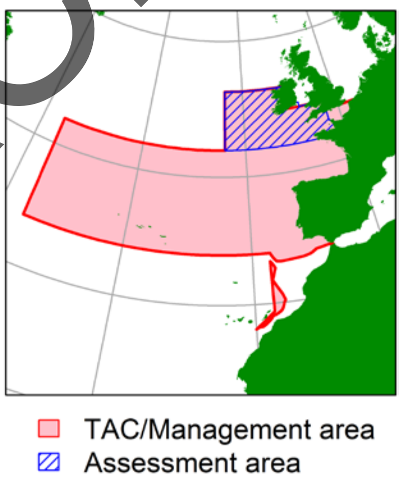
Stock Annex: Haddock (*Melanogrammus aeglefinus*) in divisions 7.b–k (southern Celtic Seas and English Channel)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Haddock
Working Group	Working Group for the Celtic Seas Ecoregion (WGCSE)
Created	
Authors	
Last updated	11 May 2013
Last updated by	Hans Gerritsen, 2017

A. General

A.1. Stock definition



For assessment purposes, the stock is defined as 7.b–k excluding 7.d and including rectangles 33E2 and 33E3. Landings from 7.d are insignificant and this division is not included in the assessment area. Irish landings from rectangles 33E2 and 33E3 are added to the stock assessment area. Landings from these rectangles were removed from the 7.a stock area following the benchmark of had-7a at WKROUND 2013. WKROUND found that landings from these rectangles had increased substantially in recent years and that geographically this fishery is contiguous with the fishery in 7.g and quite separate from the main haddock fishery in 7.a. These landings have been added to 7.g since 2003 and the landings numbers-at-age have been adjusted. Before 2007 landings from these rectangles were <1% of the total landings in 7.b, 7.c, 7.e–k, between 2007 and 2013 they contributed around 3% of the total landings.

The TAC for haddock is set for 7.b–k, 8, 9 and 10. However, official international landings from outside the assessmebt area (7.d, 8, 9 and 10) have been less than 2% of all landings in the TAC area in most years since 1973.

Adult haddock appear to be continuously distributed from the north of Biscay along the Irish coasts and the west of Scotland into the North Sea. It is not clear from their distribution if the 7.b, 7.c, 7.e–k stock is distinct from the surrounding areas. Irish Otter trawl lpue in the northernmost rectangles of 7.b is relatively high and similar lpue continues into 6.a, suggesting that the haddock in the north of 7.b might belong to the same stock as those in 6.a (Gerritsen, 2009). The pattern of lpue in the Irish Sea appears to be relatively distinct from 7.b, 7.c, 7.e–k with relatively high otter and beam trawl lpue in 7.g, low lpue in 7.a-South and high lpue in 7.a north (Gerritsen, 2009). Results from the French EVHOE-WIBTS-Q4 survey suggest that relatively low densities of haddock continue from 7.h into 8.a. Irish Groundfish Survey (IGFS-WIBTS-Q4) data indicates two distinct nursery areas with high catches of 0-group haddock: one area off the southwest coast of Ireland (7.b south and 7.j north) and one area off the southeast coast (7.g north). Catches of older haddock in 7.b are generally low and it is not clear whether the young fish from 7.b move north to 6.a or south to 7.j stock (Gerritsen and Stokes, 2006).

A.2. Fishery

Haddock in Divisions 7.b, 7.c, 7.e–k are taken as a component of catches in mixed trawl fisheries. France usually takes about 50–80% of the landings. French landings are made mainly by gadoid trawlers, which prior to 1980 were mainly fishing for hake in the Celtic Sea. Ireland has historically taken about 25–40% of the landings. Fleets from Belgium, Norway, the Netherlands, Spain, and the UK take the remainder of the landings. Landings reported between 1984 and 1995 varied between 2600 t and 4900 t, then increased sharply to 10 300 t in 1997. Since then the landings have varied between 5000 t and 10 000 t.

The vast majority of the landings are taken by otter trawls, most of the remainder of the landings are taken by seines and beam trawls.

