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Baltic sprat management strategy evaluation using a Surplus Production Model as biological model

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Problem

“**it is a mathematical fact that you will get an underestimate of Fmsy if you ignore density dependence (DD) in any of the four factors - recruitment (or rather survival from egg to recruit), growth, maturity, and natural mortality.”**

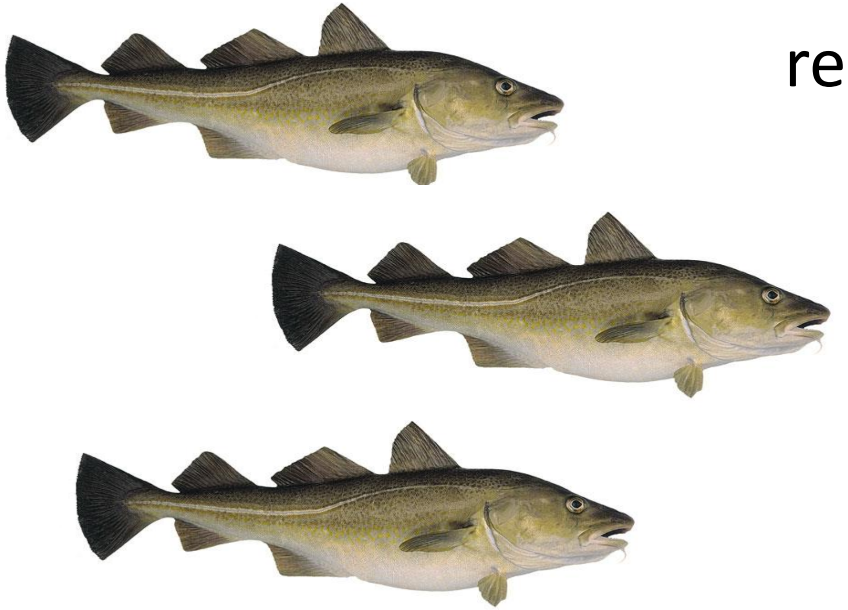
Solution

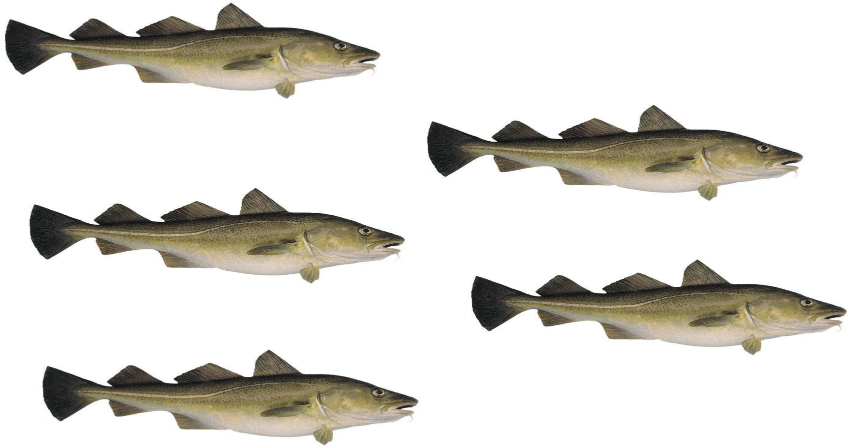
Continue using age-structed assessment models for state of the stock - but use Surplus Production Models for estimating Fmsy and Bmsy

Density dependence is how ecosystem function.

When the stock is small, individual fish:

1. Grow better
2. Have reduced natural mortality
3. Produce more eggs
4. Have better survival from egg to recruitment





Four compensatory mechanisms –

Taken into account in current management?

- Density dependent recruitment √
- Density dependent individual fish growth Not yet
- Density dependent natural mortality Not yet
- Density dependent maturity Not yet

It is a mathematical fact:
missing any of these in Fmsy calculations will give a downward bias!

The general picture based on 53 data-rich stocks in the ICES area (FAO-area 27)

Age-structured models including DD in …	Fmsy calculated from the models	Comments
No DD	0.00	Stocks should be built to infinity
R	0.26	Average of 53 data rich stocks in the ICES area (ICES 2021)
R + growth	0.31?	“Guestimate” only a few examples
R + growth + natural mortality	0.36?	“Guestimate” only a few examples
R + growth + natural mortality + maturity	0.39	Average based on Surplus Production Models, of 53 data rich stocks in the ICES area (Sparholt *et al.* 2021)

…when you one by one, add a DD factor to the model, the Fmsy estimate increases.

Solution:

Produce DD sub-models for all four parameters.

….as done for NEA-cod but we easily **run into the “known unknown” situation**.

Therefore….

Use Biomass Dynamic Model …often called Surplus Production Models

…because they include all density dependent elements by design.

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cont…Solution

- Continue to do the historic assessments and short-term projections in age-structured models

- Do the long-term projections (MSE, Fmsy and Bmsy) using SPM (based on the historic assessment) as operating model

Ecosystem approach to fisheries management

- Everybody say they will do it
- The fact is: scientific bodies giving advice to managers still use the old fashioned single species approach with DD only in recruitment
- Including all 4 density dependent factors in single species approach get close to “an ecosystem approach”

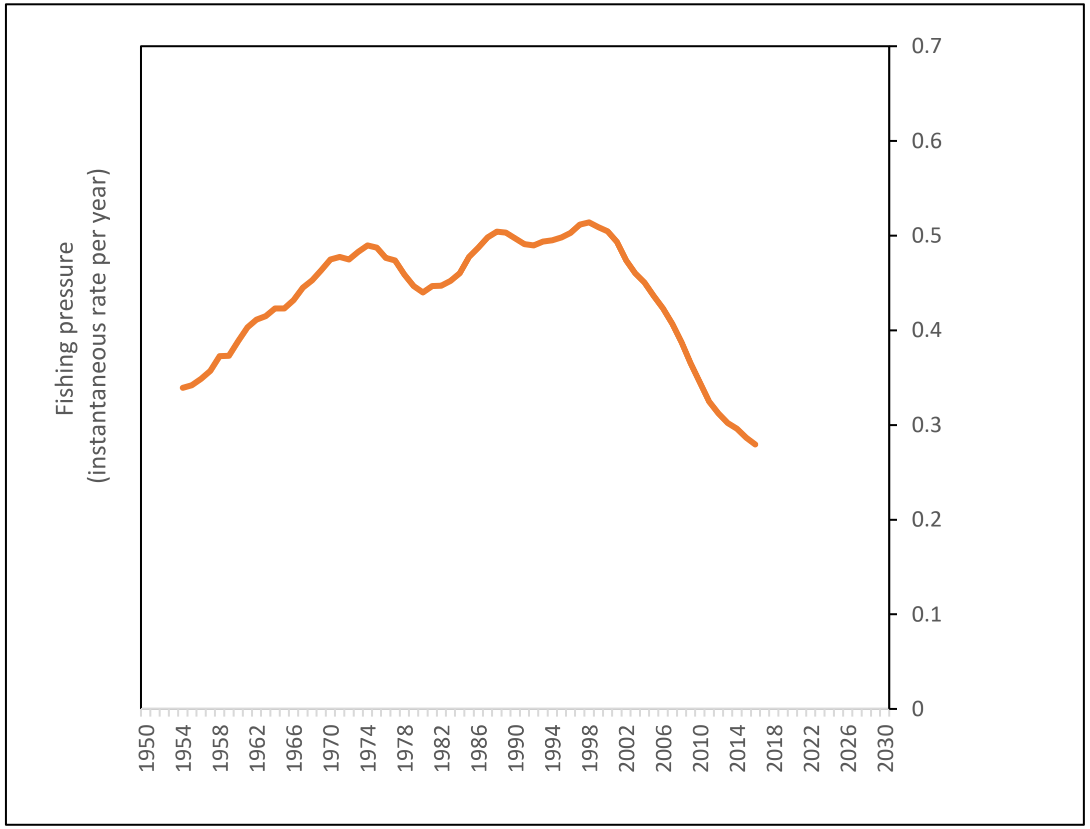
DD not a new "thing" in fisheries

- Density dependence (DD) in fish population dynamics was included from the beginning of this field of science (Baranov, 1918).
- ICES held a symposium in 1947 to consider how important DD was when fish stocks were left practically unfished during the WWII (Graham 1948).
- The seminal book by Beverton and Holt (1957) includes many concrete case studies with effects of DD on fish population dynamics.

…but maybe DD has been partly forgotten in the recent decades where overfishing made it less of a problem?

Mean fishing pressure in the Northeast Atlantic (FAO 27) – mean of 53 ICES data rich stocks.

