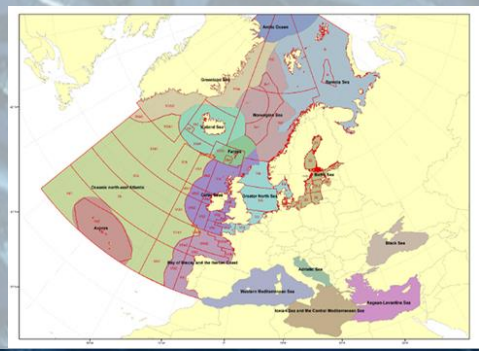
Fisheries Resource Education Programme: Introduction to Sustainable Fishing training workshop

SCIENCE 6b: Stock assessment *masterclass*

7th March 2018

Dartington Hall Conference Centre, Devon



Dr Carl O'Brien CBE
Defra Chief Fisheries Science Adviser
UK Delegate to ICES/Vice-president

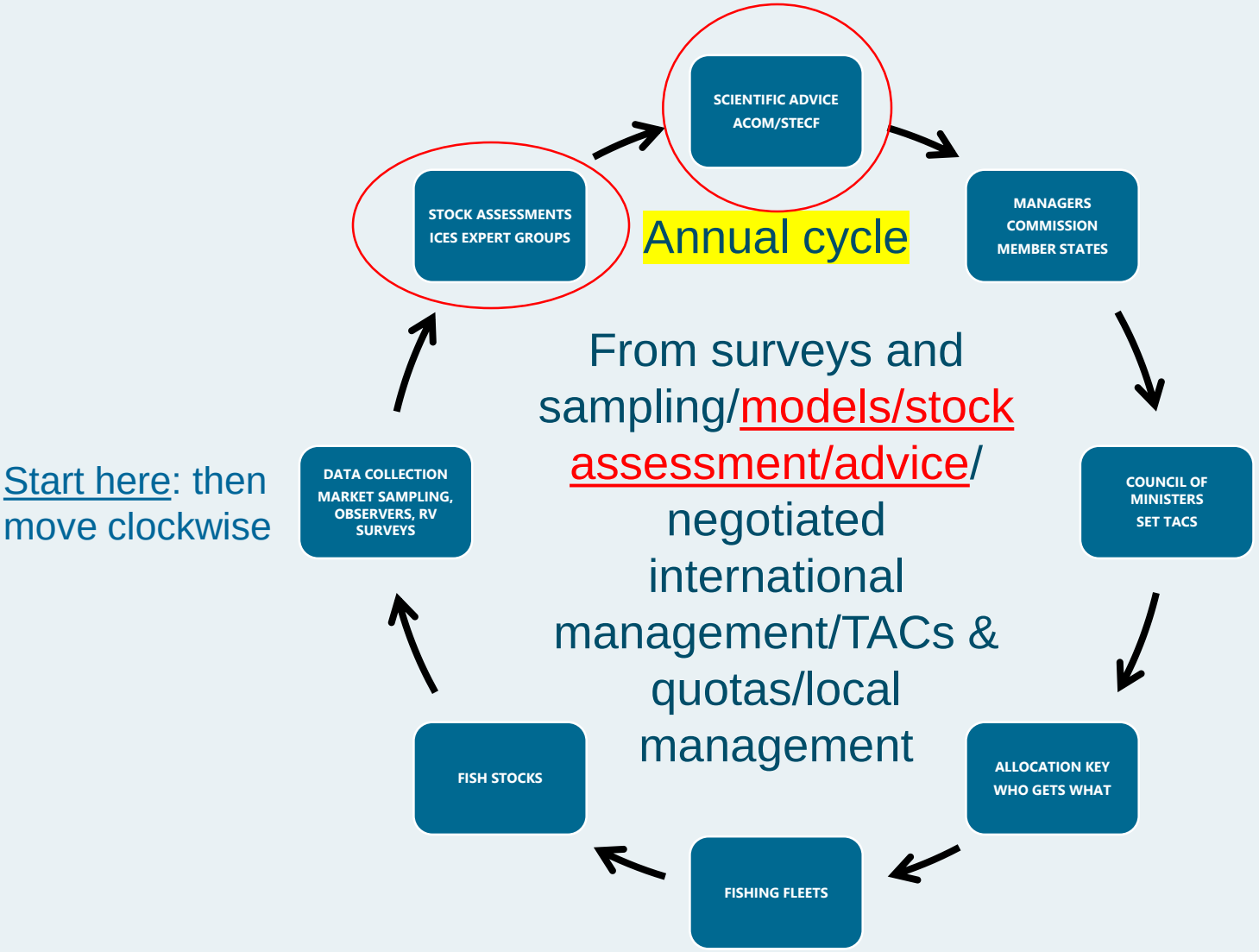
Centre for Environment Fisheries & Aquaculture Science

Cefas

Purpose

- Context of fisheries assessments and management advisory process
- Different models for assessment and advice
  - Availability and quality of data
  - Uncertainty
- ICES' advisory sheets

Cefas



Process overview: from science to management

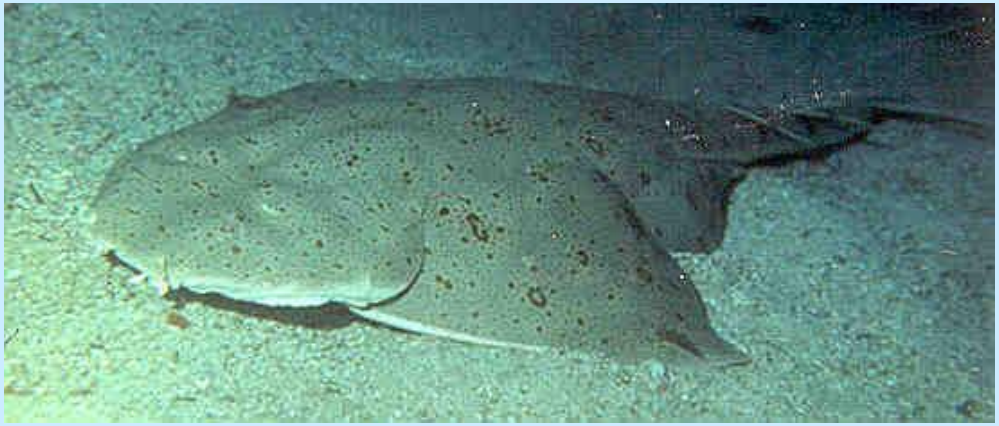
Overview

- Biological background
- Assessment and advisory process
- State of stocks
- Interpreting ICES' advice

Cefas

Diverse – over 300 shelf species

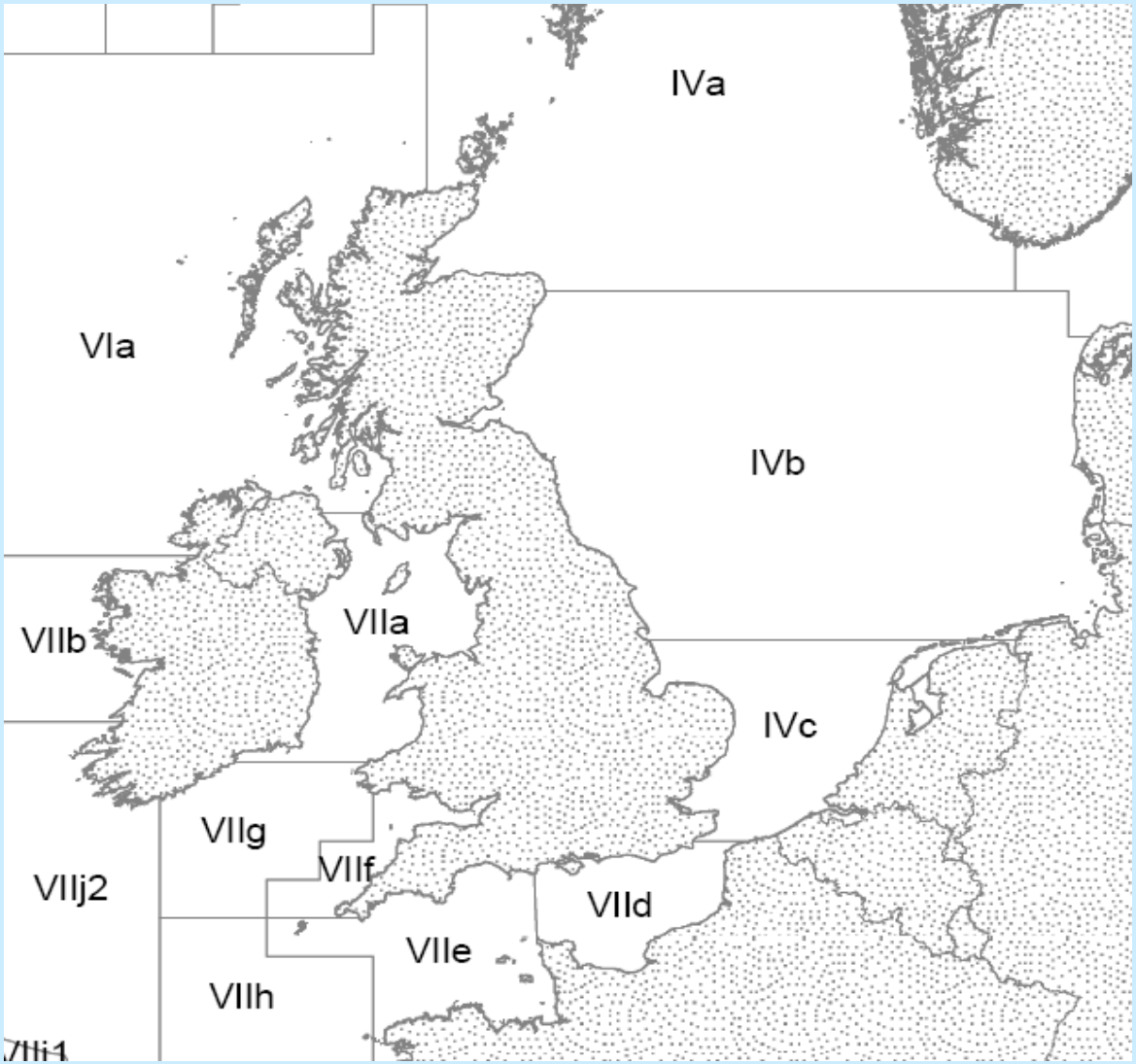
~ 20 species give over 85% value



Fish (and shellfish)

Cefas

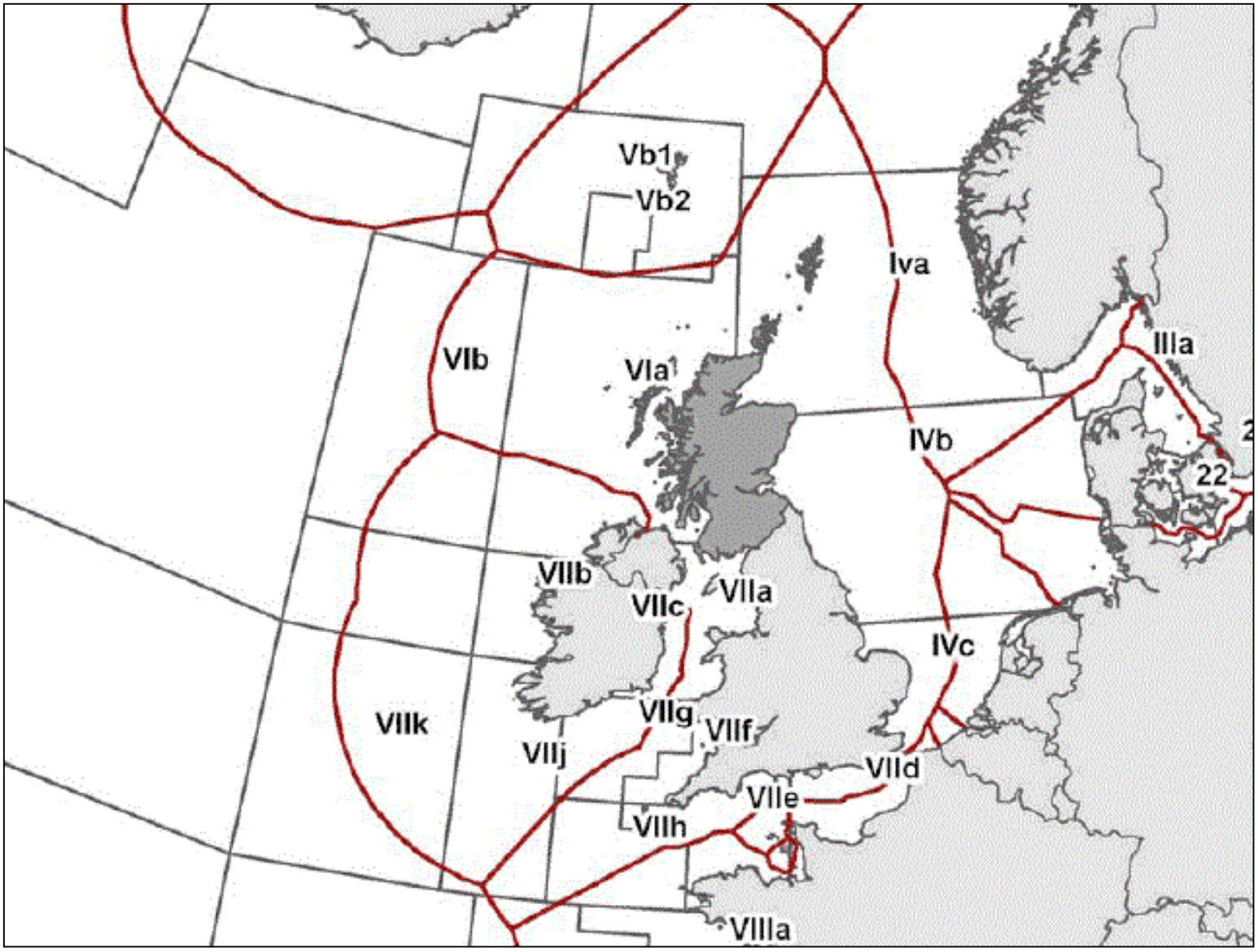
- Species
- Populations = stocks
- TACs ~~ stocks
- sometimes not even species
  - E.g. rays
- TACs by ICES' areas



Fish stocks

Cefas

ICES Divisions and Exclusive Economic Zones (EEZs)



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.

