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

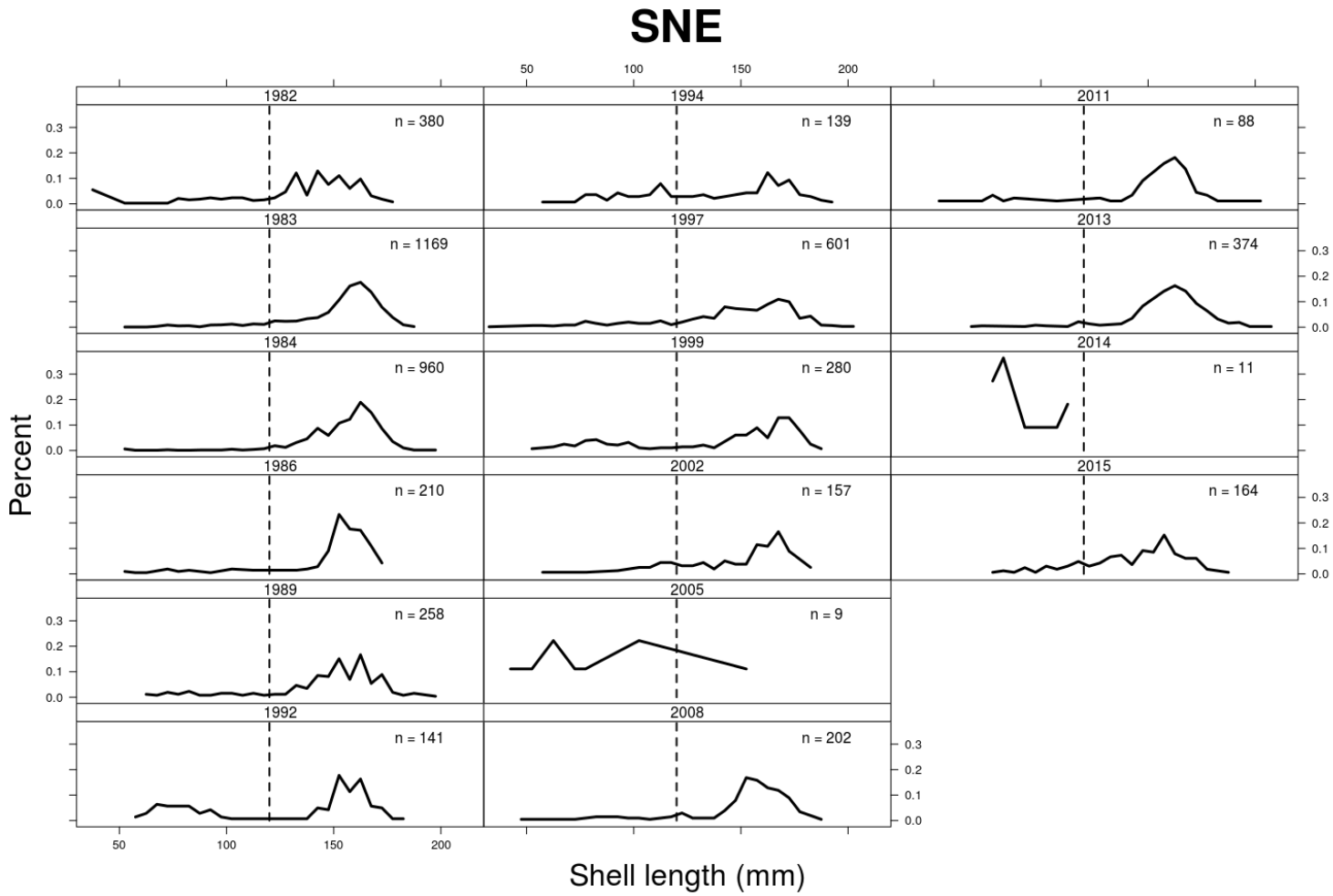

Figure 51: Length composition of Atlantic surfclam in NEFSC surveys in SNE, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

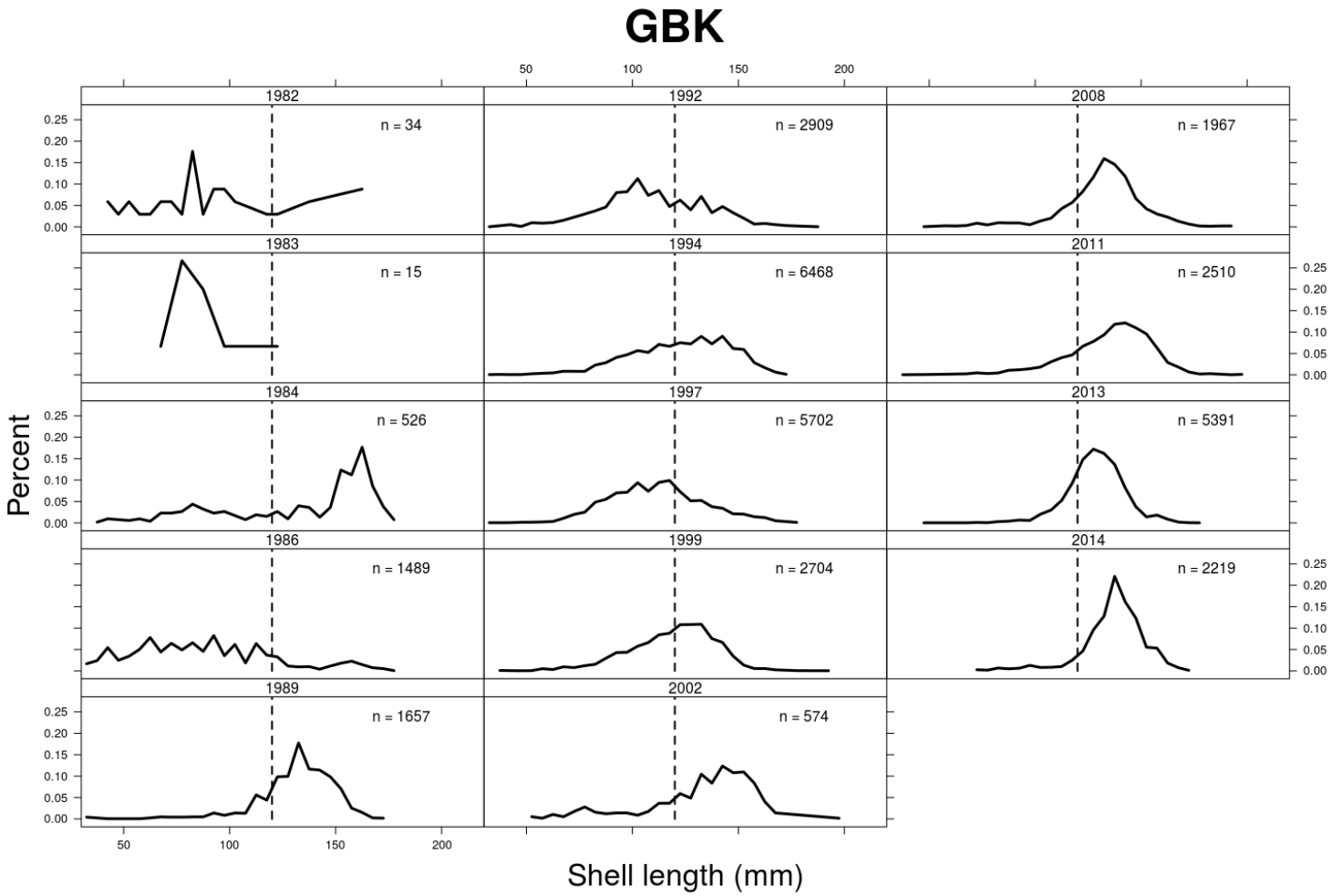

Figure 52: Length composition of Atlantic surfclam in NEFSC surveys in GBK, including the number of Atlantic surfclam measured in each year (n). The size selectivity of the survey changed after 2011 when the survey was switched to a commercial platform. Composition data from before 2011 are not directly comparable to data since 2012.

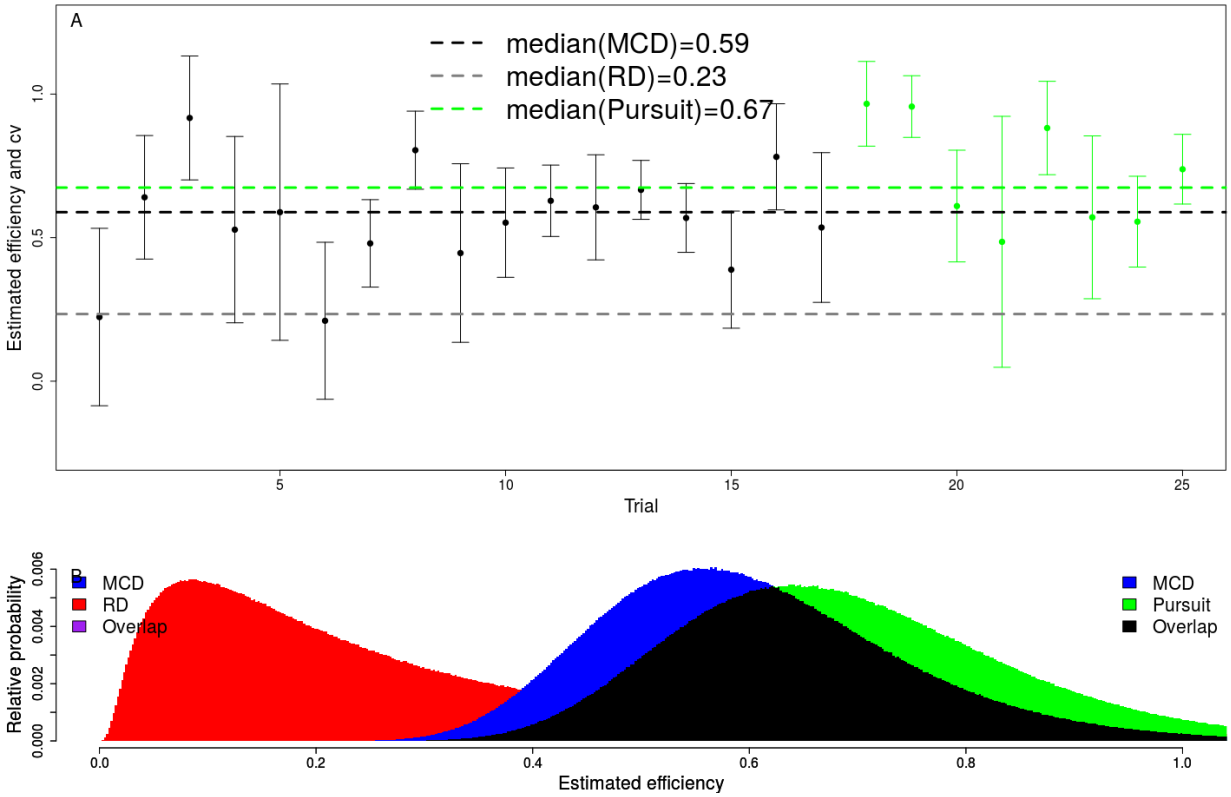

Figure 53: Panel A) Individual modified commercial dredge (MCD) capture efficiency estimates with coefficients of variation compared to median values for the MCD and the survey dredge used from the research vessel (RD) as well as the specific dredge used on the current survey (Pursuit). Panel B) A comparison of median values values incoprorating the pooled cv for each dredge where each is shown as a truncated lognormal distribution. The MCD and Pursuit dredge had higher and more precisely estimated capture efficiency than the RD.

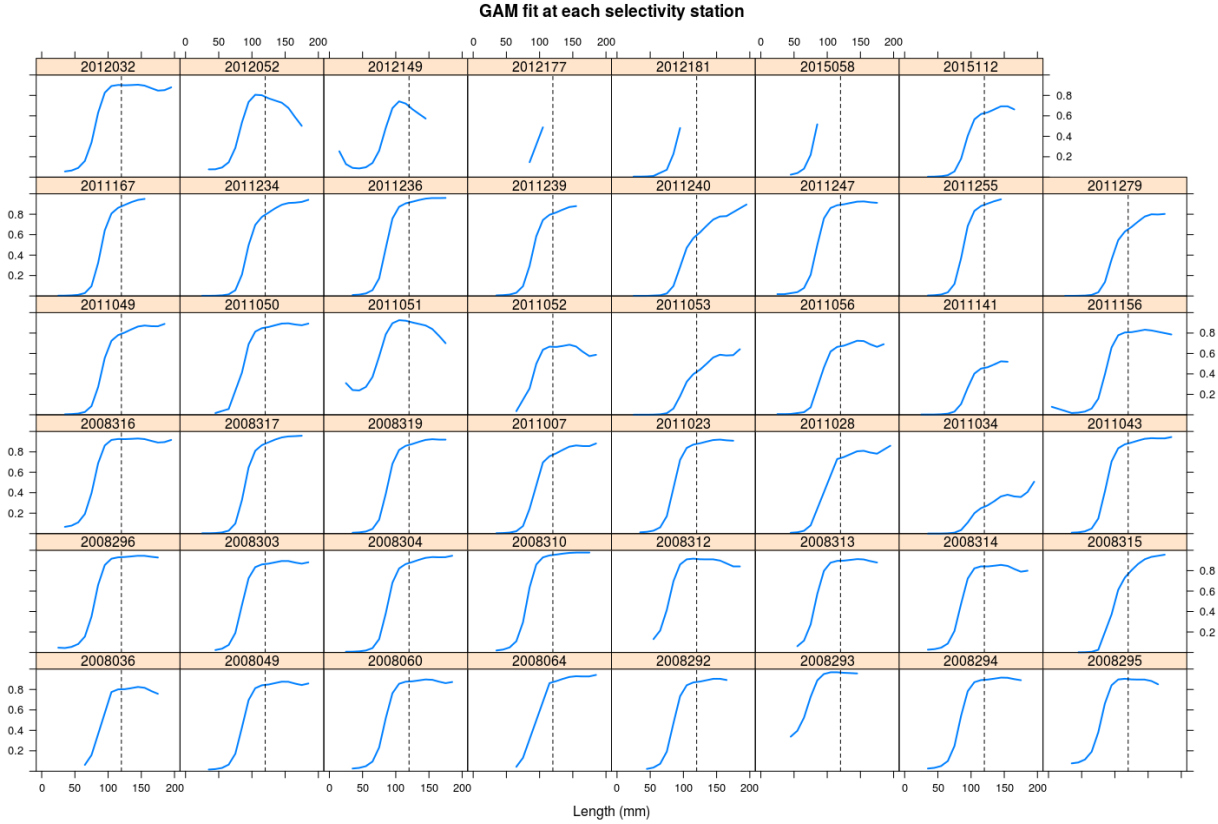

Figure 54: GAM fits to the selectivity data for Atlantic surfclam from field experiments (MCD compared to lined dredge) by year and station. The plots generally indicate flat topped selectivity curves.

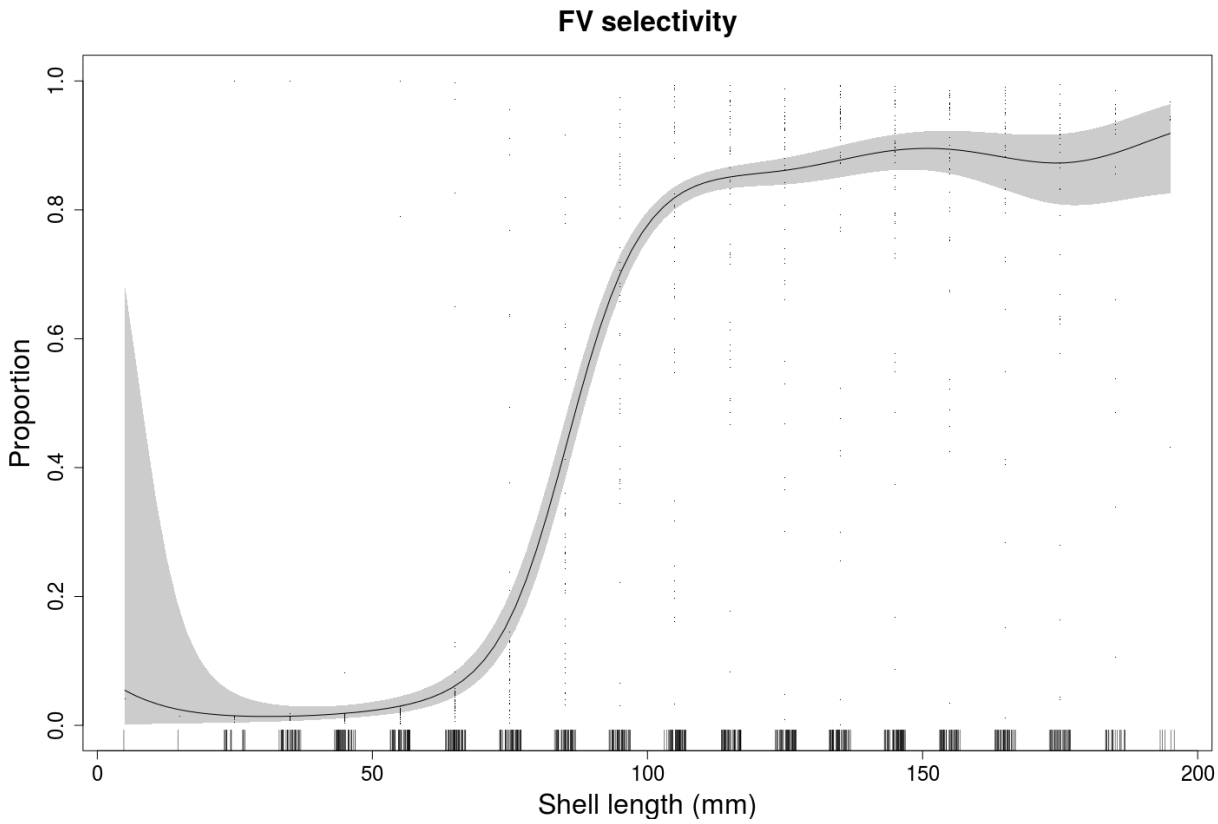

Figure 55: The GAM fit to all the selectivity data for Atlantic surfclam in the MCD in all years. The best (by AIC) model included random effects in both the intercept and spline over length. The data density is shown in the rug plot along the horizontal axis and relative confidence is represented by the shaded region.

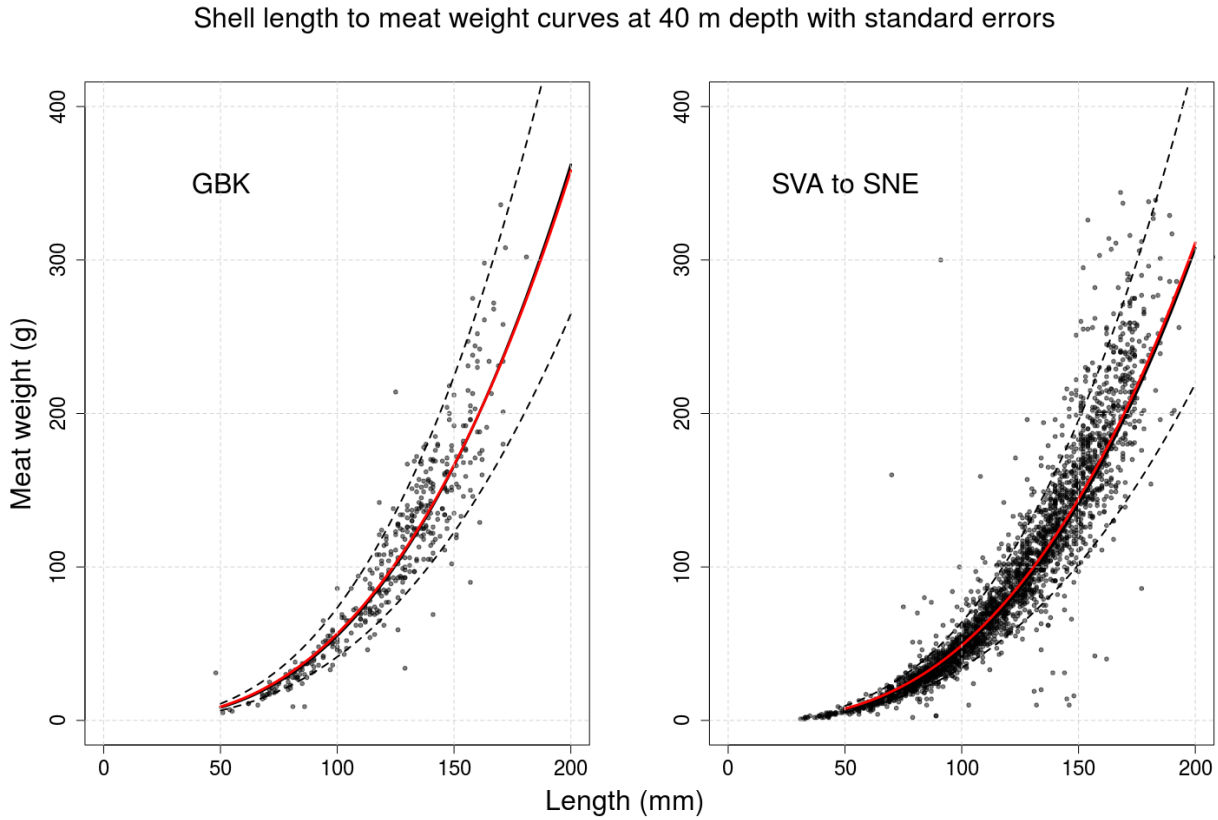

Figure 56: Broad scale area differences in allometric relationships for Atlantic surfclam based on survey data. The same depth (40 m) was used to generate the curves for each area. The 95% confidence regions are represented by the dotted line.

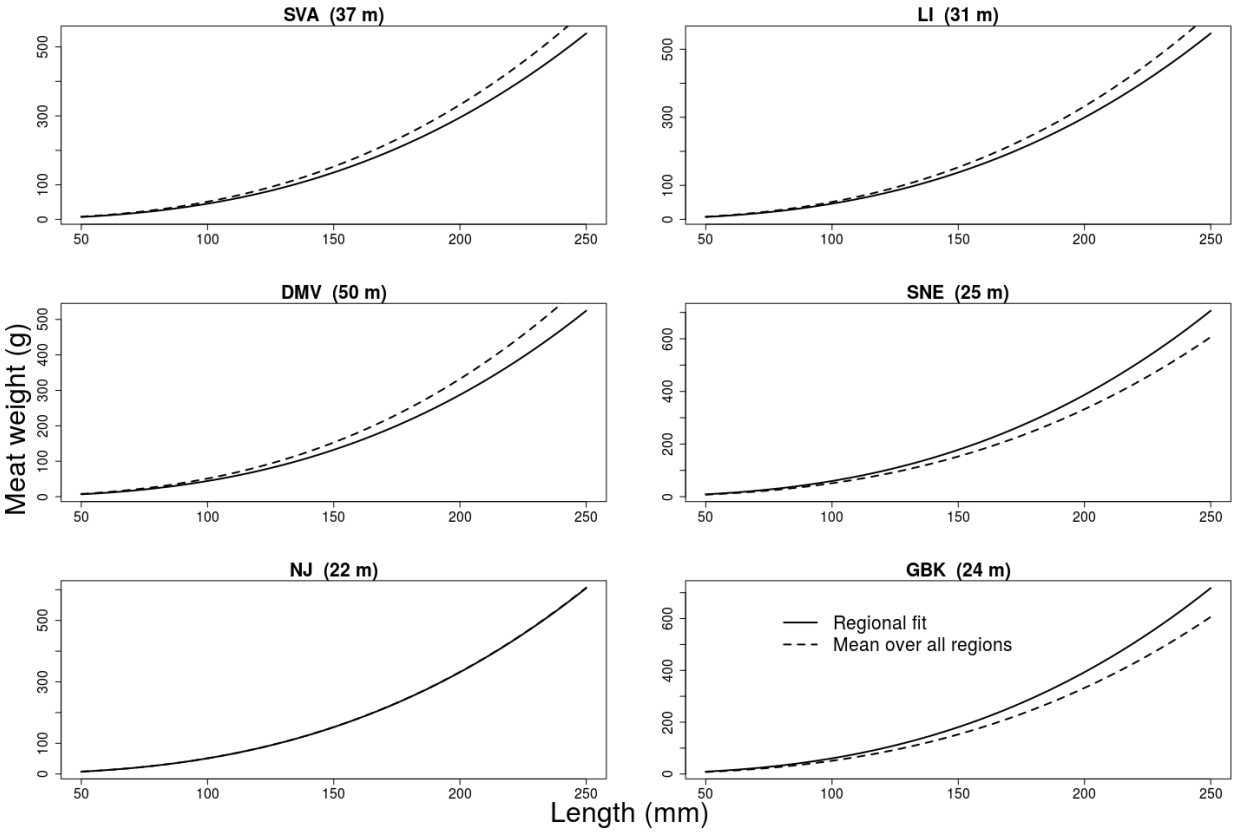

Figure 57: Regional differences in allometric relationships for Atlantic surfclam based on survey data. The median depth in each region was used to generate the curves. The global mean is represented by the dotted line.

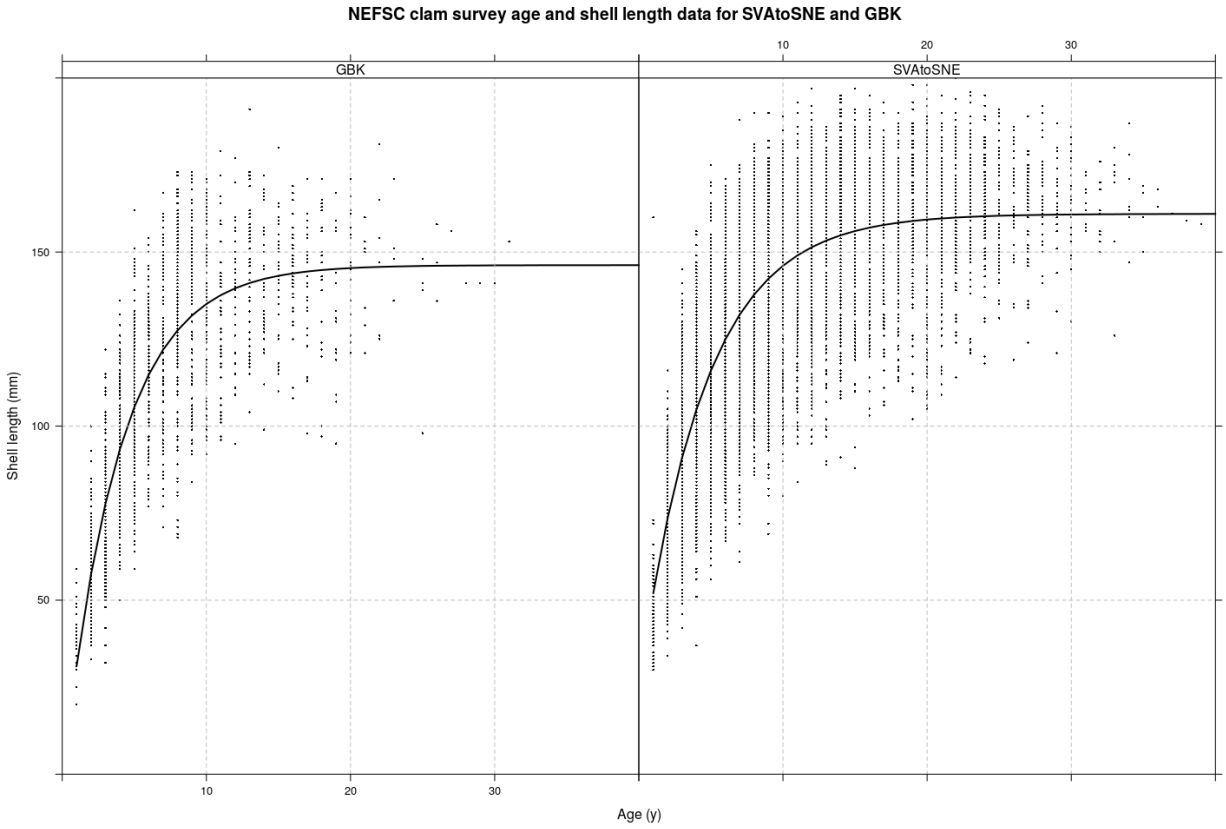

Figure 58: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve in different areas.

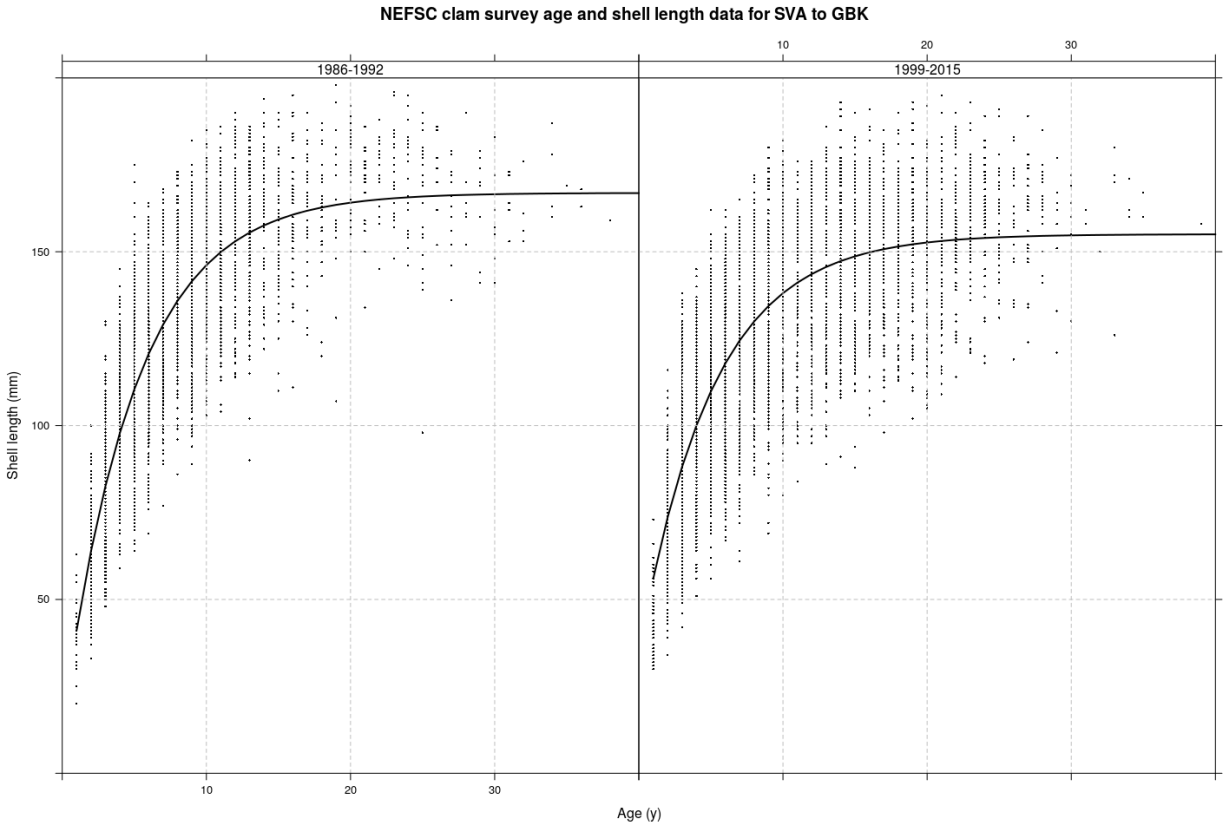

Figure 59: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve in different eras for the whole stock.

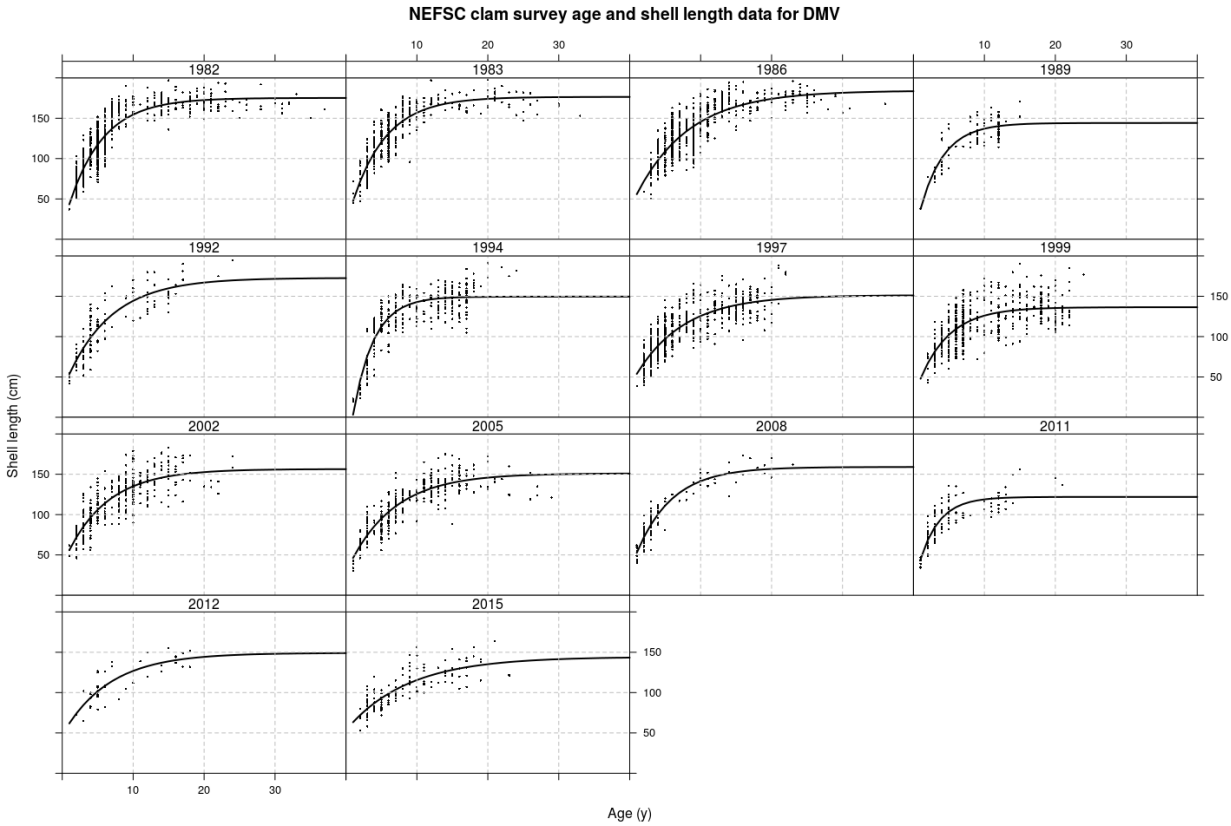

Figure 60: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve for the DMV region in each survey year.

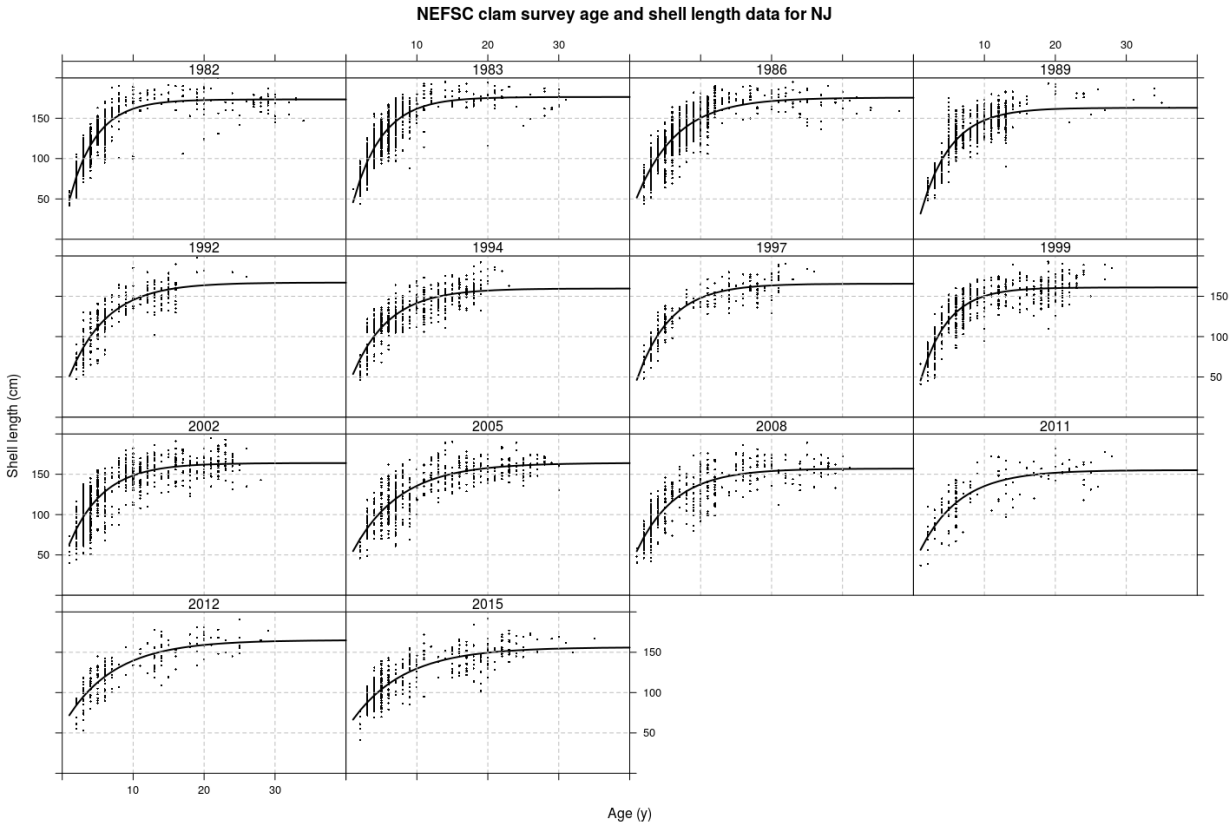

Figure 61: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve for the NJ region in each survey year.

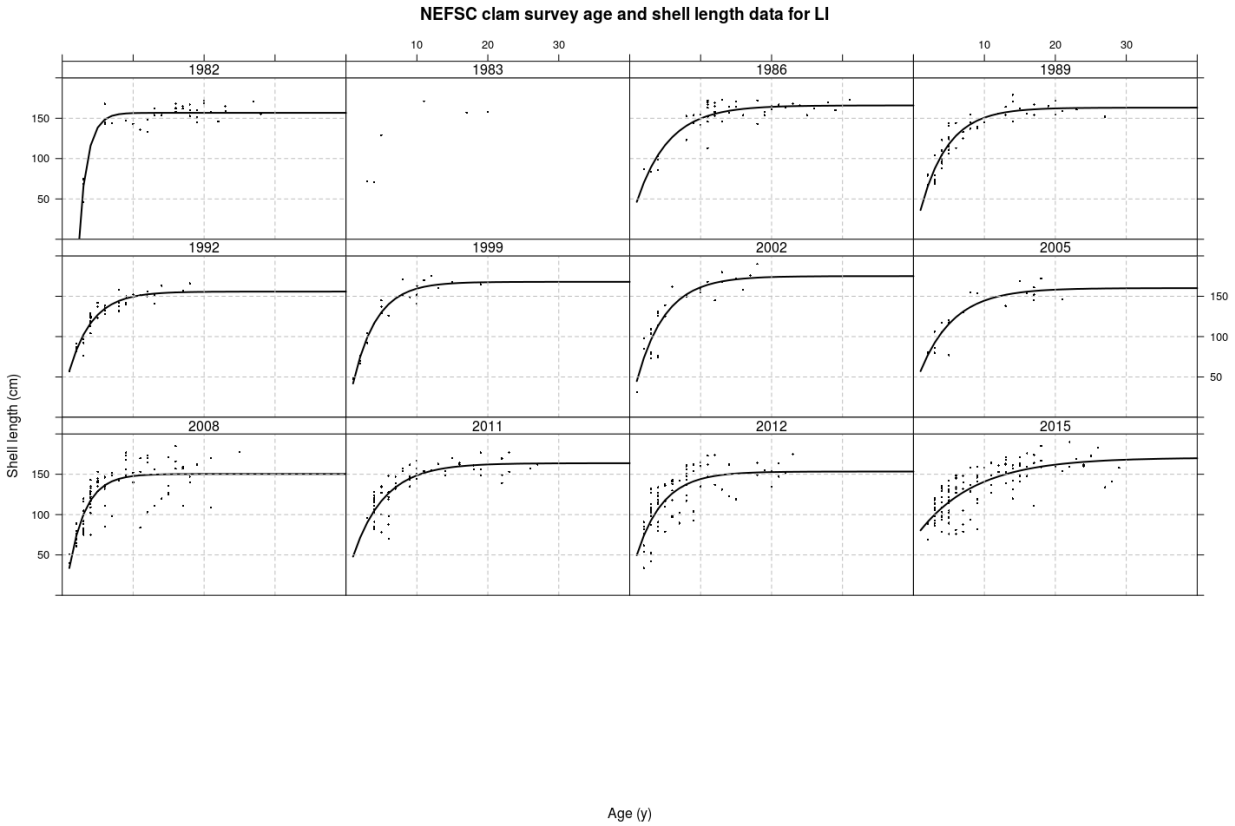

Figure 62: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve for the LI region in each survey year.

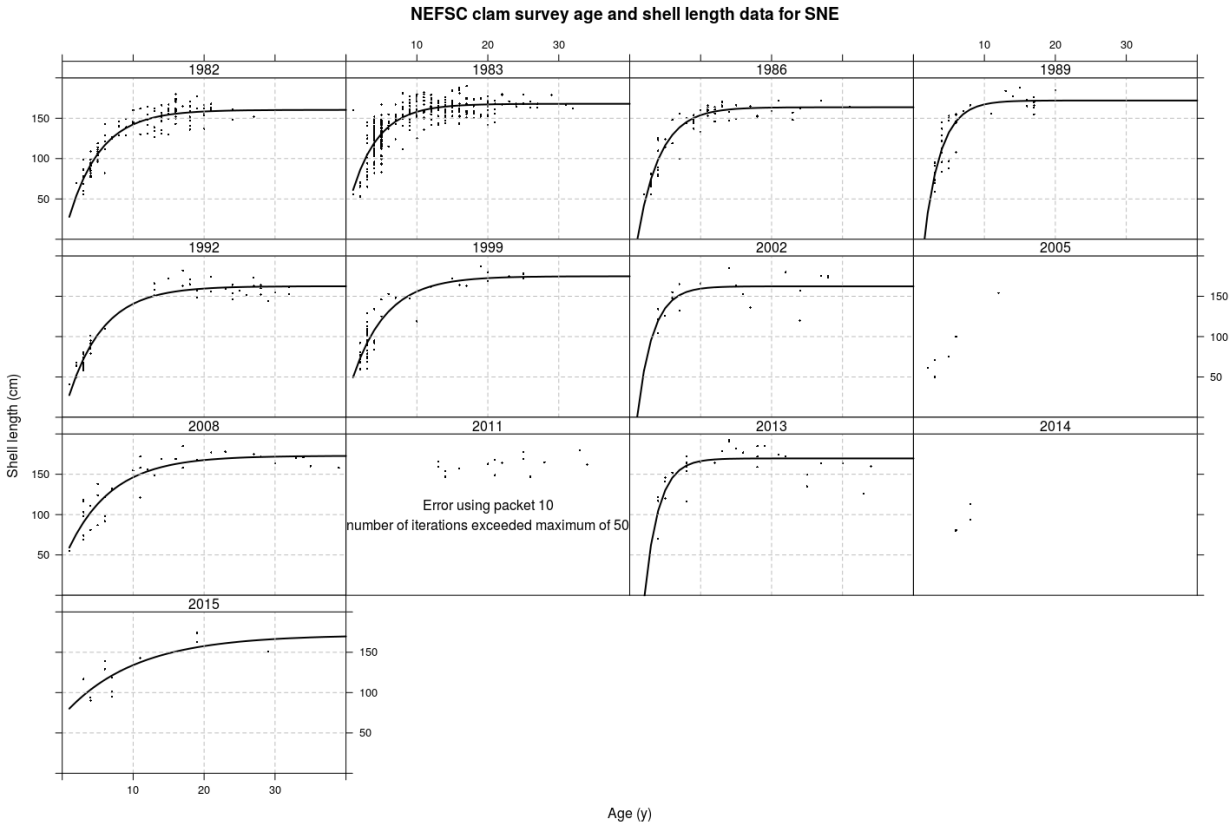

Figure 63: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve for the SNE region in each survey year.

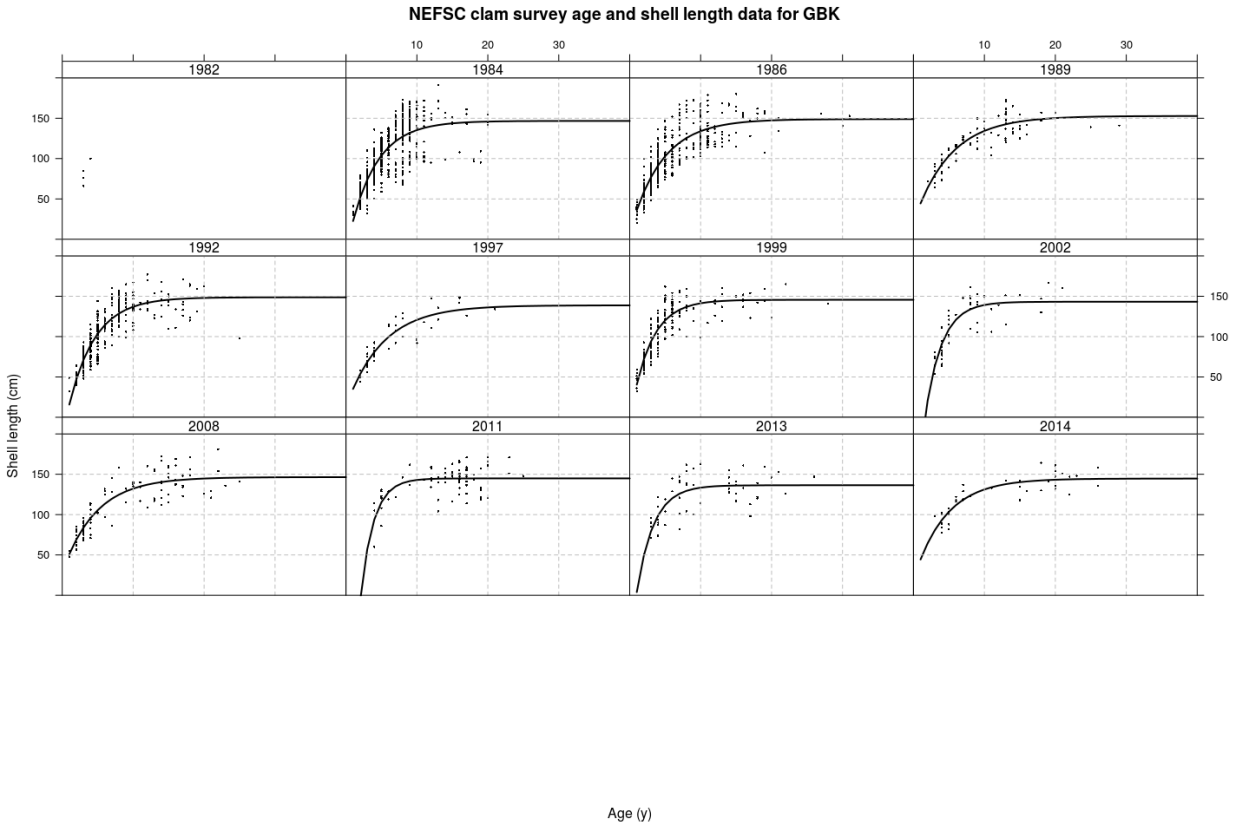

Figure 64: Age vs. length for Atlantic surfclam based on survey data with fitted Von Bertalanffy growth curve for the GBK region in each survey year.

