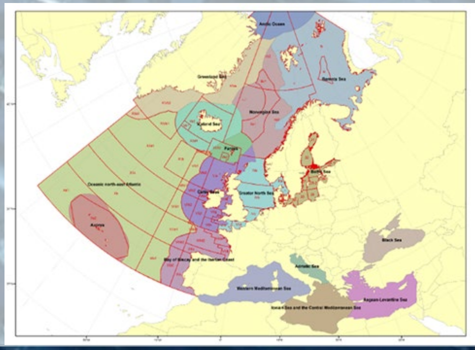
Sustainable Fisheries Education Programme: Introduction to Sustainable Fishing (#ISF2020)

Stock assessment *masterclass*

29th January 2020

London Hilton and Billingsgate Market



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UK Delegate to ICES/ICES Vice-president

Centre for Environment Fisheries & Aquaculture Science

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Modelling stocks:

- What is a fish stock?
  - SFEP YouTube video
- How are they assessed?
  - SFEP YouTube video
- Modelling straddling stocks
- Modelling shellfish – issues and problems

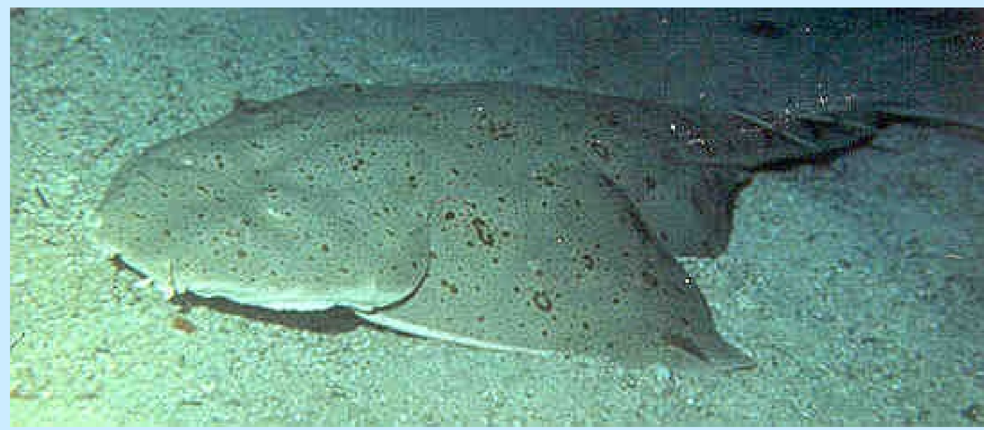
ICES' sheets and reference points:

- MSY, F_{lim}, SSB B_{lim} etcetera – demystifying acronyms
- ICES' sheets – finding what you need, reading what you find
- Shared stocks, mixed fisheries and ecosystem approach to management

Outline of presentation

Diverse – over 300 shelf species

~ 20 species give over 85% value



Fish (and shellfish)

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Context of fisheries assessments and management advisory process

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What is a fish stock?

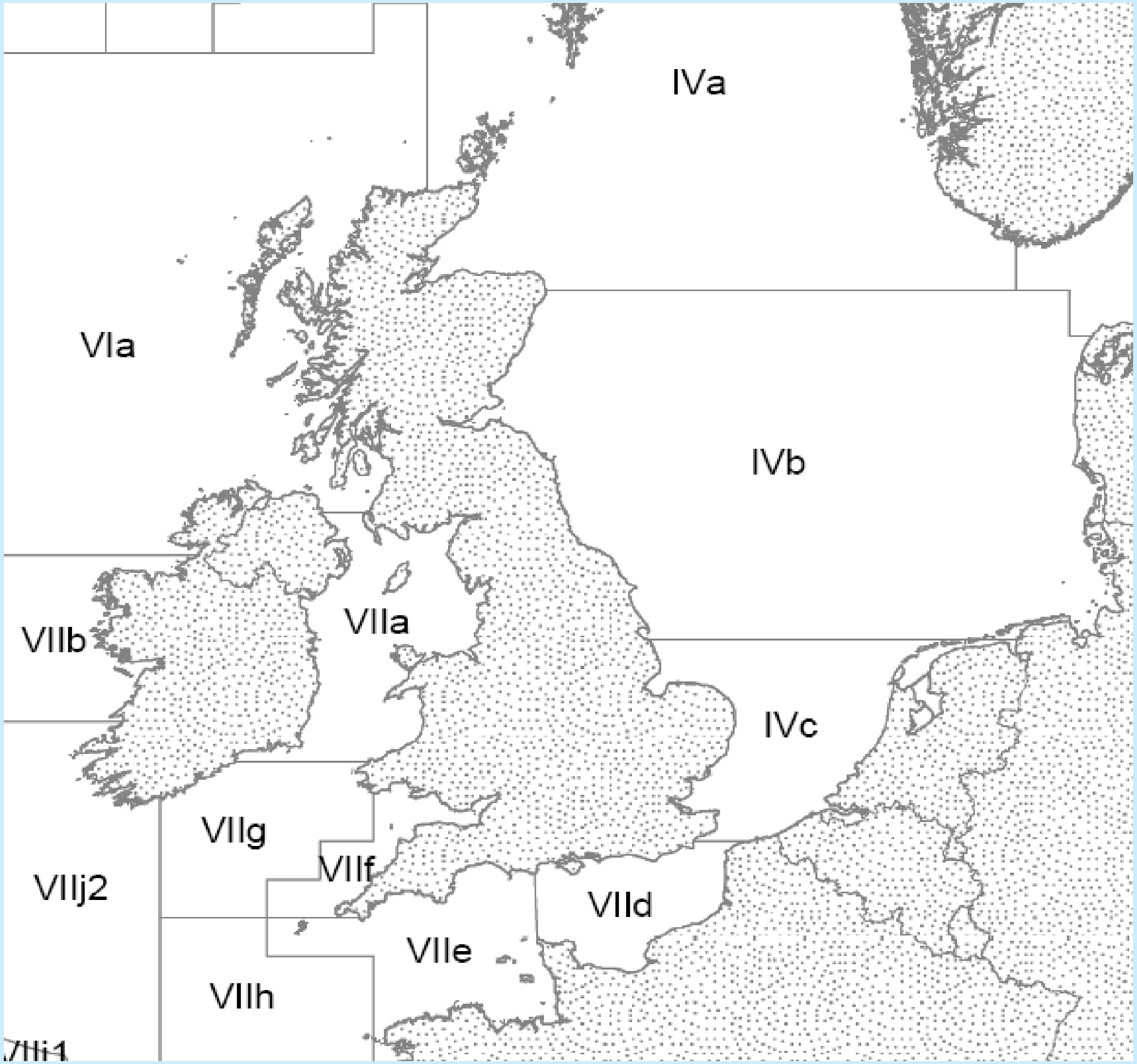
A short animation describing why fisheries scientists need to define stocks in the process of stock assessments.

- Link: https://youtu.be/YWNe951bucY

Time: 4:43

Fish stocks

- Species
- Populations = stocks
- TACs ~~ stocks
- Sometimes not even species; e.g. rays
- TACs by ICES' areas



Different models for assessment and advice:

- Availability and quality of data
- Uncertainty

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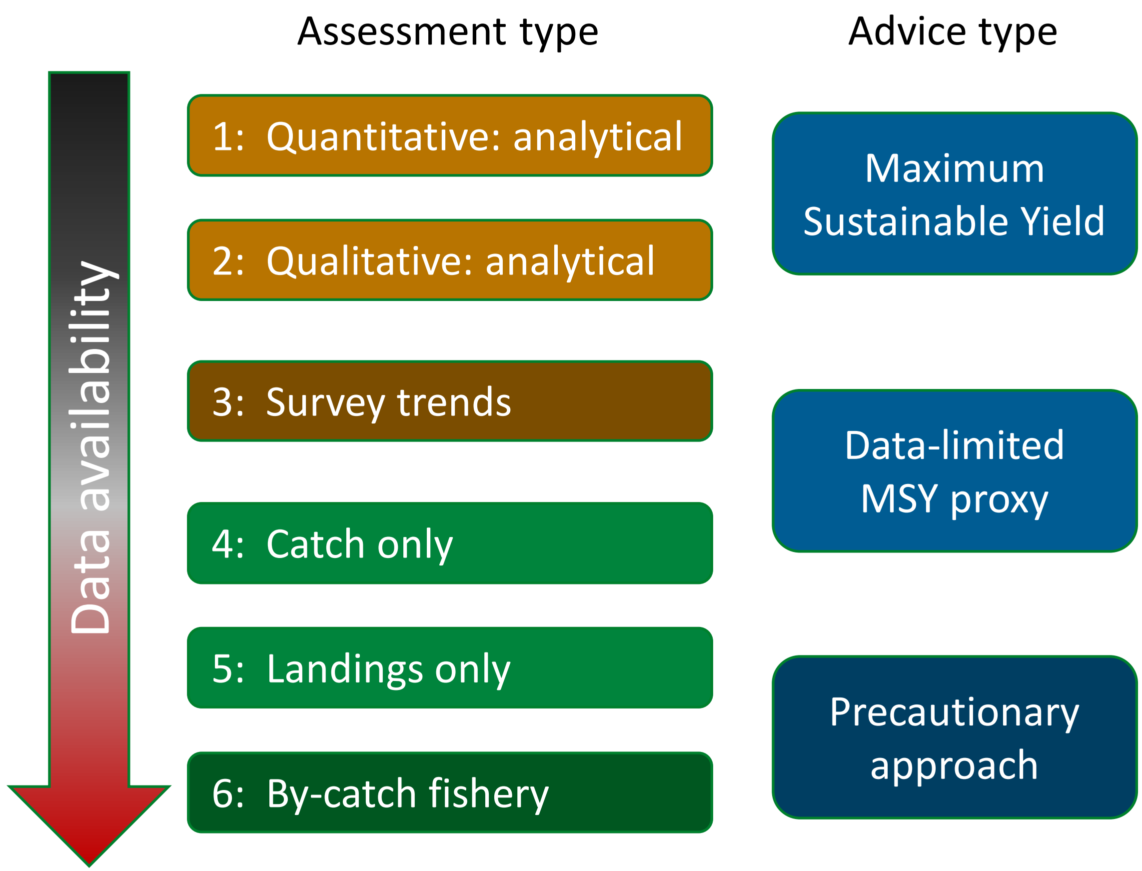
Stock assessment levels:

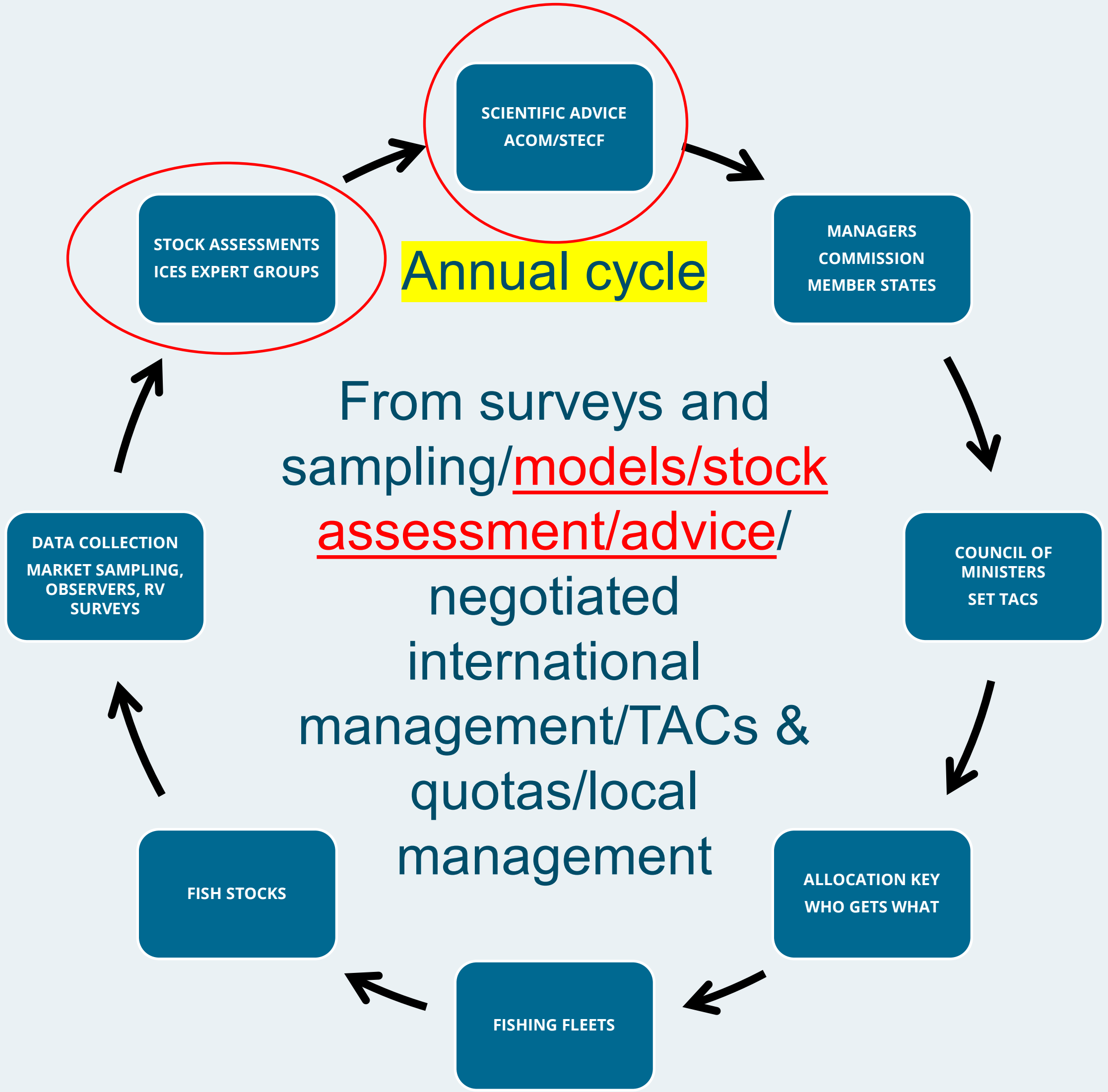
Purpose of assessment: estimation of …

- Stock status
  (Spawning stock biomass)
- Exploitation rate
  (Fishing mortality)
- Reference points

- Less *information*= more uncertainty



Process overview: from science to management



Start here: then move clockwise

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But we are getting ahead of ourselves …

Why do we need to assess fish stocks?

A short animation explaining how and why fisheries scientists measure fish stocks, and the role played by the fishing industry to ensure these assessments are accurate.

- Link: https://youtu.be/In72Jj6dGNA

Time: 4:39

Why assess fish stocks?

- To assess whether the exploitation rate is too high or too low in relation to management objectives for the fisheries exploiting them and whether the rate is sustainable in the long term.

- To assess whether there are sufficient mature fish in the sea to allow the stock to replace itself over time.

- To examine trends over time.
- To forecast future catches.

- Overall - to (*try to*) manage the exploitation rate.

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Stock assessment is easy?

Data rich stock with an accepted analytical assessment and forecast for MSY

– Cohort analysis

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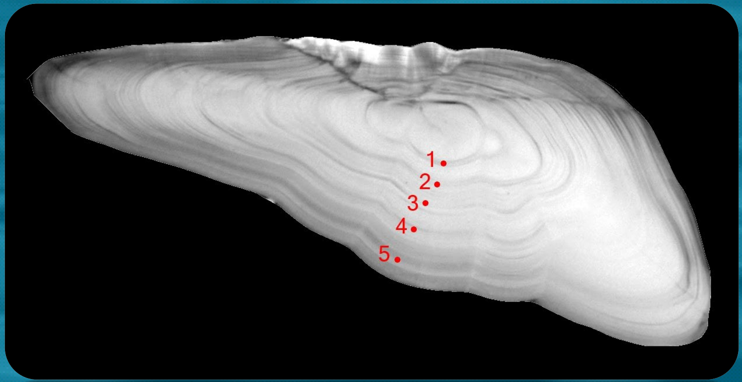
Biological data on catch:

Routine - Length, weight, sex ratio, maturity stage.

Then age determination from ear bones (otoliths).



The End Game

How many fish of each age group were caught - for use in stock assessment

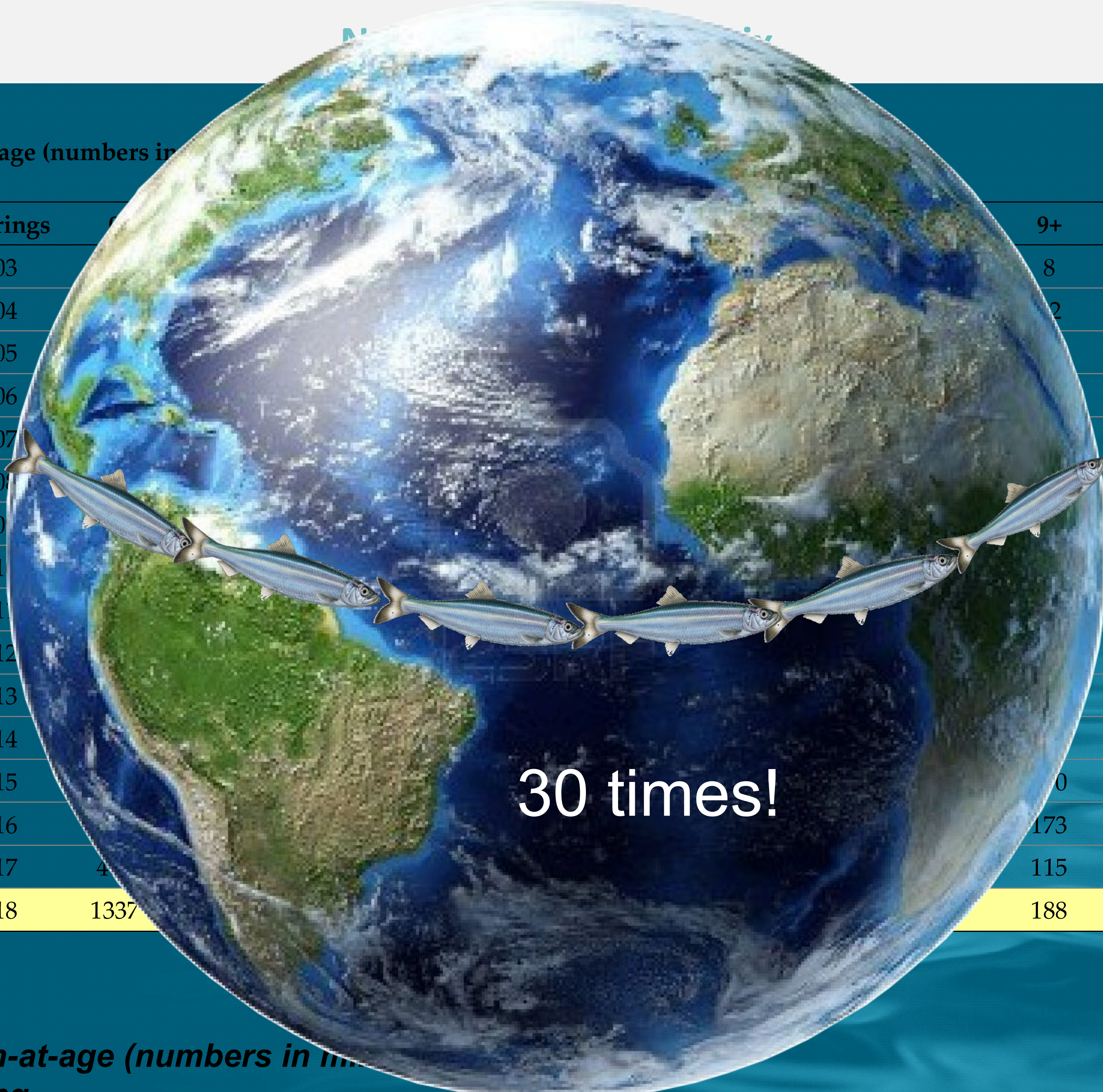
Numbers-at-age-matrix

Catch numbers in millions (North Sea herring)

