Stock Annex: Whiting (*Merlangius merlangus*) in Subarea 4 and Division 7.d (North Sea and eastern English Channel)

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

Stock	Whiting
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Created	
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A. General

A.1. Stock definition

The areas included in this whiting assessment are Subarea 4 (North Sea) and Division 7.d (Eastern English Channel). The rationale for this is based more on negotiated management units and the doctrine of relative quota stability, rather than biology or ecosystem characteristics.

Whiting are known to aggregate in some localised areas, but for the most part are caught as part of a mixed-fishery operating throughout the entire year. Adult whiting are widespread in the North Sea (although with a patchy distribution), while high numbers of immature fish occur off the Scottish coast, in the German Bight and along the coast of the Netherlands.

Tagging experiments, and the use of a number of fish parasites as markers, have shown that the whiting found to the north and south of the Dogger Bank form two virtually separate populations (Hislop and MacKenzie, 1976). It is also possible that the whiting in the northern North Sea may contain "inshore" and "offshore" populations, while there is evidence of links between the northern North Sea whiting stock and the neighbouring stock in Division 6.a (currently conceptually separated by an *ad hoc* line at 4°West). The report of the SGSIMUW (ICES, 2005) documented much of the early the work performed on whiting stock identity issues.

The 2018 benchmark (WKNSEA 2018) explored again the problem of whiting stock definition in more detail. The precise location of any north–south split in the North Sea itself is difficult to determine but a suggestion was made by Holmes *et al.* (2014). Literature suggest a spatial split in spawning aggregations during spawning season. Comparative SURBAR results by area, using area-specific survey indices and area-specific maturity at age estimates, indicate that North Sea stock dynamics are dominated by the northern component. Survey indices and maturity estimates for the northern component are found to be more consistent and less fluctuating over time than for the southern component. Nevertheless, with the recent increase in estimated recruitment and SSB in the southern component, management decisions appropriate for the combined stock are not expected to negatively impact the southern component at this point. The issue of stock definition for whiting is to be revisited at

a future date when further sampling and data confirm a continuous split throughout the year.

A.2. Fishery

For North Sea whiting, there are three distinct areas of major catch: a northern zone, an area off the eastern English coast; and a southern area extending into the English Channel.

Northern area

In the northern area, roundfish are caught in otter trawl and seine fisheries, with a 120 mm minimum mesh size since 2002. These are mixed demersal fisheries with more specific targeting of individual species in some areas and/or seasons. Cod, haddock and whiting form the predominant roundfish catch in the mixed fisheries, although there can be important bycatches of other species, notably saithe and anglerfish in the northern and eastern North Sea and *Nephrops* in the more offshore *Nephrops* grounds. The minimum mesh size in *Nephrops* trawls is 80 mm but a range of larger mesh sizes and selection grids are also sometimes used when targeting *Nephrops*. Whiting is an important species for the Scottish fleet, with many vessels actively targeting whiting during some fishing trips. Technological developments have included a shift towards pair trawling and the development of double bag trawls which reduce costs compared to twin trawling. A number of vessels use 90 mm mesh gears with a 120 mm square mesh panel close to the codend, a configuration which releases cod.

Eastern English coast

Whiting are an important component in the mixed fishery occurring along the English east coast. Industry reports suggest better catch rates are achieved here than implied by the overall North Sea assessment.

General

Whiting are a bycatch in some *Nephrops* fisheries that use a smaller mesh size, although landings are restricted through bycatch regulations. They are also caught in flatfish fisheries that use a smaller mesh size. Industrial fishing with small-meshed gear is permitted, subject to bycatch limits of protected species including whiting. Regulations also apply to the area of the Norway pout box, preventing industrial fishing with small meshes in an area where the bycatch limits are likely to be exceeded.

Historically, bycatch of whiting by industrial fisheries for reduction purposes was an important part of the catch, but due to the recent reduced fishery for sandeel and Norway pout the impact of this fishery on the whiting stock is considered to be much lower.

