Survey Index Estimation and Simulation using EBS Survey Data.

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1 Model

Survey indices are calculated using the methodology described in [2] and the `surveyIndex` package [1], although the response variable is CPUE in weight rather than numbers-at-age and we consider time-varying spatial effects.

The following equation describes the model:

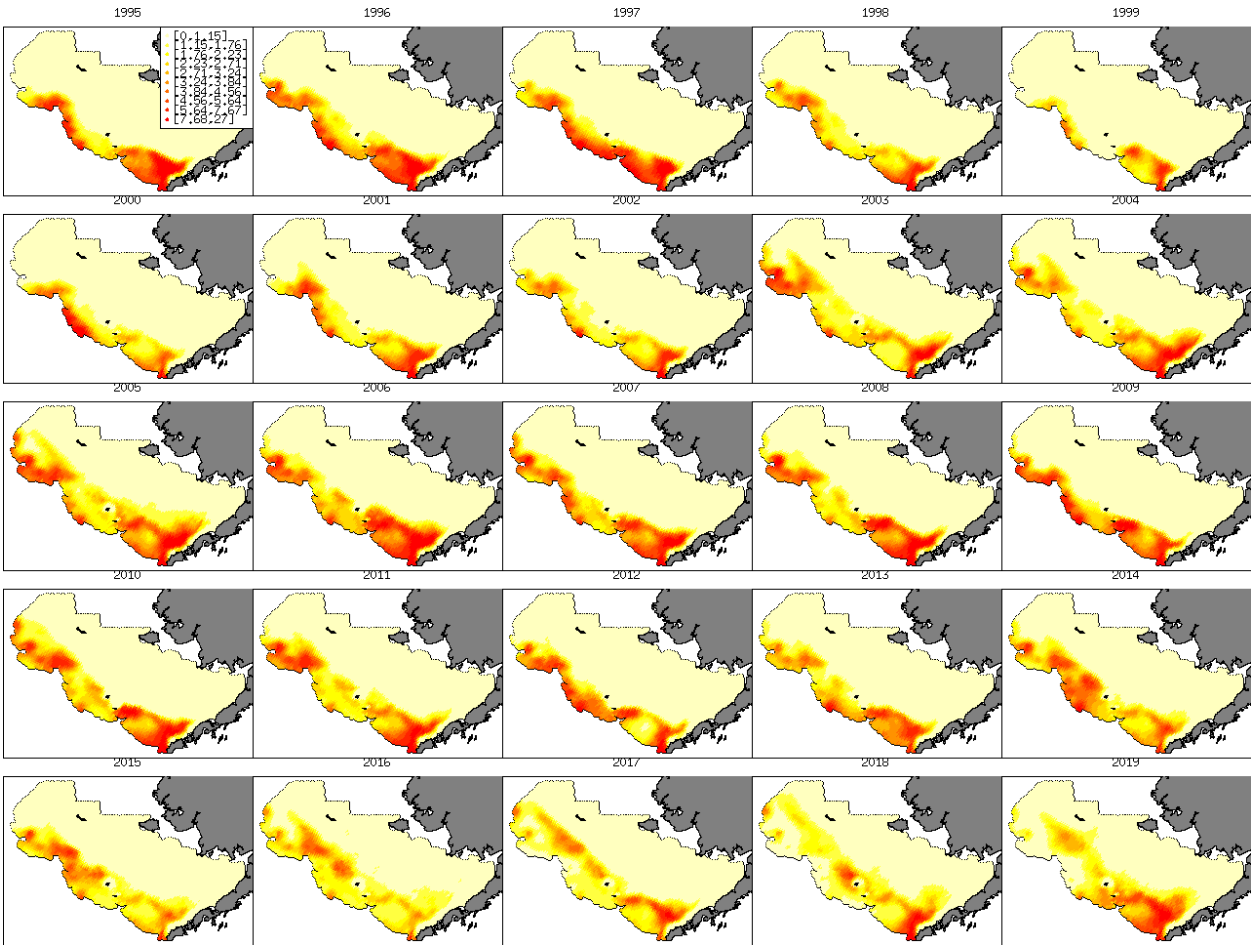
$$\log(\mu_i) = \text{Year(i)} + f_1(\text{sx}_i, \text{sy}_i) + f_2(\text{Year}_i, \text{sx}_i, \text{sy}_i) \quad (1)$$

$$+ f_3(\text{depth}_i) + f_4(\log(\text{temperature}_i + 3)) \quad (2)$$

where μ_i is the expected value of the CPUE in weight of the ith haul. The spatial effects are described by a high resolution time-invariant average distribution (f_1) and independent yearly deviations from that average (f_2). The maximal basis dimension of f_1 and f_2 are set to 376 and 50 per year respectively, and the smoothing penalty and spline basis is the same for all years in f_2. The last two splines (f_3 and f_4) describe the effect of bottom depth and gear temperature. The latter was added 3 and log-transformed because preliminary runs suggested that must variation occurred on a narrow interval at the coldest end of the observed interval. The chosen transformation stretches this interval out such that the resulting splines are more smooth and can be fitted using fewer knots while ensuring that numbers are positive before taking the logarithm. All splines are thin plate splines with shrinkage.

2 Results

2.1 Arrowtooth Flounder


1995
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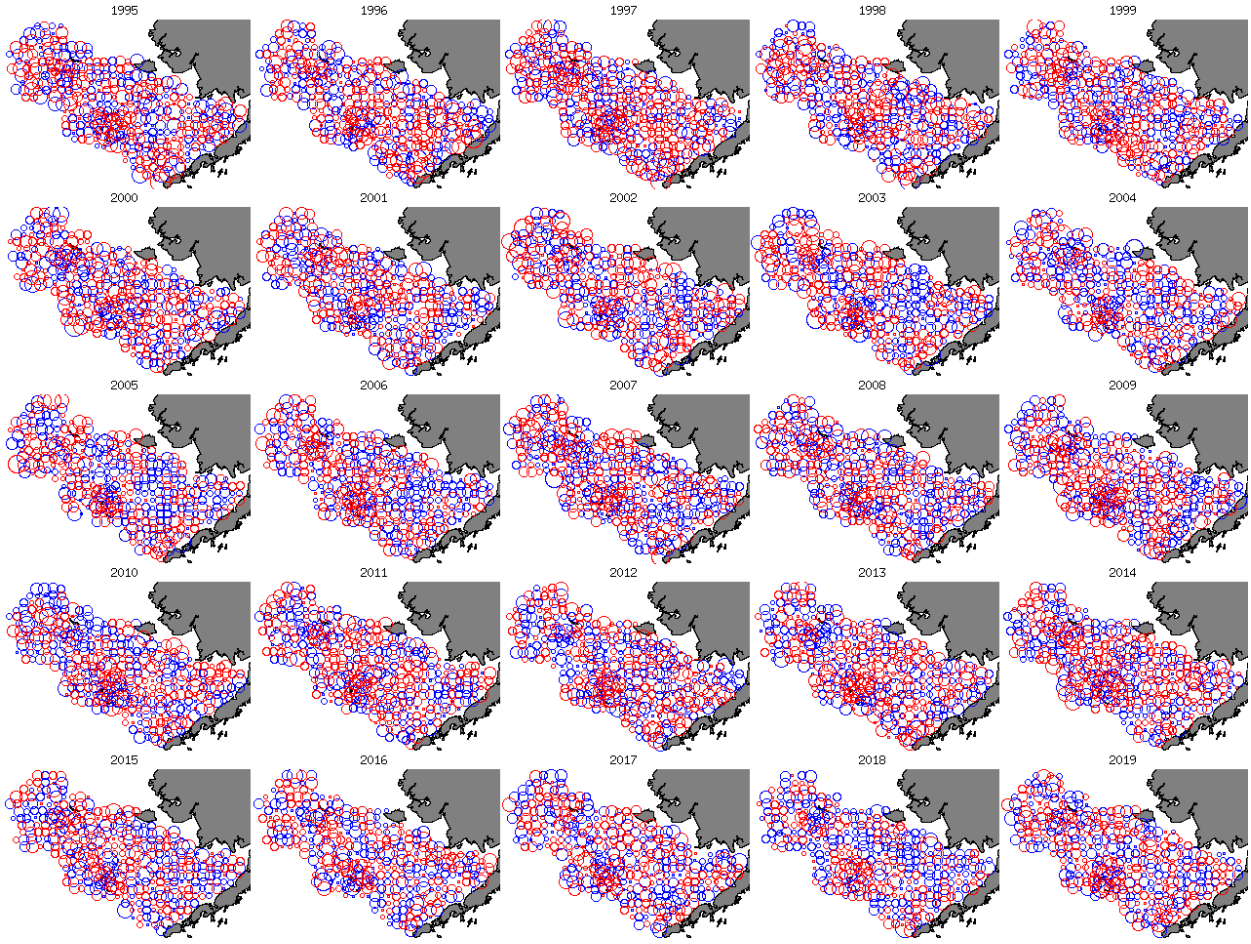
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
[0.1.15]
[1.16.1.76]
[1.76.2.23]
[2.23.2.71]
[2.71.3.04]
[3.04.3.84]
[3.84.4.96]
[4.96.5.64]
[5.64.7.67]
[7.88.27]

Figure 1


1995
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2014
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2016
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2018
2019

Figure 2

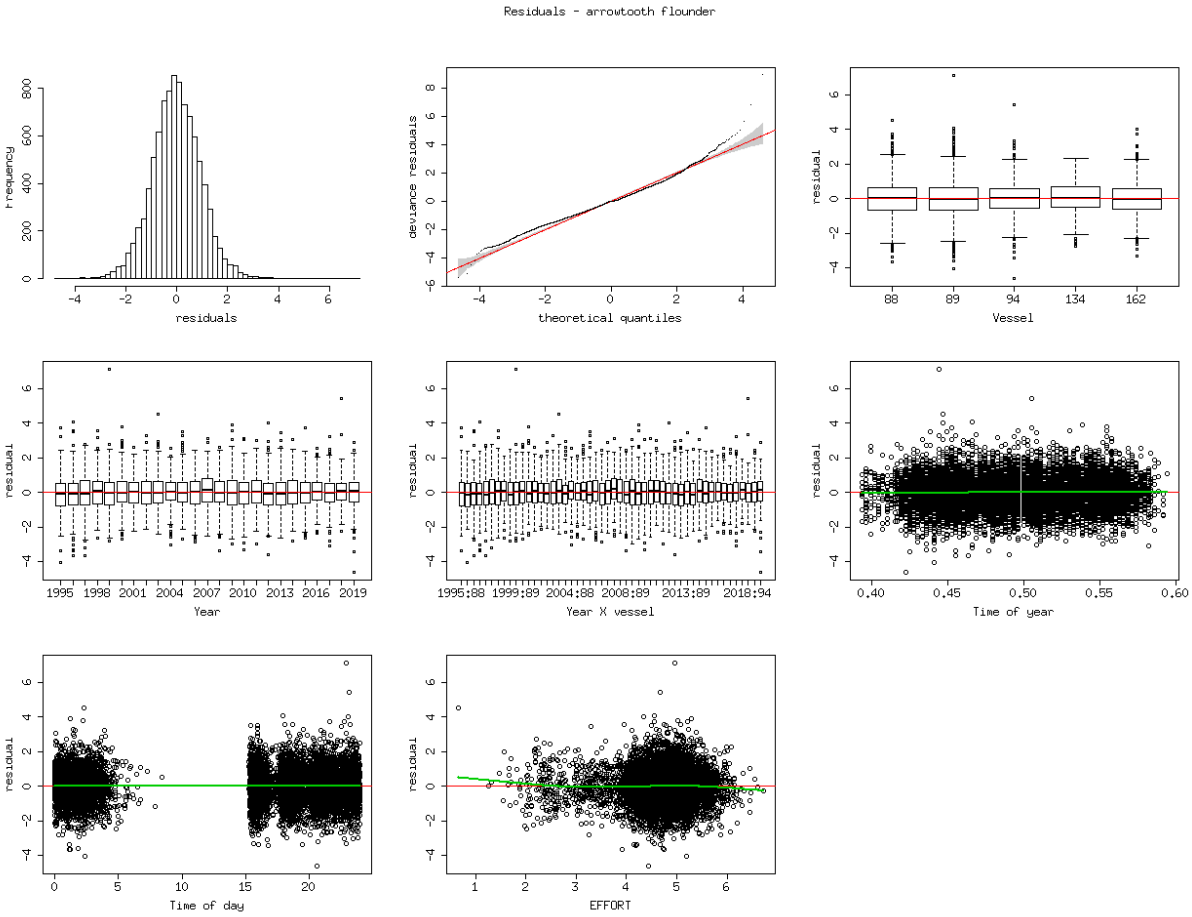

Residuals - arrowtooth flounder
Frequency
residuals
deviance residuals
theoretical quantiles
residual
Vessel
Year
Year X vessel
Time of year
Time of day
EFFORT

