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Report of the Benchmark Workshop on Southern megrim and hake (WKSOUTH)

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Executive Summary

Benchmark Workshop on Southern megrim and hake (WKSOUTH) met in Copenhagen (Denmark) from 3-7 February 2013 to perform a benchmark assessment on the stocks of Northern Hake, Southern Hake, megrim and four spot megrim in ICES Divisions VIIIc and IXa. All the terms of reference were covered during the meeting and apart from the reference point of megrim, an agreement has been reached on all assessment, projections and reference points. With the exception of the reference point for megrim and four spot megrim, all the work regarding the ToR was agreed and finalized before the end of the workshop and large parts of the report, including the summary of issues and recommendations had been finished before the end of the meeting. Additional work has been done on the reference point for both megrim stocks after the benchmark meeting and an agreement has been reached during a WebEx meeting following the benchmark meeting.

Landings, discards, survey data and commercial catch and effort data for both Northern and Southern hake were collated as well as data and information on lengths, weights, maturities and growth. Given the potential expansion in the spatial distribution for hake, the sampling levels need to be revisited by each country and additional data are needed:

- survey data on the larger fish
- sex-specific data

Because of the recent changes in stock structure for hake, the assessment models required adjustments and will require further adjustments in the future to properly account for those changes in stock structure. This may cause the assessments for hake to display some instability in the coming years. Given the large number of datasets, especially for Northern hake, and the high workload, having both a stock coordinator and stock assessor for each stock would be recommended.

For Northern Hake, given the recent changes in the size of Hake caught by the majority of the fleets, most of the assessment model exploration focused on the most appropriate way to account for changes in retention and selectivity over time. Having taken into account time varying retention and selectivity for two of the most influential fleets in the assessment model, the benchmark group considers the accepted assessment model an improvement in terms of taking into account the changes in stock structure. However, given the complexity of this stock and data, and the difficulties surrounding its assessment (due to lack of age data and the very strong changes in size structure observed in recent years), it must be acknowledged that the assessment may still display some instabilities in coming years. The group accepted the projections, and work on biological reference points was conducted during the benchmark workshop but it was agreed that the results should be further considered by the assessment working group (WGBIE). It was recommended to further explore the inclusion of additional uncertainty in the biological assumptions.

For Southern Hake, long run times and optimization issues presented limitations for model exploration during the benchmark meeting. The majority of the time at the meeting was devoted to checking that the model was consistently reaching an optimized solution. Improving the speed and stability of the optimization should be considered a priority for this stock. As a result, the group accepted the continuation of the methodology already used for the assessment, the projections and the reference points. Additional work is required in the future on both the assessment model and the reference point.

For both megrim stocks, an effort was made to improve the input data and include the missing discard information, especially from the earlier part of the time-series. Several

methods were explored to estimate discards, and, the final conclusion was to apply the simpler methodology of using averages from two historic periods in the accepted assessments. The benchmark group accepted projections and biological reference points based on the agreed assessments.

1 Introduction

An ICES Benchmark Workshop is an intense process for evaluating the current data and assessment methodology and proposed improvements outside the ICES annual assessment and advice environment. It should include experts and stakeholders from outside the ICES community to broaden the knowledge and data pool to improve assessment quality and enhance credibility.

The goal of a benchmark is consensus agreement on an assessment methodology that is to be used in future update assessments, laid down in a stock annex. This assessment methodology can be an analytical assessment, but can also be non analytical, for instance based on trends in an assessment or in a selected set of (survey) indicators, with or without forecasts. The result will be the 'best available' method that ICES advice can be based on.

The Stock Annex describes the methodology agreed by the benchmark workshop and the assumptions on which this is based. If an expert group finds that assumptions are no longer valid, or that new data or methods available might improve the assessment, experts are asked to put forward proposals for changes in the methodology and a renewed benchmark. Typically, a stock should be benchmarked every 3-5 years to keep pace with changing situations.

2 Description of the Benchmark Process

A Benchmark workshop is an 8 day meeting, which may be split up into two 3 – 5 day meetings with at least 2 months in between. The Benchmark deals with a group of stocks with similar issues that need a renewed data and/or assessment set up. Members consist of:

- Stock assessment experts
- Data collection experts
- Experts on ecosystem / environment / fisheries information
- Stakeholders
- External experts (invited by ICES on the basis of the issues at hand)

The preparation of the actual workshop (at least 6 months before the actual meeting) is guided by an ICES convener, usually a stock expert from the ICES community. The technical chairing during the workshop is done by one of the external experts. The external experts are invited by ICES and are responsible for guiding the meeting on a scientific level (also during the preparation) and at the end auditing the resulting stock annexes.

The meeting typically has an 8 day structured along the lines of:

- (day 1)- Review of current methods and data
- (day 2)- Consideration of proposals of new input data
- (day 3)- open day
- (day 4)- Review of proposals for new methods
- (days 5-6)- Analysis of candidate methods and reference points
- (days 7-8)- Report preparation and adoption.

If needed, the first 2-3 days Data Compilation Workshop (DCW) can be planned a couple of months in advance of a 5 day benchmark workshop.

Engaging stakeholders in Benchmark Workshops

Stakeholders are invited to be members of the workshops to inform the group. Science-stakeholder partnerships usually bring information to the table via the scientists, but anecdotal information is welcomed also. Experience shows that stakeholders take part in the data collection part of the meeting, but they are of course welcome to actively participate as their contributions are potentially valuable. However, the product of the workshop (report including decisions on future datasets and methods to be used as the basis of advice) will be solely the responsibility of ICES participants (nominated by member countries or invited by ACOM, including independent experts).

Scientists that work for stakeholders may participate in the same manner as other stakeholders, or they may be nominated by a member country if the country thinks they can contribute scientifically. Scientists working for a stakeholder are sometimes nominated to Expert Groups by a member country, and the same practice may occur for Benchmark Workshops.

Enhancing integration and the ecosystem approach

Benchmark Workshops are an opportunity for enhancing integration and the ecosystem approach. This might be achieved by identifying new scientific knowledge, datasets and/or modelling methods that could be integrated in to the benchmark framework for preparing advice. ACOM is working on improving this part of the benchmark results.

3 Recommendations covering all stocks

- -Continue WebEx meetings with assessor and external expert involvement prior to future benchmark workshops. These meetings have been critical for the success of this benchmark process.
- -Attempt to ensure that all datasets are available in good time prior to the start of assessment and benchmark meetings.
- -Given the high workload, having both a stock coordinator and stock assessor for each stock would be appropriate.
- -Given the increased abundance of hake in the northern areas (up to and including the Arctic), a representative from the northern areas would be useful.
- -Consider the relevance and practicalities of combining the assessment for the Northern and Southern hake
- -Northern and Southern hake should investigate the utility of a two sex model
- -Northern and Southern hake should investigate the life-history parameters (growth, natural mortality)
- -Northern and Southern hake both suffer from the lack of survey data on the larger fish, and ways to mitigate this should be investigated
- -For the Northern Hake, carry out estimation of reference point based on the approach presented in WKSOUTH and on the recommendations from WKMSYREF2, including uncertainty on biological parameters
- -For all stocks, consider the use of R0 likelihood profiling approach (Lee *et al.*, 2014) to investigate model optimization, misspecification and weighting issues.
- -As happened at this benchmark, it should be possible to ask for further advice from model experts not present at the meeting on specific technical model issues. In this case it is helpful if these experts are familiar with the ICES process.

4 Hake

4.1 Stock ID and substock structure

Northern hake are distributed principally from the French-Spanish border through the British Isles reaching as far north as Norway. Previous genetic studies have not found evidence of distinct stocks. A boundary between the northern and southern stocks has been established near the Spanish-French border. No migration studies were presented, but the spatial distribution of recruitment as observed in the surveys indicates the possibility of some mixing of recruits with the southern stock. In addition, the increasing trend of recruitment in the survey on Porcupine Bank in the north indicates that recruitment events are not uniformly distributed throughout the range of the stock.

4.2 Multispecies and mixed fisheries issues

No multispecies interactions were discussed at this benchmark workshop.

4.3 Ecosystem drivers

Ecosystem impacts were not directly examined. However, with northern hake at its maximum historical level of biomass, it seems highly probable that some shift in species interactions has occurred, taking into account that hake is a highly ichthyophagous species with euphausiids although decapod prawns are an important part of its diet for smaller hake (>20 cm).

4.4 Northern Hake

4.4.1 Issue list

4.4.1.1 Model

- SS3 convergence problems
- Estimation of parameters within the model hitting set bounds
- Very complex with a large number of parameters
- Michel Bertignac provided a presentation of a sensitivity analysis where the selectivity for the trawl fleet was changed to logistic curve selectivity pattern and 3 time blocks to allow for a change in the VBF growth parameter K.

4.4.1.2 Data

- Commercial data
    - Supplied by a large number of countries with potentially different raising methods.
    - Potential change in selectivity for Spanish trawls in area VII from 2010.
    - Detail required of country and area of origin of length distribution and landings for Gillnets, and the number of samples used for the length frequency. This is to determine if length samples are appropriate to raising to fleet level.
    - Discards are provided but not for all years.
    - 2012 is the first year of discard data for French Gillnets, confirmation was requested regarding the correctness of the data and if historical discards information is available.

- Six tuning series, includes one new longline cpue for a large fish abundance indicator.
- Growth parameters updated with in the model providing different estimates of SSB with inclusion of new data.
- Growth and other biological parameters to be reviewed along with Southern Hake.

4.4.2 Scorecard on data quality

A scorecard on the quality of the data used in the assessment and during the benchmark process was produced during the benchmark meeting; however, the scoring of the data were mainly qualitative judgement using the national and the international stock coordinators knowledge of the collection processes from each of the contributing countries. The main data quality issues are outlined in section 4.4.1.2 as well as issues with length weight conversion as some fish are landed gutted in some fleets and for some fleets and seasons length information is missing and not available.

4.4.3 Stock Assessment data

4.4.3.1 Catch – quality, misreporting, discards

Total landings from the Northern stock of hake by area for the period 1961-2012 as used by the WG are given in Table 4.4.3.1.1. They include landings from Division IIIa, Subareas IV, VI and VII, and Divisions VIIIa,b,d, as reported to ICES. Unallocated landings are also included in the table; they are high over the first decade (1961-1970), when the uncertainties in the fisheries statistics were high. In the last two data years, 2011 and 2012, they have increased again due to differences between official statistics and scientific estimations. The group decided to use scientific estimates to carry out the assessment. Table 1 of the Stock Annex provides a historical perspective of the level of aggregation at which landings have been available to the WG.

Except for 1995, landings decreased steadily from 66 500 t in 1989 to 35 000 t in 1998. Up to 2003, landings fluctuated around 40 000 t. Since then, with the exception of 2006, landings have been increasing up to 79 700 t in 2011, the highest value since 1963. Landings in 2012 were 75 200, well above the 2012 TAC (55 105 t).

The discard data sampling and data availability are presented in the Stock Annex. Table 3 in the Northern hake stock annex presents discard data available to the group from 1999 to 2012.

In relation to the commercial data used last year (ICES, 2013), there was an aspect that received special attention in this benchmark: the change in selectivity (or, even more likely, retention pattern) observed for Spanish trawls in area VII from 2010. The monitoring of this fishing strategy allowed observing a trend in the selection of large individuals in landings. In fact, during the period 2003-2009, the mean size was 43.7 cm and 23.6 cm for landings and discards, respectively. However, both mean sizes have increased to 55.2 cm and 28.8 cm for landings and discards respectively in the last three years (2010-2012).

In 2013 a Data Call was run by ICES in order to collect data on landings and discards at length, quarter, area and métier level for the stock since 2003. Most of the countries uploaded their data into InterCatch for the period 2003 to 2012. But depending on the year and country, the data provided had different spatial resolutions and length frequency data and the quarterly disaggregation required was missing for many strata. The data available through this call, for both landings and discards, in areas VII and VIII did not represent an improvement in relation to the already available data, so it was not used in the benchmark assessment. The length frequency distribution of landings outside areas VII and VIII since 2003 was compiled and used in the assessment, as it was considered somewhat better than the data available previously. The compilation of the length frequency distribution was done within InterCatch defining allocation schemes. The allocation schemes were defined by allocating the sampled strata with similar gears and same season to the unsampled strata. Previously, the length frequency distributions for these fleets were compiled manually taking into account only the season. Total discards since 2003 were compiled and used in the assessment. The length frequency distribution of discards since 2003 outside areas VII and VIII was mainly formed by Danish data. Since 2009, the Scottish discards represent around 90% of the discards in this area but there is no Scottish length frequency distribution available. It was not considered representative to use Danish discard length frequency distribution for Scottish discards. Hence, no length frequency distribution was used for discards in this area since 2009. In general, the length frequency distribution in this area, is not considered fully representative of the catches because they are formed by several countries and gears, and length frequency distributions are only available for a few of them.

Table 4.4.3.1.1. Northern hake. Estimates of catches ('000 t) by area for 1961-2012.

	Landings (1)					Discards (2)	Catches (3)
Year	IVa+VI	VII	VIIIa,b	Unallocated	Total	Total	Total
1961	-	-	-	95.6	95.6	-	95.6
1962	-	-	-	86.3	86.3	-	86.3
1963	-	-	-	86.2	86.2	-	86.2
1964	-	-	-	76.8	76.8	-	76.8
1965	-	-	-	64.7	64.7	-	64.7
1966	-	-	-	60.9	60.9	-	60.9
1967	-	-	-	62.1	62.1	-	62.1
1968	-	-	-	62.0	62.0	-	62.0
1969	-	-	-	54.9	54.9	-	54.9
1970	-	-	-	64.9	64.9	-	64.9
1971	8.5	19.4	23.4	0	51.3	-	51.3
1972	9.4	14.9	41.2	0	65.5	-	65.5
1973	9.5	31.2	37.6	0	78.3	-	78.3
1974	9.7	28.9	34.5	0	73.1	-	73.1
1975	11.0	29.2	32.5	0	72.7	-	72.7
1976	12.9	26.7	28.5	0	68.1	-	68.1
1977	8.5	21.0	24.7	0	54.2	-	54.2
1978	8.0	20.3	24.5	-2.2	50.6	-	50.6
1979	8.7	17.6	27.2	-2.4	51.1	-	51.1
1980	9.7	22.0	28.4	-2.8	57.3	-	57.3
1981	8.8	25.6	22.3	-2.8	53.9	-	53.9
1982	5.9	25.2	26.2	-2.3	55.0	-	55.0
1983	6.2	26.3	27.1	-2.1	57.5	-	57.5
1984	9.5	33.0	22.9	-2.1	63.3	-	63.3
1985	9.2	27.5	21.0	-1.6	56.1	-	56.1
1986	7.3	27.4	23.9	-1.5	57.1	-	57.1
1987	7.8	32.9	24.7	-2.0	63.4	-	63.4
1988	8.8	30.9	26.6	-1.5	64.8	-	64.8
1989	7.4	26.9	32.0	0.2	66.5	-	66.5
1990	6.7	23.0	34.4	-4.2	60.0	-	60.0
1991	8.3	21.5	31.6	-3.4	58.1	-	58.1
1992	8.6	22.5	23.5	2.1	56.6	-	56.6
1993	8.5	20.5	19.8	3.3	52.1	-	52.1
1994	5.4	21.1	24.7	0.0	51.3	*	51.3
1995	5.3	24.1	28.1	0.1	57.6	-	57.6
1996	4.4	24.7	18.0	0.0	47.2	-	47.2
1997	3.3	18.9	20.3	-0.1	42.5	-	42.5
1998	3.2	18.7	13.1	0.0	35.1	-	35.1
1999	4.3	24.0	11.6	0.0	39.8	*	39.8
2000	4.0	26.0	12.0	0.0	42.0	*	42.0
2001	4.4	23.1	9.2	0.0	36.7	-	36.7
2002	2.9	21.2	15.9	0.0	40.1	-	40.1
2003*	3.3	25.4	14.4	0.0	43.2	*	43.2
2004*	4.4	27.5	14.5	0.0	46.4	*	46.4
2005*	5.5	26.6	14.5	0.0	46.6	4.0	50.6
2006*	6.1	24.7	10.6	0.0	41.5	*	41.5
2007*	7.0	27.5	10.6	0.0	45.1	2.1	47.2
2008*	10.7	22.8	14.3	0.0	47.8	3.5	51.3
2009*	13.1	25.3	20.4	0.0	58.8	7.1	65.9
2010*	14.2	33.5	25.1	0.0	72.8	6.5	79.3
2011*	18.8	18.6	16.6	25.7	79.7	8.0	87.7
2012*	22.4	22.2	16.7	13.9	75.2	14.6	89.8

(1) Spanish data for 1961-1972 not revised, data for Sub-area VIII for 1973-1978 include data for
Divisions VIIIa,b only. Data for 1979-1981 are revised based on French surveillance data.
Divisions IIIa and IVb,c are included in column "IIIa, IV and VI" only after 1976.
There are some unallocated landings (moreover for the period 1961-1970).

(2) Discard estimates from observer programmes. In years marked with *,
partial discard estimates are available and used in the assessment.
For remaining years for which no values are presented,
some estimates are available but not considered valid and thus not used in the assessment
In the years with data only Spanish discards and discards from French Nephrops trawlers are included.

(3) From 1978 total catches used for the Working Group.

4.4.3.2 Surveys

Four surveys provide relative indices of hake abundance over time. The French RESSGASC survey was conducted in the Bay of Biscay from 1978 to 2002, the EVHOE-WIBTS-Q4 survey conducted in the Bay of Biscay and in Celtic Sea with a new design since 1997, the SpPGFS-WIBTS-Q4 survey conducted on the Porcupine Bank since 2001, and the Irish Groundfish Survey (IGFS-WIBTS-Q4) beginning in 2003 in the west of Ireland and the Celtic Sea. A brief description of each survey is given in the Stock Annex. Figure 4.4.3.2.1 presents the abundance indices obtained for these surveys.

From 1985 until the end of the survey in 2002, the index from RESSGASC followed a slightly decreasing trend.

Throughout the available time-series, the abundance index provided by EVHOEWIBTS- Q4 showed three peaks in 2002, 2004, and 2008. The index obtained in 2012 is the highest value of the series, 193% higher than the previous year index.

The abundance index provided by IGFS-WIBTS-Q4 follows a similar trend, so that from the 2008 peak, the abundance index obtained in 2012 achieves the highest value of the series, 268% higher than the previous year index.

For the SpPGFS-WIBTS-Q4 survey conducted on Porcupine's Bank since 2001, the abundance index follows an increasing trend since 2003, reaching its highest value in 2009 and slightly decreases in 2010 and 2011. The abundance index in 2012 is moderately higher than the 2011 index (+7%).

The spatial distribution of the EVHOE-WIBTS-Q4 index for hakes from 0 to 20cm is given in Figure 3.2 for the most recent years. It is apparent from this figure that interannual variations in abundance are different between areas (VII and VIII). In 2012, both areas display large abundance, even higher than in 2008, another year with high abundance index over recent years.

In order to extend the geographical coverage of the stock, new survey indices were requested from surveys developed in West of Scotland to test during the benchmark. Two surveys, conducted in the first and fourth quarters, were provided covering the period 1996-2013. They were calculated using historical data and a new survey strata design from a survey which commenced operation in 2011. As the indices were provided during the benchmark and length frequency distributions were not available they were not incorporated into the assessment.

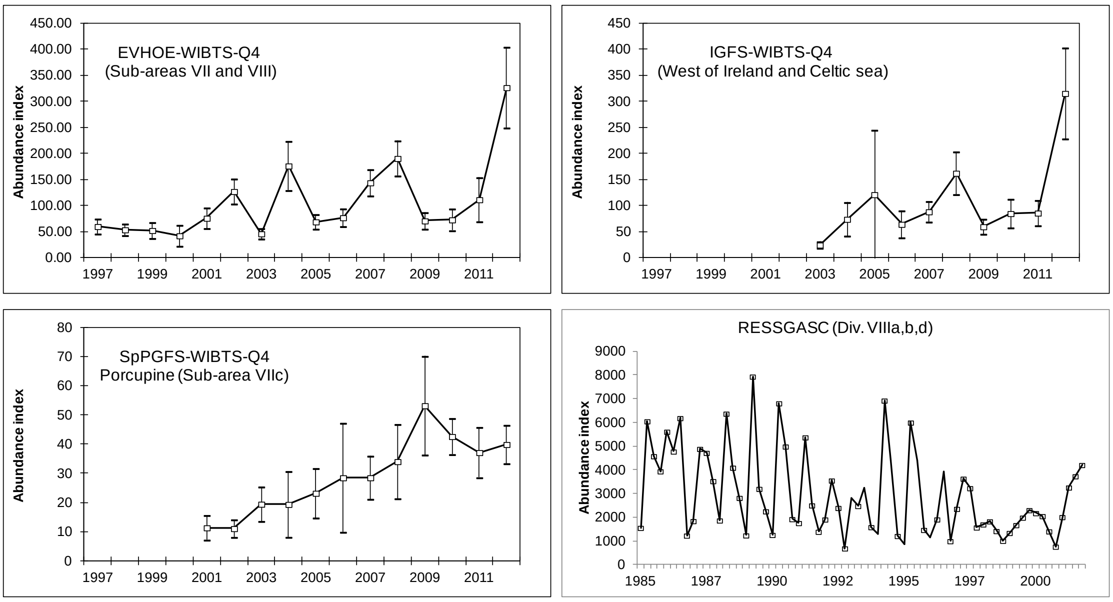


Figure 4.4.3.2.1. Hake in Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d (Northern stock) abundance indices from surveys.

4.4.3.3 Commercial catch–effort data

A description of the commercial LPUE indices available to the group is given in the Stock Annex. They are not used in the assessment model.

Effort and LPUE data for the period 1982-2012 are given in Table 4.4.3.3ab and Figure 4.4.3.3ab.

Since 1985, the LPUE of A Coruña trawlers operating in Subarea VII has fluctuated, with an increasing trend reaching its maximum value in2011, which has been interrupted in 2012 with a moderate decrease. Over the same period, LPUE from Vigo trawlers operating in Subarea VII followed a slightly decreasing trend, becoming less variable during the last 15 years. It must be taken into account that while A Coruña trawl fleet is targeting hake, the Vigo trawl fleet is directed to megrim, taking hake only as bycatch.

