Survey Index Estimation and Simulation using EBS Survey Data.

Casper W. Berg

September 29, 2020

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(ii) =Year(i) + /1(sxi,syi) + /2(Yeari,sxi,syi) (1) + /3(depthi) + /4(log(temperaturei + 3)) (2)

where ii 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 (/1) and independent yearly deviations from that average (/2). The maximal basis dimension of /1 and /2 are set to 376 and 50 per year respectively, and the smoothing penalty and spline basis is the same for all years in /2. The last two splines (/3 and /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

1

Figure 1

2

Figure 2

3

Figure 3

4

Figure 4

5

Figure 5

6

Figure 6

7

2.2 Pacific cod

Figure 7

8

Figure 8

9

Figure 9

10

Figure 10

11

Figure 11

12

Figure 12

13

2.3 Walleye Pollock

Figure 13

14

Figure 14

15

Figure 15

16

Figure 16

17

Figure 17

18

Figure 18

19

2.4 Yellowfin Sole

Figure 19

20

Figure 20

21

Figure 21

22

Figure 22

23

Figure 23

24

Figure 24

25

Figure 25

26

3 Appendix

3.1 Retrospective analyses

Figure 26

3.2 Simulation and re-estimation

27

Figure 27

28

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 \*\*\*

29

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 \*\*\*

30

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

31

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 \*\*\*

32

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()

33

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

34

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

35

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()

36

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.

37