Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b–k, 8.a,b,d (west and southwest of Ireland, Bay of Biscay)

Quality Handbook	Stock specific documentation of standard assessment procedures used by ICES.
Stock	Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7b–k and 8a,b,d_meg.27.7b-k8abd
Working Group	Working Group for the Bay of Biscay and Iberian Waters Ecoregion (WGBIE)
Date	Updated May 2018
Revised by	Ane Iriondo

A. General

A.1. Stock definition

Since the end of the 1970s ICES has assumed three different stocks for assessment and management purposes: megrim in ICES Subarea 6, megrim in Divisions 7.b–k and 8a,b,d and megrim in Divisions 8c and IXa. The stock under this Annex is called northern Megrim and defined as megrim in Divisions 7.b–k and 8a,b,d.

A.2. Fishery

Megrim in the Celtic Sea, west of Ireland, and in the Bay of Biscay are caught in a mixed fishery predominantly by French followed by Spanish, UK and Irish demersal vessels. In 2014, the four countries together reported around 96% of the total landings

French benthic trawlers operating in the Celtic Sea and targeting benthic and demersal species catch megrim as a bycatch.

Spanish fleets catch megrim targeting them and in mixed fisheries for hake, anglerfish, *Nephrops* and others. Otter trawlers account for the majority of Spanish landings from Subarea 7, the remainder, very low quantities, being taken by netters prosecuting a mixed fishery for anglerfish, hake and megrim on the shelf edge around the 200 m contour to the south and west of Ireland. The catches made by otter trawlers from the port of Vigo comprise around 50% of the total catches.

Most UK landings of megrim are made by beam trawlers fishing in ICES Divisions 7.e,f,g,h.

Irish megrim landings are largely made by multi-purpose vessels fishing in Divisions 7.b,c,g for gadoids as well as plaice, sole and anglerfish.

Countries	ICES area	% landings (based on 2014 landings data)	Fisheries
Spain	Divisions 7.b,c,e–k and 8a,b,d	25%	Otter trawls targeting mixed groups of species (hake, anglerfish, Nephrops and other). Netters targeting also mixed species (anglerfish, hake and megrim)
France	Subarea 7	32%	Benthic trawlers targeting benthic and demersal species
Ireland	Divisions 7.b,c,g	18%	Multipurpose vessels targeting gadoids, plaice, sole and anglerfish
UK (England and Wales)	ICES Divisions 7.e,f,g,h	22%	Beam trawlers
Belgium	Divisions 7.b,c,e–k and 8a,b,d	1%	Beam trawlers

A.3. Ecosystem aspects

There are two megrim species in the North eastern Atlantic: megrim (*Lepidorhombuswhiffiag-onis*) and four spot megrim (*Lepidorhombus boscii*).

Megrim (*L.whiffiagonis*, Walbaum, 1792) is a pleuronectiform fish distributed from the Faroe Islands to Mauritania (from 70°N to 26°N) and the Mediterranean Sea, at depths ranging from 50 to 800 metres but more precisely around 100–300 metres (Aubin-Ottenheimer, 1986).

Four spot megrim (*L. boscii,* Risso 1810) is distributed from the Faroe Islands (63°N) to Cape Bojador and all around the Mediterranean Sea. It is found between 150–650 m, but mostly between 200–600 m.

Although, there is no evidence of multiple populations in the Northeast Atlantic, since the end of the 1970s ICES has assumed three different stocks for assessment and management purposes: megrim in Subarea 6, megrim in Divisions 7.b,c,e–k and 8a,b,d and megrim in Divisions 8c and IXa.

Spawning period of these stocks goes from January to March. Megrim spawning peak occurs in February (8a,b,d) and March (7) along the shelf edge. Males reach the first maturity at a lower length and age than females. For both sexes combined, fifty percent of the individuals mature at about 20 cm and about 2.5 year old (BIOSDEF, 1998; Santurtún *et al*., 2000). Their eggs are spherical, pelagic, with a furrow (stria) in the internal part of the membrane and with a fat globule.

Megrim is a demersal species of small-medium size with a maximum size about 60 cm. It is believed that it has a medium-large lifespan, with a maximum age of about 14–15 years. It lives mainly in muddy bottoms, showing a gradual expansion in bathymetric distribution throughout their lifetimes, where mature males and juveniles tend to occupy deep waters, immature females shallower waters and, during the very short period when females are mature, the dynamics remain unclear.

The Bay of Biscay and Iberian shelf are considered as a single biogeographic ecotone (a zone of transition between two different ecosystems) where southern species at the northern edge of their range meet northern species at the southern edge of their range as well as for some other Mediterranean species. Since species at the edge of their range may react faster to climate changes, this area is of particular interest in accounting for effects of climate change scenarios, for instance, in the food-web models (BECAUSE, 2004).

Megrim belongs to a very extended and diverse community of commercial species and it is caught in mixed fisheries by different gears and in different sea areas. Some of the commercial species that exist in the same ecosystem are hake and anglerfish, however many other species are also found. From the northern to southern areas of the extent of the stock these species include: Octopus, *Rajidae*, *Ommastrephidae*, *Nephropsnorvegicus*, *Phycisblennoides*, *Molva molva*, *Pollachius virens*, *Trisopterus* spp (mainly *Trisopterusluscus*), *Trachurus* spp, *Sepia officinalis*, Loligidae, *Micromesistius poutassou*, *Merlangius merlangus*, *Scyliorhynus canicula* and *Pollachius pollachius*.

Demersal fish prey on megrim. Megrims are very voracious predators. Prey species include flatfish, sprat, sandeels, dragonets, gobies, haddock, whiting, pout and several squid species.

Adult megrim feed on small bottom dwelling fish, cephalopods and small benthic crustaceans; juvenile megrim feed on small fish and detritivore crustaceans inhabiting deep-lying muddy bottoms (Rodriguez-Marín and Olaso, 1993).

