Stock Annex: Cod in 7.e–k Celtic Sea cod

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

Stock	Cod in 7.e–k (Celtic Sea cod)
Expert Group	Celtic Sea Ecoregion Working Group
Last update	Marianne Robert (WKCELTIC 2019–2010 and WGCSE 2020)

A. General

A.1. Stock definition

Since 1997, this assessment has related to the cod in divisions 7.e–k, covering the Western Channel and the Celtic Sea. Tagging information presented at WKROUND 2012 confirms minimal movement of cod from 7.e–k to other areas. In the past few biological criteria have been used to justify the widening the stock area. However, recent tagging work by Ireland and the UK supports the idea that there is a resident stock in the Celtic Sea and Western Channel (7.e–k) and mixing with other areas appears to be minimal. The Irish Sea front, running from SE Ireland (Carnsore point) to the Welsh Coast, appears to act as boundary between the Irish Sea and Celtic Sea stock. Juveniles found close to the SE Irish Coast (south of 7.a) are considered part of the Celtic Sea stock. Some migrations and mixing are known to occur in this cod stock. Both conventional and DST tagging information for 7.g (where the majority of landings are made) shows that distribution remained fairly constrained within 7.g. There was some preference to central areas within 7.g during January–March. Between April and June the cod appeared to be more widely dispersed within 7.g during Q1 & Q2. Fish tagged in 7.f tended to mix with those off shore in 7.g and h, whereas some fish tagged in the western English Channel 7.e migrated into 7.d for at least part of the year (Righton, 2007). Between 1964 and 2018 a number of tagging studies have been conducted to understand the migratory behaviour and stock identity of cod in areas 6a and 7a,e–k. In combination the studies included 2500 datapoints of tagged and re-captured fish. Studies involved using both, external marker tags as well as DST tags. There is little evidence of fish migrating from area 7.e–j into are 7.a, however there is considerate evidence of fish first tagged in area 7a to be re-captured in 7.e-g. This is particularly evident for mature, older fish (3+ years) of which in the latest study 20% were seen to migrate from 7.a into 7.e–g.

In fact even within 7.e–k there seems to be limited mixing between fish tagged in 7.g or 7.a South and those tagged in 7.f and 7.e. Up to 2008, the management area was set in divisions 7.b–k,7.I, IX, X, and CECAF 34.1.1 which does not correspond to the area assessed. The management area was revised in 2009 to exclude 7.d. The new TAC covers ICES Areas 7.b–c, 7.e–k, 8, 9, 10, and CECAF 34.1.1(1). This is more representative of the stock area in recent years and landings from 7.bc, 8, 9 and 10 have been minimal. The area assessed has gradually increased from 7.fg before 1994 to 7.fgh, to 7.efgh in 1996 and finally to 7.e–k. At WGSSDS 1997, due to the lack of a long independent series of catch-at-age in divisions 7.j,k, the estimate of landings from divisions 7.jk was discussed and it was decided to combine the data of divisions 7.e,f,g,h and divisions 7.jk for the period 1993–1996 and to raise the data in divisions

7.e–h to landings in divisions 7.e–k for the period 1988–1992. The merging of divisions 7.jk with divisions 7.e–h mainly resulted in a scaling upwards of SSB and recruitment.. At the 1999 WGSSDS meeting, a long series of landings data from 1971–1987 was reconstructed following (Bellail, 1999, WD3). An average raising factor (1.24) from 7.fgh to 7.e–k in the period 1988–1997 was applied to 7.fgh landings of the series 1971–1987.

At WKCELTIC 2020, the inclusion of ICES area 7.b and 7.c was considered to increase consistency between the three gadoids stocks in the area (cod, haddock and whiting). However, an important amount of the 7.bc reported catch in the 1980s and 1990s was taken in the north of 7.b on the boundary with 6.a in Donegal bay (Colm Lordan, personal communication). This catches were recorded as 6.a. Adding in a lot of catch for 7.bc may bias the historic perception of stock size.