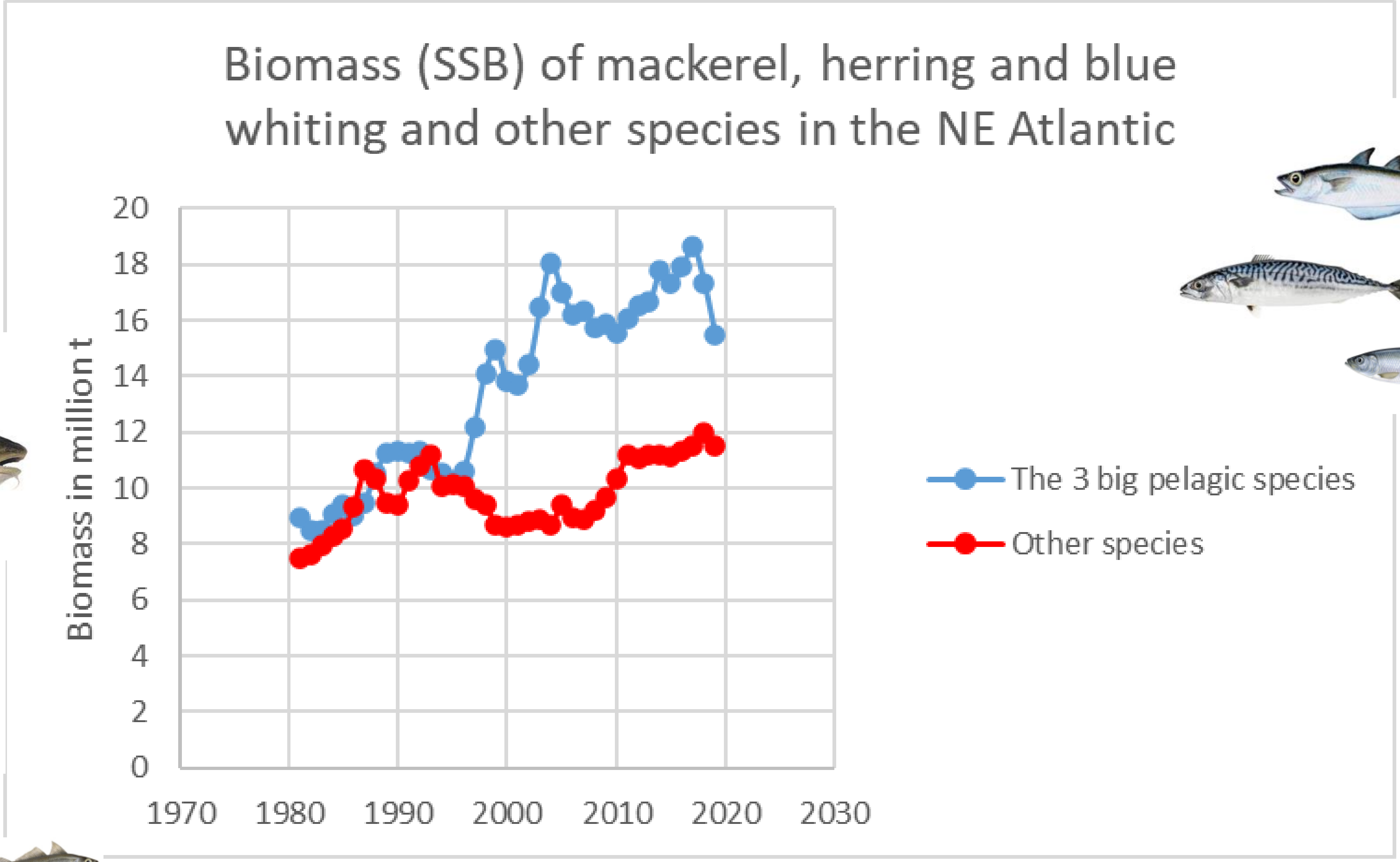
12% of Global catch



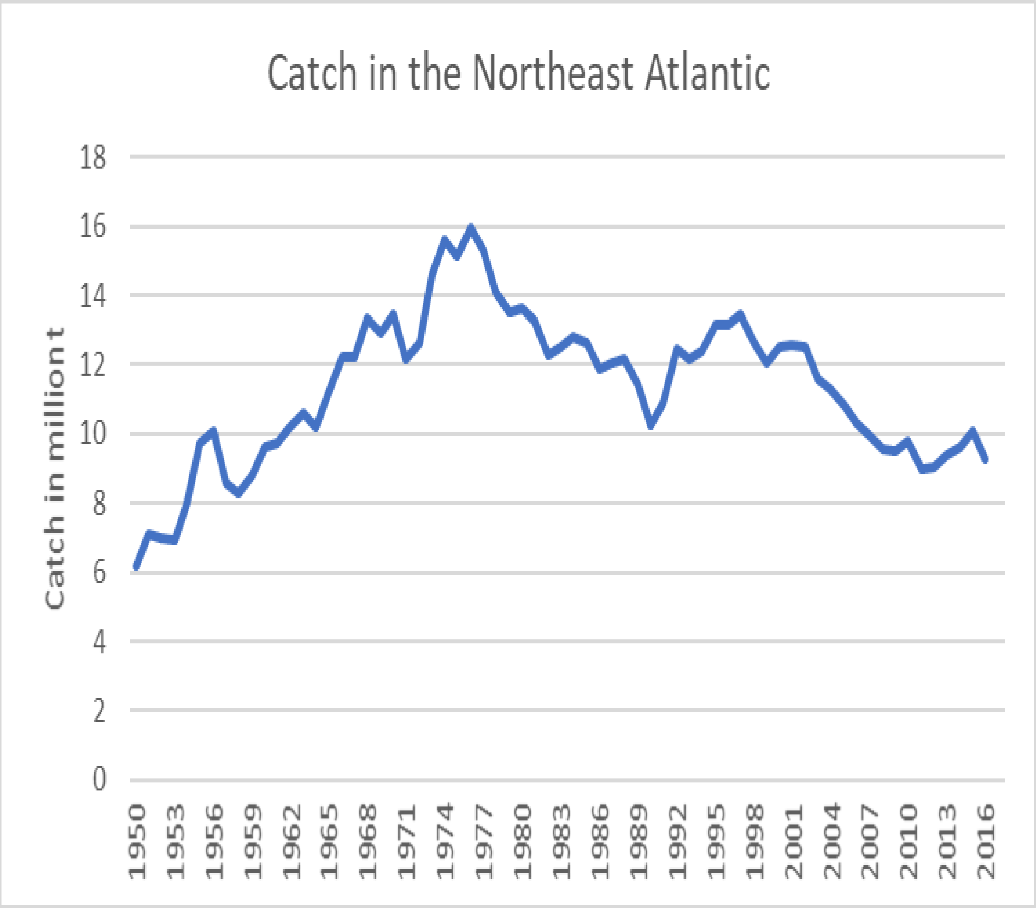
Succes story – Over-fishing has ended in the NE Atlantic!!

…about 10 year ago

Stocks increased – especially ”the 3-big pelagics”



Unfortunately, catches have decreased – where is the ”long-term gain for the short-term pain” scientists told managers in 1980-2000?



We suggest that part of the reason –

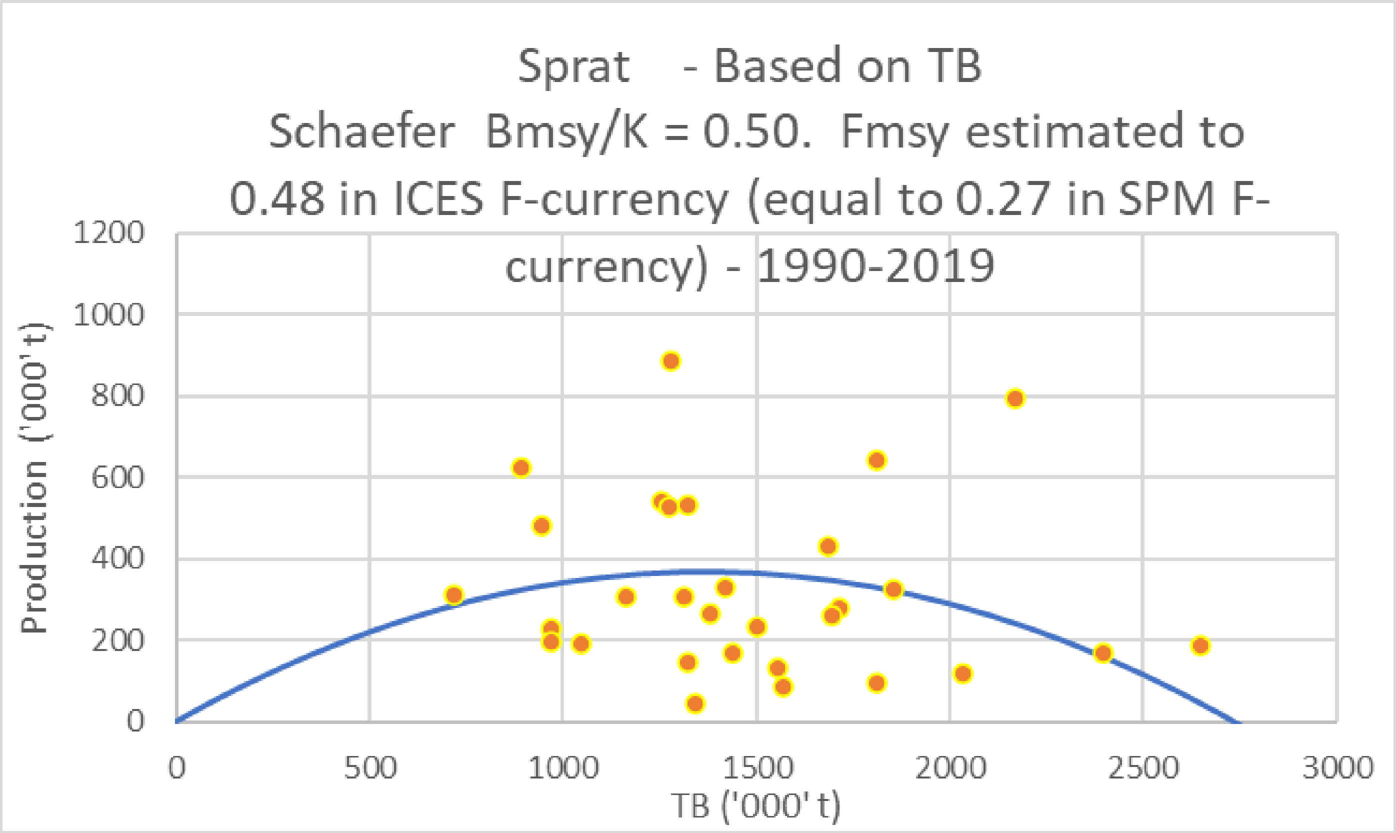
The real Fmsy (including all DD) are 50% higher than currently used values.

Steps to establish the best SPM for a given stock – here Baltic sprat

– equilibrium not needed!

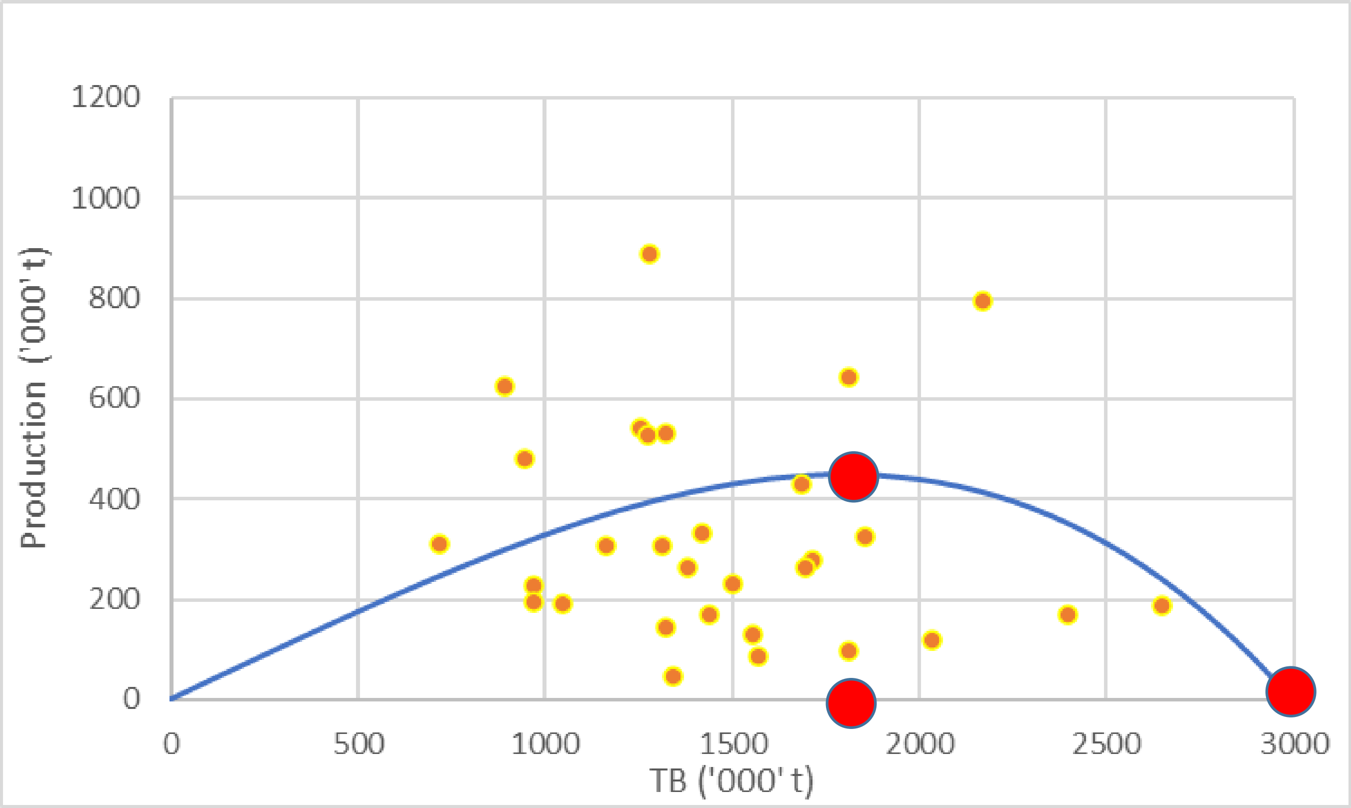
Production (annual):

