ICES IBP MEGRIM REPORT 2016

ICES ADVISORY COMMITTEE

ICES CM 2016/ACOM:32

REF. ACOM

Inter-Benchmark Protocol Workshop Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d (West and Southwest of Ireland, Bay of Biscay) (IBP Megrim 2016)

July 2015 – March 2016

By correspondence

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2016. Inter-Benchmark Protocol Workshop Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7.b–k and 8.a, 8.b, and 8.d (West and Southwest of Ireland, Bay of Biscay) (IBP Megrim 2016), July 2015 – March 2016, By correspondence. ICES CM 2016/ACOM:32. 124 pp.

Contents

Executive Summary

Inter-Benchmark Protocol Workshop on Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7.b–k and 8.a, 8.b, and 8.d (West and Southwest of Ireland, Bay of Biscay) (IBP-Megrim) met by correspondence from August 2015 to April 2016. It was chaired by Santiago Cerviño (Spain) with the participation of 9 people from 5 countries.

The main objective of the meeting was to benchmark the megrim stock assessment model with the aim at raising its assessment category from 3 (advice based on trends) to category 1 (advice based on short term projections). To this end it was considered critical to compile the historic series of discard data, with special focus on French data that was not available in the previous benchmark. Once this was done, the next objectives were to improve the model adapting the script to these new data, parameterizing the model as required, developing the short term forecast algorithm and estimating the reference points following the Workshop to consider FMSY ranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4) guidelines.

All the terms of reference were covered during the meeting. The discards data analysis lasted longer than expected, but finally, with the support of Working Group on Commercial Catches (WGCATCH), it provided useful data. Reference points were estimated following ICES guidelines. The work developed showed high sensitivity to the assumption about range of years used. Other sources of uncertainty identified were M-at-age and the stock-recruitment relationship. Furthermore, the MSY reference points (F range) reflect a level of exploitation outside the observed ranges of the population dynamics, which will need to be revised once more information about the dynamics of the stock at larger biomasses is available.

The use of the Bayesian statistical catch-at-age model, the methodology for deriving biological reference points, the methodology for short term forecast and the estimation of discards are statistically sound and adequate to the stock. The WG considers it can be used for future advice.

Terms of Reference

2016/2/ACOM33 An **Inter-Benchmark Workshop on Megrim (*Lepidorhombuswhiffiagonis*) in Divisions 7.b–k and 8.a, 8.b, and 8.d (West and Southwest of Ireland, Bay of Biscay)** (IBPMegrim), chaired by Santiago Cerviño (IEO, Spain) and reviewed by Ernesto Jardim (JRC) and Samu Mantyniemi, will be established and meet by correspondence until February 15, 2016 to improve the data inputs and model in an effort to move this stock from an ICES category 3 assessment to a category 1 assessment. This IBP was originally scheduled to conclude in September 2015.

The IBPMegrim is conditional of data available to ICES. A data call was issued with a deadline beginning of July. Provisioning and raising the data are ongoing activities, scheduled to conclude by 15 December 2015. The main activities to be undertaken are:

a) Compile the historic series of discard data, with special focus on French data that was not available in the previous benchmark, with assistance from WGCATCH 2015;
b) Improve assessment model settings:

i) Update the assessment model script to incorporate the additional data requested by the data call;
ii) Fit the model with the new data and parametrization, as required;
iii) Review the model script for the projections as some inconsistences were detected at Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE) 2015;
iv) If no analytical assessment method can be agreed, then an alternative method (the former method,) should be put forward;
v) Develop recommendations for future improvements of the assessment methodology and data collection;
vi) Propose possible reference points using the guidelines and process outlined in WKMSYREF4;
vii) Update the stock annex as appropriate.

The work will be conducted by correspondence. Working documents should be provided to the reviewers by 15 February 2016. The Inter-Benchmark Workshop will report by 15 March 2016 for the attention of ACOM.

STOCK	NAME, INSTITUTE	ROLE
Meg-78ab	Ane Iriondo, AZTI	Stock coordinator and stock assessor
	Leire Ibaibarriaga, AZTI	Model development
	Joël Vigneau and Anne-Sophie Cornou, IFREMER	Data providers

1 Introduction

1.1 Structure of the report

The report is structured in two main sections; in this Section (Section 1) the chronicle of the working group work is presented with the issues raised by the reviewers throughout the process ending with a statement confirming that the outcome of the benchmark is appropriate to provide scientific advice; a summary with progress to ToRs with references to the document addressing each ToR; and finally the recommendations for future work and final considerations.

Section 2 corresponds to an assessment model work structured in a similar way as the usual Section in an assessment working group.

Annex 1 is the list and contact details of participants.

Annex 2 is the stock annex.

Annex 3 summarises the external reviewers' considerations.

In Annex 4, two working documents are appended to the report: WD-1 by J. Vigneau is entitled "French historical (2003–2014) discards estimates of megrim (*L. whiffiagonis*) in Subarea 7 and divisions 8.a, 8.b, and 8.d" and WD-2 by L. Ibaibarriaga and A. Iriondo is entitled "Analysis of applying Mortality at age in the assessment of Megrim *(Lepidorhombus whiffiagonis*) in divisions 7.b-k and 8.a and 8.b".

1.2 Working group chronicle

The starting point was the model was initially developed and tested by The Benchmark Workshop on Flatfish and Anglerfish (WKFLAT) that was further developed until WGBIE (2015). The model gave promising results and seemed to be able to deal with the heterogeneity in the Northern Megrim data. The model fit to the data was considered adequate. However, a lack of confidence in the data used made it impossible to accept the absolute values of model results. WKFLAT (2012) concluded, in the view of the current problems and deficiencies of available data, that no precise estimates of development of the stock population structure and SSB were available at that time. WGBIE (2014) recommended the importance of delivering reliable French discard data, including annual estimates of discards to explain some of the recruitment processes detected in the analysis and not completely registered in the catch at age matrix and LPUEs.

This IBP was initially planned to be delivered in September 2015, however the whole work was conditioned in the data availability which was not ready by this time. Main problem to address the data analysis was lack of time given the unexpected problems associated with the analysis of discards data; mainly methodology to raise unsampled strata. None of the options of stratification taken for rising proved satisfactory, all of them lead to problematic unsampled strata. Moreover, there may be a bias in the representativeness of the samples and one should be cautious in regards to the raising of discards by effort and vessel length. Since WGBIE did not have experts on this kind of analysis it was decided to ask for support from WGCATCH, which met in November 2015, to help French work on discards. It was also decided to extend the deadline to get the data.

The data was provided on January 2016 initialising the modelling work of IBPMegrim. The group met by Skype on 29 January. The meeting agenda and main tasks included the following: (i) ToRs were presented by the chair and reviewed; (ii) the work on French data was presented by the French data provider and the discards-at-age data were accepted by the group as useful for the analysis; (iii) Afterwards, an exploratory data analysis for all the data included in the model was presented by the stock coordinator and (iv) the model, the changes needed to incorporate the new data and a preliminary assessment were presented by the modeller expert. Differences in results compared with the 2015 model are minor. The external experts did not find any problem with the changes, the diagnostics were considered adequate and the fit quality was considered acceptable. The external experts' recommendations regarding the model were: (i) try to reduce the autocorrelation in some variables and (ii) to explore alternative natural mortalities different than 0.2.

The stock coordinator in collaboration with the model developer started to work on the external experts' recommendations. The collaboration inside the group was mainly through email and some short skype meetings between the stock coordinator team and the chair.

The next WK skype meeting was set for 18 February. The stock coordinator team presented the results regarding the external experts' suggestions. The autocorrelation was reduced increasing the increasing the iterations and thinning. The model results did not change and the new settings were considered acceptable to the external experts. The stock coordinator team tested many different methods to estimate M. The estimation of M-at-age depends on the weight-at-age figures which are quite variable. This variability depends on the year the data was collected and also on the source of this data (catches or surveys). All the M-at-age methods provide higher M for the smaller ages (or sizes) which is considered more realistic than a constant M. However the scale of these estimations are quite sensitive to the data used (year and source) and also to the method applied (e.g Gislason's gives lower figures than Lorenzen's). The assessment model results are sensitive to the M-at-age assumed. Time series of SSB and F showed different scales although similar trends. However these scales are similar when the reference points are considered (i.e. in relative terms). The quality of the fit (retrospective patterns) was not improved when variable M-at-age was considered.

The work was considered promising nevertheless, given the uncertainty in the data affecting the M-at-age estimation and the lack of time to complete a deeper exploration of factors affecting M, and the fact that the model was not improved. It was decided that our initial guess for M, i.e. constant M=0.2, was our best guess to provide advice. However, given the impact of M on absolute decision parameters (F or SSB) it should be recommended to complete this work before next benchmark (see Recommendations for future work, Section 1.5).

Next ToRs addressed were the short term forecast and estimation of the reference points. Discussions and decisions were taken by e-mail and through some small skype meetings. Reference points were estimated with Eqsim following the WKMSYREF4 recommendations. There were not Eqsim experts in the group and some help was requested to Carmen Fernández and Michel Bertignac. The group acknowledges this collaboration to progress with the ToRs. Reference points were sensitive to the range of years used. Finally the standard 10 year mean was used. The main discussions were about the impact of M-at-age and the stock-recruitment relationship. Finally a segmented regression with break-point at B_{loss} was accepted with the other settings. Short term forecast was developed with a Bayesian ad-hoc software adapted to this stock (ICES, 2012). The group accepted the settings for short term forecast.

1.3 Conclusion

The incorporation of the requested data, mainly French discards data (but also French landings review) was completed and the script to deal with these new data was updated. The model results show that the new data does not alter substantially the perception of stock status and F compared with the preliminary model performed by WGBIE (2015).

The group considers that the model diagnosis is adequate to evaluate the quality fit. The use of the Bayesian statistical catch-at-age model, the methodology for deriving biological reference points, the methodology for short term forecast and the estimation of discards are statistically sound and adequate to the stock. The WG considers it can be used for future advice.

The group considers that the model diagnosis is adequate to evaluate the quality fit. The use of the Bayesian statistical catch-at-age model, the methodology for deriving biological reference points, the methodology for short term forecast and the estimation of discards are statistically sound and adequate to the stock. The WG considers it can be used for future advice.

Nevertheless, as in most stock assessments, the stock-recruitment relationship and natural mortality estimates remain uncertain, which have impacts on the quality of the assessment and the reference points. Although alternative M-at-age were explored, and the biological functions for variable M-at-age were considered potentially realistic, the analysis was not conclusive and therefore the group was not comfortable with using the variable M-at-age approach.

1.4 Progress to ToRs

This section summarizes the work developed in each ToR mainly using references to the section or document where each ToR is developed.

ToR a) Compile the historic series of discard data, with special focus on French data that was not available in the previous benchmark, with assistance from WGCATCH (ICES, 2016);

See the Data section of the assessment (Section 2.2). A working document with the full analysis of French discards data was presented by Joël Vigneau (WD 1, Annex 4). The French discard estimation was developed in the second semester of 2015 with the help of WGCATCH (2015). The document explains the raising problems and the way it was solved making two kinds of raising. Feedback from WGCATCH (ICES, 2016) on the estimation procedure was to regroup all métiers having a low contribution to the landings into one stratum, and regroup at best the other strata to raising by effort. Finally two raising methods were combined: one based on effort (in most cases) and another based on landings (only for some conflictive strata). Once the total discards and length distribution was agreed, the next step was the estimation of discards at age. In this case there were some years (2005–07) with scarce ALK data. Gap filling technique using linear interpolation based on moving average was used, without creating new values where age information at length was available. The French discards-at-age data were accepted by the group to be used in the model.

ToR b) Improve assessment model settings:

i) Update the assessment model script to incorporate the additional data requested by the data call;

The model was updated to consider this new data changing the script to accommodate the new discard data. The whole model is described in the stock annex (Annex 2).

ii) Fit the model with the new data and parameterization, as required;

Data reviewed compared with data used by WGBIE 2015 are: French landings (2003–14) and French discards (2004–14).

An extensive review of methods to estimate M for megrim and their impact on the assessment results was developed and it is presented in the sections of the report regarding biological data and exploratory runs. A more detailed view is available in WD-2 (Annex 4).

iii) Review the model script for the projections as some inconsistencies were detected at WGBIE 2015;

The code was reviewed and updated accordingly. The short term settings were agreed as the most adequate. See details in the short term projection section (Section 2.5) and the stock annex (Annex 2).

iv) If no analytical assessment method can be agreed, then an alternative method (the former method,) should be put forward;

The new analytical assessment method was agreed and it is documented in the stock annex (Annex 2).

v) Develop recommendations for future improvements of the assessment methodology and data collection;

See Recommendations for future work in Section 1.5.

vi) Propose possible reference points using the guidelines and process outlined in WKMSYREF4;

WKMSYREF4 guidelines were followed and Eqsim software was used to set the reference points. The results were quite sensitive to the year range. The stock-recruitment relationship and the M-at-age were considered important sources of uncertainty. However the group considered that the selected settings were the most adequate. See reference points section (Section 2.6) and stock annex (Annex 2).

vii) Update the stock annex as appropriate.

The stock annex was updated and it was finalised and considered appropriate to provide scientific advice for this stock.

1.5 Recommendations for future work

To explore alternatives for French discards-at-age in years without data (2005–07) such as review available ALK data from other countries or using the growth model.

Variable M (in age or time) seems more biological consistent. Furthermore SSB and F absolute figures are quite sensitive to M. However before their implementation in the model, the analysis performed here should be completed by:

-Explore the time series of weight-at-age (or length-at-age) to check the temporal variability of M.

-Weight-at-age estimated from catches can bias the estimated M in ages partially selected to the fishery. This should be explored.

-Improve the understanding of the biological meaning of implemented methods. Considerations like senescence or impact of maturity on M can also be explored.

-Apart from this, M could be estimated inside the model as a bayesian parameter. The model should be developed so that also M can be treated as unknown and estimated like all other parameters. Finding credible prior distributions for M-at-age should help on this.

The M analysis was also used to explore their potential use to correct the retrospective pattern without success. Alternative ways to correct this pattern should be explored in the future.

The current model assumes a deterministic population dynamics without process error. The likely effect of this is that the uncertainty about the stock status is underestimated. The inclusion of process error would help to improve the realism of the uncertainty estimation.

The usual way to deal with recruitment in short term forecast is to use some kind of mean recruitment for projected years. For this stock, as in many stocks explored in WKMSYREF4 (2015), there was also a stock–recruitment relationships set to define MSY reference points, that could be used for the short term forecast. However, we decided to go for usual mean, however, the implications of using the same S-R model for STF and those used in the estimation of reference points should be evaluated.

Develop alternative S-R relationship with biological meaning. For instance, developing a prior for steepness that can help current Bev-Holt model to estimate a more realistic steepness.

The group also encourages the development of a Management Strategy Evaluation (MSE) as a tool to evaluate reference points or any plausible Harvest Control Rule.

1.6 Final considerations

The Inter-Benchmark Protocol Workshop on Megrim (IBPMegrim) was developed by correspondence. The group considers that this approach made the activity quite time consuming being not as effective as it should be. As there is not a common time schedule and the entire participants have other commitments, it was very slow to get to agreement, take decisions and progress in work. The group considers that to be efficient in the future a physical meting making the critical work in advance would be more efficient.

1.7 References

Fernández, C., S. Cerviño, N. Pérez and E. Jardim. 2010. Stock assessment and projections incorporating discards estimates in some years: An application to the hake stock in ICES divisions VIIIc and IXa. ICES J. Mar. Sci. 67, 1185-1197.

ICES. 2012. Report of the Benchmark Workshop on Flatfish Species and Anglerfish. (WKFLAT), 1–8 March 2012, Bilbao, Spain. ICES CM 2012/ACOM:46.

ICES. 2015. Report of the Working Group for the Bay of Biscay and the Iberian waters Ecoregion (WGBIE). 6–12 May 2015, ICES Headquarters, Copenhagen, Denmark. ICES CM 2015/ACOM:11.

ICES. 2016. Report of the Working Group on Commercial Catches (WGCATCH), 9-13November 2015, Lisbon, Portugal. ICES CM 2015/SSGIEOM:34. 111 pp.

ICES. 2016. Report of the Workshop to consider FMSYranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4), 13–16 October 2015, Brest, France. ICES CM 2015/ACOM:58. 187pp.

2 Assessment – Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7.b–k and 8.a, 8.b, and 8.d

Assessment type: An Inter-Benchmark workshop has been carried out with the aim of executing a full assessment for this stock and shifting it to category 1. This stock was benchmarked in 2012 in WKFLAT. Until now it was in category 3 where the assessment was based on trends in SSB from the assessment, which includes surveys and commercial data, and a more detailed trend study on abundance of age groups from surveys and commercial fleets.

Data revisions in the Inter-Benchmark: French 2003–2014 landing data revision and French discard data are available from 2004 to 2014 which have been included in the assessment.

2.1 General

2.1.1 Fishery description

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 have reported around 96% of the total landings (Table 2.1.1.1.). Estimates of total landings (including unreported or miss-reported landings) and catches (landings + discards) as used by the Working Group up to 2014 are shown in Table 2.1.1.2.

2.1.2 Summary of ICES Advice for 2015 and Management applicable for 2014 and 2015

ICES advice for 2015

ICES advises on the basis of the approach for data-limited stocks, but cannot quantify the resulting catches. The implied landings should be no more than 15 180 tonnes.

Management applicable for 2014 and 2015

The 2014 TAC was set at 19 101 t and 2015 TAC 19 101 t, including a 5% contribution of *L. boscii* in the landings for which stock there is no assessment.

The minimum landing size of megrim was reduced from 25 to 20 cm length in 2000.

2.2 Data

2.2.1 Commercial catches and discards

The Inter-Benchmark Protocol Workshop 2016 was conditional of data available to ICES, with special focus on French discard data that was not available in previous WD 1. Data have been provided following the data-call and stock catches for the period 1984–2014, as estimated by the WD 1, are updated and given in Table 2.1.1.2.

During Inter-Benchmark 2016, France landing data series were updated from 2003 to 2014 based on the WD presented by IFREMER (WD 1, Joel Vigneau, Annex 4). In Figure 2.2.1.1., the comparison of the French landings and discard information between WGBIE 2015 and IBPMegrim 2016 is presented. The updated landing data from France in IBMegrim 2016 shows an increasing trend from 2008 onwards. Landing information by Spain, UK, Ireland and Belgium provided to the WGBIE 2015 remain without changes.

Regarding discard data, they were provided from 2004 to 2014 by France to the Inter-Benchmark 2016, which was one of the main objectives. The analysis done by IFREMER is presented in WD 1 (Annex 4). France discard data were not provided since 1999, as data appeared to be very uncertain in relation to sampling level affecting their representatively. Discard information provided by France in IBPMegrim 2016 seems stable with an average of 685 tons of discards each year.

The group stated strongly in previous WGBIE the importance of incorporating annual estimates of discards to obtain consistent data along the whole data series what finally has been fulfilled. Discard data from Ireland, Spain, UK and Belgium provided to the WGBIE 2015 remain without changes.

Due to this updated information from France, some changes in comparison with WGBIE 2015 data in the total landings and discards are shown in Table 2.2.1.1. In the time series of data updated, the main differences in landing information are in year 2009 to 2012, with an increase of 15% by year in average. Regarding discards, the increase in total discards in all updated years is significant, with an increase of 20% by year in average. Total landings in 2014 are lower than in 2013 (16%), reaching up to 13 280 t in both cases.

Discard data available by country and the procedure to derive them are summarised in Table 2.2.1.2. The discards decrease in year 2000 can be partly explained by the reduction in the minimum landing size from 25 cm to 20 cm. Since 2000, an increasing trend in the discards has been observed until a peak of 30% of catches in 2004. In 2005, the decrease in the number of small fish resulted in a large decrease of discards (Figure 2.2.1.1). In 2006 discards increased again around 24%, with a fluctuating trend in the following years. In 2014 discards were 16% in weight of total catches and decreased 47% in weight in comparison with previous year.

In the following table the comparison of WGBIE 2015 and IBPMegrim 2016 of the discard ratio in percentage (%) from catches in weight of the most recent years is presented.

Discard ratio (%)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
WGBIE 2015	11	13	15	20	27	17	22	17	19	16	25	22	19	21	14
IBP 2016	11	13	15	20	30	20	24	19	21	18	26	24	20	23	16
Difference	**0%**	**0%**	**0%**	**0%**	**3%**	**3%**	**2%**	**2%**	**2%**	**2%**	**1%**	**2%**	**2%**	**3%**	**2%**

The results of the comparison show that the update of French discards data imply an increase of 2% in the discard ratio in average in relation to total catch.

2.2.2 Biological sampling

Age and Length distribution provided by countries are explained in the stock annex for Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k and 8.a, 8.b, and 8.d (Annex 2).

Age

France and Spain provided ALKs and consequently completed number and weights at age up to 2014. Ireland and UK (England and Wales) provided number at age for discards and landings up to 2014.

Age distribution for landings and discards from 1999 to 2014 are presented in Figure 2.2.2.1.

Lengths

Table 2.2.2.1 shows the available original length composition of landings by Fishing Unit in 2014. The length compositions of the landings show an increase between 1990 and 1992 and, subsequently, a constant decrease until a rapid increase starting in 2000 (Figure 2.2.1.1) due to the change in MLS. Up to 2006, mean lengths stay relatively stable in the recent years with a decrease in length of discards. In 2013 and 2014 the mean length of landings and discards remains stable.

Natural Mortality

An extensive review of methods to estimate M for megrim and their impact on the assessment results was addressed and it is presented by Ibaibarriaga, L. and Iriondo, A. 2016 (WD 2, Annex 4). The main conclusions that can be extracted from this work are the following: The estimation of M-at-age depends on the weight-at-age figures which are quite variable. This variability depends on the year the data was collected and also on the source of this data (catches or surveys). All the M-at-age methods provide higher M for the smaller ages (or sizes) which is considered more realistic than a constant M. However we are not in conditions to select the best M-at-age among those provided since the scale of these estimations are quite sensitive to the data used (year and source) and also to the method applied (e.g Gislason's gives lower figures than Lorenzen's). Some runs were also analysed with alternative M-at-age to see the sensitivity of the model results (see model section).

M=0.2 has been used as input data for all ages and years in the final model.

2.2.3 Surveys data

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 1997–2014 are summarised in Table 2.2.3.1.

The UK-WCGFS-D and UK-WCGFS-S show the same pattern in the indices for ages 2 and 3 since 1997; in agreement with the high values of EVHOE-WIBTS-Q4 age 1 index for the years 1998 and 2000. These high indices in the Deep component of the UK Surveys are even more remarkable in 2003 for all ages and in 2004 for the younger ages.

EVHOE-WIBTS-Q4 indices for age 1+2 showed no evident general trend. Oscillations of high and low values are present from 2002 to 2007. In 2007 indices decreased sharply with a slight increase till 2010. From 2010 it remains quite stable with a slight increase in 2014 (Figure 2.2.3.2). In Figure 2.2.3.3 the time series of the age composition of abundances from 2007 to 2014 of EVHOE survey is presented.

An abundance index in ages was provided for Irish Groundfish Survey (IGFS-WIBTS-Q4) from 2003–2014. For the last five years of the data series, the survey provides the lowest values of older ages and a sharp decrease of medium age individuals. For the younger ages, it is quite stable in the last five years.

A revised abundance index in ages was provided for the Spanish Porcupine Ground Fish Survey (SpPGFS-WIBTS-Q4) from 2001 to 2014 due to a change in the calculation methodology of the tow trawling time. In Figure 2.2.3.4 the time series of the age composition of abundances from 2007 to 2014 is presented.

When comparing Spanish, French and Irish survey biomass indices some contradictory signals are detected (Figure 2.2.3.1). The EVHOE-WIBTS-Q4 index decreased from 2001 until 2005 and since then has sharply increased until 2011. In the last years until 2014, it slightly decreased. The SpPGFS-WIBTS-Q4 Porcupine survey (SP-PGFS) shows fluctuation trends from year 2003 to 2008. Afterwards, an increasing trend is observed until 2014.

Irish Ground Fish Survey (IGFS-WIBTS-Q4) gives the highest estimates in 2005 with a decrease in trend to 2007 and increasing again till 2009 in agreement with EVHOE-WIBTS-Q4. In 2010 a sharp decreased occurred in contradiction with the French and Spanish surveys. In 2011 a slight increase occurred in agreement with Spanish survey and in 2012 and 2013 a decreased was observed again with a slight in 2014.

For a more detailed inspection of the abundances indices of different age groups, these were inspected along the whole data series for surveys (Figure 2.2.3.2). Ages groups were identified as: i) age 1+age 2; ii) age 3+age 4+age 5 and iii) age 6+age 7 +age 8+age 9+age 10+. The most abundant age group was ii) at the beginning and the end of the data series for all the surveys but it shows a decreasing trend in the last three years. Age group i) appear most abundant during years 2005 to 2008. As a consequence it is difficult to conclude on the recent abundance trends by age group.

It must be noted that the areas covered by the three surveys almost do not overlap (Figure 2.2.3.5). There is some overlap between the northern component of EVHOE-WIBTS-Q4 and the southern coverage of IGFS-WIBTS-Q4, whereas the eastern boundary of SP-PGFS essentially coincides with the western one of IGFS-WIBTS-Q4.

2.2.4 Commercial catch and effort data

For 2012 Benchmark, 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 is limited to TBB with mesh sizes of 80–89mm, larger mesh sizes are disused since 2006.

The general level of effort is described in Figure 2.2.4.1. SP-CORUTR7 and SP-VIGOTR7 fleets have decreased sharply until 1993, since then it has been decreasing slightly. SP-VIGOTR7 showed a very slight increase in 2007, decreasing slightly till 2014. SP-CANTAB7 remains quite stable since 1991 and decreased slightly since 2000. In 2009, no effort has been deployed by this fleet but in 2010, some trips were recorded, for the last four years no effort was deployed. The effort of the French benthic trawlers fleet in the Celtic Sea decreased from 1991 to 1994, then increased in 1995–1996 and decreasing again in 1999. Since then, effort has been fluctuating up and down for the last 10 years. Since French logbook data were only partially available since 1999, only the LPUE data can be considered.

Commercial series of catch-at-age and effort data were available for three Spanish fleets in Subarea 7 (Figure 2.2.4.2): A Coruña (SP-CORUTR7) from 1984–2014, Cantábrico (SP-CANTAB7) from 1984–2010 as no effort has been deployed by this fleet in subarea 7 during the last four years and Vigo (SP-VIGOTR7) from 1984–2014. The CPUE of SP-CORUTR7 has fluctuated until 1990, when it started to decrease, with a slight increase in 2003 and a peak in CPUE in 2011 and decrease again in 2014. Over the same period, SP-VIGOTR7 has remained relatively stable until 1999, reaching in 2004 the historical maximum. In the last years it was fluctuations with a decrease in 2014. SP-CANTAB7 has been fluctuating up to 1999 and then a general increasing trend is observed. No LPUE value is available for this fleet in 2009, as no effort was deployed. In 2010, LPUEs increased as a result of some trips being deployed in area 7 but in 2011, but afterwards no effort was deployed.

From 1985 to 2008, LPUEs from four French trawling fleets: FR-FU04, Benthic Bay of Biscay, Gadoids Western Approaches and *Nephrops* Western Approaches were available. (Table 2.2.4.1. and Figure 2.2.4.3). No data for 2009, 2010 and 2011 were provided as effort deployed by these fleet was considered, at the time of the analysis, unreliable.

The LPUE of all Irish beam trawlers fleets oscillates up and down since 2000 to 2006 following a decreasing trend. From 2007 an increase in the LPUE is observed with a slight decrease in 2014 (Figure 2.2.4.4).

Summarizing no particular LPUE changes have been observed, so no stock changes is observed.

An analysis of the abundance indices of different age groups in data series for commercial fleets was carried out (Figure 2.2.4.5). Ages groups were identified as: i) age 1+age 2; ii) age 3+age 4+age 5 and iii) age 6+age 7+age 8+age 9+age 10+. For Spanish and Irish commercial fleets, the most abundant age group was ii) at the beginning and the end of the data series. Age group i) appear more abundant than older ages (ii) during years 2003 and 2004 in the Spanish fleet. French fleets appear to land mostly old individual at the beginning of the data series, while same quantities of medium age fish (group ii) and old fish (group iii) are presented till 2008. In general, a marked decrease in abundance index of old fish was observed for French fleet. In 2014, a decrease is observed in Spanish and Irish fleets but the proportion of age groups catches is maintained.

Based on age groups of commercial fleets, summarizing no particular LPUE changes have been observed, so no stock changes is observed.

2.3 Assessment

An analytical assessment was conducted using updated French landings and discards data. With the inclusion of French discard data, some changes to the model were executed in relation to the discard estimation coefficient and data input from the Bayesian model.

2.3.1 Data Exploratory Analysis

In summary, the stock catch-at-age matrix shows three periods: 1984–1989; 1990–1998 and 1999–2014.

The data analyzed consist of landed, discarded and catch numbers-at-age and abundance indices-at-age. Five of the available fleets were considered appropriate to inclusion in the assessment model as tuning fleets: Spanish Porcupine survey (SpPGFS_WIBTS-Q4), French Survey (EVHOE-WIBTSQ4), Vigo commercial trawl cpue series separated in two periods: 1984–1998 (VIGO84) and 1999–2010 (VIGO99), and Irish Otter trawlers lpue (IRTBB), based on their representativeness of megrim stock abundance. An exploratory data analyses was performed to examine their ability to track cohorts through time.

Several exploratory analyses were carried out on the data with the software R. The analysis of the standardized log abundance indices revealed no special trend in EVHOE-WIBTSQ4 survey (Figure 2.3.1.1). Otherwise, in SpPGFS-WIBTS-Q4 negative values for old ages from 2007 to 2011, but positive for old ages from 2012 to 2014. The analysis of the standardized log abundance indices revealed year trends for VIGO99 and the same decrease in the index of old individuals was detected by this fleet in 2008 and 2009. In 1999 and 2000, VIGO99 showed negative high values for ages 1 and 2 but in the last years positive values of ages 1–3 and bigger ages 7–9. IRTBB and SpPGFS-

WIBTS-Q4 were the fleets that showed more positive values for older ages from year 2010 onwards.

A comparison of WGBIE 2015 and IBPMegrim 2016 data exploratory analysis is presented in relation to catches, landings and discards to show which the differences between them are. In general, very minor differences are appreciated.

The time-series of catch at age (Figure 2.3.1.2) showed very low catches of ages 1–5 from 1984 to 1989. From 2004 to 2010, the catch of older ages (> 6) was remarkably low, whereas catches of ages 1 and 2 increased markedly from 2003. This could be a result of an underestimation of catches of these ages (specially age 1) before this year, probably, due to the sparseness of discard data in that period. For ages 6 and older, large discrepancies in the amount caught before and after 1990 are apparent, with large catches of these ages before 1990 and a decrease to almost no individuals caught at the end of the data series.

The analysis of the landings are presented since 1990 (Figure 2.3.1.3). Landings of ages 1 and 2 decreased from the beginning of the series to the last years where negative values have increased from 2009 onwards. In fact, the proportion of older ages in the landings decreased significantly from 2004 to 2009, as already discussed in relation to the catch. In 2014, ages 1 increased a lot (mainly from the Irish fleet) and older ages decreased.

The signal coming from the discard data showed that at the beginning of the data series discards of age 1 was low (Figure 2.3.1.4). Discards of this age increased along the data series, particularly from 2003 onwards. Ages 4, 5, and 6 appeared to be highly discarded in year 2004. From year 2010 to 2013, ages 1 to 3 appear to be highly discarded but in 2014 general discards decrease again. A slight difference between WGBIE 2015 and IBPMegrim 2016 discard data is observed for ages 7 and 8 (Figure 2.3.1.5). From year 2005 to 2010 the new data provides higher discards of older ages that were not observed in previous discards data.

2.3.2 Model

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.

The model is described in the stock annex (Annex 2).

Exploratory runs

Some exploratory runs were performed: to estimate the impact of alternative M at age. (see WD 2, Annex 4)

5 cases with different M-at-age where selected to explore the model fit:

- M=0.2 (as used up to now)
- Variable M-at-age (following Gislason)
- M constant estimated by the model
- Bayesian model averaging with the 3 previous cases
- Bayesian model averaging with first two cases

The assessment model results are sensitive to the M-at-age assumed. Time series of SSB and F showed different scales although similar trends. However these scales are similar when the reference points are considered. The quality of the fit (retrospective patterns) was not improved when variable M-at-age was considered. Given the uncertainty in the data and methods affecting the variable M-at-age estimation and the lack of time to complete a deeper exploration of factors affecting variable M-at-age, our initial guess for M, i.e. constant M=0.2, was considered our best guess.". However, given the impact of M on absolute decision parameters (F or SSB) it should be recommended to complete this work before next benchmark (see recommendations section).

2.3.3 Results

The model results were analysed looking at three different kinds of plots: convergence plots (to analyse the convergence behaviour of the MCMC chains), diagnostic plots (to analyse the goodness of the fit) and, finally, plots of the models estimates (displaying the estimated stock status over time).

Regarding the settings of the prior for the final run, some changes have been done in relation to the inclusion of discards information from France, which will be included as data instead of being estimated by the model. A comparison of the ones chosen in the Benchmark 2012 as the best one among the different model configurations run and the ones chosen in IBPMegrim 2016 are listed in Table 2.3.3.1.

In order to be sure that the model has produced a representative sample of the posterior distribution, the MCMC chain was examined for behaviour ("convergence" properties). This was done by examining trace plots and autocorrelation plots for most parameters in the model (Figure 2.3.3.1 to Figure 2.3.3.3). The trace and autocorrelation plots showed a good behaviour in the run carried out with the model, giving support to the reliability of the outputs from the MCMC simulation conducted.

Model diagnostics plots examined were: prior-posterior plots and time series and bubble plots of the residuals. Prior-posterior distributions are shown in Figures 2.3.3.4. Posterior distributions for log-population abundance in first assessment year (1984), log-f(y) and log-catchabilities of abundance indices were much more concentrated than the priors and were often centred at different places. This indicated that the model was able to extract information from the data in order to substantially revise the prior distribution. In these cases, the model fits are mostly driven by the data, with the prior having only a small influence. The posterior distributions for log-rSPD, log-rFR or log-rOTD in the first assessment year (1984) were similar to the prior distributions in most of the cases. This was especially true for log-rOTD, were data directly associated with it was not available to the model. This indicates that the available data does not contain very much information concerning these parameters and that the priors have to be chosen carefully trying to be realistic.

WGBIE 2015 and IBPMegrim 2016 results oftime series of estimated spawning stock biomass (SSB), reference fishing mortality (F_{bar}), recruits and catch, landings and discards are shown in Figure 2.3.3.5 for comparison. The SSB shows an overall decreasing trend from the start of the series in 1984 to 2005 with a marked increasing trend till 2014. The uncertainty in the SSB was low in the whole time series. The median recruitment fluctuated between 200 000 and 300 000 thousand in the whole series without any trend. As expected, uncertainty in recruitment estimates is largest at the end of the time series, as those years correspond to cohorts that are still passing through the population and additional information about them will be gained in future years. The fishing mortality showed three marked periods which coincide with the data periods, 1984–

1989, 1990–1998 and 1999–2014. The lowest F_{bar} was observed in the first period and the highest one in the year 2005 and then it decreases until 2014 with small uncertainty. This decreasing F trend in recent years explains the increase of SSB since catches and recruitment remain relatively constant. Overall, the catches showed very weak decreasing trend. The landings decreased in a higher proportion than the catches and the discards showed a slight decreasing trend. The uncertainty was small in all the years. When comparing the results from WGBIE 2015 and IBPMegrim 2016, the general trends remain the same and only slight differences in the absolute values are observed.

2.4 Retrospective pattern

Retrospective analysis was conducted for 5 years, the retrospective time series of most relevant indicators are shown in Figures 2.4.1. In terms of SSB, two groups were distinguished: one corresponding to the two shortest time series (removing the 2 and 3 final years) and a second one with the two longest time series (until 2013 and removing 1 year). The SSB estimates were very similar throughout the entire time series and there was an upward revision of SSB. The recruitment estimates towards the end of the time series showed significant revisions in the retrospective analysis, but this is something common, as recruitment in the most recent year(s) is usually not correctly estimated by assessment models. The fishing mortality was revised downwards year by year. Regarding the catches and landings, a downward revision was observed from 2006 to 2010 and a slight upward revision was done in the last 3 years. For discards the main differences in the estimates were observed at the beginning of the time series and for years 2002 and 2007.

2.5 Short term forecasts

Short-term projections have been made using Rscript developed by Fernández *et al.* (2010). Some modifications have been done to the script during IBPMegrim 2016 as the previous results of the projection were inconsistent with the stock dynamic estimated by the assessment model.

For the current projection, the following short term forecast settings are agreed: the average of the last three years is used to average F-at-age, the proportion landed-at-age, and the vectors of weight-at-age and maturity-at-age. As there is a decreasing trend of F in the results of the assessment time series, F *status quo* is scaled to F_{bar} of the final assessment year. For the recruitment, the geometric mean of the recruitment posteriors in all assessment years except for the final 2 is used. The impact of impaired recruitment when SSB is below B_{loss} on STF was not explored. However, given the current healthy stock status it was not considered an issue at this time. A recommendation for this analysis was set (see Section 1.5).

Landings in 2016 and SSB in 2017 predicted for various levels of fishing mortality in 2016 are given in Table 2.5.1. Maintaining F *status quo* in 2016 is expected to result in an increase in landings with respect to 2015 and an increase in SSB in 2016with respect to 2015.

2.6 Biological reference points

Biological reference points were calculated for this stock based on the recommendations from WKMSYREF4 (ICES, 2016). First, limit and precautionary reference points for spawning stock biomass (SSB) and fishing mortality (F), namely B_{lim}, B_{pa}, F_{lim} and

F_{pa}, were defined. Then, F_{MSY}, MSY $B_{trigger}$ and F_{MSY} ranges were estimated using Eqsim (stochastic equilibrium reference point software) which provides MSY reference points based on the equilibrium distribution of stochastic projections. Alternatively, F_{max}, $F_{0.1}$, $F_{30\%}$ and $F_{35\%}$ were estimated from equilibrium analysis that includes the uncertainty of the assessment.

