BSB Oceanography

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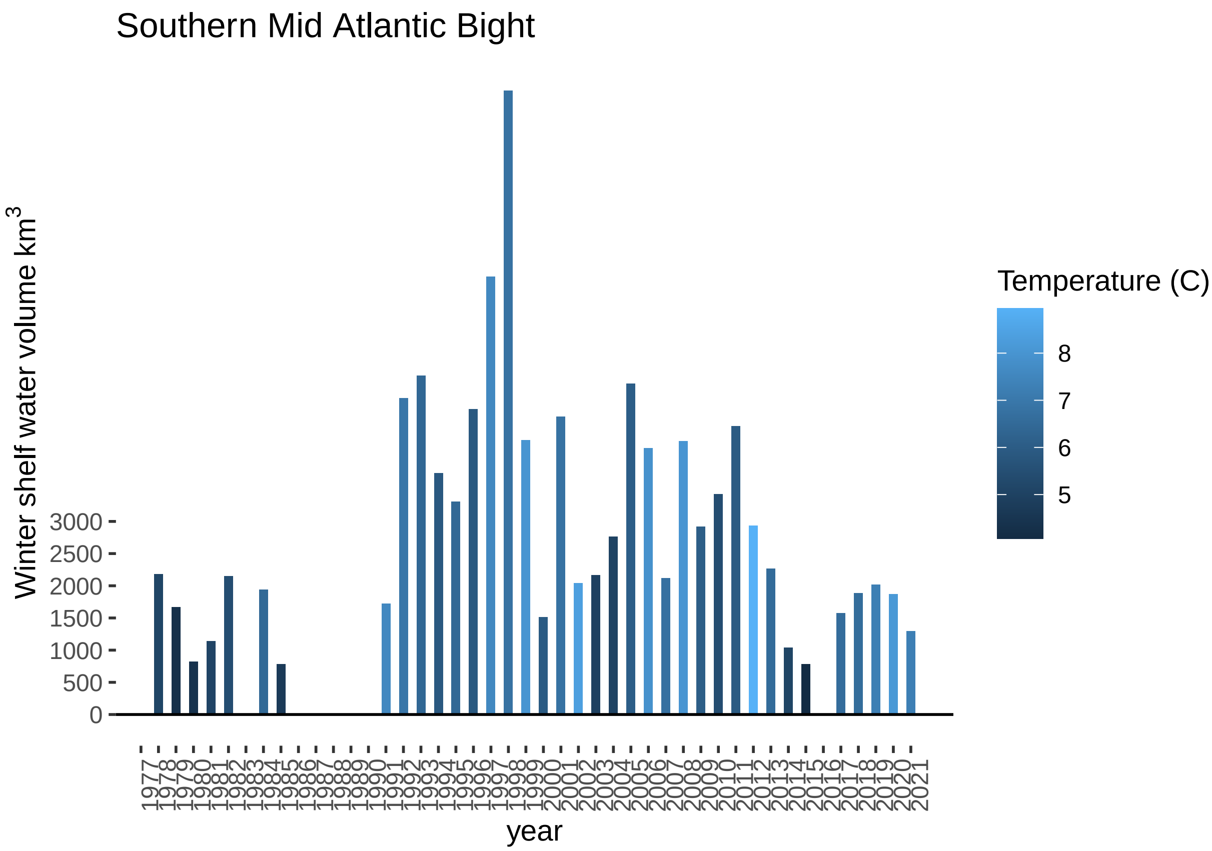
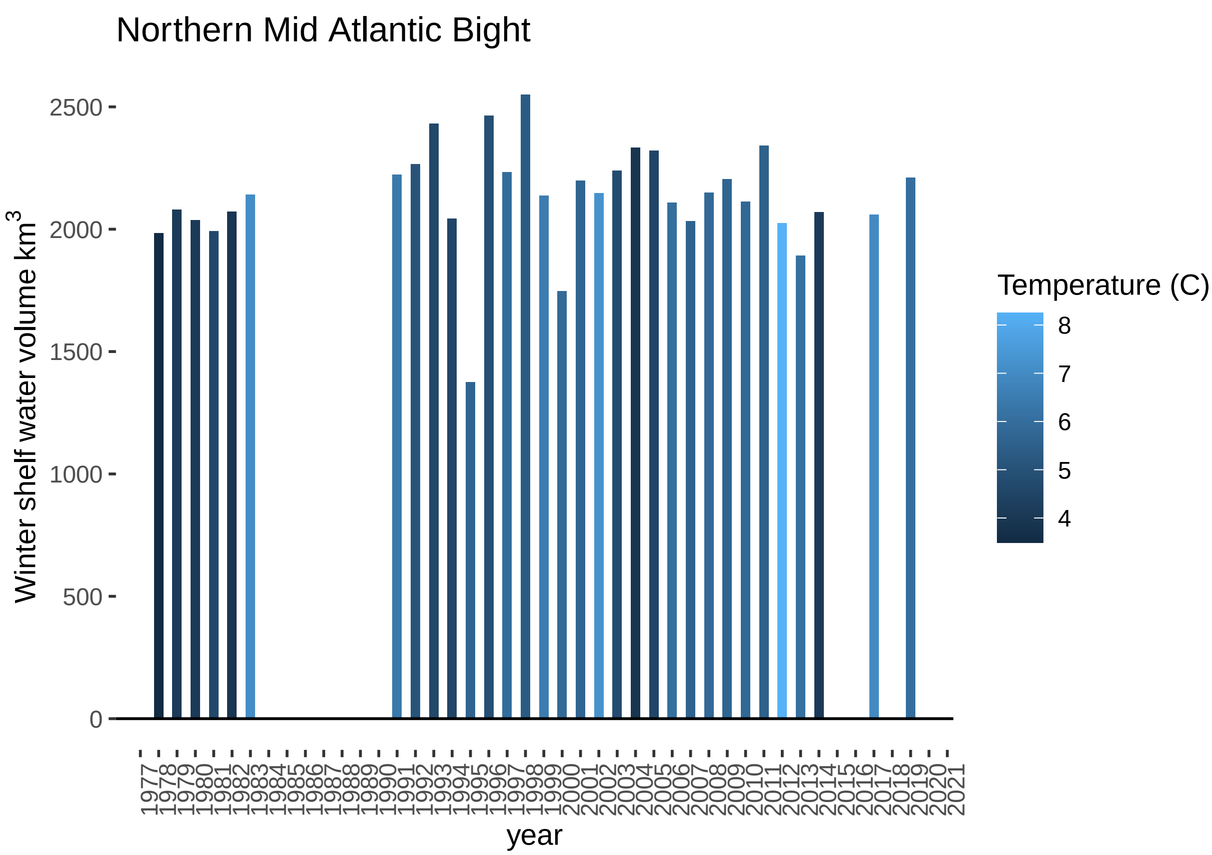
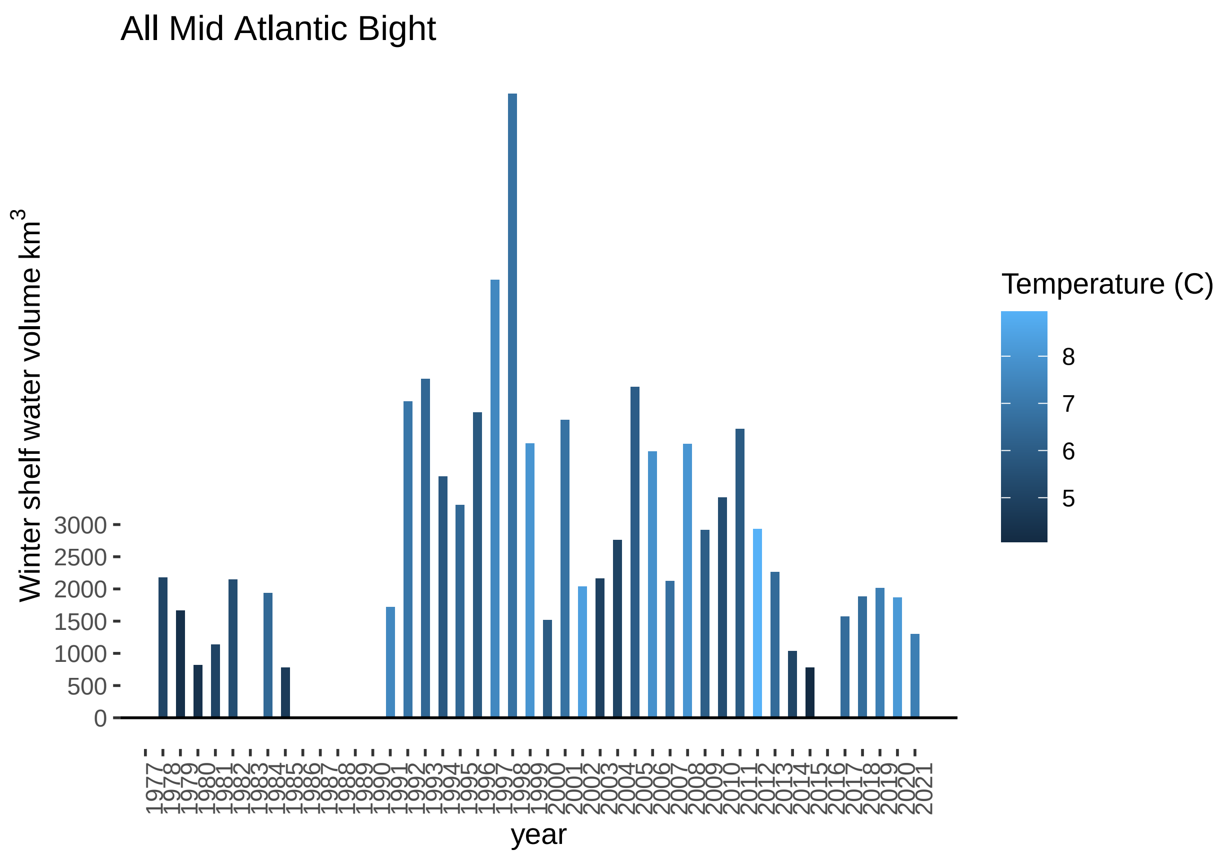
Shelf water volume

Shelf water volume which is a measure of the volume of water bounded inshore of a hydrodynamic feature called the shelf-slope front. In this analysis the shelf water is defined as all water having salinity <34. It is hypothesized that fish are migrating from the self edge and using the shelf slope font as a way-point. The position of this front will vary inter-annually with the higher values indicating the front being pushed further towards the shelf break. As this font moves closer or further from the coast, the available susceptible habitat can expand or contract as black sea bass are known to concentrate slope ward of the front. Miller et al. 2016 Identified a negative impact on catches of both juveniles and adult black sea bass when shelf water volume exceeded 4000 km^3

winter shelf water volume






All Mid Atlantic Bight
Winter shelf water volume km^3
3000
2500
2000
1500
1000
500
0
year
Temperature (C)
8
7
6
5
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
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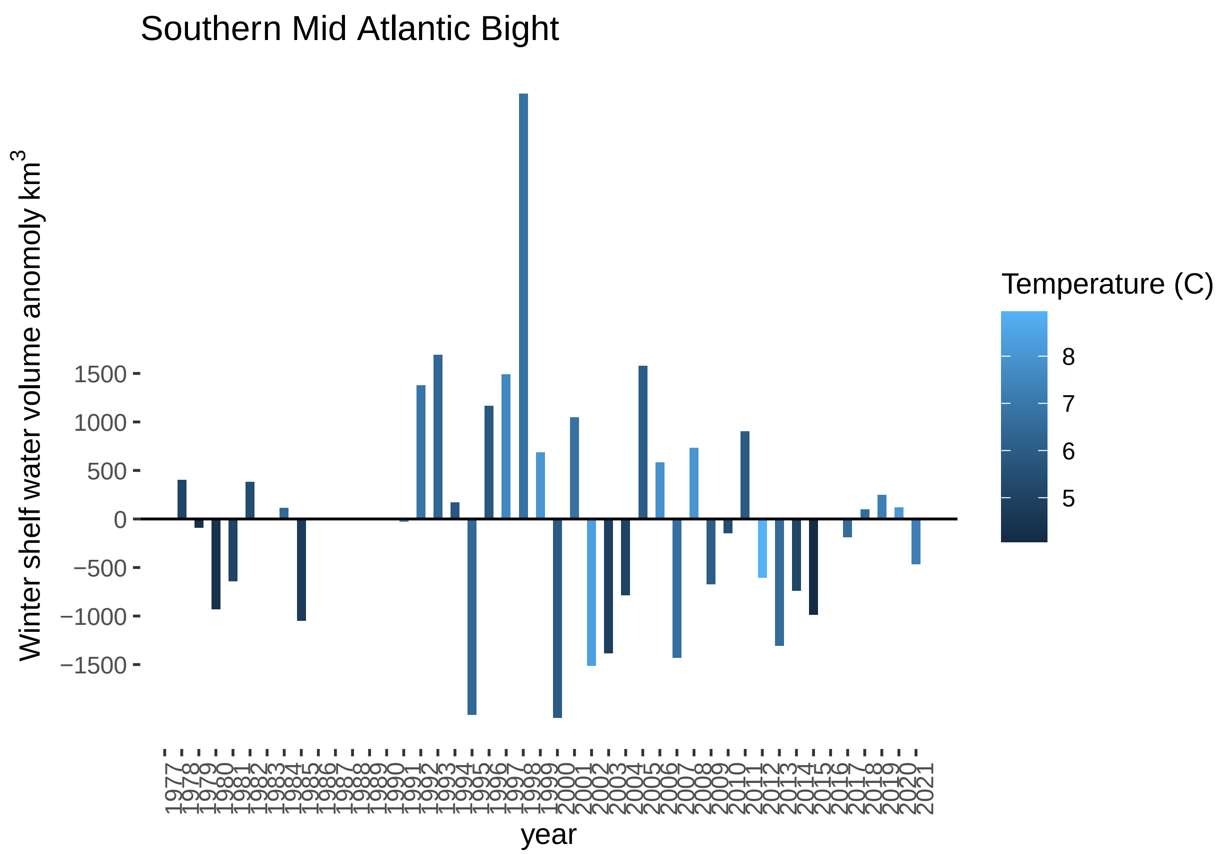
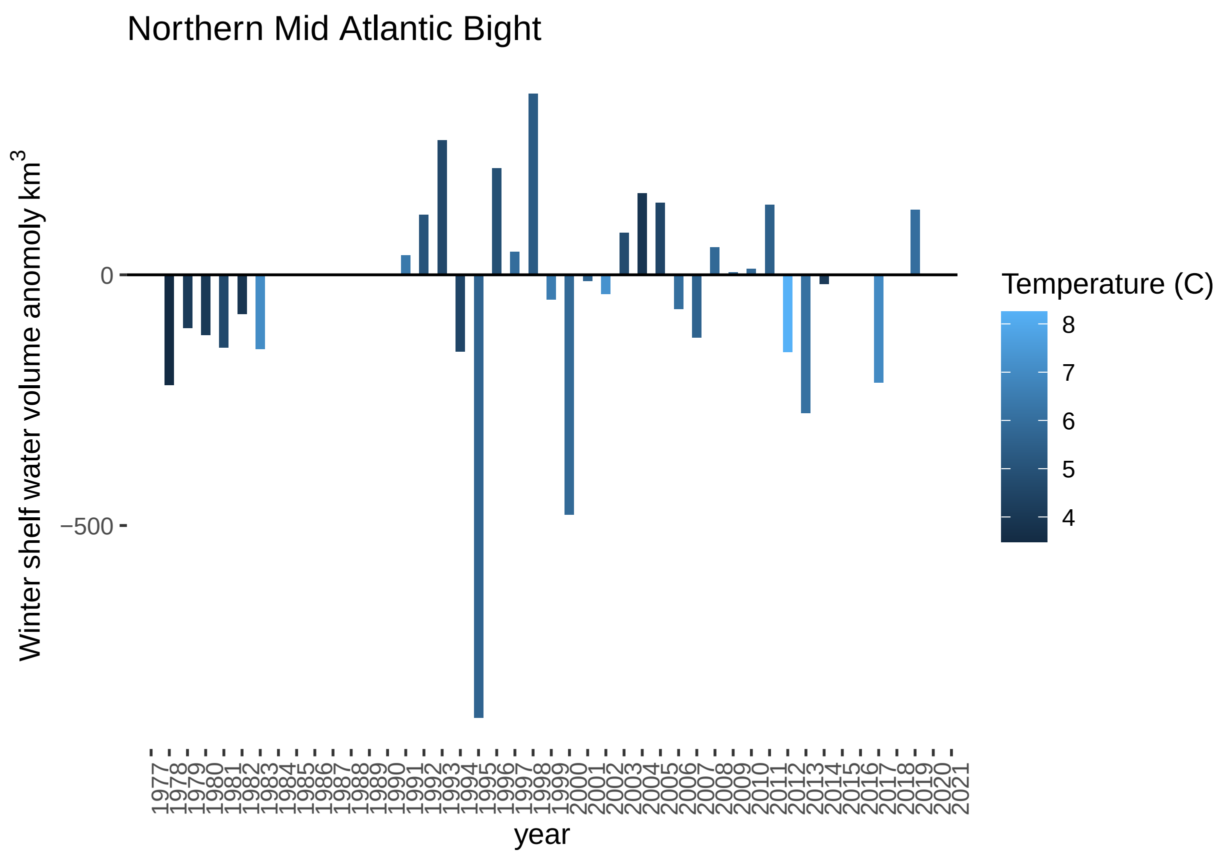
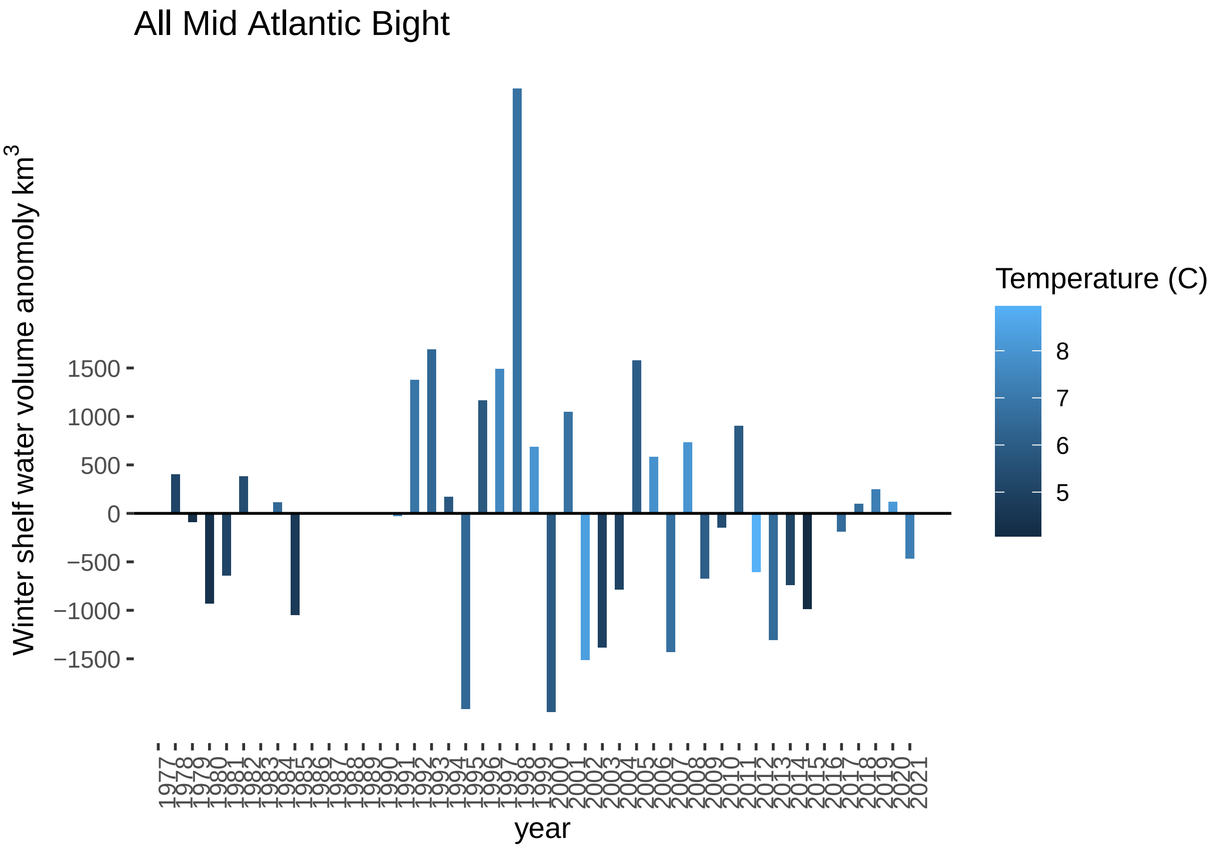
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