A.3. Ecosystem aspects

Haddock are widely distributed throughout the stock area across a range of habitats. They have a varied diet but do not appear to be cannibalistic (Needle *et al*., 2003)

The mixed trawl fisheries impacts on benthic communities through bottom contact. Other ecosystem impacts result from discarding of non-target, undersize, over-quota or low-value fish.

Recruitment of haddock is highly variable. For North Sea haddock, no link could be found between temperature and recruitment (Cook and Heath, 2005). But parental condition has been linked to recruitment success in northwest Atlantic haddock (e.g. Friedland *et al*., 2003; Marshall and Frank, 1999).

B. Data

B.1. Commercial catch

Sampling and data raising

Data on landings-at-age and mean weight-at-age-are available for fleets landing into Ireland since 1993, and from France and the UK since 2002. Irish age compositions from 7.g, 7.j were used to estimate the age compositions of the international landings. Note that Irish landings contributed around 30% of the international landings so there is considerable uncertainty about the age composition of the landings before 2002.

Data for 1993–2012

The UK landings numbers-at-age are supplied for the combined 7.e–k area and the landings data from each division are used to scale the catch numbers to each division. French 7.f, 7.g, 7.h landings numbers are combined with Irish 7.g data to estimate 7.f, 7.g, 7.h landings numbers. Since 2009, the French landings numbers-at-age are supplied for the whole stock area (7.b, 7.c, 7.e–k). The table below shows the data available and the procedures used to derive quarterly length compositions, age compositions and mean weights-at-age.

Division	Data	UK	France	Ireland	Belgium	Derivation of international landings
		Data source:				
VII b,c	Length composition			VII b		
	ALK			VII b		
	Age Composition			VII b		IRL raised
	Mean weight at age			VII b		IRL VIIb
	Landings		VIIb,c	VIIb,c		
VII e	Length composition	VIIe-k				Derived from UK VIIe-k
	ALK	VIIe-k				Raised to international Landings
	Age Composition	VIIe-k				
	Mean weight at age	VIIe-k				
	Landings	VIIe	VIIe		VIIe	
VII f,g,h	Length composition		VII f,g,h	VII g		
	ALK		VII f,g,h	VII g		
	Age Composition		VII f,g,h	VII g		IRL & FRA raised
	Mean weight at age		VII f,g,h	VII g		IRL & FRA raised
	Landings	VIIf,g	VIIf,g,h		VIIf,g,h,j,k	
VIIe-h	Length composition					VIIf,g,h & VIIe
	ALK					
	Age Composition					
	Mean weight at age					
	Landings					
VII j-k	Length composition			VII j		IRL raised
	ALK			VII j		
	Age Composition			VII j		IRL raised
	Mean weight at age			VII j		IRL VIIj
	Landings	VIIj,k	VIIj,k	VIIk		
VII b,c,e,f,g,h,j,k	Length composition					
	ALK					
	Age Composition					VIIb,c + VIIe + VIIfgh + VIIjk
	Mean weight at age					Weighted mean by numbers caught
	Landings					

Data for 2013–present

Since WGCSE 2014 the data are supplied according to a datacall and therefore available at a different level of aggregation. The allocation of unsampled data has been done as follows:

Unsampled catches					Age composition allocated from:				
Nat	CCat	Métier	Area	Quarter	Nat	CCat	Metier	Area	Quarter
BEL	Lan	All	All	All	All	Lan	TBB	All	All
BEL	Dis	Est. from overall discard rate			All	Dis	All	All	All
ESP	Lan	All	All	All	All	Lan	All	All	All
IRL	Lan	MIS_MIS	All	All	IRL	Lan	All	All	All
FRA	Lan	SSC	All	All	IRL	SSC	All	All	All
UK(EW)	Lan	GNS	All	All	UK(EW)	Lan	All	All	All
UK(EW)	Lan	OTB	All	All	UK(EW)	Lan	ALL	All	All
UK(EW)	Lan	Other	All	All	UK(EW)	Lan	All	All	All
UK(EW)	Dis	All	All	All	All				
UK(NI)	Lan	SSC	All	All	IRL	LAN	SSC	All	All
UK(NI)	Lan	OTB	All	All	UK(EW)	OTB	All	All	All
UK(Sc)	Lan	OTB	All	All	UK(EW)	Lan	All	All	All
UK(Sc)	Lan	Other	All	All	UK(EW)	Lan	All	All	All

Weights-at-age

Discard weights were estimated from a fixed length–weight relationship (a = 11.809; b = 3.069). This was applied to the discard length distributions-at-age. For the landings weights, length–weight relationships were estimated for each year and quarter from the individual weights of the fish that were aged. Landings and discard weights are combined to estimate catch weights. The values are weighted by the numbers-at-age.

