Stock Annex: Hake (*Merluccius merluccius*) in subareas 4, 6, and 7, and in divisions 3.a, 8.a–b, and 8.d, Northern stock (Greater North Sea, Celtic Seas, and the northern Bay of Biscay)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Hake
Working Group	Working Group for the Bay of Biscay and the Iberic waters Ecoregion (WGBIE)
Created:	
Authors:	
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A. General

A.1. Stock definition

European hake (*Merluccius merluccius*) is widely distributed over the Northeast Atlantic shelf, from Norway to Mauritania, with a larger density from the British Islands to the south of Spain (Casey and Pereiro, 1995) and in the Mediterranean and Black sea. Although, as demonstrated by genetic studies (Plá and Roldán, 1994; Roldán *et al.*, 1998), there is no evidence of multiple populations in the Northeast Atlantic, ICES assumes since the end of the 1970s two different stock units: the so called Northern stock, in Division 3.a, Subareas 4, 6 and 7 and Divisions 8.a,b,d, and the Southern stock in Divisions 8.c and 9.a, along the Spanish and Portuguese coasts. The main argument for this choice was that the Cap Breton canyon (close to the border between the Southern part of Division 8.b and the more Eastern part of Division 8.c, i.e. approximately between the French and Spanish borders) could be considered as a geographical boundary limiting exchanges between the two populations.

Hake spawn from February through to July along the shelf edge, the main areas extending from the north of the Bay of Biscay to the south and west of Ireland (Figure 1). After a pelagic life, 0-group hakes reach the bottom in depths of more than 200 m, then moving to shallower water with a muddy seabed (75–120 m) by September. There are two major nursery areas: in the Bay of Biscay and off southern Ireland.

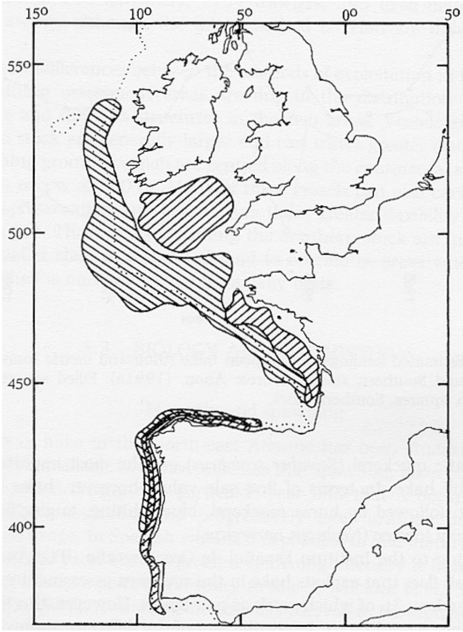

Figure 1. Main spawning and nursery areas. Spawning areas sloping downwards from left to right; Nursery areas sloping downwards from right to left. (from Casey and Pereiro, 1995)

A.2. Fishery

A set of different Fishery Units (FU) has been defined by the ICES Working Group on Fisheries Units in Sub-areas 7 and 8 in 1985, in order to study the fishing activity related to demersal species (ICES, 1991a). To take into account the hake catches from other areas, a new Fishery Unit was introduced at the beginning of the nineties (FU 16: Outsiders). This Fishery Unit was created on the basis of combination between mixed areas and mixed gears (trawl, seine, longline, and gillnet). The current FU are defined as follows:

Fishery Unit	Description	Sub-area
FU1	Longline in medium to deep water	7
FU2	Longline in shallow water	7
FU3	Gillnets	7
FU4	Non-*Nephrops* trawling in medium to deep water	7
FU5	Non-*Nephrops* trawling in shallow water	7
FU6	Beam trawling in shallow water	7
FU8	*Nephrops* trawling in medium to deep water	7
FU9	*Nephrops* trawling in shallow to medium water	8
FU10	Trawling in shallow to medium water	8
FU12	Longline in medium to deep water	8
FU13	Gillnets in shallow to medium water	8
FU14	Trawling in medium to deep water	8
FU15	Miscellaneous	7 & 8
FU16	Outsiders	3.a, 4, 5 & 6
FU00	French unknown	

The main part of the fishery is currently conducted in six Fishery Units, three of them from Subarea 7: FU 4, FU 1 and FU 3, two from Subarea 8: FU 13 and FU 14 and one in Subareas 3.a, 4, 5 and 6: FU16.

From the information reported to the Working Group, Spain accounted in recent years for the main part of the landings (around 43%) followed by France (around 29%), UK, Denmark, Ireland, Norway, Belgium, Netherlands, Germany, and Sweden contributing to the remaining.

The minimum landing size for fish caught in Subareas 4, 6, 7 and 8 is set at 27 cm total length (30 cm in Division 3.a).

From 14th of June 2001, an Emergency Plan was implemented by the Commission for the recovery of the Northern hake stock (Council Regulations N°1162/2001, 2602/2001 and 494/2002). In addition to a TAC reduction, 2 technical measures were implemented:

- A 100 mm minimum mesh size has been implemented for otter trawlers when hake comprises more than 20% of the total weight of marine organisms retained on board. This measure did not apply to vessels less than 12 m in length and which return to port within 24 hours of their most recent departure.
- Two areas have been defined, one in Subarea 7 and the other in Subarea 8, where a 100 mm minimum mesh size is required for all otter trawlers, whatever the amount of hake caught.