LPUE from Ondarroa and Pasajes pair trawlers operating in Divisions VIIIa,b,d have followed similar trends and have been quite variable. The highest two peak values have been observed in 1995 and 2002. For Ondarroa, very large increases in LPUE have been observed in 2008 and 2009, with the largest value observed in 2009. Since then indices has been decreasing, although not up to the low levels of the beginning of the time-series. Its LPUE remained at this high level in 2010. In 2005 both fleets experienced a decrease in effort (expressed in number of days), which corresponds to a decrease in number of vessels. This decrease has continued further for the Pasajes pair trawlers which were at a very low level of effort in 2007 (105 days only) and stopped their operations in 2008.

LPUE for the Ondarroa “Baka” trawlers fishing in Subareas VI show a marked increase since 2003, achieving its highest values in 2012. Ondarroa “Baka” trawlers in Subarea VII targeted hake and megrim until 1996 and megrim and anglerfish, with lower hake LPUE, since then. The Ondarroa baka trawlers in VII and Div. VIIIa,b,d, the Pasajes “Bou” trawlers fishing in Subarea VIII and the trawlers from Santander in VIIIa,b,d do not show any particular trend in the LPUE. However, in this fishing area, these fleets are not targeting hake.

Due to important reductions in the availability of log-book information in recent years for both French fleets from Les Sables and Lesconil, LPUE values for the years 1996 onwards have low reliability. Effort and LPUE for the period 1987-2003 are given in Table 4.4.3.3b and presented in Figure 4.4.3.3b only for the period 1987-1995.

The LPUE series of the two most important Spanish longline fleets operating in VII (Celeiro and Burela) have been rather stable over time, but it increased these last years until 2011, and then shows a decrease in 2012. This same pattern is also present in A Coruña longliners fishing in VII, although it is not quite as strong. These three LPUE series were compiled in order to be tested during this benchmark with the intention of providing indices of adult fish for the assessment model (WD01, Castro *et al.*, 2014). The time-series of hake LPUE (landings by fishing day) from the Spanish set-longliners operating in ICES Subarea VII was recovered for the period 1995-2012, with the respective quarterly length frequency distributions. Although the standardization of longline effort is strongly dependent of the number of hooks used by trip, this information was unrecoverable for all years. However, interviews with skippers describe this fishery as having a very homogeneous fishing tactic throughout the period recovered here, without changes due to technological improvements or new management measures. Besides, the practical lack of discards observed in this logline fleet (Pérez *et al.*, 1996) makes it reasonable to use landings (LPUE) as proxy of catches (cpue).

Table 4.4.3.3.a. Hake in Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d (Northern stock) Effort and LPUE values of commercial fleets estimated by National laboratories.

Sub-area VII

	A Coruña trawl in VII			Vigo trawl in VII		
Year	Landings(t)	Effort(days)	LPUE(Kg/day)	Landings(t)	Effort**	LPUE**
1982				2051	75194	27
1983				3284	75233	44
1984				3062	76448	40
1985	5612	14268	393	1813	71241	25
1986	4253	11604	366	2311	68747	34
1987	8191	12444	658	2485	66616	37
1988	6279	12852	489	3640	65466	56
1989	6104	12420	491	1374	75853	18
1990	4362	11328	385	2062	80207	26
1991	3332	9852	338	2007	78218	26
1992	3662	6828	536	1813	63398	29
1993	2670	5748	464	1338	59879	22
1994	3258	5736	568	1858	56549	33
1995	4069	4812	846	1461	50696	29
1996	2770	4116	673	1401	54162	26
1997	1858	4044	459	1099	50576	22
1998	2476	3924	631	1201	53596	22
1999	2880	3732	772	1652	50842	32
2000	3628	2868	1265	1487	55185	27
2001	2585	2640	979	1071	56776	19
2002	1534	2556	600	1152	50410	23
2003	3286	3084	1065	1486	54369	27
2004	2802	2820	994	1595	53472	30
2005	2681	2748	976	1323	52455	25
2006	2498	2688	929	1422	53677	26
2007	2529	2772	912	1459	58123	25
2008	2042	1872	1091	1159	54324	21
2009	2418	1884	1284	1493	51551	29
2010	4934	2484	1986	1326	48432	27
2011	5108	2232	2288	1321	43533	30
2012	2819	1452	1942	1122	32760	34

* Before 1988 landings and effort refer to Vigo trawl fleet only, from 1988 to 2002 to combined Vigo+Marín trawl fleet

** Effort in days/100HP; LPUE in kg/(day/100HP)

Sub-area VIII

	Ondarroa pair trawl in VIIIabd			Pasajes pair trawl in VIIIa,b,d		
Year	Landings(t)*	Effort(days)	LPUE(Kg/day)	Landings(t)*	Effort(days)	LPUE(Kg/day)
1993	64	68	930	na	na	na
1994	815	362	2250	540	423	1276
1995	3094	959	3226	2089	746	2802
1996	2384	1332	1790	2519	1367	1843
1997	2538	1290	1966	3045	1752	1738
1998	2043	1482	1378	2371	1462	1622
1999	2135	1787	1195	2265	1180	1920
2000	2004	1214	1651	2244	1233	1820
2001	1899	1153	1648	941	587	1603
2002	4314	1281	3368	2570	720	3571
2003	3832	1436	2669	2187	754	2902
2004	3197	1288	2482	1859	733	2535
2005	3350	1107	3026	658	252	2611
2006	4173	1236	3377	516	182	2837
2007	3815	1034	3691	278	105	2644
2008	5473	791	6916	0	0	na
2009	6716	633	10610	0	0	na
2010	8056	844	9545	0	0	na
2011	6357	893	7115	0	0	na
2012	4769	799	5969	0	0	na

Table 4.4.3.3.b. Hake in Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d (Northern stock) Effort and LPUE values of commercial fleets.

Sub-area VI

	Ondarroa trawl in VI		
Year	Landings(t)	Effort(days)	LPUE(Kg/day)
1994	164	635	259
1995	164	624	262
1996	259	695	372
1997	127	710	179
1998	89	750	118
1999	197	855	230
2000	243	763	318
2001	239	1123	213
2002	233	1234	189
2003	138	718	193
2004	306	411	743
2005	291	337	864
2006	304	368	827
2007	265	335	791
2008	451	349	1293
2009	383	380	1008
2010	580	394	1472
2011	489	339	1443
2012	902	355	2542

Sub-area VII

	A Coruña long line in VII			Celeiro long line in VII			Burela long line in VII		
Year	Landings(t)	Effort(days)	LPUE(Kg/day)	Landings(t)	Effort(days)	LPUE(Kg/day)	Landings(t)	Effort(days)	LPUE(Kg/day)
1985	3577	4788	747	na	na	na	na	na	na
1986	3038	4128	736	na	na	na	na	na	na
1987	2832	4467	634	na	na	na	na	na	na
1988	3141	3766	834	na	na	na	na	na	na
1989	2631	3503	751	na	na	na	na	na	na
1990	2342	3682	636	na	na	na	na	na	na
1991	2223	3217	691	na	na	na	na	na	na
1992	2464	2627	938	na	na	na	na	na	na
1993	2797	2568	1089	na	na	na	na	na	na
1994	2319	2641	878	4062	6516	623	2278	3804	599
1995	2507	2161	1160	5209	6420	811	2905	3444	843
1996	2111	1669	1265	5988	6720	891	3245	3636	892
1997	830	900	922	4174	6144	679	2299	3540	649
1998	292	372	784	2817	4668	603	1639	3000	546
1999	323	395	817	3447	4980	692	1982	2880	688
2000	281	276	1018	3699	4440	833	2282	2928	779
2001	229	276	830	3383	3756	901	3034	3672	826
2002	214	300	712	2769	3984	695	2399	3732	643
2003	648	1188	545	3386	4404	769	2514	3636	691
2004	280	312	899	3990	4596	868	3255	3852	845
2005	199	288	691	4177	3930	1063	3074	3507	876
2006	256	312	822	4372	4560	959	3639	5184	702
2007	271	520	520	5039	5712	882	4367	6300	693
2008	233	288	810	4302	5184	830	4058	4884	831
2009	214	192	1116	4959	4624	1072	5146	4536	1135
2010	315	375	839	7630	5556	1373	9141	5736	1594
2011	443	350	1265	9672	5172	1870	10908	5988	1822
2012	217	253	858	6621	6720	985	7440	6984	1065

Sub-area VIII

	Ondarroa trawl in VIIIabd			Santander trawl in VIIIabd		
Year	Landings(t)	Effort(days)	LPUE(Kg/day)	Landings(t)	Effort	LPUE
1993	2244	5590	401	na	na	na
1994	2817	5619	501	175	640	273
1995	2069	4474	463	131	620	211
1996	944	4378	216	62	530	117
1997	2348	4286	548	65	805	81
1998	287	3002	96	95	1445	66
1999	81	2337	34	89	1830	49
2000	157	2227	70	79	1520	52
2001	341	2118	161	94	1590	59
2002	321	2107	152	252	1260	200
2003	230	2296	100	212	1405	151
2004	165	2159	76	200	995	201
2005	257	2263	114	120	596	202
2006	216	2398	90	83	636	131
2007	296	2098	141	105	1278	82
2008	543	2017	269	na	na	na
2009	741	1807	410	120	1278	94
2010	405	1358	298	69	774	89
2011	241	1384	174	45	454	99
2012	207	1384	150	25	274	91

* From 1998 hake no more targeted   Effort (day*100 HP)

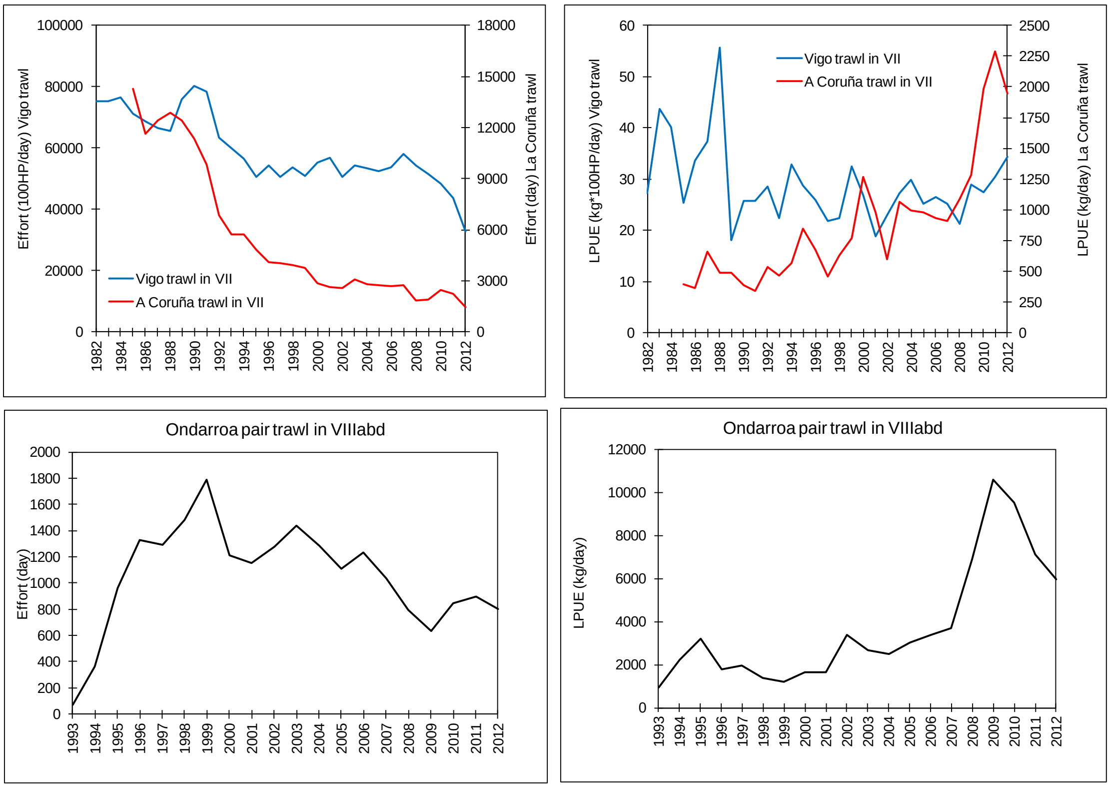


Figure 4.4.3.3.a. Northern hake. Effective effort indices and LPUE values of commercial fleets estimated by National laboratories.

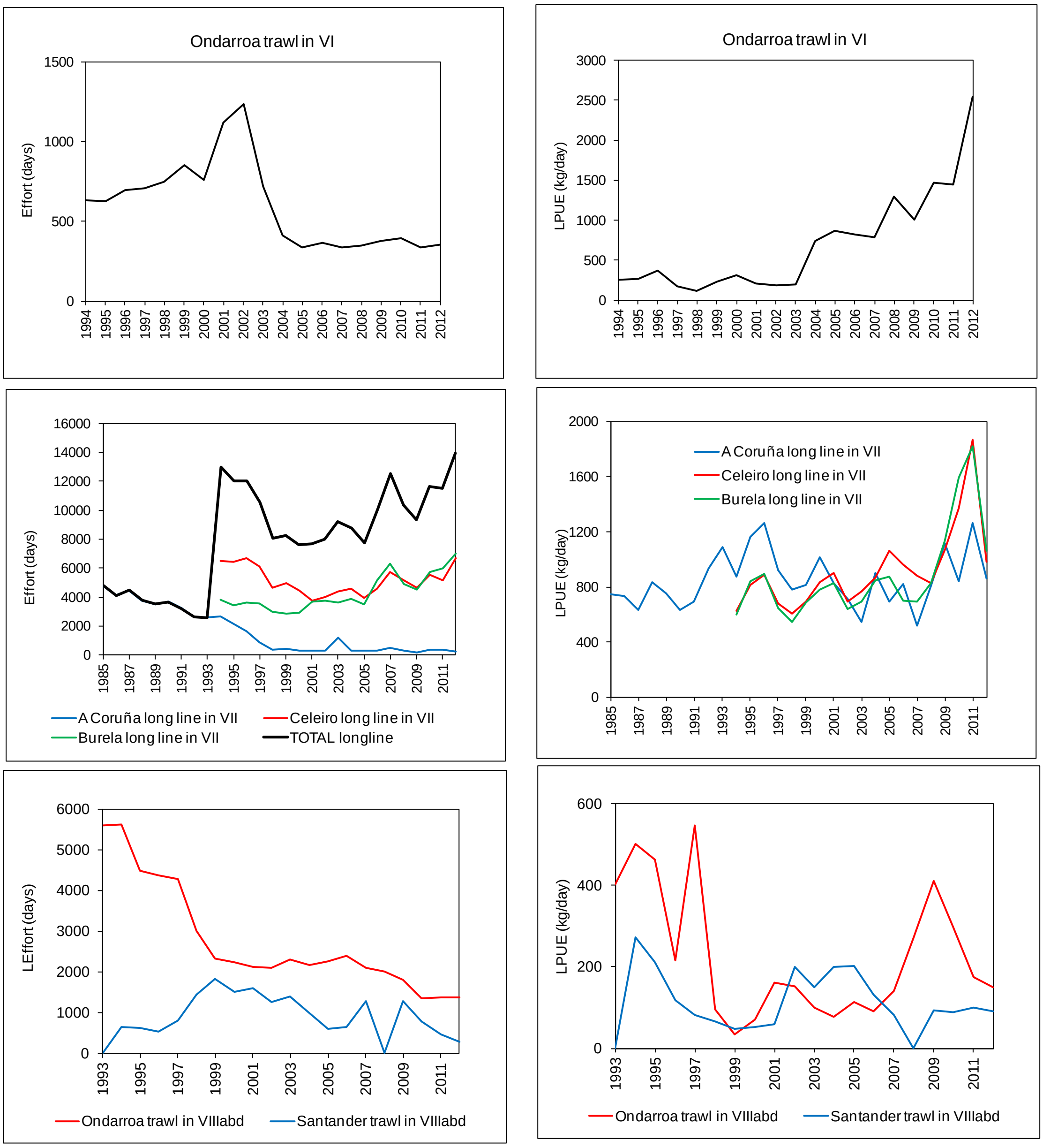


Figure 4.4.3.3.b. Northern hake. Effective effort and LPUE values of commercial fleets estimated by National laboratories.

4.4.3.4 Length, weights, maturities, growth

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

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

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

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

4.4.4 Assessment model

The model

The stock is assessed since the last benchmark (ICES, 2010) using Stock Synthesis 3 (SS3) (Methot, 2013). This model is commonly used for assessments of groundfish, tunas, and pelagic fish in the US and Australia and has been increasingly used in ICES since 2010. SS3 is written in ADMB (www.admb-project.org) and is a forward simulating, age and size-based model that is capable of being fit to a wide variety of assessment data. The model version used for this assessment is 3.24f (October 2012 2010).

Features of the model configuration for the northern hake assessment include:

Quarterly time-steps from 1978 (first assessment year) through 2012 (last assessment year).

7 fishing fleets and 7 survey indices.

Annual recruitment-at-age 0 is partitioned among the first three quarters according to estimated parameters and with the fraction occurring in quarter 2 allowed to fluctuate annually. The recruitment in last quarter is set to 0.

Recruitment is based on a Beverton–Holt function parameterized to include the equilibrium level of unexploited recruitment (R0) and the steepness (fixed at 0.999) parameter which describes the fraction of the unexploited recruits produced at 20% of the equilibrium spawning biomass level. Annual recruitments are estimated as deviations from the expected recruitment with a level of variability specified as input parameter (sigmaR = 0.4).

Growth is described through a von Bertalanffy growth curve with the distribution of lengths for a given age assumed to be normally distributed. The CV of these distributions includes two parameters, defining the spread of lengths at a young and old age with a linear interpolation between. All the parameters are fixed and equal to those used or estimated in the working group WGHMM of 2011 (Linf = 130 cm and K = 0.177, L0 = 15.84) (ICES, 2010b). In addition to growth, the relationships between weight-at-length and maturity-at-length are considered fixed along years and seasons.

Recruitment estimates extended back to 1973 in order to provide estimates of initial age composition fluctuations superimposed on the initial equilibrium age composition.

Average annual catch by fleet from 1978-1982 is used as the initial equilibrium catch from which the model estimated the initial equilibrium F for each fleet.

Discard amount and discard size composition for four fleets (Spanish trawl in area VII, French Nephrops in area VIII, Spanish trawl in area VIII and fleets operating outside areas VII and VIII) are included. The discards of the fleet operating outside areas VII and VIII were not included in the previous assessment configuration.

Retention function to separate total catch into discarded and retained portions for these 4 fleets is estimated from a 2 parameter logistic curve for each fleet. The parameters of the curves for Sptrawl7, SPtrawl8 and Others are allowed to change over time in different ways. In 1998 there were changes in the enforcement of minimum landing sizes; in order to model this change different set of parameters are used for the retention curve of Sptrawl7 and Sptrawl8 for the period from 1978 to 1997 and the period from 1998 onwards (i.e. two time blocks in SS). For Sptrawl7 fleet, an additional set of parameters is used to model the retention since 2010 (forming a new time block), following the change in the retention pattern observed in the data. The retention of the Others fleet is very uncertain, due to insufficient data availability and the heterogeneous configuration of the fleet, formed by a mix of gears and countries. In the last years a change in the LFD pattern is observed for the Others fleet, with a shift towards larger fish in the landings which could perhaps be related to the targeting of a strong cohort. This seems to be interpreted by the model by an unrealistically sharp increase in biomass which is well above observed historic levels. To allow more flexibility in the model and improve residual patterns, the selection and retention patterns of this fishery are modelled in two periods. In the first period, from 1978 to 2002, fixed selection and retention patterns are used, and in the second period, since 2003, random walks which generate yearly selection and retention curves are used.

The selectivity pattern for two of the fishing fleets, Trawloth and Others, is calculated using a logistic curve, and for the other five fishing fleets and the surveys using the "double normal" selectivity curve (pattern 24 available in the SS software). The "double normal" pattern uses up to 6 parameters to calculate two half normal curves on either side of a plateau with estimated width.

The catchability coefficient for each tuning fleet is estimated as a time-invariant parameter.

The RESSGASCS survey was conducted quarterly and a noticeable shift in mean cpue was noted among the quarters. Therefore, each quarter's data are defined as a separate survey (with its own catchability parameter) and all four quarters are set up to share the same selectivity pattern.

Sensitivity analysis

Several configurations of the model (data used and model settings) were run before and during the benchmark meeting. In this report, we only present the runs that significantly helped to reach the final model configuration.

The 2013 assessment model fit showed a marked retrospective pattern and a sharp increase in biomass in recent years. In order to identify the data source that more strongly contributed to this behaviour, eight runs were conducted using the same model settings, but removing the length frequency distributions (LFD) of landings for all fleets since 2007 in one on the runs, and then adding the LFD of only one of the fleets at a time in each of the other runs. These model runs showed that the Sptrawl7 and Others fleets were those contributing more to the strong increase in SSB, linking it to a higher recruitment estimate in 2008.

Motivated by the change in the retention pattern observed in the LFD data of Sptrawl7 fleet (section 4.4.3.1) and the poor fit of the model to the discard data in recent years, a third time block was added in the retention pattern (i.e. proportion of catches that are landed, by length class) of this fleet for years 2010 to 2012. The estimated L50% of the retention curve in the third block (2010-2012) was 20 cm higher than in the second block (1998-2009). The estimation of total discards in the last years improved significantly with the change, but the improvement in the fit of corresponding LFD was not clear. The 2008 recruitment estimate was lower using this setting and hence the increase in SSB in the last years was reduced. Besides, a run with the same model configuration but using only the LFD of Sptrawl7 since 2007, produced similar results, which suggested that the information in these dataset used together with the 3 blocks in retention was consistent with the information in the rest of the datasets.

