Stock Annex: Haddock (*Melanogrammus aeglefinus*) in Subarea 4, Division 6.a and Subdivision 20 (North Sea, West of Scotland, Skagerrak)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Haddock
Working Group:	Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
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A. General

A.1. Stock definition

Haddock in Subarea 4 and divisions 3.aW and 6.a (North Sea, Skagerrak and West of Scotland) are assessed as one stock, following the WKHAD meeting in February 2014, although quota advice is provided for the three areas separately as they are still managed on this basis. In the following text, the stock is referred to as Northern Shelf haddock for brevity.

A relatively continuous and unbroken spatial distribution of haddock extends from the west coast of Scotland, around the north of Scotland and into the the northern and central North Sea and Skagerrak. Genetic and biological marker studies suggest the possibility that a biologically distinct stock inhabits the Clyde area (in the far south-east of Division 6.a), but there is insufficient knowledge to provide a separate assessment of that stock and the area remains incorporated in the full Northern Shelf stock. A number of different spawning aggregations for haddock exist in the total stock area, mainly around the east and west coasts of Scotland. The haddock found in the Skagerrak consist mainly of younger fish.

Haddock are pelagic during the first half year of life (as eggs and larvae) and are transported both from the West of Scotland into the North Sea (as eggs and free-floating larvae, following the prevailing currents), and from the North Sea to the West of Scotland (as juveniles). Adult haddock are thought to be more sedentary.

Haddock are seldom found below 300 m in this area, although Rockall (Division 6.b) haddock can be found much deeper, and North Sea haddock prefer depths between 50 m and 200 m. They are found as juvenile fish in coastal areas in particular in the Moray Firth, around Orkney and Shetland, along the continental shelf at around

200 m and continuing round to the Skagerrak. Adult fish are predominantly found around Shetland and in the northern North Sea near the continental shelf edge.

The choice to assess haddock in the whole area (merging the former stocks in Division 6.a with the stock in Division 3.aW and Subarea 4) was based on a number of factors, including:

1. the problem in assessing the West of Scotland stock due to misreporting of landings from that area into the North Sea;
2. consistent patterns of recruitment in all former notional substocks, and relatively unbroken survey- and catch-based patterns of spatial distribution across all areas; and
3. the high likelihood of area inter-mixing at the egg, larval and juvenile stage, as evidenced by otolith micro-chemistry analyses and particle tracking studies.

A.2. Fishery

The haddock fishery is this area is principally undertaken by the Scottish demersal whitefish fleet, which receives the bulk of the available quota and consequently takes the largest proportion of the haddock stock. This fleet is not just confined to the Northern Shelf, as vessels will sometimes operate in Divisions 6.b (Rockall) and 5.b (Faeroes). The demersal fisheries in the Northern Shelf are predominantly conducted by trawlers fishing for cod, haddock, anglerfish and whiting, with bycatches of saithe, megrim, lemon sole, ling and several species of skate (along with other, less commercial species).

In the North Sea the main fisheries are carried out by demersal trawlers (single, twin, and pair), and (to a lesser extent) by seiners. Haddock are a specific target for some fleets, but are also caught as part of a mixed fishery catching cod, whiting, and *Nephrops*. The minimum permitted mesh size for targeted fisheries was increased to 120 mm in 2002. Estimates of haddock bycatch in the industrial fisheries for sandeel and Norway pout are low. Haddock in Division 6.a is caught mainly by Scottish and Irish bottom trawlers, which target mixed demersal fish assemblages. Catches are widely distributed and are concentrated in several areas, e.g. the Butt of Lewis and on the shelf west of the Outer Hebrides.

A.2.1. Management plans

As Northern Shelf haddock are still managed according to the previously-implemented stock definitions, details on extant management plans and technical regulations are given below in separate area-specific sections.