A.3. Ecosystem aspects

Whiting is a key species in the tropho-dynamics of the North Sea, both as predator and as prey, and also exhibits strong cannibalism. Information on the natural mortality exerted on whiting by predation and cannibalism, and the mortality exerted by whiting on other species, is evaluated through biennial runs of the stochastic age–length structured multispecies model (SMS; Lewy and Vinther, 2004) provided by ICES, WGSAM, most recently in 2020 (ICES, 2021a).

B. Data

B.1. Commercial catch

Human consumption landings

For North Sea catches, human consumption landings data are provided by Scotland, England, France, the Netherlands, Denmark, Belgium, Sweden, Norway and Germany. In recent years, landings age compositions are provided by Scotland, England, and France. For eastern Channel catches, human consumption landings data and age compositions are supplied by England and France.

Industrial bycatch

Since 1991, the age composition of the Danish industrial bycatch has been directly sampled, whereas it was calculated from research vessel survey data during the period 1985–1990. Whiting industrial bycatch has been relatively low since 1996 due to the limited fishery for Norway pout and a reduced sandeel fishery in several years.

In 2006 the samples used to raise Danish industrial bycatches (accounting for 98% of the industrial bycatch that year) were taken from Norwegian vessels whose catches have a different age structure. The data for 2006 have been replaced with an estimate $\hat{n}_{a,y}$ given by:

$$\hat{n}_{a,y} = \hat{N}_y \hat{p}_a ,$$

where $\hat{p}_a$ is the mean proportion-at-age over the years 1980 to 2005, and $\hat{N}_y$ is estimated to give a sums of products correction (SOP) factor of 1 by:

$$\hat{N}_y = \frac{W_y}{\sum_a \hat{p}_a \hat{w}_a} ,$$

where W_y is the reported weight of industrial bycatch. Here $\hat{w}_a$ have been estimated by taking the mean weights-at-age in the industrial bycatch over the period 1995 to 2005 (zero weights were taken as missing values). In recent years no age samples are provided for industrial bycatch, and age allocations are done using age samples of all catches. Since 2009, catch weights-at-age were used for industrial bycatch.

Discards

Discard rates for unsampled whiting fleet components in Subarea 4 and Division 7.d are obtained from samples provided by Denmark, Germany, Belgium, Netherlands, France and the UK (Scotland, England). Age samples of discards are provided by Denmark, UK, and France.

Compilation of international catch–at–age

From 2009, international catch data (landings, industrial bycatch, discards and BMS landings) have been collated within the InterCatch system provided by ICES. Discard rates are allocated to unsampled fleets following decisions made during the recent benchmark process. Industrial bycatch landings are not associated with discards.

Age compositions for landings and discards are calculated as weighted means across contributing fleets, where the weights are the landed yield for the fleets. The resultant age compositions are then applied to unsampled fleets as deemed appropriate by the

stock coordinator, following best-practice advice from ICES and decisions during the benchmark process. Some discard data, for example from Scotland, are submitted to this system on an annual basis, as sampling rates are thought to be insufficient to justify the quarterly data provided by most countries. The protocol applied within InterCatch is to divide these annual discards equally among the four quarters, which is a tractable solution but may introduce bias.

Years included in the time-series

In 2002, the assessment working group (WGNSSK) decided to truncate the catch data to start from 1980. This was due to the very large change in estimated recruitment levels around 1980 that was present in the assessment. The working group could not determine whether this was due to a shift in the recruitment regime or because discard data for years prior to 1978 were not measured but estimated according to a discard ogive. This may not have been representative of discarding during the earlier period. Biological reference points for this stock had originally been established on the basis of the truncated series, so this represented no change with respect to them.

Following ICES, WKROUND (2009), the time-series of catch data was truncated further to start from 1990. The incentive for this decision was the comparison of a catch-at-age based assessment (XSA) with a survey-based assessment (SURBA). The SURBA run indicated that estimated SSB in the earlier part of the time-series (during the 1980s) was low and then rose to a higher level in the 1990s before returning to the low level in the 2000s and beyond. Conversely, the XSA run suggested that the maximum SSB occurred during the 1980s (following three large year classes), and that the stock trend has roughly been downwards ever since. In other words, the survey and catch data generated very different perceptions of stock dynamics before 1990. All data sources are consistent after 1990, which was therefore chosen as a cut-off point.