New LFD for landings and discards and new data on total discards of the Others fleet was available since 2003 in InterCatch (section 4.4.3.1). This new data were used to condition the LFD of the landings in the Others fleet since 2003 and of the discards from 2003 to 2008. Since 2009 only total discards were used without LFD. Total landings for this period were not changed. Scotland discards make the major part of the total discards of the OTHER fleet since 2009 , which were not available before this year in InterCatch, and there is no LFD available for them, so it was considered not appropriate to use the LFD available (mainly coming from the Danish fleet) to condition the discards. The retention pattern of the Others fleet was first modelled using two periods, 1978 to 2008 and 2009 to 2013, where the retention curve was maintained fixed. The fit was not satisfactory because the variability of the LFD of both landings and discards was very high; hence it was decided to use a random walk, starting in 2003, to model both selection and retention. The total discards were very well estimated using the random walk approach. The LFD of landings was well fitted and the residuals did not show any pattern. The LFD of discards, except for some large residuals in larger length classes, fitted reasonably well and the residuals did not show any pattern.

The same model configuration was combined with the old LFD for the Others fleet, the new Longline cpue available to the group (section 4.4.3.3) and a random walk in the retention of the Sptrawl7 since 1998. Each of the settings was combined with the previous configuration in a separate scenario. In all the cases the results obtained were similar to those obtained before and there were not significant improvements in the quality of the fit. The old and new LFD for the Others fleet were derived using different LFDs and there were doubts about which of them was more representative of the fleet. As the results were similar, it was decided to use the new LFD because it was derived from the data uploaded into InterCatch, and hence data derivation is more transparent and replicable. Regarding the new Longline cpue, it was decided not to include it into the assessment because, although it gives information about large individuals, it was considered that its suitability should be analysed more in depth before incorporating into the assessment. Finally, the random walk in the retention of the Sptrawl7 did not lead to a significant improvement of the model fit, the likelihood was higher but also the model complexity. The need for additional modelling process (time-varying selectivity/retention) for this fishery was therefore not justified at this stage. Furthermore, in the retrospective pattern from this run, the time-series grouped in two groups which had different trends. This behaviour in the retrospective analysis was not considered good and there were doubts about the stability of the random walk in future assessments when more data would be added.

Results

Summary results from the assessment model are given in Figure 4.4.4.1 and Table 4.4.4.1. In 2012, F (average of F-at-length over lengths 15-80 cm) was estimated at 0.40, and SSB at 148 656 t. Recruitment fluctuation appears to be without substantial trend over the whole series. After a high recruitment in 2008 (575 million), there are 3 consecutive years of low recruitment (between 152 and 214 millions). In the last year the recruitment increases sharply again and reaches its historical maximum (717 million). This recruitment is however very uncertain. From high levels at the start of the series (97 782 t in 1980), the SSB has decreased steadily to a low level at the end of the 90s (23 468t in 1998). Since that year, SSB has increased to the highest value of the series in 2012 (148 656t). From 2007 to 2011 the SSB experienced high increases from year to year (between 14% and 70%). In 2012 the SSB decreased slightly (~2%). The fishing mortality is calculated as the average annual F for sizes 15–80 cm. This measure of F is nearly identical with the average F for ages 1–5. Values of F increased from values around

0.5-0.6 in the late 70s and early 80s to values around 1.0 during the 90s. Since 2006 it decreased sharply with annual reductions between 5% and 17% until 2012 when it increased slightly.

Likelihood profiles on the global scaling parameter R0 (virgin recruitment) were produced for the different data components in the current northern hake SS model (Figure 4.4.4.2). The profiles could be used in the future to investigate model optimization, misspecification and weighting issues, the approach is described by Lee *et al.* (2014).

Table 4.4.4.1. Summary table of the final assessment model configuration.

Year	Recruitment	Biomass	SSB	Landings (t)	Discards (t)	Catch (t)	Yield/SSB	F (15-80 cm)
1978	289284	113297	75748	50551	-	50551	0.67	0.5
1979	269832	122705	95825	51096	-	51096	0.53	0.55
1980	296329	120414	97782	57265	-	57265	0.59	0.66
1981	572831	103357	83225	53918	-	53918	0.65	0.66
1982	393551	95203	67210	54994	-	54994	0.82	0.7
1983	136131	101604	65292	57507	-	57507	0.88	0.63
1984	278518	107833	78403	63286	-	63286	0.81	0.66
1985	617941	93884	75096	56099	-	56099	0.75	0.83
1986	355946	77551	55848	57092	-	57092	1.02	0.94
1987	431794	72900	41138	63369	-	63369	1.54	0.99
1988	495007	74856	44266	64823	2.2	64825	1.46	1.02
1989	478345	75255	43640	66473	72.8	66546	1.52	1.09
1990	491975	69147	41008	59954	-	59954	1.46	1.05
1991	277303	65677	39733	58129	-	58129	1.46	0.99
1992	299682	64714	37952	56617	-	56617	1.49	1.03
1993	511025	57730	37348	52144	-	52144	1.4	1.07
1994	283003	51527	29413	51259	356.2	51615	1.74	1.08
1995	145372	57683	28563	57621	-	57621	2.02	1.13
1996	354820	53146	33834	47210	-	47210	1.4	0.97
1997	243062	45897	29304	42465	-	42465	1.45	1.09
1998	397253	42864	23468	35060	-	35060	1.49	0.98
1999	200089	47158	26944	39814	348.6	40163	1.48	0.96
2000	175086	52508	29678	42026	82.6	42109	1.42	0.9
2001	324260	52594	35213	36675	-	36675	1.04	0.74
2002	256786	55556	36362	40107	-	40107	1.1	0.81
2003	150273	60377	36613	43162	2109.8	45272	1.18	0.81
2004	308001	62700	41561	46417	2552.4	48969	1.12	0.82
2005	206456	58266	39875	46550	4675.8	51226	1.17	0.95
2006	268766	54244	32164	41467	1816.2	43283	1.29	0.85
2007	418013	59837	37481	45028	2191.4	47219	1.2	0.76
2008	574661	73182	42857	47739	3247.7	50987	1.11	0.65
2009	152868	109655	61997	58818	9870.8	68689	0.95	0.57
2010	154544	161034	105103	72799	9414.7	82214	0.69	0.45
2011	214941	184130	151381	79628	13775.0	93403	0.53	0.39
2012	716679	172664	148656	75232	12225.2	87457	0.51	0.4

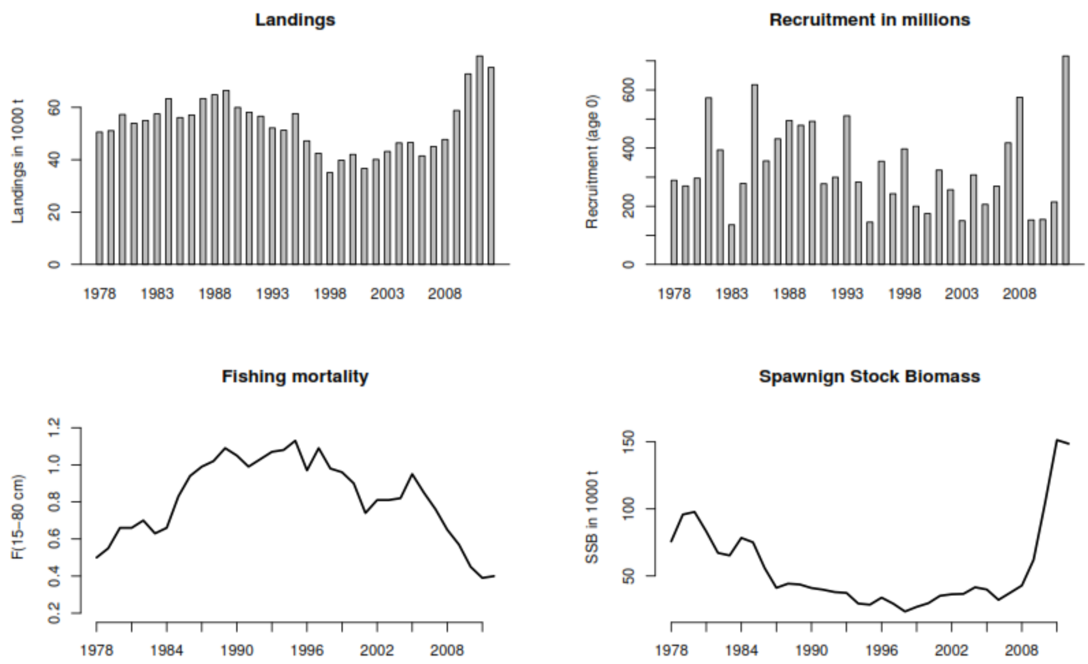


Figure 4.4.4.1. Summary plot of the final assessment model configuration.

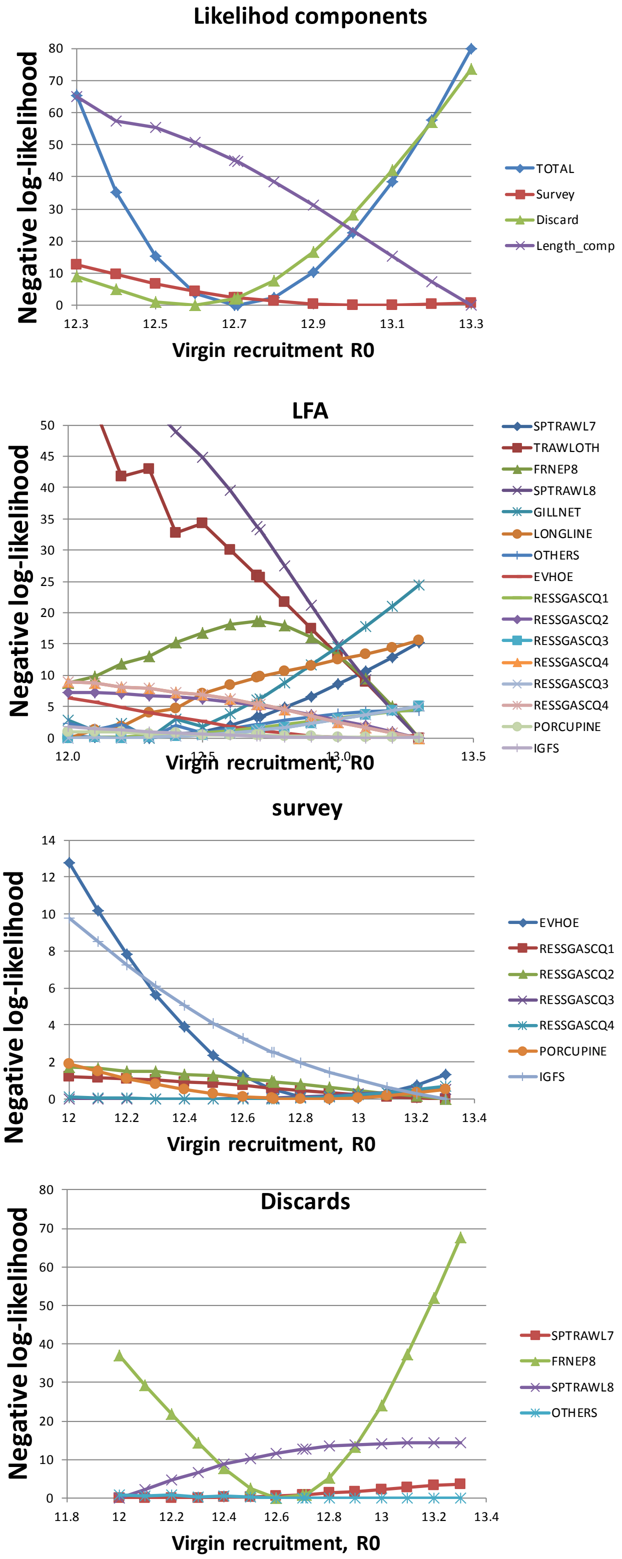


Figure 4.4.4.2. Likelihood profile for the virgin recruitment (R0) parameter estimated under the current base case model. Each line represents the profile for each data component included in the model fit. Profiles are shown for the 3 data components: Total, length frequency (LFA), survey and discards.

Retrospective pattern

The retrospective pattern is shown in Figure 4.4.4.3, in general terms is has not improved with respect to the retrospective pattern obtained in 2013 assessment. There is still a revision upwards of 2008 recruitment, although it has been somewhat minimized. This change in recruitment estimates produces a revision upwards of the SSB and downwards of the fishing mortality in following years. The biggest change is observed when last year data are added.

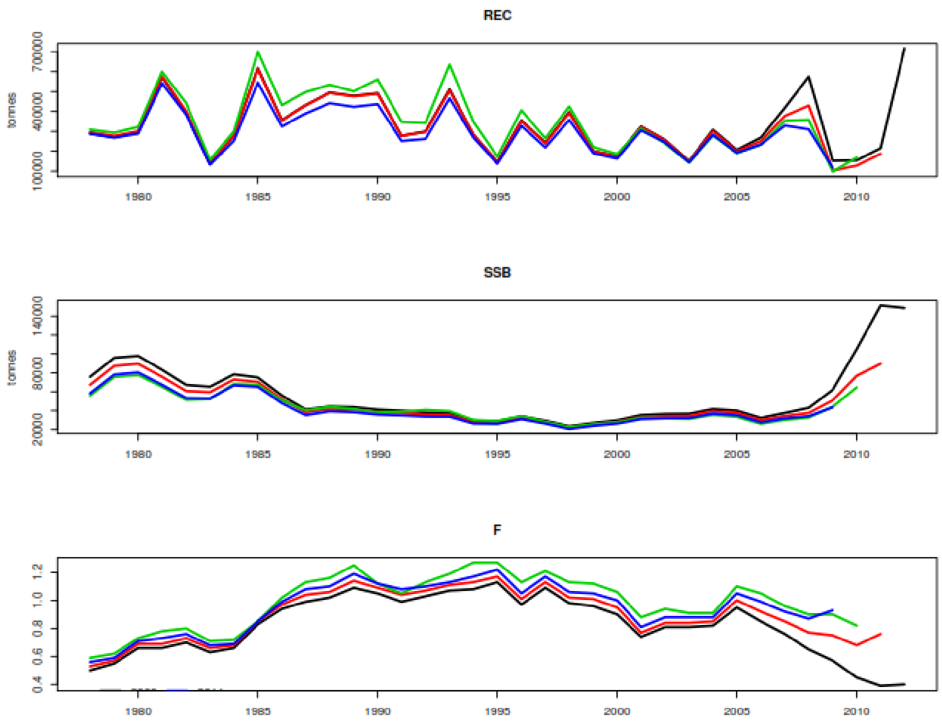


Figure 4.4.4.3. Retrospective plot using final assessment model configuration.

4.4.5 Short-term projections

No changes have been made on the short-term projections in the stock annex see section 6.

4.4.6 Appropriate Reference Points (MSY)

A preliminary exploration of potential MSY reference points was carried out during the benchmark working group using an approach derived from the approach used in the Plot-MSY software (WKFRAME, 2010; WKMSYREF, 2013).The PlotMSY software was developed by Cefas in 2010 in order to support the estimation of yield-per-recruit and MSY-based fishing mortality reference points, and was applied in ICES WGs for a number of stocks. This software programme has, however, been developed for an age-based population dynamics model with yearly time-steps. Northern hake is assessed using SS3, with quarterly time-steps and with 4 quarterly groups of hake by year (each group corresponding to a quarter of birth), which makes it impossible to use the above mentioned programme. A dedicated analysis has thus been developed for northern hake.

This estimation of MSY is conducted by combining the yields per recruit with the stock–recruitment relationships, using a deterministic equilibrium approach based on the replacement line and its intercept with the stock recruitment curve. In the present analysis, as in

PlotMSY, three stock recruitment relationships (Ricker, Beverton and Holt and Smooth Hockey stick) are fitted to historical series of recruitment and SSB estimated by SS3. The data used for this analysis come from the approved stock assessment carried out during WKSOUTH (Table 4.4.6.1).

Table 4.4.6.1. Historical series of SSB and recruitment estimated at WKSOUTH with SS3 and used to fit the 3 stock recruitment relationships.

Year	Rec	SSB
1978	289284	75748
1979	269832	95825
1980	296329	97782
1981	572831	83225
1982	393551	67210
1983	136131	65292
1984	278518	78403
1985	617941	75096
1986	355946	55848
1987	431794	41138
1988	495007	44266
1989	478345	43640
1990	491975	41008
1991	277303	39733
1992	299682	37952
1993	511025	37348
1994	283003	29413
1995	145372	28563
1996	354820	33834
1997	243062	29304
1998	397253	23468
1999	200089	26944
2000	175086	29678
2001	324260	35213
2002	256786	36362
2003	150273	36613
2004	308001	41561
2005	206456	39875
2006	268766	32164
2007	418013	37481
2008	574661	42857
2009	152868	61997
2010	154544	105103
2011	214941	151381
2012	716679	148656

Uncertainty in reference points calculations is incorporated through the parameters of the stock–recruitment relationship only. Parameters of this relationship are estimated with

ADMB and uncertainties around the estimates are characterized using the MCMC functionalities in ADMB. For a given set of parameters in the stock–recruitment relationship, the calculation of the corresponding F_{MSY} is deterministic. Combinations of YPR, SSBPR and S-R curves allow then to estimate F_{MSY} and F_{crash} reference points with uncertainty.

The fits of the stock recruitment relationship are presented in Figure 4.4.6.1. Beverton and Holt and Hockey stick model give similar results in terms of expected recruitment levels at high level of SSB (R is around 300 million individuals). Breakpoint of the smooth Hockey-Stick model is estimated at a level of SSB of about 40 000 tonnes while based on the Beverton and holt model, expected recruitment start to decrease for lower level of levels of SSB (25 000 tonnes).

Equilibrium yield and SSB based on the three stock and recruitment models estimates are presented in Figures 4.4.6.2-4, together with box plots of F_{MSY} and F_{crash}, and proxies for F_{MSY} based on the yield-per-recruit (F_{max}, $F_{0.1}$), and based on SSB per recruit ($F_{30\%}$ and $F_{35\%}$ SPR). Values of F reference points estimated for the 3 stock recruitment relationships are presented in Table 4.4.6.2. Natural mortality (sometimes also considered as a potential F_{MSY} proxy) for this stock is assumed to be M=0.4.

For the three S/R models, F_{MSY} is estimated with reasonably tight bounds (although it must be noted that only a rather limited amount of uncertainty has been incorporated in the analysis) and well below F_{crash}. F_{crash} is estimated the lowest of all for the Hockey-stick model (1.12). Estimates of F_{MSY} for the Hockey-stick and the Beverton and Holt models are 0.26 and 0.24, respectively, not "very far" from the current F_{MSY} proxy $F_{30\%}$, which is estimated to be 0.22. As expected, particularly given the shape of the Ricker SR fit in Figure 1, F_{MSY} for the Ricker model is much higher, 0.57.

Table 4.4.6.2. Estimates of F reference points for 3 stock–recruitment relationship (for F_{MSY} and F_{crash}, average values are presented)

		per recruit analysis	Hockey-Stick	Beverton-Holt	Ricker
F2012	0.40				
Fcrash			1.12	2.02	1.40
FMSY			0.26	0.24	0.57
Fmax		0.25			
F0.1		0.16			
F35%		0.19			
F30%		0.22			
F=M	0.4				

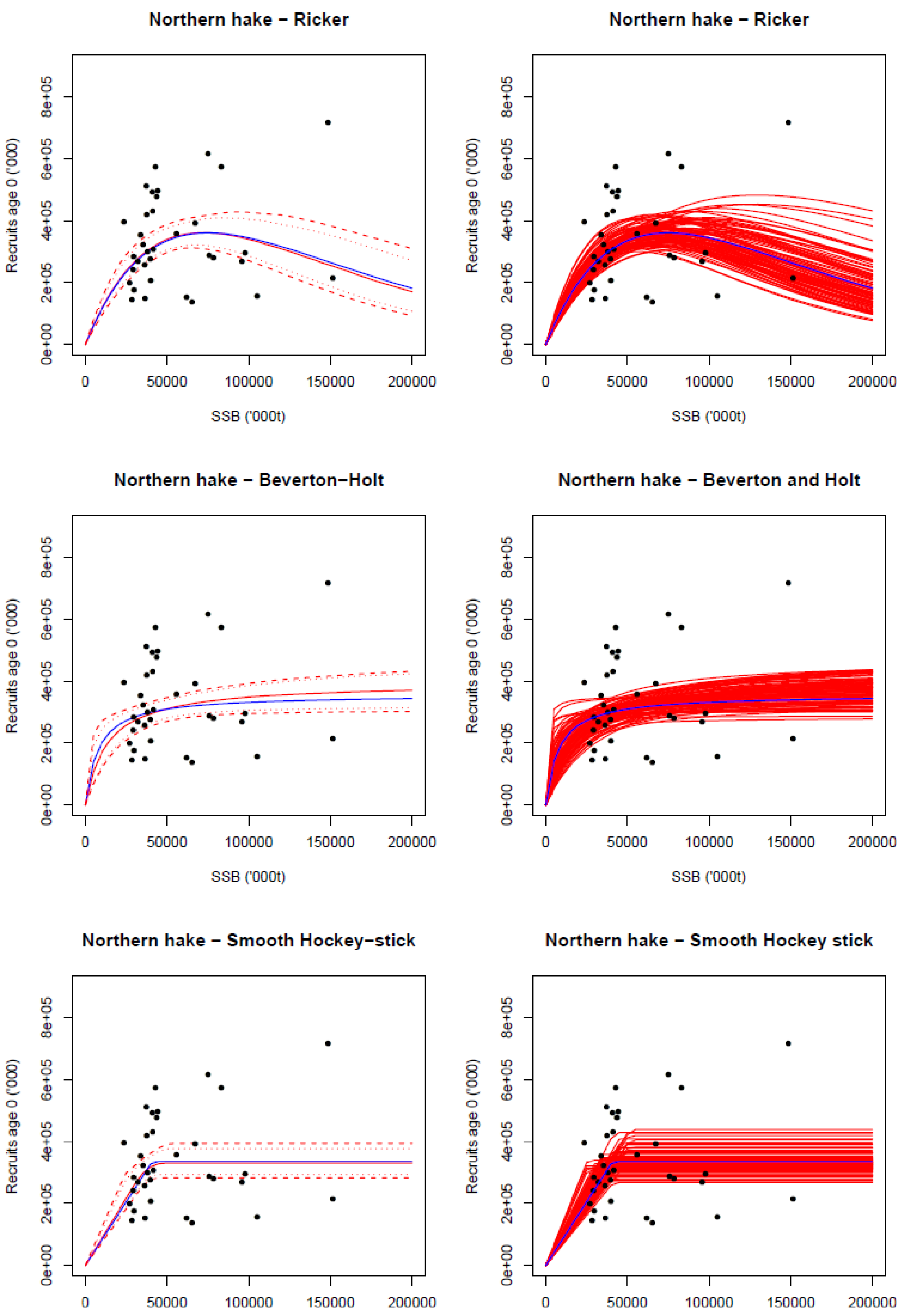


Figure 4.4.6.1. Northern hake stock-recruit fits for Ricker (top), Beverton–Holt (middle) and smooth hockey stick (bottom). The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative resamples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.