Figure 3

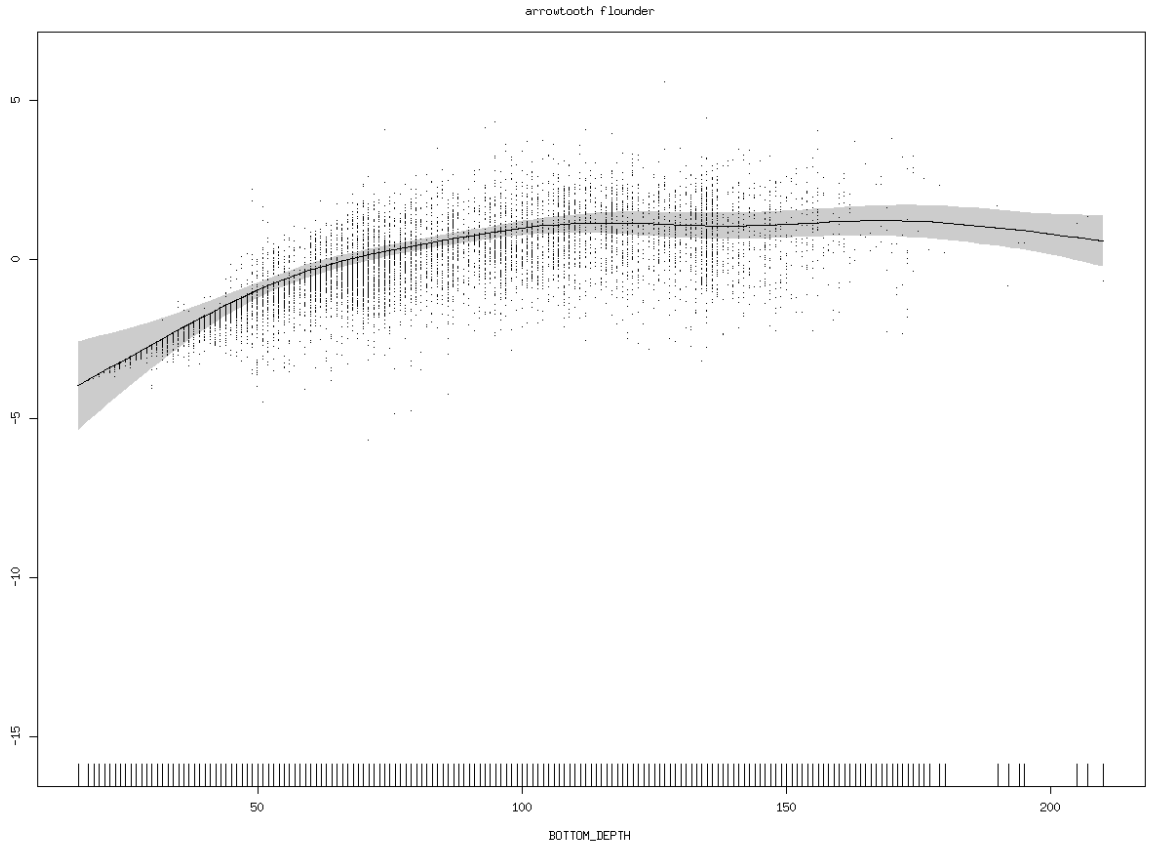


Figure 4

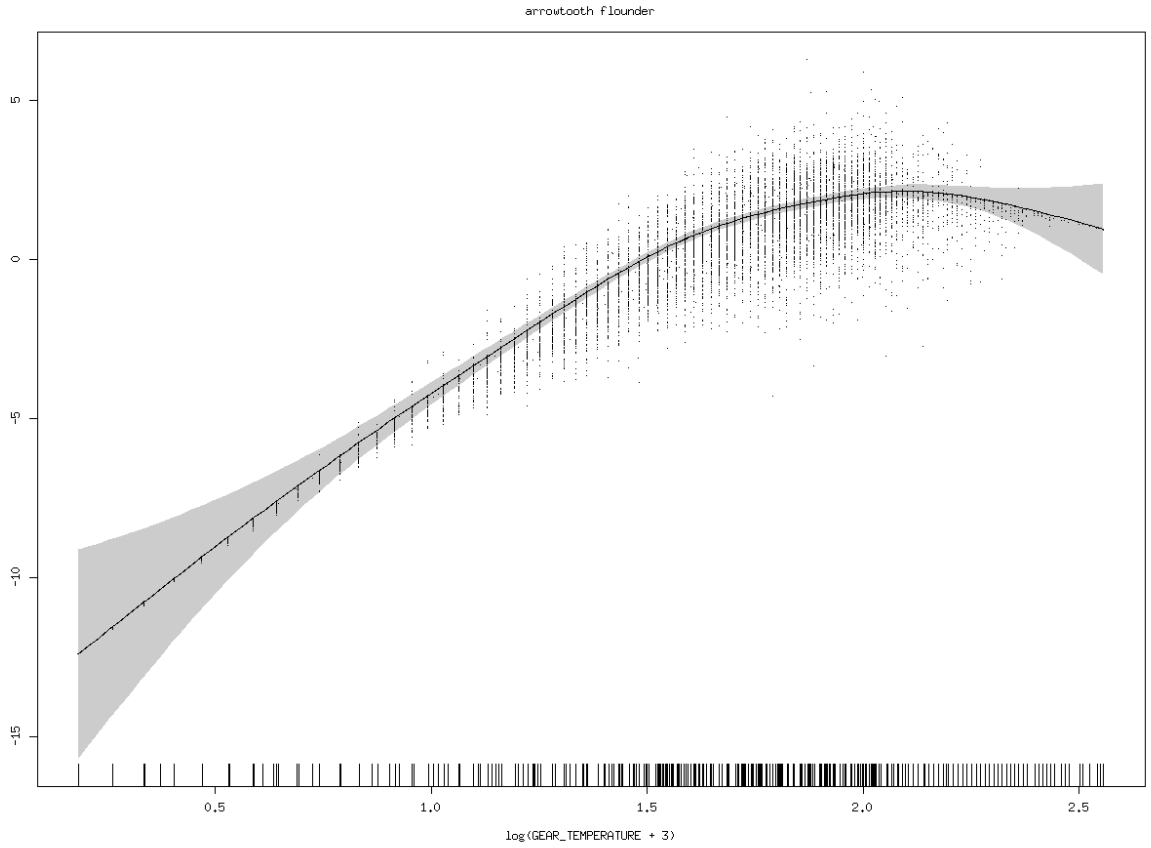

arrowtooth flounder
5
0
-5
-10
-15
0.5
1.0
1.5
2.0
2.5
log(GEAR_TEMPERATURE + 3)

Figure 5

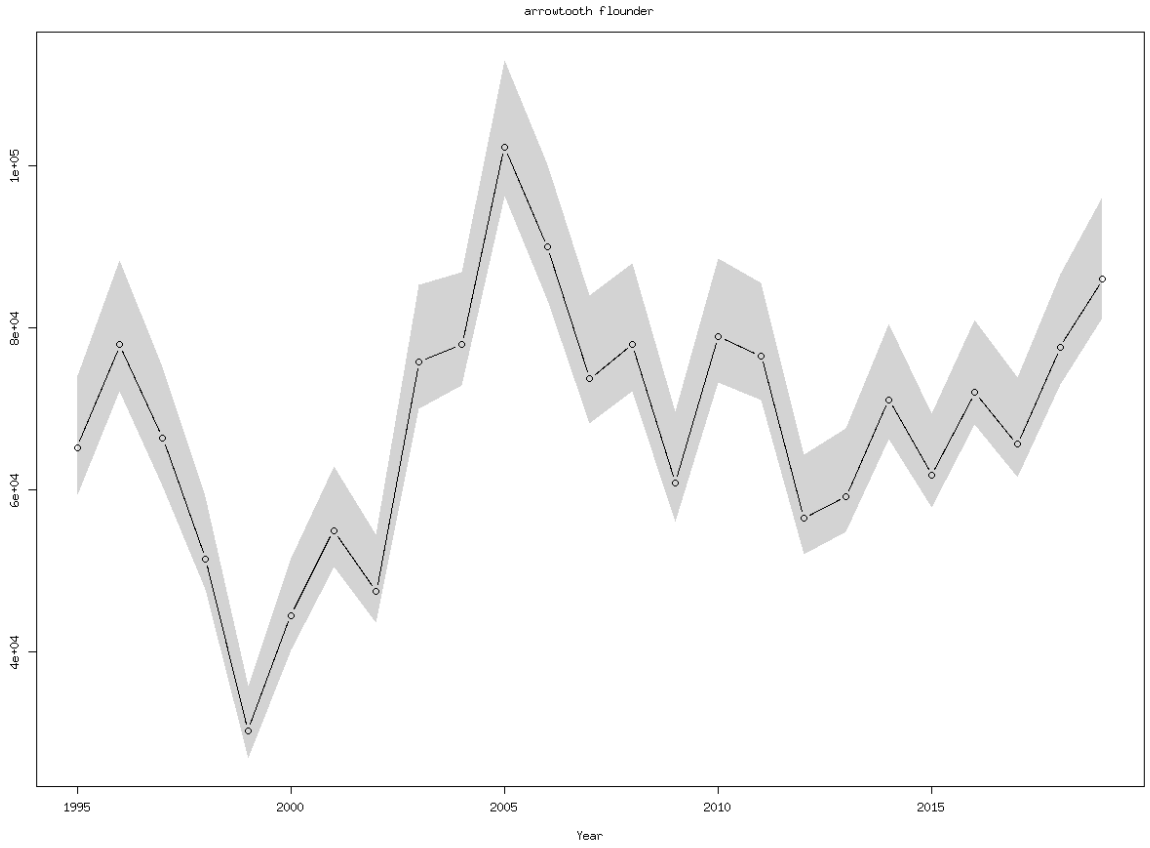

arrowtooth flounder
1e+05
8e+04
6e+04
4e+04
1995
2000
2005
2010
2015
Year

Figure 6

2.2 Pacific cod

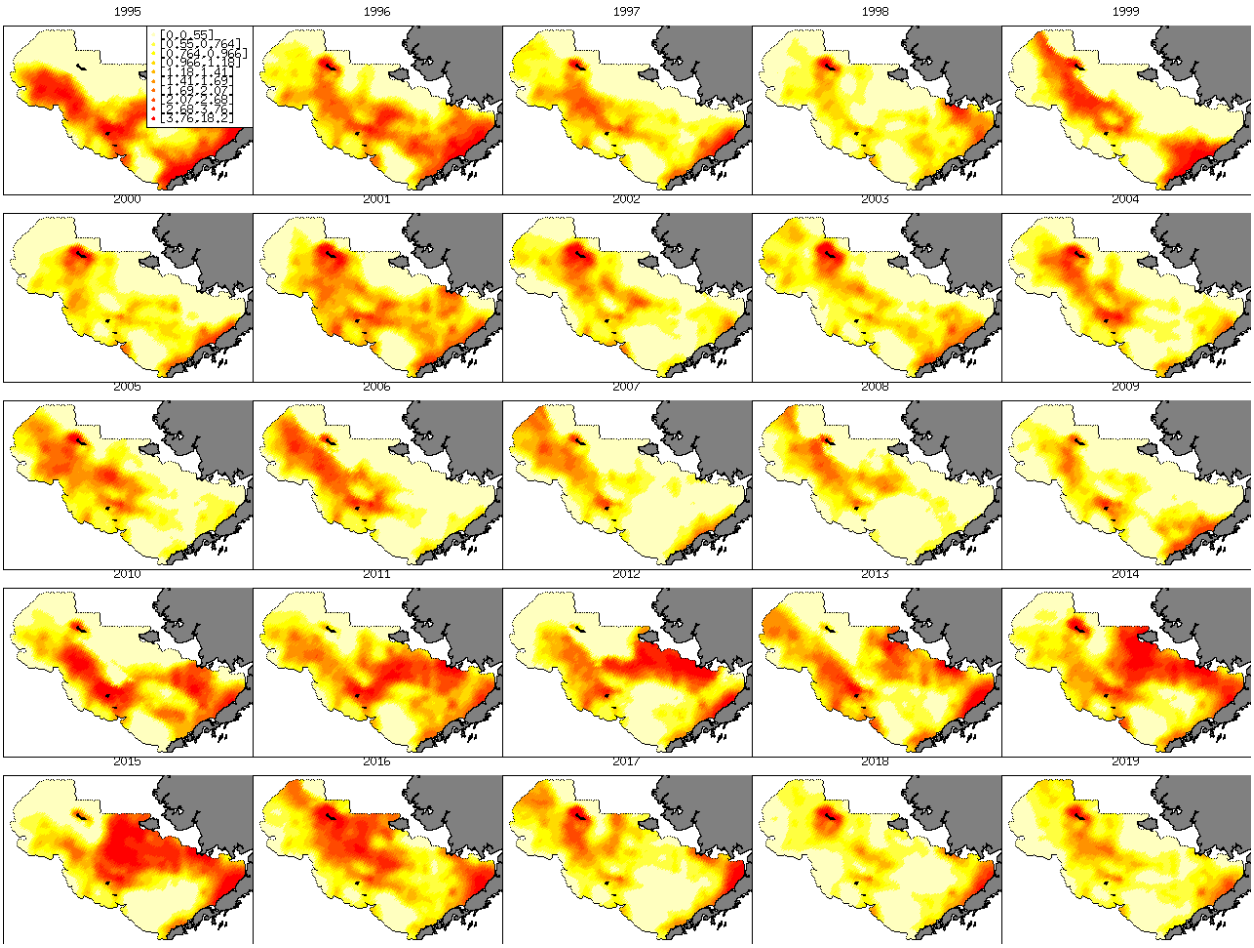
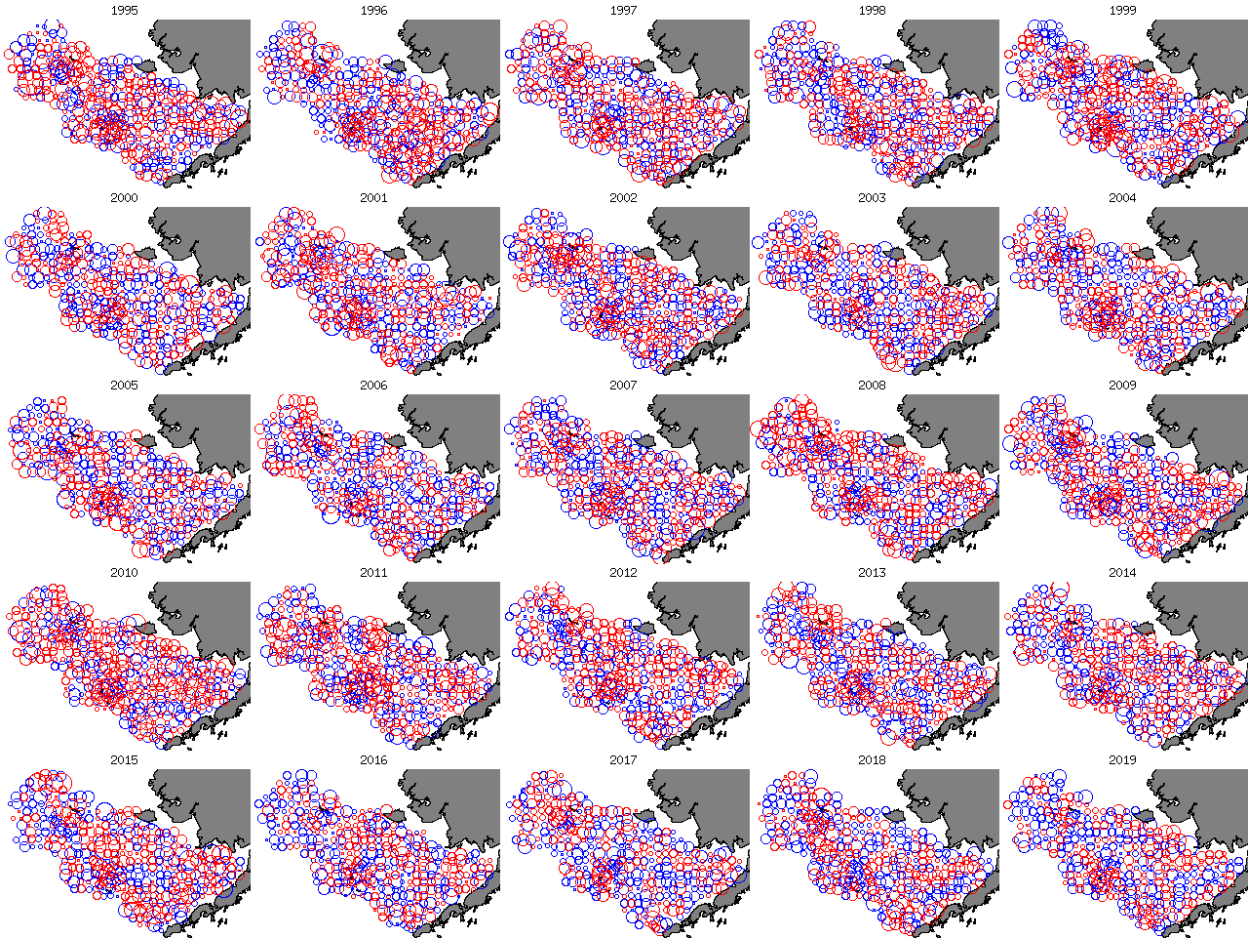


Figure 7


1995
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2012
2013
2014
2015
2016
2017
2018
2019

