Stock Annex: Whiting in Division 27.6.a (West of Scotland)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Whiting in Division 27.6.a (West of Scotland)
Working Group	Celtic Seas Ecoregion (WGCSE)
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A. General

A.1 Stock definition

Whiting occur throughout Northeast Atlantic waters, in a wide range of depths from shallow inshore waters down to 200 m. Adult whiting are widespread throughout Division 27.6.a, while high numbers of juvenile fish occur in inshore areas. Whiting are less common in Division 27.6.b, and it is likely these fish are migrants from Division 27.6.a, rather than a separate stock.

Stock identity in Division 27.6.a has recently been explored in greater detail. Tagging experiments on recruiting fish have shown that the whiting found to the south of 56°N and to the west of Ireland are distinct from those in the Minches, the Clyde and the Irish Sea. Five juvenile nursery areas have been discriminated off the west of Scotland and northern North Sea, three of them being found in Division 27.6.a. The nursery areas on the Scottish west coast contribute individuals to the spawning aggregations in the Scottish coastal North Sea and Shetland, and there is no evidence of the converse (Tobin *et al.*, 2010). Within Division 27.6.a, there is little indication of interaction between population components in the south and that off the northwest coast.

A.2 Fishery

A.2.1 General description

The demersal fisheries in Division 27.6.a are predominantly conducted by otter trawlers fishing for cod, haddock, anglerfish and *Nephrops*, with bycatch of whiting, saithe, megrim, lemon sole, ling and a number of skate species. Whiting are taken by trawlers using gear with mesh size between 80 mm and 120 mm. The cod recovery plan and the seasonal closure of some areas has lead to some switching of effort away from Division 27.6.a. This had an impact on the whiting stock.

The demersal whitefish fishery in Subarea 6 occurs largely in Division 27.6.a with the UK, Ireland, the Netherlands and France being the most important exploiters. The whiting fishery in Division 27.6.a is dominated by the UK (Scotland) and Irish fleets. French whiting landings have declined considerably since the late 1980s. Dutch landings have been reported since 2015 (for the fourth time in a row).

Most catch of whiting comes in non-whiting directed fisheries, particularly the *Nephrops* trawl fishery. The *Nephrops* trawl fishery in Division 27.6.a discards significant amounts of small whiting, making whiting landings figures a poor indicator of removals due to fishing. The proportion of whiting discarded has been very high and appears to have increased in recent years. Whiting also has a low market demand, which contributes to increased discarding and high-grading. In terms of the total weight of demersal fish landed by the Scottish fleet from the West Coast, whiting are of less importance with an annual value of £140,000 and £51,000 in divisions 27.6.a and 27.6.b respectively in 2018 (https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2018/pages/39/).

A.2.2 Fishery management regulations

Since 2019, the major demersal stocks in Division 6.a, including the whiting stock, have been subject to the EU landing obligation established under Article 15 of Regulation (EU) No 1380/2013 (the revised CFP). This regulation also agreed the adoption of regional multiannual plans (MAP) for fisheries management. The EU MAP for stocks in Western Waters and adjacent waters was adopted in 2019 under Regulation (EU) 2019/472.

There have been some problems regarding area misreporting of Scottish landings during the early 1990s, which are linked to area misreporting of other species such as haddock and anglerfish into Division 6.b. More recently there has been area misreporting of anglerfish from 27.6.a to 27.4.a (ICES, 2018), which may have affected the reliability of whiting landings distribution.

A.3 Ecosystem aspects

Unlike some species, whiting do not form distinct spawning shoals, and both ripe and immature fish are often found together. As the latitude increases, spawning of whiting occurs progressively later. This is closely associated with temperature changes, but spawning activity generally peaks in springtime, just as sea temperatures begin to rise. On the west coast of Scotland, whiting spawn between January and June. Within this period, the spawning season of an individual female lasts around fourteen weeks, during which time she releases many batches of eggs. At two years old, most whiting are mature and able to spawn. By the time it reaches four years old, a single female fish of reasonable size can produce more than 400 000 eggs. Like many other fish, whiting spend their first few months of life in the upper water layers before moving to the seabed. Male and female whiting grow very quickly reaching around 19 cm in their first year. After this, the growth rate becomes much slower. There are large differences between the growth rates of individual fish and a 30 cm fish can be as young as one year or as old as six years.