Cefas

Age and growth

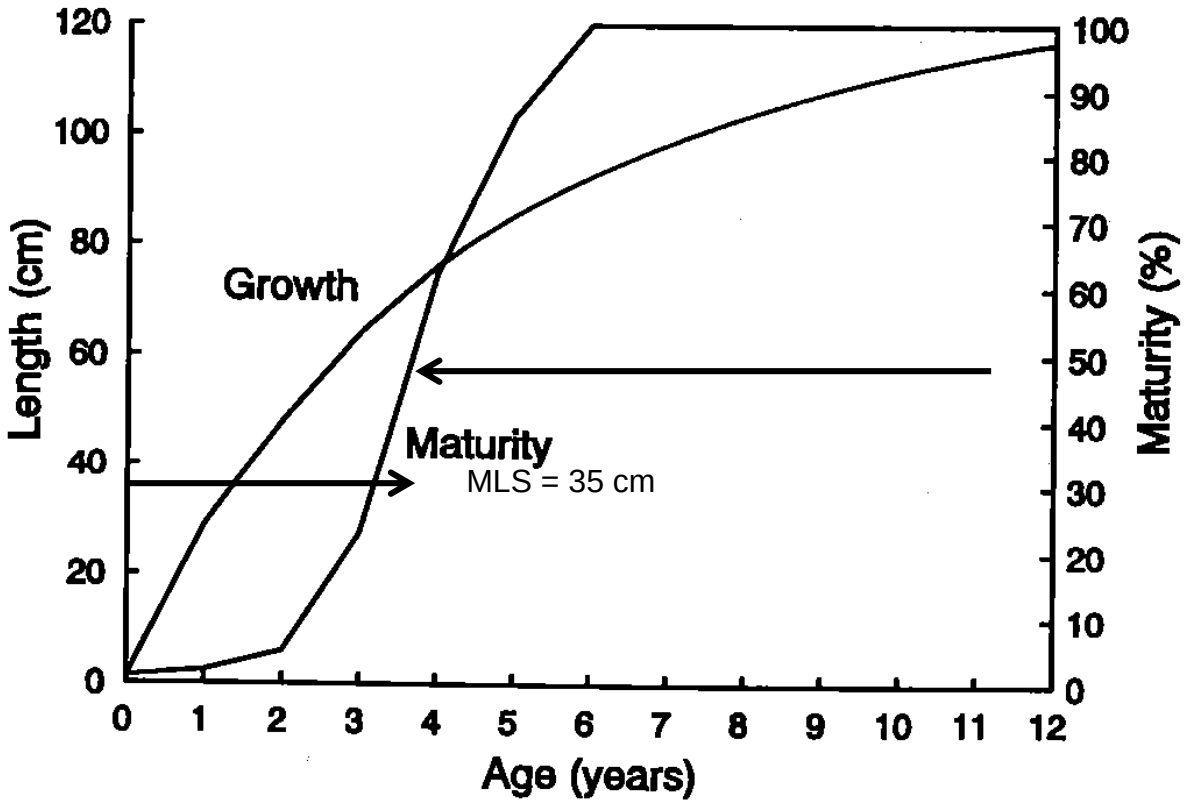


Figure 1. Growth and maturation of North Sea Cod

Cefas

- Age one year
  - 20 cm (8 ins)
- Age three years
  - 50 cm (20 ins)
- Age six years
  - 80 cm (32 ins)
- Maximum size
  - ~150 cm (59 ins)

Minimum landing size: 35 cm

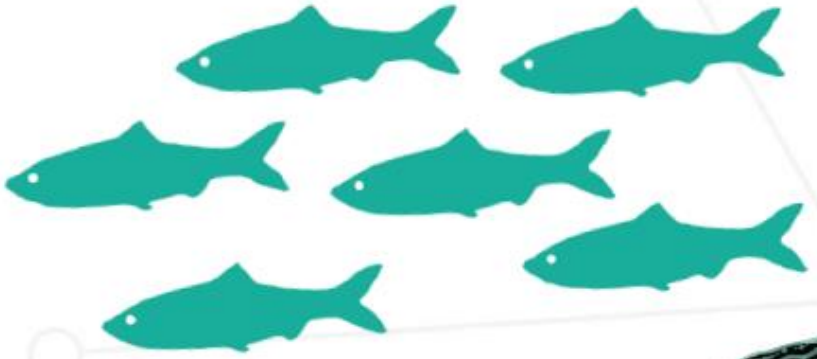
North Sea stock is mainly comprised fish below 5-years old

Maximum recorded age is 15 years (Macer & Easey)

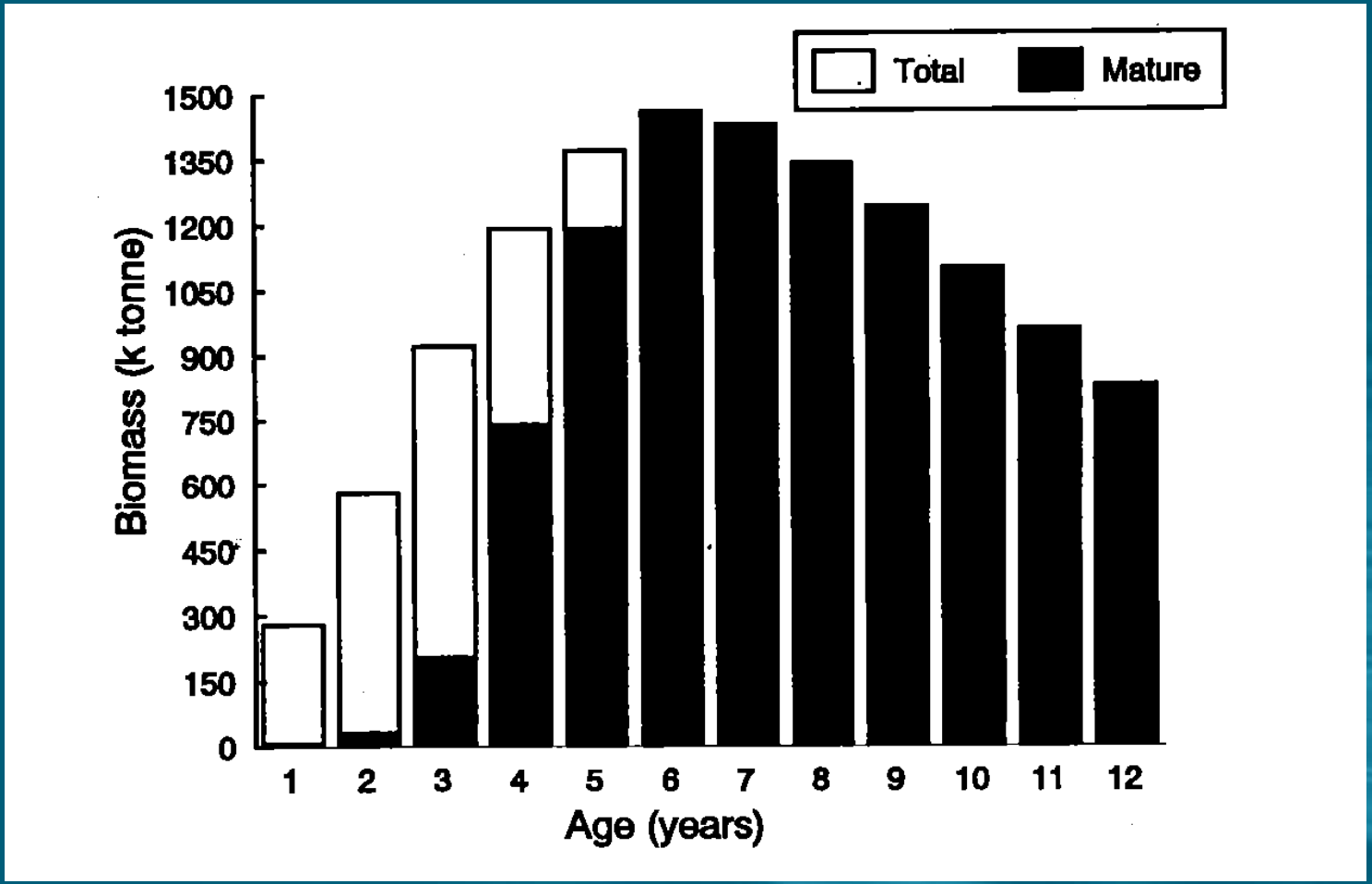
Average North Sea cod size

Information from fish

- Length
- Weight
- Age



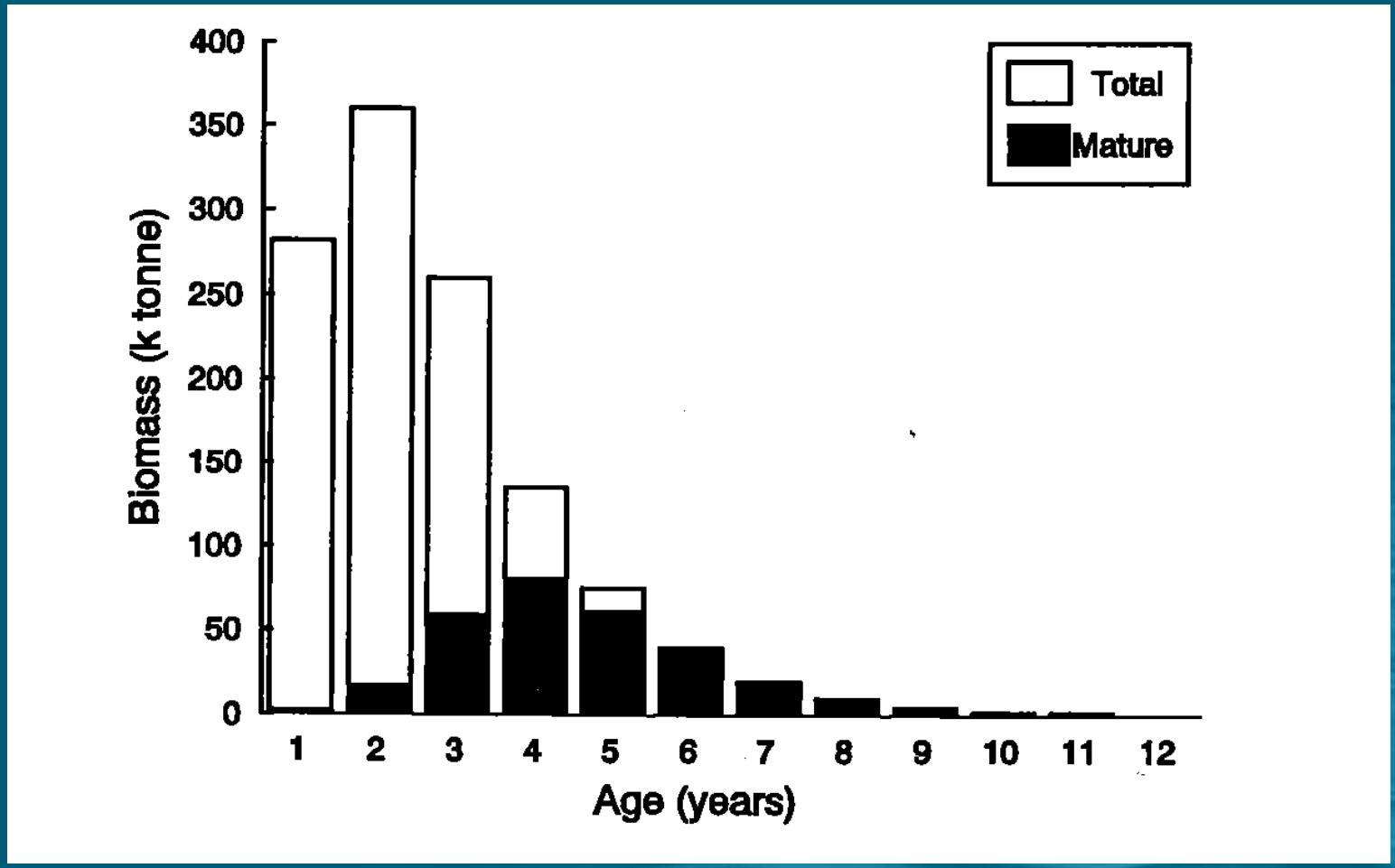
Age composition of an unfished stock



Most of the unfished stock is fish greater than 5 years old

Cefas

Age composition at high fishing rates



At current rates of fishing most of the stock is made up of fish less than 5 years old