Southern Mid Atlantic Bight
Winter shelf water volume anomoly km^3
1500
1000
500
0
−500
−1000
−1500
year
Temperature (C)
8
7
6
5

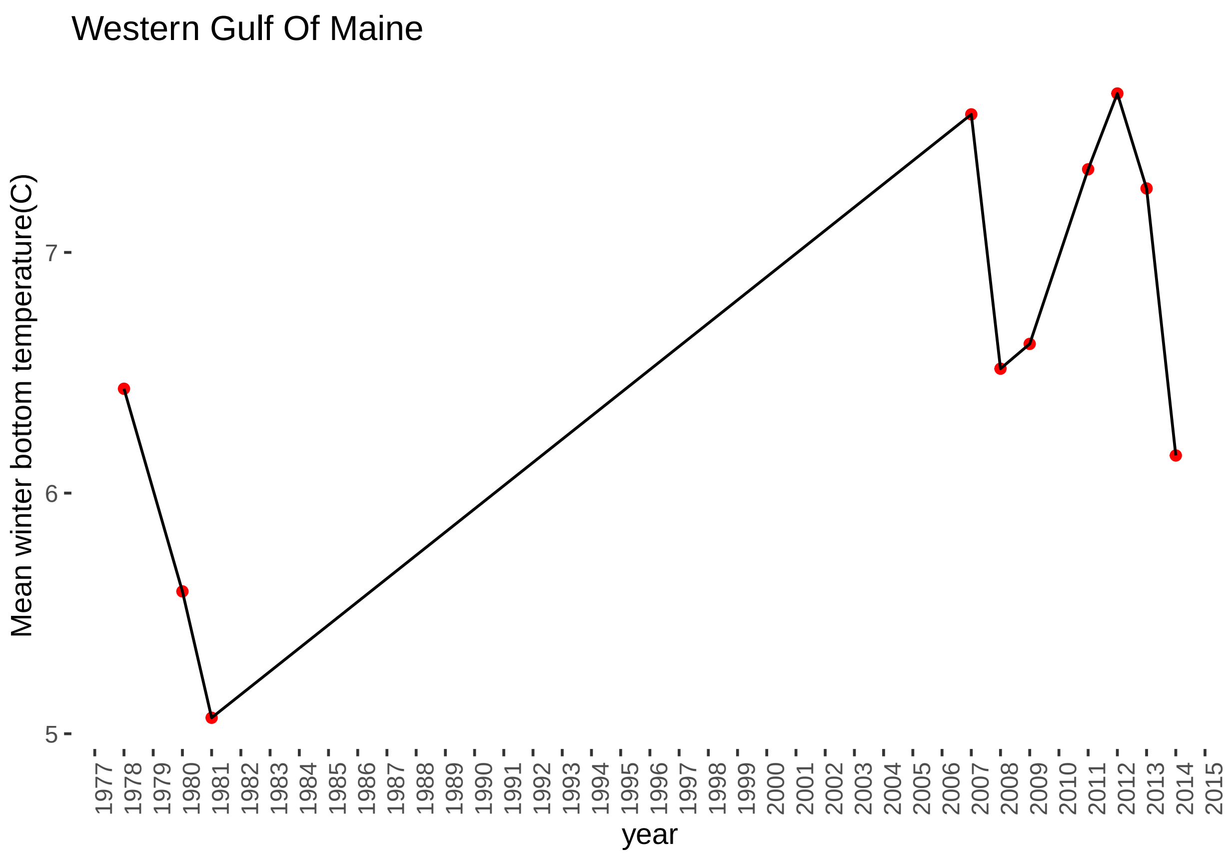

Northern Mid Atlantic Bight
Winter shelf water volume anomoly km3
0
−500
year
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Temperature (C)
8
7
6
5
4

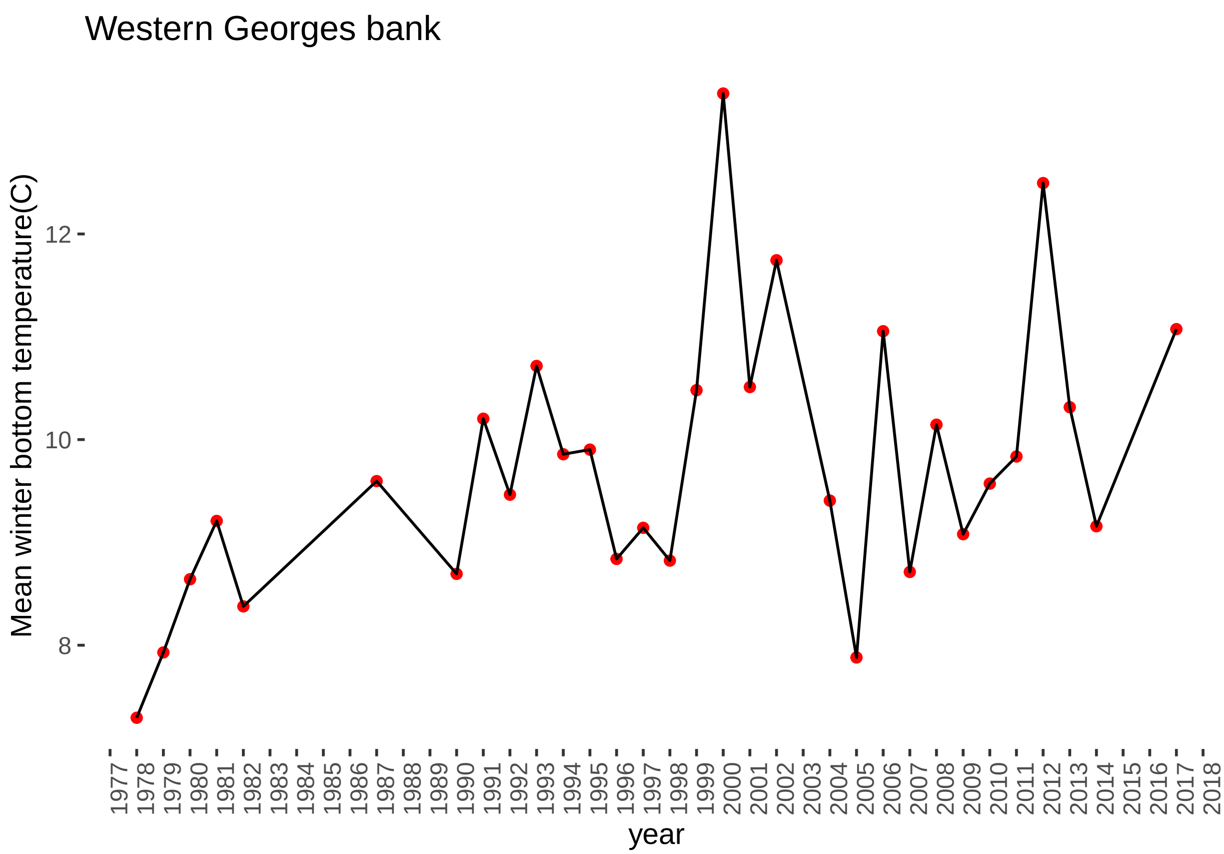


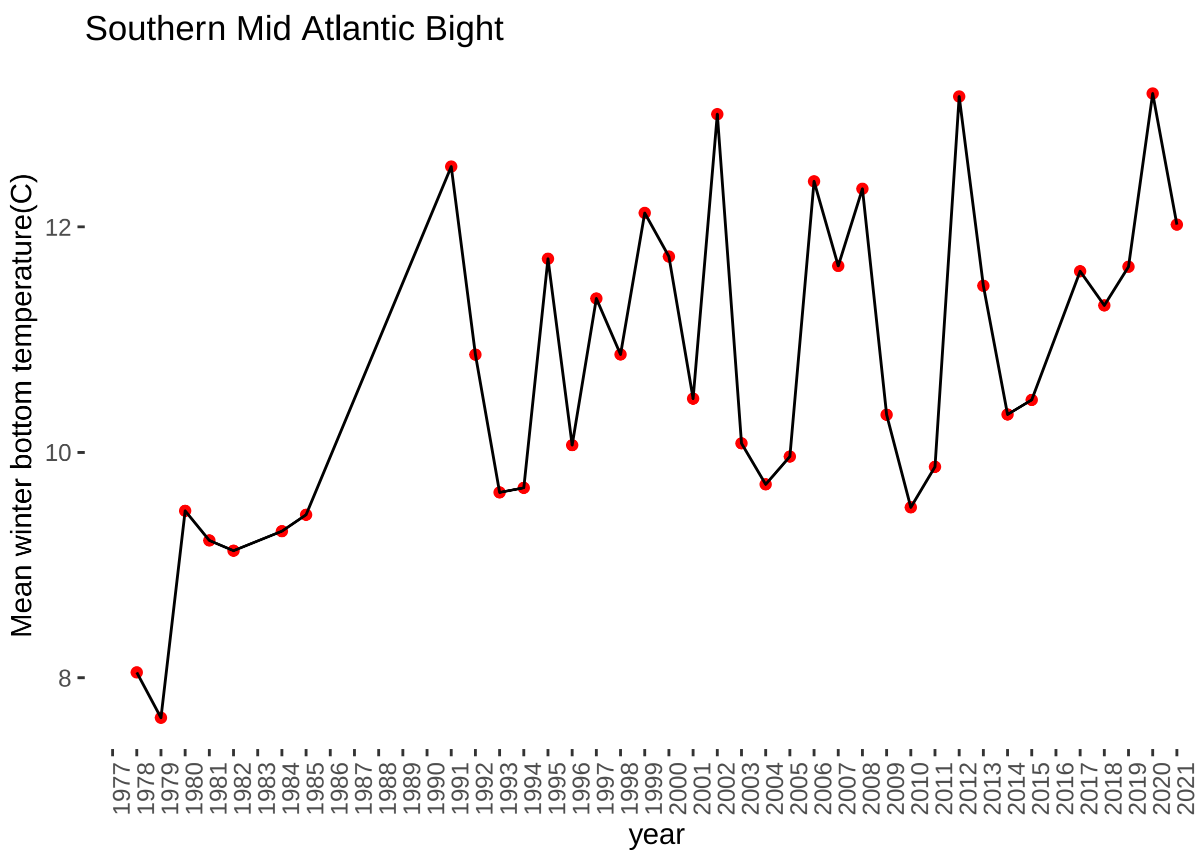
Regional in-situ winter bottom temperature and salinity with anomaly

All available CTD data within 10m of the bottom between the northern and southern MAB region and as a whole. Regional time series were computed as follows: area-weighted regional mean values were computed for each survey in the OCDBS and a reference annual cycle was removed (fit to observations from 1981-2010) to get seasonal anomalies.

note: winter coverage is very sparse due to the winter ECOMON surveys ending. A better approach may to be to use a two month span at the end of winter where coverage is better i.e. FEB-MAR rather than a whole winter.


Western Gulf Of Maine
Mean winter bottom temperature(C)
5
6
7
1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
year


Western Georges bank
Mean winter bottom temperature(C)
12
10
8
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
year


Southern Mid Atlantic Bight
Mean winter bottom temperature(C)
8
10
12
year
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
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2010
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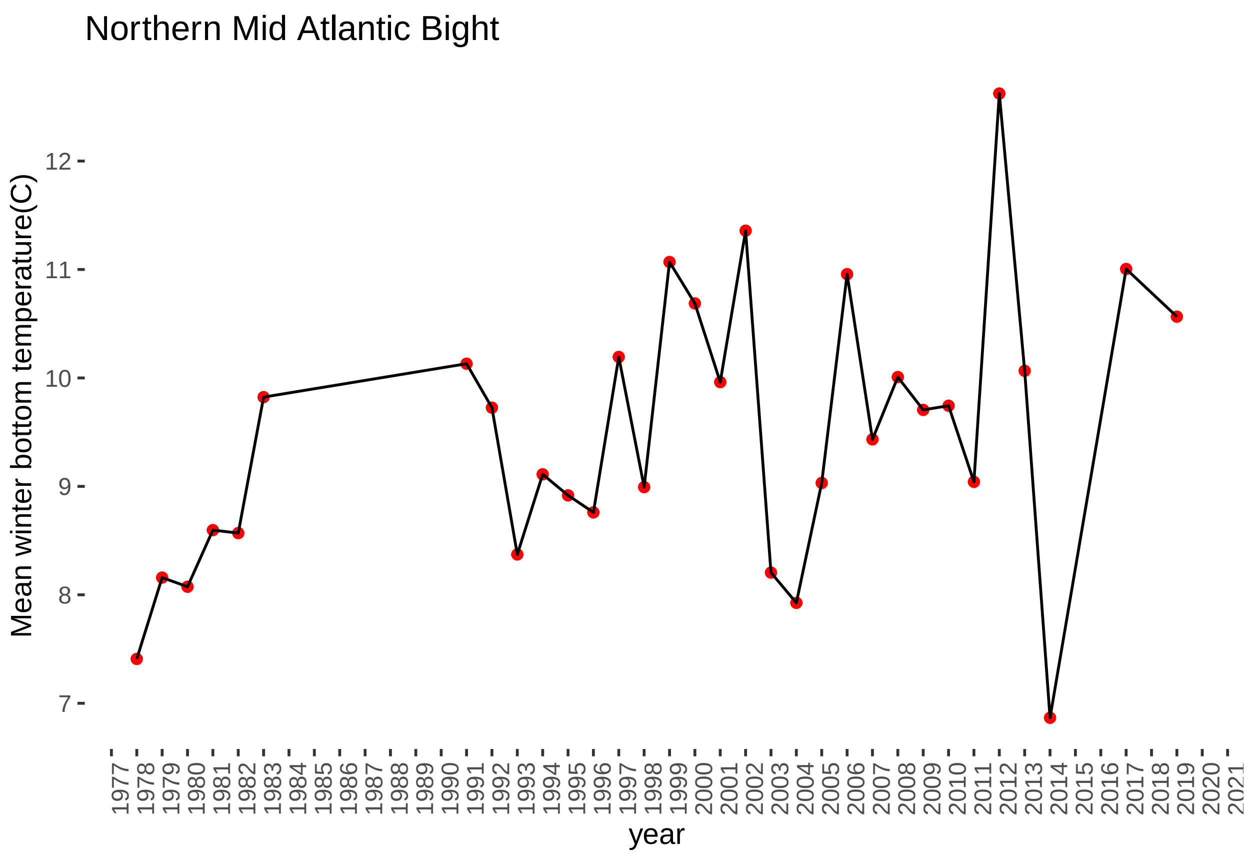
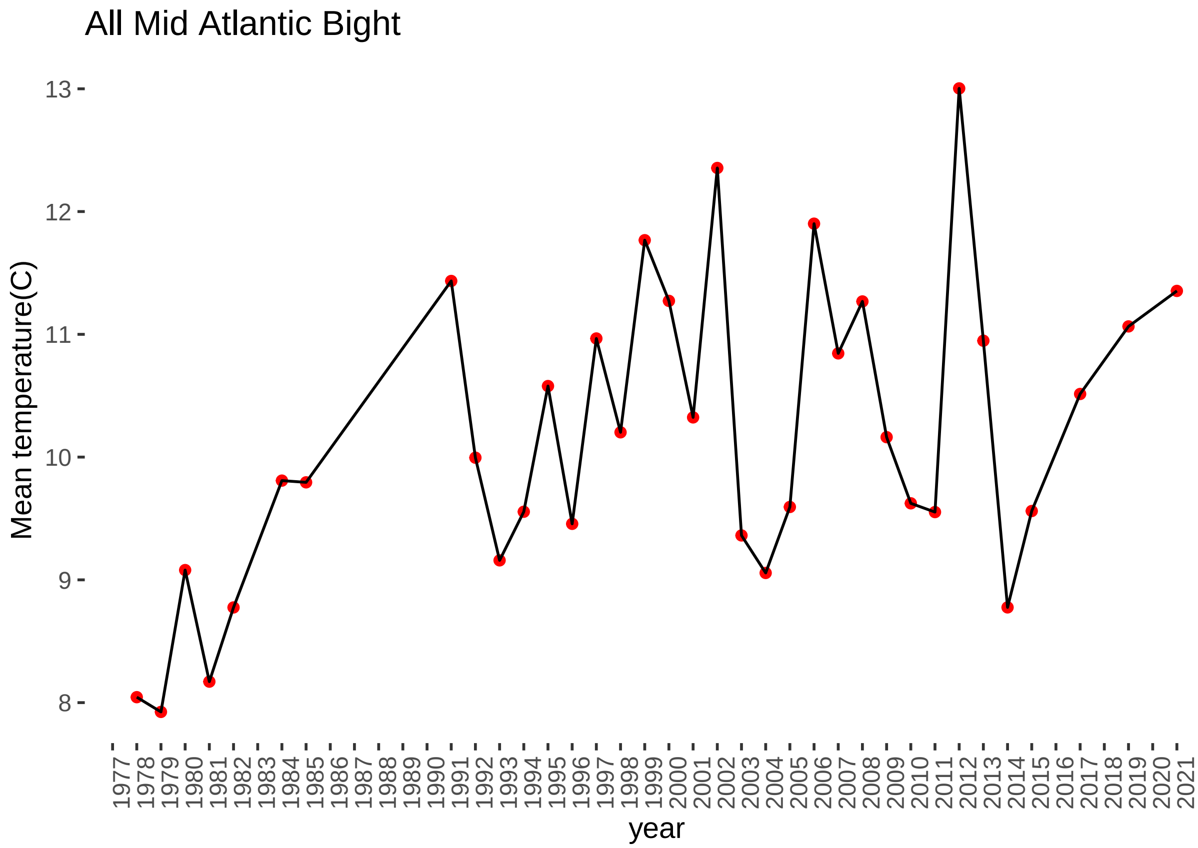
2013
2014
2015
2016
2017
2018
2019
2020
2021