Figure 8

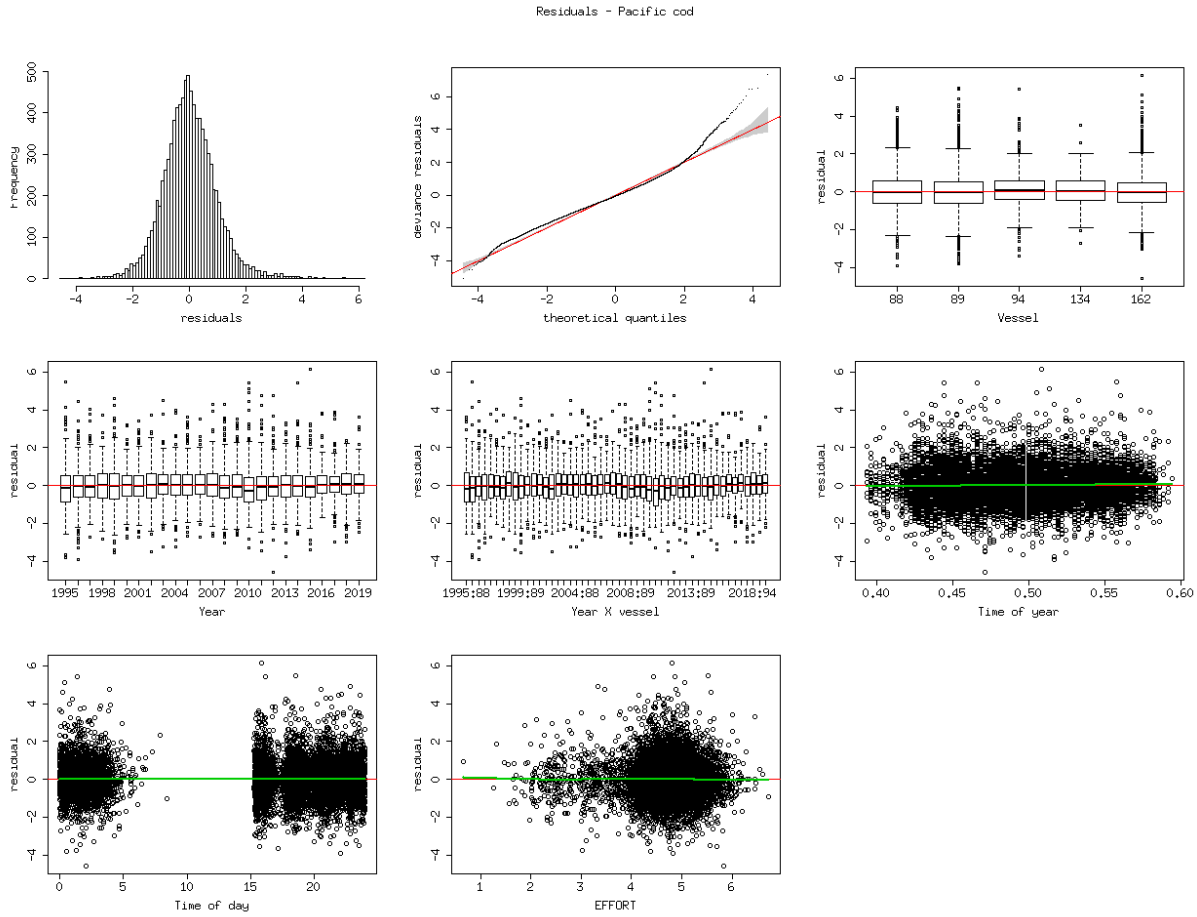

Residuals - Pacific cod
Frequency
residuals
deviance residuals
theoretical quantiles
residual
Vessel
Year
Year X vessel
Time of year
Time of day
EFFORT

Figure 9

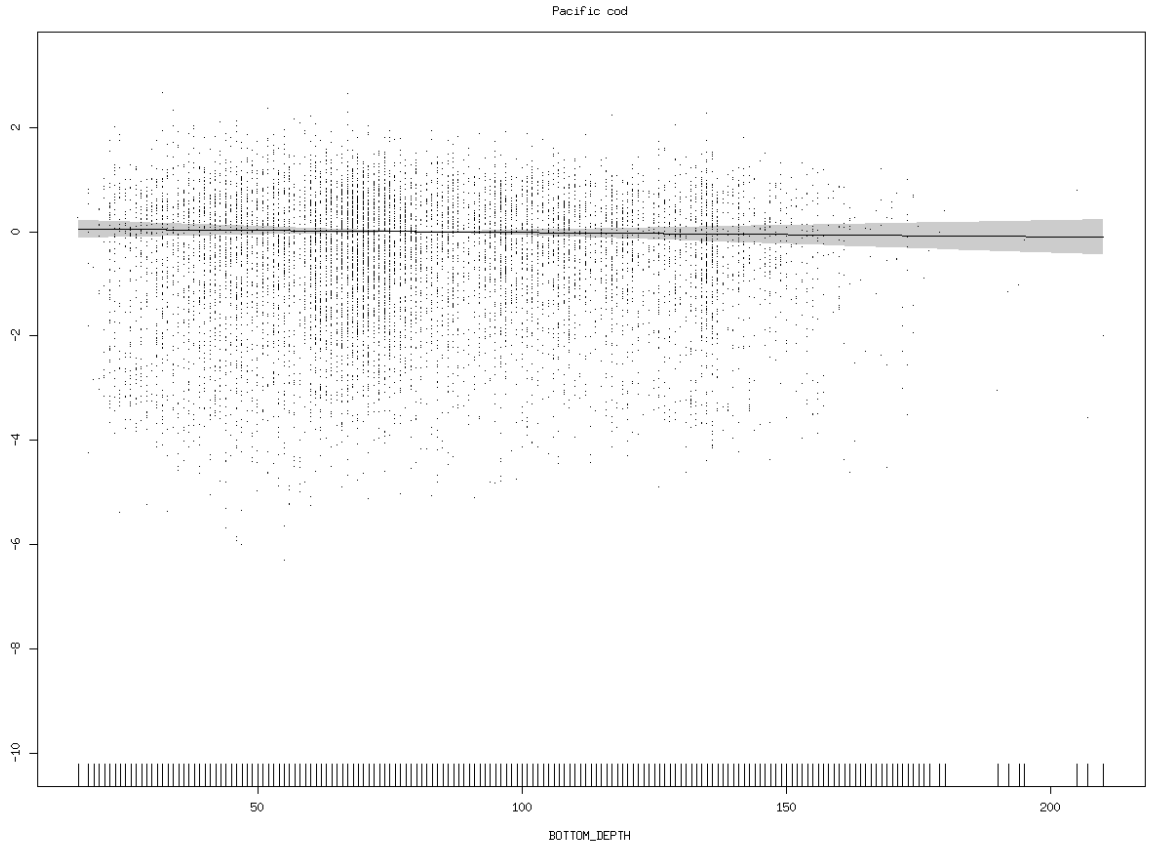


Figure 10

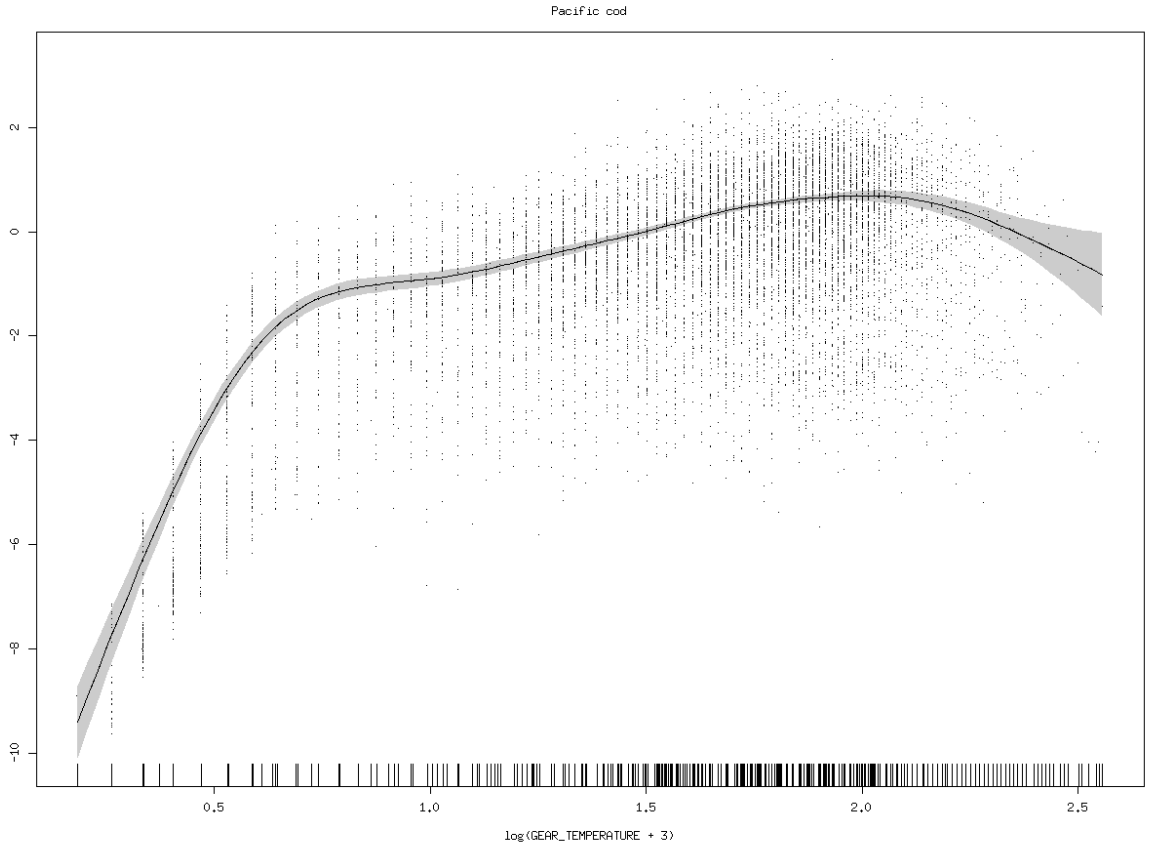


Figure 11

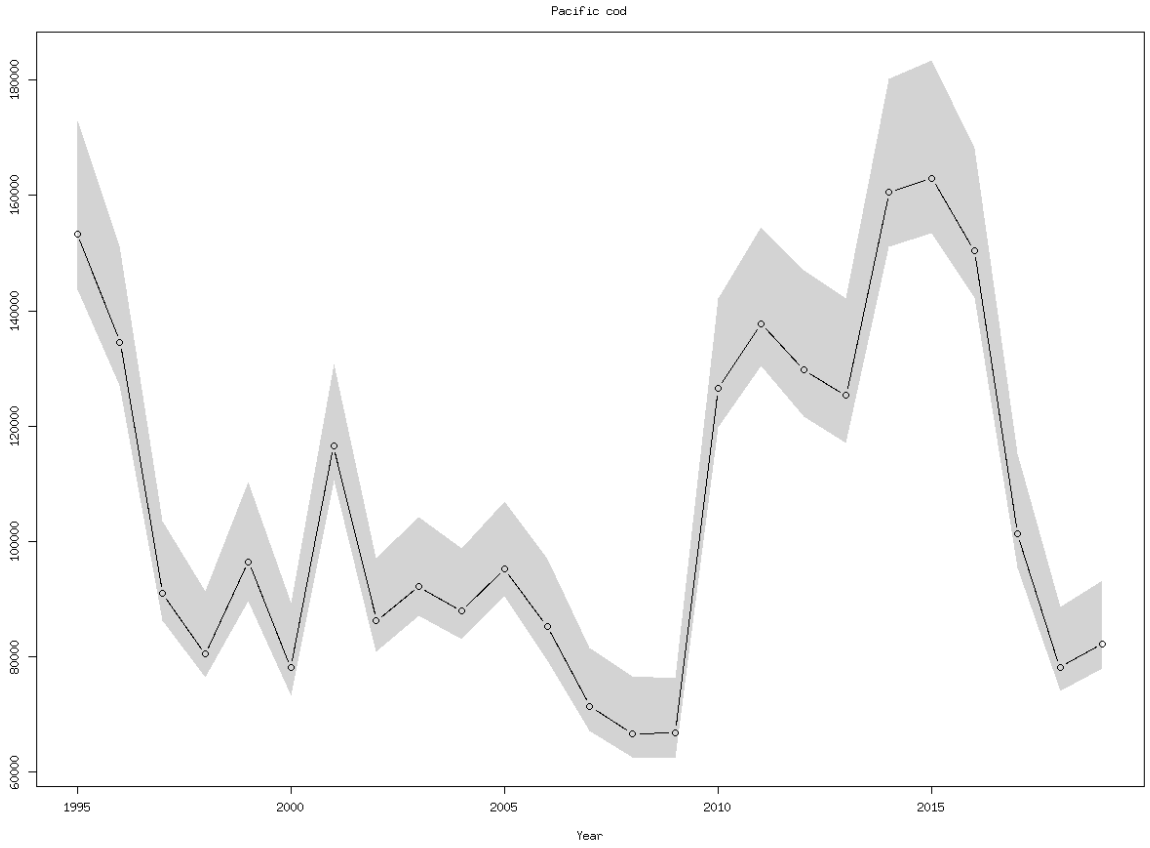

Pacific cod
180000
160000
140000
120000
100000
80000
60000
1995
2000
2005
2010
2015
Year