Whiting are active predators. Juvenile fish eat mainly crustaceans (shrimps and crabs) but as whiting grow, the amount of fish in their diet increases. The exact composition of the diet depends on the size of the fish, the area and the time of the year. Whiting is one of the main predators of other commercially important species of fish. Norway pout, sandeels, haddock, cod and even whiting themselves are frequently eaten. It has been estimated that each year the whiting population consumes several hundred thousand tonnes of these species.

B. Data

A.4 Commercial catch

Monthly length–frequency distribution data are available from Scotland for Division 27.6.a. A total international catch-at-age distribution for Division 27.6.a is obtained by raising this distribution to the WG estimates of total international catch from this area. Landings officially reported to ICES are used for countries not supplying estimates directly to the WG. The Scottish market sampling length–weight relationships (their parameters are given below) have been used to raise the sampled catch-at-length distribution data Working Group estimates of total landings for Division 27.6.a.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
a	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456	2.9456
b	0.0100	0.0094	0090	0.0088	0.0088	0.0089	0.0090	0.0092	0.0095	0.0096	0.0097	0.0097

A.4.1 Landings data

Official total landings are reported to ICES every year. Previously, there were concerns that the quality of landings data was deteriorating, giving a possible reason for the different stock dynamics implied by the commercial fleet and the annual survey (ICES, 2005). Improved compliance measures and the introduction of UK and Irish legislation requiring registration of all fish buyers and sellers may mean that the reported landings from 2006 onwards are more representative of actual landings.

Landings are uploaded to InterCatch by métier. Age distributions are estimated from market samples and annual numbers-at-age were reported annually. Annual mean weights-at-age in the landings have been variable in recent years due to the variability associated with low sample sizes. Efforts to increase sampling in these fisheries are being pursued.

Landings for 2003–2018 were revised at WKDEM 2020 and the new version was uploaded to InterCatch. Age allocations done separately for the two main fleets, TR1 (gadoid fishery) and TR2 (*Nephrops* fishery). The age structure in non-sampled landings was estimated from that in sampled landings.

A.4.2 Discards estimates

Discard data are available from 1978 but sampling was very limited before 1981. To reduce bias and increase precision of discard estimates, previous estimates (ICES, 2011) for the years 1981–2003 were replaced by those provided by Millar and Fryer (2005). Such revisions are particularly important for the estimation of total catch for this stock which has very high discards across a wide age range.

Discard age compositions are generally available from both Scotland and Ireland. In the West of Scotland, Ireland carries out a catch sampling programme on TR1 métier. A target of 14 trips per year is set. Age and length compositions is provided for this métier and in the past has been provided for the TR2 fleet and BT1 fleets.

Discards for 2003–2018 were also revised in 2020. To raise them from landings, two different ratios were used for the TR1 and TR2 fleets. Similarly to landings, the age structure in non-sampled discards was estimated from that in sampled discards.

A.5 Biological sampling

A.5.1 Maturity

Previously, a combined sex maturity was assumed, knife-edged at-age 2. The use of a knife-edged maturity ogive was a source of criticism in previous assessments. However, research on gadoid maturity conducted by the UK gives no evidence for substantial change in whiting maturity since the 1950s, although there has been an increase in the incidence of precocious maturity-at-age 1, particularly in males in the Irish Sea since 1998 (Armstrong *et al.*, 2004).

A new maturity ogive was proposed at WKDEM 2020. The analysis of maturity data for 1997–2018 showed some variability with no clear temporal pattern. Consequently, one maturity ogive was delivered to represent the whole period with two coefficients: -6.165 (intercept) and 5.103 (slope) for the logistic model. The estimated proportions of mature whiting to be used in future age-structured assessments of the stock are shown in the table below:

Age	1	2	3	4	5	6	7+
WGCSE (till 2019)	0	1	1	1	1	1	1
WKDEM	0.257	0.983	1	1	1	1	1

A.5.2 Natural morality

Natural mortality (*M*) is assumed to vary and be dependent on fish weight (Lorenzen, 1996). Previously, *M* values were assumed time-invariant and were calculated as:

$$M_a = 3.0\overline{W}_a^{\ 0.29}$$

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.