catch
+
increase in stock size



3 parameters needed for Surplus Production Models

MSY



Bmsy/K

K

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

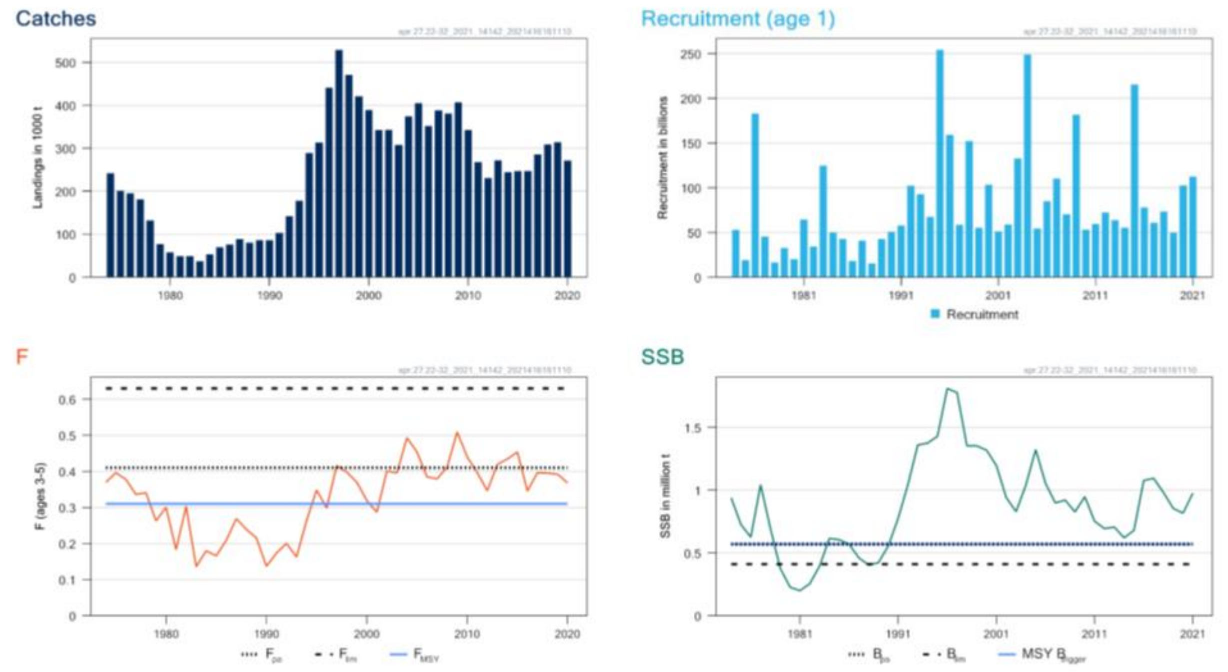


Figure 1 Sprat in subdivisions 22–32. Summary of the stock assessment. SSB at spawning time is predicted for 2021.

…available scientific knowledge

Older information

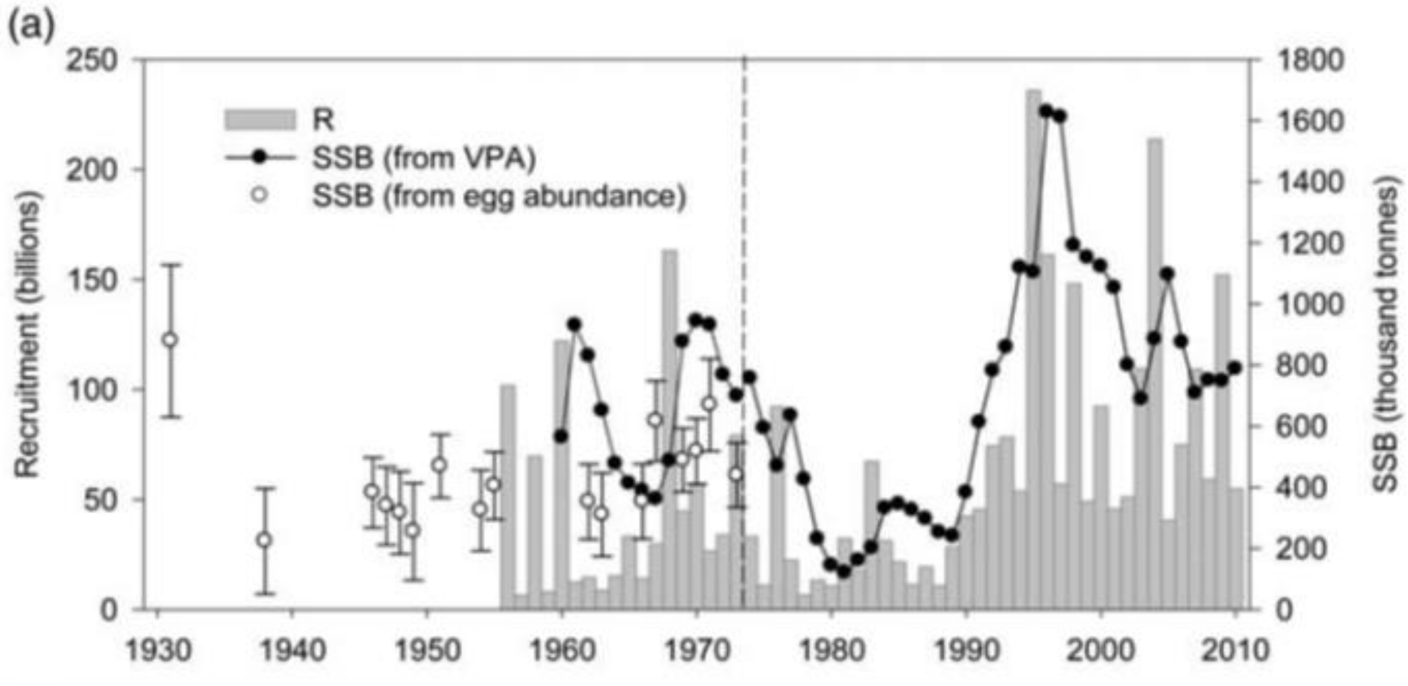


Figure 2. (a) Sprat spawning-stock biomass (SSB) and recruitment (R; numbers at age 1) in SDs 22–32 estimated from the analytical assessment (VPA); and the estimates of SSB based on egg abundance. The error bars represent 0.95 confidence intervals of the SSB, predicted from a linear regression with the average egg abundance as a predictor variable. (b) International sprat landings (L) in the Baltic Sea (Hammer *et al.*, 2008, and updates from the Baltic Assessment Working Group) together with the estimated exploitation rate (landings divided by SSB). The vertical broken lines separate the period covered by ICES assessments (from 1974 onwards) from the historical estimates produced in this study.

…available scientific knowledge

Predators

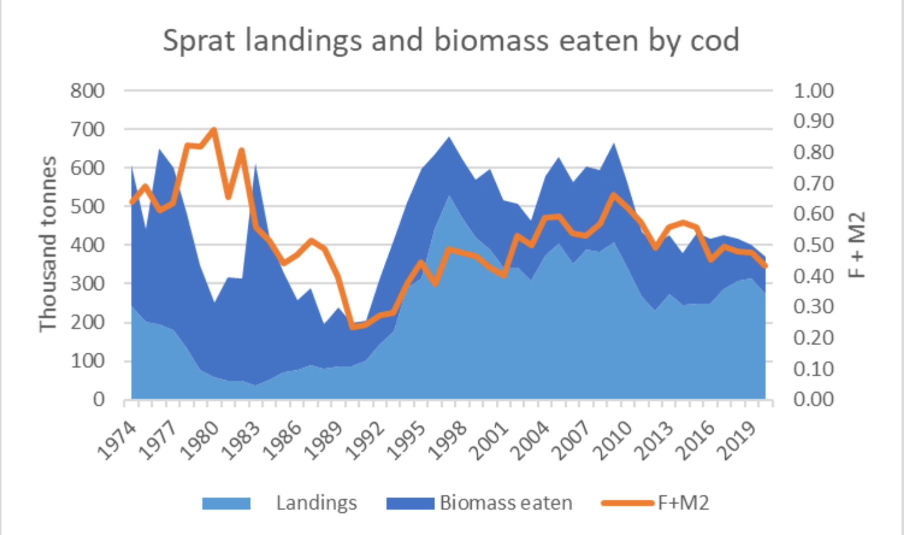


Figure 6. *Baltic sprat. Landings, biomass eaten by cod (cumulative plot) and F+M2 (fishing mortality and cod predation mortality, age 2-4). Based on data from ICES WGBFAS 2021. Biomass eaten calculated based on natural mortality minus 0.2, stock numbers and weight, by age and year.*
Note for my own sake: this figure is made in file: "K estimation Baltic sprat - - Schaefer - CV linked to SSB and n fixed Fmsy estimated but incl M2 for cod predation- 1974 - 2019 -SP includes eaten sprat.xls"

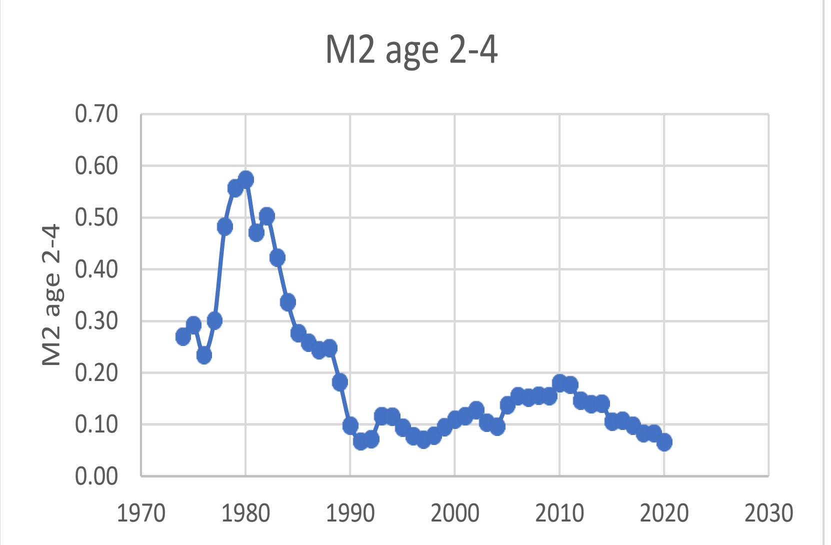


Figure 5. *Baltic sprat. M2 for age 2-4. From ICES WGBFAS 2021.* Note for my own sake: this figure is made in file: "K estimation Baltic sprat - - Schaefer - CV linked to SSB and n fixed Fmsy estimated but incl M2 for cod predation- 1974 - 2019 -SP includes eaten sprat.xls", Natmor sheet.

…available scientific knowledge

Stock-recruitment

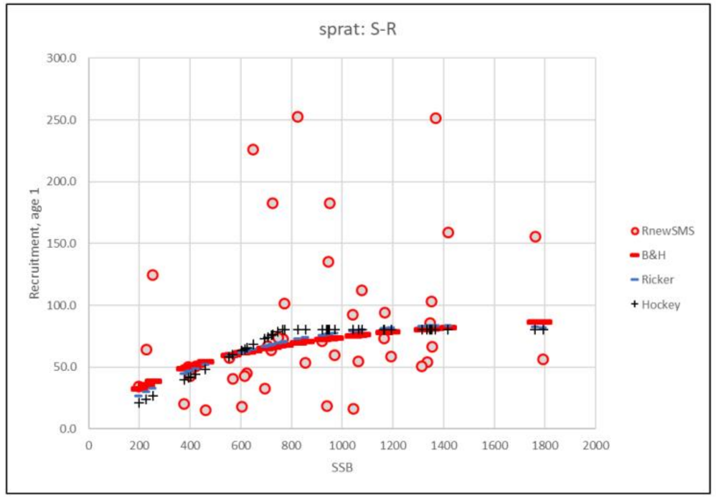


Figure 4.1. Stock–recruitment relationship for Baltic sprat; observations and fits of three models (Beverton and Holt, Ricker, and segmented regression).