It is believed that megrim movements are more aggregation and disaggregation movements in the same area instead of highly migratory movements between areas (Perez, pers. comm.).

Although a comprehensive study on the role of megrim in the ecosystem of the complete sea area distribution has not been carried out, some general studies are available.

Fisheries modify ecosystems through more impacts on the target resource itself, the species associated to or dependent on it (predators or preys), on the tropic relationships within the ecosystem in which the fishery operates, and on the habitat.

At present, both the multi species aspect of the fishery and the ecological factors or environmental conditions affecting megrim population dynamics are not taken into account in assessment and management. This is due to the lack of knowledge of these issues.

B. Data

Data are supplied from databases maintained by national Government Departments and research institutions. The figures used in assessment are considered as the best available data at the Working Group time of the year. From year to year, and before the Working Group, small revisions of data could occur. In that case, revised data are explained and incorporated into the historical data series for assessment.

Data are supplied on electronic files to a stock coordinator nominated by the ICES Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (formerly Hake, Monk and Megrim Working Group), who compiles the international landings, discards and catch-at-age data, and maintains the time-series of such data with the amendments proposed by countries.

B.1. Commercial catch

Landings data are supplied from databases maintained by national Government Departments and research institutions. Countries providing landing data by quarter and ICES division are Spain, France, Ireland, United Kingdom and Belgium.

B.2. Discard data

In many fisheries, discards constitute a major contribution to fishing mortality in younger ages of commercial species. However, relatively few assessments in ICES stock working groups take discards into consideration. This happens mostly due to the long time-series needed (not available for all the fleets involved in the exploitation of most stocks) but also to the large amount of research effort needed to obtain this kind of information (Alverson *et al.*, 1994; Kulka, 1999). The knowledge of discards and their use in stock assessment may also contribute, in cooperation with the industry, to refine fishing and management strategies (Kulka, 1999).

Spain started sampling discards on board commercial vessels in 1988, more specifically the Spanish trawl fleet operating in Subareas 6 and 7 was firstly target. During 1994, discard sampling was undertaken for other fleets (longliner (EC Project: Pem/93/005)). Sampling discards continued during 1999, 2000 for IV, 7, 8 and IX (EC Project: 98/095) and in 2001, partly just for cephalopods and during the first and last quarter of the year (Bellido *et al.*, 2003; Santurtun *et al.*, 2004). Since 2002 and under the National Sampling Programs, Spain continues sampling discards on board commercial fleets.

Until 2003, the standard procedure used for calculation of the Spanish discards estimators was based on a haul basis as described by Trenkel (2001). However, although these procedures were applied, there was not an estimate of the error and variance in every step of the analysis. Errors were only estimated on a haul basis.

From 2003 onwards and following the recommendation of the Workshop on Discard Sampling Methodology and Raising Procedures held in Charlottenlund (Denmark) in 2003 (Anon, 2003), general guidelines on appropriate sampling strategies and methodologies were described and then, the primary sampling unit was defined as the fishing trip instead of haul.

From 2000 to 2001 the minimum legal size (MLS) was reduced from 25 to 20 cm.

Since using the French discards from the 1991 survey to obtain estimates for 1999 and subsequent years was considered unreliable, only the Spanish data were used for these years, applied only to the Spanish fleets. This has led to an artificial decrease in the amount of total discards, since no estimates for French fleets were available.

The lack of discards data was considered the main problem with megrim assessment. This fact resulted in an underestimation of the international catch matrix occurs as some main countries (mostly France) involved in the fishery have not provide discard data. The lack of consistency of the catch series, which could cause great bias in assessment, was also a result of only one country (Spain) providing discard data since 1999.

During the WKFLAT (2012), Spain, United Kingdom (England and Wales) and Ireland provided discard data since 2000. Still France did not provide these data, which led to an artificial decrease in the amount of total discards. Discard data deficiencies were partly overcome as United Kingdom (England and Wales) provided discard raised data from 2000 to 2010. Irish discard data were revised and updated and a new data series were provided since 1995. Spain provided some minor revised values of discards. France did not provided discard data since 1999, as data appear to be very uncertain in relation to sampling level affecting their representatively.

In Inter-Benchmark 2016 the main aim was to obtain discard information from France which was lacking from 1991 onwards. Finally, an updated discard data from 2004 to 2014 from France was delivered based on the WD presented by IFREMER (WD XX Joel Vigneau).

Discard data available by country and the procedure to derivate them are summarised in Table B.2.1.

Table B.2.1. Megrim (*L.whiffiagonis*) in 7.b–k and 8.a,b,d. Discards information and derivation.

	FR	SP	IR	UK
1984	FR84-85	-	-	-
1985	FR84-85	-	-	-
1986	(FR84-85)	(SP87)	-	-
1987	(FR84-85)	SP87	-	-
1988	(FR84-85)	SP88	-	-
1989	(FR84-85)	(SP88)	-	-
1990	(FR84-85)	(SP88)	-	-
1991	FR91	(SP94)	-	-
1992	(FR91)	(SP94)	-	-
1993	(FR91)	(SP94)	-	-
1994	(FR91)	SP94	-	-
1995	(FR91)	(SP94)	IR	-
1996	(FR91)	(SP94)	IR	-
1997	(FR91)	(SP94)	IR	-
1998	(FR91)	(SP94)	IR	-
1999	-	SP99	IR	-
2000	-	SP00	IR	UK
2001	-	SP01	IR	UK
2002	-	(SP01)	IR	UK
2003	-	SP03	IR	UK
2004	**FR04**	**SP04**	**IR**	**UK**
2005	**FR05**	**SP05**	**IR**	**UK**
2006	**FR06**	**SP06**	**IR**	**UK**
2007	**FR07**	**SP07**	**IR**	**UK**
2008	**FR08**	**SP08**	**IR**	**UK**
2009	**FR09**	**SP09**	**IR**	**UK**
2010	**FR10**	**SP10**	**IR**	**UK**
2011	**FR11**	**SP11 (*)**	**IR**	**UK**
2012	**FR12**	**SP12 (*)**	**IR**	**UK**
2013	**FR13**	**SP13 (*)**	**IR**	**UK**
2014	**FR14**	**SP14 (*)**	**IR**	**UK**

- In bold: years where discards sampling programs provided information.