2.6.1 Precautionary reference points

The stock-recruitment relationship for this stock is shown in Figure 2.6.1.1. The dynamic range of SSB goes from 30 to 60 thousand tonnes. The highest biomasses correspond to the first four years of the assessment, on which recruitments were among the lowest observed. However, the SSB in these initial years are considered quite uncertain given the shortness of the cohorts contributing to them and the lack of observations to calibrate them (only one LPUE from fleet SP-VIGOTR7). The stock was considered of type 5, i.e. with no evidence that recruitment has been impaired or no apparent relation between stock and recruitment. Therefore, B_{lim} was taken as B_{loss}, the lowest observed biomass in the time series. This corresponds to 37 100 tonnes in year 2006.

The precautionary approach biomass (B_{pa}) is defined as the value of the estimated SSB that ensures that the true SSB has less than 5% probability of being below B_{lim}, i.e. as the upper 95 percentile on the distribution of the estimated biomass if the true biomass is at B_{lim}. Thus, B_{pa} is derived from B_{lim} as follows:

$$B_{pa} = B_{lim} e^{1.645\,\sigma},$$

where σ is the standard deviation of ln(SSB) in the final assessment year. The standard deviation of the logarithm of SSB in 2014 is 0.07, leading to B_{pa} at 41 800 tonnes.

The limit fishing mortality (F_{lim}) is the F that, in equilibrium from a long-term stochastic projection, gives 50% probability of SSB being above B_{lim}. This was computed using Eqsim for a projection based on stochastic recruitment around a segmented regression with breakpoint fixed at B_{lim} (Figure 2.6.1.2). Biological parameters (mean weights at age, maturity and natural mortality) and exploitation pattern were as in the last 10 years (2005–2014) of the stock assessment. No assessment/advice errors were considered ($F_{cv} = F_{phi} = 0$) and no advice rule was included ($B_{trigger}=0$). F_{lim} was set at 0.489 as the fishing mortality giving 50% probability of SSB being above B_{lim}.

The precautionary approach fishing mortality F_{pa} is the value of the estimated F that ensures that the true F has less than 5% probability of being above F_{lim}, i.e. the lower 5 percentile on distribution of the estimated F if true F is at F_{lim}. Thus, F_{pa} is derived from F_{lim} as follows:

$$F_{pa} = F_{lim} e^{-1.645\,\sigma},$$

where σ is the standard deviation of ln(F) in the final assessment year. The standard deviation of the logarithm of F in 2014 is 0.105, leading to F_{pa} at 0.412.

2.6.2 MSY reference points from Eqsim

For the stochastic projections in Eqsim recruitments are sampled from the predictive distribution of fitted parametric stock-recruitment models. Initially, Beverton-Holt, Ricker and segmented regression stock–recruitment models were considered and the fitted models were averaged using smooth AIC weights (Buckland *et al.*, 1997). However, the breakpoint of the segmented regression model was lower than the lowest observed SSB, the fit of the Beverton-Holt was unrealistic (a flat line) and no biological support was found for the Ricker model. Therefore, it was decided to use a segmented regression model with the breakpoint fixed at the lowest observed biomass (Figure 2.6.1.2). This is a risk adverse decision to avoid the high F_{crash} derived from bad steepness estimated in Beverton-Holt model or the high F_{MSY} caused by the over-compensatory area in the Ricker model defined by the 4 first SSBs in the time series. However it is considered that SR models with biological meaning would be preferred in the future and the definition of priors for the conflicting parameters could help to build acceptable models (see Section 1.5).

Biological parameters (weights-at-age, natural mortality and maturity) and the exploitation pattern (selectivity) were resampled at random from the last ten years of the assessment (2005–2014). Assessment/advice errors could not be estimated for this stock since the model was not used in the latest years to provide advice. Assessment/advice errors were set according to the default option in WKMSYREF4 (ICES, 2016). The conditional standard deviation in the log domain was F_{CV}=0.212 and the parameter of autocorrelation in the AR (1) process for fishing mortality was Phi=0.423. These values were estimated by WKMSYREF4 (2016) as the medians of five stocks. The biomass trigger point ($B_{trigger}$) was fixed at 0, indicating that the ICES MSY advice rule (fishing mortality is linearly reduced if the biomass in the TAC year is predicted to be lower than MSY $B_{trigger}$) was not applied.

All the settings for the base case run in Eqsim are given in Table 2.6.2.1.

F_{MSY} was computed as the F maximizing the median landings yield curve. F_{MSY} range was calculated as the F values corresponding to median landings yield that are at least 95% of the maximum yield. The value of F corresponding to the 5% probability of SSB being below B_{lim} in one year ($F_{p.05}$) was calculated to check whether the F_{MSY} values were precautionary. Yield curve for the median landings is shown in Figure 2.6.2.1. Summary table and plots from Eqsim are given in Table 2.6.2.2 and Figure 2.6.2.2. F_{MSY} is 0.161 with F_{MSY} range at 0.106–0.246. The upper range value is lower than $F_{p.05}$, which is estimated at 0.366. Thus, fishing mortality levels around F_{MSY} are precautionary. The median SSB at F_{MSY} is around 106 300 tonnes, well above the observed biomasses. Hence, the reference points reflect a level of exploitation outside the observed ranges of the population dynamics, which will need to be revised once more information about the dynamics of the stock at larger biomasses is available.

MSY $B_{trigger}$ needs to be estimated for the ICES MSY advice rule. This parameter is defined as the 5th percentile of the distribution of SSB when fishing at F_{MSY} and is calculated via stochastic simulation in Eqsim excluding assessment/advice error and without $B_{trigger}$. Note that given that the selected stock-recruitment model for the projection is the segmented regression with the breakpoint fixed at B_{lim}, this Eqsim run is the same as used for deriving F_{lim}. From this run, the initial proposal for MSY $B_{trigger}$ would be 89 700 tonnes. However, the fishing mortalities from the assessment have ranged between 0.2 and 0.6, being above F_{MSY}. Given that the fishery has not been at F_{MSY} levels in the last 10 years, MSY $B_{trigger}$ was set equal to B_{PA}.

Although not necessary because F_{MSY} was shown to be compatible with the precautionary approach, the effect of including the ICES MSY advice rule was also evaluated by running Eqsim with Btrigger equal to MSY $B_{trigger}$ at 41 800 tonnes. Summary table and plots from Eqsim are given in Table 2.6.2.3 and Figure 2.6.2.3. $F_{p.05}$ increased from 0.366 to 0.379 when including the ICES MSY advice rule.

The summary of the proposed precautionary and MSY reference points obtained with Eqsim is given in Table 2.6.2.4.

2.6.3 Per recruit equilibrium analysis

Alternatively to Eqsim, a yield per recruit equilibrium analysis was conducted. The results of the assessment are projected forward including the assessment uncertainty. The exploitation pattern, proportion landed-at-age, and the vectors of weight-at-age and maturity-at-age are averaged over the last 3 years. The resulting probability distributions of $F_{status-quo}$, F_{max}, $F_{0.1}$, $F_{30\%}$ and $F_{35\%}$ are shown in Figure 2.6.3.3 and summarised in Table 2.6.3.1. The median values of F_{max}, $F_{0.1}$, $F_{30\%}$ and $F_{35\%}$ are lower than the $F_{status-quo}$. The yield per recruit and the SSB per recruit curves for different F values are shown in Figure 2.6.3.2.

Sensitivity to the number of years over which the exploitation pattern and the biological parameters were averaged is shown in Figure 2.6.3.3. The more years are used the lower are the F reference points.

2.7 Conclusions

The incorporation of the requested data, mainly French discards data (but also French landings review) was completed and the script to deal with these new data was updated. The model results show that the new data does not alter substantially the perception of stock status and F compared with the preliminary model performed by WGBIE (2015).

The group considers that the model diagnosis is adequate to evaluate the quality fit. The use of the Bayesian statistical catch-at-age model, the methodology for deriving biological reference points, the methodology for short term forecast and the estimation of discards are statistically sound and adequate to the stock. The WG considers it can be used for future advice.

Nevertheless, as in most stock assessments, the stock-recruitment relationship and natural mortality remain uncertain, which have an impact in the assessment and the reference points. Although alternative M-at-age were explored, and the biological functions for variable M-at-age were considered potentially realistic, the analysis was not conclusive to make the group comfortable with using the variable M-at-age approach. Our initial guess for M, i.e. constant M=0.2, was considered our best guess to provide advice. Some recommendations to address these issues in the future are included.

Table 2.1.1.1. .Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Nominal landings and catches (t) by country provided by the Working Group.

	Landings									Discards								
	France	Spain	U.K. (England & Wales)	U.K. (Scotland)	Ireland	Northern Ireland	Belgium	Unallocated	Total landings	France	Spain	U.K.	Ireland	Northern Ireland	Belgium	Others	Total discards	Total catches
1984									**16659**							2169	**2169**	**18828**
1985									**17865**							1732	**1732**	**19597**
1986	4896	10242	2048		1563		178		**18927**							2321	**2321**	**21248**
1987	5056	8772	1600		1561		125		**17114**							1705	**1705**	**18819**
1988	5206	9247	1956		995		173		**17577**							1725	**1725**	**19302**
1989	5452	9482	1451		2548		300		**19233**							2582	**2582**	**21815**
1990	4336	7127	1380		1381		147		**14370**							3284	**3284**	**17654**
1991	3709	7780	1617		1956		32		**15094**							3282	**3282**	**18376**
1992	4104	7349	1982		2113		52		**15600**							2988	**2988**	**18588**
1993	3640	6526	2131		2592		40		**14929**							3108	**3108**	**18037**
1994	3214	5624	2309		2420		117		**13684**							2700	**2700**	**16384**
1995	3945	6129	2658		2927		203		**15862**		554		422			2230	**3206**	**19068**
1996	4146	5572	2493		2699		199		**15109**				410			2616	**3026**	**18135**
1997	4333	5472	2875		1420		130		**14230**		414		568			2083	**3066**	**17296**
1998	4232	4870	2492		2621		129		**14345**		381		681			4309	**5371**	**19716**
1999	3751	4615	2193		2597		149		**13305**		3135		162				**3297**	**16601**
2000	4173	6047	2185		2512		115		**15031**		1033	208	630				**1870**	**16750**
2001	3645	7575	1710		2767		80		**15778**		1275	250	736				**2262**	**18040**
2002	2929	8797	1787		2413		62		**15987**		1466	435	912				**2813**	**18800**
2003	3227	8340	1732		2249		163		**15711**		3147	279	582				**4008**	**19719**
2004	2817	7526	1622		2288		106		**14358**	1003	4511	257	472				**6243**	**20602**
2005	2972	5841	1764		2155		156		**12888**	697	1831	289	458				**3275**	**16163**
2006	2763	5916	1509		1751		99		**12037**	382	2568	271	529				**3751**	**15788**
2007	2745	6895	1462		1763		195		**13060**	330	2114	272	317				**3033**	**16092**
2008	2578	5402	1387		1514		167		**11048**	329	1479	289	764				**2860**	**13908**
2009	3032	8062	1840		1918	2	209		**15064**	674	1761	389	454				**3278**	**18342**
2010	3651	7095	1805		2283	5	261		**15101**	937	3489	463	453				**5343**	**20444**
2011	3235	3500	1845		2227		330	2089	**13226**	847	2097	898	344				**4187**	**17413**
2012	4012	4055	1744		3047		609	966	**14433**	796	2668	88	152				**3704**	**18137**
2013	4549	4982	2918		3038		538		**16025**	748	3792	53	286		5		**4885**	**20910**
2014	4311	3318	2753	176	2391		179	150	**13277**	795	1337	72	360		5		**2569**	**15846**

Table 2.1.1.2. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Nominal landings and catches (t) provided by the Working Group.

	Total landings	Total discards	Total catches	Agreed TAC (1)
1984	16659	2169	18828	
1985	17865	1732	19597	
1986	18927	2321	21248	
1987	17114	1705	18819	16460
1988	17577	1725	19302	18100
1989	19233	2582	21815	18100
1990	14370	3284	17654	18100
1991	15094	3282	18376	18100
1992	15600	2988	18588	18100
1993	14929	3108	18037	21460
1994	13684	2700	16384	20330
1995	15862	3206	19068	22590
1996	15109	3026	18135	21200
1997	14230	3066	17296	25000
1998	14345	5371	19716	25000
1999	13305	3297	16601	20000
2000	15031	1870	16750	20000
2001	15778	2262	18040	16800
2002	15987	2813	18800	14900
2003	15711	4008	19719	16000
2004	14358	6243	20602	20200
2005	12888	3275	16163	21500
2006	12037	3751	15788	20425
2007	13060	3033	16092	20425
2008	11048	2860	13908	20425
2009	15064	3278	18342	20425
2010	15101	5343	20444	20106
2011	13226	4187	17413	20106
2012	14433	3704	18137	19101
2013	16025	4885	20910	19101
2014	13277	2569	15846	19101

(1) for both megrim species and 7.a included.

Table 2.2.1.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Difference in total landings and total discards between WGBIE 2016 and IBPMegrim 2016.

Weight in tons	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Landings WGBIE 2015	15687	14300	12703	12000	13048	10853	13348	13179	11590	12689	16027	13277
Landings IBPMegrim 2016	15711	14358	12888	12037	13060	11048	15064	15100	13559	14489	15869	13277
Difference in landings:	**0.2%**	**0.4%**	**1.5%**	**0.3%**	**0.1%**	**1.8%**	**12.9%**	**14.6%**	**17.0%**	**14.2%**	**-1.0%**	**0.0%**
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Discards WGBIE 2015	4008	5240	2578	3368	2703	2531	2604	4406	3340	2908	4137	2179
Discards IBPMegrim 2016	4008	6243	3275	3751	3033	2860	3278	5343	4187	3704	4885	2569
Difference in discards:	**0.0%**	**19.2%**	**27.0%**	**11.3%**	**12.2%**	**13.0%**	**25.9%**	**21.3%**	**25.4%**	**27.4%**	**18.1%**	**17.9%**

Table 2.2.1.2. Megrim (*L.whiffiagonis*) in 7.b-k and 8.a, 8.b, and 8.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

(*) Scientific estimates were provided

Table 2.2.2.1 Megrim (*L.whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Length composition by fleet (thousands).

Length	FRANCE		SPAIN		IRELAND	UNITED KINGDOM		
class (cm)	OTB_CRU_>=70_0_0 OTB_DEF_>=70_0_0 VII	OTB_CRU_100_119_0_0 OTB_DEF_100_119_0_0 OTB_DEF_70_99_0_0 VIII	OTB_DEF_70-99_0_0. Otter trawl-med&deep VII	OTB_DEF_70_0_0. Otter trawl-med&deep VIIIabd	ALL FISHING UNITS	FU03:Fixed nets	FU05:Otter trawl-shallow	FU06:Beam trawl-all depths
10			0	0	0	0	0	0
11			0	0	0	0	0	0
12			0	0	0	0	0	0
13			0	0	0	0	0	0
14			0	0	0	0	0	0
15			0	0	0	0	0	0
16			0	0	0	0	0	0
17			0	0	0	0	0	0
18			0	0	0	0	0	0
19	0	0	0	4	0	0	0	0
20	0	0	0	22	3	0	0	0
21	8	0	0	75	8	0	0	0
22	0	0	0	115	40	0	0	0
23	58	0	20	186	79	0	0	0
24	0	0	153	218	96	0	0	8
25	118	5	829	200	129	0	0	7
26	0	0	1614	183	166	0	0	44
27	140	93	1794	199	195	0	0	102
28	0	0	1518	211	305	0	1	165
29	242	270	1227	186	346	0	8	264
30	0	0	986	203	443	1	19	256
31	227	558	768	197	502	0	41	197
32	0	0	630	187	468	0	54	178
33	219	611	545	140	506	0	65	211
34	0	0	444	104	458	0	70	198
35	215	562	366	77	450	0	57	178
36	0	0	289	63	478	0	60	177
37	205	481	239	50	389	0	55	152
38	0	0	206	46	362	0	49	134
39	172	366	173	35	278	0	35	95
40	0	0	155	31	223	0	25	79
41	144	292	135	24	190	0	16	74
42	0	0	110	21	125	0	11	56
43	137	237	93	16	112	0	8	42
44	0	0	107	10	121	1	5	43
45	108	211	60	7	59	0	3	44
46	0	0	61	5	73	1	2	33
47	106	187	39	2	54	0	2	26
48	0	0	35	1	37	0	1	26
49	52	120	24	2	26	0	0	12
50	0	0	20	1	20	0	0	16
51	36	61	10	0	16	0	0	7
52	0	0	6	0	11	0	0	6
53	10	27	3	0	11	0	0	5
54	0	0	4	0	3	0	0	6
55	6	11	1	0	7	0	0	1
56	0	0	1	0	3	0	0	2
57	2	2	0	0	1	0	0	0
58	0	0	0	0	0	0	0	1
59	0	2	0	0	0	0	0	0
60			0	0	0	0	0	0
61			0	0	0	0	0	0
62			0	0	0	0	0	0
63			0	0	0	0	0	0
64			0	0	0	0	0	0
65			0	0	0	0	0	0
66			0	0	0	0	0	0
67			0	0	0	0	0	0
68			0	0	0	0	0	0
69			0	0	0	0	0	0
70			0	0	0	0	0	0
TOTAL	2205	4097	12666	2822	6794	7	588	2845

Table 2.2.3.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Abundance Indices for UK-WCGFS-D, UK-WCGFS-S, IGFS, SP-PGFS and FR- EVHOE.

		UK-WCGFS-D							**Effort in hours**	
		Age								
	Effort	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1987	100		863	5758	0	0	0	95	1753	151
1988	100	8	256	59	49	0	228	1008	1262	632
1989	100		70	188	471	2540	788	3067	680	1060
1990	100	8	526	1745	553	2584	1985	974	1154	974
1991	100		415	1375	1250	989	912	1677	593	731
1992	100	7	28	425	414	349	189	206	132	121
1993	100		122	382	1758	1505	728	739	666	718
1994	100		69	1593	1542	2663	1325	1278	825	595
1995	100	47	582	747	1755	1686	1303	548	281	421
1996	100	15	69	475	549	1580	1231	870	327	117
1997	100		329	751	1702	1518	541	149	47	17
1998	100		120	797	1432	1134	866	242	246	13
1999	100		237	270	734	760	302	94	33	17
2000	100		143	1004	619	681	395	67	35	13
2001	100	20	384	690	1426	581	460	376	226	45
2002	100		162	2680	1915	1349	761	690	315	104
2003	100		330	1705	3149	2662	1451	676	417	179
2004	100	168	1001	1382	1069	897	628	208	47	
		UK-WCGFS-S							**Effort in hours**	
		Age								
	Effort	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1987	100		499	3082	641	891	180	794	264	587
1988	100		47	55	585	95	367	0	50	93
1989	100		616	574	547	1540	576	361	297	198
1990	100		375	1057	816	661	1220	195	454	176
1991	100	2	373	829	822	394	460	550	178	293
1992	100		149	278	323	193	109	164	93	36
1993	100		470	877	1140	601	327	321	143	233
1994	100		74	1000	1301	998	521	374	185	153
1995	100	28	435	878	1167	1054	805	488	359	130
1996	100	2	64	401	389	823	592	372	152	43
1997	100	3	284	1028	550	540	289	202	75	29
1998	100	4	30	438	665	381	209	97	48	21
1999	100		69	82	222	214	103	53	41	20
2000	100		72	377	249	313	169	81	52	20
2001	100	2	131	297	594	104	145	122	80	37
2002	100		134	808	506	757	339	326	181	82
2003	100	5	184	289	639	416	328	113	102	36
2004	100	50	343	467	270	394	303	124	49	21
		FR-EVHOE								
		Age								
	Effort	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1997	100	0.77	3.92	2.47	1.47	1.59	0.91	0.61	0.35	0.15
1998	100	1.61	0.66	4.48	3.07	1.52	0.98	0.84	0.43	0.14
1999	100	0.54	3.48	0.72	2.14	3.38	1.66	0.70	0.30	0.27
2000	100	1.38	2.79	2.64	1.35	1.22	0.73	0.40	0.28	0.14
2001	100	0.94	0.51	1.87	2.36	2.72	1.87	1.40	0.38	0.22
2002	100	3.12	2.28	4.24	3.18	1.67	0.68	0.49	0.23	0.10
2003	100	2.53	2.95	2.40	3.21	0.67	0.65	0.25	0.19	0.11
2004	100	0.97	4.64	1.70	0.96	0.77	0.66	0.33	0.25	0.12
2005	100	0.86	3.48	2.94	0.91	0.57	0.48	0.13	0.07	0.12
2006	100	2.77	5.06	3.25	0.25	0.86	0.36	0.38	0.21	0.07
2007	100	4.05	3.91	1.63	1.39	2.03	0.66	0.43	0.24	0.10
2008	100	0.54	5.52	3.72	2.05	0.69	0.38	0.22	0.06	0.01
2009	100	1.55	3.09	7.90	0.94	0.45	0.21	0.06	0.01	0.00
2010	100	2.71	2.67	2.75	4.59	1.20	0.54	0.25	0.21	0.13
2011	100	0.08	5.03	5.17	3.63	1.60	0.97	0.27	0.04	0.12
2012	100	1.26	3.89	7.87	1.89	0.94	0.78	0.66	0.08	0.03
2013	100	0.89	3.34	3.93	4.63	0.49	0.52	0.35	0.04	0.07
2014	100	0.43	4.17	2.09	4.81	1.49	0.40	0.10	0.03	

		IGFS									
		Age									
	Effort	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2003	100	0	152	316	368	238	96	36	14	5	2
2004	100	0	153	461	595	454	162	57	30	12	3
2005	100	29	414	643	431	370	215	68	44	18	17
2006	100	44	505	548	481	215	154	68	10	7	5
2007	100	1	100	293	125	91	70	25	7	7	3
2008	100	5	140	481	349	101	66	60	17	12	5
2009	100	3	1	234	371	455	346	159	53	44	23
2010	100	6	1	128	377	259	173	90	38	13	10
2011	100	5	2	121	333	331	144	69	40	25	30
2012	100	4	24	141	140	108	52	36	16	9	33
2013	100	9	31	132	93	83	58	30	10	8	22
2014	100	40	62	143	106	56	57	52	22	23	17

Table 2.2.3.1 (cont.). Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Abundance Indices by kilograms and numbers by 30 minutes haul duration.

		SP-PGFS							
		Age							
	Effort	0	1	2	3	4	5	6	7+
2001	100	43	1770	2208	2842	3434	1941	1357	740
2002	100	6	1069	2502	3168	3997	2237	1107	515
2003	100	11	1081	2913	4105	5262	2789	1284	636
2004	100	7	719	3457	5498	5569	3071	1125	828
2005	100	77	633	626	2279	8249	4959	2605	688
2006	100	5	1776	1443	3275	4719	3312	901	383
2007	100	30	4856	6990	3556	3622	1814	852	399
2008	100	14	260	2219	5406	4010	1807	1219	428
2009	100	6	534	661	5320	7097	1635	877	606
2010	100	39	318	2158	2557	6723	2313	494	476
2011	100	37	393	1174	2510	3940	5141	1452	626
2012	100	5	157	692	3759	2862	3207	2926	1902
2013	100	6	1473	1184	1174	1619	3703	2657	2579
2014	100	39	243	3174	1001	2286	4400	3409	2198

	FR-EVHOEFS Abundance Indices	
	kg/30'	Nb/30'
1997	1.98	12.35
1998	2.20	13.96
1999	1.82	13.43
2000	1.42	11.14
2001	2.21	17.04
2002	2.03	16.55
2003	1.77	13.14
2004	1.50	10.67
2005	1.43	9.88
2006	1.7	15.63
2007	1.96	14.6
2008	2.05	13.65
2009	2.5	14.8
2010	2.57	15.53
2011	3.21	17.14
2012	2.97	17.69
2013	2.91	14.58
2014	2.13	13.82

	SP-PGFS	
AÑO	kg/30'	Nb/30'
2001	6.80	143.34
2002	6.66	146.00
2003	8.16	180.81
2004	9.01	202.72
2005	9.81	201.19
2006	7.64	158.14
2007	9.15	221.18
2008	8.46	153.61
2009	11.96	167.34
2010	11.47	150.76
2011	11.89	152.72
2012	13.03	155.08
2013	12.82	143.96
2014	15.78	166.68

IGFS Abundance Indices	
2003	1227
2004	1926
2005	2254
2006	2039
2007	725
2008	1238
2009	1724
2010	1103
2011	1116
2012	583
2013	497
2014	593

Table 2.2.4.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. French and Spanish CPUEs for different bottom trawl fleets.

	French (single and twin bottom trawls combined) CPUE (kg/h)				Spanish CPUE (kg/(100day*100 hp))			Irish LPUE ('000 h)
	Benthic Bay of Biscay	Benthic Western Approaches	Gadoids Western Approaches	Nephrops Western Approaches	A Coruña -VII	Cantábrico- VII	Vigo-VII	Otter trawlers
1984					16.3	130.1	99.1	-
1985	3.0	5.3	4.7	4.7	9.8	39.5	108.9	-
1986	3.2	4.8	2.8	4.4	21.1	52.8	105.1	-
1987	3.3	5.1	2.7	4.5	8.3	80.7	96.2	-
1988	3.8	5.8	3.0	4.1	9.8	78.3	106.1	-
1989	3.6	5.5	2.6	4.2	14.6	48.1	92.1	-
1990	3.1	4.2	1.8	3.4	15.1	18.4	73.8	-
1991	2.6	4.0	1.3	2.8	12.9	25.9	85.4	-
1992	2.5	4.5	1.5	3.4	6.9	32.8	105.6	-
1993	1.9	4.6	1.2	3.5	5.1	33.5	92.3	-
1994	1.9	4.2	1.2	3.4	7.4	52.7	78.7	-
1995	2.3	4.9	1.4	3.4	7.8	61.3	94.3	13.7
1996	2.6	5.0	1.4	3.5	3.9	58.4	79.3	13.6
1997	3.3	5.6	1.2	3.0	3.0	46.9	96.0	12.1
1998	2.9	6.5	1.5	3.6	2.4	35.7	82.4	10.0
1999	3.0	6.3	0.9	3.4	1.1	32.5	137.0	11.3
2000	2.9	6.8	0.6	4.0	5.5	45.0	128.9	13.4
2001	2.2	6.8	0.7	4.1	1.3	75.6	131.2	13.1
2002	2.1	6.8	0.5	3.2	1.3	76.4	185.3	12.2
2003	1.8	5.8	0.6	3.2	11.2	54.0	192.1	8.2
2004	1.8	4.6	0.5	3.4	3.3	60.0	211.0	9.3
2005	1.9	5.1	0.4	4.2	1.7	58.46	135.3	10.0
2006	2.5	4.8	0.3	3.6	1.4	76.42	146.1	7.5
2007	2.4	5.1	0.4	2.9	2.4	87.86	144.3	8.5
2008	2.2	4.6	0.5	3.1	3.0	37.58	114.0	8.4
2009	NA	NA	NA	NA	8.3	0.00	173.2	10.3
2010	NA	NA	NA	NA	7.9	38.78	198.3	11.8
2011	NA	NA	NA	NA	19.7	0.0	151.2	13.5
2012	NA	NA	NA	NA	6.4	0.0	135.3	19.3
2013	NA	NA	NA	NA	10.0	0.0	210.2	19.4
2014	NA	NA	NA	NA	3.4	0.0	116.7	15.4

(*) LPUEs, no discards available

Table 2.3.3.1. WKFLAT 2012 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
$N(y,1) \sim LN(medrec,2)$	$medrec = 250000$
$N(1984,a) \sim LN(medrec$ $\exp[-(a-1)M - \sum_{j=1}^{a-1} medF(j)],2), a =$	$medrec$ as above, $M = 0.2$, $medF = (0.05,0.1,0.3,0.3,0.3,0.3,0.3,$
$N(1984,10+) \sim LN(medrec \exp[-9M$ $\sum_{j=1}^{9} medF(j)]/\{1-\exp[-M - medF(9)$	$medrec, M, medrecF$ as above
$f(y) \sim LN(med_f, CV_f)$	$med_f = 0.3, CV_f = 1$
$\rho \sim Uniform(0,1)$	
$r_L(1984,a) \sim LN(medr_L(a),1), a = 1,\ldots,$	$medr_L = (0.0005,0.05,1,1,1,1,1,1)$
$r_L(y,9) = r_L(y,10+) = 1$	

Parameter and prior distribution	Values used in prior settings
$r_{SPD}(1984,a) \sim LN(medr_{SPD}(a),1), a=1,...,7$	$medr_{SPD}=(0.002,0.02,0.02,0.02,0.01$
$r_{IRD}(1984,a) \sim LN(medr_{IRD}(a),1), a=1,...,8$	$medr_{IRD}=(0.001,0.01,0.01,0.01,$ $0.005,0.005,0.005,0.001)$
$r_{UKD}(1984,a) \sim LN(medr_{UKD}(a),1), a=$	$medr_{UKD}=(0.00001,0.001,0.001,0.00$ $0.001,0.001,0.001,0.001)$
$r_{OTD}(1984,a) \sim LN(medr_{OTD}(a),1), a=$	$medr_{OTD}=(0.002,0.02,0.02,0.02,$ $0.01,0.01,0.01,0.002)$
$r_{SPD}(y,7)=r_{SPD}(y,a)=r_{IRD}(y,a)$ $=r_{UKD}(y,a)=r_{OTD}(y,a)=0,\ a=8,9,1($	
$\tau_C(a),\tau_L(a), a=1,2,3; \tau_D(a), a=1,...,8$	$\Gamma(4,0.345)$
$\tau_C(a),\tau_L(a), a=4,...,10+$	$\Gamma(10,0.1)$
$\tau_{SPD}(a), a=1,...,7; \tau_{IRD}(a),\tau_{UKD}(a), a=$	$\Gamma(4,0.345)$
$\log[q_k(a)] \sim N(\mu_{Ik},\tau_{Ik}), a\le 8,$ index $k=1,...,5$	$\mu_{Ik}=-7,\ \tau_{Ik}=0.2$
$q_k(a)=q_k(8), a>8,$ indices k with ages	
$\tau_k(a),$ index $k=1,...,5$	$\Gamma(4,0.345)$

Table 2.3.3.1 (cont.) IBPMegrim 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, $M = 0.2$, $medF = (0.05,0.1,0.3,0.3,0.3,0.3,0.$
$N(1984,10+) \sim LN(medrec \exp[-9M - \sum_{j=1}^{9} medF(j)]/\{1-\exp[-M - medF(9)]\}, 2)$	$medrec, M, medrecF$ as above
$f(y) \sim LN(med_f, CV_f)$	$med_f = 0.3, CV_f = 1$
$\rho \sim Uniform(0,1)$	
$r_L(1984,a) \sim LN(medr_L(a),1), a=1,...,8$	$medr_L = (0.0005,0.05,1,1,1,1,1,1)$
$r_L(y,9) = r_L(y,10+) = 1$	
$r_{SPD}(1984,a) \sim LN(medr_{SPD}(a),1), a=1,...,7$	$medr_{SPD} = (0.002,0.02,0.02,0.02,0.01,0.01,0.01)$
$r_{IRD}(1984,a) \sim LN(medr_{IRD}(a),1), a=1,...,8$	$medr_{IRD} = (0.001,0.01,0.01,0.01,0.005,0.005,0.005,0.001)$
$r_{UKD}(1984,a) \sim LN(medr_{UKD}(a),1), a=1,...,8$	$medr_{UKD} = (0.00001,0.001,0.001,0.0$ $0.001,0.001,0.001,0.001)$
$r_{FRD}(1984,a) \sim LN(medr_{FRD}(a),1), a=1,...,8$	$medr_{FRD} = (0.002,0.02,0.02,0.02,0.01,0.01,0.01,0.01)$
$r_{OTD}(1984,a) \sim LN(medr_{OTD}(a),1), a=1,...,8$	$medr_{OTD} = (0.001,0.001,0.001,0.001,0.001,0.001,0.001,0.001)$
$r_{SPD}(y,7) = r_{SPD}(y,a) = r_{IRD}(y,a) = r_{UKD}(y,a) = r_{FRD}(y,a) = r_{OTD}(y,a) = 0,\ a = 8,9,10+$	
$\tau_C(a), \tau_L(a), a=1,2,3; \tau_D(a), a=1,...,8$	$\Gamma(4,0.345)$
$\tau_C(a), \tau_L(a), a=4,...,10+$	$\Gamma(10,0.1)$
$\tau_{SPD}(a), a=1,...,7; \tau_{IRD}(a), \tau_{UKD}(a), \tau_{FRD}(a) a=1,...,8$	$\Gamma(4,0.345)$

Parameter and prior distribution	Values used in prior settings
$\log[q_k(a)] \sim N(\mu_{Ik}, \tau_{Ik}), a \leq 8,$ index $k = 1,\ldots,5$	$\mu_{Ik} = -7,\ \tau_{Ik} = 0.2$
$q_k(a) = q_k(8), a > 8,$ indices k with ages > 8	
$\tau_k(a),$ index $k = 1,\ldots,5$	$\Gamma(4,0.345)$

Table 2.5.1. Megrim (*L.whiffiagonis*) in 7.b-k and 8.a, 8.b, and 8.d. Catch forecast: management option table.

Short term forecast table for quantile 0.5, 0.05 and 0.95.

F scaled

Recluit 2015=R(GM84-12)

2015

Rec_2015	SSB_2015	Fbar_2015	Catch_2015	Land_2015	Disc_2015	SSB_2016
234021	**71894**	**0.23**	**16424**	**12471**	**3884**	**80188**

2016

Table for quantile: 0.5

Fmult	F_2016	Catch_2016	Land_2016	Disc_2016	SSB_2017
0	0	0	0	0	108214
0.1	0.02	2008	1569	434	105735
0.2	0.05	3963	3093	861	103464
0.3	0.07	5867	4576	1280	101099
0.4	0.09	7729	6020	1692	98843
0.5	0.12	9537	7426	2098	96701
0.6	0.14	11308	8793	2498	94573
0.7	0.16	13025	10122	2889	92483
0.8	0.19	14700	11416	3275	90461
0.9	0.21	16336	12674	3655	88497
1	**0.23**	**17927**	**13894**	**4026**	**86522**
1.1	0.26	19470	15079	4391	84645
1.2	0.28	20990	16247	4750	82806
1.3	0.3	22480	17372	5105	81076
1.4	0.33	23919	18469	5453	79339
1.5	0.35	25331	19541	5796	77666
1.6	0.37	26695	20579	6130	75971
1.7	0.4	28033	21589	6464	74332
1.8	0.42	29340	22576	6793	72749
1.9	0.44	30611	23530	7115	71229
2	0.47	31861	24456	7432	69722

Table 2.5.1(cont.). Megrim (*L.whiffiagonis*) in 7.b-k and 8.a, 8.b, and 8.d. Catch forecast: management option table.

2016

Table for quantile: 0.05

Fmult	F_2016	Catch_2016	Land_2016	Disc_2016	SSB_2017
0	0	0	0	0	89511
0.1	0.02	1812	1426	347	87299
0.2	0.04	3576	2813	688	85089
0.3	0.06	5293	4164	1024	82977
0.4	0.08	6966	5478	1354	80931
0.5	0.1	8594	6753	1679	78938
0.6	0.12	10186	7992	1999	76976
0.7	0.14	11739	9202	2316	75058
0.8	0.16	13246	10373	2625	73193
0.9	0.18	14725	11514	2929	71433
1	**0.2**	**16157**	**12603**	**3230**	**69818**
1.1	0.22	17536	13677	3527	68151
1.2	0.24	18906	14721	3818	66469
1.3	0.26	20241	15735	4104	64912
1.4	0.28	21552	16722	4385	63345
1.5	0.3	22816	17681	4662	61870
1.6	0.31	24055	18617	4934	60409
1.7	0.33	25246	19520	5202	58994
1.8	0.35	26407	20381	5466	57536
1.9	0.37	27522	21248	5728	56193
2	0.39	28639	22053	5990	54922

2016

Table for quantile: 0.95

Fmult	F_2016	Catch_2016	Land_2016	Disc_2016	SSB_2017
0	0	0	0	0	133773
0.1	0.03	2255	1730	575	131400
0.2	0.05	4454	3413	1141	128946
0.3	0.08	6596	5054	1697	126364
0.4	0.11	8695	6652	2243	123797
0.5	0.14	10732	8207	2780	121299
0.6	0.16	12722	9726	3306	118858
0.7	0.19	14676	11208	3826	116475
0.8	0.22	16575	12635	4330	114151
0.9	0.25	18439	14026	4830	111913
1	**0.27**	**20257**	**15387**	**5318**	**109670**
1.1	0.3	22024	16732	5798	107516
1.2	0.33	23765	18046	6267	105407
1.3	0.36	25459	19317	6737	103251
1.4	0.38	27105	20538	7187	101236
1.5	0.41	28735	21731	7628	99337
1.6	0.44	30306	22874	8062	97475
1.7	0.47	31846	23997	8490	95611
1.8	0.49	33336	25102	8911	93791
1.9	0.52	34798	26199	9320	92014
2	0.55	36226	27244	9728	90256

Table 2.6.2.1: Settings for the base case run in Eqsim.

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Full time series (1984-2014)	
Exclusion of extreme values	No	
Trimming of R values		
Mean weights, maturity and natural mortality	2005-2014	
Exploitation pattern	2005-2014	
Assessment error in the advisory year. CV of F	0.212	Default value from WKMSYREF4
Autocorrelation in assessment error in the advisory year	0.423	Default value from WKMSYREF4

Table 2.6.2.2: Estimates of F_{MSY}, F_{MSY} ranges and $F_{p0.5}$ resulting from Eqsim without ICES MSY AR.

YIELD FROM CATCHES			YIELD FROM LANDINGS			$F_{P0.5}$
F_{MSY}	F_{MSY} lower	F_{MSY} upper	F_{MSY}	F_{MSY} lower	F_{MSY} upper	
0.186	0.121	0.312	0.161	0.106	0.246	0.366

Table 2.6.2.3: Estimates of F_{MSY}, F_{MSY} ranges and $F_{p0.5}$ resulting from Eqsim with ICES MSY AR (MSY $B_{trigger}$=B_{pa}).

YIELD FROM CATCHES			YIELD FROM LANDINGS			$F_{P0.5}$
F_{MSY}	F_{MSY} lower	F_{MSY} upper	F_{MSY}	F_{MSY} lower	F_{MSY} upper	
0.186	0.121	0.312	0.161	0.106	0.246	0.379

Table 2.6.2.4: Summary table of proposed reference points from Eqsim.

