European Union
European Maritime and Fisheries Fund

Ministry of Environment and Food of Denmark
Danish Veterinary and Food Administration

UNIVERSITY OF COPENHAGEN

Ecosystem functioning and sustainable fishing in the Northeast Atlantic – the MSE-project

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My background

- Biology and mathematics/statistics University of Copenhagen
- Greenland Fisheries Investigations 1982-1983
- DTU AQUA 1983-1992
- International Council for the Exploration of the Sea (ICES) 1992-2016
- Nordic Marine Think Tank 2016-2019
- University of Copenhagen 2020-present

…continued.

- Fish stock assessment - 39 years
- Scientific advice - 33 years
- Multispecies models - 38 years
- External reviewer of fisheries science globally – 18 years
- FAO training and fisheries statistics – 35 years
- Northeast Atlantic, Mediterranean, Black Sea, Indian Ocean, Pacific, Mid- and Southern Atlantic

Ecosystem approach to fisheries management

Ecosystem Fmsy-project

2016-2019: 3 million DKK - EU, Danish Ministry, Norwegian Ministry, Nordic Council of Ministers

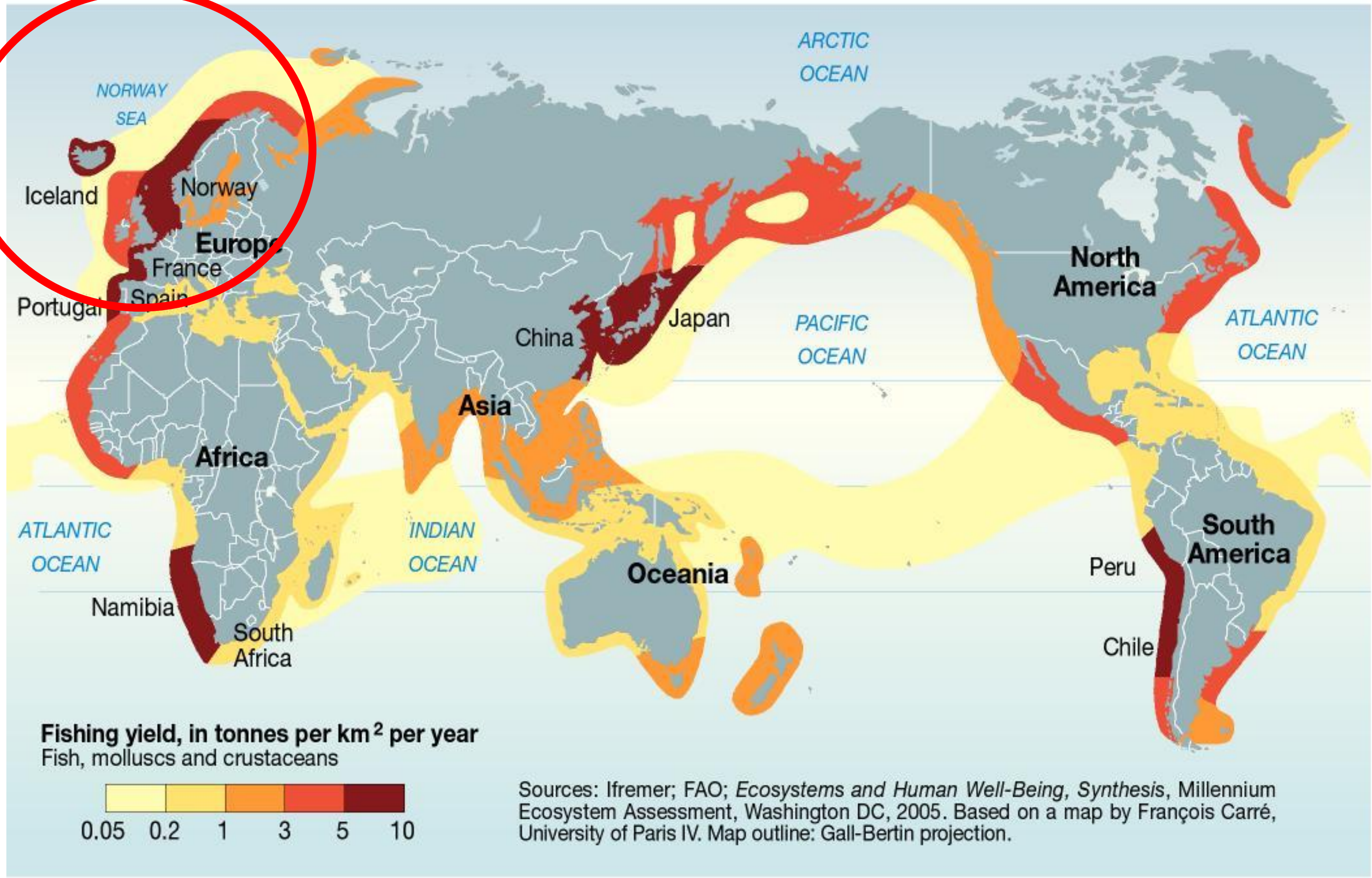
MSE-project

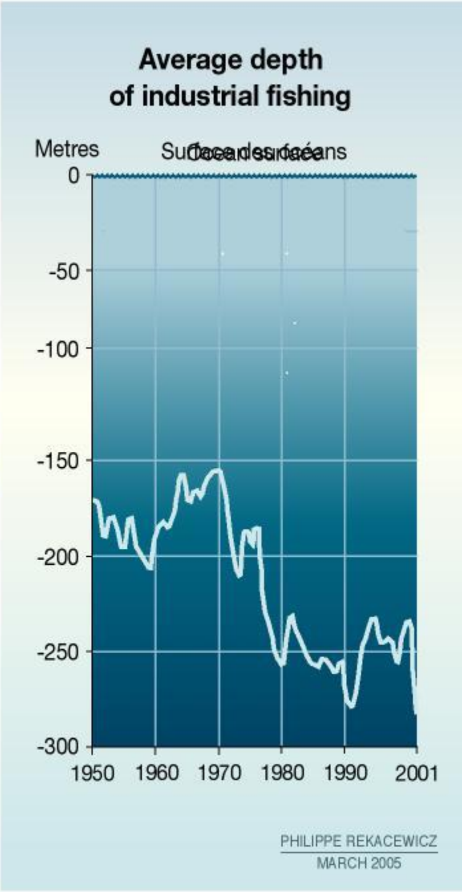
2020-2023: 3.5 million DKK – EU, Danish Ministry

Ecosystem approach to fisheries management

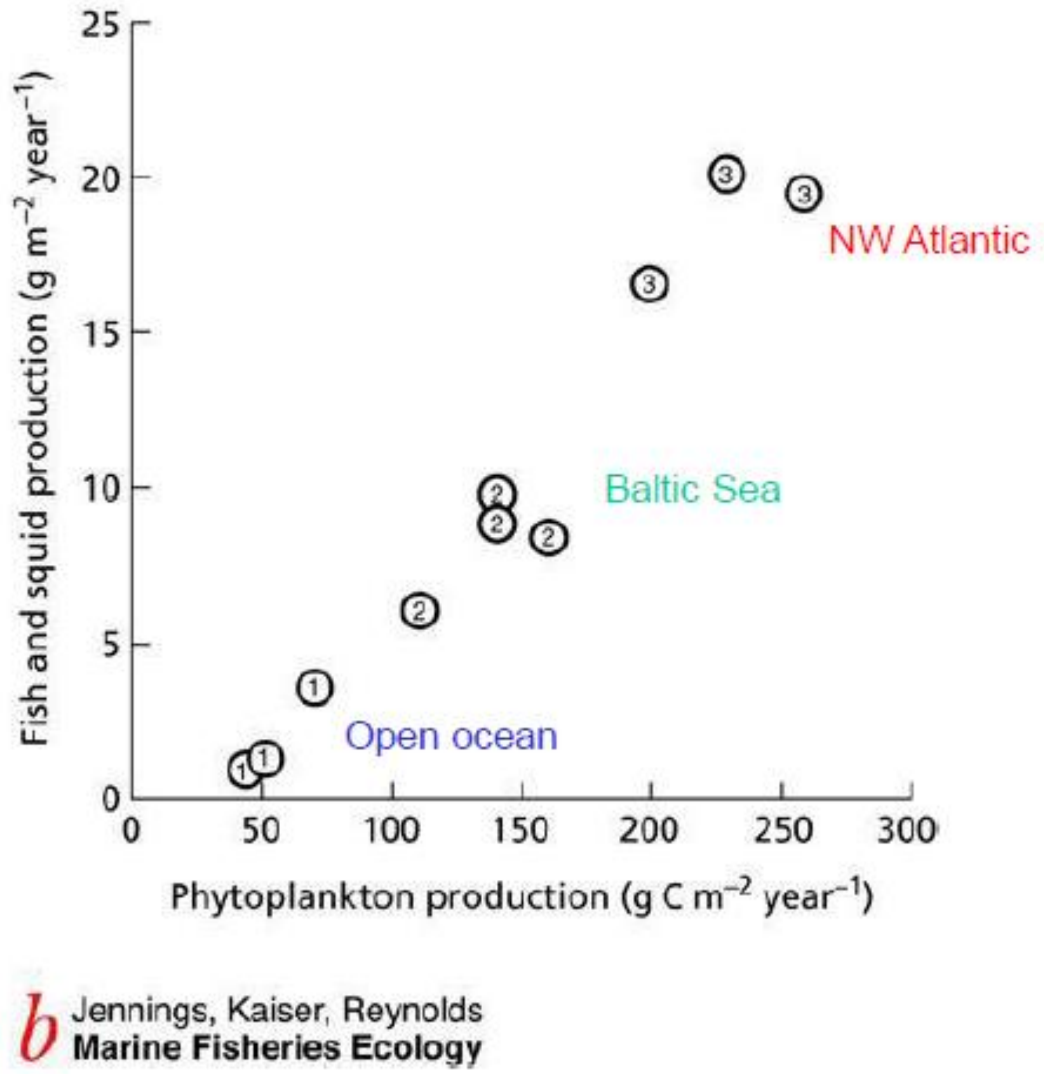
- Everybody say they will do it
- The fact is: scientific bodies giving advice to managers still use the old fashioned single species approach