Figure 12

2.3 Walleye Pollock

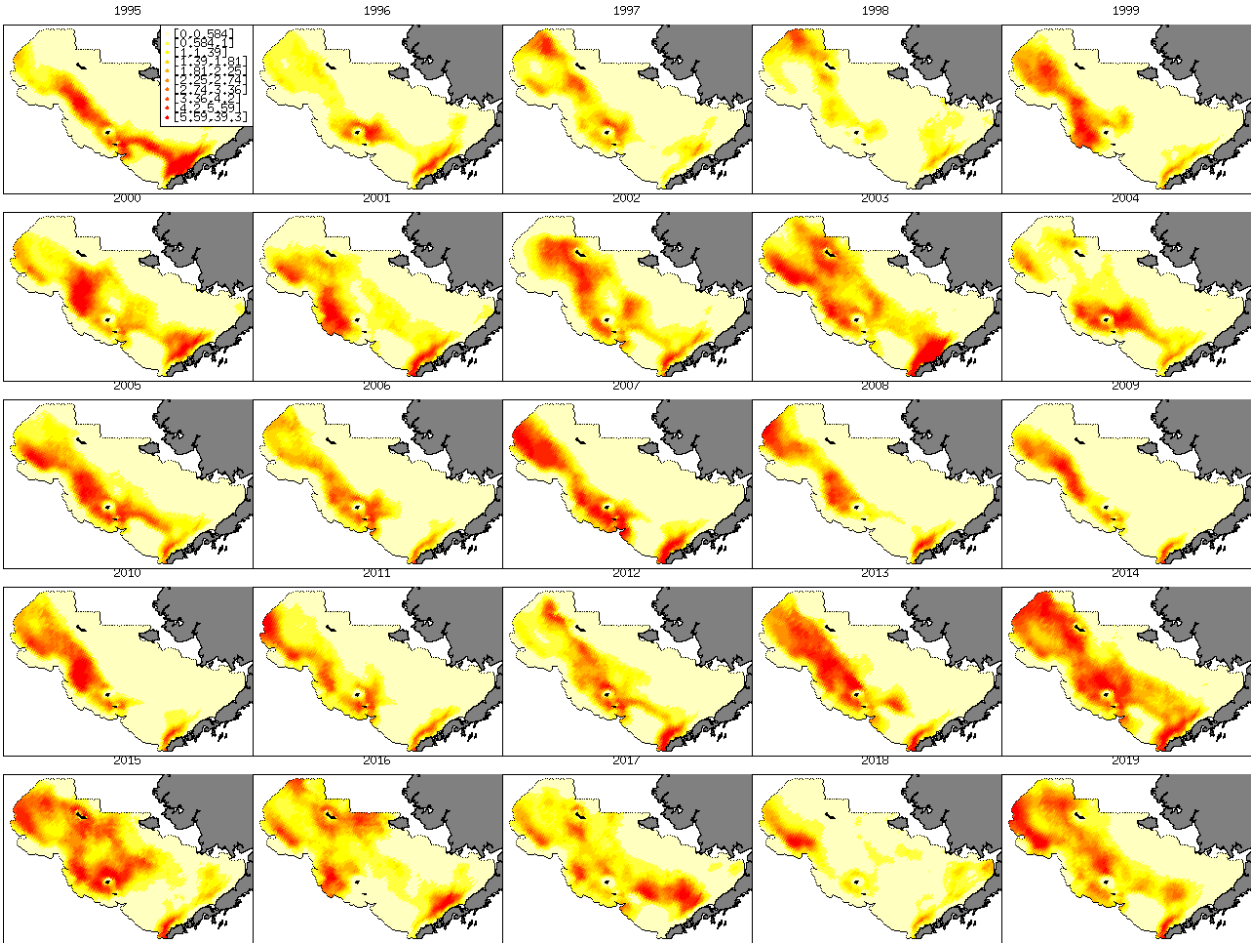
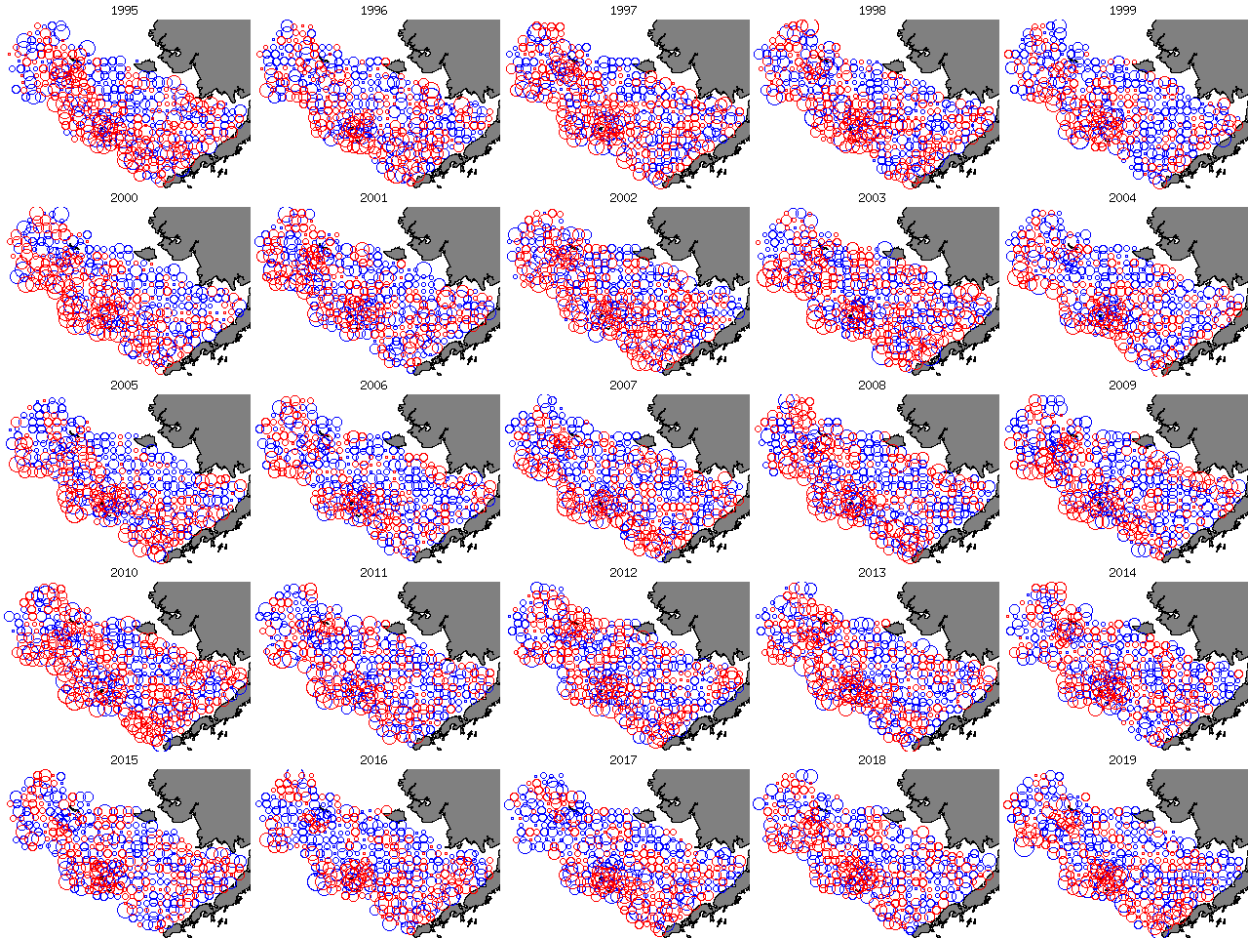


Figure 13


1995
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2016
2017
2018
2019

Figure 14

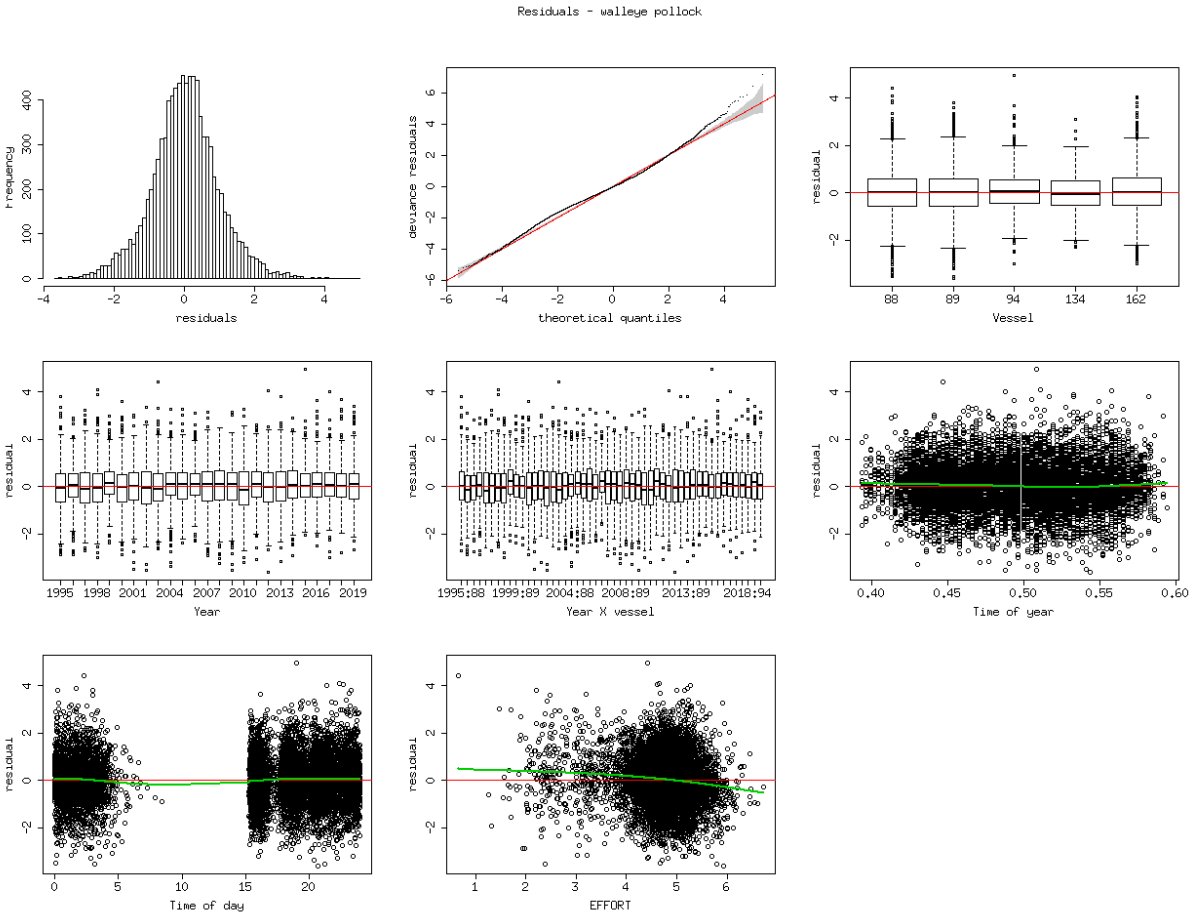

Residuals - walleye pollock
Frequency
residuals
deviance residuals
theoretical quantiles
residual
Vessel
Year
Year X vessel
Time of year
Time of day
EFFORT

Figure 15

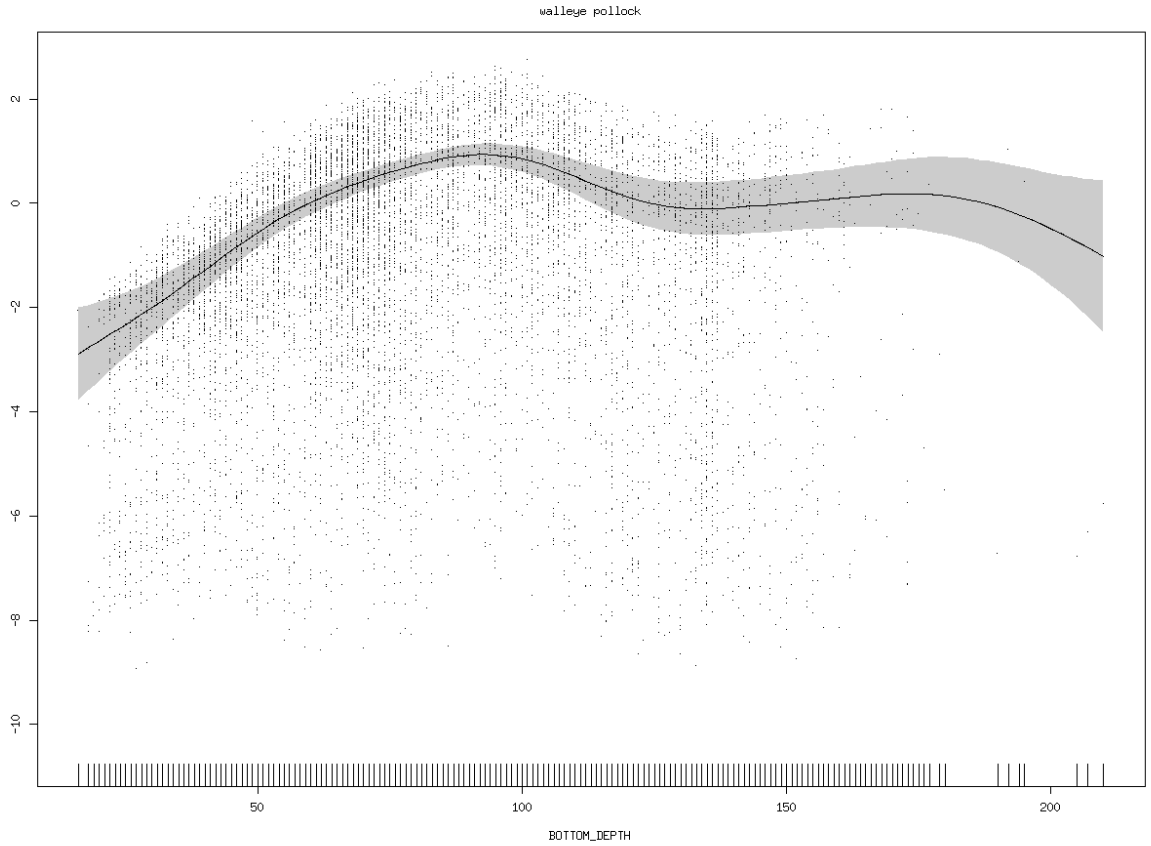


Figure 16

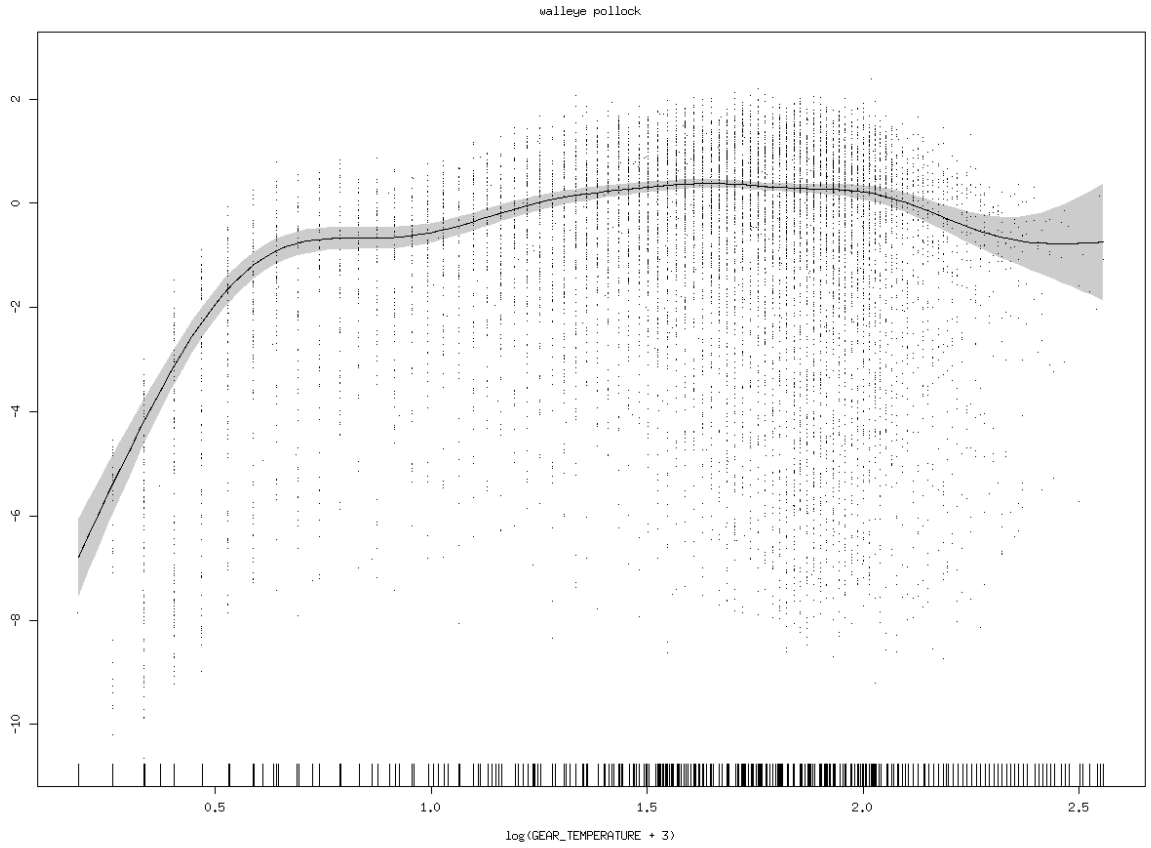

walleye pollock
2
0
-2
-4
-6
-8
-10
0.5
1.0
1.5
2.0
2.5
log(GEAR_TEMPERATURE + 3)