Council Regulation (EC) No. 1954/2003 established measures for the management of fishing effort in a biologically sensitive area in Subareas 7.b, 7.j, 7.g, and 7.h. Effort exerted within the biologically sensitive area by the vessels of each EU Member State may not exceed their average annual effort (calculated over the period 1998–2002).

There are explicit management objectives for this stock under the EC Reg. No 811/2004 implementing measures for the recovery of the northern hake stock. It is aiming at increasing the quantities of mature biomass to values equal to or greater than 140 000 t. This is to be achieved by limiting fishing mortality to 0.25 and by allowing a maximum change in TAC between years of 15%.

According to ICES in 2007, the northern hake stock has met the SSB target in the recovery plan of 140 000 t for two consecutive years (2006 and 2007). Article 3 of the recovery plan indicates that, in such a situation, a management plan should be implemented.

An annual one-month fishing activity stop has been implemented by the Spanish administration since 2004. In 2008, a specific national regulation established a 90-days stop to be distributed from August 2008 to December 2009.

In Subarea 8, for 2006, 2007 and 2008, otter trawlers using a square mesh panel are allowed to use 70 mm mesh size in the area, mentioned above, where 100 mm minimum mesh size is required for all otter trawlers. (EC Reg. No. 51/2006; EC Reg. 41/2007).

Furthermore, there was a ban on gillnets in Divisions 6.a,b and 7.b,c,j,k fishing at more than 200 m of depth (EC Reg. No 51/2006) during the first semester of 2006.

A.3. Ecosystem aspects

Although a comprehensive study on the role of hake in its ecosystem has not yet been carried out, some partial studies are available. Hake belongs to a very extended and diverse community of commercial species including megrim, anglerfish, *Nephrops,* sole, sea bass, ling, blue ling, greater forkbeard, tusk, whiting, blue whiting, *Trachurus spp*, conger, pout, cephalopods (octopus, *Loligidae*, *Ommastrephidae* and cuttlefish), and rays. The relative importance of these species in the hake fishery varies largely in relation to the different gears, sea areas, and countries involved.

Hake is preyed upon by sharks and other fish. Cannibalism on juveniles by adults is also quoted. Adults feed on fish (mainly on blue whiting and other gadoids, sardine, anchovy, and other small pelagic fish); juvenile hake prey mainly upon planktonic crustaceans (above all euphausids, copepods, and amphipods).

Ecological factors or environmental conditions impacting on hake population dynamics are not taken into account at present in the assessment or in the management. However, synchronous changes have been observed in hake recruitment success and several global, regional and local parameters, which suggest that environmental conditions may be influential for hake (Goikoetxea and Irigoien, 2013). An ecological regime shift occurred in the Northeast Atlantic shelf system in 1988/89, which was detected at global scale (NAO, Gulf Stream and northern hemisphere temperature anomaly), as well as regionally (climatology of the Northeast Atlantic and copepod variability of the Celtic Sea). The region went from a period of cool temperatures and relatively weak wind (1978–1989) to a period of warmer temperatures and stronger westerly winds (1990–2006). Given the synchronous stepwise increase in hake recruitment success, it was concluded that the environment shifted to a regime that was favourable for northern hake. Early life stages of hake were found to benefit from a warming trend (either through the widening of the optimal environmental window or/and higher growth rates). In addition, coastward transport avoided vulnerable stages from their dispersion to oceanic areas and helped in their transport from spawning areas to nursery grounds (Goikoetxea, 2011). Other previous studies also highlighted the influence of environmental parameters such as water temperature and wind-driven transport on northern hake stock (Fernandes *et al*., 2010; Álvarez *et al.*, 2001).

B. Data

In 2013 a data call was run by ICES in order to obtain more precise data on discards since 2003. Discard and Landing data were uploaded into Intercatch by most of the countries that exploit the stock. The disaggregation level varied by country and year, from season, métier and length disaggregation level to total landings or discards by year.

B.1. Commercial catch

B.1.1. Landings

Until 2010, the Spanish landings data were based on sales notes and Owners Associations records compiled by the National laboratories (IEO and AZTI). From 2011, the

Spanish data are derived from official statistics provided by the Spanish Fishery Administration derived from logbook and sale notes. French landings data are based on logbook and auction hall sales.

From 1978–1989, landings in weight are available by year, gear (trawl, gillnets and longline), country (UK, France and Spain) and ICES Divisions (Division 4.a and Sub-Area 6, Division 7 and Divisions 8.a,b). From 1990 to present, for most of the years, landings in weight by FUs and countries are available on a quarterly basis. In 1992, only data from Spain is available by FU and on a quarterly basis (Table 1).

Table 1. Landings-in-weight (and their level of aggregation) available to the Working Group.

	1978–1989	1990–1991	1992	1993–Present
By Gear, Country and ICES Divisions	X			
By FU		X	X	X
By year	X		X	
By quarter		X	X*	X

*** For Spain only**

From 1978–1989, length–frequency distributions are available by year, gear, country and ICES Divisions. From 1990 to present, length compositions of the landings are not available for all Fishery Units, quarters and countries. Only the main FUs/Countries are sampled. Table 2 presents, as an example, the length distributions available for 2008.

Table 2. Length–frequency distributions provided to the Working Group in 2008.

