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Best Surplus Production Model - North Sea plaice

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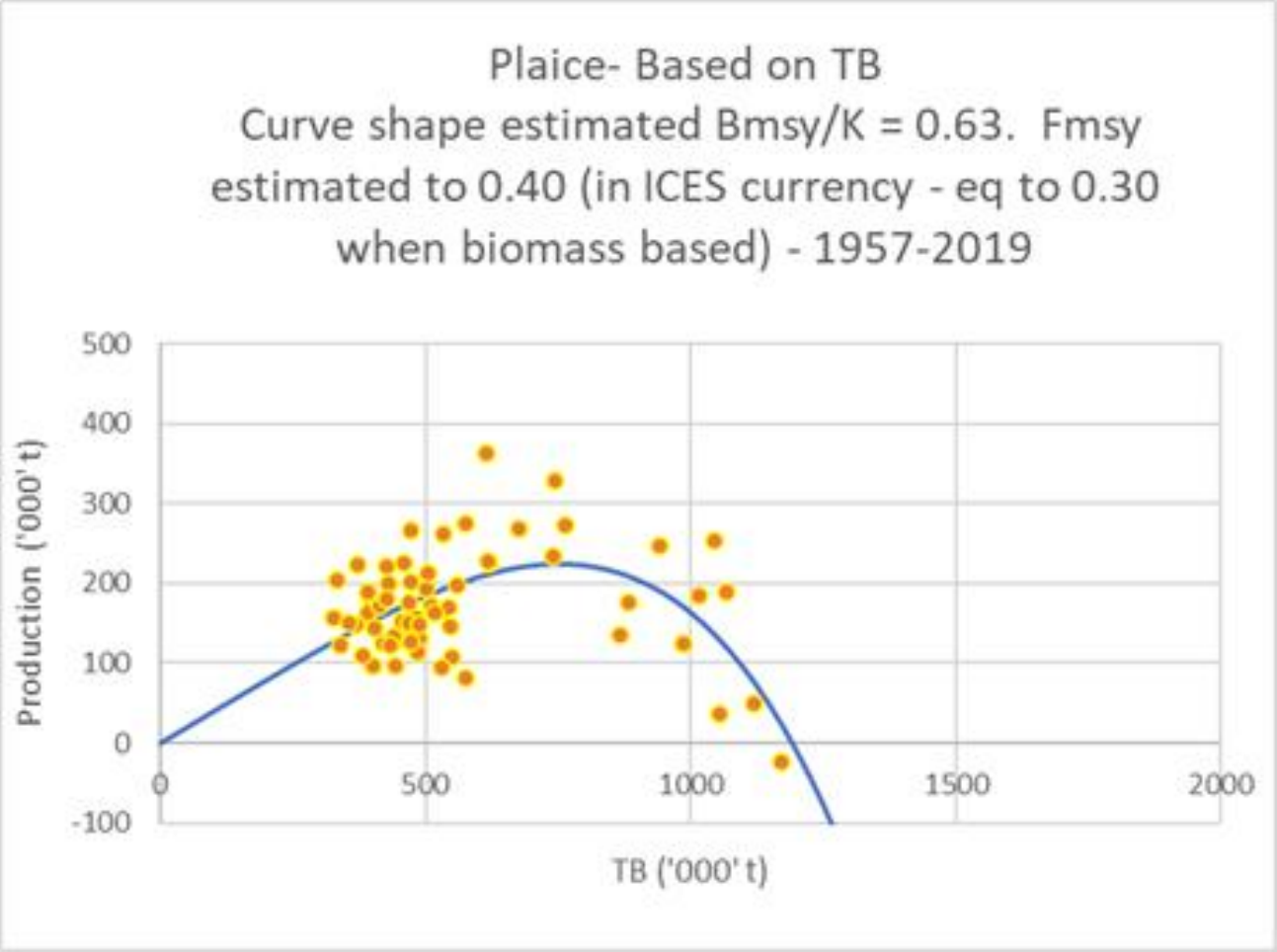
Steps to establish the best SPM for a given stock – here North Sea plaice

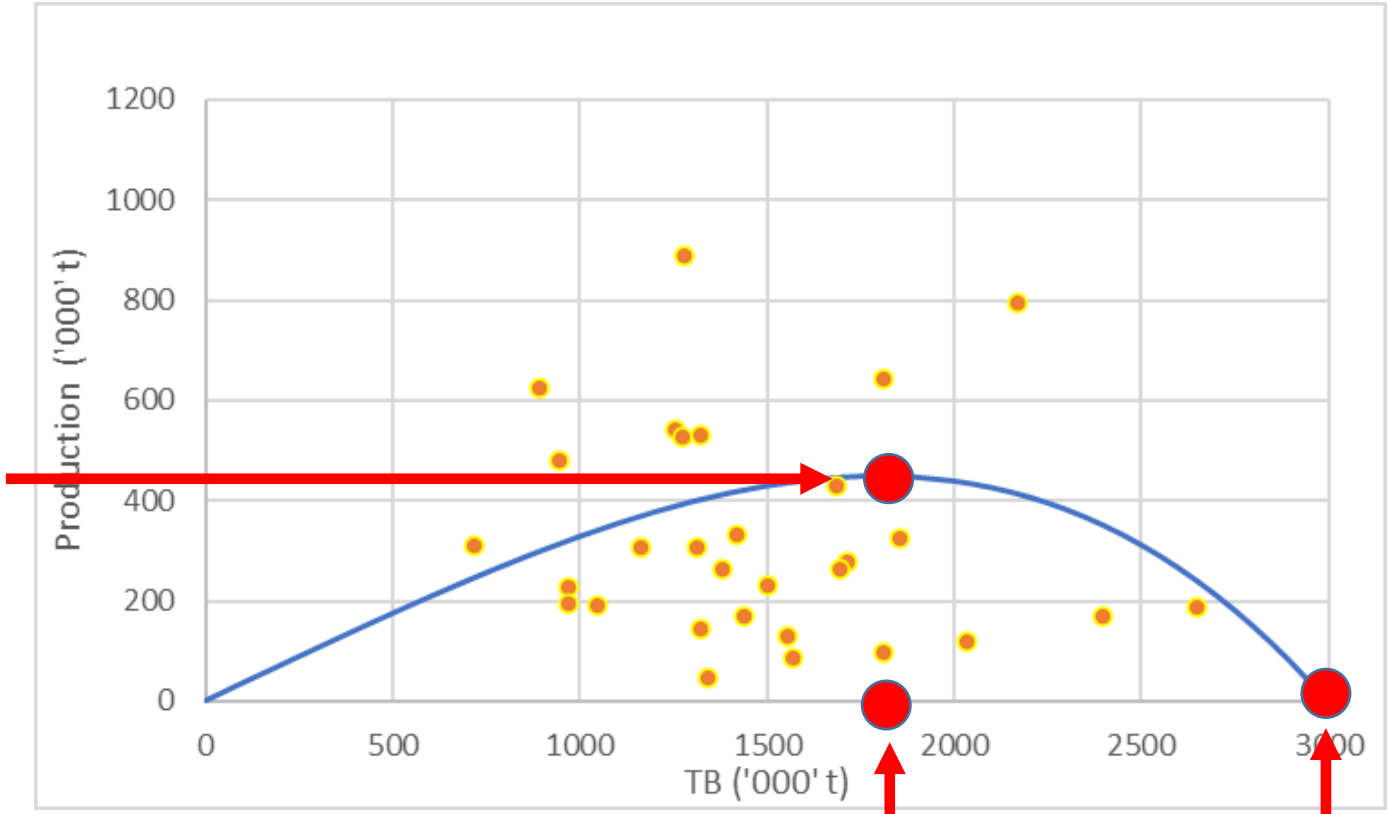
Production (annual):

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.