Global fish production

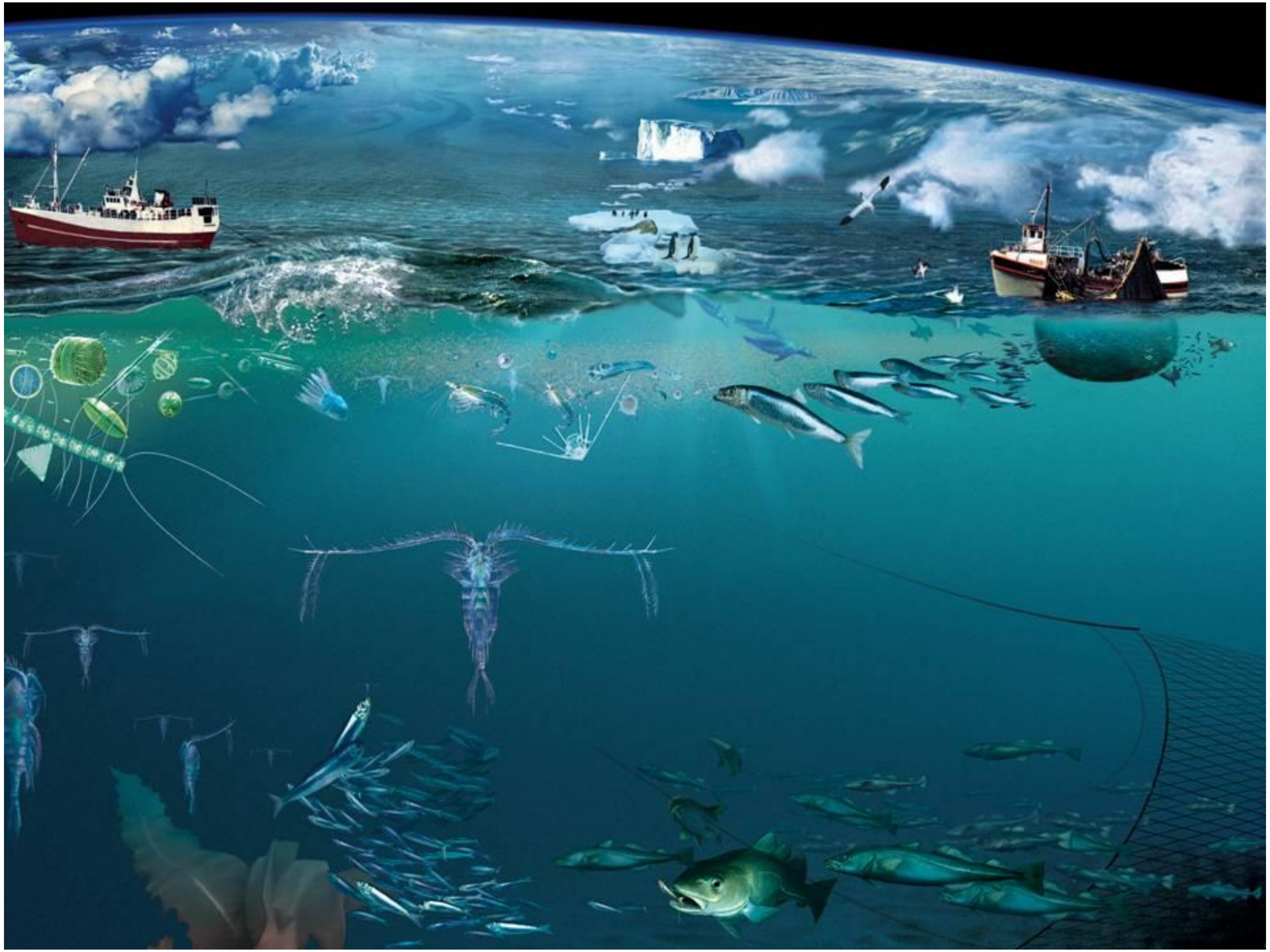




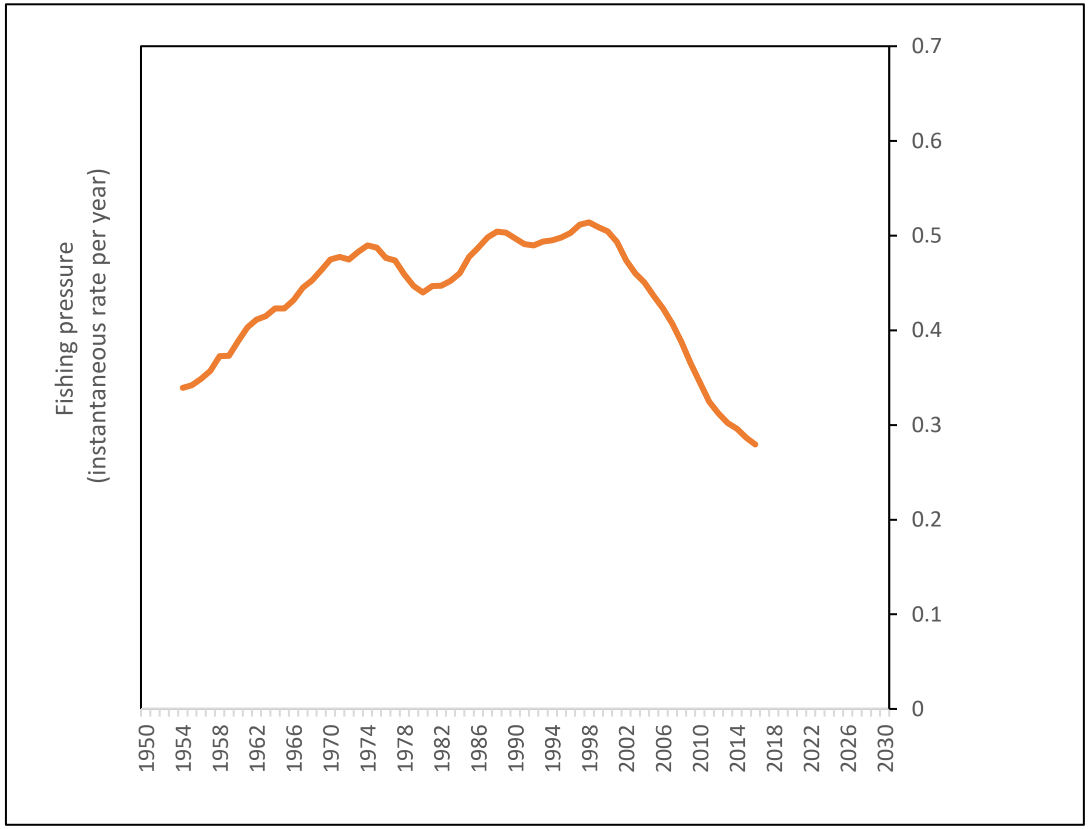
Yield depends on algae production



Northeast Atlantic



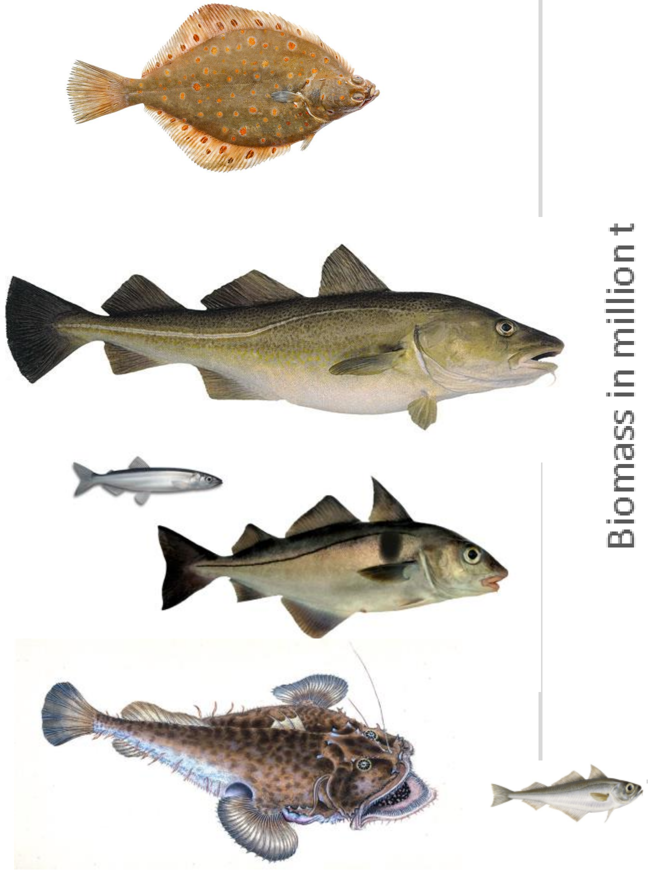
Mean fishing pressure in the Northeast Atlantic – mean of 53 ICES data rich stocks.