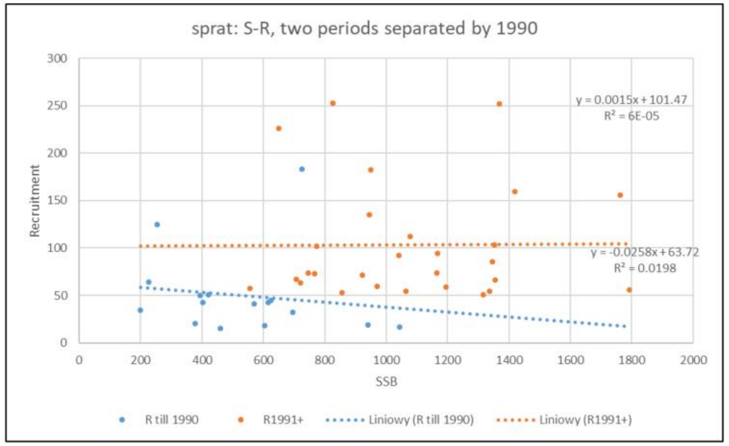


Figure 4.2. Stock–recruitment relationship for Baltic sprat separated into two periods: data before 1990 and data from 1990 onwards.

Figure 7. Baltic sprat. The S-R plots from: ICES. 2020. Inter-Benchmark Process on BAltic Sprat (*Sprattus sprattus*) and Herring (*Clupea harengus*) (IBPBash). ICES Scientific Reports. 2:34. 44 pp. http://doi.org/10.17895/ices.pub.5971.

…available scientific knowledge

Growth

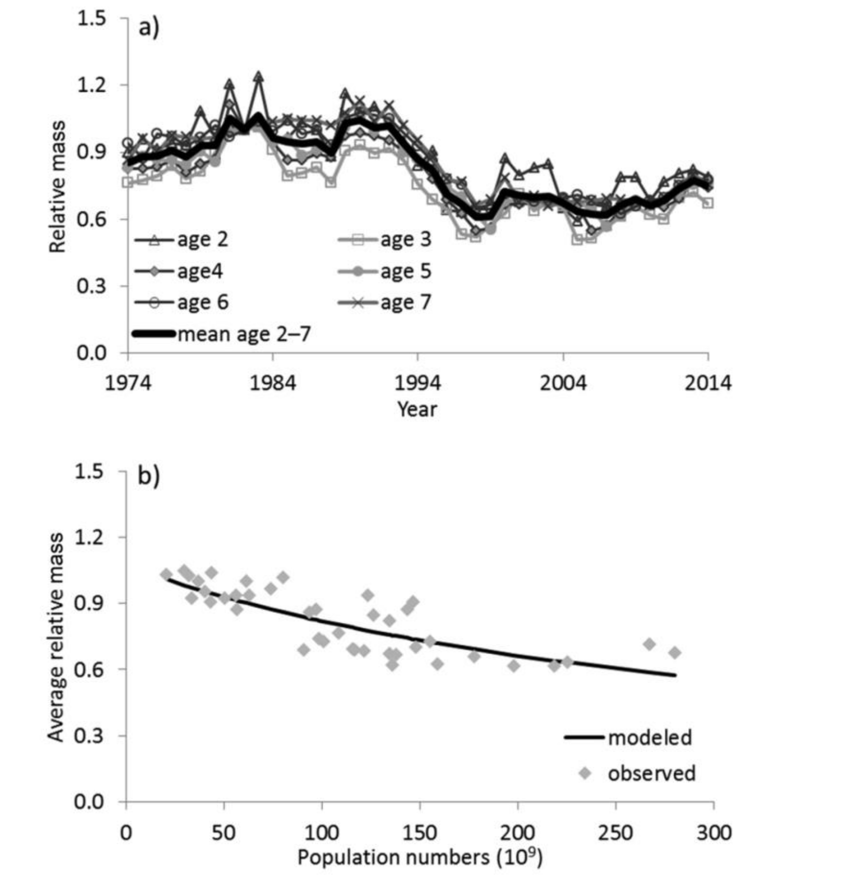


Figure 13. Baltic sprat. Relative (to the 1991 value) weight-at-age by year (a) and by stock size of sprat (b). From Horbowy and Luzenczyk (2017).

…available scientific knowledge

Carrying capacity

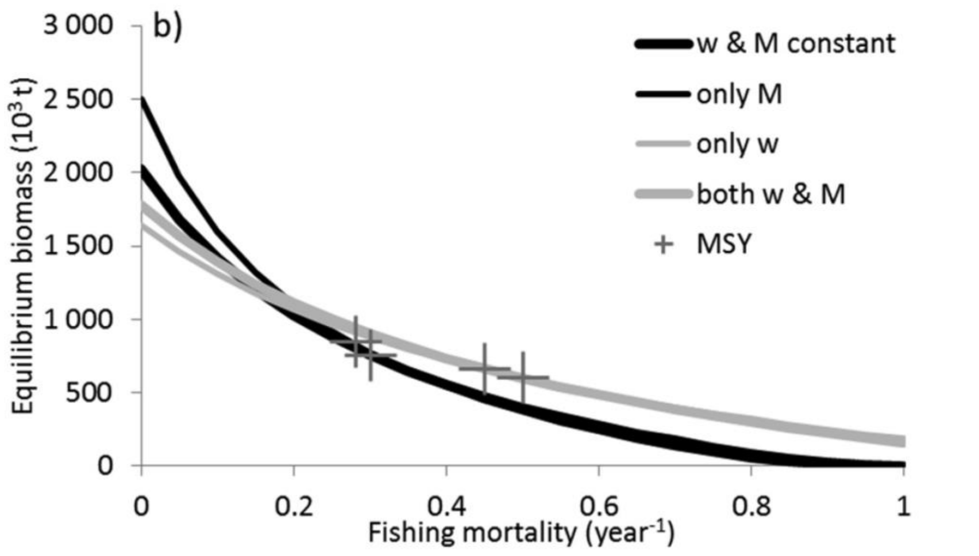


Figure 13. Baltic sprat. Equilibrium biomass of sprat relative to fishing mortality for the four combinations of density-dependent and constant growth (w) and natural mortality (M). Cod biomass is assumed at 200 × 103 t. From Horbowy and Luzenczyk (2017).

…available scientific knowledge

Food competitors – herring

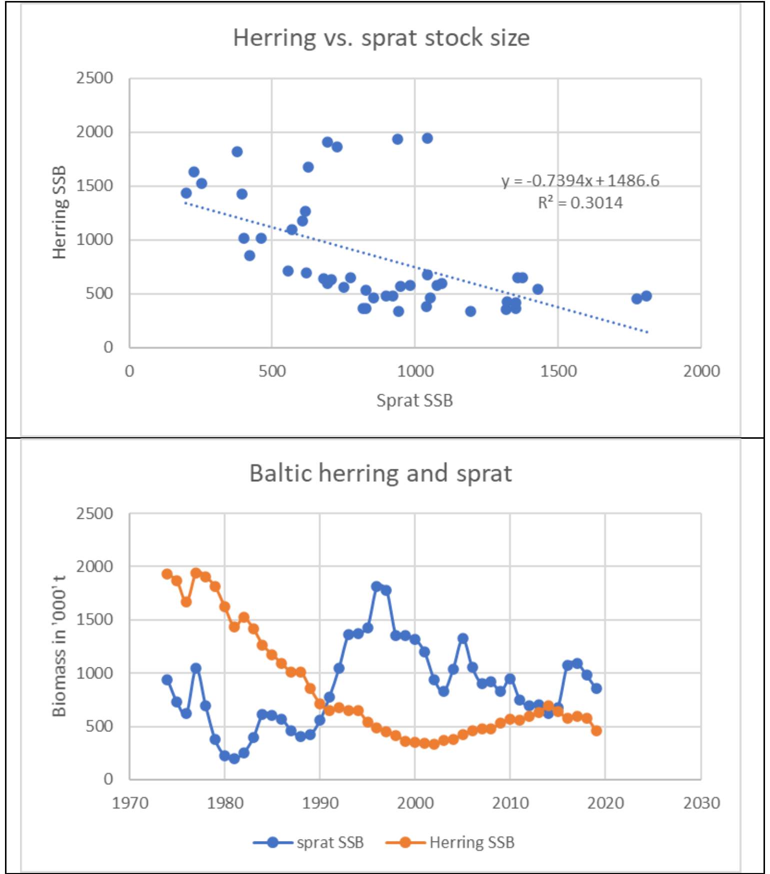


Figure 14. *Upper panel is the correlation between the SSB of sprat (SD 22-32) and herring (SD25-29 + 32) in the Baltic. The negative relationship is highly significant. Biomass units is '000' t. Lower panel shows the SSB of each stock by year. Based on data for 1974-2019 from ICES 2021.*

…available scientific knowledge

Traditional age structured calculations can give an upper bound of K, because density dependent effects are not included

Table 1. *Yield, SSB (at spawning time) and TB (at 1st January) per recruit table for F=0 and recruitment as the arithmetic mean of R in 1990-2018, where the SSB in all yeas were above Blim. Top table (A) with predation as in 2018-2020. Middle table (B) with no cod predation. Bottom table (C) with predation as in 1990-2015 which is similar to the level in Horbowy and Based on data from ICES WGBFAS 2021.*

A. **Natural mortality as mean of 2018-2020 (corresponding to the current low cod stock).**

	F factor=	0									
	R max=	99.18	aritmetric mean R 1990-2016			billion		Bias corrected mean is =			98.32839
	million			mean 2018-2020		kg	kg	000' t	000' t	000' t	million
age	N	Fsq	F	M	Mat	West	Weca	catch	SSB spawn	TB 1 Jan	N at spawn
1	99180	0.0000	0.0000	0.3180	0.17	0.0030	0.0051	0	75	298	87334
2	72164	0.2425	0.0000	0.2820	0.93	0.0068	0.0085	0	512	488	64466
3	54431	0.2903	0.0000	0.2780	1	0.0089	0.0096	0	469	484	48703
4	41221	0.3967	0.0000	0.2733	1	0.0098	0.0103	0	379	403	36951
5	31362	0.4678	0.0000	0.2687	1	0.0105	0.0108	0	304	330	28167
6	23973	0.4392	0.0000	0.2667	1	0.0114	0.0117	0	251	272	21548
7	18362	0.3649	0.0000	0.2673	1	0.0120	0.0121	0	199	220	16500
8	14054	0.3649	0.0000	0.2673	1	0.0118	0.0118	0	149	166	12629
9	10757	0.3649	0.0000	0.2673	1	0.0117	0.0118	0	114	126	9667
10	8234	0.3649	0.0000	0.2673	1	0.0117	0.0118	0	87	96	7399
11	6302	0.3649	0.0000	0.2673	1	0.0117	0.0118	0	67	74	5663
12	4824	0.3649	0.0000	0.2673	1	0.0117	0.0118	0	51	56	4335
13	3692	0.3649	0.0000	0.2673	1	0.0117	0.0118	0	39	43	3318
sum								0	2698	3055	

