# Best Surplus Production Model - North Sea plaice

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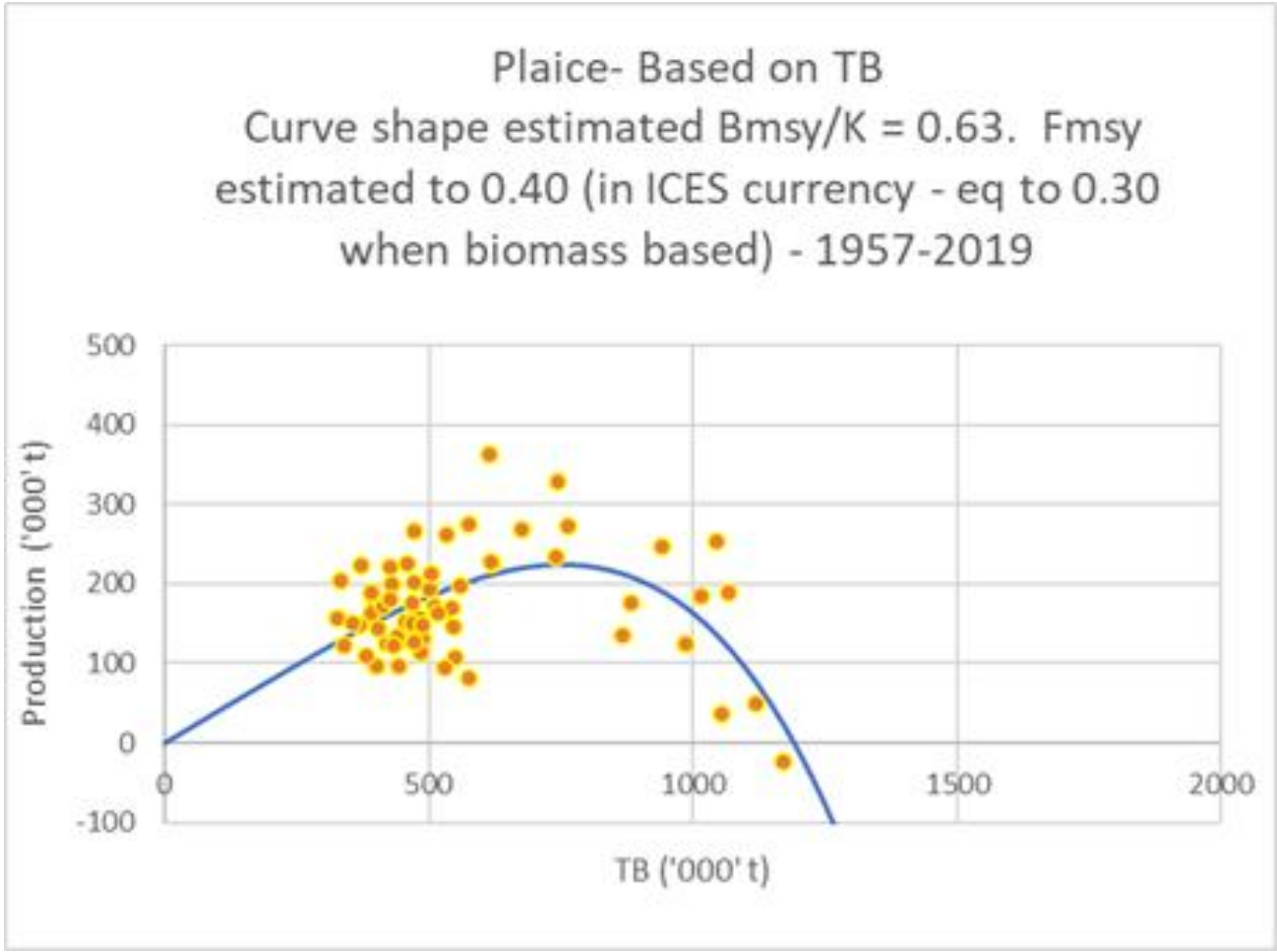
# Steps to establish the best SPM for a given stock – here North Sea plaice

Production (annual):

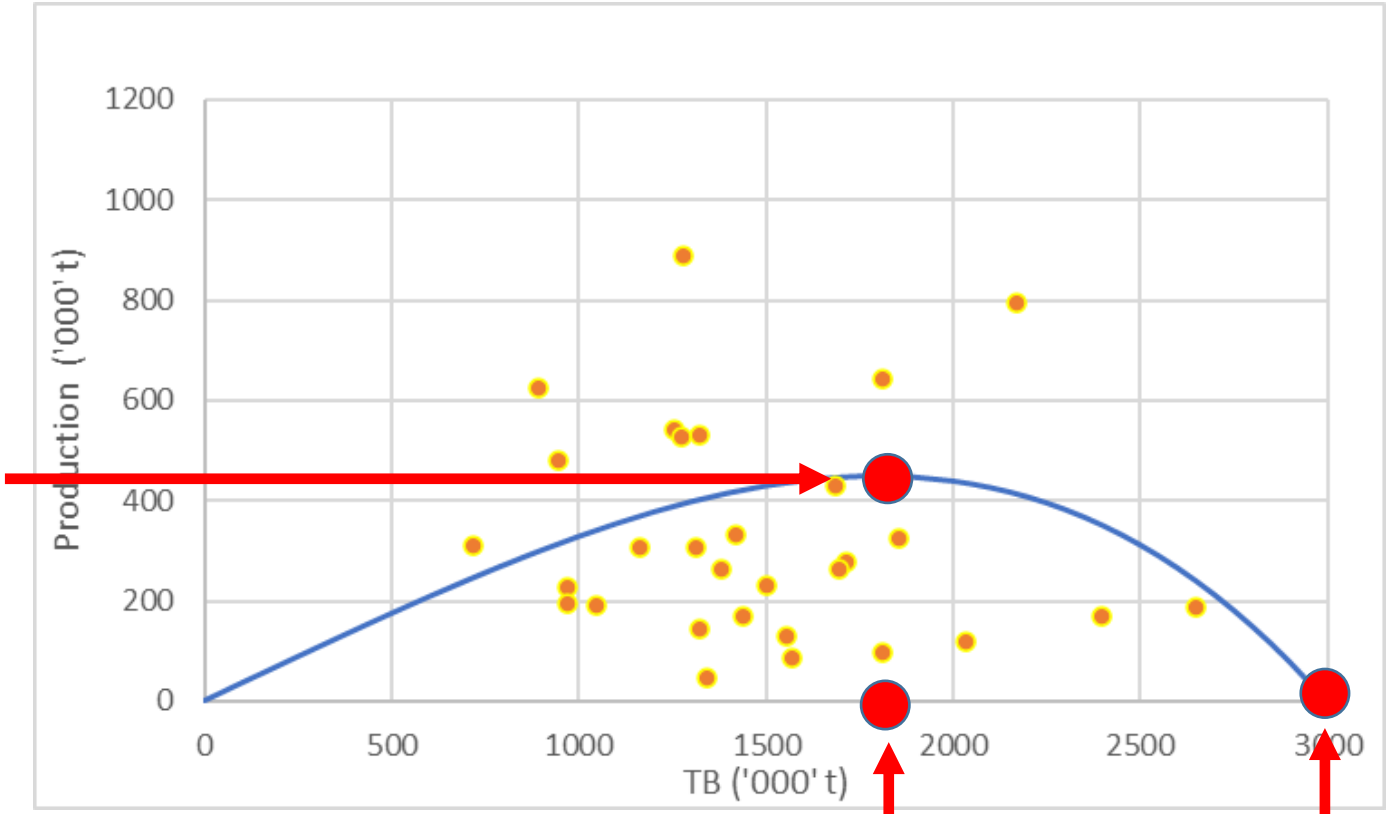
catch
+
increase in stock size

- equilibrium not needed!