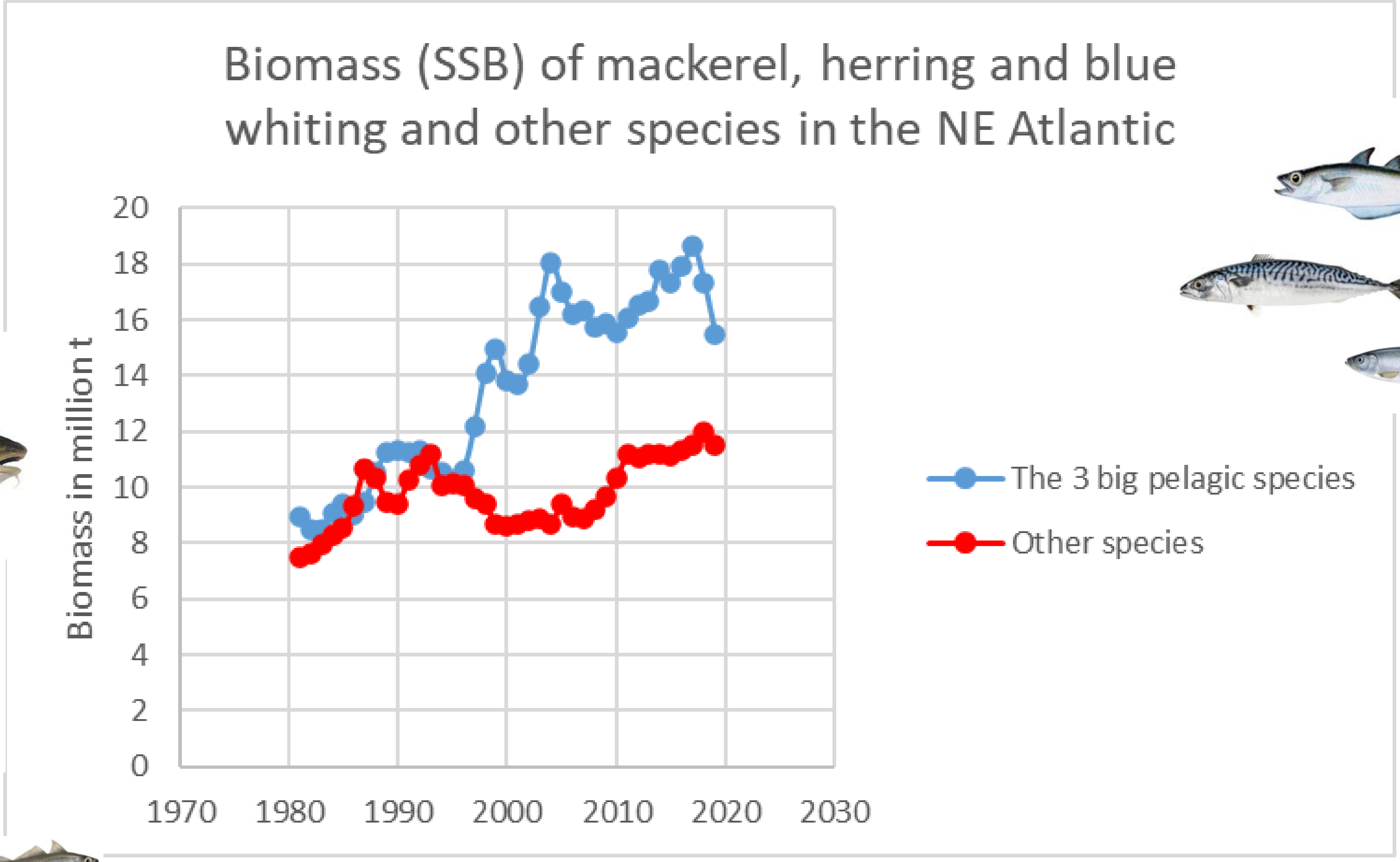


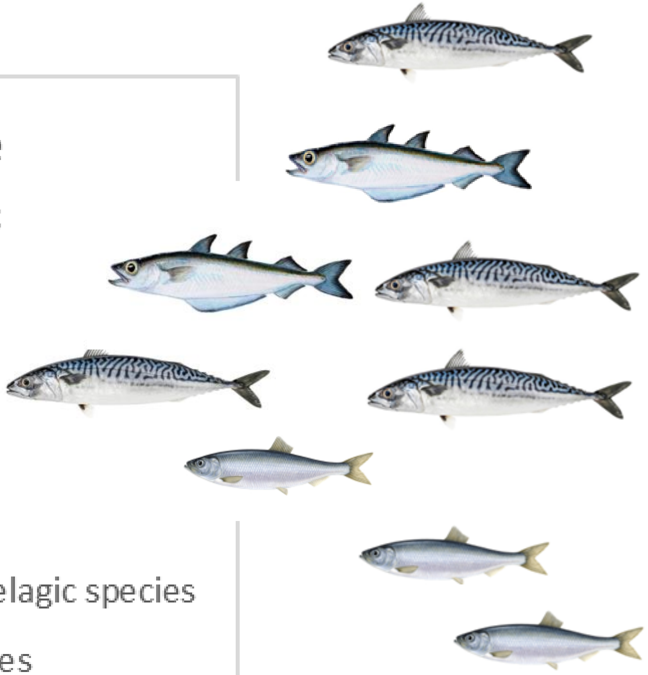
Succes story – Over-fishing has end!!

…about 10 year ago

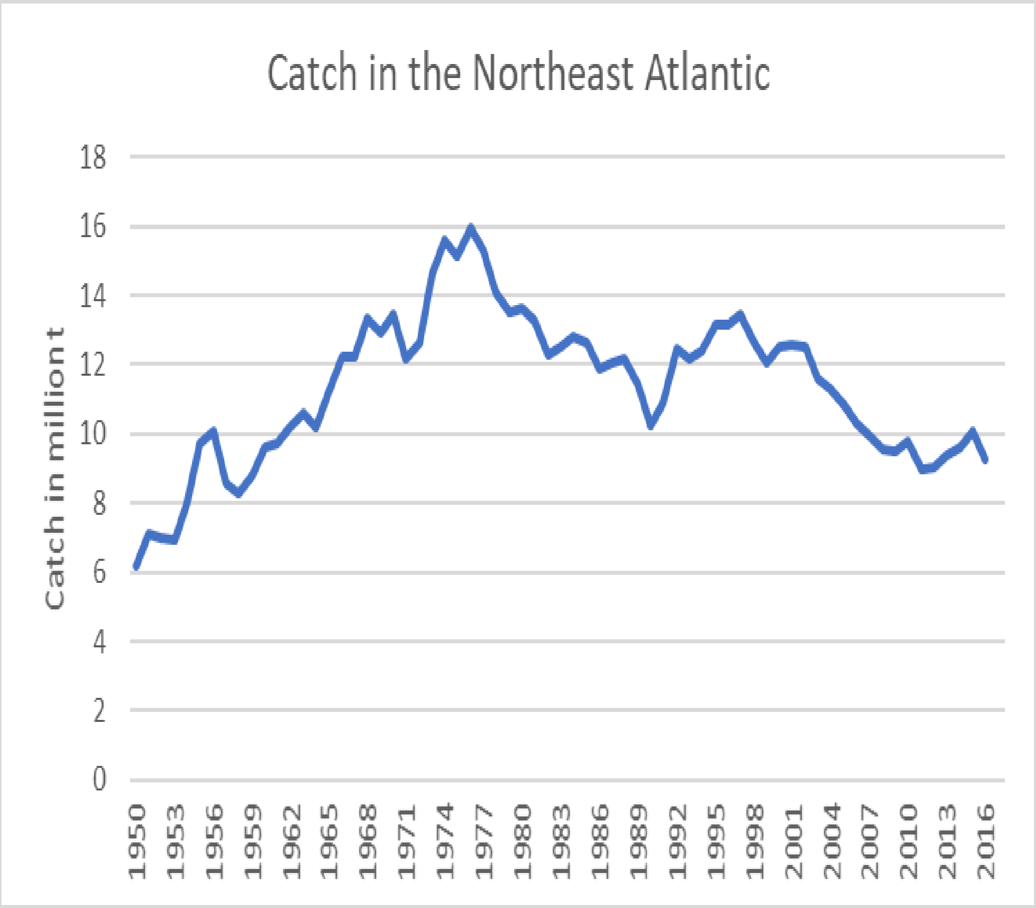
Stocks increased – especially ”the 3-big pelagics”







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



North Sea plaice

Our goal:

– to supply the managers with **improved** targets - the blue horizontal line for Fishing pressure

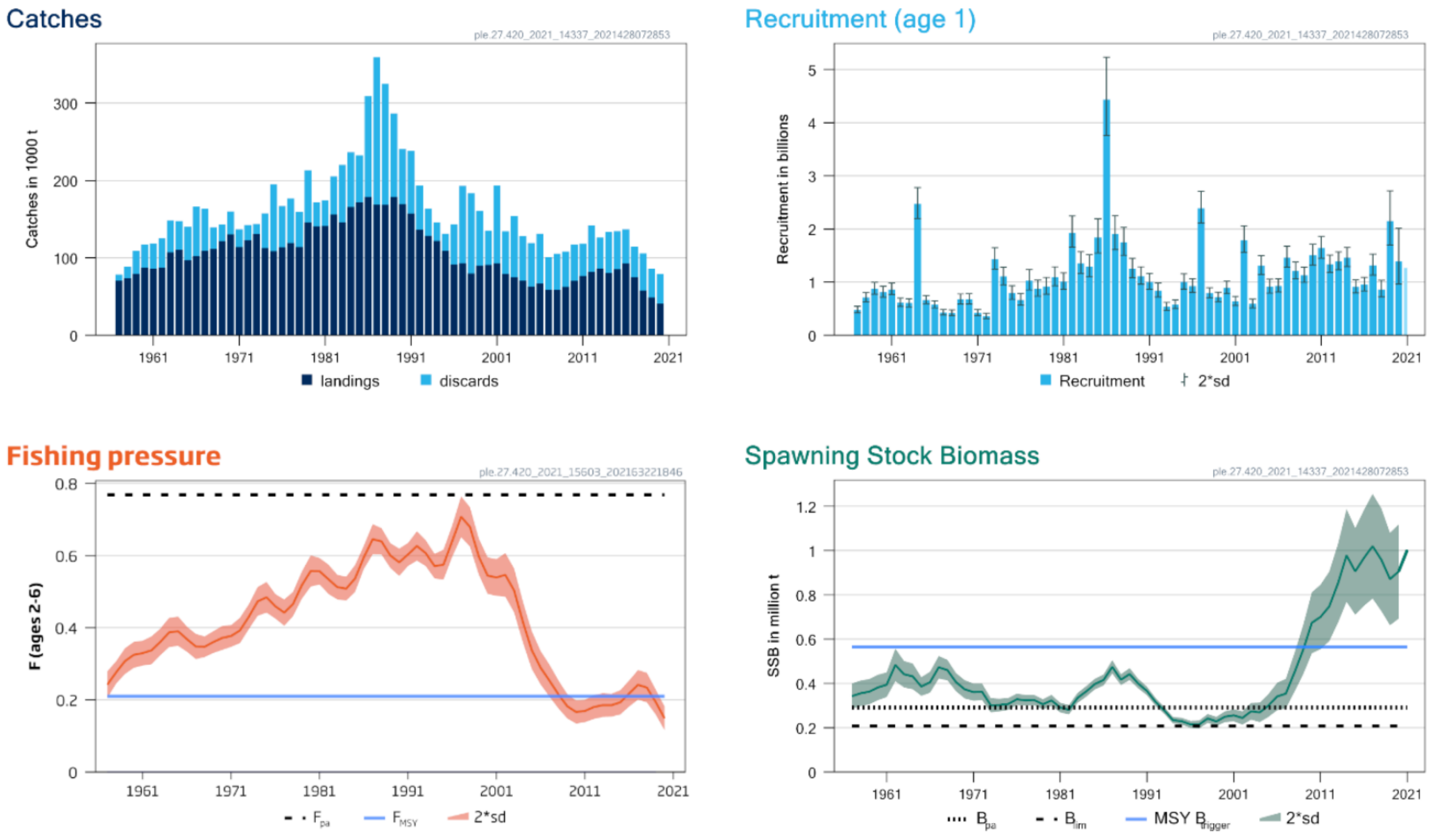


Figure 1 Plaice in Subarea 4 and Subdivision 20. Summary of the stock assessment. The assumed recruitment value for 2021 is shaded in a lighter colour.