FU	France	Ireland	Spain	UK(EW)	Scotland	Danemark
01			Quarterly			
03	Quarterly		Quarterly	Quarterly		
04			Quarterly	Quarterly		
05	Quarterly			Quarterly		
06				Quarterly		
09	Quarterly					
10	Quarterly					
12	Quarterly		Quarterly			
13	Quarterly		Quarterly			
14			Quarterly			
15		Quarterly				
16			Quarterly		Quarterly	Yearly

In 2014 the length frequency distribution, from 2003–2012, of the landings outside area 6 and 7 (the landings of OTHERS fleet in SS3) was recalculated using the data in Intercatch. The allocation schemes to disaggregate unsampled data (data without length information) in Intercatch were defined by year taken into account the area, season and gear.

B.1.2. Discards

Until 2002, the only discards series available and used by the WG were those of the French artisanal and coastal trawl fisheries in the Bay of Biscay, estimated on the basis of the length compositions obtained during FR-RESSGASC surveys. The RESSGASC survey used for their estimation ended in 2002.

EU countries are now required under the EU Data Collection regulation to collect data on discards.

A new sampling programme of discards in the French *Nephrops* trawlers fishery of the Bay of Biscay started in June 2002. Estimates obtained by this programme (see Table 3 below) were significantly different (by a factor 2–10) from previous estimates for that fishery (estimates are from 532 t in 2006 to 1597 t in 2005). Such discrepancies could be explained by changes in the sampling, changes in the discarding practices, variations in the abundance of small fish or by a combination of the three. The CVs associated with these estimates are around 20%. A huge amount of discards (~1500 t) was estimated for French Gillnetters in 2012. The discards estimates on this fleet were negligible in previous years.

Discards are available for Danish trawlers, seiners and gillnetters fishing in Subarea 4 from 1995–2012 and for gillnetters from 1995–2008. Their values are quite variable from year to year from 100–800 t.

Additional information on discards was available for the Irish otter trawlers fishery in Subareas 6 and 7 from 1999 to 2001, for 2004 and 2005 and for 2009–2012 (values from 32–700 t, between 2006 and 2008 the discards were not raised because they were not available at the requested métier level). UK-EW discards were only available from 2000–2008 (raised only to the trip level).

Estimates of discards for the Spanish trawl fleets operating in the ICES Subarea 7 and Divisions 8.a,b,d are available for 1988, 1989, 1994, from 1999–2001 and from 2003 to 2012. In Subarea 7, a significant increase in estimated discards rate was observed from 2010–2012 when compared with previous years. Discards were estimated to vary from very small amounts to more than 1000 t in 2003–2005 and over 5000 t since 2010. CVs were highly variable from 20% to more than 100%. Fixed gears were also sampled in order to design the Spanish Discards Sampling Programme, but no relevant discards were observed (Pérez *et al*., 1996).

Table 3. Summary of discards data available (weight (t) in bold, numbers ('000) in italic), those in red are included into the assessment model.

Fleet/metier	SS3 Fleet	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
French	GILLNET	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1503**
		NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*4061*
Spanish	SPTRAWL7	NA	**83**	NA	NA	NA	**1034**	**1530**	NA	**537**	**1712**	**2010**	**5674**	**5077**	**5054**
		NA	*759*	NA	NA	NA	*10666*	*17393*	NA	*4526*	*21437*	*17542*	*27619*	*27954*	*26452*
French	TRAWLOTH	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**662**	**641**	NA	NA
		NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	4637	2031	NA	NA
French trawl	TRAWLOTH	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**363**	**551**	**130**	**304**
		NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*1493*	*1159*	301	*3037*
French	FRNEP8	**565**	**341**	**417**	**172**	**1035**	**1359**	**1597**	**532**	**767**	**858**	**4283**	**726**	**871**	**624**
		9139	*7421*	*6407*	*2992*	*23676*	*39550*	*37740*	*18031*	*24277*	*18245*	*68524*	*14709*	21208	*25228*
French trawl	TRAWLOTH	**211**	**169**	**100**	**142**	NA	NA	NA	NA	NA	NA	*	*	*	*
in VIIIabd		*3053*	*3013*	*1439*	*2253*	NA	NA	NA	NA	NA	NA	*	*	*	*
Spanish	SPTRAWL8	NA	NA	NA	NA	NA	**30**	**489**	**206**	**471**	**352**	**580**	**101**	**292**	**364**
trawl in		NA	NA	NA	NA	NA	*451*	*8475*	*3397*	*10002*	*7153*	*7925*	*1719*	*5036*	*5329*
Irish trawl	TRAWLOTH	**190**	**650**	**194**	NA	NA	**32**	**94**	*	*	*	**720**	**559**	**419**	**497**
and seine in		*1868*	*892*	*1046*	NA	NA	282	*629*	*	*	*	*684*	*641*	736	2064
UK (EW)	OTHERS	NA	*	*	*	*	*	*	*	*	*	*	*	*	*
trawl in IV		NA	*	*	*	*	*	*	*	*	*	*	*	*	*
Spanish trawl in	OTHERS	NA	NA	NA	NA	NA	NA	NA	NA	NA	**6**	**31**	**120**	**NA**	**NA**
VI		NA	NA	NA	NA	NA	NA	NA	NA	NA	*11*	*36*	*146*	*NA*	*NA*
French trawl	OTHERS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**47**	**1409**	NA
in IV & VI		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*68*	*2700*	*NA*
Danish trawl,	OTHERS	**42**	**21**	**142**	**354**	**348**	**127**	**605**	**426**	**236**	**203**	**422**	**581**	**162**	**300**
seines ang		*29*	*38*	*483*	*691*	*479*	*775*	NA	NA	*849*	*642*	*508*	*234*	*275*	*NA*
Scottish		*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	NA	NA	*NA*	*NA*	**2604**	**3709**	**6895**	**5667**
Irish		*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	NA	NA	*NA*	*NA*	**68**	**88**	**207**	**136**
Others		*NA*	*NA*	*NA*	*NA*	*9*	*32*	*268*	*58*	**153**	**242**	**40**	**45**	**268**	**79**
		1008	**1182**	**854**	**668**	**1392**	**2614**	**4583**	**1222**	**2164**	**3373**	**11121**	**12842**	**15730**	**14528**
		14090	*11364*	*9376*	*5935*	*24155*	*51724*	*64237*	*21428*	*39654*	*47488*	*96712*	*31138*	*34027*	*36882*