Cefas

Age composition at high fishing rate with larger (200 mm mesh)

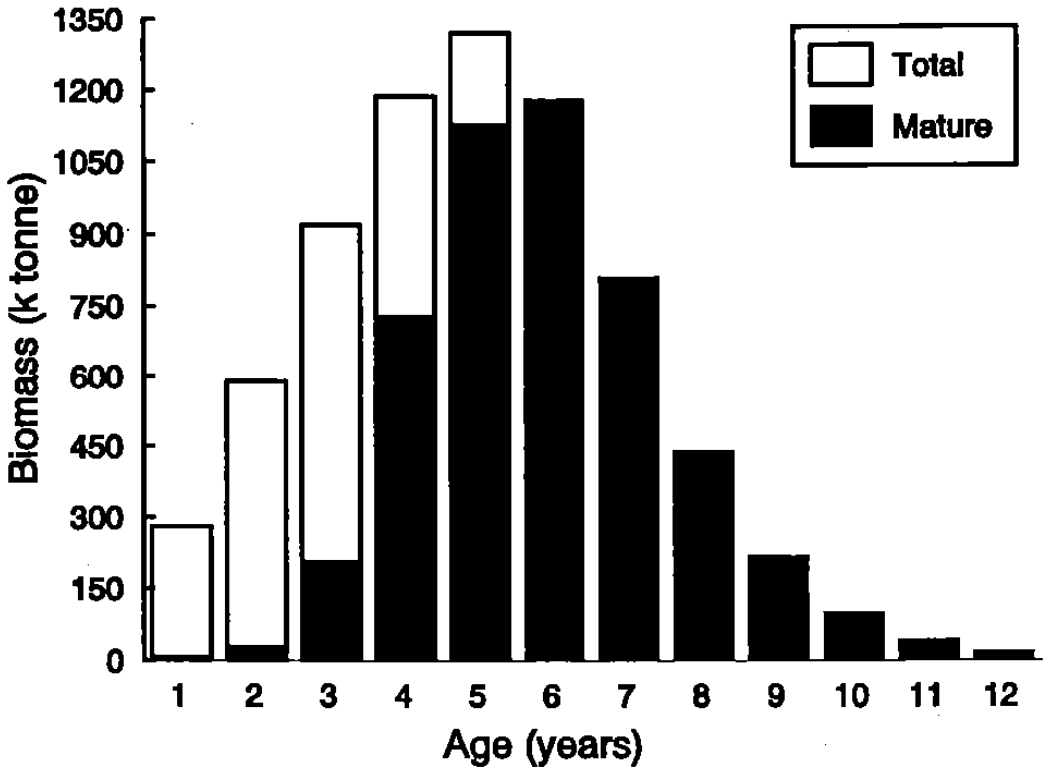


Figure 4. Age composition of North Sea Cod biomass at current rate of fishing with 200 mm mesh

A larger proportion of the stock is made up of mature fish

Cefas

The effect of mesh size

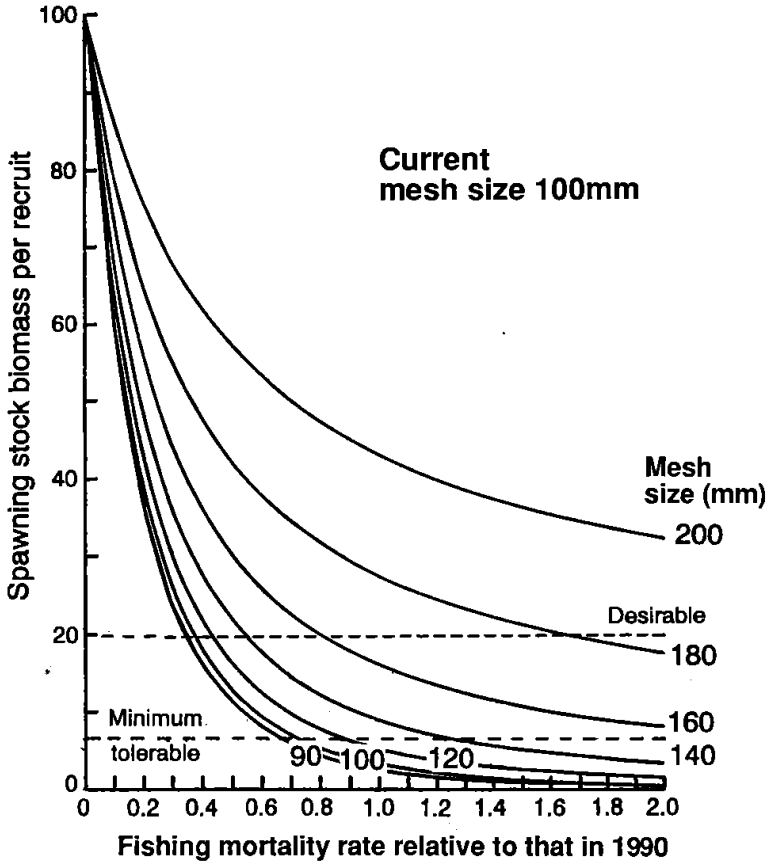


Figure 5. Effect on spawning stock biomass of fishing, for various mesh sizes

Cefas

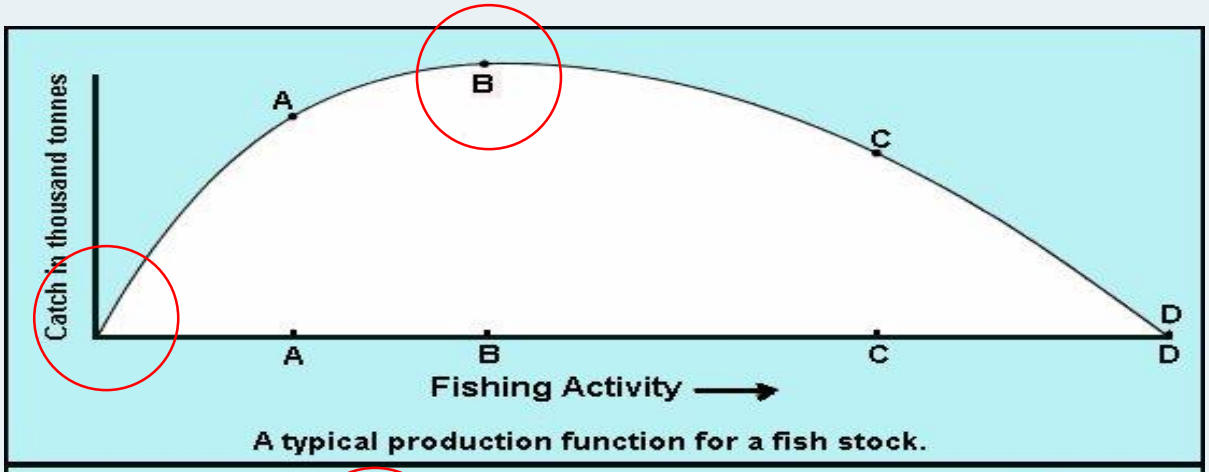
- Increasing fishing effort leads to fewer fish surviving from one year to the next.

- It changes the age/size structure of the population and leads to lower catches and lower spawning stock size …

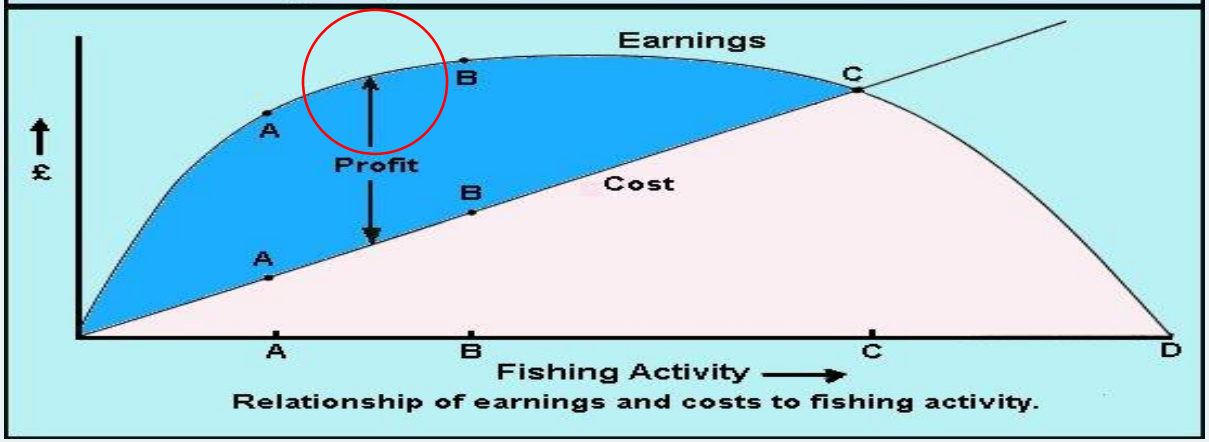
  - Therefore, you need to fish harder to take the same catch.

The bottom line

Why try to manage?

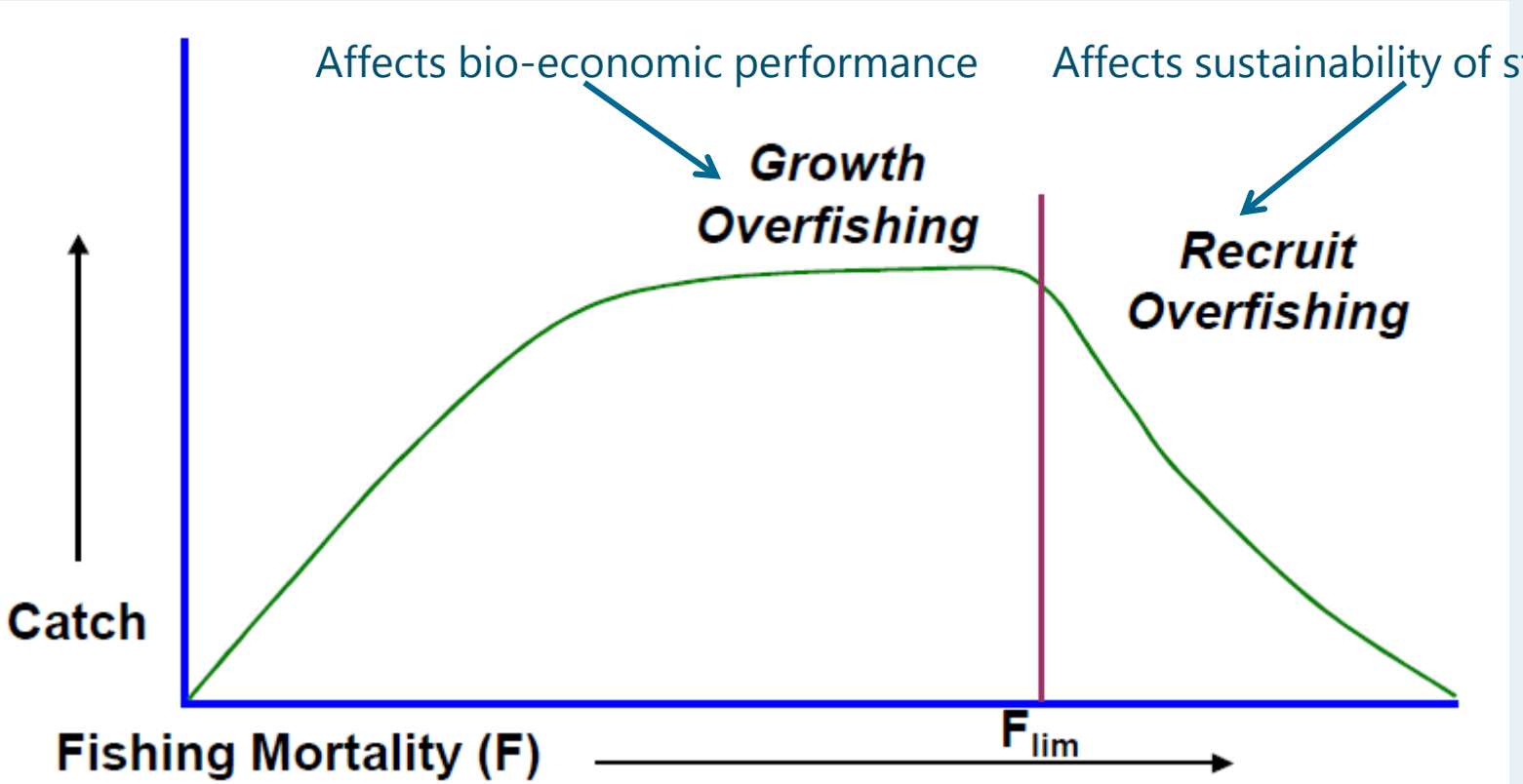


A typical production function for a fish stock.