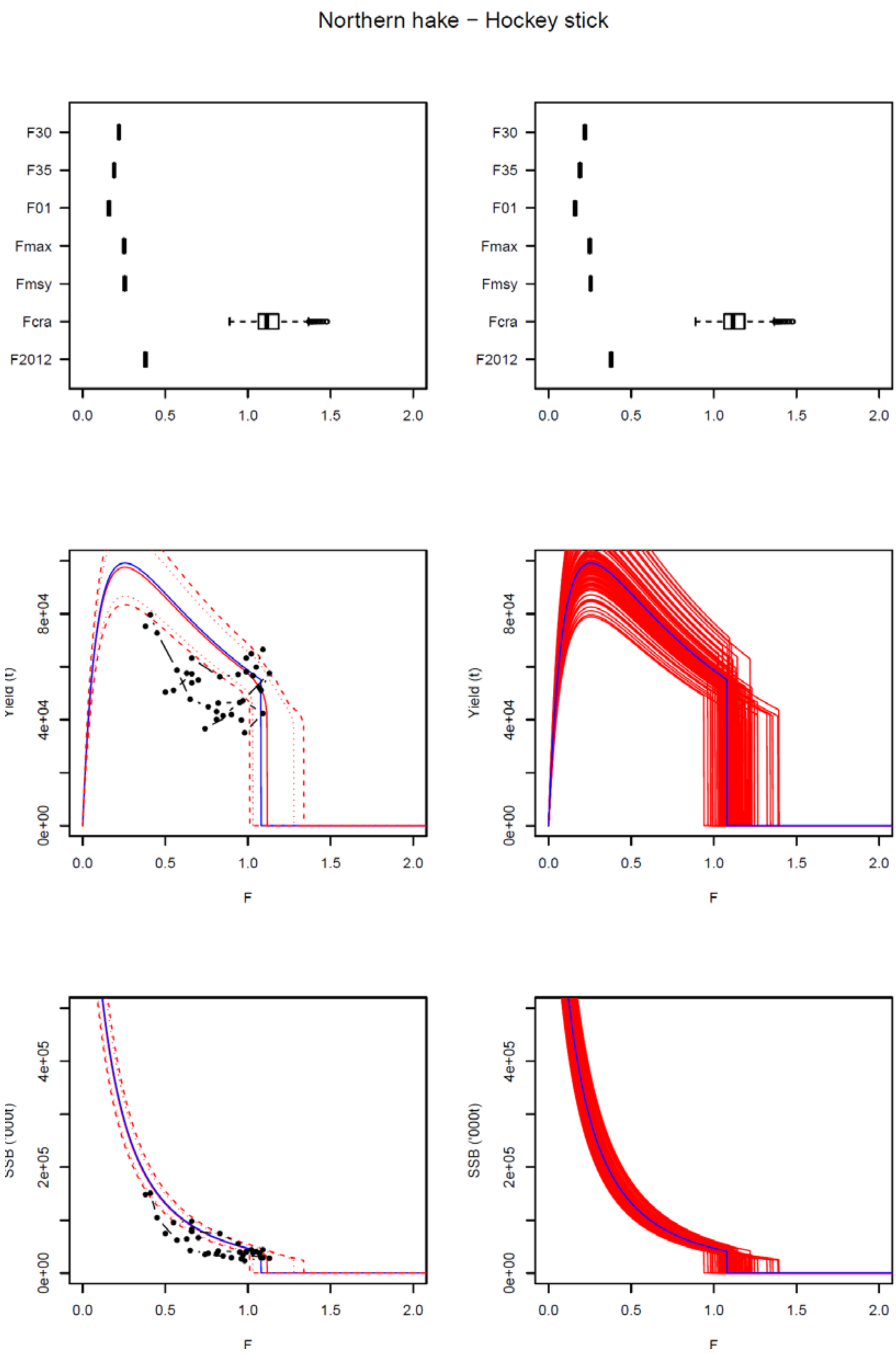


Figure 4.4.6.2. Northern hake yield and SSB based on the Hockey-stick stock and recruitment model estimates. Top: box plots of F_{MSY} and F_{crash} with proxies for F_{MSY} based on the yield-per-recruit: Fmax, F0.1, F30% and F35% SPR also F in the final year; middle: equilibrium landings vs. fishing mortality; bottom: equilibrium SSB vs. fishing mortality. The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the successful MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative resamples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.

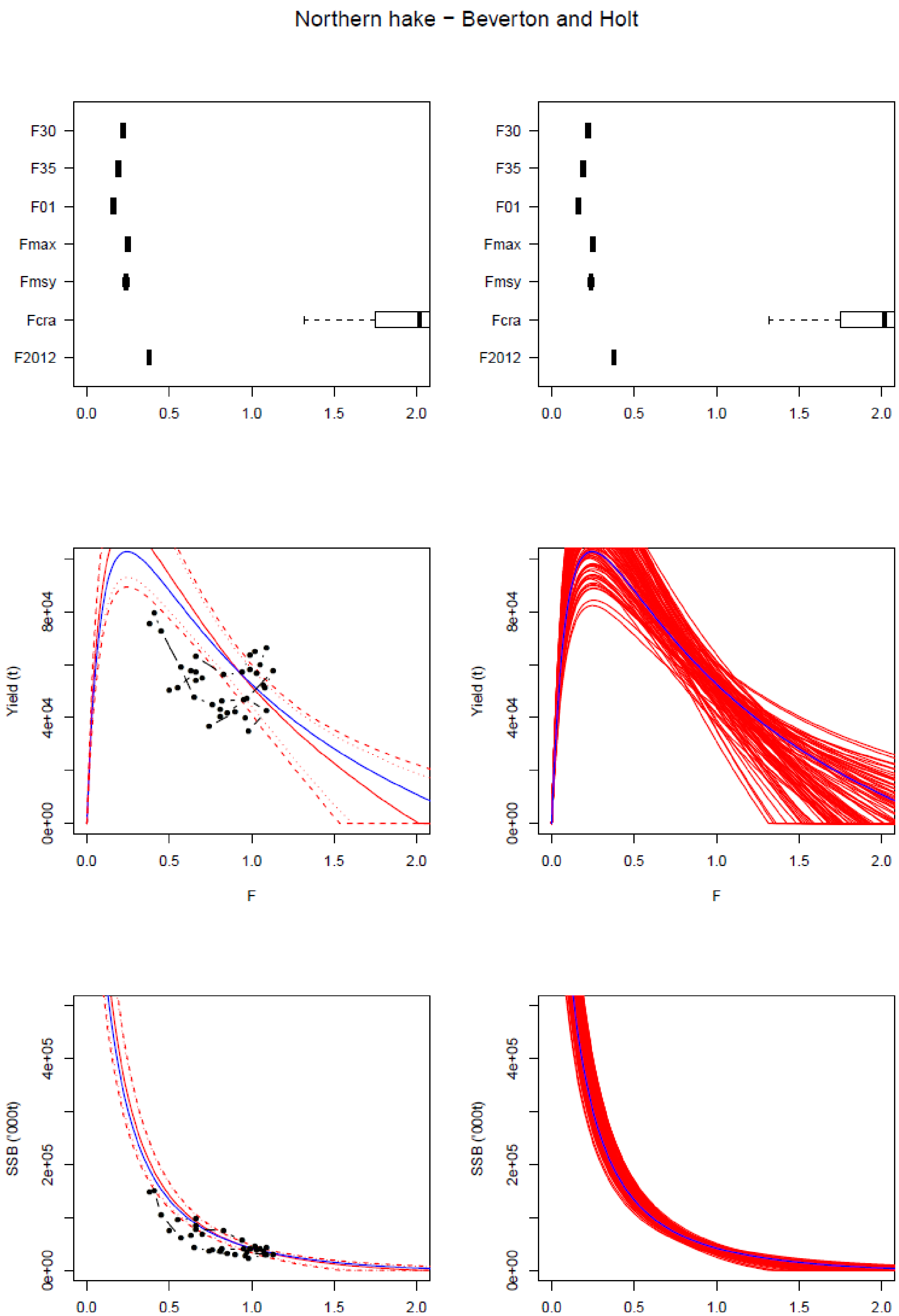


Figure 4.4.6.3. Northern hake yield and SSB based on the Beverton and Holt stock and recruitment model estimates. Top: box plots of F_{MSY} and F_{crash} with proxies for F_{MSY} based on the yield-per-recruit: Fmax, F0.1, F30% and F35% SPR also F in the final year; middle: equilibrium landings vs. fishing mortality; bottom: equilibrium SSB vs. fishing mortality. The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the successful MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative resamples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.

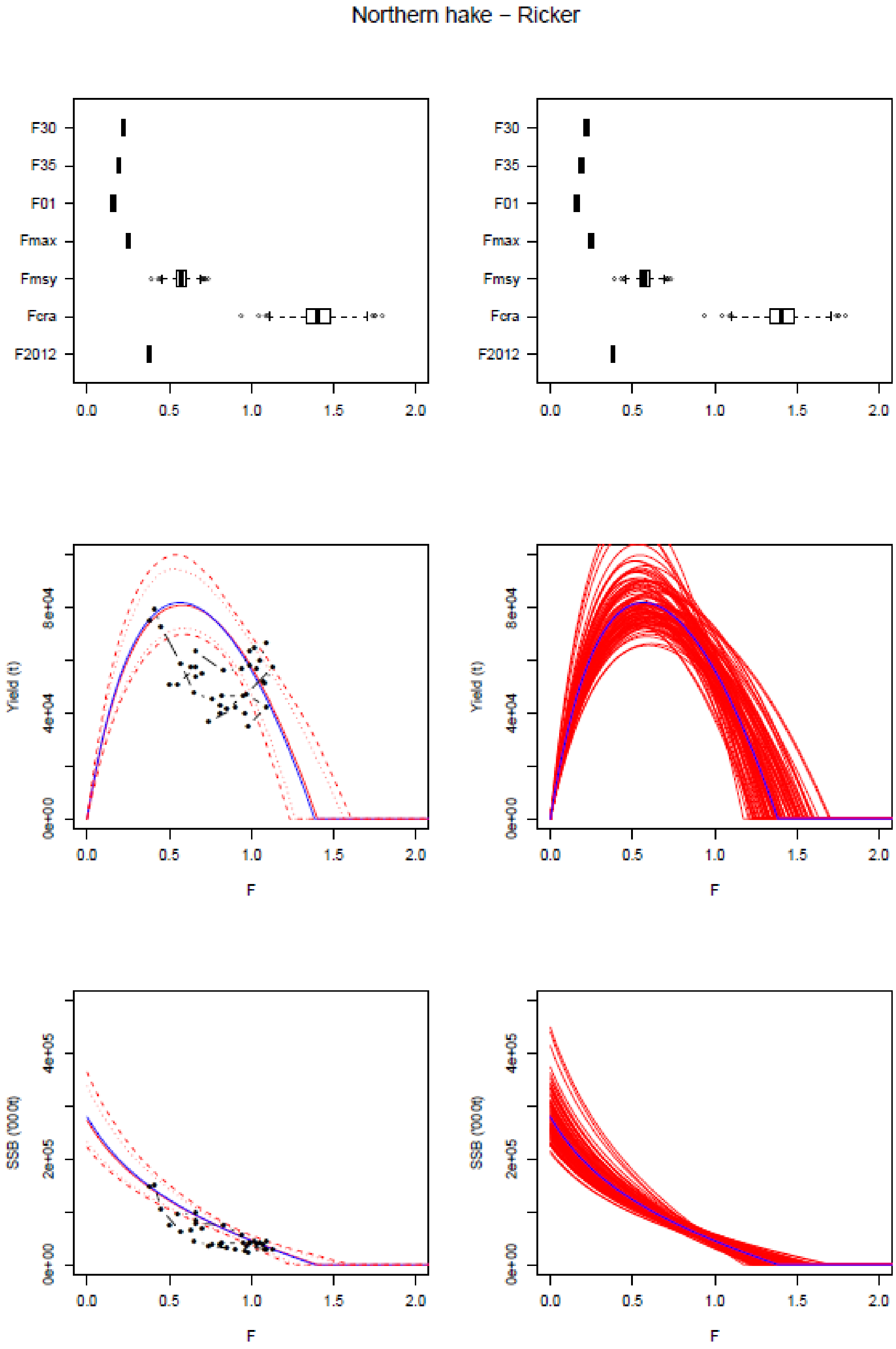


Figure 4.4.6.4. Northern hake yield and SSB based on the Ricker stock and recruitment model estimates. Top: box plots of F_{MSY} and F_{crash} with proxies for F_{MSY} based on the yield-per-recruit: Fmax, F0.1, F30% and F35% SPR also F in the final year; middle: equilibrium landings vs. fishing mortality; bottom: equilibrium SSB vs. fishing mortality. The left hand figures illustrate the 95th, 90th, median, 10th, and 5th percentiles from the successful MCMC samples, plotted with the assessment data points; the right hand figures provide 100 illustrative resamples. The estimates derived from MCMC sampling are in red; the deterministic estimates in blue.

Conclusion and recommendations

Due to time constraints and limits in the current version of the software available to estimate MSY references points for northern hake, the group was not in a position to propose any potential reference points. The results obtained during the benchmark should thus be further considered during the assessment working group (WGBIE).

The only source of uncertainty which has been accounted for in this analysis is coming from the parameters of the stock–recruitment relationship. The benchmark group considers that incorporating more sources of uncertainty as suggested by WKMSYREF2 is needed in order to analyse the impact of fishing at a selected F_{MSY} on stock biomass (e.g. to obtain a realistic estimate of the probability that long term SSB is below Blim, which should be of 0.05 or less). It must be ensured that the selected F_{MSY} is within precautionary limits. The analysis would include uncertainty on the biological parameters, such as natural mortality, maturity, mean weight at length, and fishery parameters such as selectivity at length by fleet. Biomass reference points (Blim and MSY Btrigger) will also have to be considered.

4.4.7 Future Research and data requirements

Model improvements

- -Explore sex-specific models similar to Southern Hake.
- -Improve the standard deviation assumptions taken for the random walk on selectivity/retention parameters of fleet 7 (Others). The Grant-Thompson iterative tuning approach could be used to fine tune the SDs.
- -Stock Synthesis offers selectivity functional forms that are more flexible than the double normal (e.g. cubic splines). These could be considered in the future to better track the recent 2007 cohort in many fleets.
- -Substantial improvement was made in the model fit to the recent length composition data of Fleet 7 (Others) through time-varying selectivity and retention (random walk). Improvements were also made on Fleet 1 SPTRAWL7 using wider time blocks, but not as strong as those obtained for Fleet 7 OTHERS. Continue to explore more flexible options for time-varying selectivity/retention.
- -Review growth assumptions (growth curve and variability of the length-at-age assumptions, including sex-specific growth).
- -Review natural mortality assumptions.
- -A more flexible Richards growth model is available in Stock Synthesis which could be used as an alternative to the VB. Consider once again (as was done previously) estimating growth internally (estimating K while fixing Linf).
- -Recent strong cohorts may have resulted in recent density-dependent mechanizms, such as changes in growth which are contributing to residual pattern in the length composition data of retained catches and discards. Time-varying growth options available in Stock Synthesis could be explored to improve model fit (time blocks in K, cohort specific growth options).
- -A preliminary exploration of potential MSY reference points was carried out during the benchmark working group using an approach derived from the approach used in the PlotMSY software and recommended by WKMSYREF2. The approach needs to be developed further with the inclusion of further uncertainties. This work will be carried out intersessionally and presented at WGBIE

Data improvements

- -The dataset for Fleet 7 OTHERS is currently a combined mixed fishery fleet from different fleets/countries. Given the importance of this fleet in model tuning (especially given the larger individuals caught), it is preferable to split the fleet in the most appropriate way. In order to achieve this, countries (which could include Norway, Scotland, Spain, Denmark, the Netherlands, Belgium, Germany, and Sweden) should start uploading the required length based data.
- -A similar process could be considered for other fleets. Furthermore, part of the OTHERS fleet may be better modelled as part of one of the other fleets in the model.
- -Start/continue to compile/collect as much sex-specific data as possible to provide information for the sex-specific model.
- -There are several survey datasets covering different areas. This utility of combining these could be considered.
- -There is currently a lack of survey information for the more northern areas. Incorporating more data from these regions should be considered.

4.5 Southern Hake

4.5.1 Issue list

There a number of issues which are specific to the Southern hake (specifically related to the Gadget model for that stock), and several which are common between the Southern and Northern hake. These common issues include modelling the sexual dimorphism, changes in discard patterns, limited availability of discards estimates and limited data on the larger fish.

4.5.1.1 Model

- The main issue identified with the model was the difficulty in obtaining convergence, and the existence of incorrect solutions with improved likelihood fits. This is described in section 4.5.3.5, and suggested measures to remedy the problem are in 4.5.6
- The model has a single sex structure. Given the strong sexual dimorphism in the population this is major model misspecification. With the increasing number of large fish in recent years, addressing this misspecification is becoming more important.
- Change recruitment estimation in the model to recruitment in all 4 quarters; estimating starting length directly may better model the smallest recruits.
- It is likely that the changes in discard patterns seen in the Northern hake (sections 4.4.1.2 and 4.4.3.1) apply to some extent also in the south. This should be explored within the model.
- The model presented during WGHMM 2013 was accepted without identifying any main problems beyond the optimization difficulties described below. The goal for the benchmark was to improve this model implementing new information for the beginning of the time-series (WD 02, Cerviño and Saavedra, 2014) and exploring hake biology (growth and natural mortality (M)) issues through life-history analysis (WD 03, Cerviño and Michielsens, 2014), growth in first stages and seasonal recruitment. The initial runs to implement these issues in GADGET showed problems with the optimization. Therefore, the optimization was identified as the main problem to be addressed during the WKSOUTH, leaving aside the other

problems mentioned before given the long time needed to optimize any possible configuration for the hake GADGET model. The work has confirmed that the model fitting procedure is finding a genuine optimum and can thus continue to be used as the assessment model. Further work to improve the optimization characteristics of the model has been suggested. A summary of the work performed to identify the cause of the problems and any potential solution is described in section 4.5.3.5.

4.5.1.2 Data

- Moving to a sex separated model is desirable, and this requires that some sex separated data are available
- Discards are provided but not for all years.
- Six tuning series, including one new trawl cpue for a larger fish abundance indicator at the beginning of the time-series. (WD 02, Cerviño and Saavedra, 2014) The series was evaluated and considered suitable to be implemented in the model, however due to the optimization issues this was not done during the current benchmark.
- Growth and other biological parameters to be reviewed along with Northern Hake (WD 03, Cerviño and Michielsens, 2014)
- Review of Length Weight relationship (No changes in mean figures – mean weight at length)

4.5.2 Scorecard on data quality

A scorecard on the quality of the data used in the benchmark process was discussed during the benchmark meeting. No analysis was performed to provide scores, which were only based on qualitative judgment from national stock coordinators. . Many doubts appeared whilst completing the table and it should be considered as tentative, meanwhile more clarifications, analysis and expert contributions are provided.

4.5.3 Stock Assessment data

4.5.3.1 Catch – quality, misreporting, discards

Southern Hake catches by country and gear for the period 1972-2012, as estimated by the WGHMM, 2013), are given in Table 4.5.3.1. Spanish landings data until 2010 were scientific estimates. Landings data for 2011 and 2012 are official landings. Discrepancies between national landings and scientific estimates were included as unallocated landings. In 2012, Portuguese landings were 2 607 t, slightly above those from 2011 (2 214 t). Spanish official landings in 2011 (6 462 t) and 2012 (5 831 t) are considered unreliable compared with those from previous years (16 839 in 2009 or 13 033 in 2012). Unallocated landings are 8 396 t in 2011 (49% of total landings) and 6 136 t in 2012 (42% of total landings). Total landings in 2011 were 17 072 t and 14 573 t in 2012. Total discards in 2011 were 1 893 t and 1 992 in 2012. Total catches were 18 965 t and 16 565 in 2011 and 2012, representing a 13% catch reduction.

4.5.3.2 Surveys

Biomass, abundance and recruitment indices for the Portuguese and Spanish surveys respectively are presented in Table 4.5.3.2.1 and Table 4.5.3.2.2 and Figure 4.5.3.2.1. The Spanish (SpGFS-WIBTS-Q4 and SPGFS-caut-WIBTS-Q4) and the Portuguese (PtGFS-WIBTSQ4) surveys are used to tune the model, by fitting the model estimates to the observed length proportions and survey trends. Since 1989 the Portuguese Autumn survey (PtGFS-WIBTS-Q4) has shown variable abundance indices with a minimum in 1987 and maximum in 2009. The survey was not performed in 2012. The Spanish groundfish survey (SpGFS-WIBTS-Q4) shows low values for biomass and abundance in early 2000s. These values increased from early 2000s and peaked to a historical maximum in 2009 and have remained stable since.

The recruitment indices of the SpGFS-WIBTS-Q4, SPGFS-caut-WIBTS-Q4 and PtGFSWIBTS-Q4 (Figure 4.5.2) were highly variable in the past showing good recruitments in recent years. In 2012, SpGFS-WIBTS-Q4 and SPGFS-caut-WIBTS-Q4 are around the historical mean.

