DTU Library

Report of the 2nd working group meeting on optimization of fishing pressure in the Northeast Atlantic, Vancouver November 2017

Project: Ecosystem Based FMSY Values in Fisheries Management

Sparholt, Henrik; Hilborn, Ray; Horbowy, Jan; Steingrund, Petur; Collie, Jeremy; Bogstad, Bjarte; Howell, Daniel; Christensen, Villy; Pedersen, Søren Anker; Sparrevohn, Claus Reedtz

Total number of authors:
14

Link to article, DOI:
10.6027/NA2019-905

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Nordic Council of Ministers

NORDIC WORKING PAPERS

Report of the 2nd working group meeting on optimization of fishing pressure in the Northeast Atlantic, Vancouver November 2017

Project: Ecosystem Based FMSY Values in Fisheries Management

Henrik Sparholt, Bjarte Bogstad, Villy Christensen, Jeremy Collie, Rob van Gemert, Ray Hilborn, Jan Horbowy, Daniel Howell, Michael C. Melnychuk, Søren Anker Pedersen, Claus Reedtz Sparrevohn, Gunnar Stefansson and Petur Steingrund

http://dx.doi.org/10.6027/NA2019-905
NA2019:902
ISSN 2311-0562

This working paper has been published with financial support from the Nordic Council of Ministers. However, the contents of this working paper do not necessarily reflect the views, policies or recommendations of the Nordic Council of Ministers.

Nordisk Council of Ministers – Ved Stranden 18 – 1061 Copenhagen K – www.norden.org

Report of the 2nd working group meeting on optimization of fishing pressure in the Northeast Atlantic, Vancouver November 2017

Project: Ecosystem Based FMSY Values in Fisheries Management

A 2 year project funded by:

The European Maritime and Fisheries Fund & the Danish Ministry of Environment and Food (1.372 mio DKK), the Norwegian Fisheries Research Fund via IMR Norway (0.5 mio DKK) and from the Nordic Council of Ministers (0.5 mio DKK). The total budget for the project is therefore 3.057 mio DKK.

Meeting 31 October-2 November 2017,

Vancouver, Canada

Ministry of Environment and Food of Denmark

European Union
European Maritime and Fisheries Fund

Nordic Council of Ministers

INSTITUTE OF MARINE RESEARCH

Contents

Introduction

The participants of the project "Ecosystem Based FMSY Values in Fisheries Management", in short, the "FMSY project", meet for the first time. The meeting took place at the facilities of the University of British Columbia, Vancouver, Canada, 31 October to 2 November 2017. An Agenda for the meeting was send out beforehand, and is given in Appendix 1. The list of participants are given in Appendix 2. The present report is a Minutes report of the meeting.

The meeting benefitted greatly from having Carl Walters as well as several UBC PhD students, participating on special invitations.

Adoption of agenda.

The agenda (Appendix 1) was adopted.

1. The list of stocks

The stocks to be included in the current project are data rich stocks from the Northeast Atlantic supplemented with stocks from the Northwest Atlantic. Table 1.1 gives the current list.

Table 1.1. The estimates of Fmsy from ICES and from methods that include density dependent effects in growth, maturity and/or mortality in addition to that based on a stock recruitment relationship. The "currency" for F used is the ICES ones from 2016, e.g. for North Sea cod the mean F at age 2-4. Only stocks with time series of at least 30 years and F expressed in absolute terms (not in relative terms to a mean F or to an Fmsy) like rate per year, are included. Yellow potential new stocks. Orange stocks to go out (mainly due to too short time series, whiting out due to recognized problems of either a lot of unreported industrial catches or discards, and severe inconsistencies to the IBTS survey which is very precise for whiting at least in the North Sea, and spasmodic recruitment). Green stocks on the "observation list".

			Fmsy							
Stock		ICES 2016	Froese *et al.* SPM	RAM Legacy Db	Eco-system model 1	Eco-system model 2	Eco-system model 3	ASPIC	PROST	XX?
	Comment number\letter	a	b	c	d	e	f	g	h	i
Blue whiting	1	0.32	0.37							
Cod Icelandic	2	-	0.63							
Cod W Scotland	3	0.17	-							
Cod Irish Sea	4	0.37	1.16							
Cod (*Gadus morhua*) in divisions 7.e–k (western English Channel and southern Celtic Seas)	5	0.35	0.58							
Cod North Sea	6	0.33	0.73		0.89					
Cod Northeast Arctic	7	0.40	0.56							
Cod Faroe Plateau	8	0.32	0.36							
Cod Western Baltic Sea	9	0.26	0.62							
Cod Eastern Baltic Sea	10	-	-		0.87					

Haddock Icelandic	11	-	0.47							
Haddock Faroe	12	0.25	0.27							
Haddock Rockall	13	0.20	0.29							
Haddock Irish Sea	14	0.27	0.39							
Haddock VIIb-k	15	0.40	0.87							
Haddock North Sea	16	0.19	-		0.52					
Haddock Northeast Arctic	17	0.35	0.47							
Hake Northern	18	0.28	0.78							
Hake Southern	19	0.25	0.59							
Herring Western Baltic	20	0.32	0.33							
Herring Icelandic	21	0.22	0.22							
Herring W Scotland and W Ireland	22	0.16	0.22							
Herring Irish Sea	23	0.26	0.43							
Herring Celtic Sea and South of Ireland	24	0.26	0.33							
Herring North Sea	26	0.33	0.58		0.50					
Herring Norwegian SSP	27	0.15	-							
Herring Gulf of Riga	28	0.32	0.34							
Herring Bothnian Sea	29	0.15	-							
Herring 25–29, 32 xGoR	30	0.22	-		0.35					
Horse mackerel W	31	0.13	-							
Mackerel	32	0.22	0.35							
Plaice E Channel	34	0.25	0.28							
Plaice Kattegat Sund	38	0.37	0.54							
Plaice North Sea	39	0.19	0.47							
Saithe Icelandic	40	-	0.31							
Saithe Faroe	41	0.30	0.38							
Saithe North Sea etc.	42	0.36	0.54		0.33					
Saithe Northeast Arctic	43	-	0.50							
Sole Irish Sea	44	0.20	0.18							
Sole Eastern Channel	45	0.30	0.49							
Sole Western Channel	46	0.29	0.26							
Sole Bristol Chanel Celtic Sea	47	0.27	0.31							
Sole Kattegat	48	0.23	0.38							
Sole Bay of Biscay	49	0.33	0.44							
Sole North Sea	50	0.20	0.37							
Sprat Baltic Sea	51	0.26	0.42						0.45	
Whiting W of Scotland	52	0.18	0.21							
Whiting VIIe-k	53	0.52	0.54							
Whiting North Sea	54	0.15	0.22		0.25					
Golden redfish Iceland	55									
Sandeel Sa 1	56									
Sandeel Sa 2	57									
Sandeel Sa 3	58									
Striped bass (USA east coastal waters)	59									
Summer flounder (USA east coastal waters)	60									
Menhaden US Eastcoast	61									

Table 1.1 Footnotes: Each cell in the table have an identifier, the top left one 1a and the bottom right one 61i. The comments below are linked to the cells in the table by these identifiers.

1a-54a: ICES Fmsy from ACOM 2015. "-" means not available, i.e. no Fmsy defined.

1b-54b: Fmsy from Froese et al 2016 translated into the F-unit used by ICES typically the mean F over some core exploited age groups. Based on Froese et al F/Fmsy from Surplus production models, divided by ICES actual F values from assessments. Mean values over 2000-2013.

3b: Stock not well defined, extremely small in recent years, unreliable catch data due to area misreporting historically, mainly discards in the past 8 years. No need for an Fmsy the coming 5 years until the stock has rebuild.

10b. Baltic cod in SD 2532 a major outbreak of a disease likely due to parasite infestation due

10d, 30d, 51d: Most complete model: Multispecies FMSY Gislason (1999). The options assuming constant relationship in F between the three stocks (that of 1996).

29b. This stock (herring SD30) has increased by a factor of 4 in the past 4 decades and so has the catch. Thus, surplus production modelling dubious.

6d, 16d, 26d, 42d, 54d: Most complete model: Multispecies FMSY (Collie et al 2003). Figure 4 and Table 2, combined.

51h: From J. Horbowy and A. Luzenczyk. 2016. Effects of multispecies and density-dependent factors on MSY reference points: example of the Baltic Sea sprat. Can. J. Fish. Aquat. Sci. 00: 1–7 (0000) dx.doi.org/10.1139/cjfas-2016-0220. Option with density dependence in growth and mortality, and cod (age 2+) biomass 200 000 t. Cod biomass probably a bit lower the coming 5 years, but the analysis was only sensitive to larger cod biomass.

27b. A few very large year classes. Exploitation pattern changed at lot over time. A large 0 and 1 group fishery in the 1970s.

30b. Stock not well defined and predation probably high in the 1980s when the cod stock was very high.

51b. Sprat predation mortality was very high in the 1980s when the cod stocks was very high.

52b. Stock not well defined.

RH says that NSea sandeel and other forage fish is their next target for modelling after they have completed the Peruvian Anchoveta stocks, so the three sandeel stocks listed as yellow in Table 1.1, might be appropriate to try to include in the present project. For these stocks, the changing predator field and food competition from the herring, mackerel and blue whiting stocks in the Northeast Atlantic will be issues that probably need to be addressed directly or indirectly, if we attempt to include them. A recent paper Clausen *et al*. (2017) showed that the productivity in terms of recruitment and individual fish growth have decreased in recent years and led to a lower Fmsy.

2. Progress on Work Packages

The work packages were discussed one by one.

2.1 WP 1 - The ”common currency” problem for fishing mortality

A suggestion for text for the final project report was presented by HS and is shown in Appendix 4.

It is clear that a common currency is desirable as the current Fs used by ICES for the various stocks are not directly comparable to each other. They are quite dependent on exploitation pattern and on the age groups which are included in the averaging of F-at-age.

Candidate common currency was suggested. A promising one is (1-SPR) which is "1- ratio of (SSB/R at F) to (SSB/R at F=0) ". However, it is rather insensitive to changes in F for F above 0.5 (see appendix 4 Figure 2.1.4.3). Alternative ones were suggested, but not yet tested:

1) average F over entire life span;

2) assume a common mesh size say for cod stocks about where 50% of 40 cm long cod are retained;

3) a plain average but including all ages from about the size of 40cm;

4) catch / biomass of age 1+.

The first 3 points are sensitive to which age is used as the oldest usually called the +group. Some population weighting could be considered. Further analysis seems needed.

2.2 WP2 - Regime shifts, climate changes, genetic changes due to fishing, and suspected misreporting historically.

Regime shifts, it may be necessary to separate time series of data into appropriate periods in such cases.

Maybe mega trends of increases in pelagic stocks in the Northeast Atlantic could be used to indicate regime shifts – in a rough way.

Also this issue need to be explored further before our next meeting in March 2018. ICES had a Theme Session at the 2016 ASC, which would be good to consult.

Regime shifts for Baltic cod (parasites), NEA cod (new feeding area due to temperature increase), and mackerel (new feeding areas due to temperature increase), should be considered.

2.3 WP3 Compile ecosystem and multispecies estimates of Fmsy

The task is to compile ecosystem and multispecies Fmsy from "published" work (also WG reports, Working Documents), including a short description of the model/assumptions used. It should refer to current situation in terms of balance between stocks.

Most relevant literature seems to pre-2008 as more recent literature have focused more on improving the models than extracting results that can be used in management here and now. However, also relevant are the review in 2008 and 2012 by the ICES Multispecies WG and ICES advice 2012 and 2013 on Baltic and North Sea multispecies Fmsy. BB and DH will provide reference to appropriate ICES WGSAM reports with overview of multispecies/ecosystem values for various areas.

Maybe it would be fruitful to separate the task by eco-regions and assign responsible persons by eco-regions.

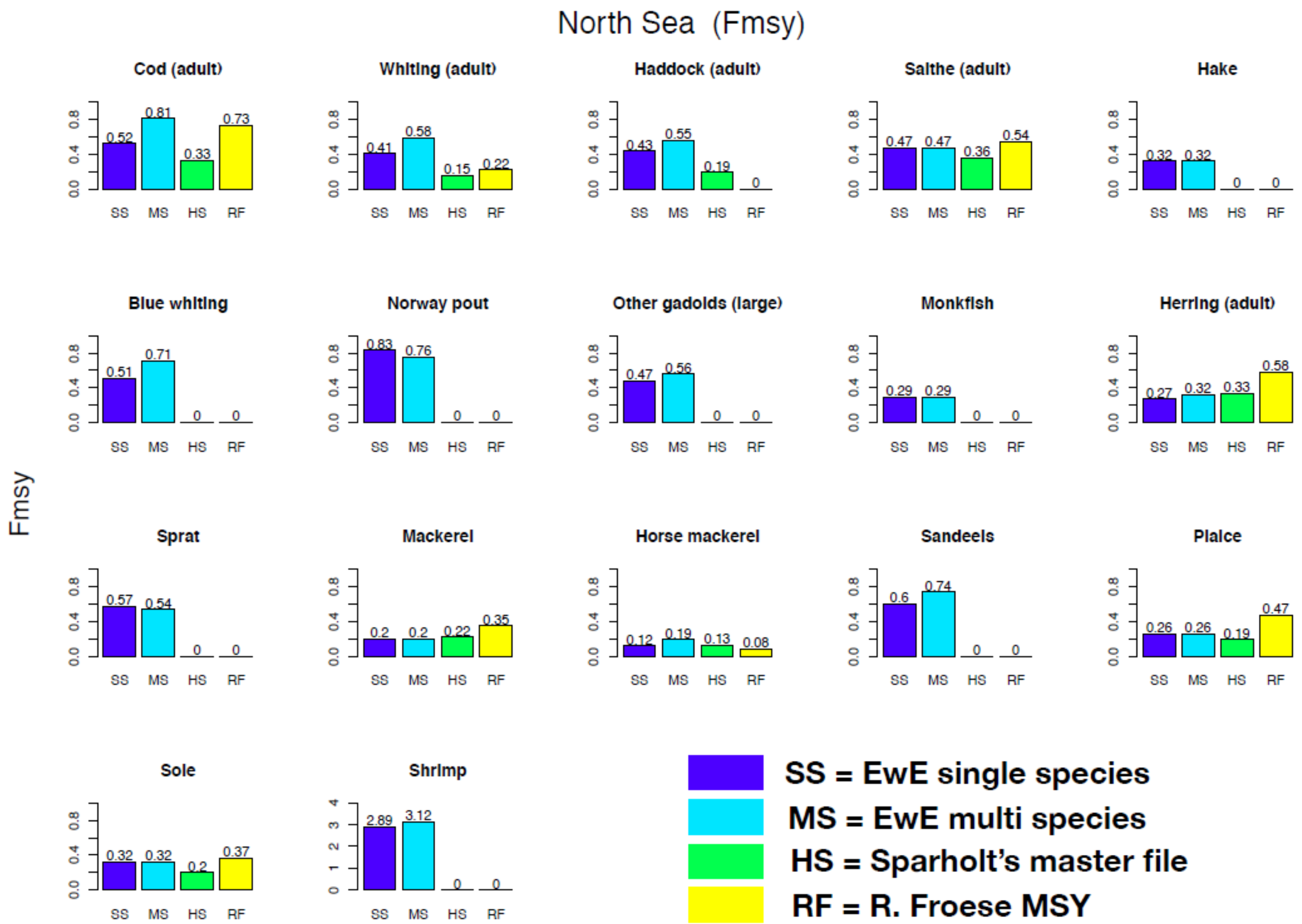
VC had looked at MSY analysis based on EwE key runs by ICES WGSAM:

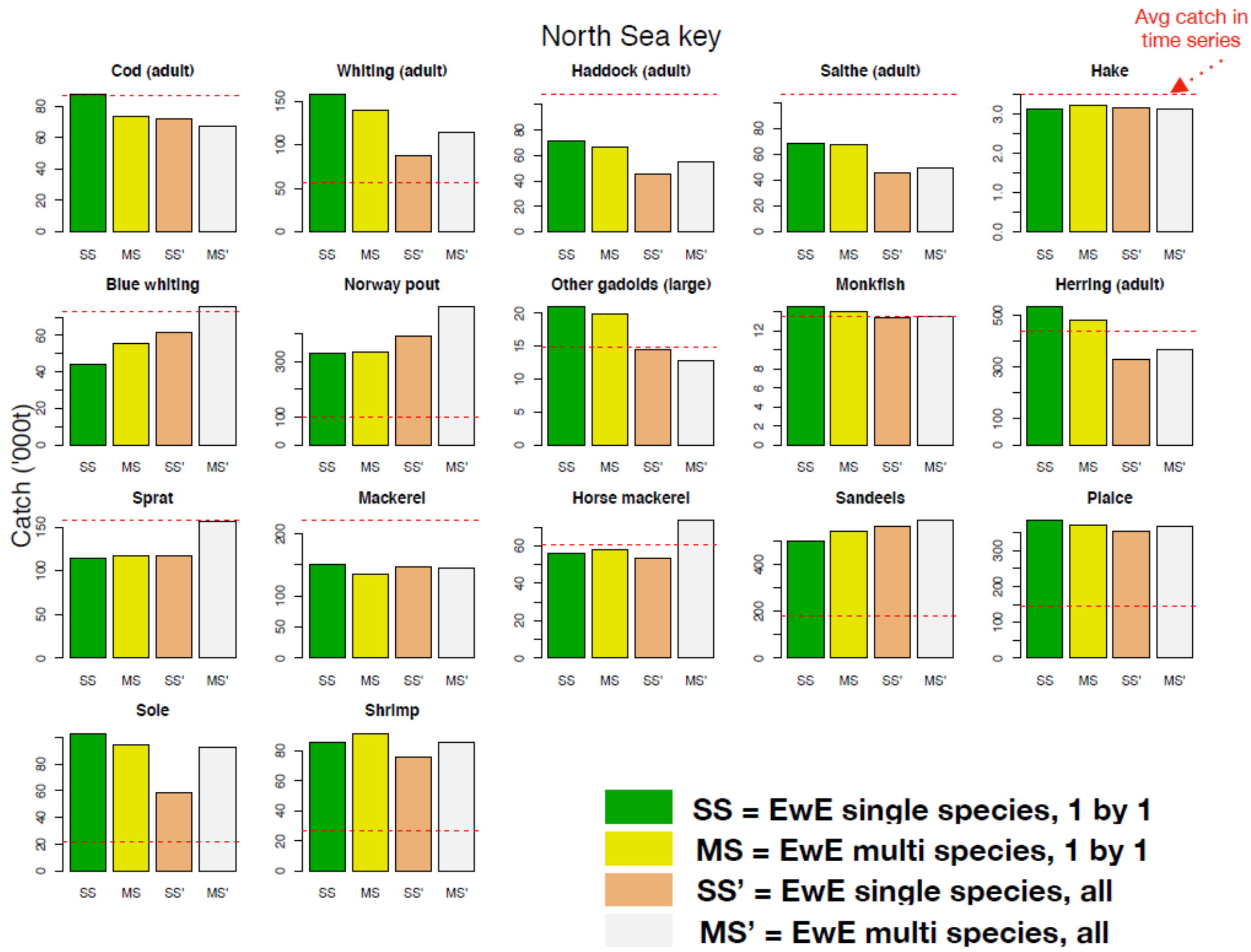
- North Sea 1991-2013 run from WGSAM (Mackinson)
- Baltic Sea 2004-2014 run from WGSAM (Bauer & Tomczak).

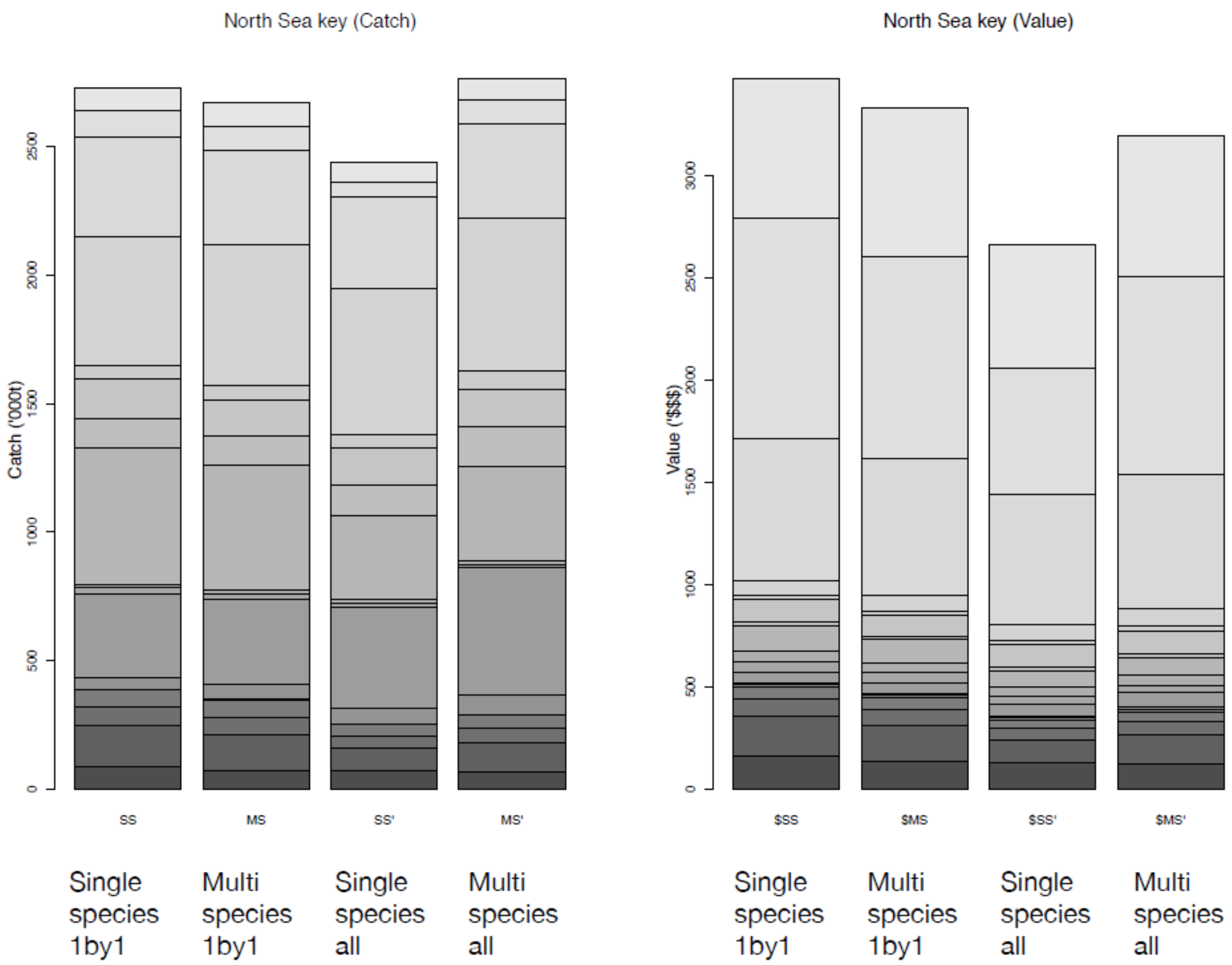
Results were extracted for two run types:

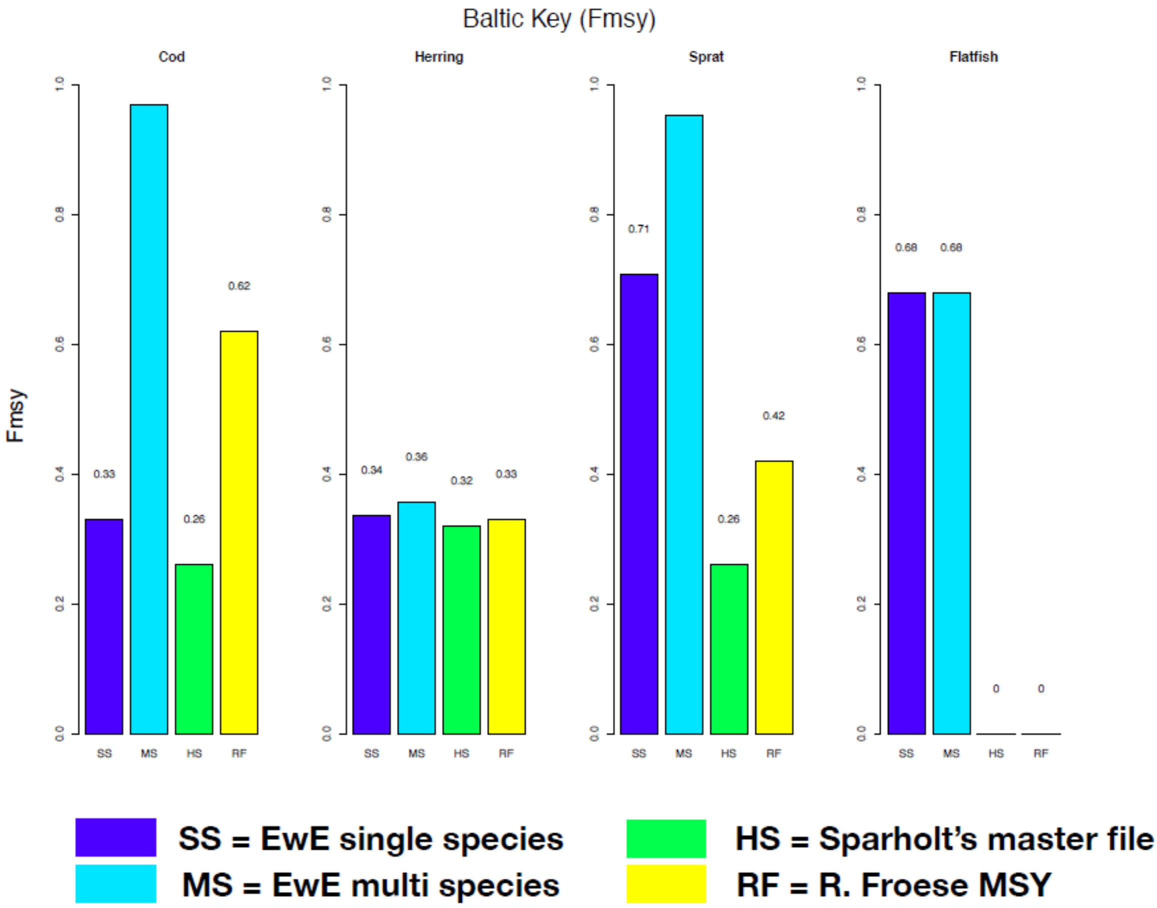
- "full compensation": target species abundance affects other species = MS run.
- "stationary system": target species abundance does not impact other species = SS run.