* sampled but not raised

(1) French trawl discards in 2012 not dissgregated by area

During the 2003 assessment, the Working Group noted that, although some improvement in discard data availability had been observed (number of fleets sampled and area coverage), sampling does not cover all fleets contributing to hake catches and discard rates of several fleets are simply not known. Furthermore, when data are available, it was not possible to incorporate them into the assessment in a consistent way. As reconstructing an historical series was found problematic, discard estimates were removed from the full time-series of catch data. From 2003–2008, the assessment was thus conducted on landings only. After 2008 Working Group assessment, discards estimates from several sampled fleets were used in the assessment. This includes the French *Nephrops* trawl in 8.a,b,d discards data from 2003–present, the Spanish trawl in 7 in 1994, 1999, 2000, 2003–present and the Spanish trawl in 8.a,b,d from 2005–present. Since 2010 the stock is assessed using SS3 and discard data are partly included into the model.

B.2. Biological

Mean weight-at-length are estimated from a fixed length–weight relationship (W(g)= 0.00513*L(cm)^3.074; ICES, 1991b).

The parameters of the time invariant logistic maturity ogive, for both sexes combined are: L_{50} = 42.85 cm and slope = - 0.2 (ICES, 2010b WD8).

Conventional tagging of European hake (de Pontual *et al.*, 2003) opened new avenues for a better understanding of the species biology and population dynamic which have remained controversial for decades (see e.g. Belloc, 1935; Hickling, 1933). The first tagging results provided evidence of substantial growth underestimation (by a factor ~2) due to age overestimation, (de Pontual *et al.*, 2006), thus challenging the internationally agreed age estimatio method. More tagging efforts, both off the Northwest Iberian Peninsula (Piñeiro *et al.*, 2007) and the Mediterranean Sea (Mellon-Duval *et al.*, 2010), proved that growth underestimation was not a regional issue. More recent recaptures of tagged fish have confirmed the growth estimated previously (de Pontual *et al.*, 2013). An ICES workshop (ICES, 2010a) confirmed that the previous internationally agreed ageing method is neither accurate nor precise and provides overestimation of age. A replacement ageing method with sufficient precision and accuracy is currently not available. Thus, in the benchmark assessment in 2010 (ICES, 2010b) the working group started to evaluate the stock using a length based assessment model.

In the absence of a direct estimate of natural mortality, a constant value of 0.4 was assumed for all age classes and years. It must be noted that this is a larger value than the one used in assessments conducted until 2008 where M was set to a value of 0.2. The rationale for this higher value is that if hake growths about two times faster, the hake longevity is reduced by about a half (from age ~20 to ~10), thus impacting on natural mortality (Hewitt and Hoening, 2005).

B.3. Surveys

Several research-vessel surveys cover part of the geographical distribution of the Northern hake stock (Figure 2).

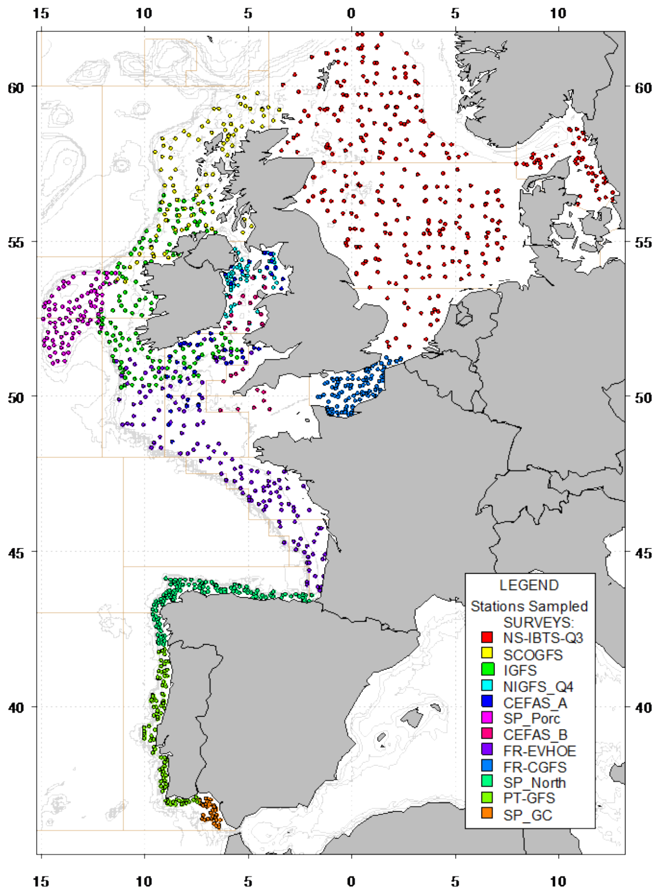

Figure 2. Map of East Atlantic groundfish surveys: stratification and trawling positions. FR-EVHOE correspond to EVHOE-WIBTS-Q4, SP Porc corresponds to SPPGFS-WIBTS-Q4 and IGFS corresponds to IGFS-WIBTS-Q4.