Relationship of earnings and costs to fishing activity.

Fishing, long-term yield and profit



Lowestoft: 1950s 1970s

Decisions made should be based on:

- Scientific advice
- Sustainability
  (*MSY for now but could be MEY* in the future)
- Need for continued discard reduction
  (*unwanted catch and by-catch*)

- On average the fishing fleet caught 10 t per week last year.
- On average the same fleet caught 5 t per week this year.
- Therefore we can infer that the stock this year is only half as big as it was last year.

- So, if they caught 50,000 t last year and it caused the stock to half in size, then the stock must have been about 100,000 t last year.

- Well not quite that easy!

Stock assessment is easy … ?

What is the state of the stock?

Evaluation of the current state of the stock and the rate at which it is being exploited

What has happened to the stock?

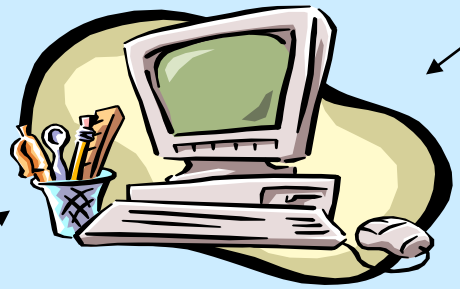
Reconstruction of the dynamic history of the stock allowing an evaluation the response to exploitation

What will happen to the stock?

Prediction of the response to future exploitation and the risks associated with harvesting strategies

Stock assessment (and advice)

Cefas



Age composition data

CPUE and survey data

Recruitment information

Discard data

We need information on:

- Life-cycle of the species
- Exploitation (catches, by-catch, discard, etc.)
- How that activity affects the population (CPUE, survey-based indicators)

Assessment

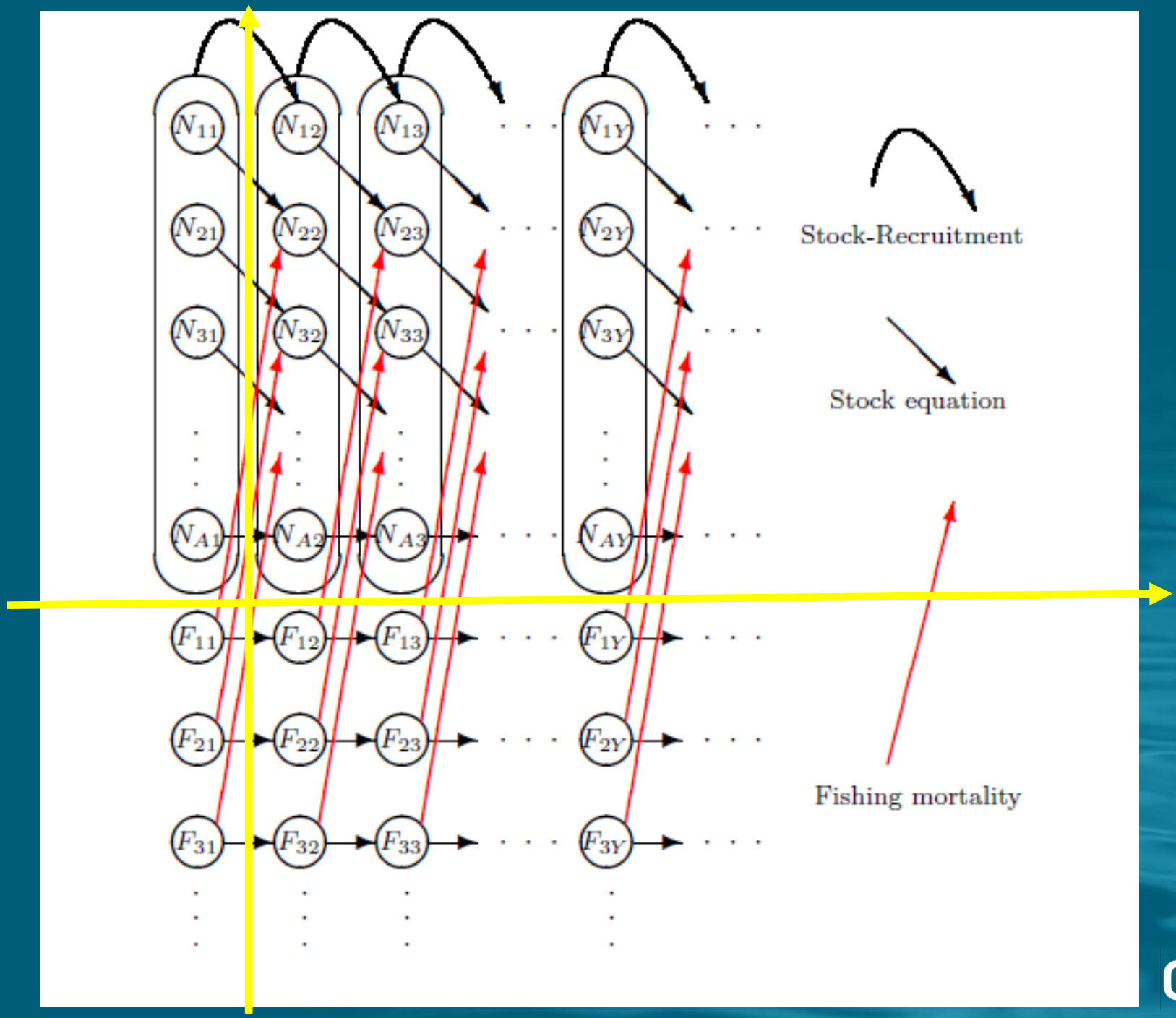
Cefas

Stock assessment is easy?

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

– Cohort analysis

Cefas


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

Cefas

- 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

Cefas

Data requirements

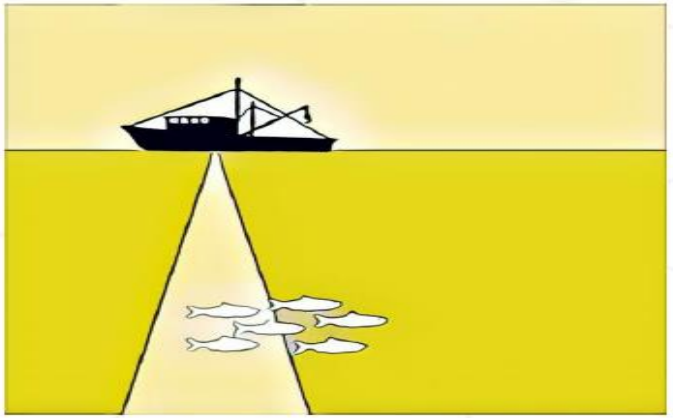
Information from catch

- Amount
- Location
- Timing
- Bycatch

From ports, log books & observers

Information on population trends: surveys

- Trawls
- Acoustics
- Plankton
- TV

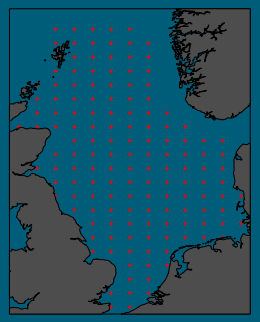


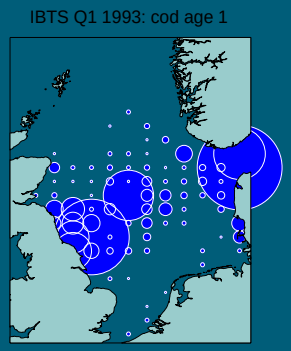
Research vessels & industry

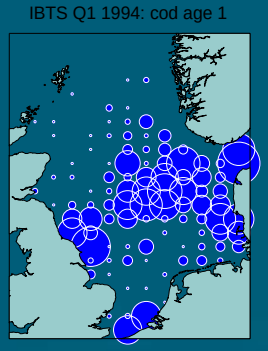
- Changes in distribution over survey area over time for many species
- Age composition by species
- Species composition
- Pre-recruit estimates – for predicting recruitment