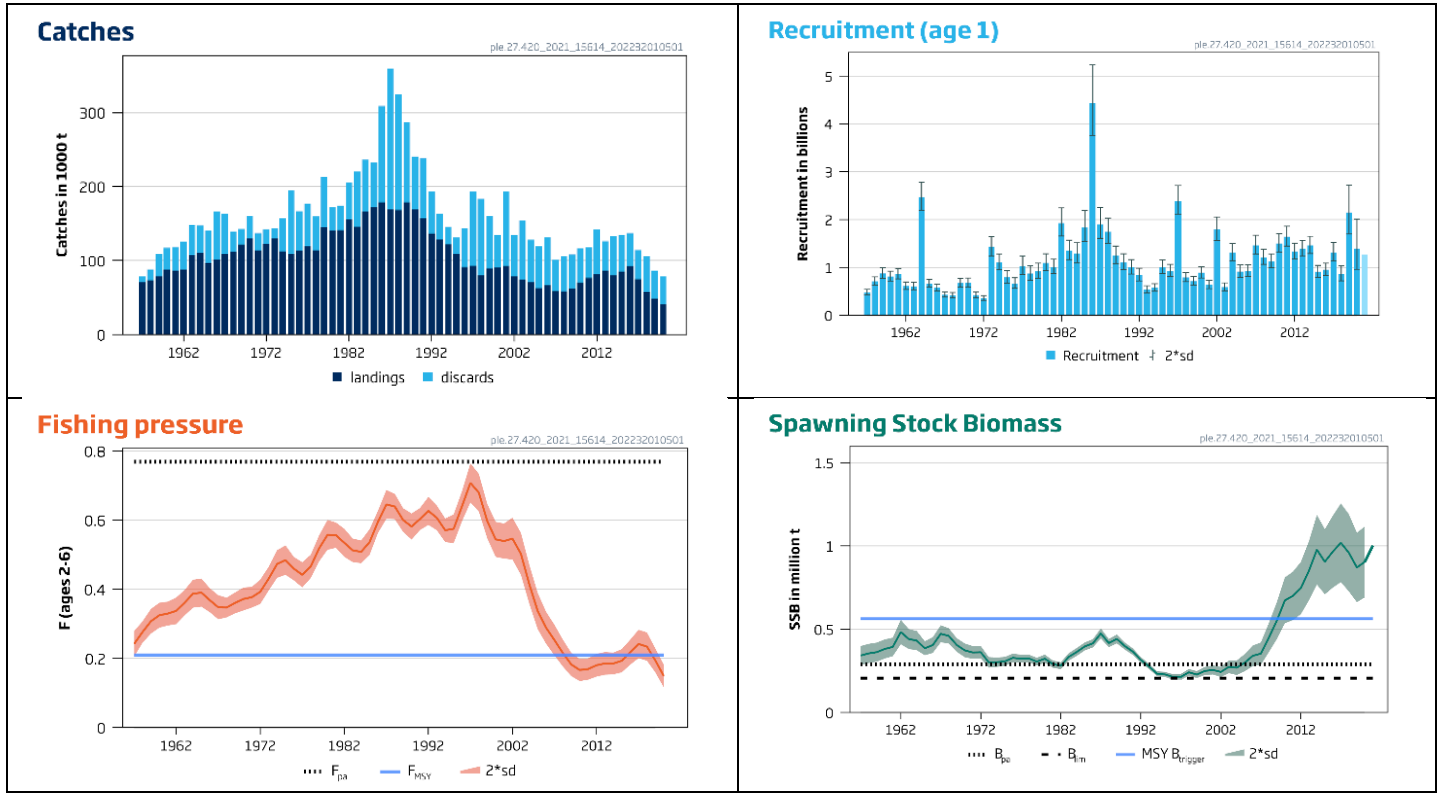
- Compare to available scientific knowledge. **A big literature review**.

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!

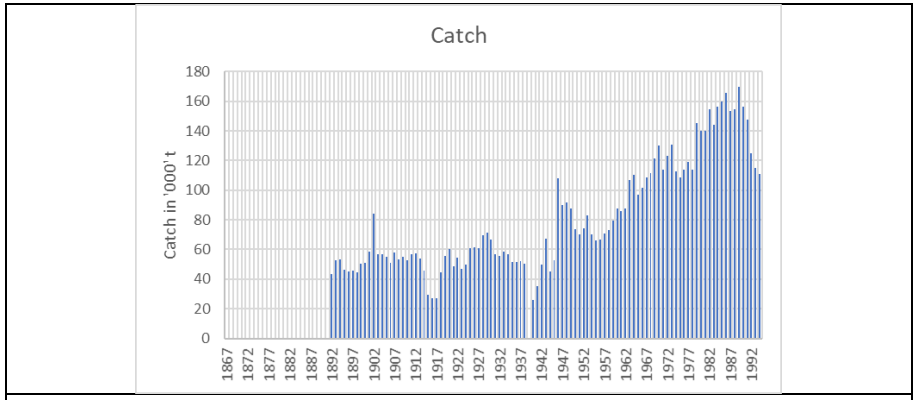
…available scientific knowledge

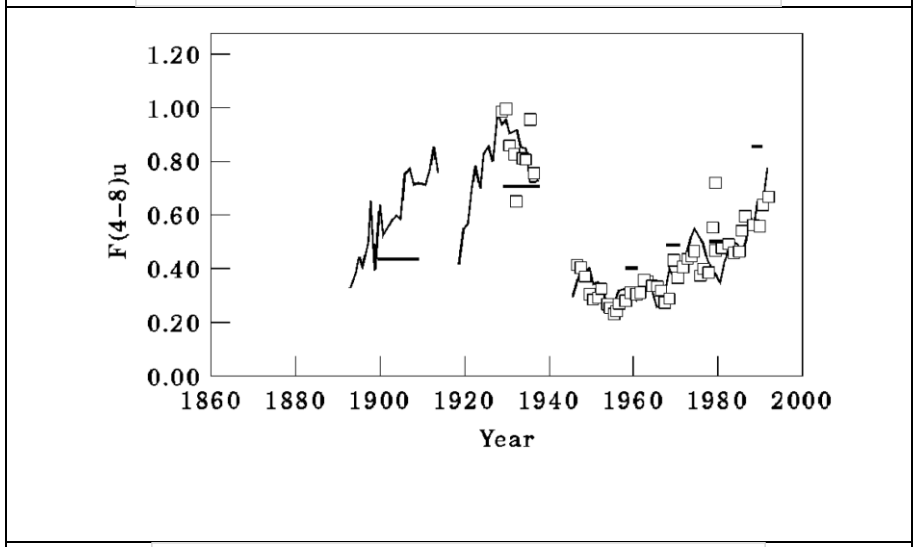
Older information

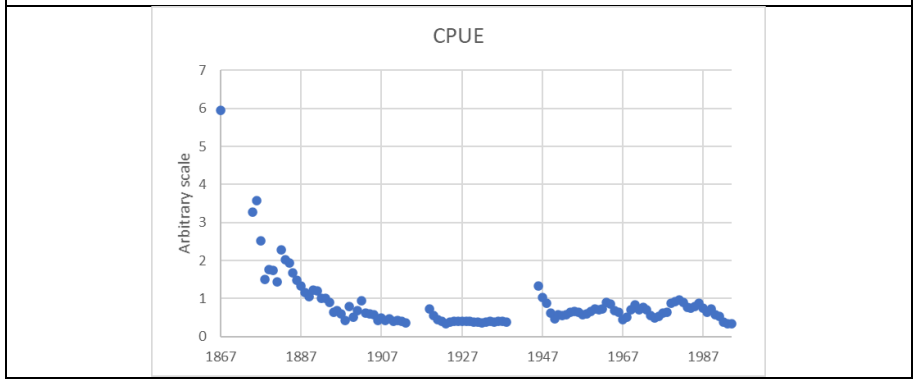
Back to late-1800s

The stock has sustained a high F in old time.