Monitoring for 2 billion DKK each year!

- Research vessel surveys
- Sampling of commercial catches to determine species and age composition
- Scientists work
- The cost is 2% of the value of the catch
- EU pays half

Objective:
annual quota setting

Unfortunately, a systematic bias in the current science – we have a suggestion for a solution

Problem:

Use of single-species models that ignore density dependent predation, food competition, and diseases.

Reason:

The current cohort-based models lack sub-models for each issue.

Solution:

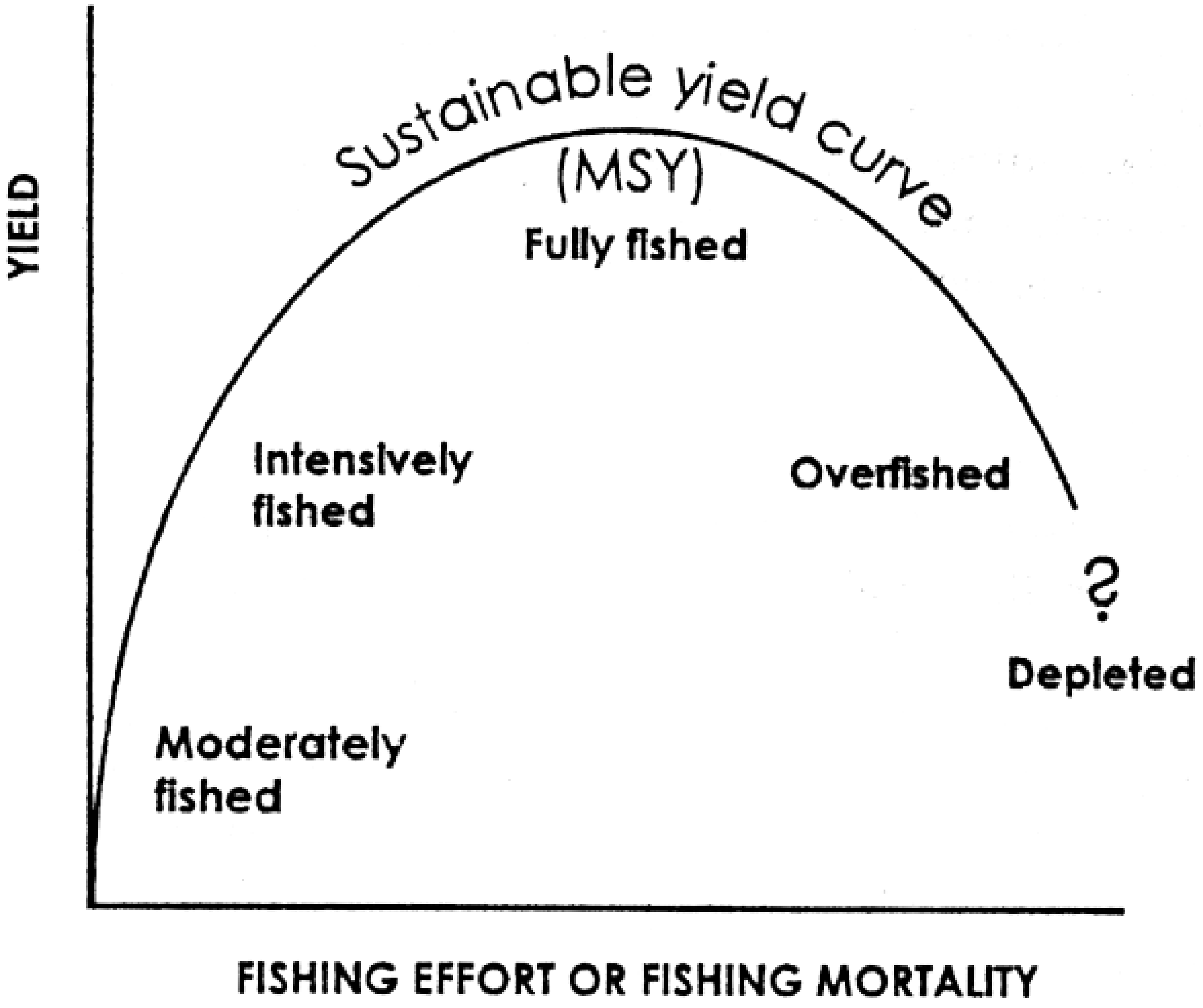
Simpler biomass based models – Surplus Production Models – include all DD (not disentangled though – which in fact is only "nice to have" but not needed)

Surplus Production Model

- Fmsy

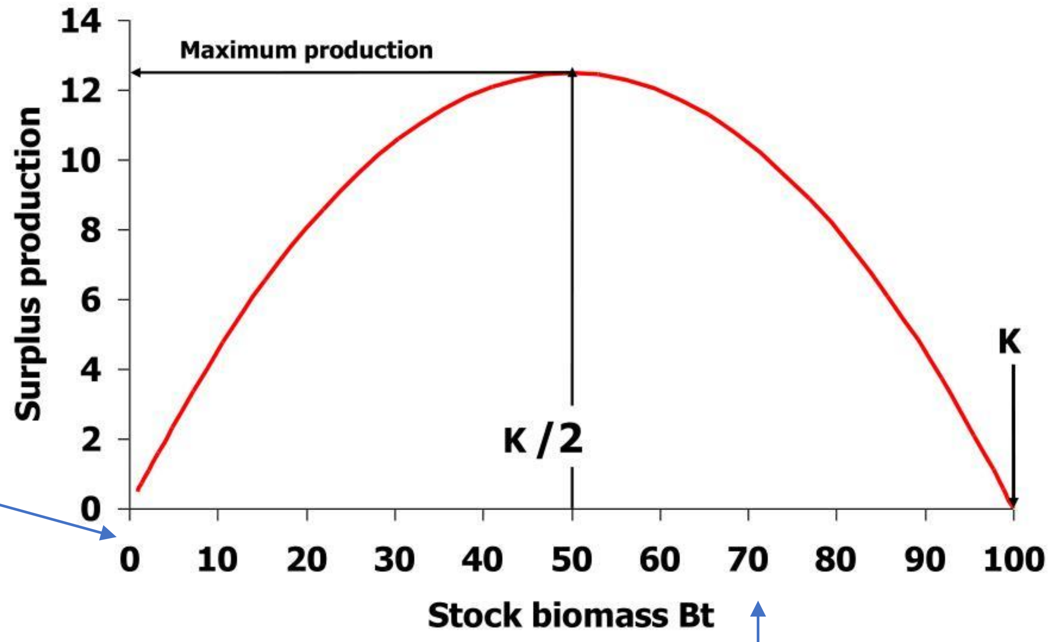
Fishing pressure at the peak of yield.

Equilibrium assumed



…expressed as a function of stock biomass…

…no equilibrium assumption
…surplus production = yield + change in stock biomass



Very high fishing

No fishing

Moderate fishing

Example: Northeast Atlantic mackerel.

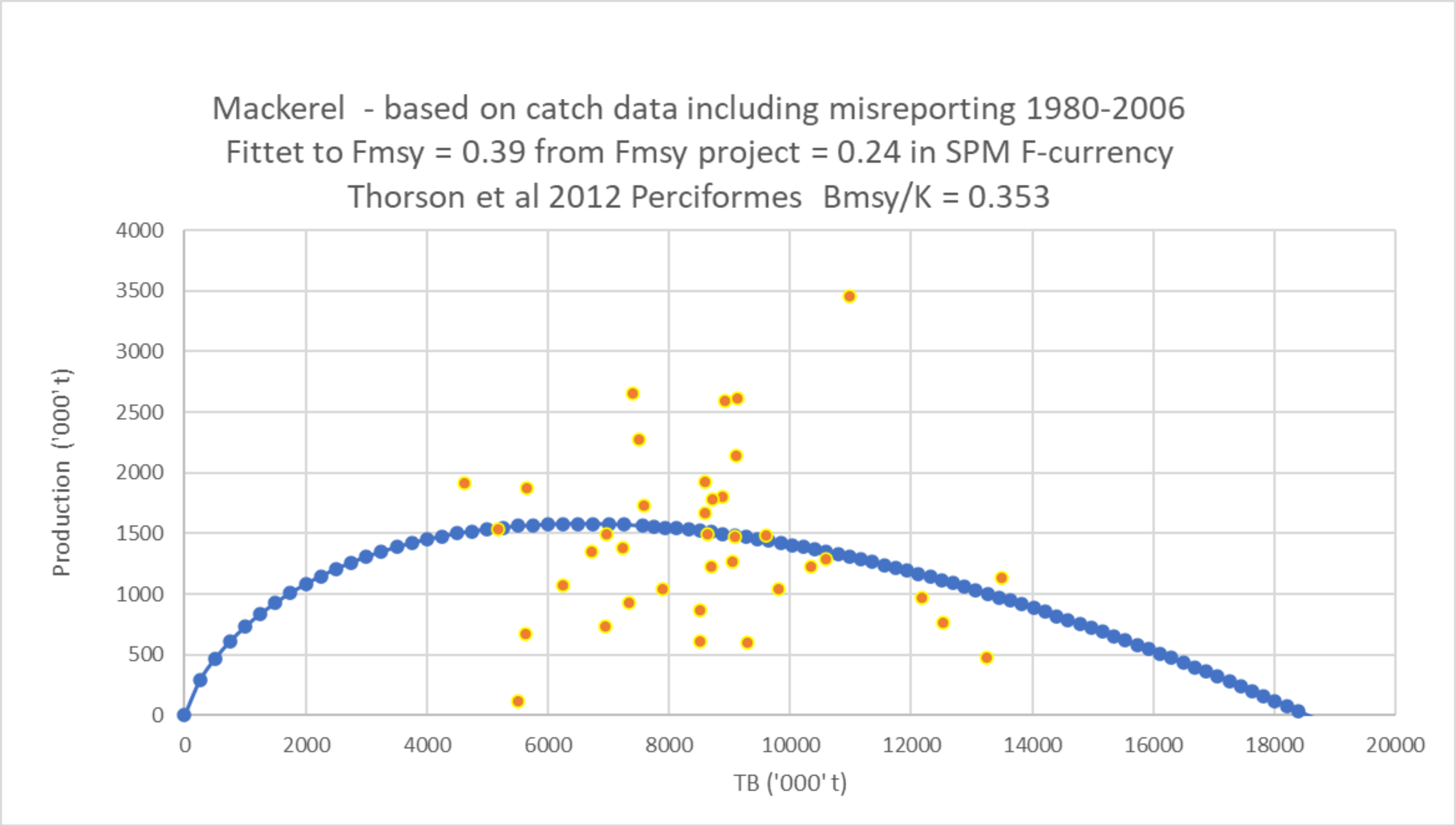
Note that the x-axis is TB (Total Biomass of the stock) – equilibrium not needed!