During WKDEM in 2020, it was agreed to use a different approach to model matural mortality. While Lorenzen's equation was still applied to estimate natural mortality from stock weights-at-age, the calculations were done for each year in the time-series. As the natural mortality varied in time and the year-to-year variability was high, it was decided to model trends rather than single-year effects. Consequently, it was decided to smooth the estimates natural mortality with a General Additive Model (GAM). The smoothed estimates by age will be used in future age-structured assessments of the stock.

A.6 Surveys

Five research vessel survey series for whiting in 27.6.a were available to the WG in 2019:

- Scottish first-quarter west coast groundfish survey (ScoGFS-WIBTS-Q1): all ages 1 and older, years 1985–2010;

- Scottish fourth-quarter west coast groundfish survey (ScoGFS-WIBTS-Q4): all ages including age 0, years 1996–2009;
- Irish fourth-quarter west coast groundfish survey (IGFS-Q4): all ages including age 0, years 2003–2018;
- Scottish first-quarter west coast groundfish survey (UK-SCOWCGFS-Q1): all ages 1 and older, years 2011–2019;
- Scottish fourth-quarter west coast groundfish survey (UK-SCOWCGFS-Q4): all ages including age 0, years 2011–2018.

The previous Irish fourth-quarter west coast groundfish survey (IreGFS, ages 0–5 used in the tuning time-series, years 1993–2002) was a comparatively short series. It was discontinued in 2003 and has been replaced by the new Irish survey.

A.6.1 Survey design and analysis

The Q1 Scottish Groundfish survey was running in the period 1985–2010, and this was performed using a repeat station format with the GOV survey trawl together with the west coast groundgear rig, 'C'. Similarly the Q4 Scottish Groundfish survey was running in 1996–2009, once again using the GOV survey trawl with groundgear 'C' and the fixed station format.

In 2011, the Q1 and Q4 Scottish Groundfish surveys were re-designed. 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 is considered a rather imprecise method for surveying both these subareas and as such a move towards some sort of random stratified survey design was judged necessary. The largest obstacle preventing an earlier move to a more randomised survey design was the lack of confidence in the 'C' rig to tackle the potentially hard substrates that a new randomised survey was likely to encounter. The first step in the process of modifying the survey design was therefore to design a new groundgear that would be capable of tackling such challenging terrain.

The Irish survey uses the RV Celtic Explorer and is part of the IBTS coordinated western waters surveys. The vessel uses a GOV trawl, and the design is a depth stratified survey with randomised stations. Effort is recorded in terms of minutes towed. Further descriptions of these surveys and distribution plots of whiting catch rates obtained on these surveys can be found in the IBTSWG Report of 2017 (ICES, 2017.a).

A.6.2 Combined abundance index from the Scottish and Irish Q4 surveys

At WKDEM in 2020, a combined index was proposed for the Scottish and Irish Q4 surveys. One rationale for combining the two indices was the fact that the Irish survey is mainly limited to the southern part of Division 6a. The combined index replaces the two individual indices used until then.

A GAM analysis with a number of explanatory variable provided unbiased estimates of the differences between the two surveys for the different age groups. The obtained ratios were subsequently used to adjust the Irish CPUE to the Scottish one. The standardised CPUEs allow to calculate the combined index in a similar way to the Scottish Q4 index.

The combined index performs better than the two indices individually. It appears to produce less noise and be more informative of the population densities. It also simplifies the modelling procedure with two indices (rather than with three indices) being produced in the following years.

A.6.3 Survey data used

The survey data include information on hauls, haul position, length frequency for all species and biological data (age, maturity, sex, weight).

For the purpose of the assessment, the indices for numbers-at at-age per 10 hours (for age groups 1+) were converted to survey biomass-at-age per 10 hours using catch weights-at-age. The latter were assumed to represent stock weights-at-age. Finally, survey biomasses-at-age per 10 hours were summed up giving the total survey biomass per 10 hours.

A.7 Commercial CPUE

Four commercial catch-effort dataseries were previously available to the WG including:

- Scottish light trawlers (ScoLTR): ages 1–7, years 1965–2005;
- Scottish seiners (ScoSEI): ages 1–6, years 1965–2005;
- Scottish *Nephrops* trawlers (ScoNTR): ages 1–6, years 1965–2005;
- Irish Otter Trawlers (IreOTB); ages 1–7, years 1995–2005.