A.2. Fishery

The majority of the landings are made by demersal trawls targeting roundfish (i.e. cod, haddock and whiting), although, in recent decades an increasing component have been from gillnets and otter trawls targeting *Nephrops* and benthic species. Cod in 7.e–k is caught as part of a mixed fishery with haddock and whiting (Mateo *et al*., 2017; Moore *et al*., 2019). Cod is no longer a target species but is bycaught in haddock and whiting dedicated fisheries.

Landings are made throughout the year but are generally more abundant during the first and second semester. Constraining TACs set between 2000 and 2010 and the impact of the Trevose Head Closure applied since 2005 have reduced landings in Q1 somewhat and spread landings more throughout the year. WGCSE should routinely monitor spatial and temporal changes in landings, effort and lpue for the main fleets catching cod in 7.e–k.

A.3. Ecosystem aspects

Cod recruitment success has generally shown an increase over the period 1970–2006 during which time sea-surface temperature in the Celtic Sea has increased (Brander, 1994; Lynam *et al.*, 2009). Notably the highest recruitment success was for cod spawned in 1986, a year with an exceptionally cold spring. Lynam *et al.* (2009) also found that SST in spring (MAM) and *Calanus helgolandicus*, abundance in the Celtic Sea, did prove to be significant predictors of recruitment in Celtic Sea cod in a GAM model. The time lag between availability of this SST and zooplankton information means that their model cannot be readily used in forecasting recruitment in advance of what groundfish surveys might detect. Nevertheless this research should be pursued further, particularly in the context ecosystem determinants of the strong 2009 and 2010 year classes. Cod recruitment success appears at low level in recent years, except in 2013.

B. Data

B.1. Commercial catch

At WKCELTIC 2020, data process at national level were presented and documented. A list of national métier grouping to provide level 6 métier as required in the ICES data call were documented for each country. Thresholds in term of number of fishing

operations, fishing trips, number of fish measured used nationally to select strata for witch raising can be performed were documented for each country.

Landings

On a quarterly basis, France, Belgium, Ireland and UK (E+W) provide catch numbers-at-age and catch weights-at-age for their landings. The Irish landings in 7.g are augmented with some landings made or reported off the southeast coast of Ireland in ICES rectangles 33E2 and 33E3. These rectangles are in the very south of 7.a.

A hierarchical decision tree, coded in R, is used to fill in missing sample data. In a first step, as gadoids growth in length within a year, for a same supra: fleet, season and year, age-structured were borrowed from other countries. The season was then disregarded. In a final step, when no other match was found, métier was disregarded. Proposition of allocated versus sampled data per catch category and year should be monitored at WGCSE. The same kind of approach was used for Celtic sea haddock and whiting, which has improved the consistency between the three stocks.

An updated dataset from 2004 for international landings was provided at WKCELTIC 2020, leading to minor revisions. However, the between year consistency in data processing at national and international level has been improved.

There is no information on the absolute level of misreporting for this stock but there is evidence that misreporting occurred when quotas became restrictive with a maximum in 2008. Misreporting has decreased since then.

Discards

Prior to WKCELTIC 2020, Discards resulting from high-grading were included in the assessment as landings in the period 2003–2011. Discard estimates other than high-grading are available since 2011 but not included in the assessment. At WKCELTIC 2020, France, UK, Belgium, Ireland, Spain and Netherlands provided time-series of discard from 2004 to 2019.

Discards has been incorporated in the assessment model as part of the WKCELTIC 2020.

Self-sampling programme

Since 2008, a French self-sampling programme on Celtic Sea cod is in place. The data collected increase the quantity of data available mainly for the French OTB and OTT fleet. These data are incorporated directly into the national data process. Mainly landings information are used because of some discrepancy on the discard estimates between Observer at sea data and self-sampling datasets.

International data processing

National data are uploaded in InterCatch (IC). Data are extracted and process outside IC.

An R markdown script is available on the SharePoint to document the procedure based on hierarchical decision tree. This script will be used each year to raise the data outside

IC. It also produce a number of plots such as the one shown in Figure 1, to support the decision made.

Level 6 métier per ICES area are grouped in supra métier, based on preliminary exploration of the datasets and quantity of data available. Six supra fleets are modelled: OTB_CRU, OTB_DEF_100_119, OTB_DEF_70_99, SSC_DEF, TBB_DEF and MIS_MIS.