FMSY estimates were extracted for each run type, and subsequently used for runs with all F by species at (1) FMSY_MS or (2) FMSY_SS. The plots below shows the results.



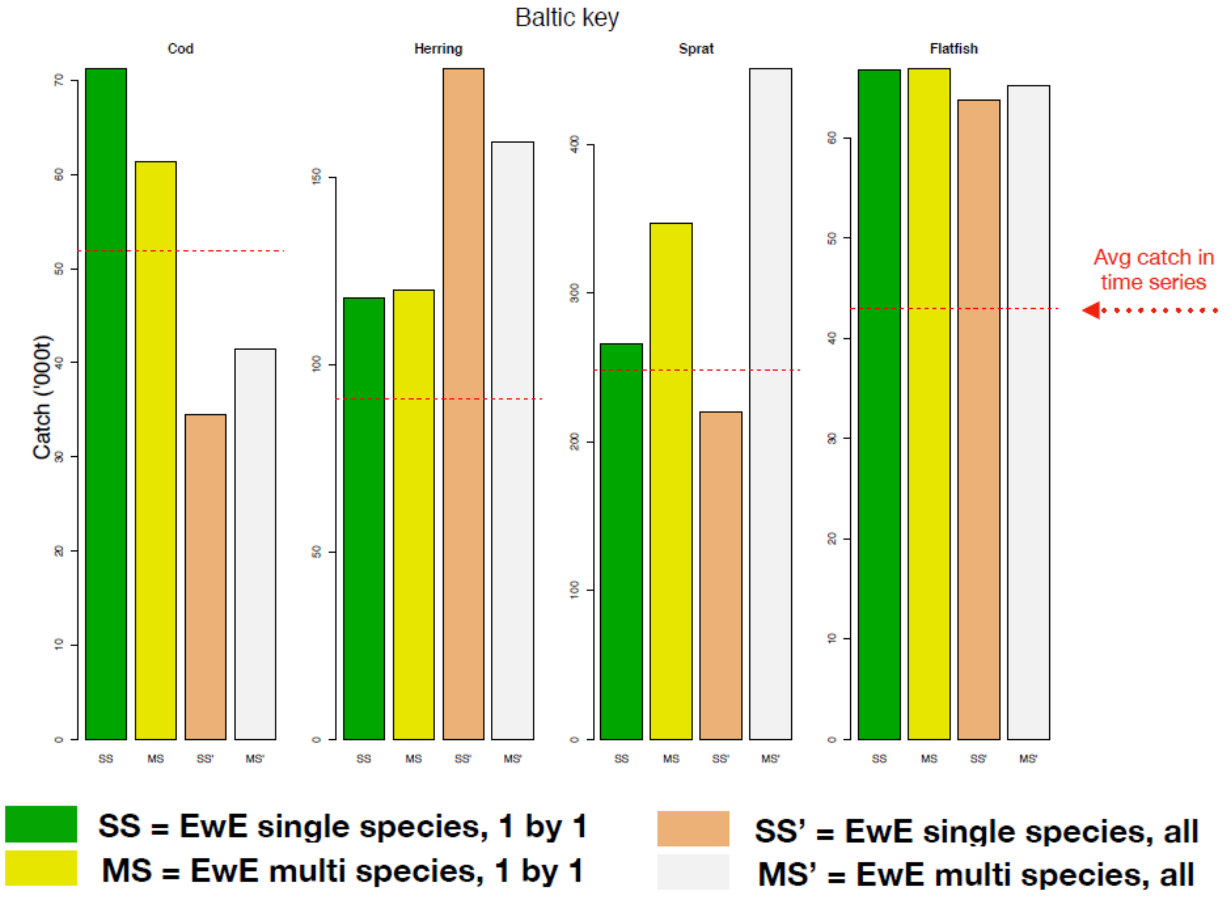

North Sea key
Avg catch in time series
Catch ('000t)
Cod (adult)
Whiting (adult)
Haddock (adult)
Saithe (adult)
Hake
Blue whiting
Norway pout
Other gadoids (large)
Monkfish
Herring (adult)
Sprat
Mackerel
Horse mackerel
Sandeels
Plaice
Sole
Shrimp
SS MS SS' MS'
SS = EwE single species, 1 by 1
MS = EwE multi species, 1 by 1
SS' = EwE single species, all
MS' = EwE multi species, all


North Sea key (Catch)
North Sea key (Value)
Catch ('000t)
Value ('$$$)
SS
MS
SS'
MS'
$SS
$MS
$SS'
$MS'
Single species 1by1
Multi species 1by1
Single species all
Multi species all
Single species 1by1
Multi species 1by1
Single species all
Multi species all

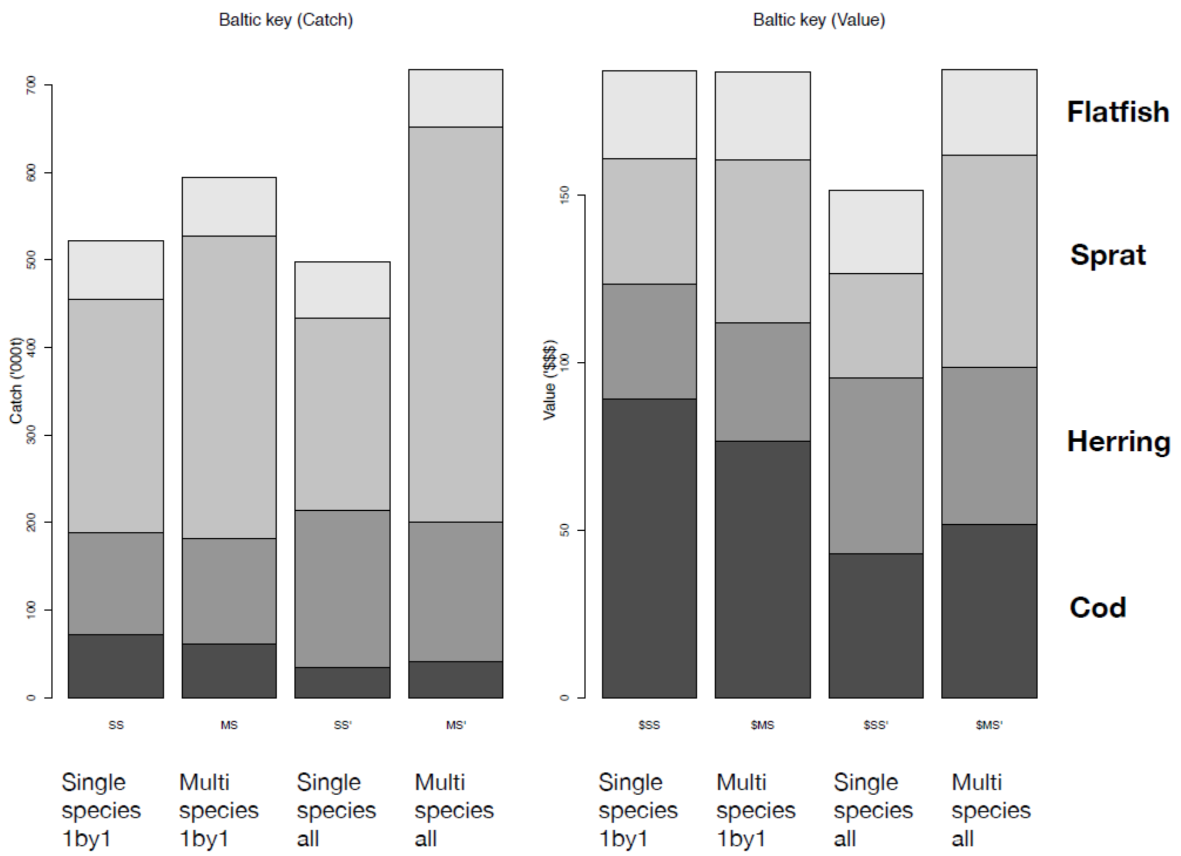


Baltic Key (Fmsy)
Cod
Herring
Sprat
Flatfish
Fmsy
0.33
0.26
0.62
0.34
0.36
0.32
0.33
0.71
0.26
0.42
0.68
0.68
0
0
SS
MS
HS
RF

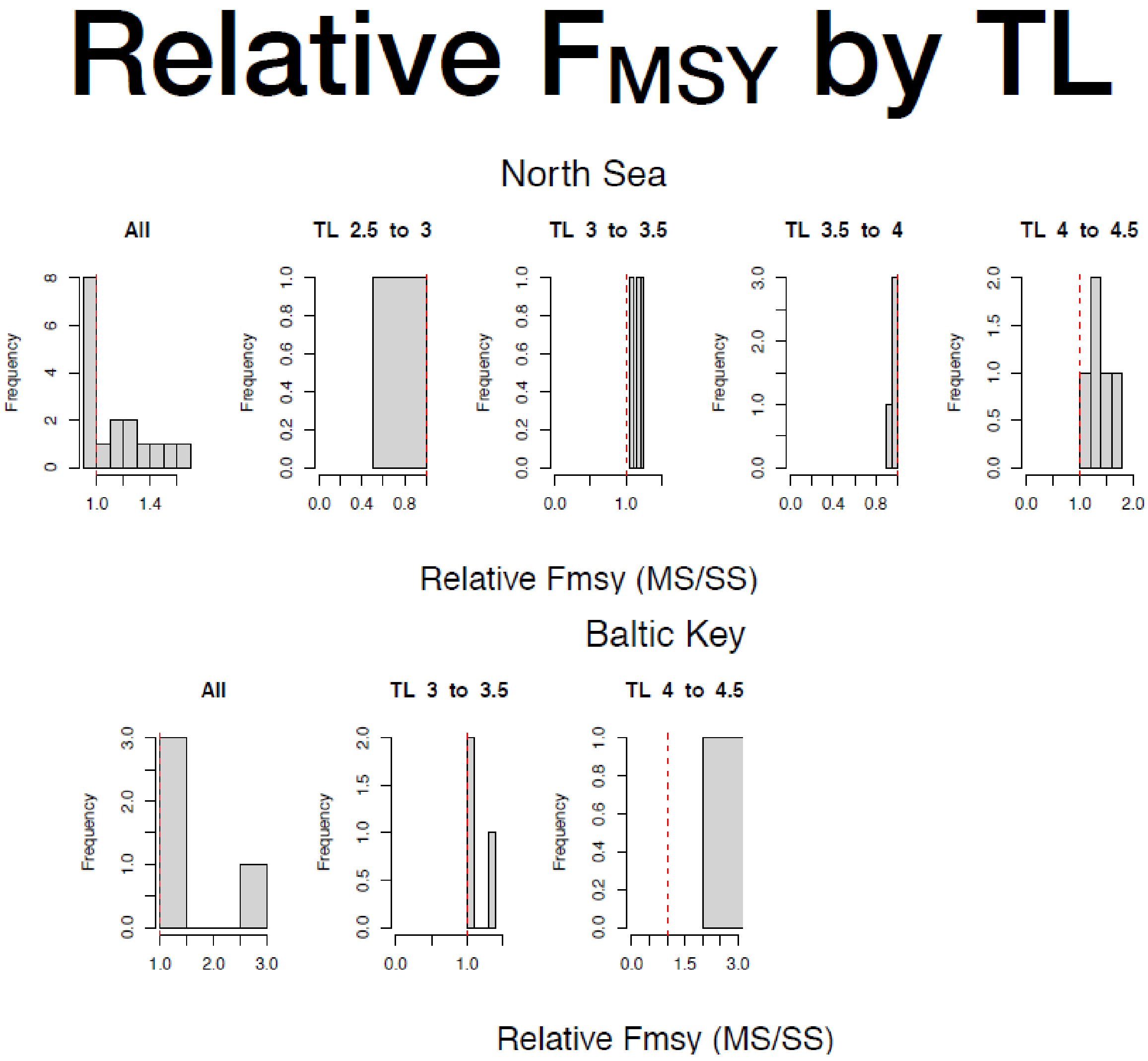
SS = EwE single species
MS = EwE multi species
HS = Sparholt's master file
RF = R. Froese MSY



Baltic key
Cod
Herring
Sprat
Flatfish
Catch ('000t)
Avg catch in time series
SS
MS
SS'
MS'
SS = EwE single species, 1 by 1
MS = EwE multi species, 1 by 1
SS' = EwE single species, all
MS' = EwE multi species, all



Baltic key (Catch)
Baltic key (Value)
Catch ('000t)
Value ('$$$)
Flatfish
Sprat
Herring
Cod
SS
MS
SS'
MS'
$SS
$MS
$SS'
$MS'
Single species 1by1
Multi species 1by1
Single species all
Multi species all
Single species 1by1
Multi species 1by1
Single species all
Multi species all



These results are preliminary and there were several issues discovered with these EwE key runs made by ICES WGSAM. Some issues are more technical and about the way the EwE models are set up and others are about the data year ranges used.

As expected the EwE models give generally substantially higher Fmsy values than the current ICES ones and Fmsy values more in line with the those based on SPMs like Froese et al. (2016) (see table 1.1).

Further work is needed. For the Baltic it would be useful to go further back in time data wise and maybe discard the recent years since about 2012 as the cod stocks have been hit by an outbreak of a parasites and exposed to increased predation. Both factors due to a substantial increase in the Baltic seal population, which now have spread from its past geographical distribution around the Aaland to the central Baltic.

The Atlantis model is quite far developed for some areas. BB will take contact to a colleague in IMR and see how far it is and whether there are aspects relevant for our Fmsy project.

2.4 WP4 Surplus production model estimates of Fmsy

In our June report we presented a suggestion for criteria for leaving out of a stock from the SPM analysis, where it was obvious that an SPM would not work. These criteria were:

1. Stock unit not well defined, e.g. cod WScot.
2. Catch data far from reliable.
3. Stock that have demonstrated large changes in carrying capacity.

4. Stocks with one or a few very large year classes in its historical time series are not suitable because the historical stock development will be driven by these year classes and mask the density dependent dynamics of the stock, e.g. W horse mackerel, maybe North Sea haddock and NSSP herring).

5. Stocks with suddenly strong parasites or diseases events or starvation – or at least these periods should be left out, e.g. cod Baltic SD2532.

6. Stocks with little dynamic range in catch and SSB.

7. Stocks with short time series.

8. Stocks with large changes in exploitation pattern over the time span considered, e.g. NSSP herring.

9. Stocks which gives very different temporal stock biomass development using surplus production models (like by Froese et al 2016) than the ICES estimated temporal biomass development.

10. Stock like cod WScot, where stock development obviously driven by some (unknown) environmental factors that goes clear against normal population regulation mechanisms. For cod WScot the stock is increasing in spite of increasing catches over time.

11. Stocks where predation pressure has varied strongly over time, e.g. Baltic sprat due to large changes in the cod SD2523 stock. Maybe a shorter time series can be used.

We stated that "The list of criteria to be used for selection of stocks for running SPMs should be finalized before the next meeting." No corrections have been identified as needed, and therefore these criteria stands.

Faroese Island case and long term trends in Fmsy

At our June meeting it was suggested to do some sensitivity analysis on importance of the criteria, e.g. if in the first part of a time series catches are biased, and the caches are considered reliable in the following years, run models for two periods separately and compare the results (i.e. model parameter estimates and MSY parameters). This has been done for Faroe cod, saithe and haddock – see appendix 5. The figure below shows the Fmsy expressed as Catch/Exploitable-Biomass. A 39 years interval that was moved in steps of 10 years were applied. There were very large fluctuations over time in Fmsy. However, in the past century they have been relatively stable especially for cod, though saithe seems to have been increasingly fit to the ecosystem since 1940s, or maybe rather the ecosystem has evolved to be more suitable for saithe and less so for haddock. There is no consensus among scientists about what has changed in the ecosystem that results in these observations. It is striking so low Fmsy was for cod back in 1740-1900. Maybe the seal population around the Faroe Islands at that time took its toll. However, there are very little information about the size of the seal population at that time. Maybe the cod stock were much higher back in those years because the fishing could not go much beyond 150m depth and thus a large "MPA" area of depths over 150m might have been "hiding" a large amount of normally big cod. Haddock has spasmodic recruitment and thus large changes in Fmsy in analysis like seen here is to be expected. Further reflection on a sensible way to deal with haddock (and other stocks with spasmodic recruitment) is needed.

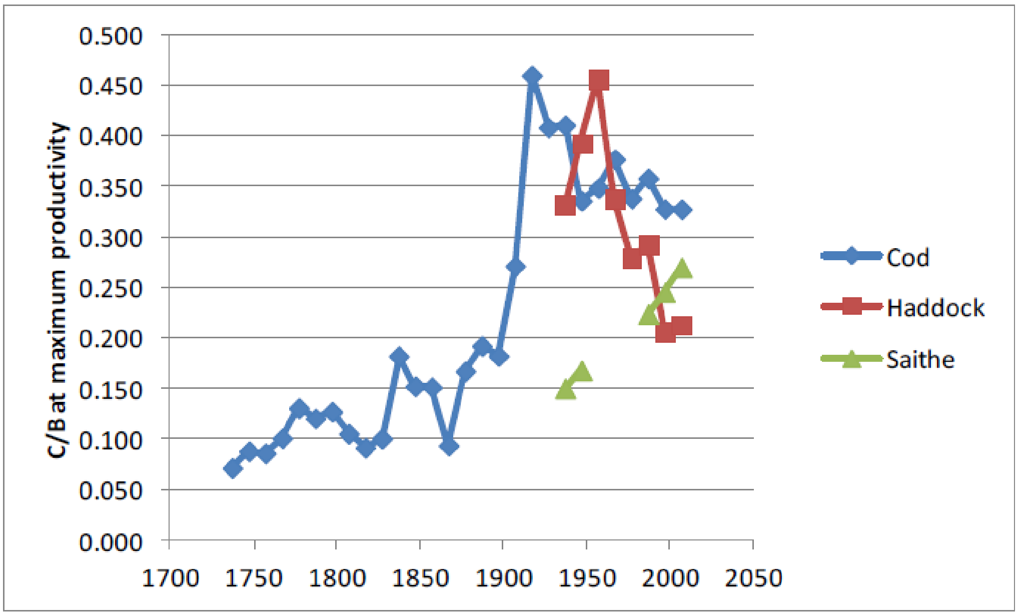


Figure 8. Catch per exploitable biomass of cod, haddock and saithe in Faroese waters at maximum productive capacity.

From Steingrund (2017)- see Appendix 5.

Estimation of F_{MSY} reference points from surplus production models and the RAM Legacy Stock Assessment Database

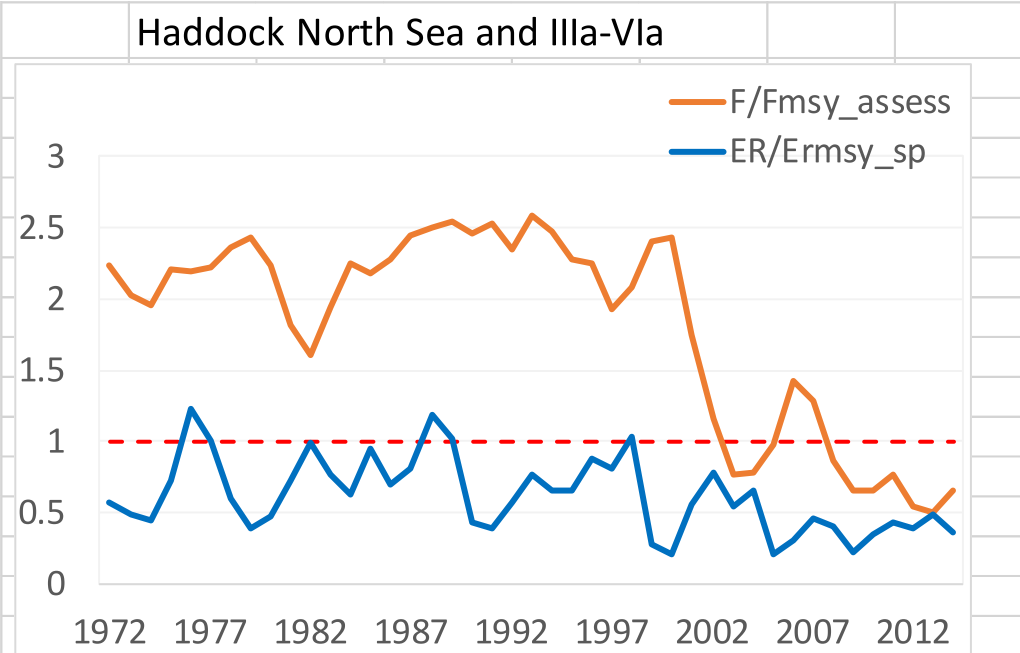
At the June meeting it was suggested that Ray's method to regress surplus-production against biomass, estimate parameters of the production model from the regression, should be explored. This has alredy been done now and was presented by Mike Melnychuk.

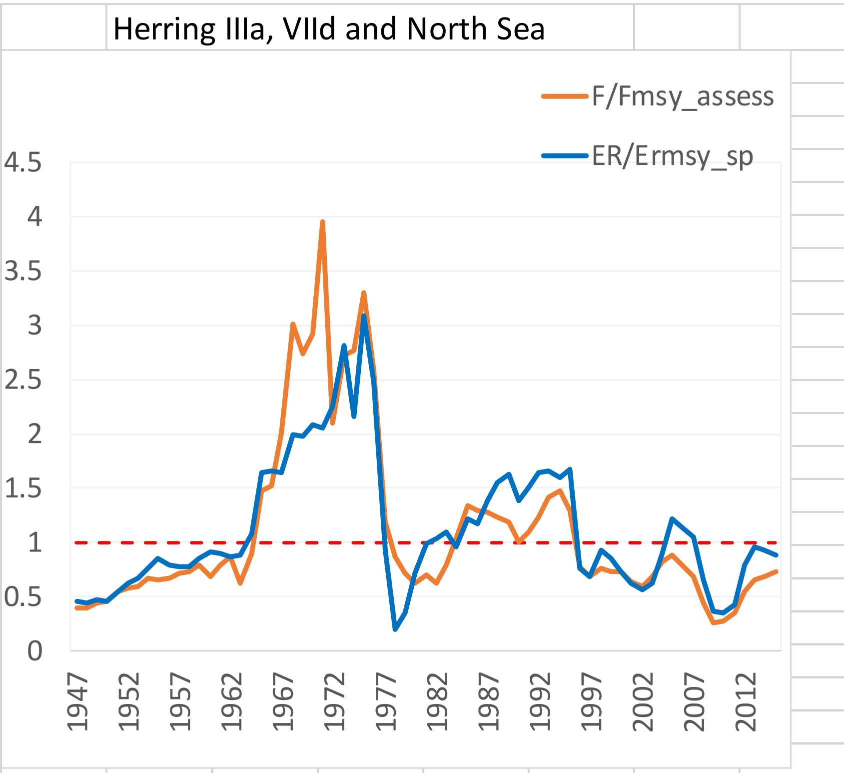
The RAM Legacy Stock Assessment Database is a compilation of stock assessment outputs from fish and invertebrate stocks around the world. The most common time series data collected include catch, estimated biomass, estimated exploitation rate or fishing mortality rate, and estimated recruitment. If target reference points for biomass or exploitation rate are presented in assessments, those are also collected, but in many cases these are not estimated or not presented in assessments.