- In (): years for which the length distribution of discards has been derived.

B.3. Biological

Quarterly/annually length/age composition data are supplied from databases maintained by national Government Departments and research institutions. These figures are used as the best available data to carry out the assessment.

France has provided quarterly length distribution by fishery unit and by sex since 1984. For 2002, 2003, 2004 and 2006 French data (length distributions, catch-at-age by FU and ALKs) were not available for the assessment. In 2005 and 2006, length distributions, catch-at-age data by quarter and sex were available. In 2007 and 2008, annual length distributions by sexes were provided. For 2010, no French data were provided to the group. In 2012 (ICES, 2012) France provided revised ALKs and consequently completed number and weights-at-age since 1999.

Annual length compositions of landings are available by country and fishery unit, for the period 1984–1990 by sex. Since 1991, annual length composition has been available for sexes combined for most countries except for France. Since 1999, the length compositions have been available on a quarterly or half-year basis. For Spain, data are available for sexes combined, except in 1993, when data were presented for separate sexes and on an annual basis. As in previous years, derivations were used to provide length compositions where no data other than weights of landings were available.

No ALKs were available for the period 1984–1986, and age compositions for these years were derived from a combined-sex ALK based on age readings from 1987 to 1990.

Quarterly ALKs for separate sexes were available for UK (E&W). Combined Annual ALKs were applied to their length distributions. Annual age composition of discards and half-year landings per fleet, based on half-year ALKs for both sexes combined, were available and applied from Spain in Subarea 7 and in Divisions 8.a,b,d. Annual age composition of discards was available based on annual ALKs for both sexes combined were available and applied to Irish and UK (England and Wales) discards. Quarterly age compositions for sexes combined were available for Irish catches for Divisions 7.b,c,e–k.

The following table gives the source of length frequencies and ages for Northern Megrim:

	France		Ireland		Spain		UK	
	Length distribution	**ALK**	**Length distribution**	**ALK**	**Length distribution**	**ALK**	**Length distribution**	**ALK**
1984–1990	Quarter, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990
1991	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1992	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1993	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, by sexes	Half-year, combined	Annual, combined	Quarter, combined
1994	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1995	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1996	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1997	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1998	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Half-year, combined	Annual, combined	Quarter, combined
1999	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes

2000	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2001	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2002	NA	NA	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2003	NA	NA	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2004	NA	NA	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2005	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2006	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2007	Annual, by sex	NA	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2008	Annual, by sex	NA	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2009	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2010	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2011	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Half-year, combined	Half-year, combined	Quarter, combined	Quarter, by sexes
2012	Quarter, by sex	Quarter, by sex	Annual, combined, bymetier	Annual, combined, bymetier	Quarter, combined	Quarter, combined	Quarter, combined	Quarter, by sexes
2013	Half-year, combined	Half-year, combined	Annual, combined, bymetier	Annual, combined, bymetier	Quarter, combined	Quarter, combined	Quarter, combined	Quarter, by sexes

2014	Half-year, combined	Half-year, combined	Annual, combined, bymetier	Annual, combined, bymetier	Quarter, combined	Quarter, combined	Quarter, combined	Quarter, by sexes

A fixed natural mortality of 0.2 is used for all age groups and all years both in the assessment and the forecast.

The maturity ogive, obtained by macroscopy, for sexes combined calculated for Subarea 7 (BIOSDEF, 1998), has been applied every year. It is as follows:

Age	0	1	2	3	4	5	6+
Maturity	0.00	0.04	0.21	0.60	0.90	0.98	1.00

As in previous years, SSB is computed at the start of each year, and the proportions of M and F before spawning were set to zero.

B.4 Surveys

UK survey Deep Waters (UK-WCGFS-D, Depth >180 m) and UK Survey Shallow Waters (UK-WCGFS-S, Depth <180 m) indices for the period 1987–2004 and French EVHOE survey (EVHOE-WIBTS-Q4) results for the period 1997–present are available.