# 3 parameters needed for Surplus Production Models

MSY




Bmsy

K – carrying capacity

# Cont…Steps to establish the best SPM …

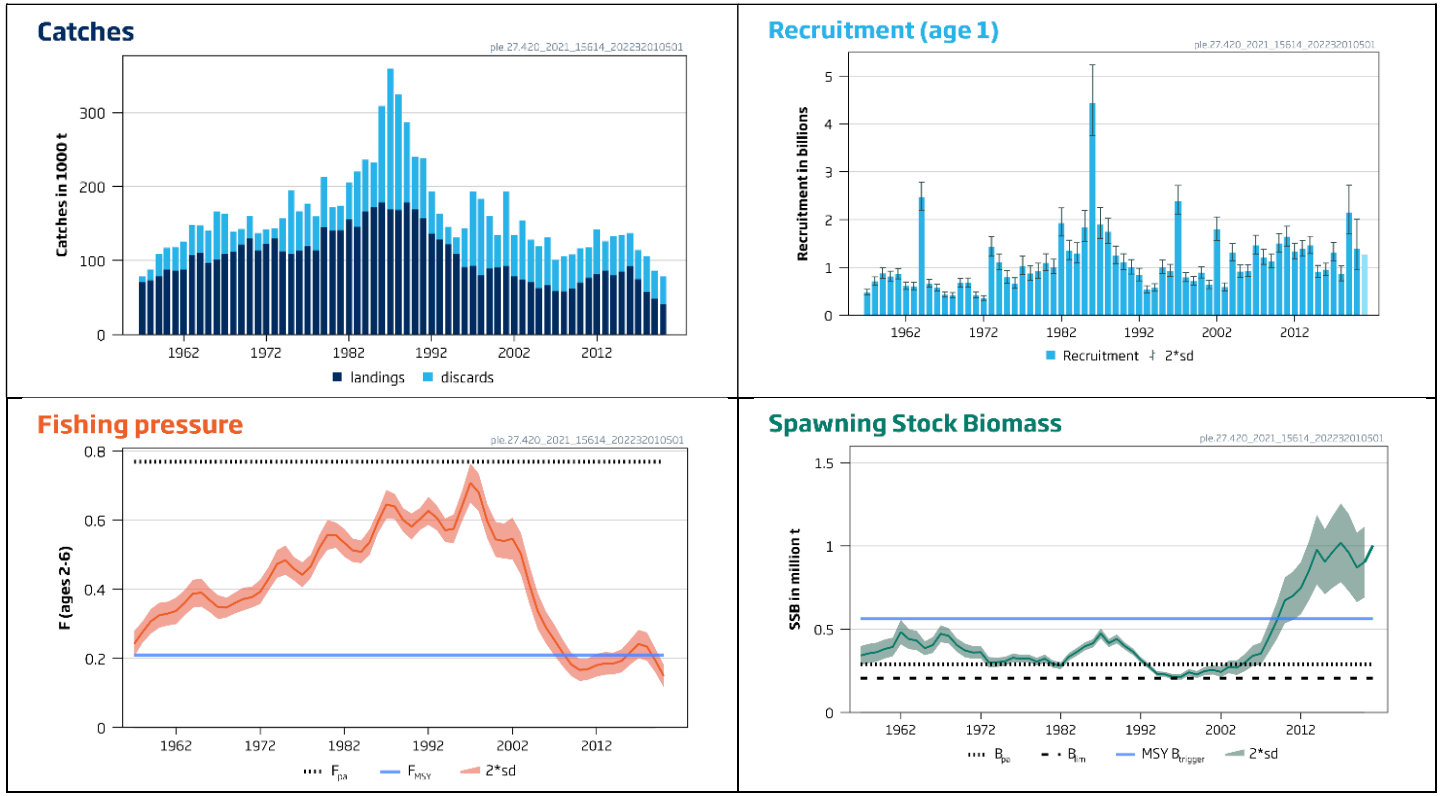
- Use stock biomass and catch from the ICES annual assessment.
- Often data are noisy and priors for the shape of the SPM-curve useful: Use a meta-analysis of 147 fish stocks from Thorson *et al*. (2012). Spawning biomass reference points for exploited marine fishes, incorporating taxonomic and body size information. Canadian Journal of Fisheries and Aquatic Sciences, 69: 1556–1568.
- Sometimes also the height of the SPM-curve is a problem: Use a meta-analysis by Sparholt *et al*. (2020). Estimating Fmsy from an ensemble of data sources to account for density-dependence in Northeast Atlantic fish stocks. ICES Journal of Marine Science. ICES Journal of Marine Science, doi:10.1093/icesjms/fsaa175.
- Compare to available scientific knowledge. **A big literature review**.

# Compare to available scientific knowledge…

## Historic assessment

It seems that SSB has stabilized in recent years with an F = 0.20 – but the catch is lower than previously, so Fmsy is likely larger than 0.2.

It also seems that Fmsy is lower than 0.6 because that led to lower catches.




A nice "experiment":
The slow increase in F until 2000 means that the stocks was close to equilibrium in all years. The fact that catch increased when F increased to around 0.5 and started to decline at 0.6 indicates that Fmsy is 0.4-0.5

K > 0.9 million t

Interesting with a could-water species booming in spite of climate changes!

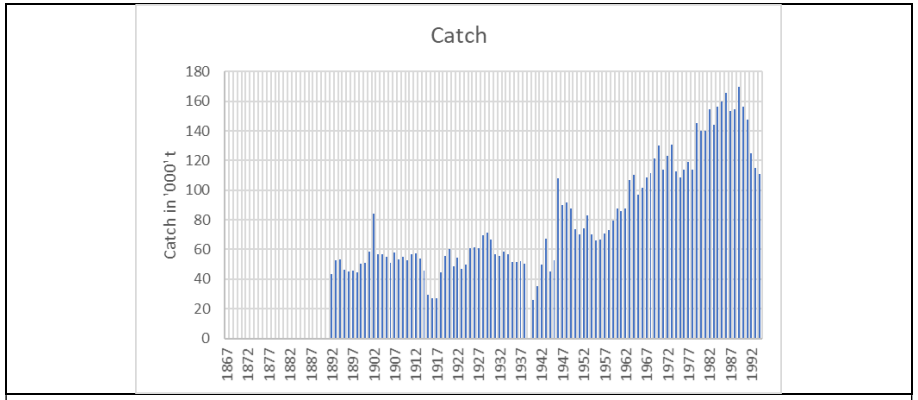
# ...available scientific knowledge

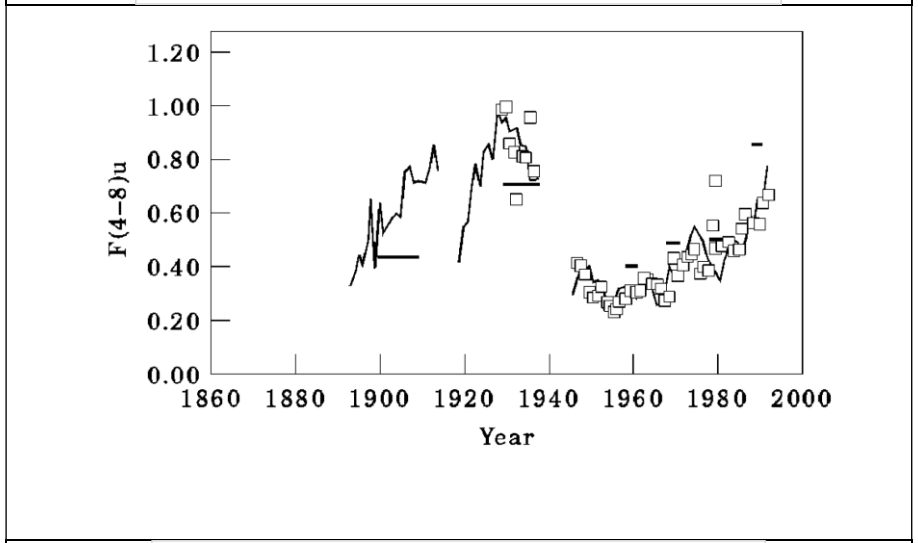
## Older information

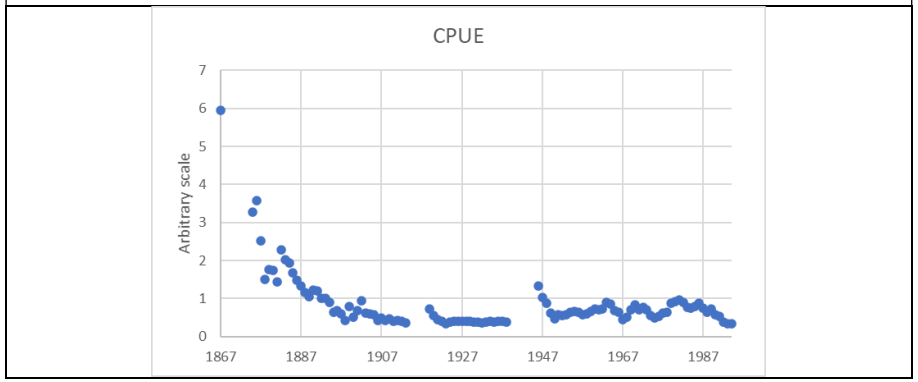
Back to late-1800s

The stock has sustained a high F in old time.

Can that gives us clues to what K is?