REFERENCE POINTS	VALUE	RATIONAL
B_{lim}	37 100	B_{loss}, which is the lowest biomass observed corresponding to year 2006
B_{pa}	41 800	$B_{lim} e^{1.645\,\sigma}$
F_{lim}	0.489	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
F_{pa}	0.412	$F_{lim} e^{-1.645\,\sigma}$
F_{MSY} without $B_{trigger}$	0.161	
F_{MSY} lower without $B_{trigger}$	0.106	

REFERENCE POINTS	VALUE	RATIONAL
F_{MSY} upper without $B_{trigger}$	0.246	
$F_{p0.5}$ (5% risk to B_{lim} without $B_{trigger}$)	0.366	
MSY $B_{trigger}$	41 800	B_{PA}, because the fishery has not been at F_{MSY} in the last 10 years
F_{MSY} with $B_{trigger}$=B_{pa}	0.161	
F_{MSY} lower with $B_{trigger}$=B_{pa}	0.106	
F_{MSY} upper with $B_{trigger}$=B_{pa}	0.246	
$F_{p0.5}$ (5% risk to B_{lim} with $B_{trigger}$=B_{pa})	0.379	

Table 2.6.3.1: Summary of the per recruit equilibrium analysis by projecting forward the current assessment results and averaging over the last 3 years for the exploitation pattern and the biological parameters.

		5%	50%	95%
F_{bar}	F_{stquo}	0.2	0.23	0.28
	F_{max}	0.17	0.18	0.2
	F_{01}	0.11	0.12	0.13
	$F_{35\%}$	0.16	0.17	0.18
	$F_{30\%}$	0.2	0.21	0.22
YPR	F_{stquo}	0.065	0.069	0.073
	F_{max}	0.067	0.07	0.074
	F_{01}	0.064	0.067	0.07
	$F_{35\%}$	0.067	0.07	0.074
	$F_{30\%}$	0.067	0.07	0.073
SSBPR	F_{stquo}	0.32	0.37	0.42
	F_{max}	0.44	0.45	0.46
	F_{01}	0.6	0.61	0.62
	$F_{35\%}$	0.47	0.47	0.47
	$F_{30\%}$	0.4	0.4	0.4
%SPR	F_{stquo}	0.24	0.28	0.32
	F_{max}	0.33	0.34	0.35
	F_{01}	0.45	0.46	0.47
	$F_{35\%}$	0.35	0.35	0.35
	$F_{30\%}$	0.3	0.3	0.3

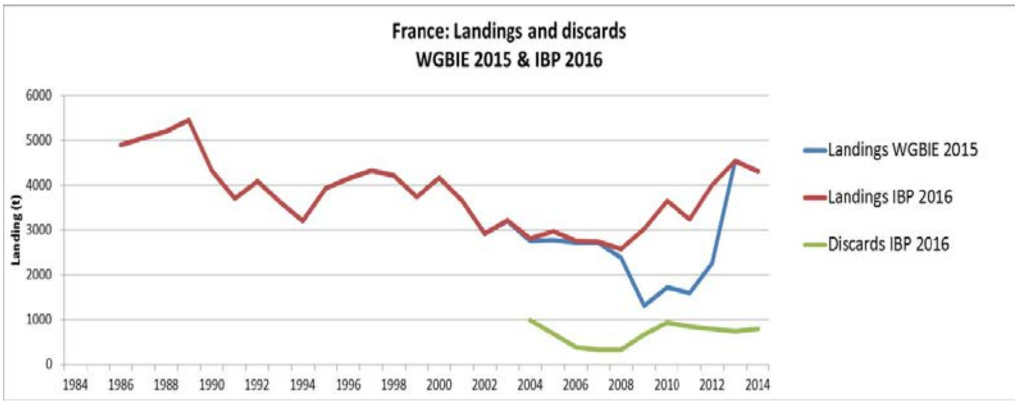


Figure 2.2.1.1. Megrim (*L.whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of landings and discards data from France in WGBIE 2015 and IBPMegrim 2016.

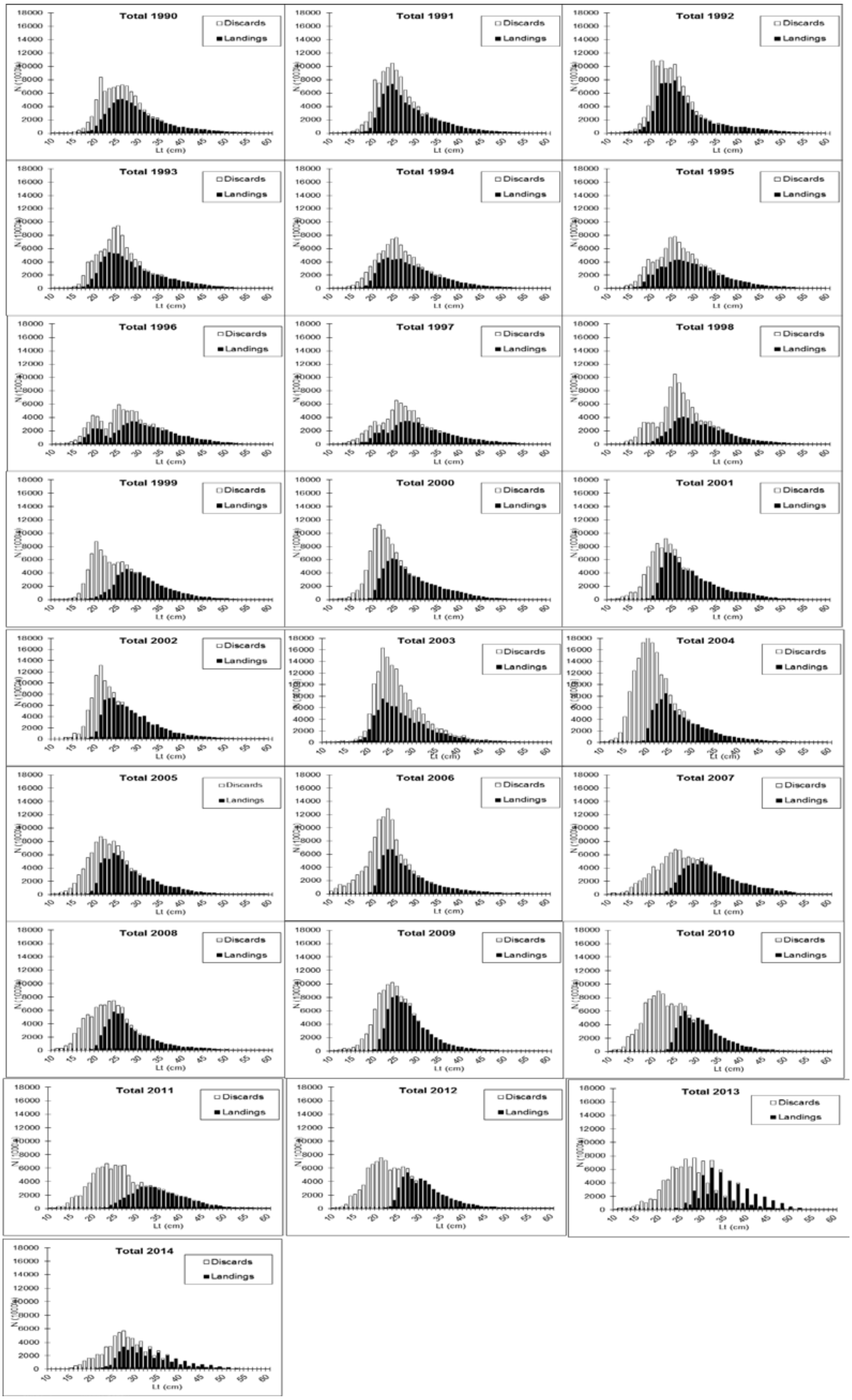


Figure 2.2.1.2. Megrim (*L.whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Length composition of catches for the years 1990 to 2014. Numbers of individuals in thousand tons.

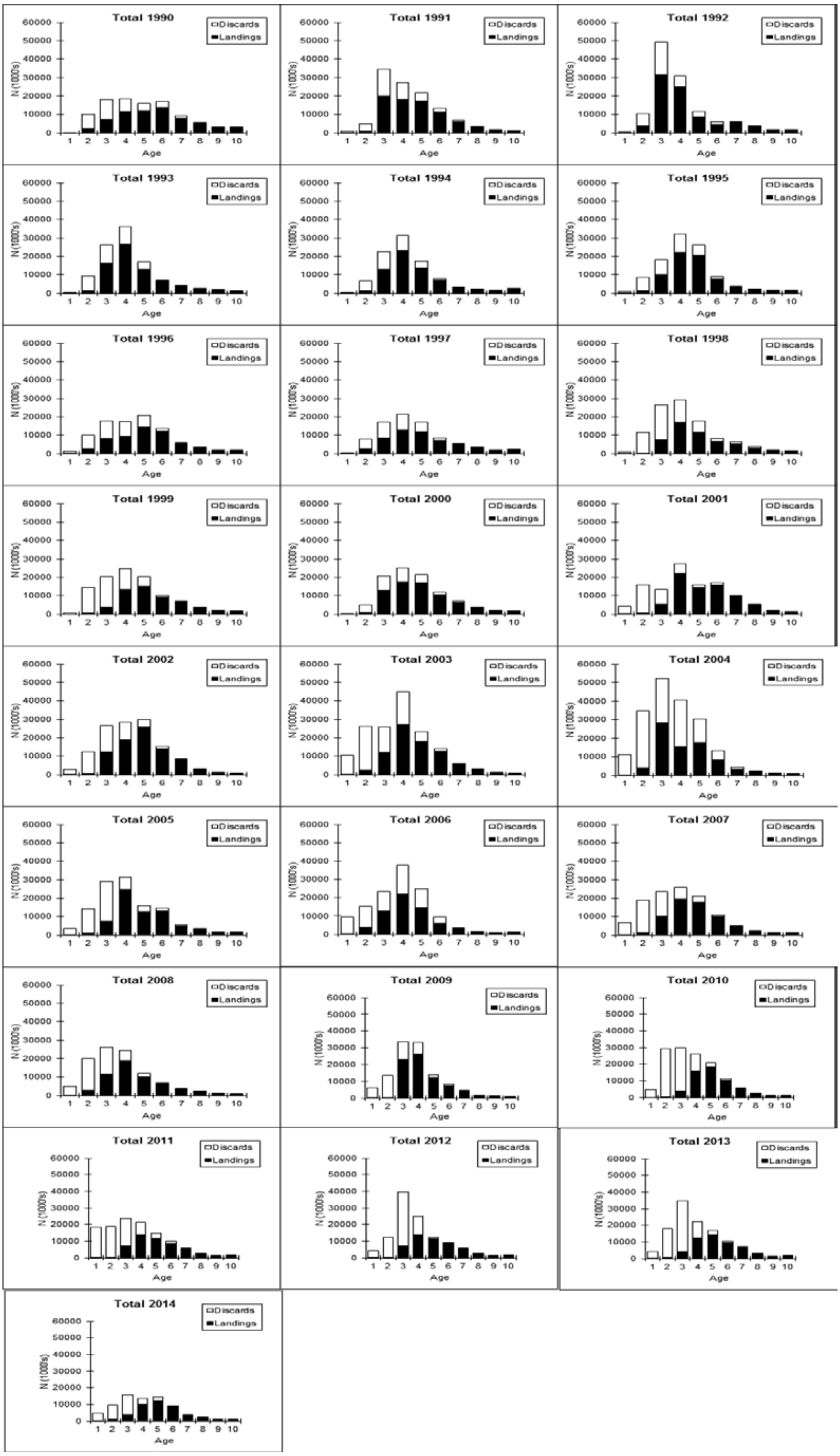


Figure 2.2.2.1. Megrim (*L.whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Age composition of catches for the years 1990 to 2014.

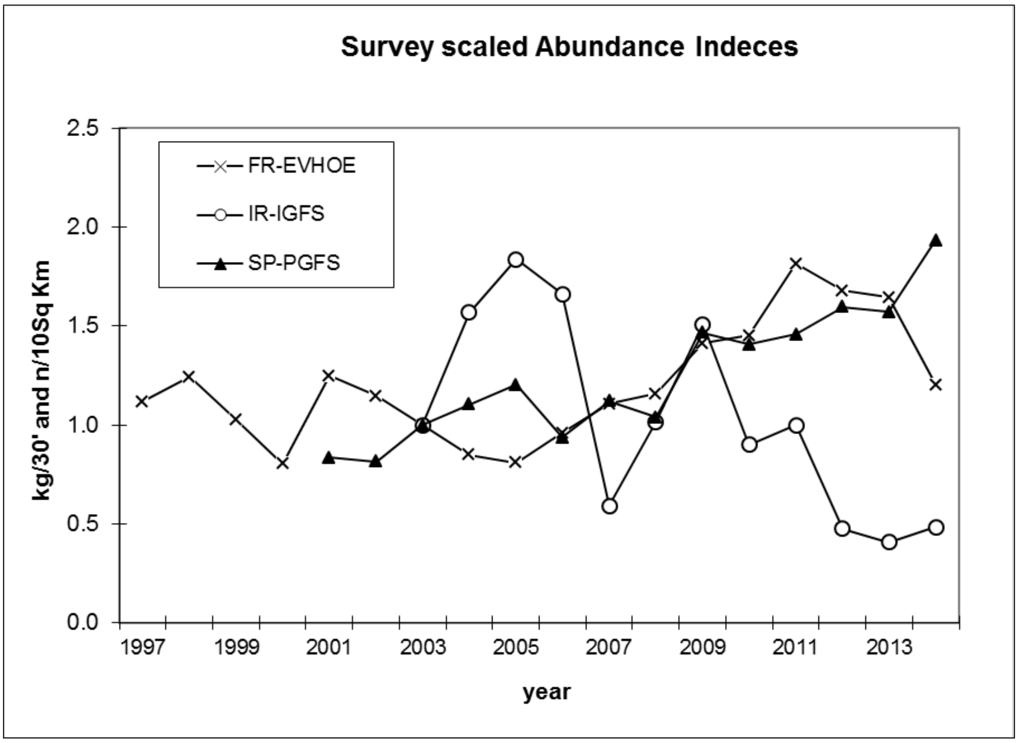


Figure 2.2.3.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Scaled Biomass Indices for FR-EVHOE, SP-PGFS and IR-IGFS.

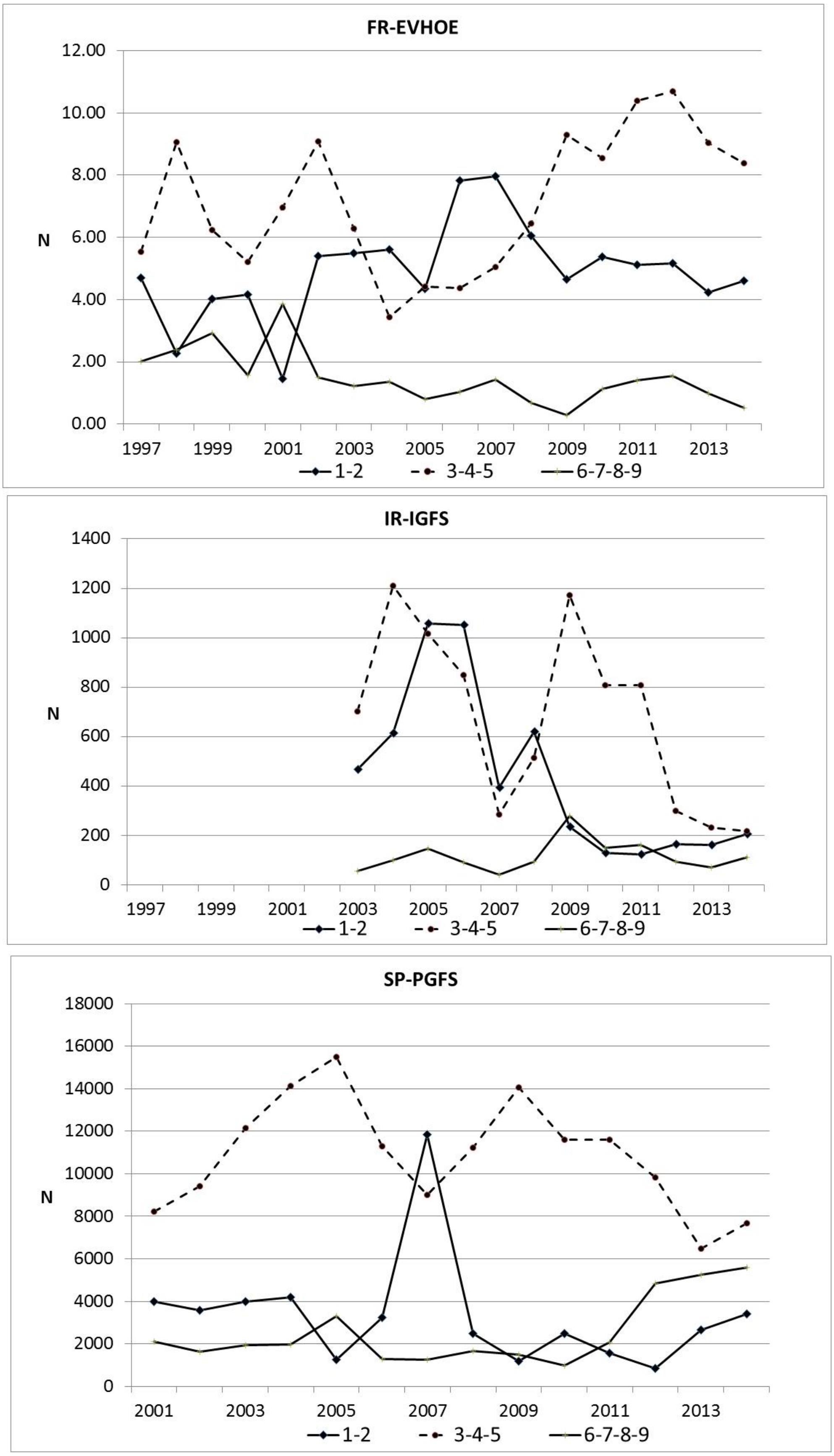


Figure 2.2.3.2. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Abundance Indices for EVHOE, IGFS and SP-PGFS by ages grouped: i) 1+2; ii) 3+4+5 and iii) 6+7+8+9+10+.

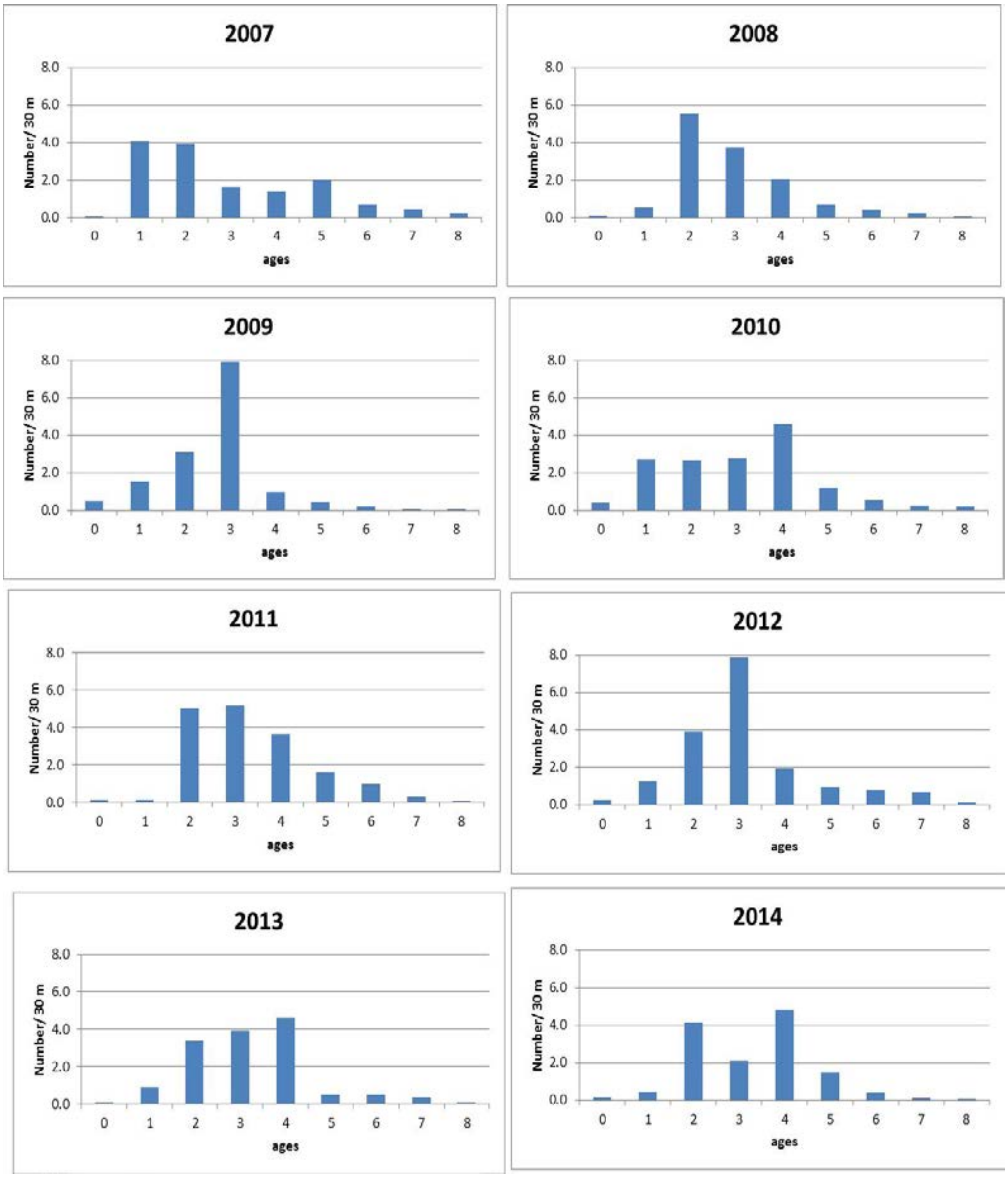


Figure 2.2.3.3. **Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Age composition of FR-EVHOE survey in abundance (numbers/30min haul).**

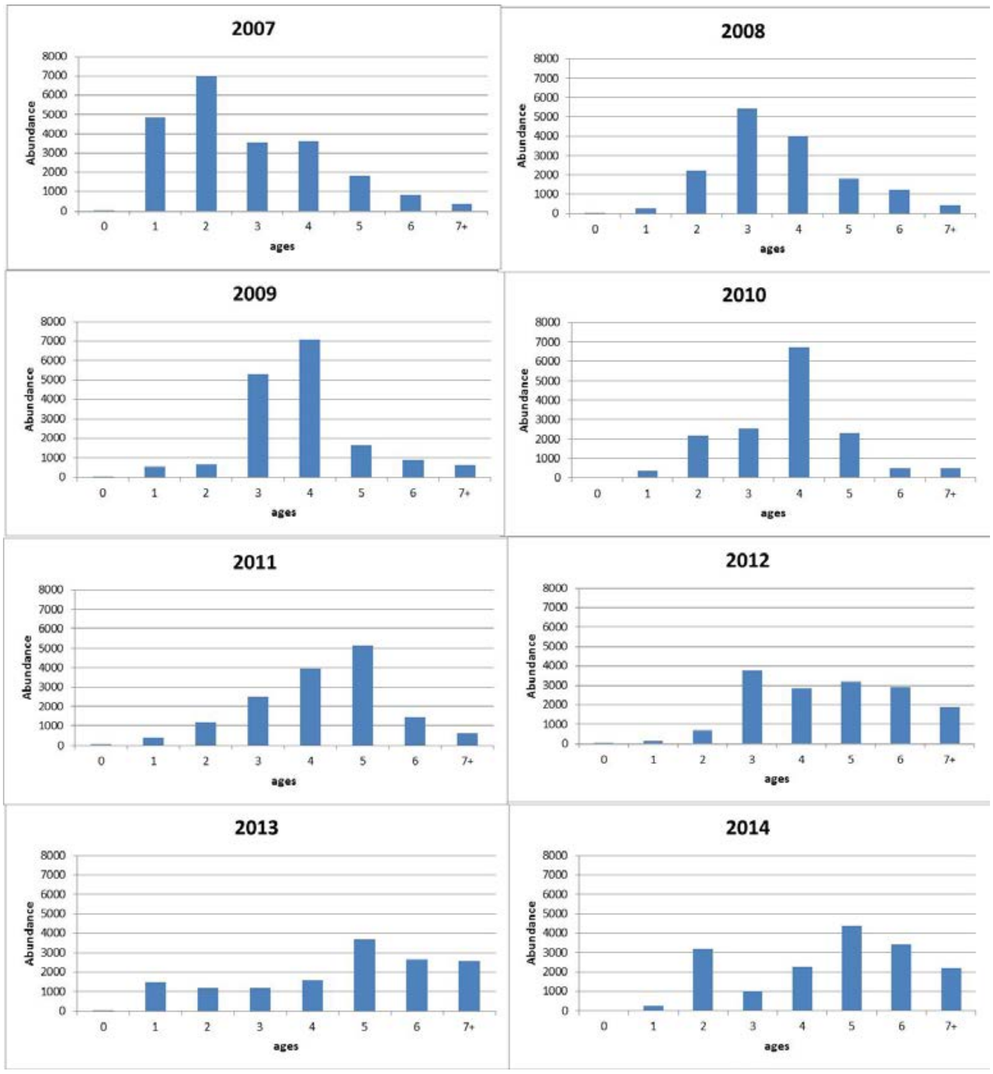


Figure 2.2.3.4. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Age composition of SP-PORCUPINE survey in abundance (numbers).

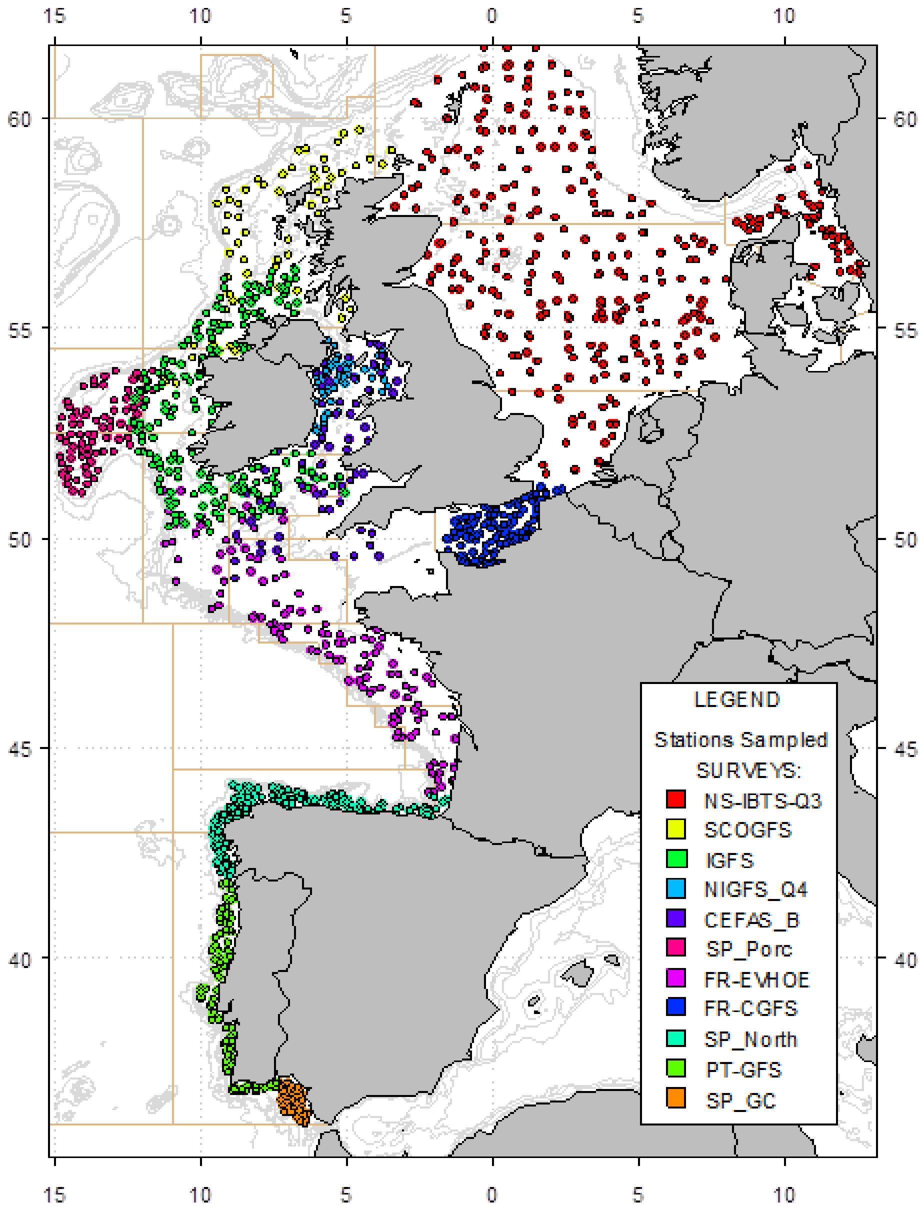


Figure 2.2.3.5. Station positions for the IBTS Surveys carried out in the Western and North Sea Area in the autumn/winter of 2008. (From IBTSWG 2009 Report). Just to be used as general location of the Surveys.

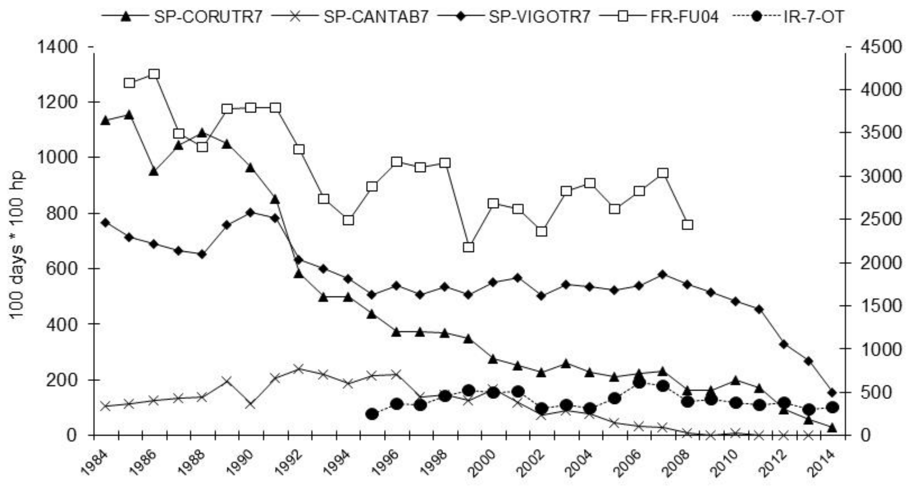


Figure 2.2.4.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Evolution of effort for different bottom trawler fleets.

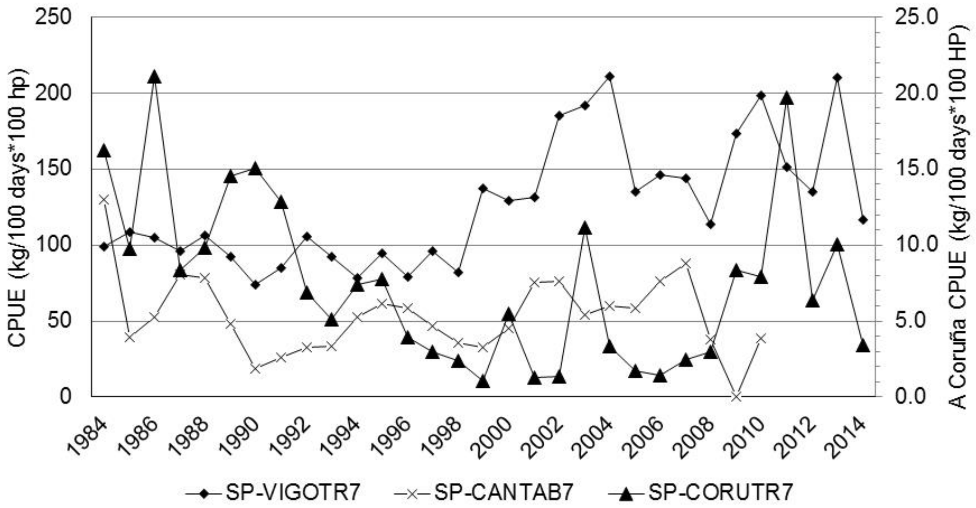


Figure 2.2.4.2. Megrim (*L. whiffiagonis*) in Divisions 7.b, 7.c, and 7.e-k and 8.a, 8.b, and 8.d. Spanish CPUE for different bottom trawler fleets.

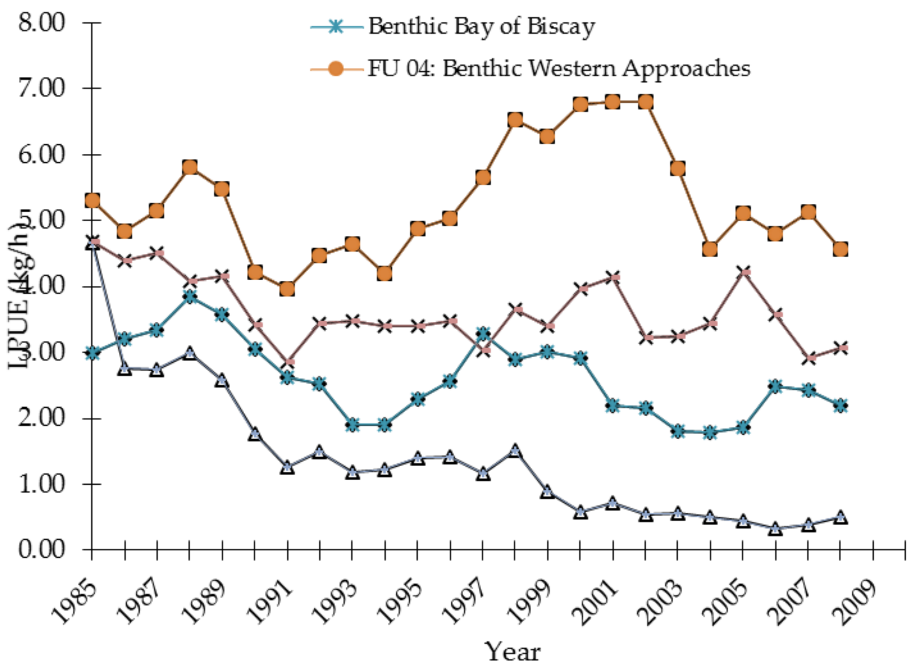


Figure 2.2.4.3. Megrim (*L. whiffiagonis*) in Divisions 7.b, 7.c, and 7.e-k and 8.a, 8.b, and 8.d. French LPUE for different bottom trawler fleet.

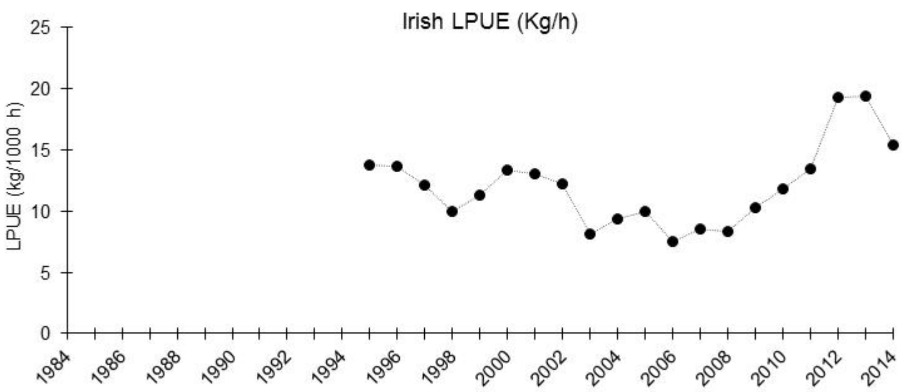


Figure 2.2.4.4. Megrim (*L. whiffiagonis*) in Divisions 7.b, 7.c, and 7.e-k and 8.a, 8.b, and 8.d. Irish LPUE for beam trawl fleet.

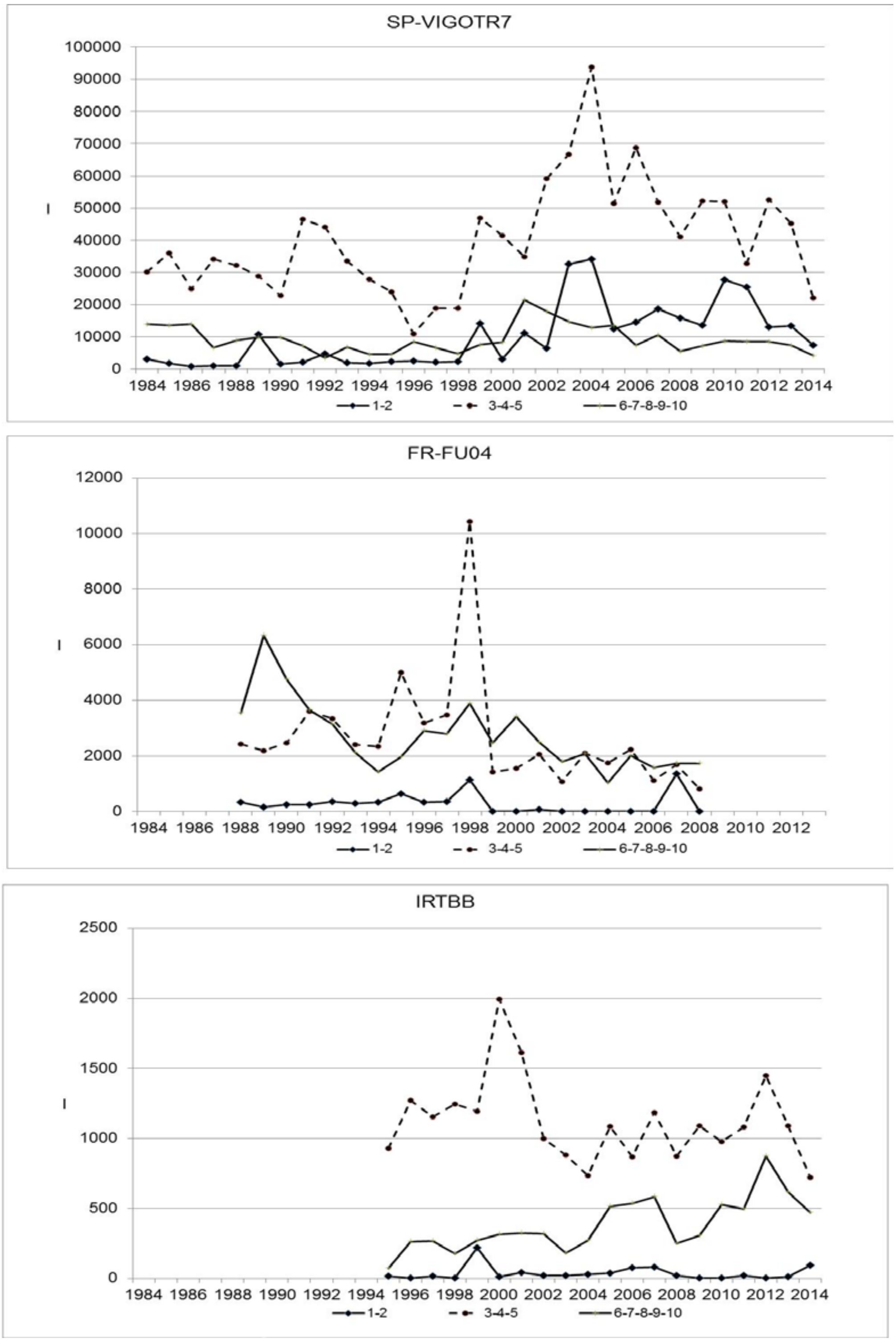


Figure 2.2.4.5. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Abundance Indices for SP-VIGOTR7, FR-FU04 and IRTBB by ages grouped: i) 1+2; ii) 3+4+5 and iii) 6+7+8+9+10+.