Abundance indices used in the SS3 assessment:

French Evhoe groundfish survey (EVHOE-WIBTS-Q4): years 1997–present. The survey occurs in autumn. The survey uses a GOV trawl with a 20 mm codend liner. It covers the shelf of both the Bay of Biscay and the Celtic Sea.

French Ressgasc groundfish survey (RESSGASC): years 1978–2002. Over the years 1978–1997 the RESSGASC surveys were conducted with quarterly periodicity. They were conducted twice a year after that (in spring and autumn). Survey data prior to 1987 have been excluded, because there was a change of vessel at that time. Weather conditions encountered by RESSGASC in 2002 gives to this index a poor reliability and it was decided not to use it. The survey uses a 25 m "Vendéen type" bottom trawl. It covers the Bay of Biscay. The survey ended in 2002.

Spanish Porcupine groundfish survey (SPPGFS-WIBTS-Q4): years 2001 to present. The area covered by this survey is the Porcupine bank extending from longitude 12° W to 15° W and from latitude 51° N to 54° N, covering depths between 180 and 800 m. The cruises are carried out every year in September on board R/5 "Vizconde de Eza", a stern trawler of 53 m and 1800 Kw. Numbers-at-age for this abundance index are estimated from otoliths collected during the survey.

Irish Groundfish Surveys (IGFS-WIBTS-Q4): years 2003–present. This survey is conducted on board the R.5. Celtic Explorer in autumn in the west of Ireland and the Celtic sea. The survey uses GOV 36/47 (Grande Ouverture Verticale).

Abundance indices not used in the SS3 assessment:

UK WCGFS survey (UK-WCGFS): years 1988–2004. This survey was conducted in March in the Celtic sea. It does not include the 0-age group. Numbers-at-age for this abundance index are estimated from length compositions using a mixed distribution by statistical method. The survey ended in 2004.

B.4. Commercial cpue

Commercial cpues indices provided to the ICES Working Group are not used in the current SS3 assessment. Landings-per-unit-effort time-series are available from the following fleets:

a) Trawlers from A Coruña and Vigo fishing in Sub-area 7 (SP-CORUTR7 and SP-VIGOTR7), pairtrawlers from Ondarroa and Pasajes fishing in Sub-area 8 (SP-PAIRT-ON8 and SP-PAIRT-PA8)
b) The A Coruña trawler fleet, targeting mainly hake, operates in deeper waters close to the slope in Division 7.b-c, j–k, while the trawler fleet from Vigo, targeting megrim, works in shallower waters in Division 7.j–h and catch hake as bycatch. Both pairtrawler fleets from Ondarroa and Pasajes are targeting hake in the Bay of Biscay.
c) Ondarroa "Baka" trawlers fishing in Subareas 6, 7 and Division 8.a,b,d, Pasajes "Bou" trawlers fishing in Subarea 8, longliners from A Coruña, Celeiro and Burela fishing in 7, longliners from Avilés in 8.a,b,d and trawlers from Santander in 8.a,b,d.
d) Lpue values of Spanish gillnetters that started to fish hake in Subareas 7 and 8 in 1998 are also provided. It is to be noted that only a small number of ships are involved in the gillnet fishery which makes lpues very sensitive to small changes in the number of trips. It is also noted that for gillnetters and longliners, lpues expressed in kg/day may not be the most appropriate.
e) Lpue data from two French fleets (Les Sables and Lesconil) fishing in Divisions 8.a,b,d are also available from Logbooks. Due to important reductions in the availability of logbook information in recent years for both fleets, lpue values for the years 1996 onwards have low reliability. No data have been provided for those two fleets after 2003.
f) Lpue from Spanish Longliners is available since 2014 Benchmark. This LPUE corresponds to the most important Spanish longline fleet operating in ICES Subarea 7 (A Coruña, Celeiro and Burela ports) and it provides an abundance

index for large individuals. The time-series starts in 1995, first year with sampling for quarterly length frequency distributions (LFD). Although effort is measured in number of days it is considered appropriate because the fishing tactic of the fleet have been quite homogeneous over the period covered, without changes due to technological improvements or new management measures. It was tested in the assessment during 2014 benchmark; however it was considered that a deeper analysis of its suitability was necessary in order to use it as an abundance index.

C. Assessment: data and method

Model currently used: Stock Synthesis 3 (SS3), (Methot, 2013).

Software used: Stock Synthesis V3.24f, Richard Methot, NOAA Fisheries Seattle, WA.

Recent assessments and sensitivity analysis carried out.

An attempt to use a non-equilibrium surplus production model (ASPIC) was carried out in the 2004 WG (ICES, 2005) and preliminary fits of a length based stock assessment model have been presented in 2007 and 2008.

In the 1998 WG it was found that the SSB estimates for 1985–1987 were very sensitive to the q plateau options between age 5, 6, and 7 (which is the last true age). To reduce this effect, it was decided to extend the ten years window to a twelve-year period in order to tune to the longest available and well behaved fleet dataseries. In the 1999 and 2000 assessments, SSB estimates for 1985–1987 were still sensitive to the extent of the tuning period, and the longest (13 years and 14 years respectively) provided the best pattern for these years, whereas other estimates were very similar for other years. In 2001 assessment, it was decided to use the whole tuning data available and a taper time weighting to reduce the influence of the older years. At that time, this choice did not change radically the estimates of trends in F and SSB and those settings were maintained in 2002–2003 assessments.