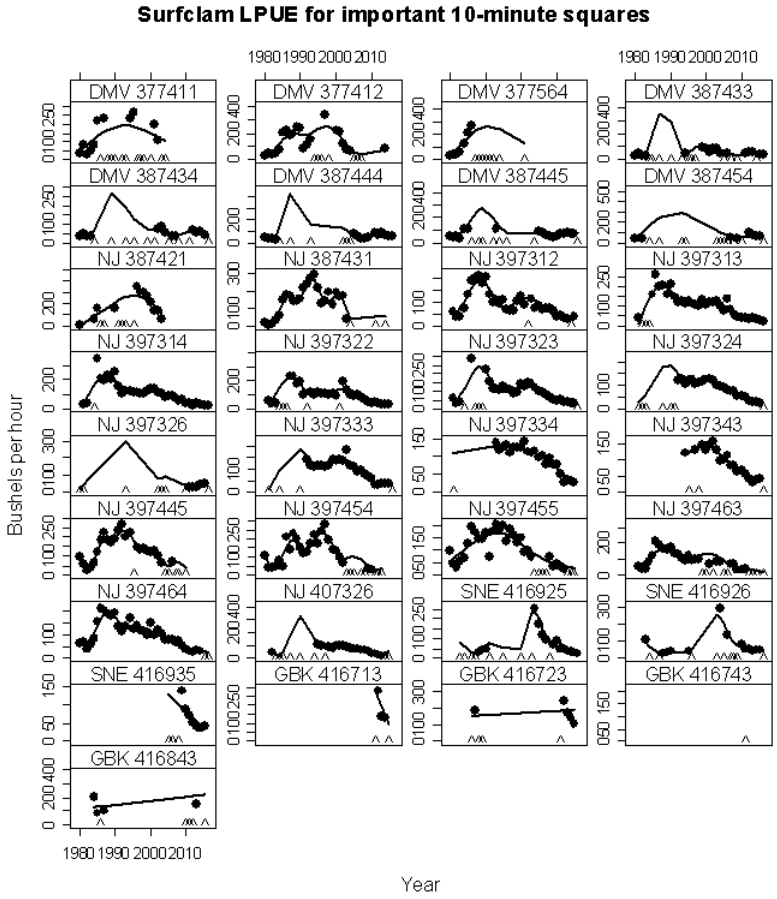

Figure 65: Observed and predicted survey catch rates in ten-minute squares that are important to the fishery.

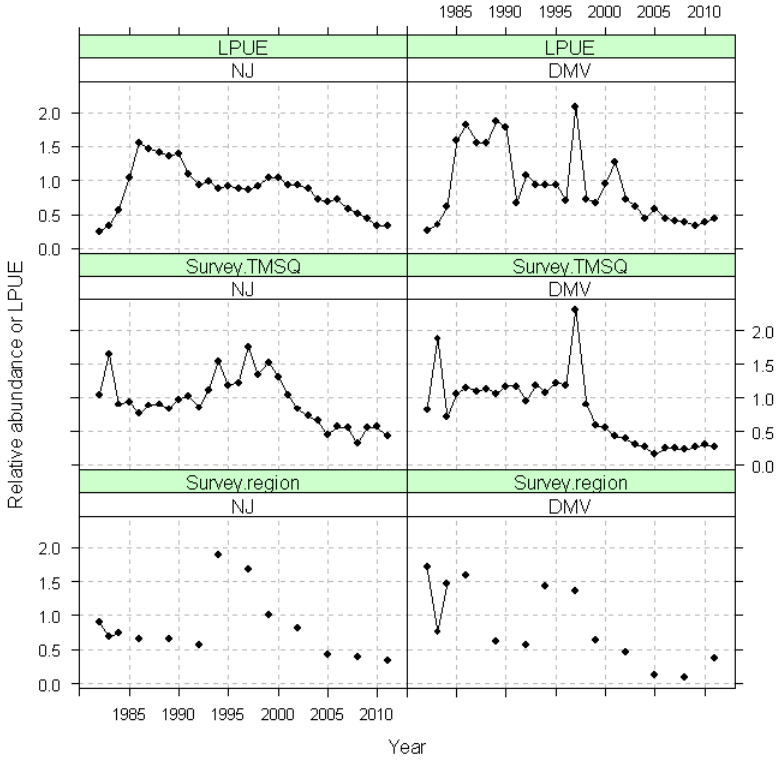

Figure 66: LPUE and survey abundance trends for Atlantic surfclam during 1982-2011 in the New Jersey (left) and Delmarva (right) regions (rescaled for convenience in plotting). LPUE and "Survey.TMSQ" are commercial catch rate and survey trends for important ten-minute squares. "Survey.region" is the survey trend for the entire region (all ten-minute squares).

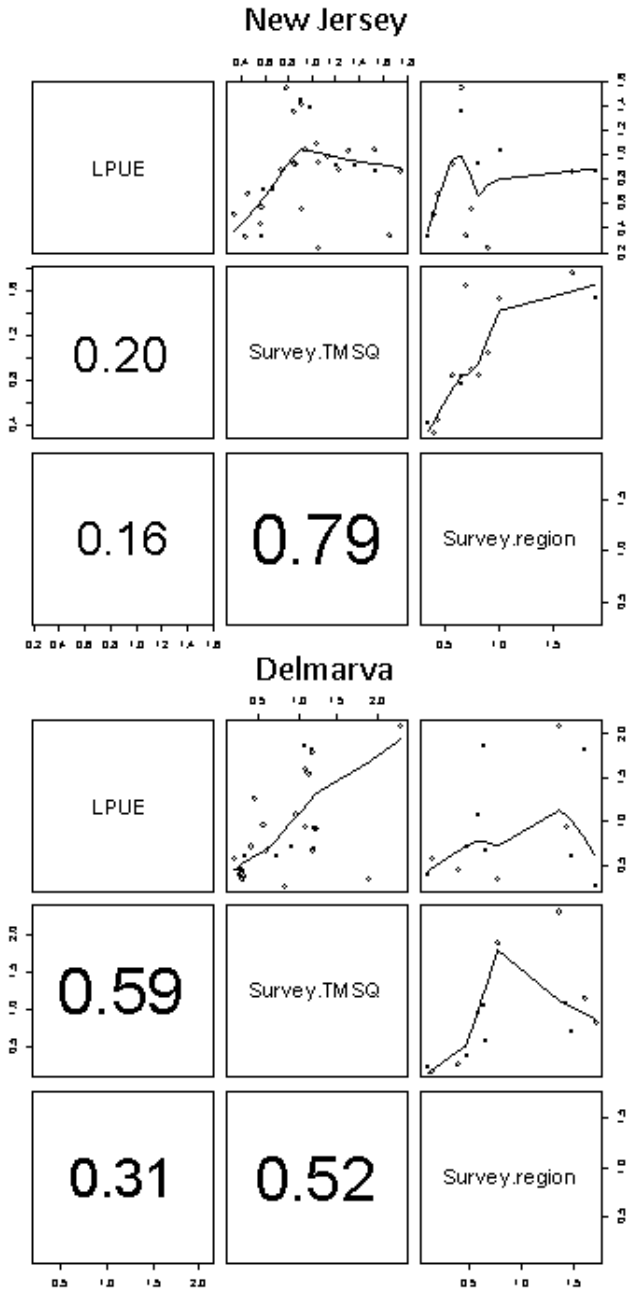

Figure 67: Relationships between LPUE and survey abundance trends for Atlantic surfclam during 1982-2011 in the New Jersey (top) and Delmarva (bottom) areas (rescaled for convenience in plotting). LPUE is commercial catch rates in important TNMS. Survey.TNMS is the survey trend in important TNMS. "Survey.region" is the survey trend for the entire region (all ten-minute squares). Scatter plots with smooth lines to show trends are above the diagonal in each panel and correlation statistics are below the diagonal.

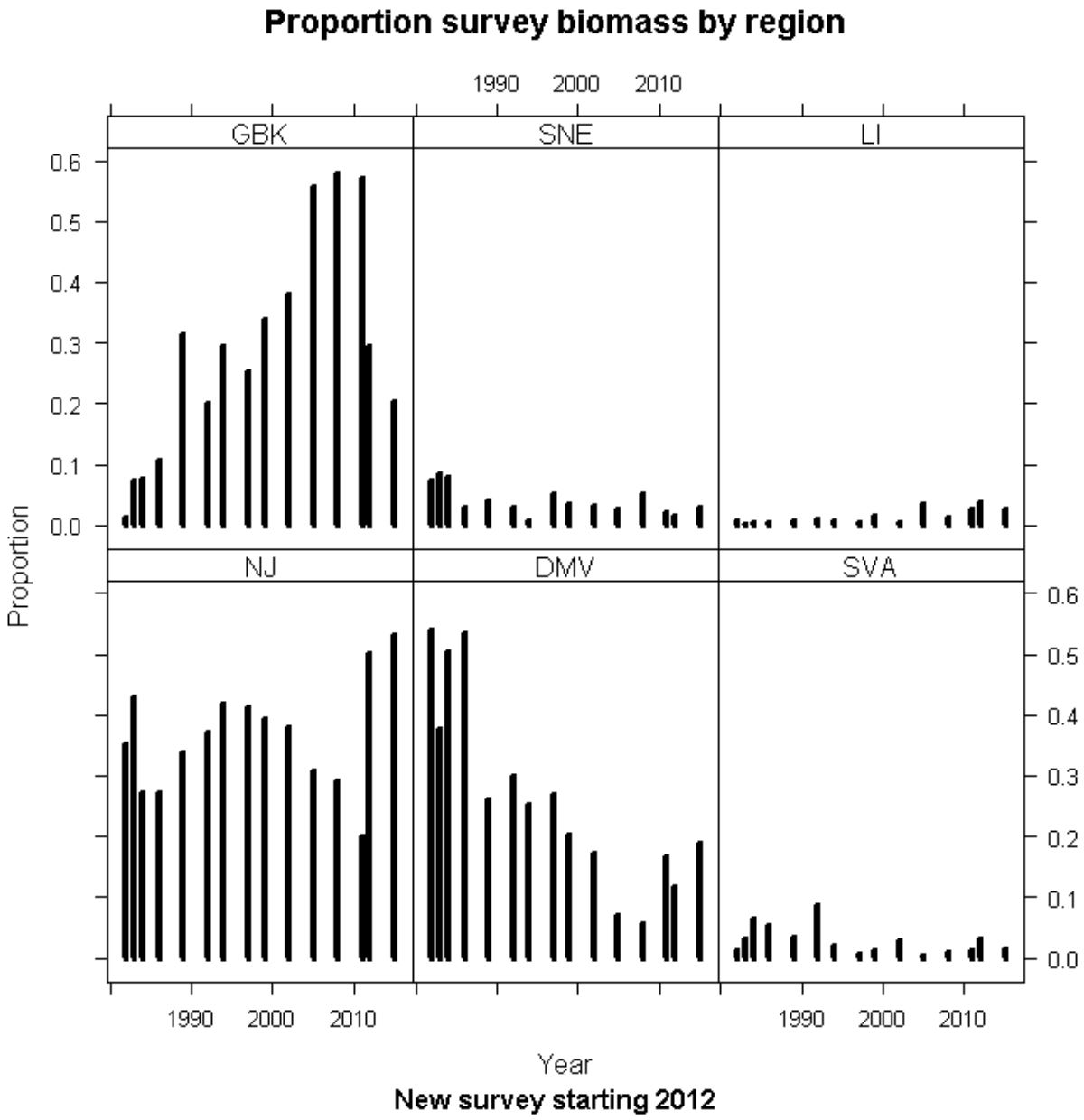

Figure 68: Proportions of relative survey biomass for surfclams by region during 1982-2015. For example, the proportion of total biomass on GBK during 2015 is about 20% and the sum of values plotted for 2015 in all regions is 100%. Estimates for 1982-2011 may not be comparable to estimates for 2012-2015 because a new survey using a different vessel, gear, etc. started in 2012.

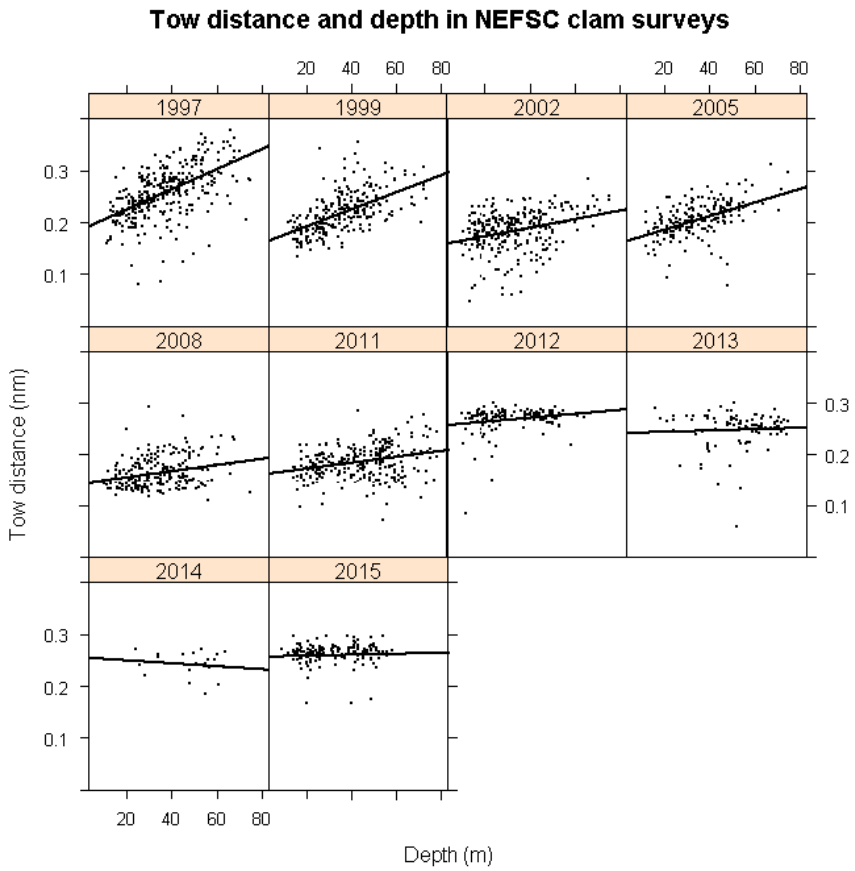

Figure 69: Relationships between tow depth and tow distance from inclinometer measurements in NEFSC clam surveys during 2007-2011 (RD) and 2012-2015 (MCD).

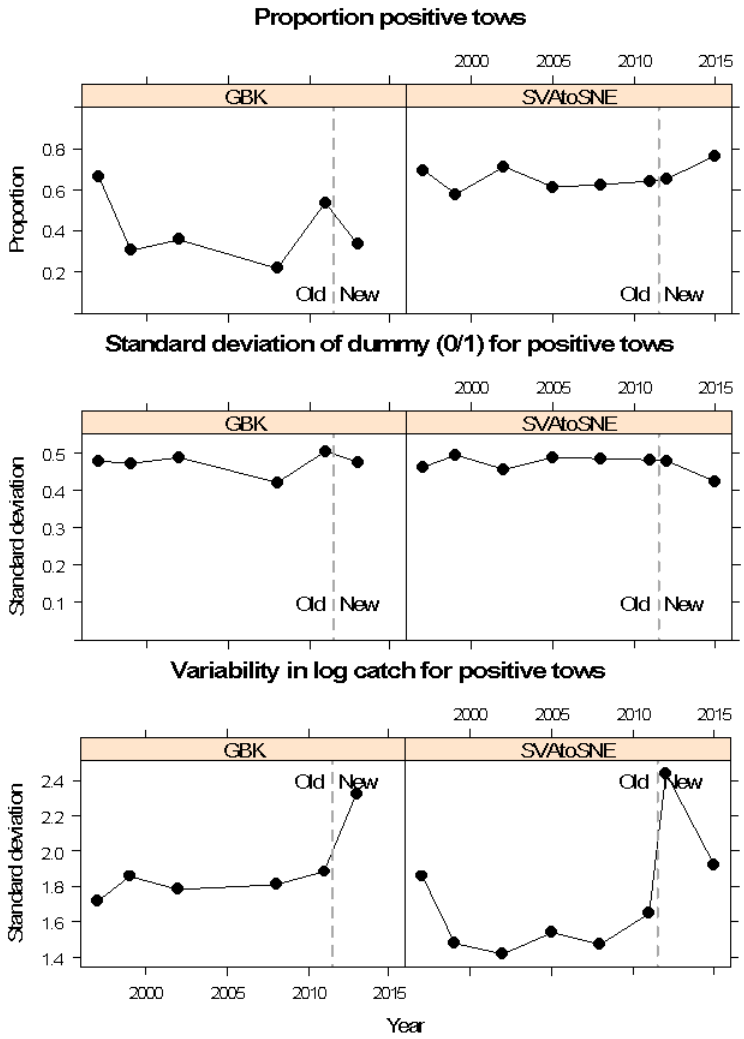

Figure 70: Trends in proportion positive tows (top), the standard deviation of a dummy variable that identifies positive tows (=0 if Atlantic surfclam catch was zero and 1 otherwise), and the standard deviation of log transformed catches (positive tows only) for Atlantic surfclam in NEFSC clam surveys during 1997-2015.

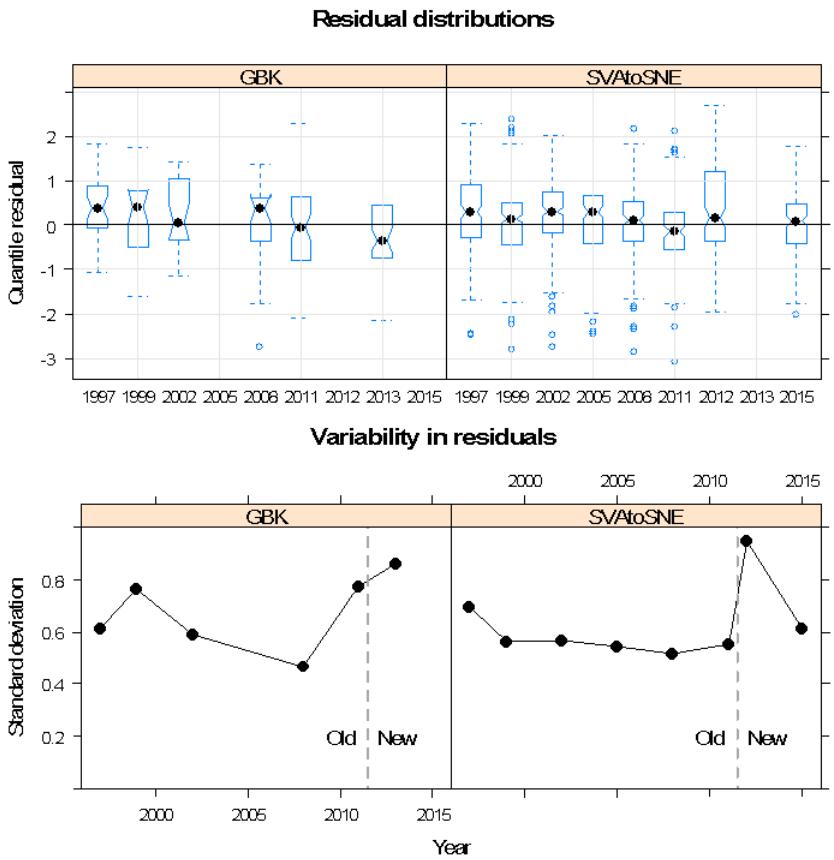

Figure 71: Top, distributions of randomized quantile residuals from the best GAM model (Tweedie family) fit to consistently sampled NEFSC clam survey strata. Bottom: standard deviations for residual distributions in top panel.

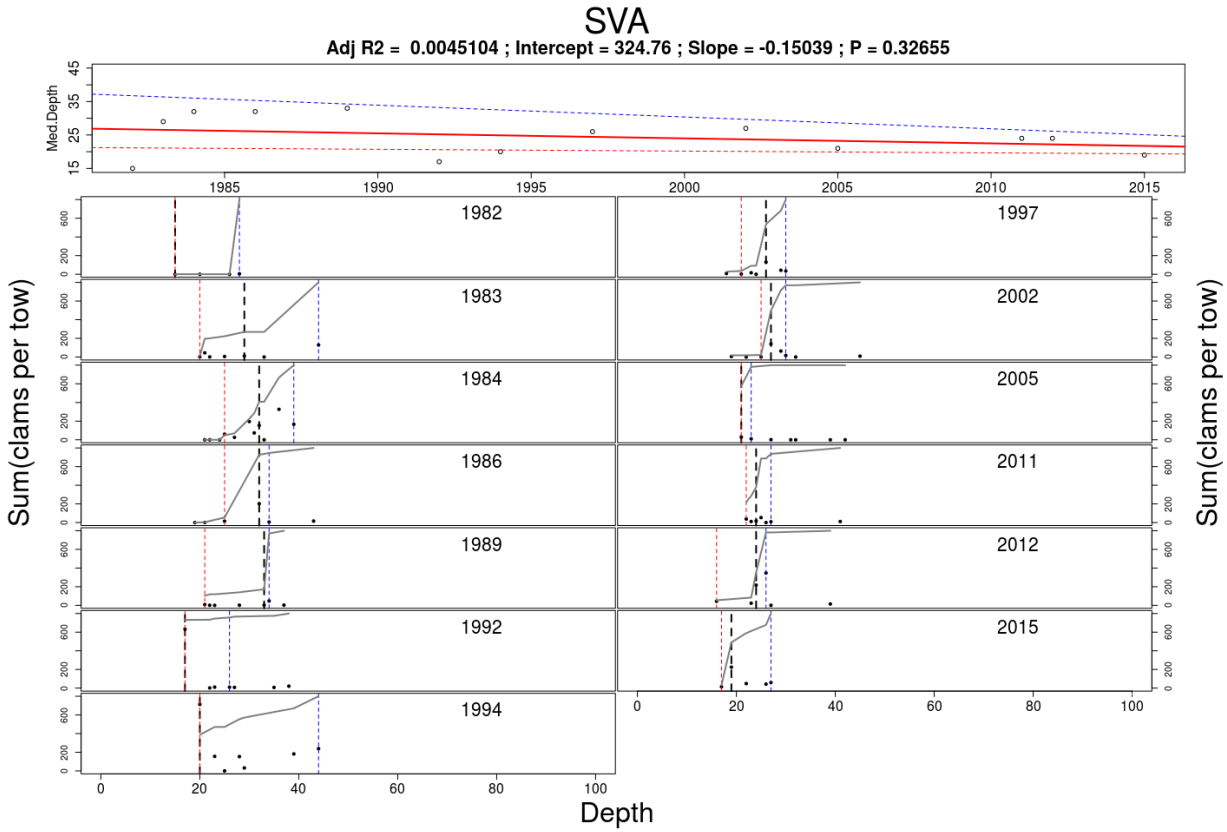

Figure 72: Total surfclams caught at depth by year in SVA. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years. Inshore (shallow) strata were not well sampled in recent years and were excluded from this analysis

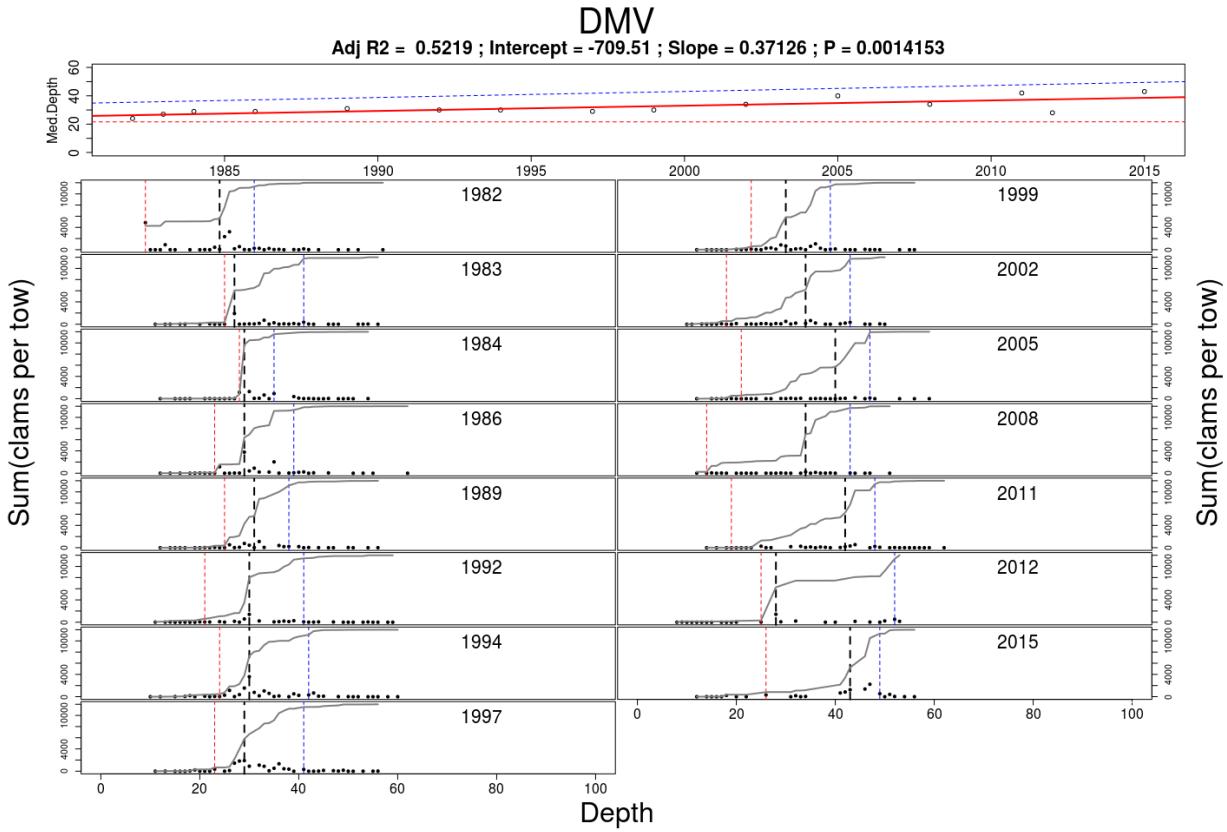

Figure 73: Total surfclams caught at depth by year in DMV. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years. Inshore (shallow) strata were not well sampled in recent years and were excluded from this analysis

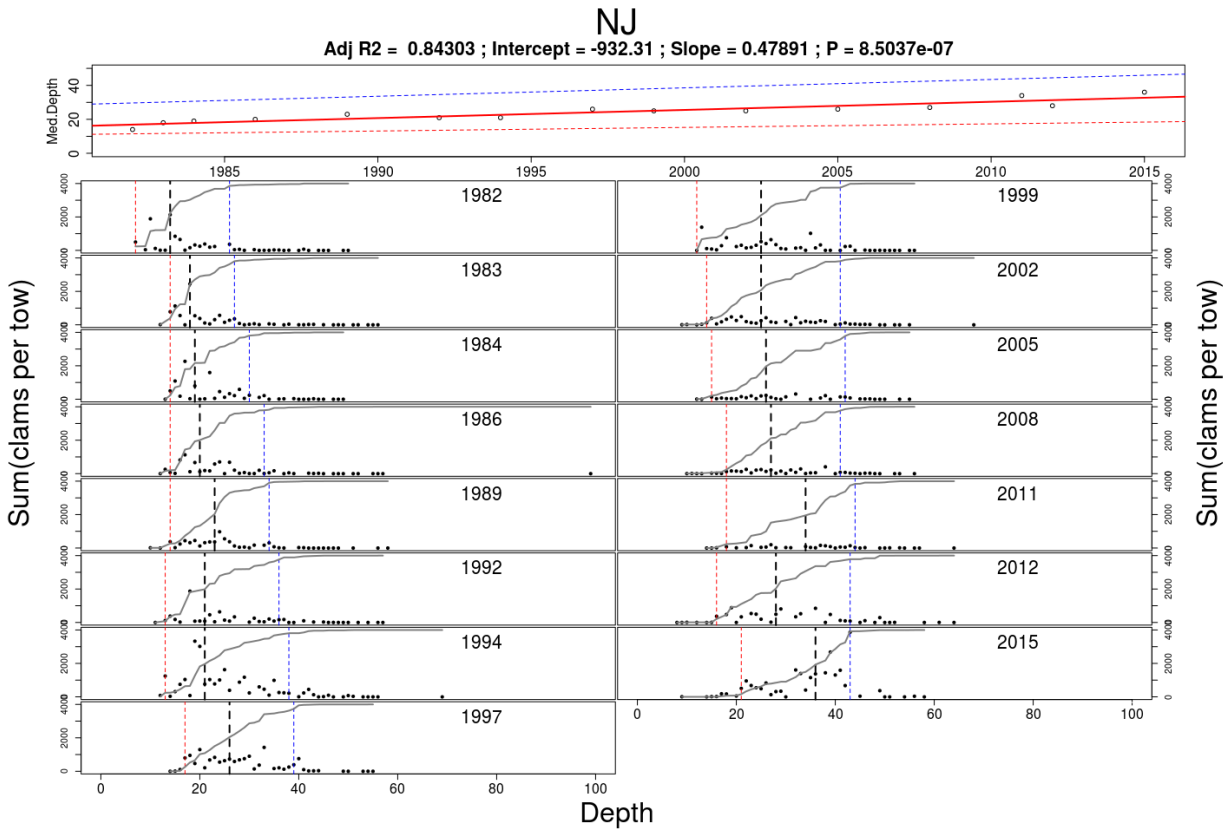

Figure 74: Total surfclams caught at depth by year in NJ. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years.

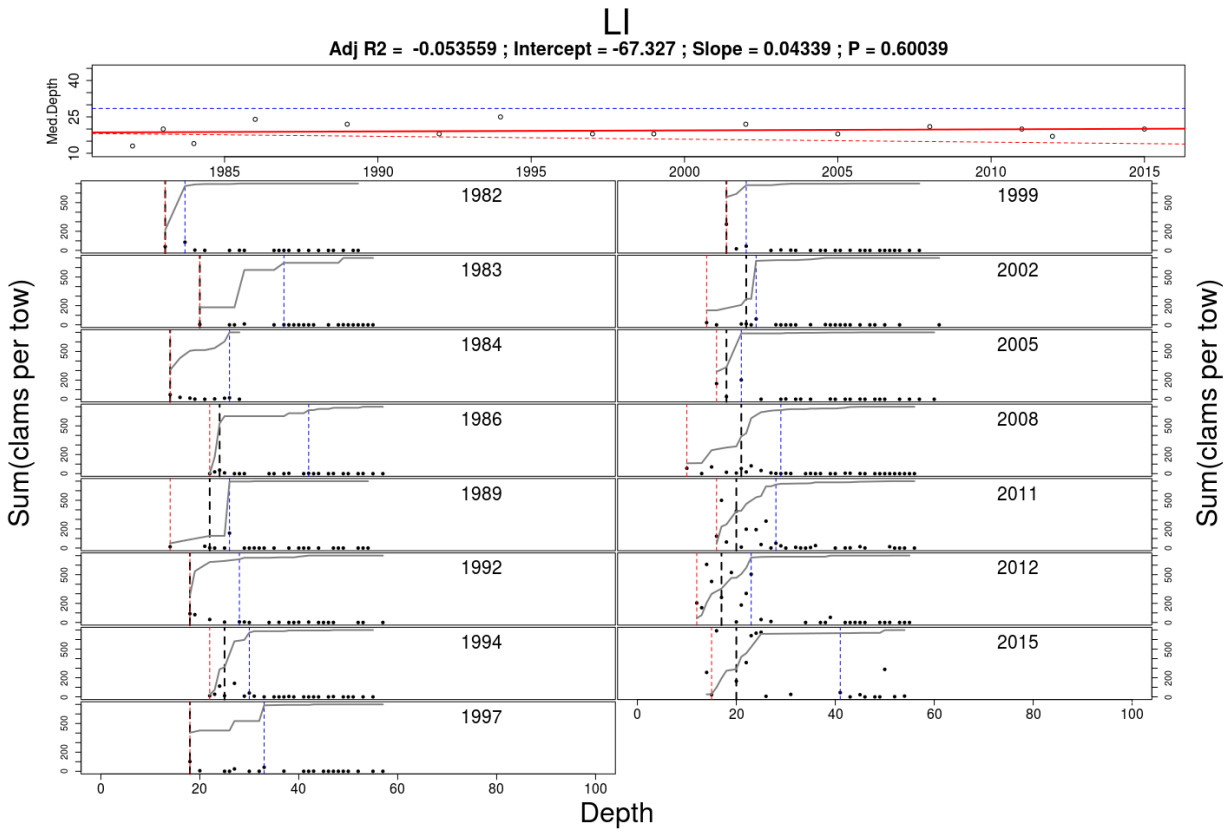

Figure 75: Total surfclams caught at depth by year in LI. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years.

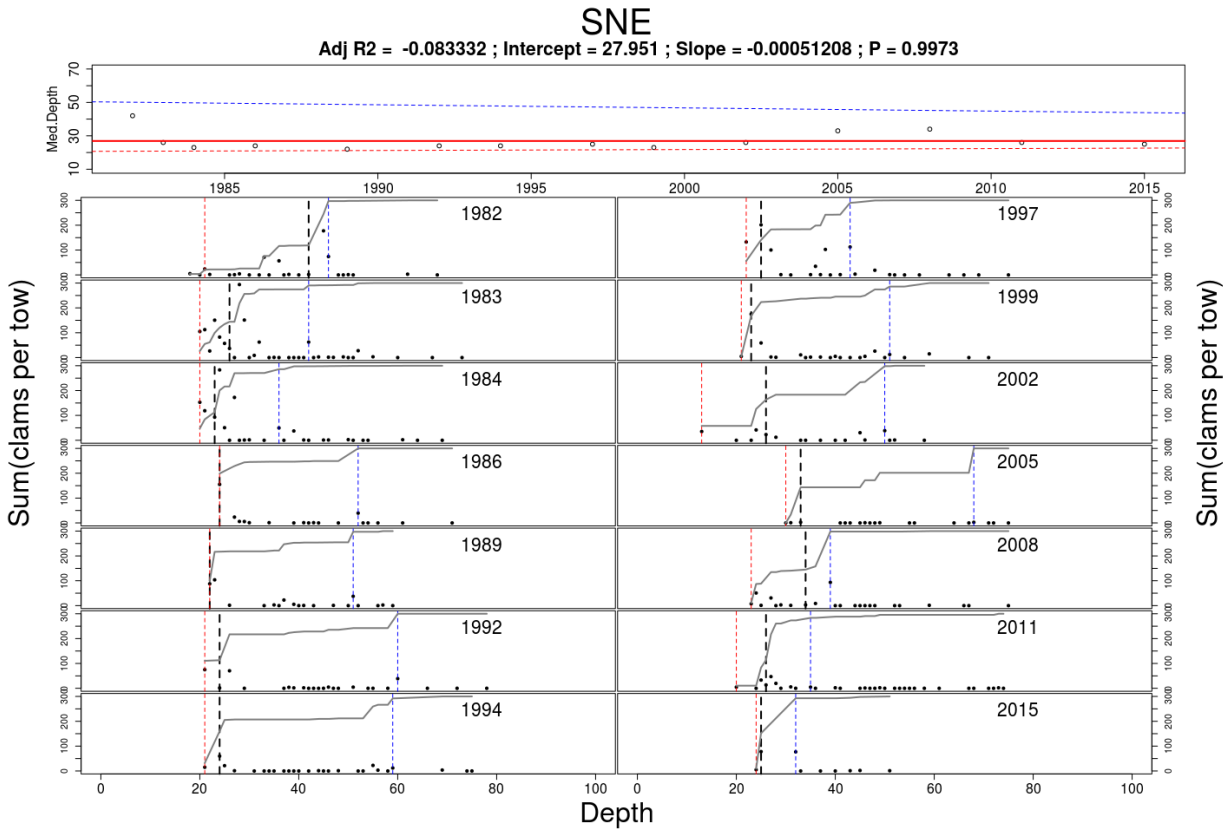

Figure 76: Total surfclams caught at depth by year in SNE. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years.

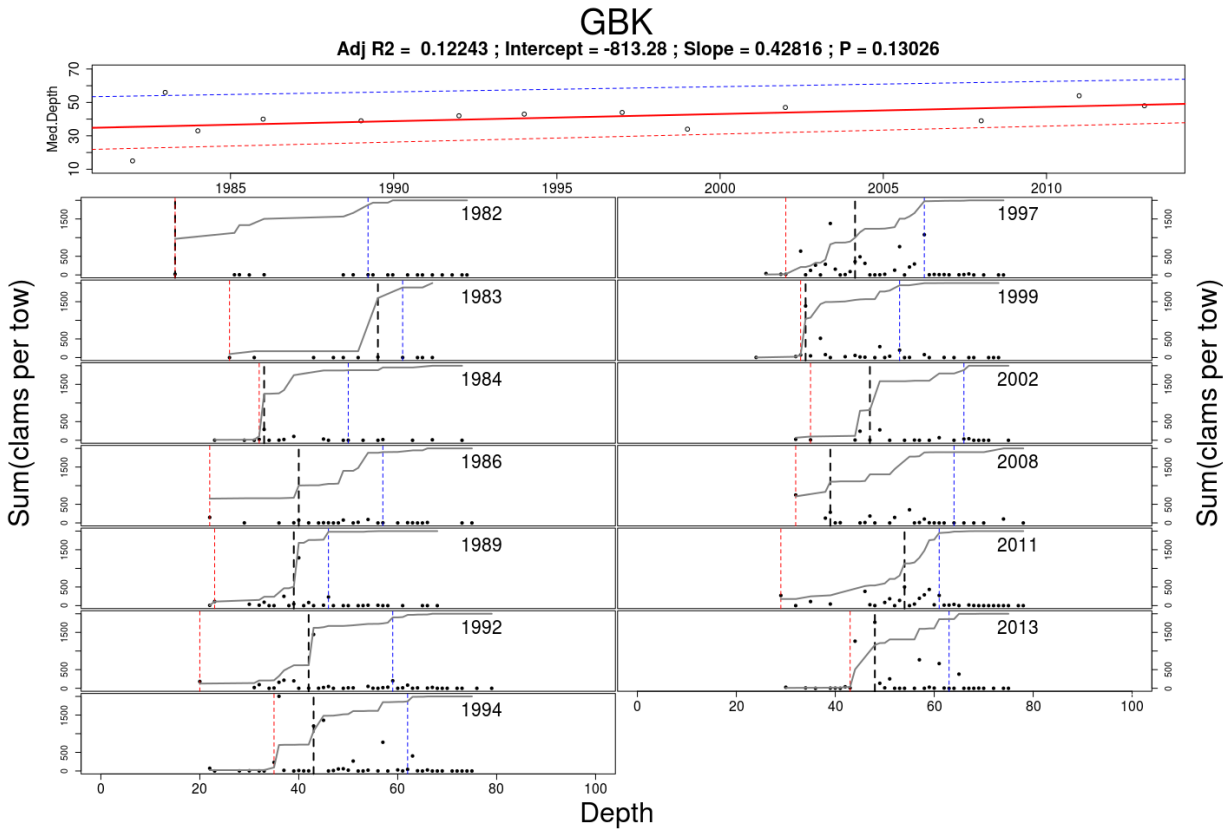

Figure 77: Total surfclams caught at depth by year in GBK. The points are clams caught aggregated by depth and the gray line is the cummulative sum of clams caught at depth. The dashed vertical line is the depth at which half of the cummulative total clams caught in that survey were taken. If the dashed vertical line is further to the right it indicates that more clams were caught in deeper water in that year. The top panel is a simple linear regression of median depth (the dashed vertical lines in each annual plot) over time. A positive slope indicates that a higher proportion of the total clams in a region were caught in deeper water in recent years.

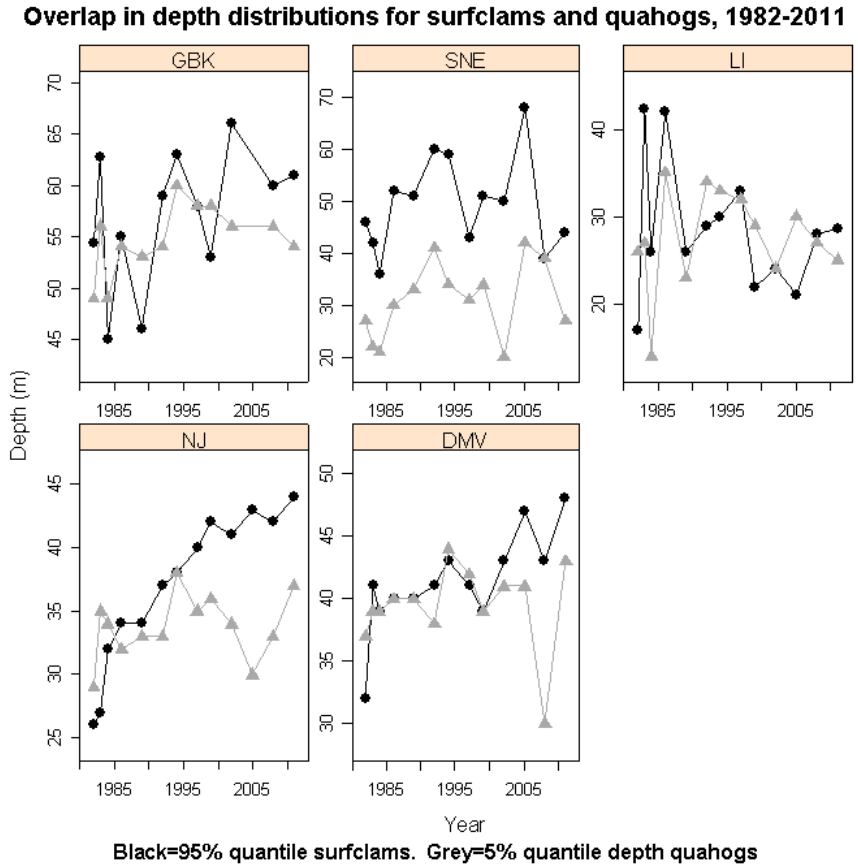

Figure 78: Trends in the offshore habitat boundary for Atlantic surfclam and the inshore habitat boundary for ocean quahog over time. The offshore boundary in each region is the 95% percentile for cumulative catch with depth in NEFSC clam surveys. The inshore habitat boundary for ocean quahogs is the 5% percentile for cumulative catch.

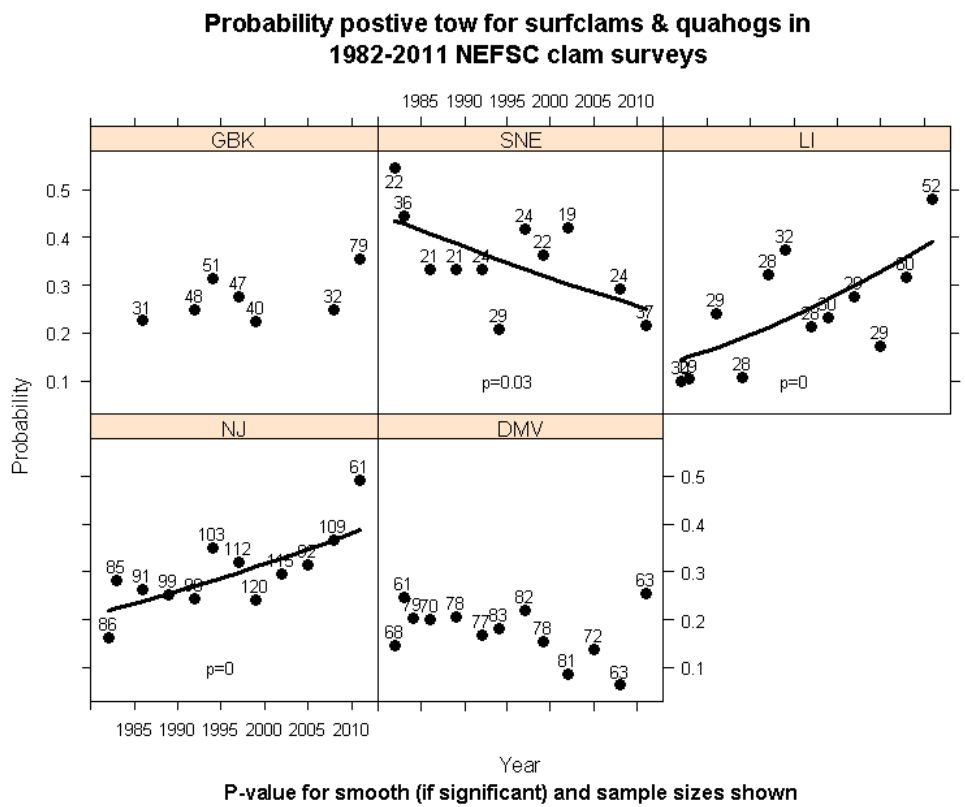

Figure 79: Probability that both Atlantic surfclam and ocean quahogs were taken in the same tow during 1982-2011 clam surveys in consistently sampled strata. Logistic regression lines and p-values are shown if the trend was statistically significant ($p < 0.1$).

