Stock Annex: Cod (*Gadus morhua*) in Division 6.a (West of Scotland)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Cod; cod.27.6a
Working group	Celtic Seas Ecoregion (WGCSE)
Created	WKROUND 2012
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A. General

A.1. Stock definition

Cod to the west of Scotland are believed to comprise of at least two subpopulations of cod that remain geographically separate throughout the year. The latitudinal boundary of these groups is between 57 and 58°30′ N. The southern component is characterised by coastal groups with a tendency towards year-round residency, although there is some exchange with the Irish Sea. The northern component appears to inter-mix with cod in 4.a at all stages of the life history (ICES, 2012, WD 4).

A.2. Fishery

The demersal fisheries in Division 6.a are predominantly conducted by otter trawlers fishing for cod, haddock, anglerfish and whiting, with bycatches of saithe, megrim, lemon sole, ling and skate sp. Fishing in the area is conducted mainly by vessels from Scotland, France, Ireland, Norway and Spain with Scottish vessels taking the majority of cod catch. Records of effort trends since 2000 can be obtained from the (STECF) [https://stecf.jrc.ec.europa.eu/home]. Cod is believed to be no longer targeted in any of the fisheries now operating in ICES Division 6.a. Cod are a bycatch in *Nephrops* and anglerfish fisheries in Division 6.a. *Nephrops* fisheries use a smaller mesh size than the 120 mm mandatory for cod targeted fisheries, but landings of cod are restricted through bycatch regulations and from 2012 all fisheries are restricted to landings of cod through bycatch only (see below).

A.2.1. General description

In recent years the countries involved in this fishery are Scotland, Northern Ireland, Republic of Ireland, England and Wales, Norway and France.

A.2.2. Fishery management regulations

The minimum conservation reference size of cod in this area is 35 cm.

Regulations and cod avoidance schemes relevant to Division 6.a cod

Area closures:

- Clyde Sea area closure – STECF (2007) noted that the Clyde closure includes the main spawning area of a reproductively isolated aggregation of cod and

concluded that the closure is likely to have a positive effect in reducing targeting of high densities of mature cod.

- Windsock closed area – STECF (2007) concluded that the extent of the Windsock closure is unlikely to be large enough to greatly reduce fishing mortality on cod, and its boundaries should be reconsidered. However, its removal would not help improve cod recovery.
- Since 2009, the Irish authorities introduced a seasonal closure in Division 6.a. The closure covers ICES statistical rectangle 39E3 and is in force from October 31 to March 31. Historically, over 40% of Irish cod landings from ICES Division 6.a are from the closed area. For contrast, standardized cpue rates observed from a dedicated survey conducted inside the closed area in 2006 were on average 26.8 kg hr^{-1} while cpue rates estimated from observer trips outside the closure gathered in the same period were 0.015 kg hr^{-1}. STECF (2012) concluded that, in accordance with the provisions of article 13 (Reg. (EC) 1342/2008), the partial cod mortality associated with the Irish fleet had declined considerably (>50%) since the introduction of the cod closure and other measures, although it is not possible to disentangle the effects of the Cape closure from other measures.

Mesh sizes and catch composition rules:

- Catch composition rules related to days-at-sea allowances (Reg. (EC) 850/1998 Annex I and Reg. (EC) 2056/2001) – These rules legislate for landings compositions, but do not restrict discards.
- Emergency measures introduced in EC regulation 43/2009 (Annex III) (and rolled forward into 2010 and 2011) prohibited all fishing activity to the east of the West of Scotland Management (French) line in Division 6.a, with the exception of a number of derogated fisheries. These measures have been incorporated into a new EC regulation 227/2013. For demersal otter trawlers targeting whitefish this required an increase in mesh size to 120 mm and the inclusion of a 120 mm square-meshed panel (SMP). Vessels targeting *Nephrops* also require the 120 mm SMP or a sorting grid. More stringent catch composition rules have also been introduced. For *Nephrops*-directed fisheries, no more than 10% of the retained catch can consist of cod, haddock, and whiting, where the limit is no more than 30% for whitefish targeted vessels. For 2012 a zero TAC for cod and a 1.5% bycatch by live weight limit was introduced and this was carried through to 2013, but in 2012 the catch composition limit on haddock was removed (Reg. (EC) 161/2012).

Effort limitations:

- Between 2003 and 2011 STECF (2012) reported that the fishing effort (in kW-days) of trawlers using >100 mm mesh declined by 59%. These vessels primarily targeted roundfish, including cod. Over the same period effort for trawlers using 70–99 mm mesh declined by 16%. These vessels primarily target *Nephrops* and in 2011 22% of the effort in this category was exempt from effort controls because of less than 1.5% of cod in the catch (article 11).
- Annex IIa of Reg. (EC) 39/2013 does not require effort reduction compared to 2012 except for French trawlers using >100 mm mesh (20% reduction).