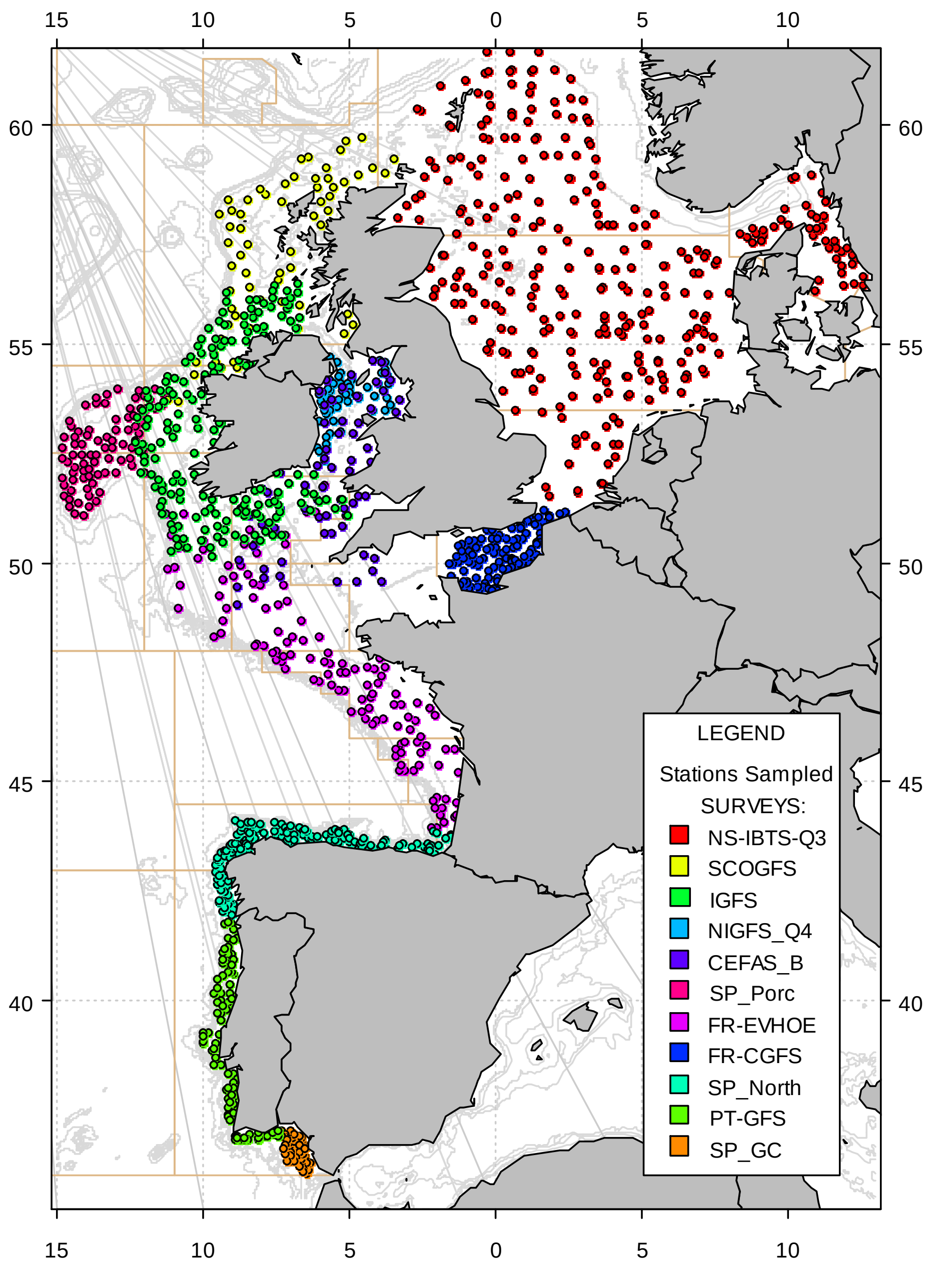
An abundance index was provided for the Spanish Porcupine Ground Fish Survey from 2001 to present.

Irish Ground Fish Survey (IGFS-WIBTS-Q4) is also from 2003 to present.

Surveys available for the assessment:

Type	Name	Year range	Age range	Used in the assessment
UK Survey Deep Water	UK-WCGFS-D	1987–2004	1–10+	No
UK Survey Shallow Water	UK-WCGFS-S	1987–2004	1–10+	No
French EVHOE Survey	EVHOE-WIBTS-Q4	1997–present	1–9	Yes
Spanish Porcupine Ground Fish Survey	SpPGFS-WBIT-Q4	2001–present	0–10+	Yes
Irish Ground Fish Survey	IGFS-WIBTS-Q4	2003–present	0–10+	No

It must be noted that the area covered by the three current surveys does not overlap, just the northern component of EVHOE-WIBTS-Q4 and the southern coverage of IGFS-WIBTS-Q4. (Map B.4).



Map B.4. Station positions for the IBTS Surveys carried out in the Western and North Sea area in the autumn/winter of 2008. (From IBTSWG 2009 Report). Just to be used as general location of the Surveys.

B.5 Commercial CPUE

Commercial series of fleet-disaggregated catch-at-age and associated effort data were available for three Spanish fleets in Subarea 7: A Coruña (SP-CORUTR7), Cantábrico (SP-CANTAB7) and Vigo (SP-VIGOTR7).

From 1985 to 2008, lpue s from four French trawling fleets: FR-FU04, Benthic Bay of Biscay, Gadoids Western Approaches and *Nephrops* Western Approaches are available. No update for the French lpues series has been provided from 2008 onwards as effort deployed by these fleets was considered, at the time of the analysis, unreliable.

In 2012, during the WKFLAT (ICES, 2012), a new Irish trawler index was provided as the result of the revision carried out for the Irish Otter trawl fleet. Irish beam trawl (TBB) data are limited to TBB with mesh sizes of 80–89 mm, larger mesh sizes are disused since 2006.

Type	Name	Year range	Used in the assessment
A Coruña otter trawl	SP-CORUTR7	1984–present	No
Cantábrico otter trawl	SP-CANTAB7	1984–2010	No
Vigo otter trawl	SP-VIGOTR7	1984–present	Yes
Irish beam trawl	IR-TBB	1995–present	Yes
French (single and twin bottom trawls	Benthic Bay of Biscay	1985–2008	No
	Benthic Western Approaches	1985–2008	No
	Gadoids Western Approaches	1985–2008	No
	Nephrops Western Approaches	1985–2008	No

B.6 Other relevant data

The estimates of discard data from France have been incorporated to the assessment in IBP Megrim 2016. The aim was to obtain consistent data along the whole data series and also to detect possible recruitment processes that were not previously completely registered in the catch-at-age matrix and lpue.

C. Assessment: data and methods

Summary of the data used for the Inter Benchmark Megrim 2016

Catch, landings and discard numbers-at-age data that were used to carry out the assessment:

i) From 1984 to 1990, international catches-at-age.

ii) From 1990 to present, total international landings-at-age (separately from discards).

iii) From 1990 to 1998 total international discards at age (separately from landings).

Discards in this period were originally available just for two countries: France and Spain. Total international discards from 1990 to 1998 were calculated raising the Spanish and French discards based on the international landings. However, the discard raising method used (which came from many years ago) has not been exactly clarified.

iv) For 1999, only Spanish and Irish discards-at-age are available. Discards-at-age are available for Ireland, Spain and UK from 2000 onwards and for France from 2004 onwards. There was no information for Belgium and Northern Ireland. However, missing discards are supposed to be small as the contribution of these two nations to the stock landings is very small.