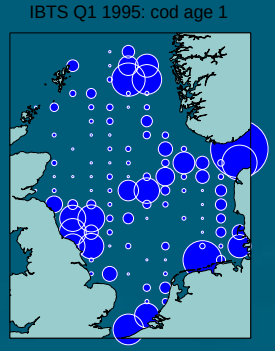
Trawl/acoustic surveys

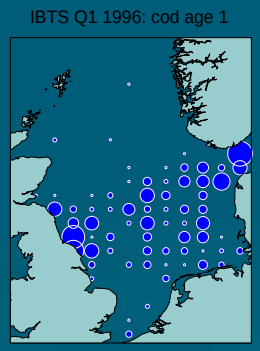
1996 year-class

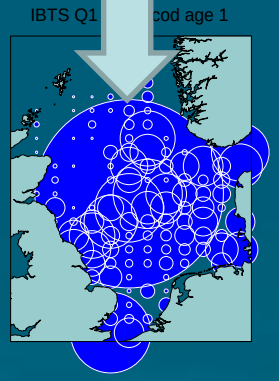


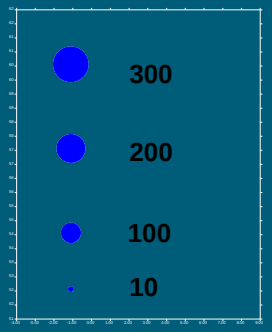


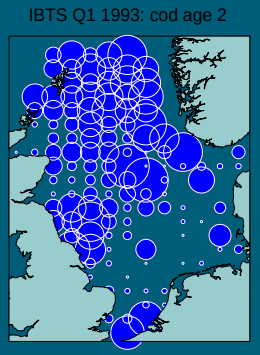


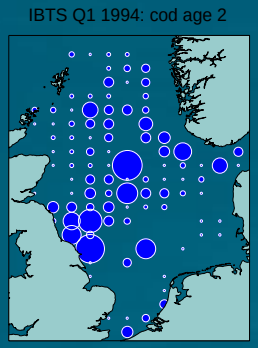


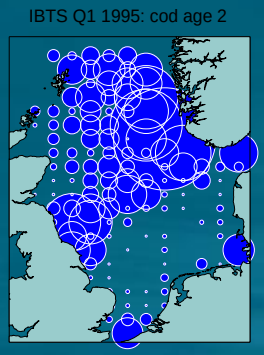


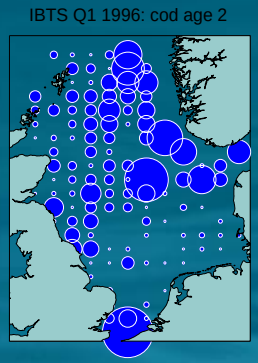


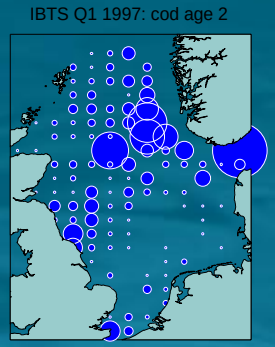


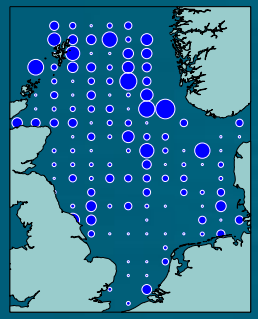


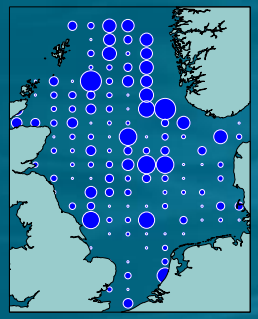


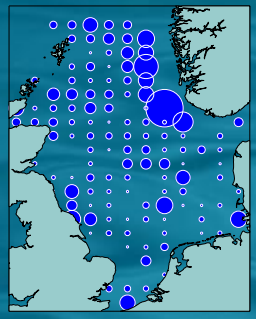


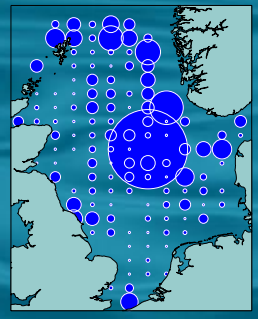


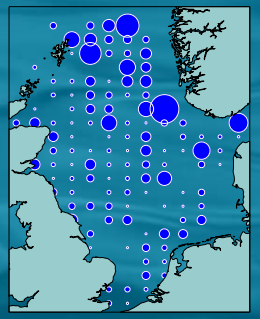




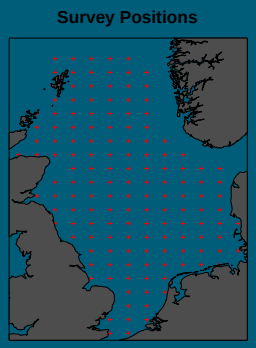


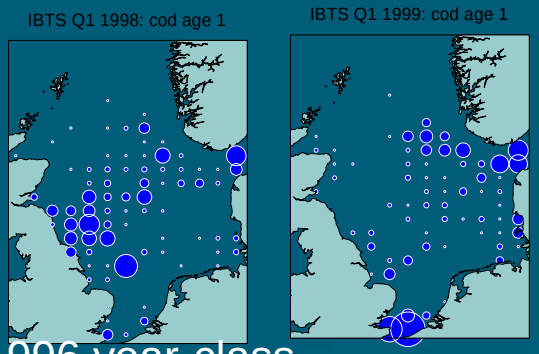


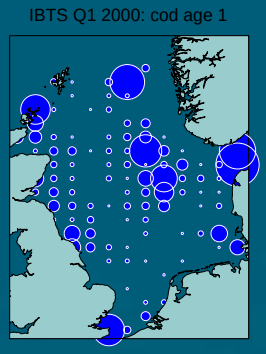


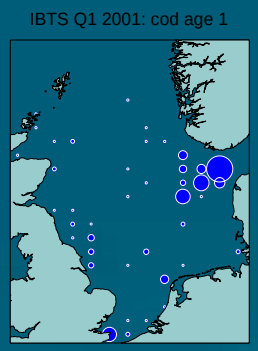


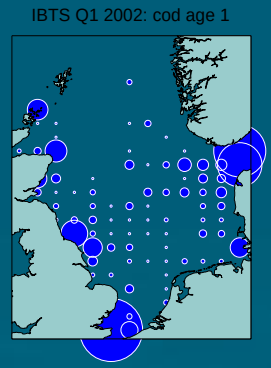
Cefas



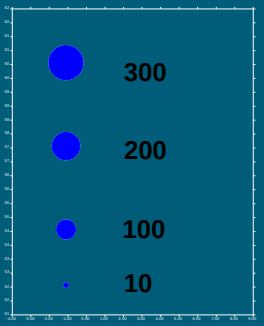


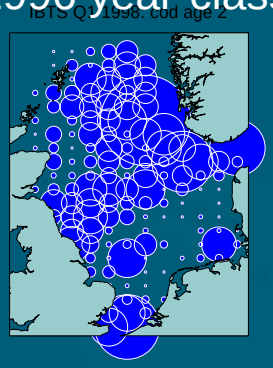


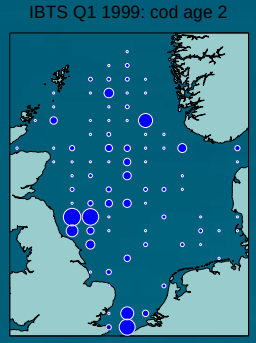


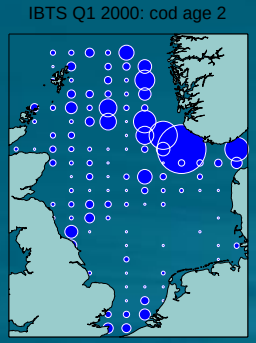


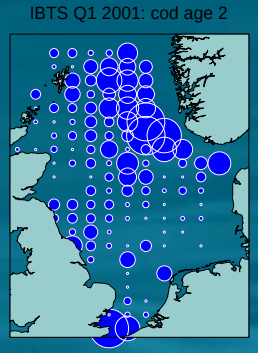
1996 year-class

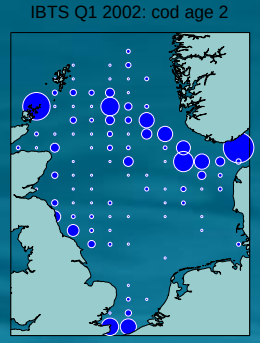




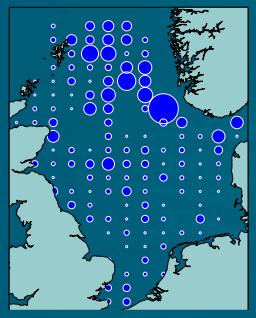


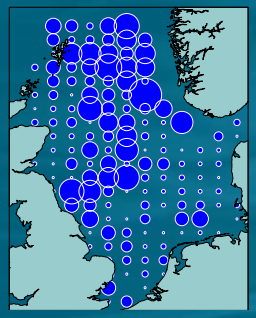


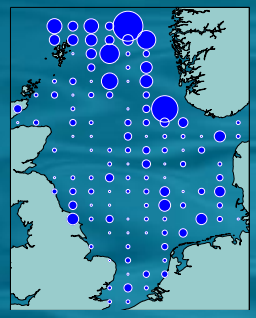


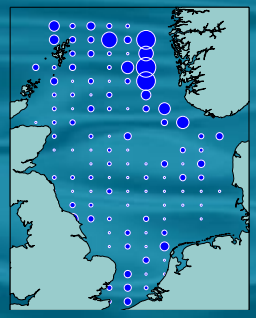


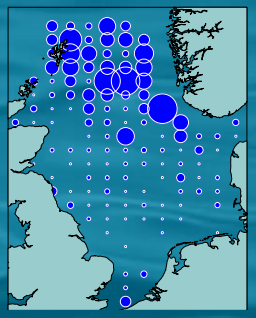
1996 year-class





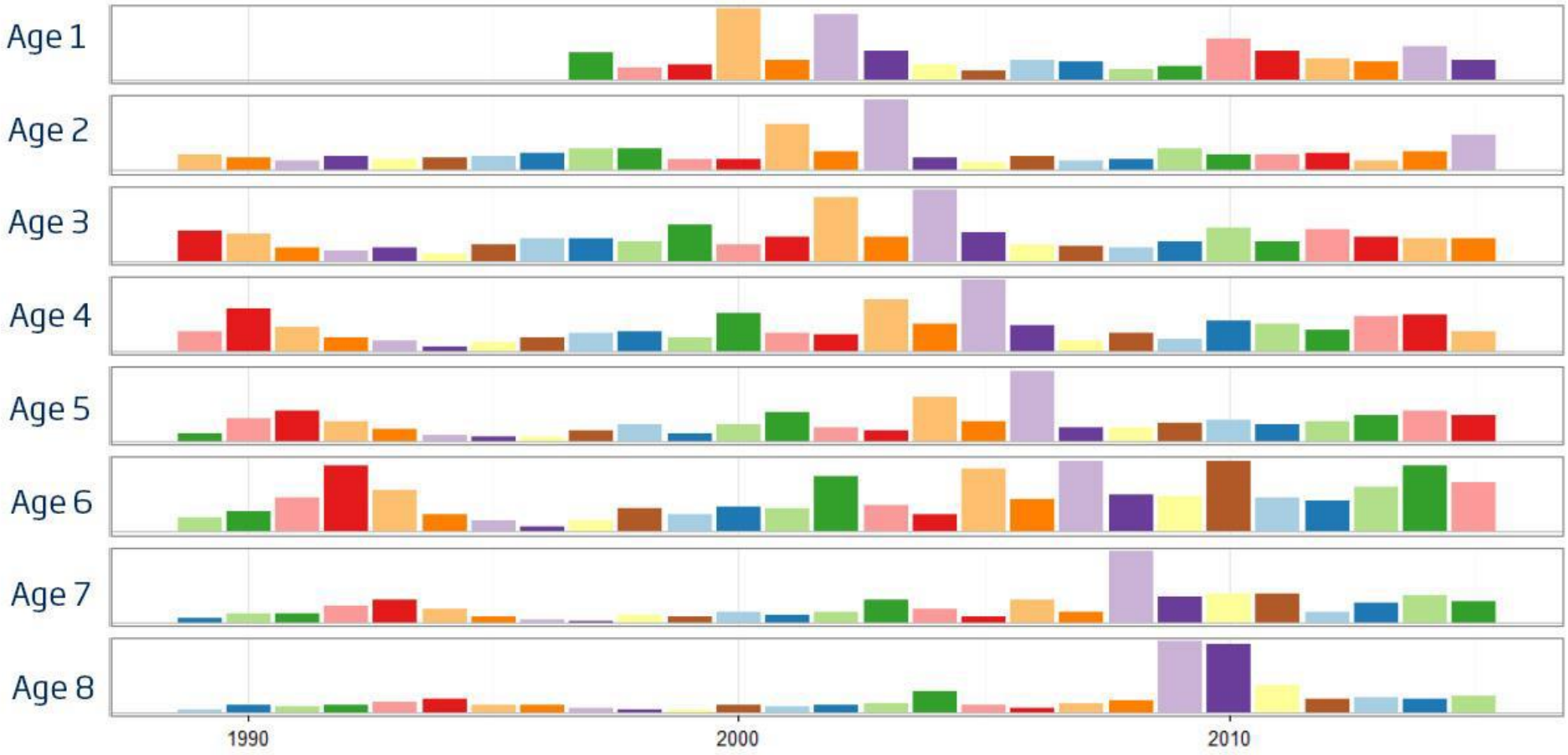






Cefas

Acoustic survey over time



Cefas

Survey time-series for selected stocks:

- distribution/abundance/size-age composition

Gear selectivity projects:

- gillnets; *Nephrops*; flatfish; industrial fisheries

FSP

Demonstration projects:

- catch composition
- survival

Other projects:

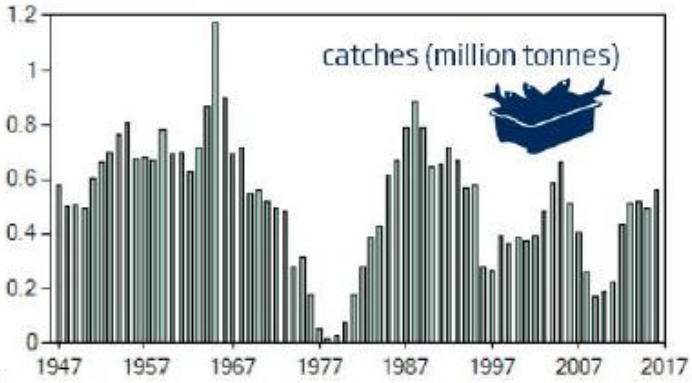
- *ghost-net* retrieval
- deep-water fishery
- new fisheries

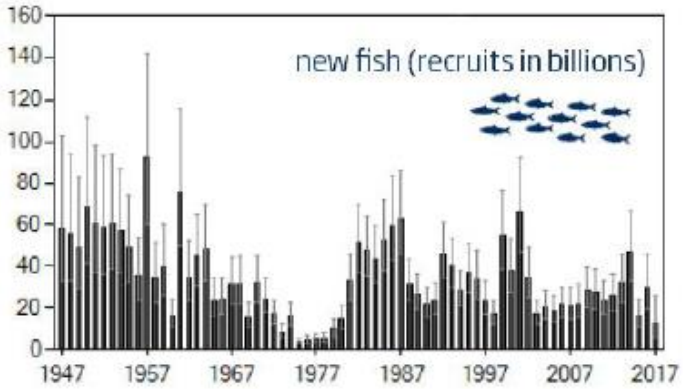
Fishery Science Partnership (FSP)