4.5.3.3 Commercial catch-effort data

Effort and landings series are collected from Portuguese logbooks and compiled by IPMA. Spanish sales notes and Owners Associations data were compiled by IEO to estimate fleet effort until 2012 and are presented in figure 4.5.3 and table 4.5.5. These data are scientific estimations based on some selected fleets from some harbours. Since the fleet dynamics are complex and include temporal movements among harbours, these values are mainly valid for LPUE trends and their use to follow landings or effort trends should be done with caution.

The two fleets included for tuning the assessment model are SP-CORUTR and P-TR. The LPUE of SP- CORUTR peaks in 2011 with 47 kg per fishing day and 100 HP. In 2012 the LPUE is the second highest with 42 kg per fishing day, similar to the mean in 2008-12. P-TR data for 2011 and 2012 are not available. The LPUE trend was increasing until 2010, with a peak of 43 kg / hour (standardized series). Data for SP-CORUTRP, SP-VIMATR, SP-SANTTR have never been included in the model and were not available in 2012.

The standardized LPUE from the Portuguese bottom-trawl fleet targeting roundfish has been routinely calculated by fitting a GLM to logbook data on landings and effort. Since 2012, logbook data have been received in different formats compared with previous years. Additionally, 2012 data were only partially available due to the implementation of the electronic logbooks in mid-year. For the moment only the last paper-based logbooks were standardized, as catch and effort data were unavailable for 2011 and 2012. These situations require some time to be corrected and therefore it is expected that during 2013 it be possible to regain a degree of control over the way data are processed. Consequently, estimates of Portuguese bottom-trawl cpue for 2011 and 2012 were not available for the benchmark meeting.

4.5.3.4 Length, weights, maturities, growth

Length Composition

Table 4.5.3.4.1 presents the length compositions of catches (landings and discards) and mean length for 2012. Mean size in landings is 36.6 cm and 19.9 cm for discards, similar to previous years.

Growth, Length-weight relationship and M

An international length-weight relationship for the whole period has been used since 1999 (see Annex 1). The assessment model follows a constant von Bertalanffy model with fixed

Linf = 130 cm, t0=0 and estimating the k parameter. Natural mortality was assumed to be 0.4 year-1 for all ages and years.

Maturity ogive

The stock is assessed with annual maturity ogives for males and females together. The maturity proportion in this assessment year is shown in Figure 4.5.4. L50 in 2012 is 31.5 cm, which is less than in previous years when L50 was relatively stable around 36-37 cm.

4.5.4 Assessment model

The assessment carried out used the gadget model (length-age based) as decided by WKSOUTH (2014) and described in the stock annex (Annex 1).

An issue was identified during one of the WebEx meetings prior to the benchmark that the model may not have been optimizing correctly, and that much of the variation seen between scenarios was in fact due to varying non-optimized solutions. This issue had not previously been identified. As a consequence, much of the work on the Southern hake model at the benchmark focused on the optimization of the model, and verifying that a genuine solution had been obtained. Additional GADGET experts from outside the group (Gudmundur Thordason and Bjarki Elvarsson from Iceland) were involved in part of this analysis.

It was discovered that choosing "unrealistic" initial parameter values for the start of the optimization could result in extremely long optimization times. It appears that the likelihood surface is rather complex, with regions of nearly flat likelihood values. Furthermore in some cases the optimization could result in unrealistic results but extremely low likelihood misfit scores. This appears to be due to artificially good fits to the likelihood components on the small fish, with an extremely large population of fish (often very slow growing) fitting the length distribution in the surveys very well, at the expense of not fitting the length distributions in catch data. Despite the extreme misfit to the larger fish, the overall fit (as measured by the likelihood score) is good, as the majority of the data are on the smallest fish. Adding a second dataset on these larger fish, if possible, may remedy this issue. It is possible that the complete lack of age data, and the limited data at the start of the assessment period, may also be leading to difficulties in obtaining good solutions.

Checks of the model approved at the previous benchmark indicated that this problem has not been recently introduced, but was an existing feature in the model, which had not previously been encountered.

The work done at the benchmark meeting was not able to significantly improve the optimization time, nor resolve the issue of artificial but unrealistic "good" fits. However the "base case" solution was thoroughly checked. Diagnostics (Figure 4.5.5) indicate that an optimum has been found, and that further optimization (within relatively tight bounds) does not alter this solution. In the tests conducted, no better solution was found, and small deviations in the starting parameter values for the optimization resulted in the same solution being obtained. It therefore seems likely that this is a valid solution, and that the small differences required in an update assessment should be within the scope of the current optimization procedure, especially given that there is time available such that the model can have a rather long optimization time to reach a solution prior to the start of the assessment working group.

However, the group recommends that work be conducted in the future to improve the optimization characteristics of the model. Faster, more reliable, optimization is required in order to develop the model further. In particular, the existence of unrealistic solutions with low likelihood scores needs to be resolved. As mentioned above, increasing the data on larger fish may well help both the speed and stability of the optimization.

Model diagnostics

Likelihood profiles for each parameter estimated by the model are presented in Figure 4.5.5. This analysis is carried out for each parameter individually and it should be noted that no method can guarantee that the model found the absolute minimum. This does however check that the minimization algorithm found a minimum. The values on the horizontal axes of the plots represent multiplicative factors with respect to the estimated parameter value. To check for convergence the minimum likelihood value must correspond to the estimated parameter value (i.e. the multiplier 1). The change in likelihood may be very large if the model gives "understocking", i.e. if it is not able to produce enough fish to subtract the observed catches from the modelled population, hence the severe asymmetries seen for some parameters. Due to the distinct impact each parameter has on the likelihood value, the plots are presented scaled and unscaled. In Figure 4.5.5, all parameter estimates correspond to the minimum of the likelihood.

Residuals for surveys and abundance indices (SpGFS-WIBTS-Q4 and PtGFS-WIBTS- Q4) and commercial fleets (SP-CORUTR and P-TR) are presented in Fig 4.5.6a-b, grouped in 15 cm classes (from 4 to 49 in surveys and 25 to 70 cm in commercial fleets). Most residuals are within the range of -1 to 1 (±1 s.d.). Surveys' residuals show a random distribution without any trend. The survey PtGFS-WIBTS-Q4 was not performed in 2012. Regarding commercial fleets, P-TR (25-40 cm) was not available for 2011 and 2012. P-TR (25-40 cm) shows a downward trend in more recent years. The difficulty of these indices to follow the abundance generated by the recent increase in recruitment may be due to the fact that discards are not included in the computation of it. Apart from this, the fits are quite consistent.

Figures 4.5.6 (c-i) present bubble plots of residuals for proportions at length. These proportions are grouped by 2 cm classes for all "fleets" used in the model calibration (see Stock Annex for descriptions). The model fits these proportions at length assuming a constant selection pattern for every "fleet" in the years and quarters in which length distributions are observed. The quality of the fit is different for different datasets, but not all of them contribute equally to the overall model fit. Projections are based on the selection patterns estimated only for landings (4.5.6-d) and discards (4.5.6- f). The residual analysis shows that there is an underestimation (positive residuals) in the most exploited lengths and overestimation on the larger sizes (negative residuals). Such patterns are not of major concern given that the residuals' values are quite small (maximum ~0.3). The model takes into account the data precision when weighting the individual likelihood components (defined in Stock Annex), so datasets with larger model residuals will have less impact on the overall model fit.

Estimated parameters

The model estimates selection parameters for each "fleet" for which length proportions are fitted. Furthermore it estimates the von Bertalanffy growth parameter k. Results are presented in Figure 4.5.7. The selection patterns of different "fleets" of catches (catches in 1982-93; landings in 1994-2012; discards 1992-2012 and Cadiz landings (1982-2004) are presented in the upper plot. The pattern corresponding to catches during 1982-93 shows higher relative efficiency for smaller fish (when compared with catches from 1994 onwards), which is in agreement with our assumption that before 1992 (when the minimum landing size was implemented) the importance of discards was relatively lower. The discards (1992-2012) and landings (1994-2012) selection patterns are used for projections.

Survey selection patterns are presented in the lower selection pattern panel. The Portuguese survey PtGFS-WIBTS-Q4 catches relatively larger fish than the Spanish surveys (SpGFS-WIBTS-Q4 and SPGFS-caut-WIBTS-Q4). Both Spanish surveys show a similar pattern, they are both performed with the same vessel and gear.

The von Bertalanffy k parameter was estimated to be 0.164, similar to the previous assessment (0.165).

Historic trends in biomass, fishing mortality, yield and recruitment

Model estimates of abundance at length at the beginning of the 4th quarter are presented in Figure 4.5.8. The figure shows a general increase of small fish after 2004 that contributes to an increase of large fish in more recent years.

Table 4.5.7 and Figure 4.5.9 present summary results with estimated annual values for fishing mortality (averaged over ages 1-3), recruitment (age 0) and SSB, as well as observed landings and discards.

The recruitment (age 0) is highly variable and presents two different periods: one from 1982 to 2003 with mean figures around 70 million, ranging from 40 to 120, and a recent period from 2004 to 2012 with a mean of 114 million ranging from 60 to 160 million. Fishing mortality increased from the beginning of the time-series (F=0.36 in 1982) peaking in 1995 at 1.18; declining to 0.77 in 1999 and remaining relatively stable until 2009 (F=0.95). There was a further decline in recent years to 0.57 in 2012. The SSB was very high at the beginning of the time-series with values around 40 000 t, then decreased to a minimum of 5 900t in 1998. Since then biomass has continuously increased reaching 20 900 in 2012.

Retrospective pattern for SSB, fishing mortality, yield and recruitment:

Figure 4.5.10 presents the results of the assessments performed using the retrospective dataseries from 2012-2008. There is a clear trend in the retrospective pattern for recruitment, F and SSB. The recruitment shows high variability with a tendency to be overestimated. SSB also shows a tendency to be overestimated in contrast to F which is underestimated.

4.5.5 Short-term projections

The methodology used was approved by the benchmark (WKSOUTH, 2010) and described in the Stock Annex (Annex 1). Results are presented in Figure 4.5.11 and Table 4.5.8. Note that GADGET is length based and F multipliers do not apply linearly to the age-based Fbar, e.g. if Fmult is 1, F (meaning F averaged over ages 1-3) is 0.57 and if Fmult=0.5 produces F is 0.27.

In 2013 the expected SSB is 25 392 t. Fsq for the intermediate year (2013) is estimated as the average of the last 3 assessment years and scaled to the F in last year since there is a reduction trend in F for recent years. Recruitment for 2012 was not accepted because of the uncertainties shown in the retrospective analysis. Recruitment used for projections in years 2012-14 was the geometric mean of 1989-2011 (81 100 thousands)

During the intermediate year, 2013, the expected yield (landings) is 17 723 t and the SSB at the end of the year is expected to be 27 393 t.

Different F multipliers applied in 2014 provide management alternatives according to different scenarios. Under Fsq (0.57) the expected yield would be 18 155 t and SSB in 2015 would be 26 627 t. Decreasing F by 10% (0.51), the yield and SSB would be 16 750 and 28 934 t. With the MSY transition scheme F would be 0.33, yield 12 025 t and SSB 36 861 t. If landings in 2014 correspond to a 15% increase with respect to the 2013 TAC, then landings are 12 266 t, corresponding to F = 0.49 and SSB in 2015 is 29 717 t. At Fmax (Fmsy proxy = 0.24) yield in 2014 would be 9 171 t and SSB in 2013 41 764 t.

4.5.6 Appropriate Reference Points (MSY)

Fmax (F=0.24) is the Southern hake Fmsy proxy. No other reference points are defined (Figure 4.5.12)

4.5.7 Future Research and data requirements

Modelling improvements:

- -The group notes that there exists funding through an EU project (MareFrame) to improve the Southern hake model, including working with GADGET modelling experts, in order to use the hake model as the basis of a multispecies model. This gives an opportunity to address a number of the modelling issues listed below.
- -Long run times and optimization issues with the GADGET model for southern hake presented limitations for model exploration during the benchmark meeting. Most time at meeting was devoted to checking that the model was consistently reaching an optimized solution. Improving the speed and stability of the optimization should be considered a priority for this stock, and a precursor to any of the other work suggested here. This work should be conducted in collaboration with experts in the GADGET model. Possibilities include: reducing the bounds on the parameter space to search, increased data (or weighting) on the larger fish, reformulating the surveys to reduce the number of different components to match, ensuring compatibility of order of magnitudes between datasets where possible, better data on the start of the time range, splitting the sex structure to reduce model misspecification.
- -Given the high sexual dimorphism in the stock, moving to a two sex assessment model would seem to be worth investigating. This could be achieved via externally estimated growth rates imported into the model; however it would be preferable to include enough sex split data to enable the model to estimate at least some growth parameters directly.
- -The high population at the start of the assessment period needs to be investigated further. There is little data currently in the model to tune this period, and therefore these results must be considered unreliable. Possibilities for further work here include adding further data to better constrain the model in this period, or starting the model at a later point to avoid this period entirely.
- -It would seem possible that the issues identified in the Northern hake concerning changing selection and discard patterns in the most recent years may also apply to the Southern hake. This should be investigated by exploring the introduction of time-varying retention and selectivity to minimize residual pattern.
- -In some of the diagnostics presented it appeared that the model may not be accurately modelling the timing of recruitment, giving misfits to data for the smallest fish in some years. At present the model assumes recruitment is occurring with an even split between the first two quarters. This could be extended to all quarters and/or annual variability of the recruitment pattern could be allowed.
- -Related to the timing of recruitment, the initial length of the recruits should be estimated as one or more parameters, rather than being calculated from the growth curve. This would have the effect of removing the assumption that $t0=0$ in the growth curve, and may give a better fit to the size distribution of the smallest fish
- -Review growth assumptions (growth curve and variability of the length-at-age assumptions, including sex-specific growth). This could include experiments to free up one parameter at a time to evaluate that the parameter estimated by the model is consistent with fixed parameter value.
- -Review natural mortality assumptions.
- -Explore the use of linear fleet instead of total fleet in the model for the surveys. This allows a variable catch (in line with changing stock size), and would give

greater flexibility in modelling survey indices, possibly reducing the number of different datasets that need to be fitted.

- Data improvements:
- -The length distribution datasets should be expanded to cover the full length range, and ensure that data on zero catches of larger sizes is not treated as missing.
- -Investigate adding further data for the early period in the model.
- -Start/continue to compile/collect as much sex-specific data as possible to provide information for the sex-specific model.
- -Additional dataset(s) covering the larger fish would improve the model accuracy and convergence issues
- -Additional dataset(s) covering the earliest part of the model would improve the accuracy for the earliest years as mentioned above
- -A joint comprehensive analysis of the maturity data from Portugal and Spain is encouraged. The two datasets could potentially be reconciled to obtain combined L50 estimates which cover a wider distribution are of the stock, and should also help the optimization process.

Table 4.5.1 HAKE SOUTHERN STOCK. Catch estimates (´000 t) by country and gear, 1972-2012

	SPAIN									PORTUGAL				FRANCE		TOTAL		
YEAR	**ART**	**GILLNET**	**LONGLINE**	**Cd-Trw**	**Pr-Bk TRW**	**Pa-Trw**	**Ba-Trw**	**DISC**	**LAND**	**ART**	**TRAWL**	**DISC**	**LAND**	**TOTAL**	**UNALLOCATED**	**DISC**	**LAND**	**CATCH**
1972	7.10	-	-	-	10.20				**17.3**	4.70	4.10	**-**	**8.8**			**-**	**26.1**	**26.1**
1973	8.50	-	-	-	12.30				**20.8**	6.50	7.30	**-**	**13.8**	0.20		**-**	**34.8**	**34.8**
1974	1.00	2.60	2.20	-	8.30				**14.1**	5.10	3.50	**-**	**8.6**	0.10		**-**	**22.8**	**22.8**
1975	1.30	3.50	3.00	-	11.20				**19.0**	6.10	4.30	**-**	**10.4**	0.10		**-**	**29.5**	**29.5**
1976	1.20	3.10	2.60	-	10.00				**16.9**	6.00	3.10	**-**	**9.1**	0.10		**-**	**26.1**	**26.1**
1977	0.60	1.50	1.30	-	5.80				**9.2**	4.50	1.60	**-**	**6.1**	0.20		**-**	**15.5**	**15.5**
1978	0.10	1.40	2.10	-	4.90				**8.5**	3.40	1.40	**-**	**4.8**	0.10		**-**	**13.4**	**13.4**
1979	0.20	1.70	2.10	-	7.20				**11.2**	3.90	1.90	**-**	**5.8**	-		**-**	**17.0**	**17.0**
1980	0.20	2.20	5.00	-	5.30				**12.7**	4.50	2.30	**-**	**6.8**	-		**-**	**19.5**	**19.5**
1981	0.30	1.50	4.60	-	4.10				**10.5**	4.10	1.90	**-**	**6.0**	-		**-**	**16.5**	**16.5**
1982	0.27	1.25	4.18	0.49	3.92				**10.1**	5.01	2.49	**-**	**7.5**	-		**-**	**17.6**	**17.6**
1983	0.37	2.10	6.57	0.57	5.29				**14.9**	5.19	2.86	**-**	**8.0**	-		**-**	**22.9**	**22.9**
1984	0.33	2.27	7.52	0.69	5.84				**16.7**	4.30	1.22	**-**	**5.5**	-		**-**	**22.2**	**22.2**
1985	0.77	1.81	4.42	0.79	5.33				**13.1**	3.77	2.05	**-**	**5.8**	-		**-**	**18.9**	**18.9**
1986	0.83	2.07	3.46	0.98	4.86				**12.2**	3.16	1.79	**-**	**4.9**	0.01		**-**	**17.2**	**17.2**
1987	0.53	1.97	4.41	0.95	3.50				**11.4**	3.47	1.33	**-**	**4.8**	0.03		**-**	**16.2**	**16.2**
1988	0.70	1.99	2.97	0.99	3.98				**10.6**	4.30	1.71	**-**	**6.0**	0.02		**-**	**16.7**	**16.7**
1989	0.56	1.86	1.95	0.90	3.92				**9.2**	2.74	1.85	**-**	**4.6**	0.02		**-**	**13.8**	**13.8**
1990	0.59	1.72	2.13	1.20	4.13				**9.8**	2.26	1.14	**-**	**3.4**	0.03		**-**	**13.2**	**13.2**
1991	0.42	1.41	2.20	1.21	3.63				**8.9**	2.71	1.25	**-**	**4.0**	0.01		**-**	**12.8**	**12.8**
1992	0.40	1.48	2.05	0.98	3.79			**0.14**	**8.7**	3.77	1.33	**0.33**	**5.1**	-		**0.5**	**13.8**	**14.3**
1993	0.37	1.26	2.74	0.54	2.67			**0.24**	**7.6**	3.04	0.87	**0.44**	**3.9**	-		**0.7**	**11.5**	**12.2**
1994	0.37	1.90	1.47	0.32		0.82	1.90	**0.29**	**6.8**	2.30	0.79	**0.71**	**3.1**	-		**1.0**	**9.9**	**10.9**
1995	0.37	1.59	0.96	0.46		2.34	2.94	**0.93**	**8.6**	2.56	1.03	**1.18**	**3.6**	-		**2.1**	**12.2**	**14.3**
1996	0.23	1.15	0.98	0.98		1.46	2.17	**0.91**	**7.0**	2.01	0.76	**0.99**	**2.8**	-		**1.9**	**9.7**	**11.6**
1997	0.30	1.04	0.76	0.88		1.32	1.78	**1.07**	**6.1**	1.52	0.90	**1.20**	**2.4**	-		**2.3**	**8.5**	**10.8**
1998	0.32	0.75	0.62	0.53		0.88	1.95	**0.57**	**5.0**	1.67	0.97	**1.11**	**2.6**	-		**1.7**	**7.7**	**9.4**
1999	0.33	0.60	0.00	0.57		0.87	1.59	**0.35**	**4.0**	2.12	1.09	**1.17**	**3.2**	-		**1.5**	**7.2**	**8.7**
2000	0.26	0.85	0.15	0.58		0.83	1.98	**0.62**	**4.7**	2.09	1.16	**1.21**	**3.3**	-		**1.83**	**7.90**	**9.7**
2001	0.32	0.55	0.11	1.20		1.06	1.12	**0.37**	**4.4**	2.02	1.20	**1.29**	**3.2**	-		**1.66**	**7.58**	**9.2**
2002	0.22	0.58	0.12	0.88		1.37	0.75	**0.38**	**3.9**	1.81	0.97	**1.11**	**2.8**	-		**1.49**	**6.70**	**8.2**
2003	0.37	0.43	0.17	1.25		1.36	1.07	**0.41**	**4.7**	1.13	0.96	**1.05**	**2.1**	-		**1.46**	**6.74**	**8.2**
2004	0.48	0.42	0.13	1.06		1.66	1.13	**0.22**	**4.9**	1.27	0.80	**0.69**	**2.1**	-		**0.91**	**6.94**	**7.9**
2005	0.72	0.63	0.09	0.88		2.77	1.14	**0.38**	**6.2**	1.10	0.96	**1.60**	**2.1**	-		**1.98**	**8.30**	**10.3**
2006	0.48	0.71	0.35	0.63		4.70	1.81	**2.65**	**8.7**	1.22	0.91	**0.61**	**2.1**	-		**3.26**	**10.80**	**14.1**
2007	0.83	1.80	0.89	0.50		6.71	2.07	**1.19**	**12.8**	1.41	0.72	**1.31**	**2.1**	-		**2.50**	**14.93**	**17.4**
2008	1.12	2.64	1.51	0.53		6.32	2.44	**1.45**	**14.6**	1.27	0.94	**0.86**	**2.2**	-		**2.31**	**16.77**	**19.1**
2009	1.41	2.92	2.10	0.55		7.37	2.54	**0.98**	**16.9**	1.39	0.96	**1.96**	**2.4**	-		**2.93**	**19.24**	**22.2**
2010	0.72	1.71	1.88	0.68		6.33	1.71	**1.00**	**13.0**	1.61	0.73	**0.58**	**2.3**	0.36		**1.58**	**15.74**	**17.3**
2011	0.42	1.09	0.76	0.53		2.18	1.48	**1.21**	**6.5**	1.72	0.49	**0.74**	**2.2**		8.40	**1.95**	**17.07**	**19.0**
2012	0.34	0.85	1.08	0.50		1.64	1.42	**1.35**	**5.8**	1.79	0.81	**0.71**	**2.6**		6.14	**2.06**	**14.57**	**16.6**