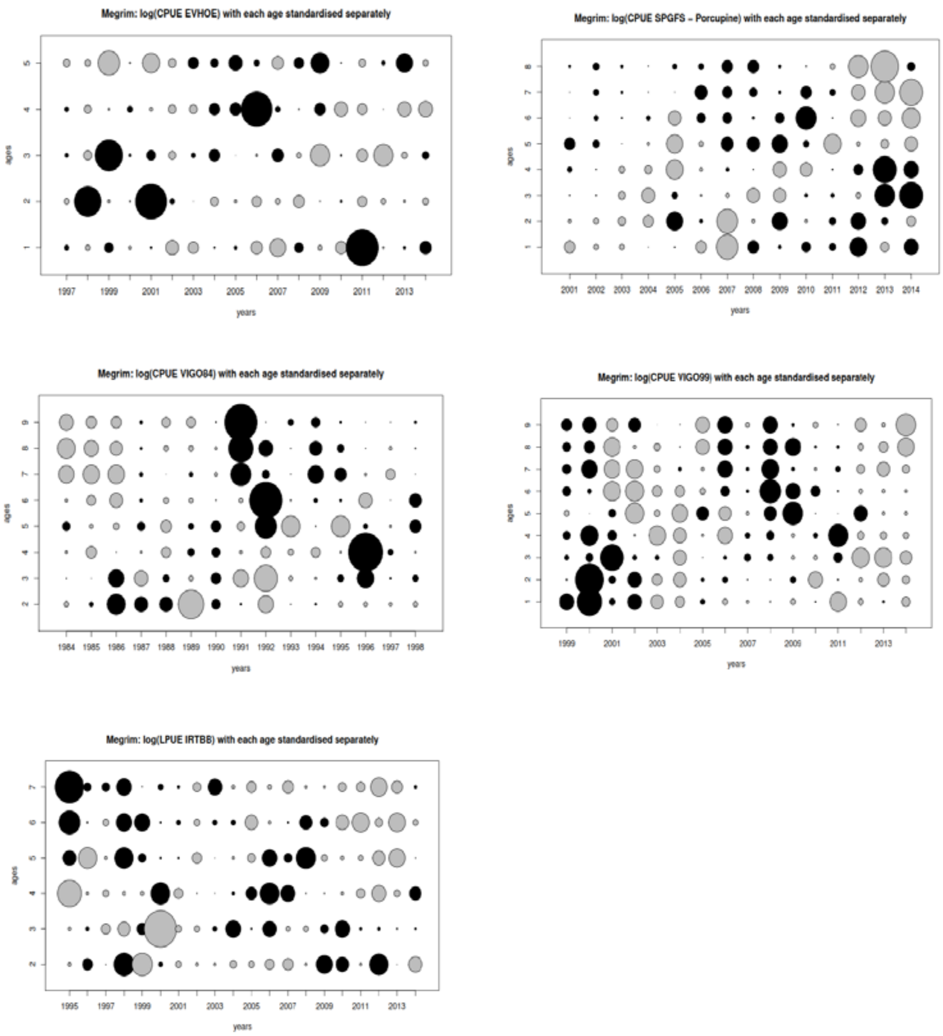


Figure 2.3.1.1. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Bubble plots of the standardized log abundance indices of the surveys and commercial fleets used as tuning fleets.

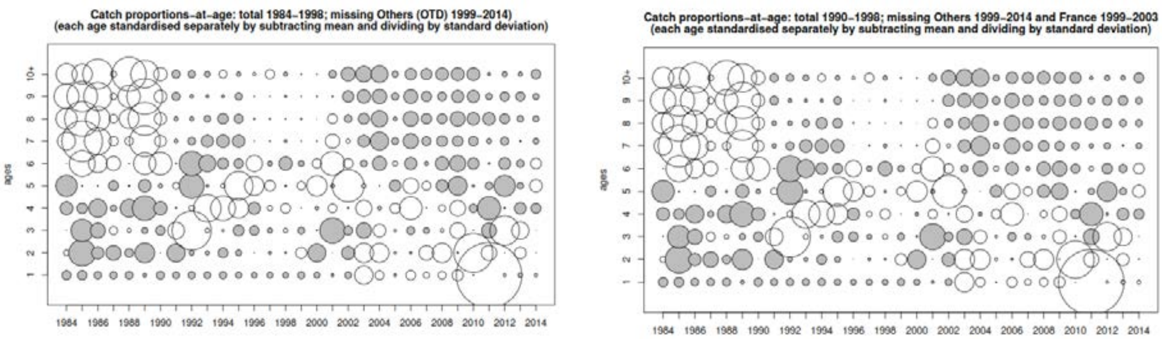


Figure 2.3.1.2. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of WGBIE 2015 (left) and IBPMegrim 2016 (right) Bubble plots for catch numbers at age from 1984 to 2014.

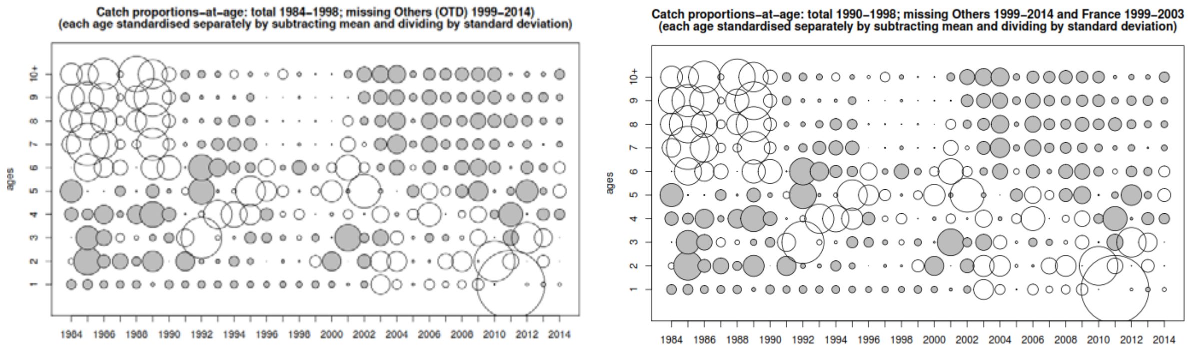


Figure 2.3.1.2. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of WGBIE 2015 (left) and IBPMegrim 2016 (right) Bubble plots for catch numbers at age from 1984 to 2014.

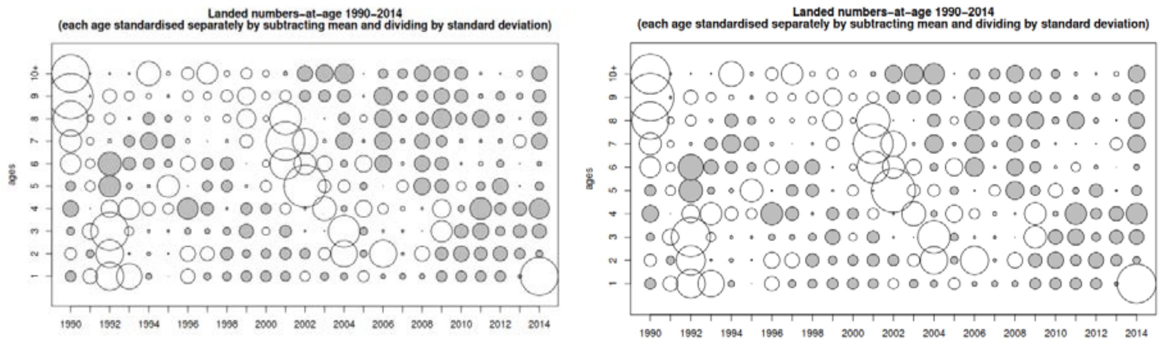


Figure 2.3.1.3. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of WGBIE 2015 (left) and IBPMegrim 2016 (right) Bubble plots for landing numbers at age from 1990 to 2014.

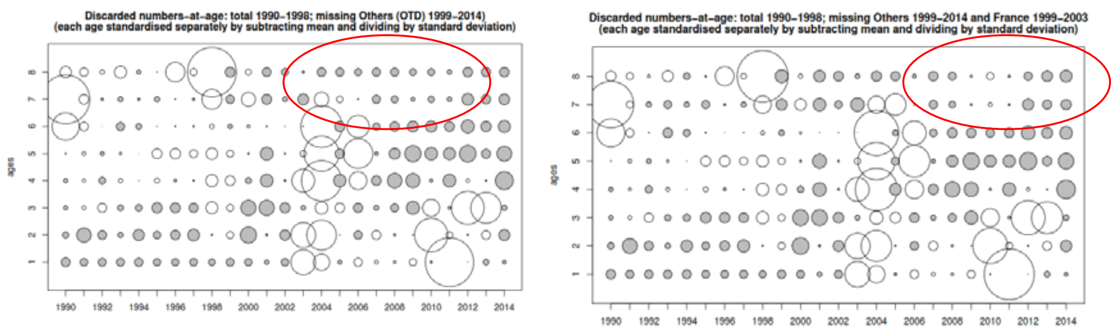


Figure 2.3.1.4. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of WGBIE 2015 (left) and IBPMegrim 2016 (right) Bubble plots for discarded numbers at age from 1990 to 2014.

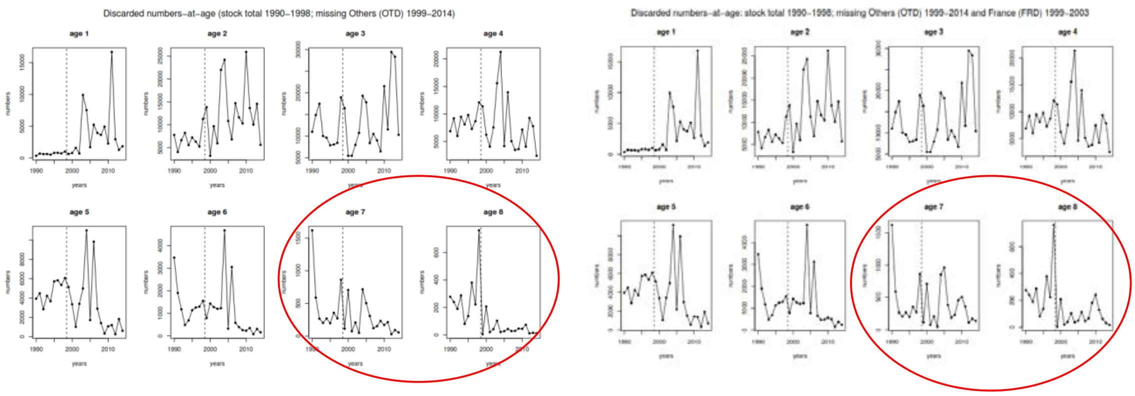
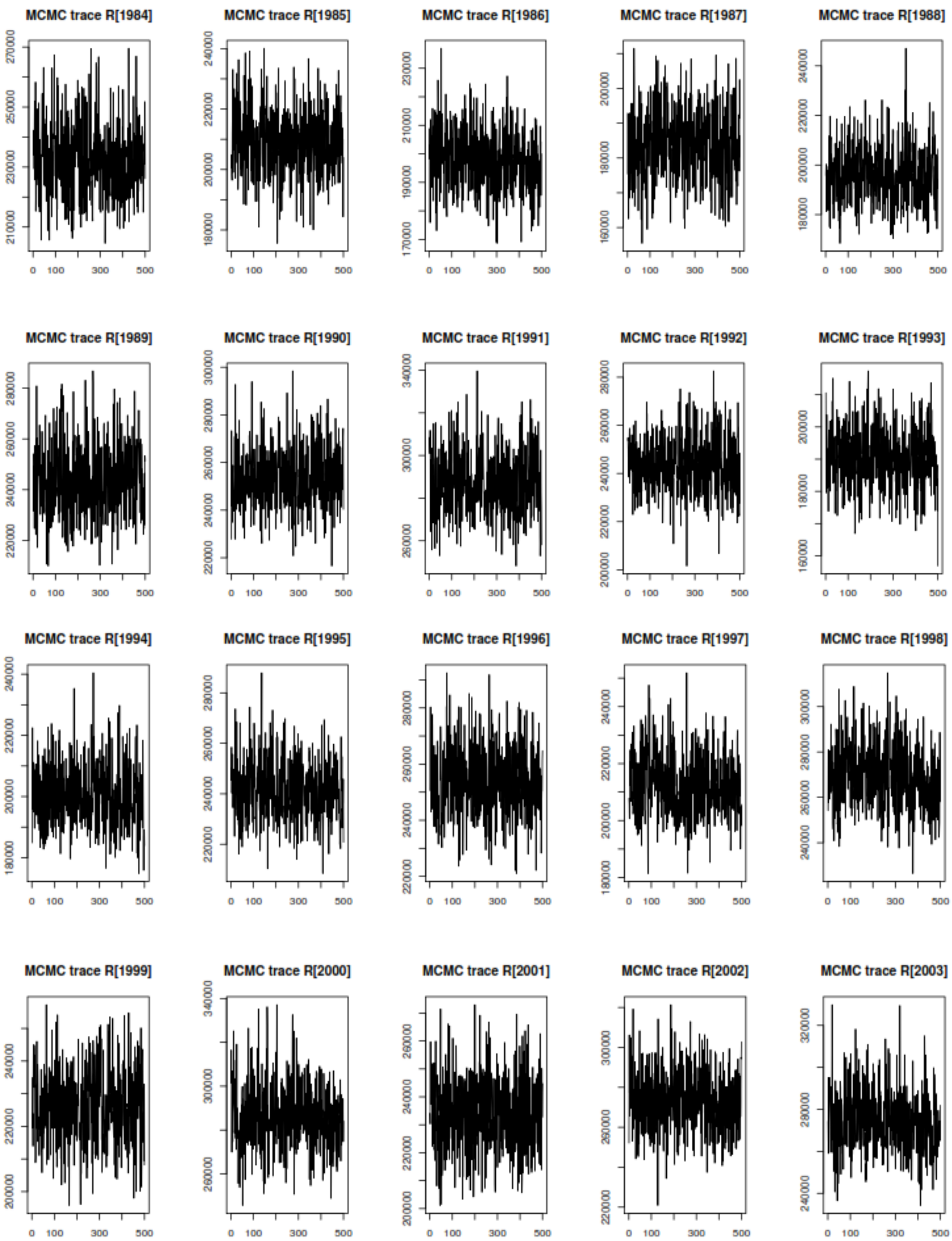


Figure 2.3.1.5. Megrim (*L. whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d. Comparison of WGBIE 2015 (left) and IBPMegrim 2016 (right) discarded numbers at age separated by age from 1990 to 2014.


MCMC trace R[1984]
MCMC trace R[1985]
MCMC trace R[1986]
MCMC trace R[1987]
MCMC trace R[1988]
MCMC trace R[1989]
MCMC trace R[1990]
MCMC trace R[1991]
MCMC trace R[1992]
MCMC trace R[1993]
MCMC trace R[1994]
MCMC trace R[1995]
MCMC trace R[1996]
MCMC trace R[1997]
MCMC trace R[1998]
MCMC trace R[1999]
MCMC trace R[2000]
MCMC trace R[2001]
MCMC trace R[2002]
MCMC trace R[2003]

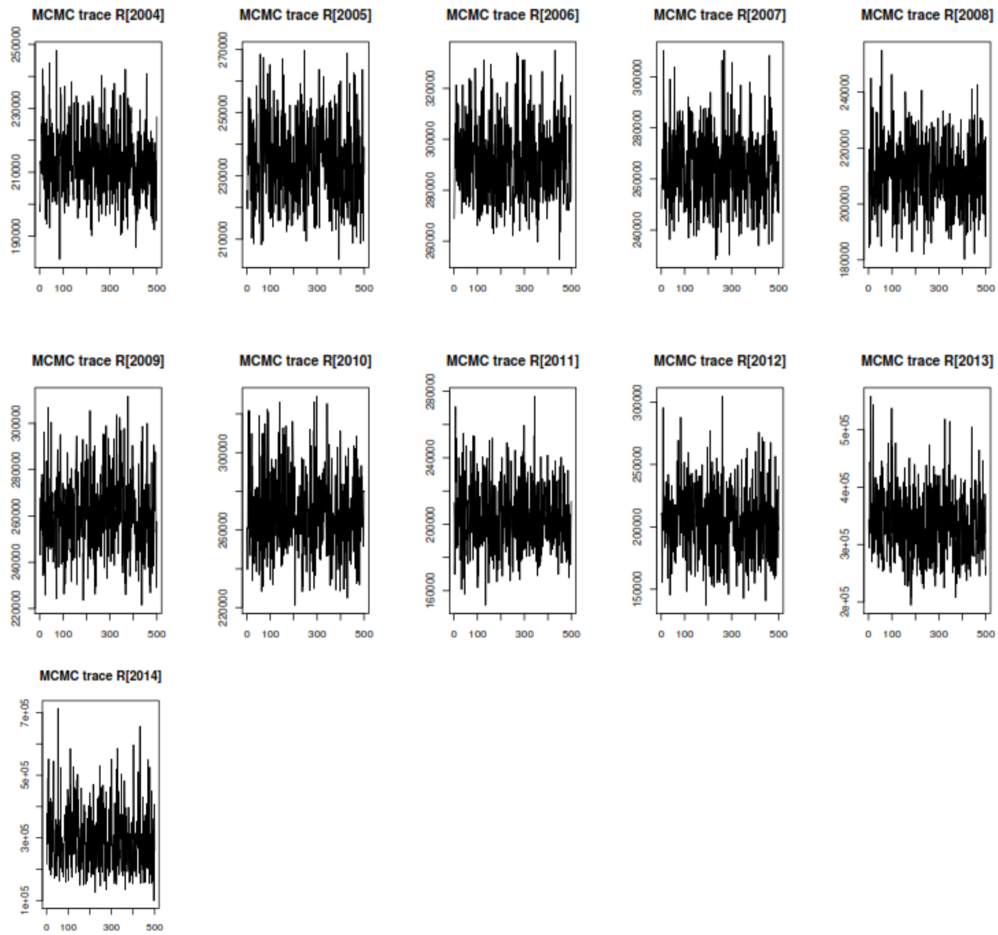


Figure 2.3.3.1. Trace plots of recruitment draws from 1984 to 2014.

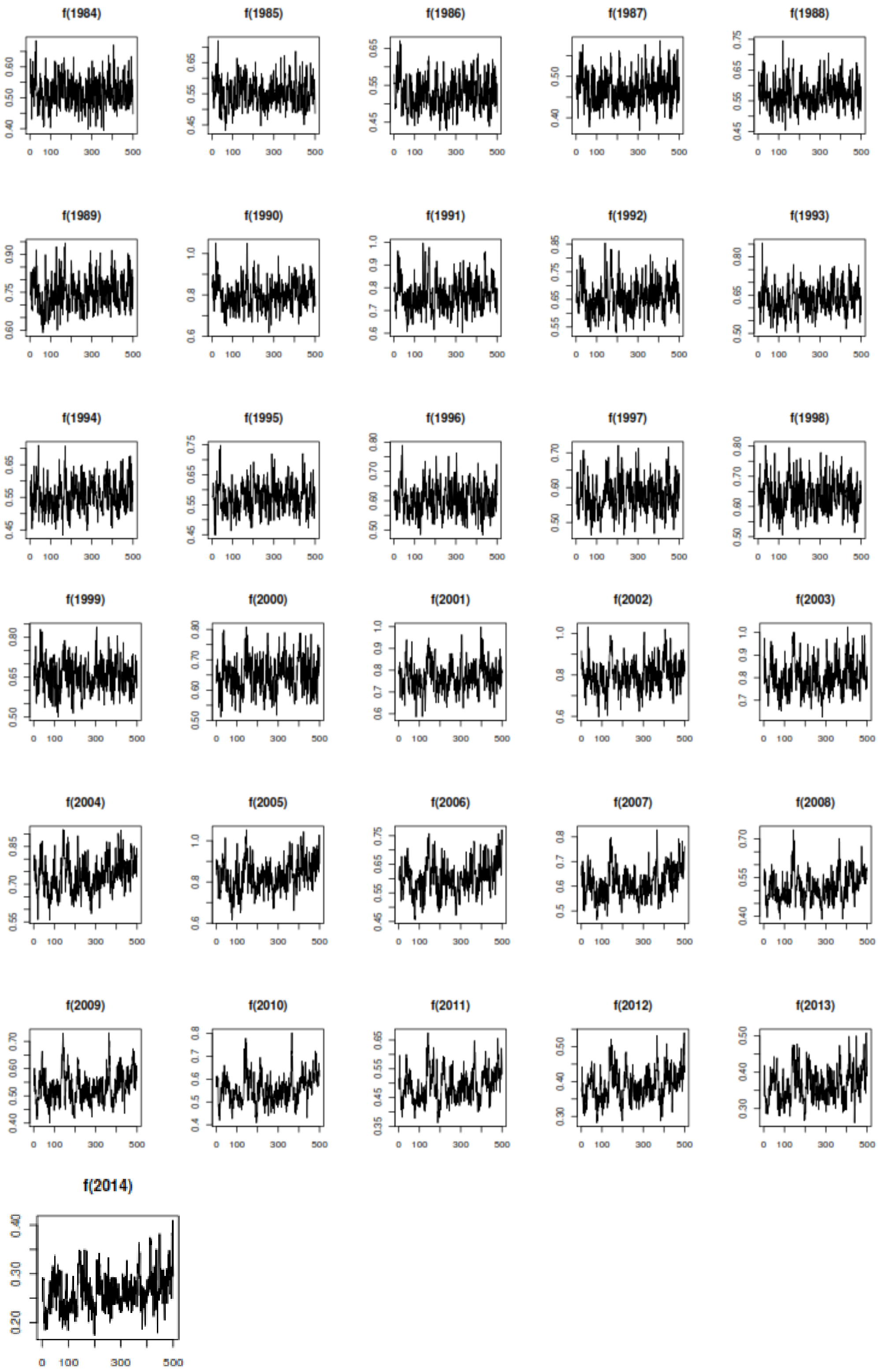


Figure 2.3.3.2. Trace plots of f(y) fishing mortality in ages 9 and 10 from 1984 to 2014.

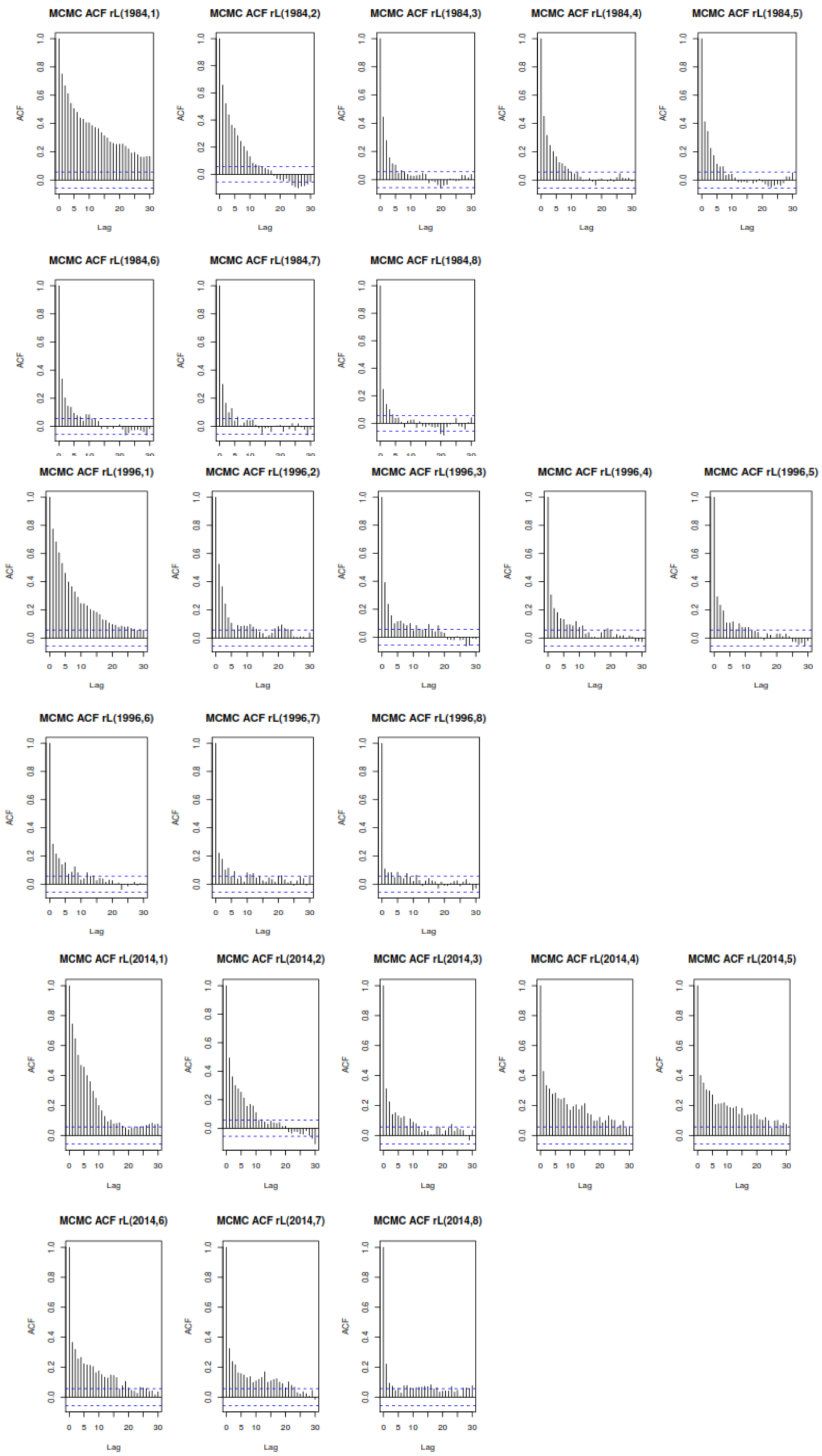


Figure 2.3.3.3. Autocorrelation plots of rL for years 1984, 1996 and 2014.

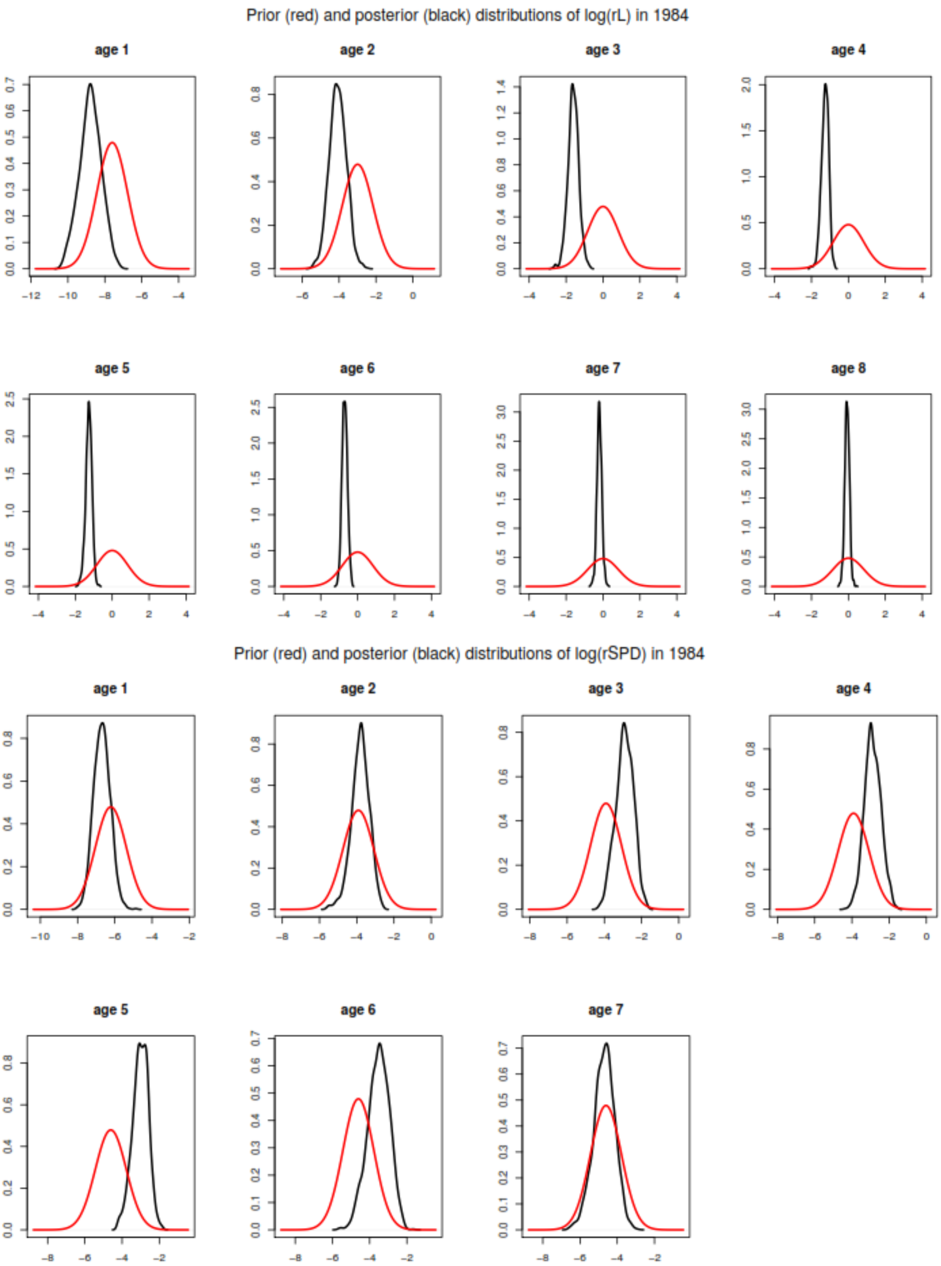


Figure 2.3.3.4. Prior (red) and posterior distribution of log (L) in 1984, log (rSPD) at age in 1984, log (rFRD) at age in 1984 and log (rOTD) at age in 1984.

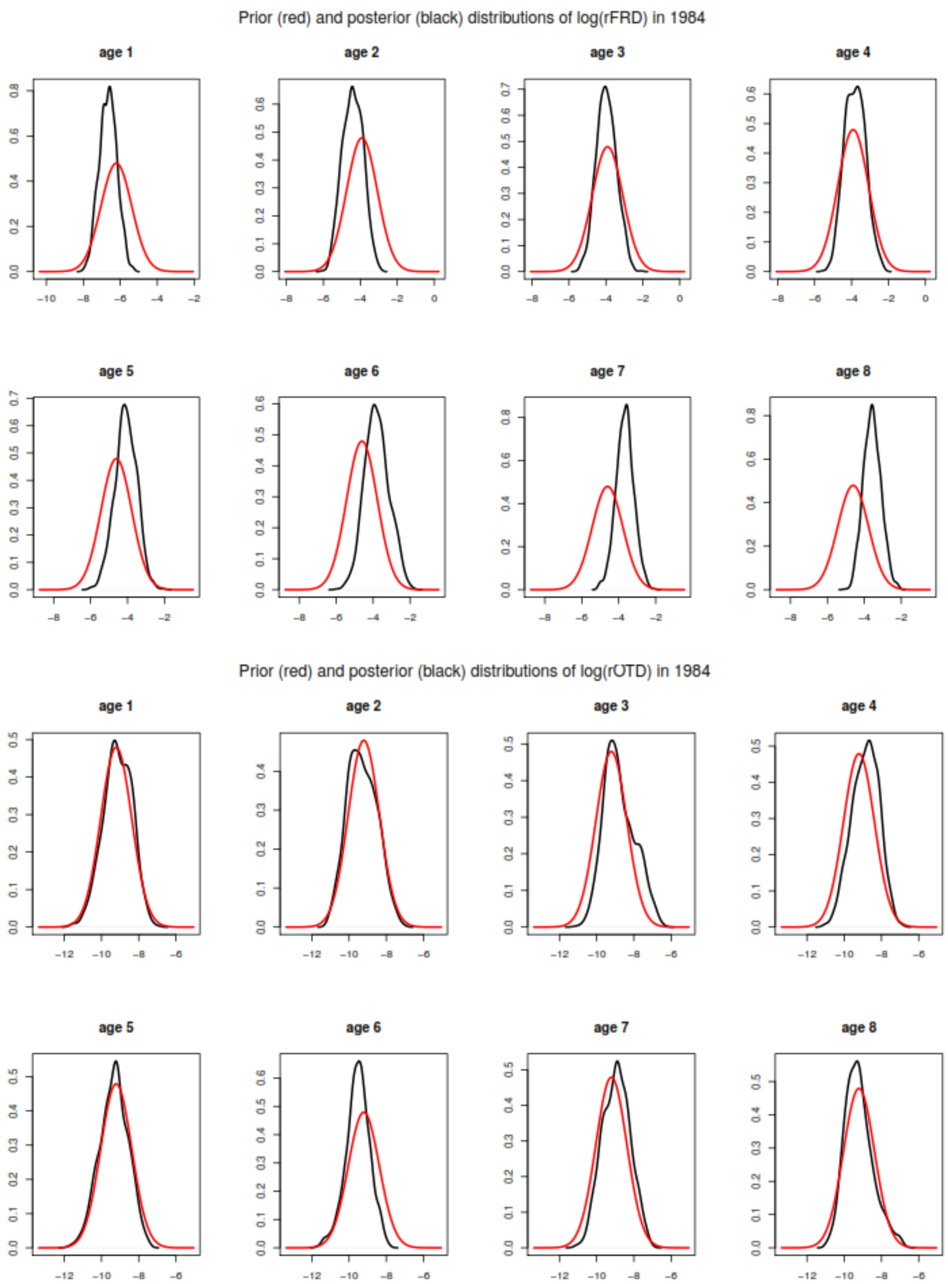
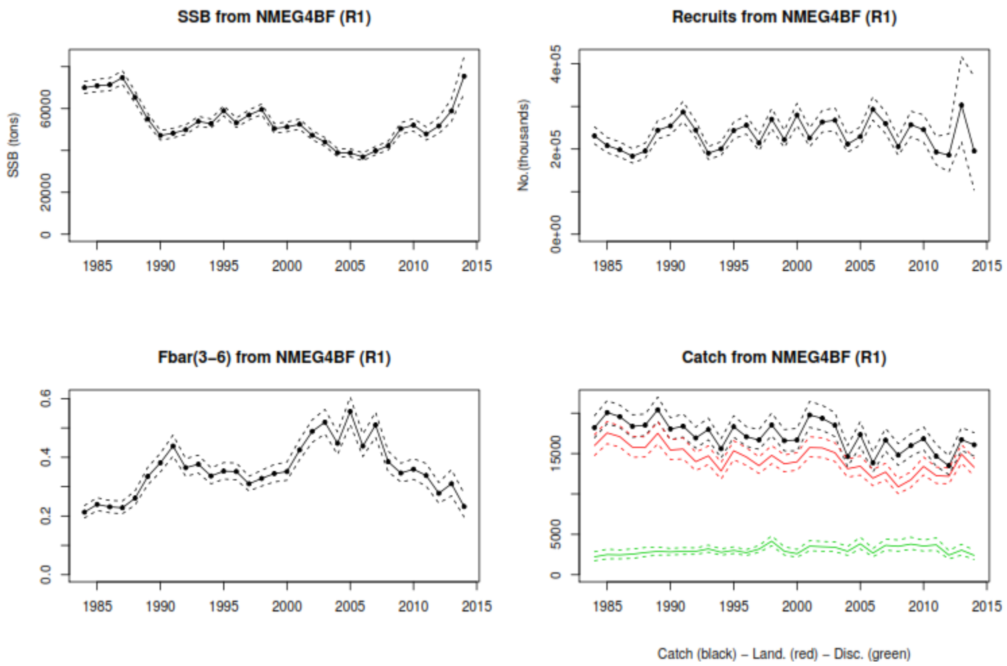


Figure 2.3.3.4 (cont.). Prior (red) and posterior distribution of log (L) in 1984, log (rSPD) at age in 1984, log (rFRD) at age in 1984 and log (rOTD) at age in 1984.