Year/rings	0	1	2	3	4	5	6	7	8	9+	Total
2003	369	617	1204	517	820	243	106	120	37	8	4042
2004	716	207	439	1326	520	726	171	101	71	22	4298
2005	1016	716	355	486	1318	480	576	115	108	39	5209
2006	879	222	401	311	465	999	253	249	63	44	3885
2007	621	236	219	412	283	308	628	147	132	23	3009
2008	798	235	332	185	199	137	118	215	74	43	2336
2009	650	176	259	107	93	86	38	53	110	33	1606
2010	575	281	287	233	123	83	63	34	59	55	1794
2011	779	160	368	274	218	130	63	52	60	65	2168
2012	773	285	455	673	404	306	150	104	88	102	3341
2013	462	413	325	484	571	422	327	145	152	160	3461
2014	1389	371	383	386	617	488	285	192	92	123	4323
2015	538	395	552	248	283	461	432	271	168	170	3517
2016	1584	109	625	819	293	280	368	307	186	173	4745
2017	462	209	109	1080	838	223	146	176	107	115	3463
2018	1337	73	206	201	1179	849	224	145	144	188	4546

Catch at age (numbers in

Year/rings	…	9+	Total
2003		8	4042
2004		2	4298
2005			5209
2006			3885
2007			3009
200			2336
200			1606
201			1794
201			2168
2012			3341
2013			3461
2014			4323
2015		0	3517
2016		173	4745
2017	4	115	3463
2018	1337	188	4546



Catch-at-age (numbers in m
herring

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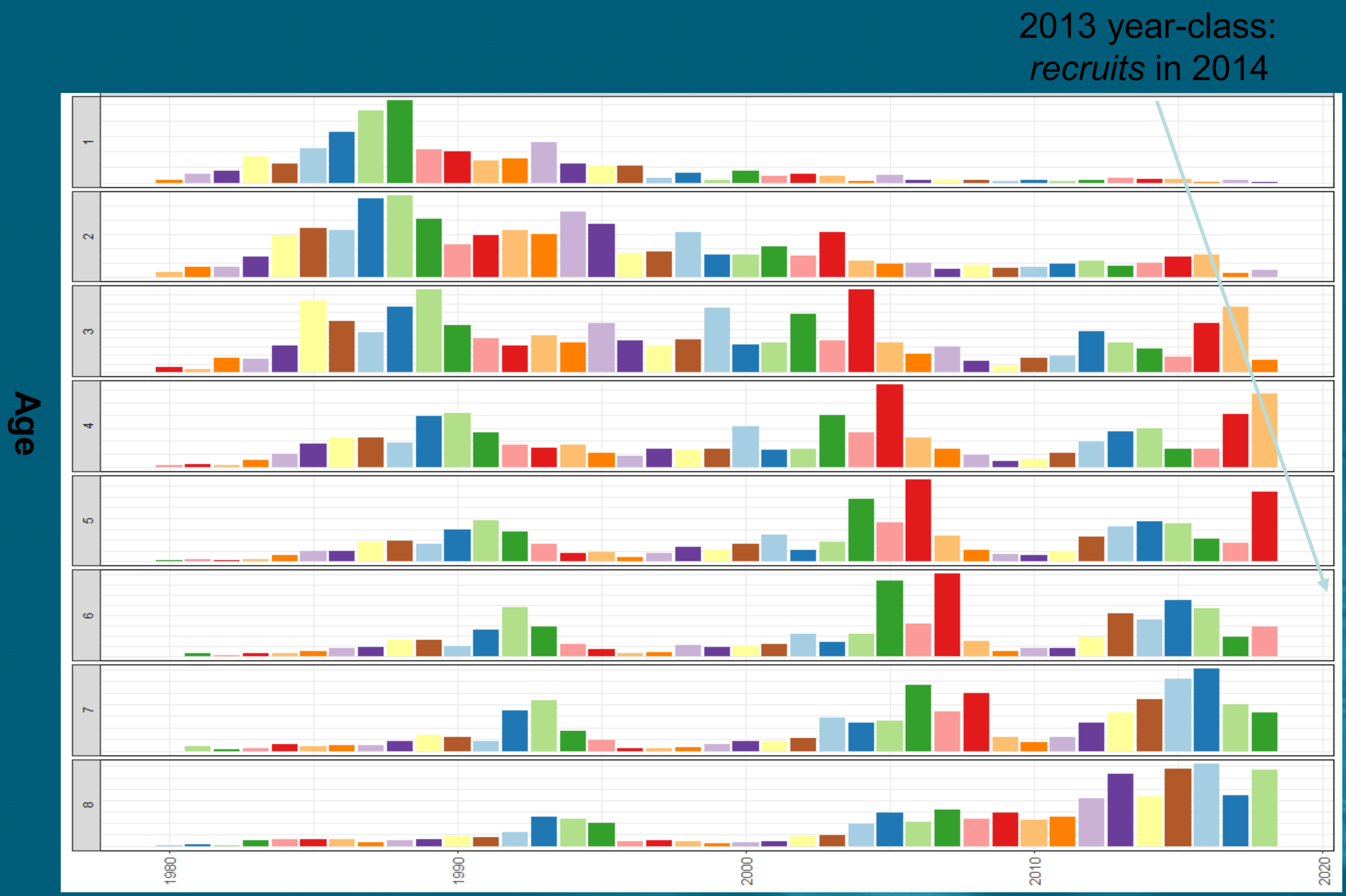
Numbers-at-age matrix: *catch*



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Russell proposed the following equation for the biomass of a population:

$$\mathbf{S_2 = S_1 + (A + G) - (C + M)}$$

where

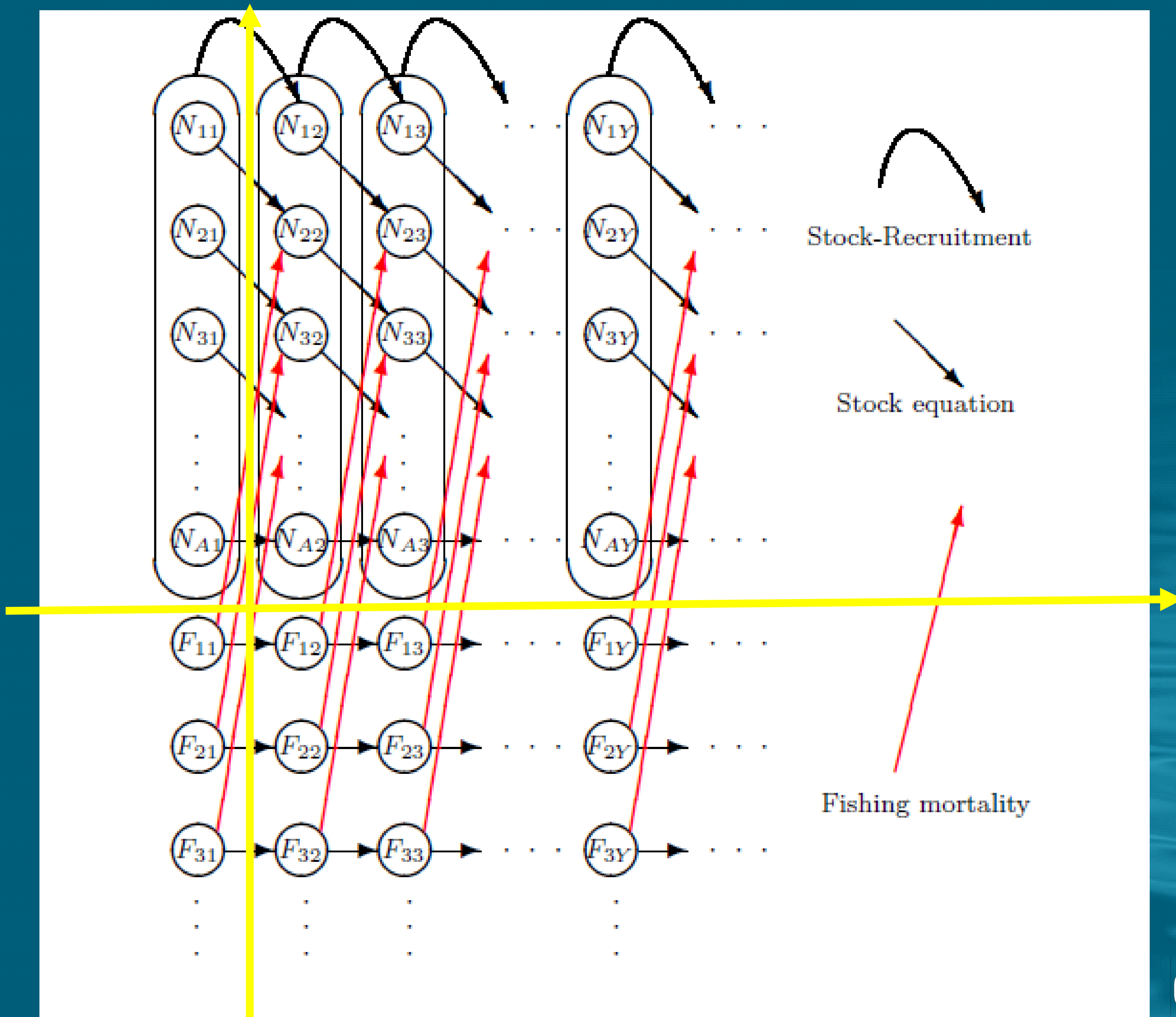
S_t – biomass of the population at time *t*

A – mass of new fish growing into the fishable component of the population (*recruits*)