Subarea 4 and Division 3.a

In 1999 the EU and Norway "agreed to implement a long-term management plan for the haddock stock, which is consistent with the precautionary approach and is intended to constrain harvesting within safe biological limits and designed to provide for sustainable fisheries and greater potential yield." This plan was implemented in

January 2005, updated in December 2006, and implemented in revised form in January 2007. It consists of the following elements:

4. Every effort shall be made to maintain a minimum level of Spawning Stock Biomass greater than 100 000 tonnes (B_{lim}).
5. For 2007 and subsequent years the Parties agreed to restrict their fishing on the basis of a TAC consistent with a fishing mortality rate of no more than 0.3 for appropriate age-groups, when the SSB in the end of the year in which the TAC is applied is estimated above 140 000 tonnes (B_{pa}).
6. Where the rule in paragraph 2 would lead to a TAC which deviates by more than 15% from the TAC of the preceding year the Parties shall establish a TAC that is no more than 15% greater or 15% less than the TAC of the preceding year.
7. Where the SSB referred to in paragraph 2 is estimated to be below B_{pa} but above B_{lim} the TAC shall not exceed a level which will result in a fishing mortality rate equal to $0.3\text{-}0.2*(B_{pa}\text{-SSB})/(B_{pa}\text{-}B_{lim})$. This consideration overrides paragraph 3.
8. Where the SSB referred to in paragraph 2 is estimated to be below B_{lim} the TAC shall be set at a level corresponding to a total fishing mortality rate of no more than 0.1. This consideration overrides paragraph 3.
9. In order to reduce discarding and to increase the spawning stock biomass and the yield of haddock, the Parties agreed that the exploitation pattern shall, while recalling that other demersal species are harvested in these fisheries, be improved in the light of new scientific advice from inter alia ICES.
10. In the event that ICES advises that changes are required to the precautionary reference points B_{pa} (140 000 t) or B_{lim} (100 000 t) the parties shall meet to review paragraphs 1–5.
11. No later than 31 December 2009, the parties shall review the arrangements in paragraphs 1 to 7 in order to ensure that they are consistent with the objective of the plan. This review shall be conducted after obtaining inter alia advice from ICES concerning the performance of the plan in relation to its objective.

In October 2007, ICES evaluated this plan and concluded that it could "provisionally be accepted as precautionary and be used as the basis for advice". The methods used to reach this conclusion (along with illustrative results) are given in Needle (2008). ICES considers that the agreed Precautionary Approach reference points in the management plan are consistent with the precautionary approach, provided they are used as lower boundaries on SSB, and not as targets.

The plan was modified during 2008 to allow for limited interannual quota flexibility, following the meeting in June of the Norway-EC Working Group on Interannual Quota Flexibility and subsequent simulation analysis (Needle, 2008).

Division 6.a

In 2009, following a request from the EC, ICES evaluated a proposal for a draft management plan for Division 6.a haddock, which was along similar lines to the EU-Norway management plan for North Sea haddock but with a different TAC constraint (±25% for biomass levels). Two more evaluations followed early in the following year after requests for modifications (Needle, 2010a; 2010b), and ICES concluded on the basis of these that the plan as presented was precautionary. However, the plan has not yet been implemented by fisheries managers in the area, and the Division 6.a part of the Northern Shelf stock continues to be managed on the basis of MSY considerations.

The TAC relating to this stock covers EU and international waters in both ICES divisions 5.b and 6.a.

A.2.2. Further technical conservation measures

Subarea 4 and Division 3.aW

Under the provisions laid down in point 8.5 of Annex IIa to the 2008 year's EU TAC and Quota Regulation, Scotland implemented in 2008 a national KWdays scheme known as the Conservation Credits Scheme. The principle of this two-part scheme involves credits (in terms of additional time at sea) in return for the adoption of and adherence to measures which reduce mortality on cod and lead to a reduction in dis discard numbers. The initial scheme was implemented from the beginning of February 2008 and granted vessels their 2007 allocation of days (operated as hours at sea) in return for observance of Real Time Closures (RTC) and a one-net rule, adoption of more selective gears (110 mm square meshed panels in 80 mm gears or 90 mm SMP in 95 mm gear), agreeing to participate in additional gear trials and participation in an enhanced observer scheme.

For the first part of 2008 the RTC system was designed to protect aggregations of larger, spawning cod (> 50 cm length). Trigger levels leading to closures were informed by commercial catch rates of cod observed by FRS on board vessels. During 2008, there were 15 such closures. Protection agency monitoring suggested good observance. A joint industry/ science partnership (SISP) undertook a number of gear trials in 2008 examining methods to improve selectivity and reduce discards and an enhanced observer scheme was announced by the Scottish Government.

The RTC system was expanded in 2009 (144 closures), 2010 (165 closures), 2011 (185 closures), 2012 (173 closures), 2013 (166 closures), 2014 (94 closures), 2015 (97 closures) and 2016 (96 closures by the end of September). The area covered by each closure has also been increased, and their shape can be modified to account for local bathymetry. Needle and Catarino (2011) used VMS data to analyse the movements of vessels affected by closures during 2009, and concluded that such vessels did move to areas of lower cod abundance during the first and third quarters (the second and fourth quarters were inconclusive). The possible impact on haddock mortality has not yet been evaluated.