1. Fill in missing discard weights. First, the mean discard ratio by country, gear and year are calculated and used to fill in missing strata. Then, the mean discard ratio by gear and year are calculated and used. Finally, for fleets that have no discard data at all, we use overall ratio per year. These hierarchical decisions were based on differences observed between countries and fleets versus a more flat signal on quarterly discard ration.

2. Fill in missing sample data. A same type of hierarchical decision were set up for sample data. However, season were kept as a first step as gadoids growth in length within a year. For a same supra fleet, season and year, age-structured were borrowed from other countries. The season was disregards and then métier. Proposition of allocated versus sampled data per countries and year (over the period available at WKCELTIC 2020), are shown in Figure 2.

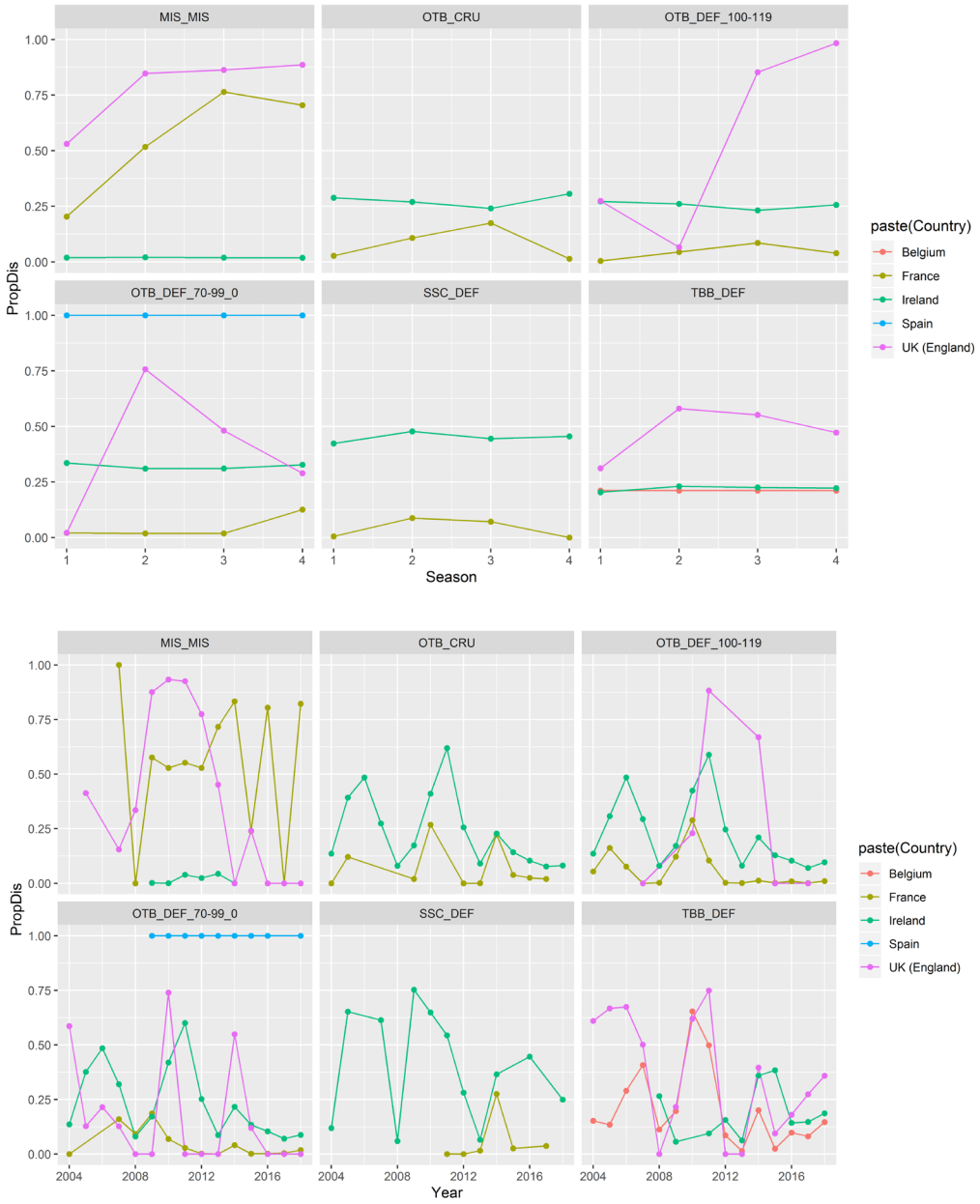

Figure 1. Proportion of discards per fleet, countries, years and quarters.