WGBIE 2015



IBPMegrim 2016

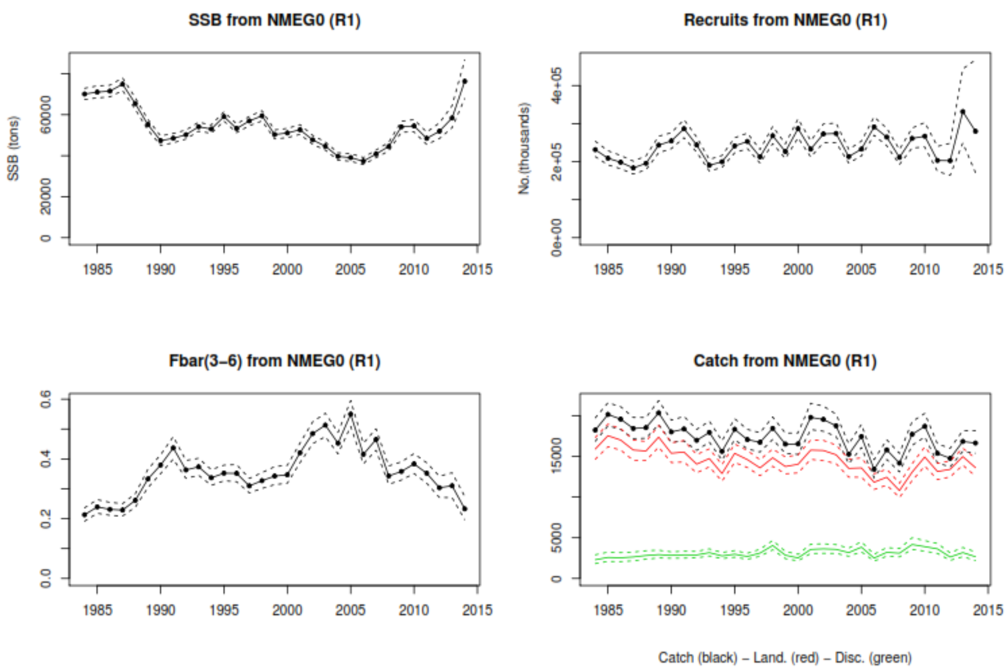


Figure 2.3.3.5. WGBIE 2015 and IBPMegrim 2016 results of time series of spawning stock biomass (SSB), recruits, F_{bar}, catch, landings and discards from 1984 to 2014. The solid dotted lines correspond with the median of the distribution and the dashed lines with 5% and 95% quantiles.

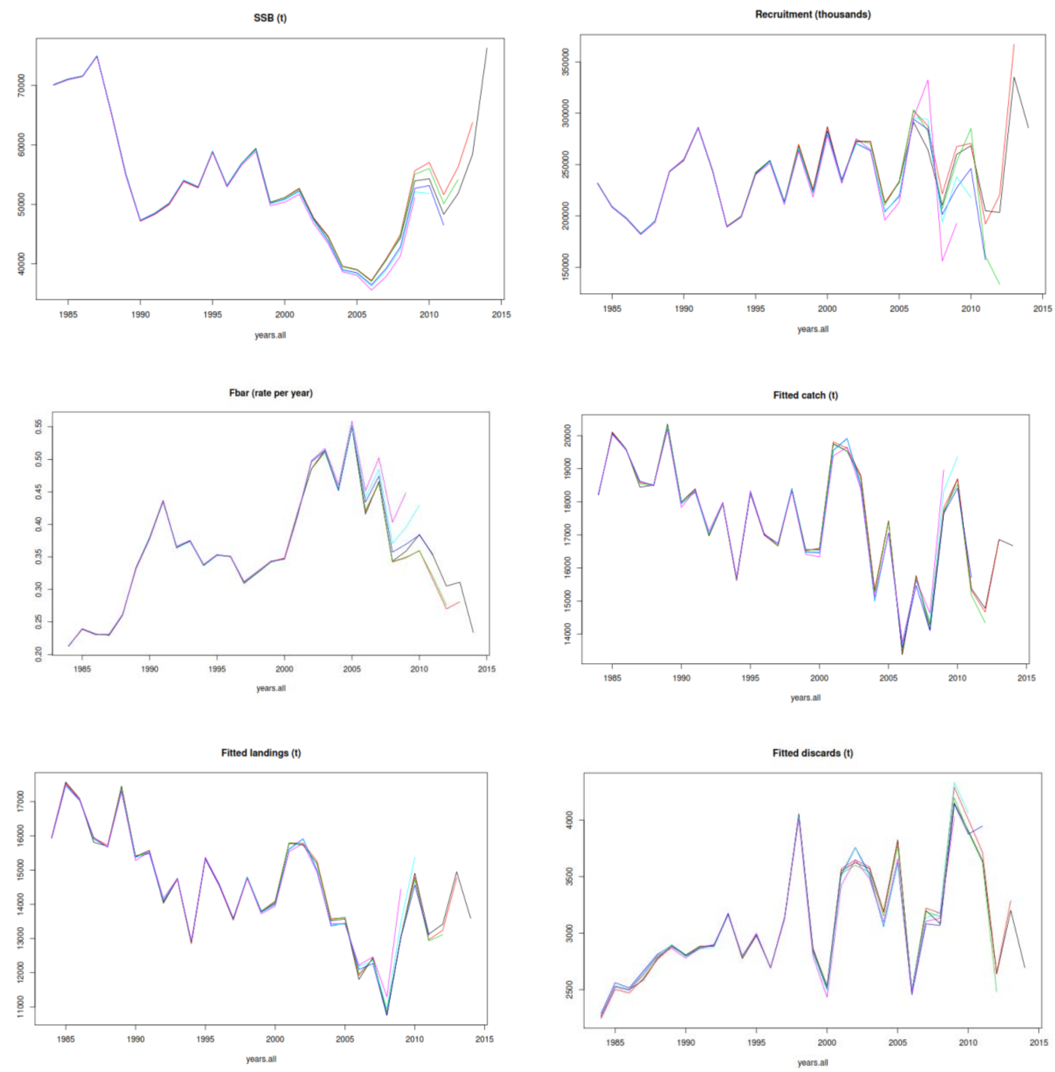


Figure 2.4.1. Time series of median SSB, recruitment and F_{bar} in retrospective analysis.

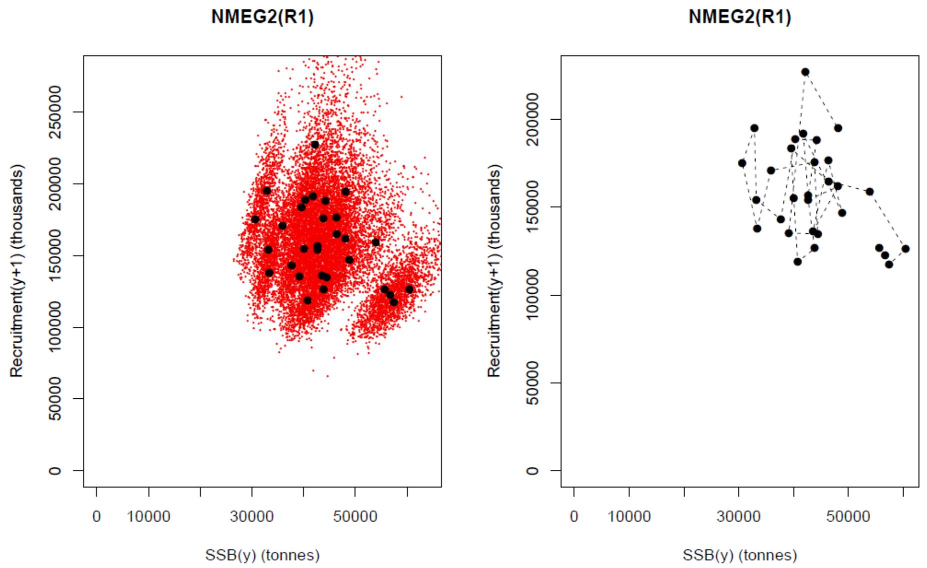


Figure 2.6.1.1: Stock-recruitment plot for the Northern megrim stock. The black bullets represent the median values. The red points (in the left panel) are the values from the MCMC draws, whereas the dashed lines (in the right panel) join the median in chronological order. Figure 2.6.1.1: Stock-recruitment plot for the Northern megrim stock. The black bullets represent the median values. The red points (in the left panel) are the values from the MCMC draws, whereas the dashed lines (in the right panel) join the median in chronological order.

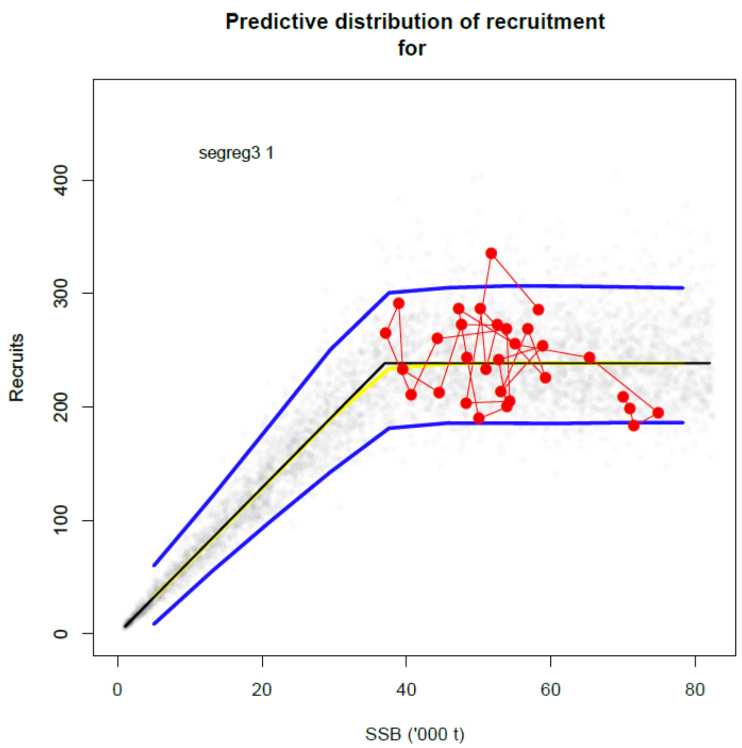


Figure 2.6.1.2: Fitted segmented regression model with the breakpoint fixed at B_{lim}.

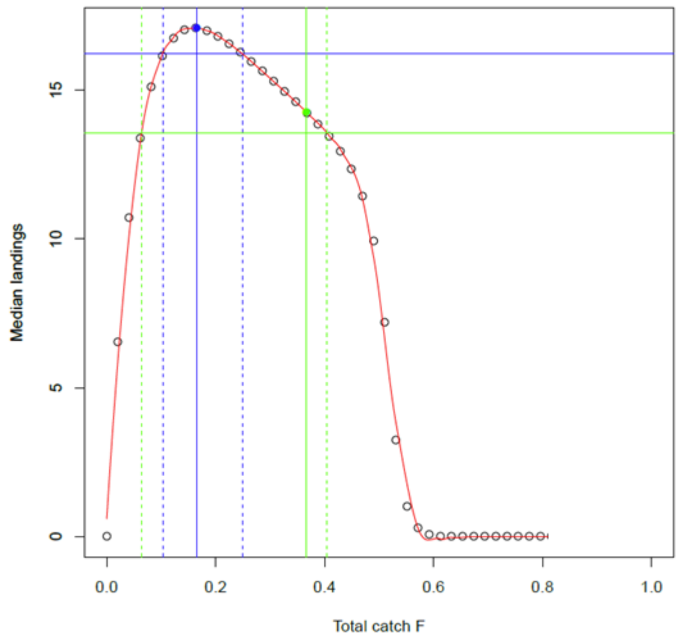


Figure 2.6.2.1: Median yield curve for different values of total catch fishing mortality. F_{MSY} and F_{MSY} ranges are given in blue (solid and dashed lines respectively) and $F_{p0.5}$ is represented as a solid green line.

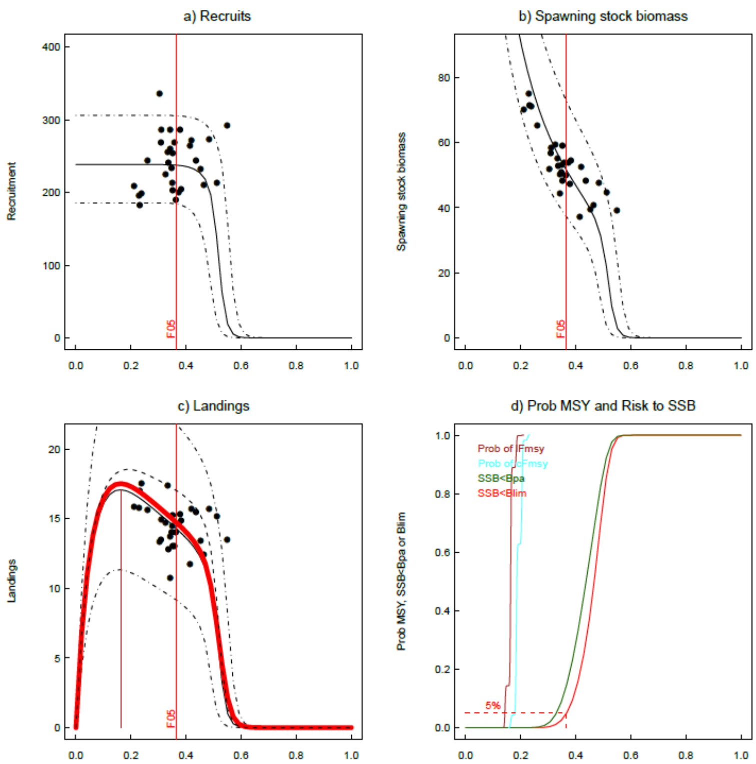


Figure 2.6.2.2: Eqsim summary plots without ICES MSY AR. From left to right and from top to bottom historical values (bullets), median (solid black) and 90% intervals (dotted black) of recruitment, SSB and landings for fixed values of F (on the x-axis). The red vertical line represents the $F_{p0.5}$ value, whereas the brown vertical line is the F_{MSY}. The last panel (bottom right) shows the probability of SSB<B_{lim} (red), SSB<B_{pa} (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

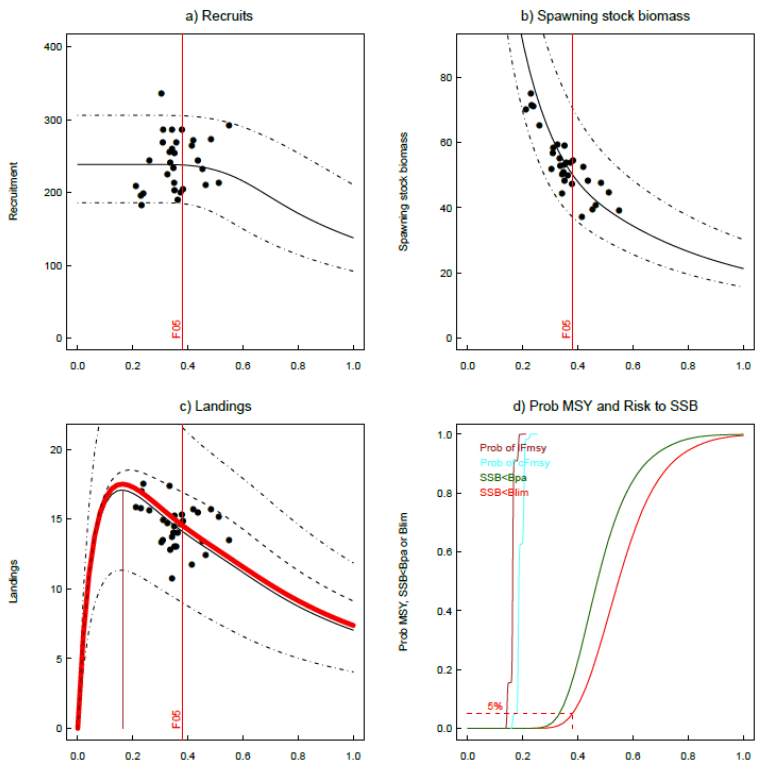


Figure 2.6.2.3: Eqsim summary plots without ICES MSY AR (MSY $B_{trigger}$=41 800 tonnes). From left to right and from top to bottom historical values (bullets), median (solid black) and 90% intervals (dotted black) of recruitment, SSB and landings for fixed values of F (on the x-axis). The red vertical line represents the $F_{p0.5}$ value, whereas the brown vertical line is the F_{MSY}. The last panel (bottom right) shows the probability of SSB<B_{lim} (red), SSB<B_{pa} (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

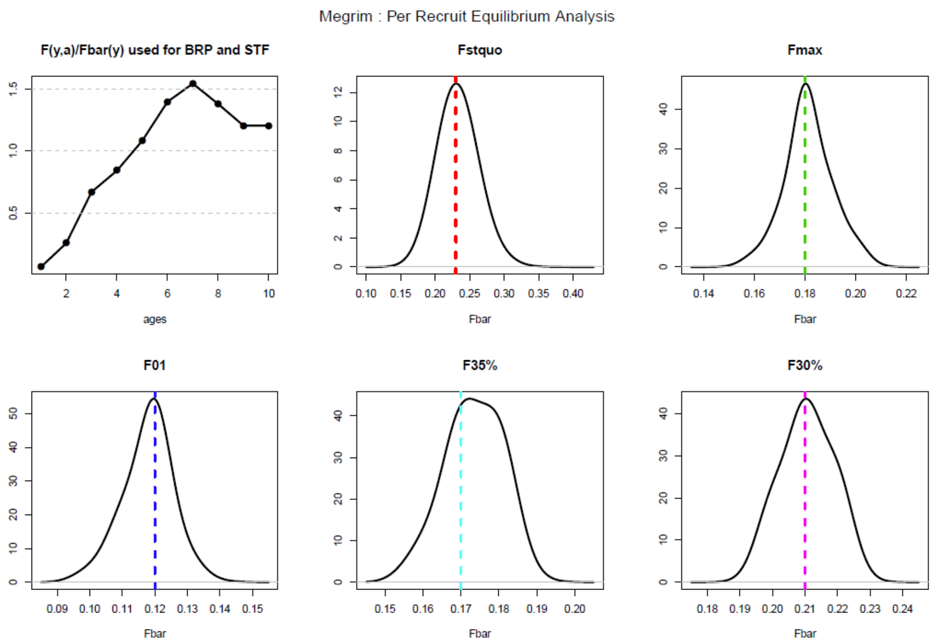


Figure 2.6.3.1: Exploitation pattern and probability distributions of F_{status} quo, F_{max}, F0.1, F35% and F30% from the per recruit equilibrium analysis.

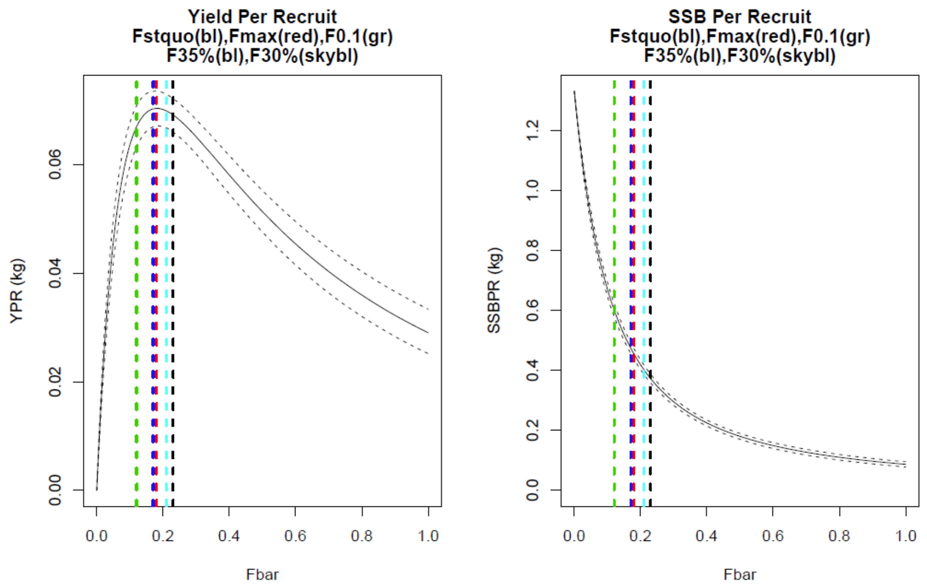


Figure 2.6.3.2: Yield per recruit on the left and SSB per recruit on the right for different levels of fishing mortalities (x-axis). The black solid line represents the median and the black dashed line the 90% probability intervals. The coloured vertical dashed lines are the estimated reference points (F_{st} in black, F_{max} red, $F_{0.1}$ in green, $F_{35\%}$ in blue and $F_{30\%}$ in cyan).

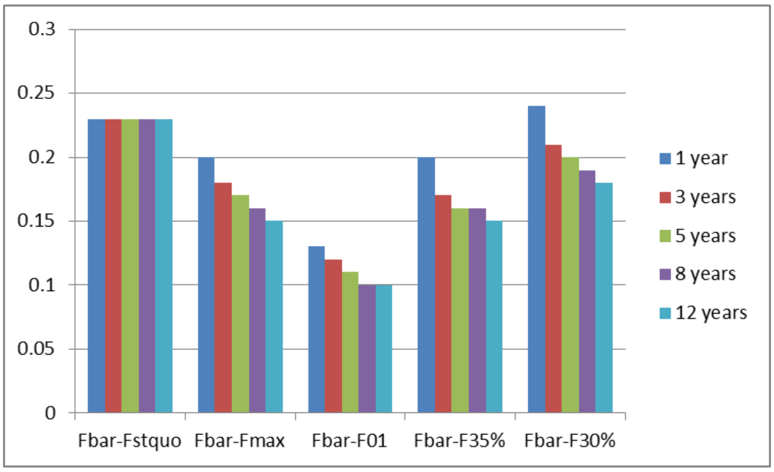


Figure 2.6.3.3: Sensitivity of the reference points obtained in the per recruit equilibrium analysis to the number of years assumed for the biological parameters and the exploitation pattern.

Annex 1 List of participants

NAME	INSTITUTE	ROLE	EMAIL
Ane Iriondo	AZTI-Tecnalia Sukarrieta Txatxarramendi ugartea z/g E-48395 Sukarrieta (Bizkaia) Spain	Stock coordinator and stock assessor	airiondo@azti.es
Leire Ibaibarriaga	AZTI-Tecnalia Sukarrieta Txatxarramendi ugartea z/g E-48395 Sukarrieta (Bizkaia) Spain	Model development	libaibarriaga@azti.es
Joël Vigneau	Port-en-Bessin Station IFREMER P.O. Box 32 Avenue du Général De Gaulle, F-14520 Port-en-Bessin France	Data provider	joel.vigneau@ifremer.fr
Anne-Sophie Cornou	Nantes Centre IFREMER P.O. Box 21105 Rue de l'île d'Yeu, 44311 Nantes Cédex 03 France	Data provider	anne.sophie.cornou@ifremer.fr
Samu Mäntyniemi	University of Helsinki Viikinkaari 2 Room 2051 FI-00014 Finland	External expert	samu.mantyniemi@helsinki.fi
Ernesto Jardim (External reviewer)	EC Joint Research Centre via Enrico Fermi 2749 21027 Ispra (VA) Italy	External expert	ernesto.jardim@jrc.ec.europa.eu
Santiago Cerviño	Instituto Español de Oceanografía Centro Oceanográfico de Vigo P.O. Box 1552 E-36200 Vigo (Pontevedra) Spain	Chair	santiago.cervino@vi.ieo.es
Anne Cooper	International Council for the Exploration of the Sea (ICES) H.C. Andersens Boulevard 1553 Copenhagen V. Denmark	ICES officer	anne.cooper@ices.dk

Annex 2 Stock Annex: Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k and 8.a, 8.b, and 8.d

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k and 8.a, 8.b, and 8.d
Working Group	IBPMegrim 2016 (Inter-Benchmark Workshop on Megrim)
Last updated:	March 2016
Last updated 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 8.a, 8.b, and 8.d and megrim in divisions 8.c and 9.a. The stock under this Annex is called northern Megrim and defined as megrim in divisions 7.b–k and 8.a, 8.b, and 8.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, 7.f, 7.g, and 7.h.

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

Countries	ICES area	% landings (based on 2014 landings data)	Fisheries
Spain	Divisions 7.b, 7.c, and 7.e–k and 8.a, 8.b, and 8.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, 7.c, and 7.g	18%	Multipurpose vessels targeting gadoids, plaice, sole and anglerfish
UK (England and Wales)	ICES Divisions 7.e, 7.f, 7.g, and 7.h	22%	Beam trawlers
Belgium	Divisions 7.b, 7.c, and 7.e–k and 8.a, 8.b, and 8.d	1%	Beam trawlers

A.3. Ecosystem aspects

There are two megrim species in the Northeastern Atlantic: megrim (*Lepidorhombus whiffiagonis*) 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, 7.c, and 7.e–k and 8.a, 8.b, and 8.d and megrim in Divisions 8.c and 9.a.

Spawning period of these stocks goes from January to March. Megrim spawning peak occurs in February (8.a, 8.b, and 8.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*, *Nephrops norvegicus*, *Phycis blennoides*, *Molva molva*, *Pollachius virens*, *Trisopterus* spp (mainly *Trisopterus luscus*), *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 MegrimWorking 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 4, 7, 8 and 9 (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; Santurtún *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 1, Joël Vigneau, Annex 4).

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, 8.b, and 8.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.

(*) Scientific estimates were provided

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, 8.b, and 8.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, 7.c, and 7.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

	France		Ireland		Spain		UK	
	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK
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

	France		Ireland		Spain		UK	
	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK
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 Sub-area 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. (Figure B.3).

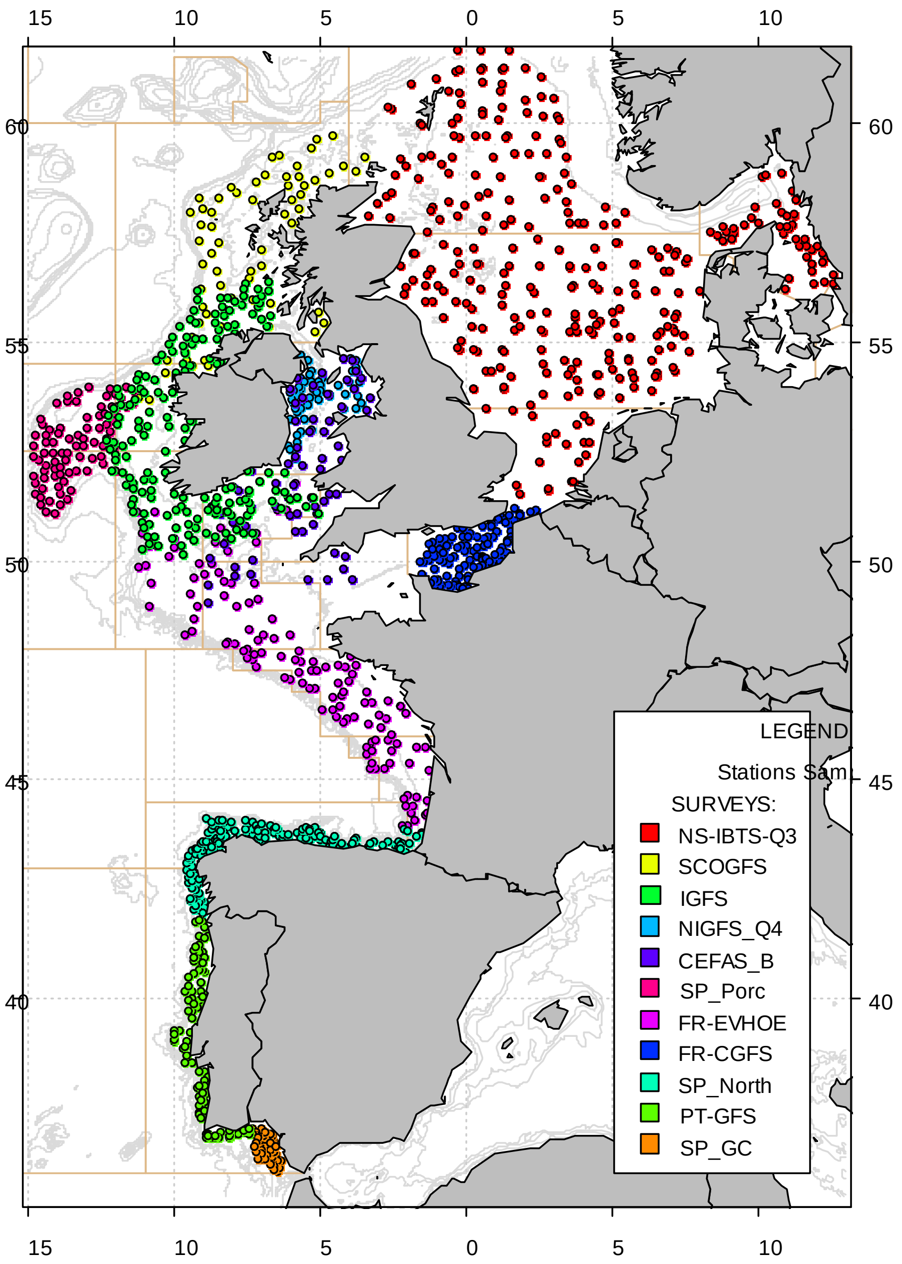


Figure B.3. Station positions for the IBTS Surveys carried out in the Western and North Sea Area in the autumn/winter of 2008. (From IBTSWG 2009 Report). Just to be used as general location of the Surveys.

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 IBPMegrim 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 Protocol Workshop 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:

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

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:

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

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

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

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

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

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

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

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

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:

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

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:

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

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 C.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 CVs 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 WKFLAT (ICES, 2012), where a sensitivity analysis to the various model configuration was conducted. The report of that workshop provides a detailed description of that work.

Table C.1. WKFLAT 2012 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
$N(y,1) \sim LN(medrec,2)$	$medrec = 250000$
$N(1984,a) \sim LN(medrec$ $\exp[-(a-1)M - \sum_{j=1}^{a-1} medF(j)],2), a = 2$	$medrec$ as above, $M = 0.2$, $medF = (0.05,0.1,0.3,0.3,0.3,0.3,0.3,$
$N(1984,10+) \sim LN(medrec\exp[-9M$ $\sum_{j=1}^{9} medF(j)]/\{1-\exp[-M - medF(9)]$	$medrec, M, medrecF$ as above
$f(y) \sim LN(med_f, CV_f)$	$med_f = 0.3, CV_f = 1$
$\rho \sim Uniform(0,1)$	
$r_L(1984,a) \sim LN(medr_L(a),1), a = 1,\ldots,8$	$medr_L = (0.0005,0.05,1,1,1,1,1,1)$
$r_L(y,9) = r_L(y,10+) = 1$	
$r_{SPD}(1984,a) \sim LN(medr_{SPD}(a),1), a = 1,\ldots,7$	$medr_{SPD} = (0.002,0.02,0.02,0.02,0.01$
$r_{IRD}(1984,a) \sim LN(medr_{IRD}(a),1), a = 1,\ldots,8$	$medr_{IRD} = (0.001,0.01,0.01,0.01,$ $0.005,0.005,0.005,0.001)$
$r_{UKD}(1984,a) \sim LN(medr_{UKD}(a),1), a =$	$medr_{UKD} = (0.00001,0.001,0.001,0.00$ $0.001,0.001,0.001,0.001)$
$r_{OTD}(1984,a) \sim LN(medr_{OTD}(a),1), a = 1$	$medr_{OTD} = (0.002,0.02,0.02,0.02,$ $0.01,0.01,0.01,0.002)$
$r_{SPD}(y,7) = r_{SPD}(y,a) = r_{IRD}(y,a)$ $= r_{UKD}(y,a) = r_{OTD}(y,a) = 0,\ a = 8,9,10$	
$\tau_C(a), \tau_L(a), a = 1,2,3; \tau_D(a), a = 1,\ldots,8$	$\Gamma(4,0.345)$
$\tau_C(a), \tau_L(a), a = 4,\ldots,10+$	$\Gamma(10,0.1)$
$\tau_{SPD}(a), a = 1,\ldots,7; \tau_{IRD}(a), \tau_{UKD}(a), a =$	$\Gamma(4,0.345)$
$\log[q_k(a)] \sim N(\mu_{Ik}, \tau_{Ik}), a \le 8,$ index $k = 1,\ldots,5$	$\mu_{Ik} = -7,\ \tau_{Ik} = 0.2$
$q_k(a) = q_k(8), a > 8,$ indices k with ages	
$\tau_k(a),$ index $k = 1,\ldots,5$	$\Gamma(4,0.345)$

Table C.1. (cont). 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
$N(y,1) \sim LN(medrec,2)$	$medrec = 250000$
$N(1984,a) \sim LN(medrec$ $\exp[-(a-1)M - \sum_{j=1}^{a-1} medF(j)],2), a = 2,\ldots,9$	$medrec$ as above, $M = 0.2$, $medF = (0.05,0.1,0.3,0.3,0.3,0.3,0.$
$N(1984,10+) \sim LN(medrec\exp[-9M -$ $\sum_{j=1}^{9} medF(j)]/\{1-\exp[-M - medF(9)]\}, 2)$	$medrec, M, medrecF$ as above
$f(y) \sim LN(med_f, CV_f)$	$med_f = 0.3, CV_f = 1$
$\rho \sim Uniform(0,1)$	
$r_L(1984,a) \sim LN(medr_L(a),1), a = 1,\ldots,8$	$medr_L = (0.0005,0.05,1,1,1,1,1,1)$
$r_L(y,9) = r_L(y,10+) = 1$	
$r_{SPD}(1984,a) \sim LN(medr_{SPD}(a),1), a = 1,\ldots,7$	$medr_{SPD} = (0.002,0.02,0.02,0.02,$ $0.01,0.01,0.01)$
$r_{IRD}(1984,a) \sim LN(medr_{IRD}(a),1), a = 1,\ldots,8$	$medr_{IRD} = (0.001,0.01,0.01,0.01,$ $0.005,0.005,0.005,0.001)$
$r_{UKD}(1984,a) \sim LN(medr_{UKD}(a),1), a = 1,\ldots,8$	$medr_{UKD} = (0.00001,0.001,0.001,0.($ $0.001,0.001,0.001,0.001)$
$r_{FRD}(1984,a) \sim LN(medr_{FRD}(a),1), a = 1,\ldots,8$	$medr_{FRD} = (0.002,0.02,0.02,0.02,$ $0.01,0.01,0.01,0.01)$
$r_{OTD}(1984,a) \sim LN(medr_{OTD}(a),1), a = 1,\ldots,8$	$medr_{OTD} = (0.002,0.02,0.02,0.02,$ $0.01,0.01,0.01,0.002)$
$r_{SPD}(y,7) = r_{SPD}(y,a) = r_{IRD}(y,a)$ $= r_{UKD}(y,a) = r_{FRD}(y,a) = r_{OTD}(y,a) = 0,\ a = 8,9,10+$	
$\tau_C(a), \tau_L(a), a = 1,2,3; \tau_D(a), a = 1,\ldots,8$	$\Gamma(4,0.345)$
$\tau_C(a), \tau_L(a), a = 4,\ldots,10+$	$\Gamma(10,0.1)$
$\tau_{SPD}(a), a = 1,\ldots,7; \tau_{IRD}(a), \tau_{UKD}(a), \tau_{FRD}(a) a = 1,\ldots,8$	$\Gamma(4,0.345)$
$\log[q_k(a)] \sim N(\mu_{Ik}, \tau_{Ik}), a \le 8,$ index $k = 1,\ldots,5$	$\mu_{Ik} = -7,\ \tau_{Ik} = 0.2$
$q_k(a) = q_k(8), a > 8,$ indices k with ages > 8	
$\tau_k(a),$ index $k = 1,\ldots,5$	$\Gamma(4,0.345)$

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. 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 F_{bar} 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

From the IBP megrim (ICES, 2016):	Type	Value	Technical Basis
MSY approach	MSY $B_{trigger}$	41 800	B_{PA}, because the fishery has not been at F_{MSY} in the last 10 years.
	F_{MSY}	0.161	F giving maximum yield at equilibriumComputed using Eqsim.
Precautionary approach	B_{lim}	37 100	B_{loss}, which is the lowest biomass observed corresponding to year 2006.
	B_{pa}	41 800	$B_{lim}e^{1.645\,\sigma}$ where $\sigma = 0.07$isthe standard deviation of the logarithm of SSB in 2014.
	F_{lim}	0.489	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 B_{lim}, without advice/assessment error and without $B_{trigger}$.
	F_{pa}	0.412	$F_{lim}e^{-1.645\,\sigma}$ 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 data series 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

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

viii) 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 IBPMegrim 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.

References

Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper. 339.

Anon. 2003. Report of ICES Workshop on Discard Sampling Methodology and Raising Procedures. Charlottenlund, Denmark, 2–4 September 2003.

Aubin-Ottenheimer, G. 1986. La cardine (*Lepidorhombus whiffiagonisi*):étude biologique et dynamique du stock de mer Celtique. Thèse Univ. Paris VI, 197 pp.

BECAUSE. Critical Interactions BEtween Species and their Implications for a PreCAUtionary FiSheries Management in a variable Environment - a Modelling Approach" (BECAUSE) (Ref: European Union 6th FP priority TP 8.1 STREPT Contract no.: 502482).

Bellido, Jose Mª., Pérez, N. and Araujo, H. Discard pattern of Hake Southern Stock from the Spanish trawl Fleet. WD presented at the WGHMM 2003, Gijon, Spain.

BIOSDEF. Biological Studies on Demersal Species (Ref.: EU DG XIV Study Contract: 95/038): finished in 1998. Growth and reproduction information was collected and analysed for hake, anglerfish, and megrim in Subarea 7, Division VIIIa,b,d and Division VIIIc & IXa.

Castro J., M. Rasero and A. Punzón. 2004. A preliminary identification of fisheries for the Spanish trawl fleets in the European Southern Shelf. WD in SGDFF.

Fernández, C., Cerviño, S., Pérez, N., and Jardim, E. 2010. Stock assessment and projections incorporating discard estimates in some years: an application to the hake stock in ICES Divisions VIIIc and IXa. ICES Journal of Marine Science, 67: 1185–1197.

Final Report. Contract Ref. 98/095. 2002. Monitoring of discarding and retention by trawl fisheries in Western Waters and the Irish Sea in relation to stock assessment and technical measures.

Gilks, W. R., Richardson, S., and Spiegelhalter, D. J. 1996. Markov Chain Monte Carlo in Practice. Chapman and Hall. London. 486 pp.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM).

Kulka, D. 1999. The integration of information collected by fishery observers into the fisheries management process: A scientific perspective. The international conference on integrated fisheries monitoring proceedings. Rome, FAO: 249–259.

Lunn, D., Spielgelhalter, D., Thomas, A., and Best, N. 2009. The BUGS project: Evolution, critique, and future directions. Statistics in Medicine, 28: 3049–3067.

R Development Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Rodriguez-Marín, E. And Olaso, I. 1993. Food composition of the two species of Megrim (*Lepidorhombus whiffiagonis* and *Lepidorhombus boscii*) in the Cantabrian Sea. Actes du Illeme Colloque d'Oceanographie du Golfe de Gascogne. Arcachon 1992: 215–219.

Santurtún, M.; Prellezo, R.; Lucio P.; Iriondo A. and Quincoces I. 2004. A first Multivariate approach for the dynamics of the Basque trawl fleet in 2002. Working Document presented to SGDFF. Ostende (Belgium) 26–30 January 2003.