Scotland has also been instrumental in the development of Catch Quota Management (http://www.scotland.gov.uk/Topics/marine/Sea-Fisheries/17681/catchquota). Participating vessels are fitted with CCTV and other remote electronic monitoring systems and are required not to discard any cod. Additional cod quota (up to 30%) is made available to these vessels, with the intention to "catch less and land more". In 2016, haddock were included in the EU Landing Obligation regulation, meaning that all haddock caught had to be landed. The consequent changes in fleet dynamics following these regulations are likely to have affected patterns of exploitation on haddock, and the implications will need to be considered carefully in future advice.

Division 6.a

The agreed minimum landing size for haddock in Division 6.a is 30 cm. Further regulations implemented for the west of Scotland include technical measures associated with the cod recovery plan (EC regulation 1342/2008) and emergency measures introduced with EC regulation 43/2009.

A.3. Ecosystem aspects

The Northern Shelf haddock stock is characterised by sporadically high recruitment leading to dominant year classes in the fishery. These large year classes may grow more slowly than less abundant year classes, possibly due to density dependent effects. Haddock primarily prey on benthic and epibenthic invertebrates, sandeels and demersal herring egg deposits. They are also an important prey species, mainly for other gadoids.

It is desirable to maintain spatial structure in spawning stock biomass; hence, spawning aggregations should be exploited approximately the same (i.e. experience the same exploitation rates) or managed with this objective, where possible. Existing spatial knowledge on spawning aggregations is currently insufficient to indicate exact areas that may need specific protection.

B. Data

B.1. Commercial catch

Subarea 4 and Division 3.a

In the North Sea and Skagerrak, three catch components are considered: landings for human consumption, discards and industrial bycatch. The sources of information on these components were as follows (this table dates from the 2010 assessment, but the sources are unchanged):

		Belgium		Denmark		France		Germany		Netherlands		Norway		Sweden		United Kingdon	
		WG	SA	WG	SA	WG	SA	WG	SA	WG	SA	WG	SA	WG	SA	WG	SA
Catches	Landings	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Discards	N	N	Y	Y	NP	N	Y	Y	NP	N	NP	N	Y	Y	Y	Y
Length Composition	Landings	NR	N	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Discards	NR	N	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Age/Length Key		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Age Composition	Landings	NP	N	Y	Y	NP	N	NP	NP	NP	N	Y	Y	Y	Y	Y	Y
	Discards	NP	N	Y	Y	NP	N	NP	NP	NP	N	NP	N	Y	Y	Y	Y
Weight at age		NP	N	Y	Y	NP	N	Y	Y	NP	N	Y	Y	Y	Y	Y	Y
Maturity Information		NR	N	NR	N	NR	N	NR	N	NR	NR	NR	NOR	NR	N	NR	NOR
Sex ratio		NR	N	NR	NR	NR	NR	NR	N	NR	NR	NR	N	NR	N	NR	NOR
Tuning fleets	Commercial fleets	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	NP	Y2	NBQ
	Surveys at sea	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	NP	Y3	Y3

In this table, the notes in the **WG** (Working Group) columns indicate the following: Y = provided to the WG, NP = not provided to the WG, and NR = not requested. In the **SA** (stock assessment) columns: Y = used in the assessment, NBQ = not used due to bad quality, NTS = not used due to short or inconsistent data time series, NOR = not used due to other reason, and NR = not relevant.

Division 6.a

The following table gives the source of landings data for Division 6.a haddock:

Country	Catch yield	Catch-at-age in numbers	Weight-at-age in the catch	Pproportion mature-by-age	Catch length composition
UK(NI)	X				
UK(E&W)	X				
UK(Scotland)	X	X	X	X	X
Ireland	X	X	X		X
France	X				
Norway	X				

Quarterly landings are provided by the UK (Scotland), UK (E/W), UK (NI), France and Ireland. The quarterly estimates of landings-at-age by UK (Scotland) and Ireland are raised to include landings by France, UK (NI) and Norway (distributed proportionately over quarters), then summed over quarters to produce the annual landings-at-age.