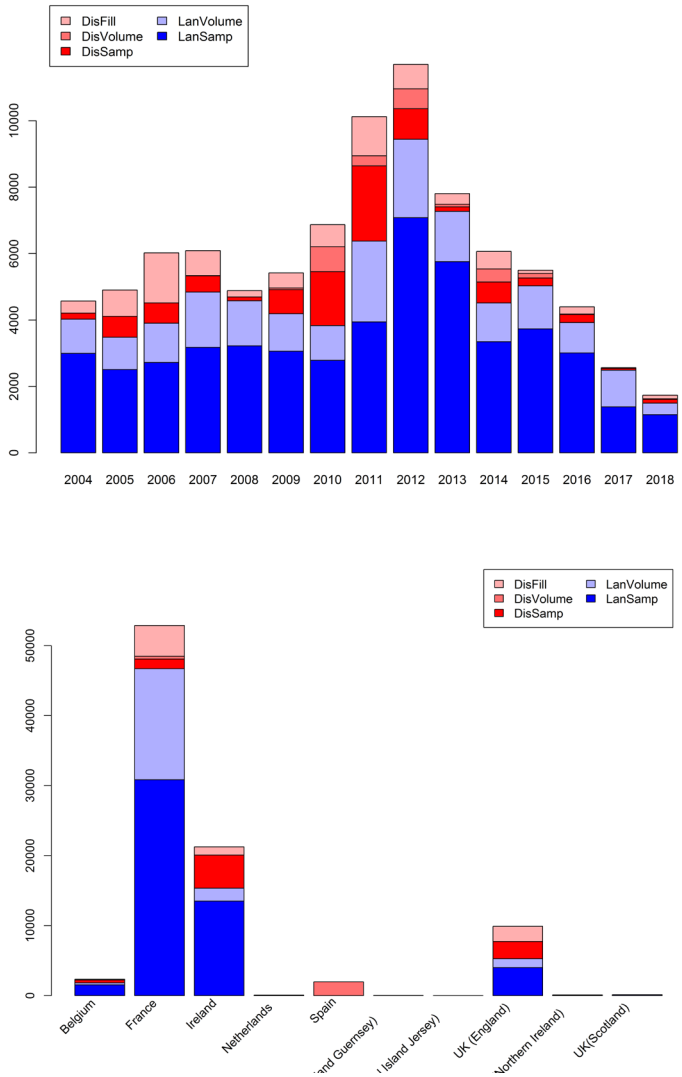

Figure 2. Proposition of data imported and raised over the recent time-series of data 2002–2018.

Lpue

Landings and effort data are available for all the main fleets operating in the area and catching cod. The table below summarizes the available data. WGCSE should monitor changes in these fleets over time.

NAME	AREA	SERIES
FR gadoid fleet [1]	7.fgh	2004-onwards
UK otter trawlers	7.e	1972- onwards
UK otter trawlers	7.e–k	1972- onwards
UK beam trawlers	7.e–k	1978- onwards
IR otter trawlers	7.g	1995- onwards
IR beam trawlers	7.g	1995- onwards
IR Scottish seiners	7.g	1995- onwards
IR otter trawlers	7.j	1995- onwards
IR beam trawlers	7.j	1995- onwards
IR Scottish seiners	7.j	1995- onwards

[1] For Q2+3+4 for consistency with the Trevose Head Closure since 2005 during the first quarter.

B.2. Biological

Weights-at-age

At the 1999 WGSSDS, data for the years 1971–1980 were set to the average 1981–1997. A revision was carried out at 2001 WGSSDS where the values for the period 1971–1980 were set to the average values 1981–2000. Depending on the annual datasets available by country for the period 1988–2001, catch weights-at-age data were calculated as the weighted means from French, Irish and UK datasets. Since 2002, 7.e–k catch weights-at-age have been calculated as the annual weighted means of French, Irish and UK datasets.