In 2004, the group investigated again the influence of the taper time weighting and runs were conducted without taper and compared with the base-case run using a tricubic taper over a 20 year period. While the group agreed on the rationale behind the use of a taper to down-weight the years for which we may have less confidence, it expressed concerns over the large influence the use of this option has on the perception of the stock dynamics and the inability of the model to account, in a satisfactory manner, for uncertainty in the data.

Due to uncertainties in hake aging, in 2005, 2006 and 2007, the group also conducted a sensitivity analysis using a simulated ALK assuming a faster growth. In each of these years, several runs were thus conducted (An Update from the previous year and a Simulated ALK, see below).

In WGHMM 2007, an update runs from 2006 has been carried out and the SPPGFS-WIBTS-Q4 survey was added to the surveys used to tune the model.

WKROUND 2010 (ICES, 2010b) reviewed the uses of the Stock Synthesis assessment model.

Current assessment

The assessment is a length-based approach using the Stock Synthesis assessment model. This approach allows direct use of the quarterly length composition data and explicit modelling of a retention process that partitions total catch into discarded and retained portions.

The underlying population can be partitioned in time to include as many seasons within a year as required. This is important where temporal aspects of biology (like growth in the case of hake), or fishing activity dictate finer than annual-level representation, however all the basic input data must then be partitioned to the level of the underlying dynamics.

Recruitment is based on a Beverton–Holt function parameterized to include the equilibrium level of unexploited recruitment (R0) and the steepness (h) parameter, describing the fraction of the unexploited recruits produced at 20% of the equilibrium spawning biomass level. Annual deviations can be estimated for any portion of the modelled time period (or the whole period), and the expected recruitments are bias-corrected to reflect the level of variability (sigmaR, an input quantity) allowed in these deviations.

Growth is described through a von Bertalanffy growth curve with the distribution of lengths for a given age assumed to be normally distributed. The CV of these distributions is structured to include two parameters which can be estimated or fixed, defining the spread of lengths at a young and old age with a linear interpolation between. In addition to growth, the relationships between weight and length, fecundity and length as well as maturity-at-length are all generalized to allow parameters to be estimated or fixed, temporally invariant or not. All model parameters can vary over time either as a function of annual deviations about a mean level, user defined 'blocks' of years in which the parameters differ or a combination of the two.

All model expectations for comparison with data are generated as observations from a 'fleet', either a fishery or a survey/index of abundance. Each fleet has unique characteristics defining relative selectivity across age or size, and can be structured to remove catch or collect observations at a particular time of the year or season. All fleets may be considered completely independent, or parameters may be shared among fleets where appropriate via 'mirroring'.

A suite of selectivity curves including logistic-based shapes of up to eight parameters, power functions and nonparametric forms can be explored through relatively simple modification of the input files.

The kinds of data that model expectations can be fit to include: absolute or relative abundance, length–frequency distributions, age frequency distributions (either total or conditional by length), length-at-age, body weight, and proportion discard. Each of these can be from the retained, discarded or total removals by a specific fleet. Each source has an error distribution (either normal, lognormal or multinomial) associated with it, described by either an input sample size or standard deviation.

Input data for SS3

The overall fishery prosecuting the northern stock of hake has been categorized into 7 "fleets", 4 of which use trawl gears, whereas the remaining three use gillnet, longline and a combination of several gears (Table 4). They are based on a combination of the Fishery Units described above. For each fleet, estimates of landings in weight and length–frequency distributions are available. For some fleet only, discards in weight and length–frequency distribution are used.

Table 4. Fleets characteristics and data available for SS3 (Length–Frequency distribution (LFD) and weight of landings and discards).

Fleets	Description	FU	Landings (quarterly)	Discards (quarterly)
SPTRAWL7*	Spanish trawl in 7	04	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	1994, 1999, 2000, 2003–2008 (LFD + Weight)
FRNEP8	French trawl targeting *Nephrops* in 8	09	Yearly : 1978-1989 (tonnage) Yearly : 1985-1989 (LFD) Quarterly : 1990-2012 (LFD+tonnage)	2003–2008 (LFD + Weight)
SPTRAWL8	Spanish trawl in 8	14	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	2005–2008 (LFD + Weight)
TRAWLOTH	All other trawl	05 + 06 + 08 + 10	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
GILLNET	Gillnet all countries	03 + 13	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
LONGLINE	Longline all countries	01 + 02 + 12	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
OTHERS	Everything else all countries	15 + 16 + 00	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	2003-2012 (Weight) 2003-2008 (Weight+LFD)

*** FU04 (and consequently SPTRAWL7) landings and discards contain small amount from area 6 as, in some cases, the sampling programme does not allow to make the distinction between area 7 and 6.**

For the two Spanish trawl fisheries, it is thought that discarding became much more substantial starting from 1998. For the French *Nephrops* fishery, discarding is thought to have occurred already from 1990. For the OTHERS fleet, since 2009 the discards are mainly formed by Scottish discards for which LFD are not available. The retention and selection of OTHERS fleet is thought to vary yearly because it is formed by a mixed of gears and countries. The remaining 3 fisheries (TRAWLOTH, GILLNET, LONGLINE) are assumed not to discard any fish.

Several surveys provide relative abundance indices of abundance and length distributions (Table 5).

Table 5. List of surveys used in SS3.