Quarter-1 catch weights were used as stock weights. If no data were available, quarter-2 weights were used. Previous to the WGSSDS 2004, a three year running average was applied to the stock weights-at-age. In 2004, the working group estimation of stock weights was done using a quadratic function fitted through cohorts to the first-quarter catch weight data. In 2005 the stock weights were modelled using a von Bertalanfy growth equation. The raw stock weight data show significant year-effects and although these might be due to changes in sampling or ageing errors, it is also possible that weights-at-age are subject to interannual variation in condition. As the modelled stock weight did not fit the data very well and because it is not clear whether stock weights-at-age are more influenced by cohort- or year-effects, it was decided in 2007 to revert to using a three year running average to smooth the data, and constraining the weights in older ages to at least those of the preceding age in the cohort.

B.2. Biological

Natural mortality estimates were derived from mean catch weights-at-age using the approach proposed by Lorenzen (1996). Parameter values were obtained from Table 1 in the Lorenzen paper (ocean ecosystems: $\alpha = 3.69$; $\beta = -3.05$).

Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
0.99	0.72	0.60	0.50	0.43	0.40	0.37	0.36	0.34

Maturity was assumed to be knife-edged at-age 2. Recent Irish Survey data are generally in agreement with this maturity ogive, although males occasionally mature at-age one.

F and M before spawning were set to 0 for all ages in all years.

B.3. Surveys and commercial tuning fleets

Description

The surveys described below are co-ordinated by the IBTSWG (International Bottom Trawl Survey Working Group).

The French 7f, 7.g, 7.h, 7.j EVHOE-WIBTS-Q4 annual groundfish has been carried out since 1997 on the RV Thalassa. Age data are available from 2001 onwards. ALK data from Irish surveys were applied to the EVHOE data for the years 1997–2000 to estimate numbers-at-age for these years. The sampling design is a stratified random allocation. The number of hauls per stratum is optimised by a Neyman allocation taking into account the most important commercial species in the area (hake, monkfish and megrim). The fishing gear used is a GOV with an average vertical opening of 4 m and a horizontal opening of 20 m.

The Irish Groundfish Survey (IGFS-WIBTS-Q4) has been carried out since 2003 and covers 6.aS, 7.b, 7.g, 7.j. This survey is carried out on RV Celtic Explorer. The IGFS has a random stratified design and uses a GOV (with rock-hopper in 6.a) with a 20 mm codend liner.

The two surveys were combined to provide a single index that covers nearly the full stock area. Gerritsen (2012a) describes the justification and for combining the surveys. The two indices are directly combined, weighted by the surface area covered by each survey (37 000 nm^2 for the IGFS and 30 000 nm^2 for the EVHOE). The combined survey starts in 2003. The EVHOE data before 2003 are not used.

A French commercial OTB DEF tuning fleet is available but this fleet takes the majority of the landings and is therefore not included as tuning fleet.

An Irish commercial OTB fleet is available from 1995 onwards. This fleet is based on the landings and effort from ICES Rectangles 32D9, 31D9, 31E0, 31E1, 31E2, 32E1 and 32E2. These rectangles were selected in order to avoid changes in lpue due to shifts in targeting behaviour. The selected rectangles do not include any major *Nephrops* or hake, monkfish or megrim fishing grounds or areas with seasonal closures.

Consistency

The survey shows good internal consistency for ages 0 to 4. The Irish tuning shows good consistency from the age of 2 to 7. However discards are not included in this index and it is not known if discarding patterns have been consistent over time, therefore ages 2 and 3 were not included.