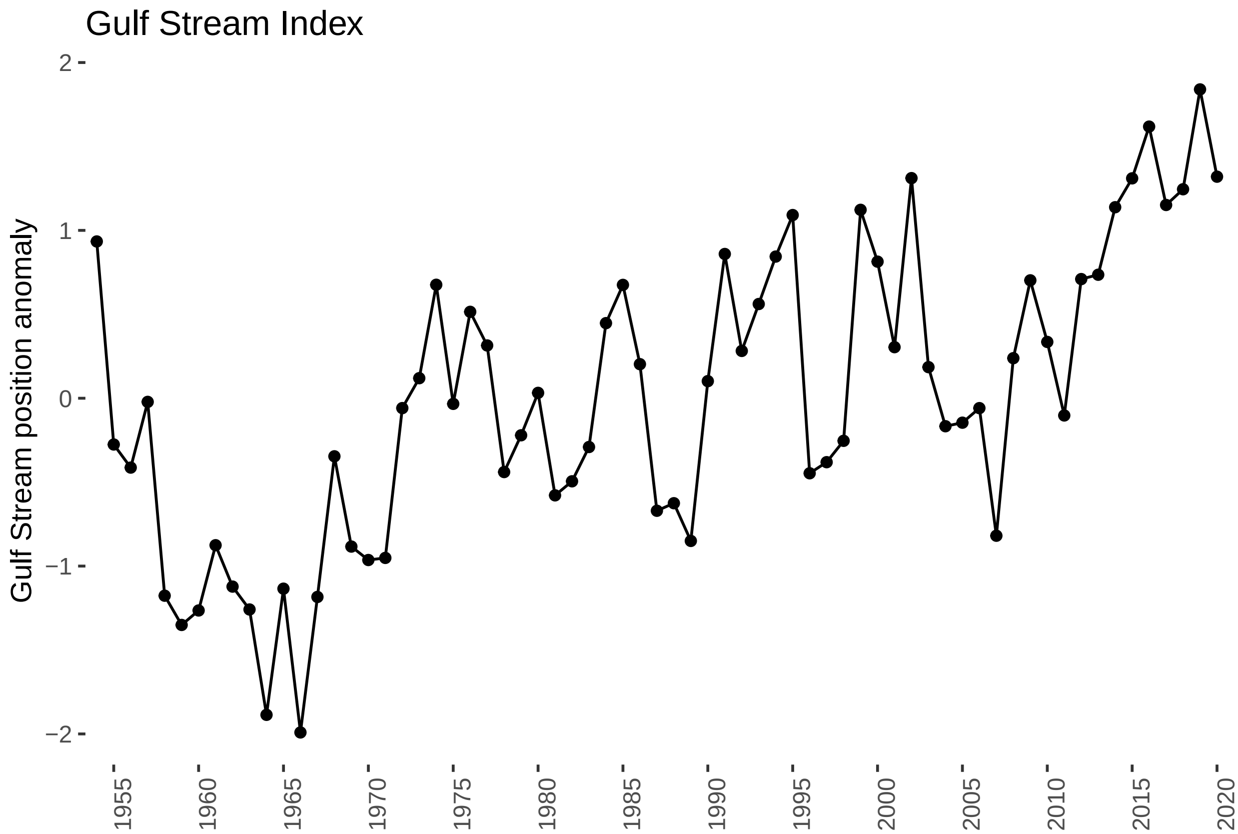


Northern Mid Atlantic Bight
Mean winter bottom temperature(C)
12
11
10
9
8
7
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year



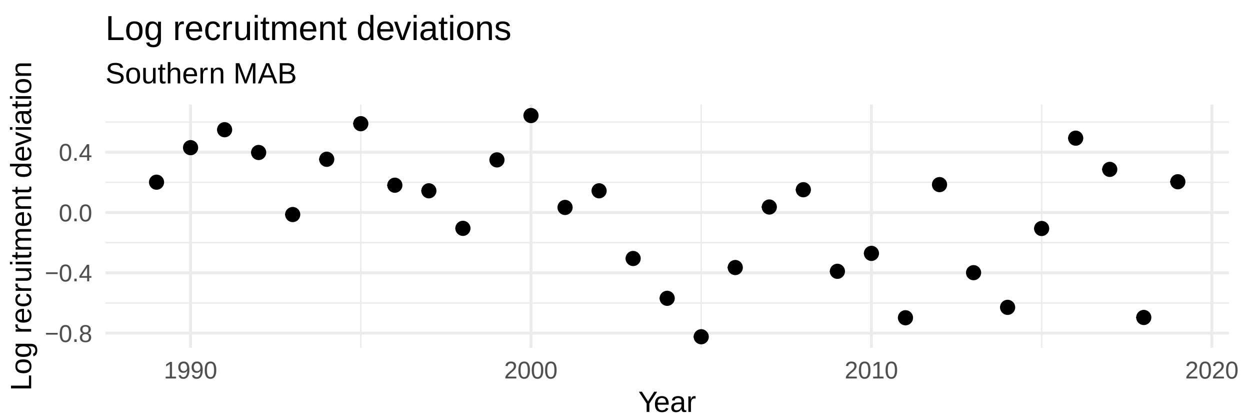
Gulf Stream Index

The GSI is calculated based on the method presented by Pérez-Hernández and Joyce (2014). This gulf stream index is a position anomaly meaning the larger the value of the index the further north the northern wall of the Gulf Stream is for that year.

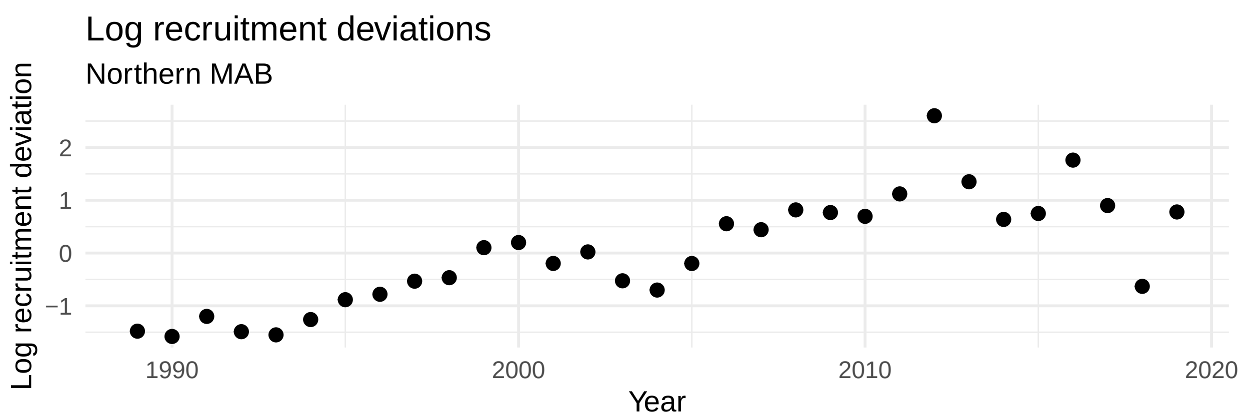


Cross correlation testing

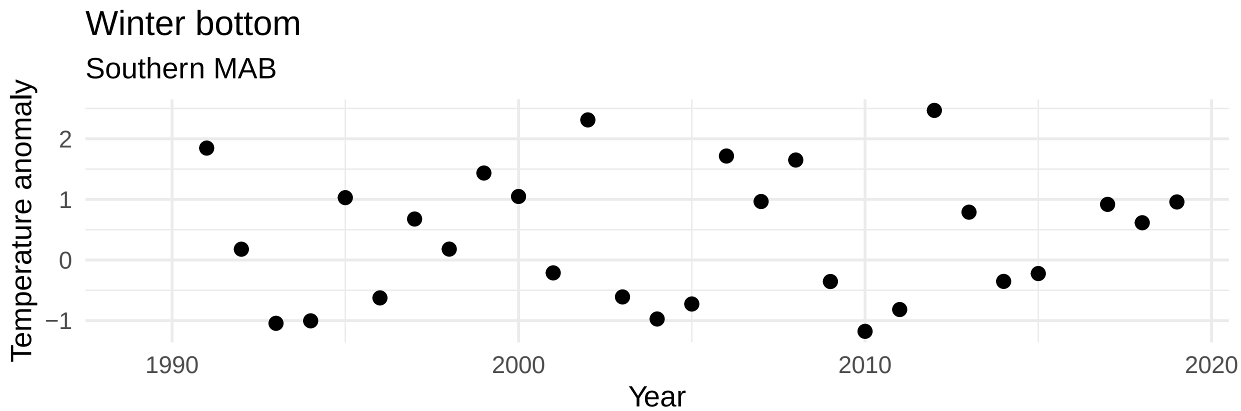
Explorations into the association between bottom conditions and Black sea bass recruitment deviations. recruitment deviations from the 2021 operational assessment. This model output lacks 2020 data and thus 2019 is the terminal year. Bottom conditions are also limited to this time span. Temperature anomaly are used to avoid seasonal and annual patterns. The association is likely to occur with a time lag as current conditions would likely manifest in following years. Horizontal line indicates significant cross correlation

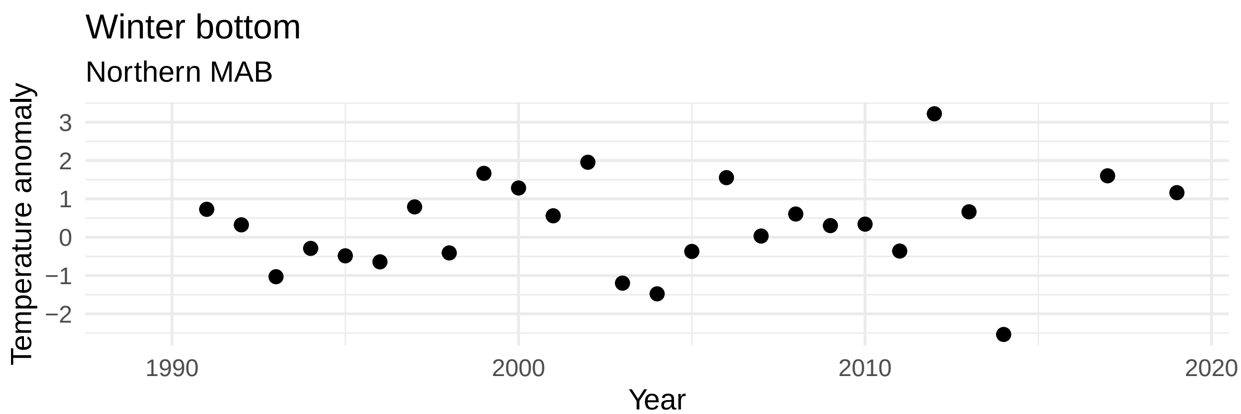


Log recruitment deviations
Southern MAB
Log recruitment deviation
0.4
0.0
−0.4
−0.8
1990
2000
2010
2020
Year



Log recruitment deviations
Northern MAB
Log recruitment deviation
2
1
0
−1
1990
2000
2010
2020
Year





Pearsons correlations

Bottom temperature

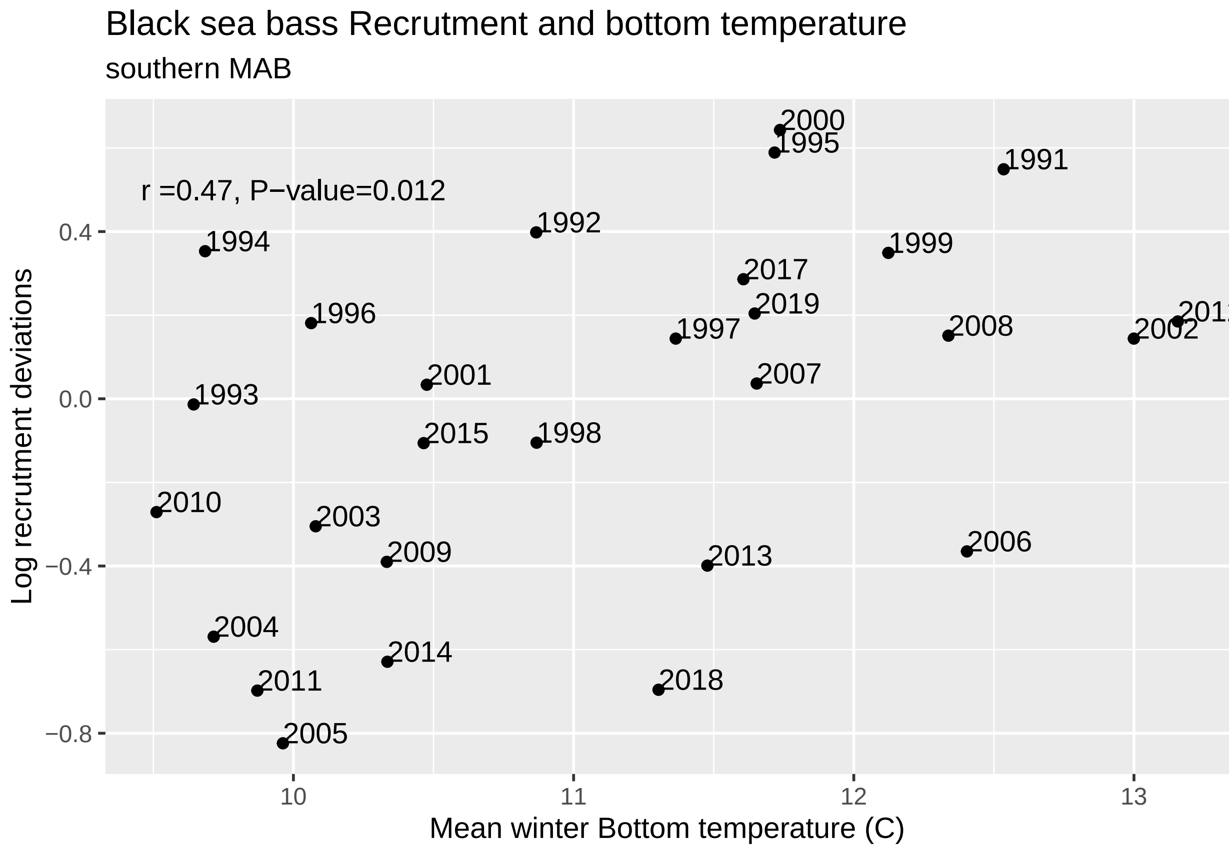
Associations between model estimates of recruitment and environmental indicators is tested using Pearsons correlations. Mean winter bottom temperature is signifcantly correlated within year estimates of recruitment in both regions (South. P-value = 0.012, t = 2.69, r=0.467; North, P-value = 0.013, t = 2.68, r= 0.480). No signifcant associations were found for lags of one or two years in mean bottom temperatures across regions. Temperature anomalys display a similar significance level and mangitude of associaiton to in-situ temperature values.