Given the problems with non-mandatory effort reporting in the UK (described further in the report of WGNSSK for 2000; ICES, 2001), these CPUE series have not been used for a number of years.

B.5. Other relevant data

Fecundity data for a number of areas are available from Hislop and Hall (1974), and was estimated at $4.933 \times L^{3.25}$ for whiting in Subarea 6, where L is fish length.

B. Assessment methods and settings

B.1 Previous assessments

Previous assessments of whiting in Division 6.a (till 2019) were conducted with TSA. At that time, the stock was classified as category 1. The benchmark process of WKDEM 2020 revealed substantial problems with getting a satisfactory TSA assessment. This was a result of poorly converged optimisation runs (with the modified survey configuration) in conjunction with excessive running times. Therefore, it was decided *ad hoc* to run the benchmark assessment using an alternative method, the age-aggregated stochastic Surplus Production in Continuous Time (SPiCT) model

(Pedersen and Berg, 2017). At the same time, the stock was downgraded to category 3 according to the ICES guidelines for data-limited stocks (ICES, 2019).

B.2 Current assessment

Model used: SPiCT (Surplus Production in Continuous Time)

Software used: SPiCT is implemented as an R package that can be downloaded from https://github.com/DTUAqua/spict (SPiCT version 1.2.8@ca04322e).

Model Options chosen:

- Catch time-series: 1978–last year
- Uncertainties around catch time-series:
  - 1978–1994 and 2006–last year: 1
  - 1995–2005: 4
- Surveys
  - ScoGFS-WIBTS-Q1 (old Scottish Q1 survey),
  - UK-SCOWCGFS-Q1 (new Scottish Q1 survey),
  - IGFS-UK-SCOWCGFS-Q4 (combined Irish and Scottish Q4 survey) and
  - IGFS-Q4 (truncated Irish Q4 survey)
- Priors: fixed n=2

Input data types and characteristics:

Type	Name	Year range	Age range*	Variable from year to year Yes/No
Caton	Catch in tonnes	1978–last year	1 to 7+	Yes
Weca	Weight-at-age in the commercial catch	1978–last year	1 to 7+	Yes
West=Weca	Weight-at-age of the spawning stock at spawning time	1978–last year	1 to 7+	Yes

* Age groups that were included in the total catch calculation.

Survey indices:

Type	Name	Note	Year range	Age range*
Tuning fleet 1	ScoGFS-WIBTS-Q1	old Scottish Q1 survey	1985–2010	1 to 7+
Tuning fleet 2	UK-SCOWCGFS-Q1	new Scottish Q1 survey	2011–last year	1 to 7+
Tuning fleet 3	IGFS-UK-SCOWCGFS-Q4	combined Irish and Scottish Q4 survey	2011–last year	1 to 7+
Tuning fleet 4	IGFS-Q4	truncated Irish Q4 survey	1985–2010	1 to 6**

* Age groups that were included in the survey biomass calculation.

** The index for whiting in the Irish survey is reported up to age 6.

C. Short-Term Projection

WKDEM (in 2020) proposed that this stock should be treated as a data-limited category 3 stock with advice provided accordingly and hence no short-term forecast is required.

In previous years, WGCSE used FLAssessfor short-term prediction.

The recruitment value was derived from TSA and used in the forecast for the assessment year. For the following year, the geometric mean for a 10-year period (preceding the assessment year) was used.

A three-year mean exploitation pattern was taken to represent *status quo* fishing mortality.

Input data to the short-term projection were summarised each year giving potential management options.

The contribution of different sources of uncertainty to the variance of predicted SSB and yield was estimated where possible by means of sensitivity analysis.

At present, with the current assessment model, no short–term prediction is being conducted.

D. Medium-Term Projection

No medium-term projections were conducted for this stock.

E. Long-Term Projection

No long-term projections were conducted for this stock.

F. Biological Reference Points

The SPICT assessment agreed at the benchmark in 2020 (WKDEM) was accepted for the provision of category 3 stock advice but not for the derivation of reference points.