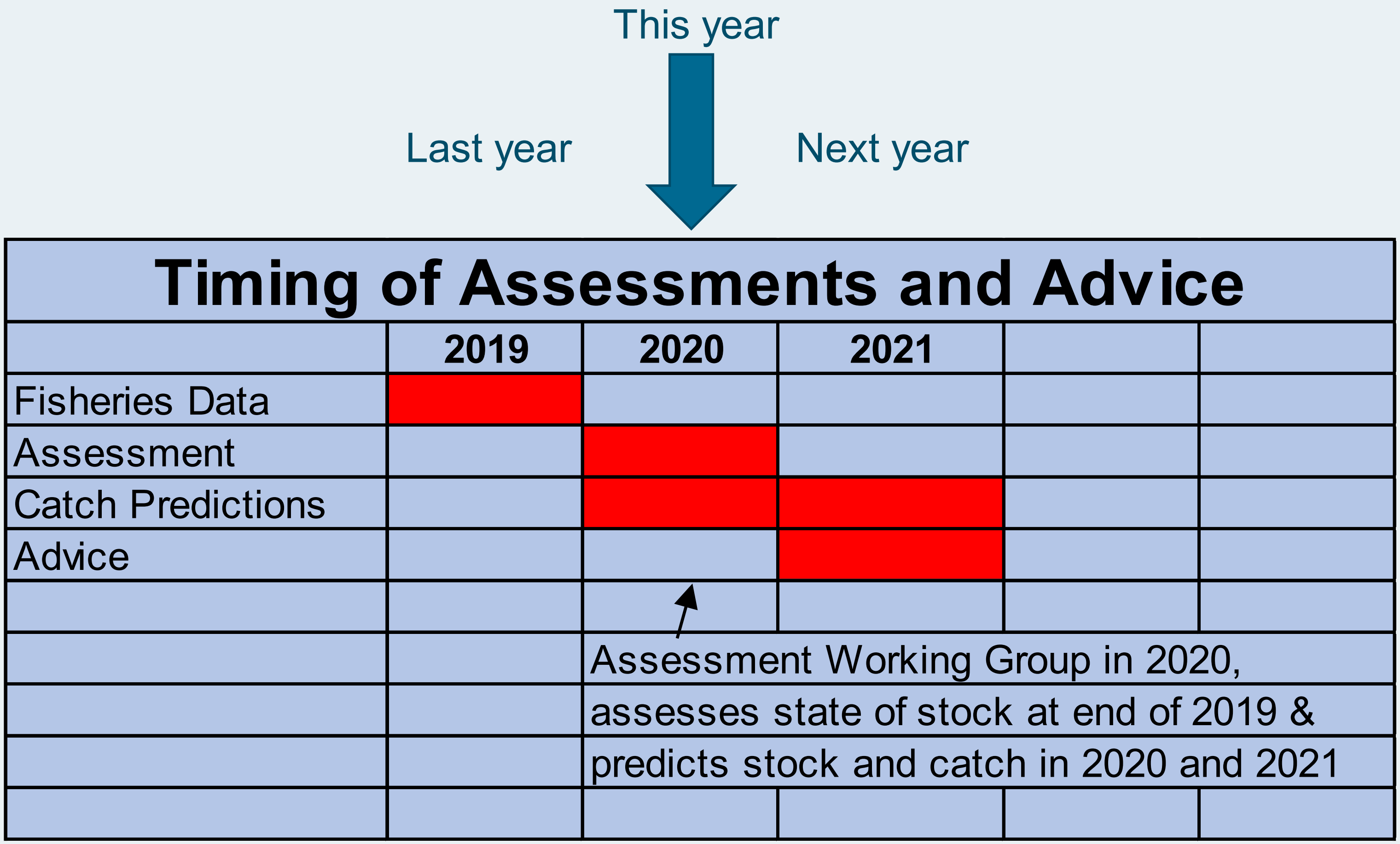
G – increase in mass of the new recruits plus other fish already of a fishable size

C – mass caught

M – mass of fish that died naturally



N_{11} N_{12} N_{13} N_{1Y}
N_{21} N_{22} N_{23} N_{2Y}
N_{31} N_{32} N_{33} N_{3Y}
N_{A1} N_{A2} N_{A3} N_{AY}
F_{11} F_{12} F_{13} F_{1Y}
F_{21} F_{22} F_{23} F_{2Y}
F_{31} F_{32} F_{33} F_{3Y}
Stock-Recruitment
Stock equation
Fishing mortality



From assessments to advice

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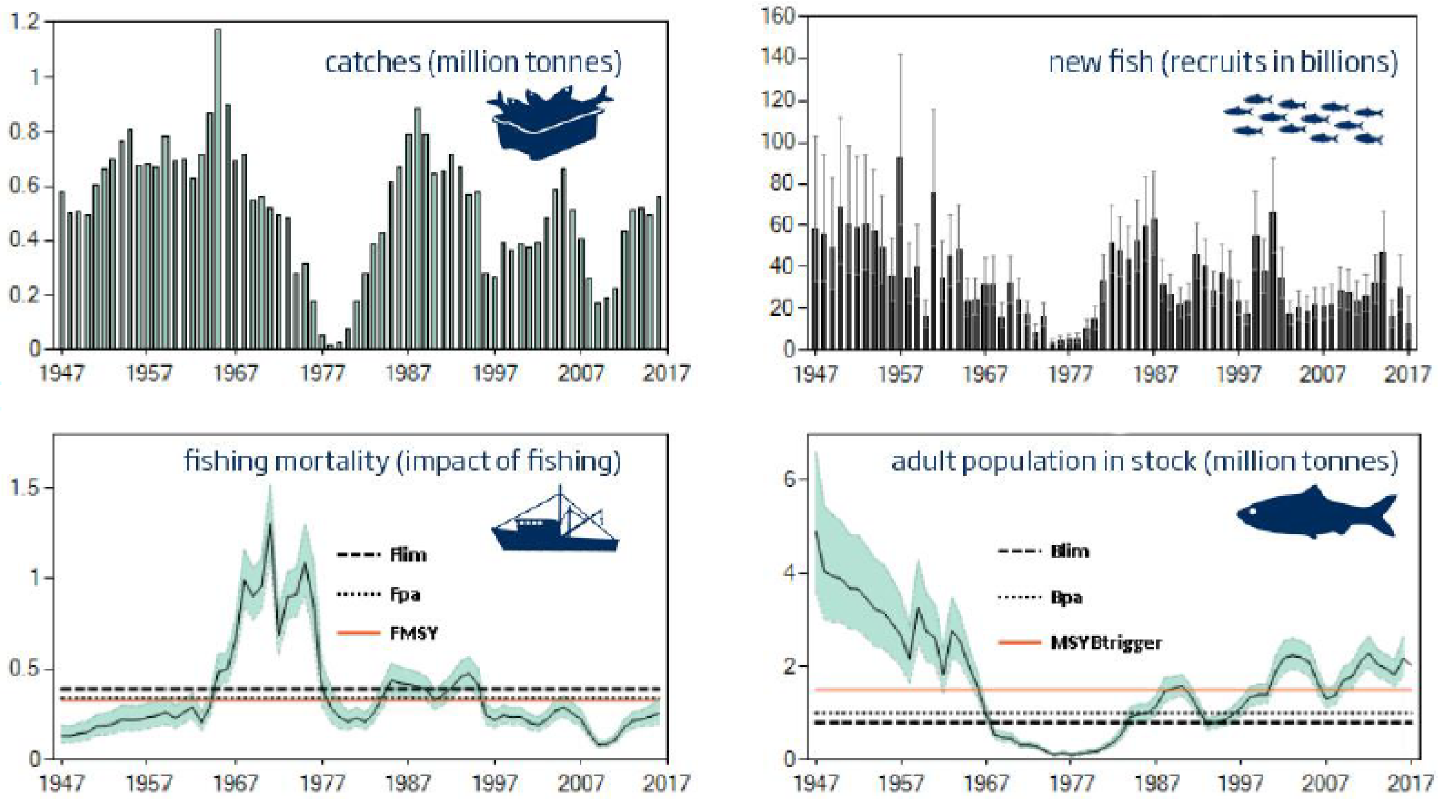
This produces a stock assessment

North Sea herring



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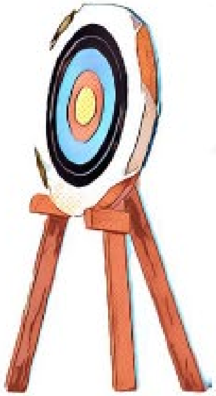
To provide the advice for next year's catches

We project forward with our best knowledge
(maturity, growth, recruits, impact of fishing gear, natural death etc)
across a range of fishing scenarios.



Brief consideration of shellfish: generally, data-limited

Shellfish fishery management

CFP regards them as a *National competence*

- EU MLS
- Western Waters Effort
  - >15m scallop dredge & crab potters

UK legislation since at least 1877
Most recent 2018 (England only)