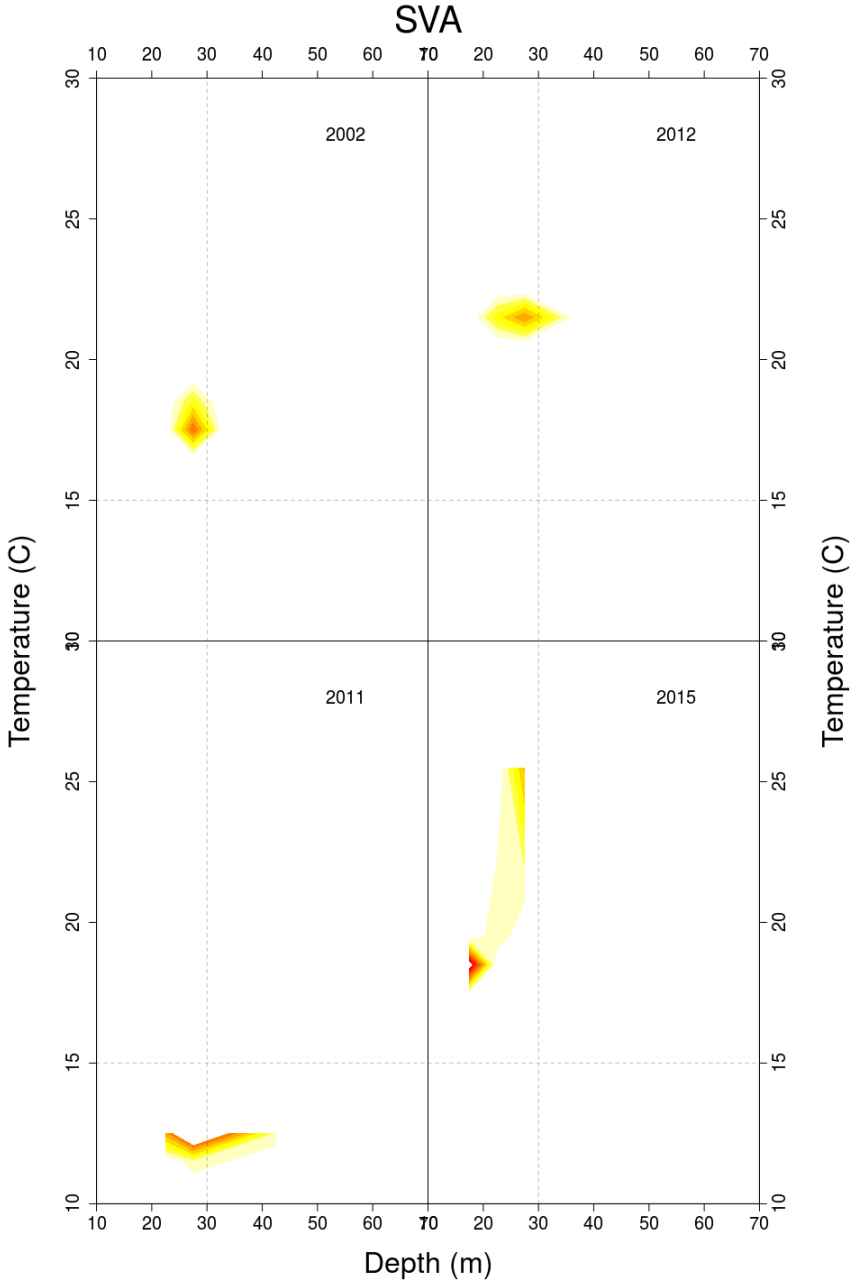

Figure 80: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in SVA. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

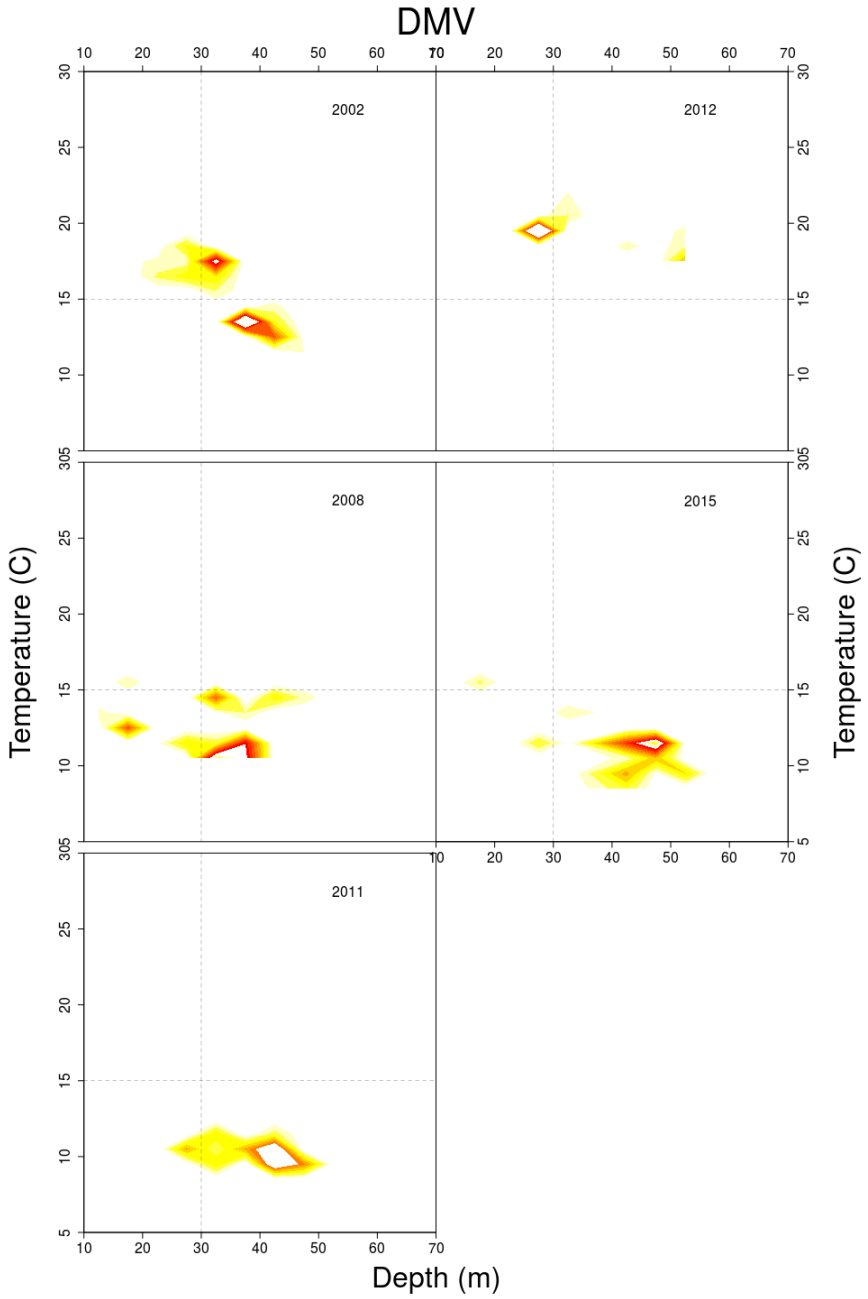

Figure 81: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in DMV. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

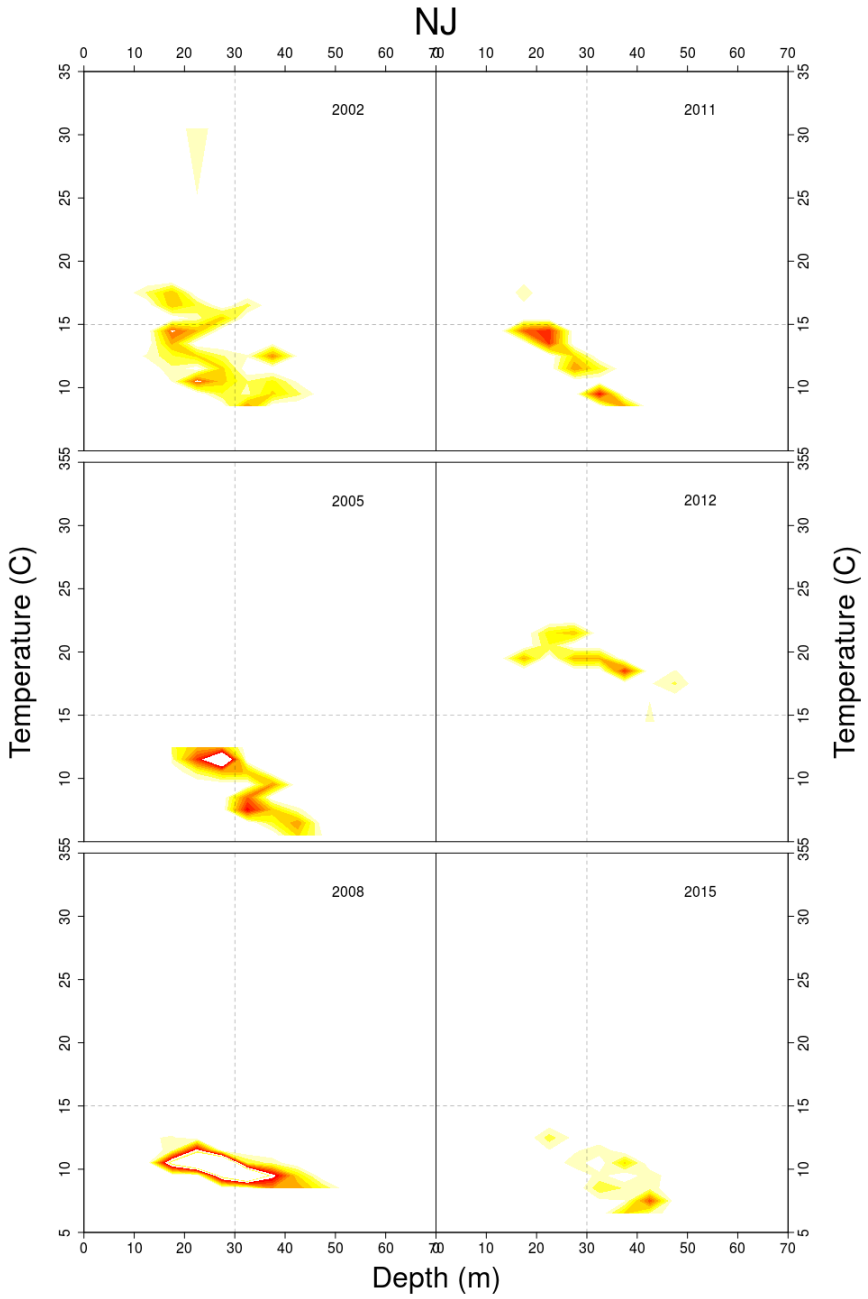

Figure 82: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in NJ. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

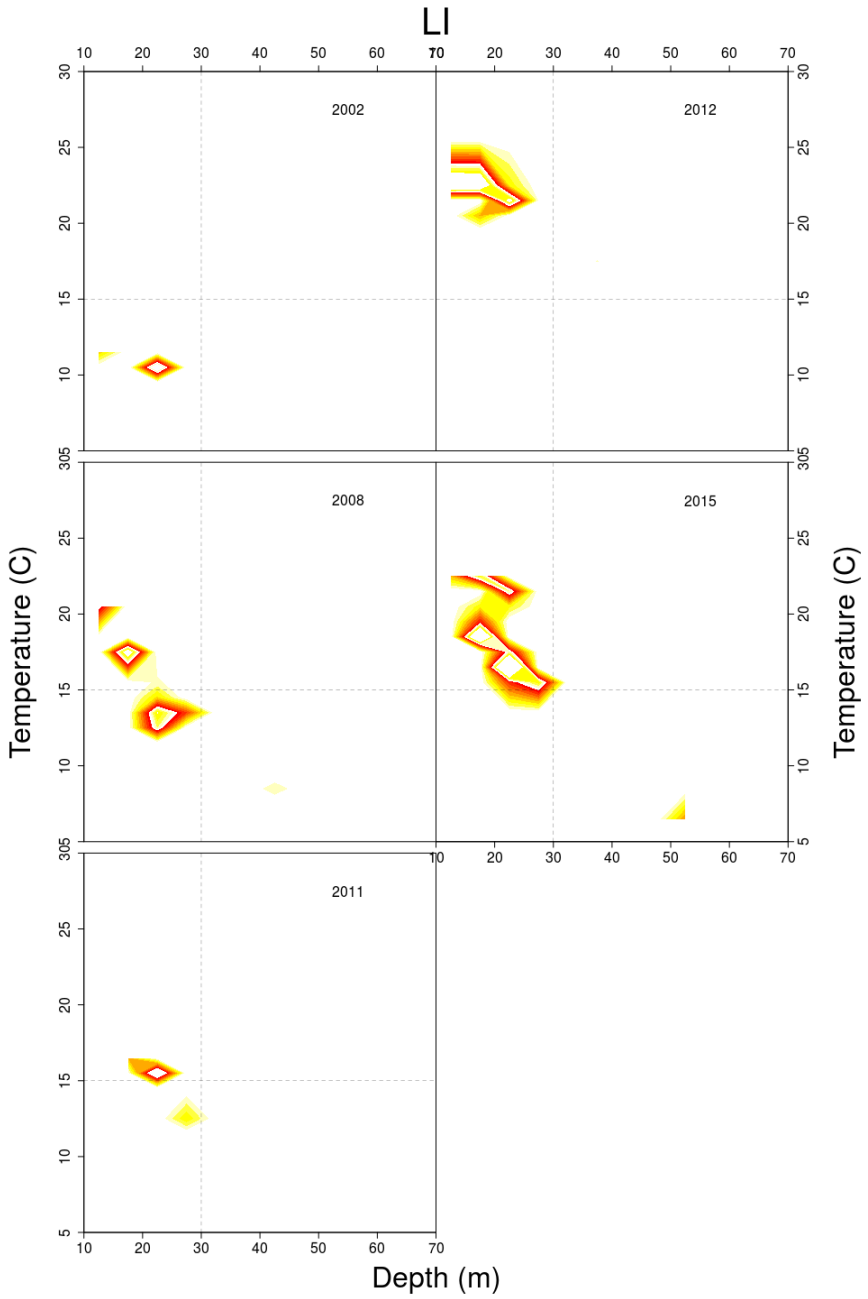

Figure 83: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in LI. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

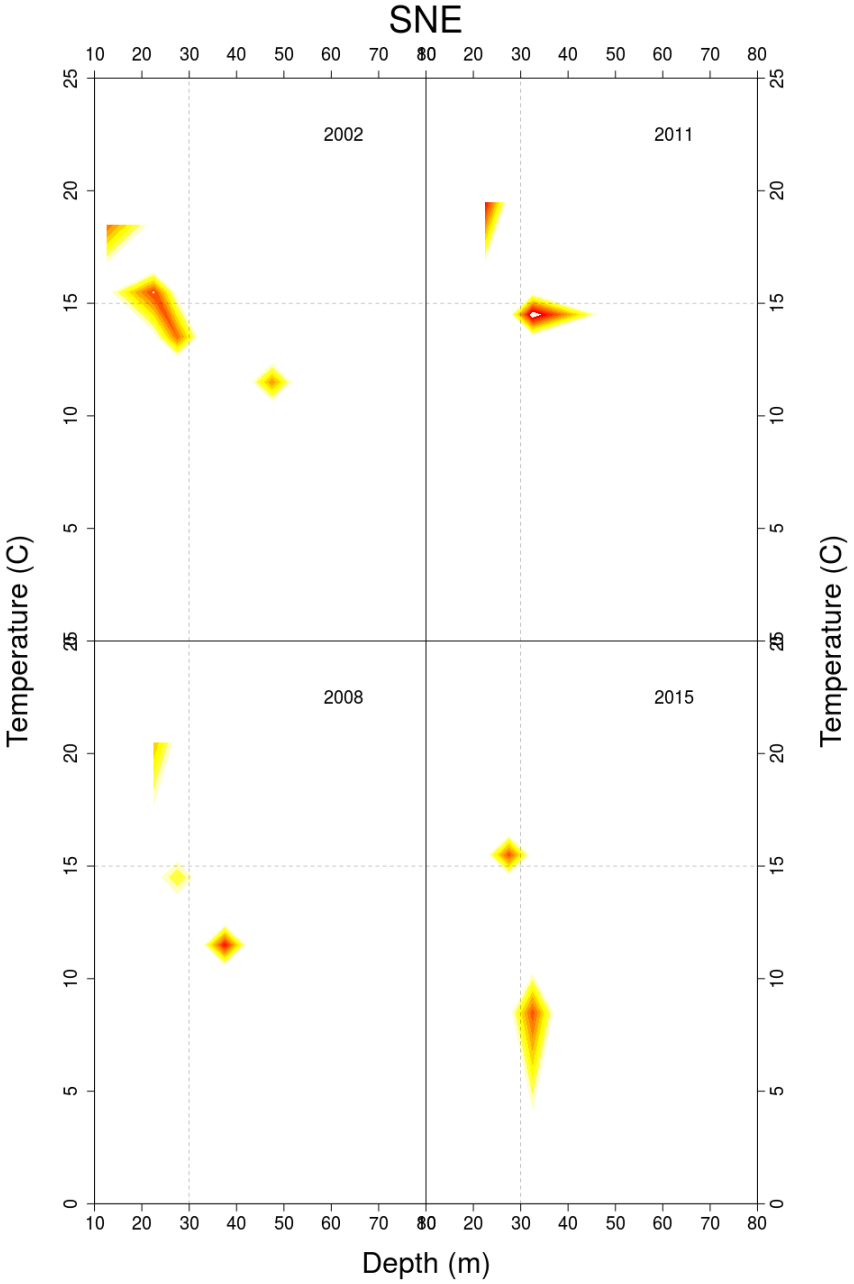

Figure 84: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in SNE. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

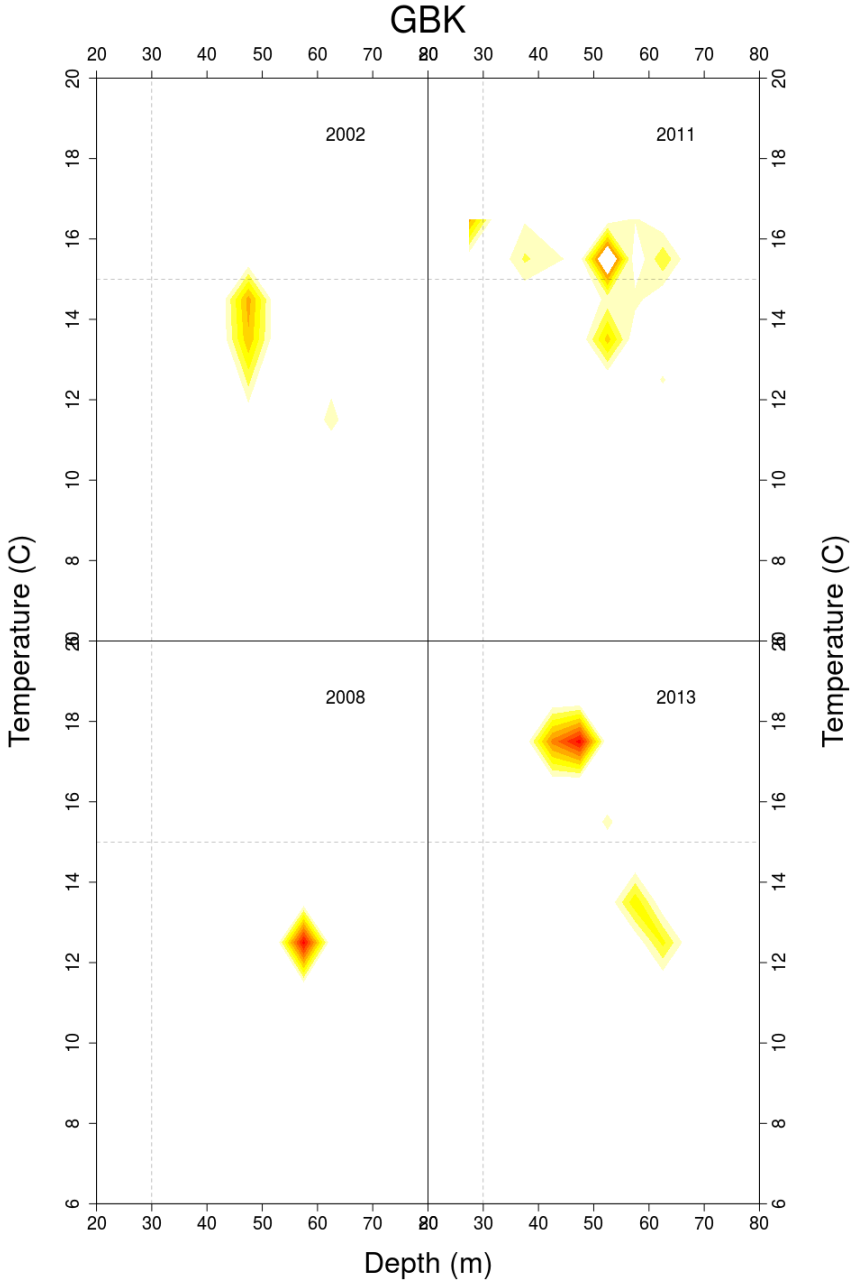

Figure 85: Total surfclams caught in the NEFSC clam survey at depth and temperature by year in GBK. Warmer colors in the contour represent larger catches. Catches are relative within each year and colors are not compareable across years. The dashed lines are drawn at 15° C and 30 m depth are for reference only.

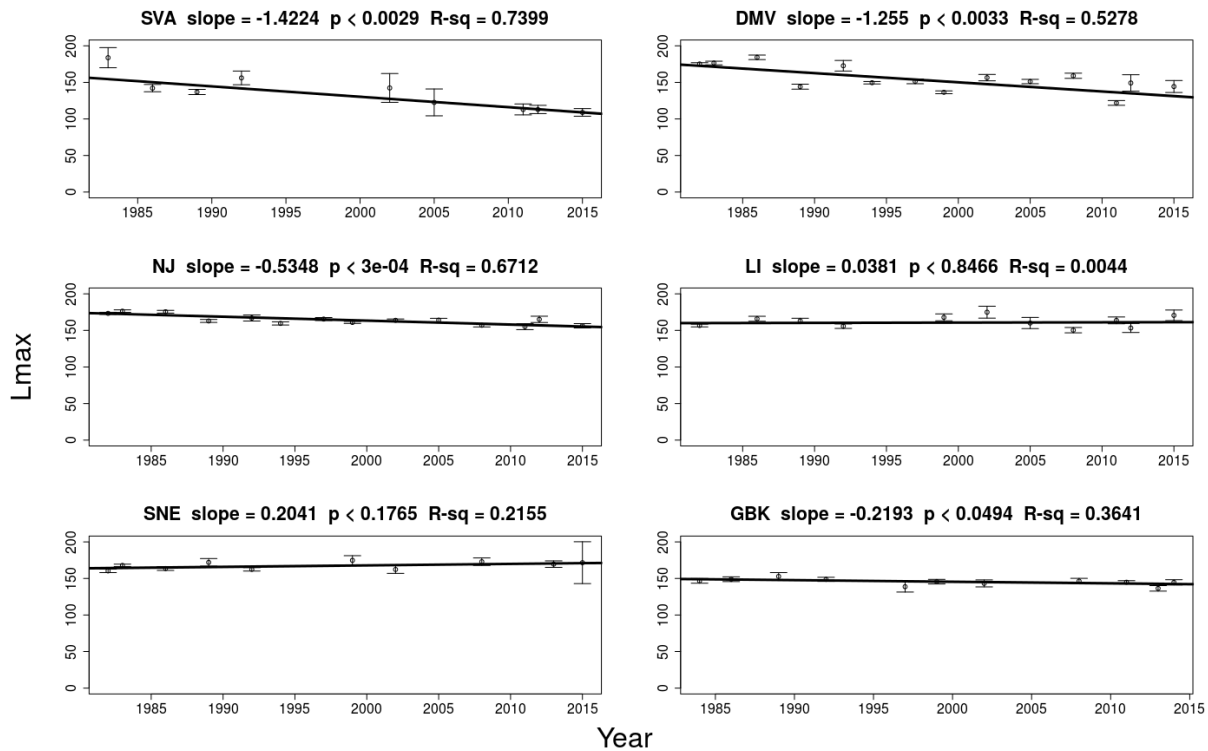

Figure 86: Estimated values of the parameter L_∞ for Atlantic surfclam in NEFSC clam surveys, over time in each region. The L_∞ values for each region were fit with an inverse variance weighted regression, and the slope, p-value and R^2 that result are shown above each plot.

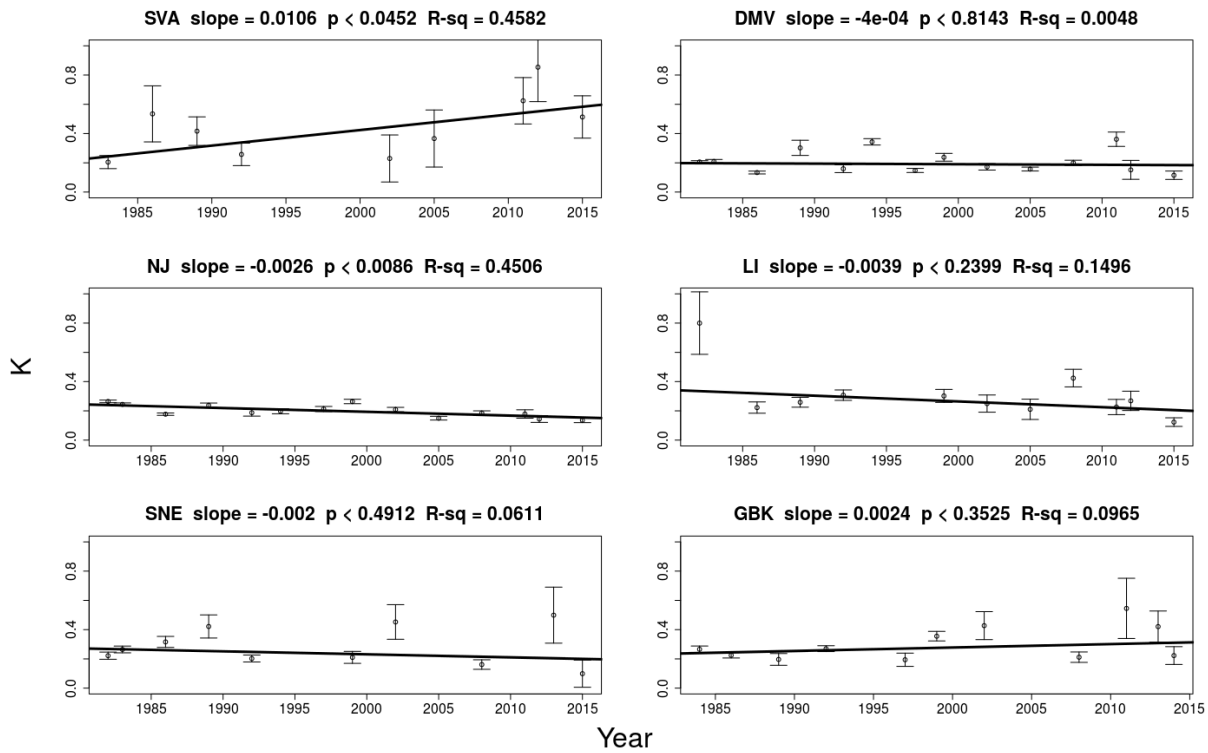

Figure 87: Estimated values of the parameter K for Atlantic surfclam in NEFSC clam surveys, over time in each region. The K values for each region were fit with an inverse variance weighted regression, and the slope, p-value and R^2 that result are shown above each plot.

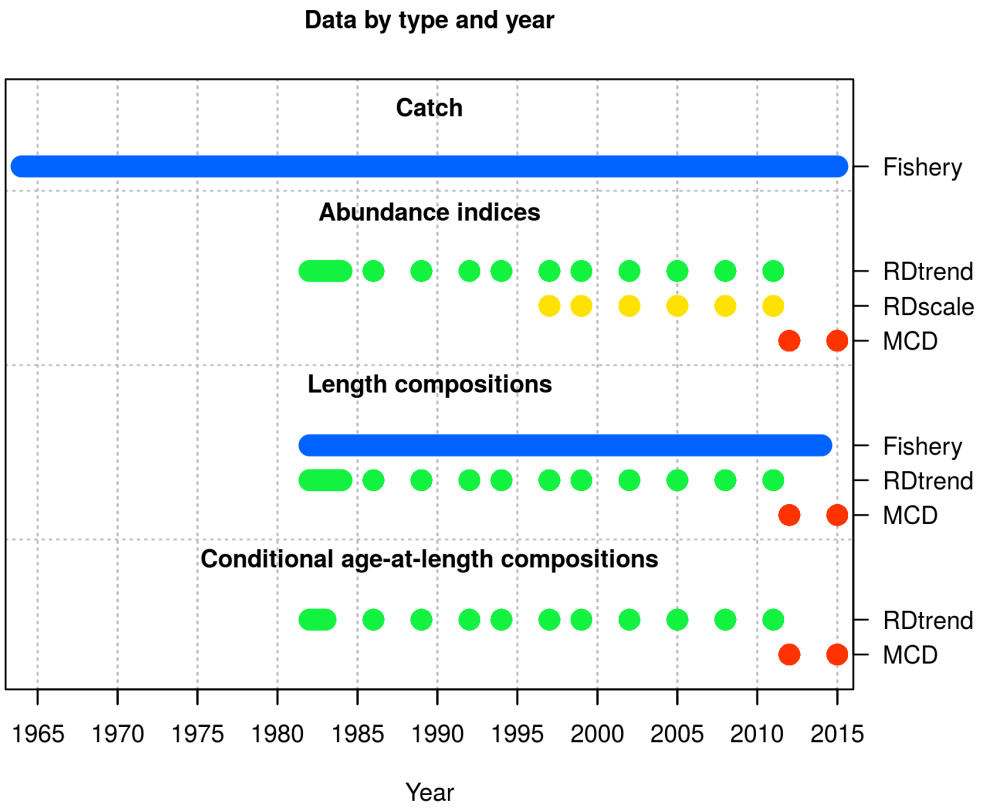

Figure 88: Data included in the Atlantic surfclam assessment model for the southern area. RD scale was not included in the likelihood.

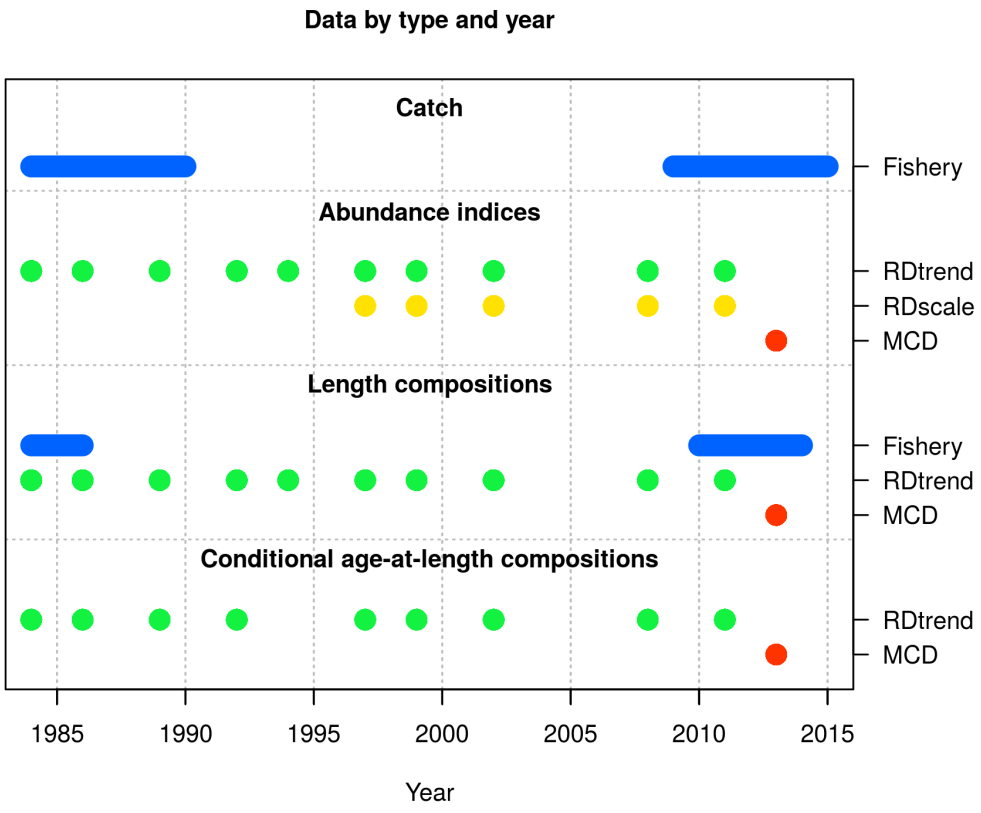

Figure 89: Data included in the Atlantic surfclam assessment model for the northern area. RD scale was not included in the likelihood.

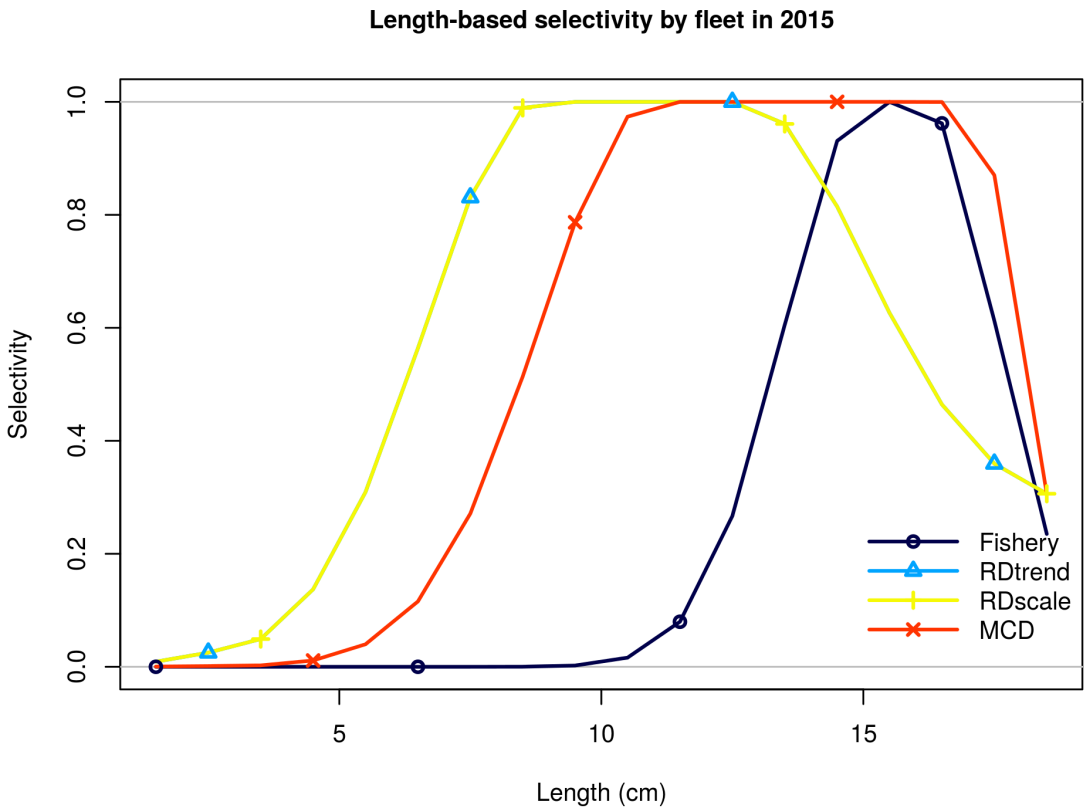

Figure 90: Comparison of selectivity curves for each fleet included in the assessment model for Atlantic surfclam in the southern area. RD trend and RD scale have identical selectivities because they are from the same survey (RD scale was not included in the likelihood).

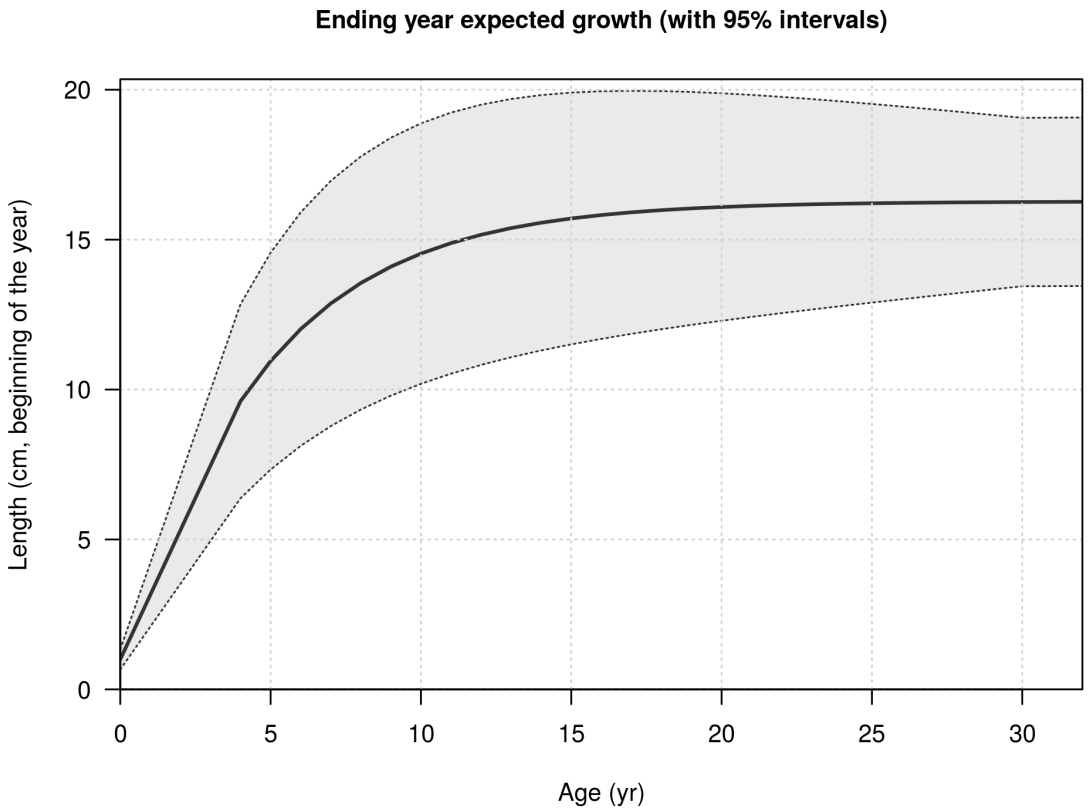

Figure 91: Length at age relationship from the assessment model for Atlantic surfclam in the southern area.

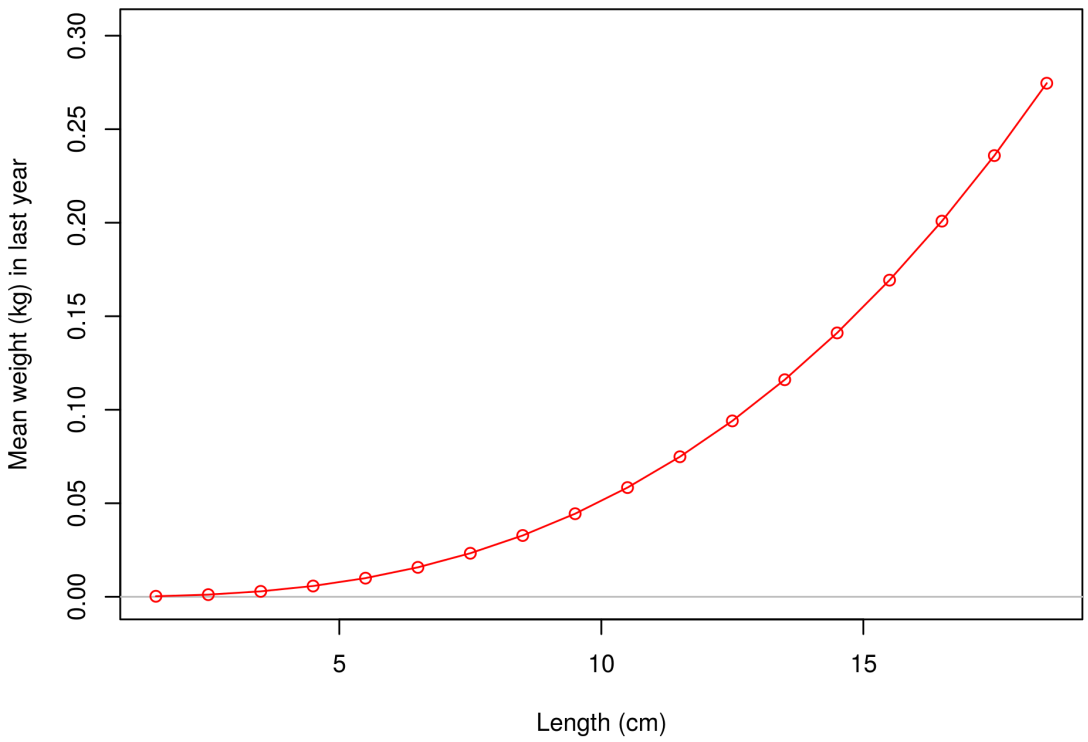

Figure 92: Weight at length relationship used in the assessment model for Atlantic surfclam in the southern area.

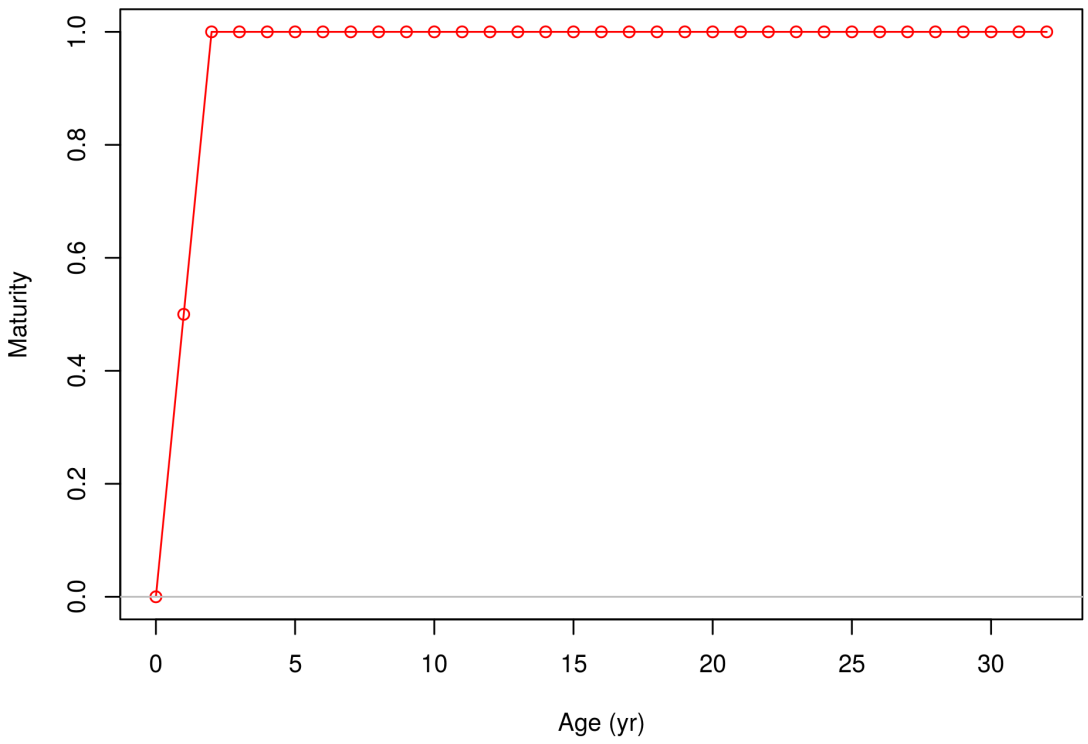

Figure 93: Maturity at age relationship used in the assessment model for Atlantic surfclam in the southern area.

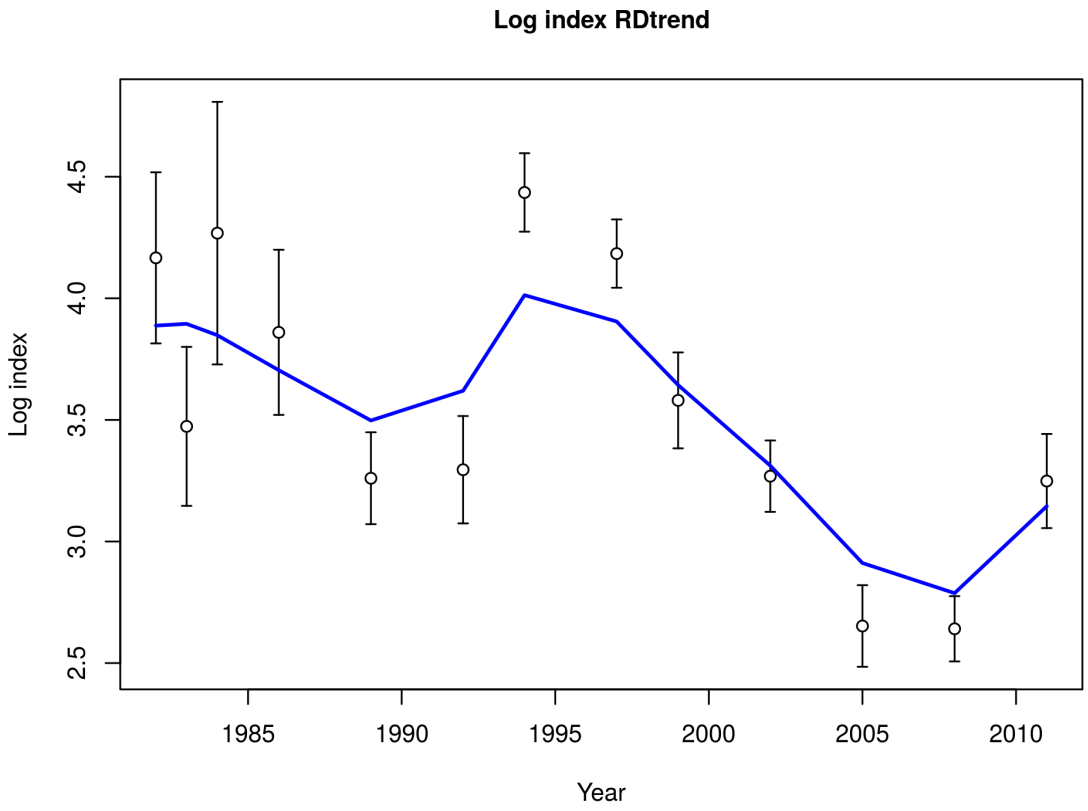

Figure 94: Fit to log index data on log scale for RDtrend survey for Atlantic surfclam in the southern area. Vertical lines are 95% confidence intervals.