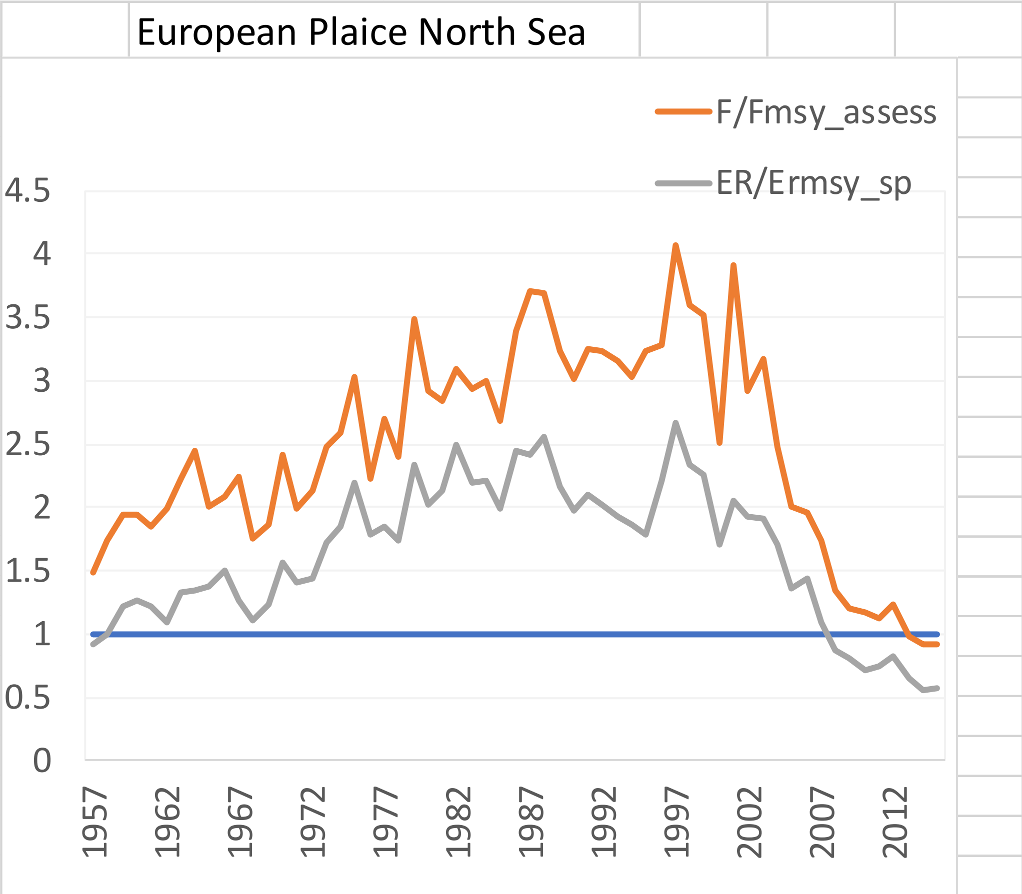
Separate from the main database which contains only assessment outputs, we supplement this with post-hoc estimated reference points if those are not available in stock assessments. We fit Pella-Tomlinson surplus production models to time series of annual surplus production (catch + change in biomass) and total biomass (or the closest representation available for exploitable biomass). We fit these models first for stocks that also have reference point estimates available from assessments (typically from age-structured models) to conduct cross-validations of reference point estimates. We fit a variety of surplus production models with varying assumptions and identify the model shapes and assumptions that tend to provide the best cross-validation predictive accuracy, treating assessment-estimated reference points as known. We then use these preferred models to estimate reference points for the stocks that did not have reference points available in stock assessments.

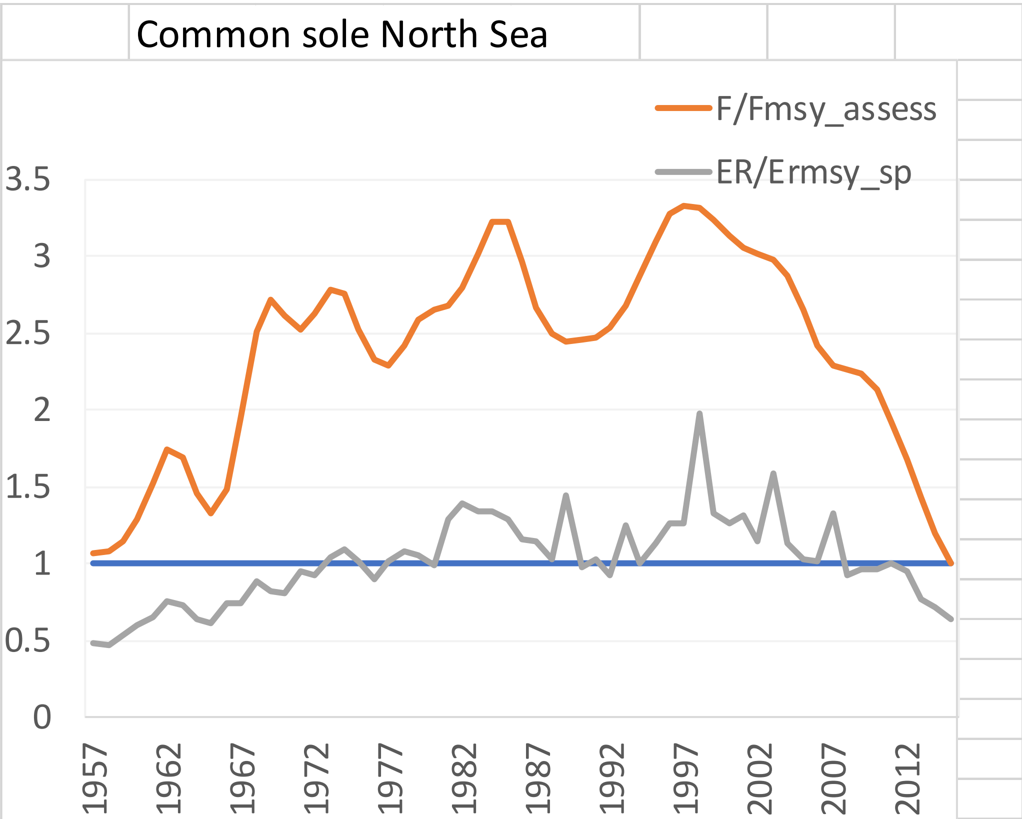
Below are some examples of comparisons of time series ratios of relative exploitation rate (or fishing mortality rate) between assessment outputs and post-hoc surplus production model fits. These relative ratios are time series of annual exploitation rate divided by the estimate of ER_{MSY}. Ideally ER and ER_{MSY} include all sources of fishing mortality over the whole stock, removed from vulnerable biomass, rather than being specific to certain fleets or age groups. In contrast, F and ratios of F/F_{MSY} from assessments may more commonly be restricted to certain fleets or ages. While not a perfect comparison, ratios of ER/ER_{MSY} (from post-hoc surplus production fits) and F/F_{MSY} (from assessments) are expected to be more correlated with one another than would be a comparison of the reference points estimates ER_{MSY} and F_{MSY} in isolation, i.e. the denominators of these ratios, because of the "F-currency" problem discussed above. In the following plots, the subscript "assess" denotes estimates taken from assessments, while "sp" denotes estimates taken from post-hoc surplus production points.

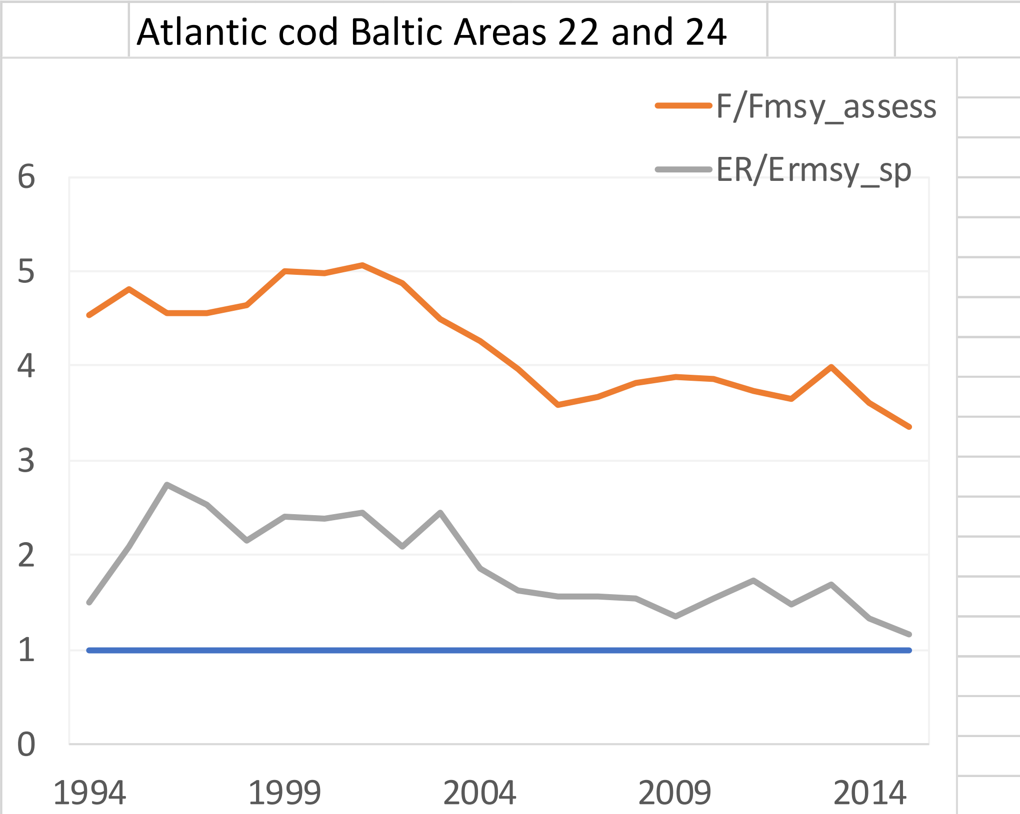
These show the range of model shapes and assumptions that were fit to each stock's time series of annual surplus production (on the vertical axis, in t) and total biomass (on the horizontal axis, in t). Data points range from blue (oldest) to red (most recent). (These plots are meant for internal review and are not user-friendly in terms of labels and legends). The surplus production fitting routines, cross-validations, and model selection procedures are currently in progress and will be further developed in late 2017 and early 2018.

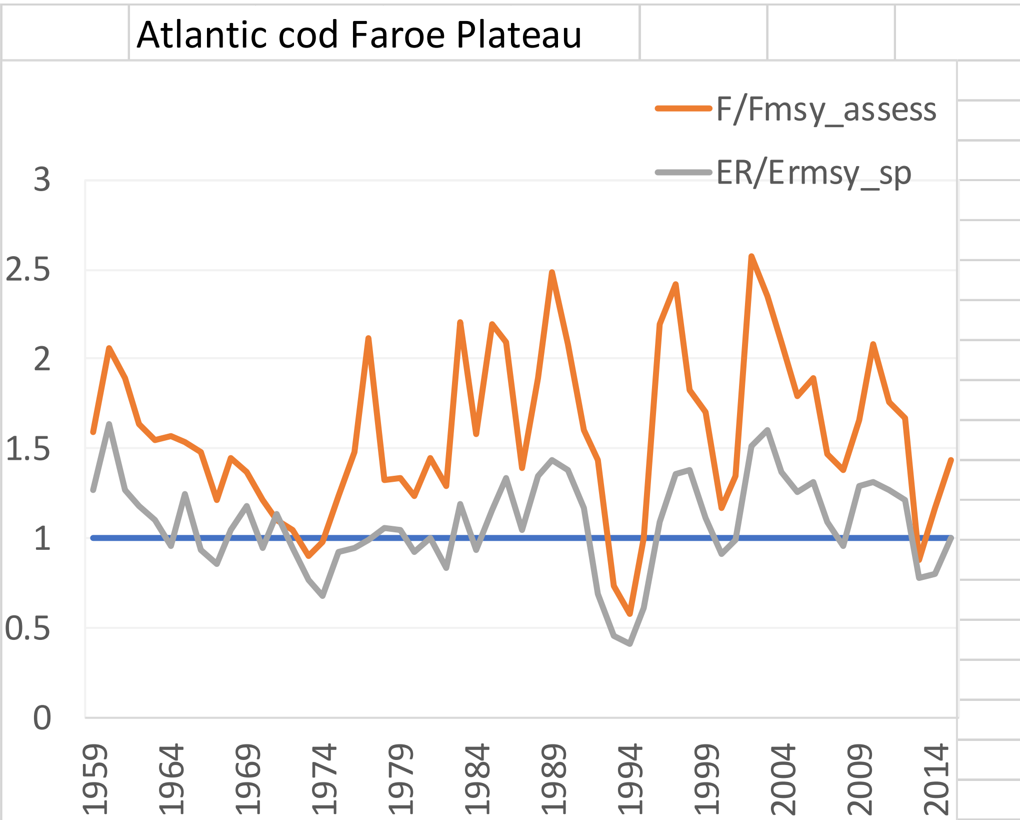


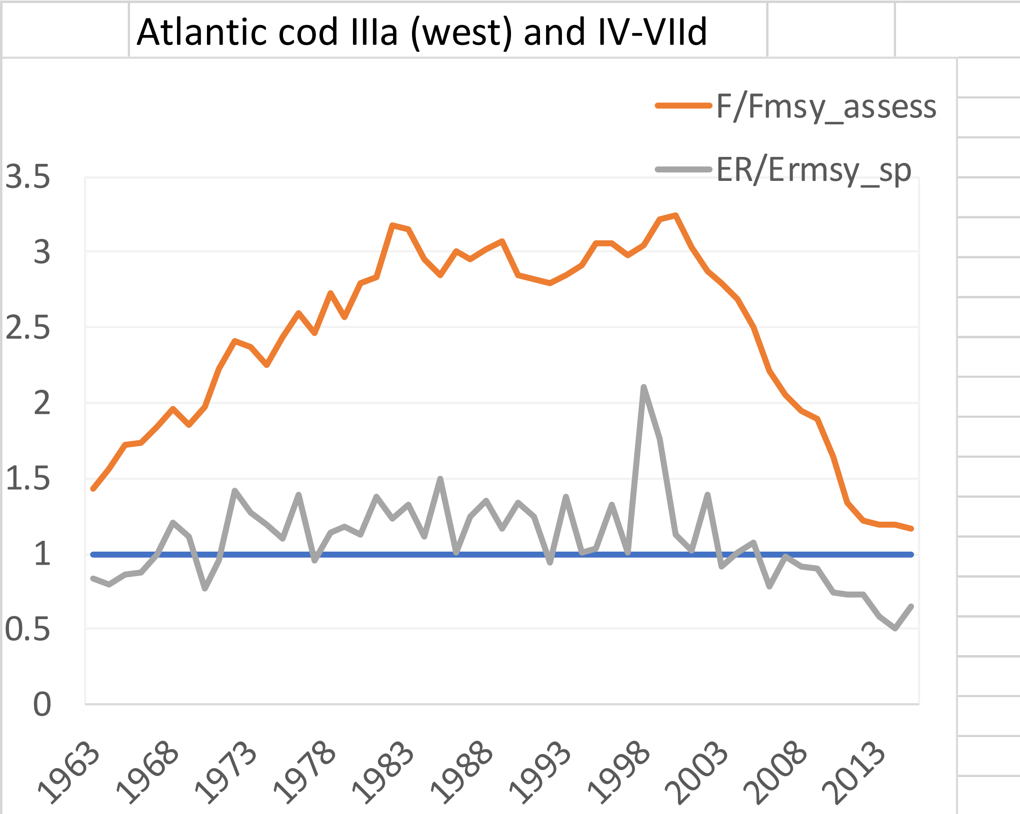


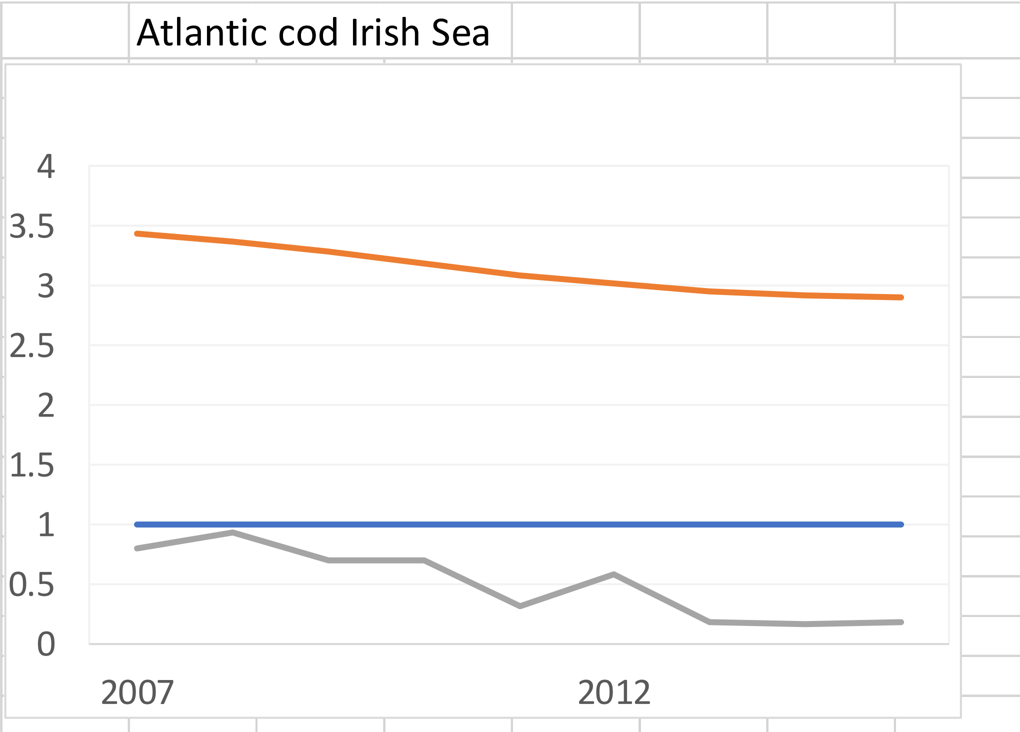

European Plaice North Sea
F/Fmsy_assess
ER/Ermsy_sp
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012

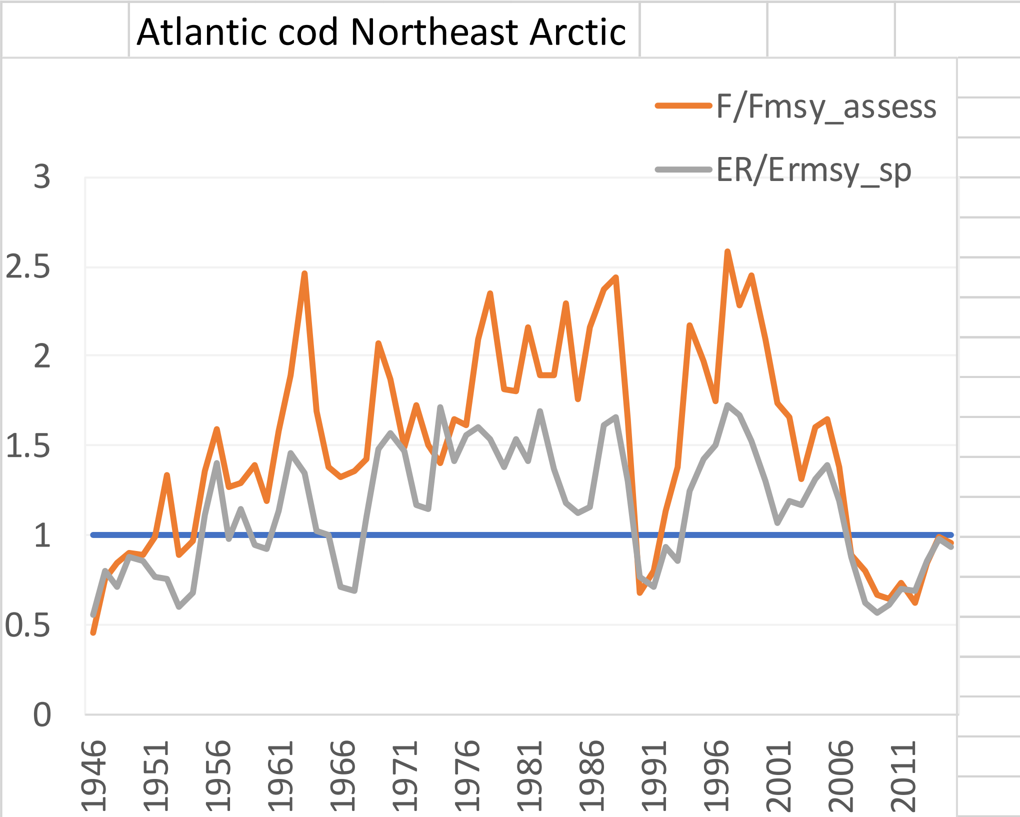

Common sole North Sea
F/Fmsy_assess
ER/Ermsy_sp
3.5
3
2.5
2
1.5
1
0.5
0
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
2012

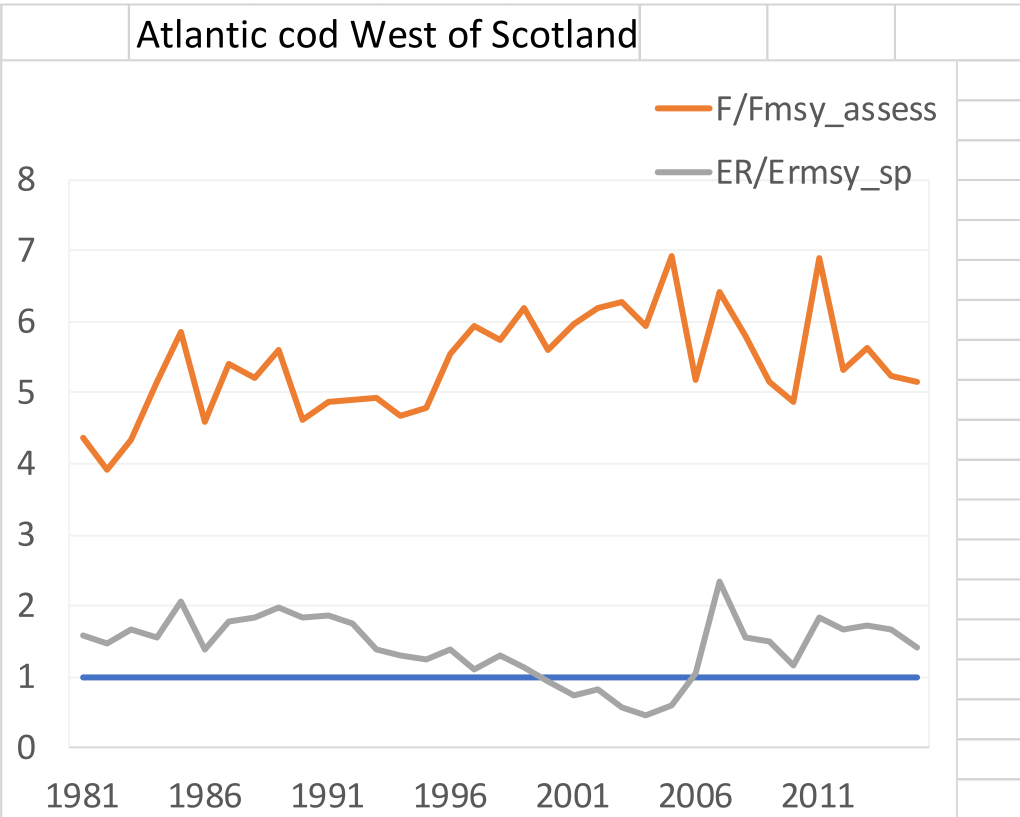

Atlantic cod Baltic Areas 22 and 24
F/Fmsy_assess
ER/Ermsy_sp
6
5
4
3
2
1
0
1994
1999
2004
2009
2014