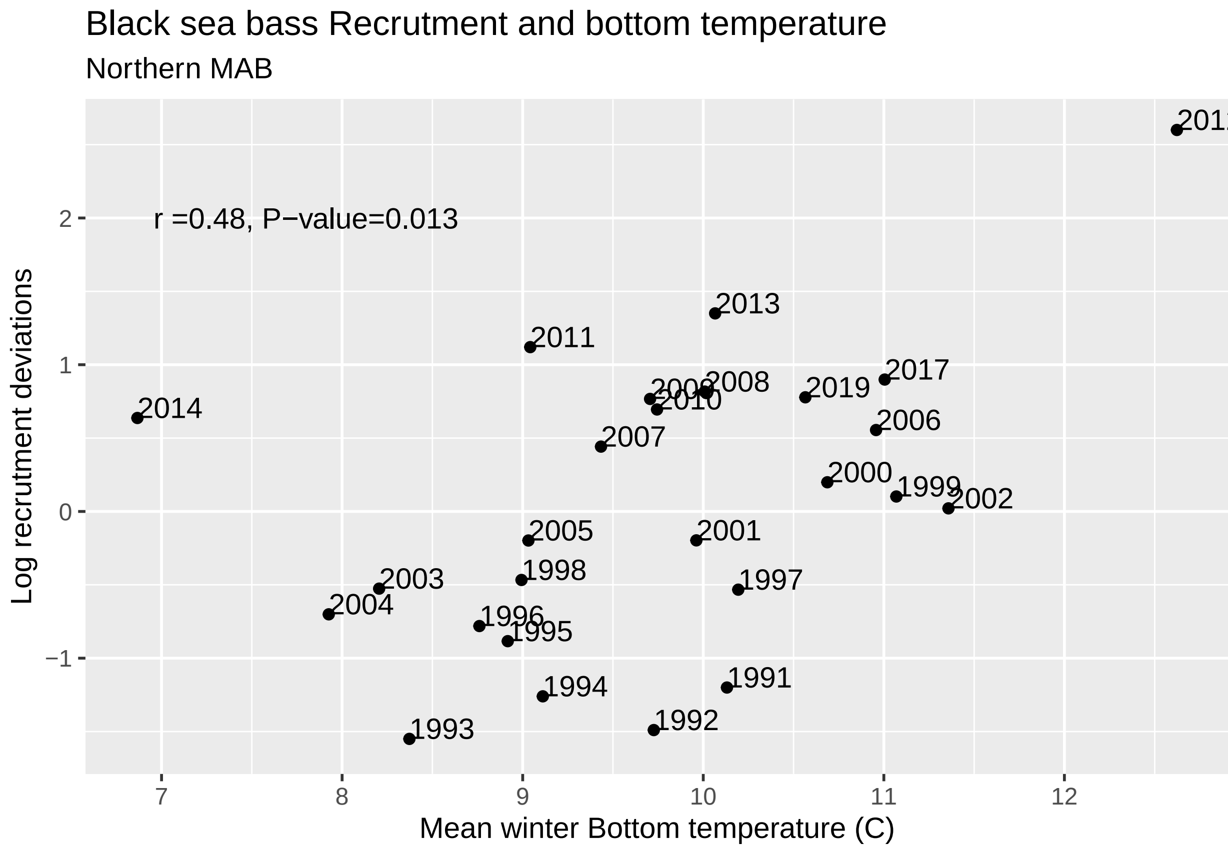
Bottom Salinity

No significant associations found in either region (South. P-value = 0.880, t = 0.151, r=0.029; North, P-value = 0.080, t = 2.68, r= 0.353). Simiarly nither one or two year lags were found to be associated with recruitment deviation.

Winter Shelf water volume

No significant associations found in either region (South, t = -1.00, p-value = 0.321, r= -0.13; North t = -1.098, p-value = 0.283, r= -0.210). Additionally no lags had significant associations for either of one or two years of winter shelf water volume.


Black sea bass Recrutment and bottom temperature
southern MAB
r =0.47, P−value=0.012
Log recrutment deviations
Mean winter Bottom temperature (C)
0.4
0.0
−0.4
−0.8
10
11
12
13
2000
1995
1991
1992
1994
1999
2017
1996
2019
1997
2008
2002
2001
2007
1993
2015
1998
2010
2003
2006
2009
2013
2004
2014
2011
2018
2005



Within indicator correlations

indicators are evaluated for their auto correlation within years to detect if meaningful confounding occurs. Bottom salinity and Shelf water volume is sigificantly negitivly correlated with shelf water volume in both regions (South ,t = -12.78, P-value= 0.001, r = -0.8551866 (North, t = -3.46, P-value= 0.001, r = -0.534). This strong association requires the selection of one of these indicators at the exclusion of the other to avoid overfitting.Shelf water volume was not associated with bottom temperature. Salinity and temperature were not significantly associated with one another in either region

Reanalysis product

A high-resolution bottom temperature ocean reanalysis and model output over the period 1989 - 2021 is compared to observed ocean temperature data using methods described in Miller et. al. 2016. The in situ dataset is subject to missing data coverage due to the timing and quality of data collection platforms resulting in Southern MAB missing 3 years, while Northern MAB is missing 7 years in coverage. The reanalysis data uses numerical simulation to interpolate for areas and times where data is limited.

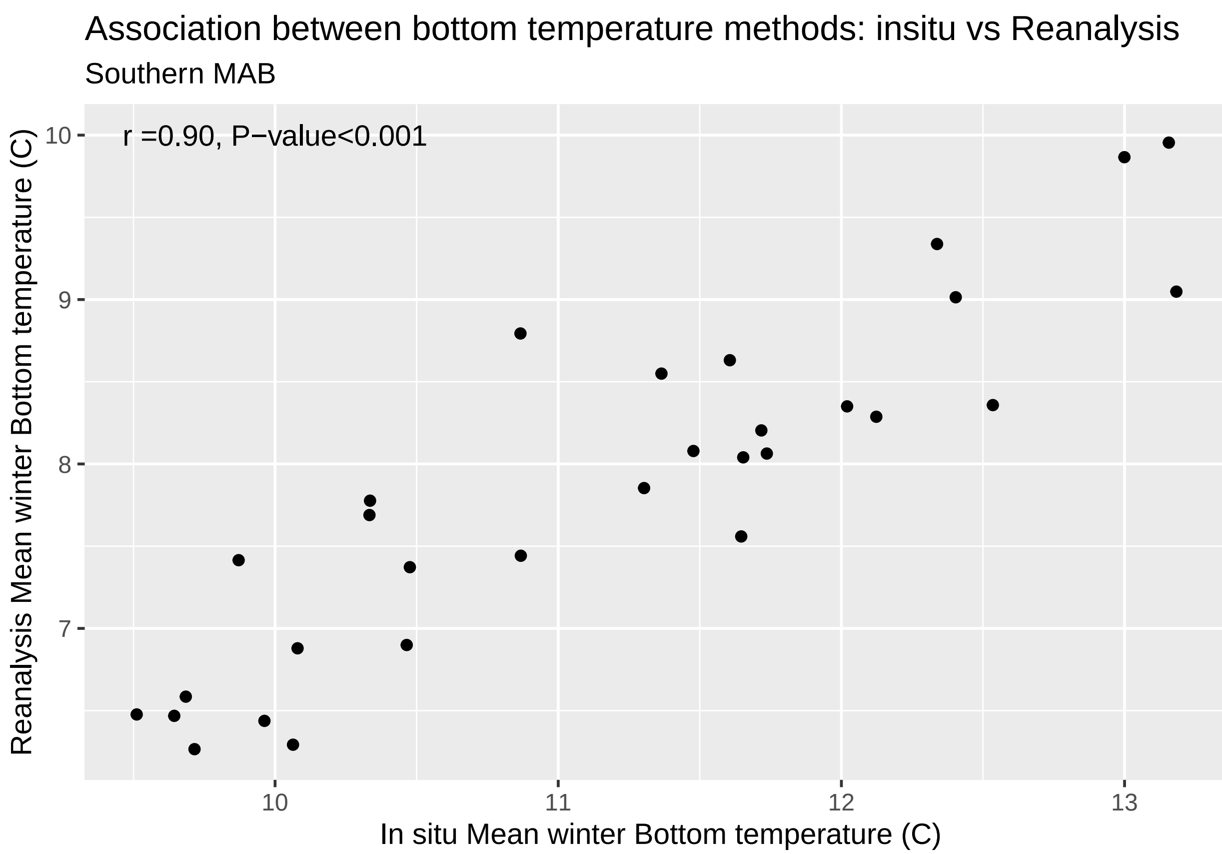
```
## # A tibble: 792 x 6
## # Groups:   "Region", year [33]
##         X Region  year month bt_temp ‘"Region"‘
##     <int> <chr>  <int> <int>   <dbl> <chr>
##   1     1 North   1989     1    7.90 Region
##   2     2 North   1989     2    6.96 Region
##   3     3 North   1989     3    5.96 Region
##   4     4 North   1989     4    7.06 Region
```

```
## 5      5 North   1989     5    8.32 Region
## 6      6 North   1989     6    8.94 Region
## 7      7 North   1989     7    9.34 Region
## 8      8 North   1989     8    9.80 Region
## 9      9 North   1989     9   11.8  Region
## 10    10 North   1989    10   12.4  Region
## # ... with 782 more rows
## # i Use `print(n = ...)` to see more rows
```

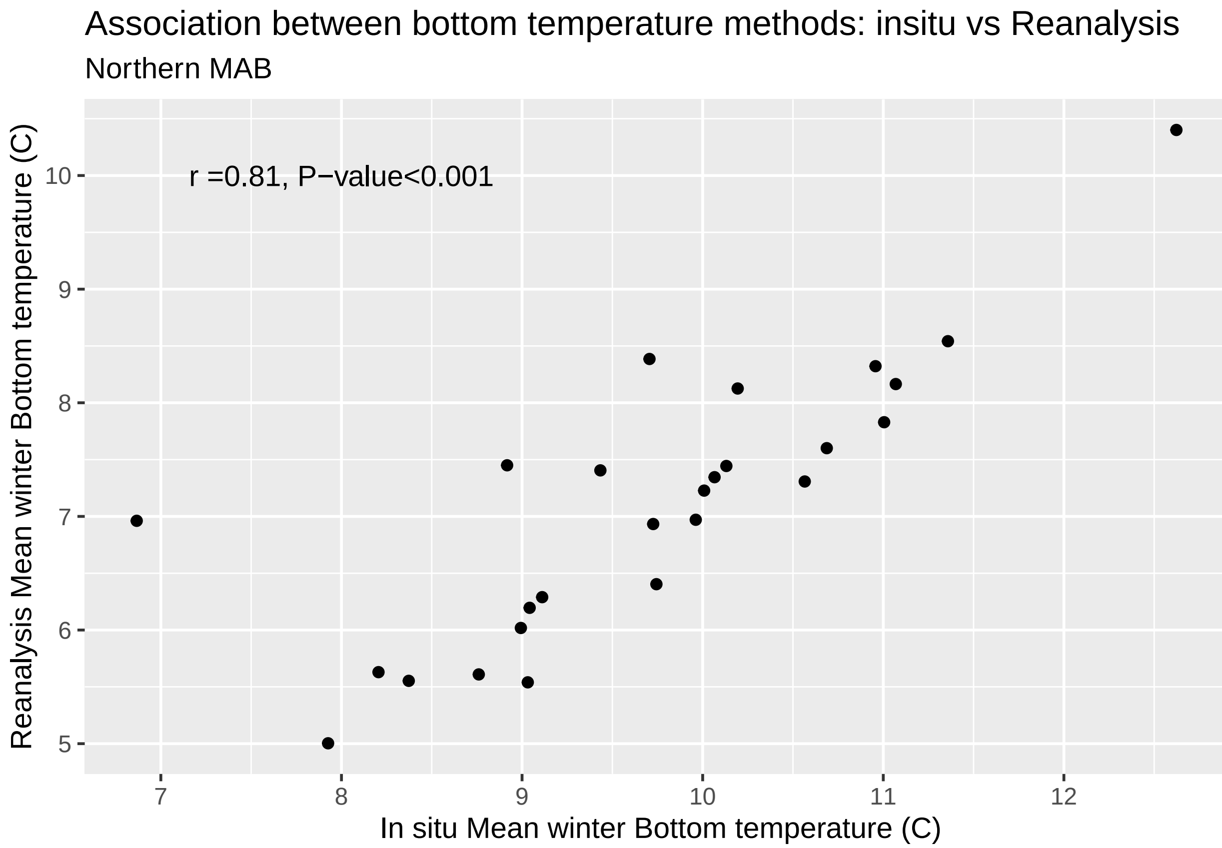
```
##
##  Pearson's product-moment correlation
##
## data:  w_bt_temp and mean_bot_T
## t = 6.6492, df = 24, p-value = 7.064e-07
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6070278 0.9089696
## sample estimates:
##       cor
## 0.8050788
```

```
##
##  Pearson's product-moment correlation
##
## data:  w_bt_temp and mean_bot_T
## t = 10.865, df = 28, p-value = 1.495e-11
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7968877 0.9512173
## sample estimates:
##       cor
## 0.8990461
```

```
## Warning: Removed 3 rows containing missing values (geom_point).
```




```
## Warning: Removed 7 rows containing missing values (geom_point).
```



linear models

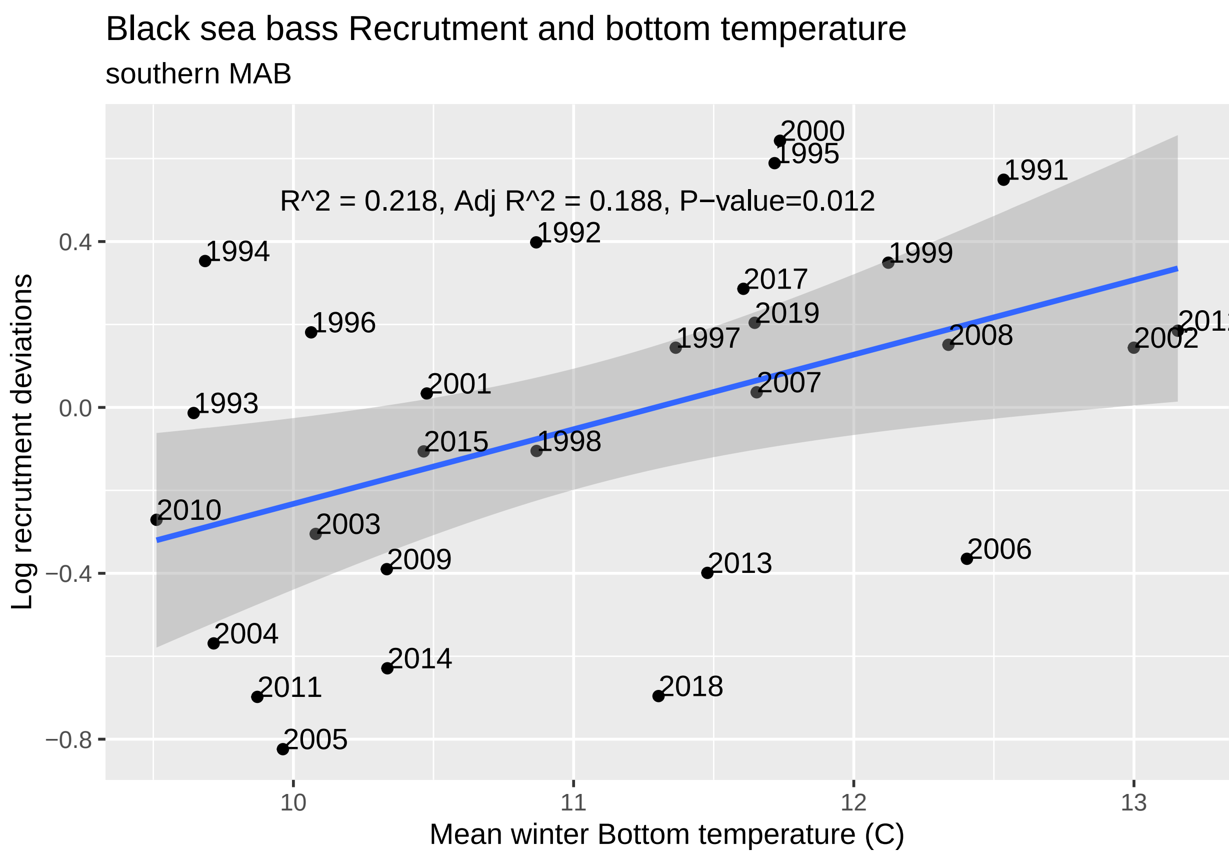
The association in mean winter bottom temperature is further investigated using linear models. Significant relationships were found between bottom temperature and recruitment deviation. Model residuals do not display any concerning patterns and positive relationships observed in both regions.