The table below summarizes the information of the tuning fleets used in the assessment.

FLEET	ACRONYMS	PERIOD	AGE RANGE
Spanish Survey	SpPGFS-WIBTS-Q4	2001–assessment year-1	1–8
French Survey	EVHOE-WIBTS-Q4	1997–assessment year-1	1–9
Spanish Vigo Trawl 7	VIGO84	1984–1998	2–9
	VIGO99	1999–assessment year-1	2–9
Irish Beam trawlers 7	IRTBB	1995–assessment year-1	2–9

Model used in Inter Benchmark 2016

The model explored during the benchmark is an adaptation of one developed originally for the southern hake stock, published in Fernández *et al.* (2010). It is a statistical catch-at-age model that allows incorporating data at different levels of aggregation in different years and also allows for missing discards data by certain fleets and/or in some years. These are all relevant features in the megrim stock. This model was proposed in WKFLAT 2012 and was adapted in IBP 2016 to include French discards data. The model is fitted in a Bayesian context, using the freely available software JAGS (Martyn Plummer, 2007).

Population dynamics

$N(y,a)$denotes the number of fish of age$a$ at the beginning of year y. In this general model description, the assessment years are labelled as$y = 1, \dots, Y$and ages as $a = 1, \dots, A+$, where A–1 is the last true age and the A+ group consists of fish aged A or older. For the megrim stock, the first assessment year is 1984 and the age plus group corresponds to 10+.

Population dynamics follow the usual equations for closed populations. For $y \geq 2$:

$$N(y,a) = N(y-1,a-1)\exp[-Z(y-1,a-1)], \quad if\ 2 \leq a \leq A-1 \qquad (1)$$

$$N(y,A+) = N(y-1,A-1)\exp[-Z(y-1,A-1)] + N(y-1,A+)\exp[-Z(y-1,A+)] \qquad (2)$$

where $Z(y,a) = F(y,a) + M$ and$F(y,a)$and$M$ are the rates of fishing and natural mortality, respectively. $M = 0.2$is assumed for all ages and years. Annual recruitment of megrim (at age 1), $N(y,1)$, and numbers-at-age in the initial assessment year, $N(1,a)$, are unknown parameters.

Modelling $F(y,a)$ taking account of discards

The rate of fishing mortality is decomposed into disjoint terms as follows:

$F(y,a) = F_L(y,a) + \sum_{j=1}^{J} F_{D,j}(y,a)$ (3) where $F_L(y,a)$ and $F_{D,j}(y,a), j = 1, \dots, J$ relate to the total stock landings and discards from each of the J fleets fishing the stock, respectively. The fleets used for the megrim stock correspond to the countries fishing it and are: Spain, Ireland, United Kingdom, France and Others, where "Others" comprises countries with minor stock catches.

The terms making up the fishing mortality are modelled as follows:

$$F_L(y,a) = f(y)r_L(y,a), F_{D,j}(y,a) = f(y)r_{D,j}(y,a), j = 1, \dots, J \qquad (4)$$

where $f(y)$ is an overall annual factor relating to total fishing effort on the stock and $r_L(y,a)$ and $r_{D,j}(y,a)$ for $j = 1, \dots, J$ determine the exploitation pattern or, in other words, the distribution of F among ages and among landings and discards of different fleets. All factors in formulation (4) are positive and for identifiability, $r_L(y,a)$ is set to

1 for an age chosen arbitrarily. This was set as age 9 in the megrim model implementation, an age for which discards are assumed to be 0, i.e. $r_{D,j}(y,9)$ for all fleets; therefore, $f(y)$ is interpreted as the total fishing mortality-at-age 9). Each of the $r(y,a)$ factors, whether it corresponds to landings or discards, is assumed to have the same values for ages A–1 and A+ , so that the fishing mortality of the + group is the same as the fishing mortality of the last true age.

A Normal random walk for $\log[r_L(y,a)]$ is assumed for each age separately. In original (non-logged) scale, this means:

$$r_L(y,a) \sim LN(r_L(y-1,a-1), CV_{rcond}), \quad (5)$$

where the log-Normal (LN) distribution is parametrized using the median (first parameter) and coefficient of variation (second parameter). As megrim discarding is believed to have increased over the assessment period, the non-stationary random walk model in Equation (5) is considered appropriate. For each age, the value in the first year of the assessment period, $r_L(1,a)$, is an unknown parameter, whereas CV_{rcond} has been fixed at 20%. The same modelling procedure is applied to $r_{D,j}(y,a)$, separately for each age and fleet $j = 1, \ldots, J$, where the values in the first assessment year, $r_{D,j}(1,a)$, are unknown parameters and CV_{rcond} is fixed at the same value as for $r_L(y,a)$.

The annual factor $f(y)$ [Equation (4)] common to all components of F is also unknown. As $f(y)$ is expected to vary slowly in time with no particular trend *a priori*, a stationary process with time autocorrelation seems appropriate. This is modelled as a multivariate Normal distribution for $(\log[f(1)], \ldots, \log[f(Y)])$ $(\log[f(1)], \ldots, \log[f(Y)])$ *a priori*, with the same mean and variance in all years and correlation ρ^n between $\log[f(y)]$ values that are n years apart. The resulting marginal prior distribution in original (non-logged) scale every year is log-Normal:

$$f(y) \sim LN\left(med_f, CV_f\right), \quad (6)$$

with median and CV denoted as med_f and CV_f, respectively. Considering only non-negative correlations, the extreme $\rho = 0$ corresponds to independence between $f(y)$ values over time, whereas $\rho = 1$ leads to the same $f(y)$ value in all years. The values med_f and CV_f are fixed and ρ is treated as unknown.