- MLS
- Technical Conservation Measures

UK management boundaries

<u>DAs</u>

Measures apply to all UK vessels

MLS & Tech Con

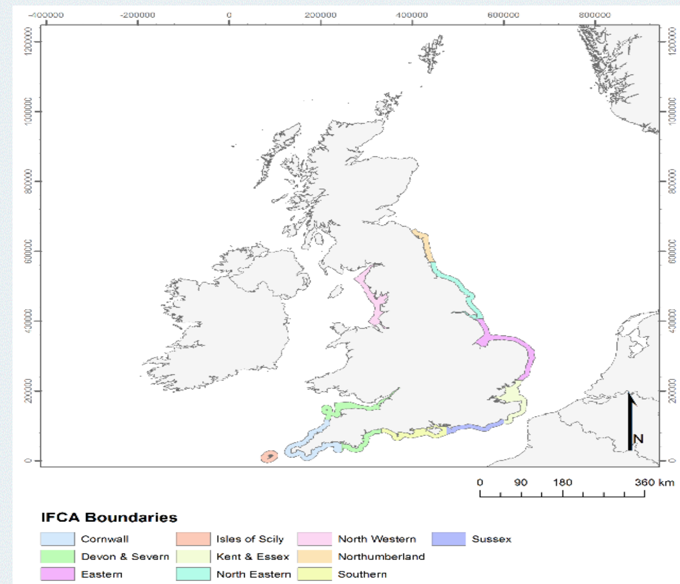
<u>IFCAs</u>

Evolved from Sea Fishery Committees

Jurisdiction to 6nm

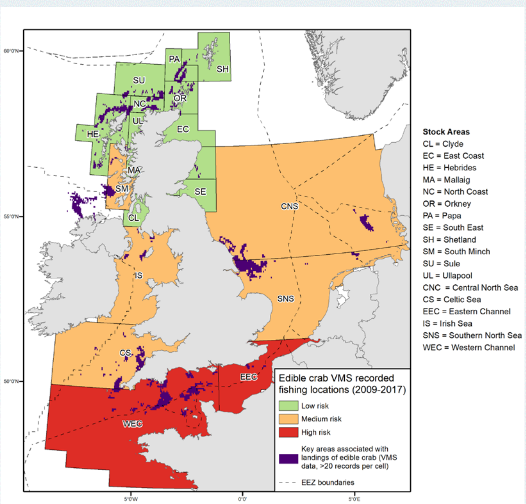
Local Authority funded

- *MLS*
- *Gear specification*
- *Effort restriction*
- *Time & space restriction*



Stock boundaries

- International assessments
- boundary definitions (& adjustments)
  - *Nephrops* only



- biology
- hydrography
- fisheries
- existing management
- data availability

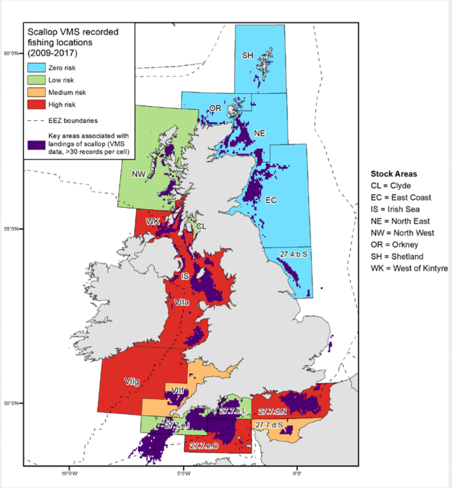
Cefas (6) & Marine Scotland (12) = 18 Crab assessment units

Scallop assessment

- Scotland 7 areas
- Age based
- Long-term monitoring

- England 9 areas (6 assessed)
- Direct biomass estimate
- 2 years monitoring

- Sedentary
- Specific habitats
- Local growth rates
- Large scale recruit distribution
- International fisheries



- Joint assessment programme Industry/Defra/Cefas
- Started 2016
- 1st Assessment 2018
  - Biomass & harvest rate estimates
  - MSY proxies to be developed
- Dredge survey (vessel paid by industry)
- Biological sampling – part industry

Next challenges

- Highly migratory
- Live 1-2 years
- Very fast growth
- Die after spawning

- Management objectives?
- Low discard survival
- International fisheries
- Some targeting
- Previous ICES' interest

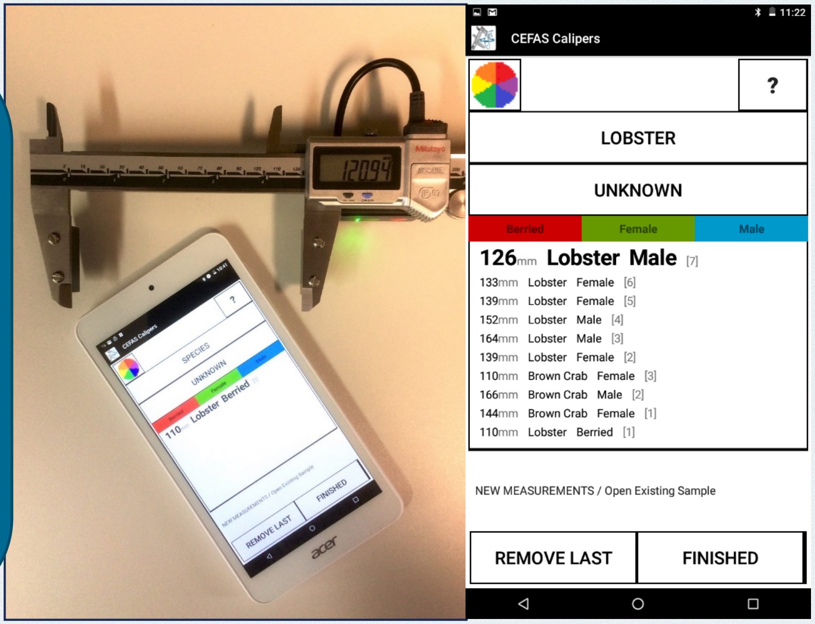
- Sedentary
- No larval dispersal
- Very local growth rates

- Domestic fisheries (over 6nm)
- IFCA interest
- Age determination possible

New solutions

Better assessments = more data!
Industry often the best platform
Use of technology

- Minimise time impact
- Maximise utility to fisher & science



ICES' sheets and reference points

- Measure of the proportion of fish taken from a stock each year by fishing activity
  - Fishing mortality (F)
- Total weight of a species population capable of reproducing
  - Spawning stock biomass (SSB)
- Number of fish becoming available to a fishery stock in a year
  - Recruitment (R)
  - Number of any one annual spawning (Year-class)

Terminology

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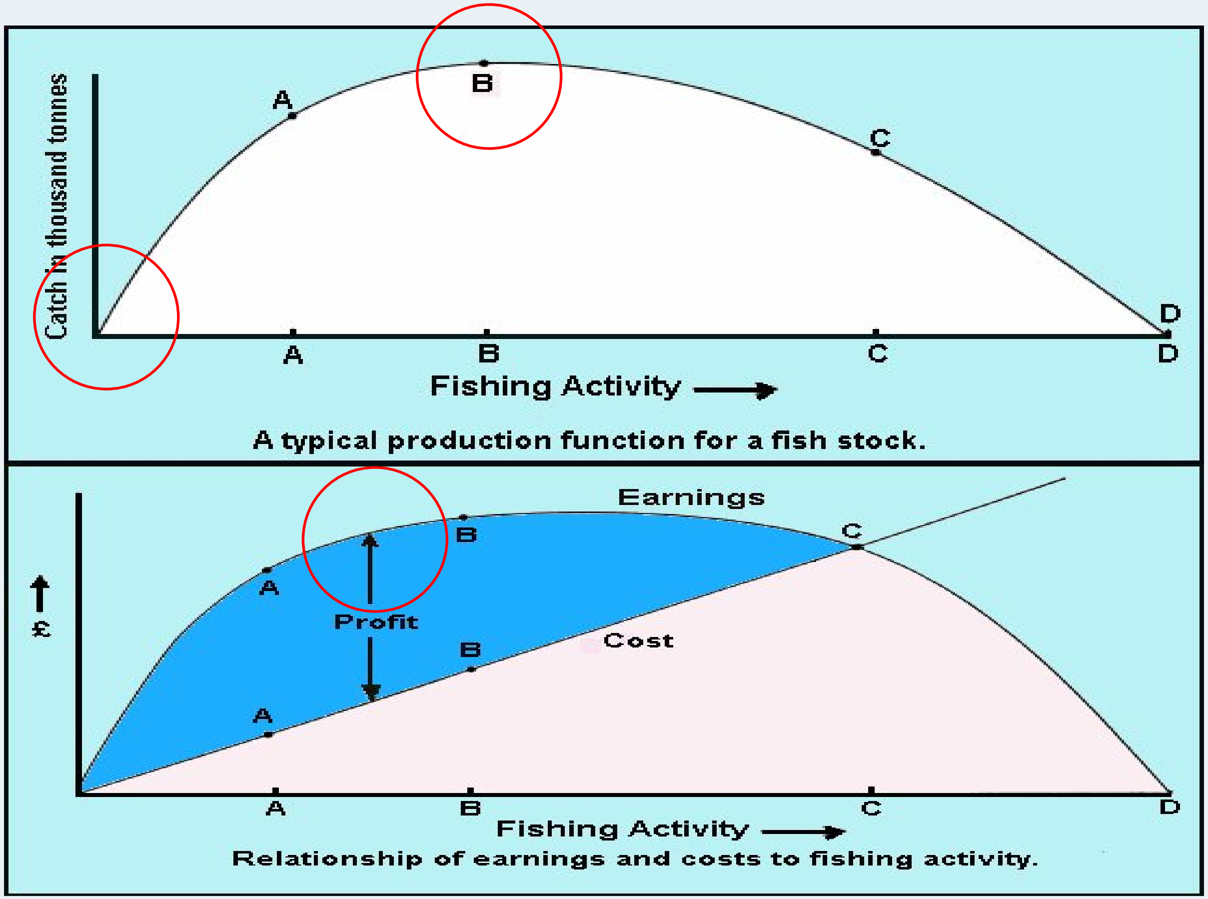
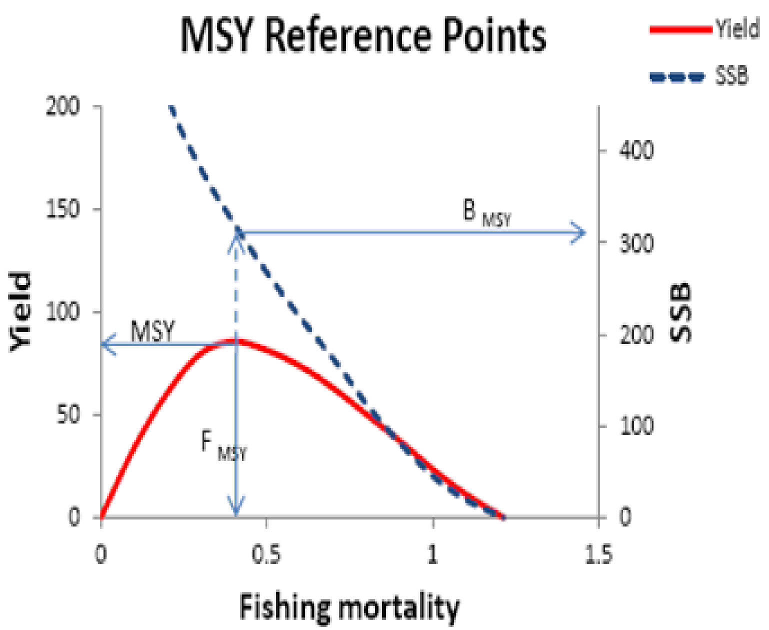
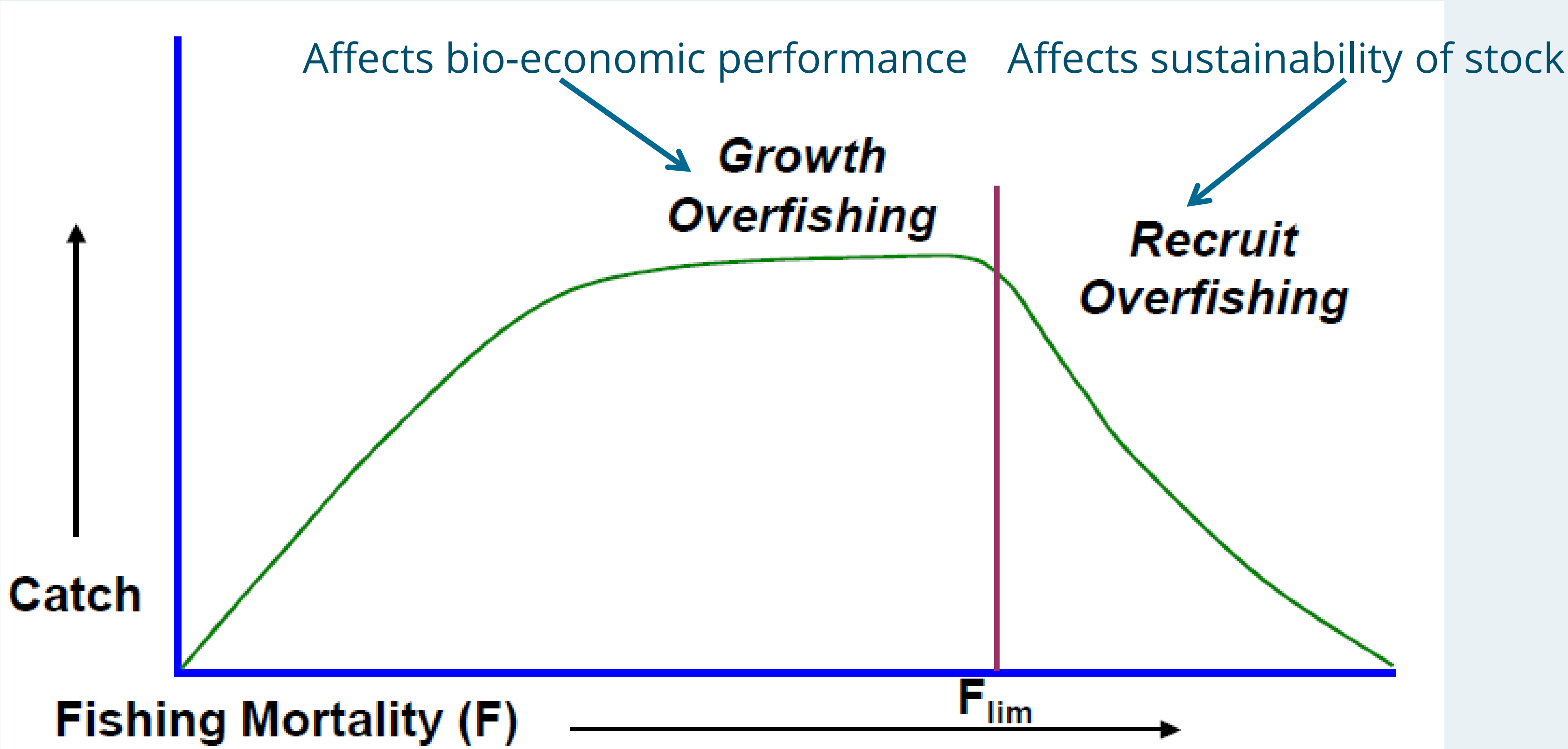