B.4. Commercial cpue

Effort and lpue data are available from the Irish otter trawl fleets operating in Divisions 7.b, 7.j and 7.g since 1995, French demeral trawlers in 7.f, 7.g, 7.h since 2004 and effort data are available for the UK beam trawl fleet in 7.e–k and all other trawl gears in 7.e–k since 1983. The effort in the French gadoid fleet has decreased in recent years and is now at a similar level to the Irish and UK fleets. Effort in the Irish OTB 7.g fleet has increased in recent years, while the Irish OTB effort in 7.b and 7.j appears to have levelled off in recent years. The lpue of the French gadoid fleet is still much higher than that of the other fleets. The Irish and UK fleets have seen a minor increasing trend in lpue in recent years.

B.5. Other relevant data

Discard data

Discard data are available from the Irish fleet since 1995. Data were raised using effort (hours fished) as auxiliary variable and stratified by ICES Division. The number of trips in some years is quite low, leading to concerns about the precision of the data.

French discard data are available since 2004. These data were also raised using effort (hours fished) as auxiliary variable. Data before 2008 are considered unreliable. Therefore French discards were estimated from the mean discard rate at-age for the period 1993–2007. It was assumed that 90% of one year olds, 50% of two year olds and 10% of three year olds were discarded. These proportions were applied to the French catch numbers-at-age to estimate historic discards. For the period 1993–2001, no French age composition data were available, therefore Irish age composition data were raised to French landings and the discard numbers were estimated from these.

French and Irish discard data were combined and a further raising factor was applied to account for discards from other countries. This raising factor was estimated from the total landings of all countries as a proportion of the combined French and Irish landings. This raising factor did not exceed 1.15 in any year.

No French age data are available for the discards. Irish age data are available but there are some concerns about the reliability of these data. For this reason, a quarterly length split is applied to the smallest length classes (where the cohorts are quite distinct). For larger fish, quarterly ALKs from the French and Irish landings are used.

Length-splits applied to the discard data. For lengths where landings ALKs were available, these were used.

Country	Area	Quarter	Age 0	Age 1	Age 2	Age 3
		1	≤10	11–18	19–27	≥28
		2	≤11	12–21	22–29	≥30
		3	≤14	15–23	24–33	≥34
		4	≤17	18–25	26–34	≥35
		1	≤15	16–23	24–34	≥35
		2	≤17	18–26	≥27	
		3	≤20	21–29	≥30	
		4	≤21	22–30	≥31	
		1	≤18	19–23	24–32	≥33
		2	≤17	18–26	27–34	≥35
		3	≤20	21–29	≥30	
		4	≤21	22–29	≥30	

C. Historical stock development

Model used:

ASAP; (XSA is also used for quality control purposes; if the two models disagree the differences will need to be explained.)

Software used:

ASAP V2.0 NOAA Fisheries toolbox (http://nft.nefsc.noaa.gov)

VPA95 (http://www.ices.dk/datacentre/software.asp)

FLR with R version 2.8.1 with packages FLCore 2.2, FLAssess 2.0.1, FLXSA 2.0 and FLEDA 2.0 (http://cran.r-project.org; http://flr-project.org)

ASAP is proposed as the main assessment model. However, due to the short time-series and noisy catch data, it is uncertain whether the separable assumption holds. Therefore it is proposed to also use XSA to monitor if the two models continue to provide similar trends and absolute estimates of SSB and F.

C.1. Input data types and characteristics

A plusgroup of 8+ was used. Age group 0 was included in the assessment data to allow inclusion of 0-group indices. However, catch numbers and selectivity-at-age 0 were set to zero in all years because catches at this age were very low or zero.

Discard estimates are included in the catch numbers and weights, therefore catch is explicitly defined here as landings + discards.