WKROUND 2012 reviewed the data and concluded that there is a downward trend in mean weights-at-age during the 1980s but they have been relatively stable since then at about 10% lower mean weights than observed in the 1980s. There is some evidence of year effects (e.g. 2001 and 2005) and cohort effects (e.g. 1999).

New stock, landings and discards weight-at-age were introduced at WKCELTIC 2020 as part of the new data submission to InterCatch for 2004–2018. The two time-series were combined.

Stock weights-at-age are the catch weight-at-age data from the 1st quarter.

Maturity

The maturity ogive applied since 1999, was estimated from the datasets of the UK-WCGFS survey (1st quarter), has been used for the overall series. It replaced an assumed ogive used for the year prior to 1999, derived from Irish Sea cod data, when both stocks (7.a and 7.fg) were assessed in the Irish Sea & Bristol Channel WG up to 1992.

WKCELTIC 2020 reviewed the data using information collected since the last benchmark (see WD as part of the benchmark report). Individual seems to mature earlier than previously estimated. The table below summarizes the maturity ogives used.

AGE	1	2	3	4	5+
Before 1999	0.00	0.05	1.00	1.00	1.00
Before 2019	0.00	0.39	0.87	0.93	1.00
WKCELTIC 2020	0.00	0.54	0.93	1.00	1.00

Natural mortality

In the assessments, natural mortality is assumed to be constant for the whole range of years and is age-dependant.

Natural mortality rates are almost never estimated directly from observation but several approaches exists to try to estimate mortality-at-age from growth parameters and assumptions Before the WKROUND 2009, it was assumed a value of M=0.2 across

all ages for Celtic sea cod. At WKROUND 2012, the Lorenzen approach (1996) was applied where:

$M@age = Mu * W@age^{b}$ with Mu = 3.69 and b = -0.305.

Those values come from the Lorenzen paper as values for oceanic ecosystem. The data source was the EVHOE time-series from 2006 to 2011.

As part of the WKCELTIC 2020, natural mortality estimate are revisited (see WD as part of the benchmark report. Considering more biological data have been available since then, the Lorenzen approach directly on the mean weight-at-age data from EVHOE and IRGFS was calculated. Except for M at age 0 which is uncertain due to the lack of data in comparison to other age classes, values of M-at-age are similar to those estimated in 2012.

The table below summarizes the values of M accordingly to age.

AGE	0	1	2	3	4	5	6	7	8	9	10
M WKROUND 2012	1.12	0.51	0.37	0.30	0.269	0.247	0.233	0.223	0.216	0.210	0.207
M WKCELTIC 2020	0.967	0.501	0.330	0.264	0.233	0.211	0.211	0.211	0.211	0.211	0.211

B.3. Tuning series

Surveys

The EVHOE (FR-WIBTS-Q4) and IrGFS (IGFS-WIBTS-Q4) surveys (1997–present) are combined to provide a time-series survey index used to tune the assessment. The two survey covers the divisions 7.fghj during 4th quarter.

The absolute numbers of cods caught in all of these surveys are extremely low. Attempts to combine survey data have been done at WKROUND 2009 and 2012 to overcome that problem.

WKROUND 2012 tested two combinations: mixing data for the whole area and just those in the overlapping area. WKROUND concluded that the overlap area combined index was an improvement on using the two surveys independently or using the full area index. This conclusion was based on the good cohort tracking and fairly consistent catch curves in the combined index Ages 1–4.

As part of constructing a combined index for whiting during the 2014 WKCELT benchmark process, a review of methods was made to speed up and simplify the spatial aggregation process. Updated indices were then recalculated for both Celtic Sea whiting and cod and offered as an alternative tuning series for consideration by the stock coordinators along with the existing time-series (see WDx: WKROUND 2012 for details). The correlation between the indices was very high, which validates the use of the new index in the assessment.

At WKCELTIC 2020, a new combined and modelled survey index, using VAST model was used in the assessment. Details on models construction and performances are available in the WD.