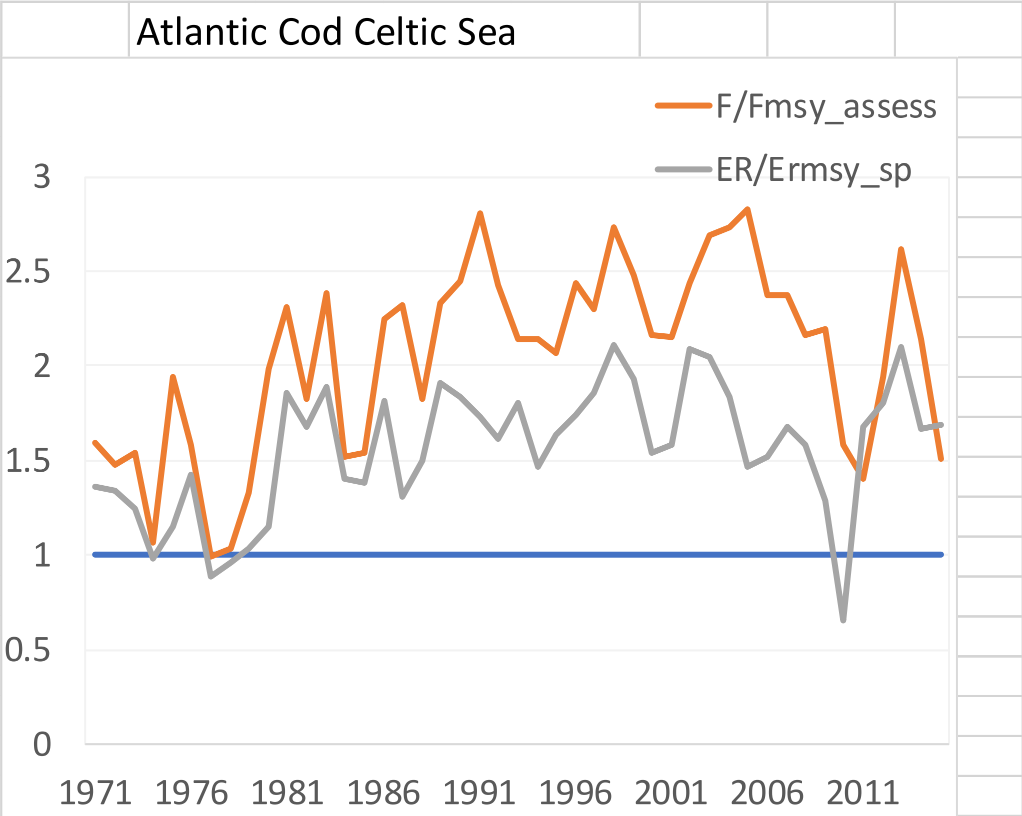

Atlantic cod Faroe Plateau
F/Fmsy_assess
ER/Ermsy_sp
3
2.5
2
1.5
1
0.5
0
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
2009
2014


Atlantic cod IIIa (west) and IV-VIId
F/Fmsy_assess
ER/Ermsy_sp
3.5
3
2.5
2
1.5
1
0.5
0
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013


Atlantic cod Irish Sea
4
3.5
3
2.5
2
1.5
1
0.5
0
2007
2012

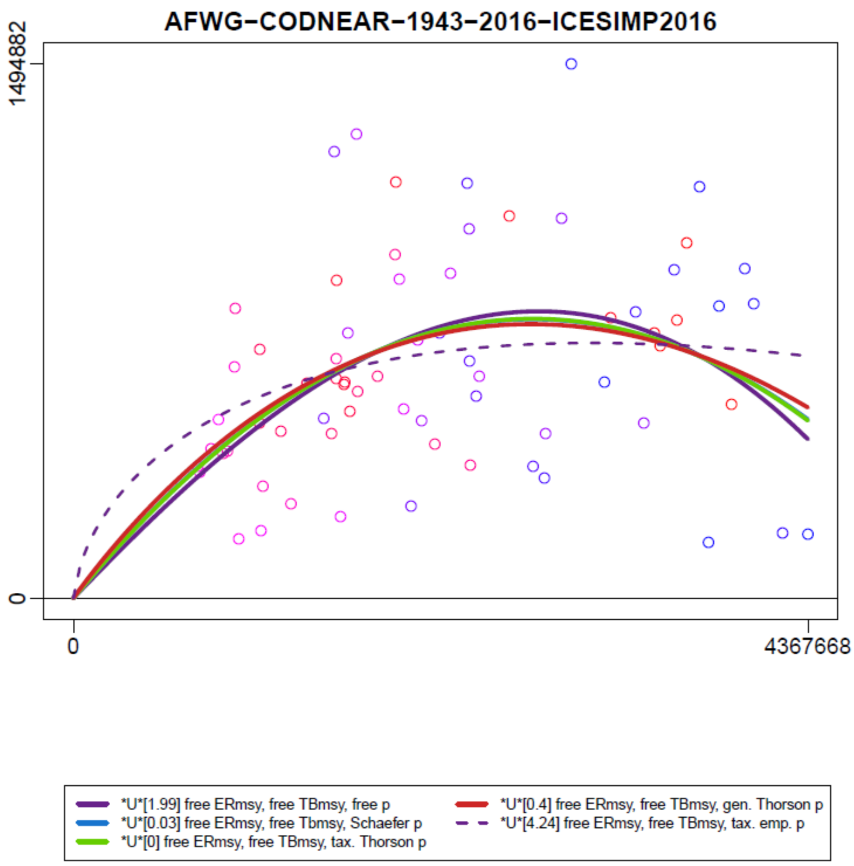

Atlantic cod Northeast Arctic
F/Fmsy_assess
ER/Ermsy_sp
3
2.5
2
1.5
1
0.5
0
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011

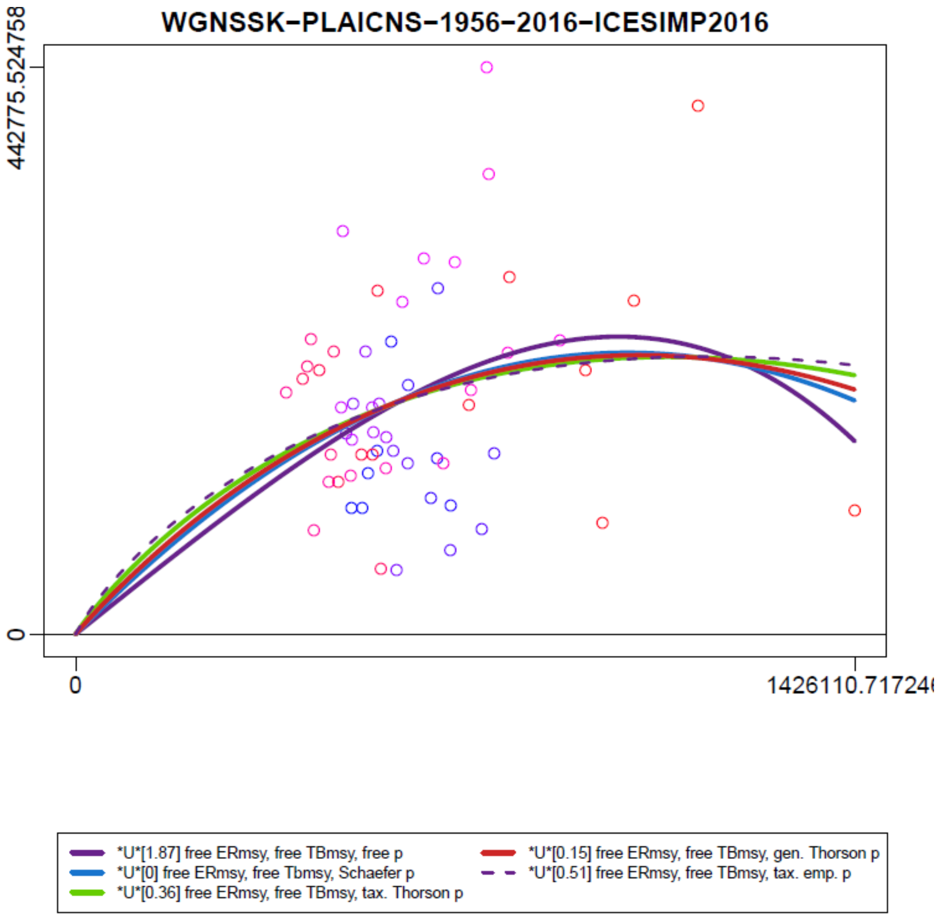

Atlantic cod West of Scotland
F/Fmsy_assess
ER/Ermsy_sp
8
7
6
5
4
3
2
1
0
1981
1986
1991
1996
2001
2006
2011



The plots above for a number of selected stocks generally confirms the preliminary results of the Fmsy based on Froese et al 2016, SPM work. They are basically grounded at the same data, but often differ in time series length, and in the implementation of the SPMs.

Examples of the surplus production fits themselves for these and other ICES stocks are show in the figure below for NEA cod and NSea plaice.





These plots show that the actual model choice is not important for these two stocks. However, for many other stocks model choice is quite important and it seems that letting the shape parameter "p" free is dangerous.

It is very relevant to include the Fmsy estimates from RAMs Legacy data shown above as a separate column in the "Main table". It should be calculated as for Froese et al 2016 data, by multiplying Fmsy/F (both F biomass based) from the SPM by F (age based) from ICES assessment.

In the RAM database they fit a variety of surplus production models with varying assumptions and identify the model shapes and assumptions that tend to provide the best cross-validation predictive accuracy, treating assessment-estimated reference points as known. In our project where we want to improve on the assessment-estimated reference points, a different model selection criteria could be used, maybe an AIC type criteria?

How to deal with discards.

This issue was only discussed very briefly and no new aspects were considered, but a decision needs to be taken well before the March meeting in order to do the SPM runs adequately.

As a general rule we should follow what ICES WGs have done in the assessment with discards. In addition we should make some sensitivity analysis of possible discard effects on assessment results. HS mentioned he did some for North Sea cod using PROST and even though there have been quite a lot of discards in this fishery it did not matter much for the Fmsy calculation. It reduced Fmsy by a few percentages only. Haddock and plaice in the North Sea have historically a very large discarding and here it might matter more.

One way might be to use landings data without discards in the SPMs and say that this is an unavoidable side effect for fishing and we expect it to continue into the future, and probably landed as what ICES call "unwanted catch".

In PROST runs we need to take specific account of it and it is not clear if the software can handle discards specifically. If not, some ways around it would be needed.

Fmsy calculations based on Froese et al (2016)

Here it should be emphasized that it is not the CMSY methods for data poor stocks that is considered in Froese et al 2016, but their ordinary SPM model for data rich stocks. This however, have a small twists by including a specific S-R model at low stocks sizes in order not to overestimate the recovery potential at low stock sizes. Whether this gives a bias in the estimates of Fmsy was not clear, but should be looked into before the next meeting in March.

HS showed the plot of Fmsy estimated by multiplying Fmsy/F by year from Froese et al 2016 with F by year from ICES assessment for North Sea cod for 2000-2014 (Figure below). Ideally, it should be constant, but there is a time trend which must be due mainly to difference in time trend between Froese et al and ICES assessment. Probably the last couple of years should not be included due to the convergence problems in ICES assessment.

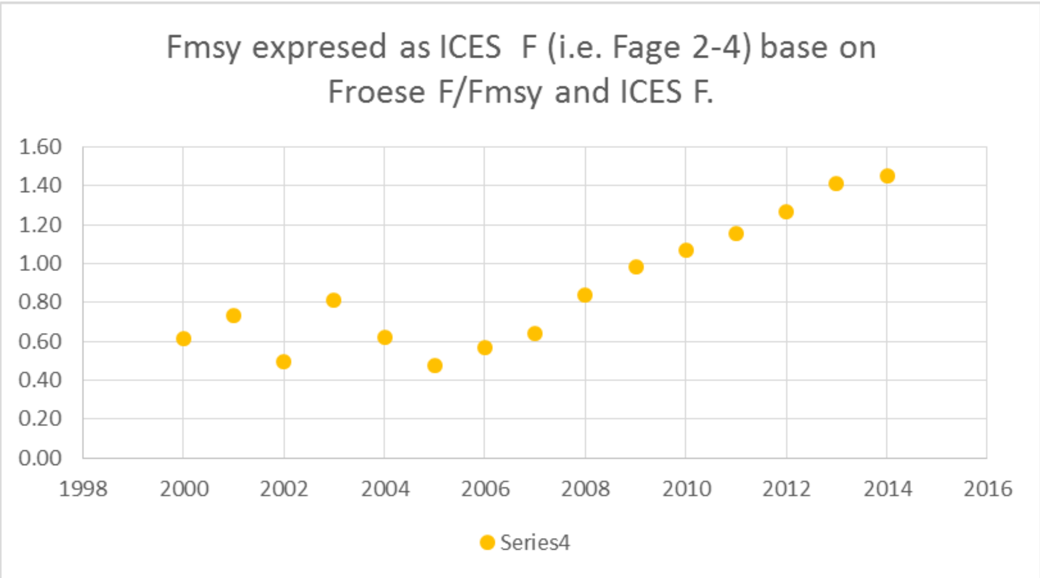


Figure. North Sea cod. Fmsy estimated from Froese et al 2016 in combination with ICES assessment of F by year.

HS has calculated Fmsy in this way for all the stocks in the "Main table" (Table 1.1), that pass the test of the criteria mentioned for an SPM approach (see above). The results (also presented in Table 1.1), shows that on average the Fmsy estimated in this way is about 50% higher than the ICES current Fmsy values.

There were some discussion about whether Froese et al (2016) overestimate Fmsy. However, it was mainly their CMSY model for data limited stocks that might do so, but this is not used in the present project, only the ordinary surplus production model based on stock assessment catch and biomass time series for data rich stocks. Here it seems that there might be a small problem at very low stocks sizes where an S-R sub-model is added to the ordinary SP model, so that stocks recover more slowly when depleted. It is uncertain whether this gives a bias in the estimate of Fmsy from the models, but this needs to be looked into before the next meeting in March.

Time series biases is a well-known phenomenon in S-R modelling but there seem to be no documentation of a similar problem in SPM models. We need to reflect on whether there is a problem in SPM models.

SPiCT

Software-wise SPiCT from Casper Berg, DTU AQUA seems to be worthwhile looking into as a better option than ASPIC for doing SPMs.

Claus Sparrevohn and Henrik Sparholt met with Casper Berg in August 2017. They had a good discussion about surplus production models and SPiCT especially. It seems that SPiCT can do what we want and we can use this instead of ASPIC.

SPiCT is an R based program, a new and up to date system, which can do what we need for the MSY project.

There is a user's guide https://github.com/mawp/spict/blob/master/spict/vignettes/vignette.pdf

The web page is https://www.stockassessment.org/login.php.

We can download the software to our own PC and make the runs there or link to the web page and modify runs there. The R code is the user interface. It might not need to change much so it seems quite simple and easy to do.

Casper used it at the ICES WKMSYKAT in spring 2017 on some about 30 SAM stock assessments, but using the basic data rather than the output from the SAM model.

He showed clearly that F/Fmsy is better estimated than F and Fmsy separately. This fits well with what we intend to do in the current project, use F/Fmsy. Because we then avoid the problem of what F means in a surplus production model context, compared to in an ICES age based model context.

Casper did not like to use SPiCT on the ICES summary data, as it is "a model on a model output". It is better in general to use the surplus model directly on basic data. Casper mentioned that SPiCT only works well when the time series of catch and biomass index are about the same time length. Thus, Casper had to shorten the time series a lot when he did runs for WKMSYKAT, which is not good because it ignores important information from the years discarded before the analyses is conducted. Therefore, we discussed to use it on the summary data and supplement it with a few cases where we run it also on only basic data (for biomass like survey CPUE indices). For that, we will select stocks for which we have very long CPUE time series.

Compared to ASPIC, SPiCT account for noise in the catch data and for process error. Furthermore, ASPIC do not produce confidence intervals on all parameters estimated (though on most) while SPiCT produce it on all.

RvG presented the SPiCT software at the present meeting and showed that it is quite easy to use. Jan Horbowy (not participating in the meeting) informed the Group that he has already done some runs with SPiCT and find it quite user-friendly and suitable for our purpose.

It was discussed which biomass metric is best to use in SPMs. SSB and sometimes also TSB is readily available form ICES Summary tables. However, alternative ones could be calculated quite easily from WEST and stock number at age data available in ICES assessment WG reports. Also catch/F which in principle is CPUE could be considered. So we have at least 4 alternatives:

1. SSB.
2. TSB (not always available but can be calculated easily from WEST and stock-number-at-age table.
3. Exploitable biomass calculated from WEST and stock-number-at-age table.
4. Catch/F.

All should be very correlated with each other, but in case F varies a lot over time TSB, Expl. Biomass and catch/F might be better to use than SSB. Catch/F might be the best, because it is closely related to exploitable biomass and simple to obtain for the entire time series. To calculate exploitable biomass from WEST and stock-number-at-age table might not be possible for the entire time series, because WEST is often constant by year in the early part of the time series and thus not including what we specifically what to include (directly or indirectly) in the current project, namely density dependent effects.

Carl Walters advised us to never try to estimate process and observation errors separately. This we need to look at in SPiCT.

Carl Walters also advised us that it often is sensible to assume catches known precisely when doing SPMs.

We were also informed that Murdock MacAlister have looked at SPiCT and might have some interesting comments to that software package.

BB will look into the best estimates of a long time series of NSSP herring for the SPM analysis. One could consider leaving out the years with industrial fishing as the exploitation pattern where very different in these years. Some SPM models do not need a continuous time series.

2.5 WP5 Density dependent growth and maturity and cannibalism

There seems to be an increasing attention in the science community on density dependent (DD) effects on growth, maturity, and cannibalism. Several new papers on the issue have been produced and many of these are uploaded to the Dropbox site of the present project. In the past almost half a century where fishing has just increased steadily year by year and overfishing a general phenomenon, DD was not very important for management because it was very early clear that it was not strong enough to counteract the increased fishing (see e.g. Graham 1947 synopsis of the ICES symposium on rebuilding of fish stocks after the WWII). However in the recent years where overfishing has ended and stocks are building up, it again becomes a hot issue because it influences the estimations of biological reference points.

"If density dependence is to be a cornerstone of ecological theory, a certain burden of proof needs to be satisfied."—den Boer (1991). That statement tricked Brook and Bradshaw (2006) do exactly that by a meta-analyze of 1198 species, including many fish. They state:

"Most biologists accept that density-dependent demographic processes (or more generally, negative feedback mechanisms; Berryman 2002) work to regulate natural populations (Turchin 1999, Lande et al. 2002), at least under some circumstances (Hixon and Carr 1997). That said, statistical detection of regulation using population abundance indices (as opposed to demographic data) can be problematic. For instance, exogenous (density independent) factors may overwhelm endogenous (density- dependent) processes (Andrewartha and Birch 1954), small sample sizes (i.e., few time steps of observation relative to the generation length of the organism being studied) reduce statistical power (Solow and Steele 1990), and sampling error can affect both Type I and Type II error rates (Shenk et al. 1998). The most biologically intuitive means of quantifying regulation (and determining critical mechanistic detail) is by direct examination of the relationship between density, realized demographic rates, and environmental covariates (Osenberg et al. 2002). However, a broad-scale evaluation of the nature and prevalence of population regulation across many species requires a different approach, such as meta-analysis of abundance time series."

They used multi-model inference (MMI), a form of model averaging, based on information theory (Akaike's Information Criterion) to evaluate the relative strength of evidence for density dependent and density-independent population dynamical models in long-term abundance time series of 1198 species. We also compared the MMI results to more classic methods for detecting density dependence: Neyman-Pearson hypothesis-testing and best-model selection using the Bayesian Information Criterion or cross-validation. Using MMI on our large database, we show that density dependence is a pervasive feature of population dynamics (median MMI support for density dependence ¼ 74.7–92.2%), and that this holds across widely different taxa. The weight of evidence for density dependence varied among species but increased consistently with the number of generations monitored.

Morgan et al (2016) analysed six well-studied depleted, or depleted and recovering, Northwest Atlantic groundfish stocks, and found that density dependence in growth and maturity were more important than in recruitment for the population dynamics. Joanne Morgan presented her study for the project group in the margin of the ICES ASC meeting in September 2017.

Andersen (2017) showed that from a theoretical point of view in size based ecosystem considerations, the size of fish where DD is most likely to be of most importance is around the size of maturity, because here the species constitute its largest part of the ecosystem biomass in its size class.

Henderson and Magurran (2014) in an analysis of species temporal variability within a single large vertebrate community of 81 species of fishes, found that the dominating species in an ecosystem are least variable in terms of temporal biomass, and concluded that they are under the heaviest density-dependent regulation.

Lorentzen and Enberg (2002) found that in 16 stocks analysed DD in growth was seen in 13 stocks and statistically significant in 9 stocks.

One of the few if not the only one, of meta-analysis studies which goes against the hypothesis of DD in growth is Brander (2007). He found for 14 cod stocks in the North Atlantic from 1970 to 2002 that there were hardly any relationship between weight-at-age and stock biomass. He concluded: "The hypothesis that growth is density-dependent is not refuted by the overwhelmingly positive relationships between total biomass and weight-at-age (Figure 2), but it does suggest that density dependent effects are neither widespread nor influential. " However, the time period Brander covered only saw periods of high F and thus changes in stock biomass were therefore only due to environmental effects. If these for instance are related to feed condition of cod then it is hardly surprising that Brander did not find density dependence. Furthermore, the dynamic range of the cod stock biomasses will be much extended towads the higher biomass side when F is reduced. With the current model used for estimating Fmsy for North Sea cod the SSB is expected to be 6 million t in case of no fishing and 1.2 million t in case of fishing at Fmsy. On Brander's plot (his Figure 2) for this stock the x-axis value of biomass/ha will go way beyond the current maximum of 22 kg/ha, to about 80 kg/ha. Therefore, in the context of Fmsy calculations Brander would have to extrapolating far outside the range of his data. In recent years F has decreased substantially for many cod stocks and stock size increased, for some stocks like the NEA cod stock to record levels and now DD in growth is apparent in the data (ICES 2017).

It was suggested that we could repeat Brander's analysis of DD growth for cod stocks in the North Atlantic now we have many more data years and better contrast in fishing mortality in the stocks.

Carl Walters made a presentation about prediction of density dependence on growth changes from bioenergetics. With the general bioenergetic model, $dW/dt = HW2/3 - mW$, where H is proportional to food intake, it implies the VBGF model, $dL/dt = KLoo - KL$, and $Loo = H/(ma1/3)$; $K = m/3$. Based on extensive trout experiments, it was found that H and m co-vary strongly, and the observed pattern is that high trout abundance leads to slower growth but almost the same maximal size as observed in low trout abundance systems. This could be looked at more closely. Niels G Andersen, DTU AQUA, is close to finalise his Dr.Sc. thesis on these matters and would be interesting to consult. Likewise Ken Andersen and his size based ecosystem model work.

Thus, there are overwhelming evidence that DD is an important ecosystem functioning. We analyse 45 data rich fish stocks and these are often dominating stocks in the ecosystem. Thus, it is prudent to expect DD to be a prominent feature of the population dynamics of these stocks.

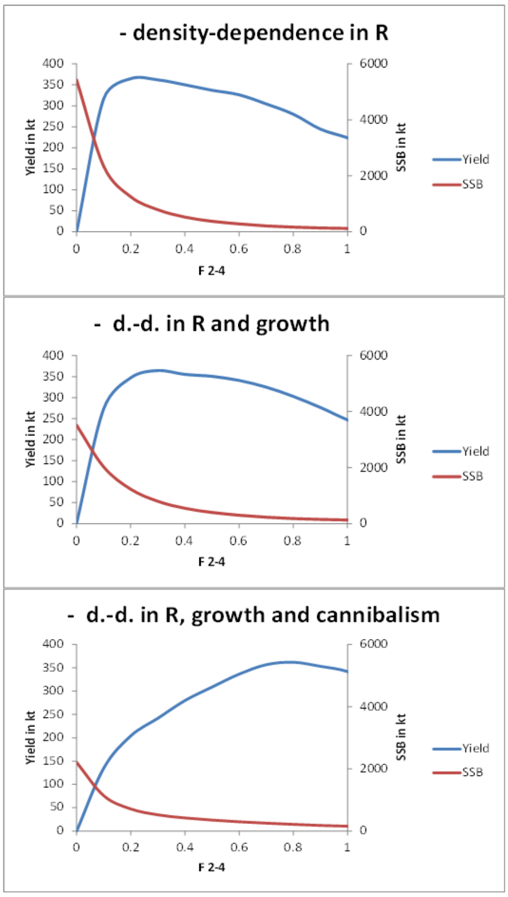
Cannibalism in cod stocks are well known. Hake are also cannibals. Blue whiting stomach analysis have shown to contain a few % juvenile blue whiting, and this might be enough to have an effect on mortality. The same with mackerel, where the 1981 stomach sampling project contain data on this showing very little cannibalism, but recent spawning along the Norwegian coast and in the inner Danish waters mean that there now a days are more overlap between adults and juvenile mackerel, and thus potentially more cannibalism.