Production (annual):

catch

+

increase in stock size



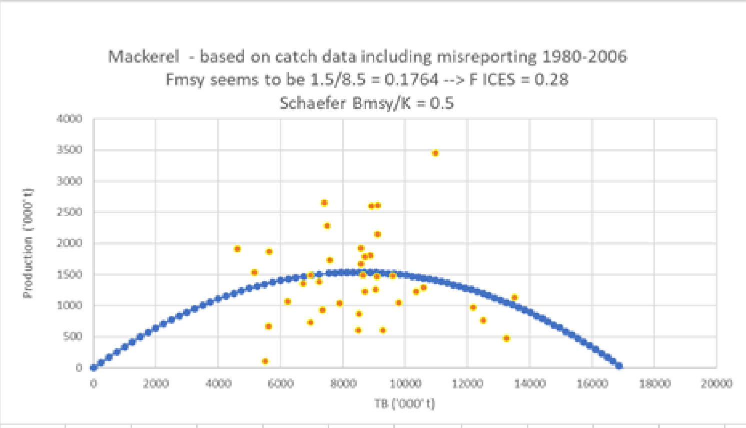
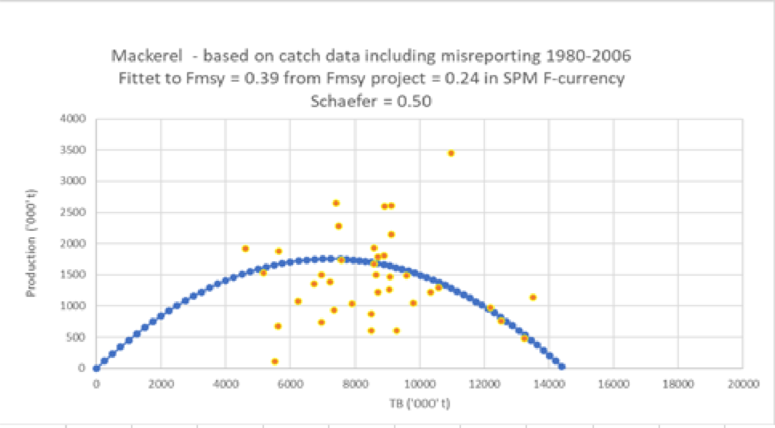
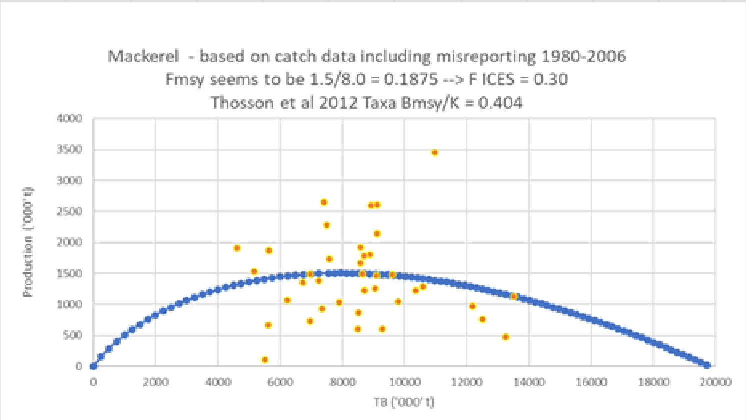
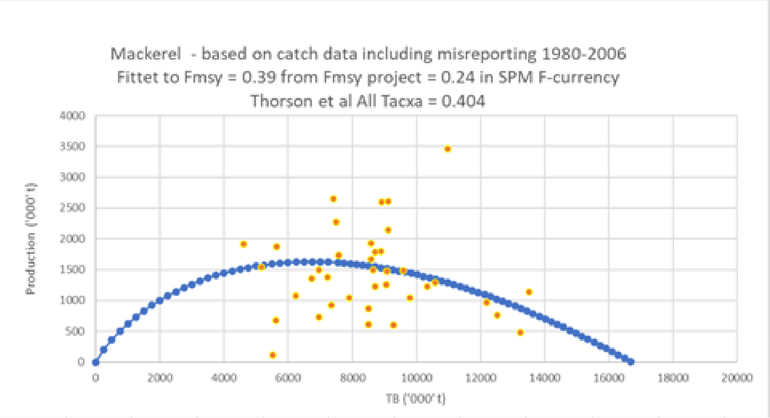
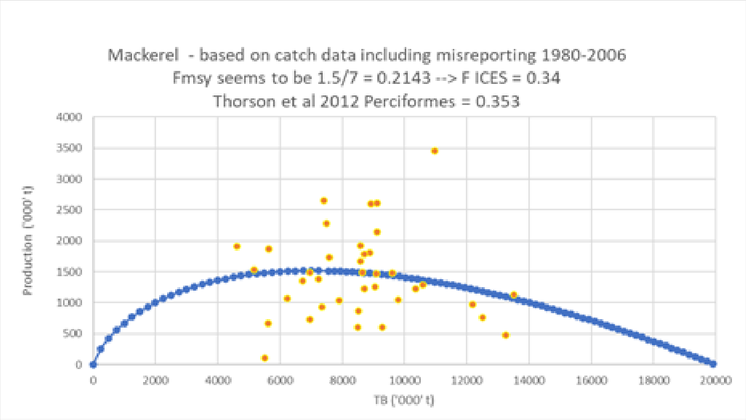
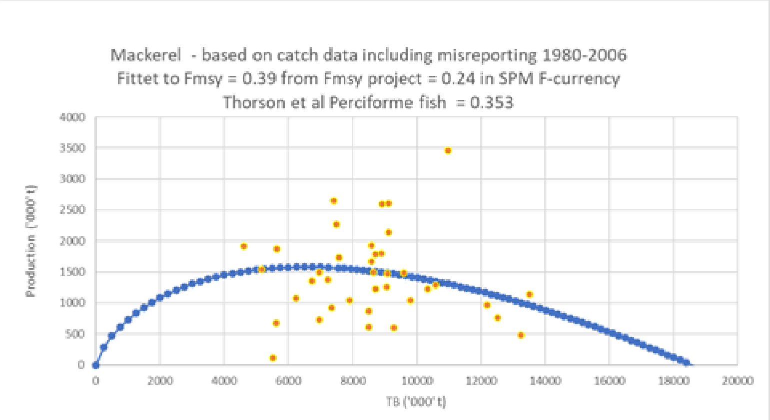
Steps to establish the best SPM for a given stock – here NEA mackerel

- Use Total 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.

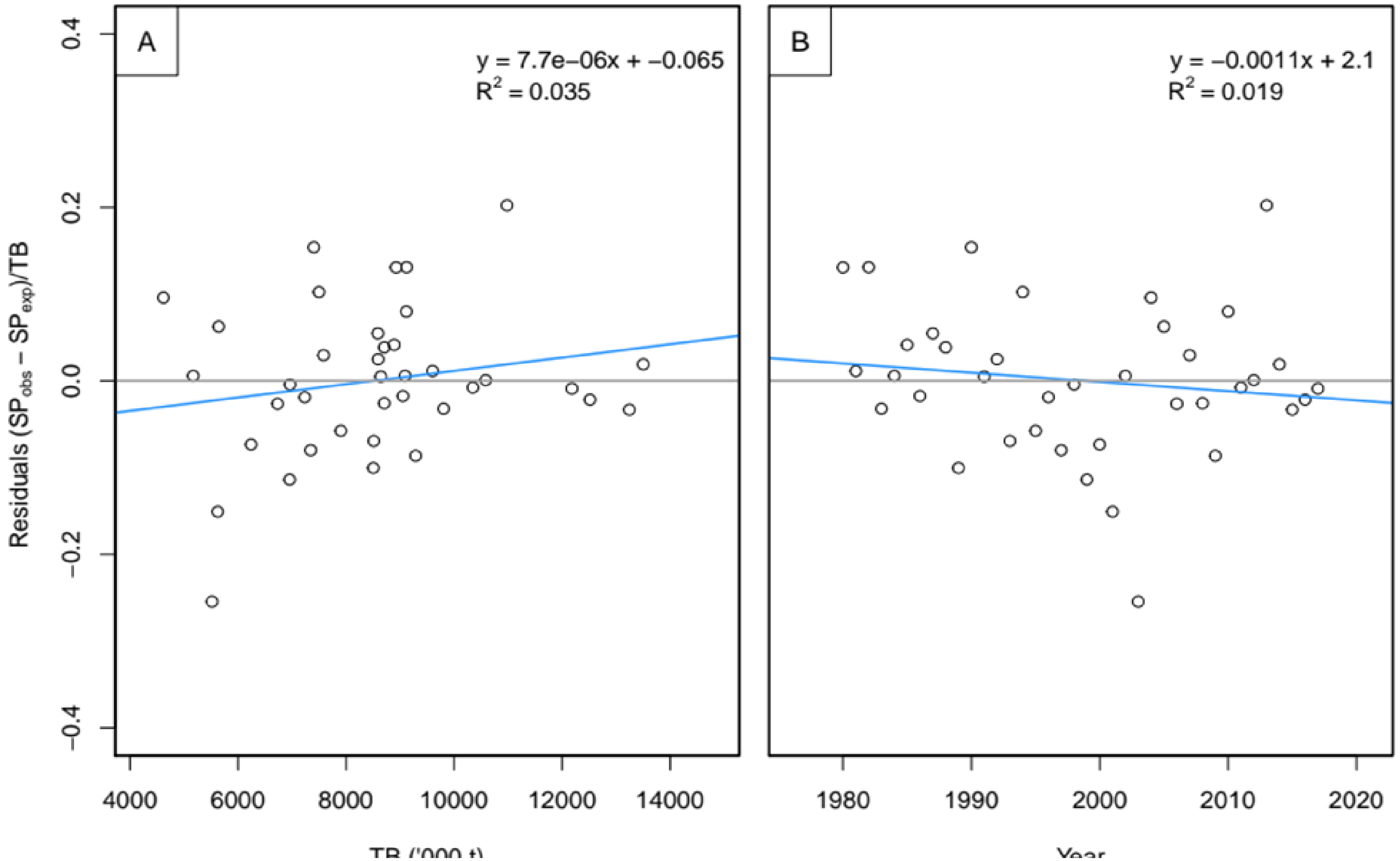
- Sometimes also the height of the SPM-curve is a problem: Use a meta-analysis by Sparholt *et al*. (2020). Estimating Fmsy from an ensemble of data sources to account for density-dependence in Northeast Atlantic fish stocks. ICES Journal of Marine Science. ICES Journal of Marine Science, doi:10.1093/icesjms/fsaa175.