ICES, WKROUND (2013) revisited the issue of the length of the assessment time-series in considerable depth. Sensitivity analyses showed that catch data would need to be reduced by around 75% for the years prior to 1990 for the survey-based and catch-based assessments to concur and no reason for this discrepancy could be found. The truncation was therefore retained in the interests of parsimony.

ICES, WKNSEA 2018 addressed the issue of time-series length during the benchmark process using SAM and new updated input data. Survey data are deemed appropriate starting at 1983 and are used only from 1983 in the assessment. SURBAR, SAM and XSA showed relative agreement in dynamics. Inconsistencies in the beginning of the time-series are not perceived large enough to justify a truncation of the series. The SAM assessment makes use of survey data starting in 1983 and catch data starting in 1978.

B.2. Biological

Weights-at-age

Weight-at-age in the stock are assumed to be proportional to weight-at-age in the catch.

Following the evaluation of weights-at-age in survey catches, WKNSEA 2018 concluded that commercial catch weights-at-age aggregated for the entire year may overestimate stock weights-at-age in the beginning of the year. As a complete survey time-series is not available for the period since 1978, the commercial catch weight-at-

age time-series is corrected using the IBTS Q1 survey weights-at-age from 2000 onwards.

Natural mortality

Natural mortality-at-age M is currently defined from the most recent key run of the stochastic age–length structured multispecies model (SMS; Lewy and Vinther, 2004) produced biennially for the North Sea ecoregion by ICES WGSAM (ICES, 2021a). Natural mortality estimates are smoothed for the assessment.

Maturity

The maturity ogives are updated annually based on North Sea IBTS quarter 1 data (WKNSEA 2018). Data are raised following ICES, WKMOG (2008). A composite maturity ogive is calculated using maturity data for northern North Sea and southern North Sea weighted by area-specific catch rates. Maturity ogives are produced by modelling the proportion of mature individuals as a binomial GLM with logit link and factors age and year. Maturity estimates are smoothed for all ages, with individual older than 6 as a plus group.

Spawning occurs in spring. Both the proportion of natural mortality before spawning (M_{prop}) and the proportion of fishing mortality before spawning (F_{prop}) are set to zero.

B.3. Surveys

International Bottom Trawl Survey (IBTS) Q1 survey is undertaken in January to March (target month February), Q3 survey takes place in July to September (target month August). Biological data are collected including length, weight, sex and maturity and ageing material. The survey covers depths of roughly 35 m to 200 m in the whole of the North Sea basin (Figure B.3.1). The IBTS indices combine haul data from multiple vessels belonging to national institutes. As such they use a higher density of survey stations than the constituent national surveys, with several hauls per statistical rectangle.

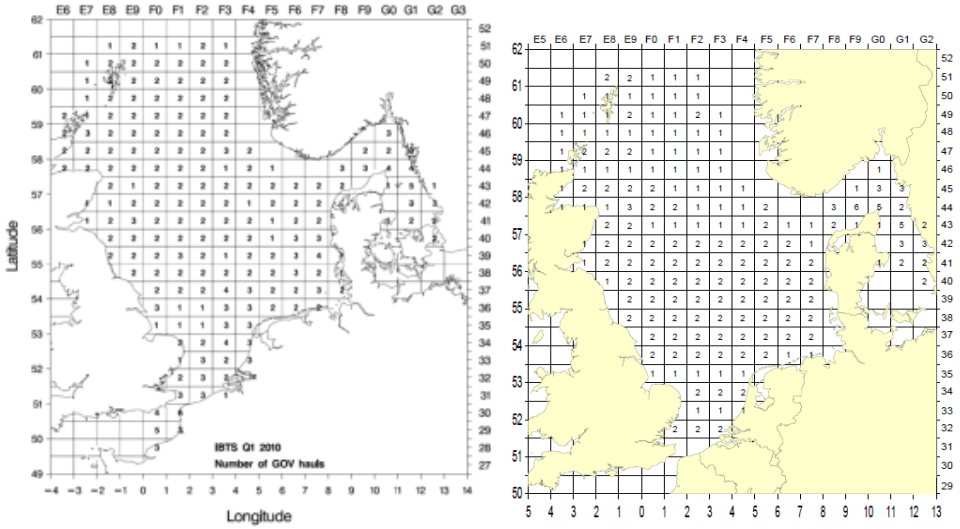

Figure B.3.1. Number of GOV trawl hauls per ICES rectangle in the IBTS Q1 survey in 2010 (left hand plot) and the IBTS Q3 survey in 2009 (right hand plot). Source: ICES IBTSWG reports.