Table 4.5.2 HAKE SOUTHERN STOCK - length compositions (thousands) in 2012

Length (cm)	STOCK		
	Land	Disc	Catch
4	0	0	0
5	0	0	0
6	0	0	0
7	0	7	0
8	0	25	25
9	3	198	200
10	0	364	364
11	0	636	636
12	0	825	825
13	0	1327	1327
14	3	1795	1798
15	19	2529	2548
16	30	2008	2038
17	47	1785	1832
18	88	1577	1665
19	150	2140	2289
20	161	2026	2187
21	136	1829	1965
22	150	2103	2253
23	116	2471	2587
24	205	1681	1886
25	302	1769	2072
26	735	1233	1968
27	1303	559	1862
28	1818	339	2157
29	2481	147	2628
30	2913	161	3074
31	2730	167	2897
32	2774	99	2872
33	2429	64	2492
34	1985	28	2013
35	1561	67	1628
36	1316	16	1332
37	1014	48	1062
38	822	10	831
39	773	33	806
40	690	1	691
41	514	8	522
42	431	0	431
43	409	0	409
44	364	0	364
45	388	0	388
46	313	0	313
47	300	0	300
48	334	0	334
49	339	0	339
50	312	0	312
51	271	0	271
52	255	0	255
53	262	0	262
54	237	0	237
55	217	0	217
56	242	0	242
57	251	0	251
58	215	0	215
59	174	0	174
60	155	0	155
61	112	0	112
62	120	0	120
63	104	0	104
64	85	0	85
65	71	0	71
66	63	0	63
67	169	0	169
68	60	0	60
69	56	0	56
70	45	0	45
71	32	0	32
72	20	0	20
73	26	0	26
74	20	0	20
75	14	0	14
76	15	0	15
77	14	0	14
78	15	0	15
79	16	0	16
80	8	0	8
81	8	0	8
82	8	0	8
83	3	0	3
84	5	0	5
85	2	0	2
86	2	0	2
87	2	0	2
88	2	0	2
89	2	0	2
90	4	0	4
TOTAL	33836	30073	63902
Nominal Weight (tons)	14.57	2.02	16.59
SOP	14.24	1.98	16.22
SOP / NW	1.02	1.02	1.02
Mean length (cm)	36.3	19.9	28.6

Table 4.5.3 HAKE SOUTHERN STOCK - Portuguese groundfish surveys; biomass, abundance and recruitment indices

Year	Winter (ptGFS-WIBTS-Q1)					Summer					Autumn (ptGFS-WIBTS-Q4)					
	Biomass (kg/h)		Abundance (N/h)			Biomass (kg/h)		Abundance (N/h)			Biomass (kg/h)		Abundance (N/h)			
	Mean	s.e.	Mean	s.e.	hauls	Mean	s.e.	Mean	s.e.	hauls	Mean	s.e.	Mean	s.e.	n/hour < 20 cm (1)	hauls
1979 *						11.7		80.4		55	9.5		na			55
1980 * (**)	11.3		178.1		36	15.4		153.0		63	12.5		108.7			62
1981 (Autumn **)	10.7	0.7	122.4	15.5	67	9.9	1.3	87.8	15.5	69	24.4	0.5	734.8	29.3		111
1982	18.1	2.5	265.6	37.5	69	11.0	2.7	93.0	32.8	70	10.6	1.8	119.5	34.7		190
1983 (Autumn **)	27.0	6.0	530.5	151.0	69	15.1	2.3	120.5	20.8	98	13.4	0.5	121.8	4.8		117
1984																
1985						14.3	0.8	170.7	15.6	101	11.0	0.7	128.7	8.4	86.7	150
1986						27.4	1.8	249.4	15.1	118	17.7	1.2	165.6	28.4	90.2	117
1987											8.6	0.9	37.4	3.7	7.3	81
1988											15.3	1.7	177.8	30.8	111.7	98
1989						11.9	0.9	80.8	8.6	114	8.4	0.5	59.6	4.6	19.8	130
1990						9.8	1.0	95.6	13.5	98	11.8	1.0	157.2	26.3	97.2	107
1991						14.2	1.2	104.2	11.3	119	20.9	4.3	195.3	41.5	92.3	80
1992	14.5	1.2	176.4	32.3	88	10.9	1.1	74.1	11.4	81	11.7	1.7	65.2	11.1	18.8	51
1993	9.0	0.7	78.7	16.8	75	11.3	1.7	105.0	34.7	66	5.5	0.8	54.4	12.9	28.4	58
1994											9.9	1.0	98.9	12.1	52.9	77
1995						15.0	1.4	129.3	16.3	81	14.8	1.7	85.8	10.7	7.9	80
1996***											9.2	1.1	109.9	17.8	18.2	63
1997						19.0	1.4	206.5	16.9	86	24.6	9.3	208.0	92.5	62.1	51
1998						10.5	0.8	71.6	8.6	87	15.6	2.0	140.6	21.7	75.9	64
1999***						11.8	0.7	116.2	10.1	65	11.6	1.5	118.3	17.1	14.4	71
2000						16.4	1.6	123.0	15.2	88	11.8	1.8	102.7	19.9	49.2	66
2001						16.6	1.7	132.5	14.2	83	15.6	2.8	164.2	38.5	89.9	58
2002											13.0	2.1	117.6	26.9	60.6	66
2003 ***											9.8	1.0	94.2	8.0	11.9	71
2004 ***											18.4	3.3	402.3	85.2	78.2	79
2005	17.7	2.6	384.0	53.8	68						19.0	1.9	214.2	23.5	131.7	87
2006	16.0	2.0	377.5	55.4	66						16.5	1.8	126.2	11.0	54.7	88
2007	22.4	3.4	609.1	114.1	63						25.8	2.8	370.2	46.7	240.0	96
2008	31.1	4.8	700.6	170.8	67						34.6	4.3	293.6	33.9	87.7	87
2009											37.5	4.4	476.4	75.9	318.6	93
2010											38.2	4.3	418.0	49.8	249.8	87
2011											18.7	1.5	272.9	25.2	179.4	86
2012																

NO surveys in 2012

all data concerns 20 mm cod end mesh size except data marked with * which concerns 40 mm

(**) all area not covered

*** R/V Capricornio, other years R/V Noruega

Strata depth:

from 1979 to 1988 covers 20-500 m depth

from 1989 to 2004 covers 20-750 m depth

since 2005 covers 20-500 m depth

since 2002 tow duration is 30 min for autumn survey

(1) n/hour <20 cm converted to Noruega and NCT

Table 4.5.4 HAKE SOUTHERN STOCK - Spanish groundfish surveys; abundances and recruitment indices for total area (Mino - Bidasoa). Biomass for Cadiz surveys.

	Spanish Survey (SpGFS-WIBTS-Q4) (/30 min)						Cadiz Survey (SPGFS-caut-WIBTS-Q4) (/hour)				Cadiz Survey (SPGFS-cspr-WIBTS-Q4) (/hour)			
	Biomass index (Kg)		Abundance Index (nº)			Recruits (<20cm)	Biomass index (Kg)			Rec (<20cm)	Biomass index (Kg)			Rec (<20cm)
Year	Mean	s.e.	Hauls	Mean	s.e.	Mean	Mean	s.e.	hauls	Mean	Mean	s.e.	hauls	mean
1983	7.04	0.65	107	192.4	25.0	177								
1984	6.33	0.60	94	410.4	53.5	398								
1985	3.83	0.39	97	108.5	14.0	98								
1986	4.16	0.50	92	247.8	46.5	239								
1987														
1988	5.59	0.69	101	390.0	67.4	382								
1989	7.14	0.75	91	487.9	73.1	477								
1990	3.34	0.32	120	85.9	9.1	78								
1991	3.37	0.39	107	166.8	15.8	161								
1992	2.14	0.19	116	59.3	5.4	52								
1993	2.49	0.21	109	80.0	8.0	73					3.04	0.53	30	
1994	3.98	0.33	118	245.0	24.9	240					2.68	0.33	30	
1995	4.58	0.44	116	80.9	8.4	68					4.66	1.28	30	71.5
1996	6.54	0.59	114	345.2	40.5	335					7.66	1.14	31	72.7
1997	7.27	0.78	119	421.4	56.5	410	5.28	2.77	27	26.7	3.34	0.52	30	72.5
1998	3.36	0.28	114	75.9	8.7	65	2.66	0.42	34	6.6	2.93	0.67	31	18.6
1999	3.35	0.25	116	95.3	10.6	89	2.71	0.44	38	23.9	3.03	0.37	38	44.6
2000	3.01	0.43	113	66.9	7.4	59	2.03	0.61	30	18.6	3.02	0.47	41	39.7
2001	1.73	0.29	113	42.0	7.6	37	2.57	0.45	39	22.7	6.01	0.79	40	72.4
2002	1.91	0.23	110	57.1	8.8	53	3.39	0.78	39	118.6	2.74	0.25	41	22.4
2003	2.61	0.27	112	92.8	11.6	86	1.61	0.28	41	17.5				
2004	3.94	0.40	114	177.0	23.5	170	2.72	0.69	40	85.8	3.65	0.47	40	92.7
2005	6.46	0.53	116	344.8	32.2	335	6.68	1.29	42	100.6	10.77	5.65	40	184.3
2006	5.50	0.39	115	224.5	21.9	211	4.99	2.00	41	212.3	2.15	0.40	41	3.7
2007	4.97	0.43	117	158.2	15.0	150	6.92	1.43	37	200.3	3.22	0.68	41	51.1
2008	4.93	0.46	115	99.3	11.5	81	4.33	0.60	41	64.4	3.48	0.67	41	50.5
2009	9.32	0.94	117	559.7	93.9	789	7.35	0.97	43	95.0	4.24	0.06	40	65.6
2010	8.36	0.65	114	201.0	14.9	175	5.82	0.83	44	46.0	6.91	1.09	36	202.5
2011	8.98	0.68	111	241.5	21.0	216	2.97	0.38	40	48.2	3.75	0.50	42	32.2
2012	8.44	0.75	115	297.3	39.5	280	5.38	0.90	37	44.0	3.49	0.65	33	62.9

Since 1997 new depth stratification: 70-120m, 121-200m and 201-500 m
Before 1997: 30-100m, 101-200m and 201-500 m

'Table 4.5.5 HAKE SOUTHERN STOCK. Landings (tonnes), Catch per unit of effort and effort for trawl fleets

	A Coruña Trawl			A Coruña Pair Trawl			Vigo and Marín trawl [1]			Santander trawl			Cadiz trawl			Portugal trawl		
YEAR	Landings	lpue *	Effort	Landings	lpue *	Effort	Landings	lpue *	Effort	Landings	lpue *	Effort	Landings	lpue ***	Effort	Landings	lpue **	Effort ****
1985	945	21	45920	1016	43	23700												
1986	842	21	39810	1009	39	25630				218	12.0	18153						
1987	695	20	34680	752	25	29820				455	30.3	14995						
1988	698	17	42180	410	32	12980				219	13.1	16660						
1989	715	16	44440	480	31	15240				245	13.9	17607				1847	38.6	47810
1990	749	17	44430	429	24	18250	438	17.5	25063	392	19.2	20469				1138	33.4	34106
1991	501	12	40440	609	20	30530	368	12.6	29260	340	15.2	22391				1245	37.7	33035
1992	589	15	38910	730	27	26670	666	21.4	31146	311	13.6	22833				1325	33.8	39257
1993	514	12	44504	350	16	21349	290	13.1	22198	390	18.2	21370				871	31.0	28053
1994	473	12	39589	319	15	20732	556	21.3	26115	296	13.0	22772	326	11.7	27823	789	31.1	25341
1995	831	20	41452	691	24	28988	1018	35.5	28677	336	23.9	14046	458	14.2	32194	1026	38.4	26690
1996	722	20	35728	249	14	17555	647	21.9	29480	274	22.7	12071	975	30.5	31951	894	34.2	26121
1997	732	21	35211	295	18	16307	347	9.2	37578	127	10.8	11776	880	27.0	32573	906	38.1	23781
1998	895	27	32563	198	12	16966	284	6.7	42371	122	11.4	10646	523	15.9	32824	913	35.0	26053
1999	691	23	30232	139	15	9322	402	10.1	39738	92	8.9	10349	570	17.4	32731	1092	40.4	27019
2000	590	20	30102	92	29	3190	371	11.0	33771	52	5.9	8779	584	19.5	29875	1162	32.0	36312
2001	597	20	29923	91	19	4873	293	8.7	33802	47	15.5	3053	1203	39.6	30416	1210	36.6	33048
2002	232	11	21823	266	37	7147	256	10.6	24288	30	7.6	3975	883	28.9	30526	970	36.0	26975
2003	274	15	18493	121	30	3988	397	17	23151	22	5.8	3837	1251	39.5	31643	962	35.8	26855
2004	259	12	21112	249	29	8582	259	23	11139	17	4.6	3776	1062	35.4	30029	800	35.0	22849
2005	330	16	20663	428	47	9025	286	29	9981	7	4.9	1404	885	27.3	32419	965	37.1	25997
2006	518	27	19264	489	78	6245	360	32	11128	24	9.0	2718	634	24.1	26248	908	35.8	25369
2007	621	29	21201	788	59	13471	375	34	11062	64	14.8	4334	505	20.7	24398	724	35.4	20447
2008	762	38	20212	631	70	8964	454	41	11034	64			529	27.7	19135	936	41.9	22353
2009	640	40	16162	886	112	7944	400	42	9468	31	27.6	1125	550	25.9	21218	964	42.2	22836
2010	553	40	13744	1440	179	8027	450	42	10672	15	15.9	1627	680	31.1	21863	727	43.1	16855
2011	538	47	11532	1915	245	7820	492	48	10206	43			507	25.1	20168			
2012	498	42	11887										380	19.4	19581			

Spanish LPUEs are scientific estimations from a selection of ships that may change from year to year and are not well designed to follow effort series

* - Kg/fishind day x100 HP

[1] since 2004 Vigo-Marin fleet change in sampling design

** - Kg/hour (new standarized lpue serie)

***- Kg/fishing day

**** - Standardized effort

Table 4.5.6 HAKE SOUTHERN STOCK - length compositions (thousands)g in 2012

Length (cm)	STOCK		
	Land	Disc	Catch
4	0	0	0
5	0	0	0
6	0	0	0
7	0	7	0
8	0	25	25
9	3	198	200
10	0	364	364
11	0	636	636
12	0	825	825
13	0	1327	1327
14	3	1795	1798
15	19	2529	2548
16	30	2008	2038
17	47	1785	1832
18	88	1577	1665
19	150	2140	2289
20	161	2026	2187
21	136	1829	1965
22	150	2103	2253
23	116	2471	2587
24	205	1681	1886
25	302	1769	2072
26	735	1233	1968
27	1303	559	1862
28	1818	339	2157
29	2481	147	2628
30	2913	161	3074
31	2730	167	2897
32	2774	99	2872
33	2429	64	2492
34	1985	28	2013
35	1561	67	1628
36	1316	16	1332
37	1014	48	1062
38	822	10	831
39	773	33	806
40	690	1	691
41	514	8	522
42	431	0	431
43	409	0	409
44	364	0	364
45	388	0	388
46	313	0	313
47	300	0	300
48	334	0	334
49	339	0	339
50	312	0	312
51	271	0	271
52	255	0	255
53	262	0	262
54	237	0	237
55	217	0	217
56	242	0	242
57	251	0	251
58	215	0	215
59	174	0	174
60	155	0	155
61	112	0	112
62	120	0	120
63	104	0	104
64	85	0	85
65	71	0	71
66	63	0	63
67	169	0	169
68	60	0	60
69	56	0	56
70	45	0	45
71	32	0	32
72	20	0	20
73	26	0	26
74	20	0	20
75	14	0	14
76	15	0	15
77	14	0	14
78	15	0	15
79	16	0	16
80	8	0	8
81	8	0	8
82	8	0	8
83	3	0	3
84	5	0	5
85	2	0	2
86	2	0	2
87	2	0	2
88	2	0	2
89	2	0	2
90	4	0	4
TOTAL	33836	30073	63902
Nominal Weight (tons)	14.57	2.02	16.59
SOP	14.24	1.98	16.22
SOP / NW	1.02	1.02	1.02
Mean length (cm)	36.3	19.9	28.6

Table 4.5.7. Southern Hake Stock Assessment summary

	Mort (1-3)	R (million)	SSB ('000 tn)	Land ('000 tn)	Disc ('000 tn)	Catch ('000 tn)
1982	0.36	98.4	41.1	17.6		17.6
1983	0.44	81.5	45.8	22.9		22.9
1984	0.45	69.5	43.1	22.2		22.2
1985	0.42	44.1	43.2	18.9		18.9
1986	0.45	41.0	40.0	17.2		17.2
1987	0.51	50.1	36.8	16.2		16.2
1988	0.65	71.2	27.0	16.7		16.7
1989	0.65	78.1	19.9	13.8		13.8
1990	0.69	82.3	16.3	13.2		13.2
1991	0.69	69.9	16.5	12.8		12.8
1992	0.84	52.5	15.6	13.8	*0.5* *	14.3
1993	0.90	60.9	12.8	11.5	*0.7* *	12.2
1994	0.89	119.4	9.0	9.9	*1.0* *	10.9
1995	1.18	51.3	7.2	12.2	*2.1* *	14.3
1996	1.14	100.4	8.6	9.7	*1.9* *	11.6
1997	1.16	80.3	6.7	8.5	*2.3* *	10.8
1998	0.93	59.3	5.9	7.7	*1.7* *	9.4
1999	0.77	65.9	7.6	7.2	*1.5* *	8.7
2000	0.86	69.5	9.0	7.9	*1.8* *	9.7
2001	0.84	49.1	9.3	7.6	*1.7* *	9.2
2002	0.80	69.8	9.7	6.7	*1.5* *	8.2
2003	0.82	60.0	9.5	6.7	*1.5* *	8.2
2004	0.71	79.4	9.5	6.9	0.9	7.9
2005	0.75	125.5	9.8	8.3	2.0	10.3
2006	0.86	96.7	11.4	10.8	3.3	14.1
2007	0.90	159.1	13.4	14.9	2.5	17.4
2008	0.89	117.9	13.4	16.8	2.3	19.1
2009	0.95	112.0	14.8	19.2	2.9	22.2
2010	0.70	69.4	14.7	15.4	1.6	16.9
2011	0.73	145.3	18.6	17.1	1.9	19.0
2012	0.57	81.1	20.9	14.6	2.1	16.6

2010 landings do not include 0.36 t from france
* estimated from survey abundance, discards and discards/landings rate
Recruitment 2012 = 81 100 million (geo mean 1989-11)

Table 4.5.8. Short-term projections

	SSB 2013	BIO 2013	F 2013 = F 2012	Yield 2013	Catch 2013	SSB 2014	BIO 2014
number	25392	33572	0.57	17723	19640	27393	34229

Fmult	F 2014	Yield 2014	Catch 2014	SSB 2015		
0.00	0.00	23	25	58009		
0.1	0.05	2264	2465	53960		
0.20	0.11	4420	4815	50106		
0.30	0.16	6470	7052	46480		
0.40	0.22	8419	9180	43070		
0.44	0.24	9171	10001	41764	*Fmax*	
0.50	0.27	10270	11202	39867		
0.60	0.33	12025	13123	36861	*-15%*	*Ftrans*
0.70	0.39	13688	14944	34043		
0.73	0.41	14170	15472	33232	*TAC 13 = 14 144*	
0.80	0.45	15262	16670	31403		
0.87	0.49	16266	17772	29717	*+15%*	
0.90	0.51	16750	18304	28934		
1.00	0.57	18155	19848	26627	*Fsq*	
1.10	0.63	19479	21307	24474		
1.20	0.69	20726	22682	22466		
1.30	0.76	21898	23977	20596		
1.40	0.82	22998	25195	18857		
1.50	0.89	24029	26338	17242		
1.60	0.95	24994	27410	15744		

There is a EC Recovery Plan (-10% annual F redution; +-15% TAC constrain)
Fmsy proxi = Fmax (0.24)
No B trigger decided
No other Biological Reference Points
TAC 2013 = 14 144 (-+15% [12 022-16 266])
F transition min (0.2*F2010+0.8*Fmax) = 0.33
Recruitment = 81.1 mill (geo mean 1989-09)

Figures.

Figure 4.5.1. Length distribution of catches used in the assessment. Landings (1982-12) plus Cadiz landings from 1994-2004. Discards from 1992-12. Minimum landing size (MLS) since 1992 at 27 cm.