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

	Fmsy estimated	Fmsy from Sparholt *et al.*
Schaefer		
Thorson *et al.* "all taxa"		
Thorson *et al.* "Perciformes"		

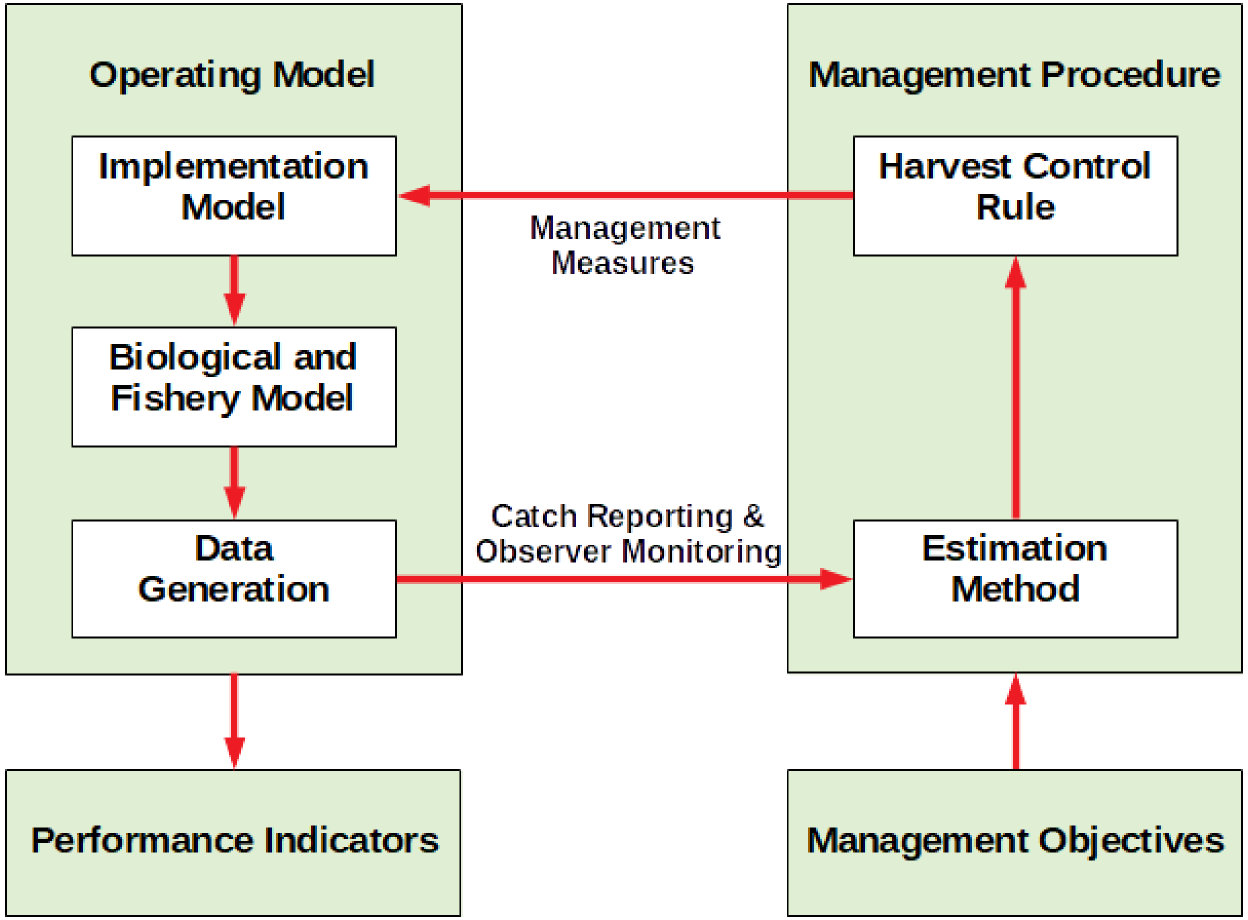
Select the best one using e.g. AICc and residual plots

SPM model	Number of para-meters estima-ted	Bmsy/K (curve shape parameter)	R^2	AICc	SSBmsy million t	MSY in million t	K (Carrying capacity) million t	MSY/ TBmsy (Fmsy)
#0 Fmsy estimated Curve estimated	3	0.529	0.24	3.17	6.5	1.54	16.7	0.17
#1 Fmsy estimated – Schaefer	2	0.500	0.24	-0.09	6.4	1.53	17.5	0.17
#2 Fmsy estimated - Thorson et al. (2012) “all taxa”	2	0.404	0.24	-0.03	6.5	1.49	21.9	0.17
#3 Fmsy estimated - Thorson et al. (2012) “Perciformes”	2	0.353	0.25	0.01	6.7	1.48	25.6	0.16
#4 Fmsy fixed –Schaefer	1	0.500	0.11	-0.36	4.9	1.68	14.0	0.24
#5 Fmsy fixed - Thorson et al. (2012) “all taxa”	1	0.404	0.20	-1.60	4.6	1.57	16.2	0.24
#6 Fmsy fixed –Thorson et al. (2012) “Perciformes”	1	0.353	0.22	-1.94	4.5	1.53	18.1	0.24

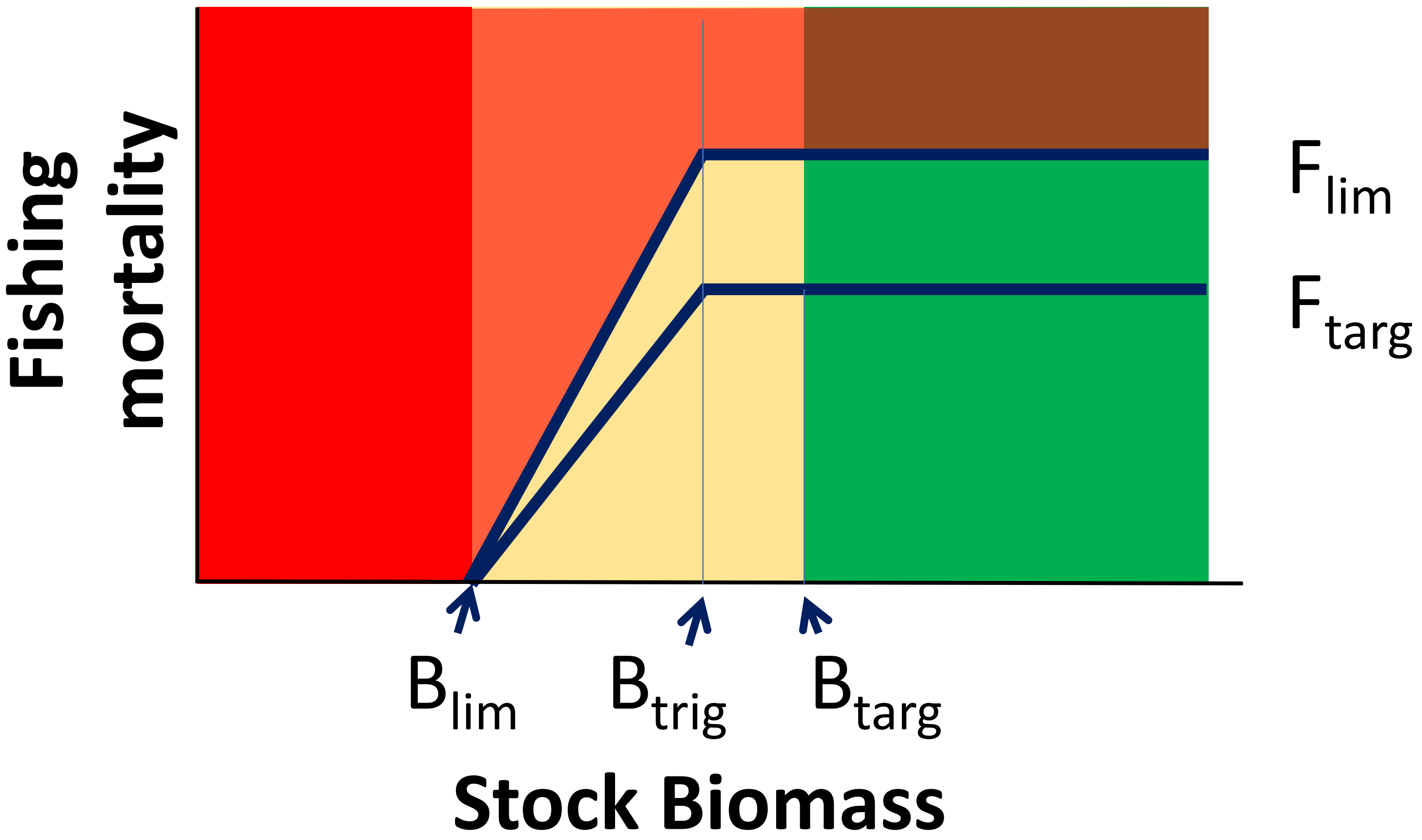


…we also look at the residuals (here model #6)

MSE – Management Strategy Evaluation



Management strategy:



2nd step…use SPM as Operating Model

- Get the observation error of Total Biomass (TB) from the assessment.
- Get the implementation error of agreed fish quota from the assessment.
- Get the process error of production for a given TB, from the observations around the selected SPM.