Observation equations for commercial catch, landings and/or discards data in numbers-at-age

The commercial catch data for the megrim stock have different levels of aggregation depending on the year. Three main time periods can be distinguished in terms of data availability and how they are used in the assessment: (1) years 1984–1989: stock catch numbers-at-age in all years, without any disaggregation into landings and discards or by fleet; (2) years 1990–1998: stock landed numbers-at-age and stock discarded numbers-at-age in all years, without any disaggregation by fleet; (3) years 1999–present: stock landed numbers-at-age in all years and discarded numbers-at-age disaggregated by fleet for the fleets mentioned earlier, i.e. Spain, Ireland, UK (missing in 1999), France (missing in 1999-2003) and Others (but all years missing). The fact that discards of the Others fleet (composed of countries with minor stock catches) are not available means that the stock discards data from 1999 to present are incomplete.

Each of these sources of information is assigned its own observation equations, with a separate equation for each age. For the catch numbers-at-age (years 1984–1989), these are:

$$\log[C^{obs}(y,a)] \sim N\left(\log\left[\hat{C}(y,a)\right], \tau_C(a)\right), \quad (7)$$

where$C^{obs}(y,a)$ is the observed and

$$\hat{C}(y,a) = N(y,a)\{1 - \exp[-Z(y,a)]\}\, F(y,a)/Z(y,a) \qquad (8)$$

the model estimated catch numbers-at-age. For the landed numbers-at-age (years 1990–present):

$$\log[L^{obs}(y,a)] \sim N\big(\log[\hat{L}(y,a)], \tau_L(a)\big), \qquad (9)$$

where$L^{obs}(y,a)$ is the observed and

$$\hat{L}(y,a) = N(y,a)\{1 - \exp[-Z(y,a)]\}\, F_L(y,a)/Z(y,a) \qquad (10)$$

the model-estimated landed numbers-at-age, obtained by applying the Baranov catch equation and using the landings component of F.

The observation equations for discarded numbers-at-age for the stock total (years 1990–1998) or by fleet (years 1999–present) are defined in a similar fashion as Equations (9) and (10), considering the appropriate component of the fishing mortality, i.e. replacing $F_L(y,a)$ by $F_{SPD}(y.a)$ (Spanish discards), $F_{IRD}(y.a)$ (Irish discards), $F_{UKD}(y.a)$ (UK discards), $F_{FRD}(y.a)$(French discards) and $F_D(y.a) = F_{SPD}(y.a) + F_{IRD}(y.a) + F_{UKD}(y.a) + F_{FRD}(y.a) + F_{OTD}(y.a)$ (total stock discards). There are no observation equations involving $F_{OTD}(y.a)$ alone, given that discards of the Others fleets are missing in all years from 1999 to present. This means that information for fitting the $F_{OTD}(y.a)$ component of the total fishing mortality is very indirect as this component of fishing mortality only in the observation equations for total stock catch-at-age during 1984–1989 and total stock discards-at-age during 1990–1998. In preliminary trial runs of this models it became apparent that it was not possible to get sensible estimates of $F_{OTD}(y.a)$ for years 1999 and onwards. To circumvent this difficulty it was decided to fix the evolution of $r_{OTD}(y.a)$from 1999 according to the formula:

$$r_{OTD}(y.a) = r_{OTD}(y-1.a)\frac{OTLW(y)/LW(y)}{OTLW(y-1)/LW(y-1)} \qquad (11)$$

where $LW(y)$ and $OTLW(y)$ denote the total stock landings in weight and the landings of the Others fleet in weight in year y, which are both known. The idea here is to say that the discarding pattern-at-age of the Others fleet has not changed since 1998 and that its change in overall level (with the same change in level for all ages) between years can be approximated by the change in overall landings of this fleet with respect to total stock landings. Clearly, this assumption can be debated, but it was the most reasonable way found to constrain the model to produce sensible fits. If discards data become available for the Others fleet, it would be recommendable to remove this assumption from the model and let $r_{OTD}(y.a)$ continue to evolve in time as a random walk (in log-scale) after 1998 too, as originally modelled.

The precision (inverse of variance) parameters of the observation equations, namely, $\tau_c(a)$ (catch numbers-at-age), $\tau_L(a)$ (landed numbers-at-age), $\tau_D(a)$ (discarded numbers-at-age) and $\tau_{D,j}(a), j = 1, \dots, J$ (discarded numbers-at-age for fleet$j = 1, \dots, J$), reflect the precision of the catch, landings and discards data and are treated as unknown and estimated when fitting the assessment model. In setting prior distributions for these parameters, the well-known relationship between the precision τ of a Normal prior distribution for the log of a variable and the CV of the corresponding log-Normal distribution for the original variable (in non-log scale) will be used. This relationship is as follows: if$\log(X) \sim N(\mu, \tau)$, where τ denotes precision (inverse of variance), then $CV(X) = (\exp(1/\tau) - 1)^{1/2}$.

Observation equations for relative indices of stock abundance

Relative indices of abundance-at-age may be obtained from research surveys or correspond to values of catch per unit of effort of commercial fleets. Let $I_k^{obs}(y,a)$ denote the index corresponding to series k, which relates to a certain time portion of the year$[\alpha_k, \beta_k] \subseteq [0,1]$. For each year and age for which the index is available, the following observation equation is assumed:

$$\log\left[I_k^{obs}(y,a)\right] \sim N\left(log\left[q_k(a)N(y,a)\frac{\exp[-\alpha_k Z(y,a)] - \exp[-\beta_k Z(y,a)]}{(\beta_k - \alpha_k)Z(y,a)}\right], \tau_k(a)\right) \quad (12)$$

(12)

The mean of the Normal distribution is the logarithm of the product of the average stock abundance during the period of the year to which the index relates and the catchability $q_k(a)$, which is unknown. The index precision, $\tau_k(a)$, is considered unknown for all indices explored in the assessment. As explained above, the relationship between the precision of a Normal distribution for the log of a variable and the CV of the corresponding log-Normal distribution for the variable in original scale will be used when setting prior distributions for the precision parameters.