EU countries are now required under the EU Data Collection regulation to collect data on discards of haddock and other species. Up to 2003, estimates of discards were available only from UK (Scotland) and Ireland. Observer data are collected using standard at-sea sampling schemes. Results are reported to ICES.

The quantity, length and age of haddock discarded by Scottish Nephrops trawlers are collected during observer trips on board commercial vessels. Haddock discarded by boats using other gears (heavy trawl, seine, light trawl and pair trawl) are also collected by Scotland. Haddock discarded by otter board trawl and otter board/twin rig gears are collected by Ireland.

Discards from Scottish and Irish boats using several different gear types are estimated by observers.

Data used in the assessment

Numbers at age and yield in the three available catch components are summed across the two previous stock areas to generate the requisite data for the Northern Shelf assessment. Weights-at-age in the catch components (and in the stock) are calculated as the average of the weights from each area, weighted by catch abundance (see below).

The catch time-series used in the assessment includes data from 1972 onwards, which is the period for which there was age sampling of the industrial by-catch fishery. Earlier data on industrial bycatch were estimated rather than observed, and are not considered reliable. Discard sampling commenced on a statistically-defensible scale in 1978, which means that the assessment period include six years (1972–1977) during

which discard estimates were inferred by applying discard rates observed during 1978–1980 to earlier years.

B.2. Biological

Natural mortality

Natural mortality (M) for the Northern Shelf assessment is determined by the smoothed estimates produced by the most recent North Sea SMS key run. When a key run has not been conducted recently, the estimates of M for the last year of the most recent SMS run are to be used in all subsequent years up to the present.

Maturity

Maturity is set to be a knife-edge at age 3 for the Northern Shelf area (that is, maturity = 0.0 for ages 0–2, and maturity = 1.0 for ages ≥ 3). This is an interim measure until a more appropriate model of reproductive potential can be determined.

Weights:

The weights-at-age for each catch component are determined by national sampling programmes for length and weight, which are then collated through the Intercatch system. This approach generates weights-at-age for the two previous stock areas separately. The combined Northern Shelf weights-at-age are then given by the weighted means of the separate stock area values, weighted by the relevant catch-component abundance N. For example, to estimate Northern Shelf catch weight $W_{a,y}^{NSh}$ at age a in year y, calculate the weighted mean of the catch component weights:

$$W_{a,y}^{NSh} = \frac{N_{a,y}^{NS} W_{a,y}^{NS} + N_{a,y}^{WC} W_{a,y}^{WC}}{N_{a,y}^{NS} + N_{a,y}^{WC}}$$

Here NSh denotes Northern Shelf, NS denotes the North Sea and Skagerrak, and WC denotes the West Coast of Scotland.

B.3. Surveys

The Northern Shelf assessment uses two survey indices, as follows:

Area	Country	Quarter	Code	Year range	Age range
Subarea 4 and Division 3.a	International	Q1	IBTS Q1	1983-present	1-5
Subarea 4 and Division 3.a	International	Q3	IBTS Q3	1991-present	0-5

In addition, the following Division 6.a survey is used as a biomass index for separating the forecast between management areas.

Area	Country	Quarter	Code	Year range	Age range
Subarea 6.a	Scotland	Q1	ScoGFS-WIBTS Q1 (new)	2011-present	1-8

In recent assessments, exploratory data analysis using survey time-series has included:

1. Distribution plots by age and year.
2. Survey log CPUE by age.
3. Log survey catch curves by cohort.
4. Bivariate correlations of survey indices by cohort, with fitted regression lines. That is, indices at age 0 are plotted against indices at age 1 for each cohort, then age 0 against age 2, and so on for all age combinations.
5. Results of SURBAR model fits (Needle, 2012). These give estimated mean Z, relative SSB and relative recruitment trends, along with confidence intervals. Further details on SURBAR settings are given below (Section C).

Although they have not been included in WGNSSK reports before, WKHAD found the production of SPAY (standardized proportions at age) plots of catch and survey age compositions to be extremely valuable in understanding data problems, and recommends that they be presented by WGNSSK as a matter of course.

B.4. Commercial CPUE

Commercial CPUE (or LPUE) data are not used for tuning the final assessment. During preparations for the 2000 round of assessment WG meetings it became apparent that the 1999 effort data for the Scottish commercial fleets were not in accordance with the historical series and specific concerns were outlined in the 2000 report of WGNSSK (ICES WGNSSK, 2001). Effort recording is still not mandatory for these fleets, and concerns remain about the validity of the historical and current estimates of commercial CPUE. In addition, the LPUE indices from Scottish commercial fleets presented at previous WGs (ScoLtr and ScoSei) can no longer be generated in that form due to changes in EU definitions of fishery metiers. Data are also available from the Irish trawler fleet fishing in Division 6.a, but are not used in the assessment as a consequence of concerns about targeting leading to hyperstability.