Supply chain traceability:
Unreported landings are expected to have reduced under the UK "Buyers and Sellers" and Irish "Sales Note" regulations. Observer data, however, show an increase in discards starting in 2006. The amount of discards relative to landings has increased and the age pattern of discarding has changed. Currently discards of fish aged 3 and above are being recorded.
Cod avoidance measures:
In 2008, Scotland introduced a voluntary programme known as "Conservation Credits", which involved seasonal closures, real-time closures (RTCs), and various selective gear options. This was designed to reduce mortality and discarding of cod. The number of RTCs west of Scotland is shown below. There have been no RTCs in this area in the years since 2012. RTCs are determined by lpue, based on fine-scale VMS data and daily logbook records, and also by on-board inspections. The low number of RTCs west of Scotland result from few instances of high lpue in the area. Estimates of continuing high discard rates in Division 6.a indicate the scheme has not been as effective to the west of Scotland as in the North Sea. *ICES Advice 2014 Book 5* 11.

Year	2008	2009	2010	2011	2012
Number RTCs	4	17	27	4[a]	9
% of total number of RTCs	27%	12%	10%	2%	5%

EU management plan

The European Commission has adopted Council Regulation (EC) No. 1342/2008 which establishes measures for the recovery and long-term management of cod stocks. The stated objective of the plan is to ensure the sustainable exploitation of the cod stocks on the basis of maximum sustainable yield while maintaining a fishing mortality of 0.4. Articles 7–9, describing aspects of the plan relevant to west of Scotland cod, are reproduced below:

Article 7

Procedure for setting TACs for cod stocks in the Kattegat the west of Scotland and the Irish Sea

1) Each year, the Council shall decide on the TAC for the following year for each of the cod stocks in the Kattegat, the west of Scotland and the Irish Sea. The TAC shall be calculated by deducting the following quantities from the total removals of cod that are forecast by STECF as corresponding to the fishing mortality rates referred to in paragraphs 2 and 3: (a) a quantity of fish equivalent to the expected discards of cod from the stock concerned; (b) as appropriate a quantity corresponding to other sources of cod mortality caused by fishing to be fixed on the basis of a proposal from the Commission.

2) The TAC shall, based on the advice of STECF, satisfy all of the following conditions: (a) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be below the minimum spawning biomass level established in Article 6, the fishing mortality rate shall be reduced by 25% in the year of application of the TAC as compared with the

fishing mortality rate in the previous year; (b) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be below the precautionary spawning biomass level set out in Article 6 and above or equal to the minimum spawning biomass level established in Article 6, the fishing mortality rate shall be reduced by 15 % in the year of application of the TAC as compared with the fishing mortality rate in the previous year; and (c) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be above or equal to the precautionary spawning biomass level set out in Article 6, the fishing mortality rate shall be reduced by 10% in the year of application of the TAC as compared with the fishing mortality rate in the previous year.

3) If the application of paragraph 2(b) and (c) would, based on the advice of STECF, result in a fishing mortality rate lower than the fishing mortality rate specified in Article 5(2), the Council shall set the TAC at a level resulting in a fishing mortality rate as specified in that Article.

4) When giving its advice in accordance with paragraphs 2 and 3, STECF shall assume that in the year prior to the year of application of the TAC the stock is fished with an adjustment in fishing mortality equal to the reduction in maximum allowable fishing effort that applies in that year.

5) Notwithstanding paragraph 2(a), (b) and (c) and paragraph 3, the Council shall not set the TAC at a level that is more than 20% below or above the TAC established in the previous year.

Article 9

Procedure for setting TACs in poor data conditions

Where, due to lack of sufficiently accurate and representative information, STECF is not able to give advice allowing the Council to set the TACs in accordance with Articles 7 or 8, the Council shall decide as follows: (a) where STECF advises that the catches of cod should be reduced to the lowest possible level, the TACs shall be set according to a 25% reduction compared to the TAC in the previous year; (b) in all other cases the TACs shall be set according to a 15% reduction compared to the TAC in the previous year, unless STECF advises that this is not appropriate.

Article 10

Adaptation of measures

1) When the target fishing mortality rate in Article 5(2) has been reached or in the event that STECF advises that this target, or the minimum and precautionary–spawning biomass levels in Article 6 or the levels of fishing mortality rates given in Article 7(2) are no longer appropriate in order to maintain a low risk of stock depletion and a maximum sustainable yield, the Council shall decide on new values for these levels.