A. **Predation mortality as in 2010-2015 (approximately corresponding to the situation of Horbowy & Luzenczyk 2017).**

PREDATION AS IN HORBOWY and LUZENCYCK 2017 - about as in 2010-2015

	F factor=	0									
	R max=	99.18	aritmetric mean R 1990-2016			billion		Bias corrected mean is =			98.32839
	million			mean 2010-2015		kg	kg	000' t	000' t	000' t	million
age	N	Fsq	F	M	Mat	West	Weca	catch	SSB spawn	TB 1 Jan	N at spawn
1	99180	0.0000	0.0000	0.4427	0.17	0.0030	0.0051	0	72	298	83085
2	63705	0.2425	0.0000	0.3613	0.93	0.0068	0.0085	0	438	431	55132
3	44387	0.2903	0.0000	0.3458	1	0.0089	0.0096	0	372	394	38652
4	31409	0.3967	0.0000	0.3385	1	0.0098	0.0103	0	282	307	27432
5	22390	0.4678	0.0000	0.3338	1	0.0105	0.0108	0	212	236	19591
6	16035	0.4392	0.0000	0.3328	1	0.0114	0.0117	0	164	182	14036
7	11495	0.3649	0.0000	0.3342	1	0.0120	0.0121	0	121	138	10057
8	8230	0.3649	0.0000	0.3342	1	0.0118	0.0118	0	85	97	7200
9	5892	0.3649	0.0000	0.3342	1	0.0117	0.0118	0	61	69	5155
10	4218	0.3649	0.0000	0.3342	1	0.0117	0.0118	0	44	49	3691
11	3020	0.3649	0.0000	0.3342	1	0.0117	0.0118	0	31	35	2642
12	2162	0.3649	0.0000	0.3342	1	0.0117	0.0118	0	22	25	1892
13	1548	0.3649	0.0000	0.3342	1	0.0117	0.0118	0	16	18	1354
sum								0	1919	2279	

B. **No predation from cod (corresponding to the collapse of the cod stock).**

WITH NO PREDATION:

	F factor=	0									
	R max=	99.18	aritmetric mean R 1990-2016			billion		Bias corrected mean is =			98.32839
	million					kg	kg	000' t	000' t	000' t	million
age	N	Fsq	F	M	Mat	West	Weca	catch	SSB spawn	TB 1 Jan	N at spawn
1	99180	0.0000	0.0000	0.2000	0.17	0.0030	0.0051	0	79	298	91555
2	81202	0.2425	0.0000	0.2000	0.93	0.0068	0.0085	0	595	549	74959
3	66482	0.2903	0.0000	0.2000	1	0.0089	0.0096	0	591	591	61371
4	54431	0.3967	0.0000	0.2000	1	0.0098	0.0103	0	516	532	50246
5	44564	0.4678	0.0000	0.2000	1	0.0105	0.0108	0	444	469	41138
6	36486	0.4392	0.0000	0.2000	1	0.0114	0.0117	0	393	414	33681
7	29872	0.3649	0.0000	0.2000	1	0.0120	0.0121	0	333	357	27576
8	24457	0.3649	0.0000	0.2000	1	0.0118	0.0118	0	266	289	22577
9	20024	0.3649	0.0000	0.2000	1	0.0117	0.0118	0	218	234	18485
10	16394	0.3649	0.0000	0.2000	1	0.0117	0.0118	0	179	192	15134
11	13423	0.3649	0.0000	0.2000	1	0.0117	0.0118	0	146	157	12391
12	10989	0.3649	0.0000	0.2000	1	0.0117	0.0118	0	120	128	10145
13	8997	0.3649	0.0000	0.2000	1	0.0117	0.0118	0	98	105	8306
sum								0	3978	4315	

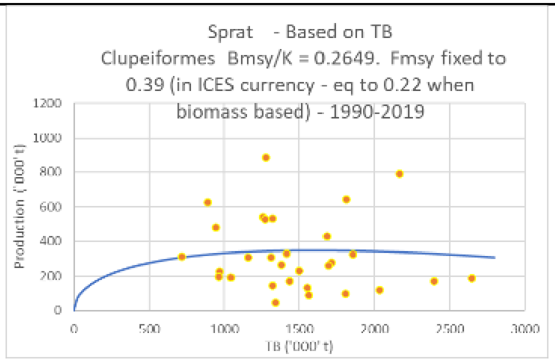
Conclusion of …available science…

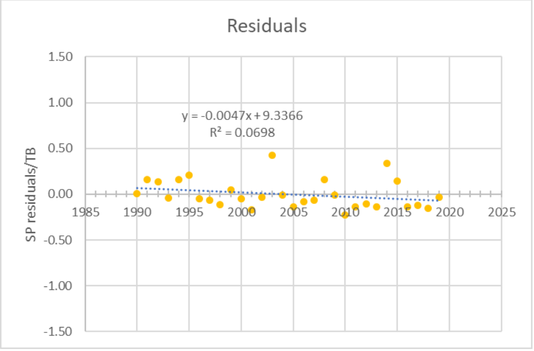
- Cod predation on sprat has varied a lot over the period 1974-2019. If cod is regarded as a part the environment for sprat two regimes can be identified, one in 1974-1989 with a high cod predation and one in 1990-2018 with a low cod predation.
- Except for cod predation no regime shifts could be identified.
- Competition for food with herring in 1990-2018 rather low and constant.
- When density dependence in growth of sprat is considered, the K should less 2300 kt.
- If cod predation is regarded as a separate “fishing fleet”, K should be less than 3500 kt.

…alternative Surplus Production Models –
informed by available science

a) Shape “Clupeiformes”
Fmsy fixed

K (TB)	6024
TBmsy	1596
SSBmsy	1205
MSY	350
R^2	0.31
AICc	16.6





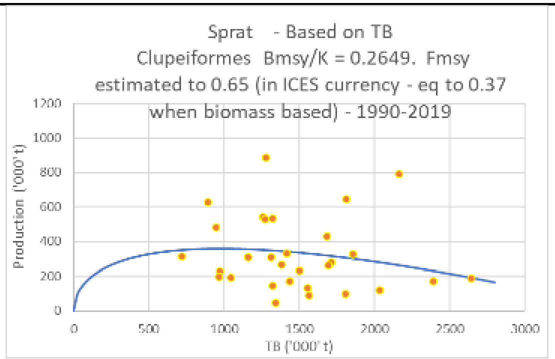
K inconsistent with available science

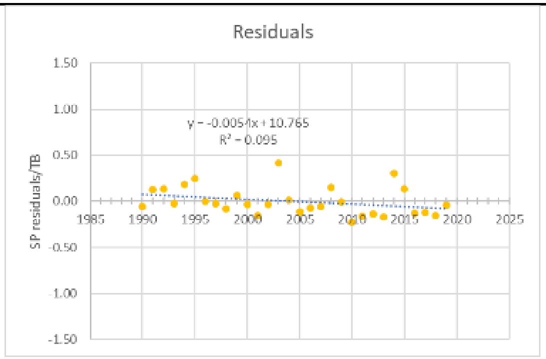
AICc low.

1 parameter estimated

b) Shape “Clupeiformes”
Fmsy estimated

K (TB)	3684
TBmsy	976
SSBmsy	668
MSY	359
R^2	0.33
AICc	19.4





K inconsistent with available science

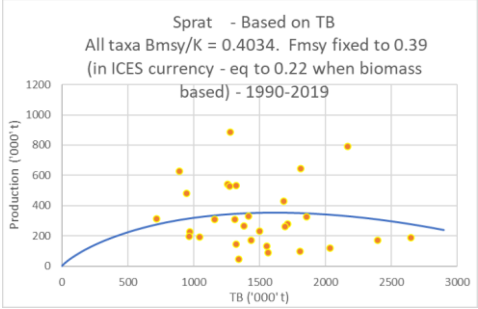
AICc high.

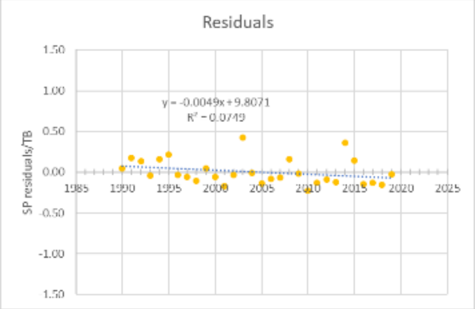
2 parameters estimated

…more alternative models

c) Shape “All taxa”
Fmsy fixed

K (TB)	3997
TBmsy	1615
SSBmsy	1220
MSY	355
R^2	0.29
AICc	16.8





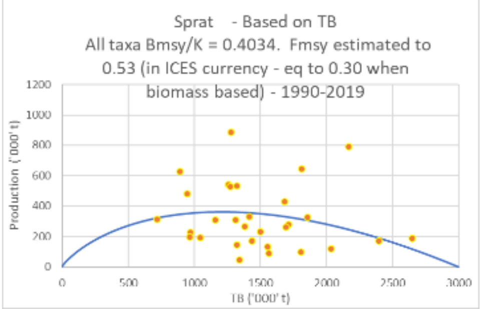
K inconsistent with available science

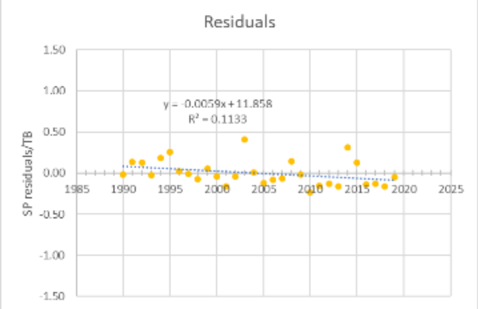
AICc low

1 parameter estimated

d) Shape “All taxa”
Fmsy estimated

K (TB)	2996
TBmsy	1208
SSBmsy	864
MSY	362
R^2	0.31
AICc	19.5





K consistent with available science altough a bit high

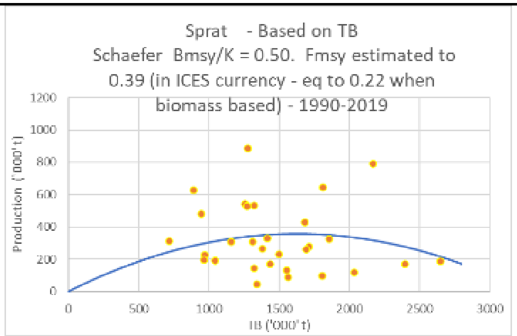
AICc high

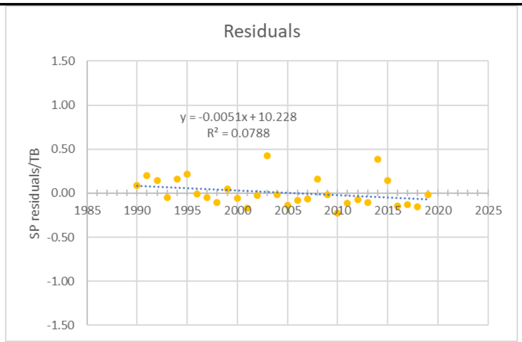
2 parameters estimated

…and more alternatives

e) Schaefer
Fmsy fixed

K (TB)	3254
TBmsy	1627
SSBmsy	1229
MSY	357
R^2	0.27
AICc	17.1





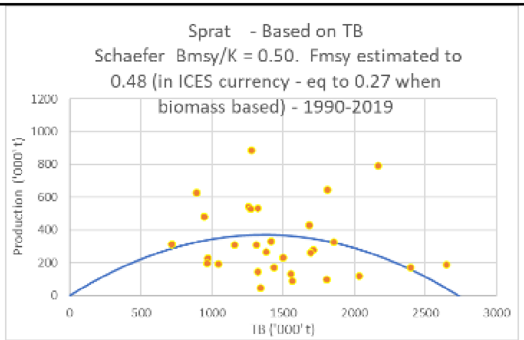
K inconsistent with available science

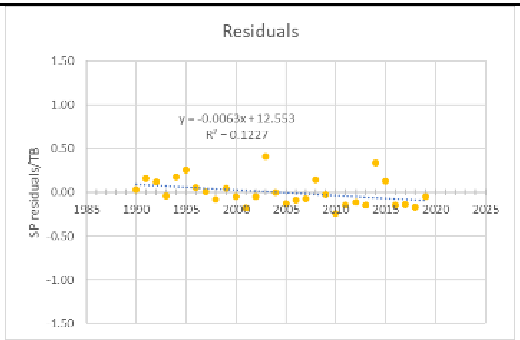
AICc low.