Jan Horbowy has offered to help out.

JC presented a case with striped bass but found only little evidence of DD growth. However, its mortality was linked to the amount of menhaden and thus mortality might be DD for this species. It was suggested to do the analysis on summer flounder, as well. But again, as also mentioned above, there are many factors in the environment that can override the effect of DD and like for S-R relation-ship this does not prove that there is no relationship between stocks size and growth or mortality. It was suggested that DD could be looked into for summer flounder as well. Here the raw data indicate that we have a quite strong effect of DD in growth at least.

Horbowy's way of estimating DD growth was considered appropriate if stock biomass data are not too noisy. A straight line regression is used for the Barents Sea cod and haddock and have been accepted by ICES. A functional regression a la Ricker (1975) should be explored, because we are not testing hypothesis, but rather aiming for the best model a la Anderson (2008), and we have noise in the independent variable, the stock size.

The case about Fmsy estimation for North Sea cod was discussed. The figure below show how dependent estimates of Fmsy are on including DD for more than recruitment. The current model used is ignoring DD in growth, maturity and cannibalism. It gives an Fmsy of 0.20. However, if DD in growth is included Fmsy increases to 0.30 and if DD in cannibalism (from multispecies models) is further included, it gives Fmsy of 0.70. The discussion focused on SSB. SSB for the zero fishing is 5.5 million t, 3.5 million t and 2.2 million t respectively. All these are much higher than ever observed. Even at the so-called “Gadoid Outburst” in the 1970s SSB was only 0.4 million t. Clearly the 5.5 million t is unrealistic and ICES also realizes this, but state that even so, the Fmsy from that model is probably OK, without giving any further justification for that statement. The analysis shown in the figure below shows that Fmsy from this model is <u>not</u> OK. Thus, using the available science tells us that Fmsy is not 0.3, but rather around 0.7. Furthermore, clearly the 5.5 million t of virgin biomass is way more than the ecosystem can support, so something is wrong with the model and including DD in growth and cannibalism improves the model significantly in this respecy. The virgin SSB using the model with DD in grown and cannibalism gives an SSB of 2.2 million t. This is still a very high biomass, but just within realistic bounds for the ecosystem (Andersen and Ursin 1977 and ICES Multispecies working group – and many ICES reports from mid-1980s till today). If it is not DD in growth and cannibalism that prevents the stock from being 5.5 million to in case of no fishing, it has to be something else that restrict the biomass of cod. One could speculate that it might be diseases and parasites and increased mortality due to that. However, there are no science available that indicates that these factors are of significance.

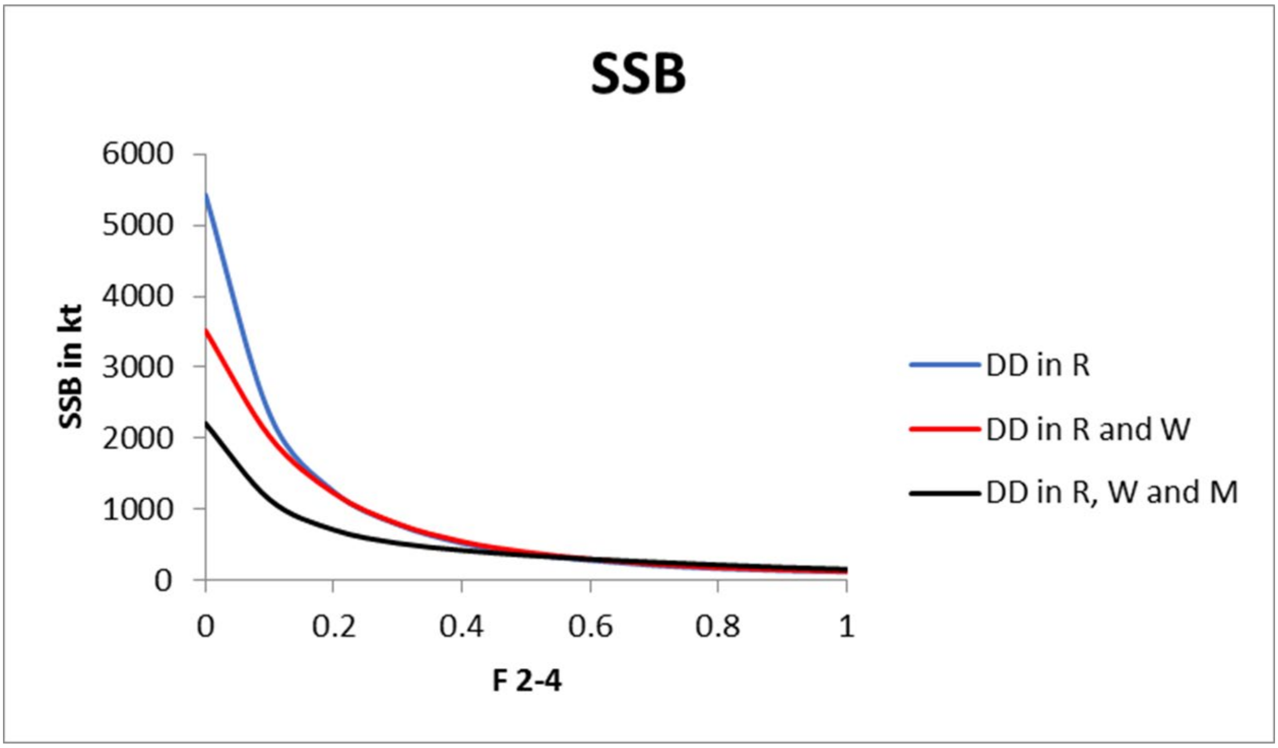


Fmsy

0.20

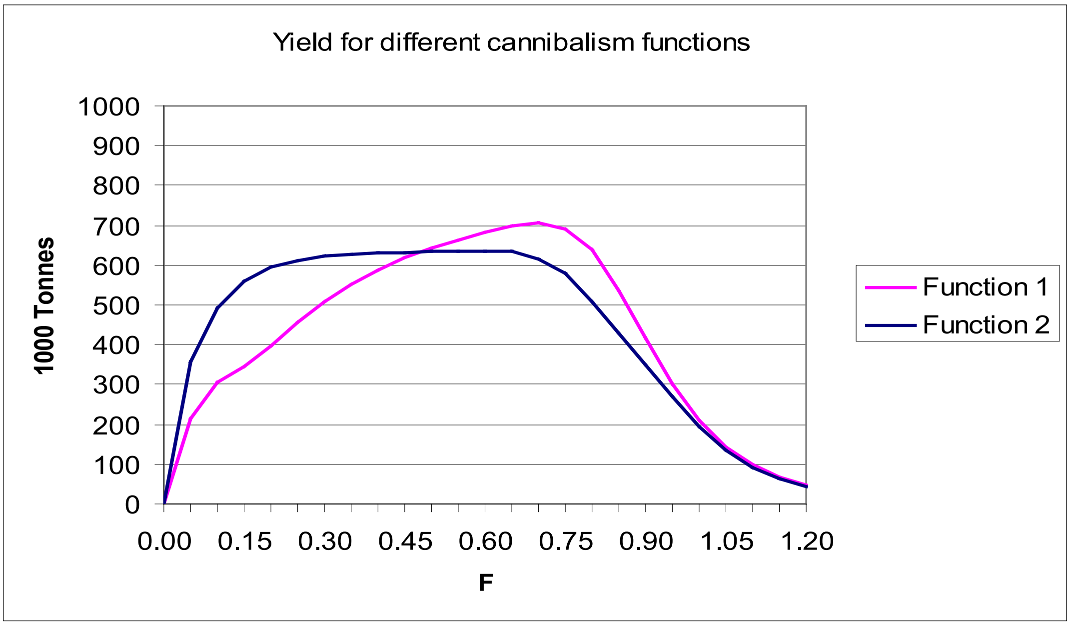
0.30

0.70



BB presented the Northeast Arctic case where Fmsy is estimated for cod and haddock including specifically DD in R, growth, maturity and cannibalism. Even multispecies aspects are considered in the agreed management plan for cod, where F is allowed to increase to a 50% higher values than Fmsy, namely to 0.6, when the stock is very large. In that way the negative impact from the cod stock on the capelin stock is taken into account.

Fmsy is estimated to 0.40 for cod and 0.35 for haddock. The estimation of Fmsy is quite sensitive to the functional form for cannibalism used, as the graph below shows from Kovalev and Bogstad (2005).



The following issues when doing PROST calculations were highlighted:

- Review status on DD growth and maturity by stock (papers, reports etc.), and also on cannibalism/mortality for stocks affected (cod, hake..)
- Methods : Regression analysis – but how? Weight/maturity at age or increments at age? Horbowy model or just linear – maybe funtional regression a la Ricker (1975) and Anderson (2008).
- Density of what – total stock (TSB), SSB, actual cohort/age group (and neighboring?), catch/F (as a CPUE index of stock biomass).
- How to disentangle DD effects from e.g. climate change effects at the same time?
- Which stock/recruitment functions to be used?
- Calculate Fmsy and also F0.1 and Fmax (the latter for e.g. present stock size and new stock size corresponding to new Fmsy).

The intension of the present project is to do similar PROST calculations for a handful of stocks to see if the new Fmsy values from SPMs can be explained by DD in growth, maturity and cannibalism. If the PROST calculations give similar Fmsy as the SPMs Fmsy values, at least we have a plausible explanation of the SPM results.

Stocks considered here are mackerel, NSea cod, NSea plaice, NSea sole, Northern hake, Baltic sprat, and summer flounder.

We should do a meta-analysis of the 45 stocks used in this project by taking WEST data from each stocks and regress it against SSB. JH will take the lead in this work.

2.6 WP6 - Life history parameters relevant for Fmsy.

Potential metrics to use is maximum age, age at 50% maturity, L_{oo}, steepness in the stock recruitment relationship and probably more. The plan is to invite Henrik Gislason and John Pope to our next meeting (in March 2018) and discuss among other thing this issue with them. Andersen (2017) suggests that Lmax or Linf should be enough to consider based on analysis in a size based model framework.

2.7 WP7 - GLM type analysis to “export” ecosystem Fmsy

No new input to this section.

2.8 WP8 – Implementation

We managed to get a Theme session at ICES ASC 2018 accepted. It will have the title: **“Sustainability Thresholds and Ecosystem Functioning: The Selection, Calculation, and Use of Reference Points in Fishery Management**”. It became merged with another proposal and we are 6 conveners. Details are included in Appendix 6.

We also managed to give a presentation of our project at the ICES WKMSYREF5 meeting in Sicily, September 2017. We suggested that the next WKMSYREF meeting should have ToRs relevant for our project, but we don’t know yet whether that was finally adopted by ICES. BB will talk to Knut Korsbrekke (one of the two Chairs of the group) about this.

2.9 WP9 - Concluding work

PA reference points (e.g. Fpa) in ICES are mainly estimated without DD effects (usually only S-R is considered), to be consistent with our Fmsy estimates which will include DD effects, it may be necessary to re-estimate PA reference points taking into account DD effects (e.g. in growth, M, maturity).

It might be a good idea to include a column with actual F in the past by stock in the main table or otherwise show what F have been, maybe by decade or as a mean over some overfishing decades e.g. 1980-2000.

Final conference – mainly to report results, discuss them with other scientists and to present it to the public. It was agree that it should be called a symposium rather than a conference because a symposium is a small event, which fits to what we plan to do.

Several aspects of the Symposium were discussed:

1. An introduction about why something is needed.
2. An intro to what will happen the at the symposium
3. It was agreed that it would be good to present the overall outcome in the way of what will society gain in sustainable catch per year if the new Fmsy values are correct, and they manage the fishery using the new Fmsy values. Maybe towards the end of the symposium.
4. And what is the risk if the single species model is the correct state of nature and vice versa, maybe presented in a 2 x 2 table of yield at Fmsy-
5. The symposium should not be too scientific.
6. Jose Olivera (one of the two Chairs of WKMSYREF) is rumored to try to organize a similar symposium, maybe a combined one could be considered?
7. The Barent Sea and Iceland cod cases should be presented.
8. Our approach is not a full multispecies one but more what is needed to do now until a full multispecies approach is agreed but this might take 5, 10, 20, …years
9. How can our results be used?
10. What is the risk of implementing the new Fmsy values?
11. History – of Fmsy, DD, multispecies
12. We should have the bullet points of our presentation ready at the March meeting.
13. MAREFRAME is having a symposium 13-14 December, that might be good to go to.

A draft Symposium programme was produced:

Towards Ecosystem Based FMSY Values in Fisheries Management in temperate waters

A scientific symposium organised by the "Fmsy-project" group

11-12 October 2018, DGI Byen Copenhagen, Denmark

Day 1 – October 11, 2018
Chair: (Carl-Christian Schmidt, Mike St John, Sten Sverdrup, Mark Dickey-Collas, Henrik Mosegaard, Manuel Barange Joanne Morgan, Carmen Fernandez, Katja Enberg, Dag Aksnes ??)

12:00 – Lunch and networking hosted by the Fmsy project

13:00 --Opening of Symposium

Welcoming Remarks Carl Christian Schmidt NMTT Chair, NMR (Gier Oddsen??) , Maybe one from the Danish Ministry or EU , IMR Geir Huse John Pope Poul Degnbol, S??

13:20 -- Keynote Introductions to Symposium -- Setting the Scene: Henrik Sparholt, Manuel Barange (FAO)

13:50 -- The Barents Sea experience – Bjarte

14:20 – The Icelandic cod experience - Gunnar

14:50 -- Coffee and Networking

15:20 -- The Multispecies ecosystem model knowledge – Daniel/Jeremy

15:50 – "Exporting" the Fmsy to other stocks – Gunnar

16:20 – Surplus production models and Fmsy – Jan Horbowy/Reinar Froese

16:50 – Historical catch data improvements – Claus/Søren

17:20 – Results from SPiCT and Oceana study – Henrik/Rob

17:50 – Closing for the day - chair

18:00 -- 21:00 Symposium Networking Buffetr, hosted by Fmsy project--
DGI Byen

Day 2 – October 12, 2018
Chair: NN

08:00 – Breakfast and networking hosted by the Fmsy project

09:00 --Density dependence in fish populations – Ray, Katja Enberg, Joanne Morgan?

09:30 -- Specific PROST calculations -- Henrik/Rob

10:00 – Regime shifts and climate changes -- Petur

10:30 – Overall conclusion about a new set of Fmsy values -- Villy

11:00 – Coffee and Networking

11:30 -- Roundtable discussion – How can these new Fmsy be implemented?
Moderator : NN (Martin Pastoors, Manuel Barange, Katja Enberg??)
Participants: ???Eskild Kirkegaard, Simon Jennings, David Agnew, Ernesto Jardin, Henrik Sparholt, Ray Hilborn, Jeremy Collie, Geir Huse, Knut Korsbrekke, ….??

12:45 -- Closing remarks by Carl-Christian Schmidt (NMTT Chair)

13:00 – 14:00 Lunch hosted by the Fmsy project

Norwegian industry/manager representative would also be appreciated as they have contributed to the fnding of the current project. BB to come up with suggestion for a relevant names.

It was also mentioned that José Olivera og Knut Korsbrekke (chairs of ICES WKMSYREF) would obviously be good to have at the symposium.

Our primary focus in relation to publication of our work should be on producing peer reviewed papers. We should already now start thinking of possible titles and who is on which papers. One title could be "Best practice for creating biological reference points in fisheries management".

However, a project report is also needed and HS will make a proposal for a list on content of this and send around for comments.

2.10 WP10 - Administration, meetings and homepage

The homepage is now up and running, but there are still quite a number of issue to be resolved. The link is https://www.fmsyproject.net/

The issues were:

1. Word files should be pdf files;
2. No need to be directed right from the start to a new address;
3. Better background color so that the text is clear and it does not look like a night sky;
4. Better and more professional logos. In English. Maybe vertically instead of horizontally presented;
5. Contact should only be HS;
6. List of participants with emails and maybe the short CV.
7. Picture of participants.
8. Click here – should be in another color.
9. WP1…11 with text.
10. When open a WP do it in a different page.
11. Video of HS explaining the project.
12. "go to site" not good.
13. FAQ. Look at MAREFRAME.
14. June 8 2017 - …what was this?
15. Maybe GF of NMTT around the 11-12 October to secure participation of NMTT members.
16. Opening text about what Fmsy is.
17. Design look at MAREFRAME.

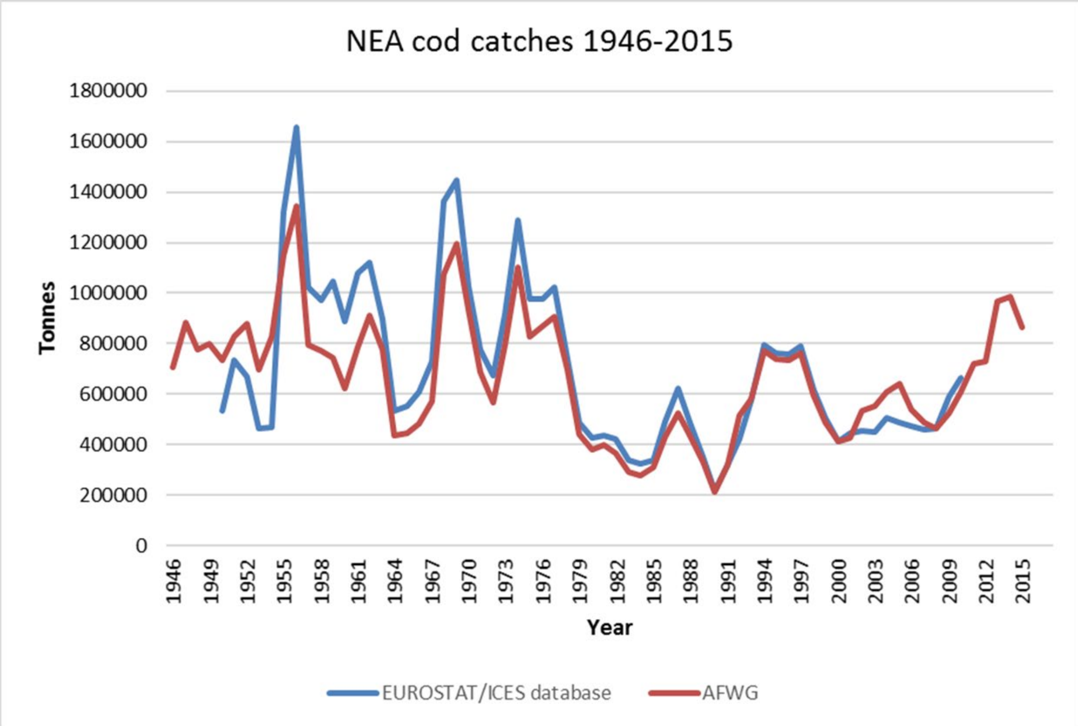
2.11 WP11 – Catch data improvements

SAP presented this point. It was agree to focus on the following stocks:

- North Sea cod
- NEA cod
- Herring North Sea
- Plaice North Sea
- Haddock North Sea

Mis-reporting, discarding, and high-grading have been reported for these stocks. Furthermore, there are relatively good information on what might have happened historically.

SAP presented comparison between FAO/ICES database catches and WG data. For NEA cod it was a surprise to see that the FAO/ICES data for the 1950s and 1960s differed quite a lot. BB will look into this.



ICES WG catch data are the default data to be used in the present project because these are linked specifically to stocks and some un-reported catches are included, when relatively solid information about it are available. The aim of this WP11 is to further improve the ICES WG data if possible. Pauly and Zeller (2015) – a "Sea Around Us" product - is an important source of information for this. Their data ('reconstructed data') are a combination of official reported data and reconstructed estimates of unreported data (including major discards). Official reported data are mainly extracted from the Food and Agriculture Organization of the United Nations (FAO) FishStat database.

One problem with Pauly and Zeller data is however, that it is by country and not by stock. Thus, some decision need to be made to distribute this to the relevant stocks.

For NEA cod there are reports from the Norwegian Coast guard about unreported catches for some years, but what about the years just prior to that. Here it is likely that un-reporting took place, but are AFWG catches data corrected for that? This could be looked into.

Historical catch data are very important for the results of the present project. Therefore, biases, mis-reporting, discards, and related issues will be scrutinized with the aim of correcting the time series. Issues that were sensitive decades ago, might now be possible to treat objectively and scientifically. Conversion factors for gutted fish to whole fish, overfilling fish boxes to be on the "safe" side in relation to quota management and the like, might have biased the current time series. There have been attempts in the scientific literature to correct for such things by e.g. ICES and the "Sea Around Us" –project. Such sources of information will be evaluated. There will be a focus on a limited number of case studies in order to show the magnitude of influence on the obtained Fmsy reference point estimates by the project.

Rudd and Branch (2017) was mentioned as a good paper to refer to, because it deals with the impact of unreported catches on stocks assessment and reference points.

We should do some simulations to explore the effect of un-reporting.

Assignment to work packages

The up-to-date assignment is given below.

Item	Bjarte	Daniel	Claus	Gunnar	Henrik	Jan	Jeremy	Postdoc	Petur	Ray	Søren	Villy	Steve Ma
Work package 1. "Common currency" of F		x		x	C	x							
Work package 2. Regime shifts, climate changes, genetic changes due to fishing, and suspected misreporting historically (strong link to WP 11).	x		x	x	x	x			C	x	x	x	
Work package 3. Compile ecosystem and multispecies estimates of Fmsy	x	C		x		x	x		x			x	x
Work package 4. Surplus production model estimates of Fmsy				x	x	C		x		x			
Work package 5. Density dependent growth, maturity and cannibalism.	C				x		x	x	x	x			
Work package 6. Life history parameters relevant for Fmsy.					x	x	x		x	x		C	
Work package 7. GLM type analysis to "export" ecosystem Fmsy	x	x		C	x								
Work package 8. Implementation. (Presentations at various fora, including ICES EGs and ASC, ACs , 95% yield interval in Fmsy)	x	x	x	x	C	x	x	x	x	x	x	x	
Work package 9. Concluding work (1) report writing to funding agencies, 2) paper writing for scientific journal, 3) final conference)	x	x	x	x	C	x	x	x	x	x	x	x	
Work Package 10. Administration, meetings and homepage.					C			x					
Extra Work Package 11 (EU + Danish funded). Extra on misreporting in cooperation with fishers. Strong link to Sub WP 2 work package			C		x			x			x		
Number of Chairships	1	1	1	1	4	1	0	0	1	0	0	1	
Number of ordinary WP participations	5	4	3	5	6	6	4	6	5	6	4	5	
Sum	6	5	4	6	10	7	4	6	6	6	4	6	

We expect that Steve Mackinson will be interested in participating in the MSY project and he is suggested to be participating in WP3 due to his expertise in ecosystem models for the North Sea.

Future meetings (dates, openness to observers, etc.)

It was agreed at our June meeting that our work should be as open as possible to the public. Observers and participants should be allowed and the ICES guidelines should be good and useful guidelines for the current project as well. Thus, the chair of our meetings will have great flexibility to invite people. However, we should avoid politics to come into our work.

It was agreed at our June meeting to meet in Rhode Island, USA 11-13 March 2018, and have the conference, which should be called a symposium from now on, because a symposium is a "small conference" like ours 11-12 October 2018.

AOB

No issues was raised.

Closing

HS closed the meeting by thanking all the participants for intensive and constructive discussions with a special thank to Carl Walters for participating at the entire meeting and making substantial contributions to the discussions. An especially big thank you went to VC for organizing the meeting,venue, hotel, practicalities, etc. so effectively and which resulted in splendid conditions for us.

References

Andersen, Ken H. (2017). Fish and Fisheries: The size- and trait-based approach. Doctoral Thesis. National Institute of Aquatic Resources, Technical University of Denmark. 152 p. ISBN: 978-87-7481-237-1.

Anderson, David R. 2008. Model Based Inference in the Life Sciences. A Primer on Evidence. Springer Verlag. ISBN 978-0-387-74073-7.

Brander, K. M. 2007. The role of growth changes in the decline and recovery of North Atlantic cod stocks since 1970. – ICES Journal of Marine Science, 64: 211–217.