2) In the event that STECF advises that any of the cod stocks is failing to recover properly, the Council shall take a decision which: (a) sets the TAC for the relevant stock at a level lower than that provided for in Articles 7, 8 and 9; (b) sets the maximum allowable fishing effort at a level lower than that provided for in Article 12; (c) establishes associated conditions as appropriate.

A.3 Ecosystem aspects

Geographic location and timing of spawning

Spawning has occurred throughout much of the region in depths <200 m. However, a number of spawning concentrations can be identified from egg surveys in the 1950s, 1992 and from recent surveys of spawning adult distribution. The most commercially important of these, range from the Butt of Lewis to Papa Bank. There are also important spawning areas in the Clyde and off Mull. The relative contribution of these areas is not known. Based on recent evidence there are no longer any significant spawning areas in the Minch. Peak spawning appears to be in March, based on egg surveys (Raitt, 1967). Recent sampling suggests that this is still the case.
The main concentrations of juveniles are now found in coastal waters.

Fecundity

Fecundity data are available from West, 1970 and Yoneda and Wright, 2004. Potential fecundity for a given length is higher than in the northern North Sea but lower than off the Scottish east coast (see Yoneda and Wright, 2004). There was no significant difference in the potential fecundity–length relationship for cod between 1970 (West, 1970) and 2002–2003 (Yoneda and Wright, 2004).

B. Data

B.1. Commercial catch

B.1.1. Landings data

An overview of the data provided and used by the WG is provided in the following text table.

	Commercial Data			
	Landings		Discards	
	No.-at-age	Wght.-at-age	No.-at-age	Wght.-at-age
Available	1978–2014 Ages : 1–7+	1978 onwards Ages : 1–7+	1978 onwards Ages : 1–7+	1978 onwards Ages : 1–7+
Used	1981–1990 & 2007 onwards Ages : 1–7+	1981 onwards Ages : 1–7+	1981–1990 & 2007 onwards Ages : 1–7+	1981 onwards Ages : 1–7+

From 1991 to 2005, only the age composition information from the commercial data was used in the assessment. This is because of concerns over bias in the data caused by under and misreporting. The problem of biased data is considered to have become serious from 1995. WKROUND 2012 considered that landings subject to underreporting could still be expected to yield unbiased age structures when sampled. Therefore, rather than exclude landings and discards data completely from 1995 it was agreed to make use of the information on age structure from the landings and discards data. The model then estimates a correction factor on overall catch amounts in these

years (1991-2005). To allow the model an overlap with a period considered to contain relatively unbiased commercial data the 'age structure only' period was started in 1991.

Area-misreported landings by the Scottish fleet are considered to represent a considerable proportion of the total landings. Since 2006, estimates of misreporting based on surveillance and consideration of VMS data by Marine Scotland Compliance, have been made available to the WG. For 2007 onwards these data are used to provide an estimate of actual landings and the resulting commercial landings and discards-at-age data used in the stock assessment are considered to be unbiased.

Data from 2006 (both total catch and age compositions) are completely excluded from the assessment. This year appears to be a transition year between the low discard and high discard fisheries (perhaps because the legislation that ended the potential for underreporting of landings was brought in midway through 2006) and as a result cannot be modelled well with the current approach to discard modelling in TSA.

Scottish landings (numbers-at-age) were adjusted for misreporting using

$$\hat{N}_{a,y} = N_{a,y} * \frac{L_y + Lm_y}{L_y},$$

where $N_{a,y}$ is number-at-age a in year y, Ly is total weight of reported landings in year y and Lm_y is weight of landings misreported in year y. The adjusted totals were then submitted to InterCatch and the aggregated international data compiled. In the 2012 assessment landings and discards were adjusted in the same way. It was agreed at the 2013 WG that only landings should be adjusted (on the grounds area misreporting would occur to avoid the need to discard). The dataset used at WGCSE 2012 is therefore different to the input data for subsequent WGs. The approach also differs to that adopted at WKROUND 2012. There international landings totals were used for the Ly term and the adjustment for misreporting was applied to all fleets. WGCSE considered the change of approach necessary because the misreporting data only relates to Scottish fleet landings. Analysis of Irish fleet behaviour indicated little likelihood of misreporting and the type of fishing conducted by other fleets in the area was also thought to lead to little area misreporting.