1 parameter estimated

f) Schaefer
Fmsy estimated

K (TB)	2733
TBmsy	1367
SSBmsy	997
MSY	369
R^2	0.29
AICc	19.8





K consistent with available science, although a bit high.

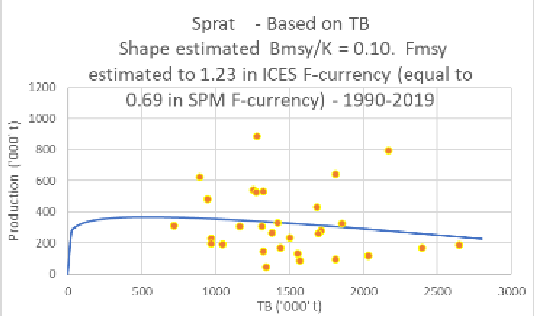
AICc high.

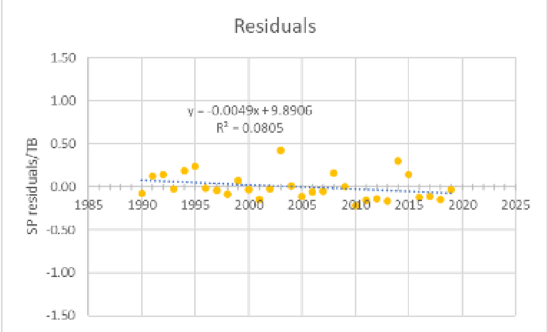
2 parameters estimated

…and more alternatives

g) Shape estimated, Fmsy estimated

K (TB)	5253
TBmsy	537
SSBmsy	256
MSY	372
R^2	0.33
AICc	23.0



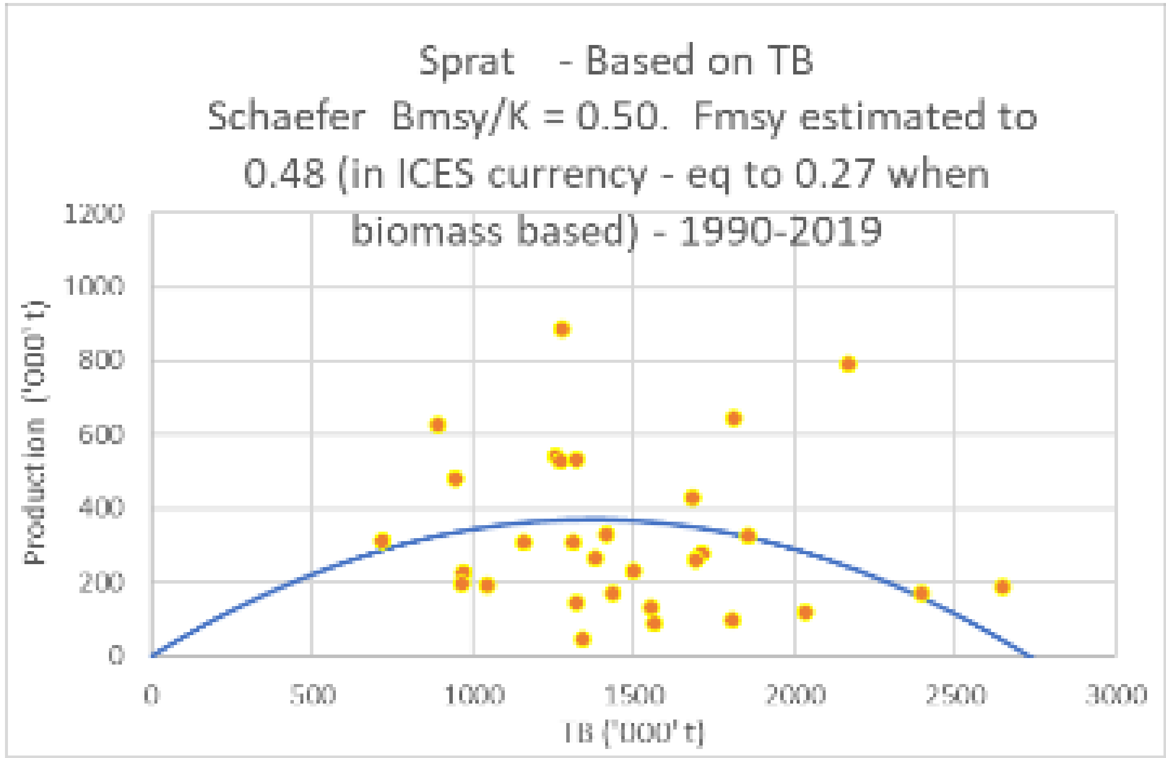


K inconsistent with available science

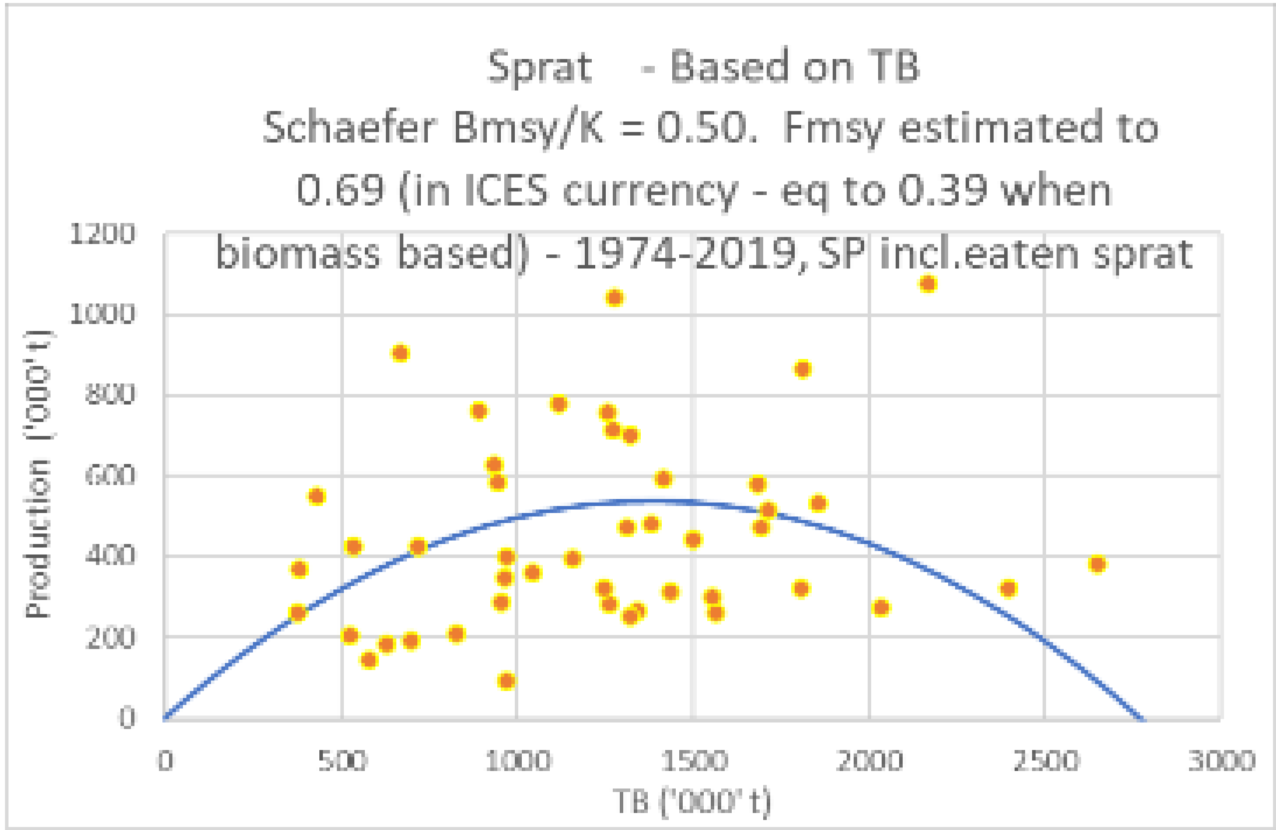
AICc high.

3 parameters estimated

Conclusion about the best SPM

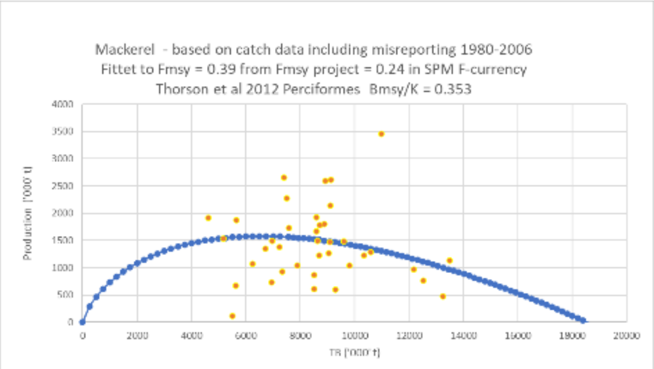


…when cod predation included as a "production" – note here that Fmsy includes predation mortality

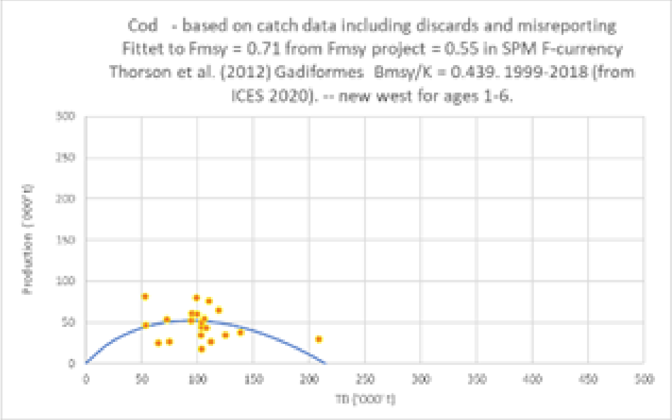


Six stock examples of final SPMs – all quite variable annual production – mainly reflecting variable recruitment