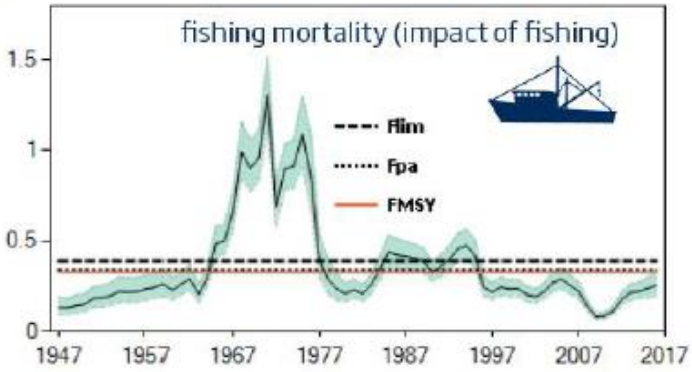
Cefas

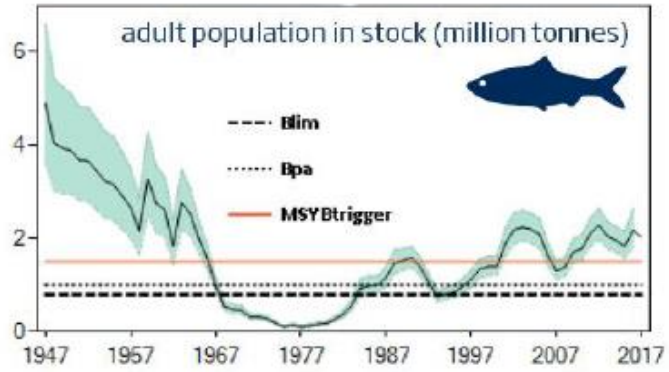
This produces a stock assessment

North Sea herring







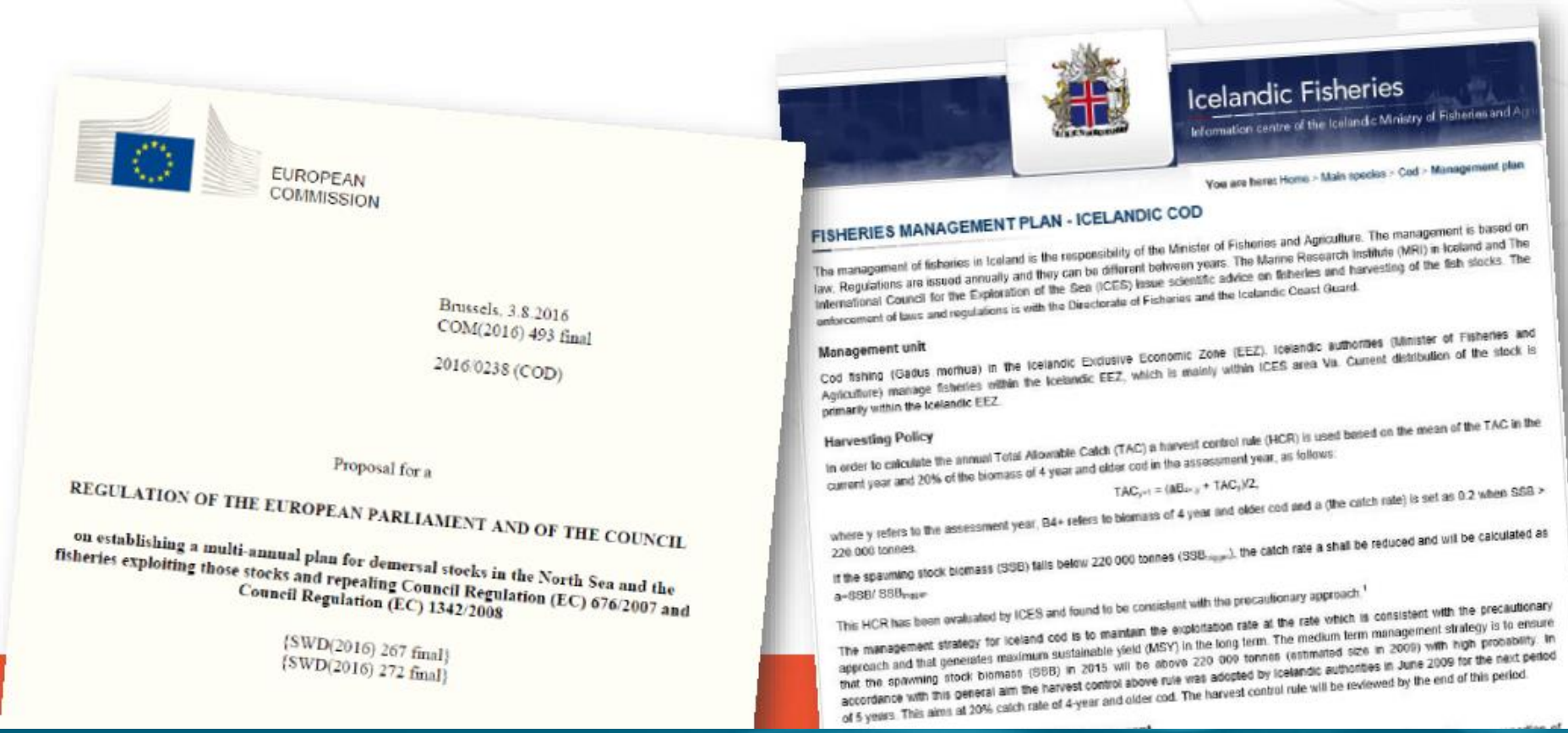


Cefas

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.

Scenarios set out in management plans



EUROPEAN COMMISSION

Brussels, 3.8.2016
COM(2016) 493 final

2016/0238 (COD)

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on establishing a multi-annual plan for demersal stocks in the North Sea and the fisheries exploiting those stocks and repealing Council Regulation (EC) 676/2007 and Council Regulation (EC) 1342/2008

{SWD(2016) 267 final}
{SWD(2016) 272 final}

Icelandic Fisheries

Information centre of the Icelandic Ministry of Fisheries and Agriculture

You are here: Home > Main species > Cod > Management plan

FISHERIES MANAGEMENT PLAN - ICELANDIC COD

The management of fisheries in Iceland is the responsibility of the Minister of Fisheries and Agriculture. The management is based on law. Regulations are issued annually and they can be different between years. The Marine Research Institute (MRI) in Iceland and The International Council for the Exploration of the Sea (ICES) issue scientific advice on fisheries and harvesting of the fish stocks. The enforcement of laws and regulations is with the Directorate of Fisheries and the Icelandic Coast Guard.

Management unit

Cod fishing (Gadus morhua) in the Icelandic Exclusive Economic Zone (EEZ). Icelandic authorities (Minister of Fisheries and Agriculture) manage fisheries within the Icelandic EEZ, which is mainly within ICES area Va. Current distribution of the stock is primarily within the Icelandic EEZ.

Harvesting Policy

In order to calculate the annual Total Allowable Catch (TAC) a harvest control rule (HCR) is used based on the mean of the TAC in the current year and 20% of the biomass of 4 year and older cod in the assessment year, as follows:

$$TAC_{y+1} = (aB_{4+,y} + TAC_y)/2,$$

where y refers to the assessment year, B4+ refers to biomass of 4 year and older cod and a (the catch rate) is set as 0.2 when SSB > 220 000 tonnes.

If the spawning stock biomass (SSB) falls below 220 000 tonnes ($SSB_{trigger}$), the catch rate a shall be reduced and will be calculated as $a=SSB/SSB_{trigger}$

This HCR has been evaluated by ICES and found to be consistent with the precautionary approach.[1]

The management strategy for Iceland cod is to maintain the exploitation rate at the rate which is consistent with the precautionary approach and that generates maximum sustainable yield (MSY) in the long term. The medium term management strategy is to ensure that the spawning stock biomass (SSB) in 2015 will be above 220 000 tonnes (estimated size in 2009) with high probability. In accordance with this general aim the harvest control above rule was adopted by Icelandic authorities in June 2009 for the next period of 5 years. This aims at 20% catch rate of 4-year and older cod. The harvest control rule will be reviewed by the end of this period.

Timing of Assessments and Advice					
	2013	2014	2015		
Fisheries Data					
Assessment					
Catch Predictions					
Advice					
		Assessment WG in 2014,			
		assesses State of Stock at end of 2013 &			
		predicts stock and catch in 2014and 2015			

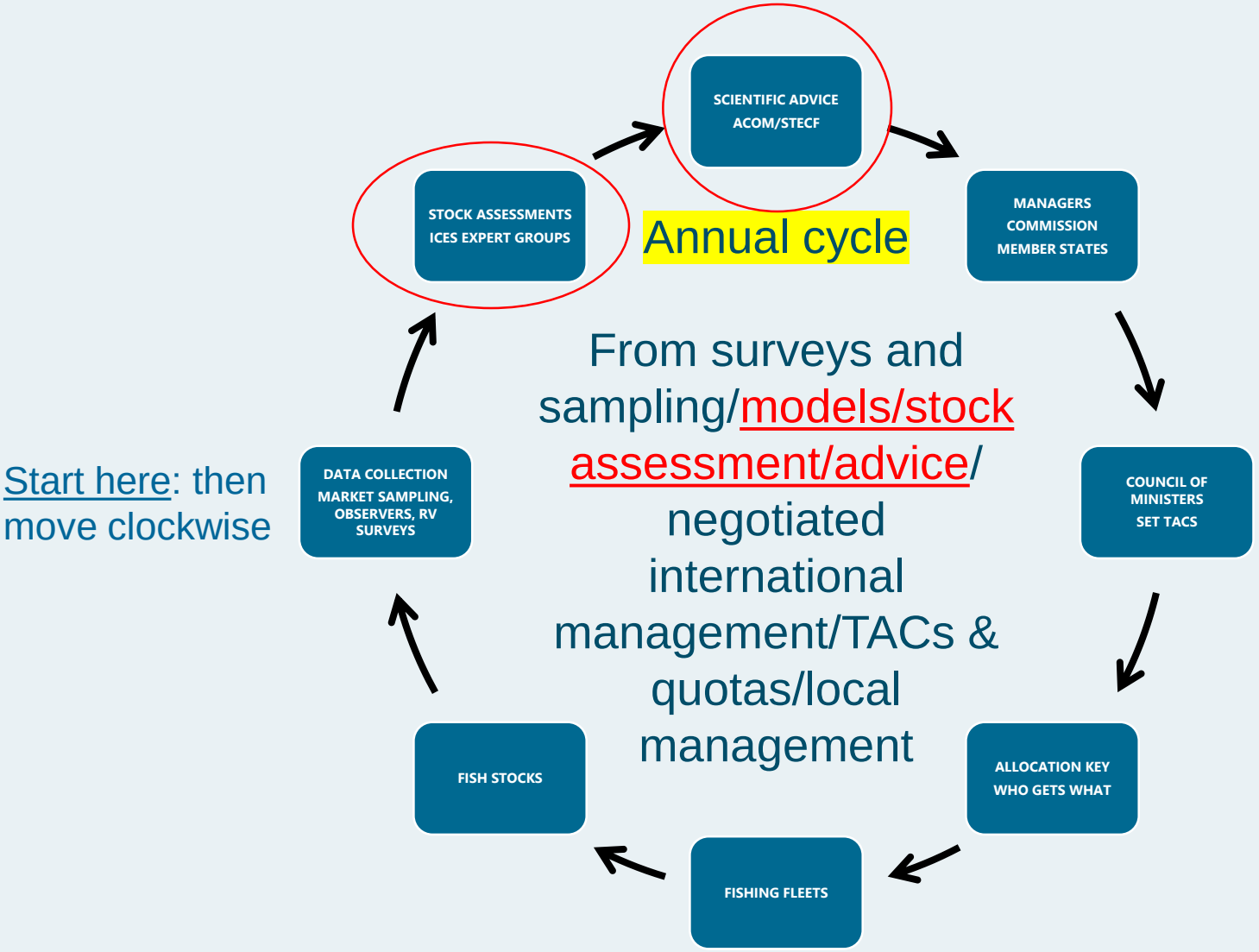
- Assessment in year 2014, gives the stock size and F at start of 2014 (those fish surviving fishing in 2013).
- Catch prediction is for 2015 so have to assume something about catch, F and recruitment in 2013 – *what?*
- Produce a range of catch options for 2015, but advise catch corresponding to MSY objective.