# ...available scientific knowledge

## ...Older information

SSB very high in 1867 – probably overestimated because the reduction the following years was larger than the accumulated catch – the 1867 year based on only one data point

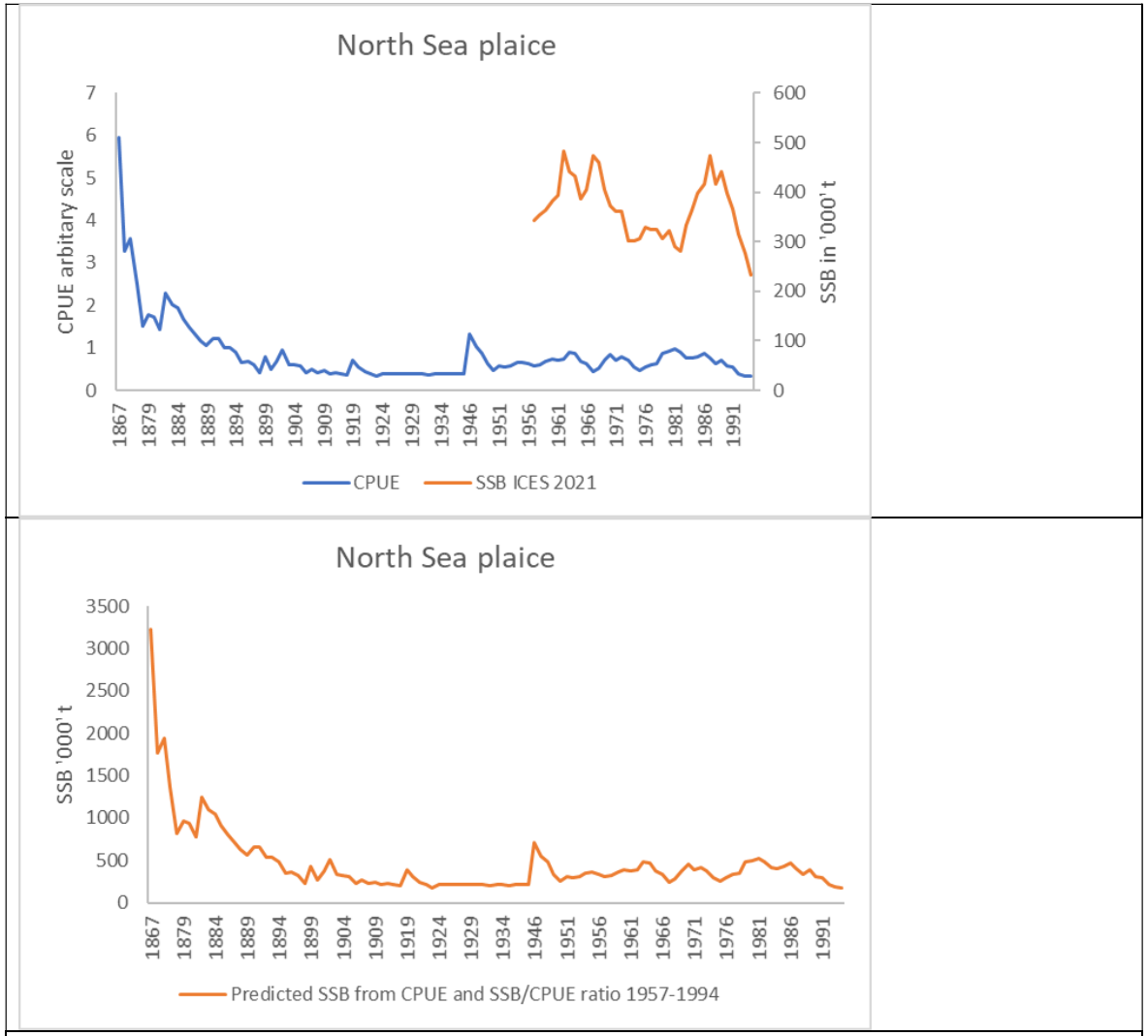



**Figure 3**. *North Sea plaice. CPUE from Rijnsdorp and Millner 1996 and SSB from ICES 2021 combined to give estimates of SSB b y year based on CPUE data back in time.*

# ...available scientific knowledge

Discards important and have  a time trend which needs to be taken account of when creating the SPM

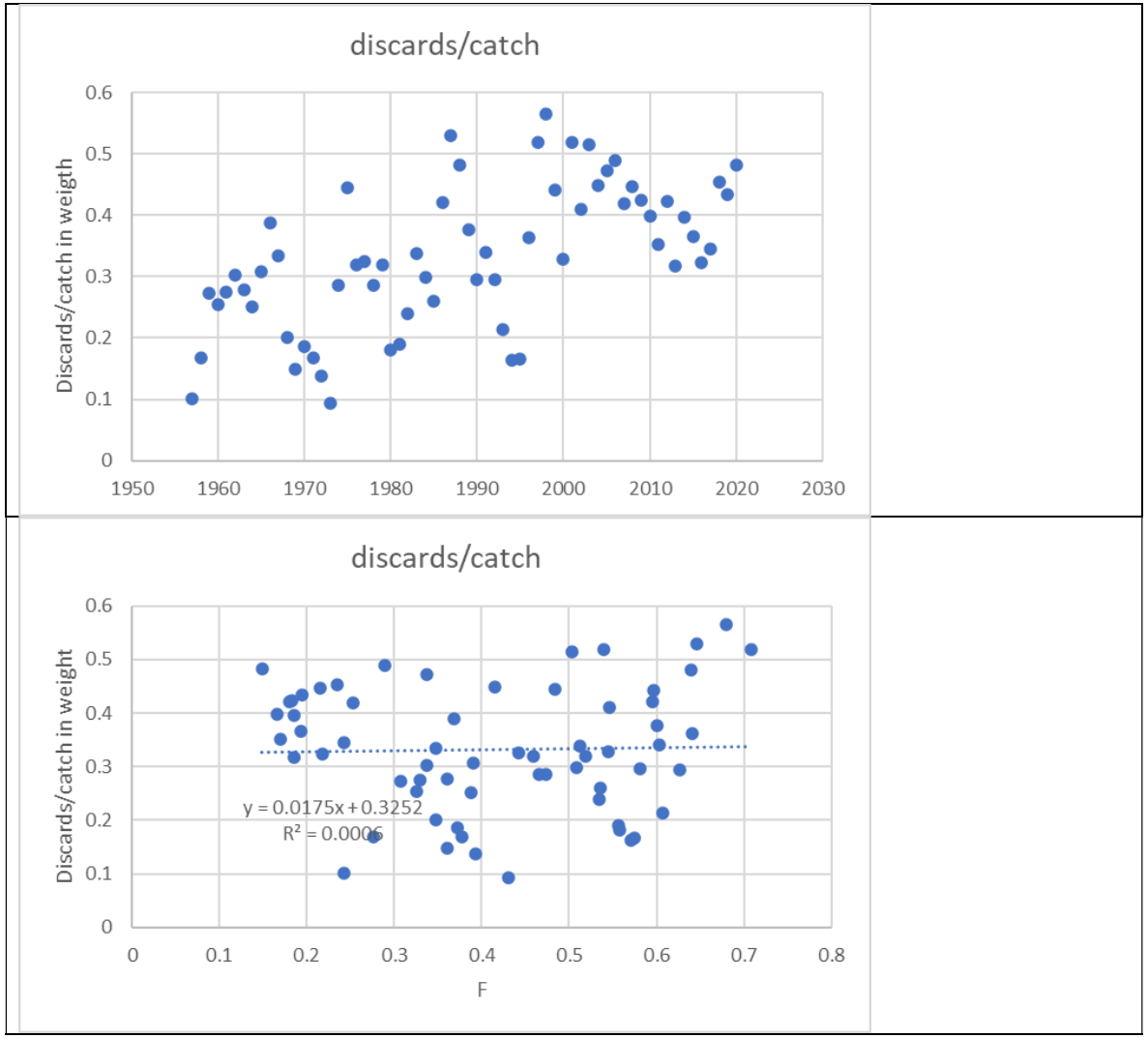



**Figure 3**. *North Sea plaice. Discards as ratio to total catch by weight vs year (top panel) and vs F (bottom panel).*