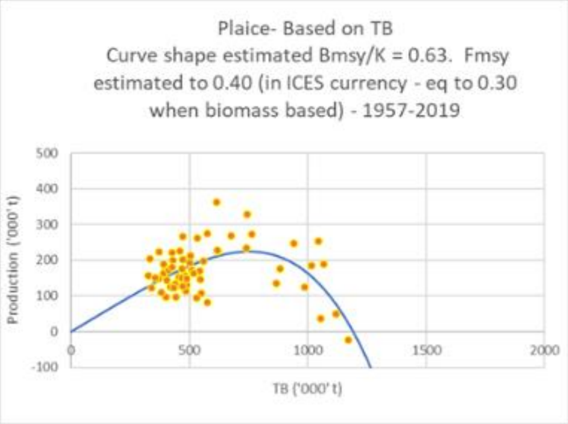
Mackerel - Northeast Atlantic



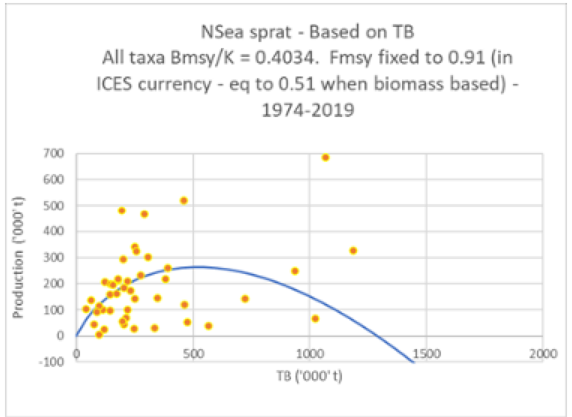
Cod - North Sea



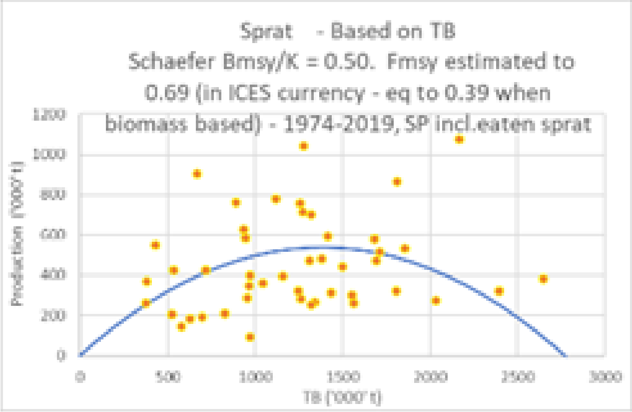
Plaice - North Sea



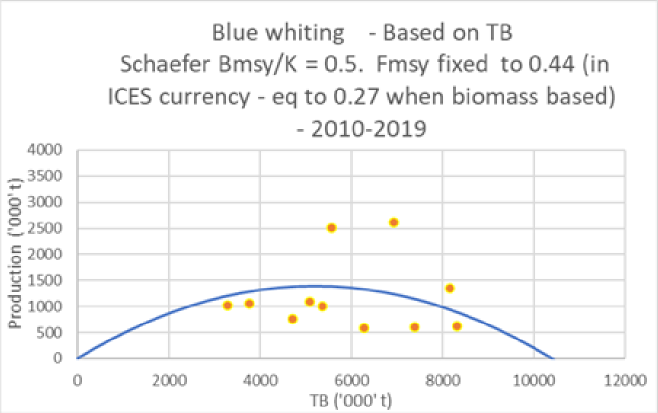
Sprat - North Sea



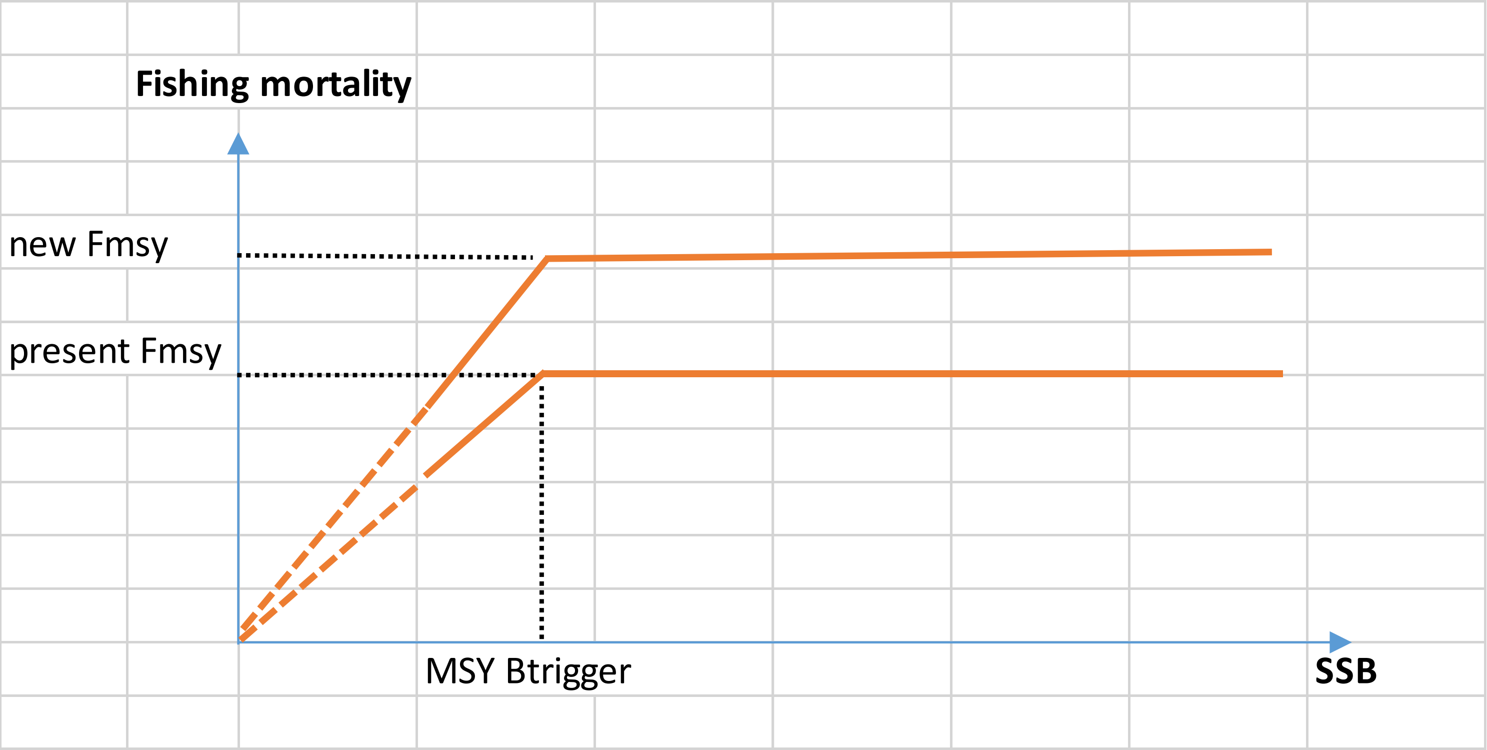
Sprat - Baltic Sea



Blue whiting - Northeast Atlantic



Harvest Control Rule still very important and will take care of the ”precautionary approach”



ICES type HCR

Using SPM as Operating Model in MSEs

SPM = Surplus Production Model) MSE = Management Strategy Evaluation

The simulations are done as described below:

- 1) start with the observed TB (2020).
- 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.

In this way it is a partial feedback MSE because the TAC in each future year is based on observed quantities rather than on OM quantities. It is based on the observed TB and SSB estimated each year from the assessment model simulated via empiric observation error. Obviously, the SPM OM cannot provide stock number by age each year in the simulations so an age-based assessment cannot be done in future years in the simulations. The approach therefore falls under the category: a "short-cut" MSE (see ICES 2020b). The observation error is based on the historical performance of the assessment.

Don't read now – read later if you need the details. when you have the SPM model it is straight forward MSE

- The approach therefore falls under the category: a “short-cut” MSE (see ICES 2020b).
- The observation error is based on the historical performance of the assessment to estimate TB (Total stock Biomass).

Results

Yield in '000't

Fishing mortality

	Yield															
0.50	236	236	241	243	238	243	252	252	258	260	255	260	267	268	268	275
0.48	235	244	247	250	255	249	258	256	264	264	265	272	272	270	275	277
0.46	240	251	250	251	257	257	258	265	264	271	267	277	274	273	280	282
0.44	254	260	259	255	263	265	268	277	277	278	283	283	282	287	285	287
0.42	262	263	270	273	278	277	273	279	283	281	283	285	288	292	289	299
0.40	282	290	280	282	286	292	292	285	289	296	292	297	298	299	301	298
0.38	297	300	304	297	309	313	301	297	313	308	307	309	306	309	310	315
0.36	323	321	322	320	320	322	328	322	324	324	322	320	322	324	325	325
0.34	336	337	342	341	335	348	336	338	343	336	339	341	335	342	334	341
0.32	355	356	356	349	351	349	349	352	341	348	352	349	349	354	349	353
0.30	357	356	358	361	359	360	357	356	360	356	358	359	357	358	361	356
0.28	364	363	362	361	366	361	363	364	358	364	363	364	363	362	363	364
0.26	361	364	363	366	360	364	364	365	364	361	363	361	362	363	362	364
0.24	358	359	359	359	359	360	357	360	358	357	361	360	361	361	359	358
0.22	354	353	352	352	351	352	350	352	352	353	349	351	351	349	353	353
0.20	339	338	339	340	339	340	342	340	341	338	338	341	342	336	340	339
0.18	326	321	324	324	324	320	323	321	322	323	324	322	325	321	320	327
0.16	304	304	303	304	305	303	303	301	303	304	307	304	303	303	305	304
0.14	279	281	278	280	279	282	281	281	280	278	278	279	280	281	280	280
0.12	253	253	250	251	251	254	254	251	253	252	254	249	251	250	254	254
0.10	220	221	220	221	219	218	220	221	219	219	219	221	219	221	222	220
	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
	Btrigger in '000' t															

Btrigger in '000't

Results - combinations of Btrigger and F that are green in all 4 plots are "good"

Yield

							Yield									
0.50	236	236	241	243	238	243	252	252	258	260	255	260	267	268	268	275
0.48	235	244	247	250	255	249	258	256	264	264	265	272	272	270	275	277
0.46	240	251	250	251	257	257	258	265	264	271	267	277	274	273	280	282
0.44	254	260	259	255	263	265	268	277	277	278	283	283	282	287	285	287
0.42	262	263	270	273	278	277	273	279	283	281	283	285	288	292	289	299
0.40	282	290	280	282	286	292	292	285	289	296	292	297	298	299	301	298
0.38	297	300	304	297	309	313	301	297	313	308	307	309	306	309	310	315
0.36	323	321	322	320	320	322	328	322	324	324	322	320	322	324	325	325
0.34	336	337	342	341	335	348	336	338	343	336	339	341	335	342	334	341
0.32	355	356	356	349	351	349	349	352	341	348	352	349	349	354	349	353
0.30	357	356	358	361	359	360	357	356	360	356	358	359	357	358	361	356
0.28	364	363	362	361	366	361	363	364	358	364	363	364	363	362	363	364
0.26	361	364	363	366	360	364	364	365	364	361	363	361	362	363	362	364
0.24	358	359	359	359	359	360	357	360	358	357	361	360	361	361	359	358
0.22	354	353	352	352	351	352	350	352	352	353	349	351	351	349	353	353
0.20	339	338	339	340	339	340	342	340	341	338	338	341	342	336	340	339
0.18	326	321	324	324	324	320	323	321	322	323	324	322	325	321	320	327
0.16	304	304	303	304	305	303	303	301	303	304	307	304	303	303	305	304
0.14	279	281	278	280	279	282	281	281	280	278	278	279	280	281	280	280
0.12	253	253	250	251	251	254	254	251	253	252	254	249	251	250	254	254
0.10	220	221	220	221	219	218	220	221	219	219	219	221	219	221	222	220
	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
							Btrigger in '000' t									