From assessments to advice

- Scientists advise a range of catch options corresponding to different levels of fishing mortality.

- Headlines: Scientists advise …; e.g. reduction in TAC:
  - Advice based on prescribed policy objectives; e.g. in line with MSY.

From assessments to advice



Process overview: from science to management

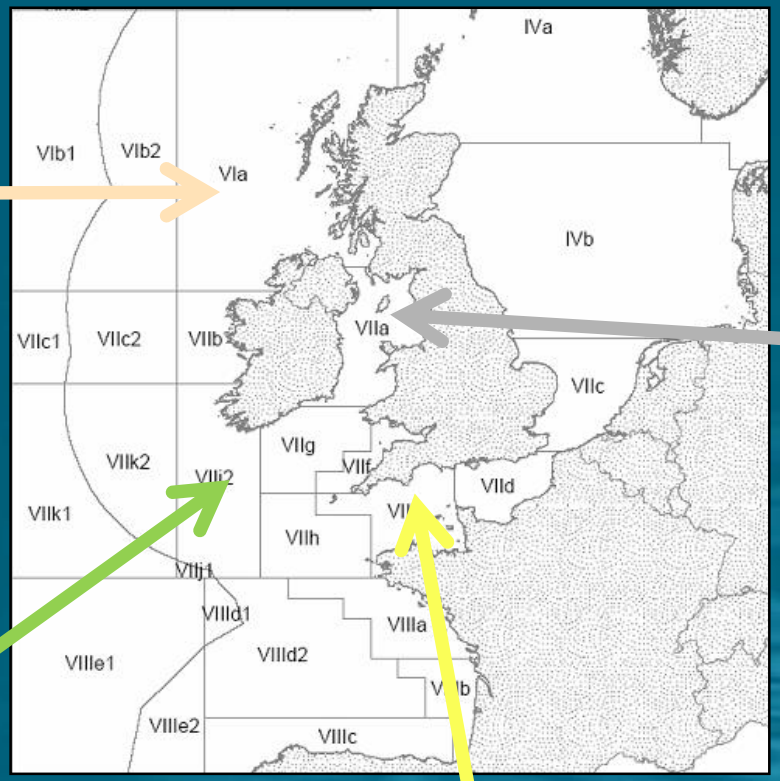
Selected examples of the state of stocks and advice

Cefas

Celtic Sea ecoregion

West of Scotland & Rockall

- **Cod** (**VIa**; VIb)
- Haddock (VIa; VIb)
- **Whiting** (**VIa**; VIb)
- Anglerfish (IIIa,IV,VI)
- Megrim (IVa-VIa; VIb)
- *Nephrops* (FUs11-12-13)



Irish Sea

- **Cod**
- Haddock
- **Whiting**
- Plaice
- **Sole**
- *Nephrops* (FUs 14-15-19)

Celtic Sea & West, Southwest Ireland

- Cod (VIIe-k)
- Haddock (VIIb-k)
- Whiting (VIIe-k)
- Plaice (CS; VIIh-k; VIIbc)
- Sole (CS; VIIh-k; VIIbc)
- Northern hake
- Anglerfish (VIIb-k, VIIIabd)
- Megrim (VIIb-k, VIIIabd)
- *Nephrops* (FUs 16-17-20-22)

Western Channel

- Plaice (VIIe)
- Sole (VIIe)

Which of the 3 stocks would you like to discuss?

Cefas

Cod VIIe-k

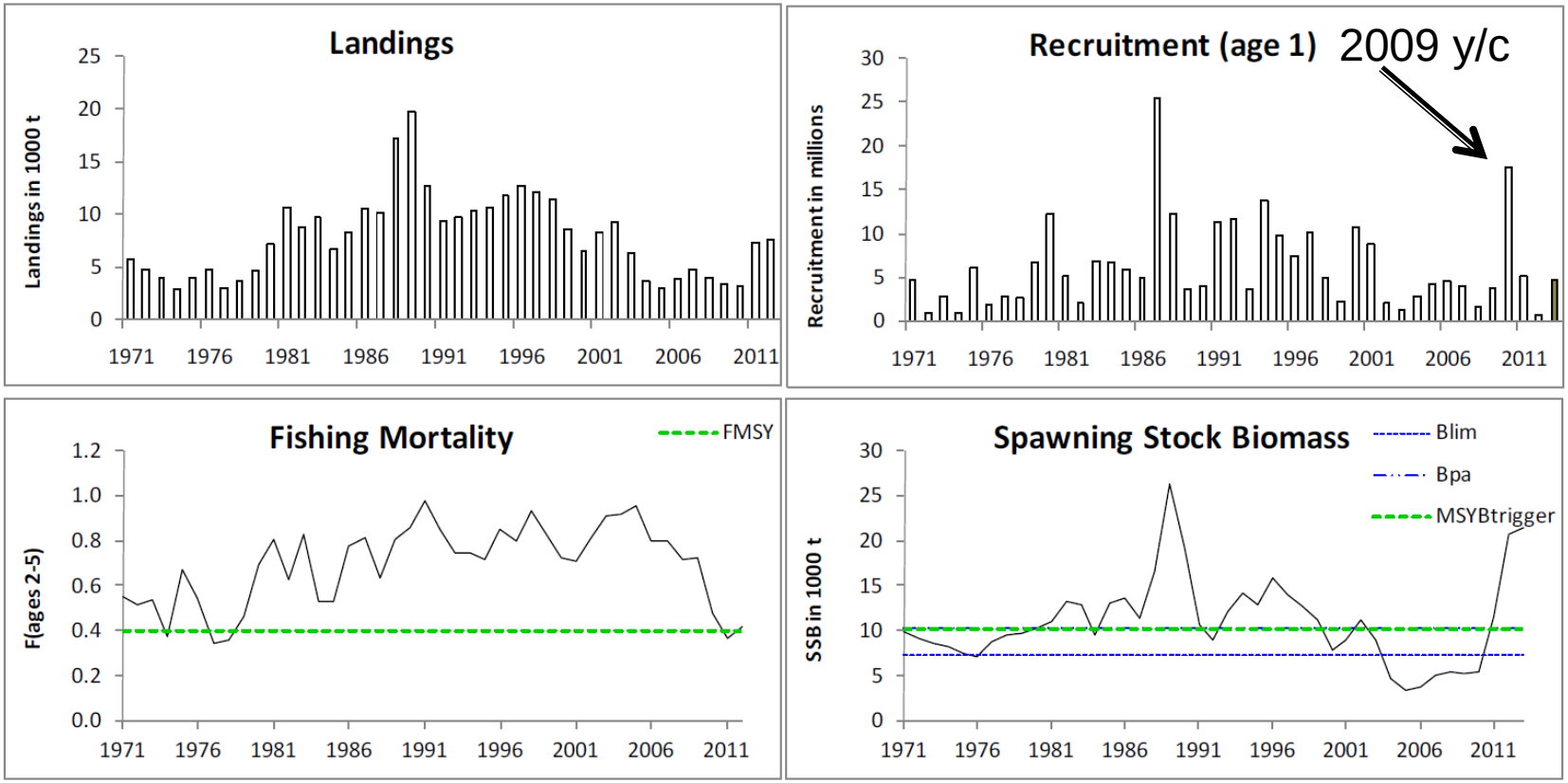


Figure 5.4.6.1 Cod in Divisions VIIe–k (Celtic Sea cod). Summary of stock assessment (weights in thousand tonnes). Predicted values are shaded. Top right: SSB/F for the time-series used in the assessment.

Cefas

Cod VII e-k Basis of 2014 TAC

- Assumptions: 2012 Fishing mortality = Average of 2010-2012 = 0.43
- Gives predicted 2013 landings of 8,398 t – c.f. TAC 2013 = 10,200 t
- Basis for 2014 forecast: F = F_{MSY} = 0.4 – gives 6,848, t (-33% on 2013 TAC): agreed 2014 TAC = 6,848 t

Cefas

Cod VIIe-k 2104 forecast

Outlook for 2014

Basis: $F_{2013} = F_{sq}$ = (mean F_{2010}–F_{2012}) = 0.43; R_{2013} = GM (1971–2010) = 4830 (thousands); landings (2013) = 8398 t; SSB (2014) = 17 206 t.

Rationale	Landings (2014)	Basis	F (2014)	SSB (2015)	%SSB change [1)]	% TAC change [2)]
MSY approach	6 848	F_{MSY}	0.40	15 290	−11%	−33%
Zero catch	0	F = 0	0	22 782	+32%	−100%
Other options	7 211	F_{2013}	0.43	14 899	−13%	−29%
	8 670	TAC−15% (F_{2013} × 0.80)	0.54	13 333	−23%	−15%
	10 200	Stable TAC	0.67	11 706	−32%	0%
	11 726	TAC+15% (F_{2013} × 1.15)	0.82	10 102	−41%	+15%

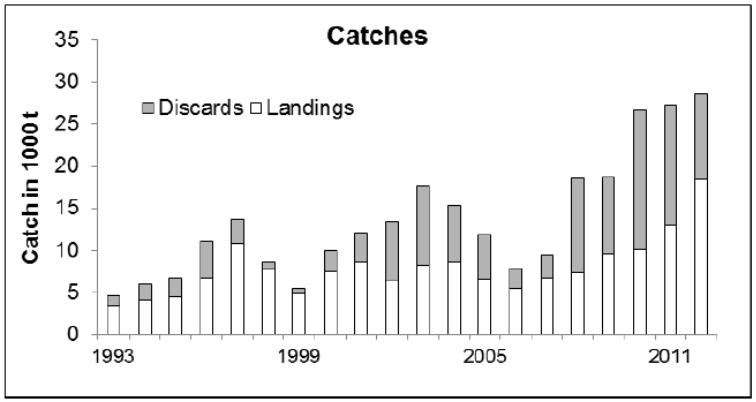
Weights in tonnes.

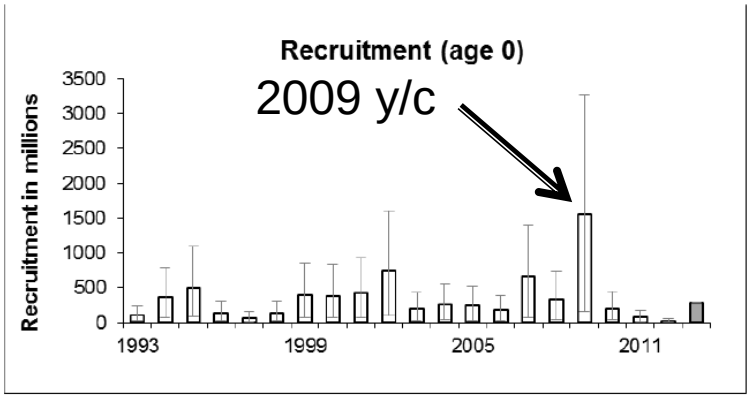
[1)] SSB 2015 relative to SSB 2014.

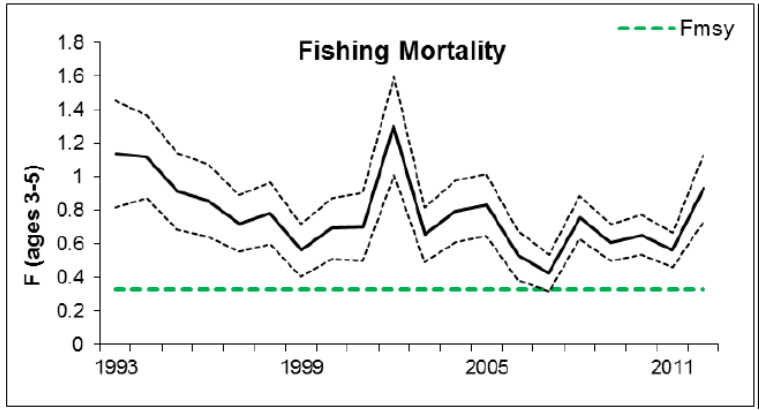
[2)] Landings 2014 relative to TAC 2013.