Fishing, long-term yield and profit

Maximum Sustainable Yield (MSY)

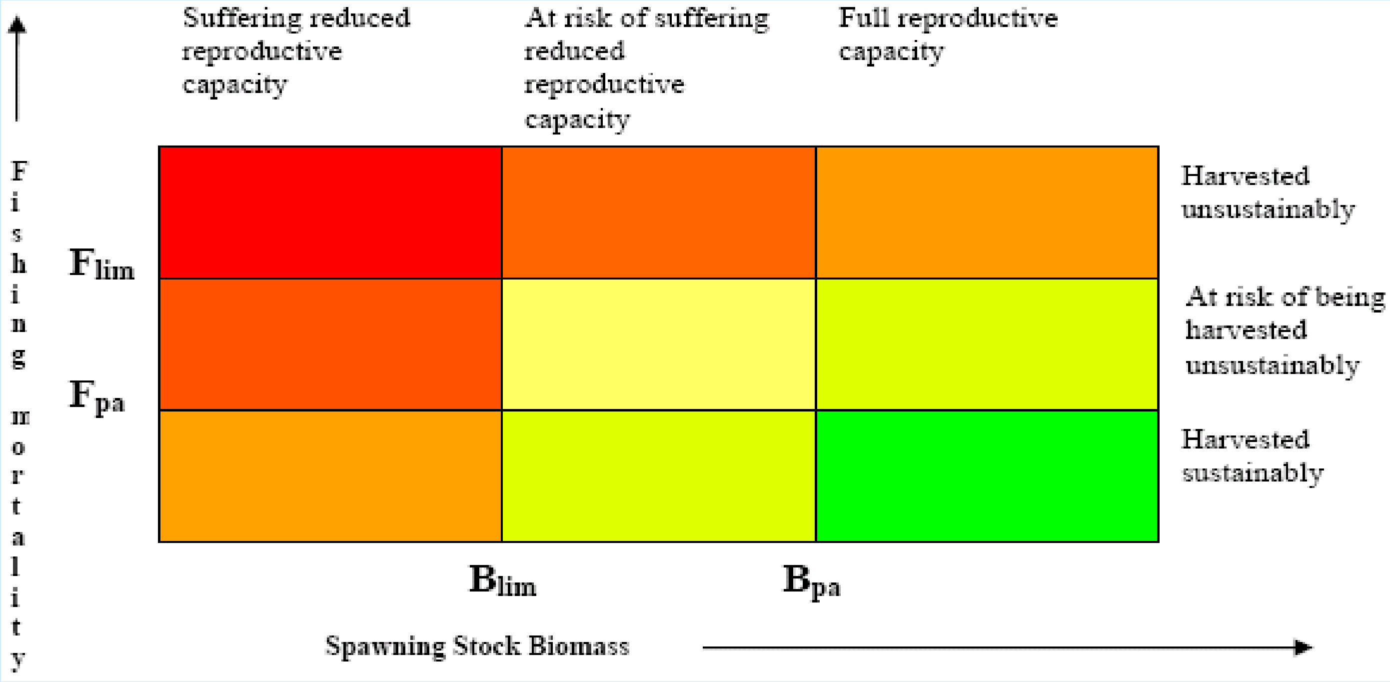
- 2013 adoption of MSY within reformed CFP
- By 2015 (2020 latest)
- MSY=Trade-off between population growth and mortality
- Management controls F not SSB
- Target therefore F_{MSY}




Affects bio-economic performance
Affects sustainability of stock
Growth Overfishing
Recruit Overfishing
Catch
Fishing Mortality (F)
F lim

ICES gives advice in relation to:

- existing management plans (MP)
- high long-term yield (MSY)
- precautionary limits (PA)
- mixed fisheries & the ecosystem



Safe biological limits

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Selected example of the state of stocks and advice

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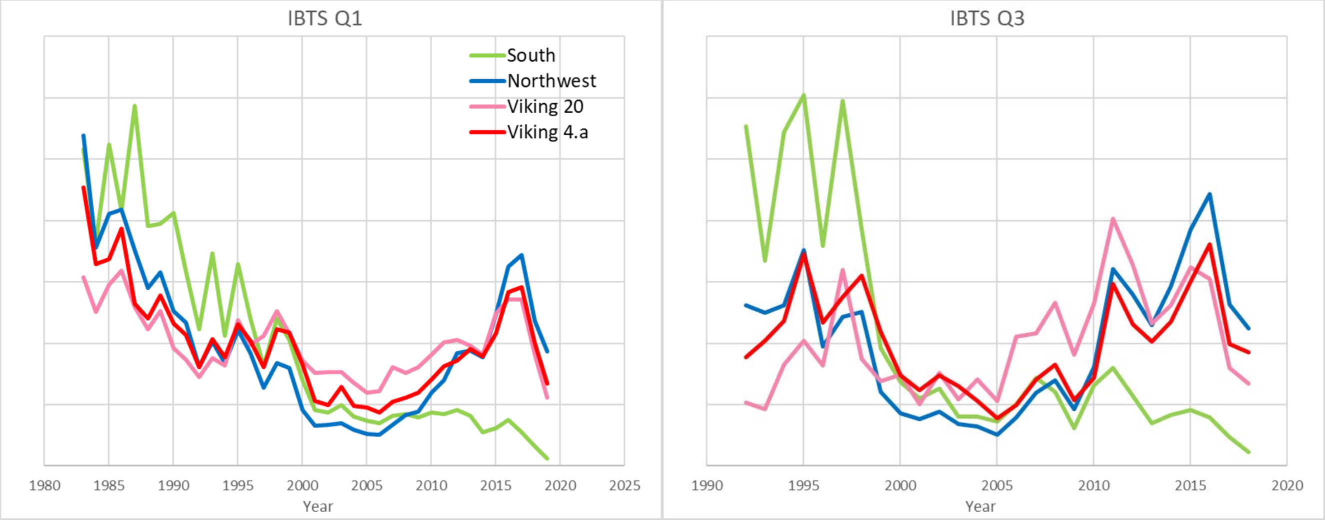
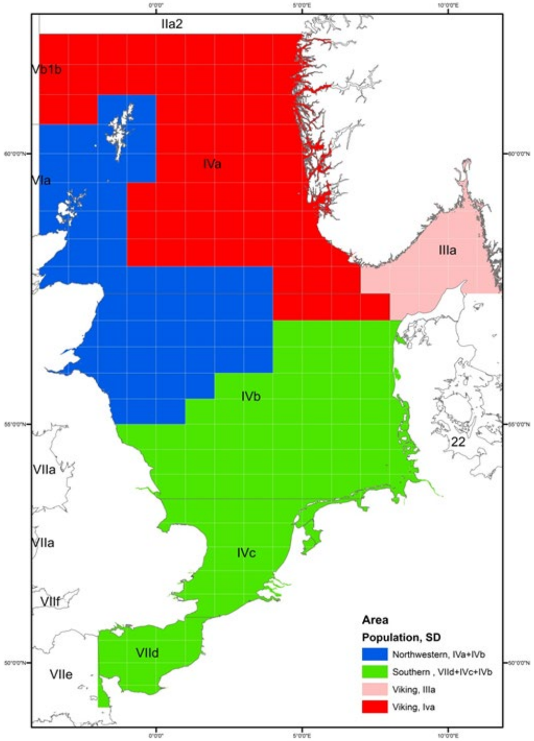
Cod in North Sea, eastern English Channel and Skagerrak