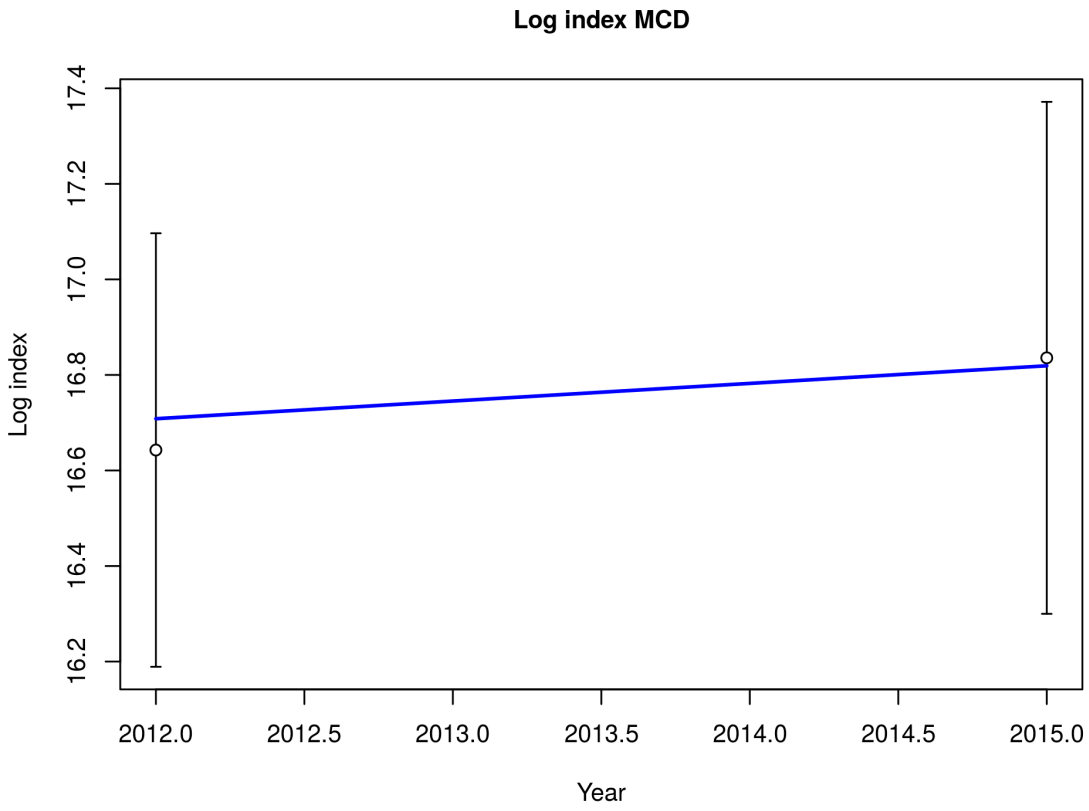

Figure 95: Fit to log index data on log scale for MCD survey for Atlantic surfclam in the southern area. Vertical lines are 95% confidence intervals.

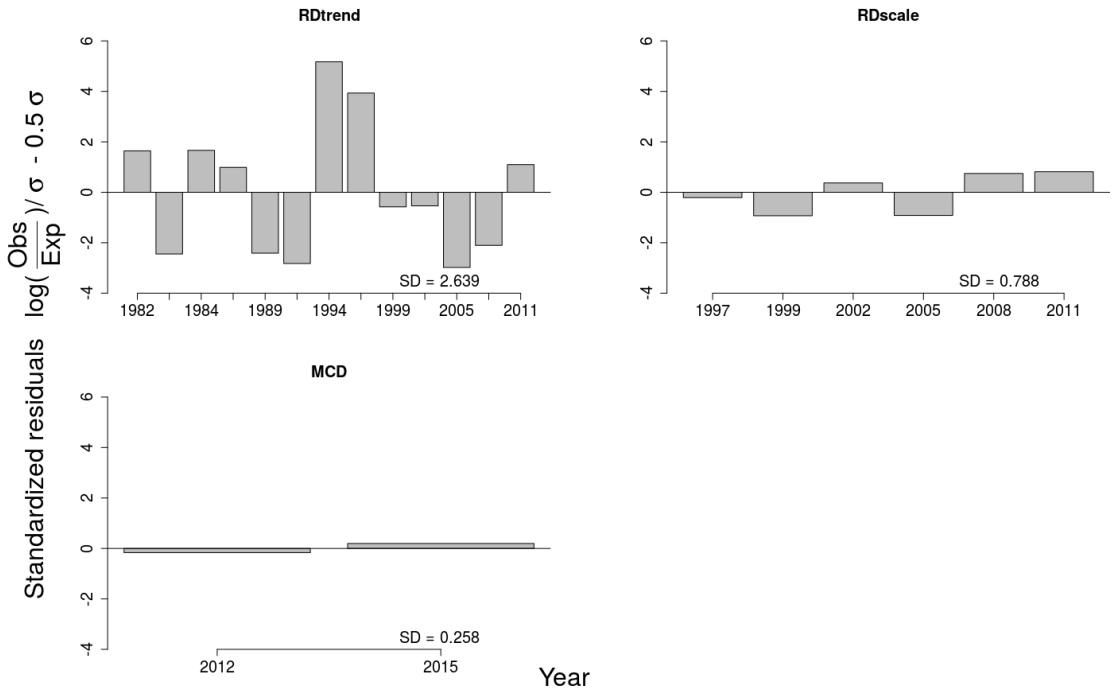

Figure 96: Residuals from the model fits to each survey index used in the assessment model for Atlantic surfclam in the southern area by year. The standard deviation of the residuals over the time series is indicated above the horizontal axis.

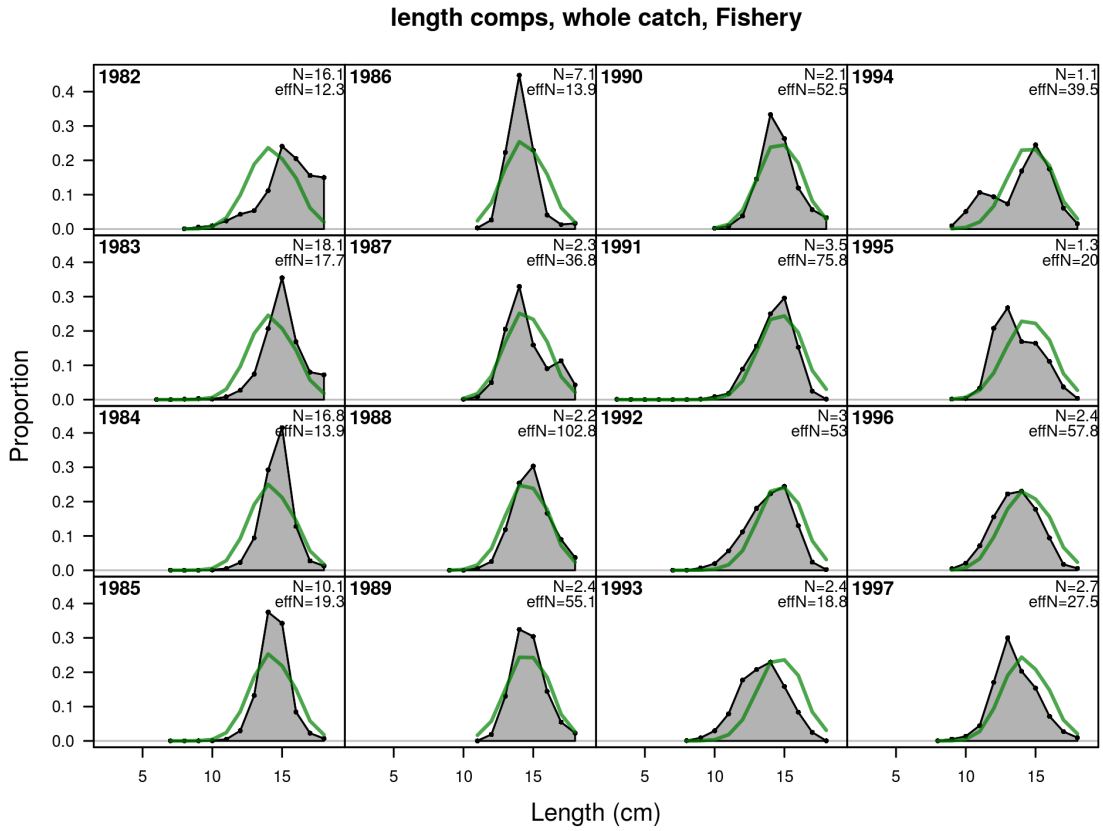

Figure 97: Model fit to length composition data from the commercial fishery used in the assessment model for Atlantic surfclam in the southern area.

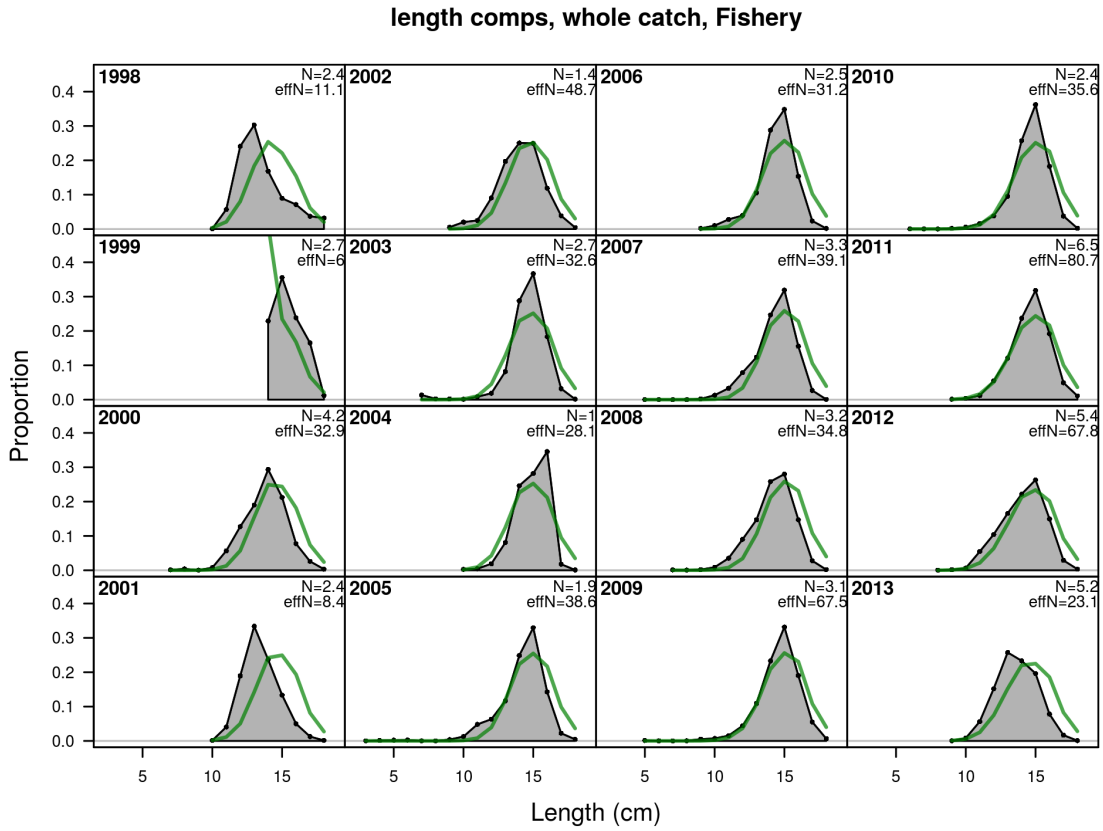

Figure 97 cont.

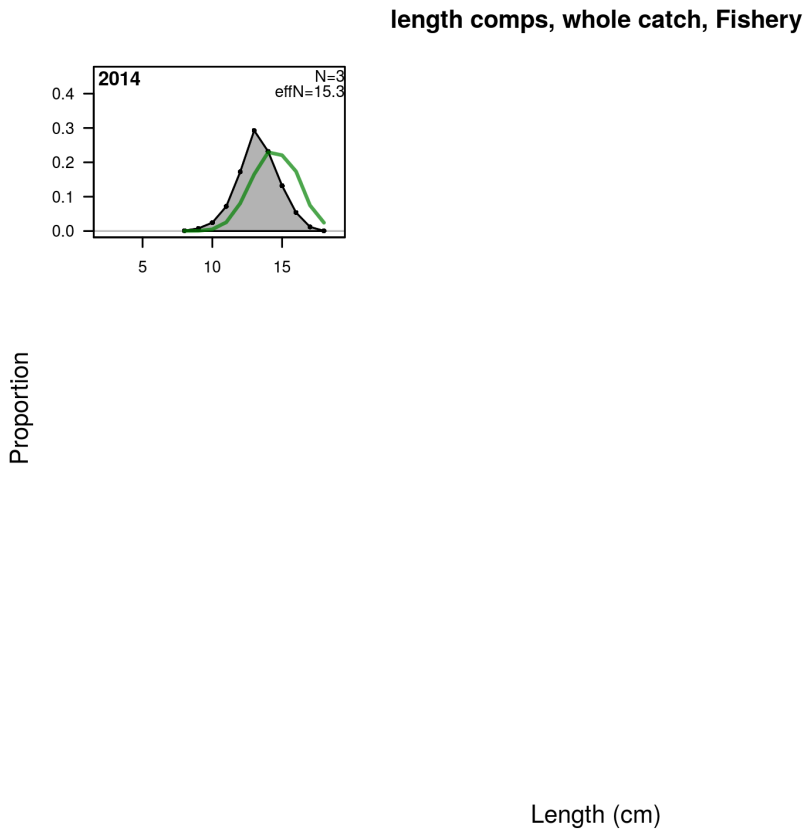

Figure 97 cont.

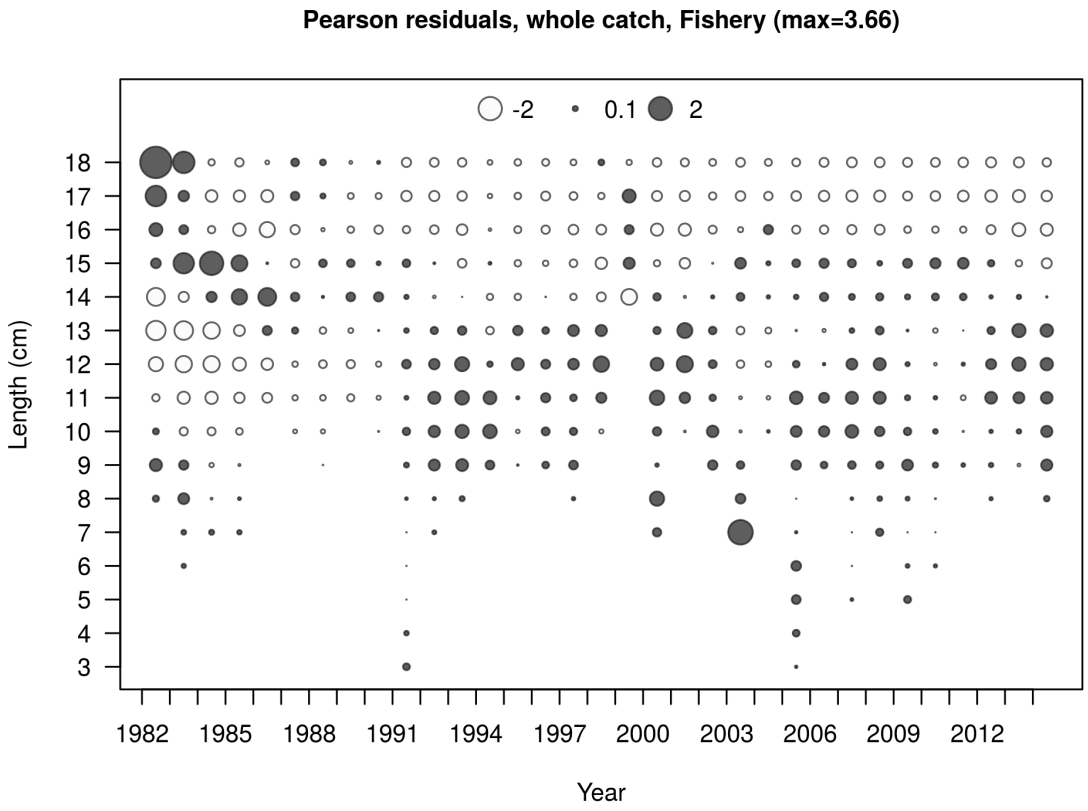

Figure 98: Pearson residuals from the fit to commercial length composition data used in the assessment model for Atlantic surfclam in the southern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

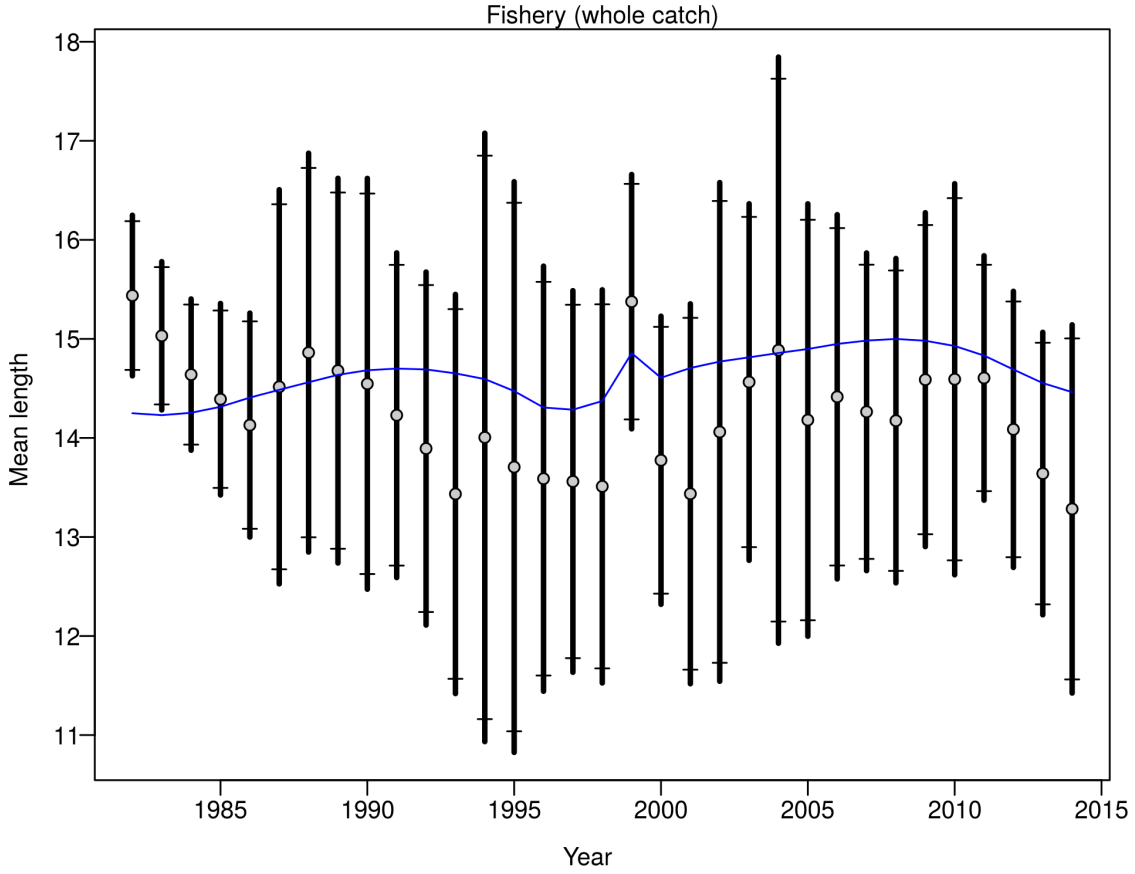

Figure 99: Observed mean length vs. the mean length predicted by the model based on fits to commercial length composition data used in the assessment model for Atlantic surfclam in the southern area.

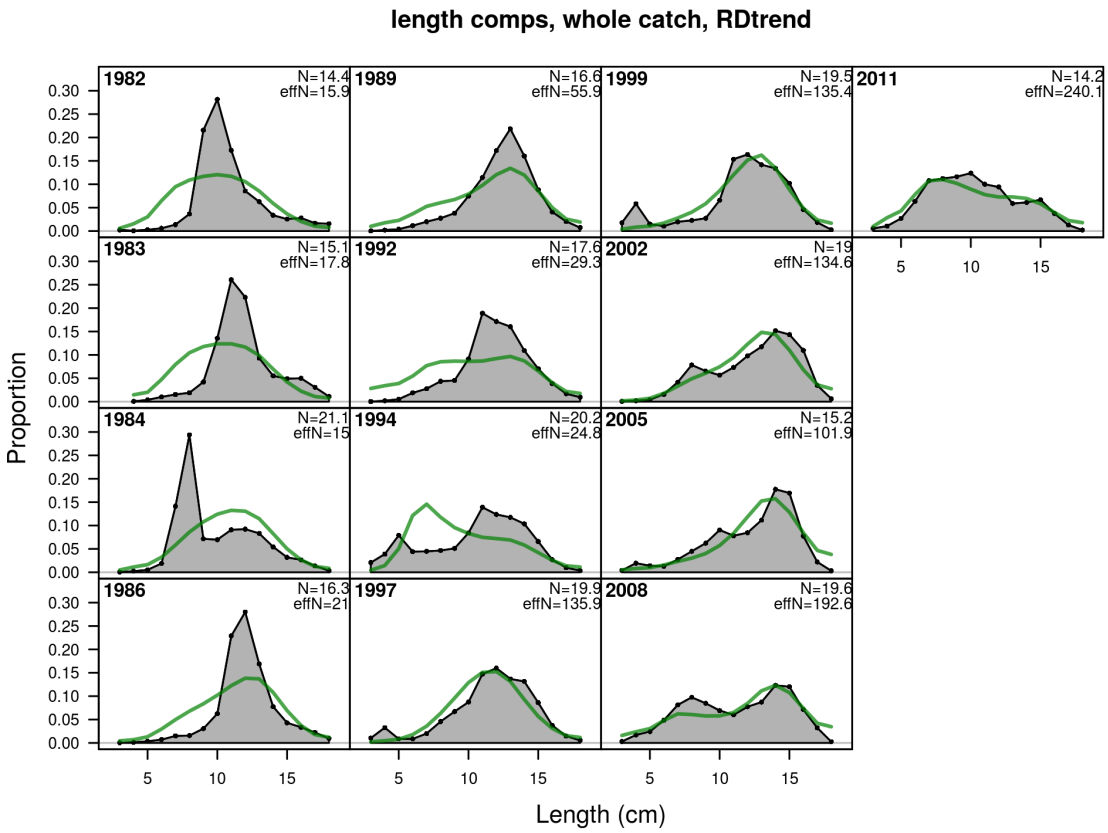

Figure 100: Model fit to length composition data from the NEFSC survey (RD) used in the assessment model for Atlantic surfclam in the southern area.

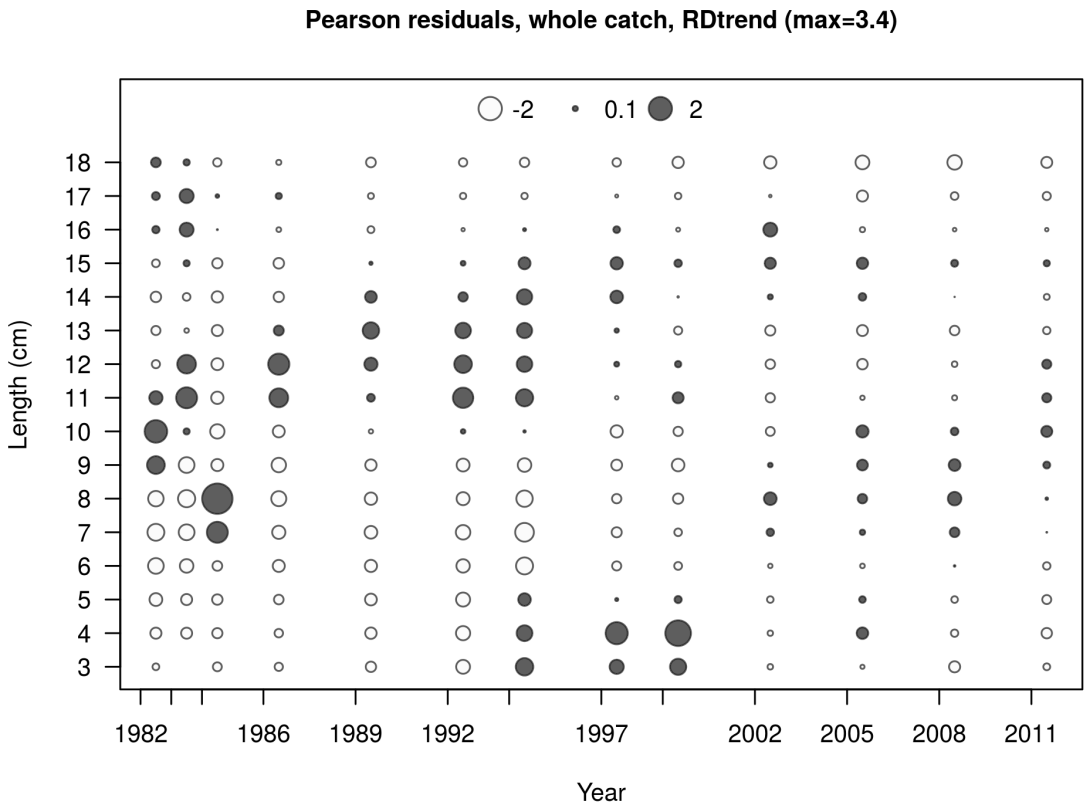

Figure 101: Pearson residuals from the fit to NEFSC survey (RD) length composition data used in the assessment model for Atlantic surfclam in the southern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

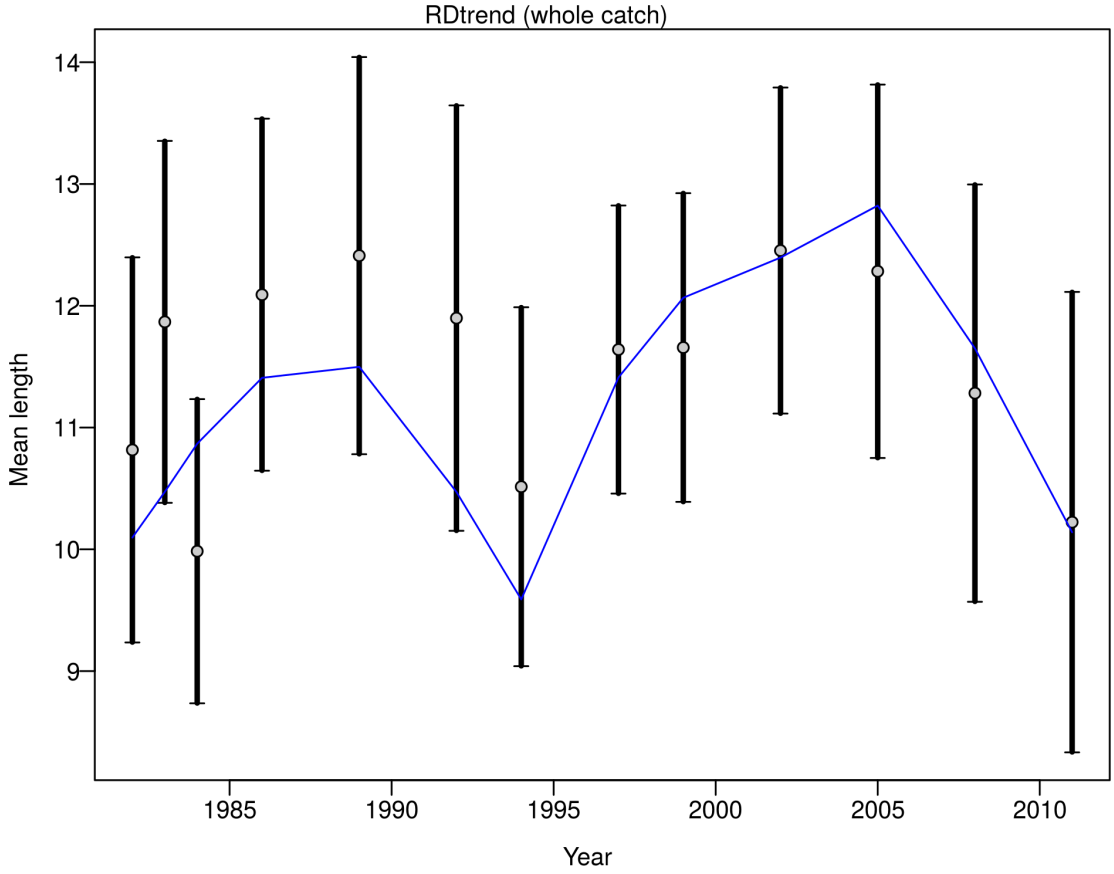

Figure 102: Observed mean length vs. the mean length predicted by the model based on fits to NEFSC survey (RD) length composition data used in the assessment model for Atlantic surfclam in the southern area.

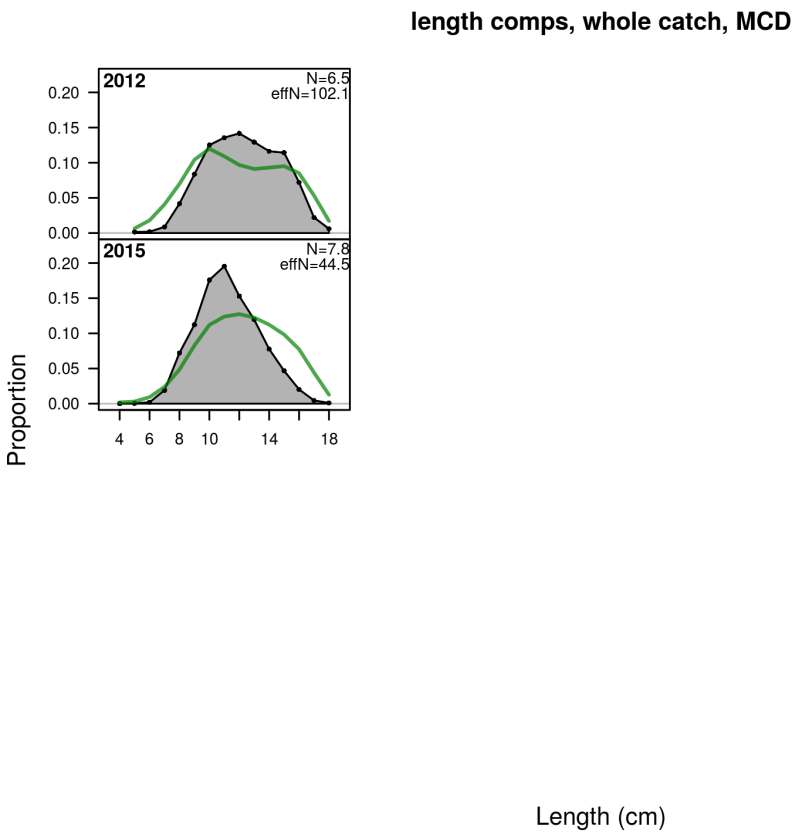

Figure 103: Model fit to length composition data from the NEFSC survey (MCD) used in the assessment model for Atlantic surfclam in the southern area.

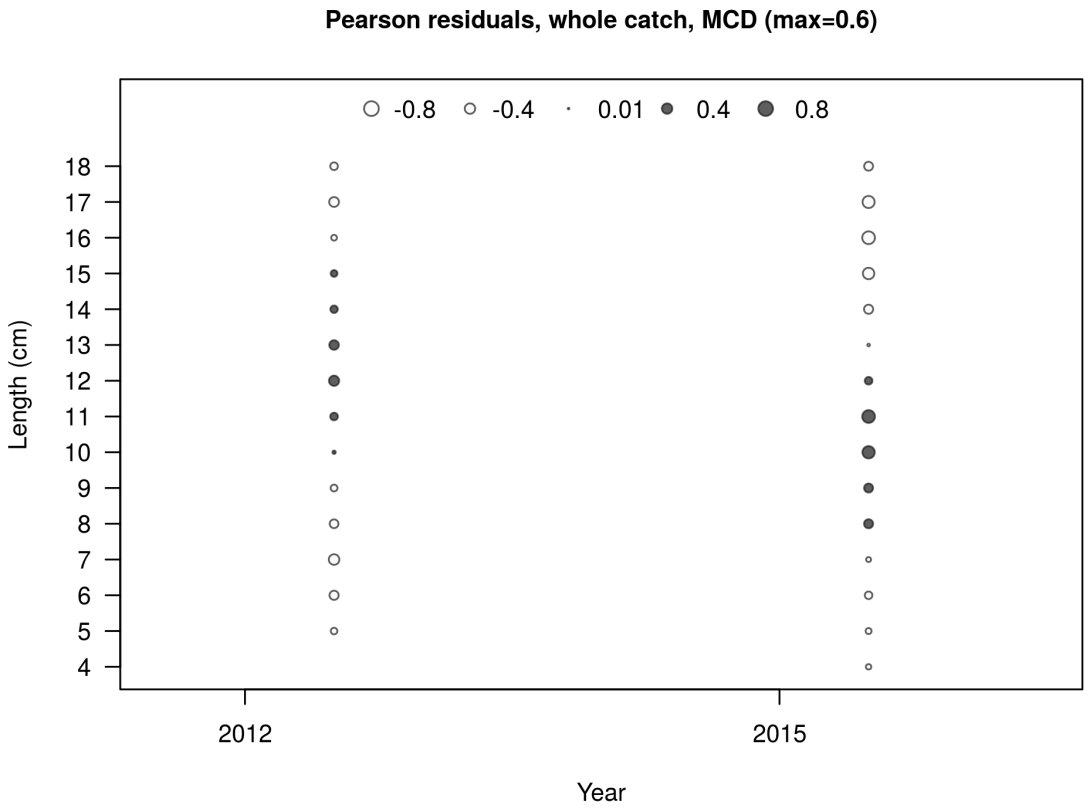

Figure 104: Pearson residuals from the fit to NEFSC survey (MCD) length composition data used in the assessment model for Atlantic surfclam in the southern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

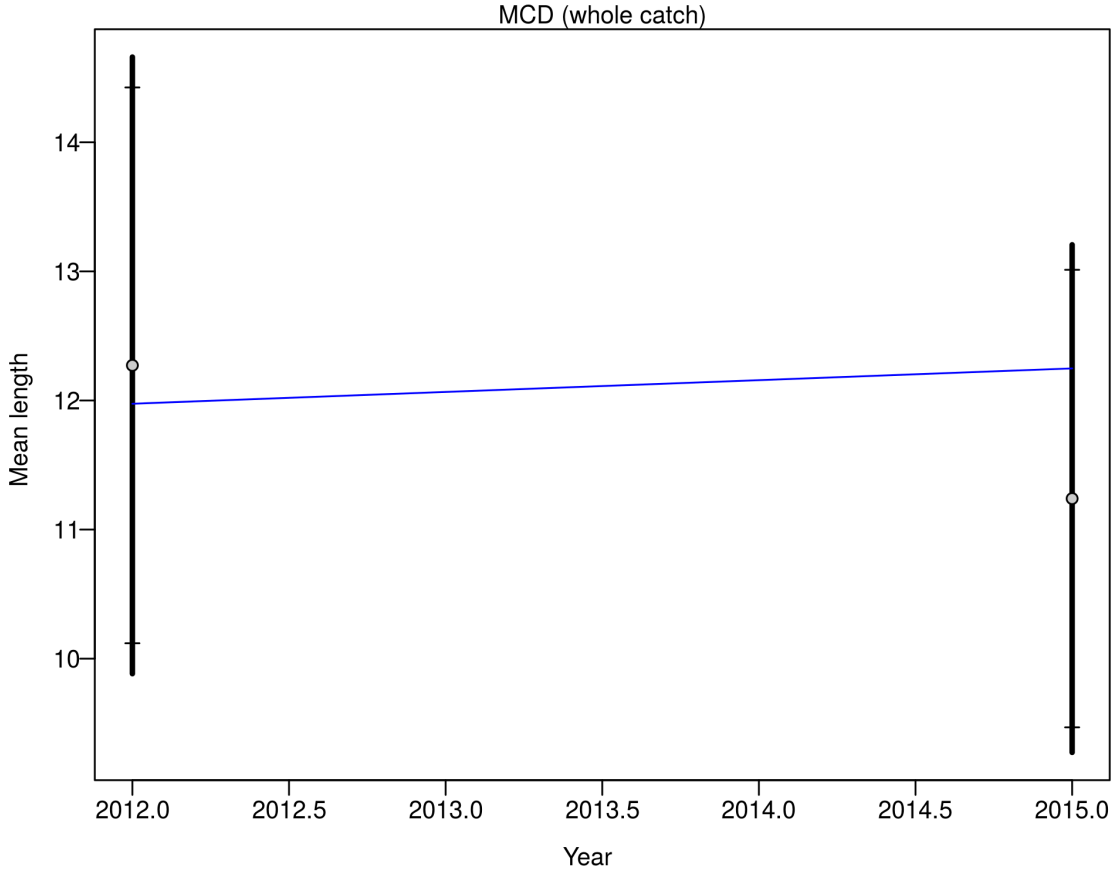

Figure 105: Observed mean length vs. the mean length predicted by the model based on fits to NEFSC survey (MCD) length composition data used in the assessment model for Atlantic surfclam in the southern area.

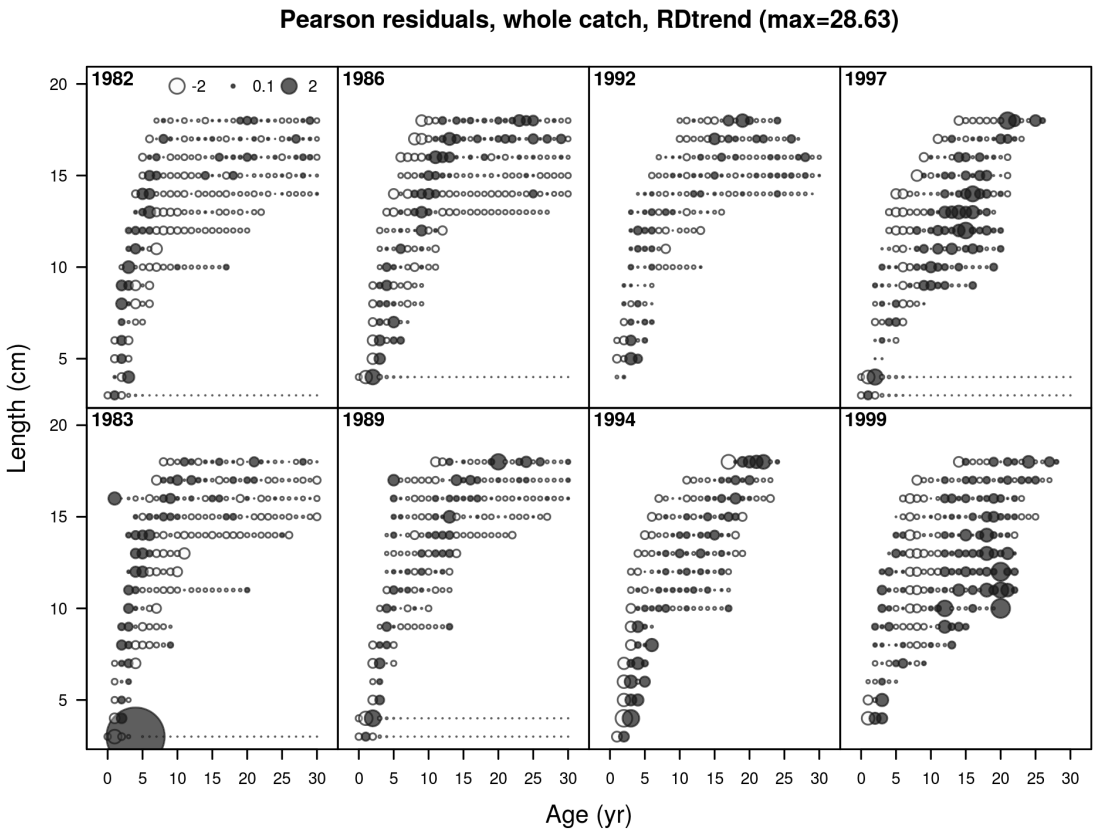

Figure 106: Pearson residuals from the fit to NEFSC survey (RD) conditional age at length composition data used in the assessment model for Atlantic surfclam in the southern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

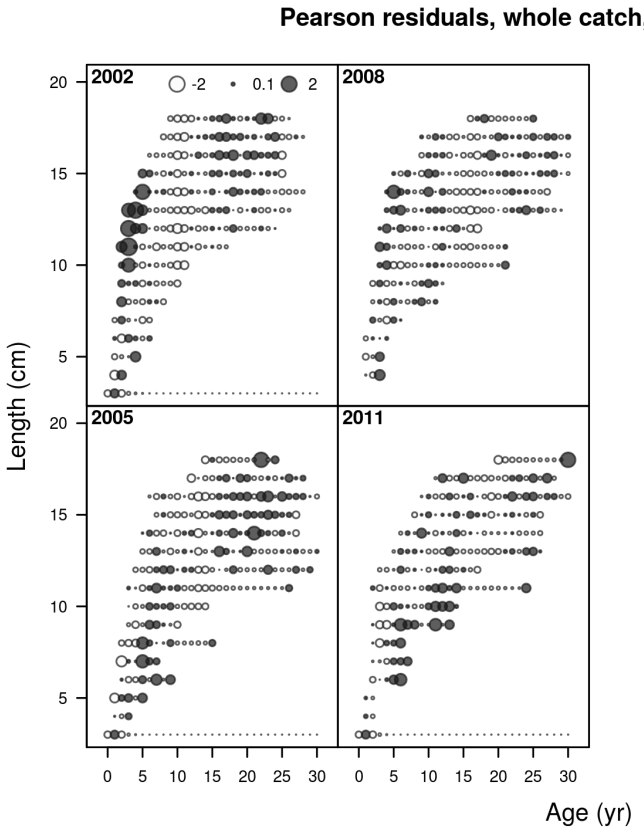

Figure 106 cont.

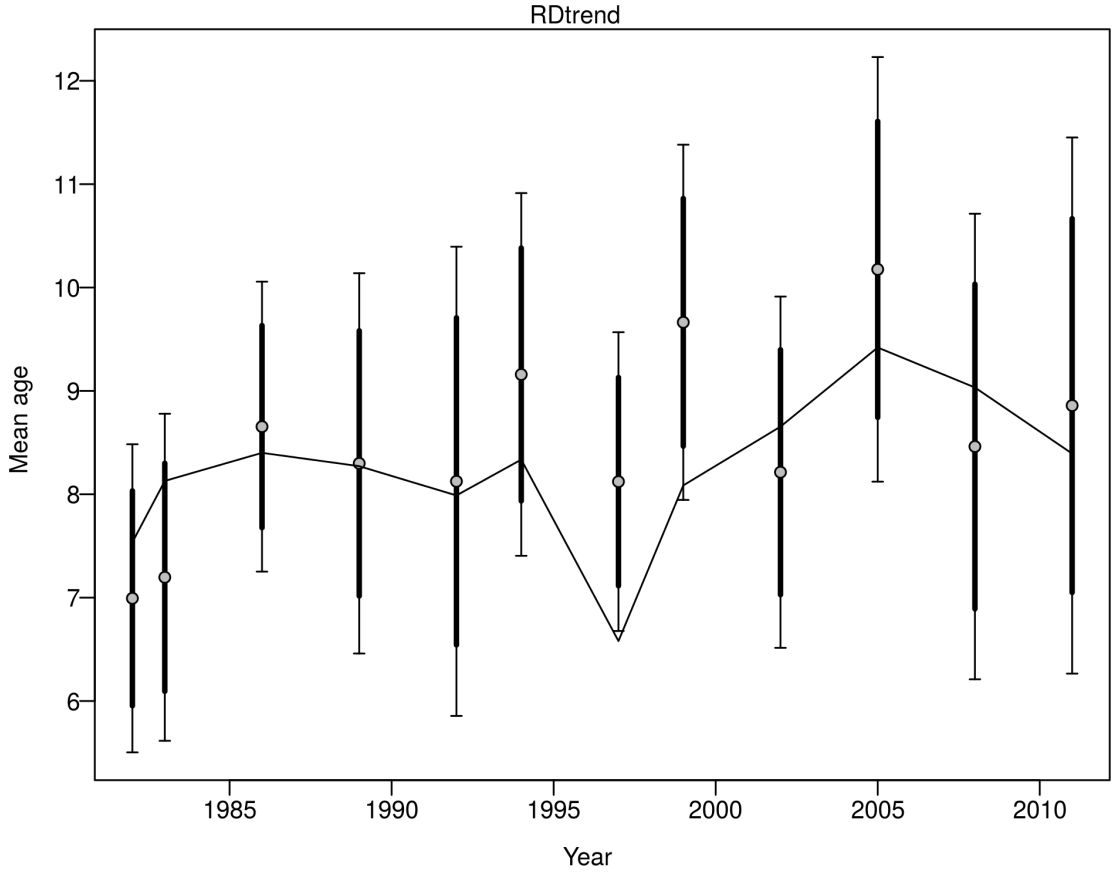

Figure 107: Observed mean age vs. the mean age predicted by the model based on fits to NEFSC survey (RD) age at length conditional composition data used in the assessment model for Atlantic surfclam in the southern area. The thicker vertical lines show the standard deviation of the observed data and the thinner lines show the standard deviation after accounting for the data weighting adjustments used in the model.