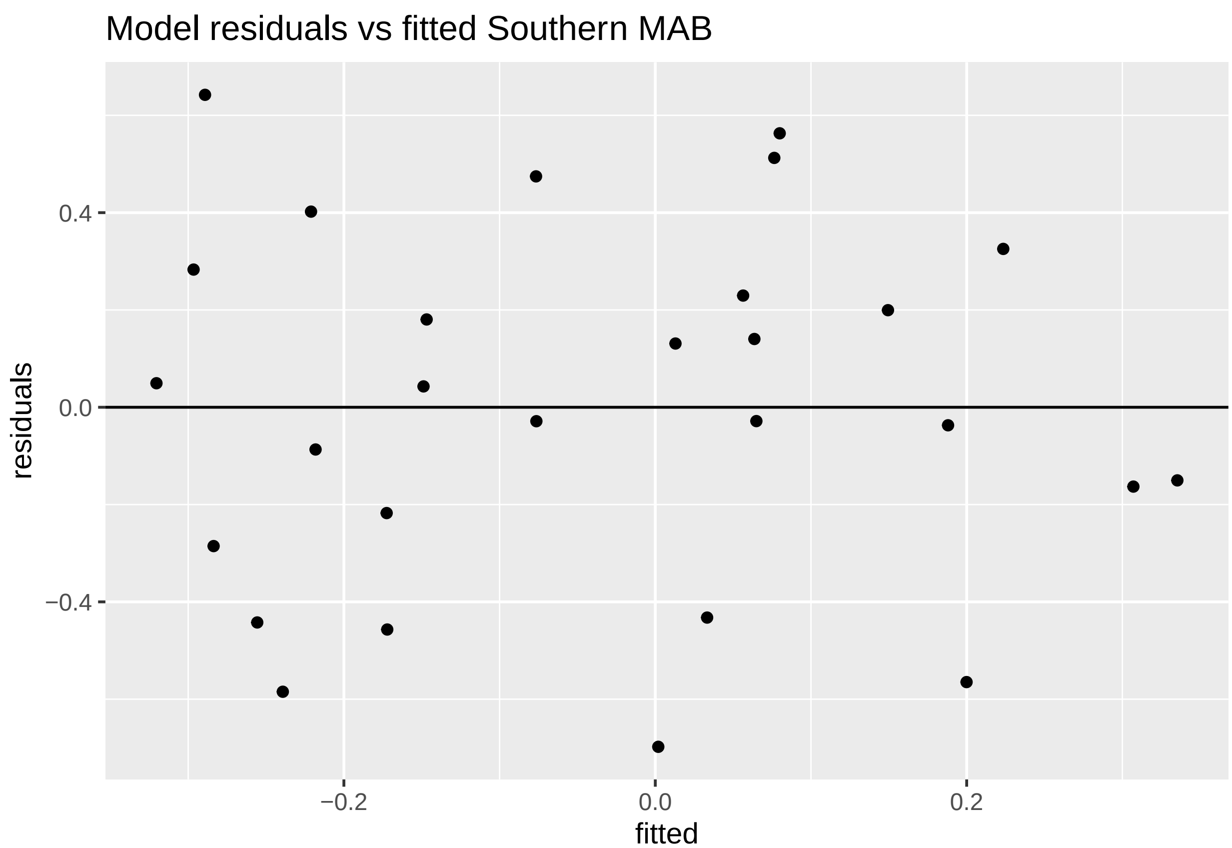
```
## Warning: Removed 3 rows containing non-finite values (stat_smooth).
```

```
## Warning: Removed 3 rows containing missing values (geom_point).
```

```
## Warning: Removed 3 rows containing missing values (geom_text).
```

```
## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## font width unknown for character 0x9
```


Black sea bass Recrutment and bottom temperature
southern MAB
R^2 = 0.218, Adj R^2 = 0.188, P−value=0.012
Log recrutment deviations
Mean winter Bottom temperature (C)
0.4
0.0
−0.4
−0.8
10
11
12
13
2000
1995
1991
1992
1994
1999
2017
2019
1996
1997
2008
2002
2001
2007
1993
2015
1998
2010
2003
2009
2013
2006
2004
2014
2011
2018
2005

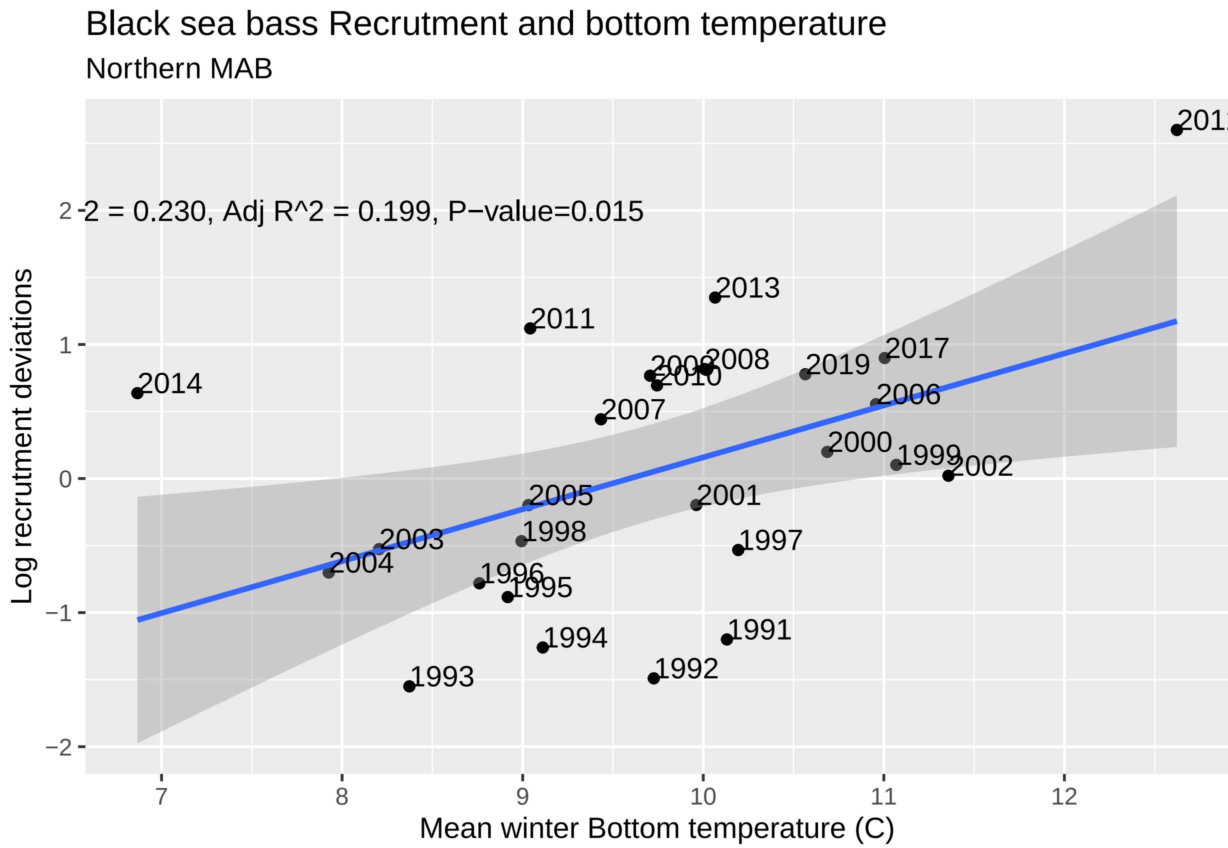


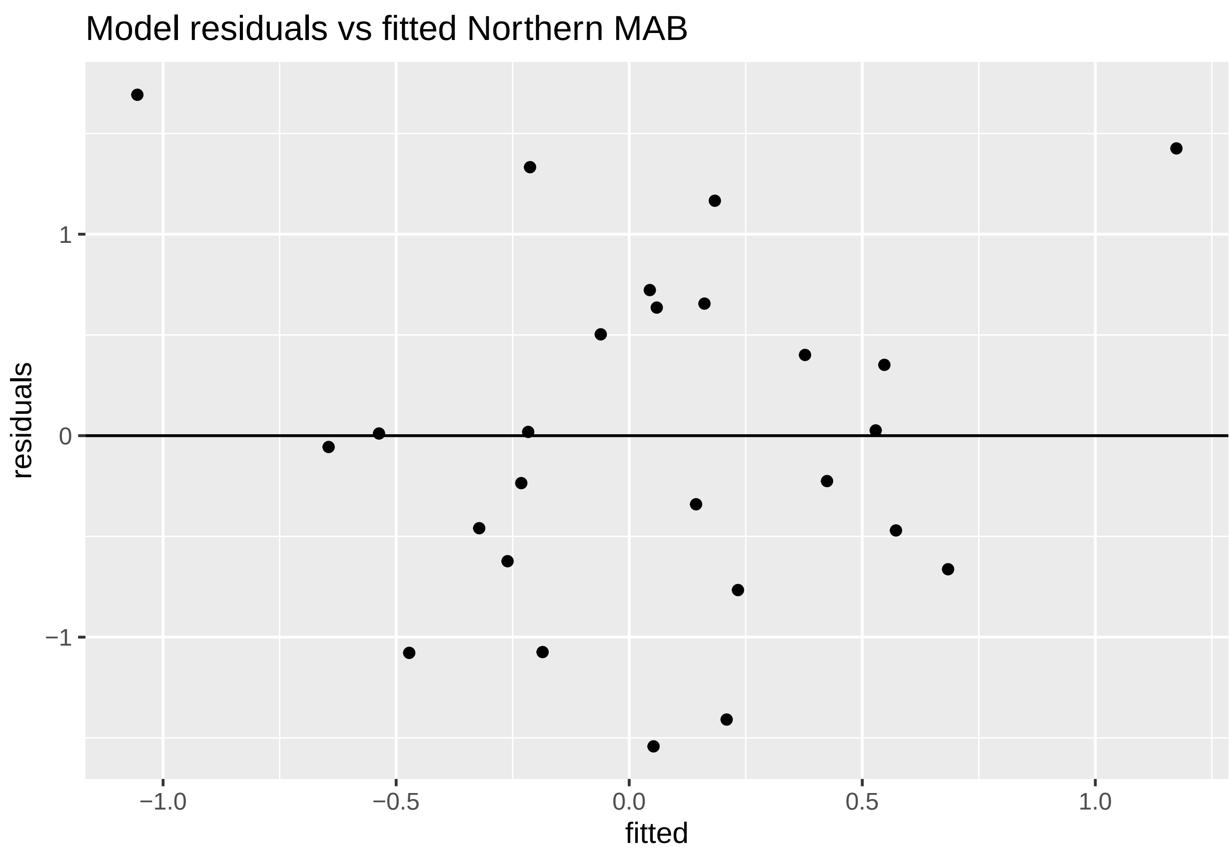

```
## Warning: Removed 5 rows containing non-finite values (stat_smooth).

## Warning: Removed 5 rows containing missing values (geom_point).

## Warning: Removed 5 rows containing missing values (geom_text).

## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## font width unknown for character 0x9
```


Black sea bass Recrutment and bottom temperature
Northern MAB
2 = 0.230, Adj R^2 = 0.199, P−value=0.015
Log recrutment deviations
Mean winter Bottom temperature (C)
2012
2013
2011
2014
2008
2010
2007
2019
2017
2006
2000
1999
2002
2005
2001
2003
2004
1998
1997
1996
1995
1994
1991
1993
1992
2
1
0
−1
−2
7
8
9
10
11
12




```
ra_S_rec<-left_join(ra_S,South_rec_dev, by= "year")
ra_N_rec<-left_join(ra_N,North_rec_dev, by= "year")


ra_S_rec %>% with(cor.test(w_bt_temp,log_recruit_devs, method=c("pearson")))
```

```
##
##  Pearson's product-moment correlation
##
## data:  w_bt_temp and log_recruit_devs
## t = 2.4632, df = 29, p-value = 0.01994
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.07227617 0.67135130
## sample estimates:
##       cor
## 0.4159633
```

```
ra_N_rec %>% with(cor.test(w_bt_temp,log_recruit_devs, method=c("pearson")))
```

```
##
##  Pearson's product-moment correlation
##
## data:  w_bt_temp and log_recruit_devs
```

```
## t = 3.3434, df = 29, p-value = 0.002294
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.2129207 0.7429472
## sample estimates:
##       cor
## 0.5274655
```

```r
re_rec_lm_N<-lm(log_recruit_devs~w_bt_temp,data =ra_N_rec)
summary(re_rec_lm_N)
```

```
##
## Call:
## lm(formula = log_recruit_devs ~ w_bt_temp, data = ra_N_rec)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.00560 -0.70274  0.09095  0.65256  1.59244
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -3.4599     1.0477  -3.302  0.00255 **
## w_bt_temp     0.4822     0.1442   3.343  0.00229 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9074 on 29 degrees of freedom
##   (2 observations deleted due to missingness)
## Multiple R-squared:  0.2782, Adjusted R-squared:  0.2533
## F-statistic: 11.18 on 1 and 29 DF,  p-value: 0.002294
```

```r
re_rec_lm_S<-lm(log_recruit_devs~w_bt_temp,data =ra_S_rec)
summary(re_rec_lm_S)
```

```
##
## Call:
## lm(formula = log_recruit_devs ~ w_bt_temp, data = ra_S_rec)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.6921 -0.2436  0.0330  0.2657  0.6122
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1.3000     0.5323  -2.442   0.0209 *
## w_bt_temp     0.1650     0.0670   2.463   0.0199 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3849 on 29 degrees of freedom
##   (2 observations deleted due to missingness)
## Multiple R-squared:  0.173,  Adjusted R-squared:  0.1445
## F-statistic: 6.068 on 1 and 29 DF,  p-value: 0.01994
```

```r
#0.173, Adjusted R-squared:  0.1445

re_rec_lm<-lm(log_recruit_devs~w_bt_temp,data =ra_N_rec)
summary(re_rec_lm)
```

```
##
## Call:
## lm(formula = log_recruit_devs ~ w_bt_temp, data = ra_N_rec)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.00560 -0.70274  0.09095  0.65256  1.59244
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -3.4599     1.0477  -3.302  0.00255 **
## w_bt_temp     0.4822     0.1442   3.343  0.00229 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9074 on 29 degrees of freedom
##   (2 observations deleted due to missingness)
## Multiple R-squared:  0.2782, Adjusted R-squared:  0.2533
## F-statistic: 11.18 on 1 and 29 DF,  p-value: 0.002294
```

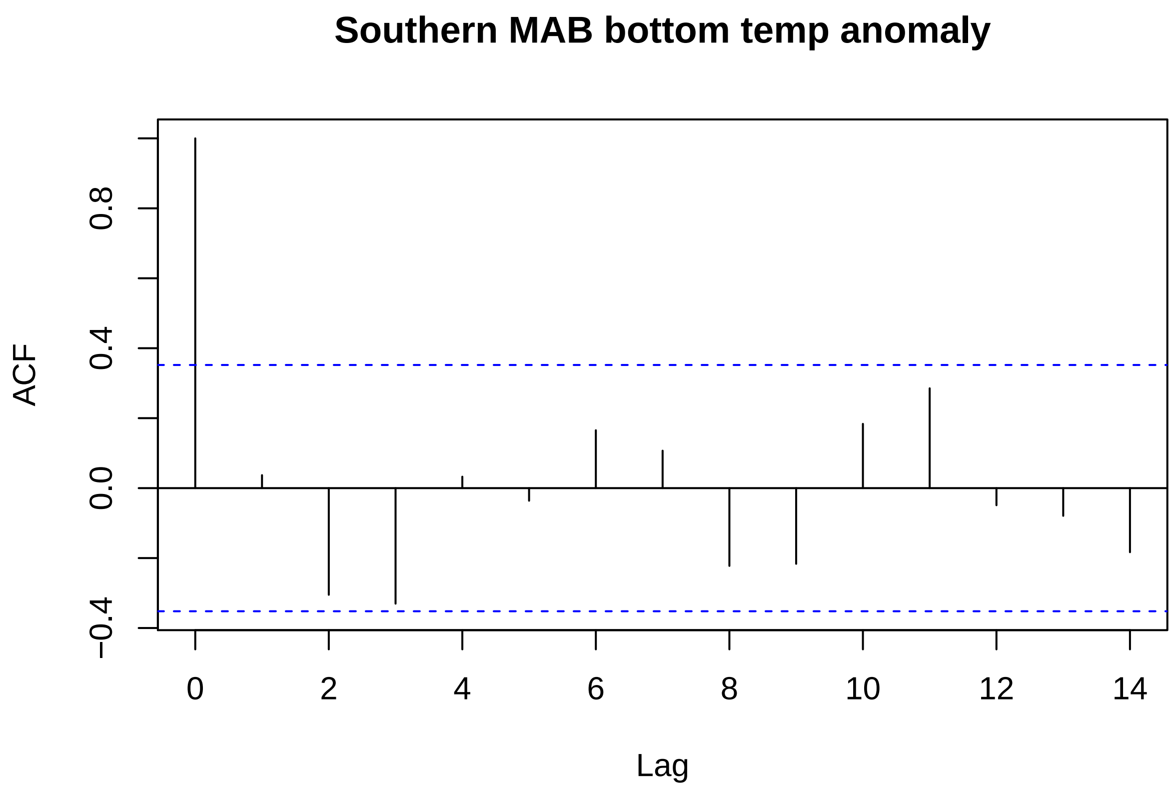
```r
#0.2782,    Adjusted R-squared:  0.2533 P-value= 0.002
```

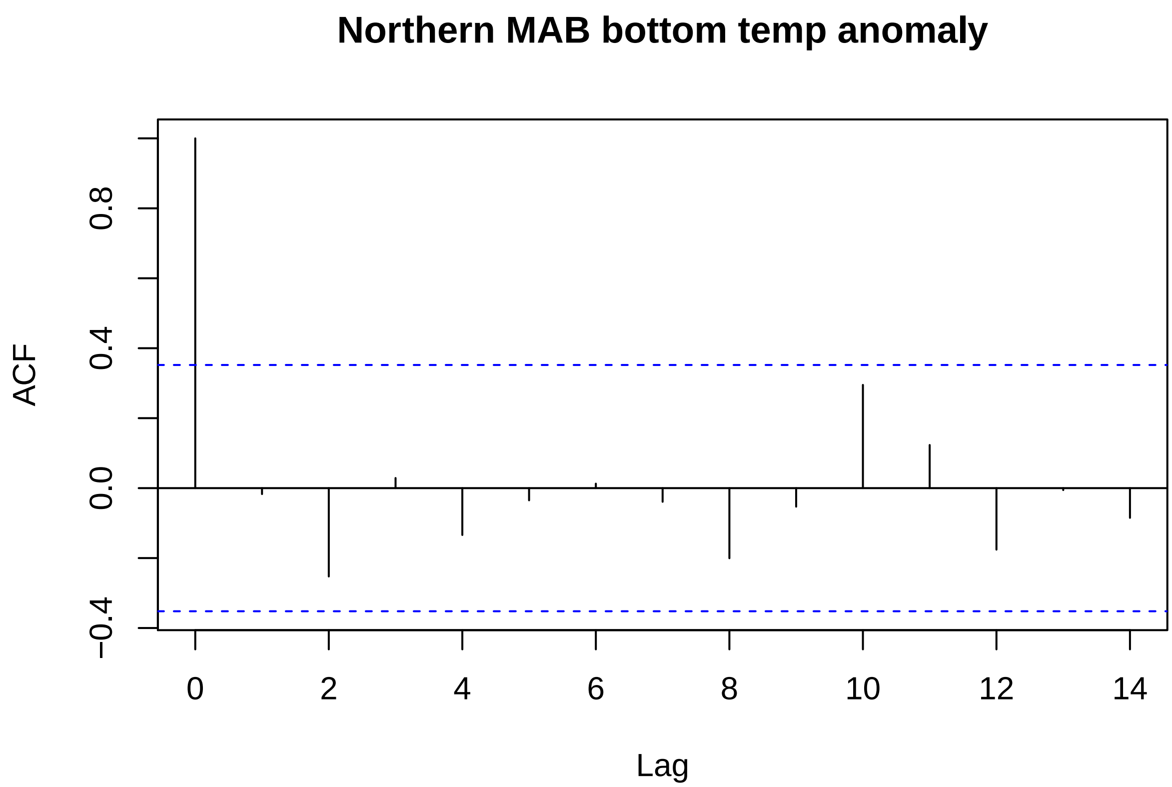
Autocorrelation function

Searching for Autocorrelation within each variable is useful for identifiying the types of structure the data may contain. Each time series is correlated with itself at differing time lags.