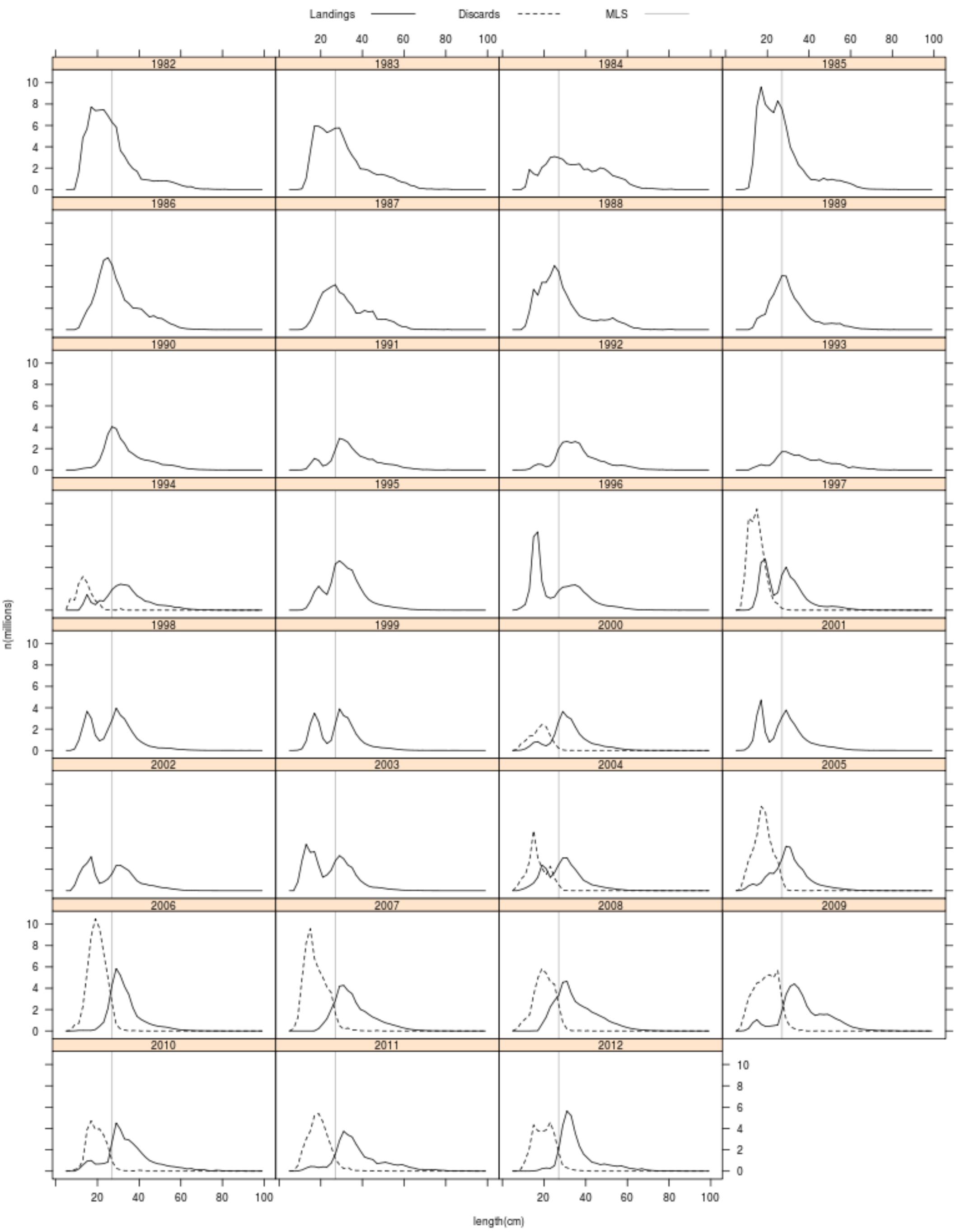
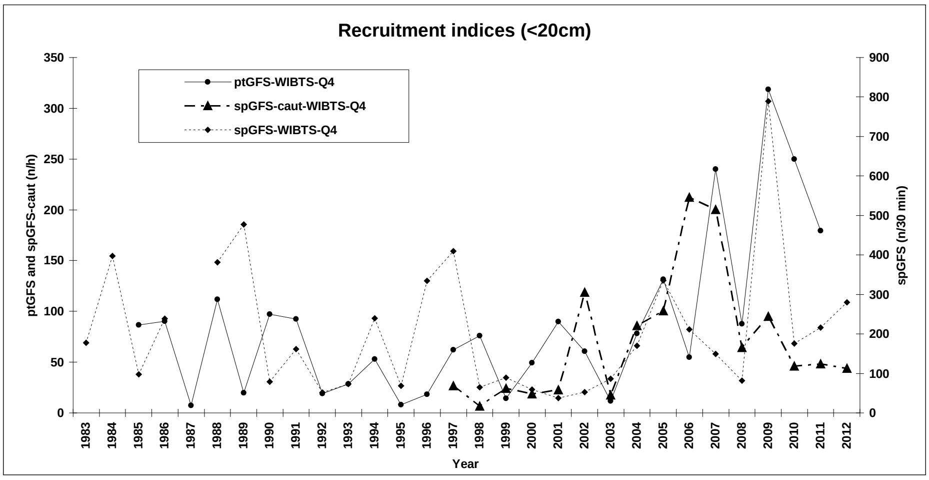


FIGURE 4.5.2 HAKE SOUTHERN STOCK - Recruitment and biomass Indices from groundfish surveys



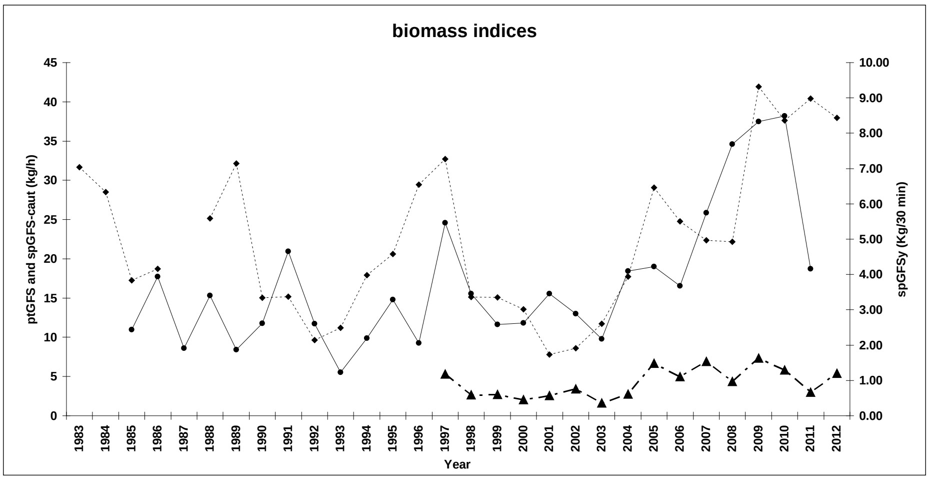


FIGURE 4.5.3 HAKE SOUTHERN STOCK - LPUE and fishing effort trends for trawl fleets

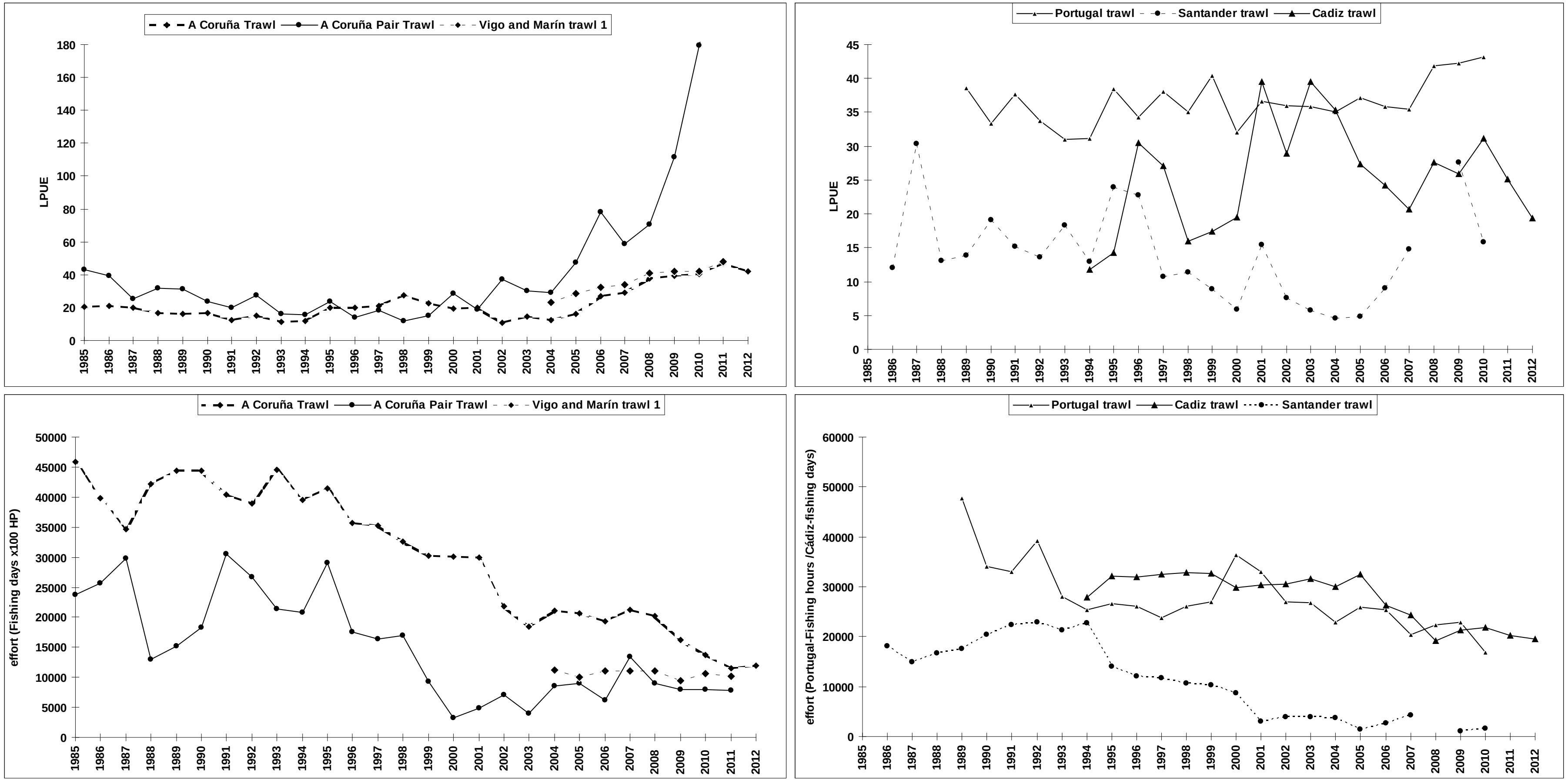


Figure 4.5.4 Maturity ogives from 1980 to 2012.

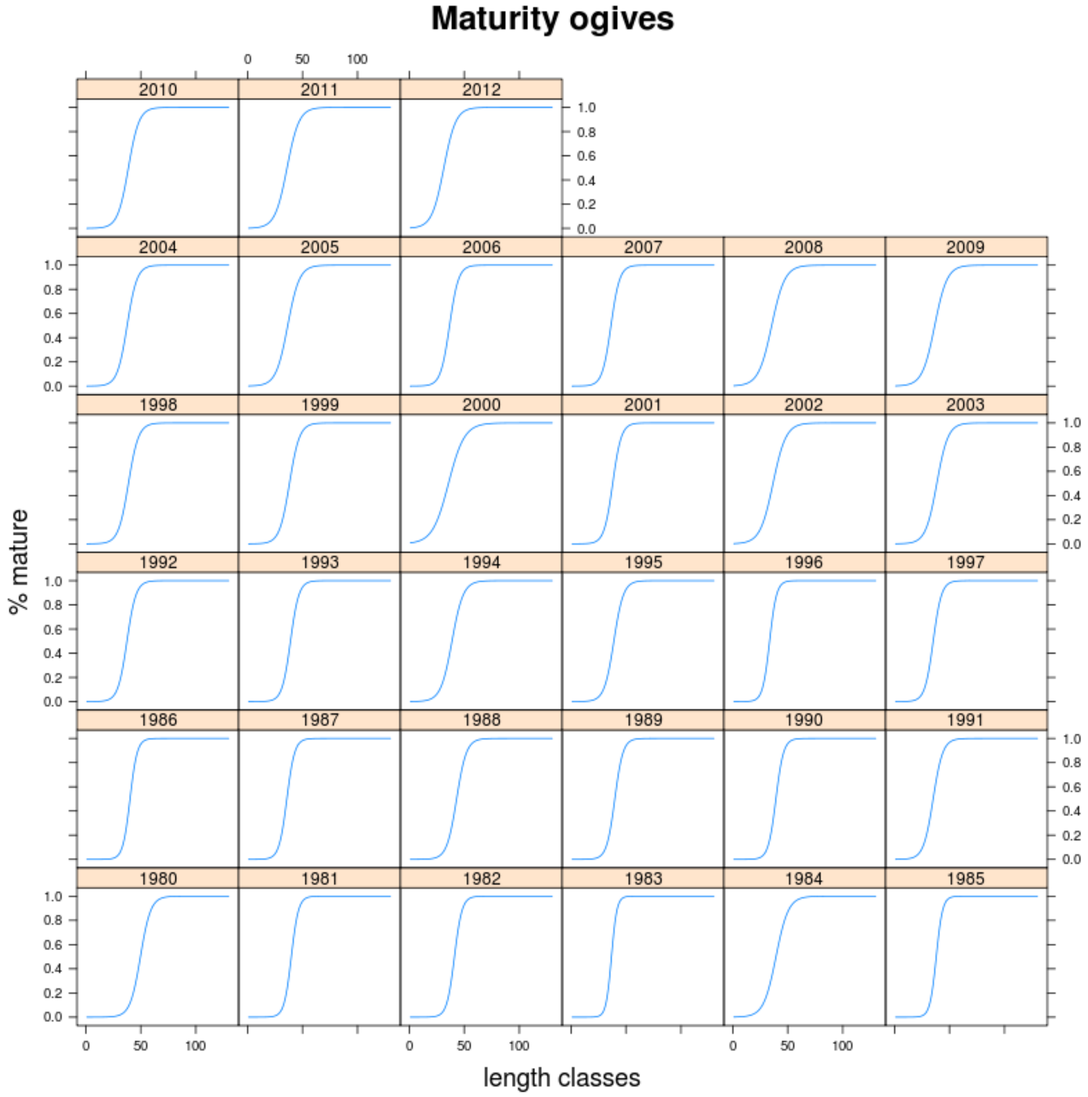


Figure 4.5.5 Gadget convergence with likelihood profiles. Free scaled (upper panel) and fixed scaled (lower panel)

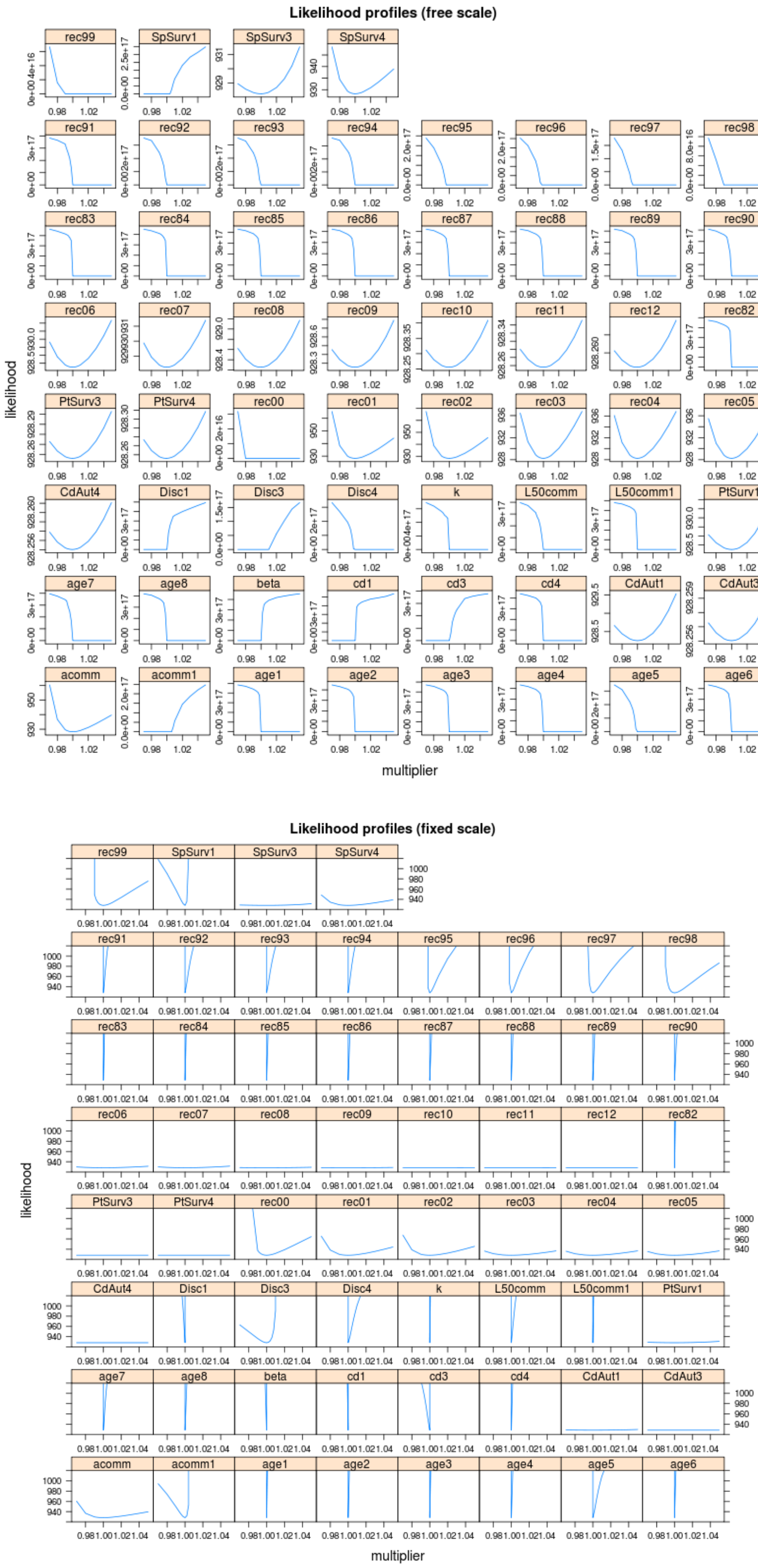
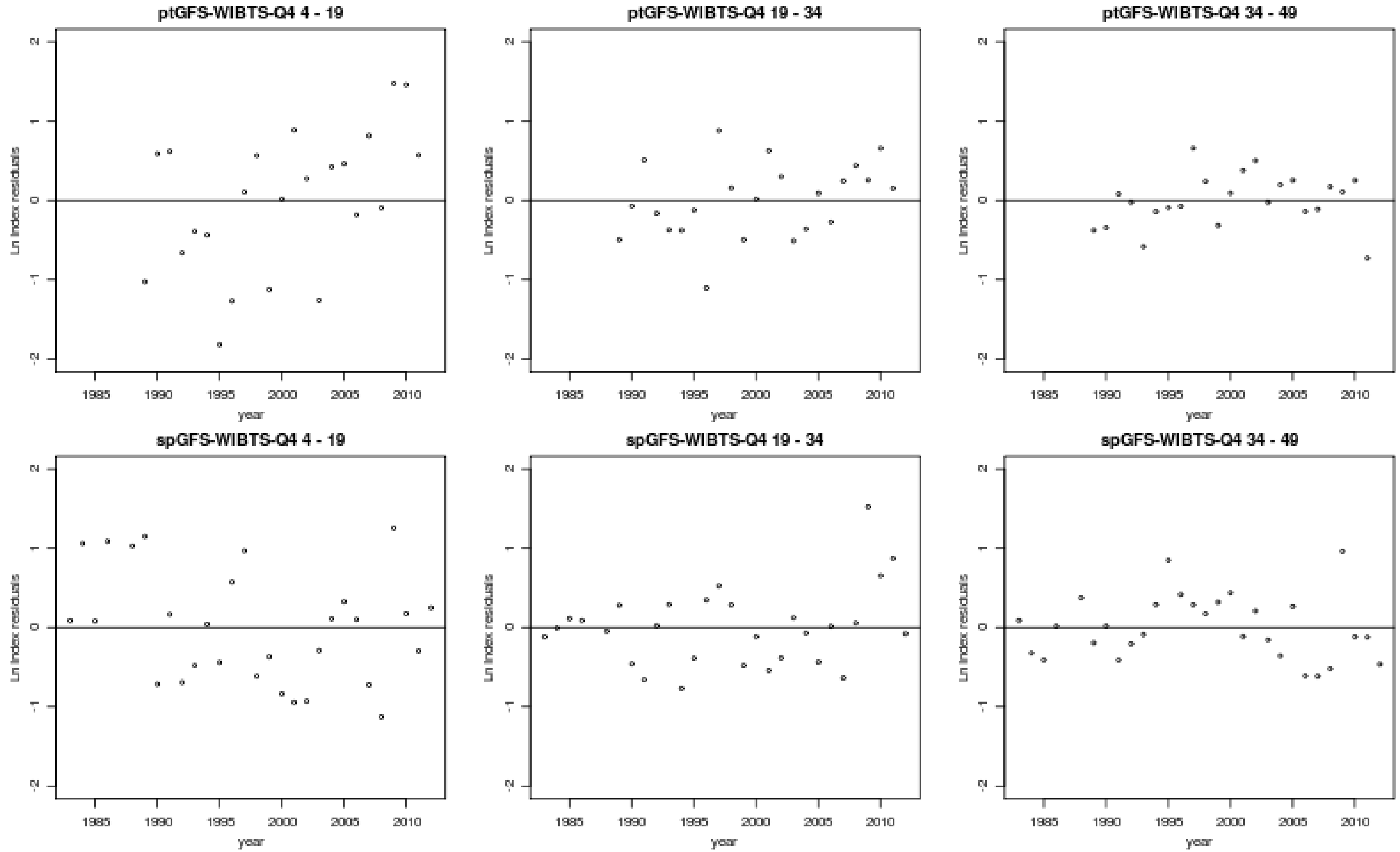
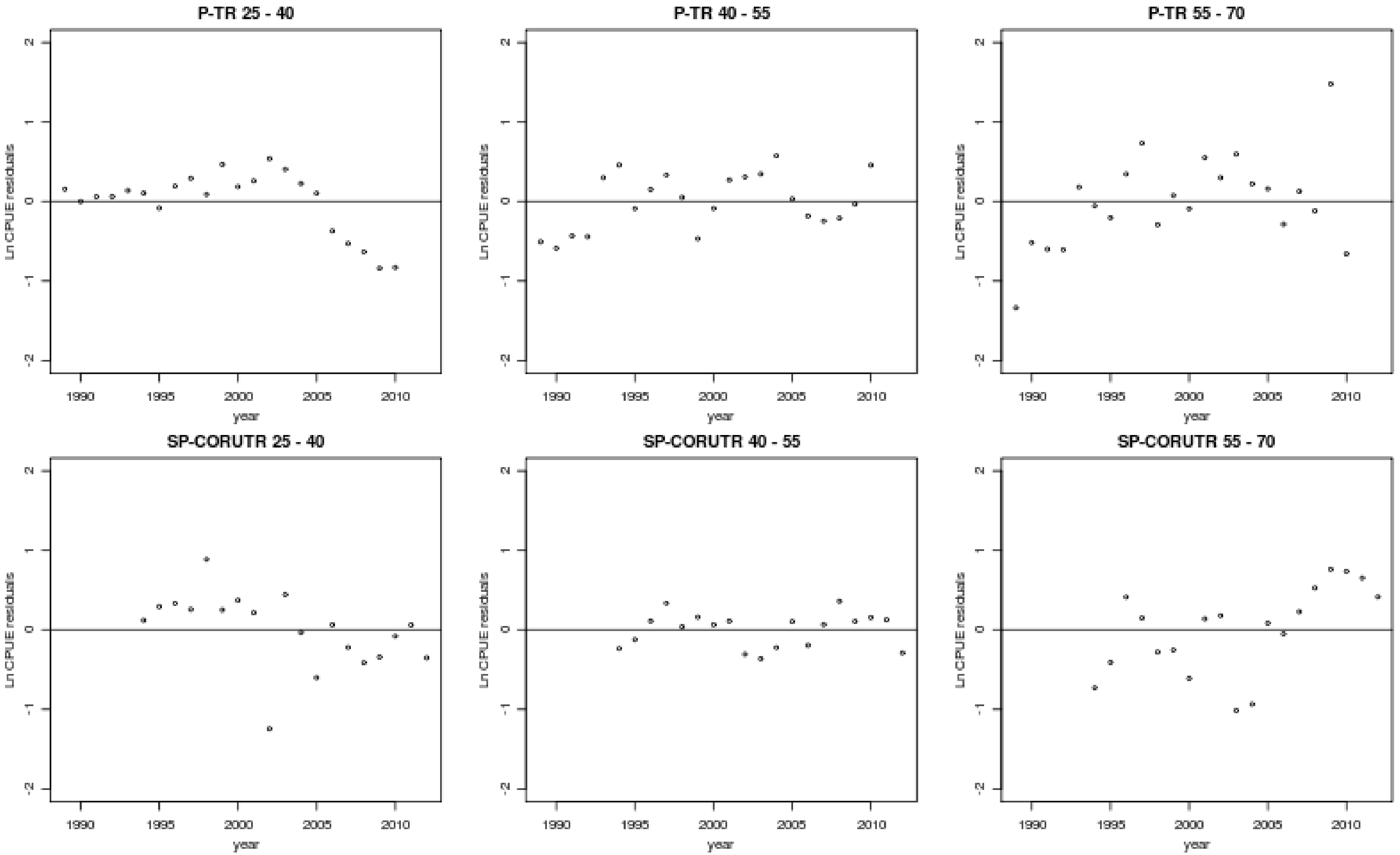