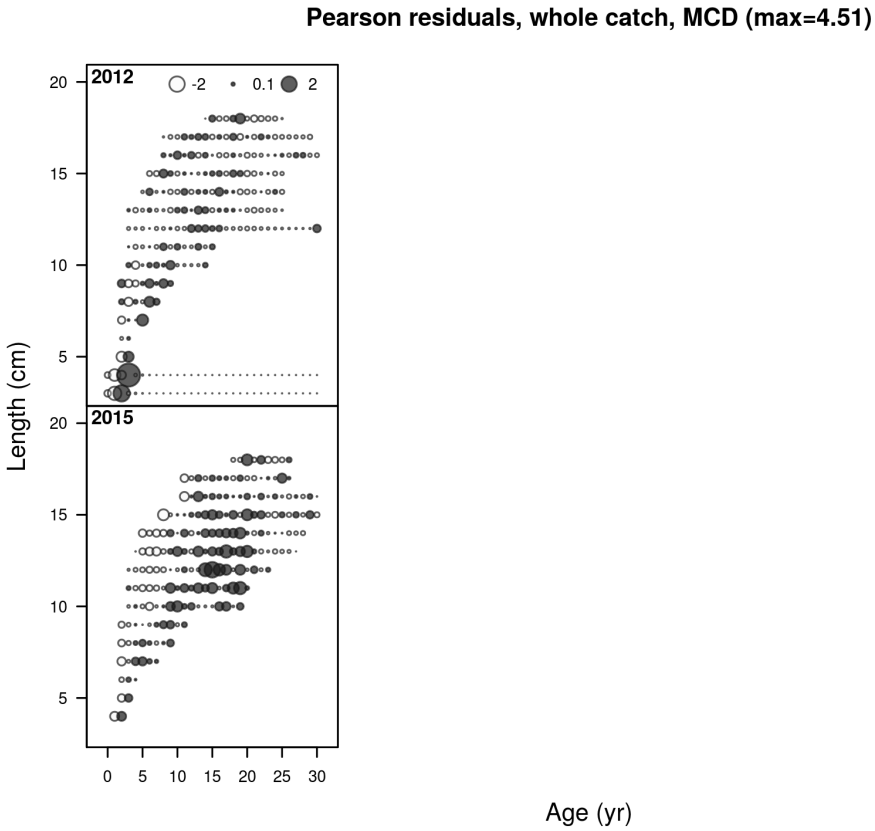

Figure 108: Pearson residuals from the fit to NEFSC survey (MCD) conditional age at length composition data used in the assessment model for Atlantic surfclam in the southern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

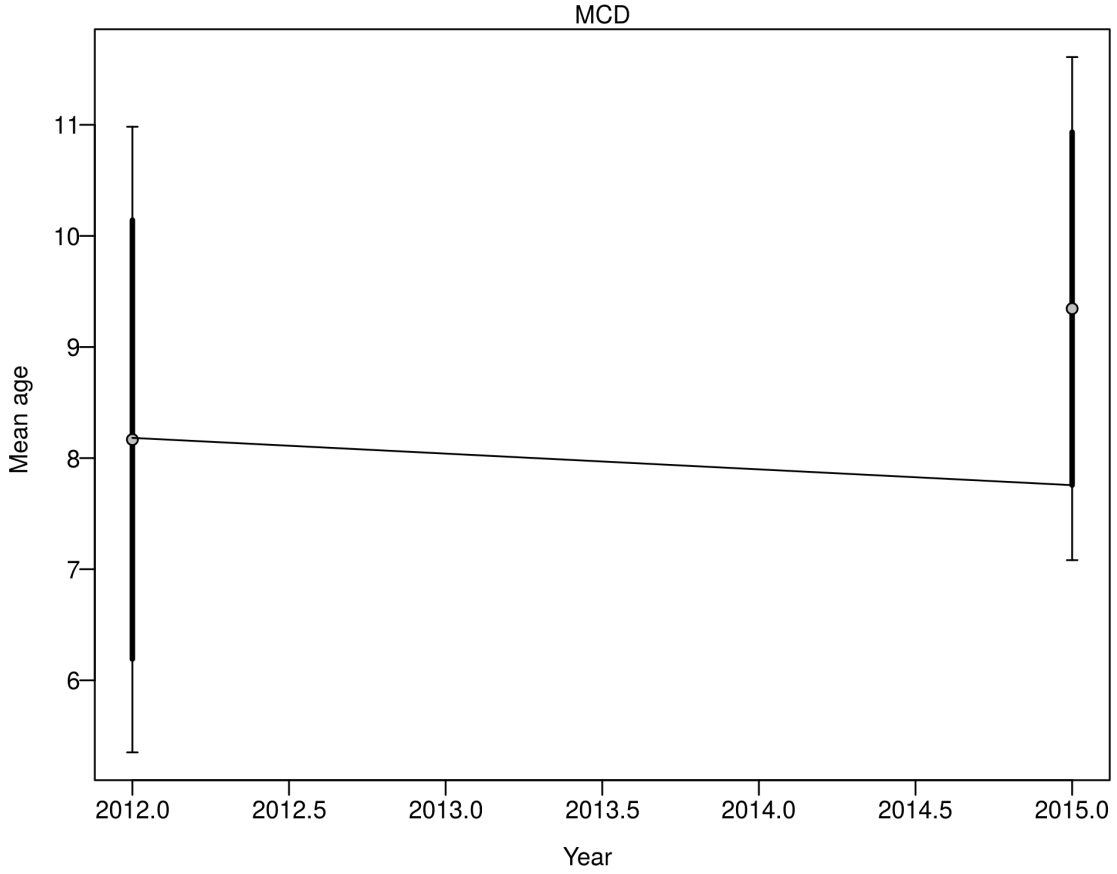

Figure 109: Observed mean age vs. the mean age predicted by the model based on fits to NEFSC survey (MCD) age at length conditional composition data used in the assessment model for Atlantic surfclam in the southern area. The thicker vertical lines show the standard deviation of the observed data and the thinner lines show the standard deviation after accounting for the data weighting adjustments used in the model.

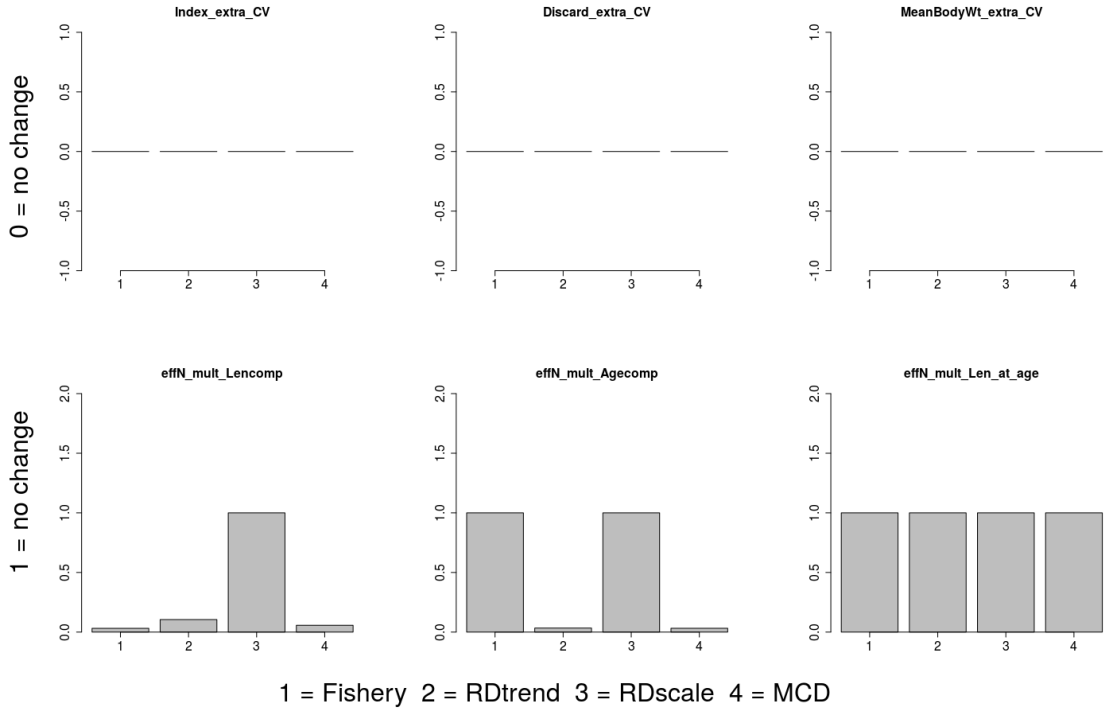

Figure 110: Adjustments made to variance components of model parameters used in the assessment model for Atlantic surfclam in the southern area. The bar plots reflect data weighting decisions. In the top row deviations from 0 are the amount added to the standard deviation around input parameters. In the bottom row, the value shown in the bar plot is multiplied by the input effective sample size associated with each composition component. Thus, for example a value of less than 1 represents a reduction in the relative weight of a component.

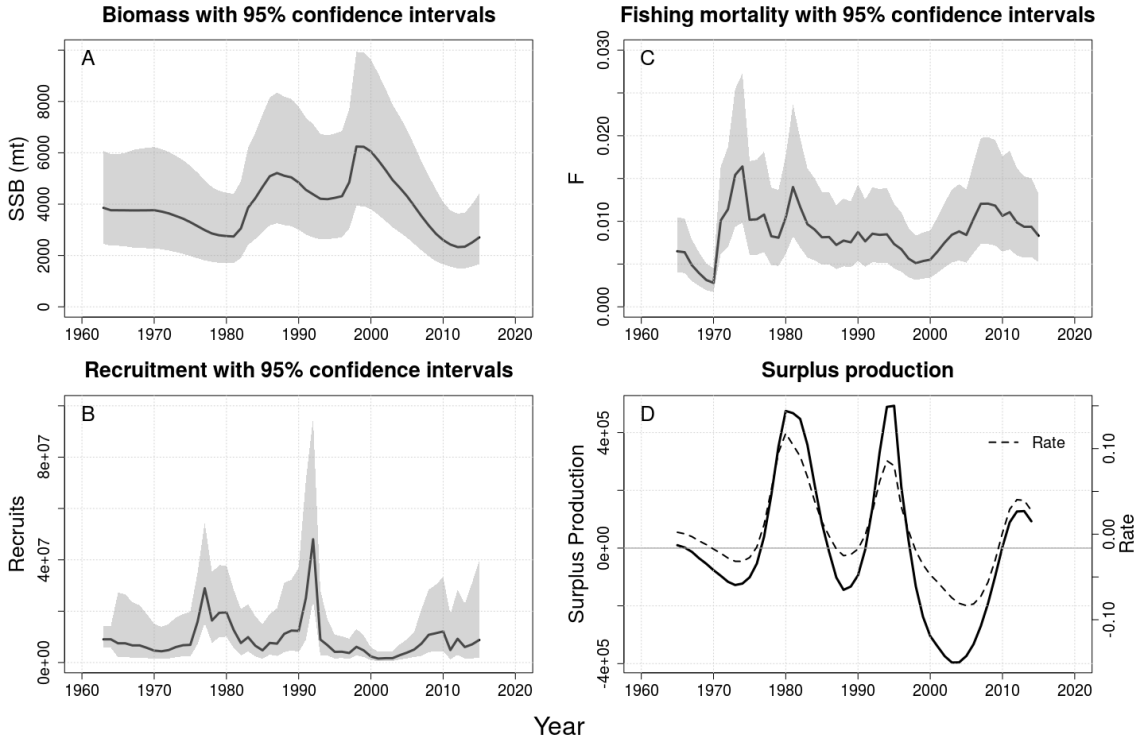

Figure 111: Estimated SSB and approximate 95% asymmetric confidence interval (A), estimated recruitment and approximate 95% asymmetric confidence interval (B), estimated fully selected fishing mortality and approximate 95% asymmetric confidence interval (C), and surplus production with surplus production rate (D), for the southern area.

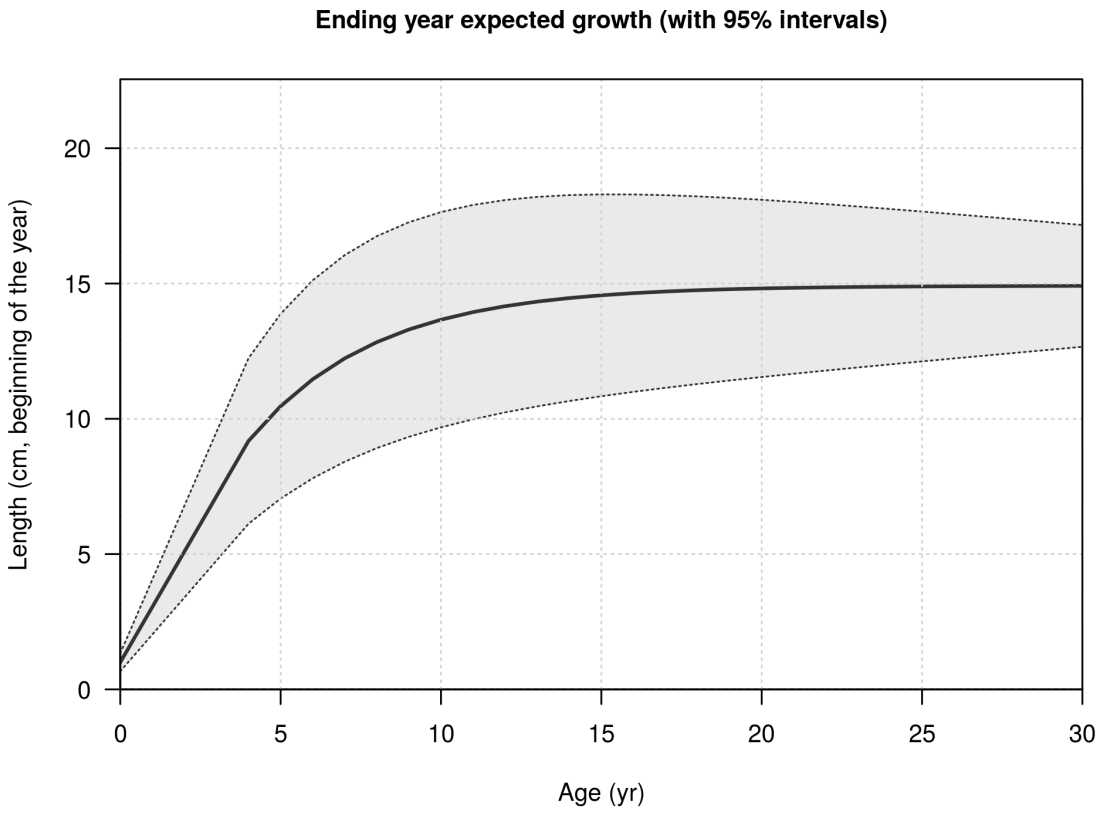

Figure 112: Length at age relationship used in the assessment model for Atlantic surfclam in the northern area.

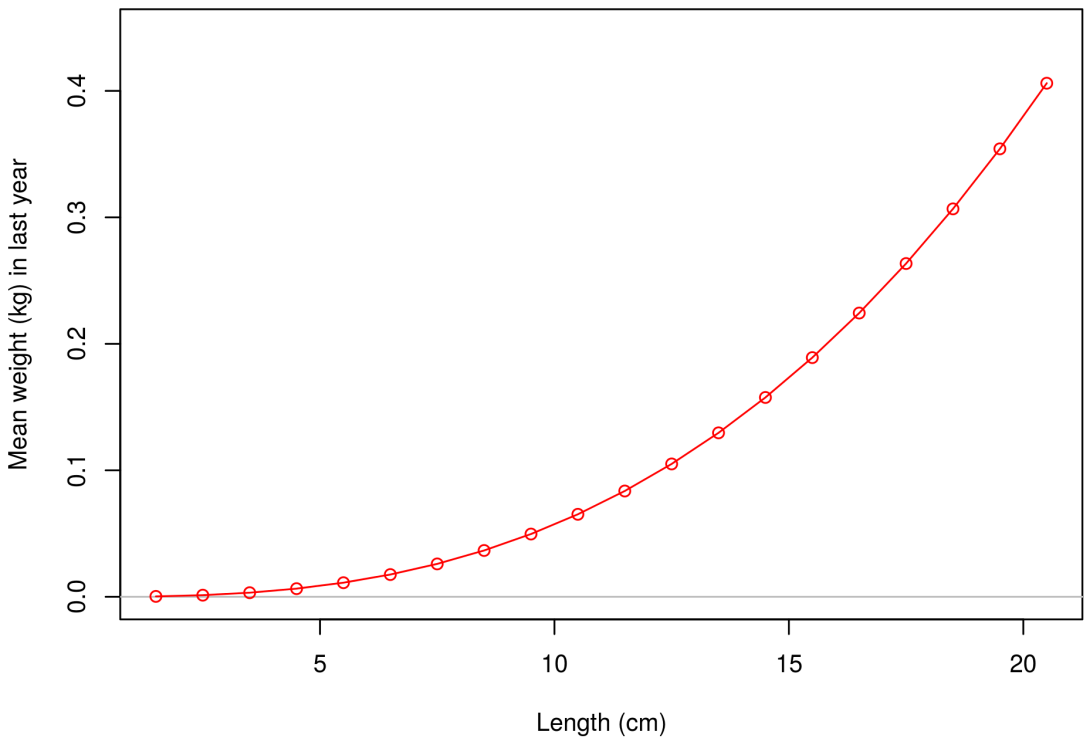

Figure 113: Weight at length relationship used in the assessment model for Atlantic surfclam in the northern area.

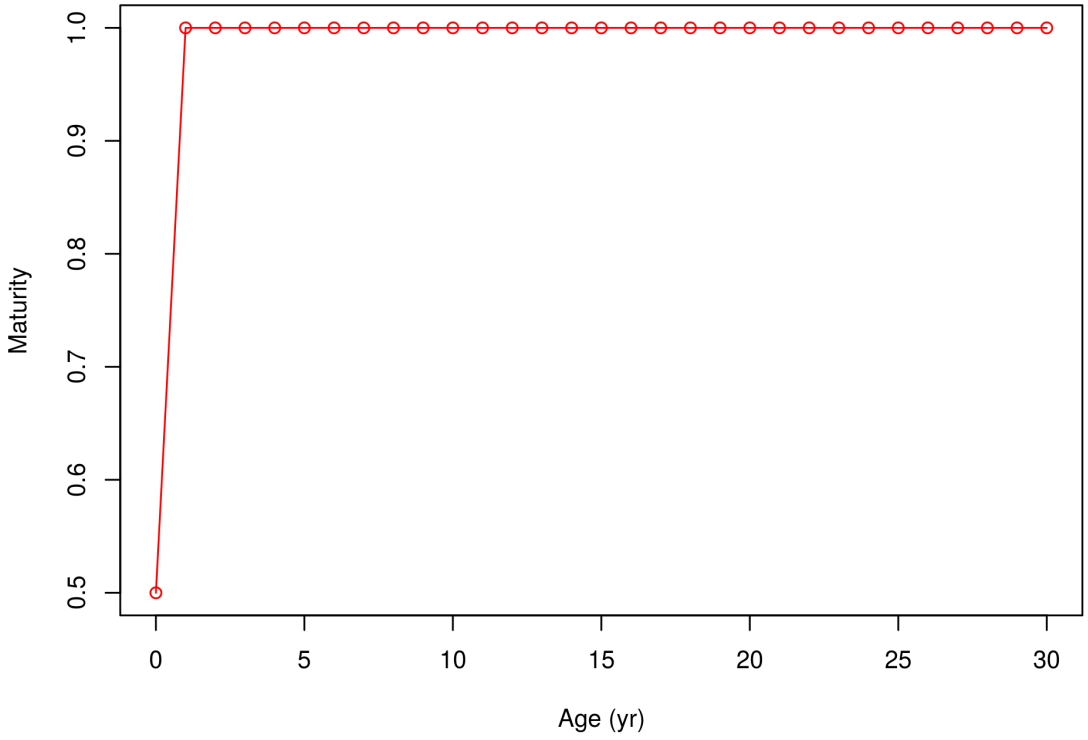

Figure 114: Maturity at age relationship used in the assessment model for Atlantic surfclam in the northern area.

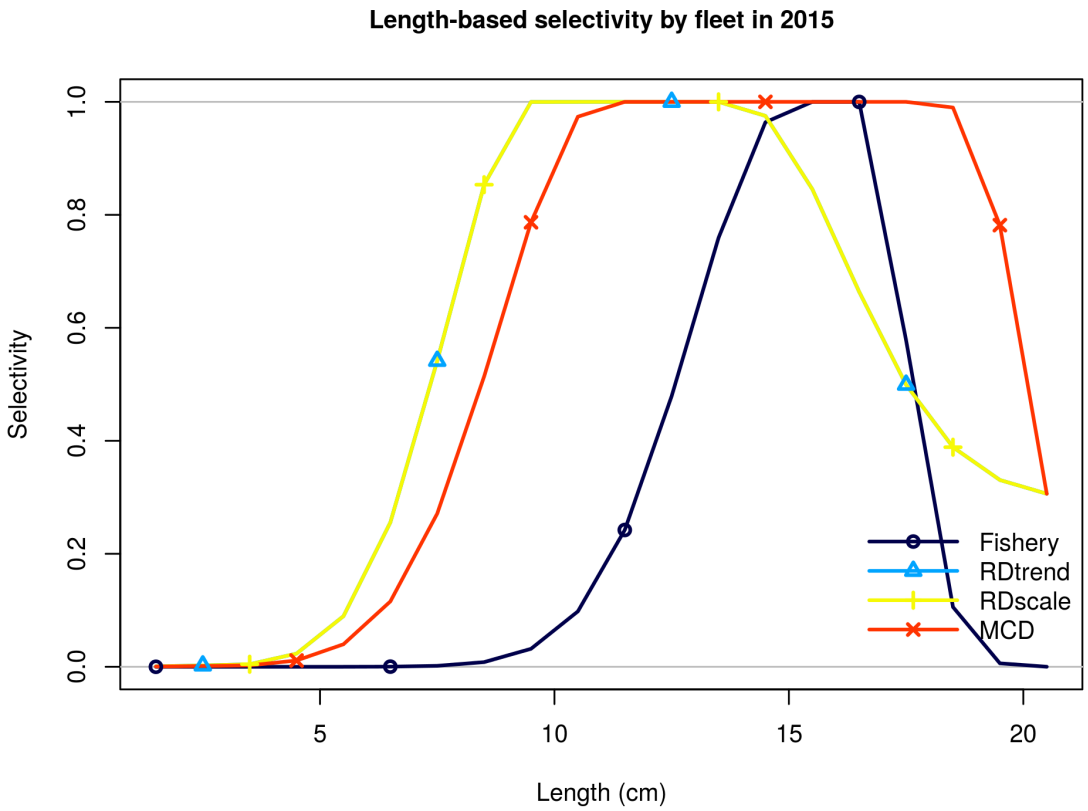

Figure 115: Comparison of selectivity curves for each fleet included in the assessment model for Atlantic surfclam in the northern area. RD trend and RD scale have identical selectivities because they are from the same survey (RD scale was not included in the likelihood).

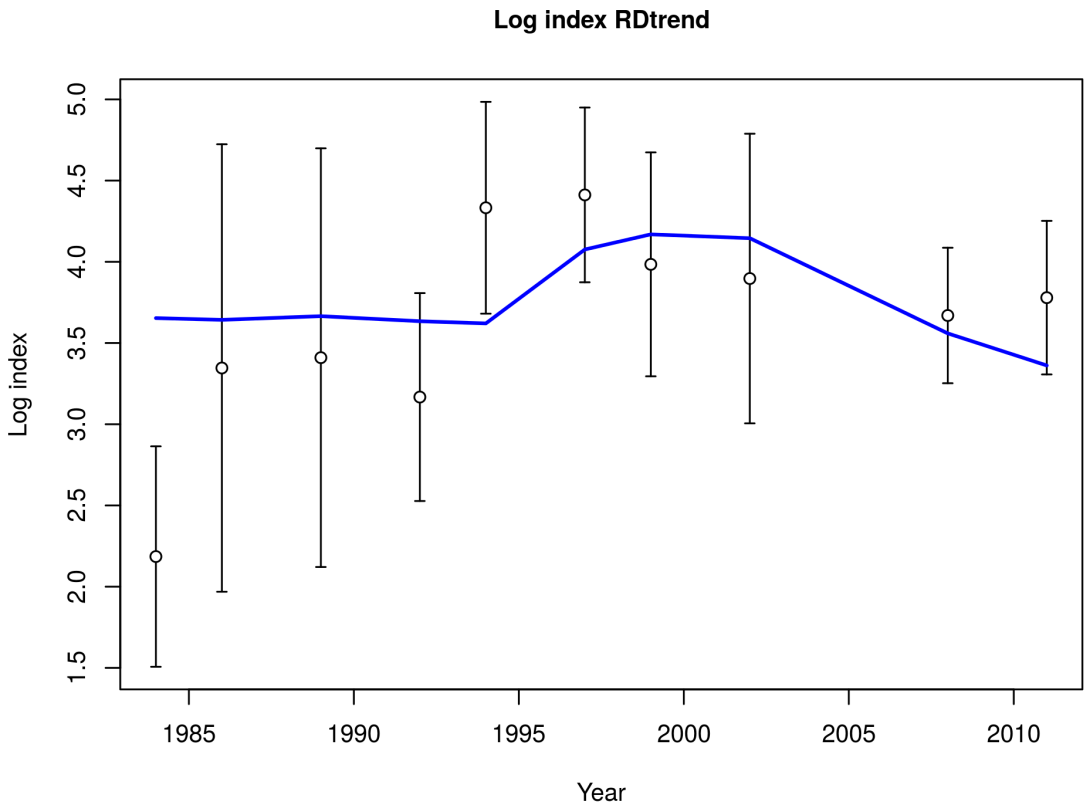

Figure 116: Fit to log index data on log scale for RDtrend survey for Atlantic surfclam in the northern area. Vertical lines are 95% confidence intervals.

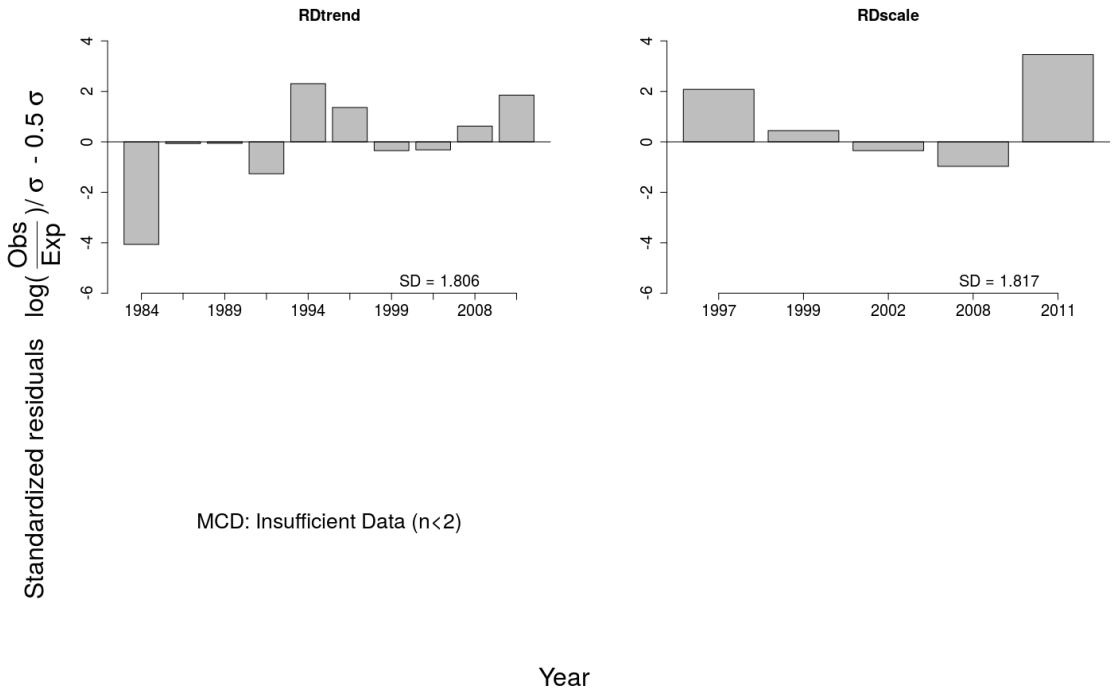

Figure 117: Residuals from the model fits to each survey index used in the assessment model for Atlantic surfclam in the northern area by year. The standard deviation of the residuals over the time series is shown over the horizontal axis.

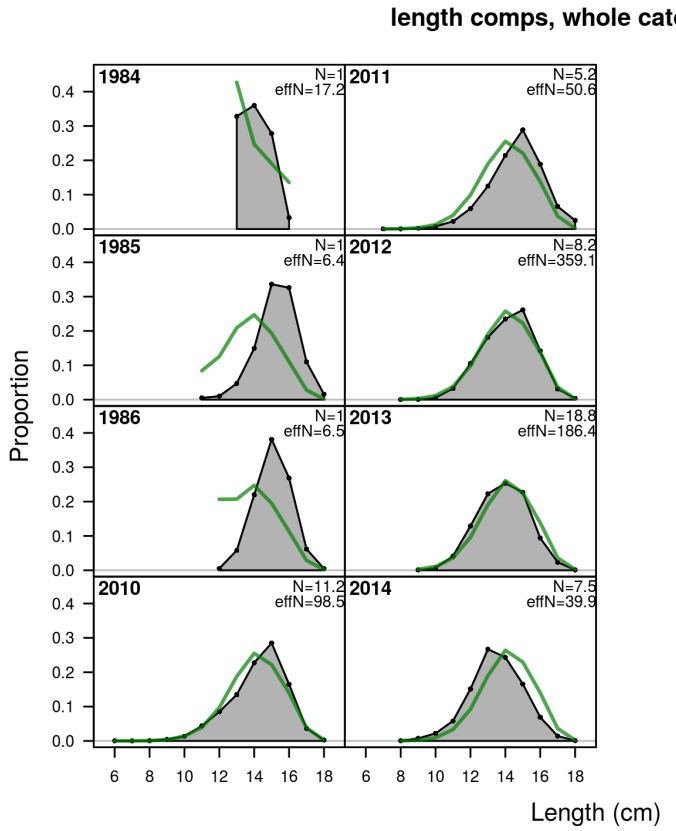

Figure 118: Model fit to length composition data from the commercial fishery used in the assessment model for Atlantic surfclam in the northern area.

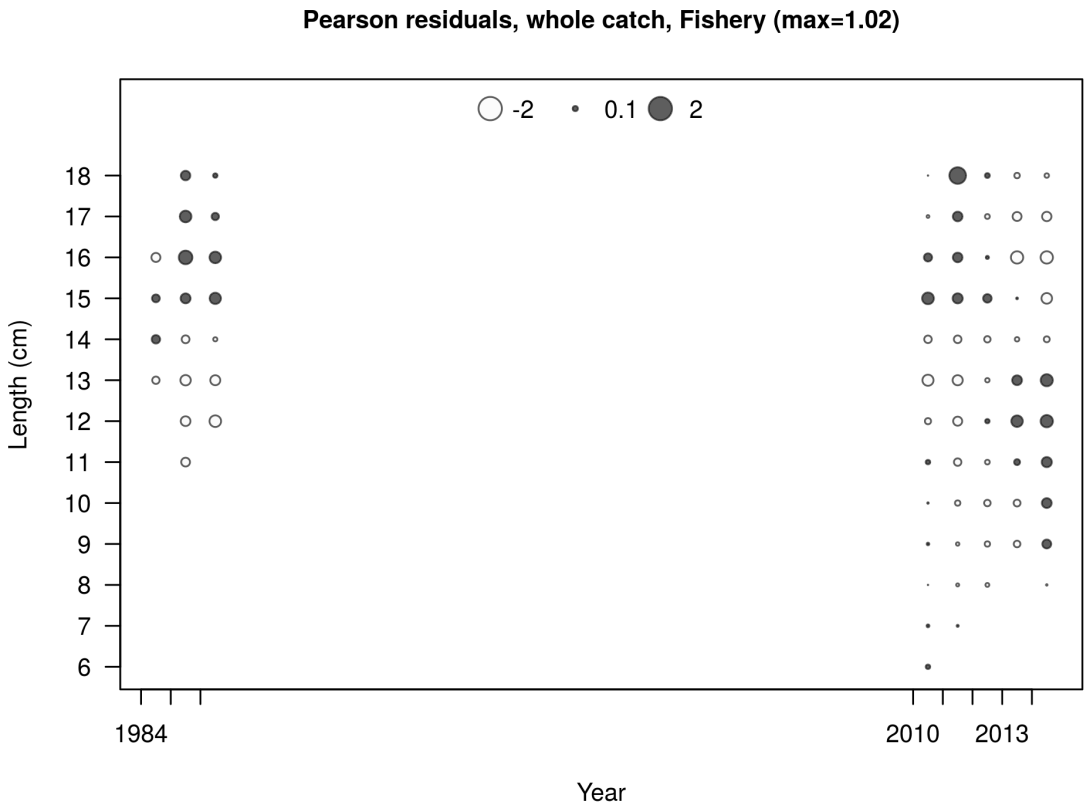

Figure 119: Pearson residuals from the fit to commercial length composition data used in the assessment model for Atlantic surfclam in the northern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

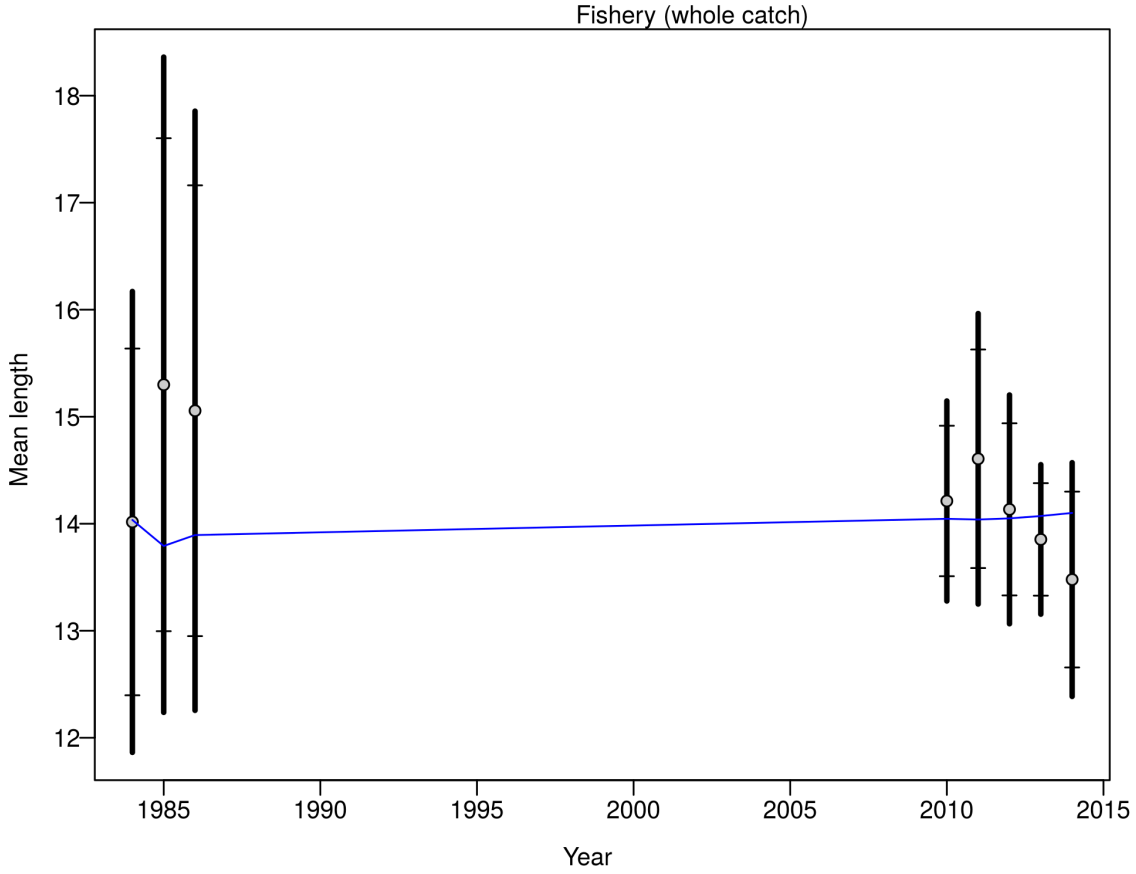

Figure 120: Observed mean length vs. the mean length predicted by the model based on fits to commercial length composition data.

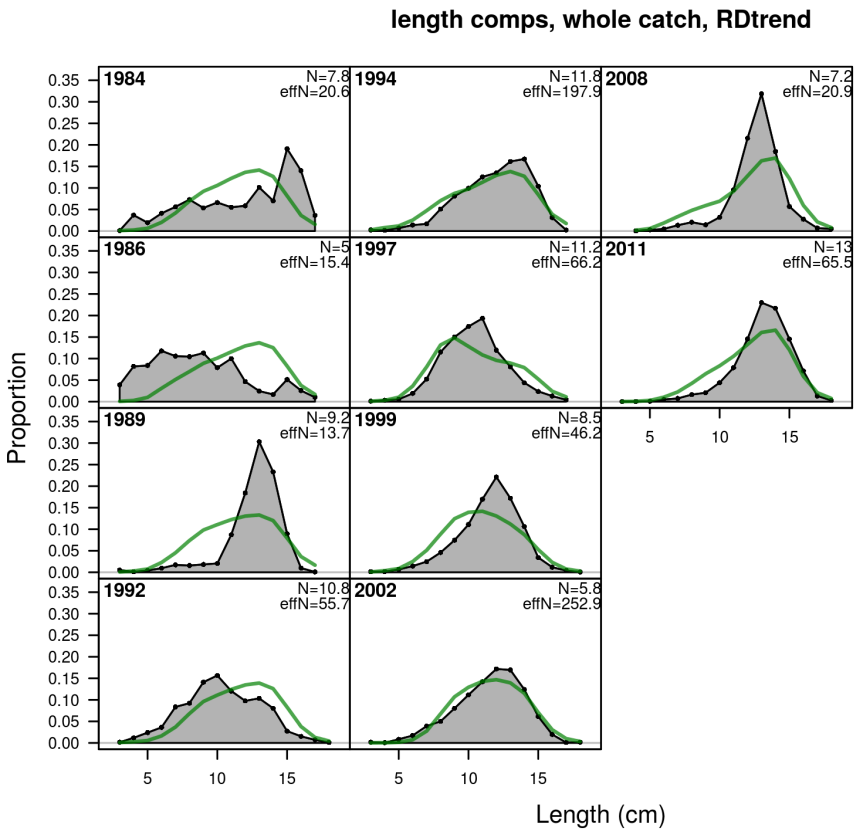

Figure 121: Model fit to length composition data from the NEFSC survey (RD) used in the assessment model for Atlantic surfclam in the northern area.

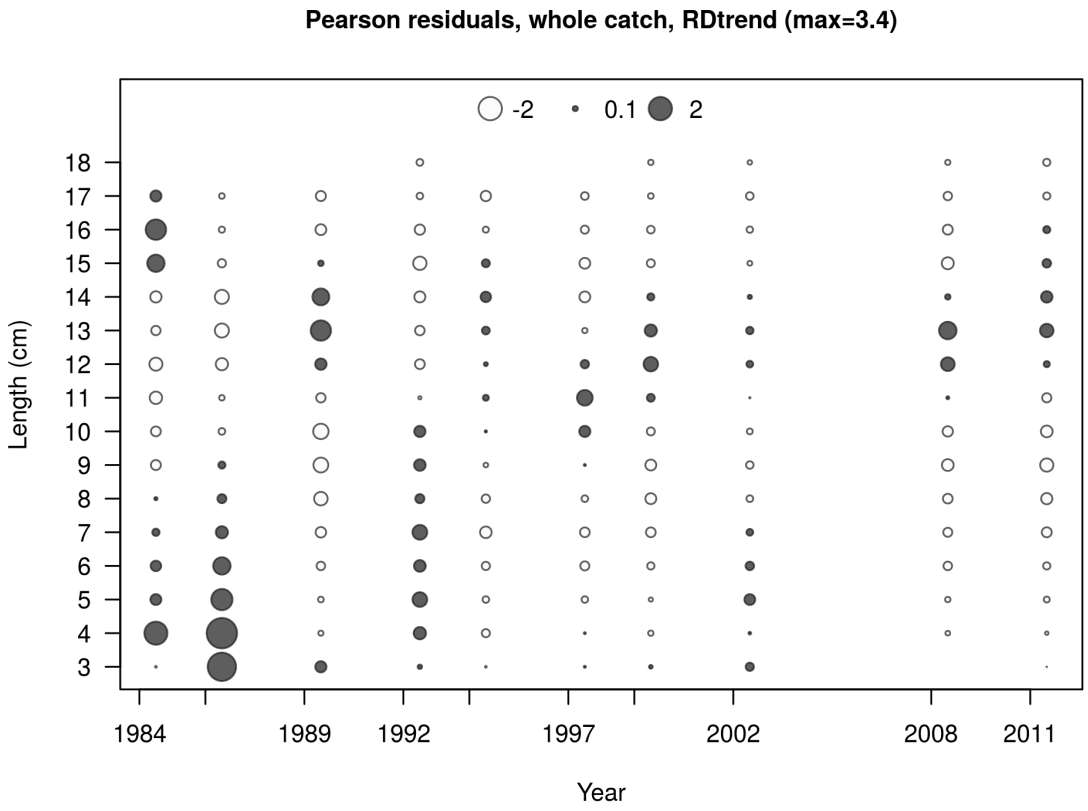

Figure 122: Pearson residuals from the fit to NEFSC survey (RD) length composition data used in the assessment model for Atlantic surfclam in the northern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

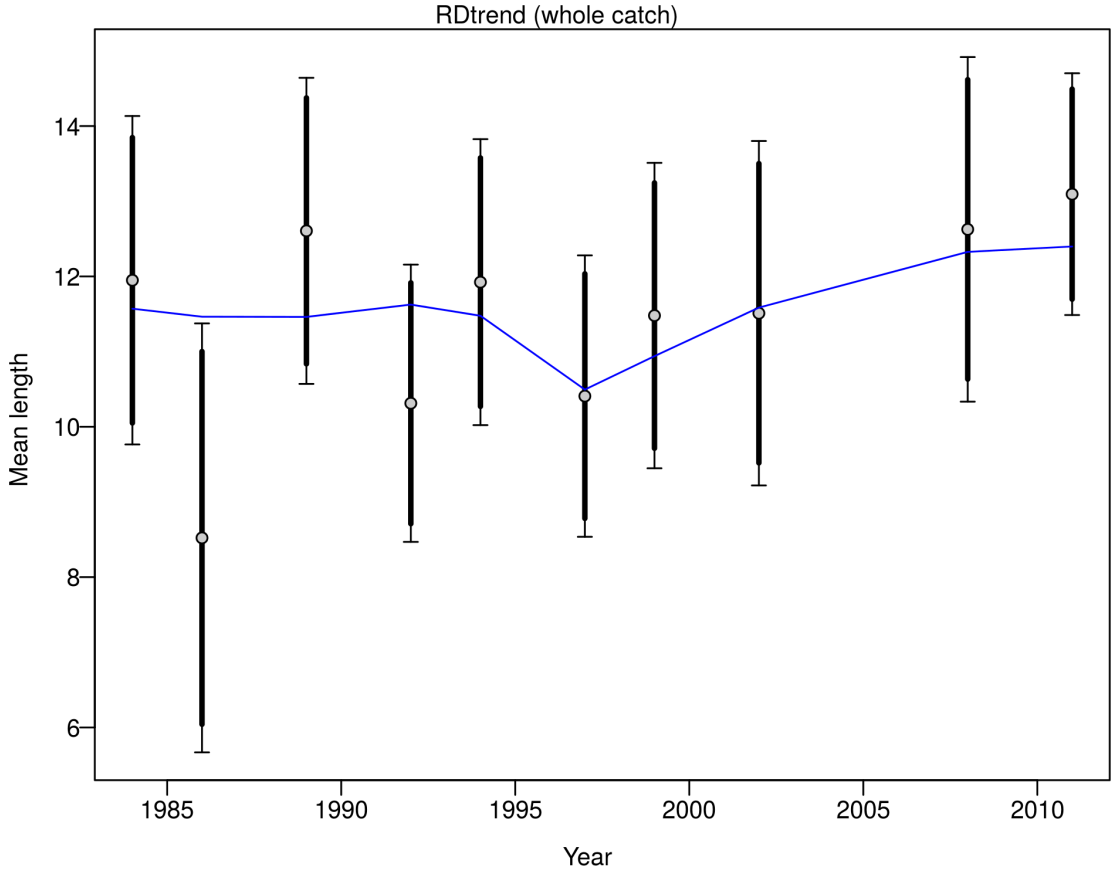

Figure 123: Observed mean length vs. the mean length predicted by the model based on fits to NEFSC survey (RD) length composition data used in the assessment model for Atlantic surfclam in the northern area. The thicker vertical lines show the standard deviation of the observed data and the thinner lines show the standard deviation after accounting for the data weighting adjustments used in the model.

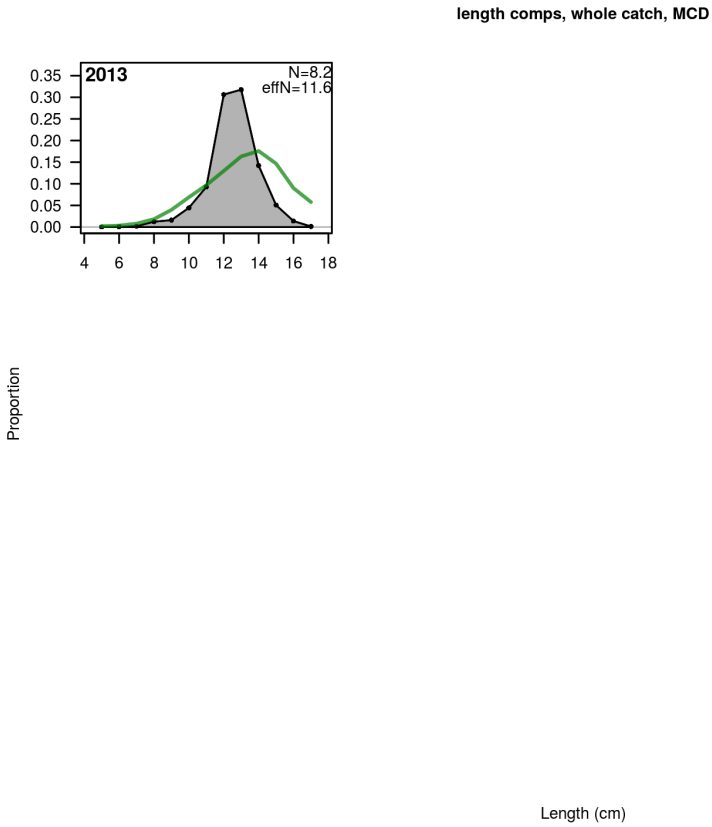

Figure 124: Model fit to length composition data from the NEFSC survey (MCD) used in the assessment model for Atlantic surfclam in the northern area.