Bottom temp anomaly ACF

Appears to display minimal issues with autocorrelations, and appears to be similar to white noise for both Northern and southern regions


Southern MAB bottom temp anomaly
ACF
0.8
0.4
0.0
−0.4
0
2
4
6
8
10
12
14
Lag



Stationarity

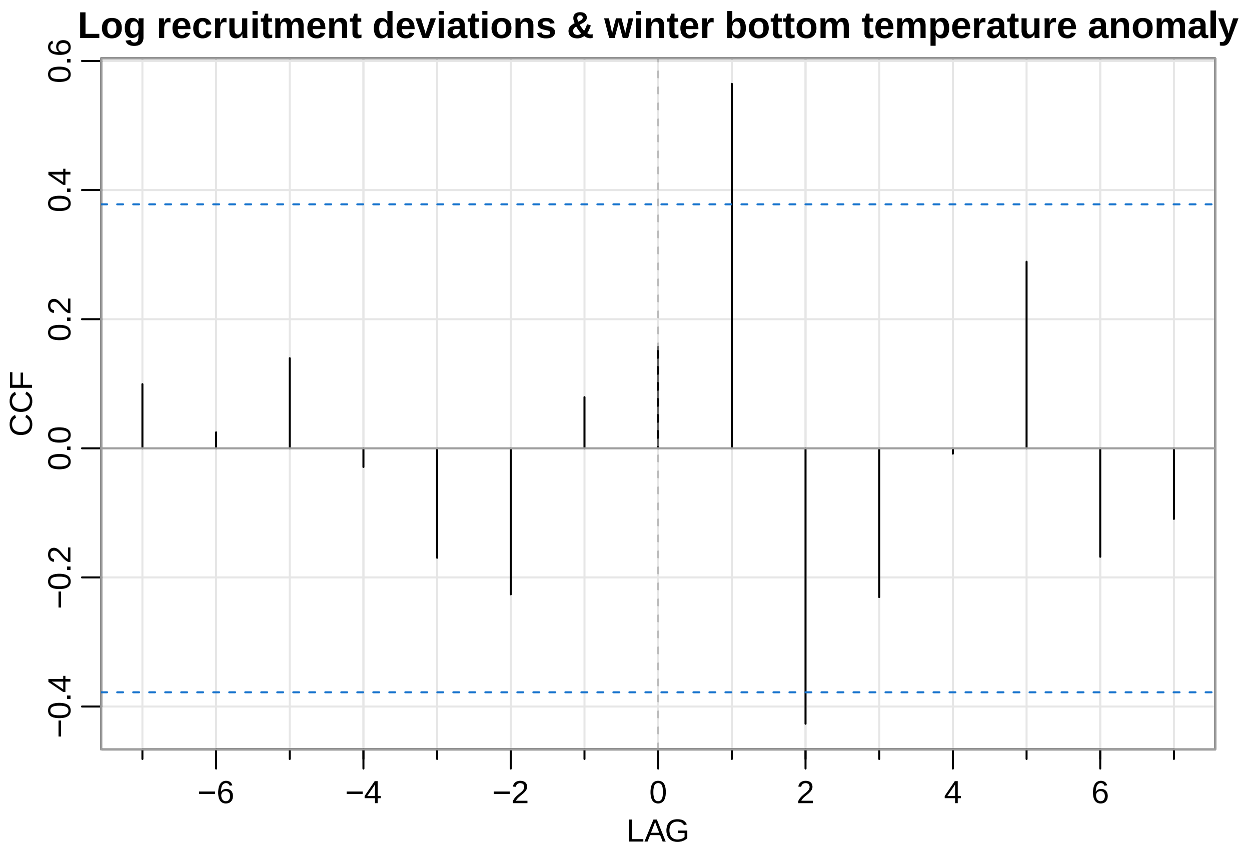
Augmented Dickey-Fuller Test indicates that recrutment time serise are not stationary. Recrutment deviations are however are corrected into stationarity when differenced, converting the data from original values to sequential rate changes in time. IE, each value is the difference of preceding years

$$Y_t - Y_{t-1}$$

southern MAB ccf

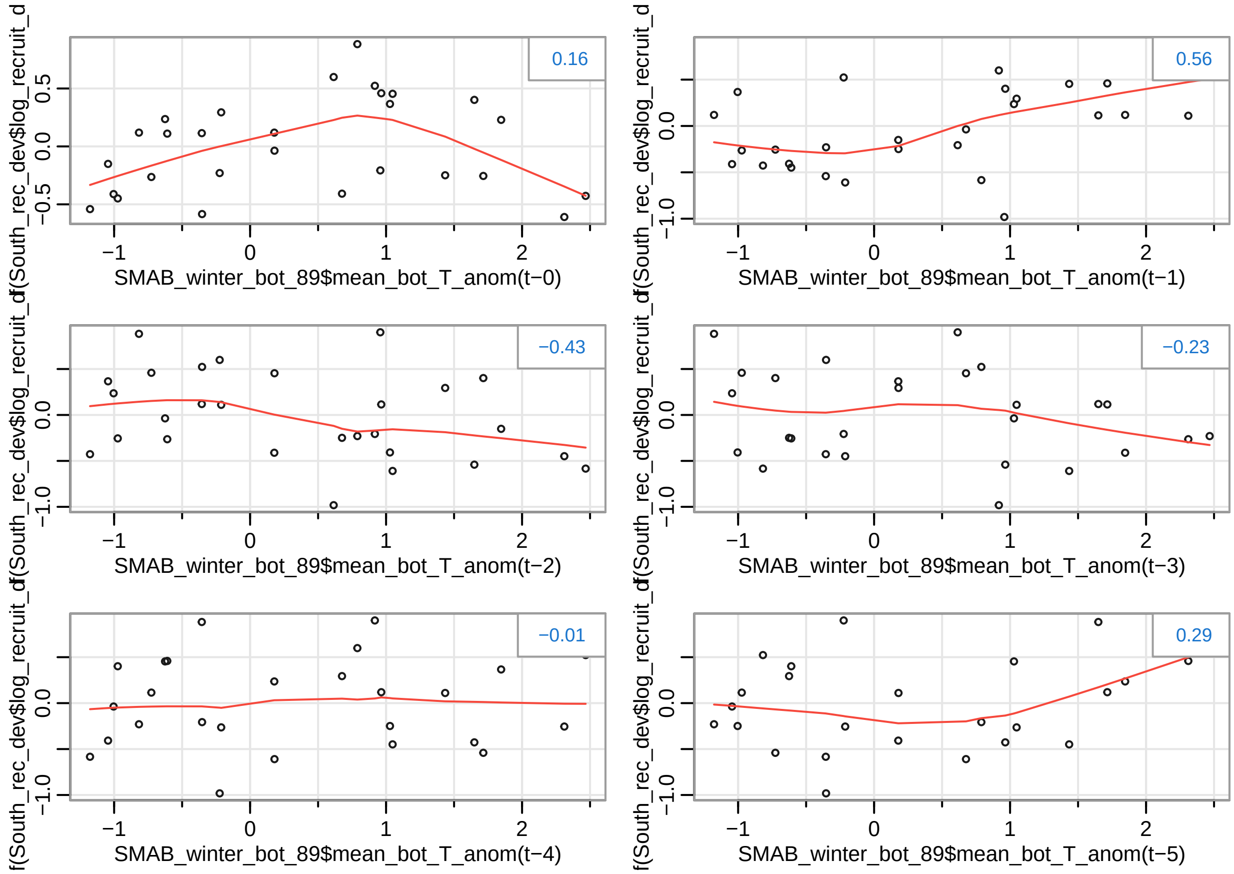
Cross Correlation Functions are useful in identifying lags in a time serise that may be predictors of another serise. This test indicates that there is a significant positive correlation between the rate of change in recruitment deviations and bottom temperature anomaly. There is more positive devation from model predictions when the previouse years anomaly is higher.

IE, the positive bottom temperature amomaly in 1999 is associated with increasing rate of recuitment deviations in 2000



southern MAB ccf visualizations

Range of lagged winter bottom temperature scatterplots with a lowess fit smoother displayed. Lag of 1 year has a positive correlations to rate of recuitment deviation.



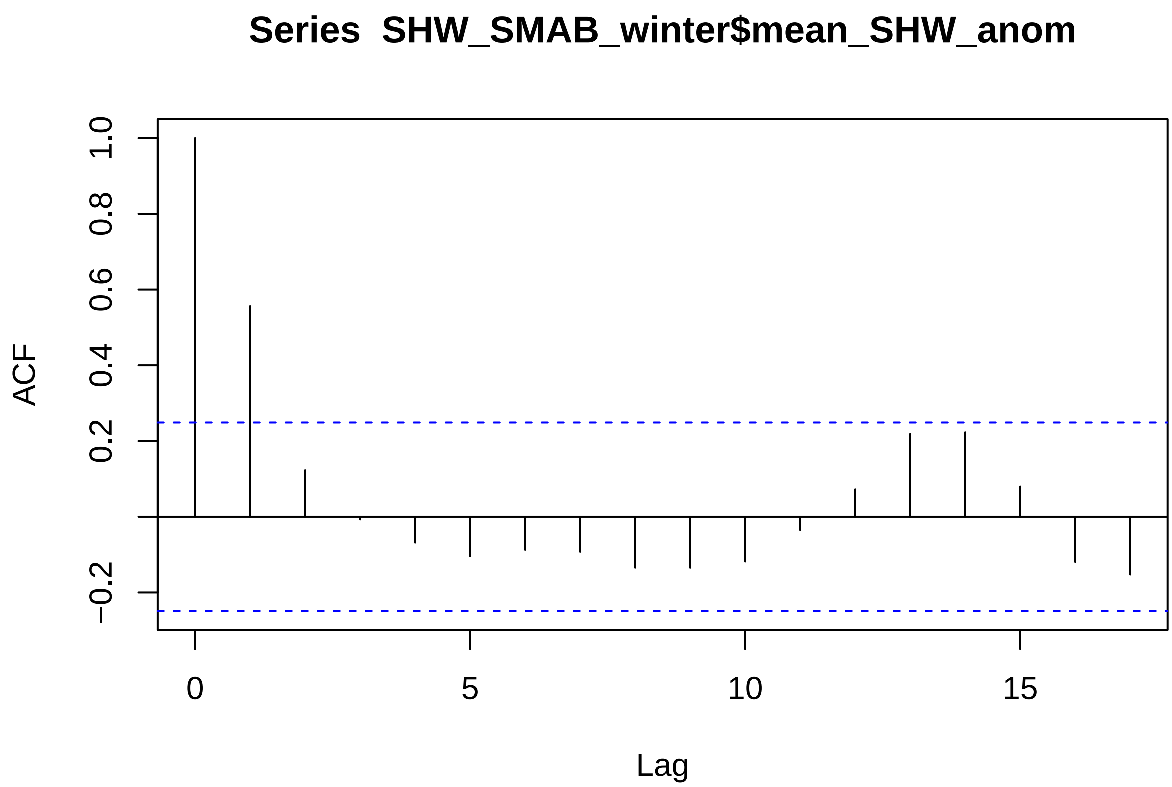
Shelf water volume and recruitment CCF

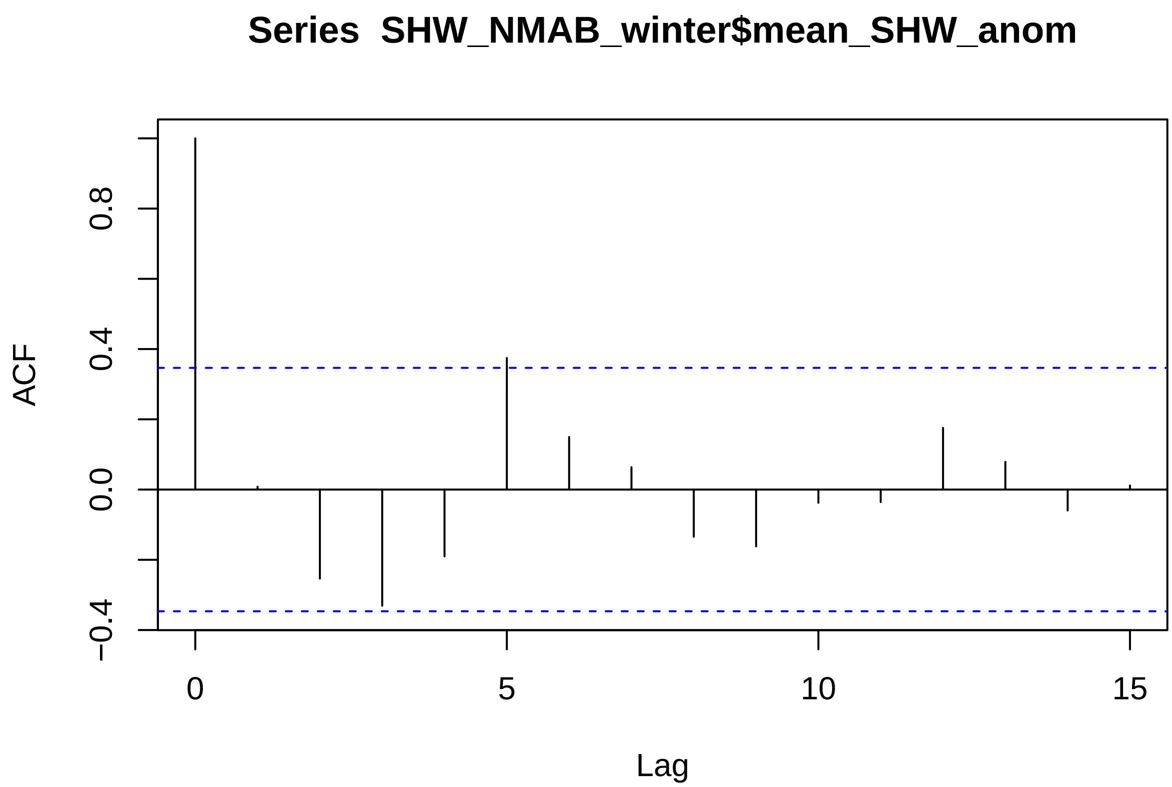
No significant correlations between Shelf water volume anomaly and the rate of recruitment deviations in either region

```
##  [1] -219.79400 -106.27200 -120.36750 -145.20500  -78.32000 -148.24400
##  [7]   39.38550  120.31400  268.37050 -153.11100 -883.50900  213.09000
## [13]   45.69000  361.65200  -48.97300 -478.33200  -12.31067  -38.00850
## [19]   83.64850  163.01400  143.74200  -67.99600 -125.30750   54.94150
## [25]    4.92950   12.23700  139.48300 -154.55400 -275.65850  -18.46200
## [31] -214.66400  129.36400
```