B.5. Other relevant data

C. Assessment: data and method

Model used: Time-Series Analysis (TSA)

Software used: Bespoke software provided by Marine Scotland Science at the Marine Laboratory, Aberdeen, Scotland.

Model options chosen:

Landings	**Ages**	**0-8+**
	Years	1972-last data year
Discards	Ages	0-8+
	Years	1972, 1978- last data year
Industrial bycatch	Ages	0-8+
	Years	1972, 1978- last data year
Survey: NS IBTS Q1	Ages	1-5
	Years	1983- last data year
Survey: NS IBTS Q3	Ages	0-5
	Years	1991- last data year (if available)
Maturity		Knife-edge at age 3 (interim measure)
Natural mortality		Age- and time-varying from NS SMS key runs
Catch weights		Catch abundance-weighted average of NS and WC catch weights
Stock weights		Set equal to catch weights (interim measure)
Large year-classes ($\lambda = 5$)		1974, 1979, 1999
Age-dependent F variability		$H(a) = (2,1,1,1,1,1,1,1)$
F plateau		a_m =8
Measurement-error multiplier for landings (estimated during collation of landings data)		$B_{landings}(a) = (*, 3.7, 1.3, 1, 1.1, 1.4, 1.6, 2.7, 2.8)$
Measurement-error multiplier for discards+bycatch (estimated during collation of discards data)		$B_{discards}(a) = (2.0, 1.7, 1, 1.5, 1.8, 2.4, *, *, *)$
Downweighted landings outliers		1996, age 7
Downweighted discards+bycatch outliers		1982, age 5; 2012, age 2
Downweighted survey outliers		NS IBTS Q1: 2011, age 5; NS IBTS Q1: 2014, age 4

Note that the correction that is applied to allow for large year-classes is not implemented automatically, but must be stipulated by the stock assessor once enough evidence has accumulated that a large recruitment event has occurred. WKHAD (2014) suggested that this decision should be made following a benchmark (or inter-benchmark) procedure.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1972 – last data year	0 – 8+	Yes
Caton landings	Landings in tonnes	1972 – last data year	1 – 8+	Yes
Caton discards	Discards in tonnes	1972, 1978 – last data year	0 – 8+	Yes
Caton bycatch	Industrial bycatch in tonnes	1972 – last data year	0 – 8+	Yes
Canum	Catch at age in numbers	1972 – last data year	0 – 8+	Yes
Canum landings	Landings at age in numbers	1972 – last data year	1 – 8+	Yes
Canum discards	Discards at age in numbers	1972, 1978 – last data year	0 – 8+	Yes
Canum bycatch	Industrial bycatch at age in numbers	1972 – last data year	0 – 8+	Yes
Weca	Weight at age in the commercial catch	1972 – last data year	0 – 8+	Yes
Weca landings	Weight at age in landings	1972 – last data year	1 – 8+	Yes
Weca discards	Weight at age in discards	1972, 1978 – last data year	0 – 8+	Yes
Weca bycatch	Weight at age in industrial bycatch	1972 – last data year	0 – 8+	Yes
West = Weca	Weight at age of the spawning stock at spawning time.	1972 – last data year	0 – 8+	Yes
Mprop	Proportion of natural mortality before spawning	1972 – last data year	0 – 8+	No – set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1972 – last data year	0 – 8+	No – set to 0 for all ages in all years
Matprop	Proportion mature at age	1972 – last data year	0 – 8+	No – the same ogive for all years
Natmor	Natural mortality	1972 – last data year	0 – 8+	Yes

Tuning data:

Type	Name	Year range	Age range
Research Vessel Survey			
Tuning fleet 1	IBTSQ1	1983 – most recent	1-5
Tuning fleet 2	IBTSQ3	1991 – most recent	0-5

Second model to run alongside in an exploratory fashion:

Model used: SAM

Software used: ADMB. The entire assessment, data, and configuration are available online (www.stockassessment.org) under the assessment name "Haddock-2014-S6".