Data	Year range	Age range	Variable from year to year
Catch (tonnes)	1993–current	0–8+	Yes
Catch-at-age in numbers (thousands)	1993–current	0–8+	Yes
Weight-at-age in the commercial catch (kg)	1993–current	0–8+	Yes
Weight-at-age of the stock at spawning time (kg).	1993–current	0–8+	Yes
Weight-at-age of the stock at Jan- 1 (same as stock weights)	1993–current	0–8+	Yes
Proportion of natural mortality before spawning (Lorenzen M)	1993–current	0–8+	No
Proportion of fishing mortality before spawning (XSA only)	1993–current	0–8+	No
Proportion mature-at-age	1993–current	0–8+	No
Natural mortality	1993–current	0–8+	No

C.2. Model Options

ASAP

Note that ASAP does not accommodate inclusion of data for age 0. Therefore the ages in ASAP are offset by 1 year. All age settings above refer to the real age, not the age group used by ASAP.

Option	Setting
Include discards separately	No
Use likelihood constant	No
Mean F (Fbar) age range	3–5
Number of selectivity blocks	1
Fleet selectivity	Fixed at 0 for age 0; freely estimated for age 1 and 2, fixed at 1 for ages 3–8+
Discards	Included in catch (not specified separately from landings)
Index units	2 (numbers)
Index month	FR_IR_IBTS: 11; IR_GAD: 7 (7 = July 1st, the middle of the year)
Index selectivity linked to fleet	-1 (not linked; the commercial index does not include discards)
Index age range	FR_IR_IBTS: 0-5; IR_GAD: 3–7
Index Selectivity – FR_IR_IBTS	Fixed at 1 for all ages
Index Selectivity - IR_GAD	Freely estimated at age 3, fixed at 1 for all other ages
Index CV & ESS – FR_IR_IBTS	CV 0.3 all years, estimated sample size 40 for all years
Index CV & ESS – IR_GAD	CV 0.2 all years, estimated sample size 40 for all years
Phase for F-Mult in 1st year	1
Phase for F-Mult deviations	2
Phase for recruitment deviations	3
Phase for N in 1st Year	1
Phase for catchability in 1st Year	3
Phase for catchability deviations	-5 (Assume constant catchability in indices)
Phase for unexploited stock size	1
Phase for steepness	-5 (Do not fit stock–recruitment curve)
Catch total CV	0.3 for 1993–2007; 0.2 for 2008–present (reliable discard data available)
Input effective sample size	25 for 1993–2001; 50 for 2002-present (only Irish age comp before 2002)
Lambda for recruit deviations	0 (freely estimated)
Lambda for total catch	1
Lambda for total discards	NA (discards included in catch)
Lambda for F-Mult in 1st year	0 (freely estimated)
Lambda for F-Mult deviations	0 (freely estimated)
Lambda for index	1 for both indices in the model
Lambda for index catchability	0 for all indices (freely estimated)
Lambda for catchability devs	NA (phase is negative)
Lambda N in 1st year deviations	0 (freely estimated)

Option	Setting
Lambda devs initial steepness	NA (phase is negative)
Lambda devs unexpl stock size	0 (freely estimated)

Discards were not included separately because this resulted in undesirable residual patterns. Only one selectivity block was used due to the short time-series, as the time-series gets longer it may be appropriate to allow a separate block for the time period where observed discard data are available. Fleet selectivity was forced to be flat topped to reduce the number of parameters to be estimated. The F-pattern from XSA indicated flat-topped selectivity.

XSA

Option	Setting
Ages catch dep stock size	None
Q plateau	4
Taper	No
F shrinkage SE	1.5
F shrinkage year range	5
F shrinkage age range	3
Fleet SE threshold	0.3
Prior weights	No

There is no evidence to suggest that catchability is dependent on stock size; the linear regression fits the data well. The effect of releasing the q-plateau was investigated and catchability appeared to level off at-age 4. There is no evidence to suggest that the tuning fleets have changed over time, therefore no tapered time weighting was applied. In recent years there has not been a clear retrospective pattern, therefore a relatively high F shrinkage SE was used with a short year and age range. The fleets are relatively well behaved so an SE threshold of 0.3 was applied.

Tuning data:

Type	Name	Year range	Age range
Survey	FR_IR_IBTS	2003–present	0–5
Commercial	IR_GAD	1995–present	3–7

D. Short-term projection

Model used: Multifleet Deterministic Projection. Landings and discards are modelled as separate fleets.