SURVEYS	AREA	YEARS	QUARTER
EVHOE-WIBTS-Q4	Bay of Biscay and Celtic Sea	1997–(y*-1)	4
RESSGASC	Bay of Biscay	1990–1997 1998–2001	1, 2 ,3 and 4 2 and 4
SPPGFS-WIBTS-Q4	Porcupine Bank	2001–(y*-1)	3
IGFS-WIBTS-Q4	North, West and South of Ireland	2003–(y*-1)	4

*** y = assessment year**

No commercial fleet tuning data are used.

Length Frequency Distribution Data compilation (From Intercatch to SS3)

In 2015 a problem with the calculation of length–frequency distributions (LFD) was detected. This year, the calculation was carried out using R statistical software instead of Intercatch. The new procedure allowed using a more detailed stratification of the data when calculating the LFDs and it solved the problem detected last year. In order to be consistent along time the procedure was applied to the data since 2013 when Intercatch was first used. The LFDs obtained were in agreement with those observed before 2013.

In SS3 it is not necessary that all the data has a length distribution assigned, it is enough to provide the proportion at length of the catch for the whole stratum (fleet/quarter and catch category (landings or discards) combination). Furthermore, if for one stratum there is no LFD data available or the available data are not reliable the model can work without it. Hence, unlike in Intercatch in R no allocations were done in the stratums without LFD data.

For all the samples with observed LFDs, first the catch in weight by length was calculated using the weight-at-length relationship agreed for this stock (W(g)= 0.00513*L(cm)^3.074; ICES, 1991b).

Then, for SPTRAWL7, FRNEP8, SPTRAWL8, GILLNET and LONGLINE fleets all the samples within each stratum were aggregated by length class summing up the catch weight at length. The obtained length distribution of catch in weight was divided by total catch in the stratum to obtain the proportion of individuals in each length class, which was then used in SS3. For TRAWLOTH and OTHER fleet the data were further disaggregated. In TRAWLOTH the target species was taken into account and the data were divided in the samples coming from métiers with *Nephrops* as target stock and from métiers with demersal stocks as target. In OTHER fleet the samples were divided in two groups considering the gear, trawlers and non-trawlers. Within these groups the proportion by length was calculated in the same way done for the rest of the fleets. Finally, the overall proportion by length within the stratum was calculated using a weighted mean of the proportion in each group. The weighting factor was the total catch in weight in each group taking into account both sampled and non-sampled data.

The code use to produce the LFDs is available in the ICES sharepoint site.

SS3 settings (input data and control files):

Years: 1978 to present, 1 area, 4 seasons, both sexes combined.

Length Frequency Distribution are available on a yearly basis from 1978–1989 and on a quarterly basis from 1990 to present. No age data are used.

Initial equilibrium catch: annual average of ten years (1978–1982) for each fishery.

Variability for landings, discards and survey abundance indices are entered as standard deviation in log-scale, as follows:

> Landings (tonnes): 10% variability
>
> Discards (tonnes): 50% variability
>
> Survey abundance indices: variability externally estimated. As the latter represents only the surveys internal variability, extra variability was added (increment to CV in SS3 control file) according to how representative each survey was felt to be of stock abundance (i.e. the area coverage of the survey as compared to the spatial distribution of the stock). Surveys' CV were increased by 0.1 (EVHOE-WIBTS-Q4), 0.2 (RESSGASC, IGFS-WIBTS-Q4), 0.3 (SPPGFS-WIBTS-Q4).

Length compositions were assigned the following sampling sizes in the SS3 input data file, on the basis of how representative they were felt to be1:

> Landings: 125 for all fleets, except SPTRAWL7 for which 50 was used for 1990-1997 and 200 was used from 1998 onwards
>
> Discards: 50 for SPTRAWL7 and SPTRAWL8, 80 for FRNEP8
>
> Surveys: 125

The following multipliers were subsequently applied to the latter sample sizes in the SS3 control file:

Landings and discards: 0.5 for all fleets, except LONGLINE to which a factor of 1 was applied

Surveys: 1 (EVHOE-WIBTS-Q4), 0.525 (RESSGASC, IGFS-WIBTS-Q4), 0.35 (SPPGFS-WIBTS-Q4)

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[1] The log-likelihood for the fit to length composition observations from fishery or survey source, is defined according to a multinomial error structure. The absolute value of the sample size (which may be many thousands of fish measured) should not be interpreted literally. The input sample size scales the variance of the data. The recommended maximum level for the sample size was 400 in Fournier and Archibald (1982). In many recent synthesis applications, a value of 200 has been used (which produces an expected coefficient of variation (CV) of approximately 20% (Methot, 2000)

M=0.4.

von Bertalanffy growth function is fixed: L_{inf}=130 cm, K = 0.177319 and mean length-at-age 0.75 = 15.8392. L_{inf} was chosen in 2010 benchmark (ICES, 2010b) and K and and mean length-at-age 0.75 were fixed and chosen in 2014 benchmark using the estimates obtained in 2011 assessment (ICES, 2011). Same growth parameters apply to all fish (across morphs, years, etc.)

Maturity ogive: length-based logistic, externally estimated and assumed constant over time

Recruitment allocation for Quarter 2 to 3 estimated with respect to Quarter 1. Quarter 2 allocation is time-varying, with annual deviates. Quarter 4 allocation set to 0.

Beverton–Holt stock–recruitment relationship: steepness h=0.999, sigma R=0.4, R0 estimated.

Recruitment deviations starting in 1970.