Model Options chosen:

SAM model configuration file (model.cfg):

```
# Min Age (should not be modified unless data is modified accordingly)
 0
 # Max Age (should not be modified unless data is modified accordingly)
 8
 # Max Age considered a plus group (0=No, 1=Yes)
 1
 # The following matrix describes the coupling
 # of fishing mortality STATES
 # Rows represent fleets.
 # Columns represent ages.
 1       2       3       4       5       6       7       7       7
 0       0       0       0       0       0       0       0       0
 0       0       0       0       0       0       0       0       0
 # Use correlated random walks for the fishing mortalities
 # ( 0 = independent, 1 = correlation estimated)
 1
 # Coupling of catchability PARAMETERS
 0       0       0       0       0       0       0       0       0
 0       1       2       3       4       4       0       0       0
 5       6       7       8       9       9       0       0       0
 # Coupling of power law model EXPONENTS (if used)
 0       0       0       0       0       0       0       0       0
 0       0       0       0       0       0       0       0       0
 0       0       0       0       0       0       0       0       0
 # Coupling of fishing mortality RW VARIANCES
 1       1       1       1       1       1       1       1       1
 0       0       0       0       0       0       0       0       0
 0       0       0       0       0       0       0       0       0
 # Coupling of log N RW VARIANCES
 1       2       2       2       2       2       2       2       2
 # Coupling of OBSERVATION VARIANCES
 4       1       1       1       1       1       1       1       1
 0       2       2       2       2       2       0       0       0
 3       3       3       3       3       3       0       0       0
 #
 0 0 0 0 0 0
 # Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more in time)
 0
 # Years in which catch data are to be scaled by an estimated parameter
 0
 # first the number of years
 # Then the actual years
 # Them the model config lines years cols ages
 # Define Fbar range
 2       4
```

Input data types and characteristics (same as for TSA, only catch input is used in SAM):

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1972 – last data year	0 – 8+	Yes
Canum	Catch at age in numbers	1972 – last data year	0 – 8+	Yes
Weca	Weight at age in the commercial catch	1972 – last data year	0 – 8+	Yes
Weca landings	Weight at age in landings	1972 – last data year	1 – 8+	Yes
Weca discards	Weight at age in discards	1972, 1978 – last data year	0 – 8+	Yes
Weca bycatch	Weight at age in industrial bycatch	1972 – last data year	0 – 8+	Yes
West = Weca	Weight at age of the spawning stock at spawning time.	1972 – last data year	0 – 8+	Yes
Mprop	Proportion of natural mortality before spawning	1972 – last data year	0 – 8+	No – set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1972 – last data year	0 – 8+	No – set to 0 for all ages in all years
Matprop	Proportion mature at age	1972 – last data year	0 – 8+	No – the same ogive for all years
Natmor	Natural mortality	1972 – last data year	0 – 8+	Yes

Tuning data:

Type	Name	Year range	Age range
Research Vessel Survey			
Tuning fleet 1	IBTSQ1	1983 – most recent	1-5
Tuning fleet 2	IBTSQ3	1991 – most recent	0-5

Third model to run alongside in an exploratory fashion:

The third standard model to be run each year is SURBAR (Needle, 2012). This is a survey-based separable assessment model which is widely used in ICES and elsewhere, both as an exploratory analysis tool and as the basis for management advice. An earlier version (SURBA 3.0) with a Windows GUI (Needle, 2003) has been available for several years, but the more recent R implementation is more robust and produces a broader range of output. SURBAR uses the same input data as TSA and SAM (see above) for stock weights and maturity, and the two NS IBTS surveys (Q1 and Q3). Run settings are as follows:

1. Moderate smoothing ($\lambda = 3.0$) on age and year effects of mortality, following the suggestion by Needle (2015) that the degree of smoothing used should be related to the time gap between spawning and the survey (here the Q1 survey is coincident with spawning, while the Q3 survey is separated from spawning by 6 months).
2. Spawning time set to 0.25.
3. Reference age (that is, the age at which the age-effect s_a of mortality is fixed to 1.0) set to 3.
4. Parameter bounds set as follows: $s_a \in (-5,5), f_y \in (-1,5), r_{yc} \in (-\infty, \infty)$.
5. SSQ age-weightings and survey catchabilities set to 1.0 for all ages and years.

SURBAR is used to generate exploratory survey-based estimates of relative SSB and recruitment, and total mortality, which can then be compared with the catch-and-survey based TSA and SAM models.