# …available scientific knowledge

Presently used age-structured models can give upper limits to K

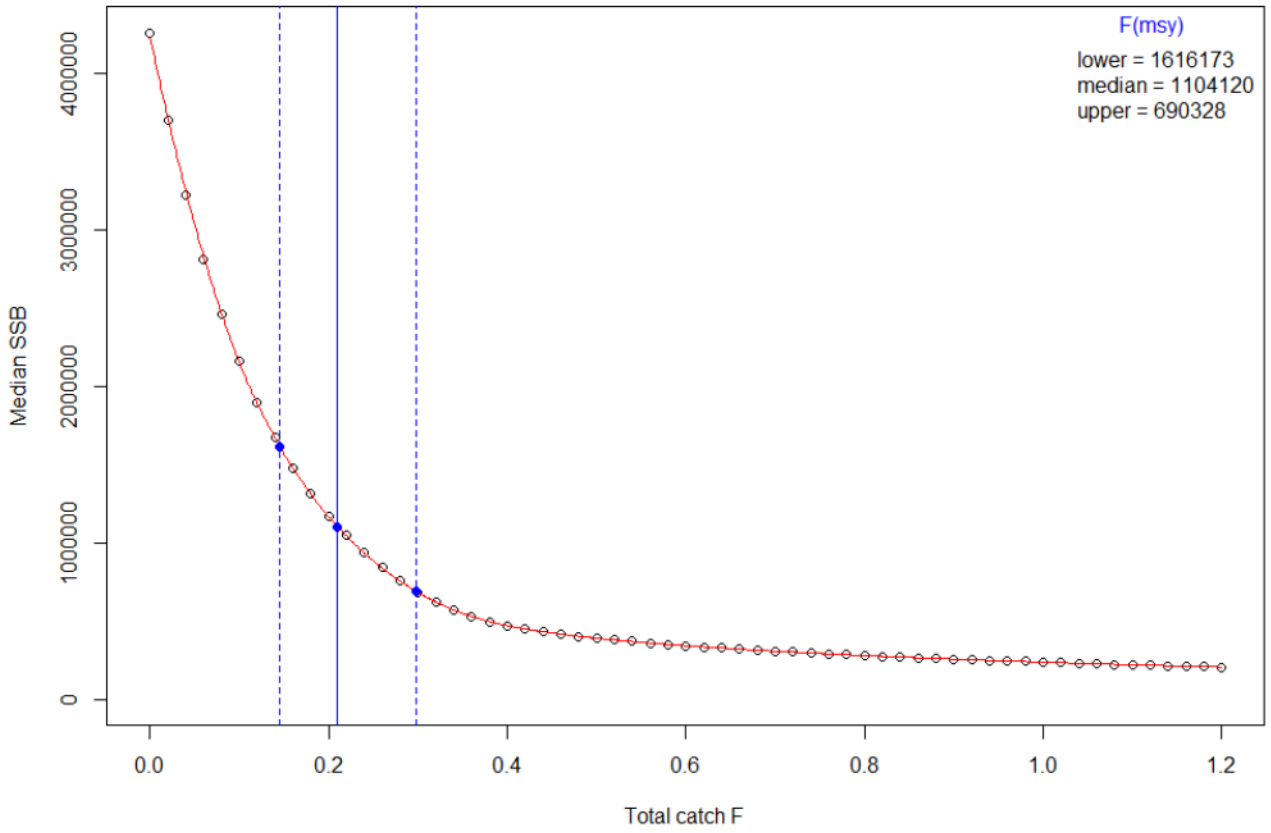



**Figure 4**. *North Sea plaice. Long-term forecast (EQSIM) equilibrium SSB vs F assuming that F is reduced linearly to zero when SSB gets lower than Btrigger (564599 t). ICES 2017.*

# This gives us an indication of the three parameters

- K (or $SSB_0$) should be substantially lower than 3 million t, but higher than 1 million t.
- F should be higher than 0.2 and lower than 0.6 (in the ICES F currency) probably around 0.4-0.5.
- MSY probably 200-250 kt incl. discards

# ...available scientific knowledge

Relationship between F in the SPM biomass based “world” and traditional age based F

- So a transition formula needed.

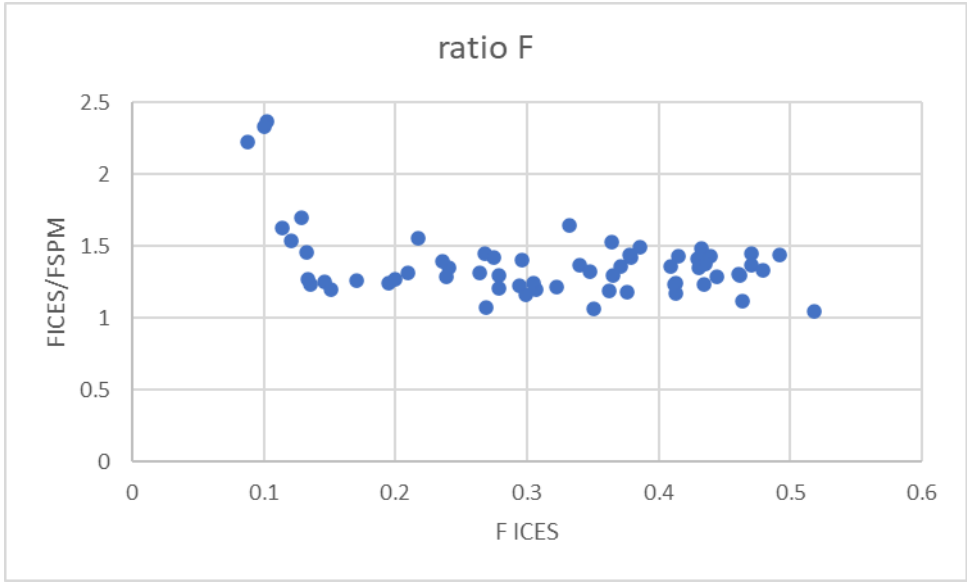



**Figure 6**. *North Sea plaice*. *The ration of F-ICES/F-SPM vs. F-ICES. Based on ICES (2021).*

# …available scientific knowledge

## Regime shifts?

Stock-recruitment – indicate regime shift in early-1970s

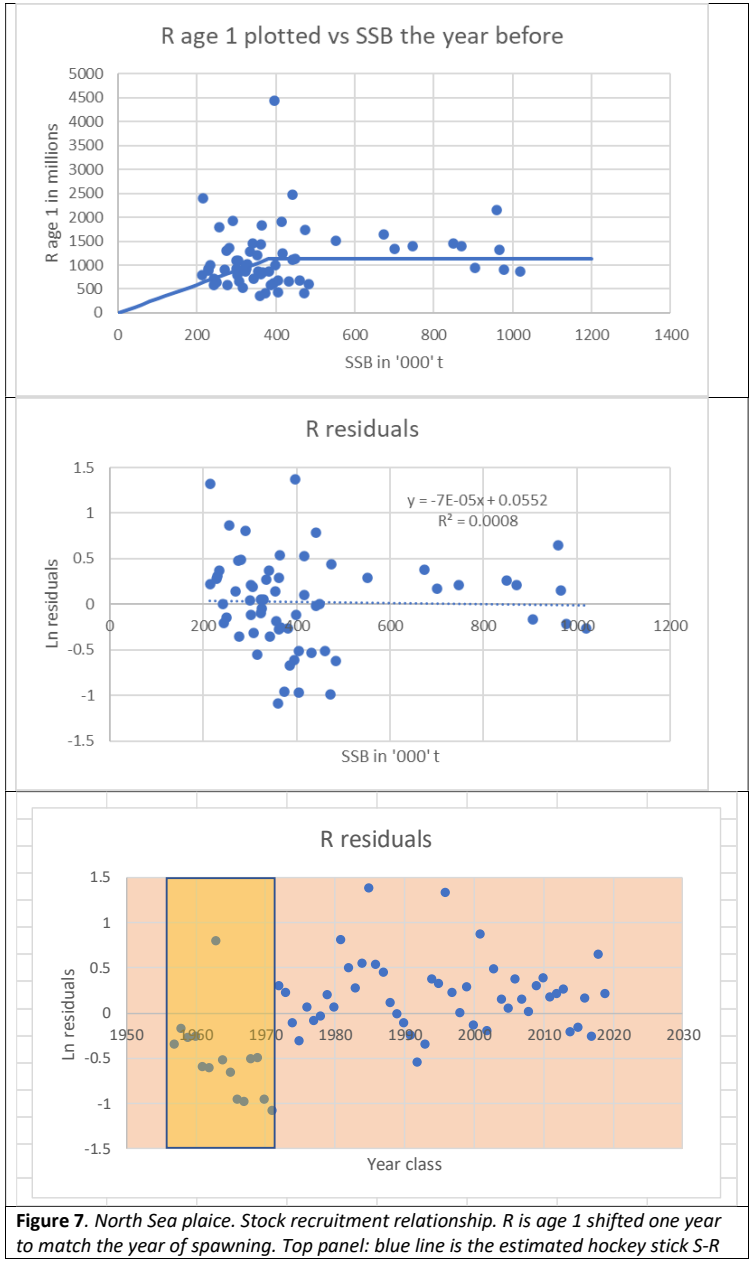



**Figure 7**. *North Sea plaice. Stock recruitment relationship. R is age 1 shifted one year to match the year of spawning. Top panel: blue line is the estimated hockey stick S-R*

# …available scientific knowledge

Big time trend in potential predators on plaice egg and larvae – but apparently no effect on this stock, judged from the S-R analysis