Shepherd, J. G. 1999. Extended survivors analysis: An improved method for the analysis of catch-at-age data and abundance indices. ICES Journal of Marine Science, 56: 584–591.

Sturtz, S., Ligges, U., and Gelman, A. 2005. R2WinBUGS: a package for running WinBUGS from R. Journal of Statistical Software, 12: 1–16.

Trenkel, V. and M.-J. Rochet. 2001. Towards a theory for discarding behaviour. ICES Doc., CM 2001/V:03. 10 pp.

Annex 3 External Experts' Report

External experts: Ernesto Jardim, Samu Mäntyniemi and Santiago Cerviño (Chair)

The external experts have to following considerations:

a) The issues raised by the reviewers throughout the process are reported in the sections named "Working group chronicle" and "Progress to ToRs".
b) The external experts confirm that the outcomes of the benchmark (i.e. the stocks annex) are appropriate to provide scientific advice as it is also stated in the "Conclusion" section.
c) The "Recommendations for future work" section compiles the problems and weakness identified by the external experts (and other members of the group) that should be addressed in the future to potentially improve the current assessment.

Annex 4 Working Documents

List of working documents:

- WD-1 by J. Vigneau is entitled “French historical (2003–2014) discards estimates of megrim (*L. whiffiagonis*) in Subarea 7 and divisions 8.a, 8.b, and 8.d”.

- WD-2 by L. Ibaibarriaga and A. Iriondo is entitled “Analysis of applying Mortality at age in the assessment of Megrim *(Lepidorhombus whiffiagonis*) in divisions 7.b-k and 8.a and 8.b”.

WD 1

French historical (2003–2014) discards estimates of megrim (*L. whiffiagonis*) in Subarea 7 and Divisions 8.a, 8.b, and 8.d

Working document to IBP Megrim, January 2016.

Joël Vigneau, Ifremer Port-en-Bessin

Abstract

In this working document the analysis of French discards data is presented. The document explores the historical French dataset, in order to test the consistencies of the time series and find the most robust raising method for estimating the discards. Feedback from WGCATCH on the estimation procedure helped to regroup all métiers having a low contribution to the landings into one strata, and regroup at best the other strata to use raising by effort as advised by the working group. Finally two raising methods were combined: one based on effort (in most cases) and another based on landings (only for the low contributor strata). Once the total discards and length distribution was agreed, the next step was the estimation of discards at age. In this case there were some years (2005-07) with scarce ALK data. Gap filling technique using linear interpolation based on moving average was used, without creating new values where age information at length was available. Eventually, a new time series of landings is proposed with corrections brought to some years where two FAO codes were used for megrim (MEG and LEZ), and the annual volume of discards and their corresponding age structures are estimated for the years 2004 to 2014.

The fishery

The French landings (table 1) are almost entirely driven by trawlers (more than 97% in both areas). The main distinction between trawlers are their target species, with demersal species accounting for 83% of the total landings and crustaceans the remaining , then single trawl or twin trawl (the latter is more used in subarea 8 with 77% of the landings vs 44% in subarea 7). Eventually, it is possible to distinct different mesh size, especially in subarea 7, where 70%of the landings are with mesh size 100-119mm and 29% with mesh size 70-99mm. The ratio between the two areas is stable and varying between 70 and 80% in favor of subarea 7 every year. The inter-annual stability is also shown by the mapping of the French landings per year (figure 1). The maps seem to display three patches that could be investigated when estimating discards. These are West of Ireland (divisions 7bc), Celtic sea (divisions 7e-k) and Bay of Biscay (subarea 8), although an option will be to consider Bay of Biscaye and Celtic Sea as a continuum (true every year except in 2008).

Ifremer

Area	Metier	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	% catch in area
VII	OTT_DEF_100-119_0_0	573	539	524	522	552	464	671	1083	974	1117	1058	983	29.5%
	OTB_DEF_70-99_0_0	601	438	428	454	449	411	541	656	717	1098	1111	1255	26.6%
	OTB_DEF_100-119_0_0	654	540	513	536	669	570	404	532	408	763	1198	900	25.0%
	OTT_CRU_100-119_0_0	248	459	506	377	268	275	352	271	168	109	190	197	11.1%
	OTB_CRU_100-119_0_0	384	107	190	153	52	69	66	37	12	12	27	13	3.7%
	OTT_DEF_70-99_0_0	163	121	113	50	93	61	56	63	48	40	83	19	3.0%
	GNS_DEF_120-219_0_0	14	19	23	17	22	10	4	2	2	3	2	2	0.4%
	SDN_DEF_100-119_0_0	0	0	0	0	0	1	3	3	2	9	15	6	0.1%
	GNS_DEF_100-119_0_0	1	0	1	0	0	0	8	11	8	4	5	7	0.1%
	MIS_MIS_0_0_0	12	10	2	2	3	8	13	9	51	6	9	10	0.4%
	Total	**2650**	**2233**	**2300**	**2111**	**2108**	**1869**	**2118**	**2667**	**2390**	**3161**	**3698**	**3392**	
VIII a,b,d	OTT_DEF_>=70_0_0	220	282	307	346	435	414	538	605	533	597	580	529	58.6%
	OTB_DEF_>=70_0_0	168	120	146	133	77	120	208	223	111	131	178	135	19.0%
	OTT_CRU_>=70_0_0	122	144	181	135	112	160	141	117	173	103	78	219	18.3%
	GNS_DEF_>=100_0_0	3	3	9	16	6	5	12	21	8	5	9	14	1.2%
	OTB_CRU_>=70_0_0	28	16	22	9	3	7	2	4	11	7	1	9	1.3%
	SDN_DEF_100_119_0_0	0	0	0	0	0	0	1	2	2	2	2	5	0.2%
	GTR_DEF_>=100_0_0	1	3	2	5	0	0	2	4	0	0	0	0	0.2%
	MIS_MIS_0_0_0	35	16	5	8	4	3	10	8	7	6	3	8	1.2%
	Total	**577**	**584**	**672**	**652**	**637**	**709**	**914**	**984**	**845**	**851**	**851**	**919**	
Grand total		**3227**	**2817**	**2972**	**2763**	**2745**	**2578**	**3032**	**3651**	**3235**	**4012**	**4549**	**4311**	

Table 1 :French landings by area, year and métier DCF level 6

It has to be noted that the grand total (table 1) differs sometimes significantly with the figures used by the Working Group, even after 2012 benchmark. The reason is the introduction of a 2nd 3-alpha code in the system in 2008 (LEZ, Lepidorhombus spp.) which was omitted to count on top of MEG (Lepidorhombuswiffiagonis).

The different effort variables (figure 2) display expected trends, at least in relative terms, with some decreasing tendency, more pronounced for trawlers targeting Nephrops. There is no counter indication here for using effort variables as auxiliary variables for discards estimates.

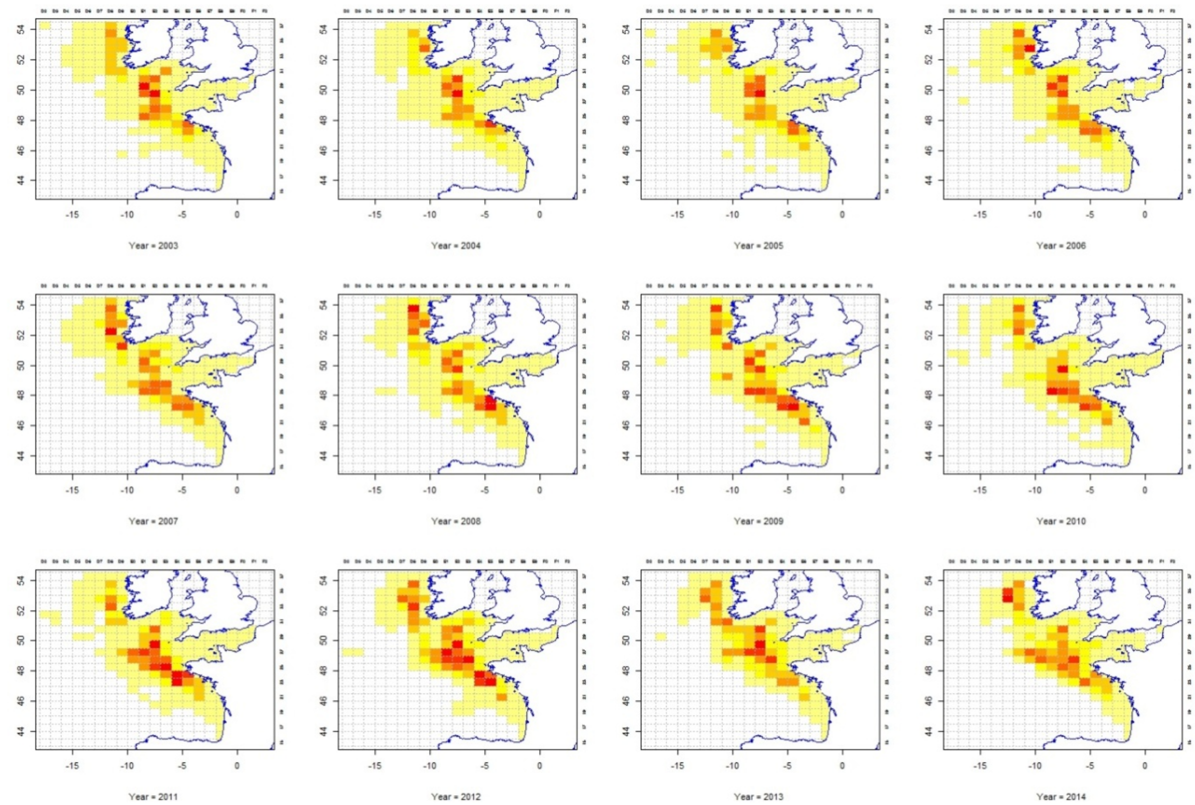


Figure 1 : Map of the French landings per year

Figure 2 : Effort for the otter trawlers (dashed lines : subarea 8, thick lines : subarea 7)

The samples

The number of trips sampled is shown table 2. The step increase of the sampling effort is clearly displayed with a first increase in 2007 in subarea 7, and a full increase in all areas from 2009 onward. The last column of the table represents the probability to catch a megrim in a sampled trip, and this column is informative. We learn that

- OTB_DEF and OTT_DEF_100-119 fishing altogether 55% of the total megrim catches (table 1) in subarea 7 are catching megrim at almost every trip (95% and 85%). Merging these two métiers for discards estimates will need to be considered.
- OTB_DEF_70-99 fishing 26% of the total megrim catches (table 1) in subarea 7 has a very low probability of catching megrim (7%). This is either due to the large number of these inshore trawlers, or due to a bad representativity of this métier in the ay-sea programme as regards megrim. In consequence, the discards estimates of this métier will need to be taken with caution, and it will be mandatory to consider mesh size ranges in the analysis (no merging with 100-119 range).
- OTB_CRU and OTT_CRU_100-119 fishing altogether 15% of the total megrim catches (table 1) in subarea 7 are catching megrim at each trip. Merging these two métiers for discards estimates will need to be considered, and they will need to be kept separate from the demersal trawling (risk of bias).

- OTT_DEF_70-99 contributing to 3% of the catches in subarea 7, has a probability of 65% of catching megrim. This between high probability (like OTB_DEF_100-119) and low probability (like OTB_DEF_70-99) will need to be investigated further.
- OTB and OTT_DEF_>=70 contributing together to 77% of the total catches in subarea 8 show different probabilities of catching megrim (78% and 25% respectively). This will be a cause of concern when estimating discards, and will need further analysis.
- OTT_CRU_>=70 contributing to 18% of the total catches displays a different probability (78%) than OTB_CRU In the area (25%) and than Nephrops trawlers in 7 (>98%). Given the importance of this métier it will be safer to consider it apart in one strata.
- Netters, seiners and miscellaneous gears contributing to less than 1% of the megrim catches in both areas, have also marginal probabilities of catching megrim in the at-sea sampled trip (except SDN_DEF in 7). In the French at-sea programme, netters and miscellaneous receive a high sampling effort (for other species), which means the expected low discards ratio and volume should be assessed with good quality.

Area	Metier	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Proba megrim
VII	OTT_DEF_100-119_0_0	0	2	6	5	6	5	17	31	13	36	27	22	95%
	OTB_DEF_70-99_0_0	12	14	19	13	27	44	90	81	93	99	90	114	7%
	OTB_DEF_100-119_0_0	0	5	6	20	0	9	16	20	34	12	16	26	85%
	OTT_CRU_100-119_0_0	0	0	4	2	0	0	13	10	4	1	0	6	98%
	OTB_CRU_100-119_0_0	0	0	3	4	0	2	3	1	1	2	4	0	100%
	OTT_DEF_70-99_0_0	0	4	1	0	2	8	7	19	9	12	4	9	66%
	GNS_DEF_120-219_0_0	1	0	1	0	4	1	11	15	14	18	16	13	3%
	SDN_DEF_100-119_0_0	0	0	0	0	0	0	0	0	0	0	9	14	83%
	GNS_DEF_100-119_0_0	1	0	0	0	0	1	27	3	8	12	8	8	30%
	MIS_MIS_0_0_0	23	36	21	14	129	178	436	430	249	329	277	257	3%
	Total	**37**	**61**	**61**	**58**	**168**	**248**	**620**	**610**	**425**	**521**	**451**	**469**	
VIII a,b,d	OTT_DEF_>=70_0_0	2	1	13	10	24	10	18	31	10	21	35	29	78%
	OTB_DEF_>=70_0_0	6	3	16	9	11	9	33	43	49	31	38	33	25%
	OTT_CRU_>=70_0_0	38	40	41	29	25	20	33	37	26	23	26	23	78%
	GNS_DEF_>=100_0_0	1	3	7	19	60	95	66	65	57	60	66	61	3%
	OTB_CRU_>=70_0_0	8	3	9	1	1	1	3	9	8	5	11	11	54%
	SDN_DEF_>=70_0_0	0	0	0	0	0	0	0	0	0	0	0	0	25%
	GTR_DEF_>=100_0_0	8	10	10	20	163	218	138	143	75	86	65	91	1%
	MIS_MIS_0_0_0	17	27	25	51	223	196	233	167	137	187	174	177	2%
	Total	**80**	**87**	**121**	**139**	**507**	**549**	**524**	**495**	**362**	**413**	**415**	**425**	

Table 2: French number of trips sampled

Table 2 also shows that OTB_DEF_70-99 in subarea 7, OTT and OTB cru in subarea 8 were traditional sampled strata for Ifremer staff. In consequences these are the best information available for the period 2003-2008. During this period, the other demersal trawlers in both areas were also monitored, but at a minimum level. Some assumptions will need to be made in order to estimate discards (e.g. merging métier, areas and/or quarters).

Exploratory analysis

After the overview of sampling information available and the recommendations for potential mergers or non mergers, the exploratory analysis will focus on the variable of interest and the differences in discarding behaviors regarding megrim. The most disaggregated stratification, each year would consider 4 quarters, 10 metiers and 12 ICES sub-divisions, for a total of 360 strata. Considering 2 subareas still leads to 80 strata, which is far too many. There is no objective number of strata for estimation, but the lesser, the better.

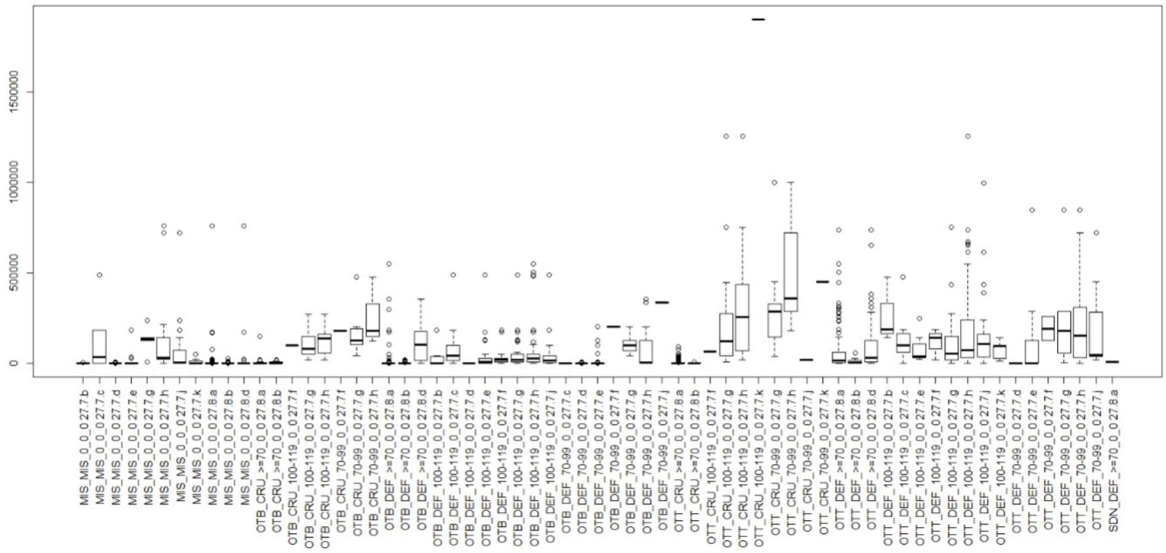
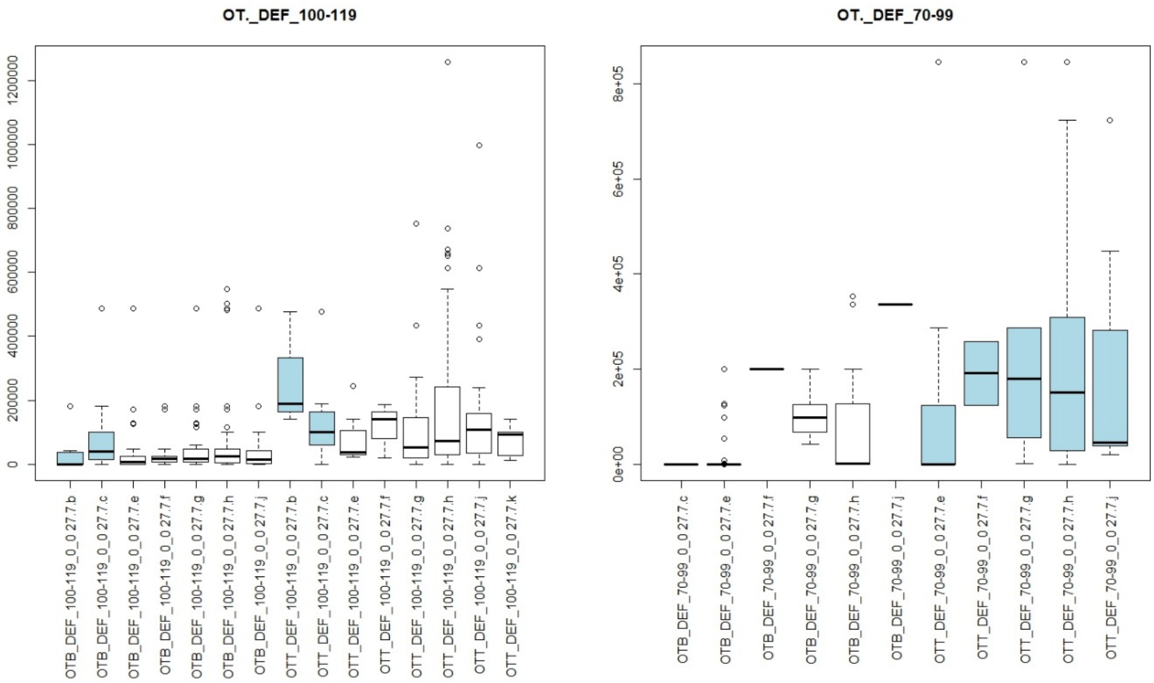


Figure 3 : Median and distribution of discarding per trips per métier * subdivisions

The COST tool allows the estimation of the discards estimates per trip (function landisVol), and this has been used to build a data frame with the estimates and the covariates time (year + quarter), space (ICES divisions) and technical (métier level 6). The search of patches in the discards estimates begins by those combination of space and technical with no or very few discards. These are MIS_MIS and SDN_DEF in all areas (given the number of samples, an estimation by subarea will be possible) and the area 7d.



Ifremer

Figure 4 : Median and distribution of discarding per trips per métier * subdivisions. Focus on demersal trawlers with mesh size ranged from 100 to 119 mm (left panel), and mesh size ranged from 70 to 99mm (right panel)

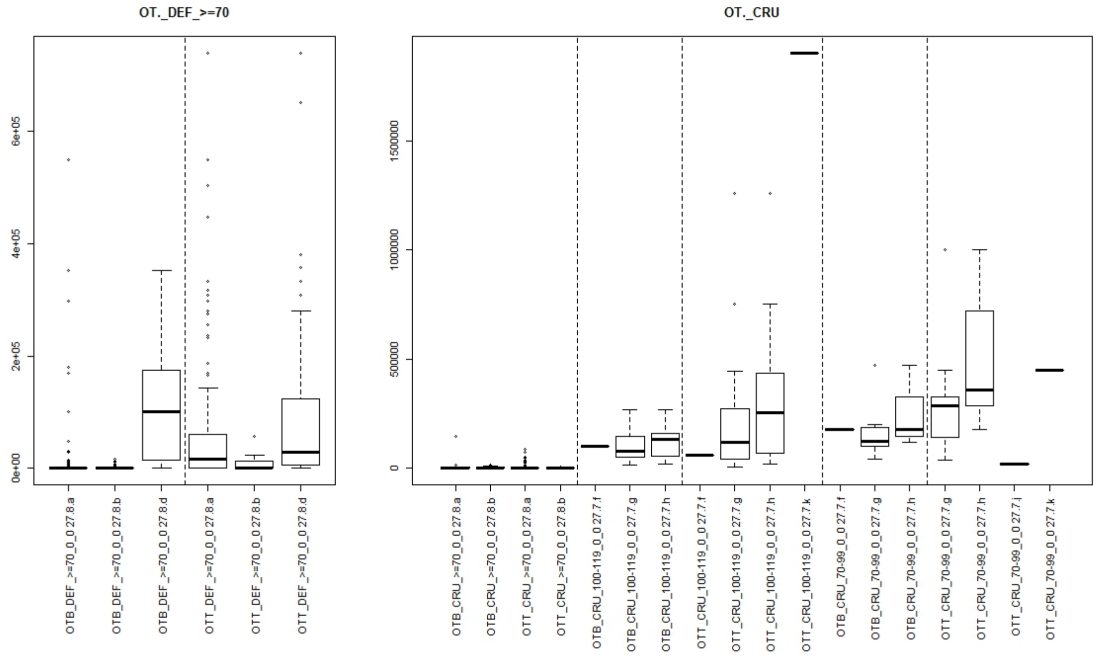


Figure 5 : Median and distribution of discarding per trips per métier * subdivisions. Focus on demersal trawlers with mesh size >=70mm in subarea 8 (left panel), and Nephrops trawlers (right panel)

A special consideration should be given to Subdivision 7ewhen raising by an effort variable, since trawling inshore is a major activity for France in this area, and they never catch megrim inshore. Including the effort of the large number of 7e trawlers would certainly lead to a bias. The safe option would be to use the raising as a ration of the megrim landings.

Ifremer

time	MIS_MIS_0_0_0	OTB_CRU_100-119_0_0	OTB_CRU_70-99_0_0	OTB_DEF_>=70_0_0	OTB_DEF_100-119_0_0	OTB_DEF_70-99_0_0	OTT_CRU_100-119_0_0	OTT_CRU_70-99_0_0	OTT_DEF_>=70_0_0	OTT_DEF_100-119_0_0	OTT_DEF_70-99_0_0	Otx_CRU_>=70_0_0
2003 - 1				1								1
2003 - 2												1
2003 - 3												1
2003 - 4	1											1
2004 - 1												1
2004 - 2												0.243
2004 - 3					0.197					0.276		0.118
2004 - 4								0.514	0.483	0.4	0.476	0.302
2005 - 1												0.679
2005 - 2		0.369		1								0.057
2005 - 3	0	0.385	0.932		0.136	0.957	0.928		0.051	0.389		0.223
2005 - 4	0.154		1	1	0.486		0.194		0.287	0.589	0.015	0.712
2006 - 1				0.419	0				0.226	0.095		0.796
2006 - 2		0.223			0.033				0.171			0.799
2006 - 3	1	0.438			0.245				0	0.138		0.582
2006 - 4	1				0.078		0.589			0.432		0.401
2007 - 1												0.889
2007 - 2									0.136			0.616
2007 - 3								0.267	0.779	0.401	0	0.622
2007 - 4				1		1		0.052	0.359	0.366		0
2008 - 1	0.063			0	0				0.779	0		0
2008 - 2		0.528								0.326		0.54
2008 - 3	0.276				0.553				0.467		0.609	0.237
2008 - 4	0.671							0.544	0.095	0.273	0.277	0
2009 - 1							0.794					0
2009 - 2	0.635	0.389		0.075		1	0.624	0.315	0.122	0.429	0.222	0.096
2009 - 3	0.182			1		0	0.408		0.827	0.17	0.261	0.164
2009 - 4	1			0.713	0.23		0.137		0.215	0.104	0.288	0.429
2010 - 1	0.12	0.173		0.003	0.107	0.105	0.295		0.228	0.152	0.293	0.986
2010 - 2	0.045		0.741		0.182	0	0.876	0.768	0.305	0.395	0.403	0.921
2010 - 3	0.313		0.561	1	0.398	0.776	0.2		0.203	0.352		0.862
2010 - 4	1		1	0.985	0.121	0.898	0.801	0.51	0.088	0.432	0.095	0.975
2011 - 1	0.913	0.634			0.13		0.265		0.597	0	0.148	1
2011 - 2				0.604	0.45	0				0.289	0.168	0.892
2011 - 3	0.983			0.936	0.336	0.227	0.18		0.073	0.52		0.718
2011 - 4				0.985	0.55	0.419		0.436	0.987	0.331		0.38
2012 - 1	0.376		0.538	0.61	0.803	0.439		0.891	0.24	0.233	0.624	0.813
2012 - 2	0.254				0.599	0	0		0.329	0.325	0.575	0.877
2012 - 3	0.125	0.286		0.486	0.504	0			0.411	0.445	0.46	0.708
2012 - 4	0				0.084	0.446			0.133	0.192		0.585
2013 - 1	0.311								0.316	0.214		0.992
2013 - 2	0.818	0.133		1	0.34				0.093	0.451		0.797
2013 - 3	0.814			0.958	0.676				0.076	0.555		0.928
2013 - 4	0.1			1	0.089				0.101	0.058		0.851
2014 - 1	0			1	0.216	0.711			0.01	0.036		0.949
2014 - 2				0.831	0.644	1	0.704	0.309	0.174	0.349	0.2	0.825
2014 - 3			0.331	0.32	0.208	0.286	0.073	0.036	0.107	0.505	0.102	0.915
2014 - 4				1	0.129	0			0.079	0.063		0.691
2015 - 1	0								0.046	0.039	0	0.766

Table 3 :Empirical discards rates by numbers (figures raised to the sampled trips). Cells in green = <40% discards, cells in red = >= 60% discards.

	27.7.b-k									27.8.abd					
	GNS_DEF_100-119_0_0	GNS_DEF_120-219_0_0	MIS_MIS_0_0_0	OTB_DEF_100-119_0_0	OTB_DEF_70-99_0_0	OTT_DEF_100-119_0_0	OTT_DEF_70-99_0_0	OTX_CRU_70-119_0_0	SDN_DEF_0_0_0	GNS_DEF_>=100_0_0	MIS_MIS_0_0_0	OTB_DEF_>=70_0_0	OTT_DEF_>=70_0_0	OTX_CRU_>=70_0_0	SDN_DEF_0_0_0
2004-1															
2004-2														0.107	
2004-3				0.064		0.101					0.546			0.044	
2004-4						0.139	0.168	0.170					0.195	0.062	
2005-1														0.108	
2005-2								0.133						0.015	
2005-3				0.056	0.708	0.104		0.733					0.013	0.043	
2005-4			0.045	0.193		0.235	0.003	0.613					0.111	0.090	
2006-1						0.028						0.128	0.094	0.202	
2006-2				0.019				0.051					0.056	0.198	
2006-3				0.061		0.028		0.139						0.261	
2006-4				0.018		0.134		0.266						0.156	
2007-1														0.317	
2007-2													0.019	0.337	
2007-3						0.106		0.053					0.206	0.264	
2007-4						0.124		0.017					0.044		
2008-1			0.015										0.099		
2008-2						0.107		0.246						0.307	
2008-3			0.080	0.272			0.275						0.169	0.126	
2008-4			0.222			0.103	0.075	0.202					0.027		
2009-1								0.608							
2009-2	0.265		0.414			0.197	0.048	0.253				0.002	0.045	0.093	
2009-3	0.468		0.054			0.098	0.108	0.141					0.406	0.025	
2009-4				0.119		0.026	0.208	0.036				0.473	0.107	0.182	
2010-1			0.081	0.030	0.055	0.069	0.153	0.047			0.093	0.001	0.052	0.526	
2010-2			0.024	0.124		0.215	0.137	0.497					0.065	0.307	
2010-3			0.178	0.187	0.686	0.107		0.120			0.358		0.049	0.491	
2010-4				0.047	0.840	0.170	0.095	0.203		0.293		0.868	0.065	0.860	
2011-1			0.047	0.018			0.048	0.094					0.403		
2011-2				0.105		0.124	0.068					0.268		0.578	0.819
2011-3			0.837	0.155	0.099	0.269		0.037				0.804	0.016	0.108	
2011-4				0.289	0.168	0.175		0.158				0.734	0.724	0.048	
2012-1			0.207	0.797	0.182	0.067	0.356	0.624				0.088	0.041	0.180	
2012-2			0.237	0.267		0.135	0.310						0.178	0.372	
2012-3	0.450	0.599	0.485	0.319		0.238	0.201	0.174			0.023	0.337	0.274	0.226	
2012-4				0.048	0.213	0.090							0.075	0.198	
2013-1			0.193			0.088			0.367	0.170			0.156	0.974	
2013-2			0.828	0.177		0.097		0.095	0.269				0.029	0.498	0.979
2013-3			0.504	0.462		0.254			0.262			0.465	0.027	0.369	
2013-4			0.051	0.038		0.027							0.039	0.500	0.356
2014-1				0.140	0.623	0.011							0.004	0.684	
2014-2			0.212	0.390		0.153	0.082	0.304	0.075			0.257	0.147	0.412	
2014-3				0.120	0.149	0.182	0.049	0.037	0.081	0.237		0.108	0.079	0.387	
2014-4				0.058		0.023							0.032	0.444	

Table 4 : Empirical discards rates by weight (figures raised to the sampled trips). Cells in green = <10% discards, cells in red = >40% discards.

Table 3 and 4 display a scattered coverage of the strata. The discards ratio estimates are derived from discards and landings estimated for the sampled trips without raising, so with minimal assumptions. It remains several metiers strata which cannot receivea quarterly stratification. Several time and/or technical stratification on subsets of the data can be tested, in order to define the optimal stratification based on the available information.

Ifremer

First stage conclusions

The objective of providing a time series of age distribution of the discards could not be attained before the deadline imposed. The reasons are an under-evaluation of the workload and a number of issues to deal with, which necessitates time, reflection and further coding.

None of the options of stratification taken for raising proved satisfactory, all of them lead to problematic un-sampled strata. Moreover, there may be a bias in the representativity of the samples as regards vessel length (figure 6) asking to be cautious about raising by effort.

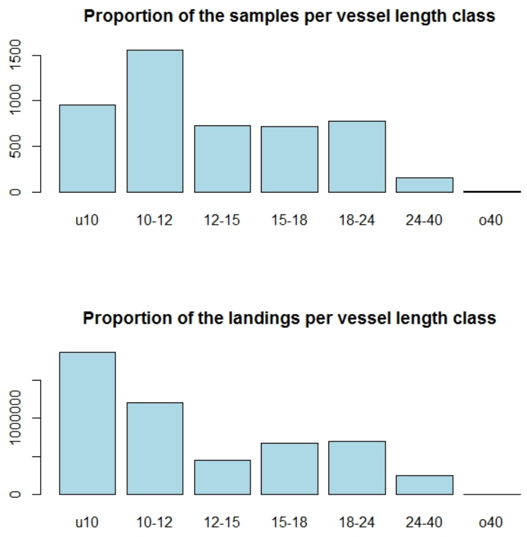


Figure 6 : Proportion of number of trips per vessel length class in the samples and in the landings

Eventually, two options have to be considered, i.e. (1) further grouping of métiers or (2) interpolation of the empirical discards ratios (table 4). The second option is unconventional but would have my preference, because the empirical discards ratios seem consistent and reliable (there is a need to filter out those figures derived from low sampling rates).

Proposing age structure of the discards for France will be possible, only when the gap filling exercise is done. Specific coding will have to be done to finalise the whole exercise, in consequence, the feedback from the IBPmegrim will be important in order to prepare this information for next year.

Second stage of estimation after WGCATCH

Feedback from WGCATCH on the estimation procedure was to regroup all métiers having a low contribution to the landings into one strata, and regroup at best the other strata in order to give a second chance to raising by effort.

Ifremer

Strata mapping

	GNS_DEF_>=100_0_0	GNS_DEF_100-119_0_0	GNS_DEF_120-219_0_0	GTR_DEF_>=100_0_0	MIS_MIS_0_0_0	SDN_DEF_0_0_0	OTB_DEF_>=70_0_0	OTT_DEF_>=70_0_0	OTB_DEF_100-119_0_0	OTT_DEF_100-119_0_0	OTB_DEF_70-99_0_0	OTT_DEF_70-99_0_0	OTX_CRU_>=70_0_0	OTX_CRU_70-119_0_0 S
2003 - 1				1			1						8	
2003 - 2				1	7						1		12	
2003 - 3				2	17		3	1			5		15	
2003 - 4	1	1	1	3	14			1			6		10	
2004 - 1				1									9	
2004 - 2				1	18		1				2		11	
2004 - 3	1			5	22		2		1	1	8		10	
2004 - 4	2			2	17			1		1	4	2	13	2
2005 - 1													10	
2005 - 2	3			4	14		5				2		18	1
2005 - 3				2	17		5	3	2	3	11		15	4
2005 - 4	4		1	4	12		4	6	1	2	6	1	7	2
2006 - 1							1	1	2	1	2		9	
2006 - 2	1				3		3	1	1		5		8	1
2006 - 3				17	30		4	3	4	1	4		9	1
2006 - 4	18			3	19		1	3	3	1	2		4	1
2007 - 1	14		2	28	56		1	1			1		9	
2007 - 2	6		2	44	76			1			5	1	5	
2007 - 3	8			52	96		1	8		1	12	1	8	1
2007 - 4	32			39	83		8	9		3	8		3	1
2008 - 1	31			55	55		1	2	1	1	1		5	
2008 - 2	12		1	48	77					1	9		4	1
2008 - 3	24			67	96		5	2	2		7	2	7	
2008 - 4	25	1		43	116		3	4	1	2	27	4	5	1
2009 - 1	31		1	71	124						21		3	1
2009 - 2	27	6	2	52	189		11	5	2	6	25	2	16	6
2009 - 3	4	14	7	8	195		11	1	2	3	20	3	10	4
2009 - 4	3	1	1	6	127		6	6	5	2	23	1	6	1
2010 - 1	29		4	34	139		2	5	1	3	24	2	10	2
2010 - 2	10	1	3	39	167		5	6	1	6	19	6	13	4
2010 - 3	6		4	32	168		23	6	5	9	26	1	14	4
2010 - 4	19	2	3	33	104		10	7	4	7	9	3	8	6
2011 - 1	15		3	28	82		7	2	1	1	8	2	6	2
2011 - 2	13	2	1	16	81	1	9	2	2	3	25	4	12	
2011 - 3	13	1	1	18	106		19	3	3	4	31	2	9	1
2011 - 4	16	5	9	11	101	7	10	1	9	1	24		6	1
2012 - 1	20	5	7	26	119	4	8	4	1	5	28	2	4	2
2012 - 2	13	3	5	20	135	3	1	4	2	6	21	3	7	1
2012 - 3	12	3	2	21	159	7	15	3	1	5	30	5	11	1
2012 - 4	15	1	4	18	92	7	5	7	2	6	12		6	
2013 - 1	17	1	3	17	85	4	4	8		6	14		6	
2013 - 2	16	3	4	20	107	4	10	4	1	4	24	2	12	2
2013 - 3	14	3	4	15	158	5	16	7	3	6	41	2	12	
2013 - 4	19	1	5	13	85	5	4	7	2	2	11		5	
2014 - 1	9		2	12	59	1	4	3	2	3	20		4	
2014 - 2	8	3	3	17	108	6	10	4	1	4	30	2	13	3
2014 - 3	22	3	4	42	170	4	10	9	6	8	44	3	9	3
2014 - 4	22	2	4	20	85	7	7	5	6	3	18		5	

Table 5 : Number of sampled trips available

	GNS_DEF_>=100_0_0	GNS_DEF_100-119_0_0	GNS_DEF_120-219_0_0	GTR_DEF_>=100_0_0	MIS_MIS_0_0_0	SDN_DEF_0_0_0	OTB_DEF_>=70_0_0	OTT_DEF_>=70_0_0	OTB_DEF_100-119_0_0	OTT_DEF_100-119_0_0	OTB_DEF_70-99_0_0	OTT_DEF_70-99_0_0	OTX_CRU_70_0_0	OTX_CRU_70-119_0_0
2003 - 1													2	
2003 - 2													7	
2003 - 3													5	
2003 - 4				1	1								4	
2004 - 1													2	
2004 - 2													5	
2004 - 3					1				1	1			3	
2004 - 4								1		1		2	3	2
2005 - 1													3	
2005 - 2				1			2						3	1
2005 - 3								2	1	2	1		6	4
2005 - 4					1		1	2	1	2		1	3	2
2006 - 1							1	1		1			5	
2006 - 2								1	1				7	1
2006 - 3					1				3	1			7	1
2006 - 4					1				2	1			2	1
2007 - 1													2	
2007 - 2								1					4	
2007 - 3								7		1			5	1
2007 - 4							4	6		2	1			1
2008 - 1					1			1					1	
2008 - 2					1					1			2	1
2008 - 3	1				1			2	2			2	2	
2008 - 4					4			2		1		4		1
2009 - 1														1
2009 - 2		1			2		1	2		5	1	2	5	6
2009 - 3		6			5		2	1		3	2	1	3	3
2009 - 4					1		1	2	5	2	1	1	1	1
2010 - 1					1		1	5	1	3	2	2	6	2
2010 - 2					2			3	1	6		4	10	4
2010 - 3					2		2	5	3	9	1		9	4
2010 - 4	1	1			2		4	3	1	5	1	3	3	5
2011 - 1					5			1	1			1	1	2
2011 - 2						1	2		1	3		1	7	
2011 - 3					2		5	2	2	3	1		2	1
2011 - 4		2					2	1	5	1	3		5	1
2012 - 1	2				3		2	2	1	4	3	2	2	2
2012 - 2					1			3	2	5		1	5	
2012 - 3		1	1		3		2	2	1	5		1	4	1
2012 - 4								4	1	6	1		2	
2013 - 1	3				1	2		6		6			2	
2013 - 2					2	3	2	2	1	3			10	2
2013 - 3			1		3	3	9	4	2	6			4	
2013 - 4					2	3	2	7	2	2			5	
2014 - 1							1	2	2	2	1		1	
2014 - 2					2	1	3	4	1	4	1	1	9	3
2014 - 3	1					2	2	8	2	7	2	1	8	3
2014 - 4					1		1	3	5	2			3	

Table 6 : Number of sampled trips available with presence of megrim in the catches

Low contributors

Were considered as low contributors all métiers contributing to less than 4% of the landings in table 1. These were all merged into a métier named MIS_MIS_0_0_0. Yearly stratification was chosen

Ifremer

because of the low discarding volume expected. Table 5 details the results by the 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). The values given by estimators based on effort are deemed over estimated due to the very high number of vessels and effort by this fleet component, emphasizing the estimates to improbable values for certain years. The estimation based on the ratio to the landings was preferred.