Can that gives us clues to what K is?



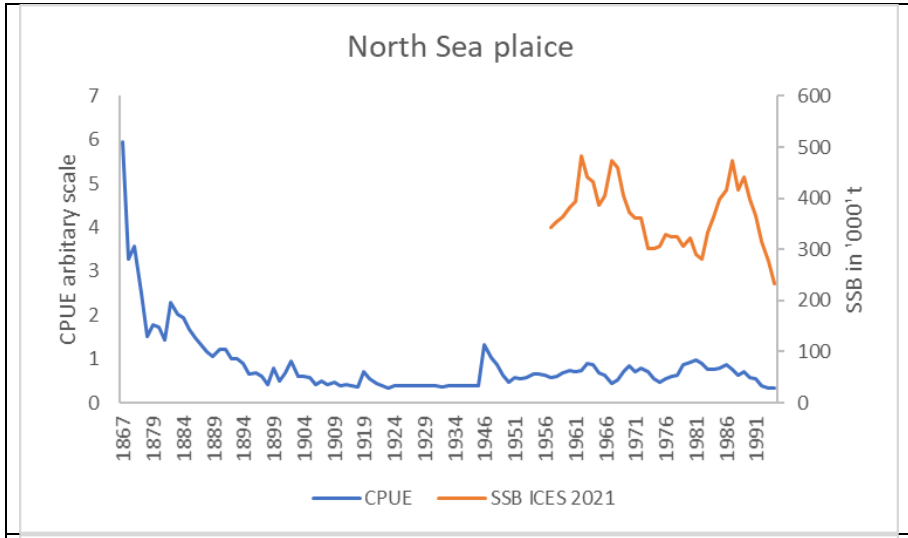




…available scientific knowledge

…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



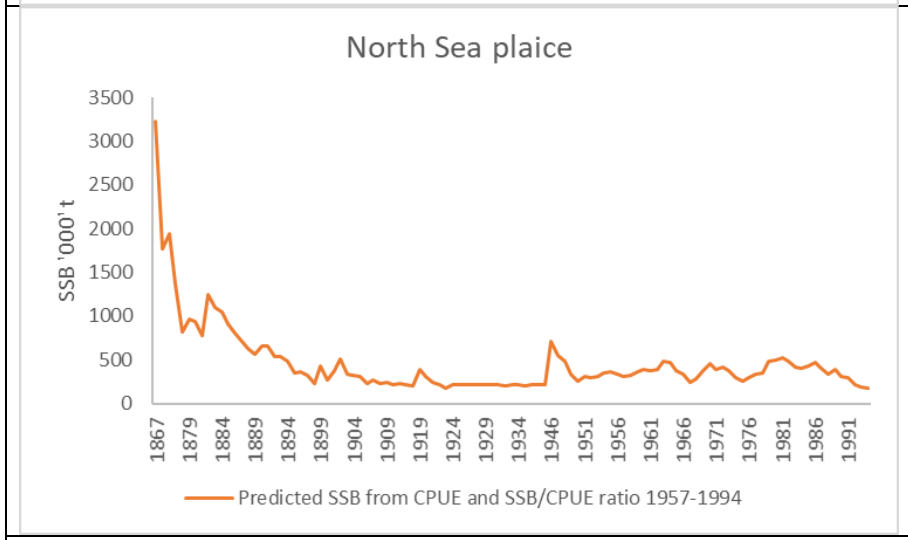


Figure 3. *North Sea plaice. CPUE from Rijnsdorp and Millner 1996 and SSB from ICES 2021 combined to give estimates of SSB b y year based on CPUE data back in time.*

…available scientific knowledge

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

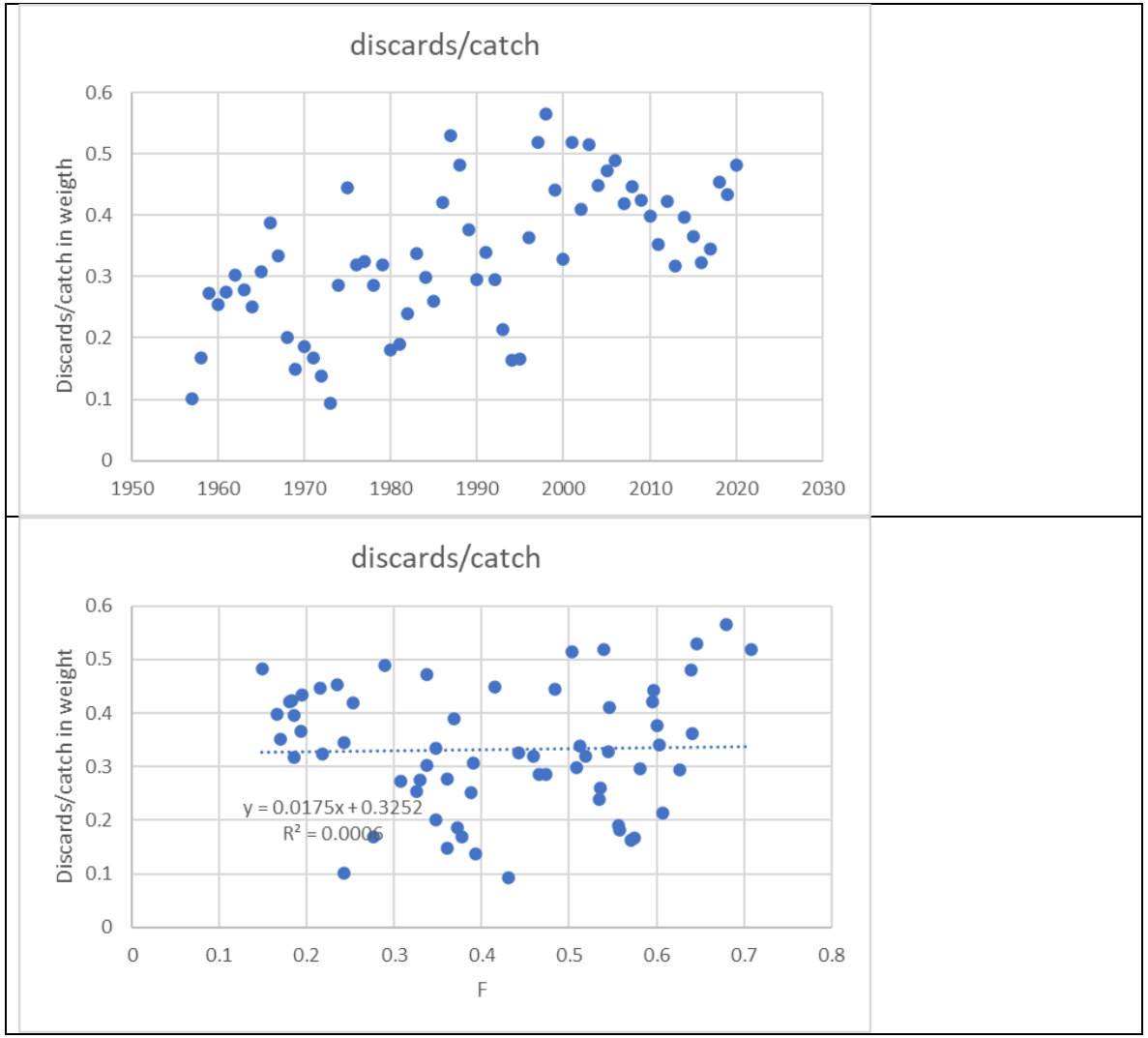


Figure 3. *North Sea plaice. Discards as ratio to total catch by weight vs year (top panel) and vs F (bottom panel).*