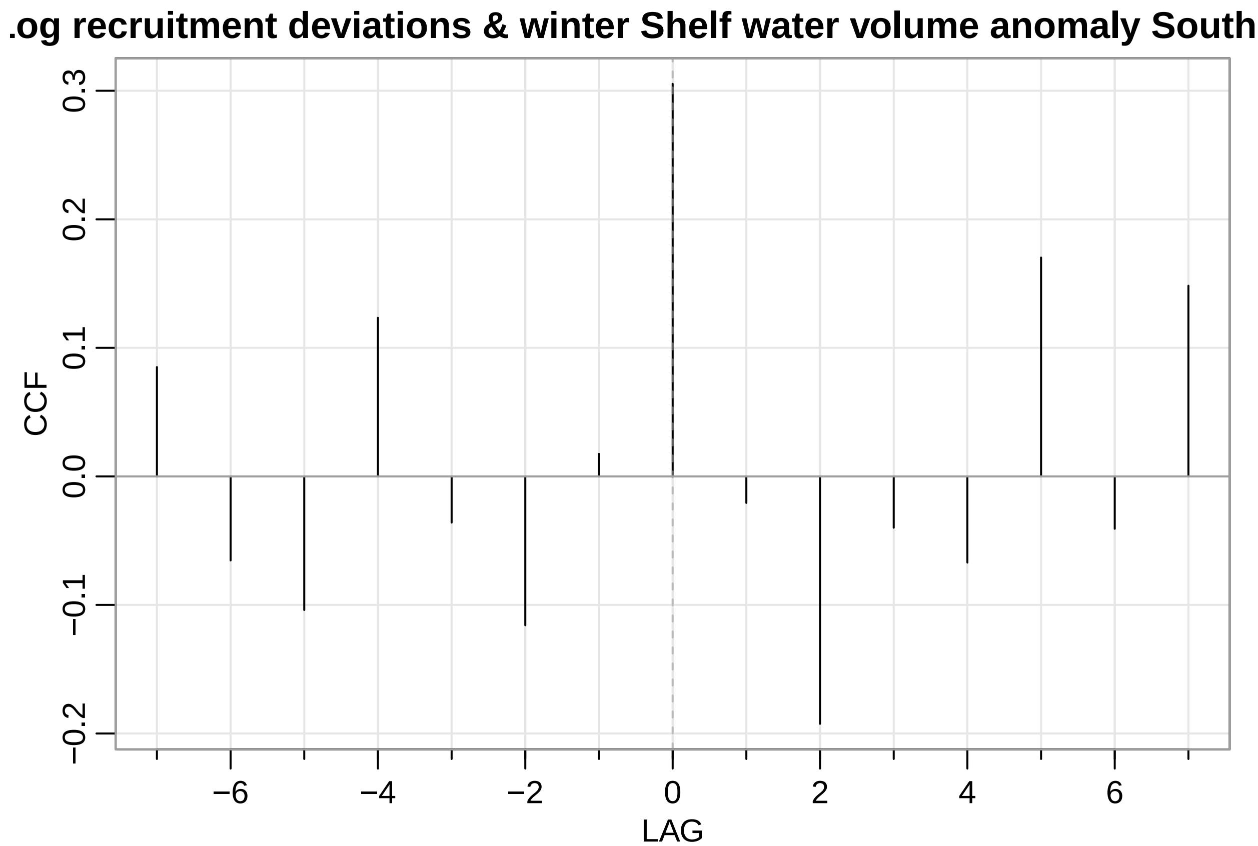
```
## [1] 0
```

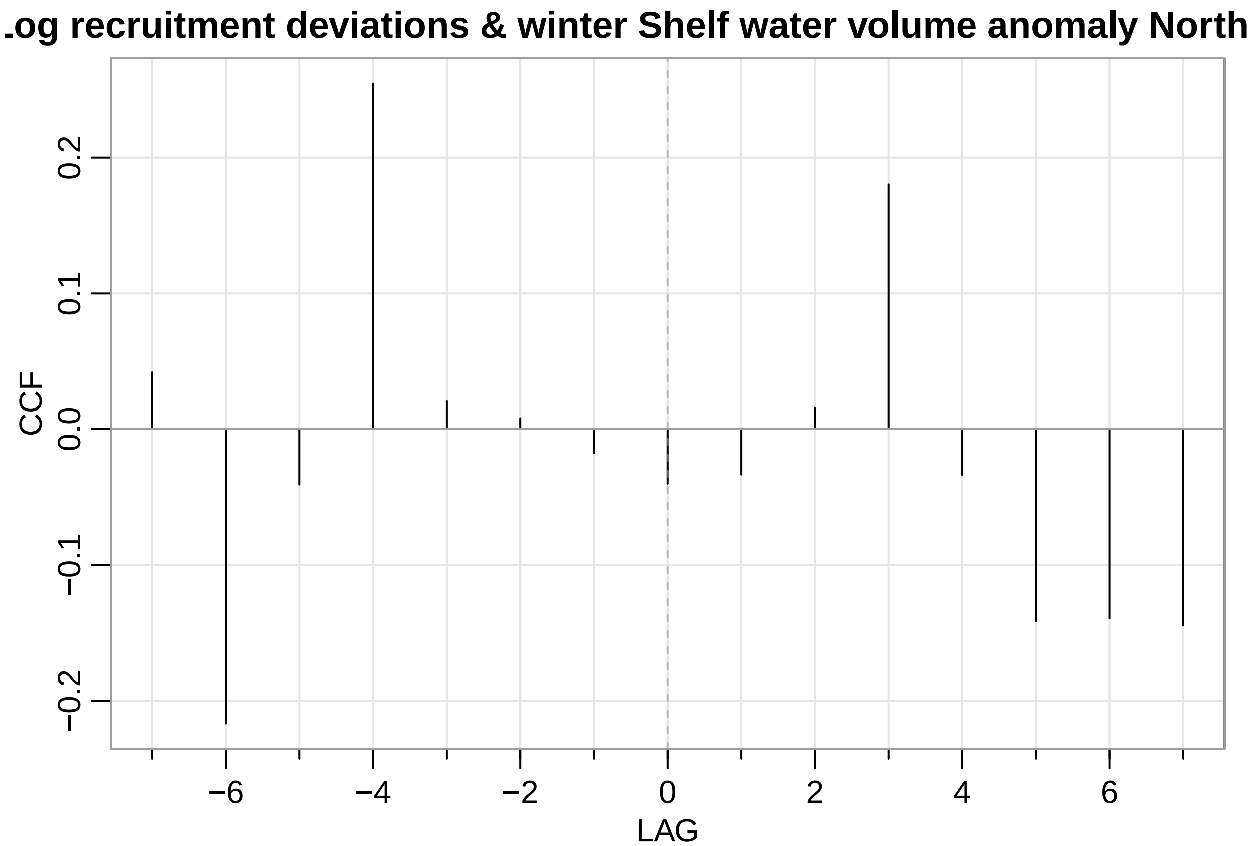
```
## [1] 0
```


Series SHW_SMAB_winter$mean_SHW_anom
ACF
1.0
0.8
0.6
0.4
0.2
−0.2
0
5
10
15
Lag



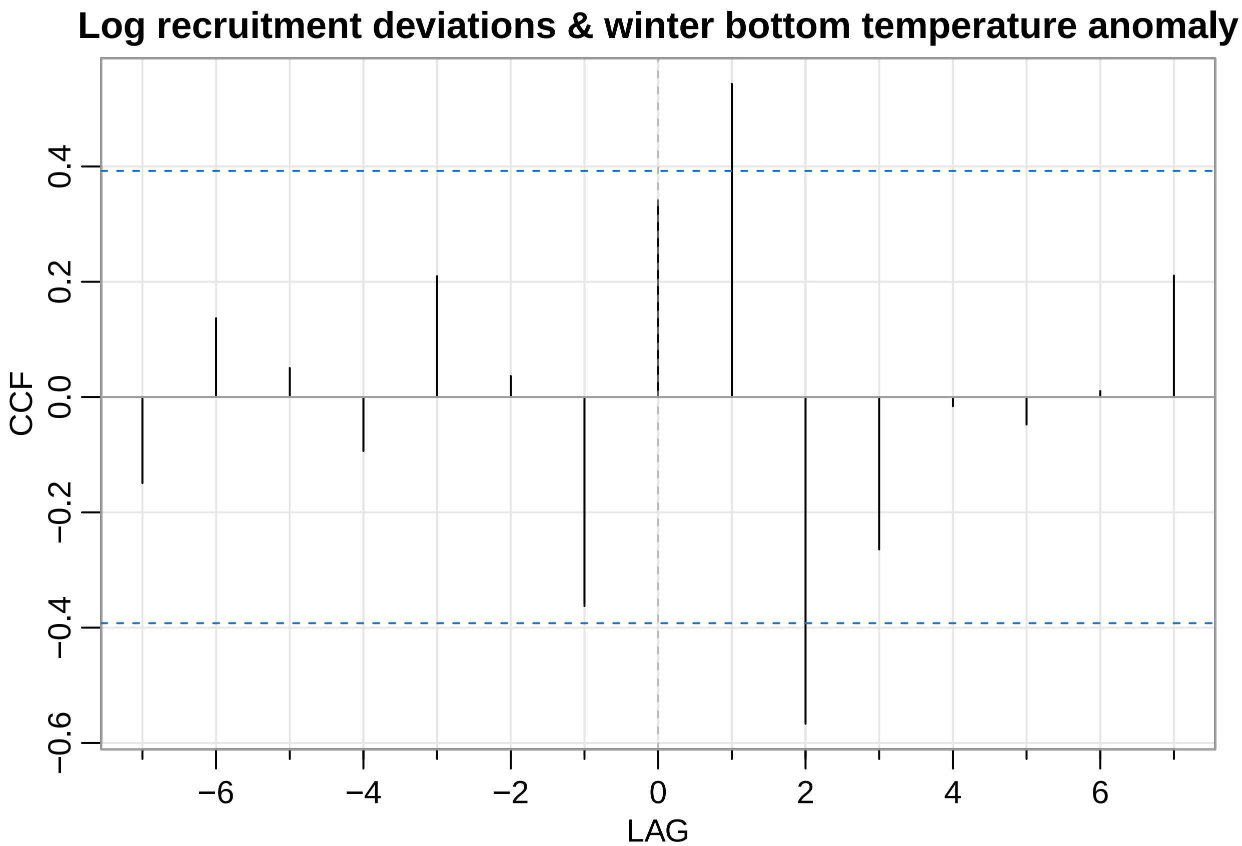

```
##
##  Augmented Dickey-Fuller Test
##
## data:  diff(SHW_NMAB_ts)
## Dickey-Fuller = -7.6407, Lag order = 3, p-value = 0.01
## alternative hypothesis: stationary
```

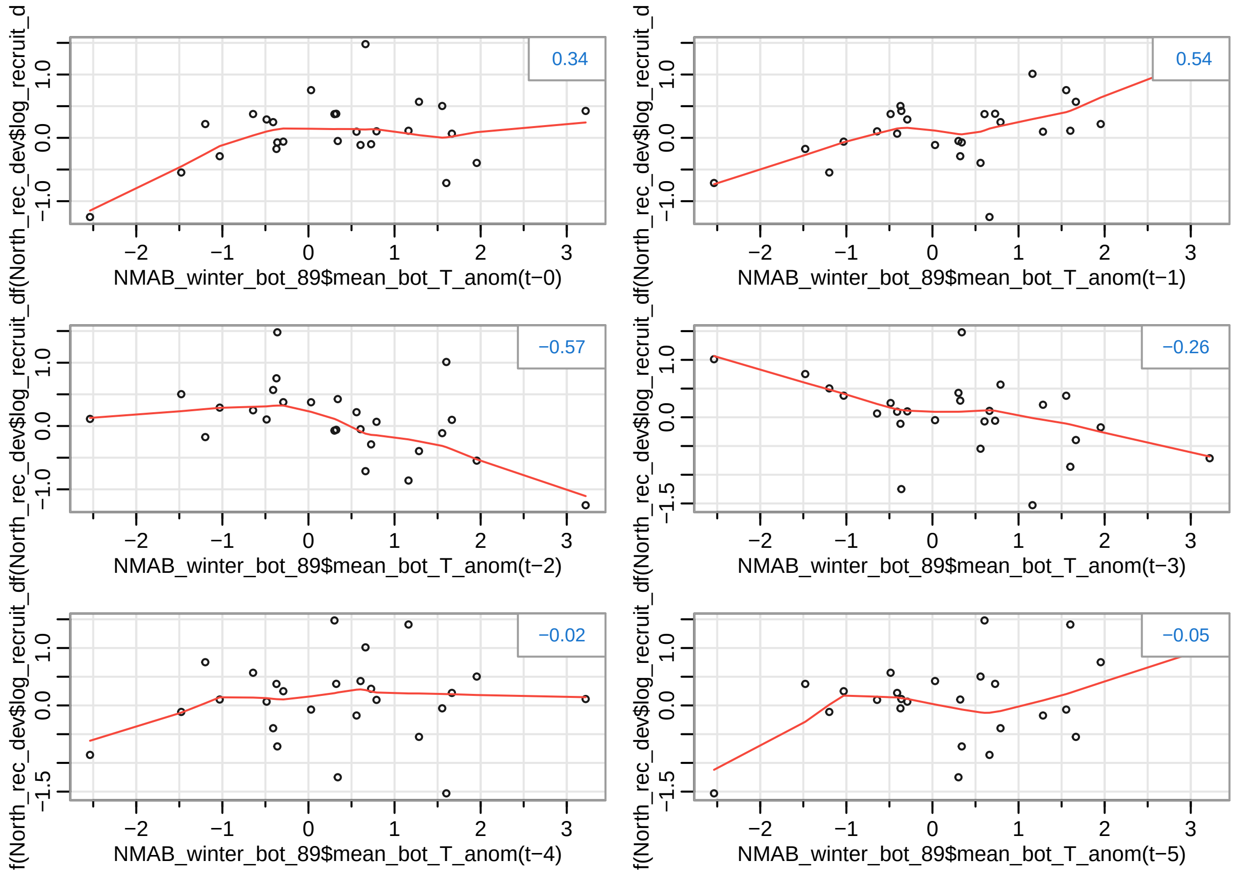

.og recruitment deviations & winter Shelf water volume anomaly South
CCF
0.3
0.2
0.1
0.0
−0.1
−0.2
−6
−4
−2
0
2
4
6
LAG



Northern MAB CCF

Peak correlation occurs with a 1 year lag.


Log recruitment deviations & winter bottom temperature anomaly
CCF
0.4
0.2
0.0
−0.2
−0.4
−0.6
−6
−4
−2
0
2
4
6
LAG



Gulf stream wall index CCF

Differing patterns in association is observed across the north vs south. Northern MAB has -3 and -7 lags, while Southern MAB has no significant time lags that correlate with recruitment deviations.

Indicator cross correlations

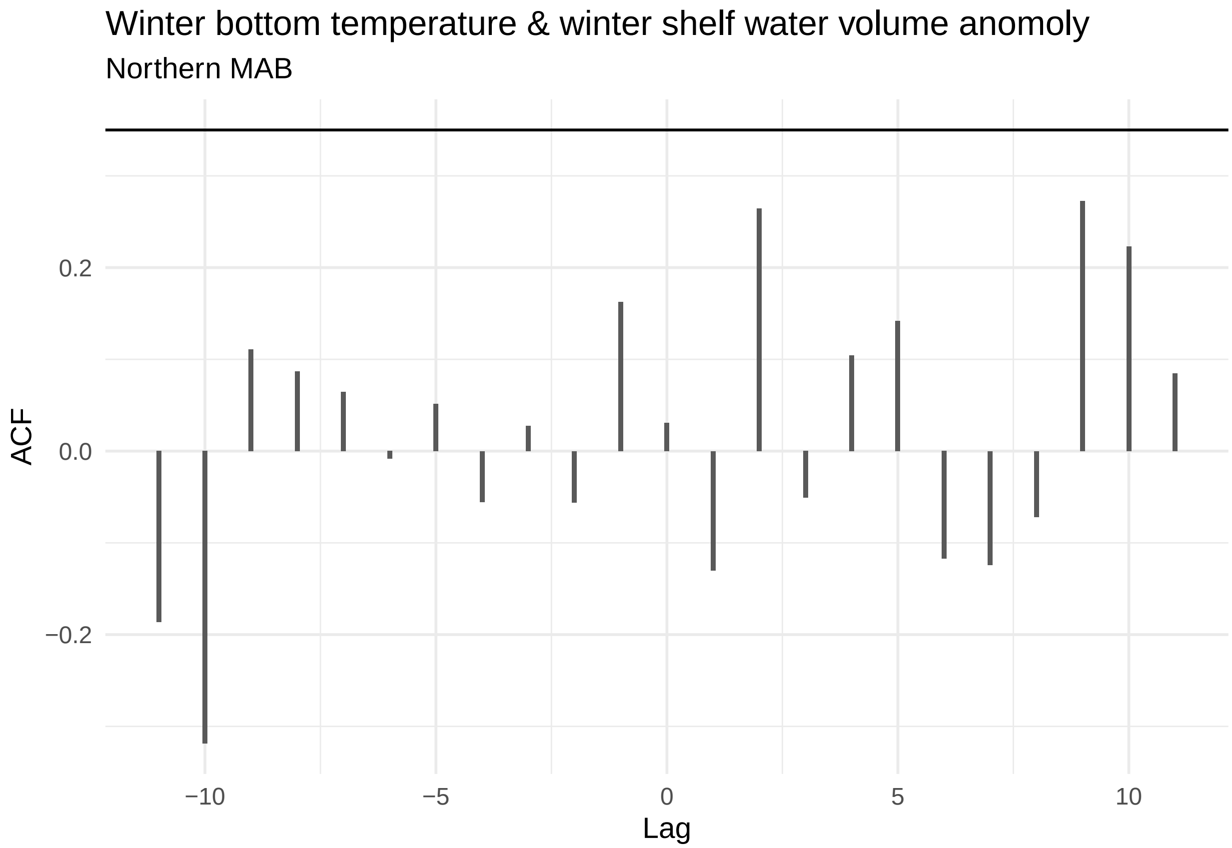
All indicators are reverted to their respective anomaly values and tested for correlations across differing lags. indicators for each region are tested for potental differences.