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004	27.7.b-k	MIS_MIS_0_0_0	-	-	-	-
2005	27.7.b-k	MIS_MIS_0_0_0	**1 246**	578 418	2 240 492	212 176
2008	27.7.b-k	MIS_MIS_0_0_0	**2 116**	96 830	222 406	8 980
2009	27.7.b-k	MIS_MIS_0_0_0	**3 593**	175 127	363 922	10 264
2010	27.7.b-k	MIS_MIS_0_0_0	**3 076**	200 355	370 265	7 612
2011	27.7.b-k	MIS_MIS_0_0_0	**3 745**	12 565	26 208	929
2012	27.7.b-k	MIS_MIS_0_0_0	**1 904**	81 682	183 586	4 105
2013	27.7.b-k	MIS_MIS_0_0_0	**7 113**	347 409	981 056	19 216
2014	27.7.b-k	MIS_MIS_0_0_0	**596**	12 813	30 805	796
2004	27.8.abd	MIS_MIS_0_0_0	**26 452**	2 723	6 400	106
2005	27.8.abd	MIS_MIS_0_0_0	**2 076**	1 063	2 649	112
2008	27.8.abd	MIS_MIS_0_0_0	**18**	237	970	66
2009	27.8.abd	MIS_MIS_0_0_0	**4 169**	72	179	10
2010	27.8.abd	MIS_MIS_0_0_0	**8 903**	75 684	147 791	8 241
2011	27.8.abd	MIS_MIS_0_0_0	**42 574**	52 534	68 782	4 556
2012	27.8.abd	MIS_MIS_0_0_0	**421**	7 839	12 612	1 086
2013	27.8.abd	MIS_MIS_0_0_0	**6 085**	9 278	14 758	988
2014	27.8.abd	MIS_MIS_0_0_0	**2 351**	83	171	7

Table 7 : discards estimation of low contributors from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

All other strata

For all other strata contributing substantially to the discards, estimation based on effort was preferred, and the one based on the ratio to the fishing days was chosen as consistent with the estimator taken for reporting to the French industry by the French at-sea observation programme. Tables 8 to 14 detail the values obtained for each estimator.

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004	27.7.b-k	OTX_CRU_70-119_0_0	116 388	**246 894**	977 116	273 749
2005	27.7.b-k	OTX_CRU_70-119_0_0	888 679	**558 370**	2 236 930	443 338
2006	27.7.b-k	OTX_CRU_70-119_0_0	98 879	**76 226**	270 174	71 621
2007	27.7.b-k	OTX_CRU_70-119_0_0	9 424	**28 727**	139 780	29 861
2008	27.7.b-k	OTX_CRU_70-119_0_0	58 356	**67 655**	350 618	50 261
2012	27.7.b-k	OTX_CRU_70-119_0_0	49 664	**90 766**	227 568	43 367
2013	27.7.b-k	OTX_CRU_70-119_0_0	22 871	**17 749**	65 369	10 105
2009 - 1	27.7.b-k	OTX_CRU_70-119_0_0	96 129	**169 687**	545 117	114 435
2009 - 2	27.7.b-k	OTX_CRU_70-119_0_0	17 447	**26 660**	106 430	15 661
2010 - 1	27.7.b-k	OTX_CRU_70-119_0_0	48 585	**47 920**	148 874	37 930
2010 - 2	27.7.b-k	OTX_CRU_70-119_0_0	31 692	**57 150**	214 099	43 044
2011 - 1	27.7.b-k	OTX_CRU_70-119_0_0	11 865	**17 266**	59 508	12 112
2011 - 2	27.7.b-k	OTX_CRU_70-119_0_0	7 746	**17 029**	115 043	10 442
2014 - 1	27.7.b-k	OTX_CRU_70-119_0_0	15 162	**31 032**	117 591	16 037
2014 - 2	27.7.b-k	OTX_CRU_70-119_0_0	1 752	**2 502**	6 927	1 198

Ifremer

Table 8 : discards estimation of (OTB+OTT)_CRU_70-119_0_0 in ICES divisions 7b-k from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004	27.7.b-k	OTX_DEF_100-119_0_0	83 029	**246 452**	1 428 773	156 725
2005	27.7.b-k	OTX_DEF_100-119_0_0	66 200	**97 481**	431 649	74 612
2006	27.7.b-k	OTX_DEF_100-119_0_0	76 605	**178 971**	682 637	157 865
2007	27.7.b-k	OTX_DEF_100-119_0_0	91 563	**135 419**	539 417	95 171
2008	27.7.b-k	OTX_DEF_100-119_0_0	42 920	**53 926**	237 019	38 208
2009 - 1	27.7.b-k	OTX_DEF_100-119_0_0	63 134	**106 187**	503 875	73 476
2009 - 2	27.7.b-k	OTX_DEF_100-119_0_0	29 593	**29 356**	123 928	23 132
2010 - 1	27.7.b-k	OTX_DEF_100-119_0_0	95 599	**169 712**	598 663	114 071
2010 - 2	27.7.b-k	OTX_DEF_100-119_0_0	67 556	**120 834**	460 851	81 333
2011 - 1	27.7.b-k	OTX_DEF_100-119_0_0	64 185	**87 800**	353 899	52 842
2011 - 2	27.7.b-k	OTX_DEF_100-119_0_0	147 563	**131 191**	510 659	85 621
2012 - 1	27.7.b-k	OTX_DEF_100-119_0_0	51 849	**63 365**	226 284	37 255
2012 - 2	27.7.b-k	OTX_DEF_100-119_0_0	65 135	**67 653**	335 618	40 164
2013 - 1	27.7.b-k	OTX_DEF_100-119_0_0	41 058	**46 157**	158 702	25 272
2013 - 2	27.7.b-k	OTX_DEF_100-119_0_0	140 555	**178 239**	648 407	96 293
2014 - 1	27.7.b-k	OTX_DEF_100-119_0_0	38 470	**54 537**	231 330	30 493
2014 - 2	27.7.b-k	OTX_DEF_100-119_0_0	62 383	**97 279**	450 776	55 016

Table 9 : discards estimation of (OTB+OTT)_DEF_100-119_0_0 in ICES divisions 7b-k from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004	27.7.b-k	OTX_DEF_70-99_0_0	198 820	**448 165**	1 996 926	341 353
2005	27.7.b-k	OTX_DEF_70-99_0_0	36 793	**23 729**	87 624	17 091
2006	27.7.b-k	OTX_DEF_70-99_0_0	45 122	**37 969**	151 232	27 225
2007	27.7.b-k	OTX_DEF_70-99_0_0	-	-	-	-
2008	27.7.b-k	OTX_DEF_70-99_0_0	110 034	**77 108**	169 277	44 722
2009 - 1	27.7.b-k	OTX_DEF_70-99_0_0	24 510	**87 624**	178 967	66 939
2009 - 2	27.7.b-k	OTX_DEF_70-99_0_0	49 692	**77 161**	207 117	33 870
2010 - 1	27.7.b-k	OTX_DEF_70-99_0_0	97 448	**235 887**	656 283	161 949
2010 - 2	27.7.b-k	OTX_DEF_70-99_0_0	110 553	**107 399**	450 840	68 246
2011 - 1	27.7.b-k	OTX_DEF_70-99_0_0	33 104	**50 015**	123 095	33 247
2011 - 2	27.7.b-k	OTX_DEF_70-99_0_0	79 079	**74 416**	242 606	49 790
2012 - 1	27.7.b-k	OTX_DEF_70-99_0_0	204 449	**139 684**	330 241	95 480
2012 - 2	27.7.b-k	OTX_DEF_70-99_0_0	272 690	**259 283**	638 452	137 576
2013 - 1	27.7.b-k	OTX_DEF_70-99_0_0	274 759	**75 815**	134 073	61 762
2013 - 2	27.7.b-k	OTX_DEF_70-99_0_0	471 196	**152 291**	342 064	108 143
2014 - 1	27.7.b-k	OTX_DEF_70-99_0_0	167 666	**228 595**	653 544	142 530
2014 - 2	27.7.b-k	OTX_DEF_70-99_0_0	56 940	**36 222**	89 691	20 099

Table 10 : discards estimation of (OTB+OTT)_DEF_70-99_0_0 in ICES divisions 7b-k from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

Ifremer

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004 - 1	27.8.abd	OTX_CRU_>=70_0_0	10 169	**10 161**	9 852	6 752
2004 - 2	27.8.abd	OTX_CRU_>=70_0_0	8 448	**2 812**	2 497	1 924
2005 - 1	27.8.abd	OTX_CRU_>=70_0_0	3 778	**2 829**	2 990	2 174
2005 - 2	27.8.abd	OTX_CRU_>=70_0_0	6 747	**5 236**	4 636	4 100
2006 - 1	27.8.abd	OTX_CRU_>=70_0_0	13 469	**15 878**	13 588	19 427
2006 - 2	27.8.abd	OTX_CRU_>=70_0_0	30 149	**47 894**	44 374	62 375
2007 - 1	27.8.abd	OTX_CRU_>=70_0_0	27 726	**42 101**	41 955	68 864
2007 - 2	27.8.abd	OTX_CRU_>=70_0_0	24 866	**14 476**	16 511	15 242
2008 - 1	27.8.abd	OTX_CRU_>=70_0_0	24 119	**8 677**	7 149	9 479
2008 - 2	27.8.abd	OTX_CRU_>=70_0_0	10 893	**11 768**	8 855	12 848
2009 - 1	27.8.abd	OTX_CRU_>=70_0_0	5 255	**5 730**	8 581	4 230
2009 - 2	27.8.abd	OTX_CRU_>=70_0_0	2 616	**1 488**	1 995	1 022
2010 - 1	27.8.abd	OTX_CRU_>=70_0_0	12 735	**13 074**	15 420	10 089
2010 - 2	27.8.abd	OTX_CRU_>=70_0_0	52 440	**30 230**	40 126	22 757
2011 - 1	27.8.abd	OTX_CRU_>=70_0_0	70 096	**90 301**	119 534	61 666
2011 - 2	27.8.abd	OTX_CRU_>=70_0_0	4 805	**4 277**	5 335	3 278
2012 - 1	27.8.abd	OTX_CRU_>=70_0_0	27 071	**53 489**	56 915	30 040
2012 - 2	27.8.abd	OTX_CRU_>=70_0_0	9 387	**10 865**	14 252	7 250
2013 - 1	27.8.abd	OTX_CRU_>=70_0_0	25 186	**58 646**	76 121	28 121
2013 - 2	27.8.abd	OTX_CRU_>=70_0_0	45 201	**71 023**	83 369	46 626
2014 - 1	27.8.abd	OTX_CRU_>=70_0_0	65 760	**38 343**	46 507	27 303
2014 - 2	27.8.abd	OTX_CRU_>=70_0_0	92 770	**88 636**	140 770	49 826

Table 11 : discards estimation of (OTB+OTT)_CRU_>=70_0_0 in ICES divisions 8abd from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

time	space	technical	estim.lnd	estim.day	estim.trip	estim.time
2004	27.8.abd	OTX_DEF_>=70_0_0	97 163	**22 518**	34 649	39 846
2005	27.8.abd	OTX_DEF_>=70_0_0	11 931	**5 987**	10 130	5 179
2006	27.8.abd	OTX_DEF_>=70_0_0	32 326	**25 305**	74 006	18 239
2007	27.8.abd	OTX_DEF_>=70_0_0	53 590	**109 158**	303 194	85 104
2008	27.8.abd	OTX_DEF_>=70_0_0	59 000	**107 439**	245 061	83 374
2009 - 1	27.8.abd	OTX_DEF_>=70_0_0	13 334	**4 461**	7 388	3 838
2009 - 2	27.8.abd	OTX_DEF_>=70_0_0	51 433	**157 883**	276 302	97 656
2010 - 1	27.8.abd	OTX_DEF_>=70_0_0	31 049	**78 445**	223 071	46 688
2010 - 2	27.8.abd	OTX_DEF_>=70_0_0	16 694	**64 671**	135 230	40 606
2011 - 1	27.8.abd	OTX_DEF_>=70_0_0	130 661	**63 512**	84 191	32 750
2011 - 2	27.8.abd	OTX_DEF_>=70_0_0	90 055	**264 637**	199 836	104 714
2012 - 1	27.8.abd	OTX_DEF_>=70_0_0	54 039	**51 344**	79 430	43 650
2012 - 2	27.8.abd	OTX_DEF_>=70_0_0	42 620	**56 757**	130 623	31 893
2013 - 1	27.8.abd	OTX_DEF_>=70_0_0	51 379	**81 980**	173 198	47 249
2013 - 2	27.8.abd	OTX_DEF_>=70_0_0	11 829	**53 388**	119 203	26 363
2014 - 1	27.8.abd	OTX_DEF_>=70_0_0	27 292	**106 134**	225 600	51 615
2014 - 2	27.8.abd	OTX_DEF_>=70_0_0	15 313	**109 076**	306 017	47 857

Table 12 : discards estimation of (OTB+OTT)_DEF_>=70_0_0 in ICES divisions 8abd from 4 estimators (ratio to landings, ratio to fishing days, raised to total number of trips, ratio to hours fishing). In bold the estimation chosen.

The estimation raised by fishing days seems extremely consistent compared to the three other estimators, regularly positioned in the middle of the other estimations. The absence of extremum or outlier values as shown in figure 7 validate the approach taken.

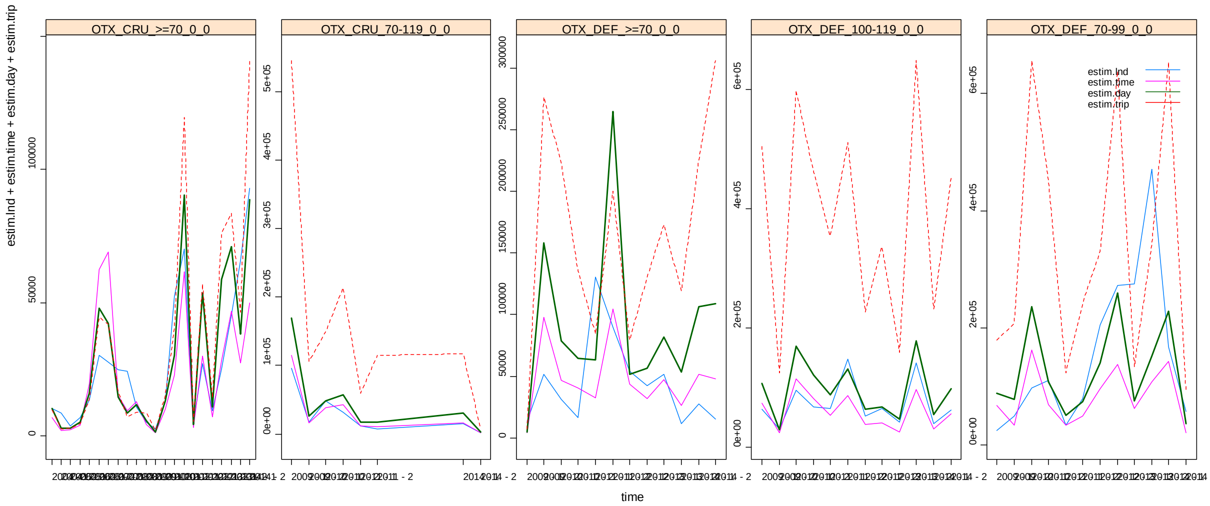


Figure 7 : discards Estimates using four estimators. The chosen estimator raised by fishing day is in displayed in black.

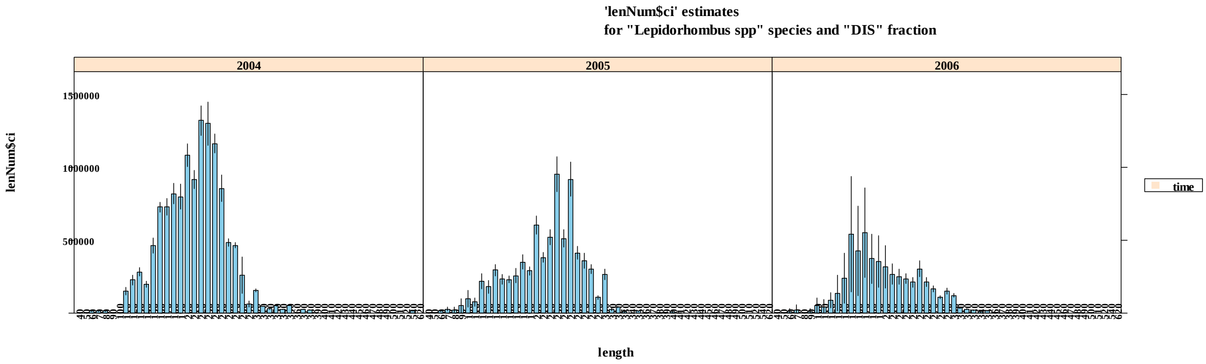
	Q1	Q2	Q3	Q4
2003	305	166	234	250
2004	147	250	214	570
2005	-	-	-	15
2006	58	-	-	423
2007	-	-	-	403
2008	249	262	88	524
2009	184	348	215	180
2010	146	370	233	110
2011	293	450	254	460
2012	176	506	126	470
2013	233	453	226	620
2014	179	156	94	352

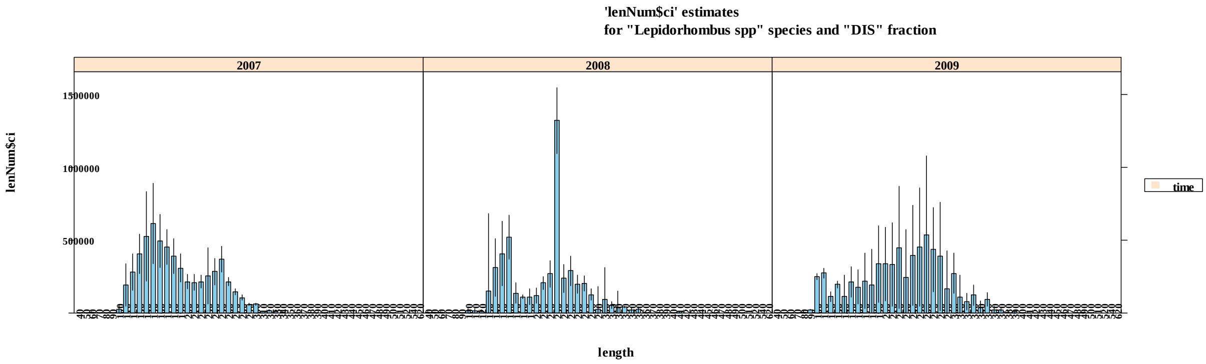
Table 15 : number of age samples available

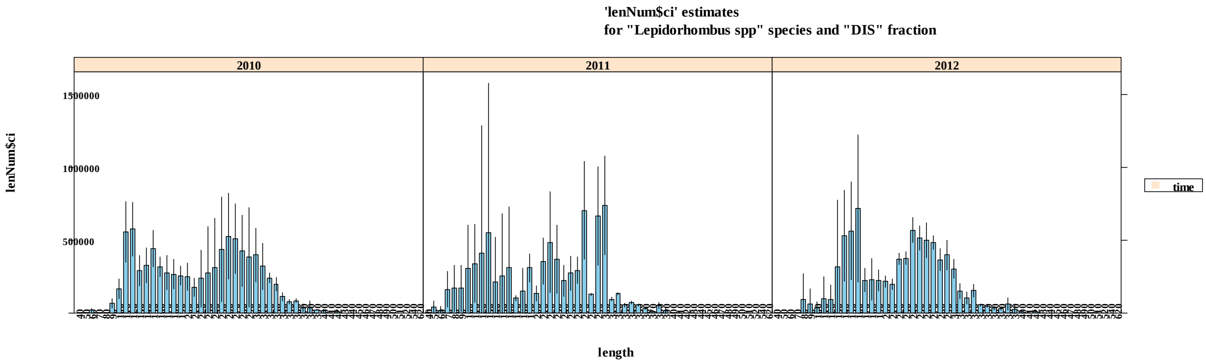
Number of otoliths interpreted for ages are presented table 15. The values are combined for ICES areas 7 and 8, and present sufficient information on a semester time frame for years 2003, 2004 and 2008 onward. One issue is the year 2005 where only 15 otoliths are available in quarter 4, and years 2006 and 2007 where Q4 are sufficiently sampled but not the other quarters.

Gap filling technique using linear interpolation based on moving average was used, without creating new values where age information at length was available. A paper is being prepared to explain the approach which is going to be generalized in France in order to unlock the data transmission issues.

The problem here concerns the year 2005 and semester 1 of year 2006 and 2007 where no or seldom information was available. The gap filling techniques proposed a solution, but may not be suitable at this level of gaps. This is a case to address by the IBPmegrim group at this stage.







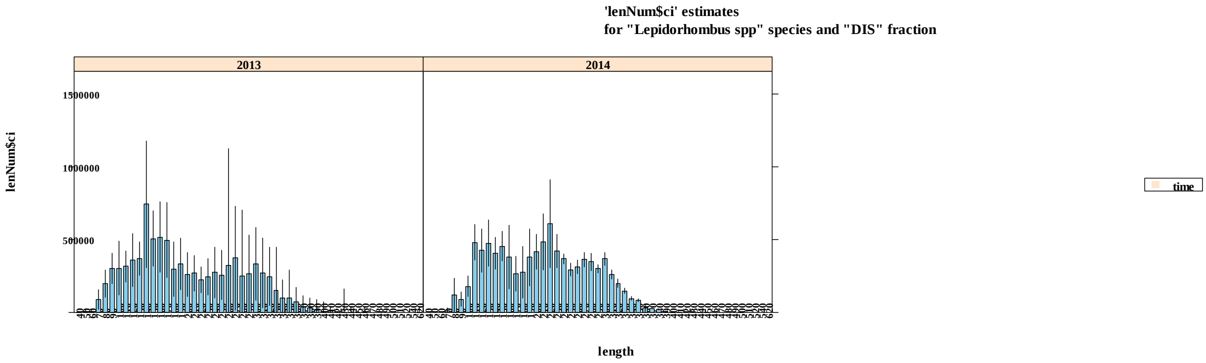
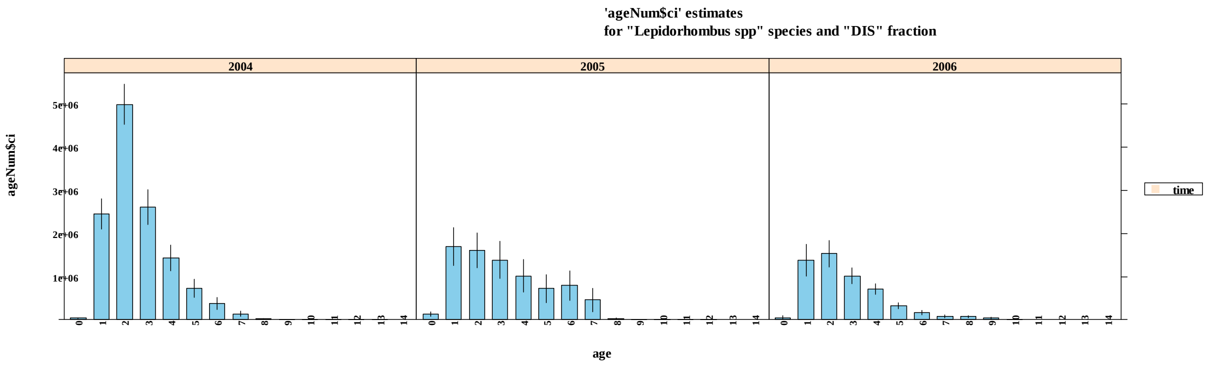
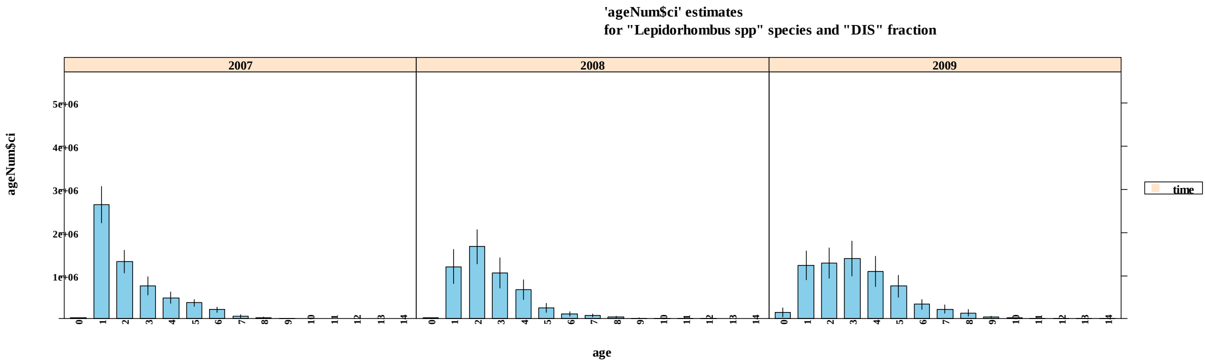
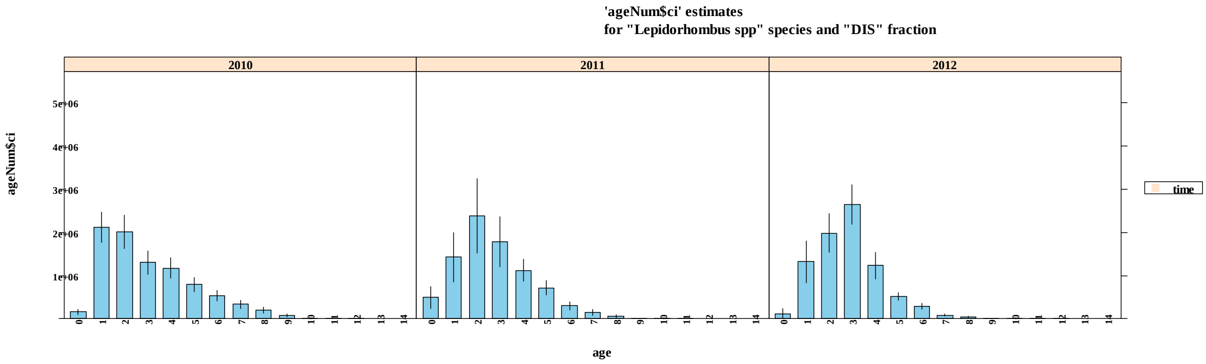


Figure 8 : length distribution of French megrim discards per year







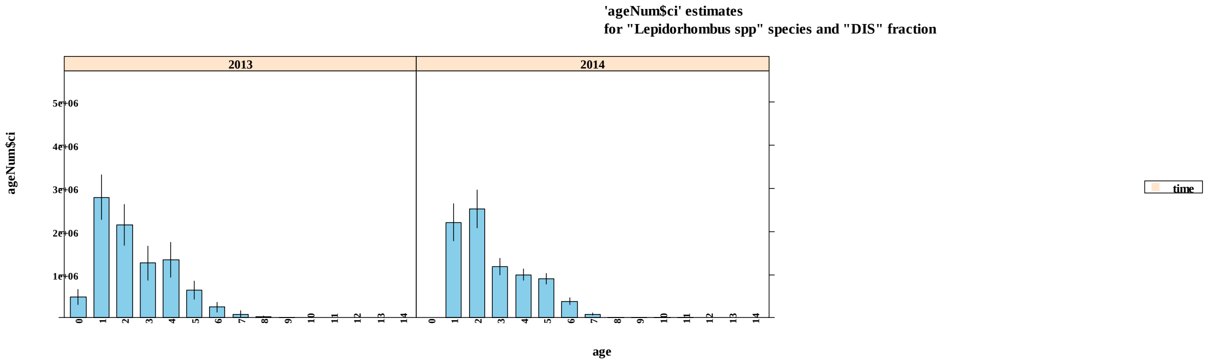


Figure 9 : age distribution of French megrim discards per year

Ifremer

Overall conclusions

The current work on estimating the French time series of discards of megrim in areas 7 and 8 was based on a thorough analysis of the empirical data. The objectives were to post-stratify the data in a way consistent with the discarding patterns in the fisheries, consistent throughout the years, and with sufficient samples in each strata to infer statistical estimates. The results in discards volume and length frequencies are quite robust and replicable in future years. The volume (in tons) of discards by métiers, area and year is given in the table 16 below.

Area	Metiers	2 004	2 005	2 006	2 007	2 008	2 009	2 010	2 011	2 012	2 013	2 014
27.7.b-k	MIS_MIS_0_0_0	-	1.2			2.1	3.6	3.1	3.7	1.9	7.1	0.6
	OTX_CRU_70-119_0_0	246.9	558.4	76.2	28.7	67.7	196.3	105.1	34.3	90.8	17.7	33.5
	OTX_DEF_100-119_0_0	246.5	97.5	179.0	135.4	53.9	135.5	290.5	219.0	131.0	224.4	151.8
	OTX_DEF_70-99_0_0	448.2	23.7	38.0	-	77.1	164.8	343.3	124.4	399.0	228.1	264.8
Total 27.7.b-k		**941.5**	**680.8**	**293.2**	**164.1**	**200.8**	**500.3**	**742.0**	**381.5**	**622.7**	**477.4**	**450.8**
27.8.abd	MIS_MIS_0_0_0	26.5	2.1			0.0	4.2	8.9	42.6	0.4	6.1	2.4
	OTX_CRU_>=70_0_0	13.0	8.1	63.8	56.6	20.4	7.2	43.3	94.6	64.4	129.7	127.0
	OTX_DEF_>=70_0_0	22.5	6.0	25.3	109.2	107.4	162.3	143.1	328.1	108.1	135.4	215.2
Total 27.8.abd		**61.9**	**16.1**	**89.1**	**165.7**	**127.9**	**173.7**	**195.3**	**465.3**	**172.9**	**271.1**	**344.5**
Total		**1 003.5**	**697.0**	**382.2**	**329.9**	**328.7**	**674.0**	**937.3**	**846.8**	**795.5**	**748.5**	**795.3**

Table 16 : Megrim 7-8 - Volume of discards in tons from 2004 to 2014 by métiers.

The more difficult phase was the estimation of age structures, since age information was extremely variable from year to year. For example, in 2005 only 15 otoliths of megrim were collected and read (table 15), which is far too few to derive estimates. Scarce age-length data availability in years 2005-07 was overcome interpolating years 2004-08. The gap filling techniques proposed a solution, but may not be suitable at this level of gaps. The interpolation approach is accepted now and IBP group recommend further inter-sessional work to estimate these ages exploring alternatives such as Spanish age data or through a growth model. The discards number at age per year as used in the assessment model is presented in table 17 below.

Year / age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2004	37	2 455	4 992	2 614	1 437	724	381	136	17	5	9	3	1	1	
2005	135	1 700	1 607	1 389	1 019	720	794	460	22	2	1	0	0		
2006	50	1 386	1 534	1 019	714	316	168	75	70	36	1				
2007	17	2 648	1 325	764	490	372	211	66	19	4					
2008	17	1 210	1 676	1 061	682	247	118	79	37	10	1	0	0		
2009	147	1 237	1 292	1 402	1 096	757	333	224	137	37	20	5	1	1	0
2010	158	2 120	2 006	1 306	1 177	794	530	336	198	73	13	4	0		
2011	495	1 428	2 387	1 784	1 120	716	298	145	56	9	0	0			
2012	107	1 324	1 985	2 651	1 231	522	293	82	50	7	1	0	0		
2013	480	2 792	2 160	1 267	1 344	638	246	75	17	1					
2014	-	2 211	2 522	1 182	997	906	383	82	6	1	0	0			

Table 17 : Megrim 7-8 – Yearly age structure of French discards (number in 000’s)

WD 2

Working Document to ICES IBP Megrim 2016

Analysis of applying Mortality at age in the assessment of Megrim (*Lepidorhombus whiffiagonis*) in Divisions 7.b-k and 8.a, 8.b, and 8.d

Leire Ibaibarriaga* and Ane Iriondo[1]
[1] AZTI-Tecnalia; Marine Research Division; Txatxarramendi irla z/g;
48395 Sukarrieta; Bizkaia, Spain.
Email: libaibarriaga@azti.es; airiondo@azti.es

1. Introduction

In previous assessments natural mortality (M) of megrim was assumed to be equal to 0.2 (per year) invariant across ages and years. The Interbenchmark Megrim (IBP Megrim) 2016 aimed at compiling historic discard data and including them in the stock assessment. There was no specific ToR regarding natural mortality and no new information was available. Therefore, the value of M=0.2 was used for the stock assessments and projections conducted during IBP megrim (see main report).

However, one of the reviewers proposed to use a natural mortality at age (M@age) considering that it could be biologically more meaningful than having a unique M value across ages. Following this suggestion during the IBP Megrim different estimates of M, both constant across ages and varying with age, were obtained using empirical methods. Then, the sensitivity of the assessment results to the M assumptions was evaluated. This annex presents a summary of this work.

2. Estimates of natural mortality

There are many empirical methods that try to derive natural mortality estimates from growth parameters, life-history traits or other measurable indices. See for instance the review provided by Kenchington (2014) or Then *et al.* (2015). Several of these methods are implemented in the function metaM() in the library FSA (Ogle, 2015) in R (R Core Team, 2015).

Table 1 lists these methods and indicates the type of data needed such as the parameters from the von Bertalanffy growth equation, maximum age and/or temperature. The reference of the source and the empirical equation are also given. The methods attempted for megrim that estimate a unique M value are colored in pink and the methods estimating a vector of M at age are highlighted in blue. Besides the methods in the FSA library, the empirical equations from Lorenzen (1996) and the posterior modification by Cook (2013) were also implemented in R and applied to megrim.

Table 1. List of methods available in the function metaM() in the R library FSA and additional methods implemented for megrim.

Method	Parameters needed									Reference	Equation
	tmax	K	Linf	t0	b	L	T	t50	Winf		
"tmax1"	X									First line of Table 3 in Then et al (2015)	5.109/tmax }
"PaulyLNot"		X	X							Sixth line of Table 3 in Then et al (2015)	4.118*(K^(0.73))*(Linf^(-0.33))
"PaulyL"		X	X				X			Pauly (1980)	10^(-0.0066-0.279*log10(Linf)+0.6543*log10(K)+0.4634*log10(T))
"PaulyW"		X					X		X	Pauly (1980)	10^(-0.2107-0.0824*log10(Winf)+0.6757*log10(K)+0.4627*log10(T))
"HoenigO"	X									Hoenig (1983) fit with OLS composite	exp(1.44-0.982*log(tmax))
"HoenigOF"	X									Hoenig (1983) fit with OLS fish	exp(1.46-1.01*log(tmax))
"HoenigOM"	X									Hoenig (1983) fit with OLS mollusc	exp(1.23-0.832*log(tmax))
"HoenigOC"	X									Hoenig (1983) fit with OLS cetacean	exp(0.941-0.873*log(tmax))
"HoenigO2"	X									Hoenig (1983) fit with GM composite	5.52*tmax^(-1.08)
"HoenigO2F"	X									Hoenig (1983) fit with GM fish	6.99*tmax^(-1.22)
"HoenigO2M"	X									Hoenig (1983) fit with GM mollusc	4.49*tmax^(-0.94)
"HoenigO2C"	X									Hoenig (1983) fit with GM cetacean	5.20*tmax^(-1.04)
"HoenigLM"	X									Modified Hoenig with LM from Then et al (2015)	exp(1.717-1.01*log(tmax))
"HoenigNLS"	X									Modified Hoenig with non-linear from Then et al (2015)	4.899*tmax^(-0.916)
"HewittHoenig"	X									Hewitt and Hoenig (2005) equation 8	4.22/tmax
"K1"		X								fourth line of Table 3 in Then et al (2015)	1.692*K
"K2"		X								fifth line of Table 3 in Then et al (2015)	0.098+1.55*K
"JensenK1"		X								Jensen (1996)	1.5*K
"JensenK2"		X								Jensen (2001)	0.21+1.47*K
"Gislason"		X	X			X				Gislason et al. (2010)	exp(0.55-1.61*log(L)+1.44*log(Linf)+log(K))
"AlversonCarney"	X	X								Alverson and Carney (1975); Zhang and Megrey (2006)	(3*K)/(exp(K*(0.38*tmax))-1)
"Charnov"		X	X			X				Charnov et al (2013); Kenchington (2014)	K*((Linf/L)^1.5)
"ZhangMegreyD"	X	X		X	X			X		Zhang and Megrey (2006) for demersal fish	(b*K)/(exp(K*(Ci*tmax-t0))-1)
"ZhangMegreyP"	X	X		X	X			X		Zhang and Megrey (2006) for pelagic fish	(b*K)/(exp(K*(Ci*tmax-t0))-1)
"RikhterEfanov1"								X		Rikhter and Efanov (1976); Kenchington (2014)	(1.521/(t50^0.720))-0.155
"RikhterEfanov2"		X		X	X			X		Rikhter and Efanov (1976); Kenchington (2014)	(b*K)/(exp(K*(t50-t0))-1)

OTHERS

Method	Parameters needed
Lorenzen	
Cook	

Method estimating constant M

Method estimating M by age

In order to estimate a unique natural mortality rate, the maximum age (tmax) was taken equal to 15 years from BIOSDEF project. The Von Bertalanffy equation parameters were based on sexed combined data from BIOSDEF and separated in male and female from Landa and Piñeiro (2000). The estimates of natural mortality for megrim ranged from 0.165 to 0.445, being on average around 0.3 (Table 2).