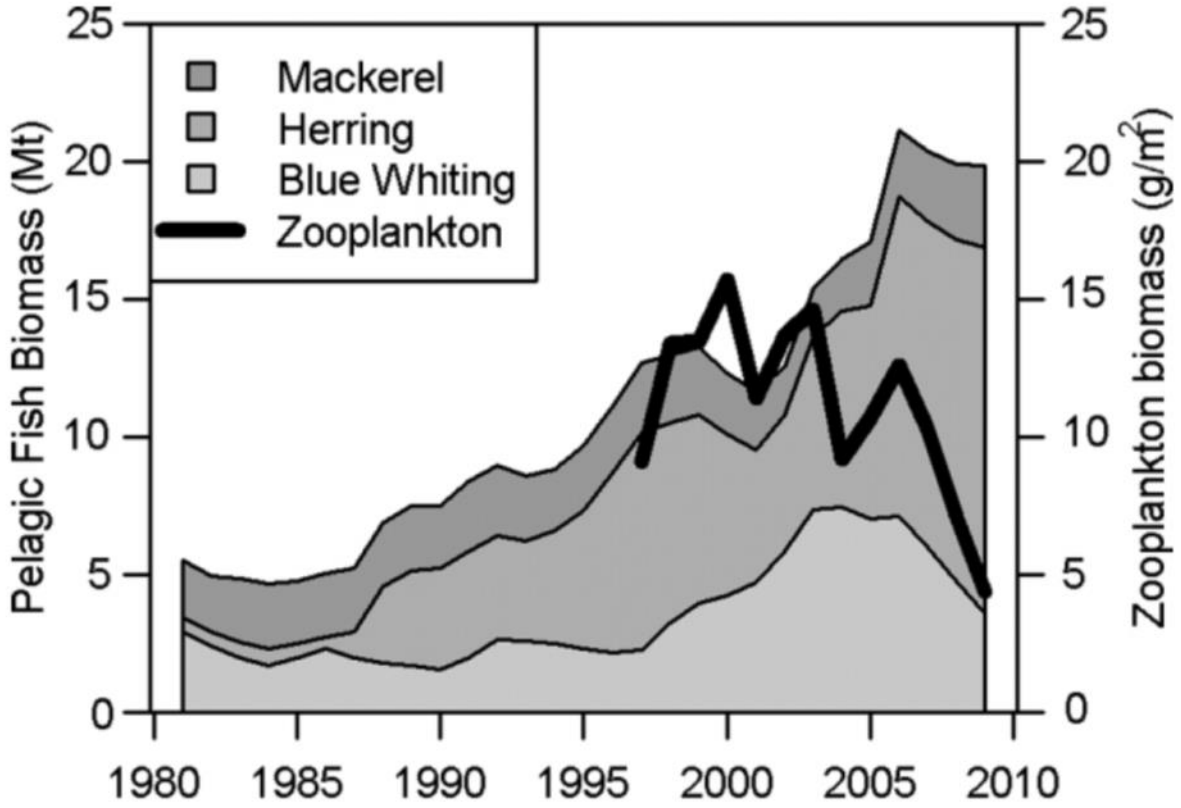


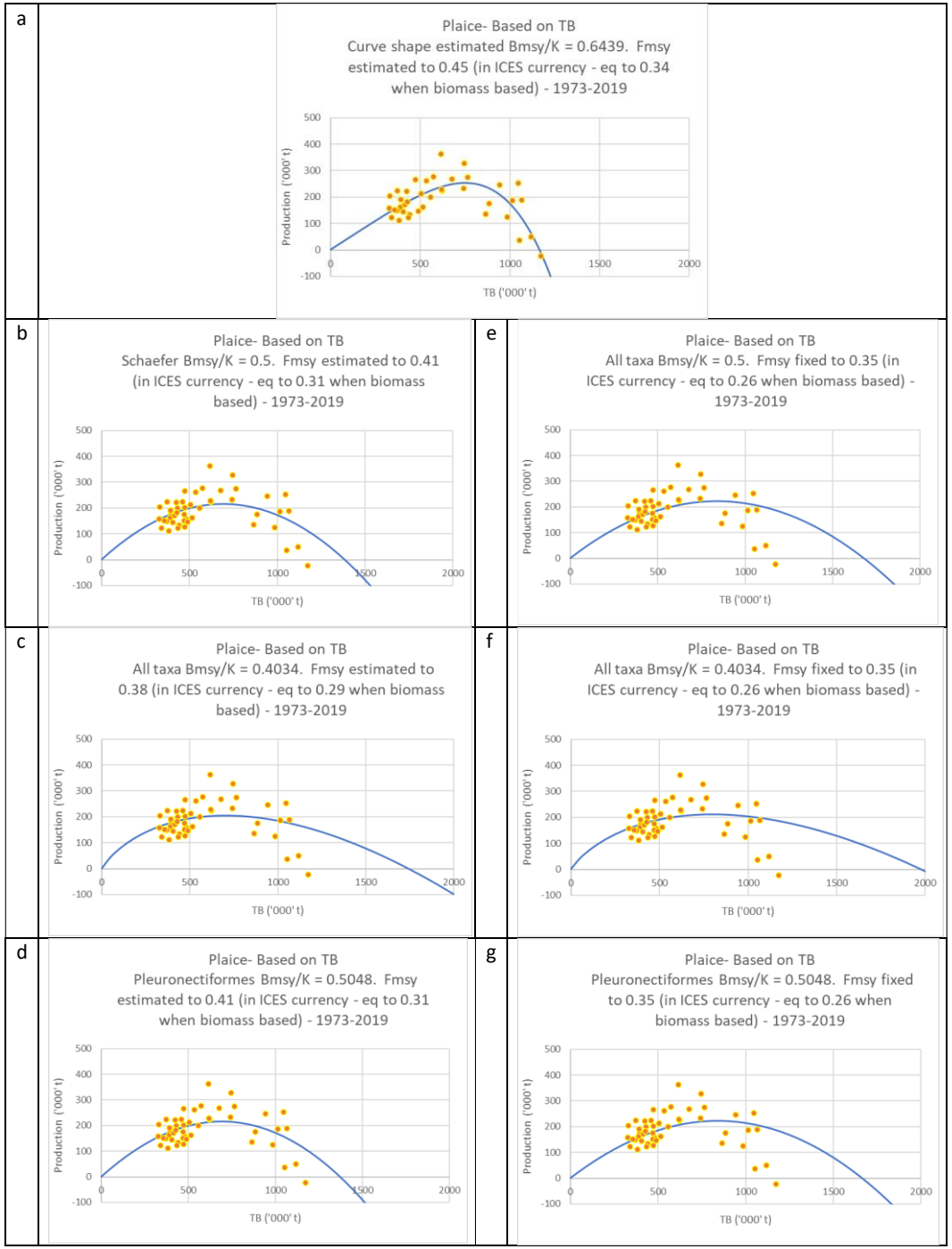

**Figure 8**. *Fluctuations in total biomass of pelagic fish and zooplankton in the Norwegian Sea. Spawning stock biomass of mackerel (dark grey area), Norwegian spring-spawning herring (grey area) and blue whiting (light-grey area) from analytical stock assessment (ICES 2010a). Average zooplankton density (g dry weight m2; heavy black line) from the international ecosystem survey in the Nordic Seas (ICES 2010b). From Payne et al. (2012).*

# …available scientific knowledge

Density dependent growth highly significant.
Thus, important to take this into account.

# Next step is to fit an SPM model to the data.

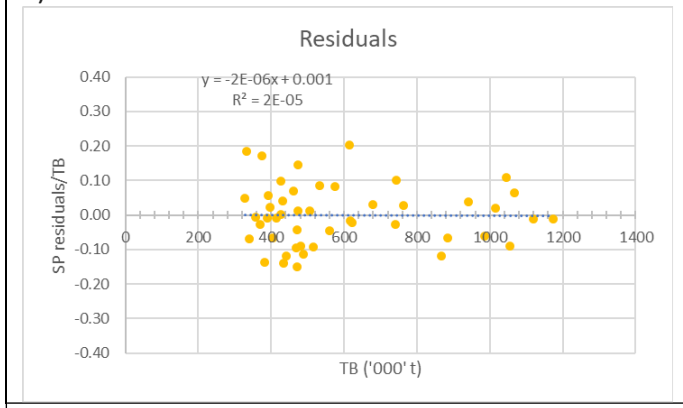
- Alternative models tested
- Judge model fits by:
  - AICc
  - Residual pattern
  - Consistency to available science