...available scientific knowledge

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

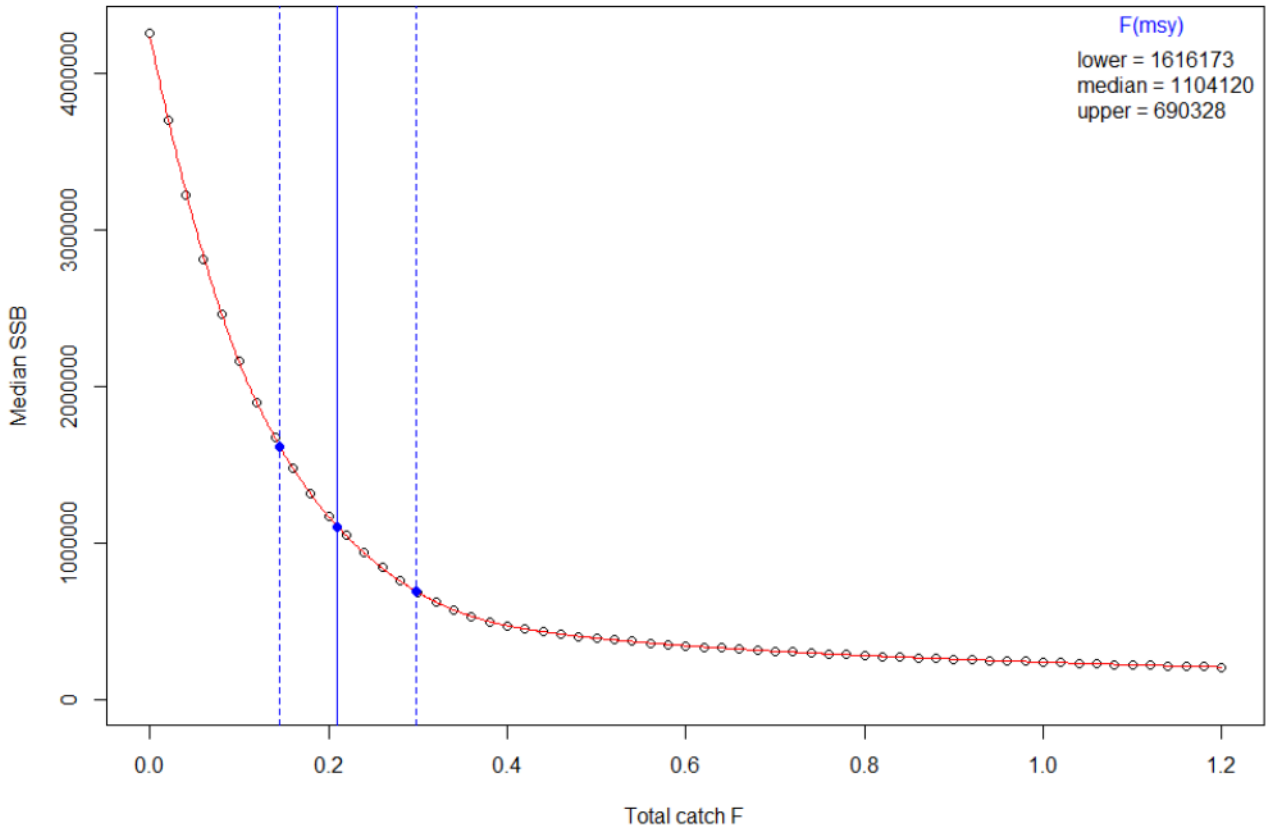


Figure 4. *North Sea plaice. Long-term forecast (EQSIM) equilibrium SSB vs F assuming that F is reduced linearly to zero when SSB gets lower than Btrigger (564599 t). ICES 2017.*

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.

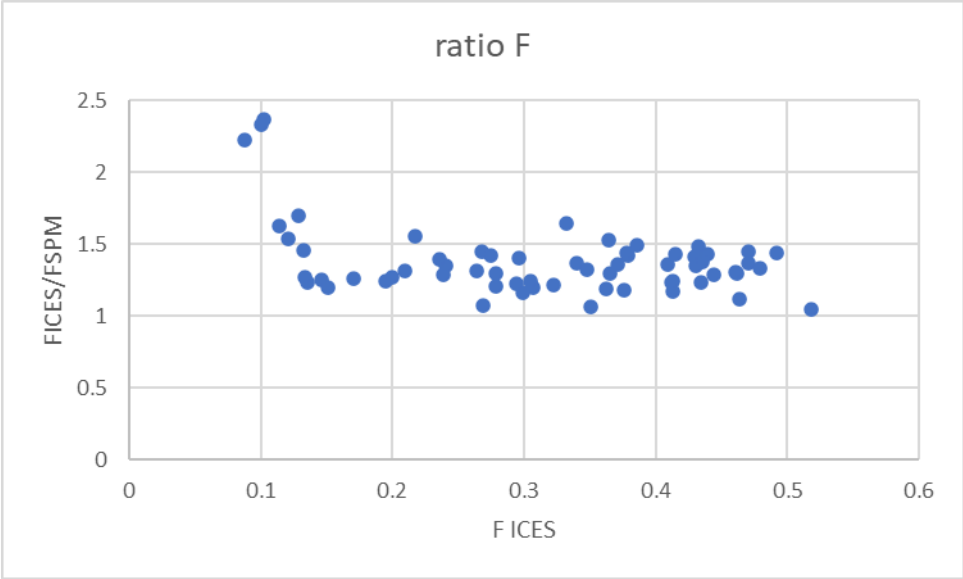


Figure 6. *North Sea plaice. The ration of F-ICES/F-SPM vs. F-ICES. Based on ICES (2021).*

…available scientific knowledge

Regime shifts?