Discard data are available from1978 but sampling was very limited before 1981. Discards in years 1981–2003 raised according to Millar and Fryer (2005).
The following table gives the source of commercial catch data for West of Scotland cod:

	Kind of data				
Country	Caton (catch-in-weight)	Canum (catch-at-age in numbers)	Weca (weight-at-age in the catch)	Matprop (proportion mature-by-age)	Length composition in catch
UK(NI)	X				
UK(E&W)	X				
UK(Scotland)	X	X	X	X	X
Ireland	X	X	X		X
France	X				
Norway	X				

Observer sampling levels are given in the table below:

	AREA 6				
	Scotland			Ireland	Northen Ireland
Year	TR1	*TR2*	Total	Total	Total
2008	9	8	17		
2009	10	22	32		
2010	5	6	11	9	
2011	8	7	15	15	
2012	10	13	23	14	37
2013	13	16	29	11	34
2014	11	21	32	18	39
2015	12	29	41	18	4

InterCatch is used to generate the total catch-at-age data (landings and discards separately) for the assessment. To estimate the discard proportion for unsampled fleets, the following protocol was followed:

- the Scottish trawl ≥100 mm fleet discard ratio was applied to all trawler fleets with mesh ≥100 mm with no discard information on the grounds they are all offshore large mesh otter trawl fisheries.
- Trawl fleets with mesh 70–100 mm were assigned a discard ratio based on a weighted average of those from the Scottish *Nephrops* fleet and N Irish vessels, (weighted by CATON).
- Longline and FDF fleets are given zero discard proportions
- All other unsampled fleets received a weighted average discard rate derived from all sampled fleets.

Where possible, age distributions were assigned to landings and discards within InterCatch on the same basis as above. The Scottish discard rates are high compared to other fleets and in reality it may not be appropriate to allocate these rates to all other

fleets. However, given that the other fleets make up such a tiny proportion of the landings, the allocation schemes do not matter to the final raised catch numbers-at-age.

B.2. Biological sampling

B.2.1. Maturity

Maturities-at-age are given by

Age	1	2	3	4+
Proportion mature-at-age	0.0	0.52	0.86	1.0

B.2.2. Natural mortality

Natural mortality-at-age (M) is assumed weight-dependent after Lorenzen (1996) with mortality assumed to be time invariant, M is calculated by finding the time-series means for stock weights-at-age before applying the Lorenzen parameters, i.e.

$$M_a = 3\overline{W_a}^{-0.29}$$

Where M_a is natural mortality-at-age a, $\overline{W}a$ is the time averaged stock weight-at-age a (in grammes) and the numbers are the Lorenzen parameters for fish in natural ecosystems.

Natural mortality (M) at-age as used at recent WGs:

WG Year/Age	1	2	3	4	5	6	7+
2012	0.528	0.386	0.305	0.261	0.236	0.222	0.210
2013	0.531	0.386	0.306	0.261	0.236	0.222	0.210
2014	0.534	0.386	0.306	0.261	0.236	0.222	0.211
2015	0.537	0.386	0.306	0.262	0.237	0.223	0.211

B.2.3. Length and age composition of landed and discarded fish in commercial fisheries

Weights-at-age are supplied separately for landings and discards. Catch weights are derived using the sum of products from the landings and discards weights-at-age. Stock weights-at-age are assumed equal to the catch weights-at-age.

B.3. Surveys

B.3.1. Survey descriptions

The Scottish surveys used for this assessment changed vessel and tow duration in 1999. Although a correction has been made based on comparative tows, there will be an additional variance associated with this correction factor which will affect the survey index. The spatial aggregation of the ScoGFS-WIBTS-Q1 survey (weighted arithmetic mean) can result in hauls catching large numbers of fish having a strong influence on

index values (as was the case in 2008). This in turn has added noise to the indices leading to high prediction errors from TSA (residuals from other models) and downweighting of datapoints.
Between 2011 to 2015 the assessment was run with no survey data. Due to a change in survey design in SCOGFSWIBTS.Q1 this survey came to an end in 2010. A new time-series was started in 2011 the UKGFSWIBTS.Q1.
For 2011 the rig and sampling design of the ScoGFS-WIBTS-Q1 survey was changed. A new groundgear was introduced broadly modelled around the rig used by Ireland for the IRGFS-WIBTS-Q4. The move to a more robust gear also allowed a move to a random stratified survey (which is again consistent with the IRGFS-WIBTS-Q4). WGCSE 2011 concluded the changes constituted a new abundance series. The ScoGFS-WIBTS-Q1 survey data therefore finishes in 2010. The 2015 inter-benchmark analysed the effect of the inclusion of the new survey UKSGFS-WIBTS-Q1.It concluded that its inclusion would be beneficial to the assessment despite the relatively poor internal consistency of the new survey. The same changes to ground gear and survey design occurred for the ScoGFS-WIBTS-Q4 and the final year of data from the ScoGFS-WIBTS-Q4 series is 2009 (the survey did not take place in 2010).
The following surveys are available for the assessment:

ScoGFS – WIBTS – Q1: Fixed station design
ScoGFS – WIBTS – Q4: Fixed station design
IGFS – WIBTS – Q4: Random stratified design (Southern part of Division 6.a)
UKSGFS – WIBTS – Q1: Random stratified design
UKSGFS – WIBTS – Q4: Random stratified design

B.3.2. Survey data used

Prior to the 2019 IBP, only survey data from the quarter 1 surveys was included in the assessment. At IBPCod6.a in 2019, the data from the quarter 4 surveys was reconsidered. The three additional surveys show reasonable consistency (between and within survey) and it was agreed that the additional indices should be included in the assessment. The available data are specified in the table below.

	Survey Data					
	cpue at-age					
	ScoGFS-WIBTS-Q1	ScoGFS-WIBTS-Q4	IreGFS	IRGFS-WIBTS-Q4	UKSGFS-WIBTS-Q1	UKSGFS-WIBTS-Q4
Available	1985–2010 Ages: 1–7	1996–2009 Ages: 0–8	1993–2002 Ages: 0–3	2003 onwards Ages: 0–4	2011 onwards Ages: 1–7	2011 onwards Ages: 0–8
Used	1985–2010 Ages: 1–6	1996–2009 Ages: 1–4	NOT USED	2003 onwards Ages: 1–3	2011 onwards (including assessment year) Ages: 1–6	2011 onwards Ages: 1–6

B.4. Commercial cpue

No reliable data available.

B.5. Other relevant data

Grey seal consumption of cod data from Hammond and Harris (2006). Supplementary model run only (used to test sensitivity of outcomes to assumptions about natural mortality).

C. Assessment methods and settings

C.1. Choice of stock assess model

Model used: TSA
Software used: NAG library (FORTRAN DLL) and functions in R.

C.2. Model used of basis for advice

The main changes to the TSA configuration agreed at the IBPCod6.a included modifications to the age-specific measurement error assumptions in the commercial data (making use of estimates from derived from market and observer sampling data as part of the assessment input data estimation process), allowing for greater flexibility in the estimation of fishery selectivity and the inclusion of three additional survey indices.
The final configuration is given below:

Parameter	Setting	Justification
Age of full selection.	$a_m = 6$	To allow flexibility when estimating fishery selectivity.
Survey catchability model	WIBTS.Q1 & WIBTS.Q4: no transitory or persistent changes SCO.Q1, SCO.Q4 & IRGFS.Q4: transitory changes estimates	Allows for survey year effects
Multipliers on variance matrices of measurements.	$B_{landings}$(a, 1981-2005) = 2 for ages 1, 6 $B_{landings}$(a, 1981-2005) = 3 for ages 7+ $B_{landings}$(1-7+, 2007 onwards) = (15.6,9.1,3.6,1.2,1.9,3.8,7.5) $B_{discards}$(1-4, 2007 onwards) = (0.96,0.62,0.91,0.87)	Allows extra measurement variability for poorly-sampled ages (based on relative size of residuals). Allows extra measurement error post Buyers & Sellers legislation (based on external estimates of CV).
Multipliers on variances for fishing mortality estimates.	H(1) = 2 v.cvmult (1986) = 3	Allows for more variable fishing mortalities for age 1 fish. Allows for greater transitory change in fishing mortality year component.

Parameter	Setting	Justification
Downweighting of particular datapoints.	Landings: Age 2 in 1987 age 6 in 1982 age 4 in 2004 Discards: age 1 in 1988, 1992 and 2016 age 2 in 1988, 1992,1998,2002. Survey (WCIBTS.Q1): Age 1 in 1987 age 2 in 2007 and 2010, age 3 in 2008, age 4 in 2001 and 2008, age 5 in 2001. Survey IRGFS.Q4: age 1	CV multiplier set to 3 or 5 as necessary. Large values indicated by exploratory prediction error plots. Survey downweighting in 2001 resulted from a single large haul, 24 fish >75 cm in 30 minutes. In 2008 due to v large haul near 4 degrees W line.
Discards	Discards are allowed to evolve over time constrained by a trend. Ages 1 to 4 are modelled independently. A step function is specified with the step occurring in 2006.	
Recruitment.	Modelled by a Ricker model, with numbers-at-age 1 assumed to be independent and normally distributed with mean $\eta 1\ S \exp(-\eta 2\ S)$, where S is the spawning–stock biomass at the start of the previous year. To allow recruitment variability to increase with mean recruitment, a constant coefficient of variation is assumed.	
Large year classes.	The 1986 year class was large, and recruitment at-age 1 in 1987 is not well modelled by the Ricker recruitment model. Instead, N(1, 1987) is taken to be normally distributed with mean $5\eta 1\ S \exp(-\eta 2\ S)$. The factor of 5 was chosen by comparing maximum recruitment to median recruitment from 1966–1996 for 6.a cod, haddock, and whiting in turn using previous XSA runs. The coefficient of variation is again assumed to be constant.	