F estimation method = 2 (F by fishery and quarter treated as unknown parameters)

Surveys catchabilities constant over time.

RESSGASC survey entered as 4 separate surveys (1 per quarter). Catchabilities are quarter-specific but all quarters use the same selectivity-at-length.

Selectivity only length-based (no age selectivity considered)

Selectivity-at-length uses Pattern 24 (double normal function, with 6 parameters) for fleets SPTRAWL7, FRNEP8, SPTRAWL8, GILLNET, LONGLINE and all surveys. TRAWLOTH and OTHERS use Pattern 1 (logistic function, with 2 parameters). When Pattern 24 is used, parameter P5 is not used except for SPTRAWL7 and SPTRAWL8.[2]

Selectivity-at-length constant overall years and for all fleets expect for OTHERS. The selectivity of OTHERS fleets varies yearly since 2003. The variation is modelled using a random walk with standard deviation equal to 5 for L50% parameter and equal to 1 for the slope.

[2] The choice of selection pattern was carried out during the 2010 Benchmark (WKROUND 2010) following the following procedure: A preliminary set of model runs indicated that results were sensitive to the degree of flexibility allowed in the shape of the fishery selectivity-at-length patterns. If all fleets are allowed to be dome-shaped, the model cannot unambiguously determine the degree to which large fish exist but are never caught, vs. a result in which these large fish have reduced abundance but remain catchable. Three approaches were used to resolve this issue. First, examination of size composition data from the 1980s indicated that the percentage of large fish in the catch was much higher during the early 1980s and declined to a much lower level by 1990. This indicated that the old fish are catchable when they exist. Second, model runs were conducted with a profile on fixed levels for the degree of domed selectivity for selected fleets. These runs confirmed that the best fit to the size composition data occurred with the maximum domed pattern but the biomass increased to unrealistically high levels when the pattern was fully domed. Third, the overall average size composition of each contemporary fleet was examined and it was found that two fleets, “other trawls in VII and VIII” and “others”, had the lowest slope of the right hand side of the length composition. These two fleets were assigned an asymptotic selectivity pattern (two parameter logistic function) and all other fleets were modelled with the flexible double normal pattern. This change stabilized model performance.

Retention patterns for fisheries with discards: length-logistic with asymptotic retention = 1 in all cases, and unknown L50 and slope. For SPTRAWL7 three different patterns of retention over time are assumed, one for years 1990–1997, a second one for years 1998-2009 and a third one from 2010 . For SPTRAWL8, two different patterns of retention over time are assumed, one for years 1990–1997 and the another one from 1998 onwards. For OTHERS, the retention is the same for years 1978-2002 and it varies yearly since 2003. The variation is modelled using a random walk with standard deviation equal to 5 for both parameters L50% and the slope.

D. Short-Term Projection

- Model used: length and age-based.
- Software used: R script based on SS3 hake stock dynamics.
- Initial stock size. Taken from the SS3 in the last assessment year.
- Natural mortality: Set to 0.4 for all ages in all years.
- Growth model: von Bertalanffy model, with parameters estimated in the assessment model.
- Maturity-at-length: The same ogive as in the assessment is used for all years.
- Weight-at-length in the stock and in the catch: The same length–weight relationship as in the assessment model.
- Exploitation pattern: Average of the final 3 assessment years (with the possibility of scaling to final year F).
- Intermediate year assumptions: *status quo* F
- Stock–recruitment model used: Beverton–Holt Stock Recruitment relationship estimated in the assessment, with deviances chosen so that recruitment in the projection years approximately matches the geometric mean of estimated recruitment from 1990 until the final assessment year minus 2.

E. Medium-Term Projections

- No medium-term projections are conducted for this stock.

F. Long-Term Projections

- Model used: yield and biomass-per-recruit over a range of F values.
- Software used: R script based on SS3 hake stock dynamics.
- Selectivity pattern: Average of final 3 assessment years.
- Stock and catch weights-at-length: Same length–weight relationship as in the assessment model

Maturity: Fixed maturity ogive as used in assessment

G. Biological Reference Points

	WG 1998	ACFM 1998	ACFM 2003	ACOM 2010	WKMSYREF4 (ICES 2016)
MSY $B_{trigger}$				not defined	45 000
F_{MSY}				0.24	0.28
F_{lim}	No proposal	0.28 (= Floss WG 98)	0.35 (= Floss WG 03)	not defined	0.87

F_{pa}	No proposal	0.20 (= Flim*e-1.645*0.2)	0.25 (= Flim*e-1.645*0.2)	not defined	0.62
B_{lim}	No proposal	120 000 t (~ Bloss= B94)	100 000 t (~ Bloss= B94)	not defined	32 000
B_{pa}	119 000 t (=Bloss= B94)	165 000 t (= Blim*e1.645*0.2)	140 000 t (= Blim*e1.645*0.2)	not defined	45 000

Biological Reference Points in force (ICES 2016)

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY $B_{trigger}$	45 000	Bpa (ICES 2016)
Approach	F_{MSY}	0.28	Fmsy in the combined stock recruitment relationship (ICES 2016)
	B_{lim}	32 000	SSB2006 Low level of SSB followed by a sharp increase, lower level of SSB would led to lower recruitment level.
Precautionary	B_{pa}	45 000	1.4Blim (ICES 2016)
Approach	F_{lim}	0.87	Fishing mortality resulting in a 5% probability of SSB falling below Blim (ICES 2016)
	F_{pa}	0.62	Flim/1.4 (ICES 2016)

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