Brook, Barry W. and Corey J. A. Bradshaw. 2006. Strength of evidence for density dependence in abundance time series of 1198 species. Ecology, 87(6), 2006, pp. 1445–1451.

Clausen LW, Rindorf A, van Deurs M, Dickey-Collas M, Hintzen NT. Shifts in North Sea forage fish productivity and potential fisheries yield. J Appl Ecol. 2017;00:1–10. https://doi.org/10.1111/1365-2664.13038-

Cordue, P. L. 2012. Fishing intensity metrics for use in overfishing determination. – ICES Journal of Marine Science, 69: 615–623.

Goodyear, C.P. 1977. Assessing the impact of power plant mortality on the compensatory reserve of fish populations. Proceedings of the conference on assessing the compensatory reserves of fish populations.

Goodyear, C.P. 1993. Spawning-stock biomass per recruit in fisheries management: foundation and current use. Can. Spec. Pub. Fish. Aquat. Sci.

Henderson PA, and Magurran AE. 2014 Direct evidence that density-dependent regulation underpins the temporal stability of abundant species in a diverse animal community. Proc. R. Soc. B 281: 20141336. http://dx.doi.org/10.1098/rspb.2014.1336.

ICES. 2017. Report of the Working Group on Inter-benchmark Protocol on Northeast. Arctic Cod (2017), 4–6 April 2017, Copenhagen, Denmark. ICES CM 2017/. ACOM:29. 236 pp.

Lorenzen, K. 2016. Toward a new paradigm for growth modeling in fisheries stock assessments: Embracing plasticity and its consequences. Fisheries Research 180 (2016) 4–22. https://doi.org/10.1016/j.fishres.2016.01.006

Morgan, M. Joanne, Peter A. Shelton, Fernando González-Costas, and Diana González-Troncoso. 2016. Compensation potential in six depleted groundfish stocks from the Northwest Atlantic. Can. J. Fish. Aquat. Sci. Vol. 73, 2016.

Rudd, M. B. and T. A. Branch. 2017. Does unreported catch lead to overfishing? FISH and FISHERIES, 18:, 313–323.

Appendix 1. Agenda and Minutes assignments

1. Welcome
2. Adoption of agenda
3. Progress on Work Packages
    a. WP1 **"Common currency" of F** - Henrik HS
    b. WP2 **Regime shifts, climate changes, genetic changes due to fishing, and suspected misreporting historically** - Petur BB
    c. Wp3 **Compile ecosystem and multispecies estimates of Fmsy** – Daniel/Bjarte BB
    d. WP4 **Surplus production model estimates of Fmsy**
        i. General – Jan JC
        ii. Froese et al based – Henrik JC
        iii. SPICT software - Rob HS
    e. WP5 **Density dependent growth and maturity and cannibalism** – Bjarte VC
    f. WP6 **Life history parameters relevant for Fmsy** – Villy HS
    g. WP7 **GLM type analysis to "export" ecosystem Fmsy** –
    h. WP8 **Implementation –** Henrik SAP
    i. WP11 **Catch data improvements –** Søren/Claus RvG
4. ICES Theme Session ASC 2018 – Bjarte
5. Conference program – Henrik SAP
6. AOB VC
7. Closing

Appendix 2. List of participants.

Participant name	Participant organization name	Country	Short name	Particpa ted
Henrik Sparholt	Nordic Marine Think Tank (NMTT)	Denmark	HS	Yes
Ray Hilborn	University of Washington	USA	RH	Yes 31 Oct
Jan Horbowy	National Marine Fisheries Research Institute (NMFRI)	Poland	JH	No
Petur Steingrund	Marine Research Institute, Faroe Islands	Faroe Islands	PS	No
Jeremy Collie	University of Rhode Island	USA	JC	Yes
Bjarte Bogstad	Institute of Marine Research (IMR)	Norway	BB	Yes
Daniel Howell	Institute of Marine Research (IMR)	Norway	DH	No
Villy Christensen	University of British Columbia	Canada	VC	Yes
Søren Anker Pedersen	EUFISHMEAL	Denmark	SAP	Yes
Claus Reedtz Sparrevohn	Danish Pelagic Producer Organization	Denmark	CRS	No
Rob van Gemert	DTU AQUA	Denmark	RvG	Yes
Mike Melnychuk	University of Washington	USA	MM	Yes
Carl Walters	UBC	Canada	CW	Yes
Gunnar Stefansson	Univ. of Iceland	Iceland	GS	No

Appendix 3. Assignment to Workpackages.

Item	Bjarte	Daniel	Claus	Gunnar	Henrik	Jan	Jeremy	Postdoc	Petur	Ray	Søren	Villy	Steve Ma
Work package 1. "Common currency" of F		x		x	C	x							
Work package 2. Regime shifts, climate changes, genetic changes due to fishing, and suspected misreporting historically (strong link to WP 11).	x		x	x	x	x			C	x	x	x	
Work package 3. Compile ecosystem and multispecies estimates of Fmsy	x	C		x		x	x		x			x	x
Work package 4. Surplus production model estimates of Fmsy				x	x	C		x		x			
Work package 5. Density dependent growth, maturity and cannibalism.	C				x		x	x	x	x			
Work package 6. Life history parameters relevant for Fmsy.					x	x	x		x	x		C	
Work package 7. GLM type analysis to "export" ecosystem Fmsy	x	x		C	x								
Work package 8. Implementation. (Presentations at various fora, including ICES EGs and ASC, ACs , 95% yield interval in Fmsy)	x	x	x	x	C	x	x	x	x	x	x	x	
Work package 9. Concluding work (1) report writing to funding agencies, 2) paper writing for scientific journal, 3) final conference)	x	x	x	x	C	x	x	x	x	x	x	x	
Work Package 10. Administration, meetings and homepage.					C			x					
Extra Work Package 11 (EU + Danish funded). Extra on misreporting in cooperation with fishers. Strong link to Sub WP 2 work package			C		x			x			x		
Number of Chairships	1	1	1	1	4	1	0	0	1	0	0	1	
Number of ordinary WP participations	5	4	3	5	6	6	4	6	5	6	4	5	
Sum	6	5	4	6	10	7	4	6	6	6	4	6	

Appendix 4. Text suggested for the final report for WP1

It is expected that the text below will be section 2 of the final project report.

2. The ”common currency” problem for fishing mortality

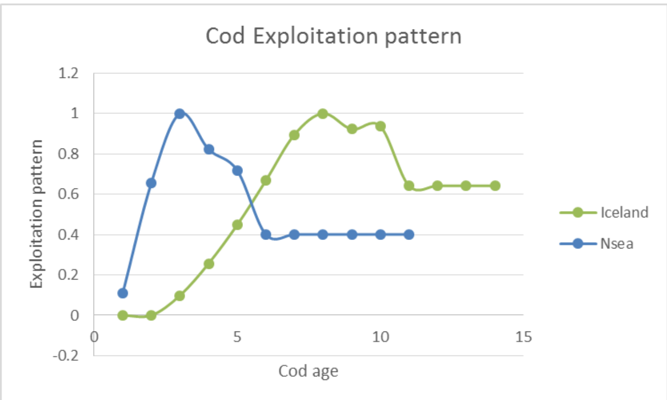
The current project will attempt to apply various methods to estimate Fmsy for the data rich stocks listed in Table 1.1. These methods do not all operate with the same basic unit when calculating F. The age range used to calculate the mean F varies. Some stocks are fished with a small mesh size and others with a large one and this will also influence the actual value of an estimated Fmsy. For instance one would expect that a stock fished with a large mesh size will have a higher Fmsy than a stocks fished with a small mesh size, everything else being equal. Surplus production models (SPM) operate with stock biomass as the basic unit instead of numbers and it can be difficult to translate Fmsy values from these models to the age and number based Fmsy used currently. It is therefore important to find a “common currency” for F to compare and contrast the model estimates of Fmsy in the kind of meta-analysis that is attempted the current project.

2.1 Common currency for age-based Fs

Fishing mortality for data rich stocks dealt with in the present report, is age- and number-based. A mean F at age over some age groups are used to represent the overall fishing pressure in a given year. For Northeast Arctic cod for instance, it is the mean F over ages 5-10, and for North Sea cod a mean over ages 2-4. Sometimes the age range represents the flat part of the exploitation-by-age curve, sometimes it includes also age groups partly recruited to the fishery if these are an important part of the catch. Some stocks are fished with a small mesh size others with a large one and the corresponding Fmsy will depend on this. A further issue is the comparability of Fs when estimated by models that uses different natural mortality-at-age. For the meta-analysis attempted in the current project it is important to define a “common currency”, for F, so that Fmsy can be compared in a fair way between stocks.

2.1.1. Exploitation pattern and mesh size difference

Several of the above mentioned issues are reflected in the exploitation pattern. If for instance the mesh size used is small there will be a high F on young age groups and if mesh size is large there will be a low F on young age groups. An illustrative example here is the difference between fisheries on North Sea cod and Icelandic cod. In the North Sea cod fishery the mesh size used is much smaller than in the Icelandic cod fishery. Figure 2.1.1 shows the resulting exploitation pattern.



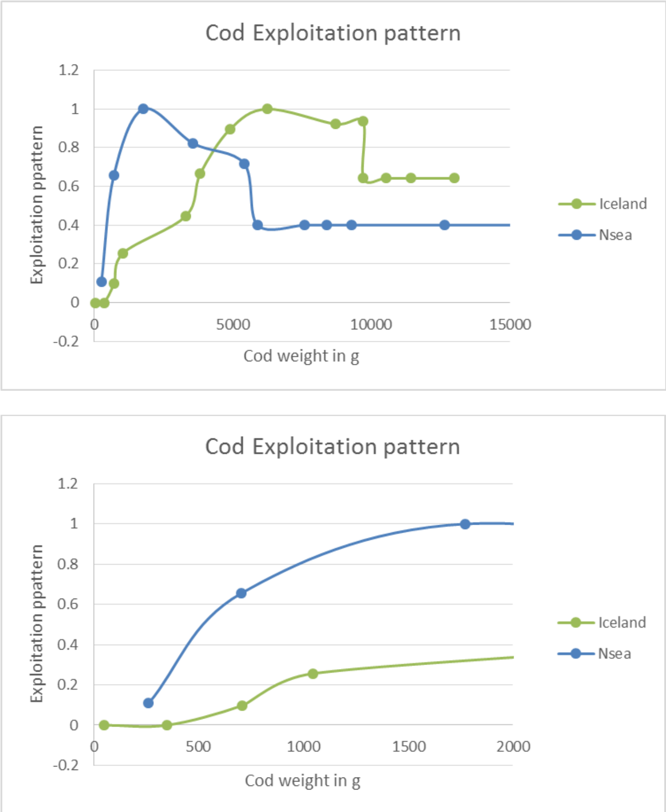


Figure 2.1.1. Comparison between exploitation pattern in the North Sea cod fishery and the Icelandic cod fishery. In the top panel expressed as age based F and in the bottom panel as size based until a weight of 2 kg(From ICES WG reports).

A stock that is fished with a large mesh size can probably tolerate a higher fishing mortality and has a higher Fmsy (calculated as an average of the important age groups caught in the fishery) than one fished with a small mesh size. For the North Sea cod ages 2-4 is used for the mean F calculations and with the current ICES data and assumption (ICES 2017) for the calculation, Fmsy becomes 0.35. However, if the mesh size is increased so that the exploitation pattern shift one age down, meaning that F-at-age 1 becomes F-at-age 2, F-at-age 2 becomes F-at-age 3 etc., the corresponding Fmsy becomes 0.43. If the mean F is calculated over age 3-5 instead if will be an increase from 0.35 to 0.54. Clearly, this is very much and important to correct for when doing meta-analysis as we attempt below, where the basic assumption is that for stocks with similar population dynamics, Fmsy should be the same.

Often there are very little information in an assessment to determine the shape of the exploitation pattern on older age groups. The question about whether it should be flat or dome shaped is often not easy to answer. If the settings of the assessment model is such that F on old ages are lower than the true values in the population with the current fishing, then the biomass of the stock will be overestimated and F thus underestimated. However, we assume that the ICES assessments are correct in their settings of exploitation of older ages and will not attempt to correct for it in the present report.

2.1.2 Use of different age ranges for calculating mean F

Another issue is that the range of age groups used to obtain a stock average F vary by stock and this can make comparisons difficult.

Clearly it matters which age groups are included in the calculation of mean F by age. For NEA cod age 5-10 is used in the assessment, but the graphs below shows the alternative Fs based on ages 3-10, 4-10 and 6-10. On average over 1963-2015 the values are 0.50, 0.57, 0.64 and 0.70 for the mean over ages 3-10, 4-10, 5-10, and 6-10 respectively. This means that Fmsy based on ages 6-10 should be 40% higher than Fmsy based on ages 3-10. The current Fmsy is 0.40, but if F is averaged over ages 3-10 instead of age 5-10 it is only 0.33.

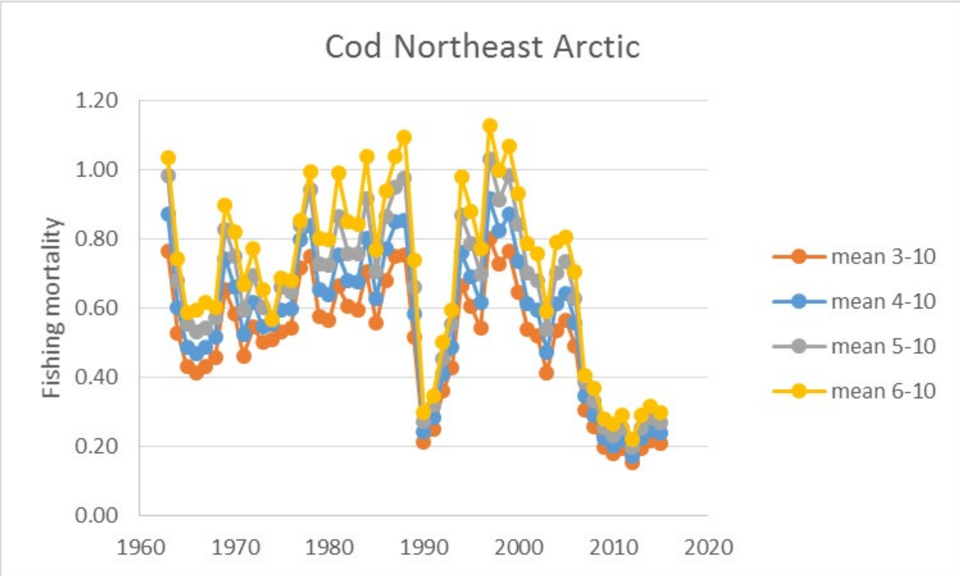


Figure 2.1.2. NEA cod. The F time series for different span of ages used to calculate the mean F.

Even if there are some degree of inconsistency and randomness in the selection of age ranges for mean F used in assessment, often the difference in age range used is justified by the stock specific population dynamics and the selection in the fishery. For instance for North Sea cod F is averaged over ages 2-4 and it would make little sense to used ages 5-10 instead, as there are hardly any North Sea cod older than 5 years, and vice versa for NEA cod, as there are hardly any fishery on age 2-4. Therefore, a simple approach where F is averaged over a standardized span of age groups is not prudent.

2.1.3 Use of different natural mortality arrays

The assessment of North Sea cod uses quite high M on young age groups based on multispecies modelling results. Many other stock assessments use a constant M-by-age. Potentially, this can make comparison of Fmsy difficult. However, for those age groups that are fully recruited to the fishery, the difference in M-at-age are not in any case among the stocks considered in the present report very large, because these size groups are generally not heavily predated. It should be mentioned though that for SSB/R and Yield/R it can matter quite a lot and in the present report whenever these ratios are dealt with, this potential inconsistencies in M-at-age will be considered.

2.1.4 Goodyear and Cordue F metric – a possible "common currency"

For a given fishing pattern, SPR(F) is the ratio of SSB per recruit, when fishing at an intensity of F, divided by the SSB per recruit with no fishing (Goodyear, 1993 and Cordue, 2012). In the usual notation, if a fishing intensity F has an SPR of x%, then the intensity is denoted as Fx% (e.g. Clark, 2002). From the definition of SPR, it follows, for a given fishing pattern, that under constant virgin recruitment, the fishing intensity, Fx%, will produce an equilibrium SSB of x%B0. Often the final metric is calculated as 1 – SPR(F) [called (1-SPR)], because it then is an increasing function of fishing intensity. Thus, (1-SPR) is ”1- ratio of (SSB/R at F) to (SSB/R at F=0) ”. Figure 2.1.4.1 illustrates the concept of (1-SPR) with data from the North Sea cod stock.

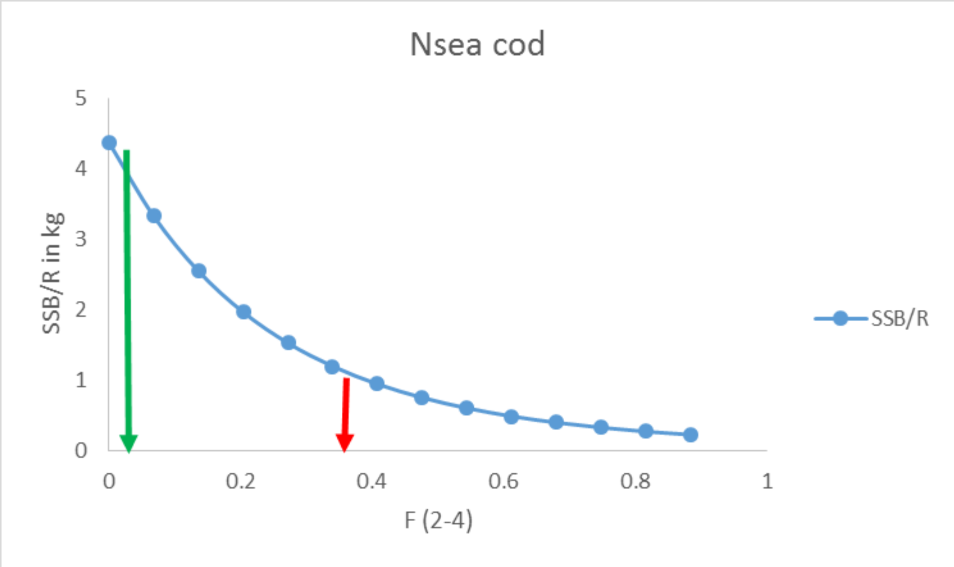


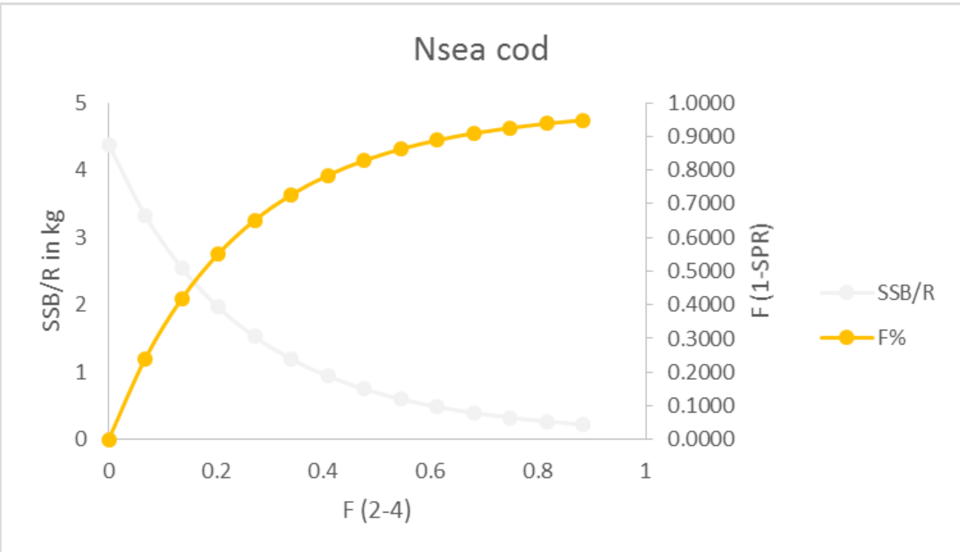
Figure 2.1.4.1. *Illustration of the fishing mortality metric (1-SPR). The red arrow correspond to SSB/R at F and the green arrow to SSB/R at no fishing. The ratio between the length of the red arrow and the length of the green arrow is (1-SPR). The F metric (1-SPR) is then 1 minus this ratio.*

The (1-SPR) metric seems useful here to create a level playing field for F so that the meta-analysis attempted in the current project becomes meaning full. Clearly, it solves the problem of possible incompatibility between F of different stocks due to the age ranges used when calculating mean Fs.

Below we will explore the metric (1-SPR) a bit more and see if it also resolved the incompatibility due to different mesh sizes used on the stocks that are compared.

We will first look at the relationship between the ordinary F and the (1-SPR) metric for some selected stocks.

For the North Sea cod and Northeast Arctic cod stock Figure 2.1.4.2 shows this relationship. The (1-SPR) is very sensitive to changes in F around F of 0.0-0.4 and quite in-sensitive for F greater than 0.5.



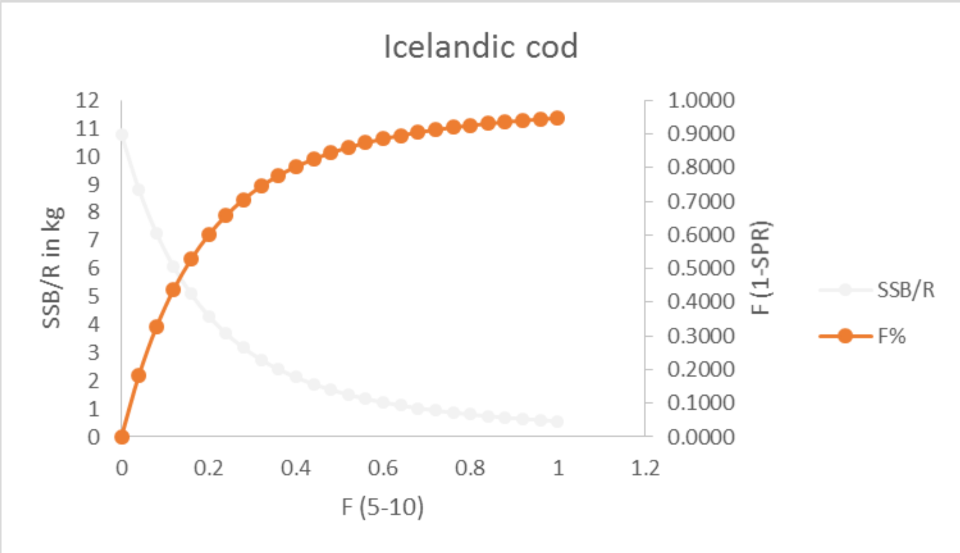


Figure 2.1.4.2. *The relationship between an ordinary average F over some age groups and the F metric calculated as 1-SPR_F/SPR_0 as suggested by e.g Goodyear (1993) and Cordue (2012).*

The effect of a mesh size increase for the North Sea cod fishery, resulting in a shift in exploitation pattern one age down, meaning that F-at-age 1 becomes F-at-age 2, F-at-age 2 becomes F-at-age 3 etc., is shown in Figure 2.1.4.3. As stated above this results in an increase in the Fmsy from 0.35 to 0.43 (measured as a mean over ages 2-4), but when expressed in $(1\text{-SPR})_{msy}$ only changed from 0.74 to 0.77. So even in the sensitive part of the F scale for (1-SPR) a quite small change, indicating that (1-SPR) is a good way of comparing MSY values across stocks, with similar population dynamics but different exploitation pattern.