Figure 17

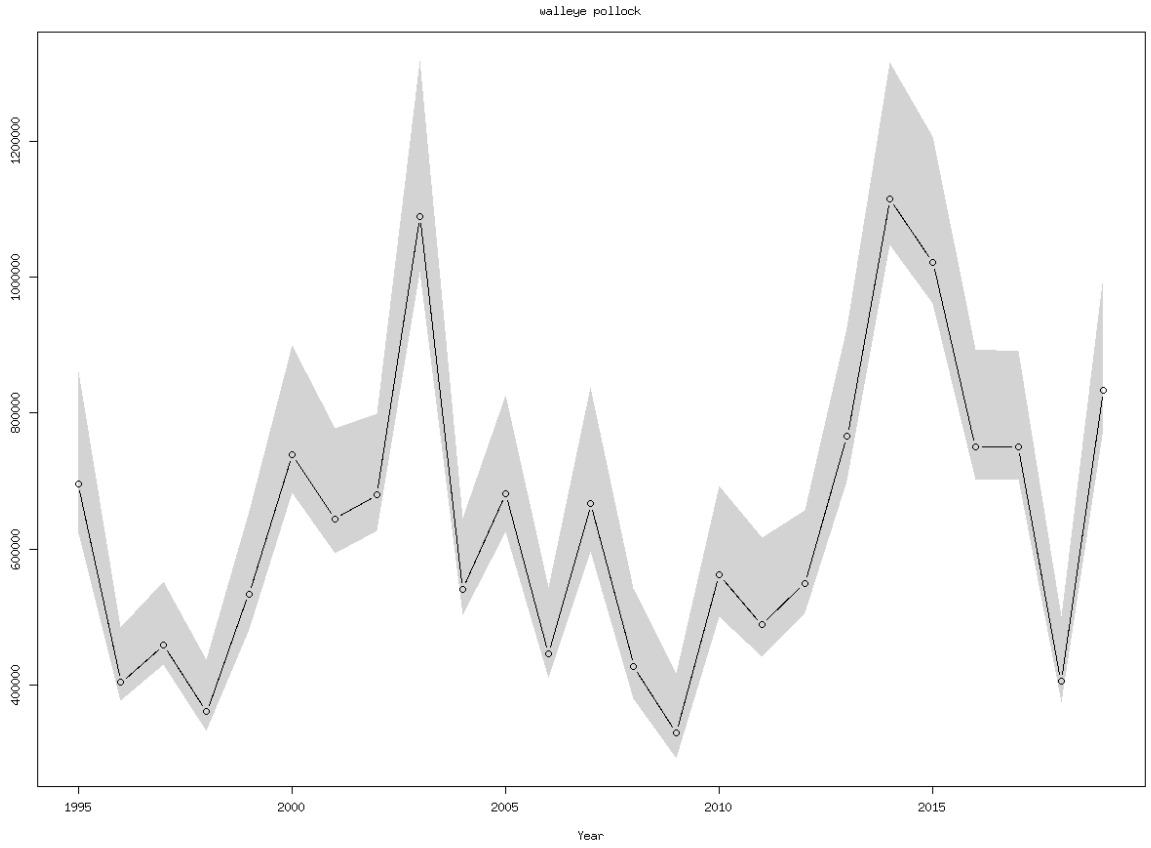

walleye pollock
1200000
1000000
800000
600000
400000
1995
2000
2005
2010
2015
Year

Figure 18

2.4 Yellowfin Sole

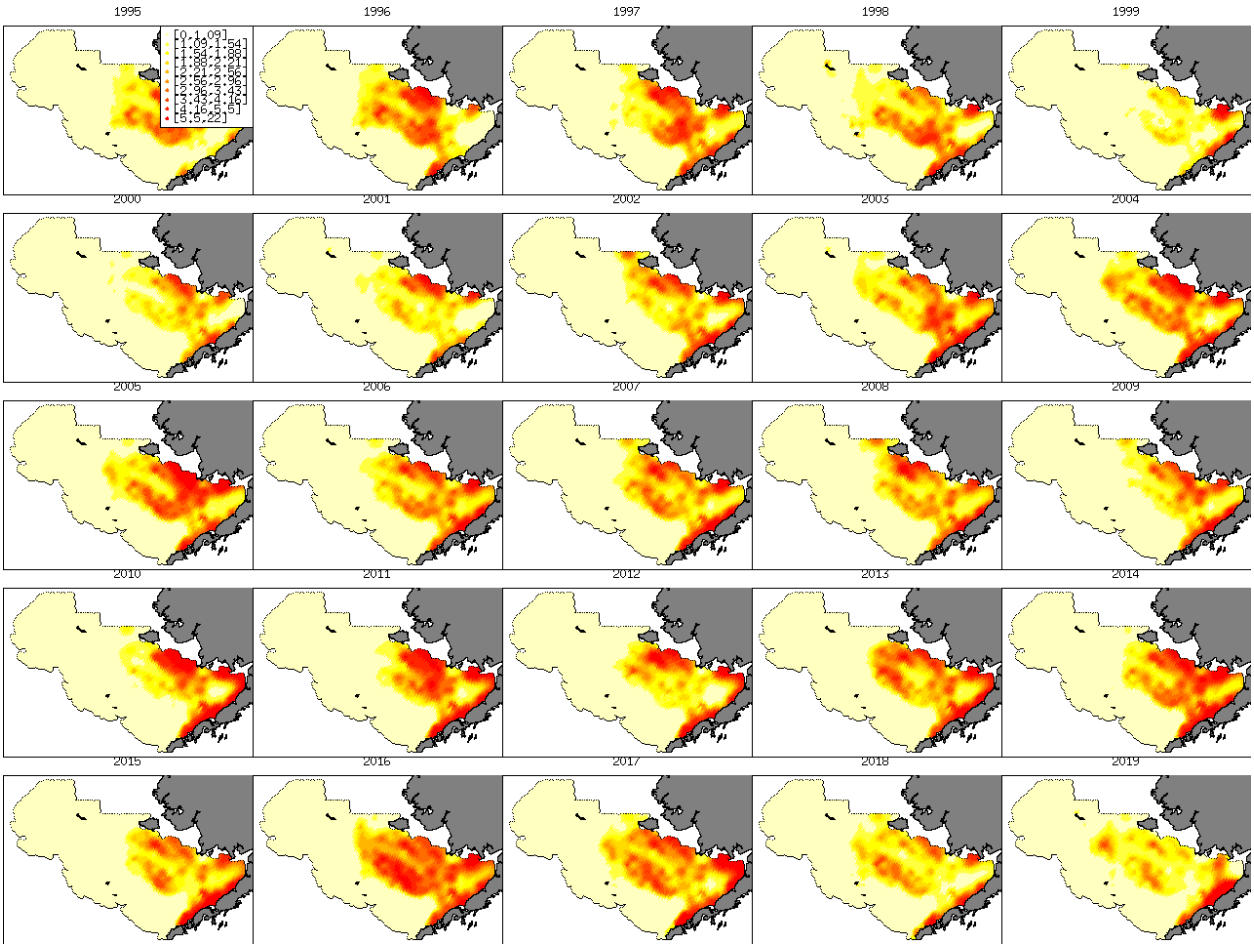
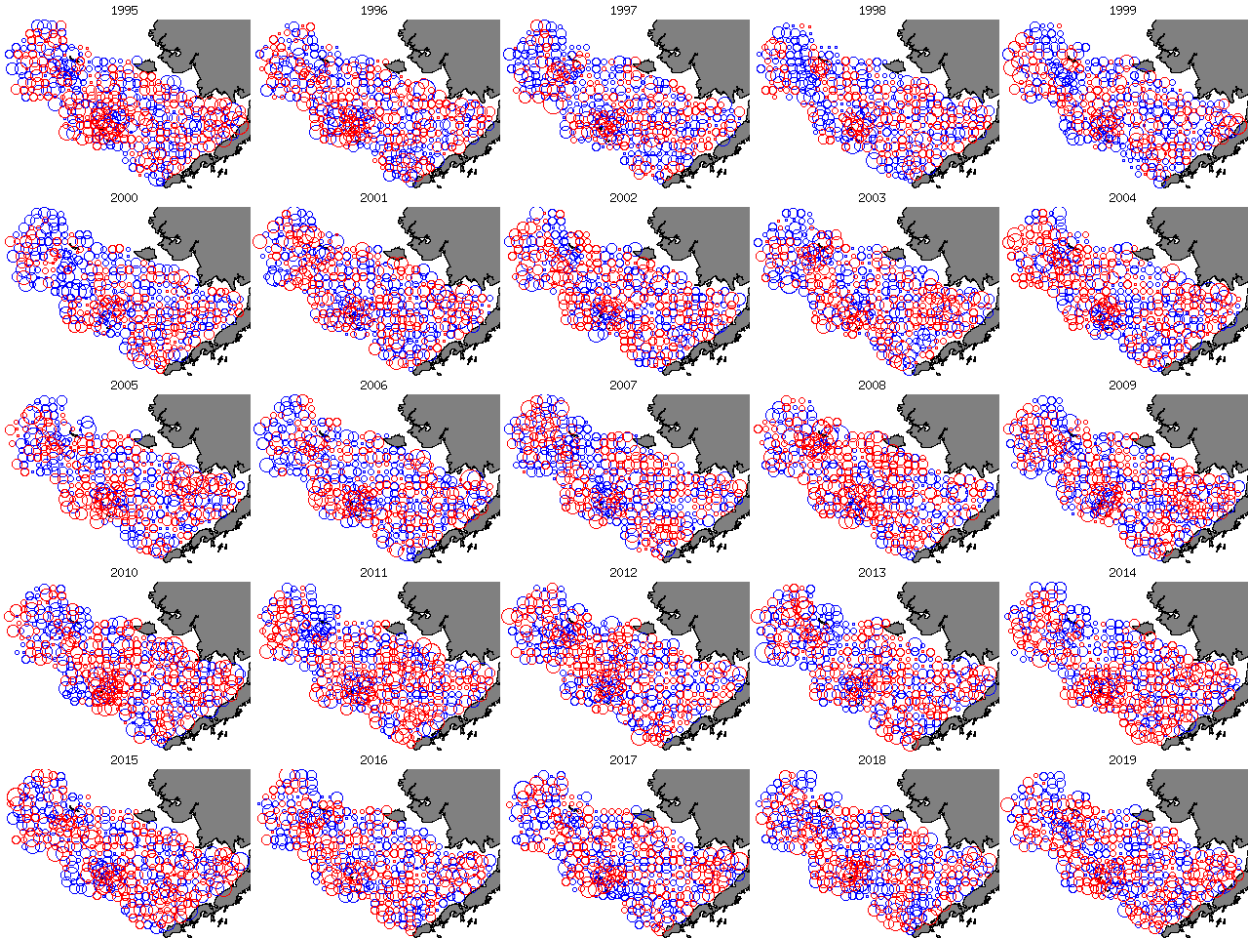


Figure 19


1995
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2019

Figure 20

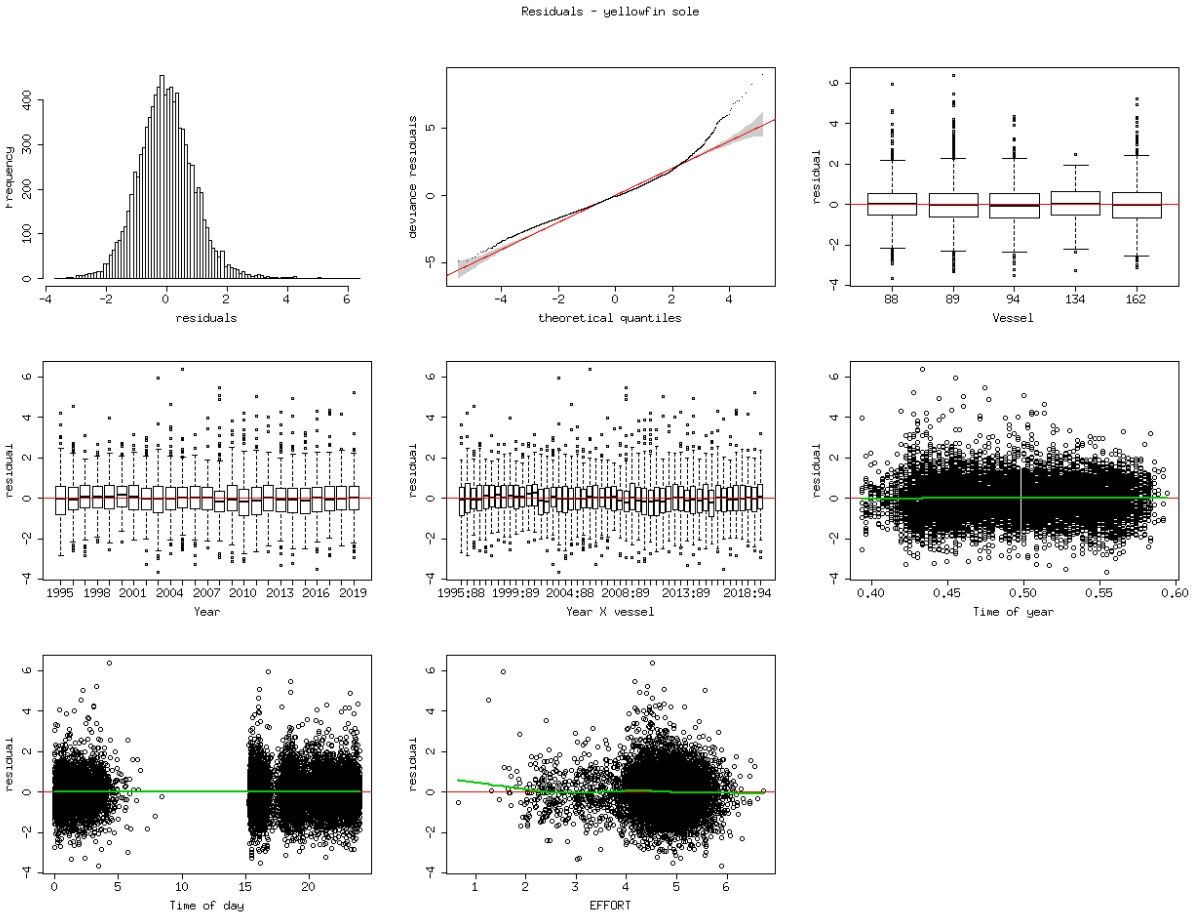
Residuals - yellowfin sole
Frequency
residuals
deviance residuals
theoretical quantiles
residual
Vessel
Year
Year X vessel
Time of year
Time of day
EFFORT