Table 2. Summary table of natural mortality estimates (constant across ages) for megrim based on empirical relationships with life-history parameters.

	Method	tmax=15 All	Landa and Piñeiro (2000) Females	 Males	BIOSDEF Sex combined
Methods based on tmax	tmax1	0.34060			
	HoenigO	0.29544			
	HoenigOF	0.27939			
	HoenigO2	0.29632			
	HoenigLM	0.36127			
	HoenigNLS	0.41002			
	HewittHoenig	0.28133			
Methods based on VB	PaulyLNoT		0.25019	0.31070	0.20628
	K1		0.23688	0.27072	0.18612
	K2		0.31500	0.34600	0.26850
	JensenK1		0.21000	0.24000	0.16500
	JensenK2		0.41580	0.44520	0.37170
Methods based on tmax and VB	AlversonCarney		0.34395	0.32230	0.37845

Min	0.16500
Max	0.44520
Median	0.29632
Mean	0.30189

Alternatively, empirical equations for estimating natural mortality at age were based on mean length at age. Different data sources of mean length at age were available for megrim (Table 3). ALK SP 2012, 2013 and 2014 are the mean length at age taken from annual Spanish ALK from Subarea VII for sex combined. BIOSDEF columns refers to the data taken from BIOSDEF project and finally VB columns refers to the values estimated according to the annual parameters of the von Bertalanffy growth equation for both sexes combined for megrim (*L. whiffiagonis*) in subarea VII (Linf = 66, to = -0.49, K = 0.11) estimated in BIOSDEF project.

Table 3. Summary of different data sources of mean length at age in Subarea VII for sex combined.

AGE (years)	Mean L (cm)				
	ALK SP 2012	ALK SP 2013	ALK SP 2014	BIOSDEF	VB
1	17.850	NA	NA	16.5	9.977
2	20.868	21.909	21.668	18.300	15.813
3	26.079	25.913	26.130	21.300	21.041
4	27.442	27.381	28.415	25.000	25.724
5	29.132	29.214	29.490	28.200	29.919
6	31.697	31.255	32.309	33.600	33.678
7	35.368	35.356	36.007	38.300	37.045
8	38.098	40.956	41.067	44.500	40.061
9	42.624	45.573	45.203	49.600	42.763
10+	50.291	49.936	52.555	52.000	45.183

For each of these vectors of length at age, different M at age estimates were calculated according to the empirical equations by Gislason, Charnov, Lorenzen and Cook (modification of Lorenzen). The resulting vectors of natural mortality are given in Table 4.

Table 4. Different M at age estimates are provided (according to Gislason, according to Charnov, according to Lorenzen, according to Cook (modification of Lorenzen)) by age.

AGE	M at age estimates according to Gislason				
(years)	ALK SP 2012	ALK SP 2013	ALK SP 2014	BIOSDEF	VB
1	0.771	NA	NA	0.871	1.959
2	0.596	0.552	0.561	0.738	0.933
3	0.416	0.422	0.416	0.578	0.589
4	0.385	0.385	0.364	0.446	0.426
5	0.350	0.348	0.342	0.368	0.334
6	0.305	0.311	0.296	0.277	0.276
7	0.255	0.255	0.248	0.225	0.237
8	0.227	0.201	0.200	0.176	0.209
9	0.189	0.170	0.172	0.148	0.188
10+	0.145	0.147	0.135	0.137	0.172

AGE	M at age estimates according to Charnov				
(years)	ALK SP 2012	ALK SP 2013	ALK SP 2014	BIOSDEF	VB
1	0.785	NA	NA	0.880	1.871
2	0.617	0.575	0.583	0.753	0.938
3	0.442	0.447	0.442	0.600	0.611
4	0.411	0.411	0.390	0.472	0.452
5	0.376	0.374	0.368	0.394	0.360
6	0.330	0.337	0.321	0.303	0.302
7	0.280	0.280	0.273	0.249	0.262
8	0.251	0.225	0.224	0.199	0.233
9	0.212	0.192	0.194	0.169	0.211
10+	0.165	0.167	0.155	0.157	0.194

AGE	M at age estimates according to Lorenzen				
(years)	ALK SP 2012	ALK SP 2013	ALK SP 2014	BIOSDEF	VB
1	1.080	NA	NA	1.157267	1.832
2	0.933	0.894	0.901	1.053	1.203
3	0.761	0.767	0.761	0.917	0.927
4	0.728	0.728	0.705	0.792	0.772
5	0.689	0.687	0.681	0.710	0.672
6	0.638	0.645	0.627	0.605	0.603
7	0.577	0.577	0.568	0.537	0.553
8	0.539	0.504	0.503	0.468	0.515
9	0.487	0.458	0.461	0.424	0.485
10+	0.418	0.421	0.402	0.406	0.461

AGE (years)	M at age estimates according to Cook (modification of Lorenzen)				
	ALK SP 2012	ALK SP 2013	ALK SP 2014	BIOSDEF	VB
1	1.250	NA	NA	1.345612	2.188
2	1.071	1.023	1.033	1.217	1.402
3	0.864	0.870	0.864	1.051	1.064
4	0.824	0.824	0.796	0.901	0.876
5	0.778	0.775	0.767	0.802	0.757
6	0.716	0.725	0.703	0.677	0.675
7	0.643	0.643	0.633	0.596	0.616
8	0.599	0.558	0.557	0.516	0.571
9	0.538	0.504	0.508	0.464	0.536
10+	0.458	0.462	0.439	0.444	0.508

The results of different methods for BIOSDEF length-at-age data are compared in Figure 1. The four methods give parallel estimates at age, with Cook giving the highest estimates by age. The Gislason method gives the lowest M estimates by age, followed very closely by the Charnov estimates. Alternatively, Figure 2 compares the results of M at age obtained with the Gislason method using different data sources of length-at-age. The annual Spanish ALK's provide very similar estimates. The BIOSDEF project gives larger M-at-age estimates up to age 5 and slightly lower natural mortality for the older ages (6 years old and older). The M estimates at the youngest ages (ages 1 and 2) from the Von Bertalanffy parameters are much higher than for the rest data sources and were considered unrealistic.

Figure 1. Different methods for BIOSDEF length-at-age data.

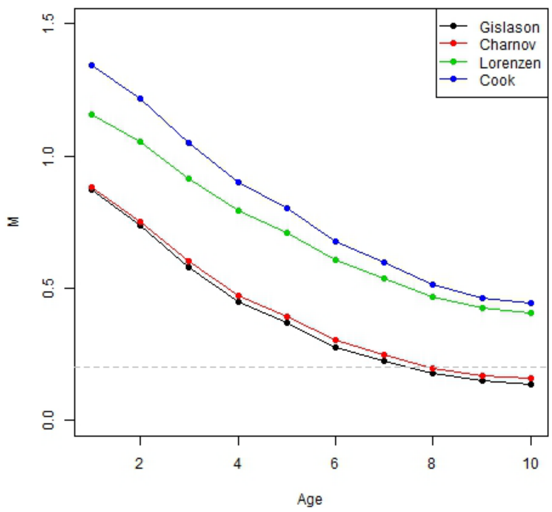
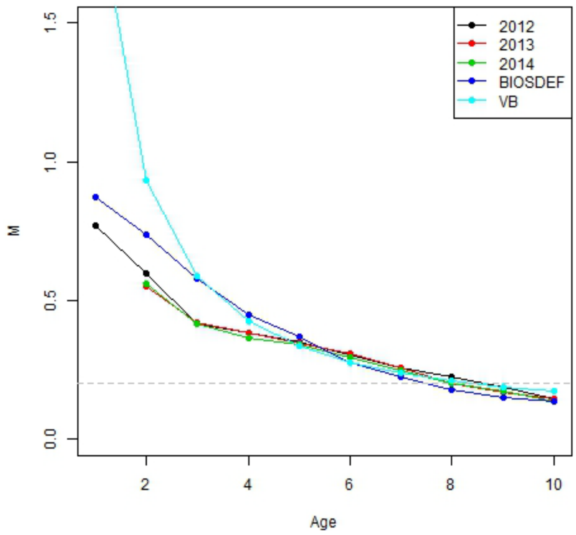


Figure 2. Different length-at-age data with the Gislason model.



Based on the previous analysis, and after some comments and discussion, the length at age vector was taken as the average from the 2012, 2013 and 2014 ALK's and the BIOSDEF project. The final M@age vector was obtained by applying the Gislason method to the aforementioned vector of lengths at age. The vector of natural mortality at age ranged from 0.87 for the younger individuals to 0.14 for the 10+ group (Figure 3 and Table 5).

Table 5. Vector of natural mortality at age computed according to the Gislason method from the average length-at-age data.

Age	1	2	3	4	5	6	7	8	9	10+
M	0.87	0.61	0.45	0.4	0.35	0.3	0.25	0.2	0.17	0.14

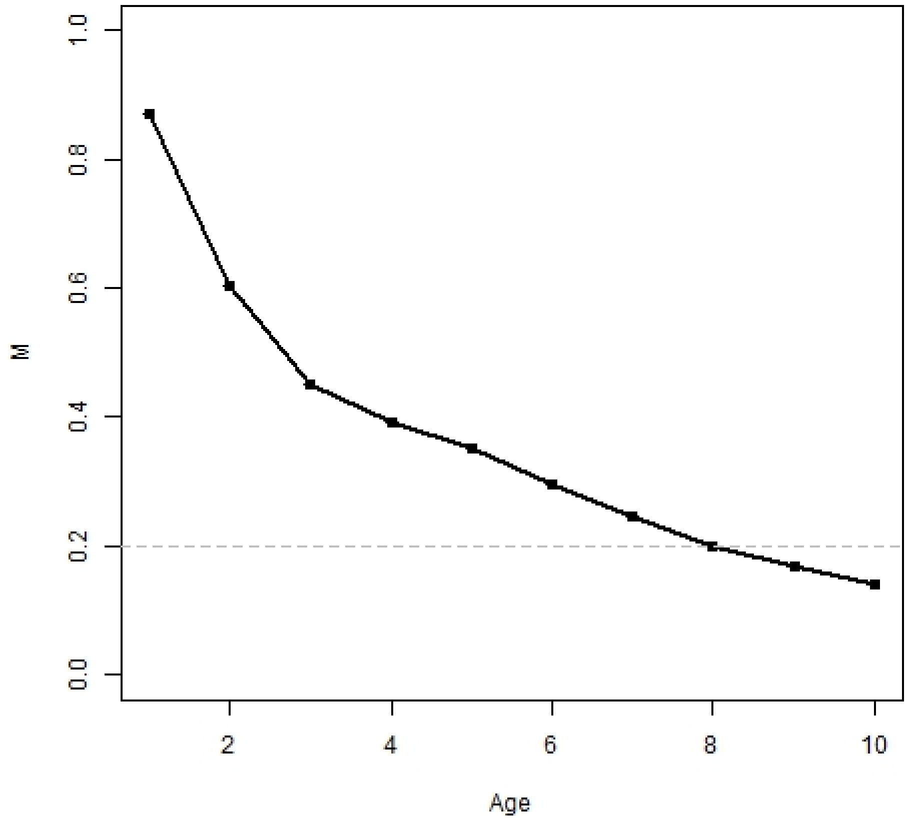


Figure 3: Natural mortality at age from applying the Gislason method to the average length-at-age vector from the Spanish ALK in 2012-2014 and the BIOSDEF project.

3. Results

In order to test the sensitivity of the assessment to the natural mortality assumption, 3 different scenarios were run:

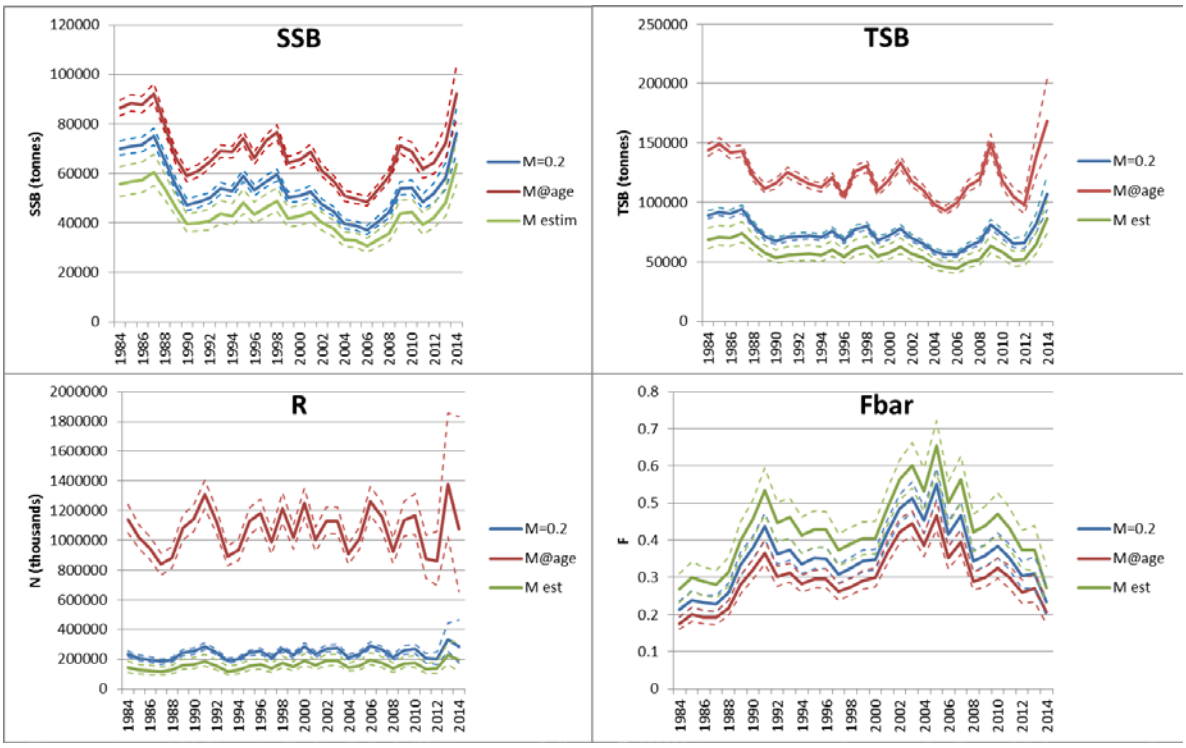
1. Run with M=0.2.

2. Run estimating M unique with a log-normal prior with median 0.2 and precision 2.

3. Run with M at age (M@age from Gislason applied to average L@age).

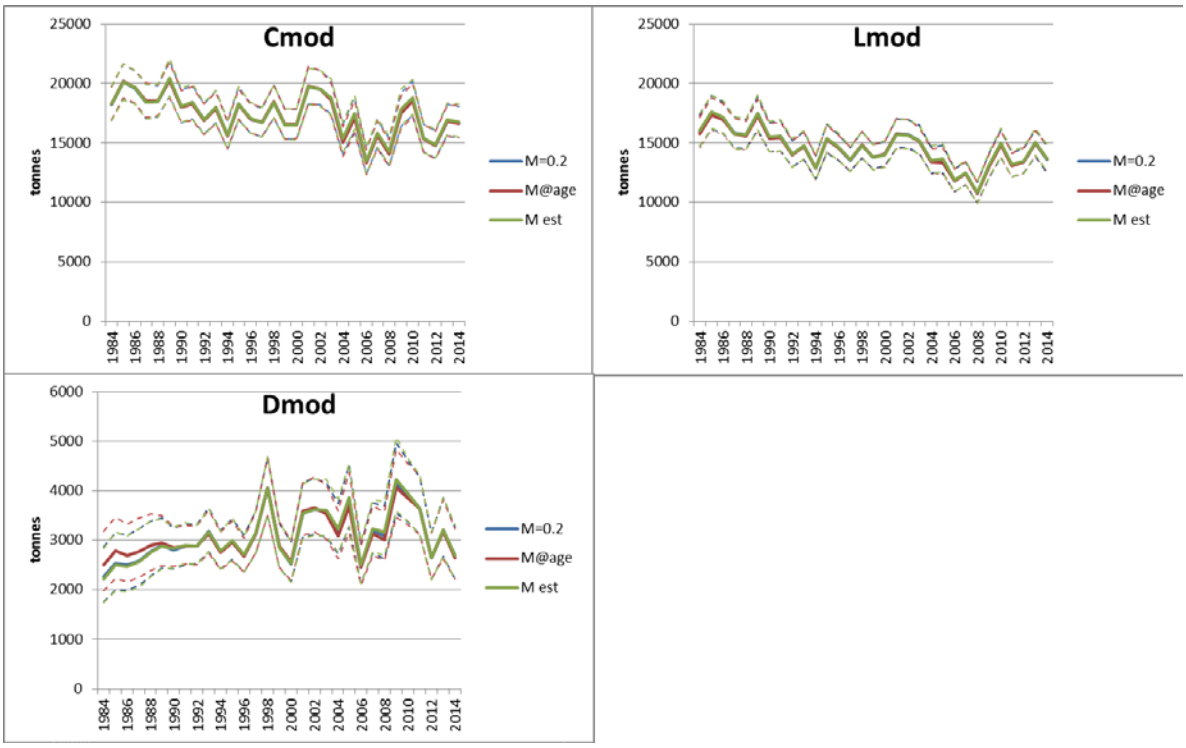
In the following figures the results from different runs are presented. Looking to the Figure 4 the estimates of SSB, TBS, R and Fbar show the same trends but different scale under different M assumptions. In SSB, TSB and R the highest values are given by using M@age and the lowest by M estimated, and in the case of Fbar, the highest values are given by M estimated and the lowest by M@age. In all cases using M=0.2 provides intermediate results in absolute values. When a unique M is estimated, the median natural mortality is 0.097 with a 90% probability interval between 0.05 and 0.15.

Figure 4. Estimates of SSB, TBS, R and Fbar (medians are solid lines and 90% probability intervals are dashed lines) for 3 different scenarios with M=0.2 (blue), M@age (red) and M estimated (green).



When comparing the results of three scenarios of M for catches, landings and discards, the three of them gave very similar results as the Bayesian model is adjusted to catches (Figure 5).

Figure 5. Estimates of catches, landings and discards (medians are solid lines and 90% probability intervals are dashed lines) for 3 different scenarios with M=0.2 (blue), M@age (red) and M estimated (green).



Regarding model parameters, the assumptions on natural mortality affect the initial population at age, the indices catchability at age and selection at age (Figure 6 and Figure 7). The difference in the selection at age is smaller for older ages, for which the assumed natural mortalities are smaller (Figure 7).

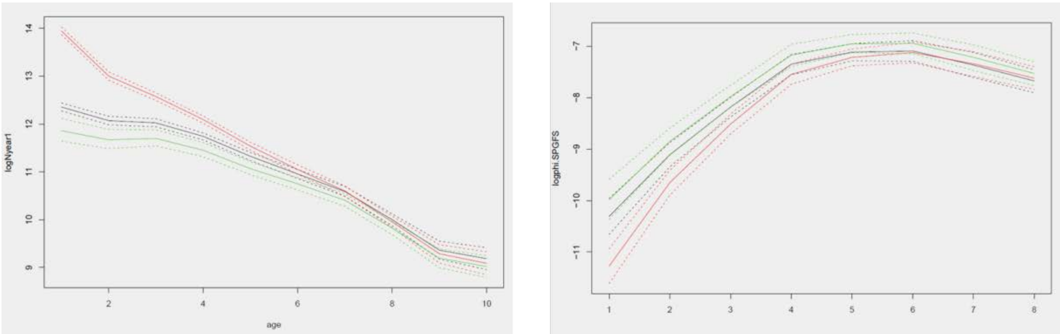


Figure 6. Changes in the initial population (on the left) and in the survey indices catchability (in the right) for different assumptions on M. The black, red and green lines represent the cases when M=0.2, M@age and M is estimated respectively.

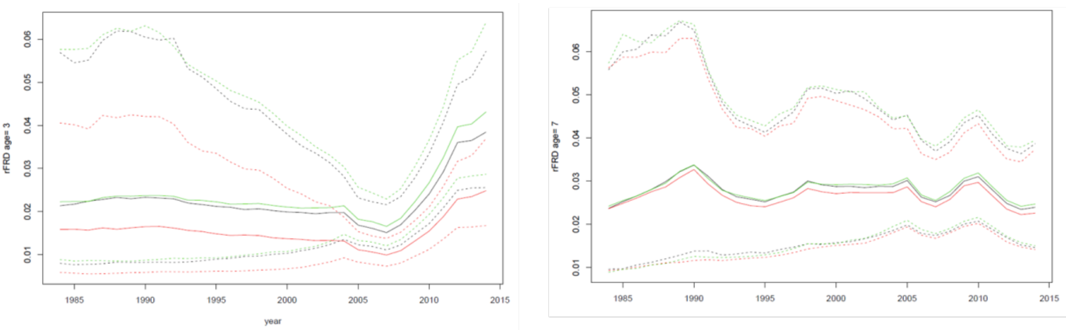


Figure 7. Changes in the selection at age 3 (on the left) and at age 7 (on the right) for different assumptions on M. The black, red and green lines represent the cases when M=0.2, M@age and M is estimated respectively.

This is explained by the posterior correlation between the natural mortality and the rest parameters. Natural mortality is negatively correlated with the year effects of fishing mortality and the survey indices catchability and positively correlated with the recruitment and the initial population at age (Figure 8). The natural mortality is apparently independent of the autocorrelation in f, the precisions of the observation equations and the r's.

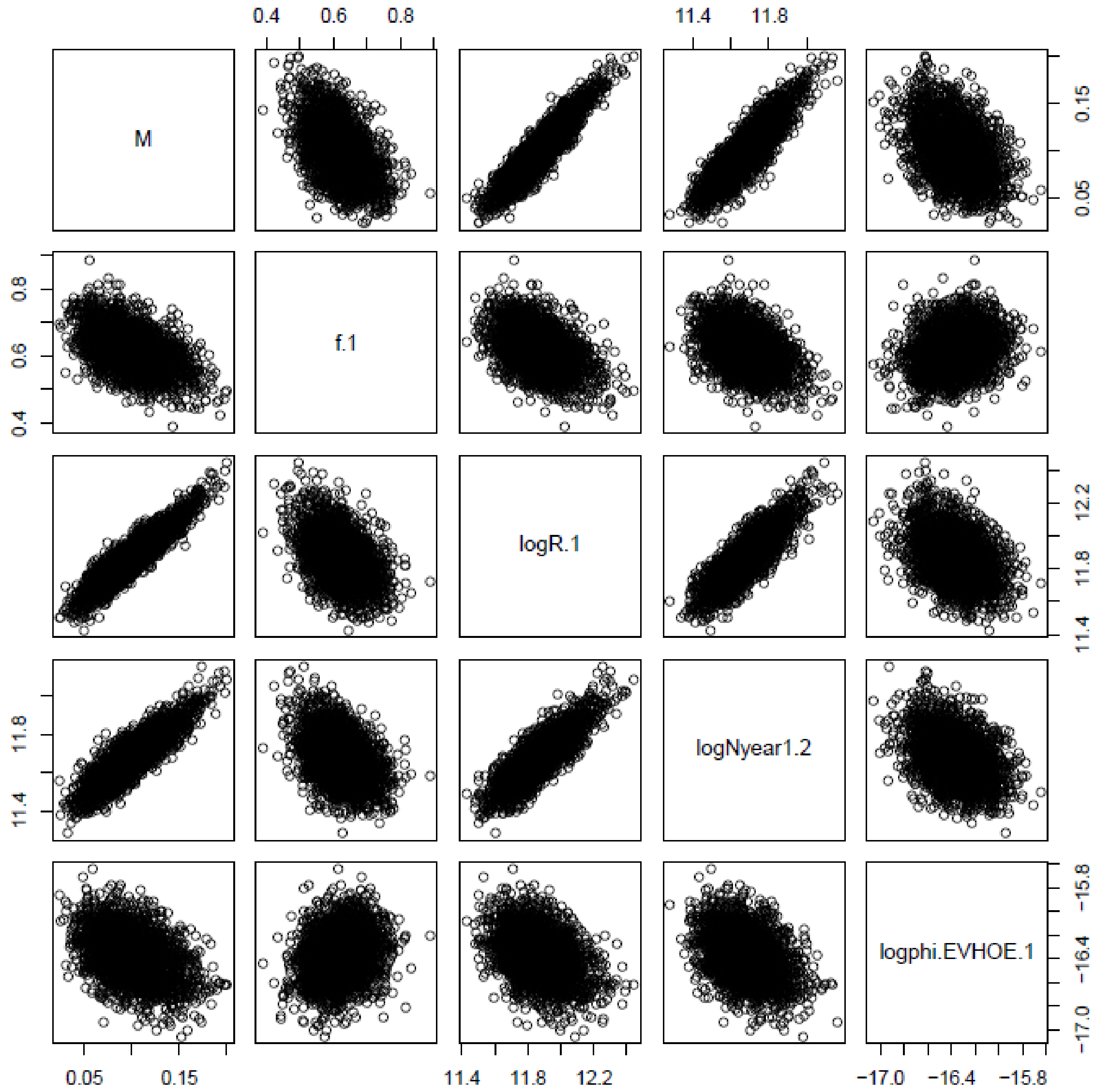


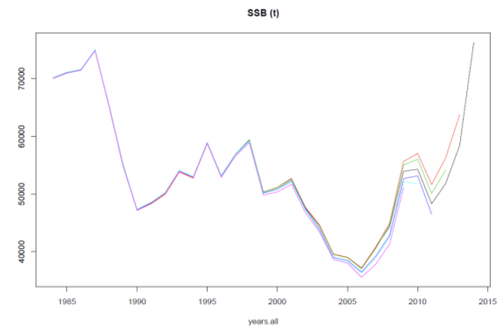
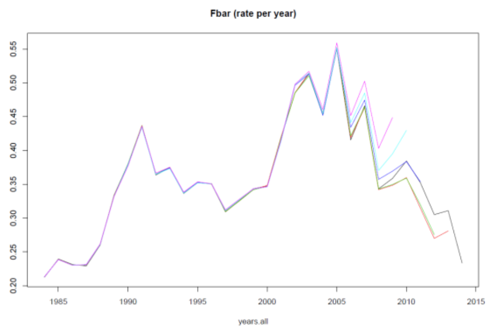
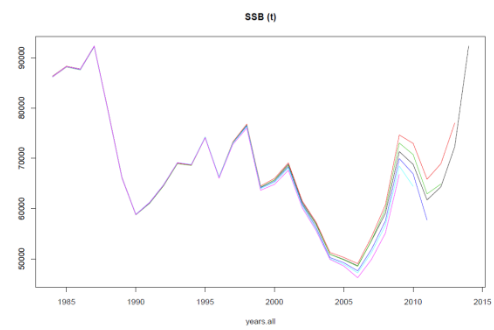
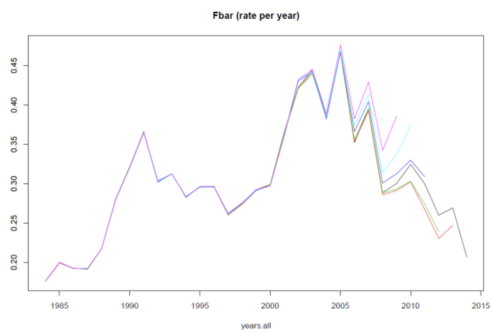
Figure 8: Cross-correlation between natural mortality and the annual effect of fishing mortality, recruitment, initial population at age 2 and the log catchability of the EVHOE survey for age 1.

In addition to the individual fit of each model, the three models were averaged by assigning a prior probability to each of them and by fitting them together in a Bayesian setting. Three chains, each of them starting from a different model, were run. The prior and posterior probabilities of each model are shown in Table 6. Almost of the posterior weight is given to the case in which M is estimated. However, the models are somehow nested and are not exclusive. So, the results were not considered conclusive in this case.

Table 6: Prior and posterior probabilities of each model for the Bayesian model-average.

	M=0.2	M@age	M estimated
Prior	0.4	0.3	0.3
Posterior	0.026	0	0.974

The retrospective analysis results of SSB and F under different M assumptions are shown in Figure 9 in absolute levels and in Figure 10 scaled to the final year assessment. The SSB retrospective results show similar trends for M=0.2 and M@age with an upward revision of the estimates at the end of the time series. Using M estimates shows a slight retrospective pattern in SSB. For the F value, results show similar trends for M=0.2 and M@age with a downward revision of the estimates until 2011 and upward revision from 2012 in the time series. For the M estimated, the time series shows a downward revision of the values and a slight retrospective pattern in F in the whole time series.

	SSB	F
M=0.2		
M@age		

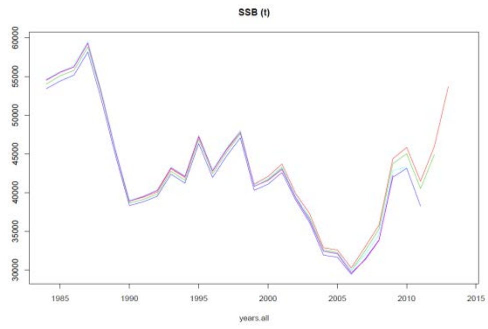
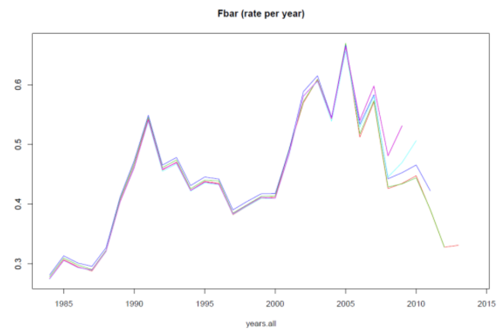
M estimated		

Figure 9. Retrospective pattern of estimates of SSB and F when applying different M values.

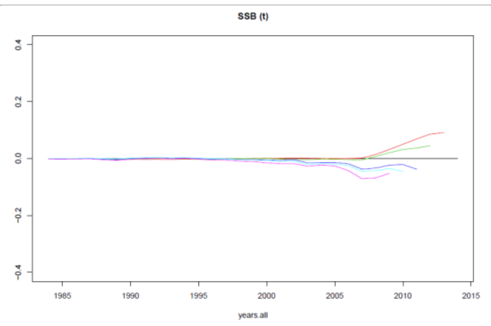
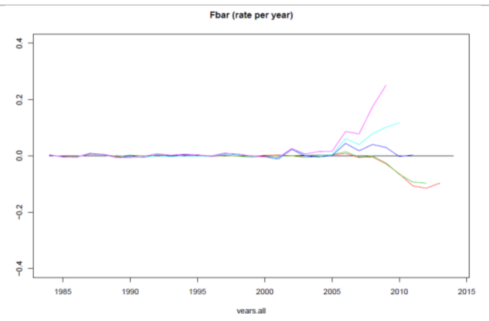
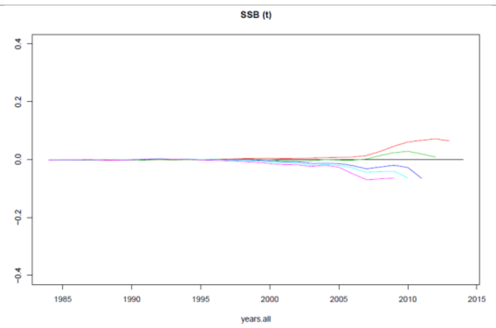
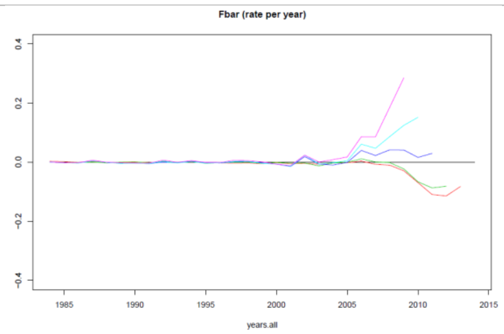
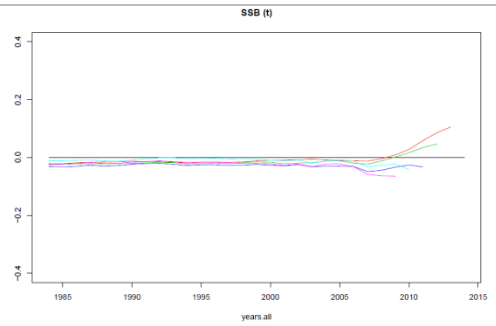
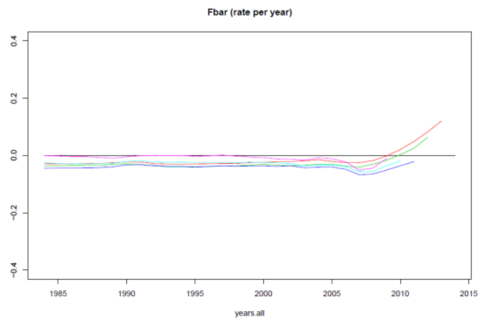
	SSB	F
M=0.2		
M@age		
M estimated		

Figure 10: Scaled retrospective pattern of estimates of SSB and F for different M assumptions.

Several statistics were computed to better quantify the potential retrospective patterns (Hanselman et al., 2013). Let p=1, …, P denote the years of data that were left out at the end, Y the last year in the assessment and $X_{y,p}$ the estimate of some quantity of interest in year y obtained by fitting the model with the last p years left out. The revised Mohn's statistics, which is a modifition of Mohn (1999) is the average of relative differences between an estimated quantity from an assessment with a reduced time series and the same quantity estimated from the full time series:

$$\frac{1}{P}\sum_{p=1}^{P}\frac{X_{Y-p,p}-X_{Y-p,0}}{X_{Y-p,0}}.$$

The Wood's Hole statistic suggested by Legault (2009) uses the same concept but averaging along the whole series as follows:

$$\frac{1}{P}\sum_{p=1}^{P}\frac{1}{Y-p}\sum_{y=1}^{Y-p}\frac{X_{y,p}-X_{y,0}}{X_{y,0}}.$$

The root-mean-squared error (RMSE) suggested by Parma (1993) but for all years is given by:

$$\sqrt{\frac{1}{P}\sum_{p=1}^{P}\frac{1}{Y-p}\sum_{y=1}^{Y-p}\left(\log(X_{y,p})-\log(X_{y,0})\right)^2}.$$

These statistics were computed for SSB, R, Fbar, Cmod, Lmod and Dmod under different M assumptions (Table 7). As expected the parameter with larger retrospective pattern is the recruitment. However, in general all the statistics are low and do not show any major patterns or differences in the retrospective behaviour for any M assumption.

Table 7: Retrospective statistics for the models under different M assumptions.

		Mohn's rev	Wood'sHole	RMSE
M=0.2	SSB	0.0002	-0.0041	0.0210
	R	-0.1861	-0.0123	0.0721
	Fbar	0.0356	0.0050	0.0381
	Cmod	0.0201	0.0003	0.0122
	Lmod	0.0202	0.0009	0.0134
	Dmod	0.0124	-0.0014	0.0187
M@age	SSB	-0.0236	-0.0041	0.0211
	R	-0.2635	-0.0194	0.0924
	Fbar	0.0607	0.0051	0.0406
	Cmod	0.0206	0.0001	0.0122
	Lmod	0.0209	0.0010	0.0130
	Dmod	0.0064	-0.0024	0.0198
M estimated	SSB	0.0027	-0.0162	0.0258
	R	0.0195	-0.0199	0.0296
	Fbar	0.0267	-0.0238	0.0335
	Cmod	-0.0168	-0.0190	0.0268
	Lmod	0.0028	-0.0234	0.0311
	Dmod	0.0117	-0.0276	0.0364

4. Conclusions

- Under the three M assumptions, SSB, R and Fbar show the same trends, but re-scaled.
- When using M@age the patterns of the initial population at age, indices'catchabilities at age and selection at age change.
- When estimating M, the assessment results in larger uncertainty (wider intervals). There is high correlation with other parameters and the estimated M (around 0.1) is low in comparison with the empirical studies and observed age range. However, the sensitivity to the prior distribution of M was not tested, which might require further studies.
- The Bayesian model was designed to investigate in detail the fishing mortality, especially the inclusion of discards, given a M value. The initial objective was not to estimate natural mortality.
- In general, precision of observation equations is rather invariant across models.
- In terms of the retrospective pattern, M=0.2 seems the most stable case both in the terminal year and in the whole series.

AS THERE ARE NO CLEAR INDICATIONS THAT MODELS M@AGE OR M ESTIMATED ARE BETTER THAN M=0.2, WE PROPOSE TO KEEP M=0.2 AS NATURAL MORTALITY VALUE FOR THE ASSESSMENT.

References

Cook, R.M. 2013. A fish stock assessment model using survey data when estimates of catch are unreliable. Fisheries Research, 143: 1– 11.

Hanselman, D., Clark, B. and M. Sigler. 2013. Report of the Groundfish Plan Team Retrospective Investigations Group. Part II.

Kenchington, T.J. 2014. Natural mortality estimators for information-limited fisheries. Fish and Fisheries, 15: 533-562.

Legault, C.M., Chair. 2009. Report of the Retrospective Working Group, January 14-16, 2008, Woods Hole, Massachusetts. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-01; 30 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/nefsc/publications/

Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. J. Fish Biol., 49 (1996), pp. 627–647

Lorenzen, K. 2000. Allometry of natural mortality as a basis for assessing optimal release size in fish-stocking programmes. Can. J. Fish. Aquat. Sci. 57: 2374–2381.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES J. Mar. Sci. 56: 473-488.

Ogle, D.H. 2015. FSA: Fisheries Stock Analysis. R package version 0.8.3.

Parma, A. N. 1993. Retrospective catch-at-age analysis of pacific halibut: implications on assessment of harvesting policies. In Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations, pp. 247-265. Ed. by G. Kruse, D. M. Eggers, C. Pautzke, R. J. Marasco, and T. J. Quinn II. Alaska Sea Grant College Program.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Then, A.Y., Hoenig, J.M., Hall, N.G. and Hewitt, D.A. (2015) Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science, 72: 82-92.