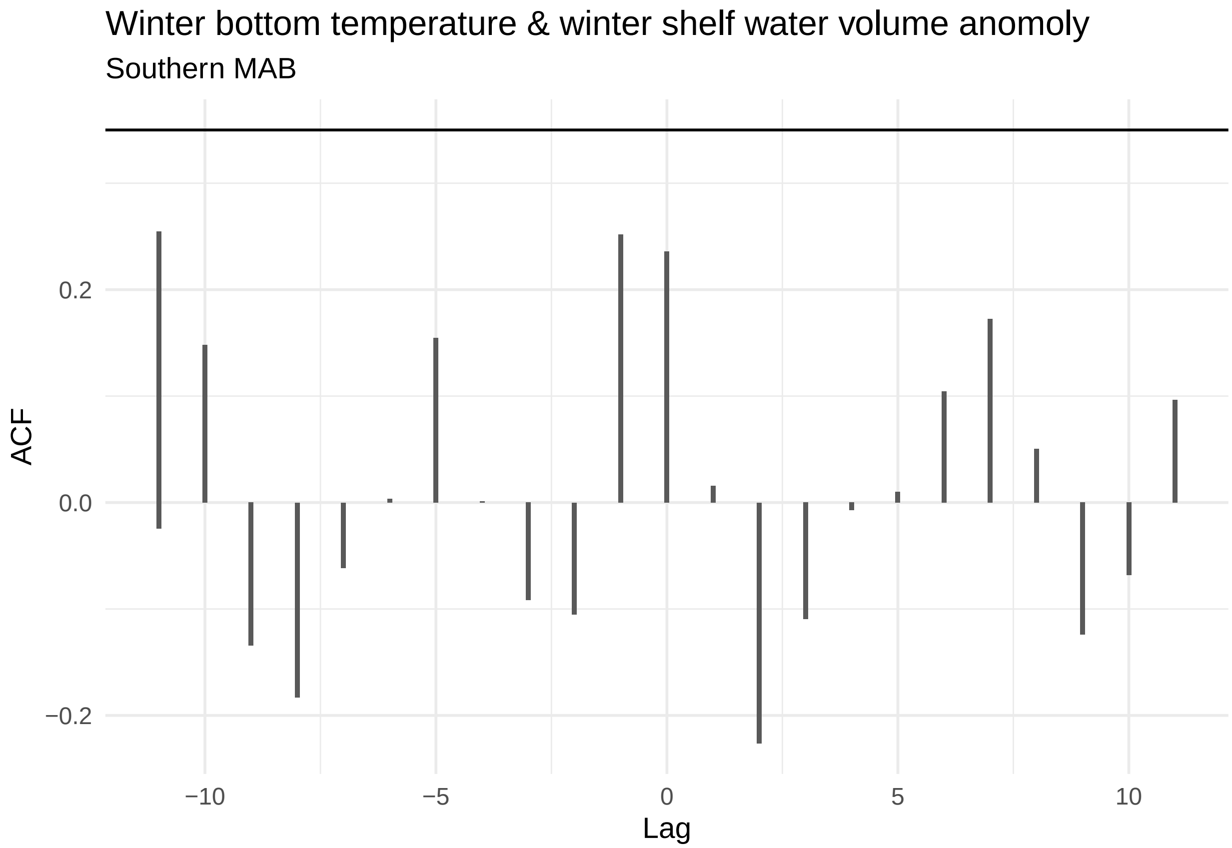
Winter bottom temperature vs Shelf water volume

No meaningful correlations detected across time lags across ether region between winter bottom temperature and Shelf water volume

```
## function (series1, series2, max.lag = 0, corr = TRUE, smooth = TRUE,
##     col = gray(0.1), lwl = 1, bgl = "white", box.col = 8, ...)
## {
##     as.ts = stats::as.ts
##     par = graphics::par
##     plot = graphics::plot
##     lines = graphics::lines
##     ts.intersect = stats::ts.intersect
```

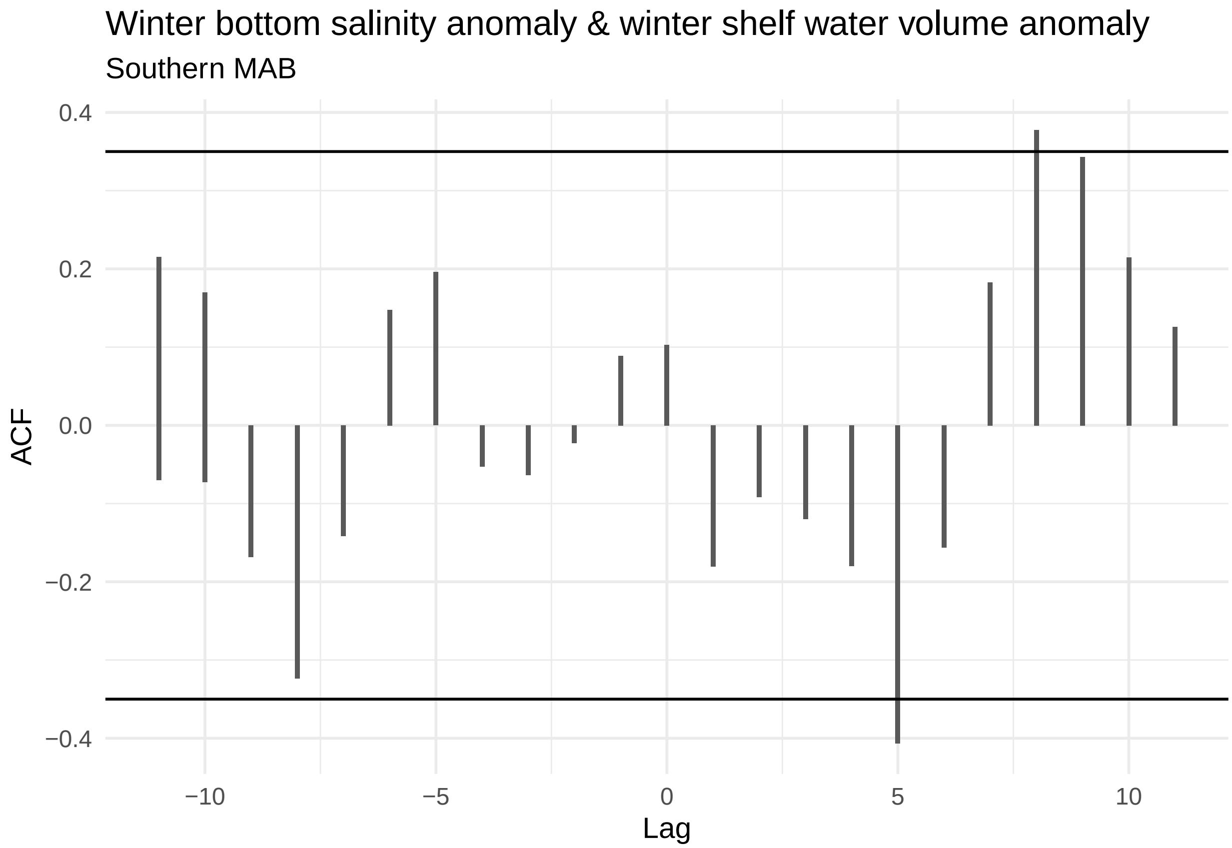
```
##     legend = graphics::legend
##     name1 = paste(deparse(substitute(series1)), "(t-", sep = "")
##     name2 = paste(deparse(substitute(series2)), "(t)", sep = "")
##     series1 = as.ts(series1)
##     series2 = as.ts(series2)
##     max.lag = as.integer(max.lag)
##     m1 = max.lag + 1
##     prow = ceiling(sqrt(m1))
##     pcol = ceiling(m1/prow)
##     a = stats::ccf(series1, series2, max.lag, plot = FALSE)$acf
##     old.par <- par(no.readonly = TRUE)
##     par(mfrow = c(prow, pcol))
##     for (h in 0:max.lag) {
##         tsplot(stats::lag(series1, -h), series2, xy.labels = FALSE,
##             type = "p", xlab = paste(name1, h, ")", sep = ""),
##             ylab = name2, col = col, ...)
##         if (smooth == TRUE)
##             lines(stats::lowess(ts.intersect(stats::lag(series1,
##                 -h), series2)[, 1], ts.intersect(stats::lag(series1,
##                 -h), series2)[, 2]), col = 2, lwd = lwl)
##         if (corr == TRUE)
##             legend("topright", legend = round(a[m1 - h], digits = 2),
##                 text.col = 4, bg = bgl, adj = 0.25, cex = 0.85,
##                 box.col = box.col)
##         on.exit(par(old.par))
##     }
## }
## <bytecode: 0x000000002d59c8b0>
## <environment: namespace:astsa>
```

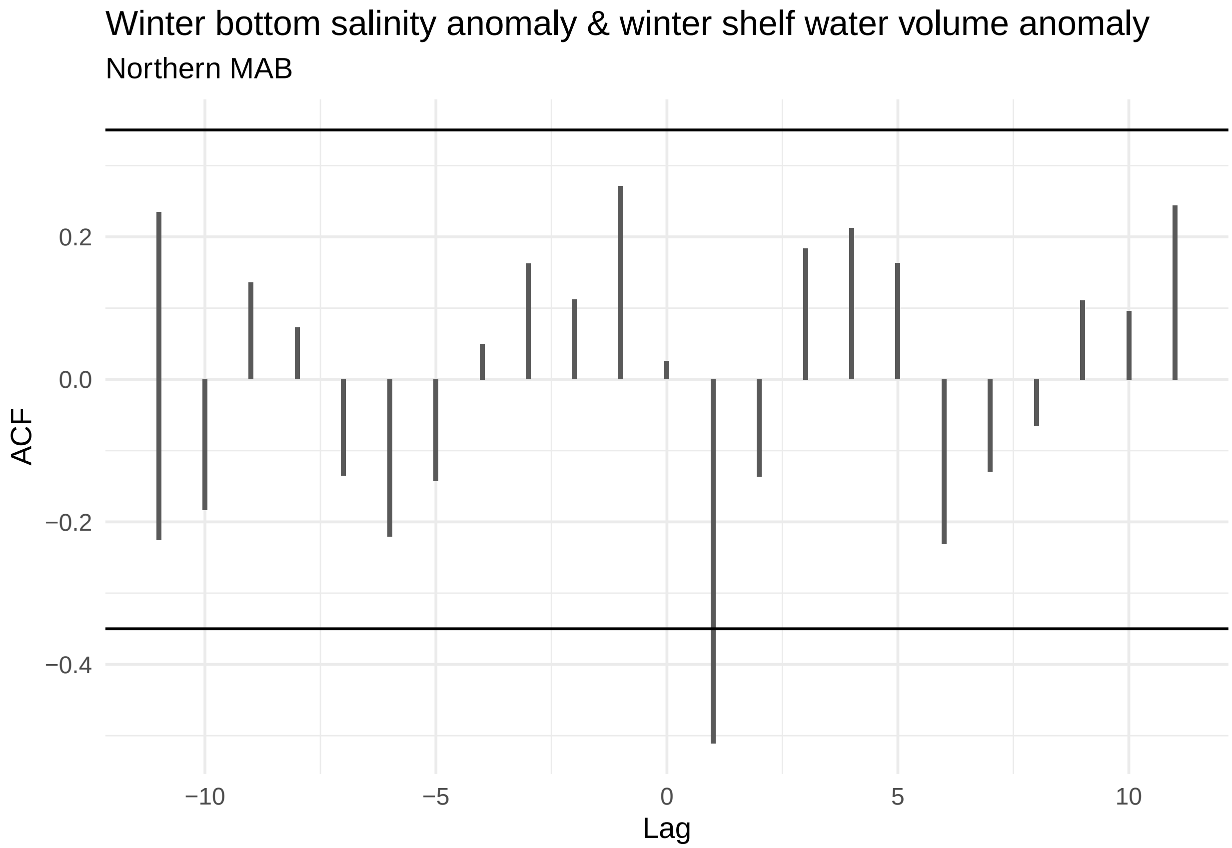

Winter bottom temperature & winter shelf water volume anomoly
Northern MAB
ACF
0.2
0.0
−0.2
−10
−5
0
5
10
Lag

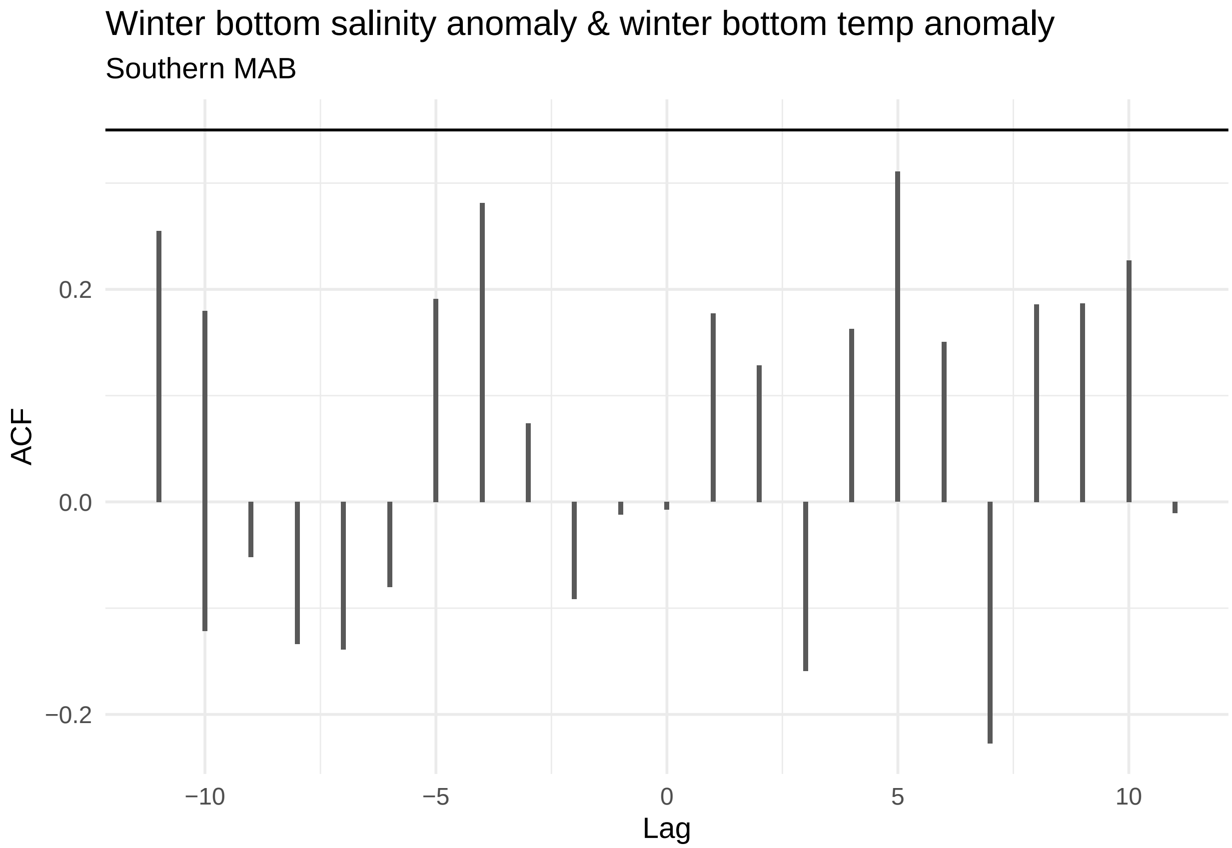


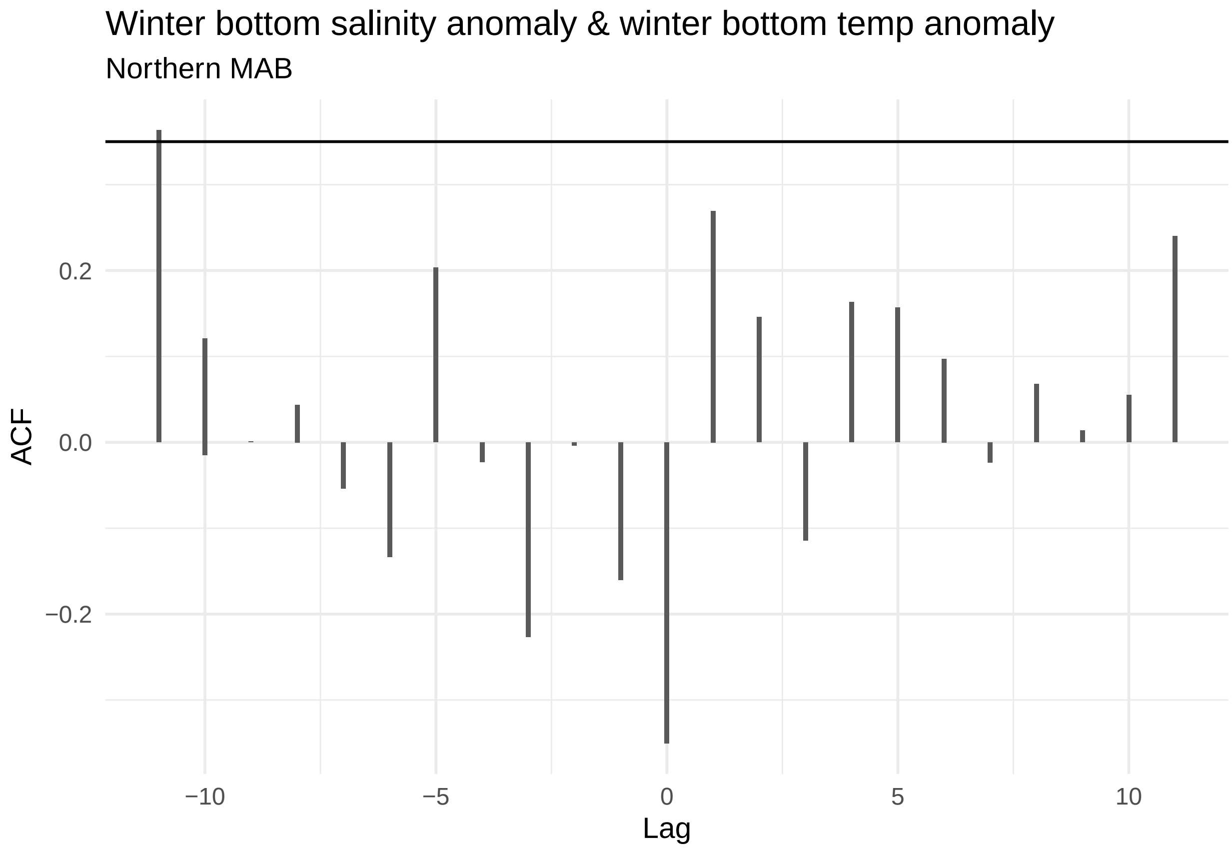
Winter bottom salinity vs Shelf water volume

Southern MAB displays some correlations between variables at the 5 and 8 year lag, while northern MAB has a negitive correlation at a one year lag.


Winter bottom salinity anomaly & winter shelf water volume anomaly
Southern MAB
ACF
0.4
0.2
0.0
−0.2
−0.4
−10
−5
0
5
10
Lag


Winter bottom salinity anomaly & winter shelf water volume anomaly
Northern MAB
ACF
0.2
0.0
−0.2
−0.4
−10
−5
0
5
10
Lag


Winter bottom salinity anomaly & winter bottom temp anomaly
Southern MAB
ACF
0.2
0.0
−0.2
−10
−5
0
5
10
Lag


Winter bottom salinity anomaly & winter bottom temp anomaly
Northern MAB
ACF
0.2
0.0
−0.2
−10
−5
0
5
10
Lag