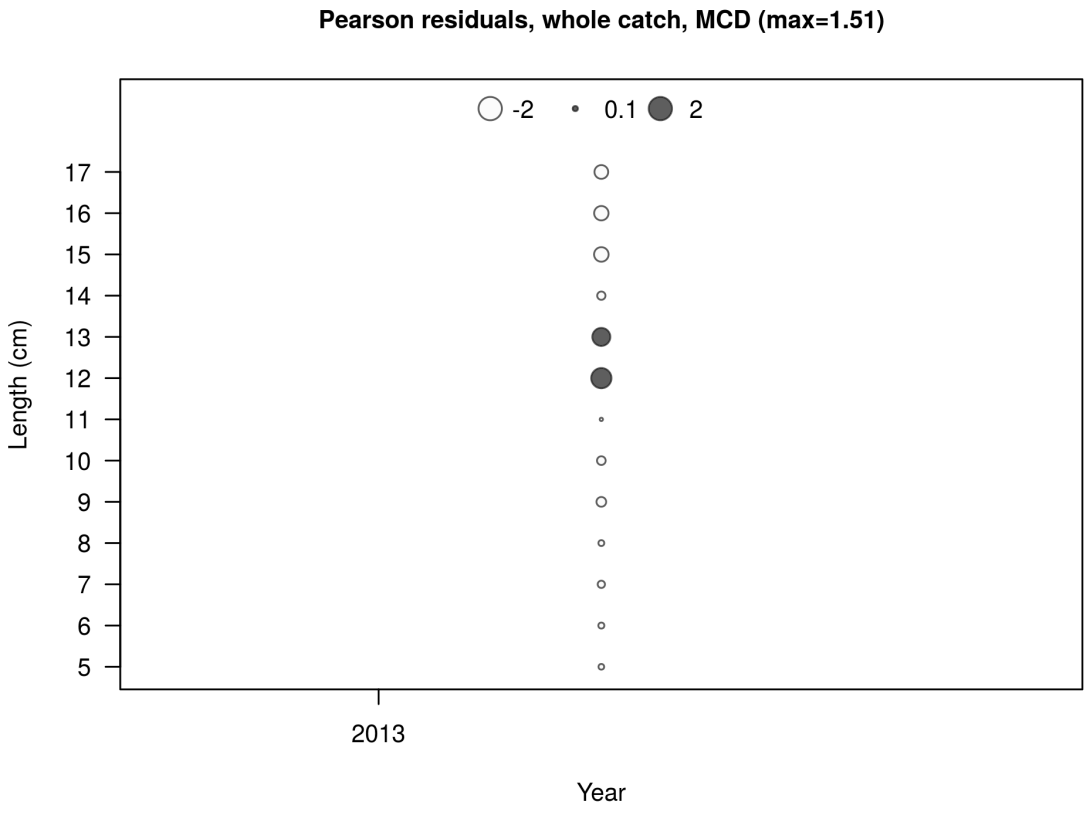

Figure 125: Pearson residuals from the fit to NEFSC survey (MCD) length composition data used in the assessment model for Atlantic surfclam in the northern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

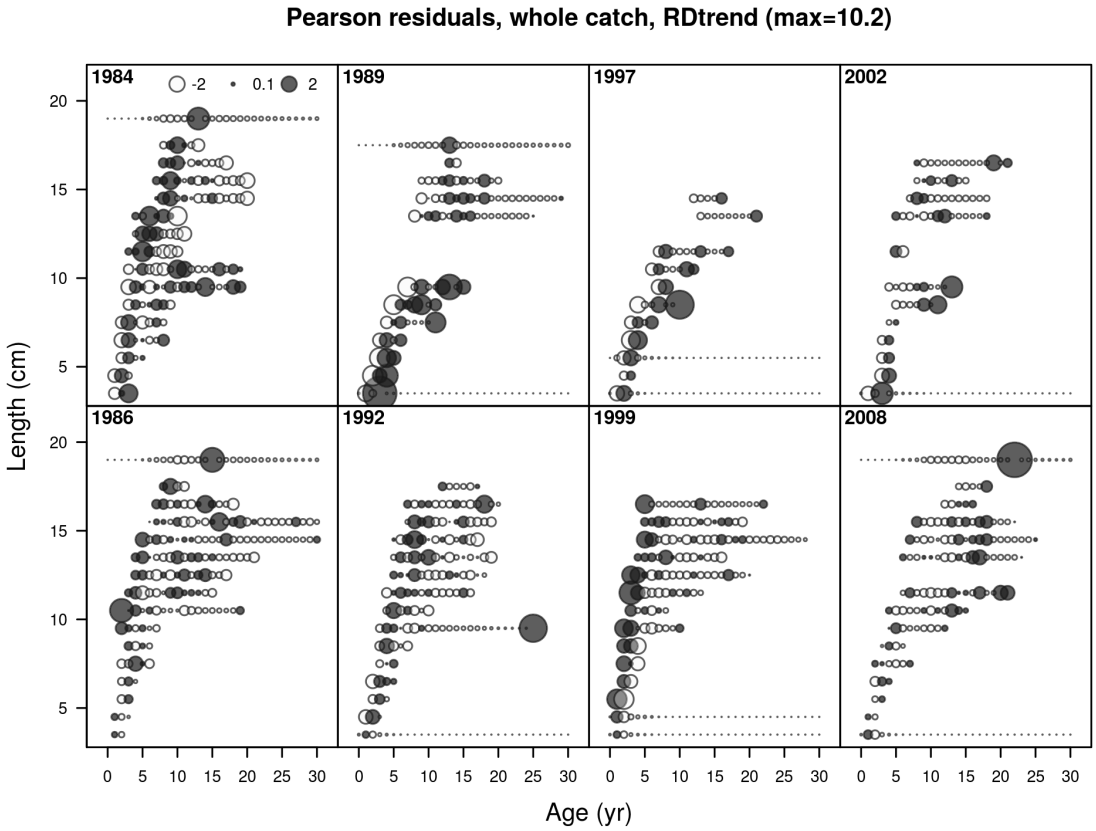

Figure 126: Pearson residuals from the fit to NEFSC survey (RD) conditional age at length composition data used in the assessment model for Atlantic surfclam in the northern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

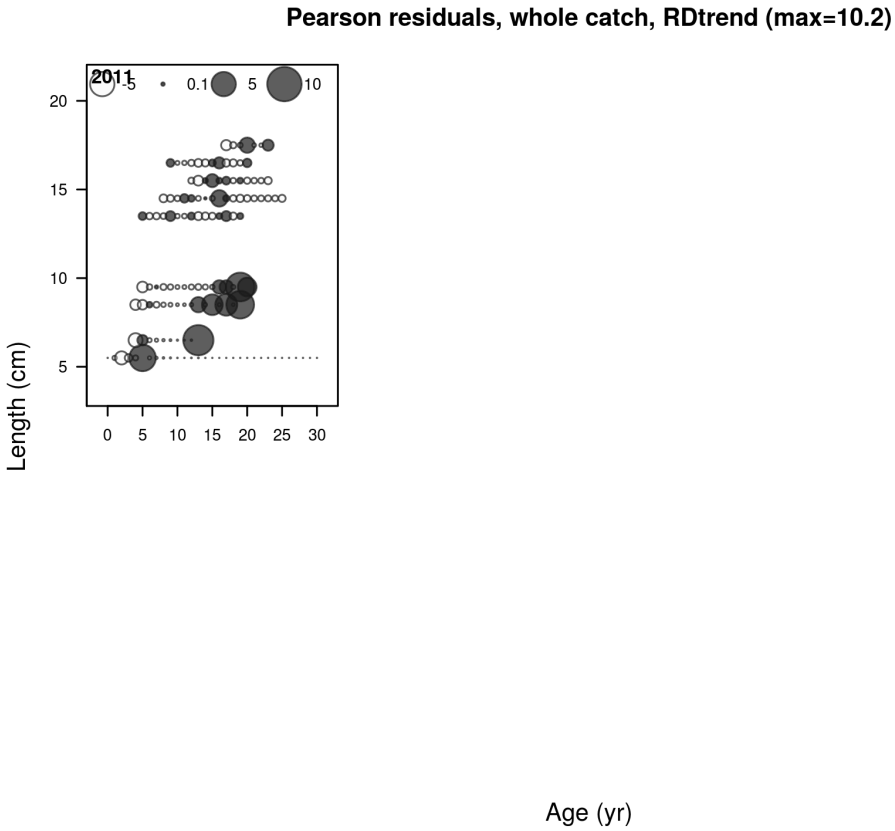

Figure 126 cont.

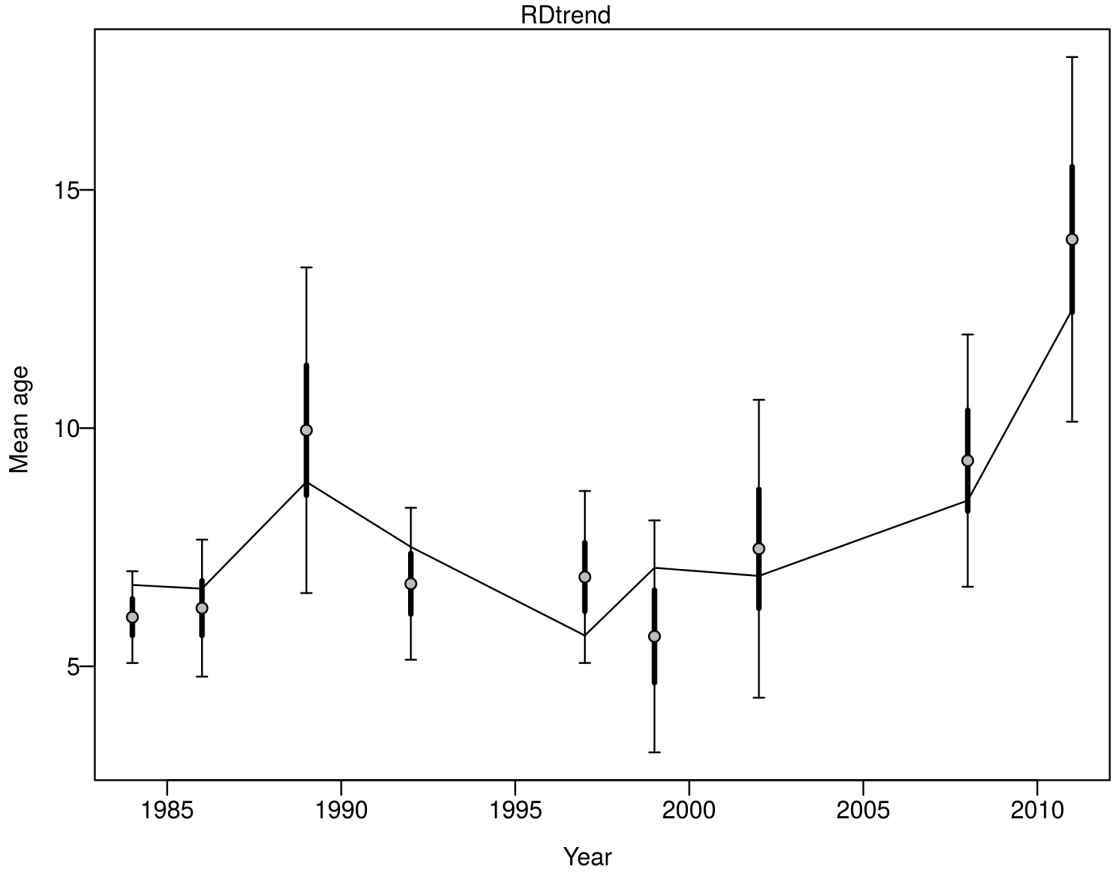

Figure 127: Observed mean age vs. the mean age predicted by the model based on fits to NEFSC survey (RD) age at length conditional composition data used in the assessment model for Atlantic surfclam in the northern area. The thicker vertical lines show the standard deviation of the observed data and the thinner lines show the standard deviation after accounting for the data weighting adjustments used in the model.

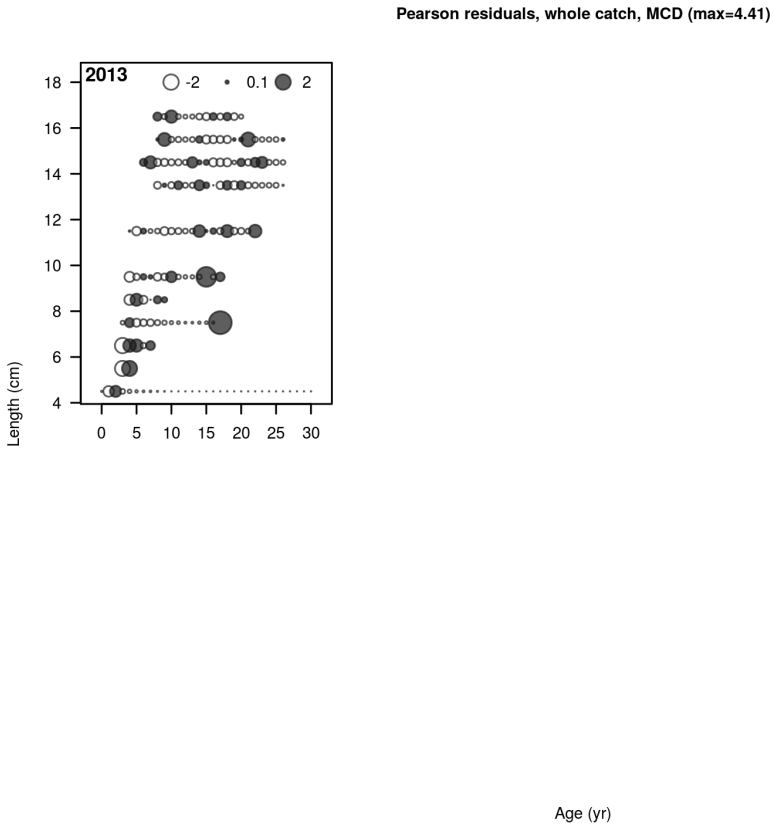

Figure 128: Pearson residuals from the fit to NEFSC survey (MCD) conditional age at length composition data used in the assessment model for Atlantic surfclam in the northern area. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

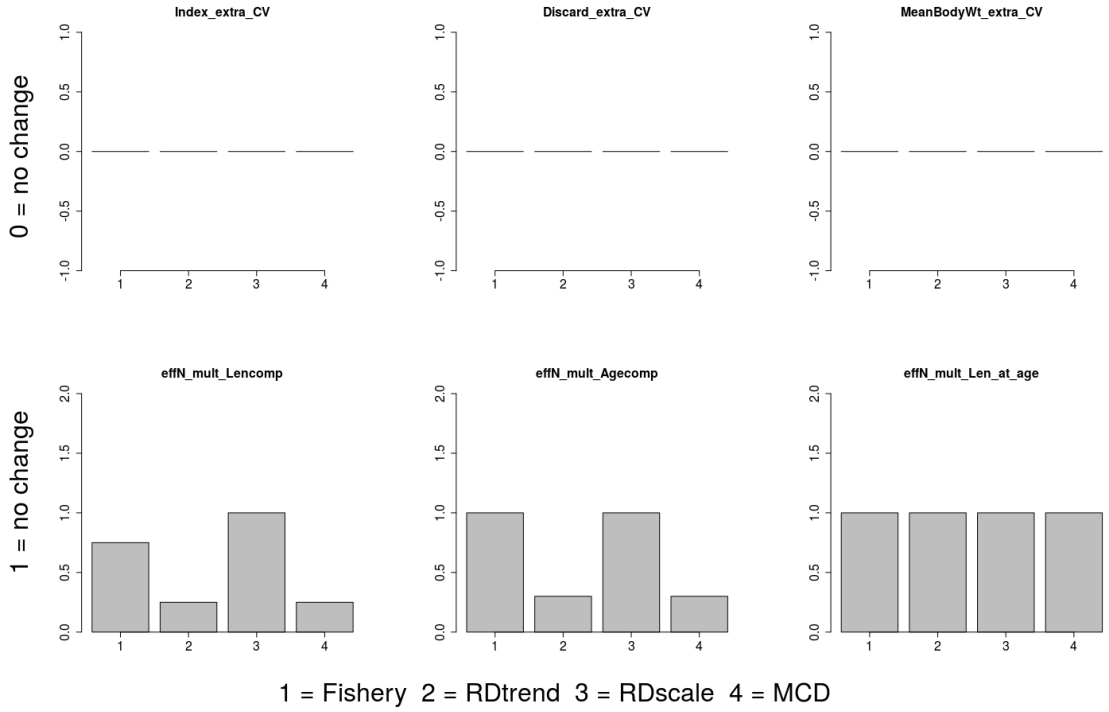

Figure 129: Adjustments made to variance components of model parameters used in the assessment model for Atlantic surfclam in the northern area. The bar plots reflect data weighting decisions. In the top row deviations from 0 are the amount added to the standard deviation around input parameters. In the bottom row, the value shown in the bar plot is multiplied by the input effective sample size associated with each composition component. Thus, for example a value of less than 1 represents a reduction in the relative weight of a component.

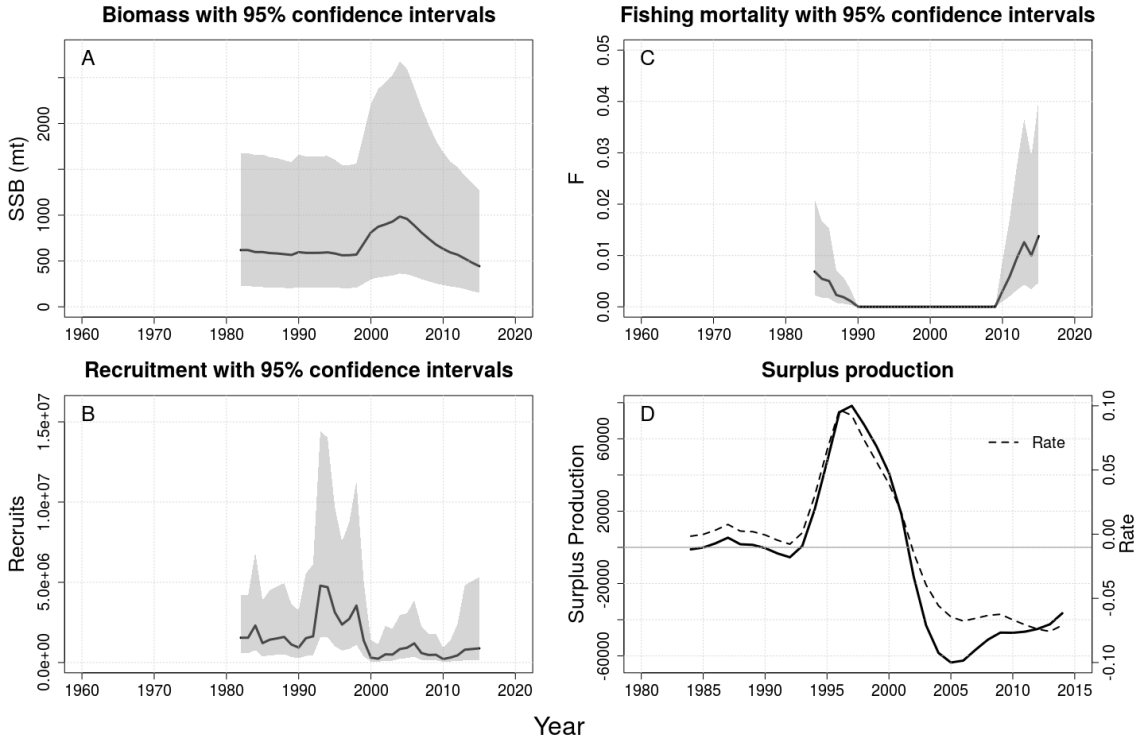

Figure 130: Estimated summary biomass and approximate 95% asymmetric confidence interval (A), estimated recruitment and approximate 95% asymmetric confidence interval (B), estimated fully selected fishing mortality and approximate 95% asymmetric confidence interval (C), and surplus production with surplus production rate (D), for Atlantic surfclam in the northern area.

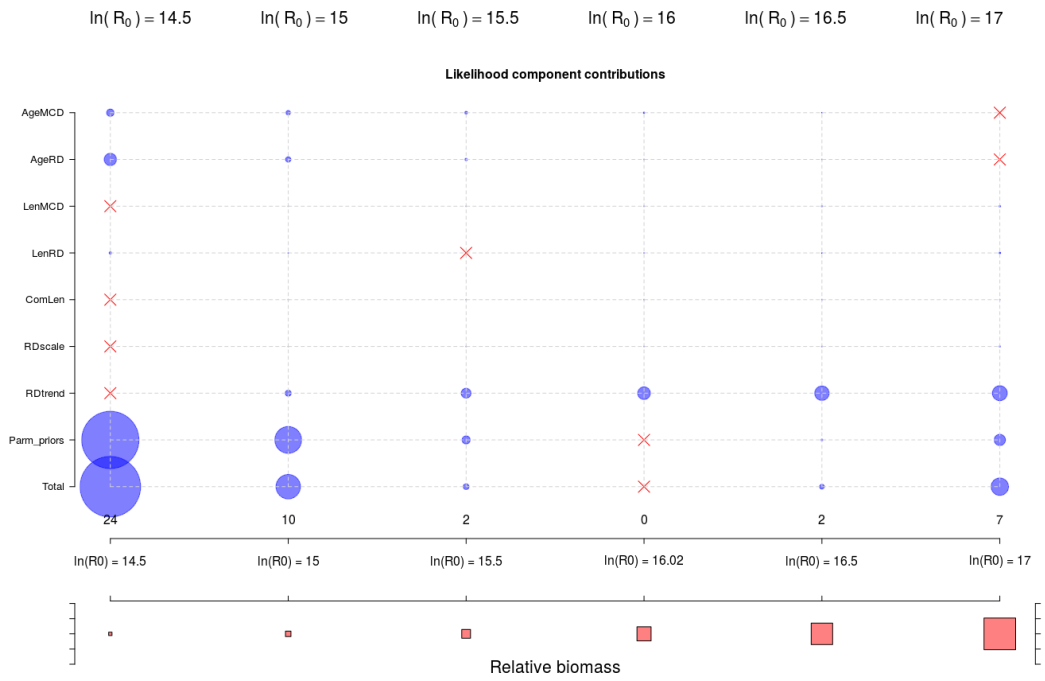

Figure 131: Likelihood profile over the virgin recruitment parameter (R0). A total of 5 model runs are depicted here. In each case, the R0 parameter was fixed at a different value. The columns of the large plot show how the component and total likelihoods change as the R0 parameter is varied. Each column of the large bubble plot represents one model run and the non-zero likelihood components in each run are shown in rows. For each row, the minimum likelihood component value was subtracted from each individual value, such that the minimum value in each row is represented by a red x. Bubbles are proportional to the values of each likelihood component in each run. The base value for R0 is the value at the model solution (middle column). The difference (in likelihood units) between each column and the minimum total likelihood is shown just above the x axis. Conflicts within the data are apparent when the minimum likelihood values (red x's) occur in different columns for each row. The red boxes show the relative difference in estimated terminal year biomass between runs.

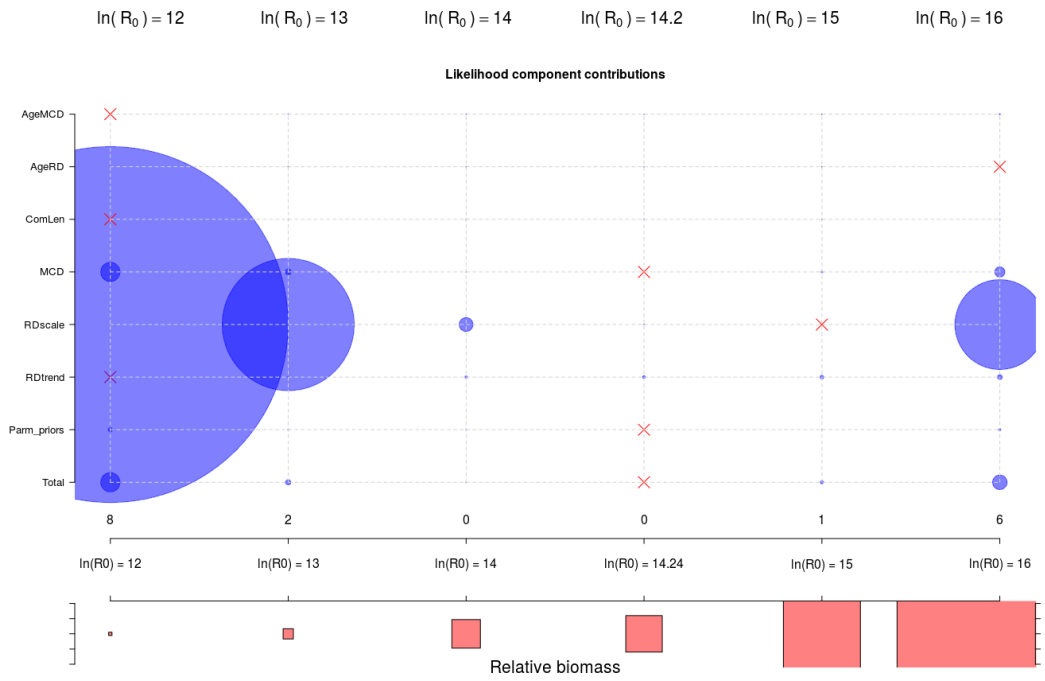

Figure 132: Likelihood profile over the virgin recruitment parameter (R0). A total of 5 model runs are depicted here. In each case, the R0 parameter was fixed at a different value. The columns of the large plot show how the component and total likelihoods change as the R0 parameter is varied. Each column of the large bubble plot represents one model run and the non-zero likelihood components in each run are shown in rows. For each row, the minimum likelihood component value was subtracted from each individual value, such that the minimum value in each row is represented by a red x. Bubbles are proportional to the values of each likelihood component in each run. The base value for R0 is the value at the model solution (middle column). The difference (in likelihood units) between each column and the minimum total likelihood is shown just above the x axis. Conflicts within the data are apparent when the minimum likelihood values (red x's) occur in different columns for each row. The red boxes show the relative difference in estimated terminal year biomass between runs.

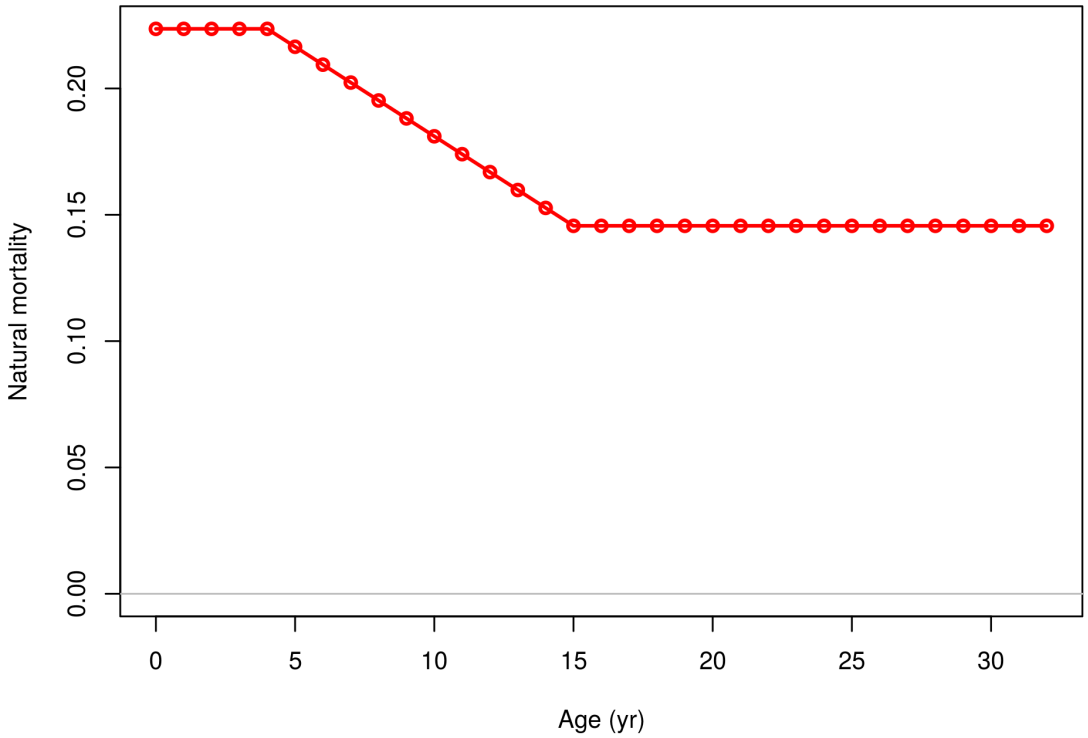

Figure 133: Natural mortality at age estimated in a model sensitivity run for Atlantic surfclam in the southern area.

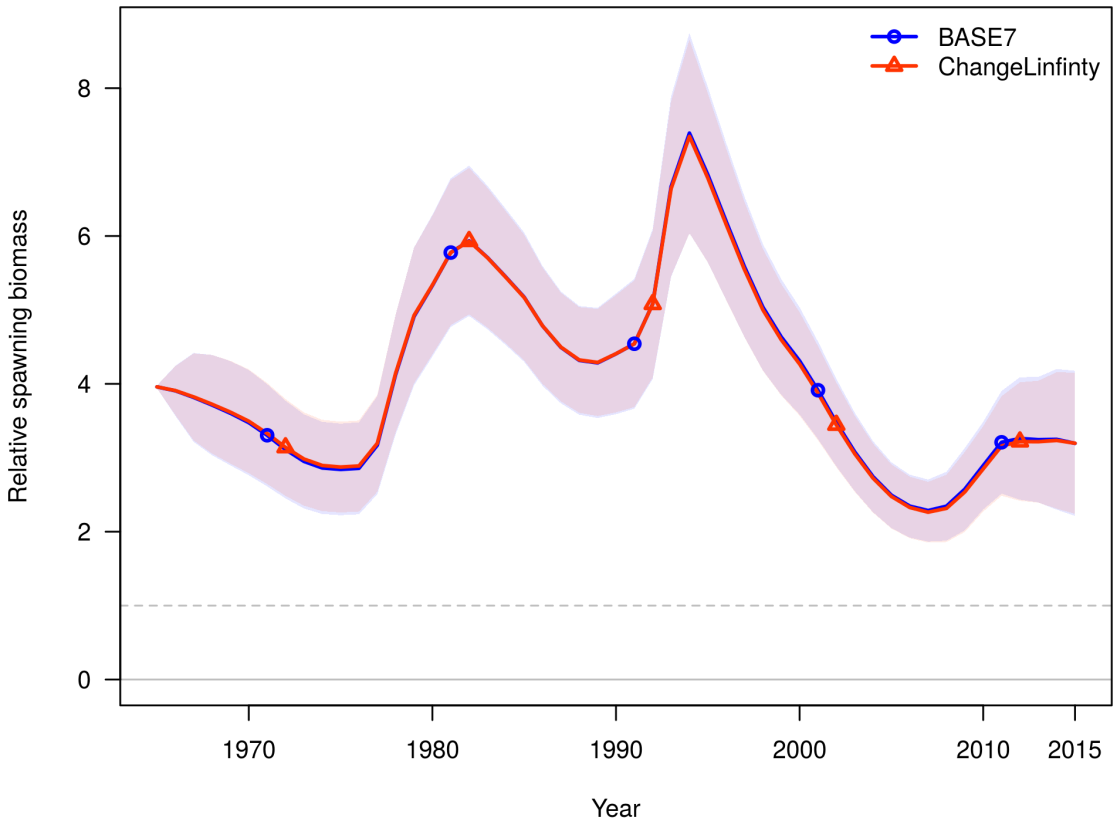

Figure 134: A comparison of the biomass trends of the base model (BASE7) for Atlantic surfclam in the southern area and a sensitivity run in which the length at A_{max} was estimated for each of two time blocks (<2000 and >1999). There was very little difference between the two runs. The trends depict the ratio of the biomass in each year to B_0 and include a dashed line at $\frac{B}{B_0} = 0.25$.

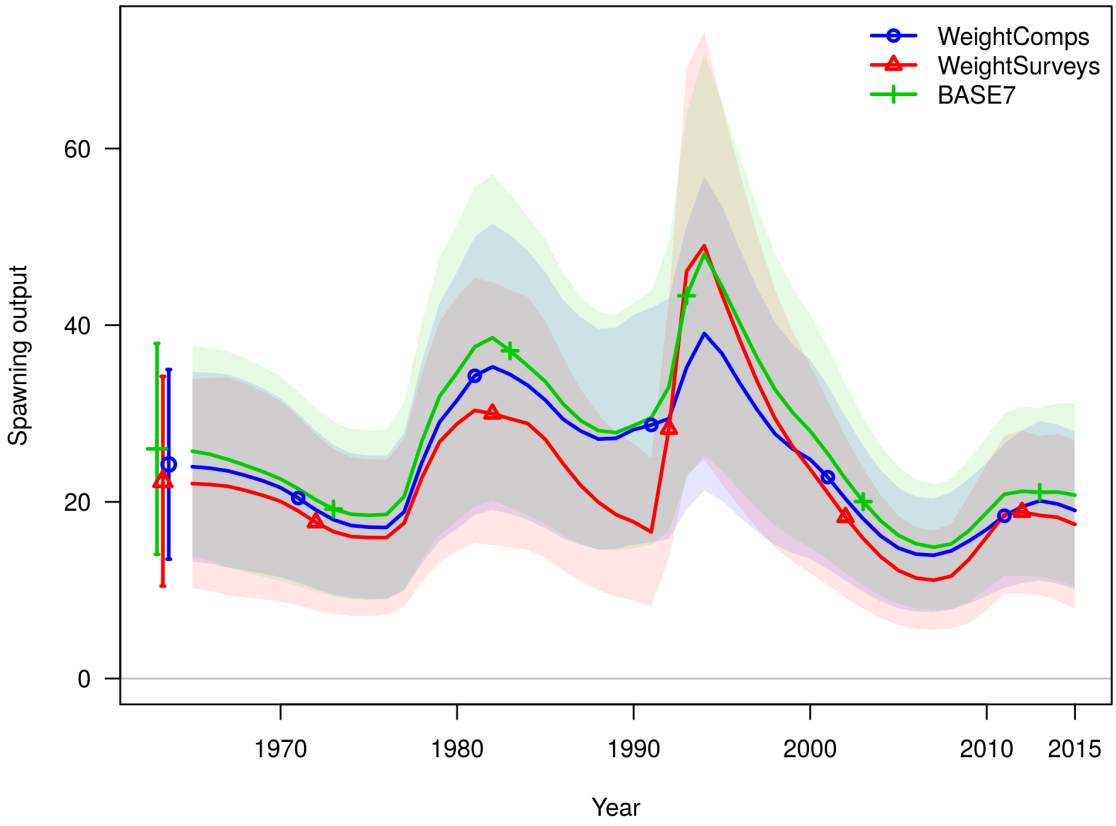

Figure 135: A comparison of the estimated biomass scales between the base run for Atlantic surfclam in the southern area (BASE7) and sensitivity runs in which the likelihood component associated with the fit the RD survey was increased by an order of magnitude (WeightSurveys), and where the variance associated with the composition data (both length and age at length) was adjusted so that the harmonic mean of the effective sample size matched the mean of the input sample size.

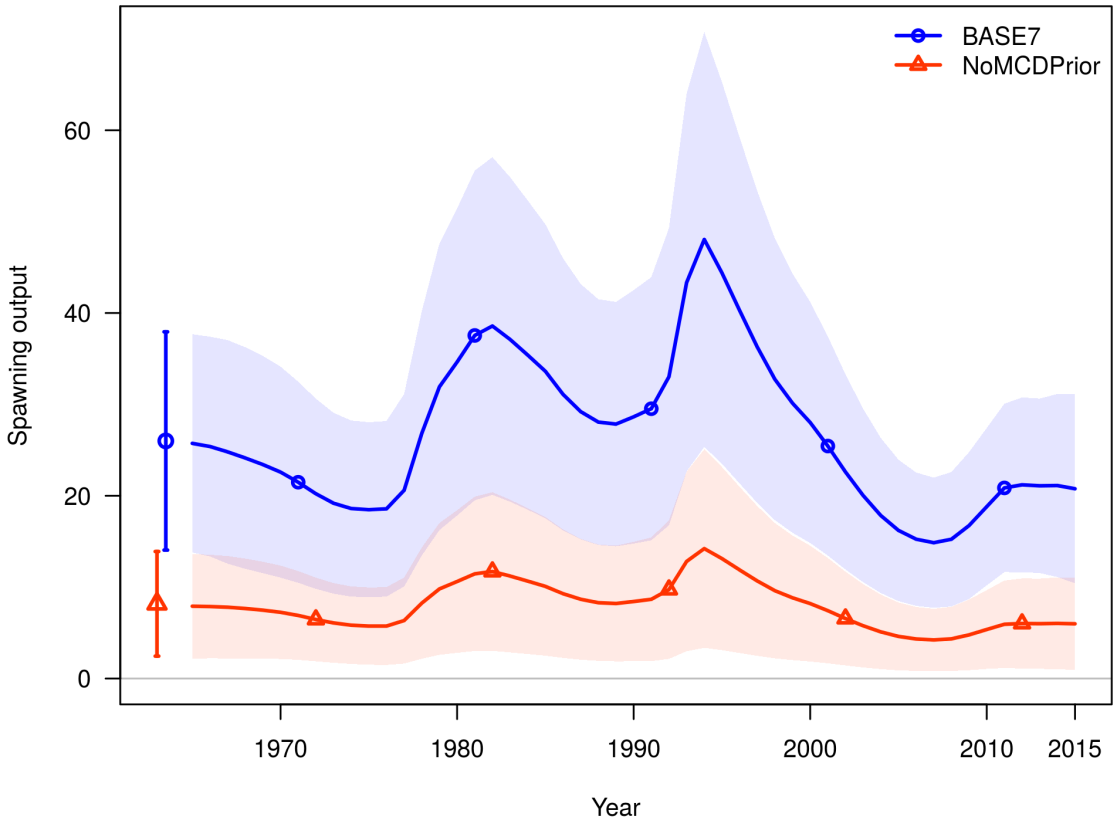

Figure 136: Biomass scale in a model sensitivity run for Atlantic surfclam in the southern area in which the prior for the MCD survey was not used compared to the base model (BASE7). The scale differs between the two but the trend is similar.

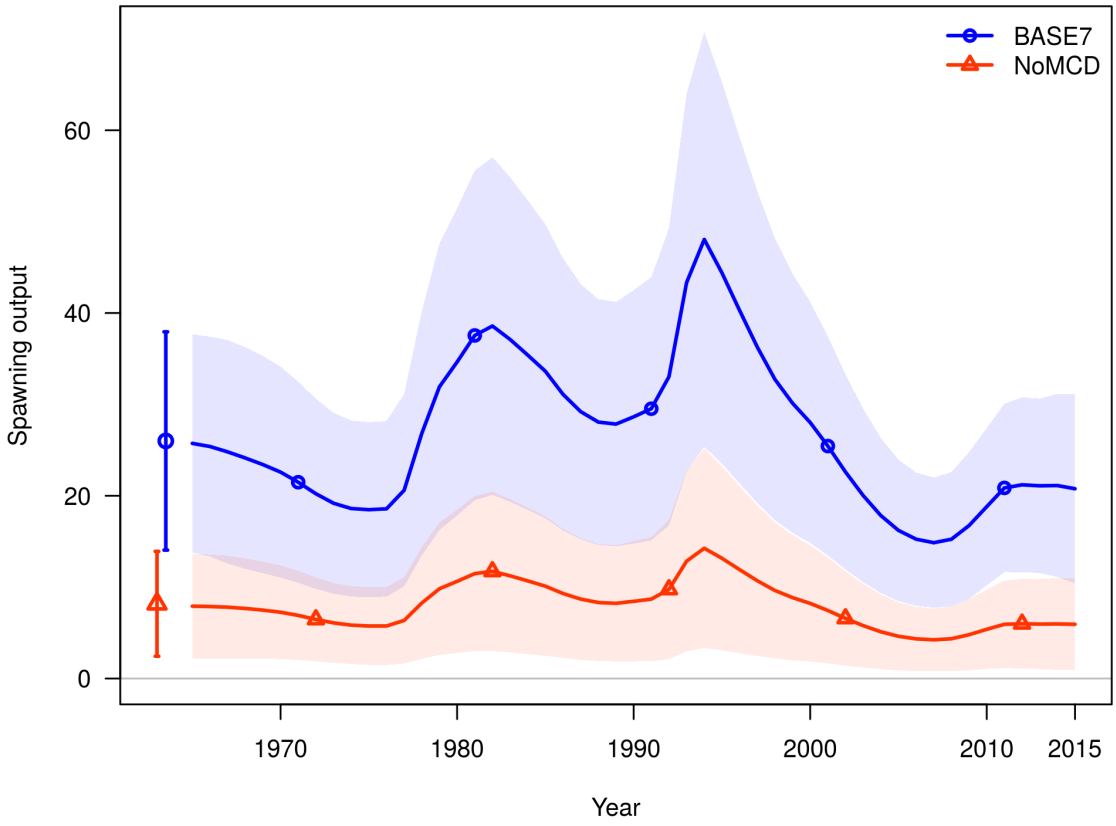

Figure 137: Biomass trend in a model sensitivity run for Atlantic surfclam in the southern area in which the likelihood component associated with the fit the MCD survey was reduced to 0, compared to the base model (BASE7). The scale differs between the two but the trend is similar.

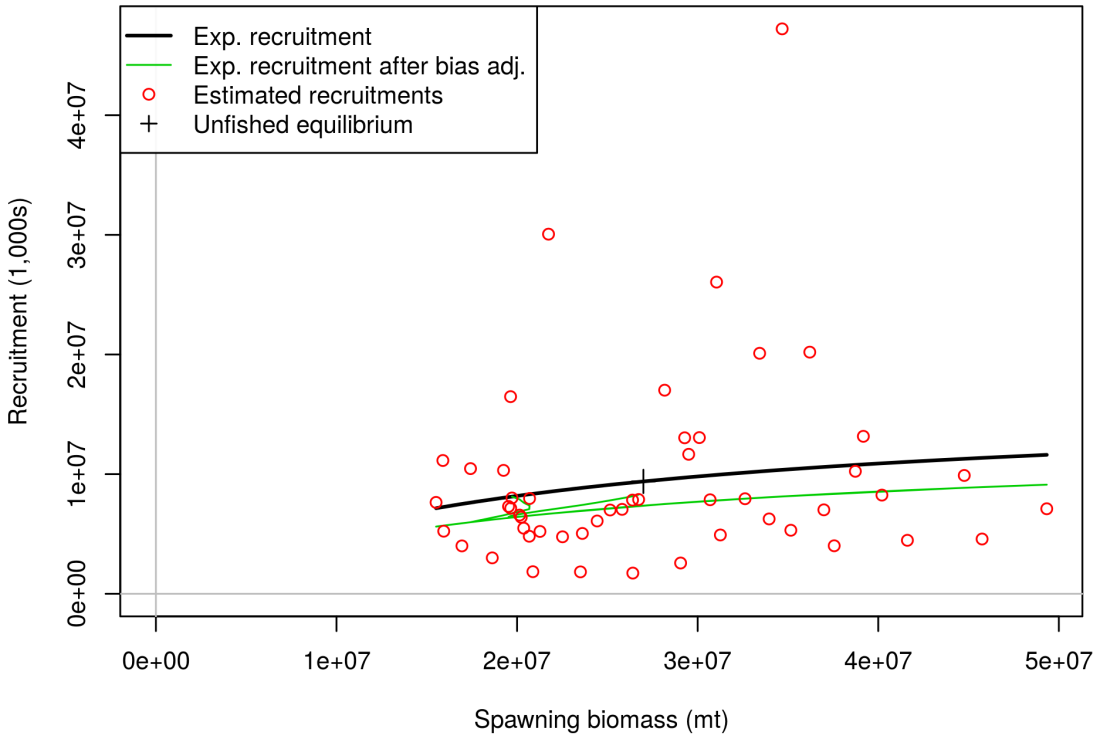

Figure 138: Stock recruit relationship with steepness estimated in a model sensitivity run for Atlantic surfclam in the southern area. There is no information to inform the left side of the stock recruit curve because no low stock sizes have been observed.

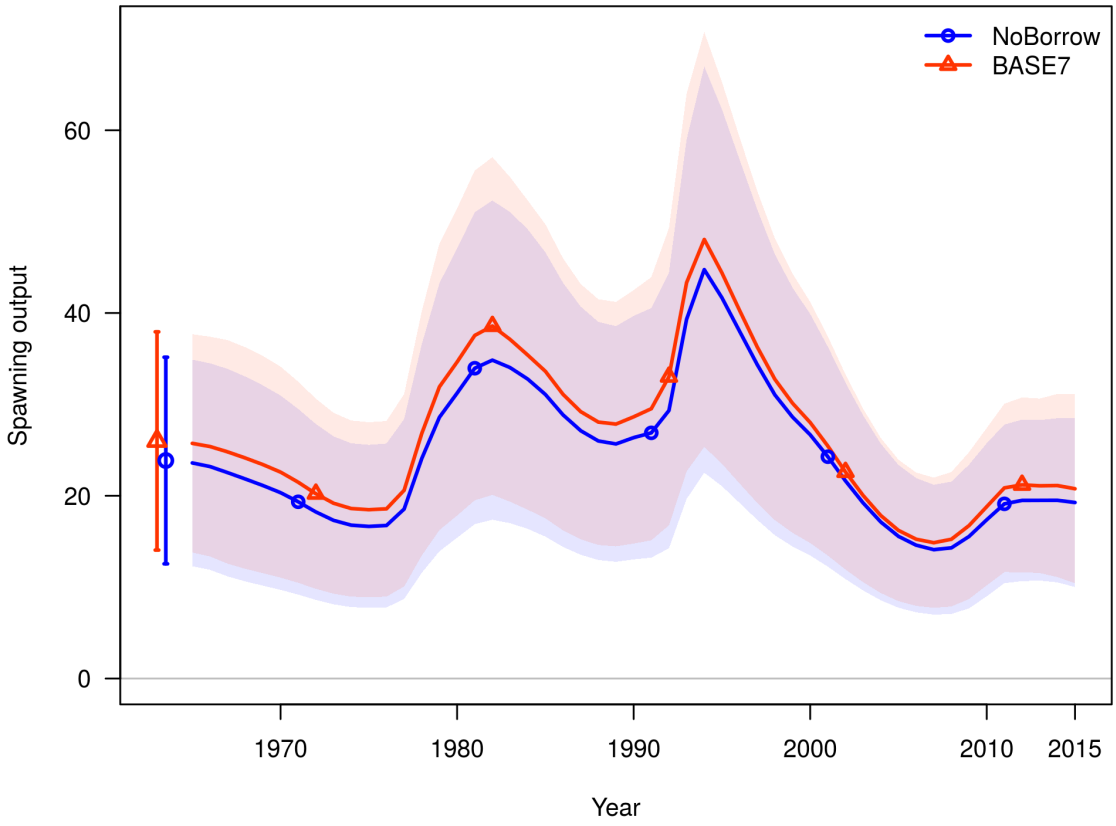

Figure 139: Biomass scale and uncertainty from 2 model runs, one in which the conditional age at length data was not borrowed from 2013 to 2012 (NoBorrow) and the other being the base model run for Atlantic surfclam in the southern area (BASE7). The biomass trajectories from each run were nearly identical.