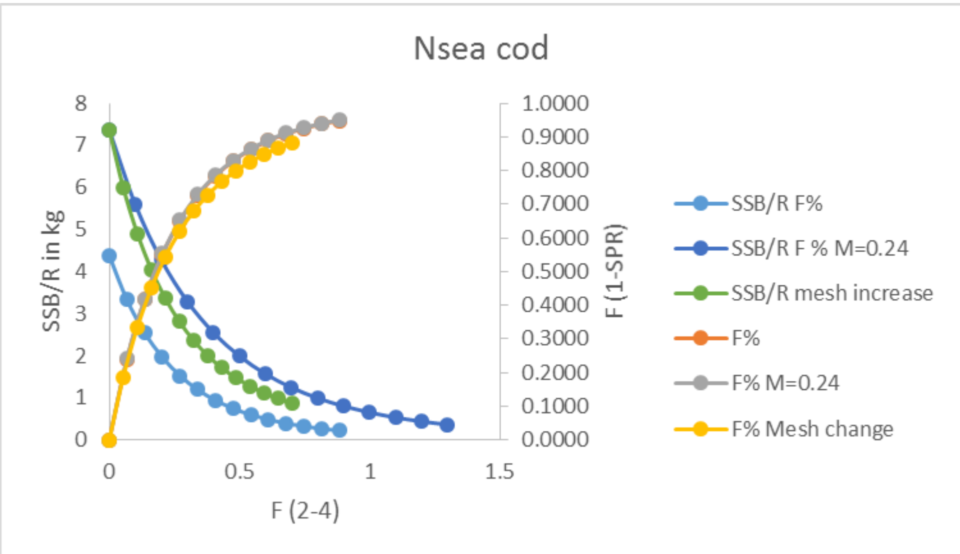


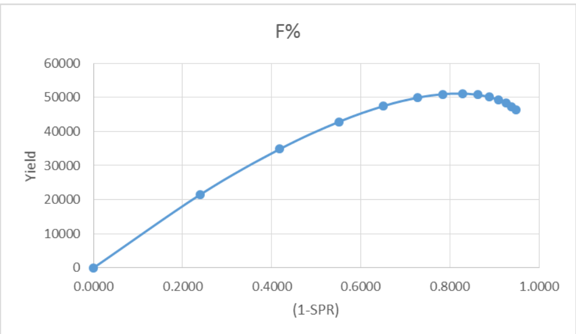
Figure 2.1.4.3. *The relationship between an ordinary average F over age groups and the F metric calculated as (1-SPR) for North Sea cod where the red line is with M1+M2 (almost completely hidden by the grey line), the grey lien with M=0.24 for all age groups, and the yellow line for a mesh size increase corresponding to a shift in exploitation pattern by one age group so that F at age 1 becomes 0.0, F at age 2 become the former F at age 1, F at age 3 the former F at age 2, etc. M for the yellow line scenario is 0.24 for all ages.*

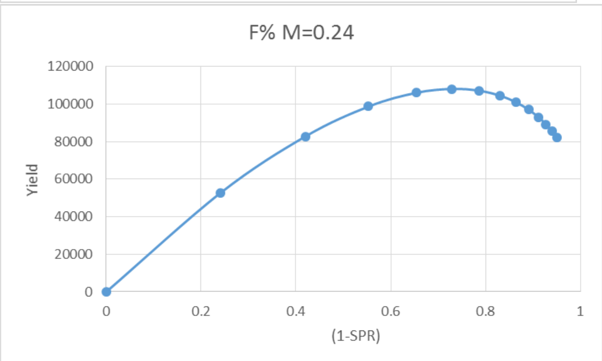
The issue of different M-at-age arrays used in the calculations of Fmsy was also tested with North Sea cod as an example. Here the M values given in Table 2.1.4.1 were compared. The results can be seen in Figure 2.1.4.3. Even though the SSB/R differ a lot as expected the (1-SPR) does not differ almost at all (the red line is hidden beneath the grey line in the plot).

Table 2.1.4.1. *Set of natural mortality M values used in the scenario calculations for North Sea cod.*

Age	M1+M2 per year	M per year
1	0.56	0.24
2	0.38	0.24
3	0.28	0.24
4	0.26	0.24
5	0.25	0.24
6	0.24	0.24
7+	0.24	0.24

However, the F on the x-axis differ slightly and it might be more illustrative to plot the results as the Yield vs (1-SPR) so that (1-SPR)msy is considered directly. Figure 2.1.4.4 show these plots for North Sea cod. The (1-SPR)msy varied from 0.73 for the constant M=0.24 scenario, to 0.76 for the constant M=0.24 and mesh size increase scenario, to 0.83 for the base case scenario. So, quite sensitive to variation in the M array, but robust to a mesh size change.





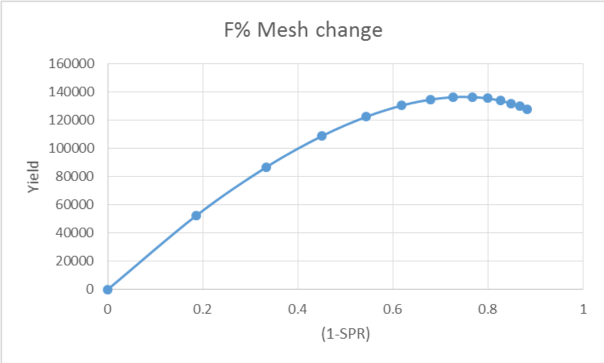


Figure 2.1.4.4. *North Sea cod. The sensitivity of (1-SPR)msy to M at age used and mesh size changes. Top panel based on ICES (2017) data, middle panel, M=0.24 for all ages, and bottom panel M=0.24 and exploitation pattern shifted one age group "down" simulating a mesh size increase.*

In conclusion (1-SPR) seems to be a suitable metric for fishing pressure for meta-analysis of the fishing pressure that gives MSY, but that care had to be taken if stocks are inconsistent with regard to the M values used in the calculations. Thus, for those stocks where we "know" Fmsy from multispecies and ecosystem models, these will have to be translated into an (1-SPR)msy by way of the relationship between (1-SPR) and F-at-age by stock, as shown in Figure 2.1.4.2-3, before used in a meta-analysis. The resultant (1-spr)msy for those stocks which do not have an Fmsy estimate from multispecies and ecosystem models, needs to be translated back to F-at-age by stock. Thus, plots like Figure 2.1.4.2 need to be made for all stocks considered in the present project.

2.2 How is Surplus Production Model Fs related to ICES F?

In order for Fmsy estimated by surplus production models (SPM) to be useful for the current scientific advice on fisheries, they need to be "translated" into the "currency" or unit for F used by ICES. The unit for F used by ICES is a mean value over F-at-age for some selected age groups and number rather than biomass based.

In Surplus Production Models (SPM) fishing mortality is given by the formula in the box below, taken from Prager (2002):

Corresponding dynamics of the generalized model as restructured by Fletcher (1978) are described by the differential equation:

$$\frac{dB_t}{dt} = \gamma m \frac{B_t}{K} - \gamma m \left(\frac{B_t}{K}\right)^n, \tag{2}$$

where m is maximum sustainable yield, also symbolized MSY, with units biomass·time^{-1}; n is a unitless exponent determining the shape of the production curve; and γ is a function of n:

$$\gamma = \frac{n^{n/(n-1)}}{n-1}. \tag{3}$$

Equation (2), has a removable singularity at $n = 1$; at that value of n, the generalized model is equivalent to the Fox (1970) exponential yield model.

In the logistic model ($n = 2$), parameters of Eqs. (1) and (2) are related by $m = \frac{1}{4}rK$. Thus Eq. (1) describing the logistic model can be rewritten as:

$$\frac{dB_t}{dt} = 4m \frac{B_t}{K} - 4m \left(\frac{B_t}{K}\right)^2. \tag{4}$$

Either model can include fishing by addition of the term $-F_tB_t$ to its right-hand side, where F_t is the instantaneous fishing mortality rate, with units of time^{-1}.

Thus, F in SPM is referring to biomass and is an instantaneous mortality rate. The stock is considered as one big unit of biomass and wherein no attempt is made to model on an age or length base. The biomass it refers to is a bit uncertain. Is it the exploitable biomass, which is the biomass of each age group in the stock multiplied by the exploitation pattern of the fishery, the biomass of fish recruited to the fishery and older fish (different from exploitable biomass because for which old fish contribute to the biomass in a reduced way if we have a dome shaped exploitation pattern), the total biomass of recruited and older fish, an arbitrary biomass linked to a biomass index used in the SPM by a catchability parameter, or something else? Thus, F in this context reflects both reduction in stock numbers of each cohort, biomass growth of individuals and recruitment of juveniles into the exploitable stock biomass.

The biological reasoning behind the model was adequately formulated by Ricker (1975) as given in the box below:

"1. Near maximum stock density, efficiency of reproduction is reduced, and often the actual number of recruits is less than at smaller densities. In the latter event, reducing the stock will increase recruitment.

2. When food supply is limited, food is less efficiently converted into fish flesh by a large stock than by a smaller one. Each fish of the larger stock gets less food individually; hence a larger fraction is used merely to maintain life, and a smaller fraction for growth.

3. An unfished stock tends to contain more older individuals, relatively, than a fished stock. This makes for decreased production, in at least two ways: (a) Larger fish tend to eat larger foods, so an extra step may be inserted in the food pyramid, with consequent loss of efficiency of utilization of the basic food production, (b) Older fish convert a smaller fraction of the food they eat into new flesh - partly, at least because mature fish annually divert much substance to maturing eggs and milt."

Ricker 1975.

An important point here is that F is an instantaneous rate with unit of $time^{-1}$, and proportional to fishing effort. This means that the ratio F/Fmsy from a SPM is equal to the ratio F/Fmsy in age based models, because F in age based model is also proportional to effort. If for instance F/Fmsy for a given stock in a given year is 0.75 as estimated by a SPM, and F from the age based assessment model is 0.3 for that year and stock, then Fmsy in F "currency" of the age based model is 0.3/0.75, equal to 0.4 for that stock. In this way Fmsy from SPM can very easily be translated into Fmsy in age based "currency".

The relationship between these two metrics of fishing pressure, in the following called F_{SPM} and F_{ICES}, is rather simple. Implicitly, when applied to historical catches of a given stock they assume the same exploitation pattern, i.e. F by age measured in numbers. They are both proportional to fishing effort. Therefore, they are proportional to each other:

$$F_{SPM} = a * F_{ICES},$$

where "a" is a proportionality constant. This means that $F_{SPM,y}$ for a given year for a given stock divided by $F_{SPM,MSY}$ for that stock is equal to $F_{ICES,Y}$ divided by $F_{ICES,MSY}$:

$$F_{SPM,y}/F_{SPM,MSY} = F_{ICES,Y}/ F_{ICES,MSY}.$$

Thus, when $F_{ICES,Y}$ and the ratio $F_{SPM,y}/F_{SPM,MSY}$ are known, $F_{ICES,MSY}$ can obviously be calculated by:

$$F_{ICES,MSY} = F_{ICES,Y}/(F_{SPM,y}/F_{SPM,MSY}).$$

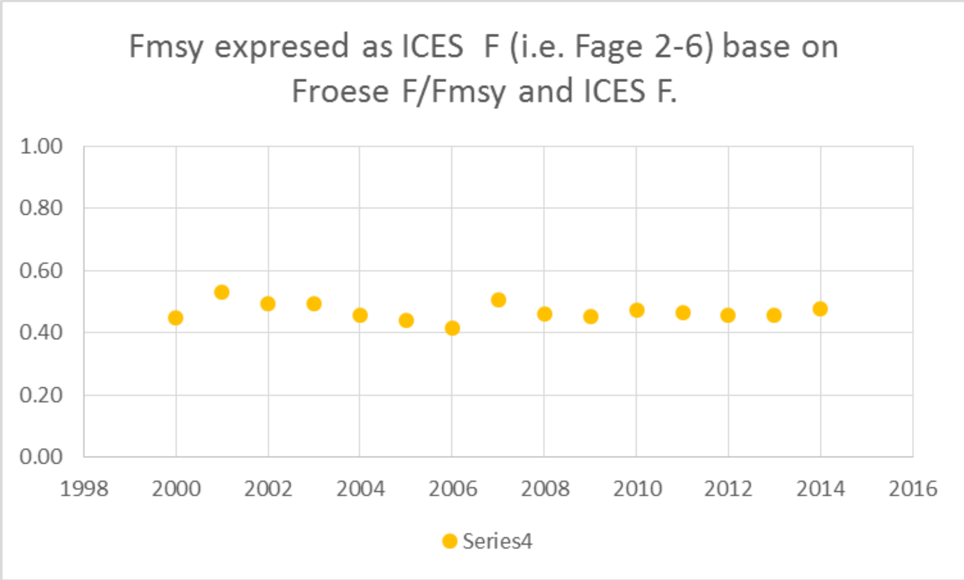
Froese *et al.* (2016) have used SPMs to estimate the ratio $F_{SPM,y}/F_{SPM,MSY}$ for all ICES data rich stocks considered in the present project, and this combined with the $F_{ICES,Y}$ from ICES routine fish stock assessments, allow us to calculate $F_{ICES,MSY}$. This latter one is directly comparable to ICES current F_{msy} values used in the ICES process to obtain advice on TAC (Total Allowable Catch). The current project have done the SPMs in a slightly different and we think improved way from Froese et al. using the new software SPiCT, for all the stocks and these are also presented in a separate section below.

Example: *Surplus Production Model estimate of F/Fmsy translated into ICES F currency for North Sea plaice.*

Method: Take SPM estimate of F/Fmsy for a given year say 2004 and divide by ICES F value for 2004, gives Fmsy expressed in the ICES F "currency".

Example North Sea plaice:

> Take say F(2004)/Fmsy = 1.03 (from Froese *et al*. 2016) , ICES F(2004)=0.47 (from ICES ACOM 2016 report) → Fmsy = 0.45.
>
> As Froese *et al.* estimates F/Fmsy for each year, one can get an estimate of Fmsy as above for each year:



It is prudent to disregard the most recent two or three years due to convergence uncertainties, and if we use a mean over 2000-2012 we get **Fmsy = 0.47**.

As is clear from the above we only use the ratio of F/Fmsy from SPMs models and there is an extra benefit in that compared to use Fmsy from SPMs. The ratio F/Fmsy is more precisely estimated than Fmsy, because SPMs models need to estimate an additional parameter, catchabilty, to get to Fmsy, and that of course add uncertainty to the estimation process. This is also clearly coming out of the SPiCT software when running SPMs as more narrow confidence bounds around the F/Fmsy ration estimate than around Fmsy estimate are generally seen.

By this simple approach we can get SPM model Fmsy values into the ICES F -“currency”, for all our stocks.

References:

Goodyear, C. P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. In Risk Evaluation and Biological Reference Points for Fisheries Management, pp. 67–81. Ed. by S. J. Smith, J. J. Hunt, and D. Rivard. Canadian Special Publication of Fisheries and Aquatic Sciences, 120.

Froese et al. 2016

Ricker 1975

Appendix 5. Time varying population parameters for Faroe fish stocks

Ecosystem Based FMSY Values in Fisheries Management, Vancouver meeting 31. October – 02 November 2017

Working Document 1

(Do not quote without prior reference to the author)

Time varying population parameters for Faroe fish stocks

Petur Steingrund, Faroe Marine Research Institute

Abstract

Absolute estimates of biomasses as well as catch is available for the Faroese stocks of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*) from 1925 to 2016. A Schaefer stock production model is applied to these stocks in order to evaluate changes in intrinsic growth rate (r), carrying capacity (K) and maximum sustainable yielt (MSY) by applying a moving 39 year window. MSY decreased for cod over time but increased for saithe, thus giving a more constant MSY for the three stocks combined. The results could be due to the fishery targeting saithe in the 1950s or be related to large scale processes in the North Atlantic Ocean. Hence, management measures may only partially regulate the MSY for these three fish stocks.

Introduction

It is well established that ecosystems set upper boundaries for fish production and that there are interactions between fish species. However, it is extremely difficult to incorporate this knowledge into stock assessment and management and therefore most fish stocks are assessed and managed as single stocks. Another obstacle is the fact that most fish stock assessments cover a relatively short time period, 20-50 years, which limits the possibilities to estimate how MSY changes with time.

The Faroe Plateau has been intensively fished for more than a decade by the introduction of British steam trawlers in 1898, although a moderate fishery for cod had been conducted well before that time. Information about catch per unit effort for British trawlers was combined with absolute stock assessments to extend the absolute estimates of biomass back to the 1920s for cod, haddock and saithe (ICES, 2016a). For cod, the period was considerably longer, cpue estimates were compiled back to around 1860 and a modelling approach was applied to extend the biomass back to 1709.

These long time series of biomass and catch are used as basis to estimate changes in productivity over time.

Materials and Methods

Stock assessment data

Biomass estimates prior to the absolute age disaggregated stock assessments, i.e. prior to around 1960, were estimated in ICES (2016a). The method was quite simple as illustrated for cod. The age disaggregated stock assessment covered the time period from 1959 to 2015. A catch per unit effort

(CPUE) time series in tons per million ton-hours was available for British steam trawlers for the time period 1924 to 1972. There was an overlap between the CPUE series and the absolute biomass estimates for the period 1959 to 1972 and a scaling factor between absolute biomass and CPUE was calculated for this period and applied to scale the absolute biomass back to 1924.

For the calculation of time-varying MSY, a slightly different approach was used, since it was necessary to operate with the fishable biomass (age 3+ for cod and haddock and age 4+ for saithe) instead of the total biomass (age 2+ for cod and haddock and age 3+ for saithe). The fishable biomass back in time was estimated with the same method as in ICES (2016a). For Faroe Plateau cod, the catch figures prior to 1959 were scaled down by 10% to account for the catches on the Faroe Bank (ICES sub-division Vb2) that were included in the original catch figures.

For cod, catches were estimated back in time by applying the same C/B ratio as in 1906-1908 and a reduction by 1% per year back in time. This allowed a rough calculation of time-varying population parameters, see next paragraph, where the stock size was close to a virgin state.

The biomass of Faroe and Icelandic saithe was obtained from ICES (2017a), of Barents Sea saithe from ICES (2017b), of saithe in the North Sea and adjacent waters from ICES (2017c) and of Blue whiting from ICES (2016b).

Time varying population parameters

Since the absolute biomass estimates were available, the only unknown parameters in the Schaefer equation were the intrinsic growth rate (r) and the carrying capacity (K).

$$B_{t+1} = B_t + rB_t(1-B_t/K) - C_t \qquad \text{(Schaefer equation)}$$

Here, B is the absolute biomass in tonnes in year t or t+1, r is the intrinsic growth rate of the population ($year^{-1}$) and K is the carrying capacity in tonnes.

It follows from the Schaefer equation, that the maximum sustainable yield (MSY) is obtained at half biomass of the carrying capacity (B = ½K) and MSY = rK/4 and C/B = r/2.

In order to investigate changes in these population parameters over time, a 39 year time window was used that was moved in steps of 10 years.

The residuals were calculated as the difference between the observed biomasses and the biomasses obtained by the Schaefer equation. The sum of the squared residuals (over 39 years) was minimized by the use of Microsoft Excel Solver. In some circumstances it was impossible to get a fit, e.g. the K of saithe increased to unresonable values above 1 million tonnes in some periods.

Results

While the biomass of cod, haddock and saithe varied much, the combined biomass of all three stocks was more constant and ranged between 150 and 600 thousand tons, usually though between 300 and 400 thousand tons (Figure 1). A reconstruction of cod biomass back in time to 1860 and even to 1709 showed that the fishable biomass did not exceed 250 thousand tons, despite the very limited fishery prior to 1800 (Figure 2), although these estimates of biomass should be taken with care. Up to around 1960, cod and saithe biomasses were on the same level and varied in the same way whereas after 1960 cod and haddock were on the same level and varied in the same way (Figure 1).

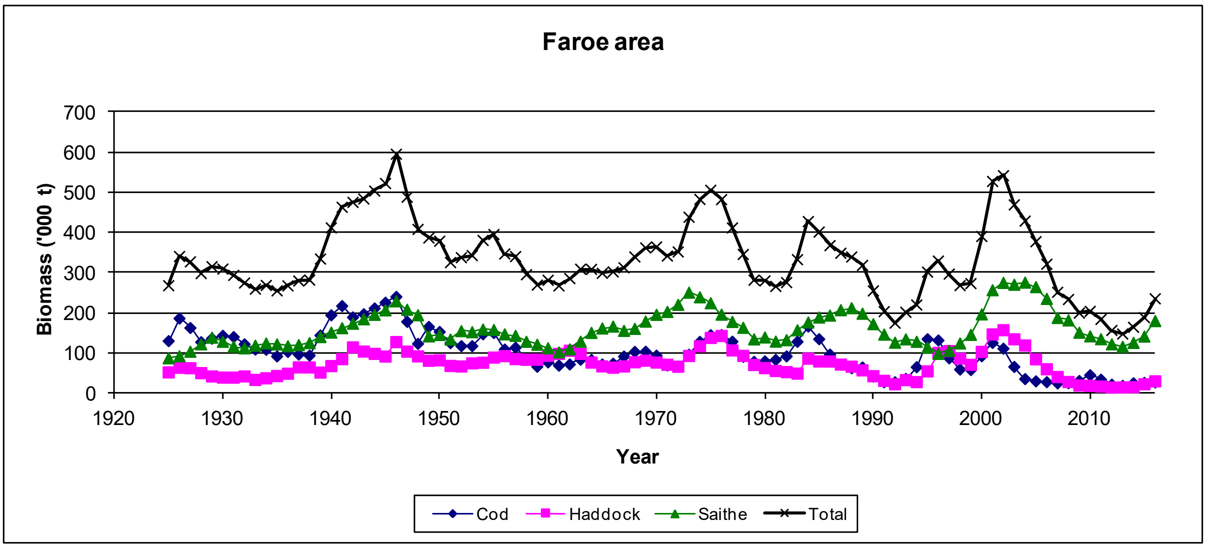


Figure 1. Biomass of cod, haddock and saithe in Faroese waters, from ICES (2017a).

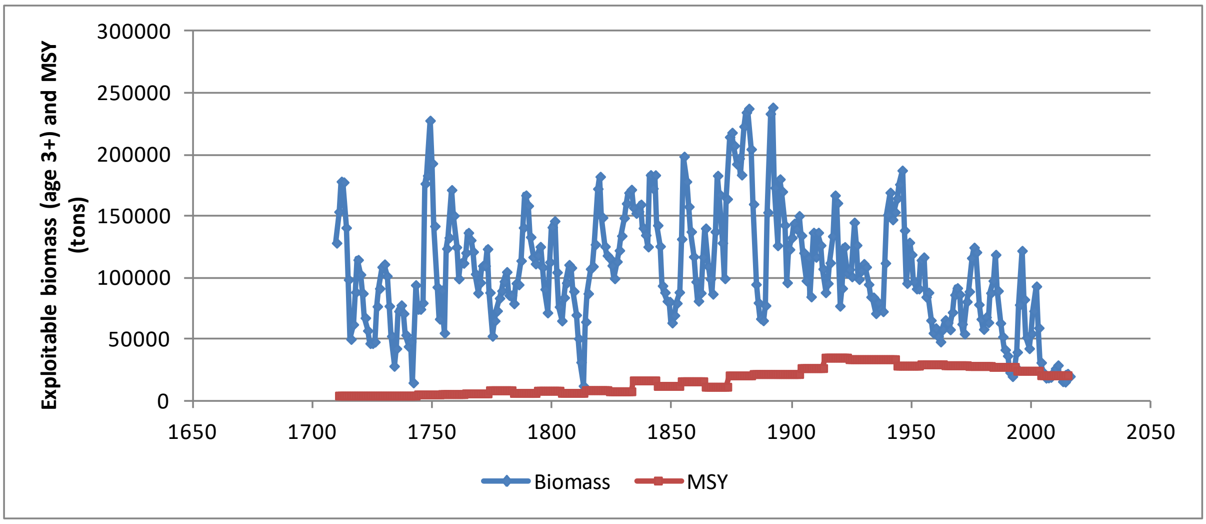


Figure 2. Faroe Plateau cod exploitable biomass and maximum sustainable yield.

It is noteworthy that even though the combined biomass of cod, haddock and saithe fluctuated without any trend the proportion of cod steadily decreased from 50% to 10% and the proportion of saithe increased from 30% to 80% (Figure 3). The proportion of haddock fluctuated without any clear time trend.

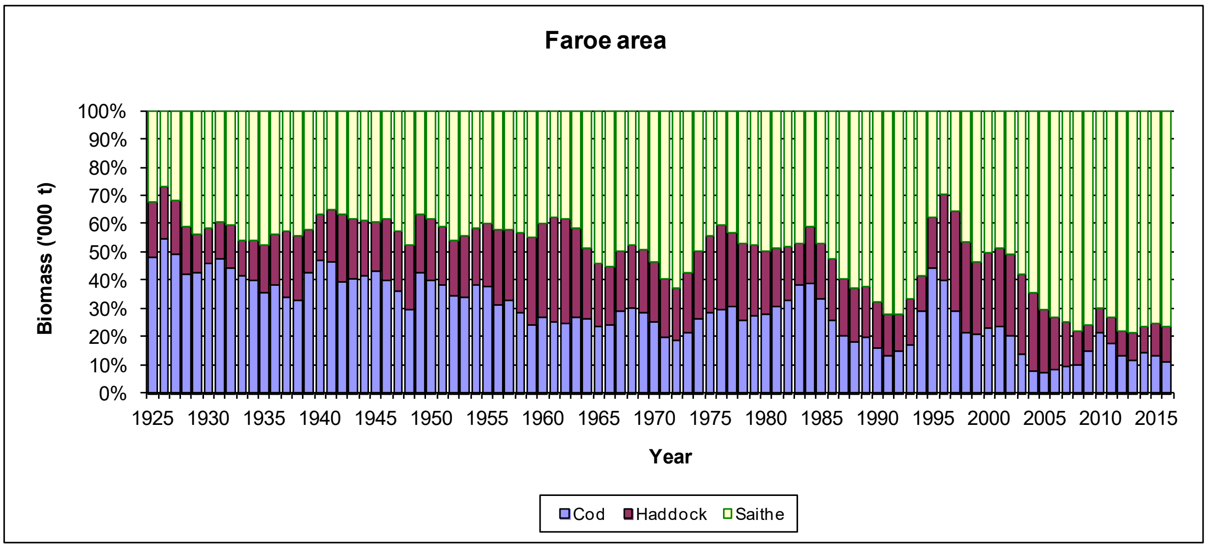


Figure 3. Biomass of cod, haddock and saithe in Faroese waters shown as proportion, from ICES (2017a).