Commercial

FR-OTDEF

Due to the implementation of box closure in the Trévose area since 2005, the tuning fleet has only been defined for the three last quarters of the year. Indeed, during the first quarter of 2005, the rectangles 30E4, 31E4, and 32E3 (3) were closed for fishing. Since 2006, the box is only closed in February and March each year.

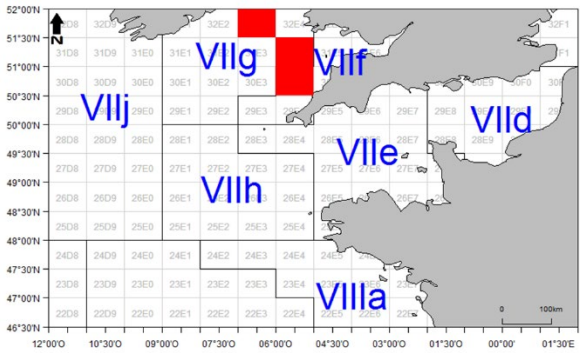

Figure 3. Trevose box (in red).

Over the years, several issues have been pointed out regarding the WKROUND 2012 tuning fleet: i) The tuning indices are being built upon landings only, ii) The selection criteria for the vessel was based on threshold of proportion of landed gadoids among a fixed set of species (14 species). In case of strong recruitment events of one of these species, the approach selects additional vessels that are normally not catching enough gadoids to be considered as reference vessels. The above point has led to a use in the recent years of a frozen set of vessels IDs from 2009.

At WKCELTIC 2020 a French tuning OTT_OTB_7ek_O12m was proposed, tested and used in the assessment. Detailed on exploratory work undergone to provide the time-series is well documented in (WD-WKCELTIC - French commercial tuning fleets_Final_2020, see annex of the benchmark report). Tuning fleet focuses on OTB and OTT gears only and vessels longer than 12 m. Trips are selected if their land more than 25% of cod, haddock and whiting. The raising procedure of landings and discards catch-at-age matrix are based on the same threshold than for the landings and discards data (WD-WKCELTIC - Method to compile French time-series of landing and discard data for Cod 2002–2017 final, see annex of the benchmark report). The tuning index was incorporated as a Biomass index (effort and total catch) to reduce double dipping between national data and commercial index.

B.5. Other relevant data

Input from industry

French self-sampling programme

The French self-sampling programme was initiated in 2009 as a Fishery–Science partnership, under the auspices of the main fishermen's organisation P.D.B (Les Pêcheurs de Bretagne). Depending of the year, up to six otter trawlers have been participating, providing data for métiers targeting either gadoids (OTB or OTTPD), *Nephrops* (OTTLN) or benthic species such as monkfish, megrim, rays, john dory (OTB or OTTPB). As cod is no longer a target species, the number of vessels involved in the program has decreased in recent years. Since 2012, data are incorporated in the SIH Ifremer database and used to inform on landings length structure.

Ireland-UK tagging programme in the Irish and Celtic Seas and Irish industry–science partnership quarter 1 cod survey

A tagging programme on both nursery areas and spawning aggregations of cod in the Irish and Celtic Seas, involving conventional (plastic) tags and sophisticated electronic data storage tags, was initiated in 2007. The main objectives were to examine the movements of cod in relation to closed areas and in respect to stock mixing; to determine fine-scale movements and behaviour of cod during spawning; to examine vertical distribution (in relation to catchability) and thermal experiences (in relation to gonad development). Detailed results were presented to the ICES ASC in 2009 (Bendall *et al*., 2009) and are summarized in the WGCSE 2012 report. No additional information was presented to the group this year.

In recognition of ICES advice (ICES, 2009), the Marine Institute and the Federation of Irish Fishermen, in 2010 initiated an annual Q1 fishery-independent survey for Celtic Sea Cod (See WGCSE 2012 for complementary information and Figure 7.2.1). No updated information was presented to the group this year and no further survey is planned.

Between 1964 and 2018 a number of tagging studies have been conducted to understand the migratory behaviour and stock identity of cod in areas 6.a and 7a,e–k. In combination the studies included 2500 datapoints of tagged and re-captured fish. Studies involved using both, external marker tags as well as DST tags. There is little evidence of fish migrating from area 7.e–j into are 7.a, however there is considerate evidence of fish first tagged in area 7.a to be re-captured in 7.e–g. This is particularly evident for mature, older fish (3+ years) of which in the latest study 20% were seen to migrate from 7.a into 7.e–g.