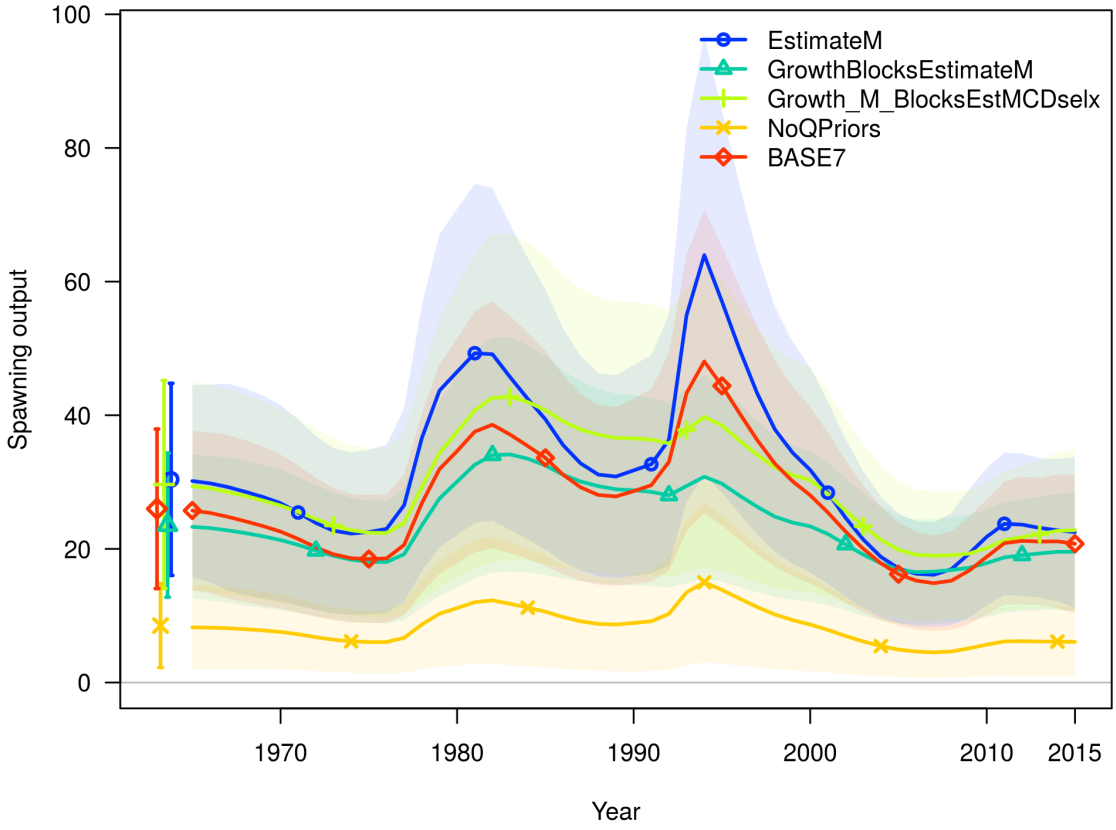

Figure 140: Biomass scale and uncertainty from several sensitivity model runs compared to the base run (BASE7) for Atlantic surfclam in the southern area. Each of the runs produced similar trends and only the run in which no prior distributions for catchability were used produced large differences in scale.

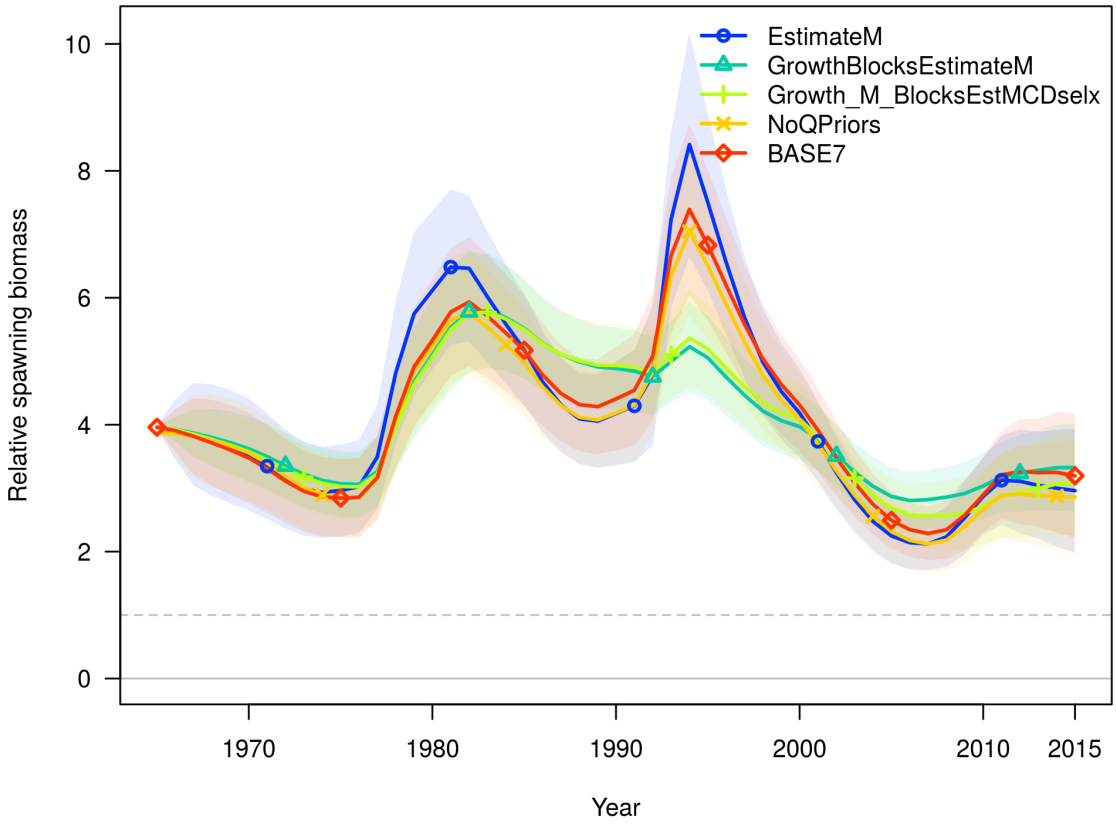

Figure 141: Relative spawning biomass and uncertainty from several sensitivity model runs compared to the base run (BASE7) for Atlantic surfclam in the southern area. Each of the runs produced similar trends. There was very little difference between the two runs. The trends depict the ratio of the biomass in each year to B_0 and include a dashed line at $\frac{B}{B_0} = 0.25$.

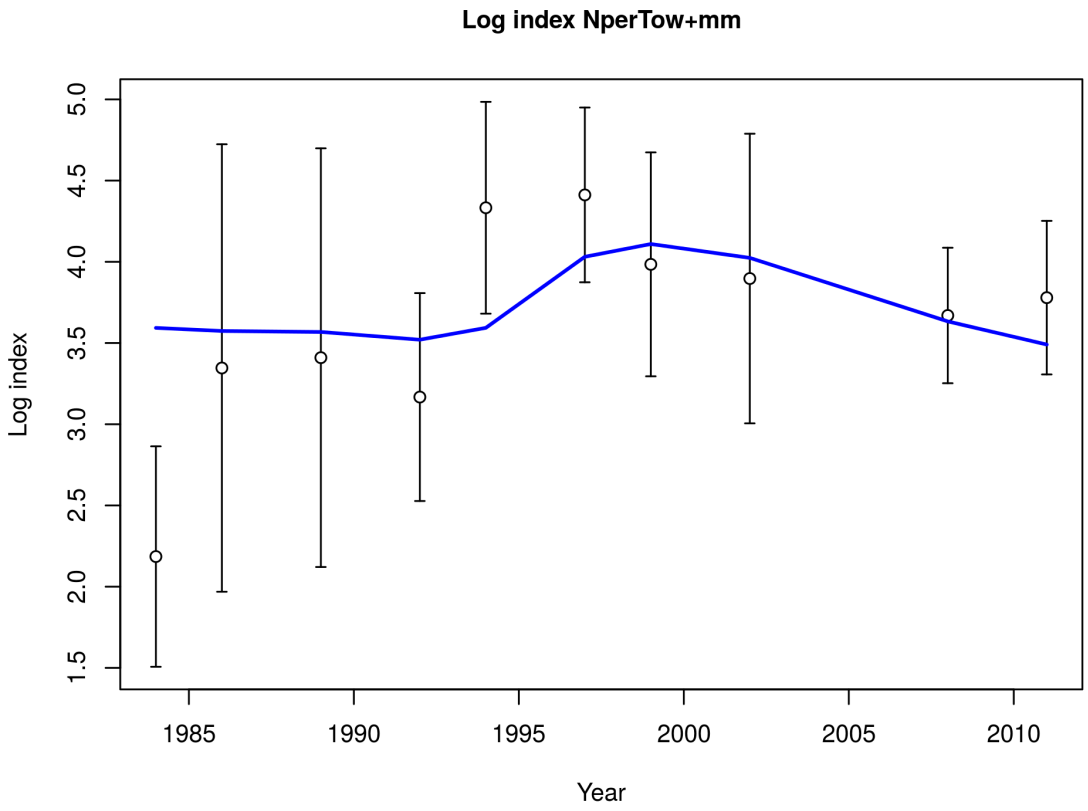

Figure 142: Model fit to the log of the RD survey index estimated in a model sensitivity run for Atlantic surfclam in the northern area in which the R_0 parameter was allowed to vary over time in two blocks (before and after 1995).

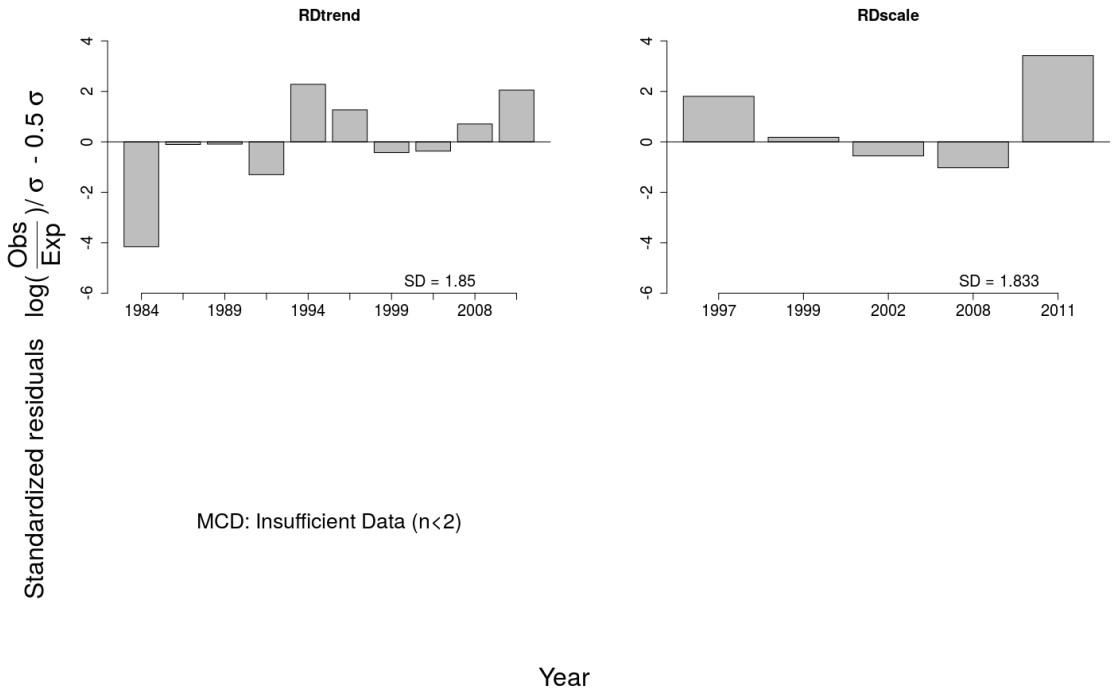

Figure 143: Standardized residuals from the model fit to the RD survey index estimated in a model sensitivity run for Atlantic surfclam in the northern area in which recruitment variance was increased by 100%.

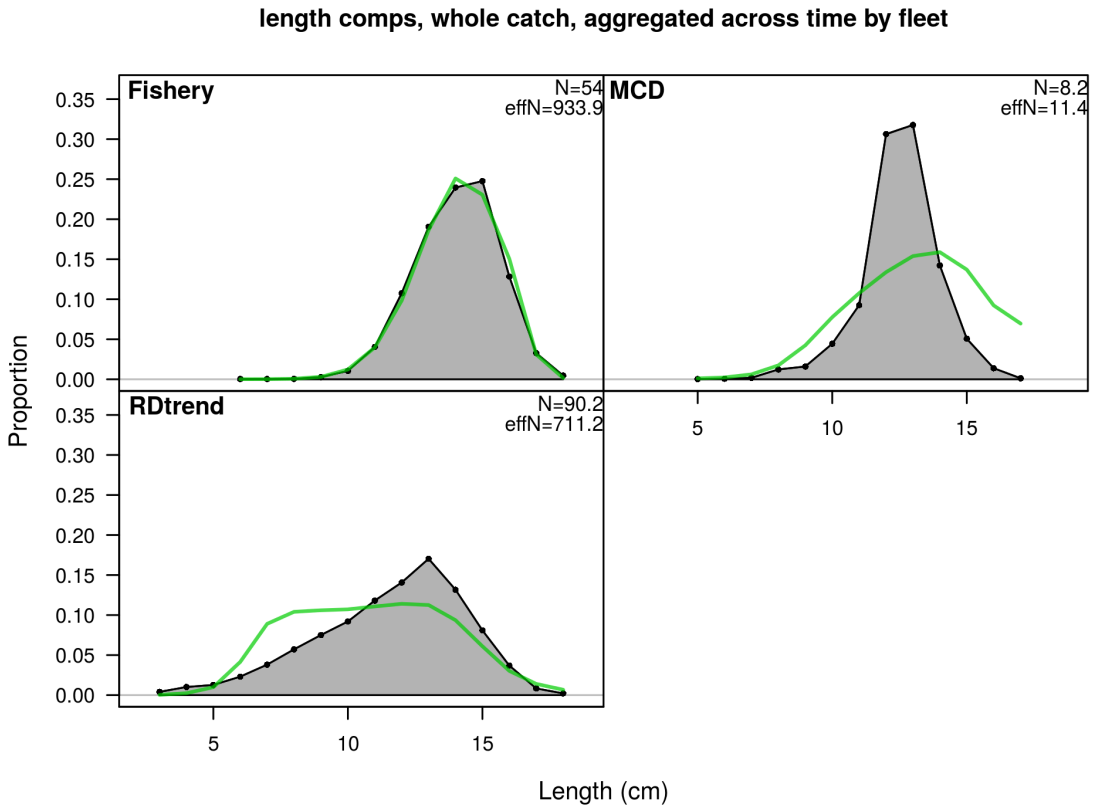

Figure 144: Length composition fits in a model sensitivity run for Atlantic surfclam in the northern area in which the weight of the likelihood component associated with the RD survey was increased by 1000%.

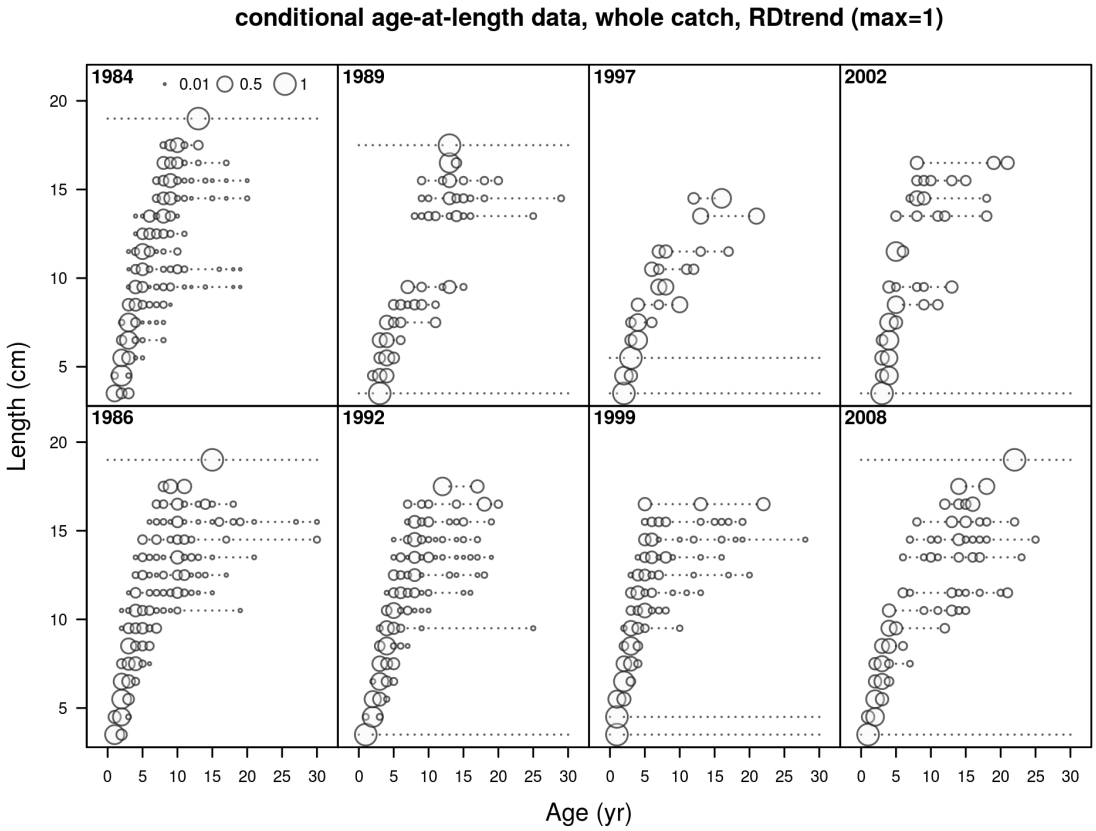

Figure 145: Standardized residuals from conditional age at length composition fits in a model sensitivity run for Atlantic surfclam in the northern area in which the weight of the likelihood component associated with the RD survey was increased by 1000%.

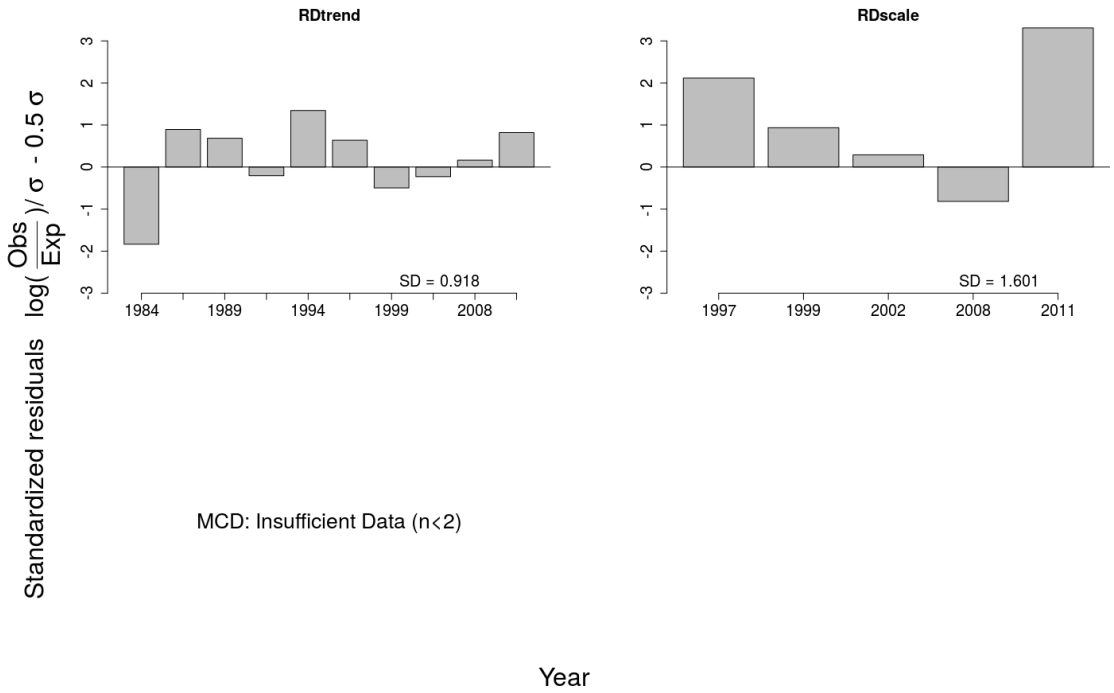

Figure 146: Standardized residuals from the model fit to the RD survey index estimated in a model sensitivity run for Atlantic surfclam in the northern area in which recruitment variance was increased by 100%.

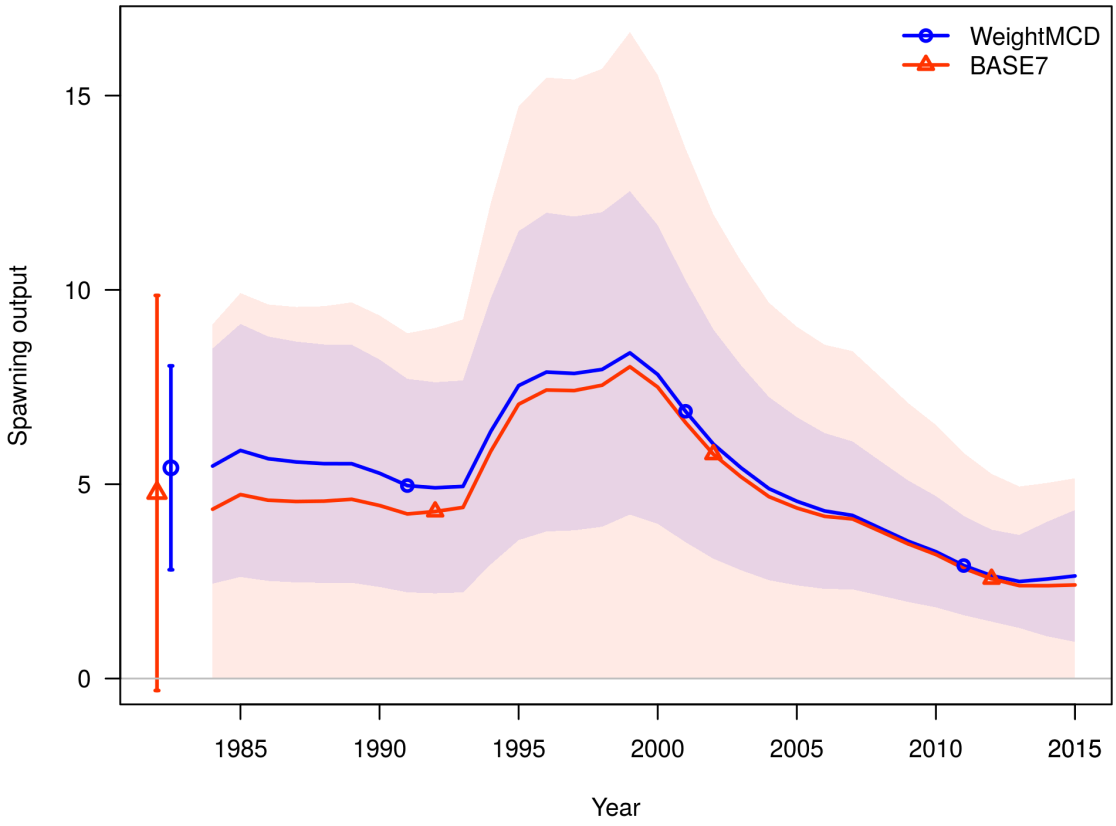

Figure 147: Estimated biomass from a model sensitivity run for Atlantic surfclam in the northern area in which the relative variance associated with the MCD survey index was reduced by about 50%, compared to estimated biomass from the base model run (BASE6).

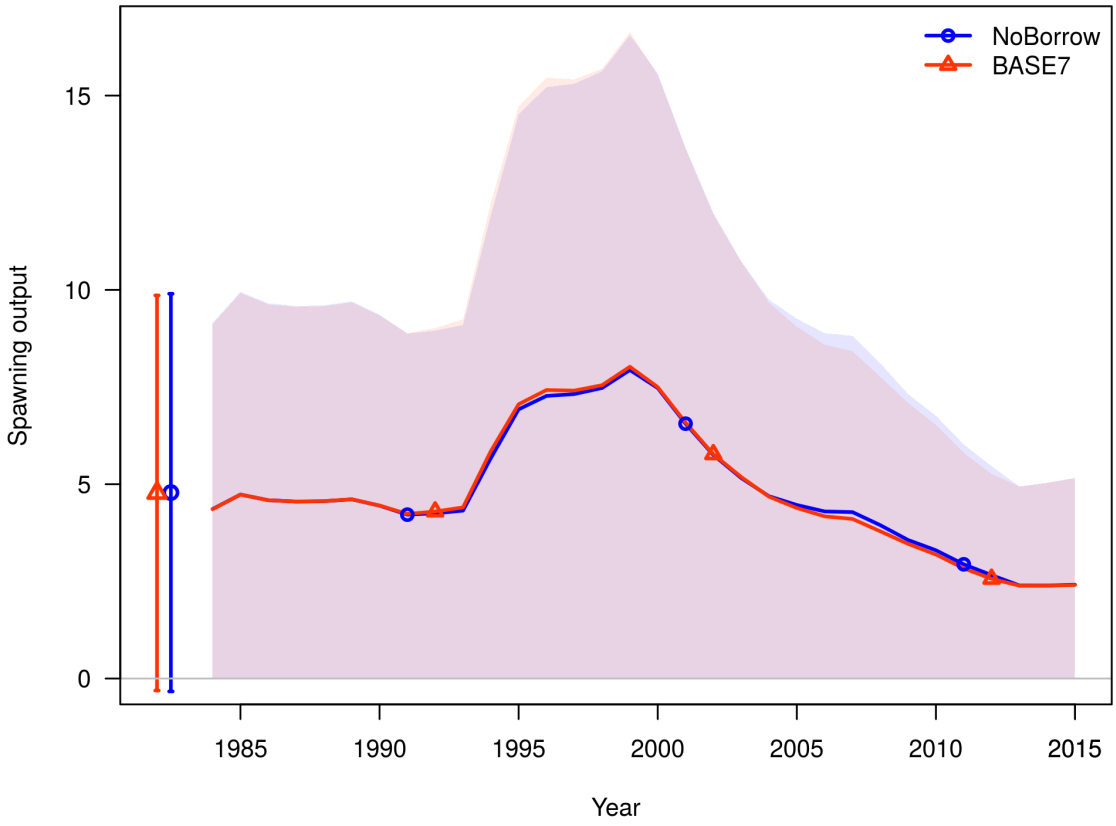

Figure 148: Biomass scale and uncertainty from 2 model runs, one in which the likelihood weight on the MCD survey trend information was set to 0 (RemoveMCD) and the other being the base model run for Atlantic surfclam in the northern area (BASE6). The biomass trajectories from each run were similar but the scale was not.

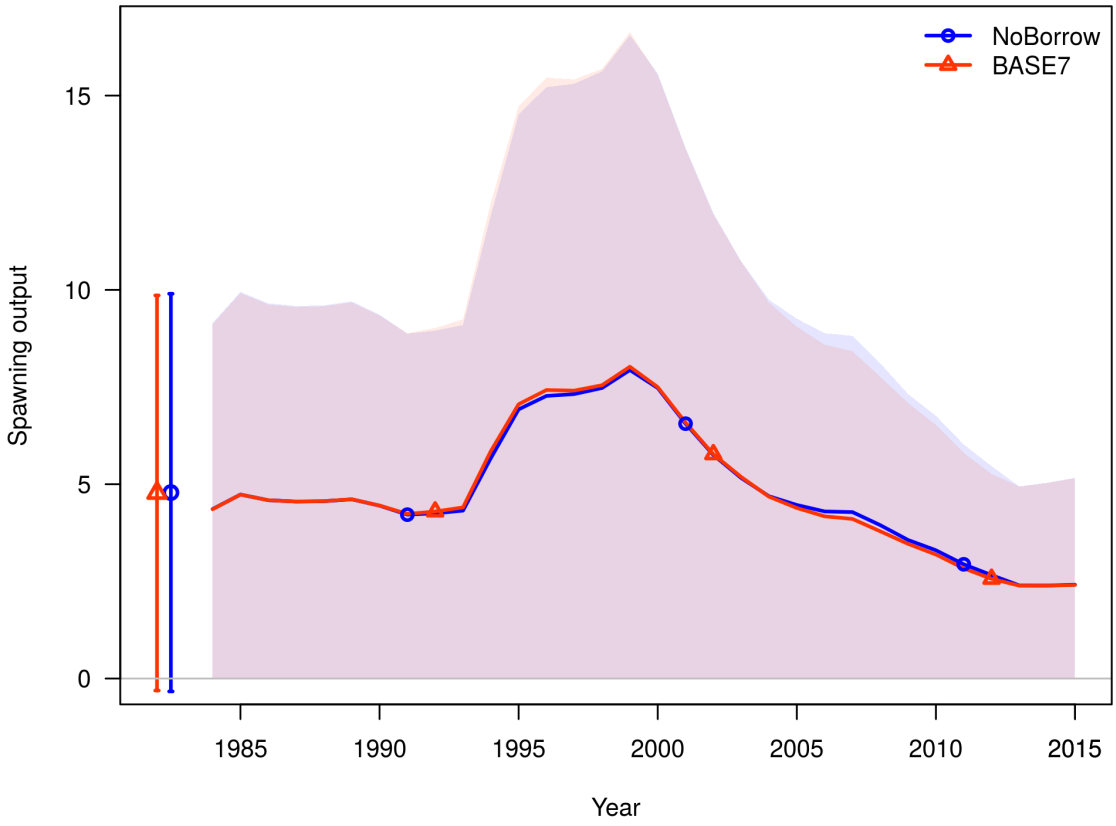

Figure 149: Biomass scale and uncertainty from 2 model runs, one in which the conditional age at length data was not borrowed from 2014 to 2013 (NoBorrow) and the other being the base model run for Atlantic surfclam in the northern area (BASE6). The biomass trajectories from each run were similar and the confidence regions overlapped.

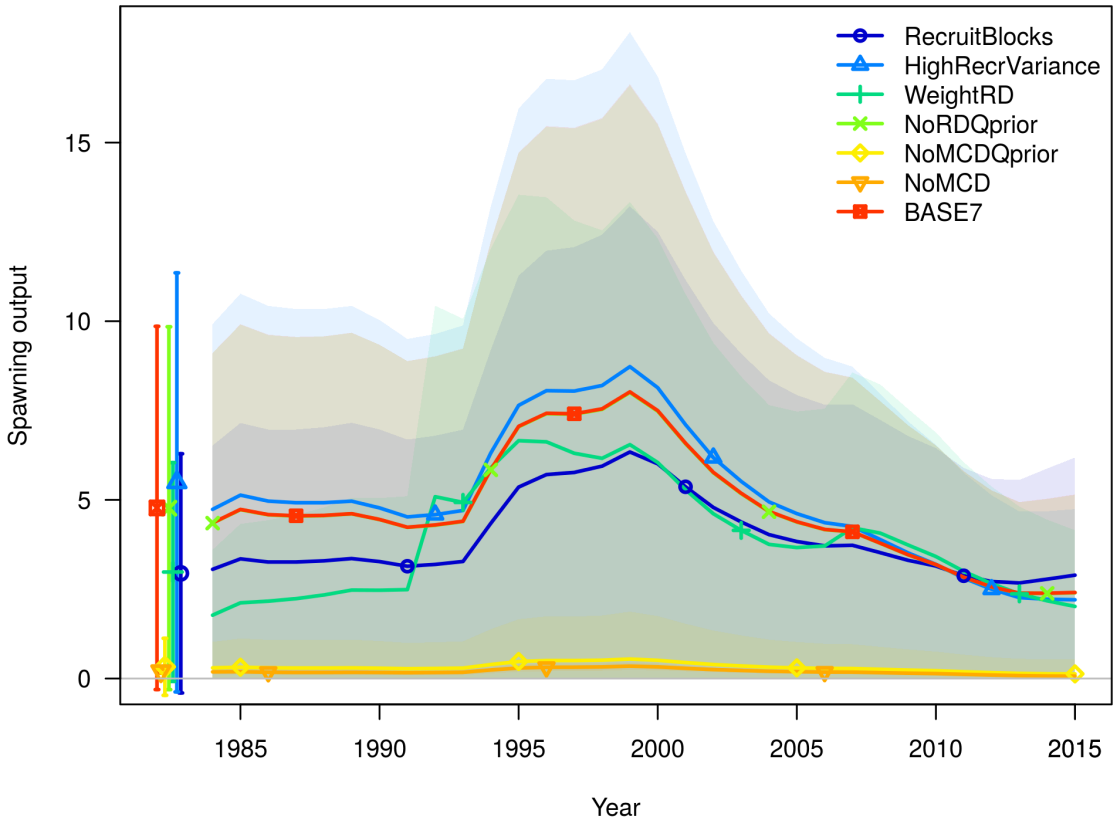

Figure 150: Biomass scale and uncertainty from several sensitivity model runs compared to the base run (BASE6) for Atlantic surfclam in the northern area. Each of the runs produced similar trends except when the model was forced to fit the early survey time series (WeightRD), but different scales when the information from the MCD survey was removed (NoMCD) or when the prior distribution for the catchability of the MCD was turned off (NoMCDprior).

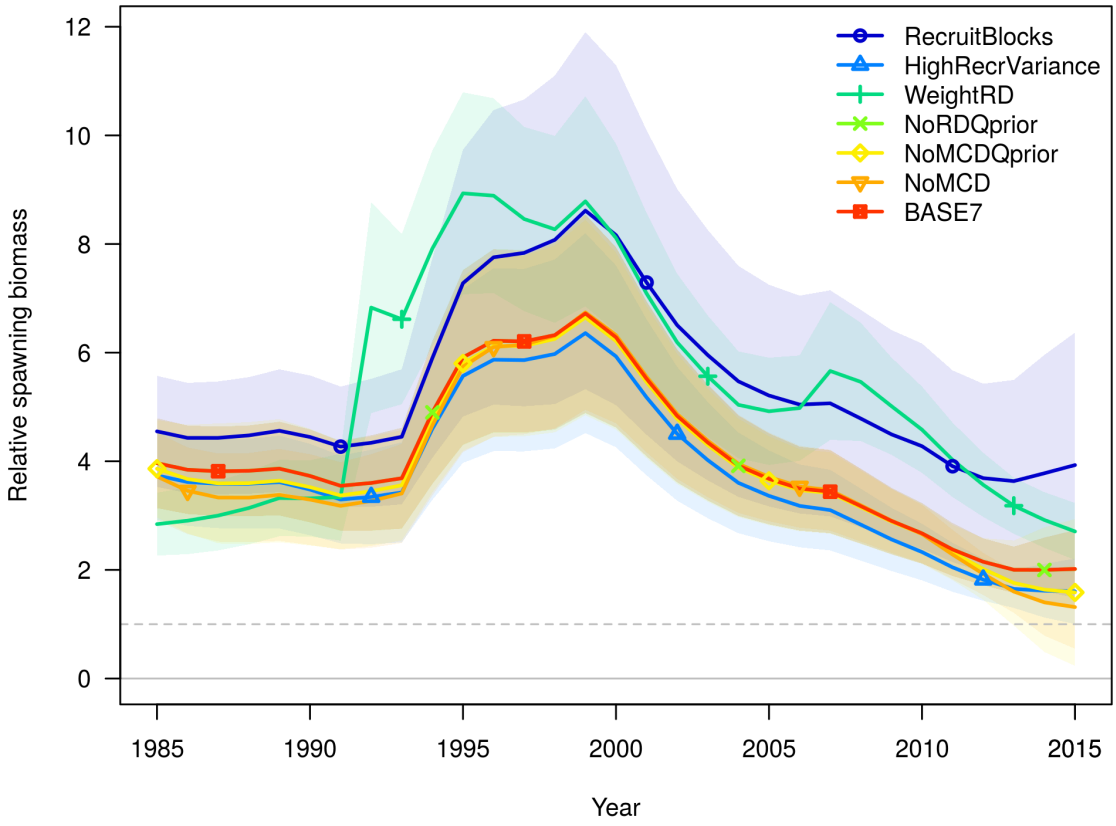

Figure 151: Relative spawning biomass and uncertainty from several sensitivity model runs compared to the base run (BASE6) for Atlantic surfclam in the northern area. Each of the runs produced similar trends except when the model was forced to fit the early survey time series (WeightRD). The trends depict the ratio of the biomass in each year to B_0 and include a dashed line at $\frac{B}{B_0} = 0.25$.

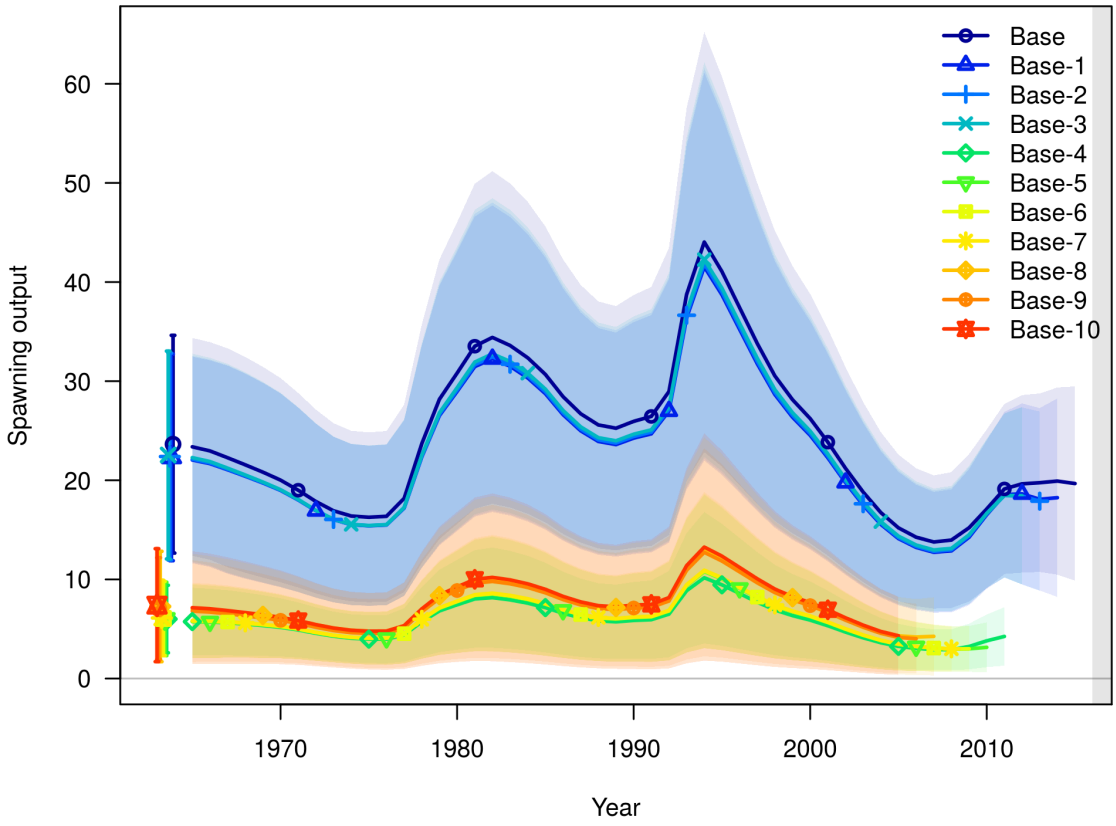

Figure 152: Biomass scale and uncertainty from 10 retrospective runs of the model for the southern area. The biomass scale shifts when the MCD survey is removed from the model. The dashed line represents a theoretical threshold value where the biomass is equal to 25% of the virgin biomass estimated in each retrospective run.

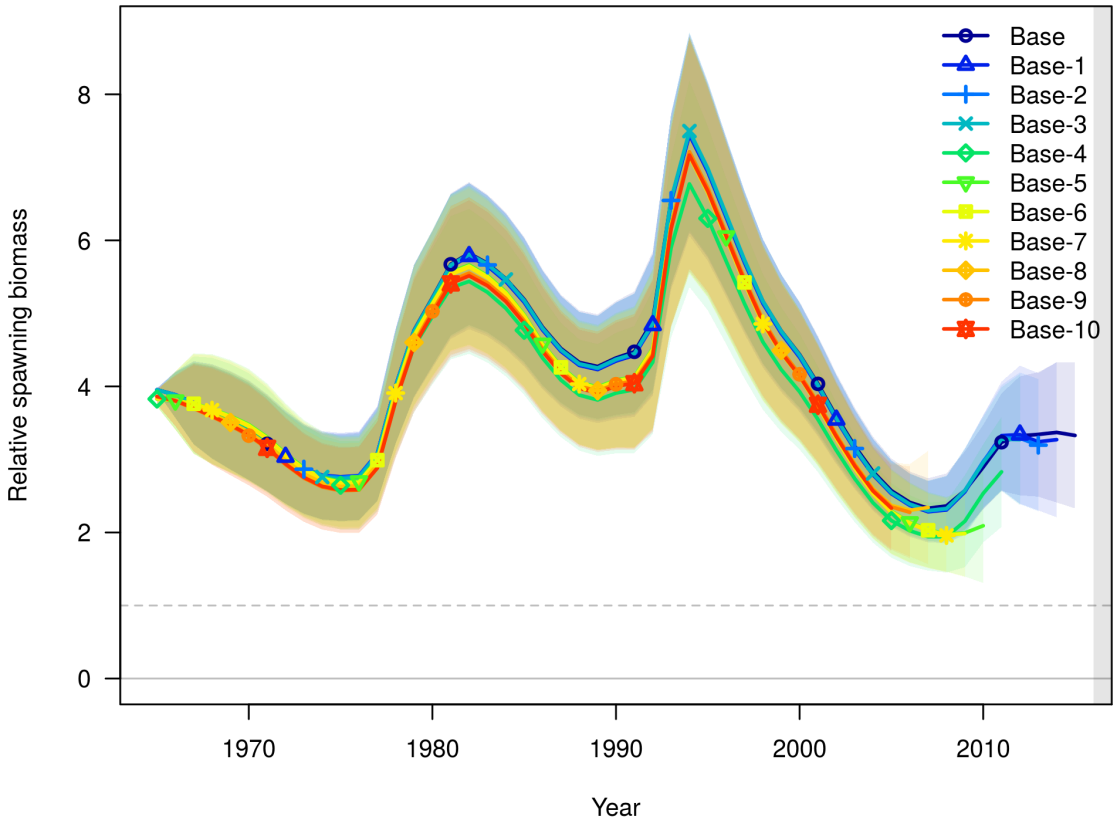

Figure 153: Relative spawning biomass and uncertainty from 10 retrospective runs of the model for the southern area. The trend in biomass is robust to the removal of data from recent years.

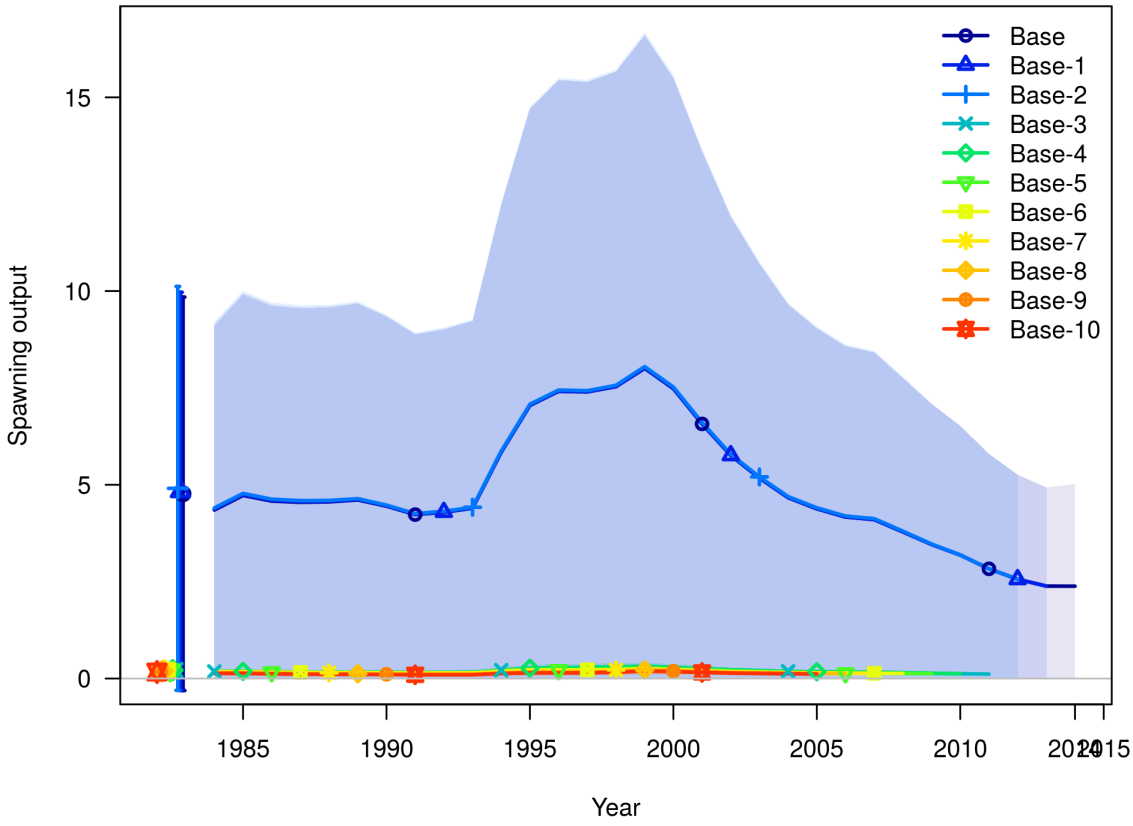

Figure 154: Biomass scale and uncertainty from 10 retrospective runs of the model for the northern area. The biomass scale shifts when the MCD survey is removed from the model.