Saithe was not targeted until the 1950s, as shown in Figure 4. The intrinsic growth rate of saithe started off quite low at around 0.3, but increased up to around 0.5 whereas the values for cod and haddock decreased (Figure 5). The carrying capacity of saithe also increased considerably, as well as for haddock (Figure 6). The maximum sustainable yield, which may be more robust to model performance than either r or K, decreased for cod, increased for saithe and showed a dome-shaped pattern for haddock (Figure 7). Interestingly, the combined maximum yield for cod, haddock and saithe was almost constant for the last three data points. The sustainable harvest rate (C/B) decreased for cod and haddock and increased for saithe (Figure 8).

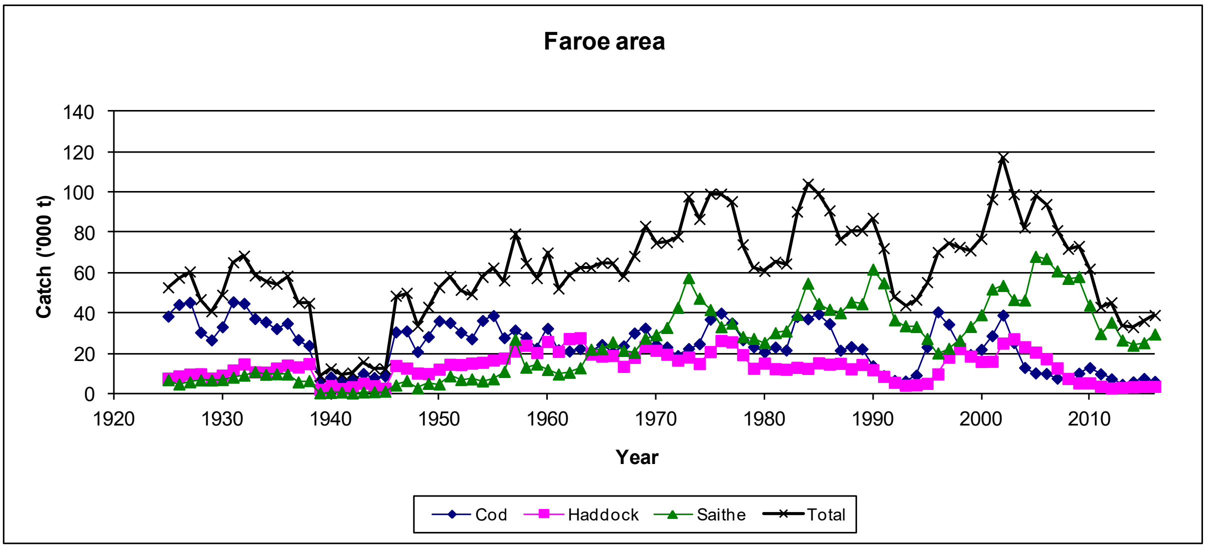


Figure 4. Catch of cod, haddock and saithe in Faroese waters, from ICES (2017a).

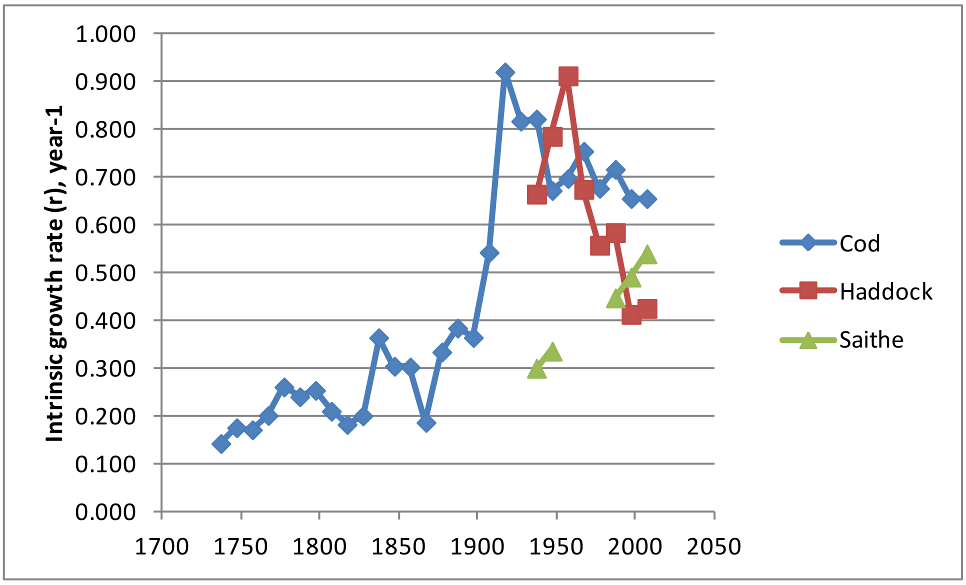


Figure 5. Intrinsic growth rate (r) of cod, haddock and saithe in Faroese waters.

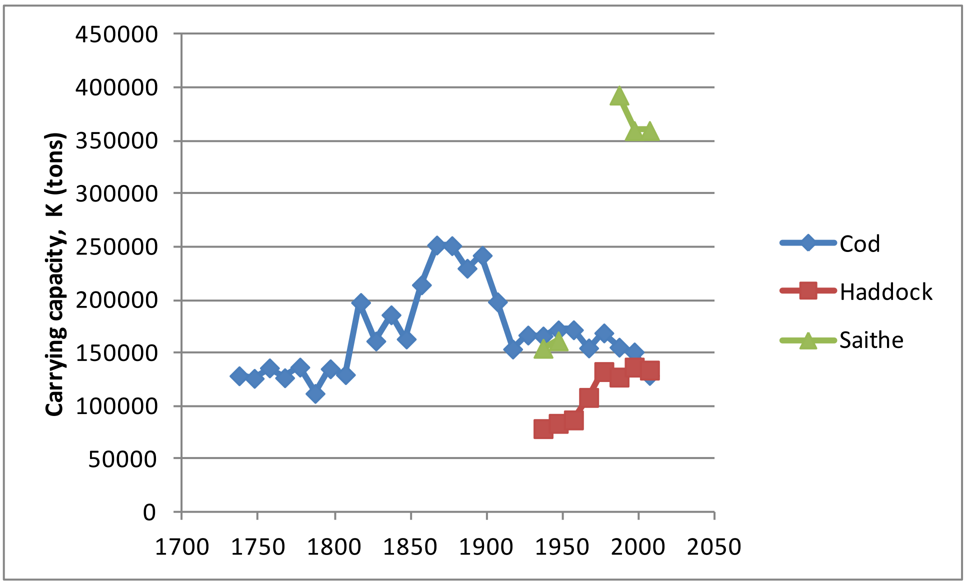


Figure 6. Carrying capacity (K) of cod, haddock and saithe in Faroese waters.

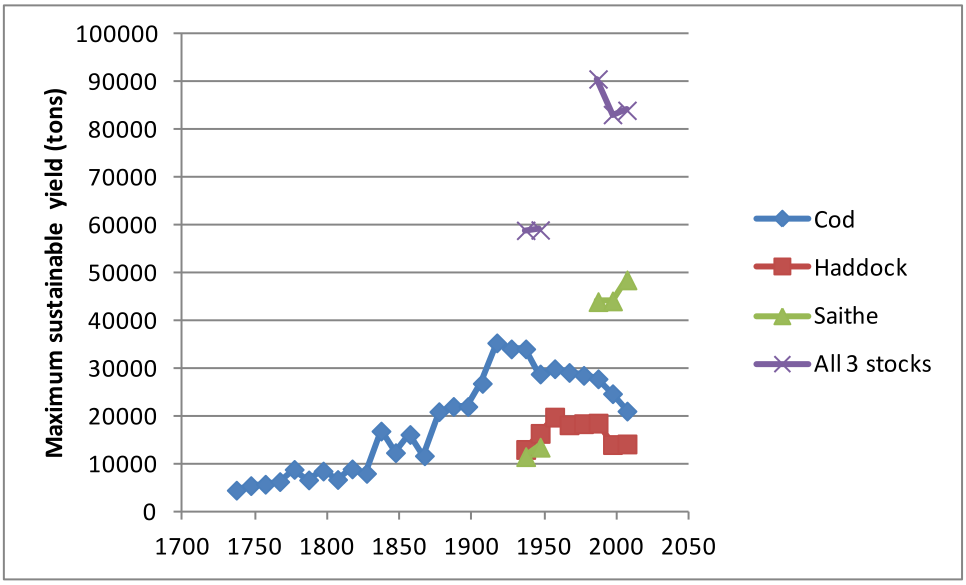


Figure 7. Maximum sustainable yield of cod, haddock and saithe in Faroese waters.

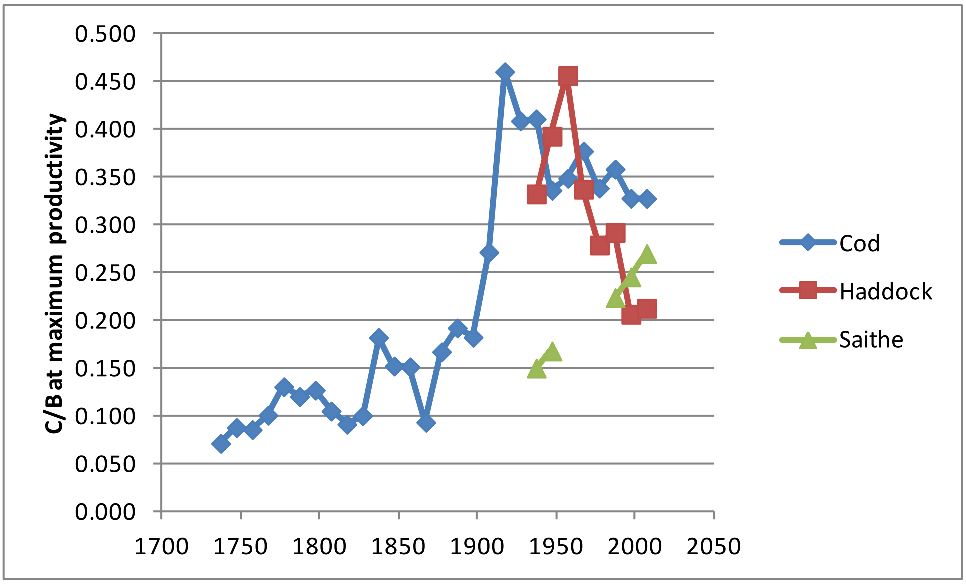


Figure 8. Catch per exploitable biomass of cod, haddock and saithe in Faroese waters at maximum productive capacity.

The material in this working document suggests that saithe have taken an ever bigger share of resources in Faroese waters and one question is whether this is only caused by the shift from a virgin stock to a fished stock. There is a high correlation between the stock sizes of all four saithe stocks in the North Atlantic, and there is also a high correlation between the sum of biomass for the four saithe stocks and the size of the Blue whiting stock in the North Atlantic (Figure 9, Figure 10).

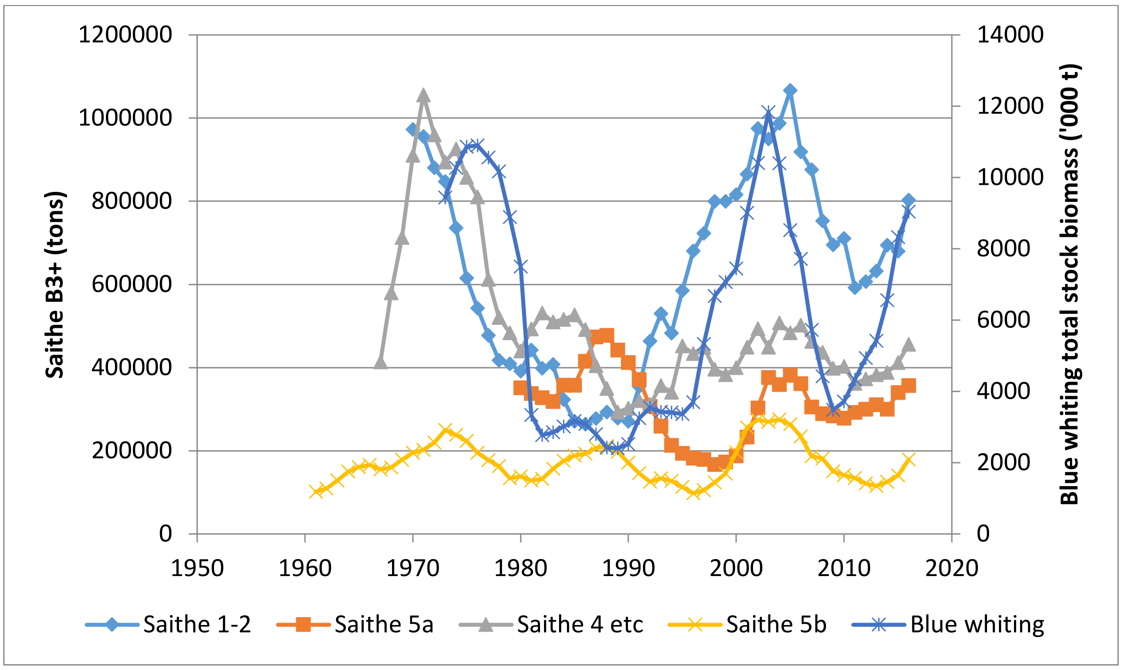


Figure 9. Total biomass (age 3+) of saithe stocks in the North Atlantic compared with the total stock biomass of Blue whiting.

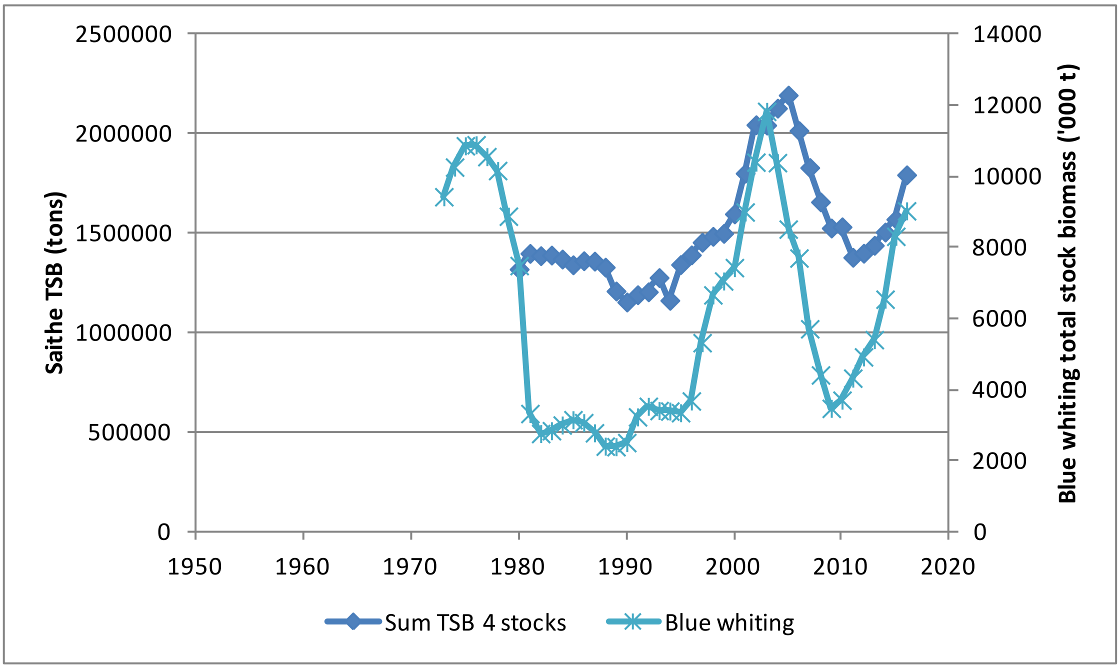


Figure 10. Total biomass (age 3+) of all 4 saithe stocks combined compared with the total stock biomass of Blue whiting.

Discussion

A virgin stock certainly has a low productivity as illustrated by Faroe cod in the 1700s to mid 1800s and Faroe saithe prior to 1960. Increasing the fishery increased the productivity of these stocks. There are also indications that decimated stocks – caused by fishery or environmental factors – have low productivity, as illustrated by cod and haddock after 2005. However, these observations do not comply fully to the classic Schaefer production formulation of stock productivity – being highest at intermediate stock sizes – because the virgin biomass was actually lower than the biomass of moderate exploitation. However, if the size composition of the virgin stock is taken into account the dominance of large individuals in the stock nevertheless seems to cause a higher use of space/cannibalism than the biomass at intermediate exploitation. It should be noted that the productivity of the ecosystem is unknown back in time.

The variation in population parameters between the three fish stocks together with the rather constant values for the combined stocks points to the limited capacity of the ecosystem, i.e. it may be impossible to maximize the sustainable yield for all fish stocks at the same time.

The increase in saithe productivity in Faroese waters may be partially due to the increased fishing for saithe but the availability of food may also be important. Stomach content analyses have shown that Blue whiting (*Micromestitius poutassou*) is the most important food for saithe in Faroese waters, at least during the feeding time in summer. The biomass of all four saithe stocks in the North-east Atlantic is highly correlated and also positively correlated with the biomass of Blue whiting. The biomass and recruitment of Blue whiting may be affected by the extent of the subpolar gyre and associated changes in the plankton community (Hátún et al., 2009). This indicates that the partition of resources between cod, haddock and saithe in Faroese waters may not only rely on management measures, but also on natural factors.

References

ICES. 2016a. Report of the North-Western Working Group (NWWG), 27 April–4 May, 2016, ICES Headquarters, Copenhagen. ICES CM 2016/ACOM:08.

ICES. 2016b. ICES WGWIDE report 2016.

ICES. 2017a. Report of the North-Western Working Group (NWWG), 27 April–4 May, 2017, ICES Headquarters, Copenhagen. ICES CM 2017/ACOM:08.

ICES. 2017b. Report of the Arctic Fisheries Working Group (AFWG), 19 April–25 April 2017, ICES HQ, Copenhagen. ICES CM 2017/ACOM:06. 486 pp.

ICES. 2017c. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 26 April–5 May 2017, ICES Headquarters, Copenhagen, Denmark. ICES CM 2017/ACOM:21.

Hátún, H., Payne, M.R., Beaugrand, G., Reid, P.C., Sandø, A.B., Drange, H. Hansen, B., Jacobsen, J.A., and Bloch, D. 2009. Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography 80 (2009) 149–162.

Appendix 6. Theme Session at the ICES AC 2018.

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Contact person's name:	Daniel R. Goethel
Contact person's institute (and contact details):	NOAA SEFSC, 75 Virginia Beach Dr., Miami, FL, USA, 33149
Contact person's email:	daniel.goethel@noaa.gov
Contact person's telephone:	+1 603-9187-7869
Name of theme session convener 1:	Daniel R. Goethel
Email of theme session convener 1:	daniel.goethel@noaa.gov
Name of theme session convener 2:	Henrik Sparholt
Email of theme session convener 2:	henrik.sparholt@gmail.com
Name of theme session convener 3:	Aaron M. Berger
Email of theme session convener 3:	aaron.berger@noaa.gov

Name of theme session convener 4/rapporteur:	Patrick D. Lynch
Email of theme session convener 4/rapporteur:	patrick.lynch@noaa.gov
Name of theme session convener 5/rapporteur:	Bjarte Bogstad
Email of theme session convener 5/rapporteur:	bjarte.bogstad@imr.no
Name of theme session convener 6/rapporteur:	Joanne Morgan
Email of theme session convener 6/rapporteur:	Joanne.Morgan@dfo-mpo.gc.ca
SHORT TITLE:	**Sustainability Thresholds and Ecosystem Functioning: The Selection, Calculation, and Use of Reference Points in Fishery Management**
Description:	Fishery management systems worldwide rely on defining biological reference points, which serve as a basis for setting limits and targets to fishing intensity (catch and bycatch) and population sizes (e.g., stock biomass). These values govern the establishment of harvest specifications and are used to determine whether a stock's biomass is too low (overfished) and whether fishing intensity is too high (overfishing occurring). In addition, biological reference points can be critical to harvest control rules and management procedures when they contain pre-specified policy measures to be implemented when excessive harvests or depleted biomass occur relative to reference levels. Despite fisheries management being fundamentally reliant on reference points, there are challenges and uncertainties surrounding the choice and calculation of different reference points or proxies and related to the various applications of reference points used in a management/policy context (e.g., at the national or multi-national level) to achieve sustainable fisheries. For instance, equilibrium population assumptions underlying the calculation of many reference points are challenged by spatial and temporal variation due to density-dependent mechanisms (recruitment, individual growth, maturity, and mortality), climate change, variable management and fishing practices, predator-prey dynamics, and myriad other factors. Assuming equilibrium in the presence of regime shifts may limit the reliability and robustness of static reference points and it remains uncertain whether these changes should be accounted for in a stock management plan.

	Additionally, multispecies and ecosystem-level reference points often provide a different view of species-specific sustainable harvest levels, because single species approaches do not account for the various trade-offs and uses at the system level. For example, single species F_{MSY} management paradigms form the basis of policy advice provided by ICES (and many countries worldwide), but ignore important aspects of ecosystem functions (e.g., carrying capacity, density dependent population dynamics, and species interactions). Ignorance of ecosystem dynamics often leads to current F_{MSY} approaches being biased and possibly impeding stock rebuilding initiatives and achievement of MSY from the system. There has been increasing exploration of ecosystem dynamics and indicators that could be utilized as part of a holistic approach to integrated ecosystem assessment. The scientific basis of fishery management decisions in the coming years must be robust and adaptable in order to deal with the changing environment and complexities of multi-sector resource utilization across a variety of stakeholders with competing objectives. This session offers a forum to explore best practices and new approaches to selecting, calculating, and using reference points in fishery management. We solicit research, perspectives, and case studies on new approaches and best practices that ensure reference points support sustainable fishery management given complex and varying ecosystems, communities, and management objectives. Priority will be given to approaches that are operational in the short to medium term. Papers are welcome on the following topics: • Enhancing single species reference point models through incorporation of density-dependent processes, time-varying parameters, spatial components, and climate-related drivers • Development of multispecies reference points • Development of ecosystem thresholds and reference points • Incorporation of socioeconomic factors into biological models to address how fishery removals may be modified to account for alternate resource utilization metrics • Implementation of management strategy evaluations that test the reliability and robustness of reference points • Formulation and testing of alternate management procedures and harvest control rules that replace or augment traditional target, trigger, or limit reference points
Suggested theme session format:	The symposium will start with double plenary speakers (one on single species reference points and the other on ecosystem considerations). The meeting will primarily consist of scientific presentations with the opportunity for short poster presentations. The symposium will wrap-up with a discussion panel focused on soliciting input on the use and future of reference points from a stakeholder perspective (industry and NGO stakeholders will be invited along with managers and scientists).
Expected participation:	ICES biologists, assessment, and social scientists; policy analysts and fisheries managers; fisheries stakeholders including industry and NGOs.
Linkages to ICES Strategic Plan:	The theme directly addresses goals 1-3 and tangentially applies to goal 4 of the ICES Strategic Plan.
Linkage to emerging science priorities of SCICOM:	• Climate change • Connectivity • Ecosystem monitoring • Ecosystem forecasting • Linking pressure and state • Tools to support integrated advice

Linkages to ICES Steering Groups and/or Advisory Committee (if relevant):	• Ecosystem Processes and Dynamics Steering Group • Ecosystem Pressures and Impacts Steering Group • Integrated Ecosystem Assessments Steering Group • Integrated Ecosystem Observation and Monitoring Steering Group • Methods Working Group • Advisory Committee • Science Committee
Linkages to ICES Strategic Initiatives and/or ICES action areas on Aquaculture and the Arctic:	• ICES-PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems • Strategic Initiative on the Human Dimension • Arctic Research