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

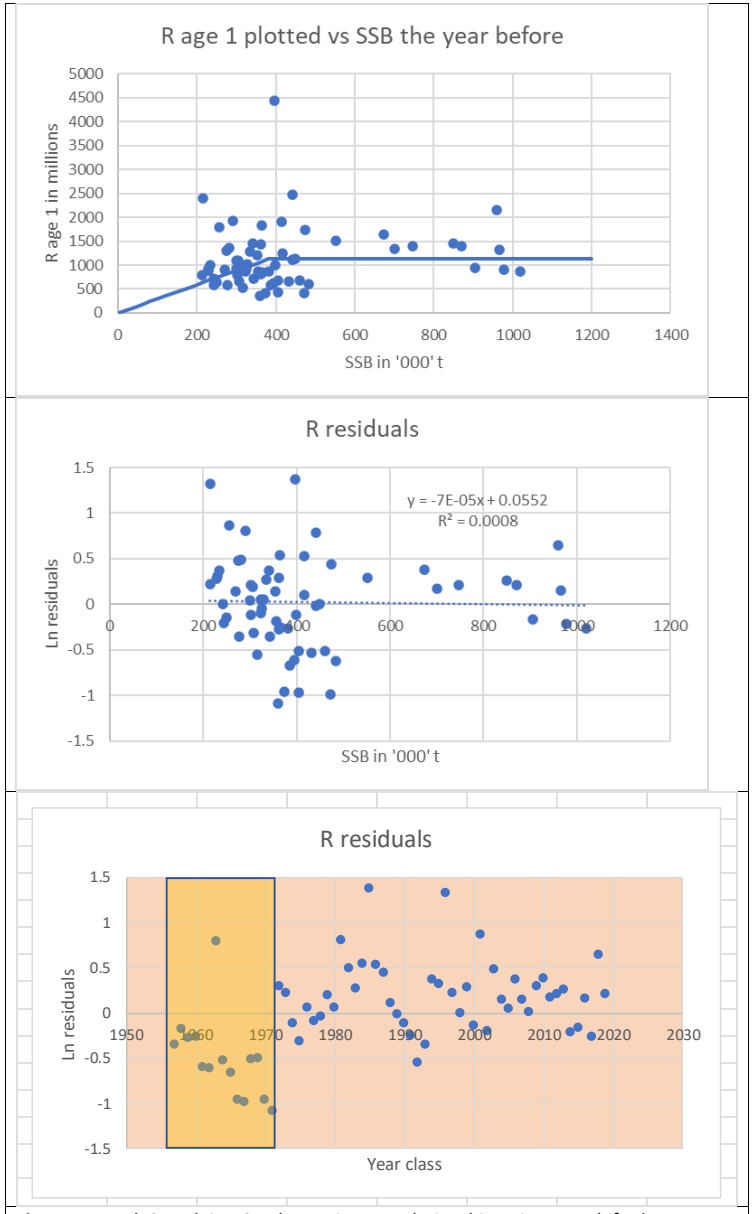


Figure 7. *North Sea plaice. Stock recruitment relationship. R is age 1 shifted one year to match the year of spawning. Top panel: blue line is the estimated hockey stick S-R*

…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

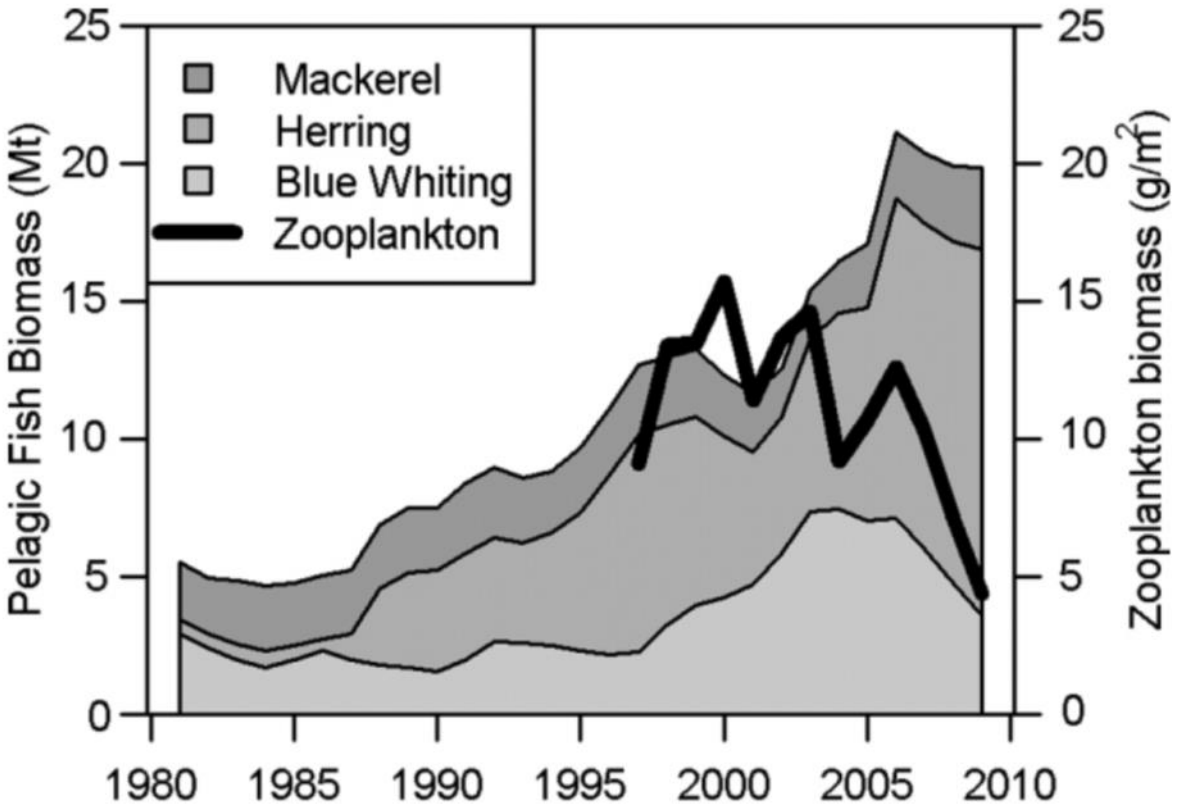
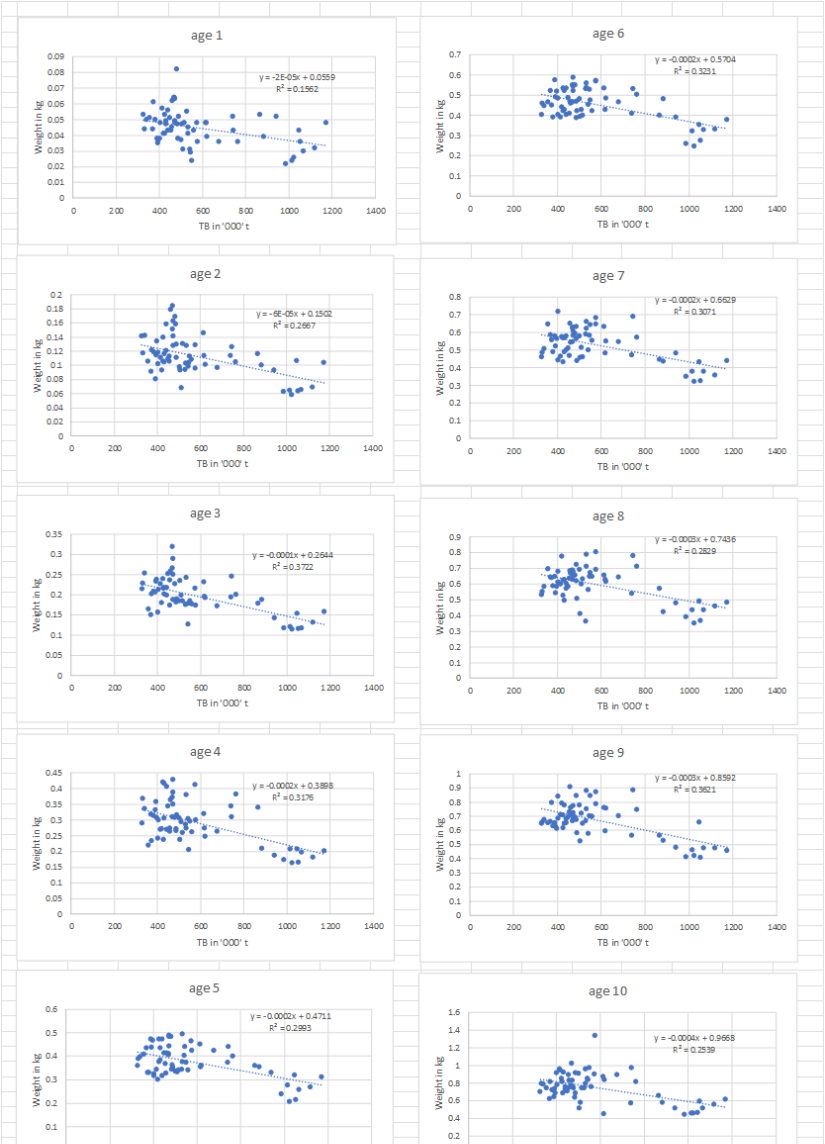