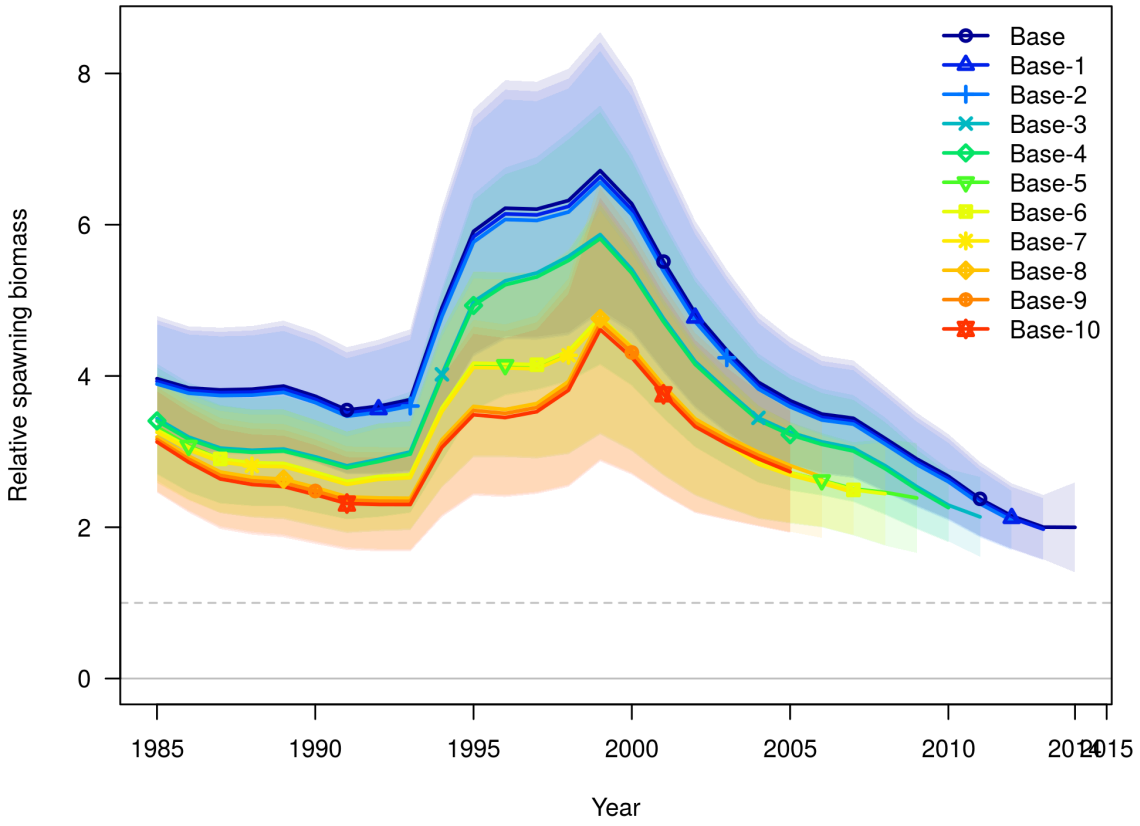

Figure 155: Relative spawning biomass and uncertainty from 10 retrospective runs of the model for the northern area. The dashed line represents a theoretical threshold value where the biomass is equal to 25% of the virgin biomass estimated in each retrospective run.

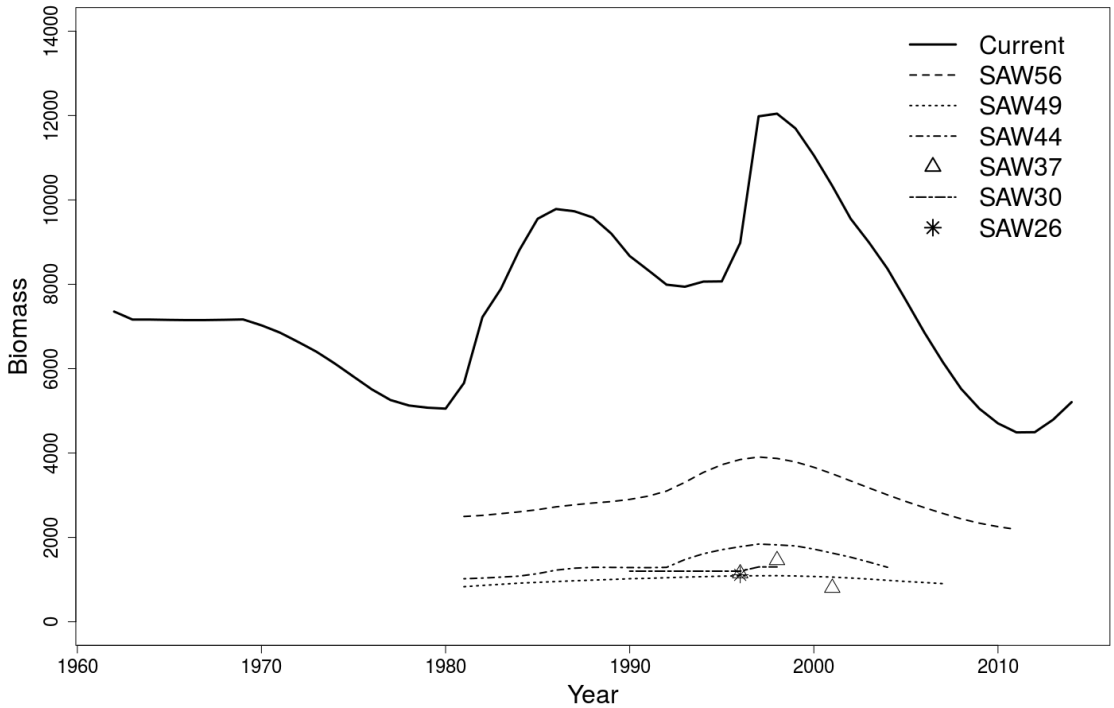

Figure 156: Historical retrospective plot showing the biomass trajectory from each of the previous Atlantic surfclam assessments.

Figures

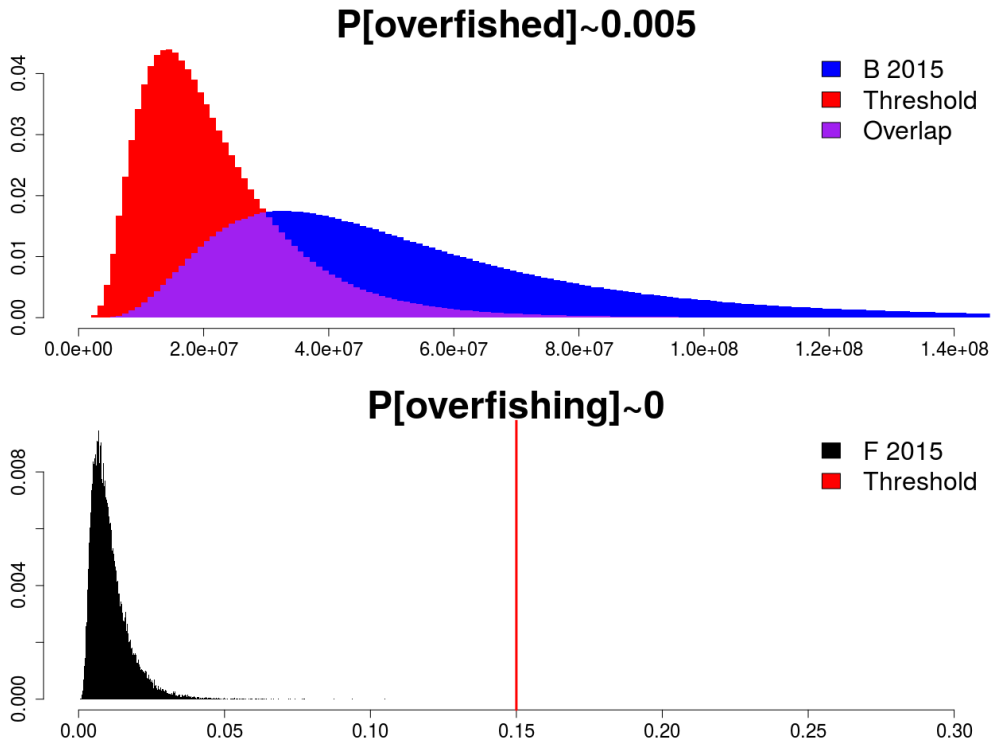

Figure 157: Probability of overfished and overfishing status during 2015 using the current reference points from the previous assessment. The overfished probability (upper panel) presented in this figure accounts for the positive correlation between the reference point ($\frac{B_{1999}}{4}$) and the biomass in 2015, which results in a probability of overfished status that is less than the apparent overlap between the two distributions. The current $F_{Threshold}$ is a point estimate and uncorrelated to F_{2015}. Therefore, the probability of overfishing was equal to the probability of overlap between the distribution of F_{2015} and the point estimate of $F_{Threshold}$.

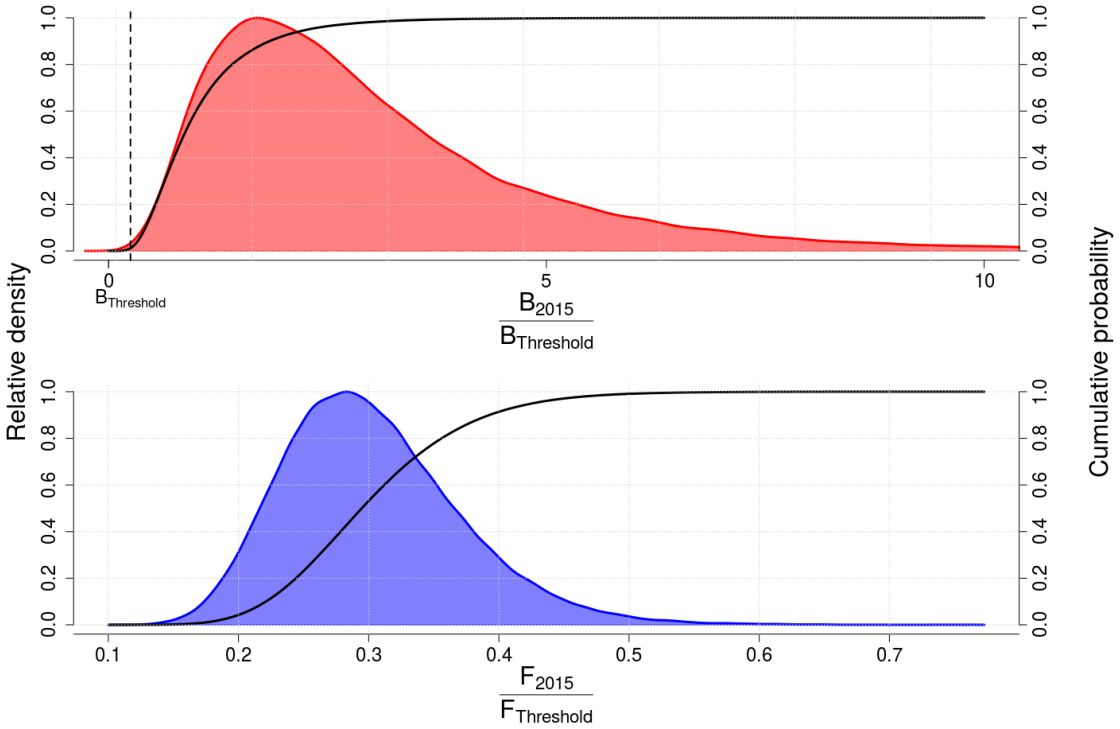

Figure 158: Probability distributions of $\frac{B_{2015}}{B_{Threshold}}$ and $\frac{F_{2015}}{F_{Threshold}}$, using the recommended reference points. The probability of overfished status during 2015 is equal to the area of the red, upper curve that is less than $B_{Threshold}$. The probability of overfishing status during 2015 is equal to the area of the blue, lower curve that is greater than $F_{Threshold}$. The probability of overfished and overfishing status can be approximated by the elevation (y axis scale) at which the solid line representing the cumulative probability distribution crosses the dashed vertical line representing the reference point in each plot. The probability distributions presented in this figure account for the positive correlation between the reference points ($B_{Threshold} = \frac{B_0}{4}$ and $F_{OFL} = F_{Threshold} = F^* \frac{F_{MSY}}{F^*_{Max}}$) and the fishing mortality and biomass estimates in 2015, as well as the uncertainty in the estimation of both the point estimates and their respective reference points.

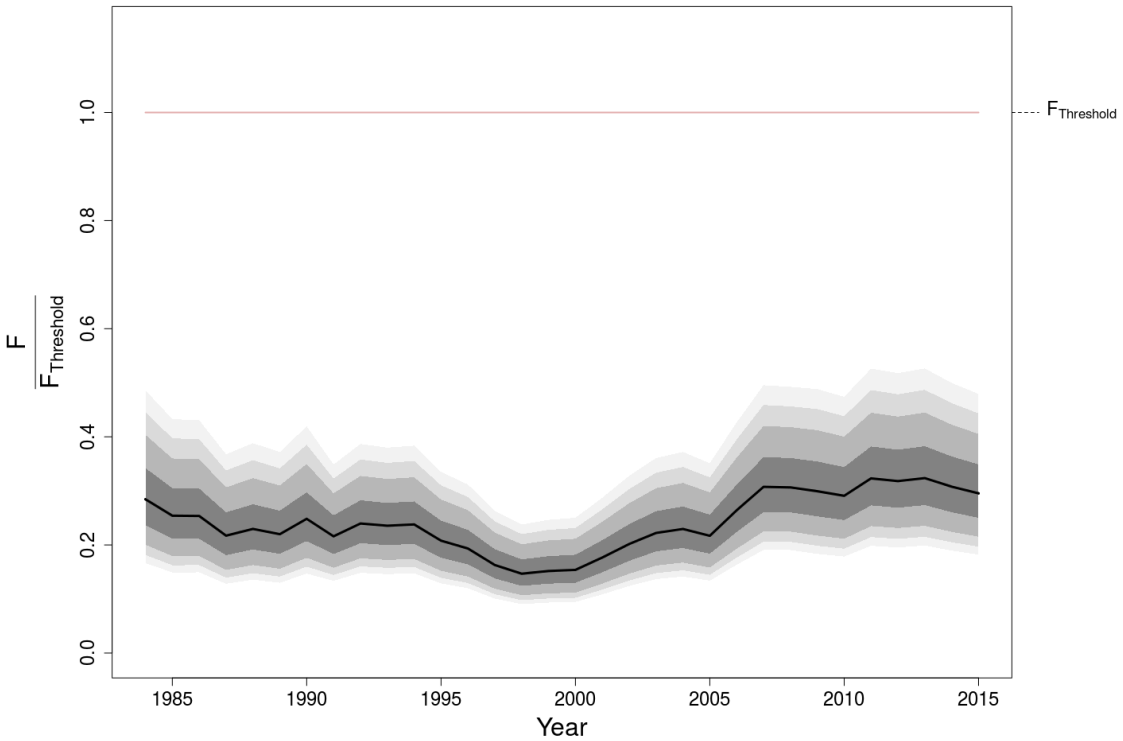

Figure 159: The time series of the ratio of fishing mortality estimates to the recommended F threshold, with the 50, 80, 90, and 95 % lognormal confidence intervals in shades of gray. The confidence intervals account for the correlation between F and $F_{Threshold}$. Over fishing would occur if the ratio exceed 1.0.

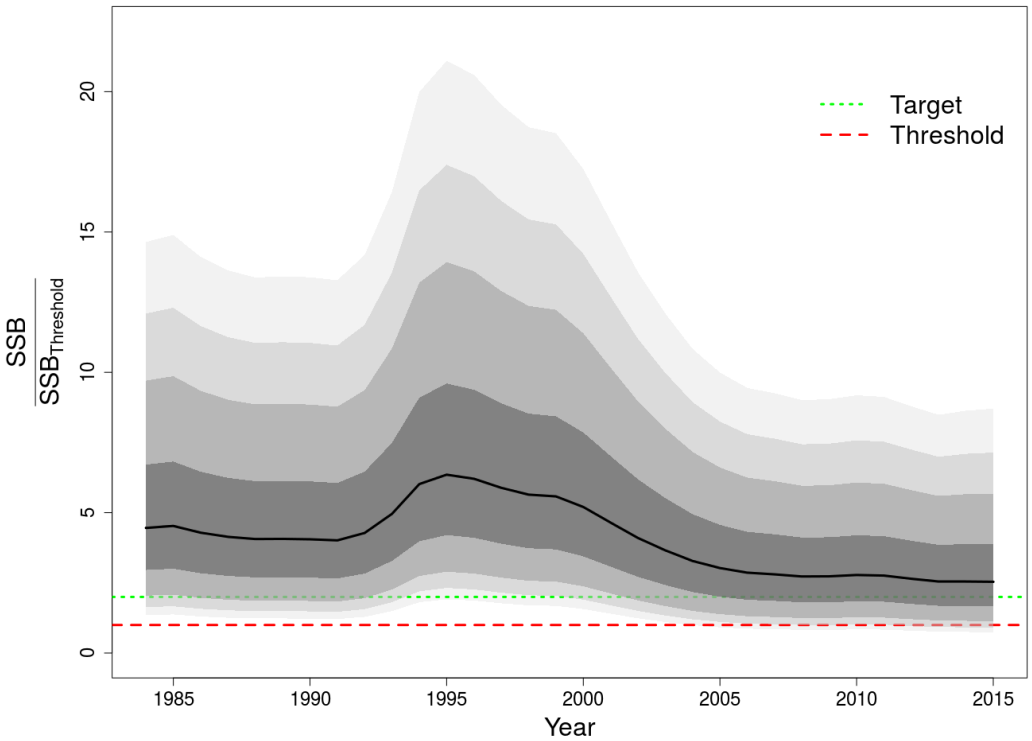

Figure 160: The time series of the ratio of biomass estimates to the unfished biomass (B_0), with the 50, 80, 90, and 95 % lognormal confidence intervals in shades of gray. The confidence intervals account for the correlation between B and B_0. Overfished status would occur if the ratio went below 0.25.

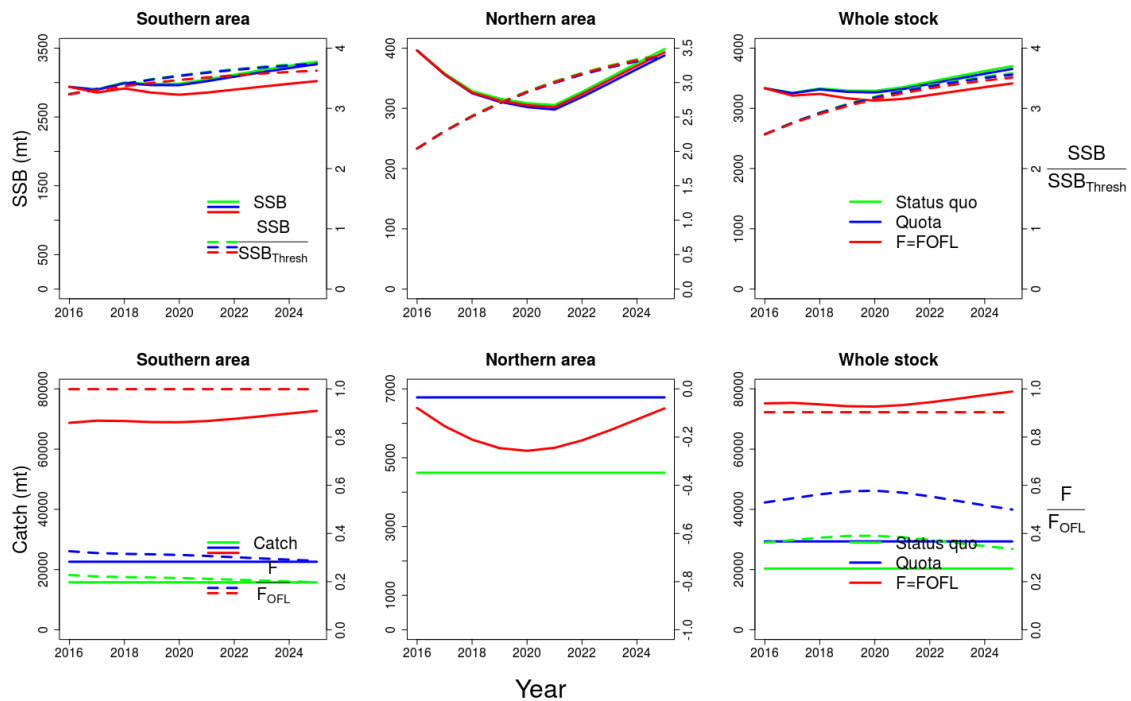

Figure 161: Projections using three different catch scenarios in the southern, northern and whole stock areas. The upper row of plots show the biomass trends over time (solid lines) and the ratio of biomass to biomass threshold (dashed lines). The lower plots show the landings (solid lines) and the ratio of F to F_{OFL}. In all plots the status quo catch scenario is green, the quota catch scenario is blue and the $F = F_{OFL}$ scenario is red. Determination of $\frac{F}{F_{OFL}}$ for the northern area was not possible due to a lack of the exploitation history required to generate an area specific fishing mortality threshold.

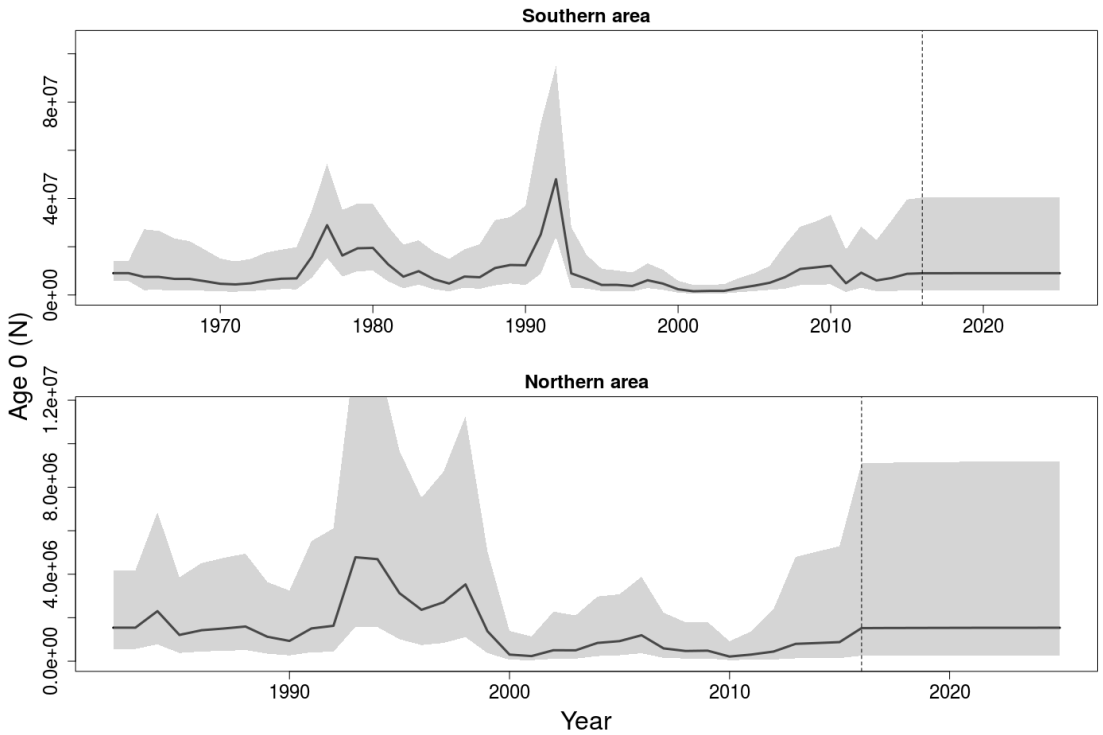

Figure 162: Forecast and time series recruitment estimates for the southern, and northern areas. Projections begin at the vertical dashed line. Note the different ranges of the vertical axes.

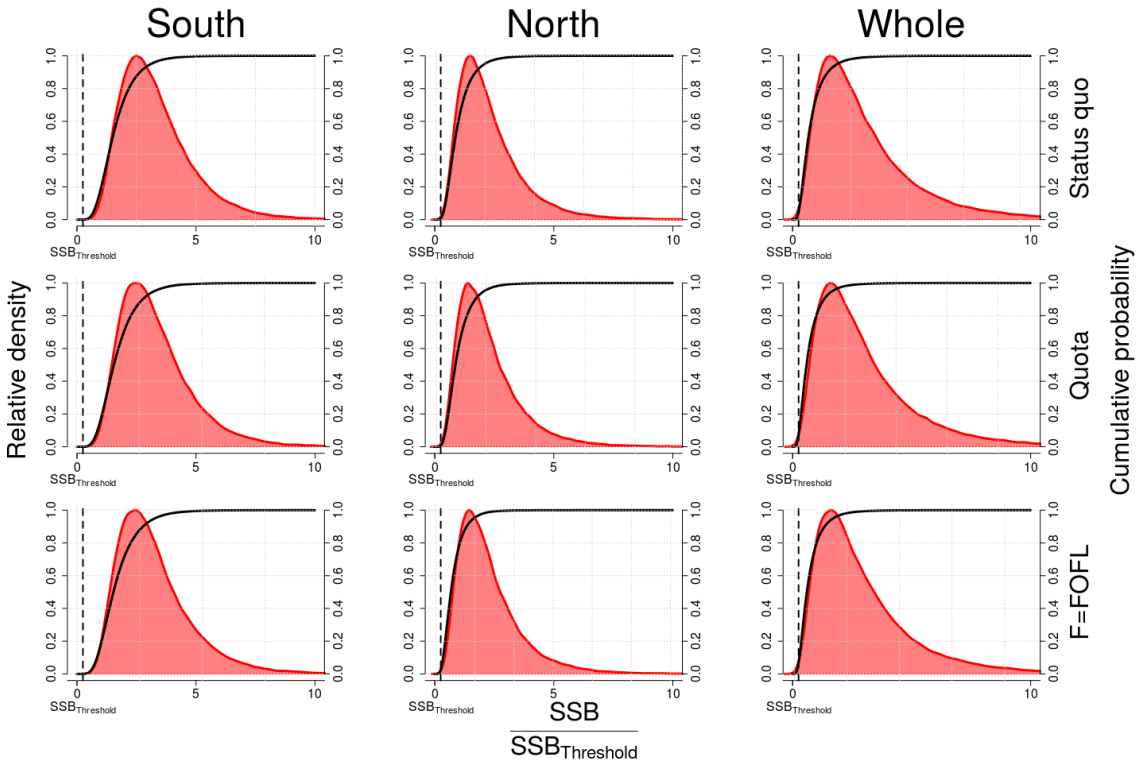

Figure 163: Probability of overfished status for Atlantic surfclam during the projection year with the lowest biomass from 2016-2025. The different catch scenarios are in rows and the different areas are in columns.

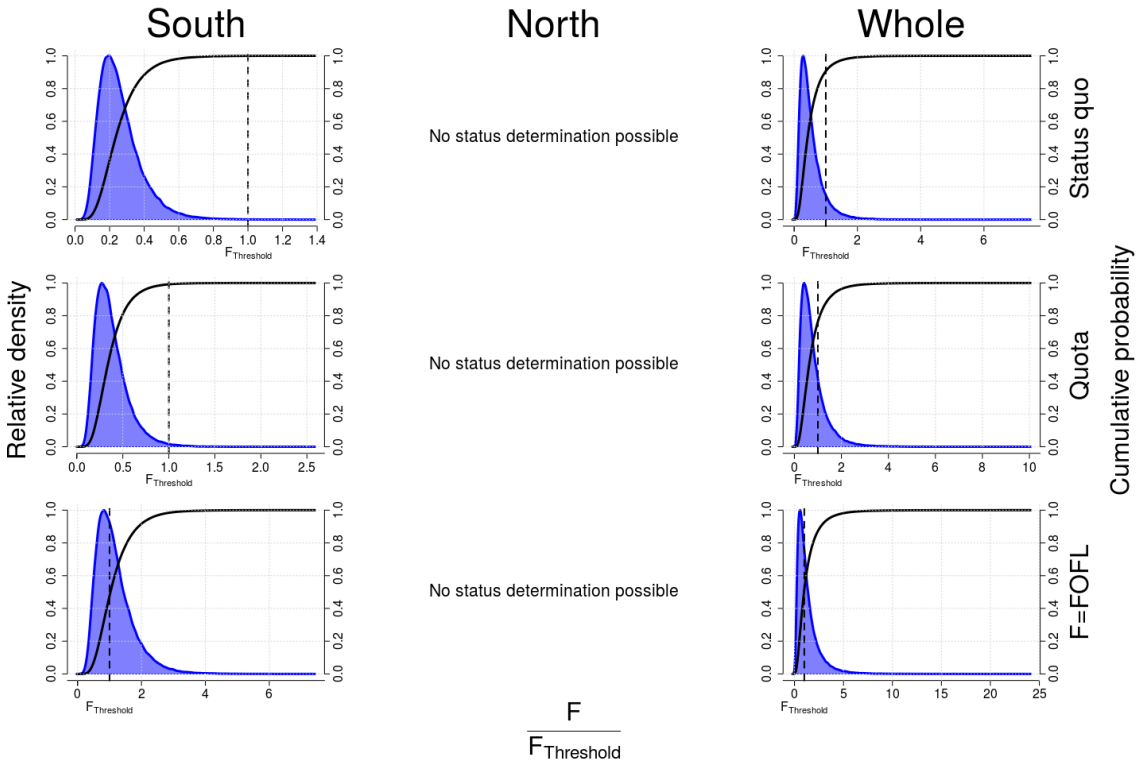

Figure 164: Probability of overfishing status for Atlantic surfclam during the projection year with the highest F from 2016-2025. The different catch scenarios are in rows and the different areas are in columns. Determination of F_{OFL} for the northern area was not possible due to a lack of the exploitation history required to generate an area specific fishing mortality threshold.

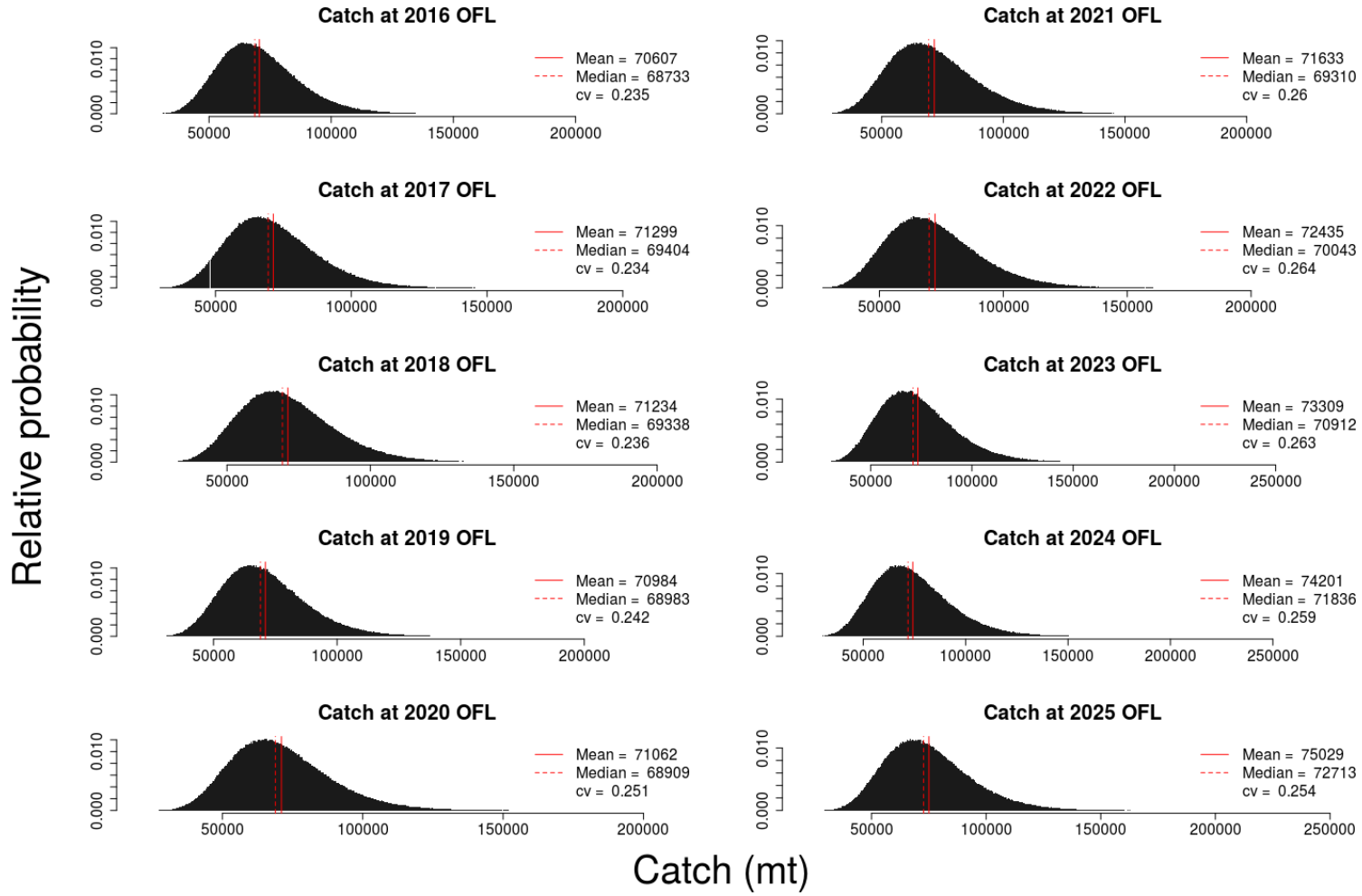

Figure 165: Distribution of catch (landings + incidental mortality) at the Over Fishing Limit (OFL) from 2016-2025 for Atlantic surfclam in the southern area.

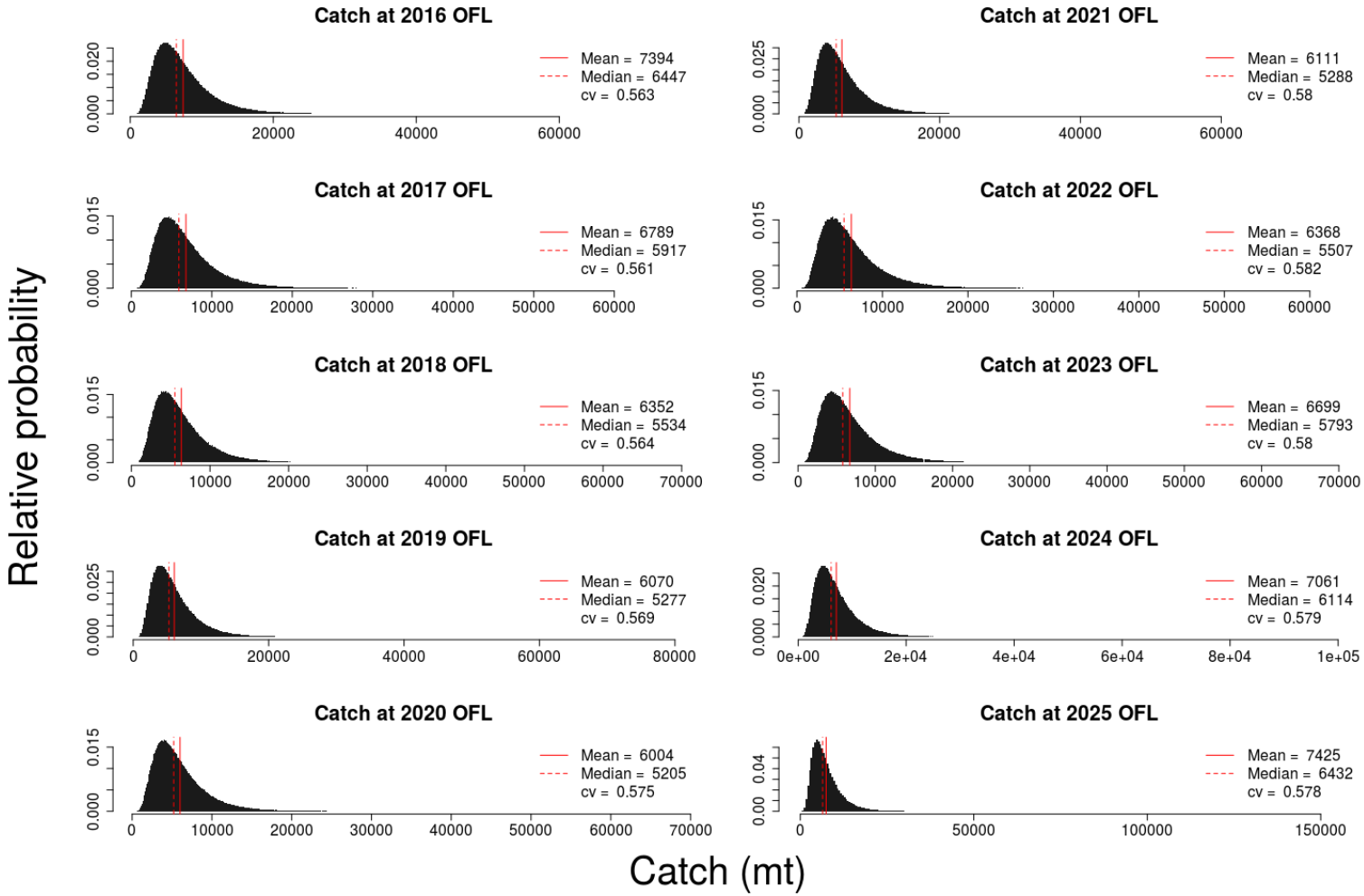

Figure 166: Distribution of catch (landings + incidental mortality) at an approximation of the Over Fishing Limit (OFL) from 2016-2025 for Atlantic surfclam in the northern area. There was not sufficient catch history to generate an OFL for the northern area, so one was approximated based on the average F during years in which fishing occurred.

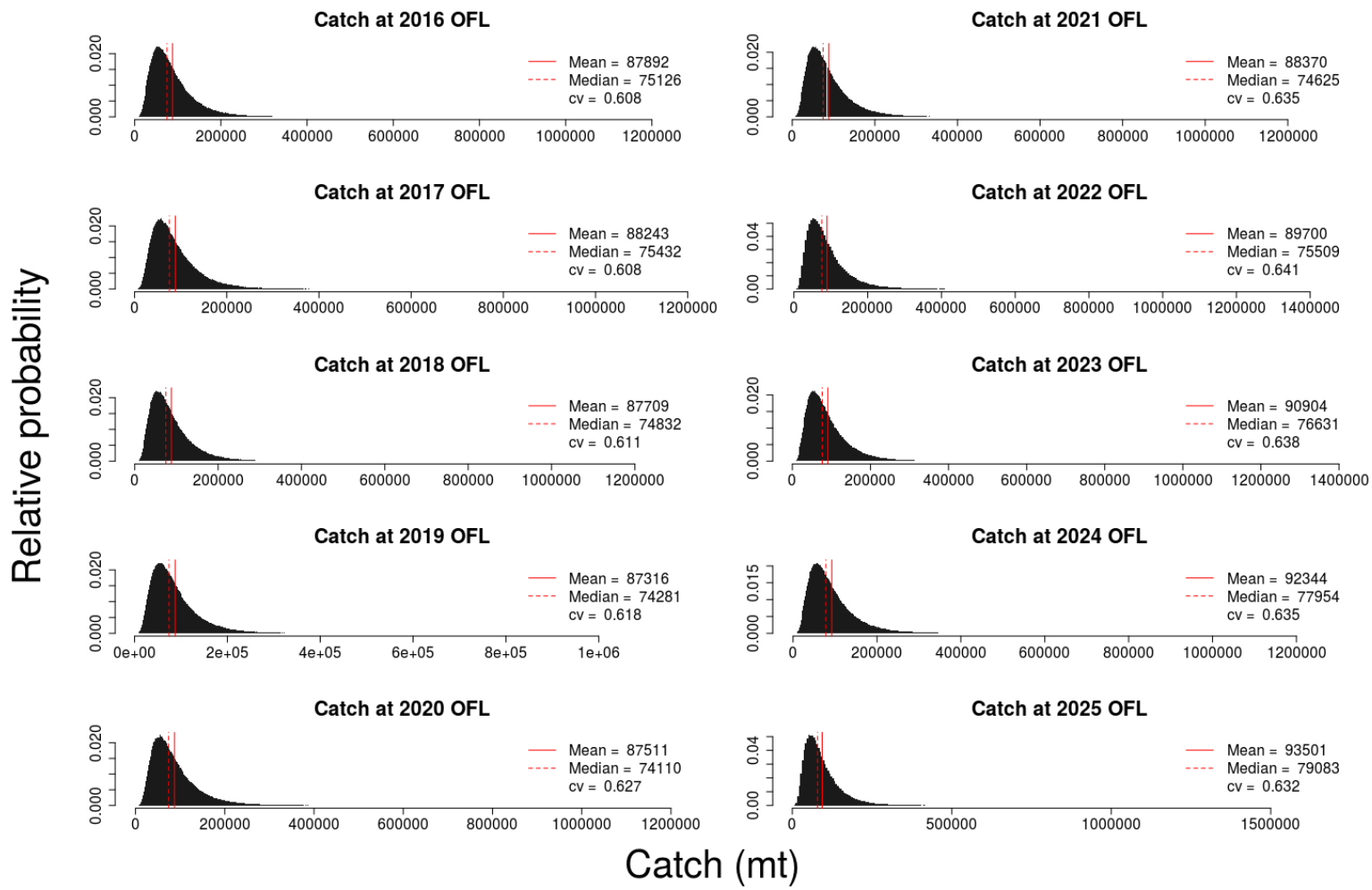

Figure 167: Distribution of catch (landings + incidental mortality) at the Over Fishing Limit (OFL) from 2016-2025 for Atlantic surfclam in the whole stock.

Pro	Con	References
Spatial Patterns in Biological and Other Characteristics		
Growth curves and shell length-meat weight differ markedly between GBK and the southern region.	The differences are clinal or continuous and the split could be made elsewhere or not at all.	Table Table A14, Table A16, Figure A57, A58-62; Kim and Powell (2004); Marzec, et al. (2006); Weinberg (2005)
Post-settlement survival has decreased in the south but not on GBK.	Southern and northern portions of a large stock should respond differently to environmental change. The differences are clinal or concentrated in shallow water south of New Jersey and the split could be made elsewhere or not at all.	NEFSC 2010
Georges Bank tends to retain larvae spawned there due to a persistent gyre current. Published larval drift models for scallops show substantial movement of larvae from GBK to the south, but none from the south to GBK. A detailed unpublished surfclam larval drift presented to the Working Group indicates no movement of larvae from GBK to Southern New England and other southern areas occurs or *vice-versa* assuming no daily mortality during the assumed 35 day larval lifetime observed in culture (X. Zhang and D. Haidvogel, IMCS, Rutgers).	Larval drift models are not definitive and do not cover the whole time period of interest or all possible oceanographic conditions when substantial interchange may occur, particularly between GBK and Southern New England which is directly to the south. In certain circumstances, up to 10% of GBK larvae would reach Southern New England and these larvae would be 'unsuccessful' in the model, but near a reasonable size for metamorphosis in a biological sense.	Miller et al 1998; Werner et al 1993; Gilbert et al 2010; Tian et al 2009; Table A19
Georges Bank and MAB surfclam habitats are entirely within different and well recognized eco-regions.		Fogarty et al. (2011)

Figure 168: Points made to support splitting the Atlantic surfclam into two stocks with counterpoints (Copied directly from Table A17 in (Northeast Fisheries Science Center 2013)). The status quo is a single stock and the alternative is two stocks with the break southwest of Georges Bank. Under this option, the Georges Bank stock in the north would be separated from the rest of the resource in the south. Points made to support the status quo and counterpoints are listed in Figure 169. The tables presented here have not been updated with any new information since the last assessment.

The split south of GBK crosses an area that separates the two major concentrations of the resource in the south (off New Jersey) and on GBK.	The split could be made elsewhere or not at all.	Appendix A7
Population Dynamics		
Surfclams in GBK and south resemble two independent populations based on abundance, recruitment and life history trends.	The northern and southern portions of SVASNE differ as well, why not identify three stocks?	POPULATION DYNAMICS (Figures A26, A27, A74, A75, A77 and A78)
Strong year classes occur independently and more often in the south and often over wide areas within the region.	Recruitment patterns are regional and the split could be made elsewhere or not at all.	Fig A67
Fishery Patterns		
The split south of GBK crosses an area of relatively low fishing activity and catch.		See Table A3, Figures A3,A4, and A8
Practical		
The new cooperative survey cannot sample the whole resource in one year but can be extended to include all of the SVASNE area.	Does not mean the split has to be made at GBK. Spatially explicit assessment models could be developed to handle areas incompletely sampled in annual surveys.	
Including GBK in a whole stock assessment model means that certain survey years cannot be included because GBK was not sampled in all years.	Areas can modeled separately but managed together, with results combined.	
Previous reviews of the surfclam assessment have been critical of the current stock definition.	Restoration of fishing on GBK invalidates some of these previous criticisms.	
The proposed boundary is along lines historically used to assess the stock and to collect survey data.	Historical use and best practice are not necessarily the same.	
Utility of Biological Reference Points		
"Average" biological reference points for two quasi-populations with different population dynamics do not result in MSY for either population unit, particularly when differences are as large as for GBK and the southern region.	The same argument can be made with respect to different portions of the southern area.	Hart, D. R. 2001. Can. J. Fish. Aquat. Sci. 58:2351–2358.

Figure 168 cont.

The surfclam stock could be removed entirely in the south or on GBK without triggering an overfishing or overfished status determination because biomass would remain > Bmsy/2 for the combined areas.	This scenario is unlikely to occur in either GBK or the southern area now that GBK is open to fishing	
Combining two quasi-populations with different population dynamics obscures the condition of both.	Assessments should contain information about both stock components and other important regions, regardless of stock definitions.	

Figure 168 cont.

Pro	Con	References
Split is a needless departure from historical precedent.	Historical precedent is not necessarily best practice particularly given biological and ecological changes.	
Scallops and ocean quahogs (other sessile bivalves) are managed as one stock	Many species (lobsters and relatively sessile fish such as goosefish and flounders) with interconnected meta-populations are managed as separate stocks. Precedent does not define best practice.	
Split made at the proposed point is not optimal - this aspect should be studied further before management action occurs	GBK is the most distinct region based on biological characteristics, oceanography, geography, larval dispersal and general ecological classifications. Additional divisions in the south can be made later if warranted.	
No genetic differences were found among samples of surfclams from Georges Bank to Virginia.	Lack of significant differences in genetic studies does not prove population homogeneity.	Weinberg, J.W. 2005. Mar. Biol. 146(4): 707-716
Recruitment in SNE may come from GBK at periods that have not been observed in models	There is insufficient age data for SNE to evaluate this hypothesis. However, the limited available data indicate that recruitment patterns differ between the major population centers (GBK in the north and New Jersey and Delmarva in the south).	TABLE A19

Figure 169: . Points made to support maintaining the status-quo (single) stock definition for Atlantic surfclam, with counterpoints (copied from Table A18 in (Northeast Fisheries Science Center 2013)). The status quo is a single stock and the alternative is two stocks with the break just southwest of Georges Bank.