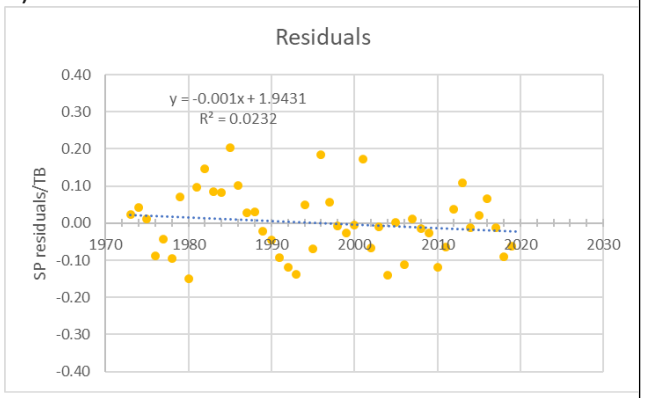
| SPM model | Number of para-meters estima-ted | Bmsy/K (curve shape parameter) | $R^2$ | AICc | SSBmsy '000' t | MSY in '000' t | K (Carrying capacity) '000' t | MSY/ TBmsy |
|---|---|---|---|---|---|---|---|---|
| #0 Fmsy estimated Curve estimated | 3 | 0.643 | 0.80 | 16.9 | 542 | 253 | 1166 | 0.34 |
| #1 Fmsy estimated – Schaefer | 2 | 0.500 | 0.78 | 15.3 | 511 | 216 | 1385 | 0.31 |
| #2 Fmsy estimated - Thorson *et al.* (2012) "all taxa" | 2 | 0.404 | 0.75 | 16.4 | 528 | 205 | 1744 | 0.29 |
| #3 Fmsy estimated - Thorson *et al.* (2012) "Pleuronectiformes" | 2 | 0.505 | 0.78 | 15.3 | 511 | 216 | 1373 | 0.31 |
| #4 Fmsy fixed –Schaefer | 1 | 0.500 | 0.74 | 14.6 | 643 | 222 | 1680 | 0.26 |
| #5 Fmsy fixed - Thorson *et al.* (2012) "all taxa" | 1 | 0.404 | 0.75 | 14.0 | 611 | 211 | 1977 | 0.26 |
| #6 Fmsy fixed –Thorson *et al.* (2012) "Pleuronectiformes" | 1 | 0.505 | 0.74 | 14.7 | 644 | 222 | 1665 | 0.26 |

# Model #0 has better residuals - maybe a little time trend – could it be climate?

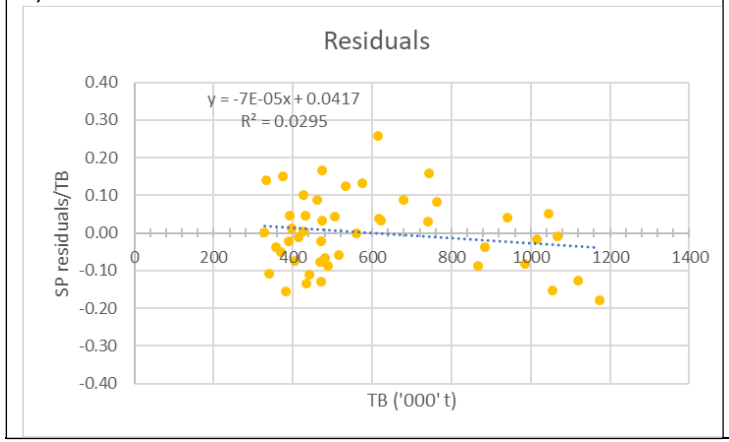
a) Model #0



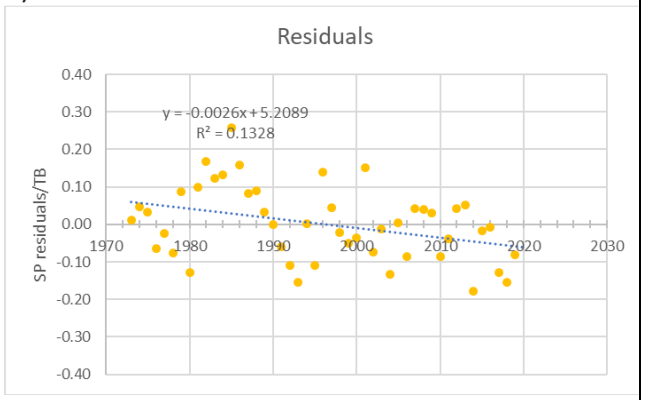

b) Model #0




c) Modfel #5

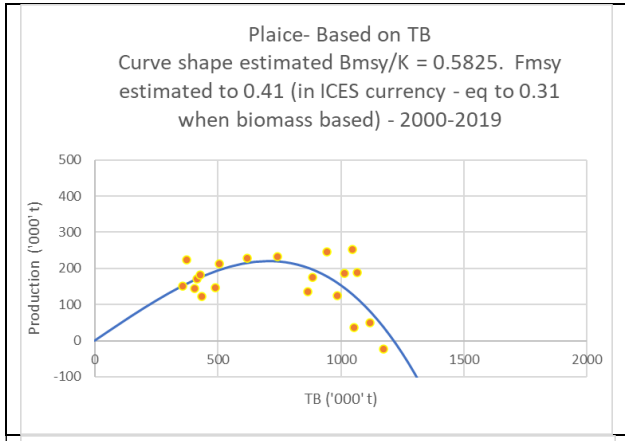


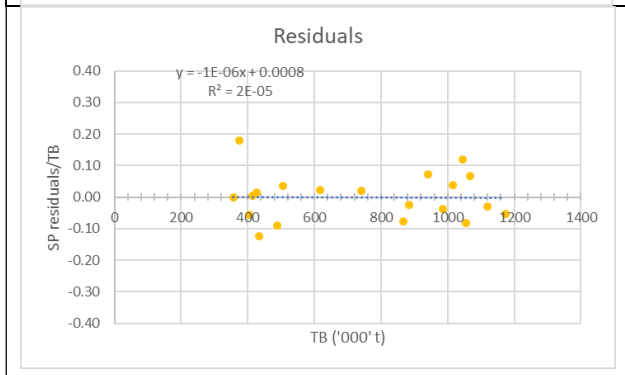

d) Model #5

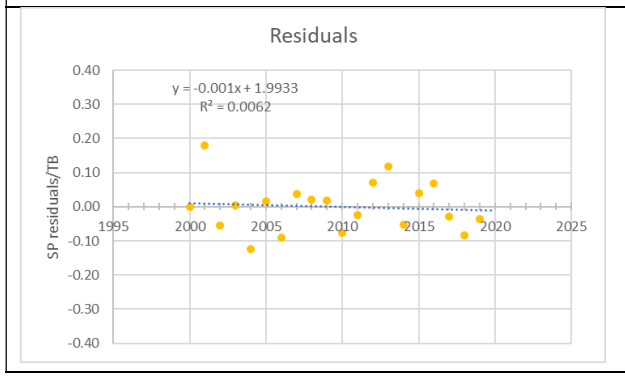


Reduced time window to after 2000 to make it more up-to-date and less trend dependent