Data, priors, and computational method

Catch numbers-at-age data correspond to: total stock catch (years 1984–1989), total stock landings (1990–present), total stock discards (1990–1998), Spanish discards (1999–present), Irish discards (1999–present), French discards (2004-present), UK discards (2000–present, with year 1999 missing). Discards of Others (countries with minor stock catches) from 1999–present are missing in all years. Catch and landings correspond to ages 1–10+. Discards of ages 8 and older are minimal and assumed to be exactly 0 for ease of modelling (except for Spain, for which the very low number of discards from age 7 make it more convenient to assume that discards are 0 already from age 7).

After considering various potential abundance indices available at the benchmark, with the corresponding ranges of available ages, the ones finally explored within the assessment model correspond to the following indices, years and ages: EVHOE-WIBTS-Q4 survey (1997–present, ages 1–5), Porcupine survey (2001–present, ages 1–8), Vigo bottom-trawl cpue (split into two parts: 1984–1998, ages 2–9; 1999–present, ages 1–9; this splitting was done because of the strong increase in cpue shown by this fleet around the late 1990s and early 2000s, which, after exploration, was considered much more likely to be caused by an increase in catchability rather than be reflective of a strong increase in megrim abundance) and Irish beam trawl lpue (1995–present, ages 2–7).

In a Bayesian context, all unknown parameters are assigned prior distributions, which are meant to reflect the knowledge available before observing the data. The prior distributions considered are centred at values deemed reasonable according to current knowledge of the stock and the fishery while trying to ensure they are not too narrow, so as not to influence unduly the assessment results. Table C.1. lists all the prior choices made for the final run. The parameters of the Gamma prior distribution for the precisions of all observation equations (the τ parameters towards the bottom of Table 9.9.1.1), were chosen using the well-known statistical fact that if $\log(X) \sim N(\mu, \tau)$, then $CV(X) = (\exp(1/\tau) - 1)^{1/2}$, as already mentioned, because it seems easier to think in terms of CVs of the observations than to think in terms of the inverse variance in logarithmic scale. With a $\Gamma(4, 0.345)$ prior distribution on τ, the resulting prior distribution for the *CV*s of the observations in original (non-logged) scale has median 0.31 and (0.20, 0.61) as the 95% central probability interval. These values become 0.10 and (0.08, 0.15), when a $\Gamma(10{,}0.1)$ prior distribution is used for τ. The prior distributions for the exploitation pattern parameters in the first assessment year ($y = 1$, which corresponds to 1984) reflect the idea that discards were very low at that time. When setting the prior distribution for these parameters, it is useful to remember that $r_L(y, 9) = r_L(y, 10+) = 1$has been set, so that all other selection-at-age parameters for landings and discards should be interpreted as departures from the fishing exploitation at ages 9 and 10+.

Model fitting was done using MCMC to simulate the posterior distribution (Gilks *et al.*, 1996, provide an accessible introduction to MCMC). This was programmed in the free software JAGS and run from R (R Development Core Team, 2015).MCMC simulates the posterior distribution with each draw depending on the one immediately preceding it. As a consequence of this dependence, many iterations are typically needed to obtain a representative sample from the posterior distribution, particularly when this is highly dimensional and strong correlations between some of its dimensions exist. The results for the main runs conducted during the benchmark are based mostly on chains of 250 000 iterations. The first 50 000 were discarded to eliminate the effect of start-up values, and 2000 equally spaced iterations out of the other 200 000 iterations were kept. This was considered enough to provide a good representation of the posterior distribution.

Sensitivity analysis

Current assessment settings were decided on the benchmark IBP Megrim (ICES, 2016). This is an update of WKFLAT 2012 benchmark setting where a sensitivity analysis to the various model configurations was conducted. The report of that workshop provides a detailed description of that work.

Table C.1. IBP 2016 Prior distributions of final run. $LN(\mu,\psi)$ denotes the lognormal distribution with median μ and coefficient of variation ψ, and $\Gamma(u,v)$ denotes the Gamma distribution with mean u/v and variance u/v^2.

Parameter and prior distribution	Values used in prior settings
$N(y,1) \sim LN(medrec, 2)$	$medrec = 250000$
$N(1984,a) \sim LN(medrec \exp[-(a-1)M - \sum_{j=1}^{a-1} medF(j)], 2), a = 2,...,9$	$medrec$ as above, $M = 0.2$, $medF = (0.05, 0.1, 0.3, 0.3, 0.3, 0.3, 0.3, 0.3, 0.3)$
$N(1984,10+) \sim LN(medrec \exp[-9M - \sum_{j=1}^{9} medF(j)]/\{1-\exp[-M - medF(9)]\}, 2)$	$medrec, M, medrecF$ as above
$f(y) \sim LN(med_f, CV_f)$	$med_f = 0.3, CV_f = 1$
$\rho \sim Uniform(0,1)$	
$r_L(1984,a) \sim LN(medr_L(a), 1), a = 1,...,8$	$medr_L = (0.0005, 0.05, 1, 1, 1, 1, 1, 1)$