C. Historical stock development

Model to be used: SAM-Stochastic State–space model; Aged-based analytical assessment (Nielsen, 2008).

Software: https://www.stockassessment.org/

Model setting agreed at WKCELTIC 2020 (Cod_7ek_WGCSE2020):

The final accepted SAM run is detailed below in terms of model setting and models diagnostics.

```
# Configuration saved: Tue Feb 11 10:53:28 2020
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 1

$maxAge
# The maximum age class in the assessment
 7

$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 0 0

$keyLogFsta
# Coupling of the fishing mortality states (normally only first row is used).
  0  1  2  3  4  5  5
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry,
2 AR(1), 3 separable AR(1).
 2

$keyLogFpar
# Coupling of the survey catchability parameters (normally first row is not used, as that
is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1
  0 -1 -1 -1 -1 -1 -1
  1  2  3 -1 -1 -1 -1

$keyQpow
# Density dependent catchability power parameters (if any).
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
$keyVarF
# Coupling of process variance parameters for log(F)-process (normally only first row
is used).
  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1
```

```
$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
  0  1  2  2  2  2  2
  3 -1 -1 -1 -1 -1 -1
  4  4  4 -1 -1 -1 -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "ID" "AR"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#1-2 2-3 3-4 4-5 5-6 6-7
 NA  NA  NA  NA  NA  NA
 -1  -1  -1  -1  -1  -1
 0   0   -1  -1  -1  -1

$stockRecruitmentModelCode
# Stock–recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton–Holt, and 3 piece-wise constant).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and highest age included in Fbar
 2 5

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index, 3 total catch, 4 total landings and 5 TSB index).
 -1 0 -1

$obsLikelihoodFlag
```

Option for observational likelihood | Possible values are: "LN" "ALN"
"LN" "LN" "LN"

$fixVarToWeight
If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix varia
Comnce to weight).
0

$fracMixF
The fraction of t(3) distribution used in logF increment distribution
0

$fracMixN
The fraction of t(3) distribution used in logN increment distribution
0

$fracMixObs
A vector with same length as number of fleets, where each element is the fraction of t(3) distribution used in the distribution of that fleet
0 0 0

$constRecBreaks
Vector of break years between which recruitment is at constant level. The break year is included in the left interval. (This option is only used in combination with stock–recruitment code 3)

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Landings in tonnes	1980–	1–7+	Yes
Canum	Landings-at-age in numbers	1980–	1–7+	Yes
Weca	Weight-at-age in the commercial catch	1980–	1–7+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1980–	1–7+	Yes
Mprop	Proportion of natural mortality before spawning	1980–	1–7+	No
Fprop	Proportion of fishing mortality before spawning	1980–	1–7+	No
Matprop	Proportion mature at age	1980–	1–7+	No
Natmor	Natural mortality	1980–	1–7+	No

Tuning data:

Type	Name	Year range	Age range
French Otter Trawler in 7.ek Q2-Q4	FR-OTDEF	2000–	Biomass index
Combined EVHOE-WIBTS, IGFS-WIBTS	FR-IR-WIBTS	2003–	1–3

D. Short-term projection

Model used: Age structured – Stochastic forecast

Software used: stockassessment.org

Maturity: same ogive as in the assessment

F and M before spawning: 0 (for all ages and years)

Weight-at-age in the stock: average stock and catch weights over the preceding three years.

Recruitment is sampled over the recruitment time-series restricted to the 2015 to present, as recent recruitment are observed to be lower than historical one.

The F vector used will be a average F at age in the last three years, unless there is a strong indication of a significant trend in F. In the latter case, the F will be rescaled to the final F in the series.

Catches were split into landings and discards using the proportions of the catch that were discarded over the last three years.

E. Medium-term projections

Medium-term forecasts are not provided for this stock.

F. Yield and biomass per recruit

No stock–recruit relationship exists for this stock.