In previous years (up to 2014), WGCSE considered the reference points listed below:

Reference point	Value	Technical basis
B_{lim}	16 000 t	B_{loss} (SSB in 1998 as estimated at the 1999 WG)
B_{pa}	22 000 t	1.4 × B_{lim}
F_{lim}	1.0	F above which stock decline has been observed
F_{pa}	0.6	

(ICES, 2015a).

The WG explored the use of the srmsymc package for defining MSY reference points (ICES, 2012). Estimates of F_{MSY} and potential proxies (e.g. F_{MAX}) were highly uncertain and parameter values were successfully estimated on only 50% of iterations for all three stock–recruit relationships. Consequently, the WG concluded that the data did not support the provision of estimates of F_{MSY}.

IBPWSRound attempted to estimate F_{MSY} using the procedure EqSim developed by WKMSYREF3 (ICES, 2014). It was applied to produce median yield and F estimates for whiting in Division 27.6.a. The year range used for the biological and selectivity data was ten years, which was considered the default option by WKMSYREF3. The F_{MSY} estimates were deemed as too uncertain and were not included in the 2015 assessment.

To provide an update for B_{lim}, IBPWSRound proposed to use the SSB value at the change point in the segmented regression stock–recruitment function (ICES, 2015b).

The reference points were explored further by WKMSYREF4 (ICES, 2016) and updated by WGCSE in 2016. Their values (after rounding) from 2015 to 2019 are summarised in the table below:

Reference point	IBPWS-Round	WGCSE 2015	WKMSY-REF4	WGCSE 2016	Rationale (WKMSYREF4)
B_{lim}	28 500 t	28 500 t	28 500 t	31 900 t	SSB value at the change point in the segmented regression stock–recruit function.
B_{pa}	39 900 t	39 900 t	39 900 t	44 600 t	B_{lim} × 1.4
F_{lim}	Not defined	Not defined	0.25	0.27	Based on segmented regression simulation of recruitment with B_{lim} as the breakpoint
F_{pa}	Not defined	Not defined	0.18	0.19	F_{lim}/1.4
F_{MSY}	0.22	Not defined	0.22	0.23	with $B_{trigger}$(=B_{pa})
		Not defined	0.16	0.18	upper precautionary with $B_{trigger}$(=B_{pa})
F_{MSY} upper		Not defined	0.34	0.32	with $B_{trigger}$(=B_{pa})
F_{MSY} lower		Not defined	0.16	0.15	with $B_{trigger}$(=B_{pa})
MSY $B_{trigger}$	39 900 t	Not defined	39 900 t	44 600 t	B_{pa}
Median SSB at F_{MSY}	45 600 t	Not defined	36 600		The estimate obtained by running the procedure EqSim.

At present, with the current assessment model, no reference points are defined.

G. Other Issues

G.1 Historical overview of previous assessment methods

Data	2016 assessment	2017 assessment	2018 assessment	2019 assessment
Method	TSA	TSA	TSA	TSA
Catch data	Years: 1981–2015 Ages: 1–7+	Years: 1981–2016 Ages: 1–7+	Years: 1981–2017 Ages: 1–7+	Years: 1981–2018 Ages: 1–7+
Survey: ScoGFS-WIBTS-Q1	Years: 1985–2010 Ages: 1–7	Years: 1985–2010 Ages: 1–7	Years: 1985–2010 Ages: 1–7	Years: 1985–2010 Ages: 1–7
Survey: ScoGFS-WIBTS-Q4	Years: 1996–2009 Ages: 0–7	Years: 1996–2009 Ages: 0–7	Years: 1996–2009 Ages: 0–7	Years: 1996–2009 Ages: 0–7
Survey: IGFS-Q4	Years: 2003–2015 Ages: 0–7	Years: 2003–2016 Ages: 0–7	Years: 2003–2017 Ages: 0–7	Years: 2003–2018 Ages: 0–7
Survey: UK-SCOWCGFS-Q1	Years: 2011–2016 Ages: 1–7	Years: 2011–2017 Ages: 1–7	Years: 2011–2018 Ages: 1–7	Years: 2011–2019 Ages: 1–7
Survey: UK-SCOWCGFS-Q4	Years: 2011–2015 Ages: 0–7	Years: 2011–2016 Ages: 0–7	Years: 2011–2017 Ages: 0–7	Years: 2011–2018 Ages: 0–7

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