In more details: (to be read when you have time)

1) start with the observed TB (2021) from the assessment.

2) The real TB(2021) is obtained taking observation error into account.

3) Then the SP(2021) is obtained considering process error.

4) The real SSB(2021) is obtained by a linear link to TB influenced by F.

5) Then the observed SSB(2021) is obtained taking account of observation error.

6) Then intended F(2021) is obtained taking account of the HCR (linearly reduced when SSB < $B_{trigger}$).

7) The TAC(2021) is then obtained.

8) The realised yield(2021) is obtained taking implementation error into account.

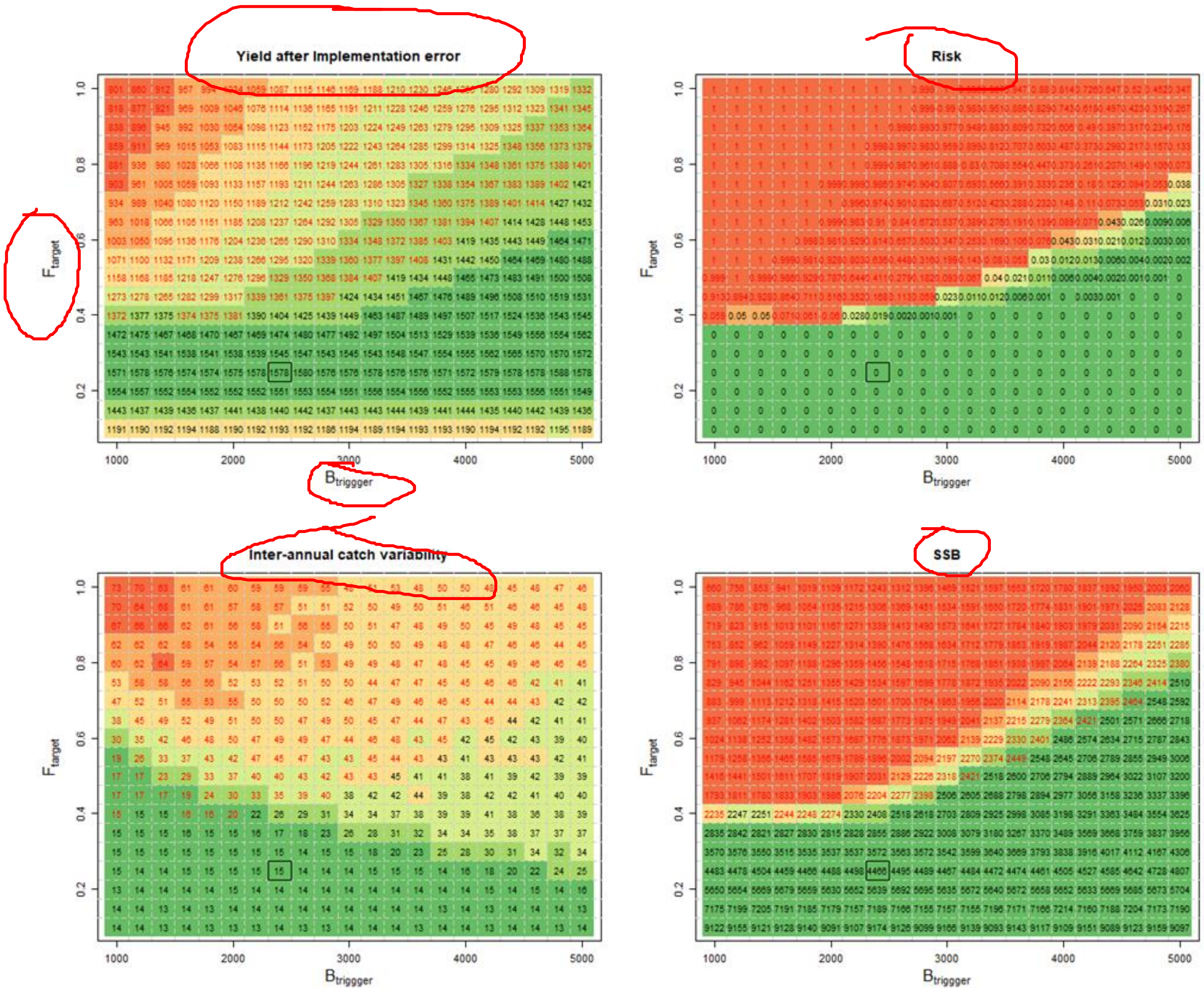
9) The real TB for the following year is then obtained from the real TB the current year + real SP – realised yield.

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.

Result:

of Ftarget vs Btrigger for current Blim of 1.990 million t – the top left diagram give you Fmsy



Main result so far

- The SPM approach <u>very sound and robust </u>– mainly due to priors of curve shape and curve top point from meta-analysis by Thorson *et al.* 2012 and *Sparholt et al.* 2020.

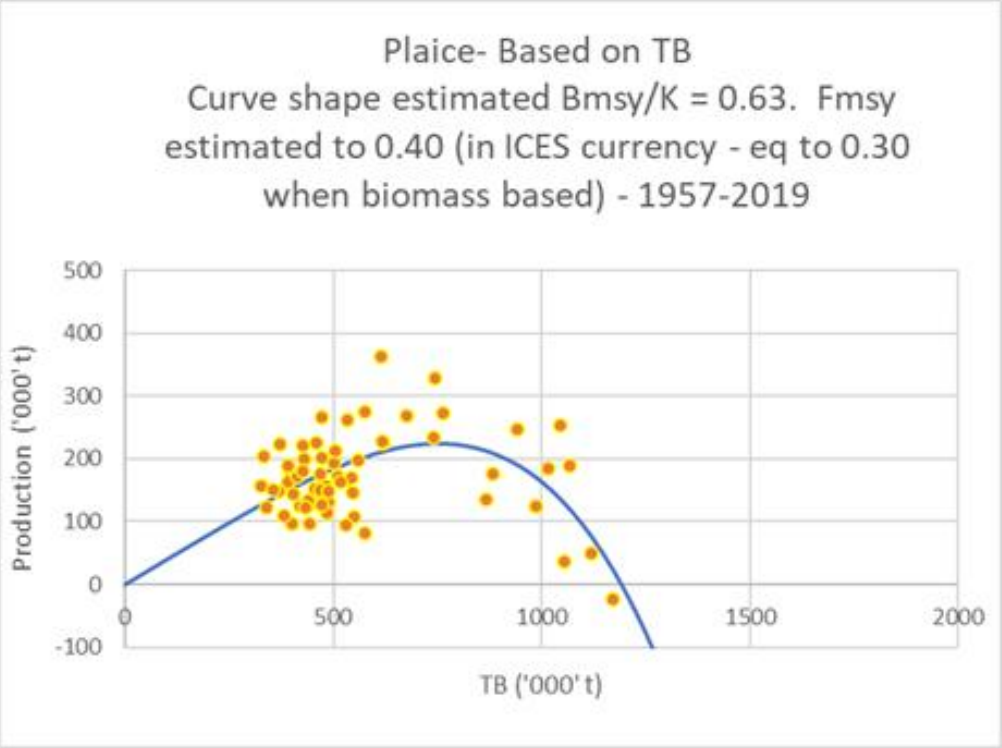
Project status

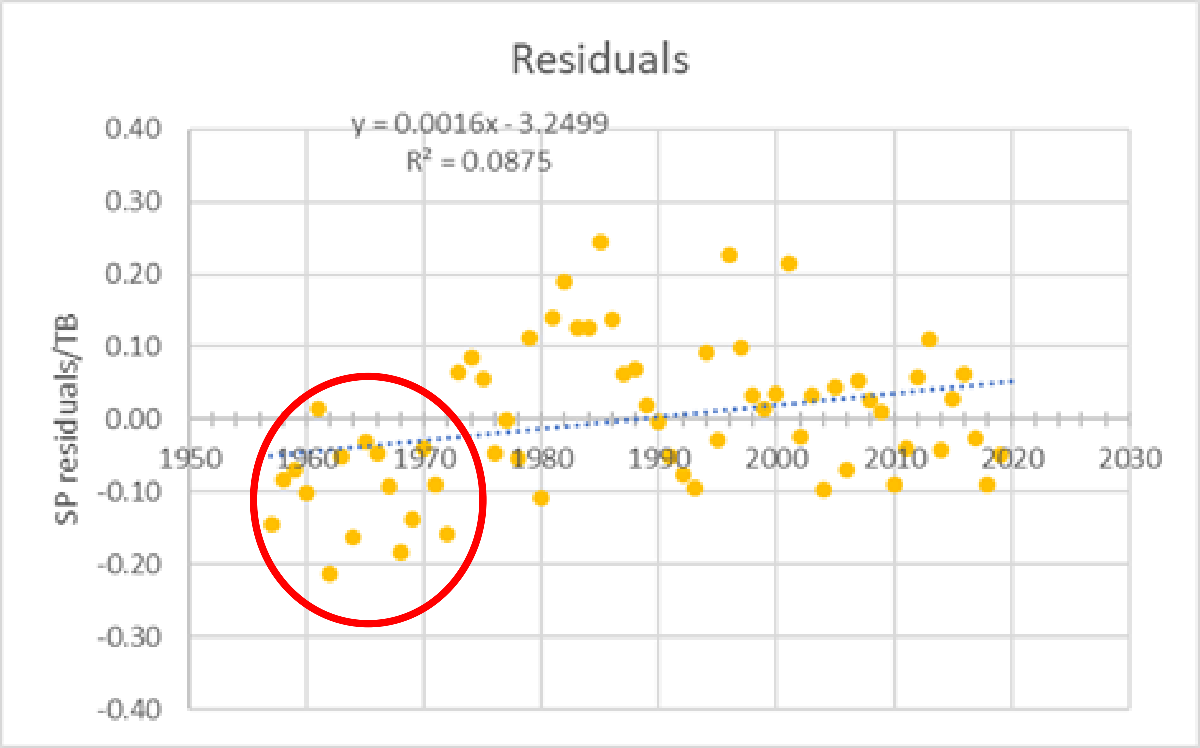
- SPMs for all 6 stocks done – but open for refinements -
- MSEs done for 5 out of 6 stocks
- SPM MSE Software developed but need to be made user-friendly
- Age-based MSE including DD in growth, maturity and natural mortality done for 2, 4 stocks pending
- 21 working documents produced
- 1 draft paper for a scientific journal submitted. Material for many more papers.
- 1 PhD and 1 MSc students involved.