Figure 8. *Fluctuations in total biomass of pelagic fish and zooplankton in the Norwegian Sea. Spawning stock biomass of mackerel (dark grey area), Norwegian spring-spawning herring (grey area) and blue whiting (light-grey area) from analytical stock assessment (ICES 2010a). Average zooplankton density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

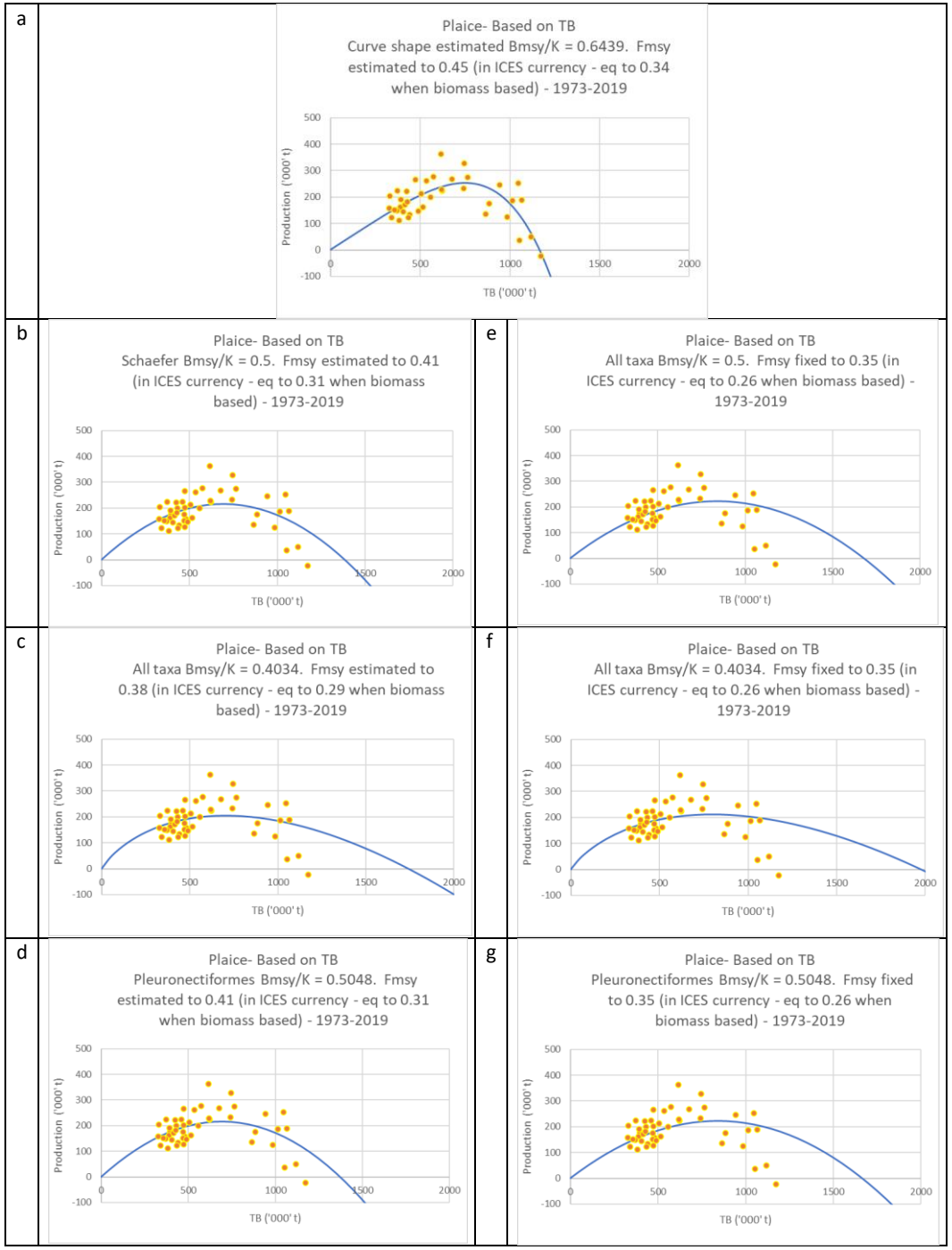
…available scientific knowledge

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



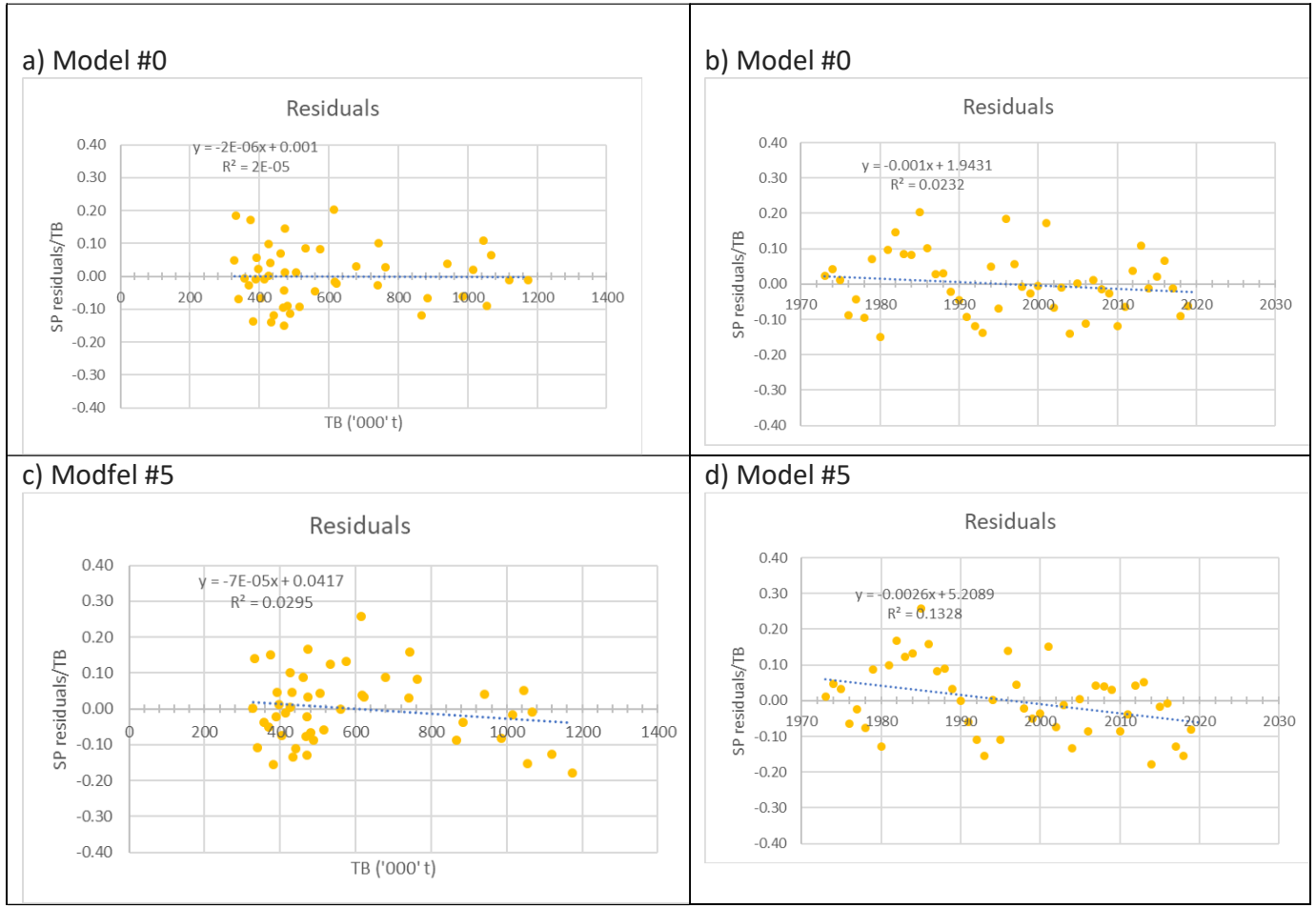
Next step is to fit an SPM model to the data.