Parameter and prior distribution	Values used in prior settings
$r_L(y,9)=r_L(y,10+)=1$	
$r_{SPD}(1984,a) \sim LN(medr_{SPD}(a),1), a=1,...,7$	$medr_{SPD}=(0.002,0.02,0.02,0.02,0.01,0.01,0.01)$
$r_{IRD}(1984,a) \sim LN(medr_{IRD}(a),1), a=1,...,8$	$medr_{IRD}=(0.001,0.01,0.01,0.01,0.005,0.005,0.005,0.001)$
$r_{UKD}(1984,a) \sim LN(medr_{UKD}(a),1), a=1,...,8$	$medr_{UKD}=(0.00001,0.001,0.001,0.001,0.001,0.001,0.001,0.001)$
$r_{FRD}(1984,a) \sim LN(medr_{FRD}(a),1), a=1,...,8$	$medr_{FRD}=(0.002,0.02,0.02,0.02,0.01,0.01,0.01,0.01)$
$r_{OTD}(1984,a) \sim LN(medr_{OTD}(a),1), a=1,...,8$	$medr_{OTD}=(0.002,0.02,0.02,0.02,0.01,0.01,0.01,0.002)$
$r_{SPD}(y,7)=r_{SPD}(y,a)=r_{IRD}(y,a)$ $=r_{UKD}(y,a)=r_{FRD}(y,a)=r_{OTD}(y,a)=0,\ a=8,9,10+$	
$\tau_C(a),\tau_L(a), a=1,2,3;\ \tau_D(a), a=1,...,8$	$\Gamma(4,0.345)$
$\tau_C(a),\tau_L(a), a=4,...,10+$	$\Gamma(10,0.1)$
$\tau_{SPD}(a), a=1,...,7;\ \tau_{IRD}(a), \tau_{UKD}(a), \tau_{FRD}(a) a=1,...8$	$\Gamma(4,0.345)$
$\log[q_k(a)] \sim N(\mu_{Ik},\tau_{Ik}), a \le 8,$ index $k=1,...,5$	$\mu_{Ik}=-7,\ \tau_{Ik}=0.2$
$q_k(a)=q_k(8), a>8,$ indices k with ages >8	
$\tau_k(a)$, index $k=1,...,5$	$\Gamma(4,0.345)$

D. Short-term projection

Model used: Age structured.

Software used*:* Rscript developed by Fernández et al. (2010).

Type of projection: stochastic.

Initial stock size: Survivors of ages 2 to 10+ from the assessment. All the MCMC draws are used, so that uncertainty from the assessment is taken forward to the projection.

Number of years of projections: 3 years (interim year and 2 additional years).

Recruitment-at-age 1: It is assumed equal in all projection years. It is calculated as the geometric mean of all the recruitments since 1984 except the last two years. If the last year recruitment data is not considered credible, it could also be changed by the geometric mean of all the recruitments since 1984 except the last two years. It includes uncertainty from the assessment, as recruitment is calculated for each MCMC draw. Note that this assumption makes recruitment independent of the current SSB level. Other recruitment scenarios, based on bootstrapping recruitment and/or selecting specific years are also available.

F-at-age, the proportion landed-at-age, weight-at-age and maturity-at-age are taken as the average of the last three years.

Exploitation pattern: If there is a decreasing trend of F in the results of the assessment time series, F status quo should be scaled to Fbar of the final assessment year (default option). Otherwise, this is not necessary.

E. Medium-term projections

No medium-term projections are proposed for this stock.

F. Long-term Projections (until 2006)

No long-term projections are proposed for this stock.

G. Biological reference points

They have been last updated in WGBIE 2018.

From the IBP megrim (ICES, 2016):	Type	Value	Technical Basis
MSY approach	**MSY Btrigger**	41 800	B_{PA}, because the fishery has not been at F_{MSY} in the last 10 years
	FMSY	0.191	**F giving maximum yield at equilibriumComputed using Eqsim.**
	F_{MSY} ranges	0.122-0.289	
Precautionary approach	**Blim**	37 100	B_{loss}, which is the lowest biomass observed corresponding to year 2006
	Bpa	41 800	$\mathbf{B_{lim}} e^{1.645\,\sigma}$ where $\sigma = 0.07$ isthe standard deviation of the logarithm of SSB in 2014
	Flim	0.533	It is the F that gives 50% probability of SSB being above B_{lim} in the long term. It is computed using Eqsim based on segmented regression with the breakpoint fixed at Blim, without advice/assessment error and without Btrigger
	Fpa	0.451	$\mathbf{F_{lim}} e^{-1.645\,\sigma}$ where $\sigma = 0.105$ is the standard deviation of the logarithm of F in 2014

H. Other issues

Historical development

Data improvement during the Benchmark 2012

i) A new Irish trawler index was provided as the result of the revision carried out for the Irish Otter trawl fleet. Irish beam trawl (TBB) data are limited to TBB with mesh sizes of 80–89 mm, larger mesh sizes are disused since 2006.

ii) France provided revised ALKs and consequently completed number and weights-at-age since 1999.

iii) Spain, United Kingdom (England and Wales) and Ireland provide discard data since 2000.

iv) Irish discard data were revised and updated and a new dataseries was provided since 1995.

v) Spain provided some minor revised values of discards.

vi) Some minor revisions were carried out for SP-VIGOTR7 due to the incorporation of catches previously not recorded.

Data deficiencies after Benchmark 2012

i) France did not provided discard data since 1999, as data appear to be very uncertain in relation to sampling level affecting their representatively.

ii) No update for the French lpues series has been provided to the Benchmark group for 2009 and 2010 as effort deployed by this fleet was considered, at the time of the analysis, unreliable.

Software change in WGBIE 2014

Until last year working group, the model was fitted in a Bayesian context, using the freely available software WinBUGS (Lunn *et al.*, 2009). Due to the high amount of time needed to run the model in this software (3 days to run the final assessment) and the low effectiveness that it implicates to make trial runs with different inputs during the group, another freely available software JAGS (Martyn Plummer, 2007) was tested. In JAGS software the final run took 1.5 hours to run. A comparison of the results of both software was done in order to check the outputs. As the results obtained where nearly the same (Figure 5.3.2.1) it was decided to used JAGS software for the assessment.

Updates during IBP Megrim 2016

During IBP Megrim these are the main updates executed:

-French discard estimates are provided from year 2004 to 2014 and included in the assessment.
-Short term forecast script was revised and projections are presented.
-Biological reference points are defined for this stock.

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