Challenges

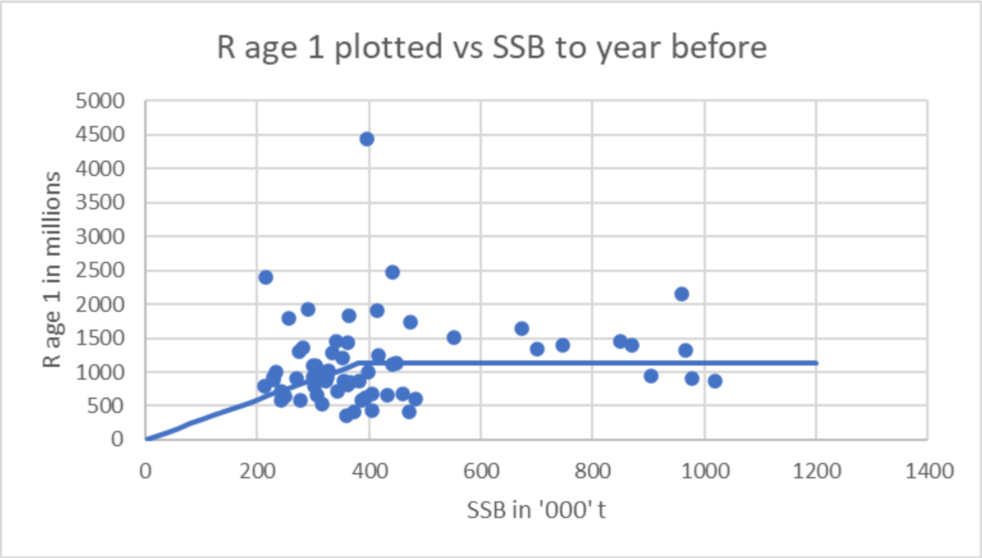
- Linking climate changes to the SPM changes
- Linking time trends in sea mammal predation to the SPMs changes
- Consultants (ICES stock coordinators) to do cohort-based MSEs not possible due to Corona – we are looking into doing it ourselves.

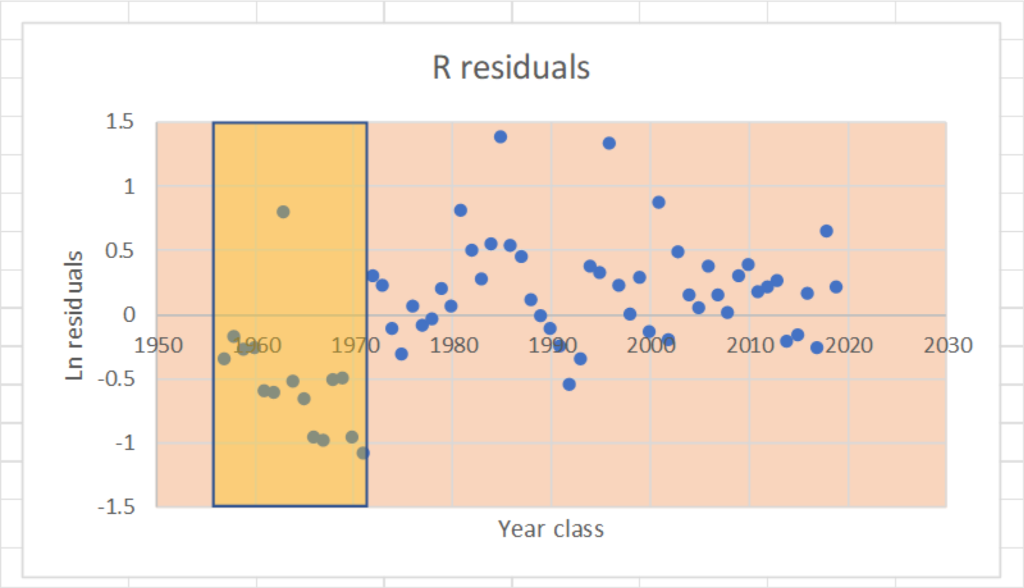
North Sea plaice:
Low productivity 1957-1972



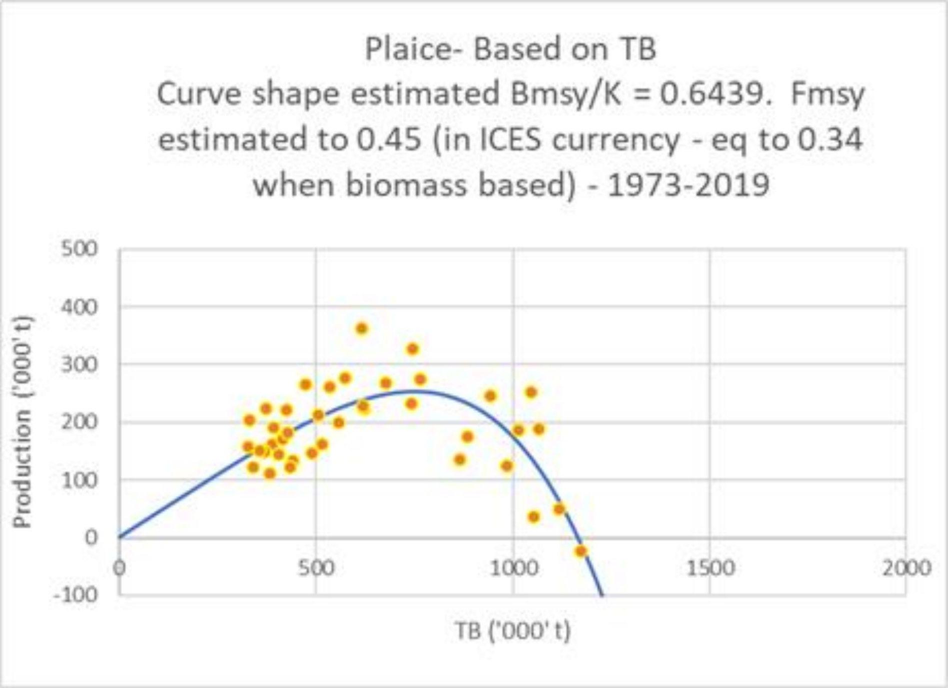


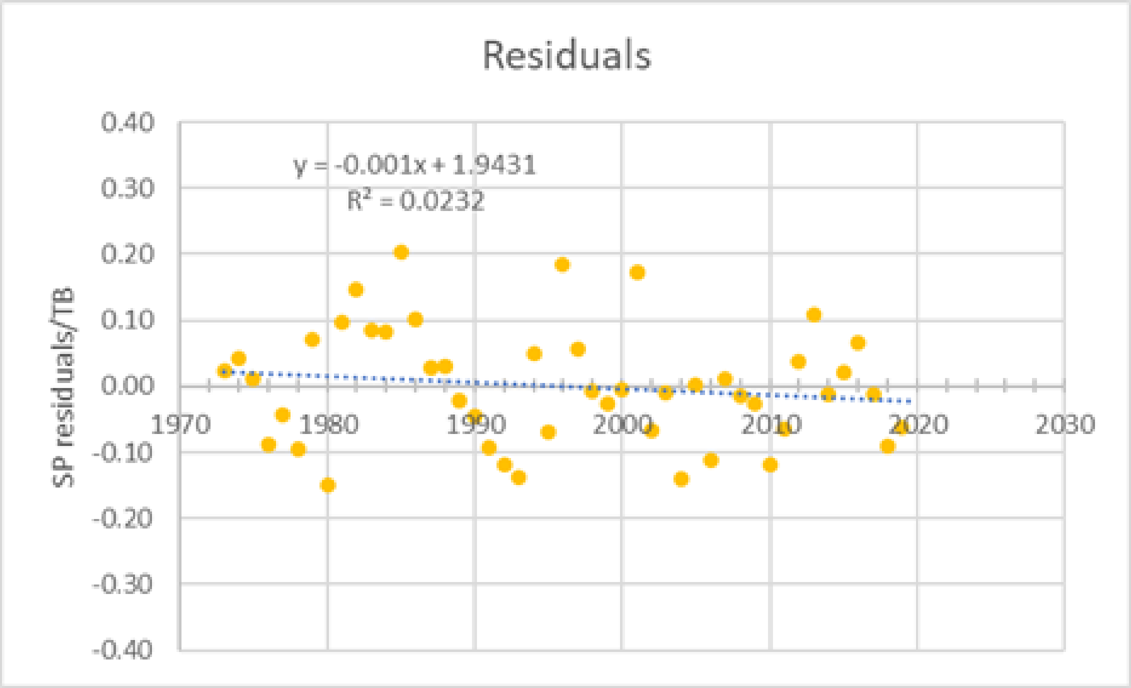
-poor recruitment 1957-1971





…1973-2019 – a slight trend – maybe climate?





Why here at CMEC ?

- Fish population dynamics for stocks in the Northeast Atlantic is obviously Macro-ecology,

Evolution is used to extract knowledge of the population dynamics

– why do fish spawn so enormously many eggs?

– what is the evolutionary advantage?

– why are some species much more fecund than others?

We can deduct information about natural mortality from fecundity and the knowledge that stocks do manage the evolutionary ”struggle”

Why here at CMEC ?

- Fishery induce some evolutionary pressure and how do fish react to that?

- Climate changes is impacting the balance between stocks in each ecosystem.

- …and many thanks for having me ☺. …I had hoped to be more available here and interacting more… but Corona came…

Thank you for listening!

Robustness

North Sea plaice.

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

North Sea sprat

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

North Sea cod – SPM (SPiCT R-code)