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



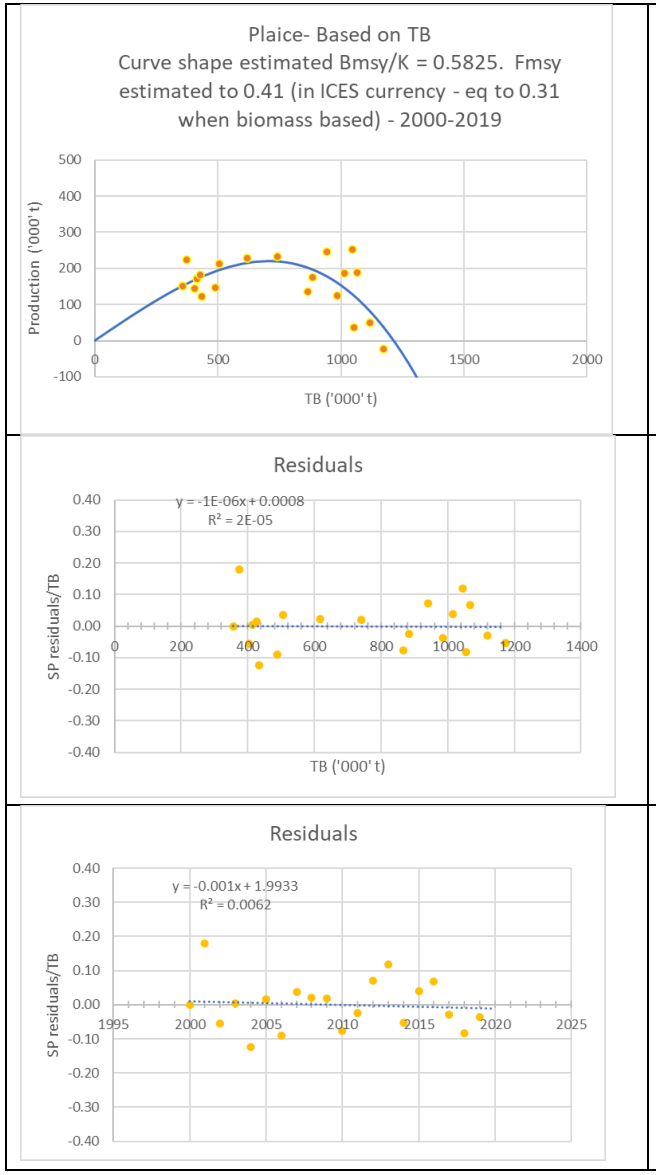
SPM model	Number of para-meters estima-ted	Bmsy/K (curve shape parameter)	R^2	AICc	SSBmsy '000' t	MSY in '000' t	K (Carrying capacity) '000' t	MSY/ TBmsy
#0 Fmsy estimated Curve estimated	3	0.643	0.80	16.9	542	253	1166	0.34
#1 Fmsy estimated – Schaefer	2	0.500	0.78	15.3	511	216	1385	0.31
#2 Fmsy estimated - 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?

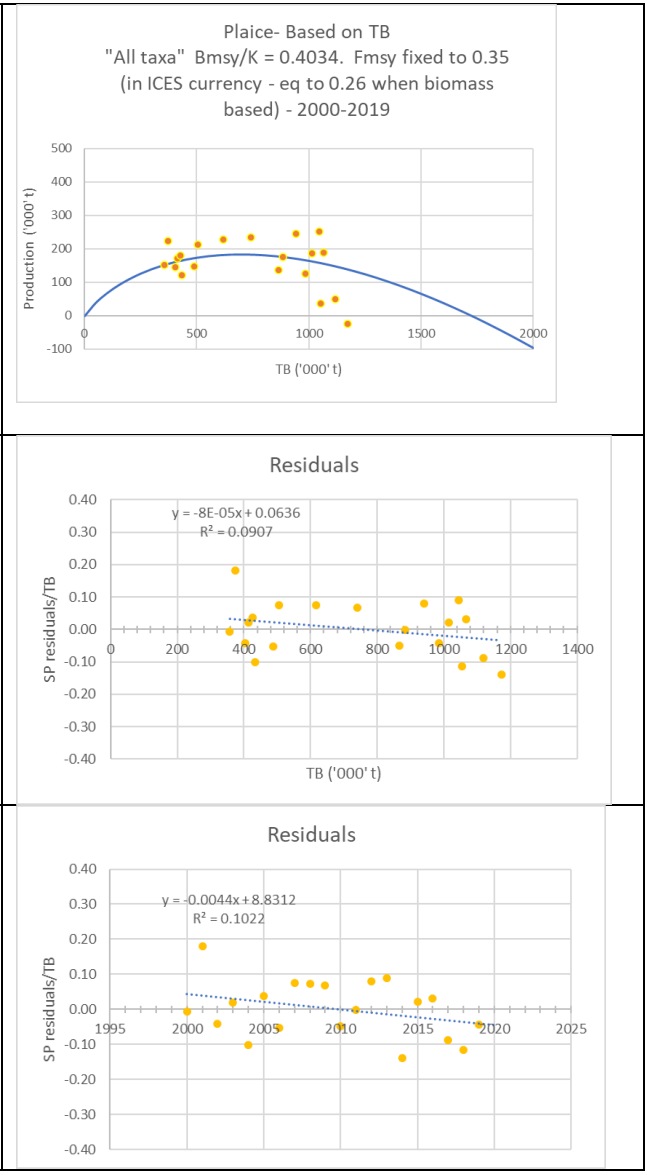


Reduced time window to after 2000 to make it more up-to-date and less trend dependent