In previous assessments the Scottish third quarter Groundfish Survey (Sco-IBTS-Q3) and English third quarter Groundfish Survey (EngGFS-IBTS-Q3) were used as independent surveys. The Sco-IBTS-Q3 is carried out in August each year, and covers depths of roughly 35 m to 200 m in the North Sea to the north of the Dogger Bank. It samples at most one survey station per statistical rectangle. In 1998 the coverage of this survey was extended into the central North Sea, but the index available to the Working Group has been modified so as to cover a consistent area throughout the time-series. The English third quarter Groundfish Survey (EngGFS-IBTS-Q3) is carried out in August each year, and samples at most one station per rectangle. It covers depths of roughly 35 m to 200 m in the whole of the North Sea basin. In 1991 the EngGFS-IBTS-Q3 changed fishing gear from the Granton trawl to the GOV trawl.

The time-series of the survey indices of whiting supplied by the French Channel Groundfish Survey (CGFS) was revised in 2002. In 2001, the Eastern Channel was split into five zones. Abundance indices were first calculated for each zone, and then averaged to obtain the final CGFS index. This procedure was not thought to be entirely satisfactory, as the level of sampling was inconsistent across geographical strata. In 2002, it was thought more appropriate first to raise abundance indices to the level of ICES rectangles, and then to average those to calculate the final abundance index. Previous to the 2002 WG, only the hauls in which whiting were caught were used to derive abundance indices. This procedure biased estimates, and therefore, the indices supplied from 2002 were calculated on the basis of all hauls. However lack of internal consistency of this series means it has not been used in the assessment to date.

There is an unresolved problem in that the surveys available provide a different indication of stock trends before 1990 compared to an assessment based on catch data. The IBTS indices combine haul data from multiple vessels belonging to national institutes and periodically these vessels were replaced. In 1998 FRS (Aberdeen) introduced a new survey vessel; it was considered at the time that no evidence existed to say the new vessel had different catchabilities to the old vessel (Zuur *et al*., 2001). This is now generally considered not to be the case. ICES, WKROUND (2009) investigated the possibility that changes in survey catchability over the period from the mid-1980s to the mid-1990s accounts for this mismatch. The required change in catchability was estimated to be approximately a factor of two. Details of the investigations can be found in the benchmark report. Evidence for a change in catchability was not found (although the meeting recommended further work) but the following was concluded with respect to survey data.

Only IBTS-Q1 and IBTS-Q3 indices should be used. The Sco-IBTS-Q3 and EngGFS-IBTS-Q3 are incorporated into the IBTS-Q3 survey which involves several other fleets and is likely to better represent the North Sea as a whole (Figure B.3.1).

The IBTS-Q1 survey should only be used from 1983 because the gear employed was not standardised before this date.

The IBTS-Q1 and IBTS-Q3 data can be downloaded from the DATRAS website at http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx.

B.4. Commercial CPUE

Effort data are available for two Scottish commercial fleets: seiners (SCOSEI) and light trawlers (SCOLTR), both for the years 1978-2006. Non-mandatory reporting of

fishing effort for these fleets means that they cannot be viewed as reliable for use for catch-at-age tuning.

Effort data are available for two French commercial fleets: otter trawl (FRATRO) 1986–2006 and beam trawl (FRATRB) 1978–2001. The same comment on non-mandatory reporting of fishing effort applies to these fleets.

B.5. Other relevant data

The North Sea Fishers' Survey presents fishers' perceptions of the state of several species including whiting. The survey covers the years 2003 to the present.