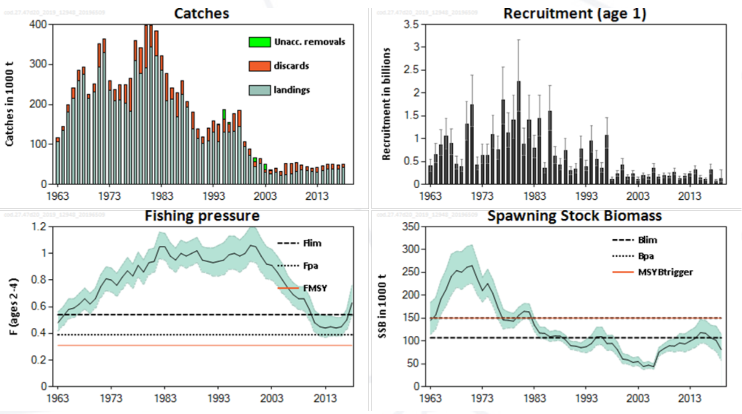
Biomass indices by sub region



- Large downward revision in final 2 years in all areas
- No recovery in the southern area in the mid 2000s.

Cod in North Sea, eastern English Channel and Skagerrak

- Large reduction in fishing pressure
- State of the ecosystem affecting the stock
  - Low recruitment last ~15 years
  - Increasing water temperatures making parts of the North Sea less suitable for cod in recent years



An **EU multiannual management plan (MAP)** has been agreed by the EU for this stock (EU, 2018). This plan is **not adopted by Norway**, thus not used as the basis of the advice for this shared stock. ICES was requested by the EC to provide advice based on the MSY approach and to include catch scenarios for the MAP. EU–Norway have requested an evaluation of **multiple management strategies (ICES 2019b), which are currently under consideration**.

ICES advice on fishing opportunities

ICES advises that when the MSY approach is applied, catches in 2020 should be no more than 10 457 tonnes.

ICES advice on fishing opportunities

Please note: The present advice replaces the advice given in June 2019 for catches in 2020.

ICES advises that when the MSY approach is applied, catches in 2020 should be no more than 13 686 tonnes.

Stock and exploitation status

ICES assesses that fishing pressure on the stock is above F_{MSY}, F_{pa} and F_{lim}; spawning stock size is below MSY $B_{trigger}$, B_{pa}, and B_{lim}.

Table 1 Cod in Subarea 4, Division 7.d, and Subdivision 20. State of the stock and fishery relative to reference points.

		Fishing pressure					Stock size			
		2016	2017	2018			2017	2018	2019	
Maximum sustainable yield	F_{MSY}	✖	✖	✖	Above	MSY $B_{trigger}$	✖	✖	✖	Below trigger
Precautionary approach	F_{pa},F_{lim}	○	○	✖	Harvested unsustainably	B_{pa},B_{lim}	✖	✖	✖	Reduced reproductive capacity
Management plan	F_{MGT}	–	–	–	Not applicable	B_{MGT}	–	–	–	Not applicable

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Published 28 June 2019

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Reference points

Table 5 Cod in Subarea 4, Division 7.d, and Subdivision 20. Reference points, values, and their technical basis. All weights are in tonnes.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	150 000	B_{pa}	ICES (2017)
	F_{MSY}	0.31	EQsim analysis based on the recruitment period 1988–2016.	ICES (2017)
Precautionary approach	B_{lim}	107 000	SSB associated with the last above-average recruitment (1996 year class).	ICES (2017)
	B_{pa}	150 000	$B_{lim} \times \exp(1.645 \times 0.2) \approx 1.4 \times B_{lim}$	ICES (2017)
	F_{lim}	0.54	EQsim analysis based on the recruitment period 1998–2016.	ICES (2017)
	F_{pa}	0.39	$F_{lim} \times \exp(-1.645 \times 0.2) \approx F_{lim} / 1.4$	ICES (2017)
EU Management Plan (MAP) EU (2018)	MAP MSY $B_{trigger}$	150 000	MSY $B_{trigger}$	ICES (2017)
	MAP B_{lim}	107 000	B_{lim}	ICES (2017)
	MAP F_{MSY}	0.31	F_{MSY}	ICES (2017)
	MAP range F_{lower}	0.198–0.31	Consistent with ranges provided by ICES (2017), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2017)
	MAP range F_{upper}	0.31–0.46	Consistent with ranges provided by ICES (2017), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2017)

Catch scenarios

Table 2 Cod in Subarea 4, Division 7.d, and Subdivision 20. Assumptions made for the interim year and in the forecast. All weights are in tonnes and recruitment is in thousands.

Variable	Value	Notes
$F_{ages\ 2\text{–}4}$ (2019)	0.50	Average exploitation pattern (2016–2018) with median total catch in 2019 set equal to the TAC in 2019.
SSB (2020)	83 301	Short-term forecast.
$R_{age\ 1}$ (2019)	184 342	Median recruitment estimated from the assessment in 2019.
$R_{age\ 1}$ (2020)	183 205	Median recruitment resampled from the years 1998–2018.
Total catch (2019)	35 358	Median catch based on TAC in 2019.
Wanted catch (2019)	29 769	Assuming 2018 wanted catch fraction by age.
Unwanted catch (2019)	5 589	Assuming 2018 unwanted catch fraction by age.

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Published 8 November 2019

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Table 3 Cod in Subarea 4, Division 7.d, and Subdivision 20. Annual catch scenarios. All weights are in tonnes.

Basis	Total catch (2020)	Wanted catch * (2020)	Unwanted catch * (2020)	F_{total} (2020)	F_{wanted} (2020)	$F_{unwanted}$ (2020)	SSB (2021)	% SSB change **	% TAC change ***	% Advice change ^
ICES advice basis										
MSY approach: SSB (2021) = B_{lim}	13686	10881	2805	0.170	0.131	0.039	107000	28	−61	−51
Other scenarios ^^^										
MSY approach: F_{MSY} × SSB (2020) /MSY $B_{trigger}$	13820	10986	2834	0.172	0.132	0.040	106871	28	−61	−51
F = MAP^^ $F_{MSY-lower}$ × SSB (2020)/MSY $B_{trigger}$	9046	7196	1850	0.110	0.085	0.025	111678	34	−74	−68
F = 0	0	0	0	0.00	0.00	0.00	121366	46	−100	−100
F_{pa}	28689	22756	5933	0.39	0.30	0.090	91399	9.7	−18.9	1.72
F_{lim}	37587	29717	7870	0.54	0.42	0.125	82448	−1.02	6.3	33
SSB (2021) = B_{lim}	13686	10881	2805	0.170	0.131	0.039	107000	28	−61	−51
SSB (2021) = B_{pa}	0	0	0	0.00	0.00	0.00	121366	46	−100	−100
SSB (2021) = MSY $B_{trigger}$	0	0	0	0.00	0.00	0.00	121366	46	−100	−100
TAC (2019) − 20%	28286	22428	5858	0.38	0.30	0.088	91851	10.3	−20.0	0.29
TAC (2019) − 15%	30053	23840	6213	0.41	0.32	0.095	89893	7.9	−15.0	6.6
TAC (2019) − 10%	31821	25186	6635	0.44	0.34	0.102	88282	6.0	−10.0	12.8
TAC (2019) − 5%	33589	26579	7010	0.47	0.36	0.108	86473	3.8	−5.0	19.1
Constant TAC	35358	27966	7391	0.50	0.38	0.116	84777	1.77	0.00	25
TAC (2019) + 5%	37125	29361	7764	0.53	0.41	0.123	82906	−0.47	5.0	32
TAC (2019) + 10%	38893	30719	8174	0.56	0.43	0.130	81220	−2.5	10.0	38
TAC (2019) + 15%	40661	32043	8618	0.60	0.46	0.137	79538	−4.5	15.0	44
TAC (2019) + 20%	42429	33345	9084	0.63	0.48	0.145	77831	−6.6	20	50
F = F_{2019}	35291	27914	7377	0.50	0.38	0.116	84852	1.86	−0.187	25
F=$F_{MSY\ lower}$	15718	12497	3221	0.198	0.152	0.046	105041	26	−56	−44
F = F_{MSY}	23558	18688	4870	0.31	0.24	0.072	96848	16.3	−33	−16.5

* "Wanted" and "unwanted" catch are used to describe fish that would be landed and discarded in the absence of the EU landing obligation, based on discard rate estimates for 2018.