Figure 21

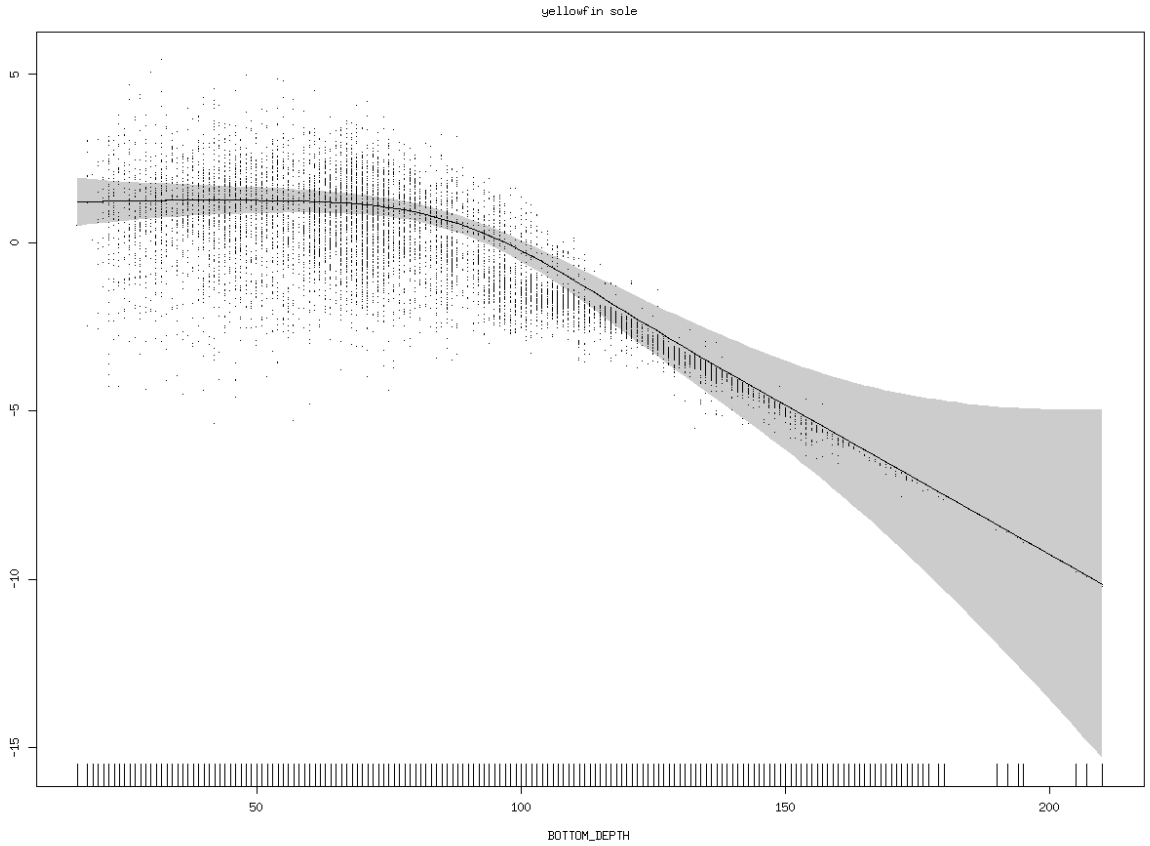

Figure 22

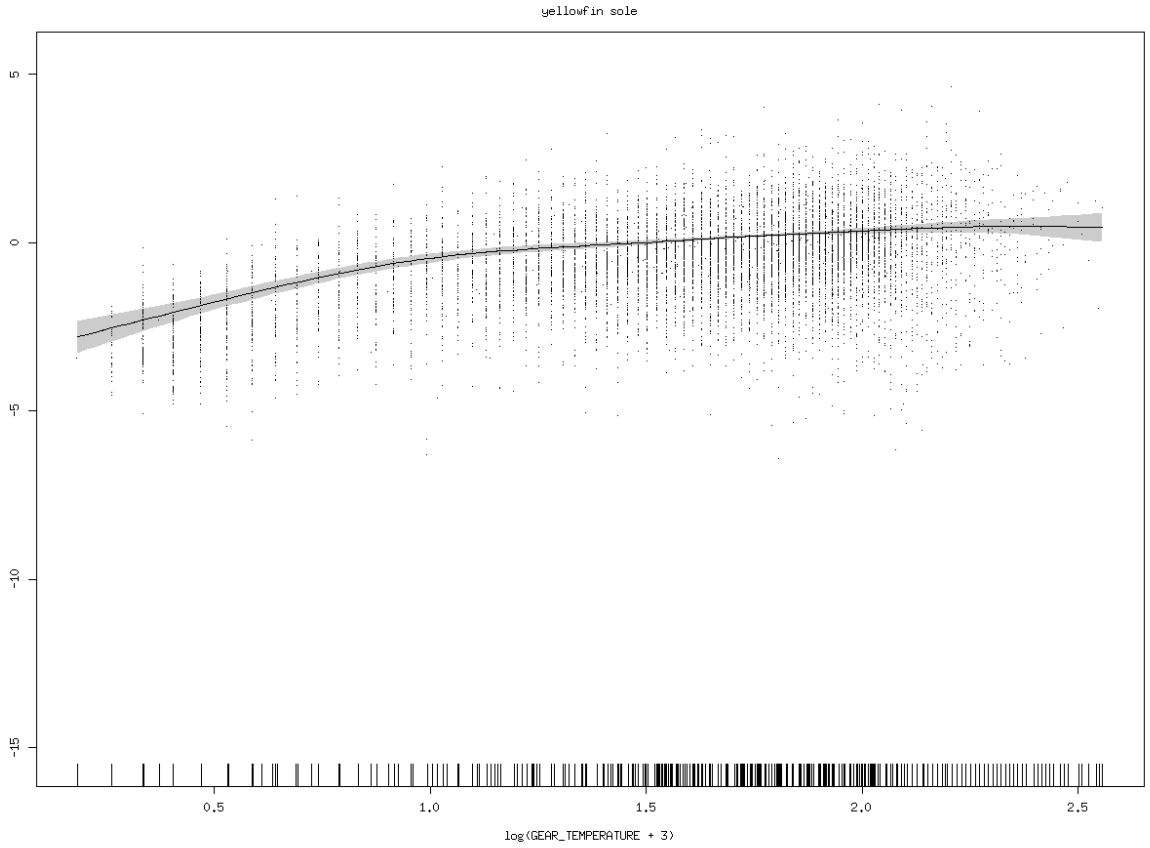

Figure 23

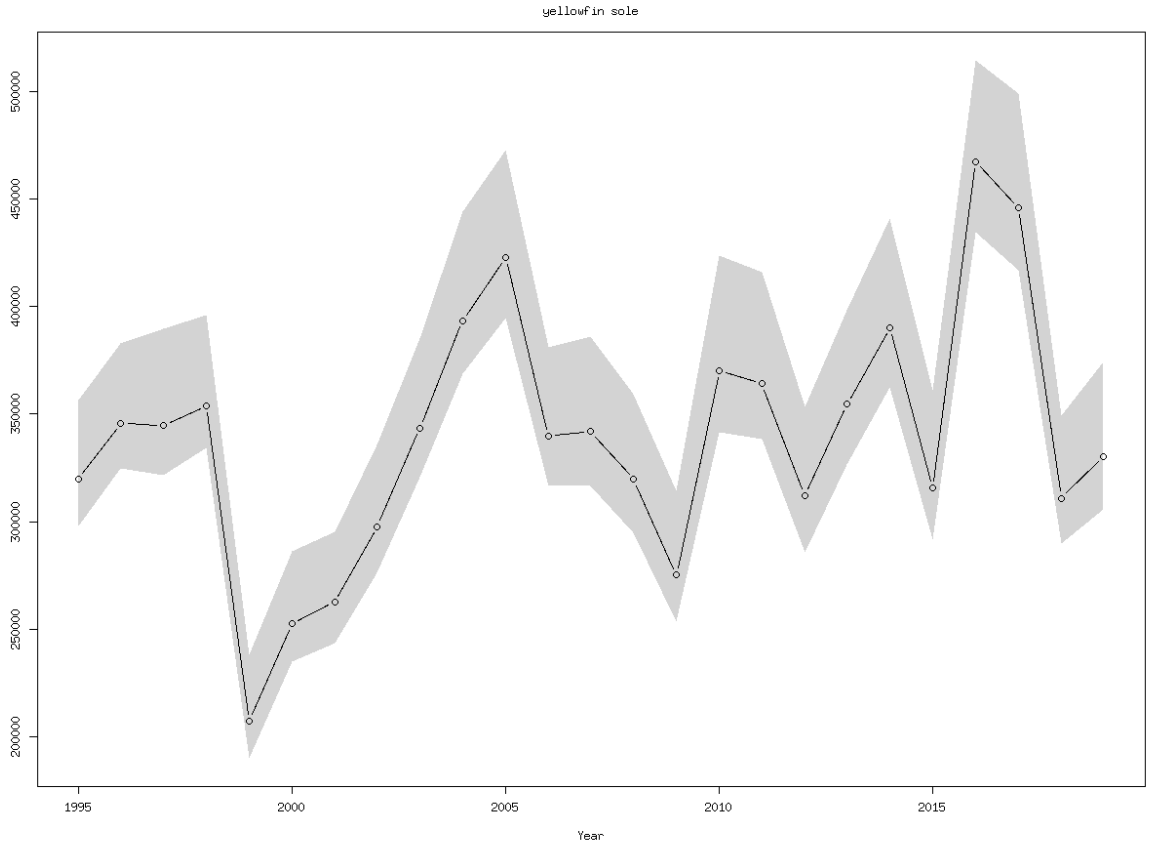
yellowfin sole
500000
450000
400000
350000
300000
250000
200000
1995
2000
2005
2010
2015
Year