C. Assessment: data and method

The following outlines the method currently used for North Sea whiting. WKNSEA (2018) considered that recent trends in the North Sea and eastern Channel whiting stock are appropriately estimated by the current assessment and are suitable for providing management advice. The assessment uses survey data from 1983 and catch data from 1978, and recruitment at age 0 in the model. The state–space model (SAM: Nielsen, 2010; Nielsen and Berg, 2014) used for North Sea whiting offers a flexible way of describing the entire stock dynamic with relatively few model parameters. It allows for objective estimation of important variance parameters, leaving out the need for subjective *ad hoc* adjustment numbers, which is desirable when managing natural resources. It also allows for error in input data and provides estimates of uncertainty in summary statistics. In WKNSEA 2018, SAM is selected as the baseline assessment method.

Model used: SAM. A SURBAR run (with smoothing parameter λ set to 5.0) will also be conducted to provide corroboration of the SAM run.

Software used: The baseline software is SAM.

Model settings chosen:

$minAge

0

$maxAge

8

$maxAgePlusGroup

1

$keyLogFsta

0 1 2 3 4 5 6 7 7

-1 -1 -1 -1 -1 -1 -1 -1 -1

-1 -1 -1 -1 -1 -1 -1 -1 -1

$corFlag

2

$keyLogFpar

-1 -1 -1 -1 -1 -1 -1 -1 -1

-1 0 1 2 3 3 -1 -1 -1

```
  4  5  6  7  8  8 -1 -1 -1
$keyQpow
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarF
  0  0  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
$keyVarLogN
 0 1 1 1 1 1 1 1 1
$keyVarObs
  0  1  1  1 1  1  1  1  1
 -1  2  2  2  2  2 -1 -1 -1
  3  3  3  3  3  3 -1 -1 -1
$obsCorStruct
 "ID" "AR" "AR"
$keyCorObs
  NA  NA  NA  NA  NA  NA  NA  NA
 -1  0  1  1  1 -1 -1 -1
  2  2  3  3  3 -1 -1 -1
$stockRecruitmentModelCode
 0
$noScaledYears
 0
$keyScaledYears
$keyParScaledYA
$fbarRange
 2 6
$keyBiomassTreat
 -1 -1 -1
$obsLikelihoodFlag
 "LN" "LN" "LN"
$fixVarToWeight
 0
```

Input data types and characteristics:

TYPE	NAME	YEAR RANGE	AGE RANGE	VARIABLE FROM YEAR TO YEAR YES/NO
Caton	Catch in tonnes	1978-	NA	Yes
Canum	Catch-at-age in numbers	1978-	0-8+	Yes
Weca	Weight-at-age in the commercial catch	1978-	0-8+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1978-	0-8+	Yes
Mprop	Proportion of natural mortality before spawning	1978-	0-8+	No
Fprop	Proportion of fishing mortality before spawning	1978-	0-8+	No
Matprop	Proportion mature at age	1978-	0-8+	Yes
Natmor	Natural mortality	1978-	0-8+	Yes

Tuning data:

TYPE	NAME	YEAR RANGE	AGE RANGE
Tuning fleet 1	IBTS-Q1	1983-	1-5 (age 6+ not used)
Tuning fleet 2	IBTS-Q3	1991-	0-5 (age 6+ not used)

D. Short-term projection

Model used: Deterministic short-term catch forecast

Software used: MFDP.

Initial stock size: SAM assessment results.

F and M before spawning: Fixed at 0.0.

Maturity: Recent three-year average at age.

Weight-at-age in the stock: Recent three-year average at age.

Weight-at-age in the catch: Recent three-year average at age, by catch component (landings, discards, industrial bycatch).

Exploitation pattern: Recent three-year average exploitation pattern by catch component, scaled to the last historical year.

Intermediate year assumptions: No TAC constraint.

Recruitment assumption: Geometric mean of recruitment (age 0) in the historical assessment since 2002.

Procedures used for splitting projected catches: The partial F at age for each catch component is estimated by splitting the forecast F at age using the mean proportion in the catch of each catch component over the last three historical years.

E. Medium-term projections

Regular medium-term projections are not undertaken for this stock. Forward stochastic simulations of a similar nature are conducted as part of management strategy evaluations for North Sea whiting, but as these are done every three or four years and outwith the assessment Working Group, they are not considered further here.