The main diagnostics of the quality of the model fit come from consideration of the objective value (-2*log likelihood), prediction errors and residuals, and a consideration of how well the model has replicated discard ratios in the input data. As new years of data become available, these diagnostics will indicate the need to down-weight individual datapoints or that the data, be it landings, discards or survey, for a given age is more or less variable than previously thought. It is therefore important that changes to the variance structures used in the TSA models are allowed if they improve model diagnostics.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1981 onwards (excluded 1991–2006)	1 to 7+	Yes
Canum landings	Landings-at-age in numbers	1981–2005 & 2007–onwards (age comps only 1991–2005)	1 to 7+	Yes
Canum discards	Discards-at-age in numbers	1981–2005 & 2007–onwards (age comps only 1991–2005)	1 to 7+	Yes
Weca	Weight-at-age in the commercial catch	1981–onwards	1 to 7+	Yes
Weca landings	Weight-at-age in the commercial landings	1981–onwards	1 to 7+	Yes
Weca discards	Weight-at-age in the commercial discards	1981–onwards	1 to 7+	Yes
West=Weca	Weight-at-age of the spawning stock at spawning time.	1981–onwards	1 to 7+	Yes
Mprop	Proportion of natural mortality before spawning	1981–onwards	1 to 7+	No, set to 0 for all ages and years
Fprop	Proportion of fishing mortality before spawning	1981–onwards	1 to 7+	No, set to 0 for all ages and years
Matprop	Proportion mature at age	1981–onwards	1 to 7+	No
Natmor	Natural mortality	1981–onwards	1 to 7+	Differs between assessment years (but fixed over years within a particular assessment)

Survey indices:

Type	Name	TSA survey acronym	Year range	Age range
Tuning fleet 1	ScoGFS – WIBTS – Q1	WCIBTS.Q1	1985–2010	1 to 6
Tuning fleet 2	UKSGFS – WIBTS – Q1	SCO.Q1	2011 onwards (including assessment year)	1 to 6
Tuning fleet 3	ScoGFS – WIBTS – Q4	WCIBTS.Q4	1996–2009	1 to 4
Tuning fleet 4	UKSGFS – WIBTS – Q1	SCO.Q4	2011 onwards	1 to 6
Tuning fleet 5	IRGFS-WIBTS-Q4	IRGFS.Q4	2003 onwards	1–3

D. Short-term prediction

Model used: Age structured
Software used: MFDP prediction with management option table and yield-per-recruit routines. MLA suite (WGFRANSW) used for sensitivity analysis and probability profiles.

The following configuration was agreed at WGNSDS 2008

Initial stock size: Taken from TSA for age 1 and older.
Weight-at-age in the catch: Average weight of the three last years.
Weight-at-age in the stock: Average stock weights for last three years. Assumed equal to the catch weight-at-age, (adopted because mean weights-at-age have been relatively stable over the recent past). CVs are calculated from the standard errors on weights-at-age.
Maturity: The same ogive as in the assessment is used for all years.
F and M before spawning: Set to 0 for all ages in all years.
Exploitation pattern: Average of the three last years.
Not partitioned to give landings, misreporting and discard F. If further work can solve this problem, this partition should be applied.
Stock–recruitment model used: None, recruitment in the intermediate year (terminal year year class at age 1) is taken from the TSA assessment, (the value is based largely on the ScoGFSQ1 survey datum from the terminal year). For the TAC year and following year the short-term (ten years to year before terminal year) geometric mean recruitment-at-age 1 is used.

E. Medium-term prediction

Medium-term projections are not carried out for this stock.

F. Long-term prediction

Medium-term projections are not carried out for this stock.

G. Biological reference points

Reference points were reconsidered at IBPCod6.a, in the main, to bring the definition of yield in line with other stocks for which a significant amount of under MCRS discarding is known to occur. In this case, yield is approximated as total catch less discards, where the discard proportion at age is taken as the average of historical discards before the change in discarding practices occurred (1981–2000).