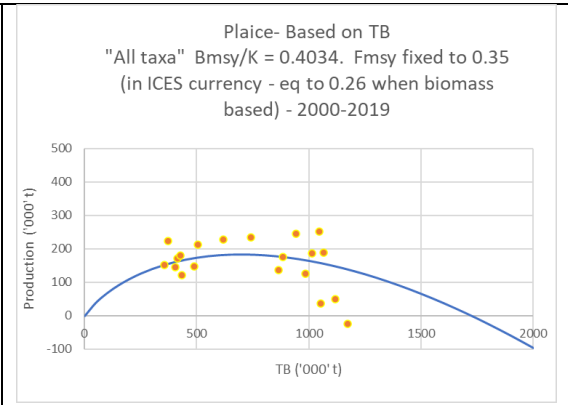
Model 0#

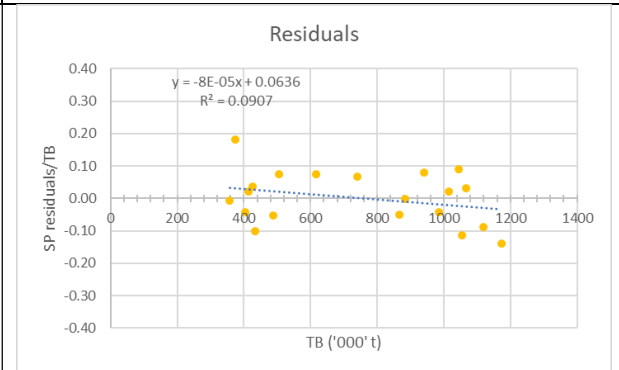


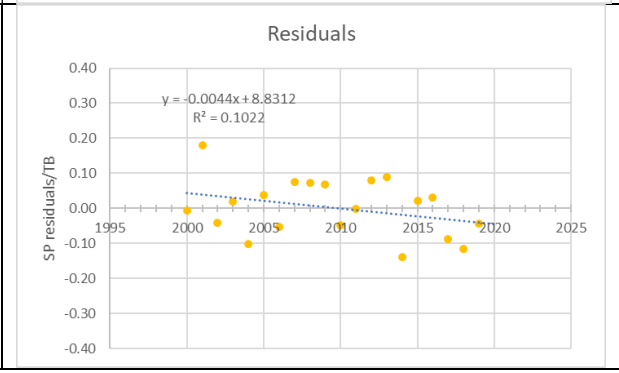




Model 5#



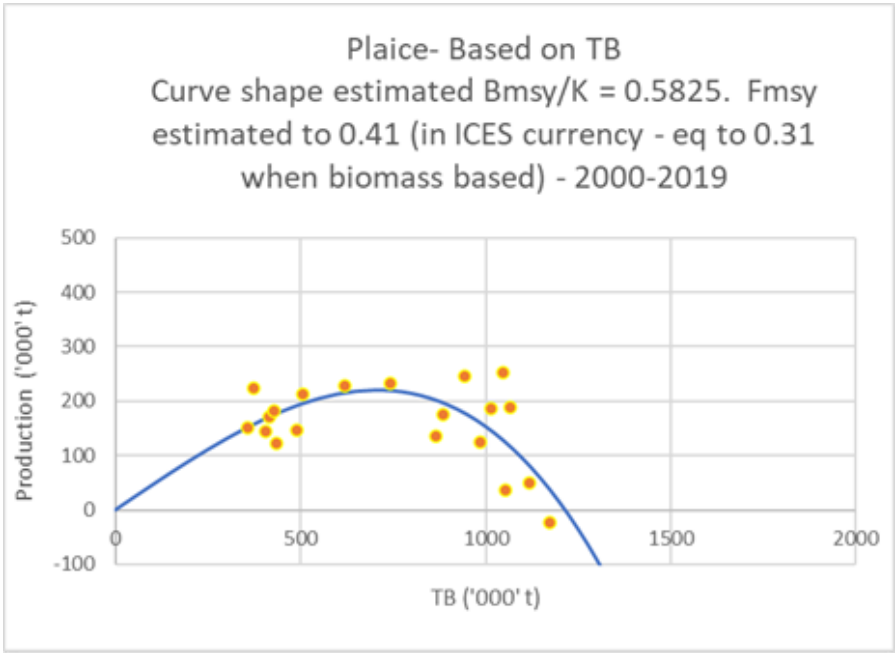



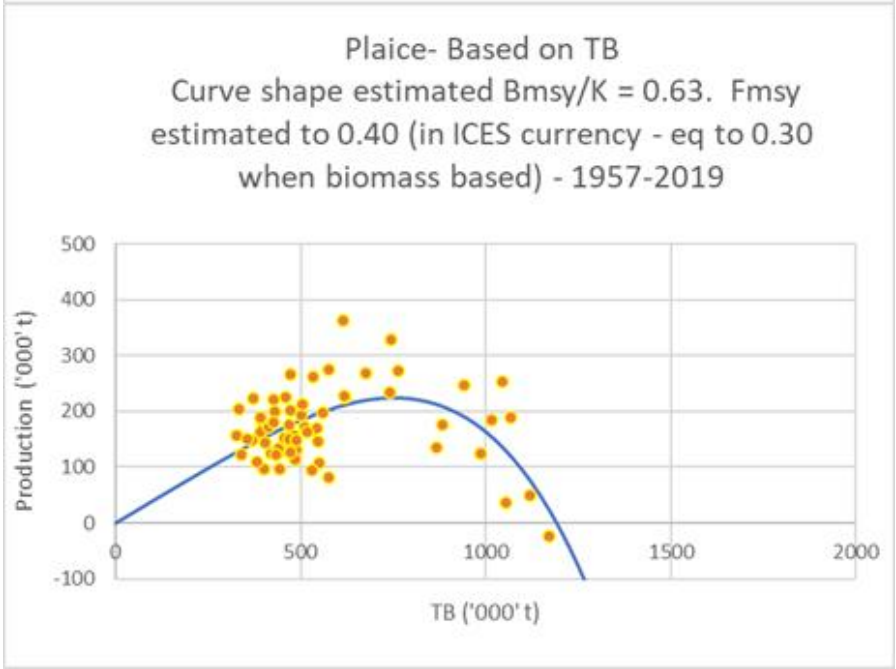



| SPM model | Number of para-meters estima-ted | Bmsy/K (curve shape paramet er) | $R^2$ | AICc | SSBmsy '000' t | MSY in '000' t | K (Carryin g capacity ) '000' t | MSY/ TBmsy |
|---|---|---|---|---|---|---|---|---|
| #0<br>K, curve and Fmsy estimated – 2000-2019 | 3 | 0.5825 | 0.81 | 12.8 | 522 | 220 | 1215 | 0.31 |
| #5 "All taxa", fixed Fmsy -2000-2019 | 1 | 0.40 | 0.77 | 5.4 | 534 | 184 | 1727 | 0.26 |

- The best SPM for the North Sea plaice stock to be used in MSEs for 2020-2030 is one based on the data series from 2000-2019 (a period where the productivity was stable), with K of 1215 kt, $F_{MSY}$ 0.31 (0.41 in the ICES F-currency) and $B_{MSY}/K$ of 0.58.
- An alternative SPM Model with an “All taxa” shape from Thorson *et al.* (2012) and $F_{MSY}$ from Sparholt *et al.* (2020) was almost as good and might be tested in a sensitivity analysis. For this model, K is 1727 kt, $F_{MSY}$ 0.26 (0.35 in the ICES F-currency), and $B_{MSY}/K$ 0.40.

- The Key-run is quite similar to the run based on the full time series.



# How does this compare to present reference points – biomass is in '000't

| | Fmsy (ICES F-currency) | Bmsy (SSB) | Btrigger (SSB) | K carrying capacity (SSB) |
|---|---|---|---|---|
| Present | 0.152 | - | 474 | - |
| SPM Keyrun | 0.41 | 522 | | 806 |
| SPM alternative run | 0.35 | 579 | | 919 |

# Robustness

## Plaice - North Sea….very robust to adding a new data year.

| SPM model | Number of para-meters estima-ted | Bmsy/K (curve shape parameter) | $R^2$ | AICc | SSBmsy '000' t | MSY in '000' t | K (Carrying capacity) '000' t | MSY/TBmsy (Fmsy) |
|---|---|---|---|---|---|---|---|---|
| 2000-2015 | 3 | 0.5762 | 0.81 | 14.3 | 534 | 222 | 1253 | 0.31 |
| 2000-2016 | 3 | 0.5650 | 0.81 | 13.8 | 540 | 221 | 1288 | 0.30 |
| 2000-2017 | 3 | 0.5904 | 0.81 | 13.3 | 539 | 226 | 1235 | 0.31 |
| 2000-2018 | 3 | 0.5910 | 0.81 | 13.2 | 529 | 224 | 1214 | 0.31 |
| 2000-2019 | 3 | 0.5825 | 0.81 | 12.8 | 522 | 220 | 1215 | 0.31 |

# MSE with the SPM Keyrun as Operating Model – pretty straight forward

To read later if you need the details. When you have the SPM model it is a straight forward MSE

The simulations are done as described below:

- 1) start with the observed TB (2022).
- 2) The real TB is obtained taking observation error into account (log normally distributed obtained from historic assessment).
- 3) Then the production, S, is obtained considering process error (assumed normally distributed and CV linearly related to TB).
- 4) The real SSB is obtained by a linear link to TB influenced by F (regression obtained from the historic assessment).
- 5) Then the observed SSB is obtained taking account of observation error.
- 6) Then intended F is obtained taking account of the HCR (linearly reduced when SSB < MSYBtrigger).
- 7) The TAC is then obtained.
- 8) The realised yield obtained taking implementation error into account.
- 9) The real TB for the following year is then obtained from the real TB the current year + real SP – realised yield.
- 10) The observed TB the following year is obtained from the real TB and observation error.

…repeat the sequence from stage 3) above for each year into the future in the simulations.