F. Long-term projections

See comments for medium-term projections above.

G. Biological reference points

In 2016, ICES requested precautionary and limit reference points for all stocks. The expert group proposed values, which were reviewed by RGPA and finalized in the ADG_NorthSea_2016. During the benchmark WKNSEA in 2018, new assessment model and input data are introduced. In 2021, and interbenchmark was conducted to assess the impact of new natural mortality estimates from WGSAM (ICES, 2021a) on the assessment, and calculate new reference points (ICES, 2021b). Reference points are updated using EqSim. Estimates were determined using the SAM assessment results (1983–2019) and segmented regression as stock–recruit model.

These are the reference points used in the 2021 advice. More information is available in the interbenchmark report (ICES, 2021b).

The updated reference points and their technical bases are as follows.

FRAMEWORK	REFERENCE POINT	VALUE	TECHNICAL BASIS	SOURCE
MSY approach	MSY $B_{trigger}$	143 905 t	B_{pa}	ICES (2021b)
	F_{MSY}	0.371	F leading to 5% probability to fall below B_{lim}	ICES (2021b)
Precautionary approach	B_{lim}	103 560 t	B_{loss} (SSB in 2007 in the 2020 assessment)	ICES (2021b)
	B_{pa}	143 905 t	$B_{lim} \times \exp(1.645\sigma B)$; $\sigma B = 0.2$	ICES (2021b)
	F_{lim}	0.718	F leading to 50% probability to fall below B_{lim}	ICES (2021b)
	F_{pa}	0.385	$F_{p.05}$	ICES (2021b)

H. References

Hislop, J. R. G. and MacKenzie, K. 1976. Population studies of the whiting *Merlangius merlangus* (L.) of the northern North Sea. *J. Cons. int. Explor. Mer* **37** (1): 98–110.

Holmes, S. J., Millar, C. P., Fryer, R. J., and Wright, P. J. 2014. Gadoid dynamics: differing perceptions when contrasting stock vs. population trends and its implications to management. ICES Journal of Marine Science, 71: 1433–1442.

ICES. 2005. Report of the study group on stock identity and management units of whiting (SGSIMUW), 15–17 March 2005, Aberdeen, UK. ICES CM 2005/G:03: 50 pp.

ICES. 2018. Interim Report of the Working Group on Multispecies Assessment Methods (WGSAM), 16–20 October 2017, San Sebastian, Spain. ICES CM 2017/SSGEPI:20: 395 pp.

ICES. WKROUND 2009. Report of the Benchmark and Data Compilation Workshop for Roundfish (WKROUND). ICES CM 2009/ACOM:32.

ICES. WKROUND 2013. Report of the Benchmark Workshop on Roundfish Stocks 4–8 February 2013 in Aberdeen, Scotland. ICES CM 2013/ACOM:47.

ICES. 2018. Report of the Benchmark Workshop on North Sea Stocks (WKNSEA 2018), 5–9 February 2018, Copenhagen, Denmark. ICES CM 2018/ACOM:33. 634 pp.

ICES. 2021a. Working Group on Multispecies Assessment Methods (WGSAM; outputs from 2020 meeting). ICES Scientific Reports. 3:10. 231 pp. https://doi.org/10.17895/ices.pub.7695

ICES. 2021b. Inter-benchmark Protocol of North Sea Whiting (IBPNSWhiting). ICES Scientific Reports. 3:34. 38 pp. https://doi.org/10.17895/ices.pub.7924

Lewy P. and Vinther M. 2004. A stochastic age–length-structured multispecies model applied to North Sea stocks. ICES CM/FF 2004:20–33.

Nielsen, A. 2010. State–space fish stock assessment model. http://www.stockassessment.org.

Nielsen, A., and Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state–space models. Fisheries Research, 158: 96–101.

Zuur, A.F, Fryer, R.J. and Newton, A.W. 2001. The comparative fishing trial between *Scotia II* and *Scotia III*. Fisheries Research Services (FRS) Marine Laboratory Rep. No. 03/01.