	Type	Pre 2016	2016–2018	Curent value (IBP 2019)	Technical basis
MSY Approach	MSY $B_{trigger}$	22 000	20 000 t	20 000 t	B_{PA}
	F_{MSY}	0.19	0.17	0.29	F giving max yield in the long term given current error, biology & fishery and applying the ICES advice rule (Ricker/Seg reg stock recruitment fitted to full time series minus the final year)
	F_{MSY} lower			0.2	F at 95% MSY (below FMSY) without ICES AR.
	F_{MSY} upper			0.41	F at 95% MSY (above FMSY) without ICES AR.
	$F_{p.05}$			0.64	F that gives a 5% probability of SSB < Blim when the ICES advice rule is applied.
Precautionary Approach	B_{lim}	14 000	14 000 t	14 000 t	$B_{lim} = B_{loss}$, the lowest observed spawning stock from which the stock has increased (SSB in 1992 as estimated in 2015 WG)
	B_{PA}	22 000	20 000 t	20 000 t	Considered to be the minimum SSB required to ensure a high probability of maintaining SSB above B_{lim}, taking into account the uncertainty of assessments. 1.4 x Blim
	F_{lim}	0.8	0.82	0.77	Based on simulation with segmented regression recruitment with Blim as the breakpoint: F at which 50 % probability of being above Blim
	F_{PA}	0.6	0.59	0.55	$F_{lim}/1.4$

H. Other issues

H.1. Change of Scottish Research Survey

For 2011 the rig and sampling design of the ScoGFS-WIBTS-Q1 survey was changed. A new groundgear capable of tackling challenging terrain was introduced broadly modelled around the rig used by Ireland for the IRGFS-WIBTS-Q4. The move to a more robust groundgear also allowed a move to a random stratified survey (which is again consistent with the IRGFS-WIBTS-Q4) as the previous repeat station survey format consisting of the same series of survey trawl positions being sampled at approximately the same temporal period every year was considered a bias prone method for

surveying the area. It is hoped the greater compatibility between Scottish and Irish surveys will facilitate both being used to assess gadoids west of Scotland.
New survey strata were designed using cluster analysis on aggregated data from the previous ScoGFS-WIBTS-Q1 data (1999–2010) as well as the data collected from a dedicated gadoid survey which took place during quarter 1 of 2010. Species considered were cod, haddock, whiting, saithe and hake. Cluster analysis yielded four specific clusters. Two additional strata were added; the Clyde area and the 'windsock' which is an area that has been designated as a recovery zone since 2002 and has therefore experienced no mobile gear exploitation during this time. The new strata are shown in Figure H.1. Each individual polygon was treated as a separate stratum and the number of survey stations for each was allocated according to polygon size and the variability of indices within each stratum. Strata were weighted by surface area to build the final indices.

H.2. Biology of species

H.3. Stock dynamics, regulations in 20th century, historic overview

2004 to 2011.
Model used: TSA
Software used: Compaq visual FORTRAN using NAG library.
Model Options chosen:
Natural mortality (M) 0.2 at all ages.
Commercial data

- 1978–1994: treated as unbiased
- 1995–AY-1: omitted
- landings cvmult-at-age = c(1, 1, 1, 1, 1, 2, 2): extra variability for ages 6 and 7+

Discard model

- 1978–1994: ages 1and 2 modelled
- 1995–AY-1: omitted

Stock–recruit model

- Ricker
- large year class: 1986

Fishing selection model

- amat = 4: fishing selection flat (apart from noise) from age 4
- gudmundssonH1 = c(4, 1, 1, 1, 1, 1, 1): extra variability for age 1

Survey model (IBTS Q1)

- amat = 4: catchability flat (apart from noise) from age 4
- survey catchabilities up to amat assumed to follow a log-linear model
- survey cvmult-at-age = c(2, 1, 1, 1, 2, 2): extra variability for ages 1, 5 and 6
- ages 1 to 6 modelled

- only transitory changes in catchability allowed; modelled using the additive scale.

Summary of data ranges used in recent assessments (no accepted assessment in 2011):

Data	2007 assessment	2008 assessment	2009 assessment	2010 assessment
Catch data	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+
Survey: WCIBTS.Q1	Years: 1985–AY Ages: 1–6	Years: 1985–AY Ages 1–6	Years: 1985–AY Ages 1–6	Years: 1985–AY Ages 1–6
Survey:	Not used	Not used	Not used	Not used
Survey:	Not used	Not used	Not used	Not used

Data	2012 –2014 ASSESSMENT	2015 –2018 assessment
Catch data	Years: 1981–(AY-1) (1991–2005 age comps only) Ages: 1–7+	Years: 1981–(AY-1) (1991–2005 age comps only) Ages: 1–7+
Survey: WCIBTS.Q1	Years: 1985–2009 Ages: 1–6	Years: 1985–2009 Ages: 1–6
Survey: SCO.Q1	Not used	Years: 2010–AY Ages: 1–6
Survey:	Not used	Not used

AY – Assessment year.