# MSE with the SPM Keyrun as Operating Model – results

Yield

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 129 | 145 | 168 | 174 | 177 | 177 | 203 | 208 | 212 |
| 0.48 | 136 | 158 | 167 | 177 | 194 | 194 | 210 | 210 | 216 |
| 0.46 | 138 | 157 | 175 | 194 | 197 | 197 | 212 | 209 | 219 |
| 0.44 | 148 | 169 | 181 | 187 | 189 | 189 | 210 | 210 | 219 |
| 0.42 | 166 | 172 | 186 | 192 | 202 | 202 | 209 | 211 | 215 |
| 0.40 | 175 | 186 | 192 | 194 | 204 | 204 | 209 | 214 | 209 |
| 0.38 | 191 | 196 | 197 | 200 | 212 | 212 | 216 | 213 | 213 |
| 0.36 | 200 | 197 | 195 | 208 | 212 | 212 | 215 | 215 | 213 |
| 0.34 | 201 | 213 | 207 | 213 | 214 | 214 | 219 | 212 | 217 |
| 0.32 | 219 | 213 | 220 | 214 | 213 | 213 | 208 | 215 | 210 |
| 0.30 | 215 | 213 | 213 | 215 | 215 | 215 | 213 | 212 | 215 |
| 0.28 | 214 | 215 | 214 | 213 | 217 | 217 | 212 | 212 | 205 |
| 0.26 | 213 | 208 | 208 | 209 | 213 | 213 | 211 | 205 | 204 |
| 0.24 | 199 | 202 | 199 | 201 | 202 | 202 | 208 | 201 | 200 |
| 0.22 | 193 | 197 | 191 | 195 | 191 | 191 | 193 | 190 | 190 |
| 0.20 | 182 | 182 | 180 | 183 | 185 | 185 | 182 | 185 | 179 |
| 0.18 | 167 | 169 | 173 | 168 | 173 | 173 | 170 | 169 | 171 |
| 0.16 | 157 | 156 | 157 | 161 | 156 | 156 | 157 | 158 | 156 |
| 0.14 | 140 | 141 | 142 | 141 | 142 | 142 | 142 | 142 | 141 |
| 0.12 | 127 | 125 | 126 | 125 | 126 | 126 | 125 | 123 | 127 |
| 0.10 | 108 | 108 | 106 | 107 | 108 | 108 | 108 | 105 | 108 |
| | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 |

Btrigger in '000' t

5% lower SSB

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 153 | 171 | 198 | 211 | 244 | 255 | 272 | 288 | 303 |
| 0.48 | 158 | 193 | 205 | 233 | 256 | 277 | 307 | 313 | 341 |
| 0.46 | 170 | 198 | 231 | 253 | 274 | 283 | 308 | 298 | 342 |
| 0.44 | 186 | 213 | 237 | 247 | 269 | 291 | 317 | 340 | 340 |
| 0.42 | 214 | 229 | 246 | 267 | 302 | 311 | 331 | 321 | 367 |
| 0.40 | 217 | 260 | 271 | 279 | 294 | 332 | 340 | 369 | 378 |
| 0.38 | 279 | 283 | 286 | 302 | 341 | 340 | 346 | 367 | 376 |
| 0.36 | 301 | 304 | 314 | 338 | 344 | 366 | 365 | 382 | 412 |
| 0.34 | 323 | 356 | 358 | 364 | 369 | 388 | 395 | 402 | 427 |
| 0.32 | 407 | 396 | 408 | 387 | 398 | 394 | 401 | 431 | 445 |
| 0.30 | 437 | 436 | 425 | 439 | 418 | 429 | 439 | 456 | 476 |
| 0.28 | 462 | 477 | 461 | 453 | 474 | 471 | 475 | 476 | 474 |
| 0.26 | 507 | 499 | 481 | 502 | 503 | 493 | 504 | 516 | 516 |
| 0.24 | 540 | 523 | 532 | 531 | 544 | 542 | 551 | 536 | 546 |
| 0.22 | 547 | 570 | 546 | 557 | 534 | 542 | 547 | 537 | 549 |
| 0.20 | 595 | 598 | 571 | 595 | 608 | 599 | 591 | 580 | 586 |
| 0.18 | 601 | 609 | 632 | 599 | 644 | 615 | 632 | 610 | 632 |
| 0.16 | 650 | 644 | 655 | 693 | 667 | 648 | 643 | 640 | 642 |
| 0.14 | 682 | 684 | 661 | 688 | 680 | 686 | 702 | 698 | 671 |
| 0.12 | 713 | 729 | 716 | 724 | 722 | 723 | 684 | 695 | 734 |
| 0.10 | 756 | 745 | 716 | 723 | 747 | 725 | 764 | 734 | 761 |
| | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 |

Btrigger in '000' t

IAV

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 49 | 46 | 48 | 53 | 52 | 55 | 61 | 53 | 50 |
| 0.48 | 44 | 46 | 52 | 48 | 50 | 55 | 47 | 51 | 48 |
| 0.46 | 44 | 44 | 47 | 45 | 47 | 49 | 49 | 62 | 55 |
| 0.44 | 31 | 37 | 39 | 46 | 50 | 50 | 50 | 52 | 55 |
| 0.42 | 30 | 32 | 40 | 44 | 45 | 50 | 45 | 57 | 51 |
| 0.40 | 27 | 28 | 32 | 41 | 41 | 44 | 49 | 46 | 49 |
| 0.38 | 23 | 26 | 29 | 34 | 36 | 38 | 46 | 48 | 48 |
| 0.36 | 24 | 22 | 26 | 25 | 34 | 37 | 42 | 46 | 45 |
| 0.34 | 25 | 23 | 23 | 24 | 31 | 31 | 37 | 42 | 39 |
| 0.32 | 22 | 21 | 22 | 24 | 23 | 31 | 36 | 38 | 39 |
| 0.30 | 23 | 24 | 23 | 22 | 23 | 29 | 30 | 34 | 33 |
| 0.28 | 22 | 21 | 23 | 25 | 22 | 25 | 25 | 30 | 34 |
| 0.26 | 23 | 21 | 22 | 23 | 23 | 24 | 28 | 31 | 31 |
| 0.24 | 22 | 22 | 20 | 21 | 21 | 19 | 22 | 28 | 28 |
| 0.22 | 21 | 19 | 22 | 22 | 22 | 21 | 22 | 27 | 27 |
| 0.20 | 21 | 22 | 24 | 22 | 20 | 23 | 22 | 22 | 25 |
| 0.18 | 23 | 23 | 19 | 24 | 21 | 22 | 20 | 20 | 24 |
| 0.16 | 24 | 21 | 19 | 20 | 21 | 23 | 22 | 24 | 26 |
| 0.14 | 21 | 20 | 20 | 20 | 21 | 22 | 19 | 21 | 22 |
| 0.12 | 22 | 21 | 19 | 19 | 19 | 21 | 24 | 19 | 21 |
| 0.10 | 20 | 20 | 22 | 22 | 19 | 20 | 20 | 22 | 19 |
| | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 |

Btrigger in '000' t

SSB

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 207 | 242 | 287 | 307 | 323 | 364 | 387 | 408 | 434 |
| 0.48 | 225 | 266 | 295 | 322 | 356 | 375 | 404 | 424 | 453 |
| 0.46 | 235 | 272 | 311 | 355 | 372 | 392 | 422 | 427 | 468 |
| 0.44 | 257 | 292 | 330 | 351 | 369 | 413 | 438 | 456 | 477 |
| 0.42 | 293 | 308 | 350 | 367 | 404 | 427 | 442 | 453 | 486 |
| 0.40 | 327 | 353 | 370 | 381 | 419 | 441 | 457 | 490 | 501 |
| 0.38 | 383 | 392 | 393 | 413 | 442 | 470 | 483 | 500 | 527 |
| 0.36 | 418 | 414 | 413 | 452 | 465 | 492 | 500 | 525 | 544 |
| 0.34 | 446 | 488 | 470 | 484 | 508 | 514 | 537 | 537 | 566 |
| 0.32 | 535 | 525 | 534 | 522 | 526 | 547 | 542 | 575 | 580 |
| 0.30 | 562 | 568 | 561 | 573 | 563 | 580 | 584 | 589 | 614 |
| 0.28 | 609 | 605 | 606 | 617 | 616 | 598 | 620 | 635 | 633 |
| 0.26 | 665 | 639 | 635 | 651 | 657 | 648 | 658 | 660 | 670 |
| 0.24 | 681 | 694 | 685 | 693 | 686 | 682 | 701 | 679 | 693 |
| 0.22 | 728 | 725 | 714 | 723 | 725 | 733 | 715 | 718 | 732 |
| 0.20 | 759 | 757 | 762 | 770 | 776 | 769 | 764 | 766 | 758 |
| 0.18 | 796 | 802 | 806 | 794 | 802 | 802 | 800 | 806 | 801 |
| 0.16 | 845 | 834 | 833 | 852 | 843 | 848 | 835 | 840 | 829 |
| 0.14 | 872 | 875 | 876 | 865 | 870 | 868 | 876 | 876 | 870 |
| 0.12 | 907 | 908 | 909 | 914 | 908 | 912 | 914 | 907 | 908 |
| 0.10 | 942 | 933 | 941 | 954 | 939 | 943 | 942 | 937 | 945 |
| | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 |

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**Figure 7**. *North Sea plaice. Results of long-term forecast simulations using the surplus production operating model with a* $B_{lim}$ *set to 207kt. Top left panel: Yield in kt. Top right panel: Risk of SSB falling below* $B_{lim}$ *in terms of the 5% lower percentile of SSB. Bottom left: Interannual variation in TAC in percentage. Bottom right: SSB in kt. All four plots show the mean values of 200 simulations. Target-F is given in the SPM F-currency.*


Thank you !