Figure 24

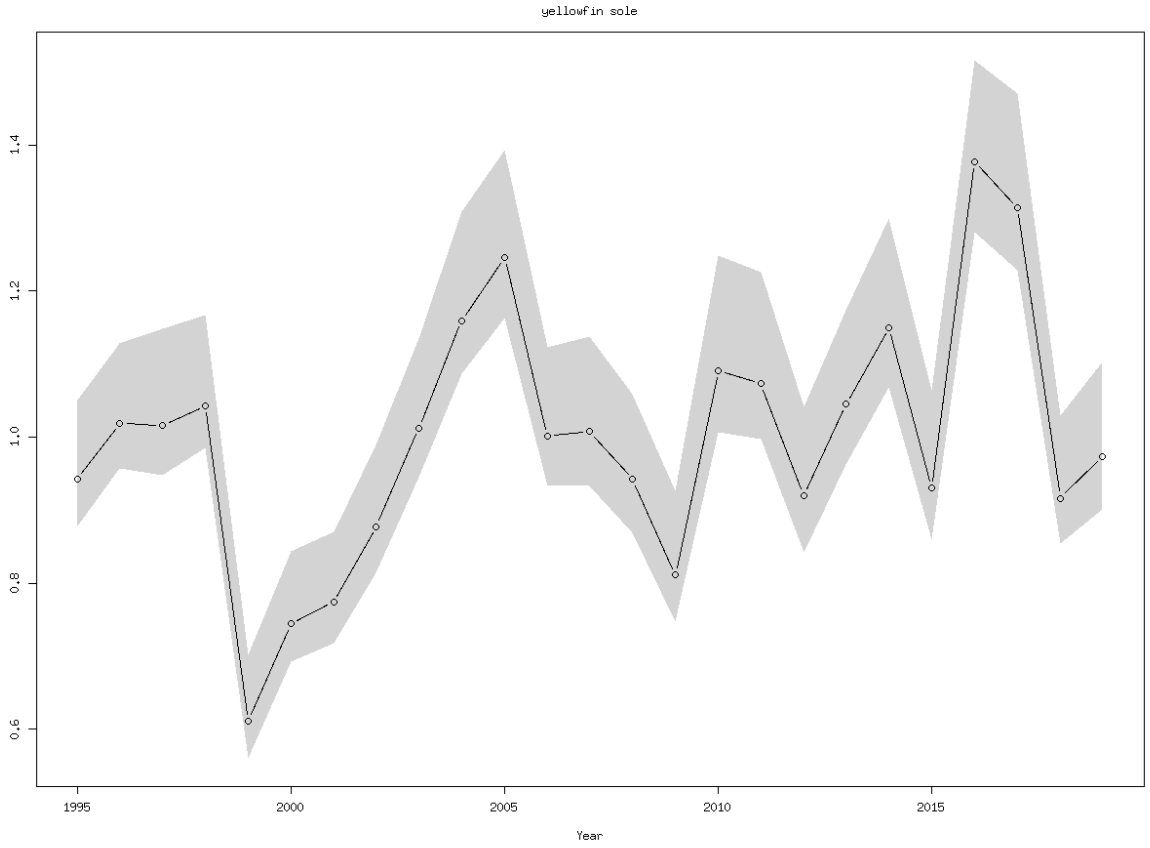

Figure 25

3 Appendix

3.1 Retrospective analyses

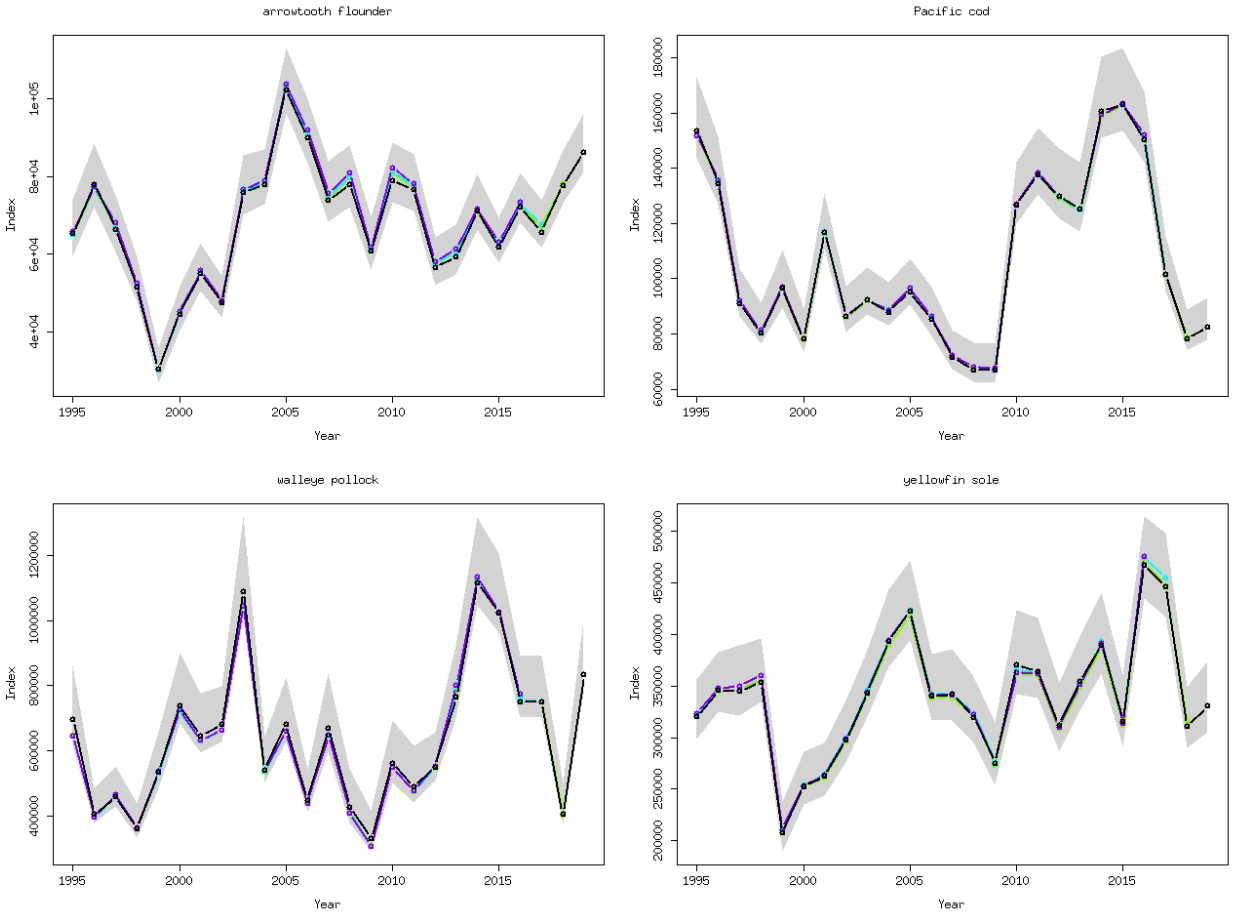

Figure 26

3.2 Simulation and re-estimation

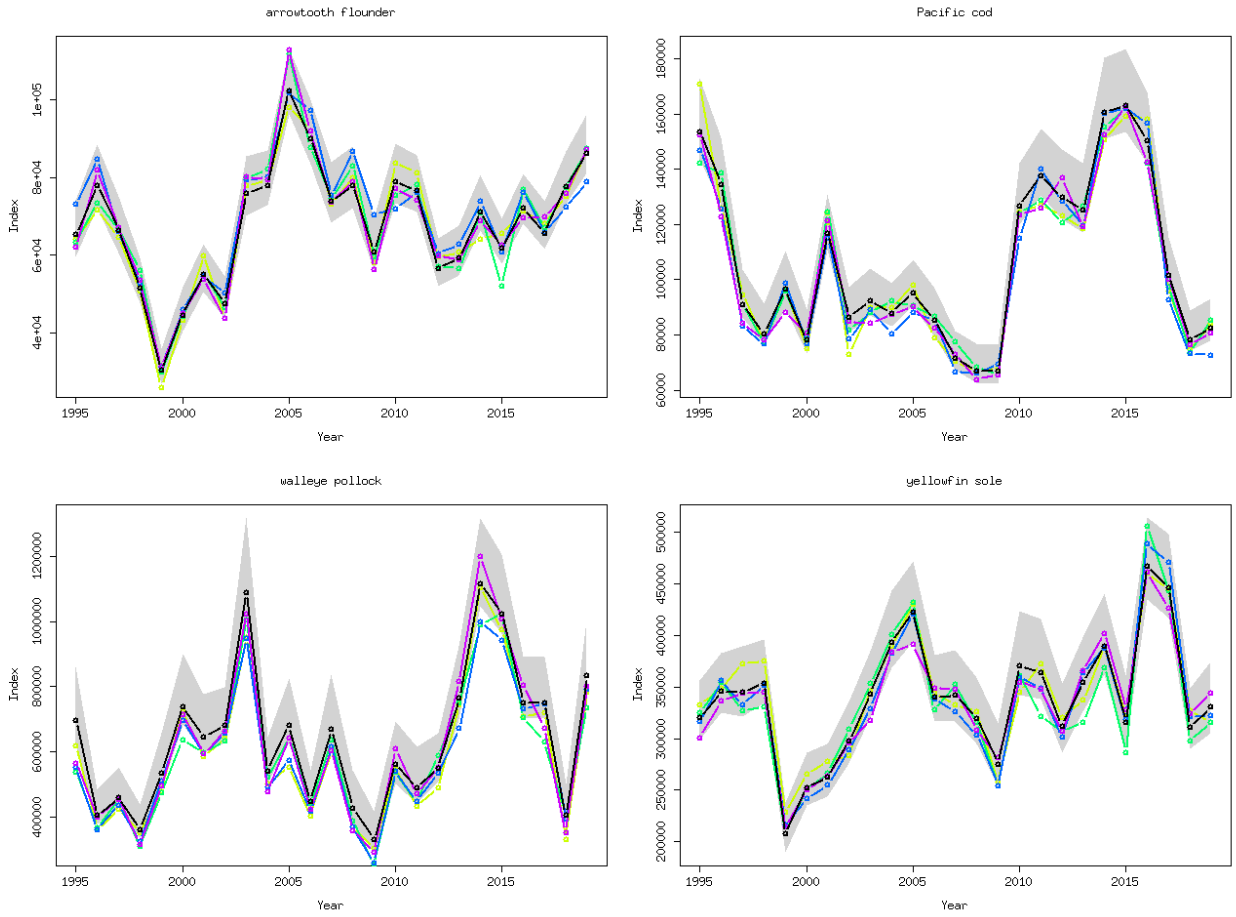
arrowtooth flounder
Index
Year
Pacific cod
walleye pollock
yellowfin sole

Figure 27

3.3 Model summaries

```
> lapply(models,function(x) summary(x$pModels[[1]]))
$`arrowtooth flounder`

Family: Tweedie(p=1.474)
Link function: log

Formula:
A1 ~ Year + s(sx, sy, bs = c("ts"), k = 376) + s(sx, sy, bs = c("ts"),
    k = 50, by = Year, id = 1) + s(BOTTOM_DEPTH, bs = "ts", k = 10) +
    s(log(GEAR_TEMPERATURE + 3), bs = "ts", k = 10)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -4.0146     0.3386 -11.855  < 2e-16 ***
Year1996      0.2471     0.3880   0.637 0.524256
Year1997     -1.5989     0.4691  -3.409 0.000656 ***
Year1998     -0.7966     0.4161  -1.915 0.055580 .
Year1999     -2.0330     0.5815  -3.496 0.000474 ***
Year2000     -0.2848     0.4265  -0.668 0.504244
Year2001     -0.2261     0.4054  -0.558 0.576996
Year2002     -0.5920     0.4110  -1.440 0.149831
Year2003      1.3209     0.3659   3.611 0.000307 ***
Year2004      1.5948     0.3655   4.364 1.29e-05 ***
Year2005      2.6777     0.3538   7.569 4.13e-14 ***
Year2006      1.5239     0.4055   3.758 0.000172 ***
Year2007      1.5530     0.4033   3.851 0.000119 ***
Year2008      2.5197     0.4013   6.279 3.58e-10 ***
Year2009      1.0640     0.4341   2.451 0.014273 *
Year2010      1.8781     0.3967   4.734 2.23e-06 ***
Year2011      1.7768     0.3712   4.787 1.72e-06 ***
Year2012      2.3444     0.4127   5.681 1.39e-08 ***
Year2013      1.8036     0.3931   4.589 4.52e-06 ***
Year2014      1.5352     0.3701   4.148 3.38e-05 ***
Year2015      1.4205     0.3765   3.773 0.000162 ***
Year2016      3.0735     0.3508   8.762  < 2e-16 ***
Year2017      2.5873     0.3556   7.276 3.74e-13 ***
Year2018      3.0920     0.3487   8.866  < 2e-16 ***
Year2019      2.7424     0.3534   7.761 9.39e-15 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                              edf Ref.df       F  p-value
s(sx,sy)                  194.795    375   4.206  < 2e-16 ***
s(sx,sy):Year1995          15.573     49   1.449  < 2e-16 ***
s(sx,sy):Year1996          19.342     49   1.239 1.88e-13 ***
s(sx,sy):Year1997          15.962     49   1.501  < 2e-16 ***
s(sx,sy):Year1998          17.535     49   0.979 3.96e-10 ***
s(sx,sy):Year1999          12.658     49   1.785  < 2e-16 ***
s(sx,sy):Year2000          16.365     49   0.902 2.21e-09 ***
s(sx,sy):Year2001          17.836     49   0.709 5.14e-06 ***
s(sx,sy):Year2002          17.522     49   0.511  0.00176 **
s(sx,sy):Year2003          21.909     49   0.786 8.79e-06 ***
s(sx,sy):Year2004          21.552     49   0.957 3.09e-08 ***
s(sx,sy):Year2005          23.744     49   1.950  < 2e-16 ***
s(sx,sy):Year2006          18.840     49   1.041 1.50e-10 ***
s(sx,sy):Year2007          18.090     49   0.799 2.92e-07 ***
s(sx,sy):Year2008          18.411     49   0.902 1.24e-08 ***
s(sx,sy):Year2009          16.236     49   1.145 1.57e-13 ***
s(sx,sy):Year2010          18.434     49   1.153 1.37e-12 ***
s(sx,sy):Year2011          20.460     49   0.554  0.00252 **
s(sx,sy):Year2012          16.836     49   0.875 6.88e-09 ***
```

```
s(sx,sy):Year2013             17.966     49   0.847 5.33e-08 ***
s(sx,sy):Year2014             20.851     49   1.399 2.82e-15 ***
s(sx,sy):Year2015             20.053     49   0.754 6.58e-06 ***
s(sx,sy):Year2016             24.497     49   3.210  < 2e-16 ***
s(sx,sy):Year2017             21.559     49   2.367  < 2e-16 ***
s(sx,sy):Year2018             25.314     49   4.519  < 2e-16 ***
s(sx,sy):Year2019             24.513     49   4.236  < 2e-16 ***
s(BOTTOM_DEPTH)                6.100      9  10.575  < 2e-16 ***
s(log(GEAR_TEMPERATURE + 3))   6.034      9 131.639  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.667   Deviance explained = 90.1%
-ML =  17536  Scale est. = 1.5924    n = 9384

$‘Pacific cod‘

Family: Tweedie(p=1.679)
Link function: log

Formula:
A1 ~ Year + s(sx, sy, bs = c("ts"), k = 376) + s(sx, sy, bs = c("ts"),
    k = 50, by = Year, id = 1) + s(BOTTOM_DEPTH, bs = "ts", k = 10) +
    s(log(GEAR_TEMPERATURE + 3), bs = "ts", k = 10)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.64496    0.05085  52.019  < 2e-16 ***
Year1996    -0.45197    0.07271  -6.216 5.33e-10 ***
Year1997    -0.64965    0.06821  -9.524  < 2e-16 ***
Year1998    -0.92022    0.07296 -12.613  < 2e-16 ***
Year1999    -0.21910    0.07109  -3.082  0.00206 **
Year2000    -0.74665    0.06761 -11.044  < 2e-16 ***
Year2001    -0.41667    0.06684  -6.234 4.78e-10 ***
Year2002    -0.92248    0.07273 -12.684  < 2e-16 ***
Year2003    -0.97593    0.07925 -12.315  < 2e-16 ***
Year2004    -0.84616    0.07388 -11.453  < 2e-16 ***
Year2005    -0.74524    0.07479  -9.965  < 2e-16 ***
Year2006    -0.49470    0.06749  -7.330 2.51e-13 ***
Year2007    -0.55840    0.06654  -8.392  < 2e-16 ***
Year2008    -0.41801    0.06782  -6.164 7.43e-10 ***
Year2009    -0.56906    0.06913  -8.232  < 2e-16 ***
Year2010    -0.06746    0.06561  -1.028  0.30387
Year2011    -0.23320    0.06534  -3.569  0.00036 ***
Year2012     0.18523    0.06686   2.770  0.00561 **
Year2013    -0.03940    0.06530  -0.603  0.54622
Year2014    -0.21130    0.06957  -3.037  0.00239 **
Year2015    -0.33181    0.07283  -4.556 5.29e-06 ***
Year2016    -0.24466    0.08434  -2.901  0.00373 **
Year2017    -0.49622    0.06820  -7.276 3.76e-13 ***
Year2018    -1.09104    0.08513 -12.816  < 2e-16 ***
Year2019    -0.93164    0.08677 -10.737  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                               edf Ref.df       F  p-value
s(sx,sy)                   260.1556    375   4.403  < 2e-16 ***
s(sx,sy):Year1995           26.3557     49   2.908  < 2e-16 ***
s(sx,sy):Year1996           27.0969     49   1.040 2.85e-07 ***
s(sx,sy):Year1997           26.0467     49   0.976 9.08e-07 ***
s(sx,sy):Year1998           26.0935     49   1.404 7.87e-13 ***
s(sx,sy):Year1999           24.4457     49   4.373  < 2e-16 ***
s(sx,sy):Year2000           25.3893     49   1.983  < 2e-16 ***
s(sx,sy):Year2001           26.6074     49   1.617 7.65e-16 ***
```

```
s(sx,sy):Year2002             25.8847     49   1.377 1.67e-12 ***
s(sx,sy):Year2003             26.0720     49   1.465 9.40e-14 ***
s(sx,sy):Year2004             25.9032     49   0.873 1.71e-05 ***
s(sx,sy):Year2005             26.1291     49   0.784 0.000233 ***
s(sx,sy):Year2006             24.9854     49   1.328 3.56e-12 ***
s(sx,sy):Year2007             25.0859     49   1.255 4.83e-11 ***
s(sx,sy):Year2008             24.7428     49   1.882  < 2e-16 ***
s(sx,sy):Year2009             24.3875     49   2.472  < 2e-16 ***
s(sx,sy):Year2010             25.8600     49   3.870  < 2e-16 ***
s(sx,sy):Year2011             27.0687     49   1.756  < 2e-16 ***
s(sx,sy):Year2012             26.0366     49   2.462  < 2e-16 ***
s(sx,sy):Year2013             26.3077     49   2.119  < 2e-16 ***
s(sx,sy):Year2014             27.4053     49   3.369  < 2e-16 ***
s(sx,sy):Year2015             26.9707     49   3.292  < 2e-16 ***
s(sx,sy):Year2016             27.3574     49   1.262 3.06e-10 ***
s(sx,sy):Year2017             26.3894     49   1.251 1.90e-10 ***
s(sx,sy):Year2018             26.0931     49   2.039  < 2e-16 ***
s(sx,sy):Year2019             26.0659     49   0.952 1.88e-06 ***
s(BOTTOM_DEPTH)                0.2803      9   0.042 0.093818 .
s(log(GEAR_TEMPERATURE + 3))   8.7453      9 148.403  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.299   Deviance explained = 59.2%
-ML =  32074  Scale est. = 1.4565    n = 9384

$‘walleye pollock‘

Family: Tweedie(p=1.802)
Link function: log

Formula:
A1 ~ Year + s(sx, sy, bs = c("ts"), k = 376) + s(sx, sy, bs = c("ts"),
    k = 50, by = Year, id = 1) + s(BOTTOM_DEPTH, bs = "ts", k = 10) +
    s(log(GEAR_TEMPERATURE + 3), bs = "ts", k = 10)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.47867    0.06542  53.175  < 2e-16 ***
Year1996    -0.28839    0.09711  -2.970  0.00299 **
Year1997    -0.19221    0.08711  -2.207  0.02737 *
Year1998    -0.45103    0.09534  -4.731 2.28e-06 ***
Year1999    -0.09562    0.08636  -1.107  0.26825
Year2000     0.18236    0.08234   2.215  0.02680 *
Year2001     0.08372    0.08553   0.979  0.32770
Year2002     0.05806    0.09257   0.627  0.53052
Year2003     0.43904    0.10272   4.274 1.94e-05 ***
Year2004     0.02975    0.09488   0.314  0.75390
Year2005    -0.02600    0.09807  -0.265  0.79095
Year2006    -0.46343    0.08408  -5.512 3.66e-08 ***
Year2007    -0.78046    0.08553  -9.125  < 2e-16 ***
Year2008    -1.09437    0.08804 -12.431  < 2e-16 ***
Year2009    -1.61948    0.09042 -17.910  < 2e-16 ***
Year2010    -0.75648    0.08544  -8.854  < 2e-16 ***
Year2011    -0.59394    0.08698  -6.829 9.17e-12 ***
Year2012     0.05184    0.08387   0.618  0.53655
Year2013    -0.02041    0.08230  -0.248  0.80413
Year2014     0.70548    0.09001   7.838 5.14e-15 ***
Year2015     0.98858    0.09277  10.656  < 2e-16 ***
Year2016     0.63022    0.11423   5.517 3.55e-08 ***
Year2017     0.62097    0.08502   7.304 3.06e-13 ***
Year2018    -0.11777    0.11305  -1.042  0.29757
Year2019     0.35637    0.11572   3.080  0.00208 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Approximate significance of smooth terms:
                               edf Ref.df      F  p-value
s(sx,sy)                   251.260    375  4.358  < 2e-16 ***
s(sx,sy):Year1995           32.517     49  3.905  < 2e-16 ***
s(sx,sy):Year1996           32.674     49  1.812 6.65e-16 ***
s(sx,sy):Year1997           32.776     49  1.516 9.70e-12 ***
s(sx,sy):Year1998           32.655     49  2.227  < 2e-16 ***
s(sx,sy):Year1999           32.037     49  2.176  < 2e-16 ***
s(sx,sy):Year2000           33.250     49  2.001  < 2e-16 ***
s(sx,sy):Year2001           33.296     49  2.611  < 2e-16 ***
s(sx,sy):Year2002           33.181     49  2.665  < 2e-16 ***
s(sx,sy):Year2003           33.807     49  2.657  < 2e-16 ***
s(sx,sy):Year2004           33.123     49  1.859 2.23e-16 ***
s(sx,sy):Year2005           32.933     49  1.377 7.83e-10 ***
s(sx,sy):Year2006           31.841     49  1.725 5.27e-15 ***
s(sx,sy):Year2007           31.532     49  2.021  < 2e-16 ***
s(sx,sy):Year2008           30.801     49  2.609  < 2e-16 ***
s(sx,sy):Year2009           30.090     49  2.946  < 2e-16 ***
s(sx,sy):Year2010           31.436     49  2.123  < 2e-16 ***
s(sx,sy):Year2011           32.249     49  1.404 2.04e-10 ***
s(sx,sy):Year2012           32.333     49  3.010  < 2e-16 ***
s(sx,sy):Year2013           32.479     49  2.733  < 2e-16 ***
s(sx,sy):Year2014           33.948     49  1.632 6.60e-13 ***
s(sx,sy):Year2015           34.295     49  3.020  < 2e-16 ***
s(sx,sy):Year2016           33.828     49  3.296  < 2e-16 ***
s(sx,sy):Year2017           33.956     49  3.638  < 2e-16 ***
s(sx,sy):Year2018           33.119     49  3.755  < 2e-16 ***
s(sx,sy):Year2019           33.487     49  2.933  < 2e-16 ***
s(BOTTOM_DEPTH)              7.031      9 12.969  < 2e-16 ***
s(log(GEAR_TEMPERATURE + 3))  8.570      9 53.074  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.218   Deviance explained = 64.9%
-ML =  43891  Scale est. = 2.2291    n = 9384

$‘yellowfin sole‘

Family: Tweedie(p=1.596)
Link function: log

Formula:
A1 ~ Year + s(sx, sy, bs = c("ts"), k = 376) + s(sx, sy, bs = c("ts"),
    k = 50, by = Year, id = 1) + s(BOTTOM_DEPTH, bs = "ts", k = 10) +
    s(log(GEAR_TEMPERATURE + 3), bs = "ts", k = 10)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -0.3295     0.1575  -2.092 0.036461 *
Year1996     -0.2647     0.2135  -1.239 0.215220
Year1997      0.1852     0.1953   0.948 0.342987
Year1998      1.6461     0.1696   9.704  < 2e-16 ***
Year1999      0.7492     0.1787   4.191 2.80e-05 ***
Year2000     -0.2490     0.2021  -1.232 0.218000
Year2001     -0.3313     0.2056  -1.611 0.107114
Year2002     -0.7905     0.2128  -3.715 0.000205 ***
Year2003     -1.0058     0.2221  -4.528 6.03e-06 ***
Year2004     -0.2179     0.2044  -1.066 0.286448
Year2005     -0.1188     0.2046  -0.580 0.561720
Year2006     -0.1089     0.2065  -0.527 0.598098
Year2007     -0.3555     0.2141  -1.660 0.096910 .
Year2008      0.1417     0.1981   0.715 0.474494
Year2009     -0.6346     0.2163  -2.934 0.003359 **
Year2010     -0.9092     0.2334  -3.895 9.89e-05 ***
```

```
Year2011     -1.3411     0.2345  -5.718 1.11e-08 ***
Year2012     -0.0310     0.2047  -0.151 0.879661
Year2013     -0.3022     0.2067  -1.461 0.143918
Year2014     -1.4150     0.2524  -5.607 2.12e-08 ***
Year2015     -0.9652     0.2296  -4.203 2.66e-05 ***
Year2016     -0.6363     0.2329  -2.732 0.006303 **
Year2017      0.5584     0.1921   2.906 0.003665 **
Year2018      0.1317     0.2029   0.649 0.516281
Year2019      0.5525     0.1908   2.896 0.003790 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                               edf Ref.df      F  p-value
s(sx,sy)                   256.348    375  7.077  < 2e-16 ***
s(sx,sy):Year1995           21.225     49  1.211 6.94e-12 ***
s(sx,sy):Year1996           21.516     49  1.566  < 2e-16 ***
s(sx,sy):Year1997           22.008     49  0.675 0.000344 ***
s(sx,sy):Year1998           24.360     49  4.959  < 2e-16 ***
s(sx,sy):Year1999           21.511     49  1.742  < 2e-16 ***
s(sx,sy):Year2000           20.918     49  0.554 0.004681 **
s(sx,sy):Year2001           21.240     49  0.751 2.57e-05 ***
s(sx,sy):Year2002           20.993     49  0.871 5.31e-07 ***
s(sx,sy):Year2003           21.193     49  1.448 1.47e-15 ***
s(sx,sy):Year2004           22.031     49  1.047 3.97e-09 ***
s(sx,sy):Year2005           22.148     49  1.066 2.30e-09 ***
s(sx,sy):Year2006           21.395     49  0.441 0.065885 .
s(sx,sy):Year2007           20.980     49  0.687 0.000135 ***
s(sx,sy):Year2008           21.349     49  0.904 2.42e-07 ***
s(sx,sy):Year2009           20.090     49  0.995 4.11e-09 ***
s(sx,sy):Year2010           20.050     49  1.783  < 2e-16 ***
s(sx,sy):Year2011           20.047     49  1.306 6.95e-14 ***
s(sx,sy):Year2012           20.814     49  1.317 1.02e-13 ***
s(sx,sy):Year2013           20.547     49  1.280 3.03e-13 ***
s(sx,sy):Year2014           20.232     49  1.157 1.89e-11 ***
s(sx,sy):Year2015           20.389     49  0.983 8.21e-09 ***
s(sx,sy):Year2016           21.738     49  1.038 4.24e-09 ***
s(sx,sy):Year2017           22.833     49  2.001  < 2e-16 ***
s(sx,sy):Year2018           22.552     49  1.241 8.72e-12 ***
s(sx,sy):Year2019           22.971     49  3.786  < 2e-16 ***
s(BOTTOM_DEPTH)              4.536      9  7.134  < 2e-16 ***
s(log(GEAR_TEMPERATURE + 3))  5.849      9 28.026  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.517   Deviance explained = 89.5%
-ML =  28609  Scale est. = 1.9959    n = 9384


> sink()
```