Risk to SSB to get below Blim

							5% lower SSB									
0.50	304	309	311	316	316	321	340	335	338	358	353	348	362	368	366	376
0.48	317	321	337	317	341	339	349	340	359	365	372	381	382	387	390	391
0.46	331	339	341	344	356	357	363	366	372	380	388	406	405	390	417	407
0.44	358	363	356	363	377	368	385	392	384	406	406	410	419	413	418	430
0.42	366	368	380	396	413	406	395	406	423	421	421	419	452	443	438	452
0.40	422	427	420	434	446	437	412	426	442	461	461	465	459	470	481	468
0.38	482	463	495	478	486	504	487	476	514	500	502	497	502	505	484	511
0.36	543	552	544	546	546	545	561	541	565	540	545	549	534	561	544	551
0.34	606	614	629	613	613	639	622	613	638	595	637	645	603	610	607	621
0.32	702	702	671	676	696	690	680	699	671	679	690	699	681	703	680	715
0.30	773	747	778	752	768	779	757	737	760	744	772	750	753	770	753	757
0.28	831	844	848	839	850	825	815	840	818	821	823	848	818	826	828	858
0.26	903	914	917	914	894	899	930	916	917	892	893	907	934	901	901	905
0.24	978	940	974	969	981	985	979	972	981	972	988	1007	984	987	984	971
0.22	1065	1061	1053	1075	1068	1036	1051	1080	1067	1085	1055	1050	1052	1070	1074	1067
0.20	1135	1150	1133	1106	1132	1117	1131	1133	1124	1146	1132	1137	1148	1140	1148	1120
0.18	1192	1193	1201	1200	1224	1169	1210	1197	1200	1196	1182	1200	1241	1200	1208	1221
0.16	1294	1307	1284	1268	1306	1303	1317	1290	1294	1298	1289	1304	1270	1287	1318	1280
0.14	1360	1385	1321	1362	1369	1396	1374	1381	1377	1364	1372	1371	1389	1383	1402	1395
0.12	1440	1459	1428	1444	1456	1486	1446	1421	1419	1454	1453	1404	1447	1451	1473	1459
0.10	1543	1537	1534	1494	1532	1496	1565	1517	1544	1526	1548	1540	1568	1495	1544	1523
	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
							Btrigger in '000' t									

Annual variation in Yield

							IAV									
0.50	41	39	37	42	42	38	38	42	40	40	38	44	44	41	41	42
0.48	37	37	38	36	35	35	35	39	38	37	36	39	41	40	38	40
0.46	34	36	31	35	33	30	34	33	34	37	36	32	36	39	35	40
0.44	29	31	31	31	31	26	31	34	35	30	36	35	36	36	35	35
0.42	27	26	24	25	26	22	32	30	29	26	29	30	28	32	34	33
0.40	19	20	21	22	20	17	26	24	24	23	24	26	26	28	27	29
0.38	16	18	16	18	18	17	19	20	19	19	19	22	23	25	24	25
0.36	18	18	18	17	17	17	16	17	18	18	19	18	21	16	20	21
0.34	17	17	17	18	17	17	16	17	15	18	16	16	17	17	18	17
0.32	17	16	16	17	15	17	18	16	16	17	17	16	17	16	16	14
0.30	17	18	16	16	15	16	16	17	16	17	16	17	16	15	17	17
0.28	16	16	16	17	15	15	18	16	18	17	16	16	17	16	17	16
0.26	16	15	15	16	16	16	15	17	16	17	16	16	14	17	15	18
0.24	17	17	18	16	16	18	14	17	17	15	16	15	16	16	18	16
0.22	18	17	16	15	15	18	16	15	17	16	15	16	17	15	15	15
0.20	14	15	16	17	17	16	17	16	16	16	16	16	15	15	17	17
0.18	17	16	16	17	16	14	16	17	16	16	17	14	15	16	13	18
0.16	16	17	17	17	16	15	15	16	14	15	17	15	15	14	15	16
0.14	15	14	17	15	15	14	15	16	15	15	15	16	15	15	14	14
0.12	16	15	16	15	14	15	15	15	16	15	17	14	15	14	18	16
0.10	15	15	14	17	16	13	14	17	14	17	14	14	13	14	16	16
	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
							Btrigger in '000' t									

SSB

							SSB									
0.50	392	394	401	406	398	408	429	428	439	448	439	446	464	465	468	481
0.48	394	413	417	427	435	429	448	446	459	462	468	479	479	481	491	497
0.46	411	431	433	435	448	450	447	470	469	480	480	492	499	500	505	517
0.44	443	458	457	451	467	472	482	501	499	504	519	517	518	530	530	538
0.42	468	476	488	498	506	510	502	516	527	525	529	534	541	558	547	568
0.40	525	547	530	526	539	556	556	536	554	566	560	576	571	577	583	577
0.38	576	589	602	582	612	623	594	585	614	610	605	613	620	618	624	640
0.36	674	667	672	665	666	670	694	671	675	678	667	672	671	686	686	688
0.34	741	752	770	766	757	785	742	754	768	740	753	755	745	774	739	759
0.32	860	850	855	832	838	825	829	846	804	819	834	831	834	857	832	850
0.30	913	917	915	935	922	927	925	908	932	917	919	925	901	925	924	909
0.28	1001	1030	1008	1002	1010	1007	996	1009	974	1007	1002	1010	990	993	1013	997
0.26	1093	1092	1087	1101	1090	1102	1118	1104	1095	1085	1100	1082	1094	1080	1090	1095
0.24	1182	1180	1189	1173	1184	1193	1180	1177	1186	1179	1176	1172	1192	1187	1175	1174
0.22	1277	1268	1262	1265	1256	1275	1268	1271	1261	1261	1259	1262	1275	1258	1271	1260
0.20	1360	1356	1361	1361	1353	1364	1352	1350	1353	1360	1350	1341	1335	1359	1371	1364
0.18	1454	1442	1452	1444	1446	1442	1447	1443	1441	1438	1440	1453	1442	1451	1444	1447
0.16	1538	1534	1534	1543	1531	1545	1541	1534	1536	1544	1539	1541	1544	1530	1538	1543
0.14	1627	1625	1625	1632	1636	1634	1634	1630	1632	1630	1627	1640	1632	1629	1629	1620
0.12	1718	1718	1723	1726	1731	1724	1721	1721	1721	1722	1718	1729	1733	1732	1725	1721
0.10	1810	1819	1812	1817	1818	1815	1821	1811	1808	1820	1812	1819	1821	1816	1816	1812
	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600
							Btrigger in '000' t									

Figure 7. *Baltic sprat. Results of long-term forecast simulations using the surplus production operating model with a Blim set to 410 kt. Top left panel: Yield in kt. Top right panel: Risk of SSB falling below Blim 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 mean values of 200 simulations.*

Conclusion

Continue using age-structed assessment models for state of the stock and short-term forecast - but use Surplus Production Models for MSEs and for estimating Fmsy and Bmsy


Thank you !

- Supplementary slides

Robustness

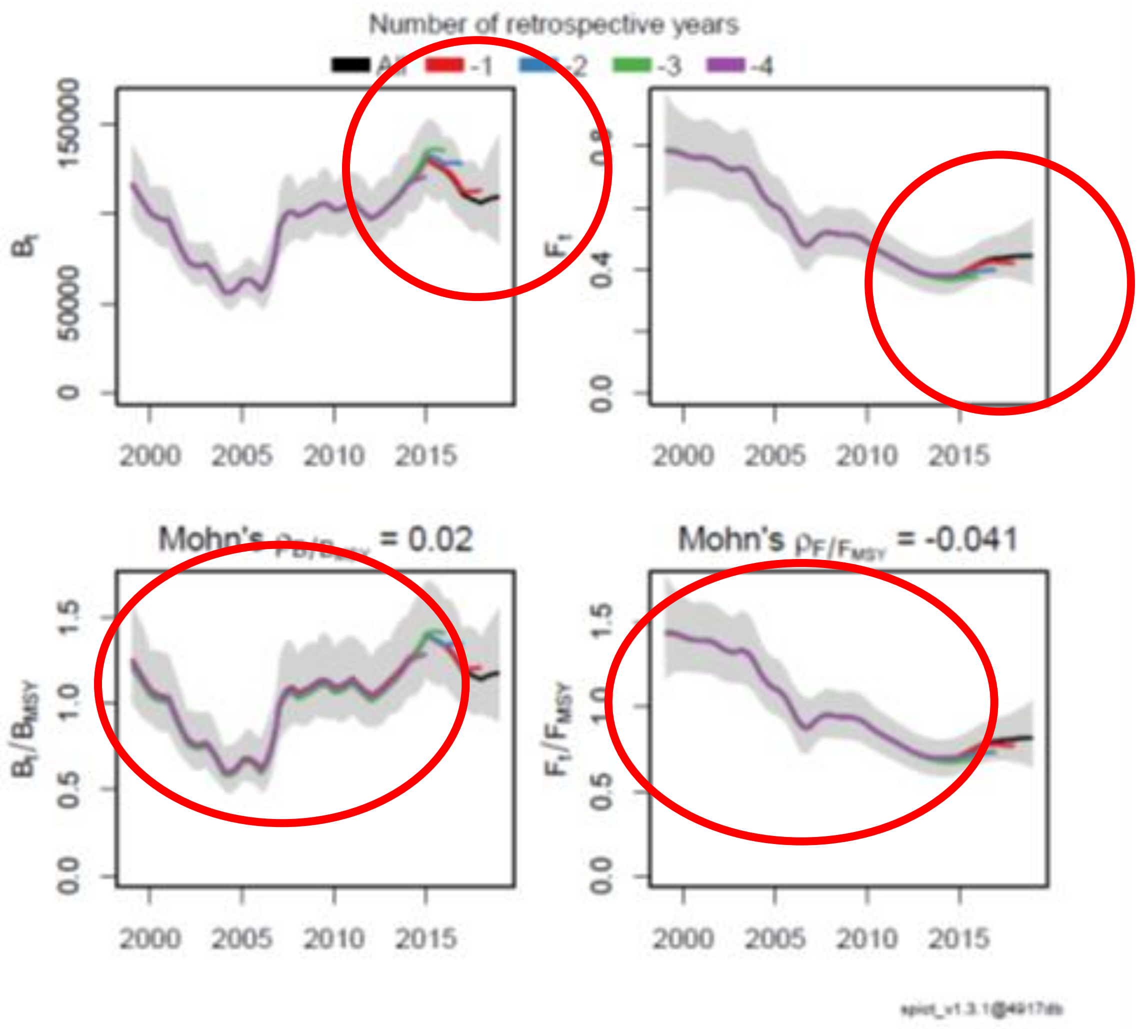
Plaice - North Sea....very robust to adding a new data year.

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

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.

Argument against the new Fmsy values

”ICES Fmsy includes a precautionary element, the new ones does not…”

Yes, right… …and the reasons are:

- We don’t think it is correct to include a management objective in a scientific concept like Fmsy. Science should be neutral, unbiased and non-political.
- The present Fmsy is not the fishing pressure that gives msy (maximum sustainable catch) – very confusing and non-transparent.
- Inconsistent with what is done on other parts of the World.
- Will make the management in the Northeast Atlantic look worse than it is, because fishing pressures will be compared with too low Fmsy values (See e.g. FAO The State of Worlds Fisheries, 2020).

But the management is still precautionary, because F is reduced when the stock is small (see previous slide) - only a 5% risk to get below Blim

The SPM approach often used for data-poor stocks

- Why should data rich stocks have a higher degree of precautionarity?
- It should rather be the other way around - the less data you have about a stock, the more precautionary you should be!!