Software used: MFDP1a (http://www.ices.dk/datacentre/software.asp)

Option	Setting
Initial stock size	Long-term GM (omitting last two years) Stock numbers-at-age 1 and older from model
Natural mortality	Lorenzen M, as in model
Maturity	Knife-edged at-age 2
F and M before spawning	0 for all ages in all years

Option	Setting
Stock / catch weights-at-age	Average last 3 years
Exploitation pattern	Average last 3 years
Intermediate year assumptions	F in the last year – check retrospective pattern for evidence of bias
Stock–recruit model	None, long-term GM recruitment (omitting last two years)
Fbar range	5–5*
Rescale to last year	No

*** The F_{BAR} age range used in the assessment model outputs is 3–5 this F refers to the catch (including discards). Ages 3–5 are fully selected in the catch (but not landings). MFYPR output supplies YPR based on landings F. In order to compare (landings) F reference points with the (catch) F_{bar} it was decided to calculate F_{BAR} only for age 5 because at this age the catch and landings are both fully selected and because a flat-topped selection pattern was applied in ASAP the result will be correct. So, in this context F_{MAX} refers to the catch F where the landings per recruit are maximised.**

E. Medium-term projections

F. Yield and biomass per recruit

No stock–recruit relationship exists for this stock; recruitment is characterised by sporadic extreme recruitment events.

Software used: NOAA fisheries toolbox YPR V3.0.

Option	Setting
Stock / catch weights-at-age	Average last 3 years
Selectivity	Average last 3 years
Natural mortality	Lorenzen M, as in model
Maturity	Knife-edged at-age 2

G. Biological reference points

An MSY evaluation was carried out following the approach outlined by WKMSYREF2 and WKMSYREF3. This evaluation is fully described in a working document to WGCSE 2015 (Gerritsen and Lordan, 2015). The working document established the following reference points:

B_{lim}: 6700 t

B_{PA}: 10 000 t (B_{lim} + assessment error)

F_{MSY}: 0.40 (95%msy range: 0.26–0.60)

F_{lim}: 1.41

F_{PA}: 0.89 (F_{lim} – assessment error)

H. Other issues

I. References

Cook, R.M. and Heath, M.R. 2005. The implications of warming climate for the management of North Sea demersal fisheries. ICES JMS 62: 1322–1326. doi:10.1016/j.icesjms.2005.04.023.

Friedland K D, Hare JA. Wood GB. Col LA, Buckley LJ, Mountain DG, Kane J, Brodziak J, Lough RG, Pilskaln CH. 2003. Does the fall phytoplankton bloom control recruitment of Georges

Bank haddock, *Melanogrammus aeglefinus*, through parental condition? Canadian Journal of Fisheries and Aquatic Sciences, Volume 65, Number 6, pp. 1076–1086.

Gerritsen, H. 2009. Spatial distribution of Irish Landings, Effort and LPUE of Demersal Stocks in Divisions VI and VII in 1995–2008. Working Document 1 to ICES WGCSE, Copenhagen 12–19 May 2009.

Gerritsen H. 2012a. Haddock 7b–k Combined IGFS-WIBTS-Q4 and EVHOE_WIBTS-Q4 surveys. Working document 12 ICES WKROUND, Aberdeen 23–29 February 2012.

Gerritsen H. 2012b. Irish haddock discards in VIIb–k. Evaluation of raising methods. Working document 13 ICES WKROUND, Aberdeen 23–29 February 2012.

Gerritsen H and Lordan C. 2015. MSY reference points for haddock in VIIbce–k. Working document to ICES WGCSE, Copenhagen 12–21 May 2015.

Gerritsen H and Stokes D. 2006. Stock structure of Haddock in VIIb–k: Information from the Irish Groundfish Surveys Working document 7. ICES WGSSDS, Copenhagen, 27 June–6 July 2006.

Lorenzen K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49, 627–647.

Marshall CT, Frank, KT. 1999. The effect of interannual variation in growth and condition on haddock recruitment. Canadian Journal of Fisheries and Aquatic Sciences, 56:347–355.

Needle CL, O'Brien CM, Darby CD, and Smith MT. 2003. Incorporating time-series structure in medium-term recruitment projections. Sci Mar 67 (suppl 1): 201–209.