** SSB 2021 relative to SSB 2020.

*** Catch in 2020 relative to TAC in 2019: North Sea (29 437 t) + Skagerrak (4205 t) + Eastern English Channel (1715 t) = 35 357 t.

^ Total catch 2020 relative to advice value 2019 (28 204 t).

^^ EU multiannual plan (MAP) for the North Sea (EU, 2018).

^^^ Other scenarios do not include $F_{MSY\ upper}$ because SSB(2020) < MSY $B_{trigger}$.

5.7 **Cod**

5.7.1 Based on its MSY approach ICES advices that total and wanted catches in 2020 should not be more than 13,686 and 10,881 tonnes, respectively. The Delegations noted that according to the latest ICES assessment the stock is at a low level. ICES consider the biomass to be below B_{lim}. The fishing mortality has seen a major decline since 2001, but has been increasing since 2016 and it is since 2018 above F_{lim}.

5.7.2 The Delegations pointed out that ICES in its basis for advice assumes unwanted catches, including discards in 2018 to be 46% of total catch in numbers corresponding to 16% in biomass. In the catch option table for 2019, ICES present levels of unwanted catches to be around 21% of total catch.

5.7.3 The Delegations noted that the cod assessment during recent years (since 2017) faces some challenges. These challenges have resulted in a downscaling of spawning stock biomass (SSB) and an upward revision of the fishing pressure (F) in the assessment. The Delegations therefore agreed to underline the relevance of the process that ICES is going to launch in 2020 with the purview of carrying out an assessment benchmark for cod in 2021, and for which the relevant scientific support should be made available.

5.7.4 The Delegations agreed to establish a TAC in 2020 of 17,679 tonnes for cod in Subarea 4, Division 7.d, and Subdivision 20 (North Sea, Eastern English Channel, Skagerrak). This constitutes a decrease of 50% compared to the TAC in 2019.

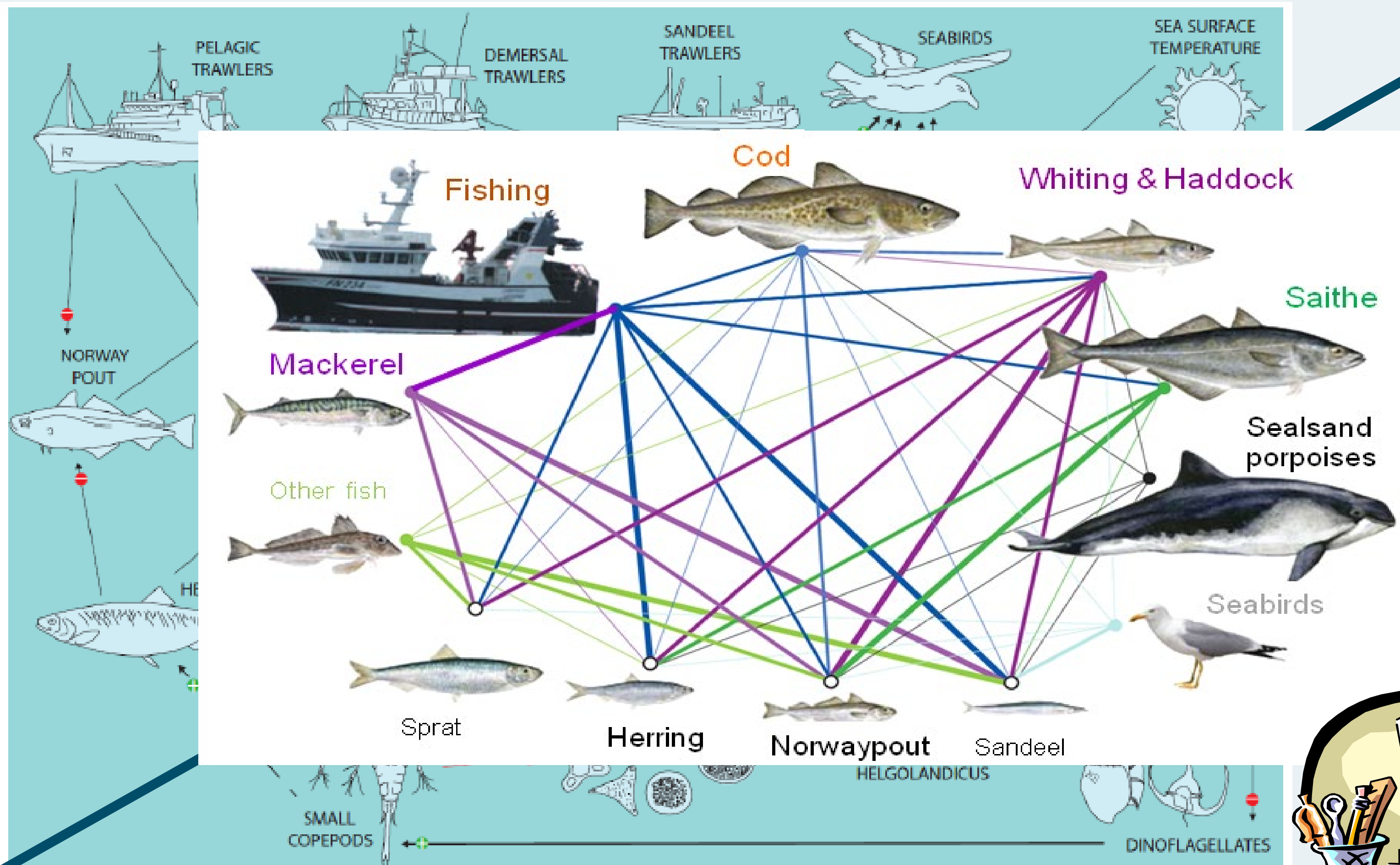
5.7.5 The Delegations agreed that the resulting TAC for ICES Subarea 4 (North Sea) is 14,718 tonnes and the TAC in Subdivision 20 (Skagerrak) is 2,103 tonnes.

5.7.6 The EU Delegation informed the Norwegian Delegation of its intention to base its TAC in 2020 according to a traditional approach and yearly agreed split, resulting in a TAC for cod in ICES Div. 7.d. (Eastern Channel) of 858 tonnes.

On cod in the North Sea (United Kingdom)

The United Kingdom is committed to the use of the best scientific advice and available evidence to inform sustainable stock management decisions. Cod is widely distributed throughout the North Sea, but there are now indications of differences that have developed over a period of time in the abundance of cod throughout the North Sea. Any implications of these differences for advice and management decisions are not clear and so the United Kingdom urges that work commence immediately to improve overall understanding of the impacts such differences may have on the scientific advice that is generated by ICES. This work should be completed so that it can inform negotiations and management decisions next year.

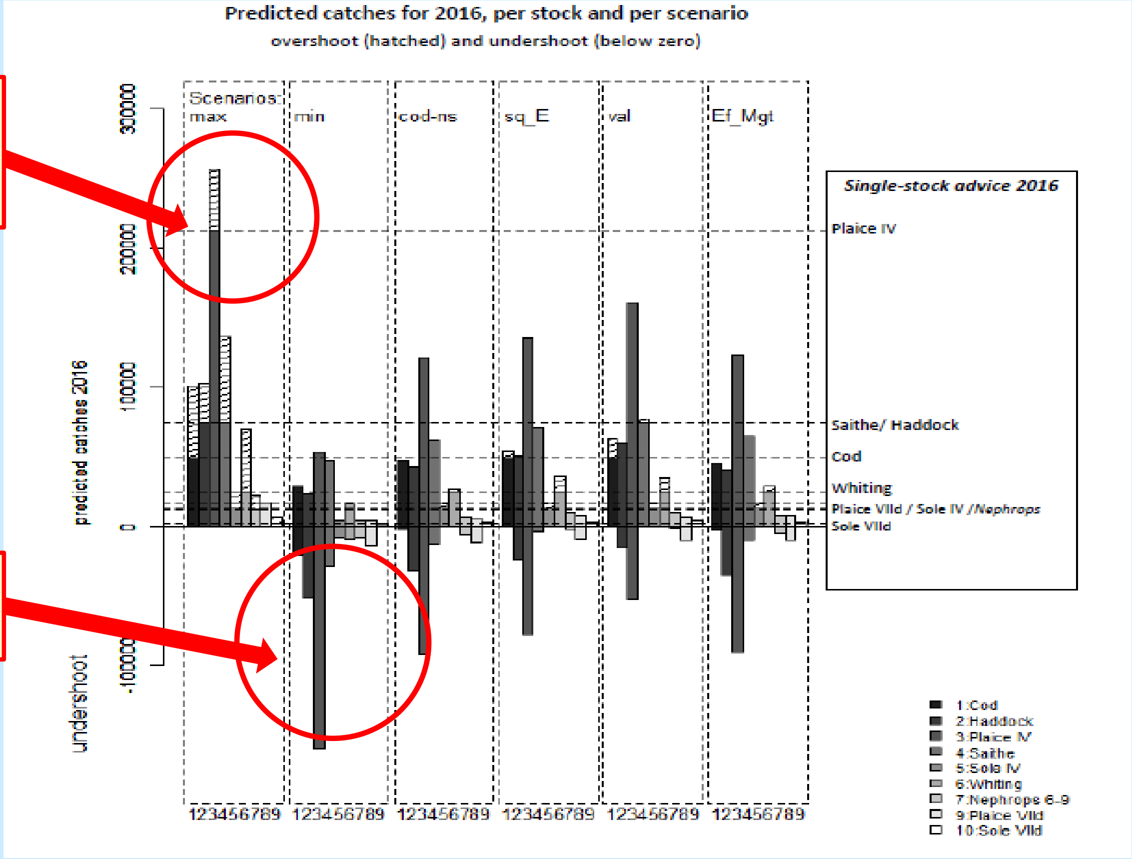
December 2019: Council of the European Union (Fisheries)



Food webs and more

Landings bigger than TAC

Landings below TAC



Centre for Environment Fisheries & Aquaculture Science

Mixed fisheries approach

Cefas