3.4 gam.check output

```
> lapply(models,function(x) gam.check(x$pModels[[1]]))

Method: ML   Optimizer: outer newton
full convergence after 5 iterations.
Gradient range [-0.002136276,0.00194813]
(score 17535.69 & scale 1.592435).
Hessian positive definite, eigenvalue range [1.342862,3891.959].
Model rank =  1643 / 1643

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                               k'    edf k-index p-value
s(sx,sy)                   375.00 194.80    0.91   0.325
s(sx,sy):Year1995           49.00  15.57    0.91   0.350
s(sx,sy):Year1996           49.00  19.34    0.91   0.320
s(sx,sy):Year1997           49.00  15.96    0.91   0.350
s(sx,sy):Year1998           49.00  17.54    0.91   0.365
s(sx,sy):Year1999           49.00  12.66    0.91   0.245
s(sx,sy):Year2000           49.00  16.36    0.91   0.330
s(sx,sy):Year2001           49.00  17.84    0.91   0.325
s(sx,sy):Year2002           49.00  17.52    0.91   0.360
s(sx,sy):Year2003           49.00  21.91    0.91   0.345
s(sx,sy):Year2004           49.00  21.55    0.91   0.315
s(sx,sy):Year2005           49.00  23.74    0.91   0.335
s(sx,sy):Year2006           49.00  18.84    0.91   0.325
s(sx,sy):Year2007           49.00  18.09    0.91   0.295
s(sx,sy):Year2008           49.00  18.41    0.91   0.360
s(sx,sy):Year2009           49.00  16.24    0.91   0.390
s(sx,sy):Year2010           49.00  18.43    0.91   0.315
s(sx,sy):Year2011           49.00  20.46    0.91   0.395
s(sx,sy):Year2012           49.00  16.84    0.91   0.330
s(sx,sy):Year2013           49.00  17.97    0.91   0.355
s(sx,sy):Year2014           49.00  20.85    0.91   0.320
s(sx,sy):Year2015           49.00  20.05    0.91   0.345
s(sx,sy):Year2016           49.00  24.50    0.91   0.260
s(sx,sy):Year2017           49.00  21.56    0.91   0.380
s(sx,sy):Year2018           49.00  25.31    0.91   0.290
s(sx,sy):Year2019           49.00  24.51    0.91   0.330
s(BOTTOM_DEPTH)              9.00   6.10    0.90   0.075 .
s(log(GEAR_TEMPERATURE + 3))   9.00   6.03    0.87  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Method: ML   Optimizer: outer newton
full convergence after 6 iterations.
Gradient range [-0.004418967,0.002864712]
(score 32074.49 & scale 1.456504).
Hessian positive definite, eigenvalue range [0.03936054,6935.119].
Model rank =  1643 / 1643

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                               k'    edf k-index p-value
s(sx,sy)                   375.00 260.16    0.93    0.40
s(sx,sy):Year1995           49.00  26.36    0.93    0.41
s(sx,sy):Year1996           49.00  27.10    0.93    0.43
s(sx,sy):Year1997           49.00  26.05    0.93    0.38
s(sx,sy):Year1998           49.00  26.09    0.93    0.30
s(sx,sy):Year1999           49.00  24.45    0.93    0.40
s(sx,sy):Year2000           49.00  25.39    0.93    0.38
```

```
s(sx,sy):Year2001             49.00  26.61    0.93    0.42
s(sx,sy):Year2002             49.00  25.89    0.93    0.47
s(sx,sy):Year2003             49.00  26.07    0.93    0.44
s(sx,sy):Year2004             49.00  25.90    0.93    0.46
s(sx,sy):Year2005             49.00  26.13    0.93    0.46
s(sx,sy):Year2006             49.00  24.98    0.93    0.41
s(sx,sy):Year2007             49.00  25.09    0.93    0.44
s(sx,sy):Year2008             49.00  24.74    0.93    0.42
s(sx,sy):Year2009             49.00  24.39    0.93    0.34
s(sx,sy):Year2010             49.00  25.86    0.93    0.42
s(sx,sy):Year2011             49.00  27.07    0.93    0.39
s(sx,sy):Year2012             49.00  26.04    0.93    0.45
s(sx,sy):Year2013             49.00  26.31    0.93    0.42
s(sx,sy):Year2014             49.00  27.41    0.93    0.42
s(sx,sy):Year2015             49.00  26.97    0.93    0.43
s(sx,sy):Year2016             49.00  27.36    0.93    0.41
s(sx,sy):Year2017             49.00  26.39    0.93    0.38
s(sx,sy):Year2018             49.00  26.09    0.93    0.43
s(sx,sy):Year2019             49.00  26.07    0.93    0.42
s(BOTTOM_DEPTH)                9.00   0.28    0.97    0.98
s(log(GEAR_TEMPERATURE + 3))   9.00   8.74    0.93    0.19

Method: ML   Optimizer: outer newton
full convergence after 7 iterations.
Gradient range [-0.01721491,2.286906e-05]
(score 43890.63 & scale 2.229106).
Hessian positive definite, eigenvalue range [1.887655,7560.673].
Model rank =  1643 / 1643

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                              k'    edf k-index p-value
s(sx,sy)                  375.00 251.26    0.88   0.020 *
s(sx,sy):Year1995          49.00  32.52    0.88   0.025 *
s(sx,sy):Year1996          49.00  32.67    0.88   0.050 *
s(sx,sy):Year1997          49.00  32.78    0.88   0.025 *
s(sx,sy):Year1998          49.00  32.66    0.88   0.030 *
s(sx,sy):Year1999          49.00  32.04    0.88   0.020 *
s(sx,sy):Year2000          49.00  33.25    0.88   0.025 *
s(sx,sy):Year2001          49.00  33.30    0.88   0.010 **
s(sx,sy):Year2002          49.00  33.18    0.88   0.025 *
s(sx,sy):Year2003          49.00  33.81    0.88   0.010 **
s(sx,sy):Year2004          49.00  33.12    0.88   0.020 *
s(sx,sy):Year2005          49.00  32.93    0.88   0.010 **
s(sx,sy):Year2006          49.00  31.84    0.88   0.025 *
s(sx,sy):Year2007          49.00  31.53    0.88   0.020 *
s(sx,sy):Year2008          49.00  30.80    0.88   0.030 *
s(sx,sy):Year2009          49.00  30.09    0.88   0.010 **
s(sx,sy):Year2010          49.00  31.44    0.88   0.030 *
s(sx,sy):Year2011          49.00  32.25    0.88   0.035 *
s(sx,sy):Year2012          49.00  32.33    0.88   0.025 *
s(sx,sy):Year2013          49.00  32.48    0.88   0.025 *
s(sx,sy):Year2014          49.00  33.95    0.88  <2e-16 ***
s(sx,sy):Year2015          49.00  34.30    0.88   0.010 **
s(sx,sy):Year2016          49.00  33.83    0.88   0.005 **
s(sx,sy):Year2017          49.00  33.96    0.88   0.020 *
s(sx,sy):Year2018          49.00  33.12    0.88   0.025 *
s(sx,sy):Year2019          49.00  33.49    0.88   0.010 **
s(BOTTOM_DEPTH)             9.00   7.03    0.91   0.645
s(log(GEAR_TEMPERATURE + 3))   9.00   8.57    0.91   0.745
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Method: ML   Optimizer: outer newton
```

```
full convergence after 8 iterations.
Gradient range [-0.0002554647,0.0001669659]
(score 28608.91 & scale 1.995875).
Hessian positive definite, eigenvalue range [1.817765,5950.313].
Model rank =  1643 / 1643

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                               k'    edf k-index p-value
s(sx,sy)                   375.00 256.35    0.91   0.115
s(sx,sy):Year1995           49.00  21.22    0.91   0.145
s(sx,sy):Year1996           49.00  21.52    0.91   0.130
s(sx,sy):Year1997           49.00  22.01    0.91   0.160
s(sx,sy):Year1998           49.00  24.36    0.91   0.135
s(sx,sy):Year1999           49.00  21.51    0.91   0.115
s(sx,sy):Year2000           49.00  20.92    0.91   0.115
s(sx,sy):Year2001           49.00  21.24    0.91   0.155
s(sx,sy):Year2002           49.00  20.99    0.91   0.105
s(sx,sy):Year2003           49.00  21.19    0.91   0.160
s(sx,sy):Year2004           49.00  22.03    0.91   0.135
s(sx,sy):Year2005           49.00  22.15    0.91   0.140
s(sx,sy):Year2006           49.00  21.40    0.91   0.170
s(sx,sy):Year2007           49.00  20.98    0.91   0.175
s(sx,sy):Year2008           49.00  21.35    0.91   0.130
s(sx,sy):Year2009           49.00  20.09    0.91   0.130
s(sx,sy):Year2010           49.00  20.05    0.91   0.120
s(sx,sy):Year2011           49.00  20.05    0.91   0.135
s(sx,sy):Year2012           49.00  20.81    0.91   0.145
s(sx,sy):Year2013           49.00  20.55    0.91   0.100 .
s(sx,sy):Year2014           49.00  20.23    0.91   0.160
s(sx,sy):Year2015           49.00  20.39    0.91   0.165
s(sx,sy):Year2016           49.00  21.74    0.91   0.095 .
s(sx,sy):Year2017           49.00  22.83    0.91   0.165
s(sx,sy):Year2018           49.00  22.55    0.91   0.145
s(sx,sy):Year2019           49.00  22.97    0.91   0.150
s(BOTTOM_DEPTH)              9.00   4.54    0.92   0.325
s(log(GEAR_TEMPERATURE + 3))  9.00   5.85    0.93   0.695
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
$`arrowtooth flounder`
$`arrowtooth flounder`$mfrow
[1] 2 2


$`Pacific cod`
$`Pacific cod`$mfrow
[1] 2 2


$`walleye pollock`
$`walleye pollock`$mfrow
[1] 2 2


$`yellowfin sole`
$`yellowfin sole`$mfrow
[1] 2 2



> sink()
```

References

[1] Casper W. Berg. `surveyIndex`: R package for calculating survey indices by age from DATRAS exchange data. `https://github.com/casperwberg/surveyIndex`, 2014.

[2] Casper W Berg, Anders Nielsen, and Kasper Kristensen. Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. *Fisheries Research*, 151:91–99, 2014.