H.4. Current fisheries

H.5. Management and advice

H.6. Others (e.g. age terminology)

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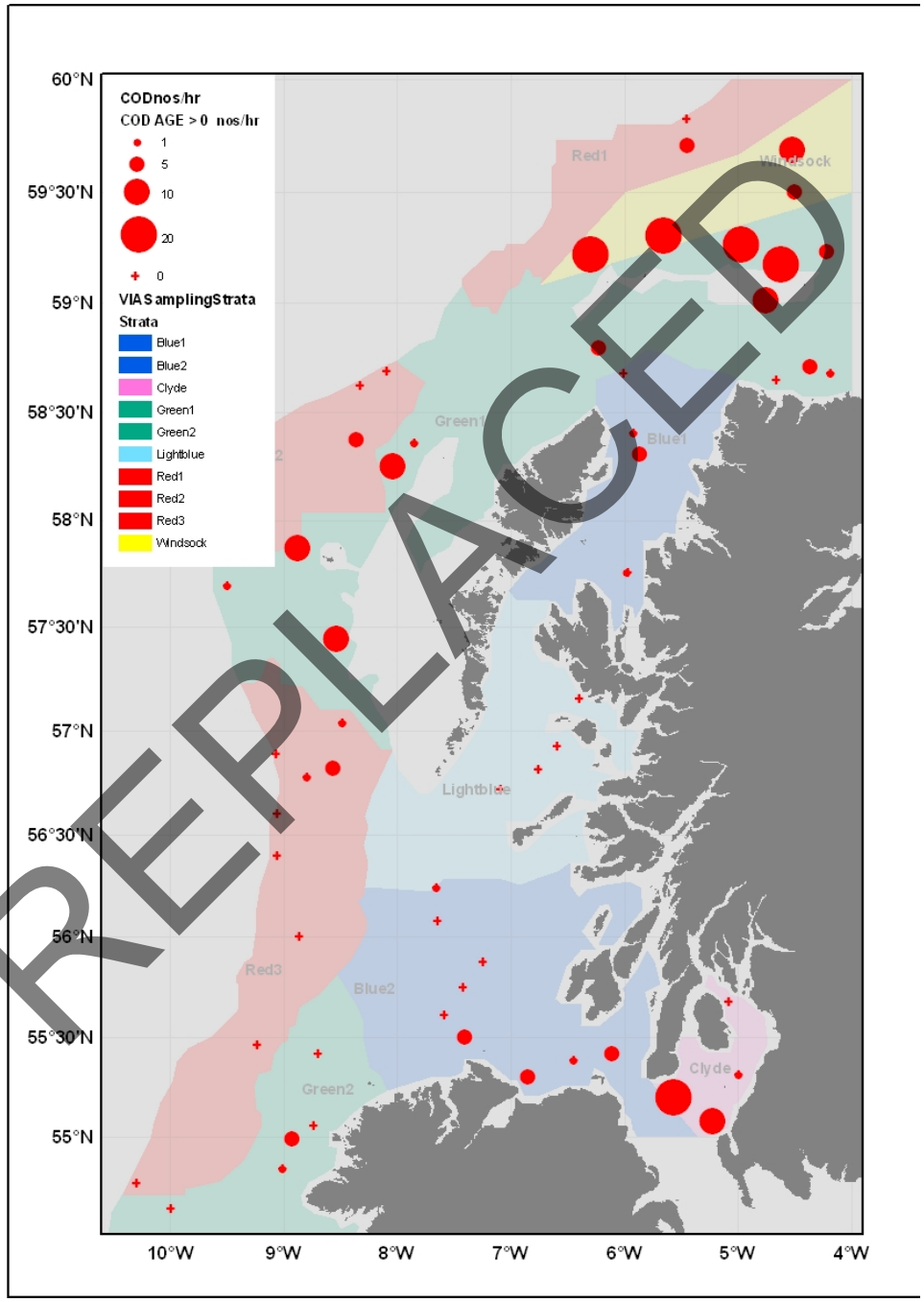

Figure H.1. Sampling strata of UKSGFS-WIBTS-Q1 survey. Figure also shows cpue numbers for fish aged at 1+ by haul for cod in 2011 (numbers standardised to 60 minutes towing).