Cefas

Haddock VIIb-k







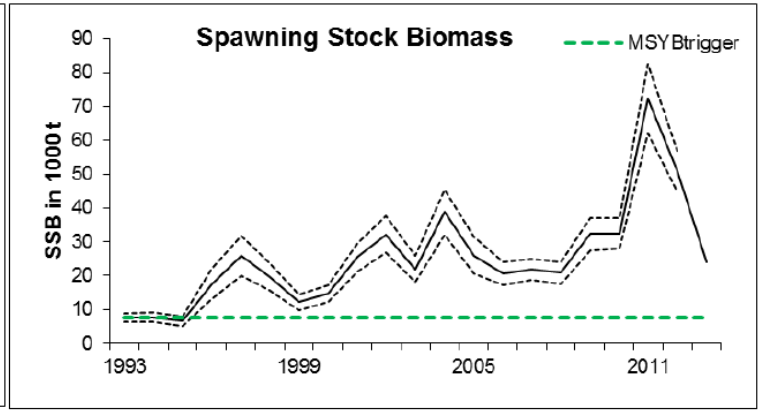


Figure 5.4.11.1 Haddock in Divisions VIIb–k. Summary of stock assessment (weights in thousand tonnes). Predicted recruitment values are shaded; Recruitment, fishing mortality, and SSB: dotted lines 1 standard error. Top right: SSB/F for the time-series used in the assessment.

Cefas

Haddock VIIb-k Basis of 2014 TAC

- Assumptions: 2012 Fishing mortality = Average of 2010-2012 = 0.72
- Gives predicted 2013 landings of 10,061 t, catches of 11,621 t – c.f. TAC 2013 = 14,148 t
- Basis for 2014 forecast: F = F_{MSY} = 0.39 – gives catch of 5,218 t and landings of 3,602 t, t (-75% on 2013 TAC): agreed 2014 TAC = 9,479 t (-33% on 2013 TAC)

Cefas

Haddock VIIb-k 2014 forecast

Outlook for 2014

Basis: F (2013) = F_{sq} (2010–2012) = 0.72; SSB (2014) = 12.6; R (2013) = 290.479 million = $GM_{1993–2010}$; Landings (2013) = 10 061; Catches (2013) = 11 621.

Rationale	Catch (2014)	Land. (2014)	Disc. (2014)	Basis	F Total (2014)	F land[1] (2014)	F disc.[1] (2014)	SSB[5] (2015)	%SSB[5] change[2]	%TAC change[3]
MSY approach	4 521	3 098	1 423	F_{MSY} = 0.33	0.33	0.28	0.05	20 218	+60%	−78%
MSY transition	5 281	3 602	1 679	(F_{2010} × 0.2) + (F_{MSY} × 0.8)	0.39	0.34	0.06	19 398	+54%	−75%
Zero catch	0	0	0	F = 0	0	0	0	25 140	+99%	−100%
Other options	0	0	0	F_{2013} × 0.8	0.57	0.49	0.09	17 329	+37%	−66%
	7 202	4 852	2 350	F_{2013} × 0.9	0.64	0.55	0.1	16 576	+31%	−63%
	7 907	5 300	2 607	F_{2013}	0.72	0.61	0.11	15 863	+26%	−60%
	8 576	5 720	2 856	F_{2013} × 1.1	0.79	0.67	0.12	15 187	+20%	−57%
	21 385	12 026	9 359	−15% TAC	3.99	3.39	0.59	3 077	−76%	−15%
		13 172		Stable TAC	inf[4]					
		15 148		+15% TAC	inf[4]					

Weights in tonnes.

[1] Total F was split into a discards and landings component based on the average ratio of landings and discards in the last three years.

[2] SSB 2015 relative to SSB 2014.

[3] Commercial landings 2014 relative to TAC 2013 (14 148 t).

[4] Due to the projected decline in the population it will not be possible to land more than approx 13.2 kt in 2014, even at very high F.

[5] The projected SSB in 2015 is highly dependent on assumed recruitment in 2013 and therefore very uncertain.

Cefas

Sole VIIe

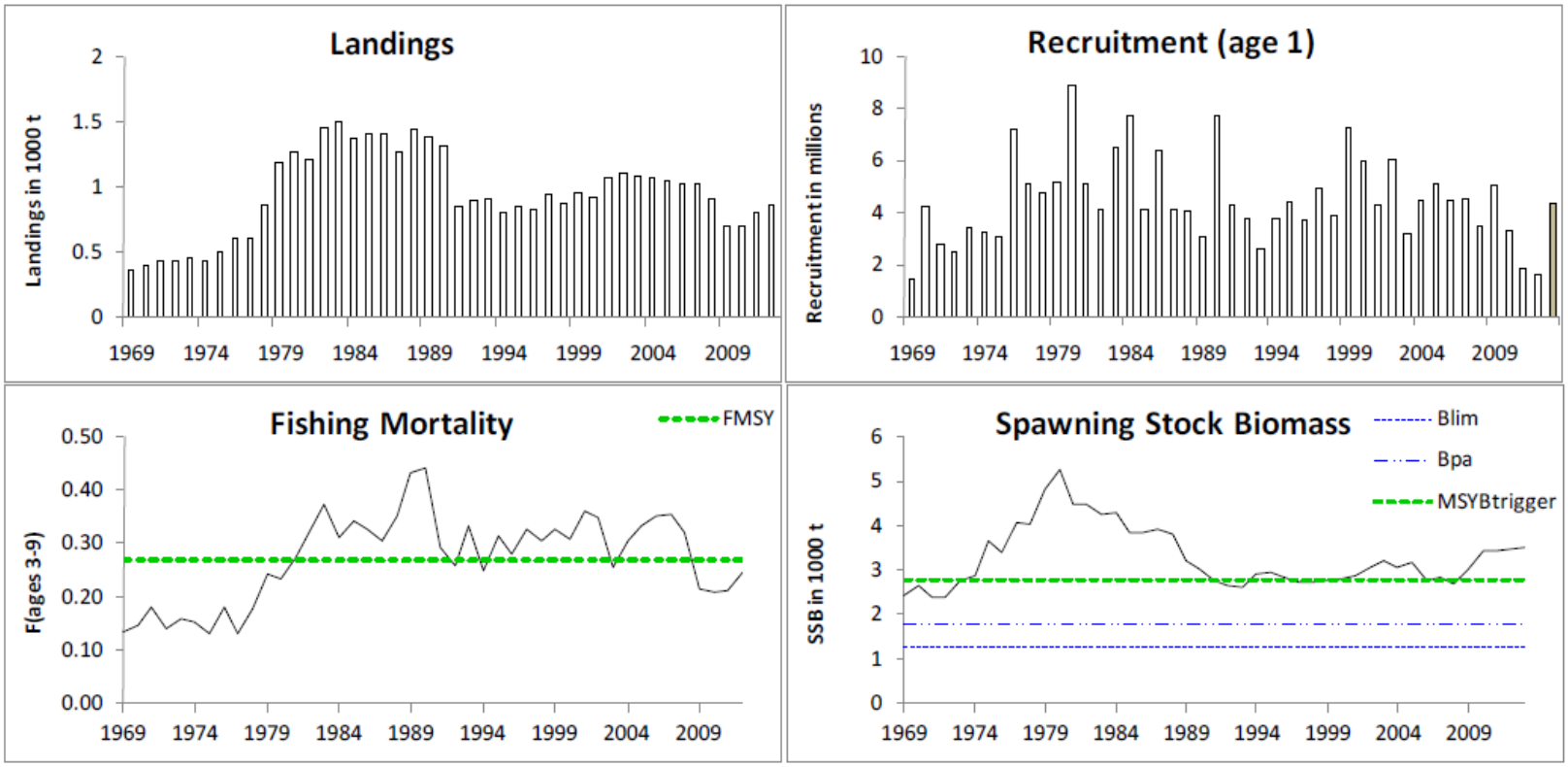


Figure 5.4.36.1 Sole in Division VIIe (Western Channel). Summary of stock assessment. Assumed recruitment values are shaded. Top right: SSB and F for the time-series from the assessment.

Cefas

Sole VIIe Basis of 2014 TAC

- Assumptions: 2012 Fishing mortality = Average of 2010-2012 = 0.25
- Gives predicted 2013 landings of 866 t – c.f. TAC 2013 = 890 t
- Basis for 2014 forecast: F = F_{MSY} = 0.27 – gives 832, t (-% on 2013 TAC): agreed 2014 TAC = 832 t

Cefas

Sole VIIe 2014 Forecast

Outlook for 2014

Basis: F (2013) = F_{sq} = $F_{2010–2012}$ rescaled = 0.25; SSB (2014) = 3129; R (2013) = $GM_{1969–2010}$ = 4345 thousand; landings (2013) = 866.

Rationale	Catch (2014)	Basis	F_{total} (2014)	SSB (2015)	%SSB Change[1)]	%TAC Change[2)]
MSY approach	832	F_{MSY}	0.27	2894	−8%	−7%
Management Plan	832	$F_{MP\ target}$	0.27	2894	−8%	−7%
Zero catch	0	F = 0	0	3713	+19%	−100%
Other options	764	TAC_{2013} − 15%	0.24	2961	−5%	−15%
	1028	TAC_{2013} + 15%	0.35	2701	−14%	+15%
	483	F_{2013} × 0.6	0.15	3237	+3%	−46%
	628	F_{2013} × 0.8	0.20	3093	−1%	−30%
	898	F_{2013} × 1.2	0.30	2829	−10%	0%
	1023	F_{2013} × 1.4	0.35	2706	−14%	114%

Weights in tonnes.

[1)] SSB 2015 relative to SSB 2014.

[2)] Catches 2014 relative to TAC 2013.

Cefas

Brief consideration of shellfish: generally, data-limited

Cefas

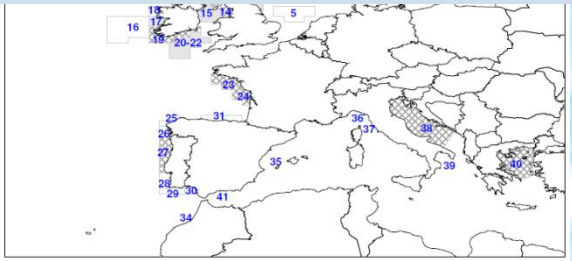
Shellfish

- Cefas deals with:
  - Scallops
  - Crabs
  - Lobsters
  - *Nephrops*
  - Whelk
- IFCAs – deal with stocks that are exclusively inside 6-mile limit

Cefas

Commercial importance

	UK: 2014		England: 2014	
1	Mackerel	105.5	Scallops	22.0
2	Nephrops	98.2	Crabs	21.1
3	Scallops	58.2	Lobsters	17.7
4	Haddock	49.4	Sole	12.2
5	Crabs	44.2	Whelks	11.4
6	Lobsters	33.3	Nephrops	10.1
7	Monks or Anglers	31.4	Monks or Anglers	8.4
8	Cod	27.8	Cockles	7.9
9	Hake	19.7	Bass	6.7
10	Whelks	16.2	Cuttlefish	6.5



ICES Landings &
MMO annual statistics

Cefas

Shellfish

- Data are more limited than for fin-fish
- South-west shellfish stocks reasonable to good
- North Sea shellfish stocks less good
- Lobster fishing mortality in North Sea seems to be very high, but is somehow sustainable
- Only a few scallop assessments at present; e.g. inshore Cornish waters and Lyme bay
- Both indicate moderate - high exploitation rate. Not dangerously high but probably above MSY reference points

Cefas

Shellfish - issues

- Need for accurate recording of shellfish landings and effort – data are poor.

- FAD records of <10 m landings for crab in North Norfolk indicate low tonnage, whereas shellfish return records show significantly higher tonnage.

Cefas

Shellfish issues

- Need good estimate of numbers of pots deployed, but not routinely recorded.
- Also true for scallop dredges – need good estimates of catch and effort.

Looking to the future

- Importance of life-history/length-based assessment
  - Inclusion of more diverse species in the assessment process where expertise and difficulty in reading otoliths/scales and the collection of them is limited.
    - Species where ageing methods are not yet developed such as elasmobranches.
    - Large uncertainties in the aging methodologies - hake.
  - Managing stocks other than through an international TAC is becoming more important and wide spread.

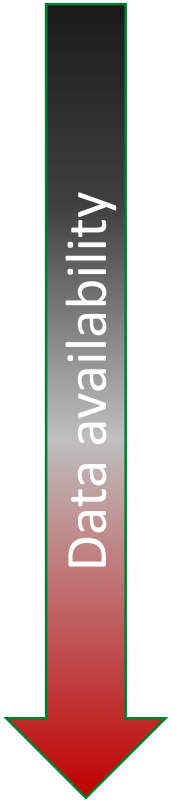
Cefas

Stock assessment levels:

Purpose of assessment: estimation of …

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

- Less *information*= more uncertainty



Assessment type	Advice type
1: Quantitative: analytical	Maximum Sustainable Yield
2: Qualitative: analytical	
3: Survey trends	Data-limited MSY proxy
4: Catch only	
5: Landings only	Precautionary approach
6: By-catch fishery	