G. Biological reference points

Cod in Divisions 7.e–k. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	5800	Tonnes; B_{pa}	ICES (2020b)
	F_{MSY}	0.29	Segmented regression with B_{lim} (EqSim).	ICES (2020b)
Precautionary approach	B_{lim}	4200	Tonnes; Bloss, lowest observed SSB (2005) rounded value	ICES (2020b)
	B_{pa}	5800	Tonnes; B_{lim} × 1.4	ICES (2020b)
	F_{lim}	1.13	Segmented regression with B_{lim} (EqSim).	ICES (2020b)
	F_{pa}	0.77	F05	ICES (2020b)
Management plan	MAP MSY $B_{trigger}$	5800	Tonnes; MSY $B_{trigger}$	ICES (2020b)
	MAP B_{lim}	4200	Tonnes; B_{lim}	ICES (2020b)
	MAP F_{MSY}	0.29	F_{MSY}	ICES (2020b)
	MAP range F_{lower}	0.17	Consistent with ranges provided by ICES (2017), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2020b)
	MAP range F_{upper}	0.41	Consistent with ranges provided by ICES (2017), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2020b)

H. Other issues

J. Historical management consideration

The stock distribution is considered to have been reduced significantly according to the international landings and lpue distribution maps. However, it can extend substantially when recruitment is strong as seen with the 2009 year class when the FR-IBTS Q4 EVHOE survey started to catch cod in the southern part of the Bay of Biscay in 2010.

This stock has had a very truncated age structure with age 2 fish having been the most numerous in landings over many years. The historical dynamics of Celtic Sea cod have been "recruitment driven", i.e. the stock increased in the past in response to good recruitments and decreased rapidly during times of poor recruitment, which is the case in the most recent years. Recruitment before 2009 was poor. The 2009 and 2010 year classes have been strong. The 2013 year class (age 1 in 2014) was also well above the average recruitment. Recruitment are again very poor since then.

Fishing mortality should be reduced in the longer term to maximize the contributions of recruitment to future SSB and yield and will result in reduced risk to the stock.

The exclusion of ICES Division 7.d in the TAC area since 2009 makes the management area more in line with the boundaries of the stock as the stock in 7.d is considered as an extension of the cod population in the North Sea.

Since 2005, ICES rectangles 30E4, 31E4, and 32E3 have been closed during the first quarter (Council Regulations 27/2005, 51/2006, and 41/2007, 40/2008 and 43/2009) with the objective of reducing fishing mortality on cod. When investigated, maps of international effort distribution did not show evidence that this closure had redistributed effort of otter trawlers to other areas (Biseau, A. 2005; Biseau, A. 2007; Biseau, A.; Bellail, R. 2006).

There have been major changes in fleet dynamics over the period of the assessment. Effort in the French otter trawlers has been declining since 1999 and a decommissioning plan has occurred in 2008 and a new plan is ongoing since 2009. Similarly, over the last ten years, there has been a fleet modernisation and several decommissioning schemes in Ireland both within the national whitefish fleet and beam trawl fleet.

Cod in divisions 7.e–k are caught in a range of fisheries including gadoid trawlers, *Nephrops* trawlers, otter trawlers, beam trawlers, and gillnetters. Other commercial species that are caught by these fisheries include haddock, whiting, *Nephrops*, plaice, sole, anglerfish, hake, megrim, and elasmobranchs (Mateo *et al*., 2016; Moore *et al*., 2019, Robert *et al*., 2019). Due to limited fisheries opportunities in recent years, Cod is no longer a target of this fisheries.

Over the last decade, there have been indications of underreporting of cod landings in some fleets. The introduction of the buyers and sellers legislation in the UK and Ireland may have reduced this, but may also have increased discards. Measures aimed at reducing discarding and improving the fishing pattern should be encouraged. These might include spatial and temporal changes in fishing practices or technical measures. Technical mesh size regulation was introduced 14th August 2012 (EC Regulation 737/2012). Additional technical measures were introduced in the Celtic Sea, with a mandatory square mesh panels in the extension, which mesh size were increased over the years from 100 to 160 mm. In 2019, the use of a raised line was introduced under certain conditions (EU regulation 2019/124). These measures would need to be evaluated in the context of other species caught in mixed fisheries (Robert *et al*., 2020).

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