D. Short-Term Projection

Initial stock size

Deterministic starting populations taken from TSA survivors' estimates.

Maturity

Knife edge at age 3 for the whole area. This is an interim measure until a more appropriate model of reproductive potential can be generated.

Natural mortality

Average of final three years of assessment data.

F and M before spawning

Both taken as zero.

Weight at age in the catch:

Modelled using a linear cohort-based approach (Jaworski, 2011). Weights at age a for cohort c are fit with the linear model

$$W_{a,c} = \alpha_c + \beta_c a$$

where parameters α_c and β_c are cohort-specific. For recent cohorts, for which there are fewer than three data points, weights at age are taken as an average of three previous weights at the same age (as estimates of α_c and β_c cannot reliably be generated for these cohorts). This procedure is applied separately for each catch component (catch/stock, landings, discard, industrial bycatch). If there is insufficient cohort-based weight information, a simple three-year mean is used here instead.

Weight at age in the stock:

These are assumed to be the same as weight-at-age in the catch.

Exploitation pattern:

Same as the last year, considering that exploitation is smoothed within the TSA model.

Intermediate year assumptions:

Fishing mortality estimate for the current year are taken to be the same as the final year, considering that F is smoothed within the model. Where this results in landings that overshoot the TAC, a TAC constraint should be considered.

Stock recruitment model used:

Recruits in the intermediate year (IY) and recruits in IY + 1 will be based on the TSA estimate of forecasted recruits at age 0 in the intermediate year, as this ensures consistency between assessment and forecast.

In the autumn, following the IBTS Q3 survey: rerun TSA with the autumn survey, comparing the projected recruitment at age 0 in the intermediate year, between the April run and the October run. If the approximate pointwise 95% confidence intervals about the two estimates do not overlap, this indicates that the difference is significant. If this is the case, then rerun the forecast with the autumn intermediate year TSA projection for age 0. The IY+1 will remain at the same value as the spring assessment.

This differs from the protocol outlined in ICES AGCREFA (2008), which used successive runs of the RCT3 survey regression program to determine significant difference. However, this was mostly necessary because the XSA method (predominant at the time) could not use in-year survey data (and standard errors on the the XSA abundance estimates were not available). TSA can use such data and does provide uncertainty estimates, and it is therefore appropriate to use the TSA estimates directly.

Procedure used for splitting the projected catch over the areas

The forecast provides catch options for the full Northern Shelf area, but the stock is managed as three subunits (Subarea 4, Division 3.a and Division 6.a). In order to split the advised catch between these subunits in a way that accounts for changes in stock distribution within the Northern Shelf, WKHAD (2014) suggested the application of the following procedure:

Generate a recalculated survey index based on IBTS Q1 but only including sampling area 8 (Skaggerak). This is the survey for Division 3.a.

Generate a second survey index, also based on IBTS Q1 but including samplings areas 1-7 and 10. This is the survey for Subarea 4.

The survey for Division 6.a is the ScoGFS-WIBTS Q1 (new) index.

For each of the three last years, and for each of the three surveys, calculate a survey-based estimate of biomass at age by multiplying the survey index (mean numbers

caught per hour per stat square across the survey area) by the appropriate weight at age, and then by the number of stat squares covered by the survey. Sum across ages to estimate total exploitable biomass (ages 1–5 in the surveys are assumed to be fully exploitable). Calculate the mean over the three years.

Express each mean biomass as a proportion of the total across all three survey areas. These mean proportions then give the ratio by which the Northern Shelf catch advice should be split between the three areas.

Note that this proposal has not been implemented by ICES in providing advice for this stock, given concerns over the potential to violate relative quota stability.

Procedures used for splitting projected catches between landings/discards/IBC:

Three-year average of catch component ratios.

E. Medium-Term Projections

F. Long-Term Projections

G. Biological Reference Points

	Type	Value	Technical basis
MSY approach	MSY Btrigger	132 000 t	Bpa
	FMSY	0.19	Estimated by application of EqSIM evaluation (IBPHaddock 2016).
Precautionary approach	Blim	94 000 t	IBPHaddock (2016) estimate of lowest SSB to produce a large year-class (1979).
	Bpa	132 000 t	Bpa ~ 1.4 * Blim.
	Flim	0.38	Estimated by application of EqSIM evaluation (IBPHaddock 2016).
	Fpa	0.27	Fpa ~ Flim / 1.4.

H. Other Issues

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