Model 0#



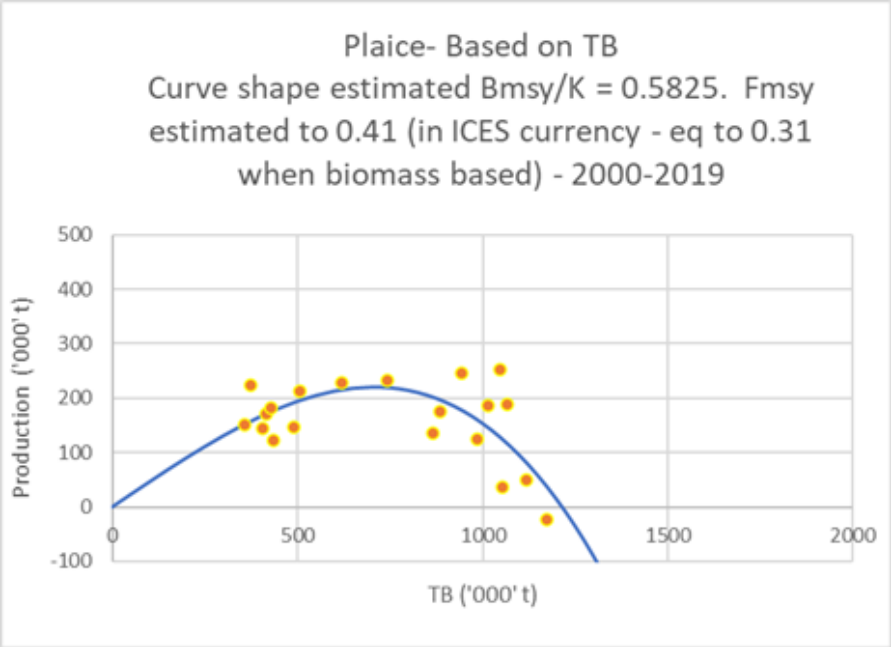
Model 5#

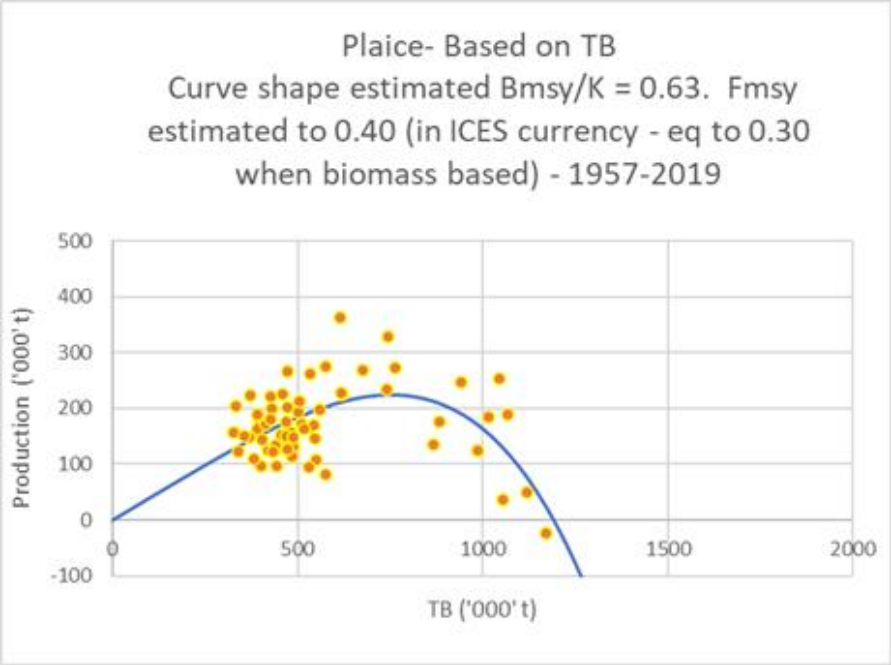


SPM model	Number of para-meters estima-ted	Bmsy/K (curve shape parameter)	R^2	AICc	SSBmsy '000' t	MSY in '000' t	K (Carrying capacity) '000' t	MSY/ TBmsy
#0 K, curve and Fmsy estimated – 2000-2019	3	0.5825	0.81	12.8	522	220	1215	0.31
#5 "All taxa", fixed Fmsy -2000-2019	1	0.40	0.77	5.4	534	184	1727	0.26

- 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

	250	300	350	400	450	500	550	600	650
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

Btrigger in '000' t

5% lower SSB

	250	300	350	400	450	500	550	600	650
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

Btrigger in '000' t

IAV

	250	300	350	400	450	500	550	600	650
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

Btrigger in '000' t

SSB

	250	300	350	400	450	500	550	600	650
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

Btrigger in '000' t

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.*

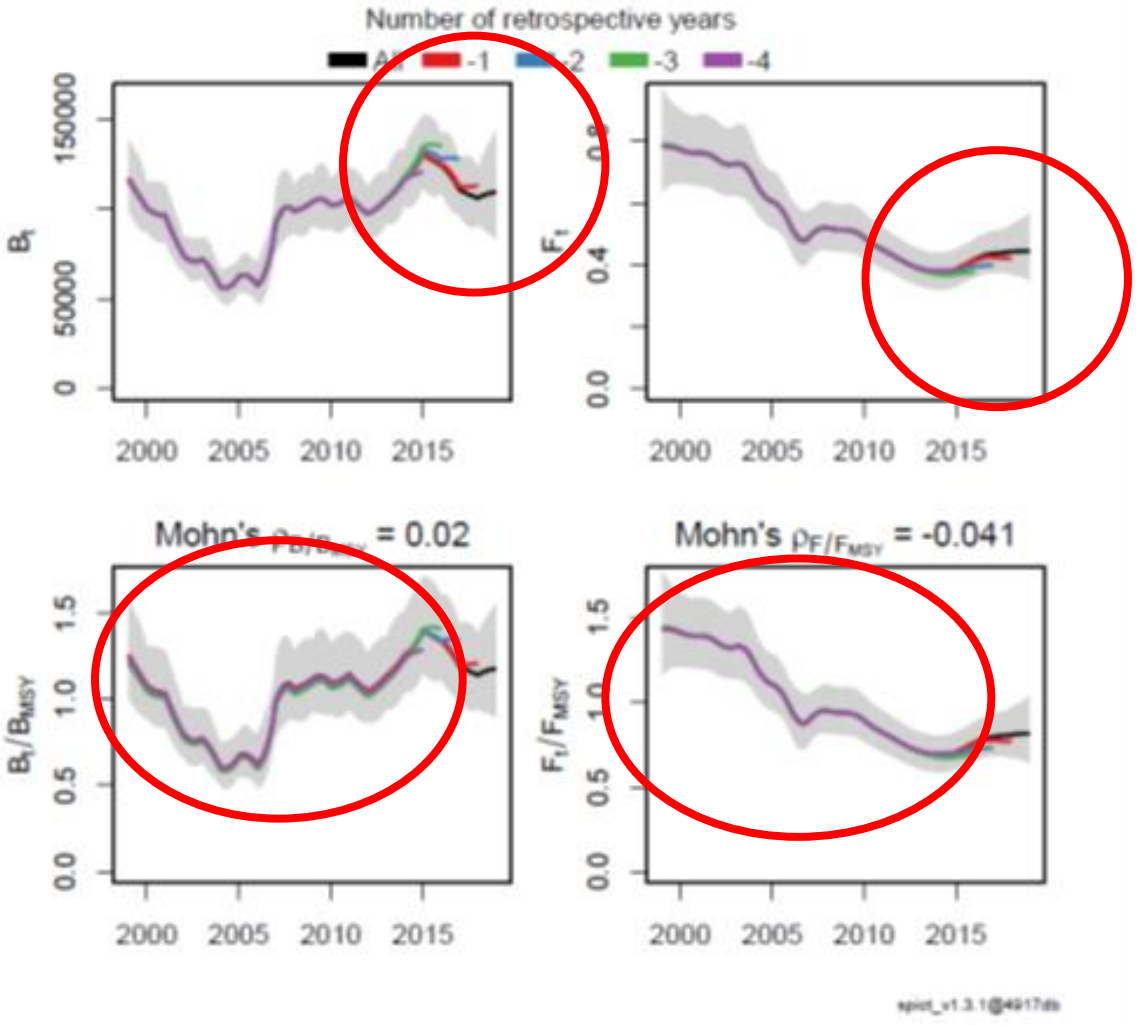
Thank you !

- Supplementary slides

Sprat - North Sea…very robust to adding a new data year

SPM model #6	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)
1996-2015	1	0.265	0.70	22.5	227	186	1388	0.51
1996-2016	1	0.265	0.71	22.4	232	191	1421	0.51
1996-2017	1	0.265	0.71	23.6	233	191	1426	0.51
1996-2018	1	0.265	0.71	24.4	231	190	1416	0.51
1996-2019	1	0.265	0.71	25.1	234	192	1429	0.51

Cod - North Sea…retrospective analysis using SPiCT, quite robust



Caveat for this and the previous 2 slides – it is only the SPM which have been tested – not the annual assessment it is based on.