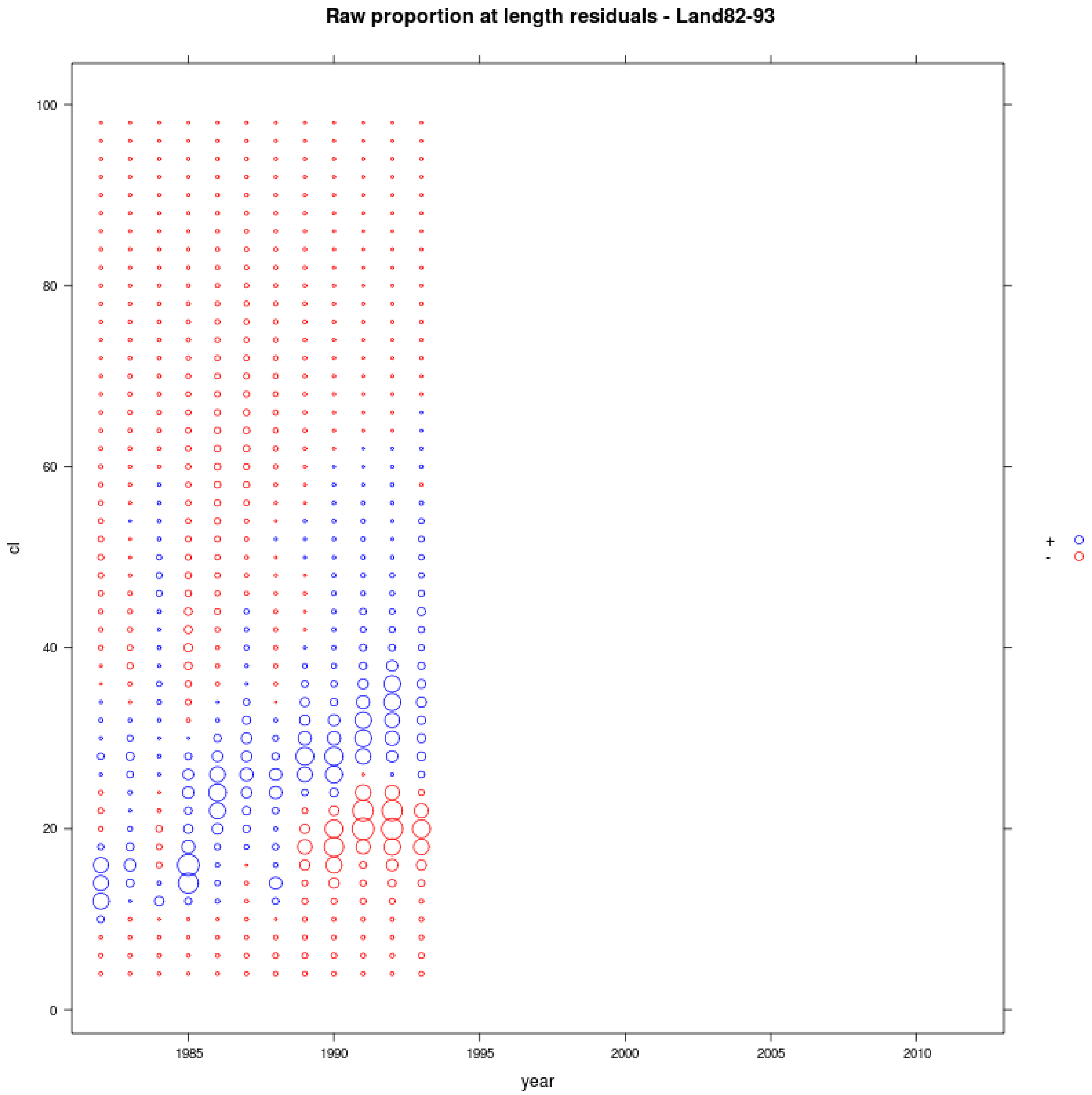
Figure 4.5.6 Diagnostics Residuals (3.5.6 a and b). Observed vs. expected length proportions (3.5.6 c-i))



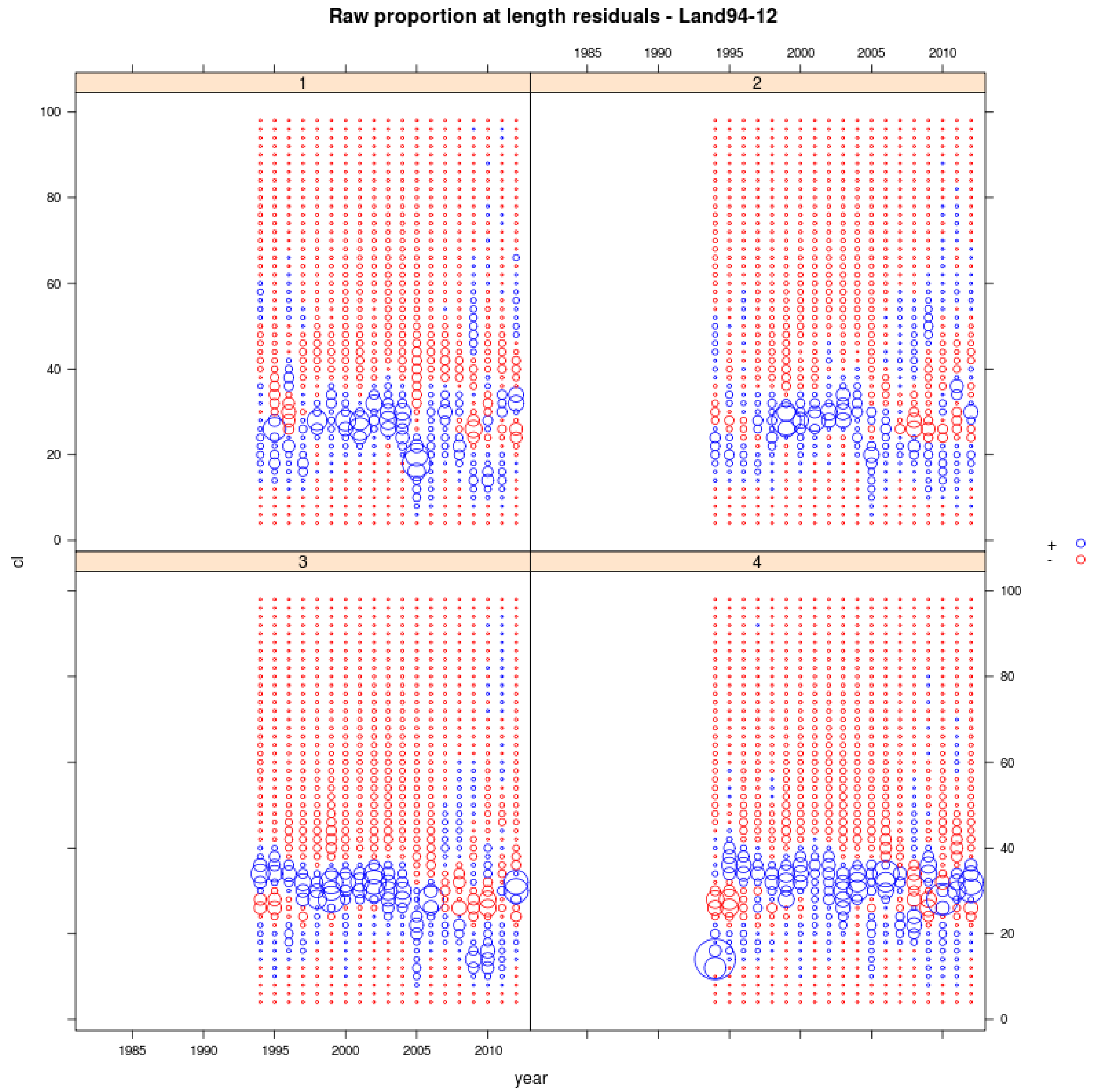
(4.5.6 a) Survey residuals by 15 cm groups (4-19, 19-34, 34-49 cm)



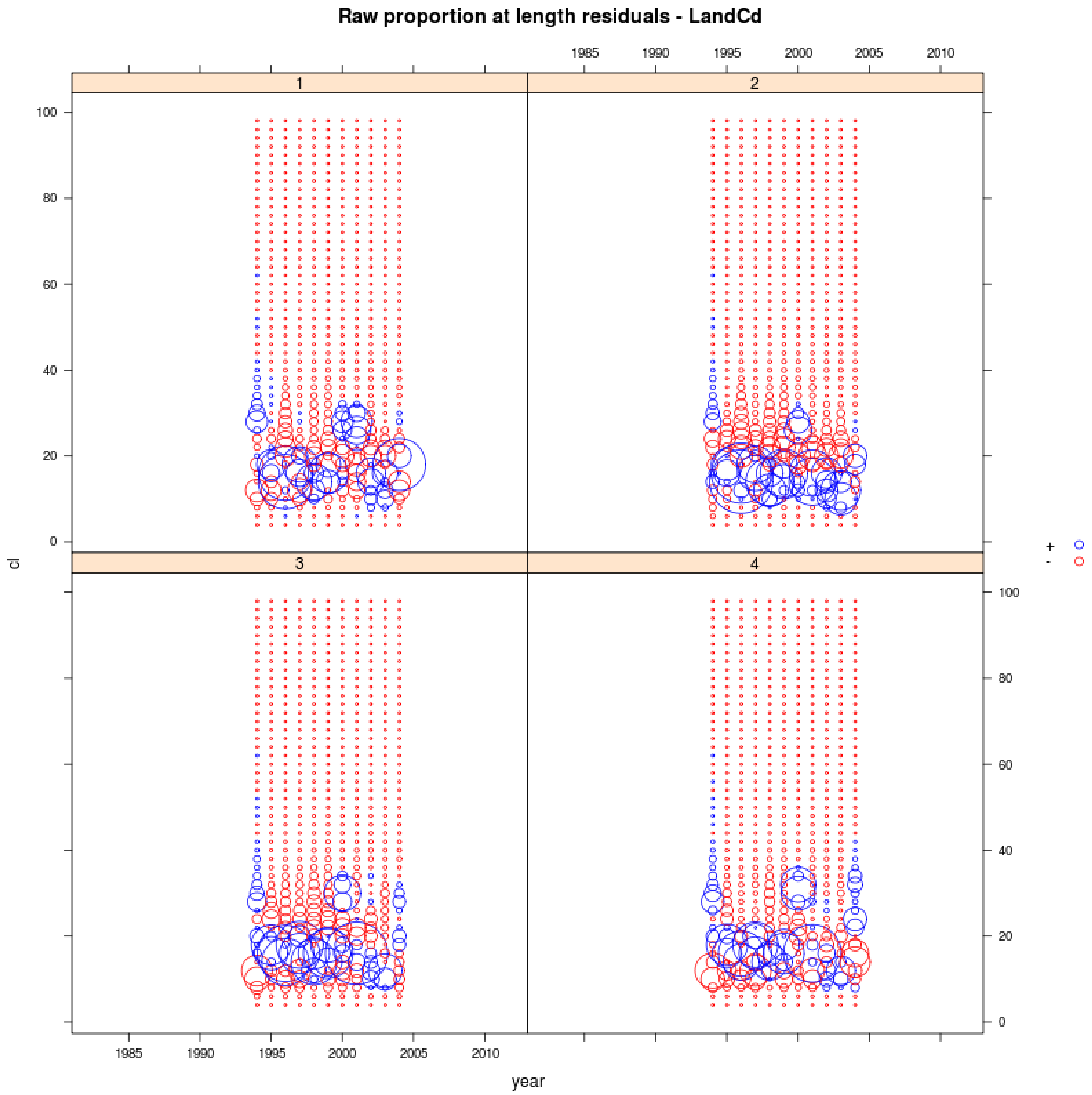
(4.5.6 b) LPUE residuals by 15 cm groups (25-40, 40-55, 55-70 cm)



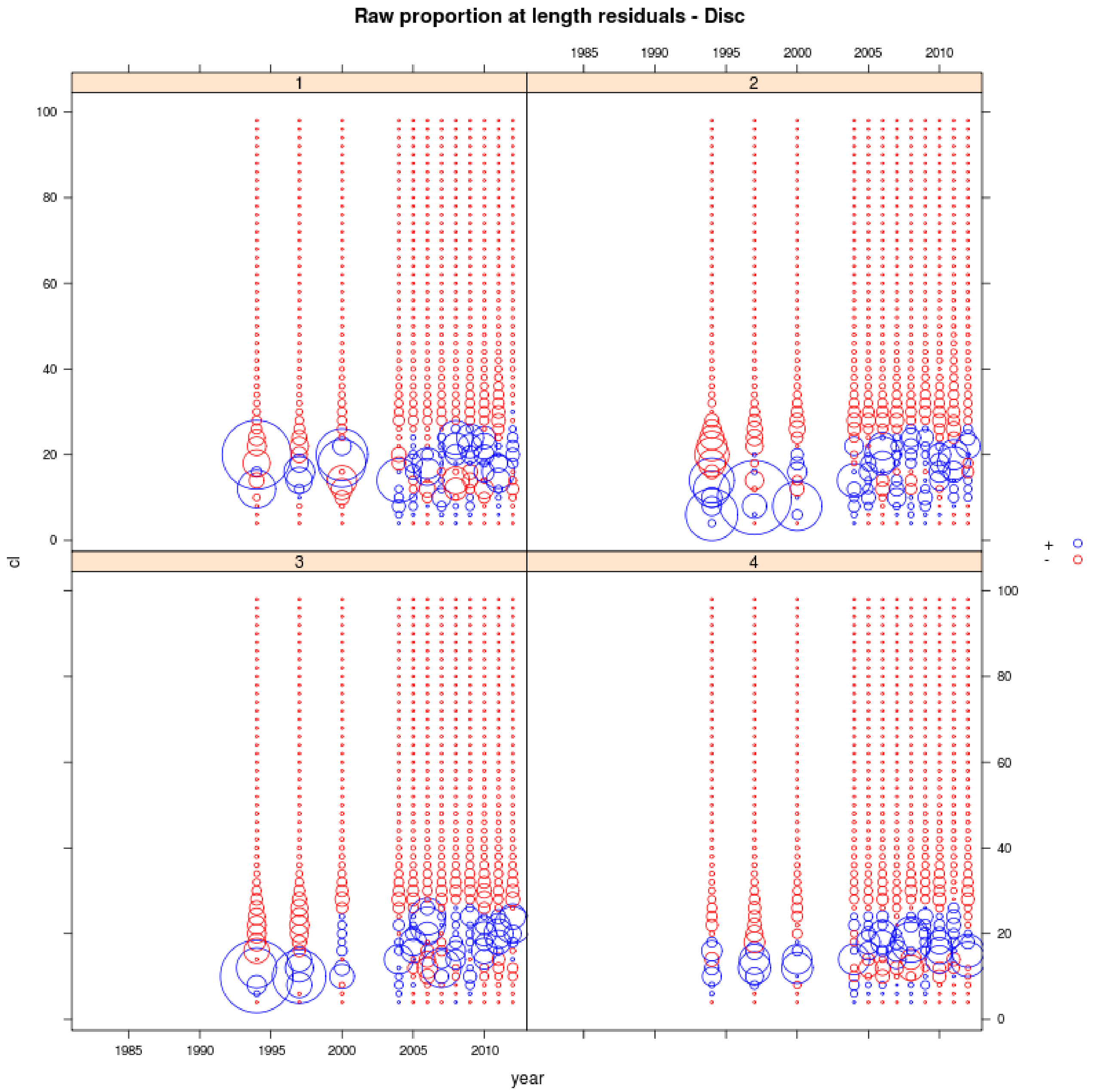
(4.5.6 c). Bubble plot for landings length distribution from 1982 to 1993.



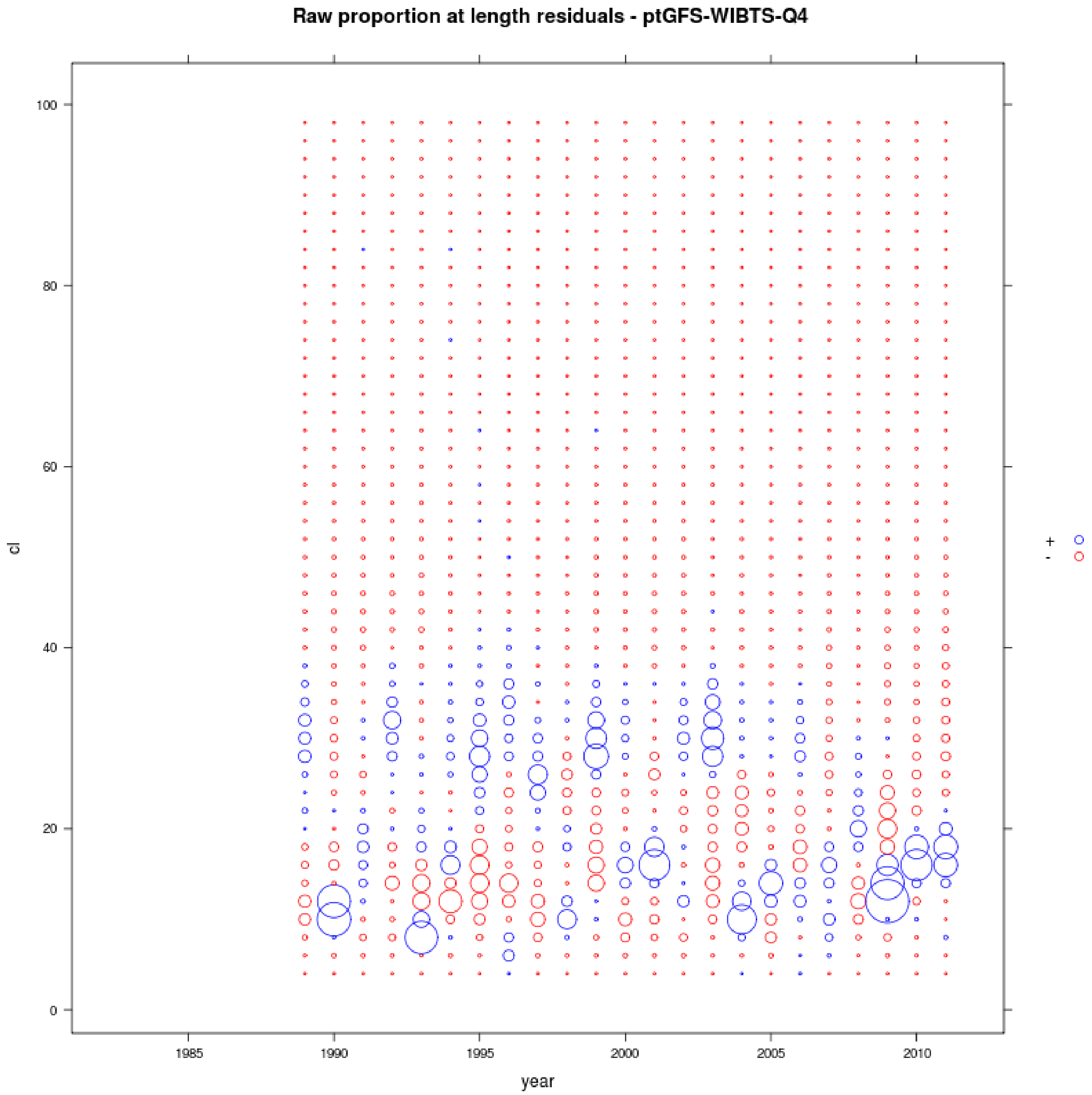
(4.5.6 d). Bubble plot for landings length distribution from 1994 to 2012.



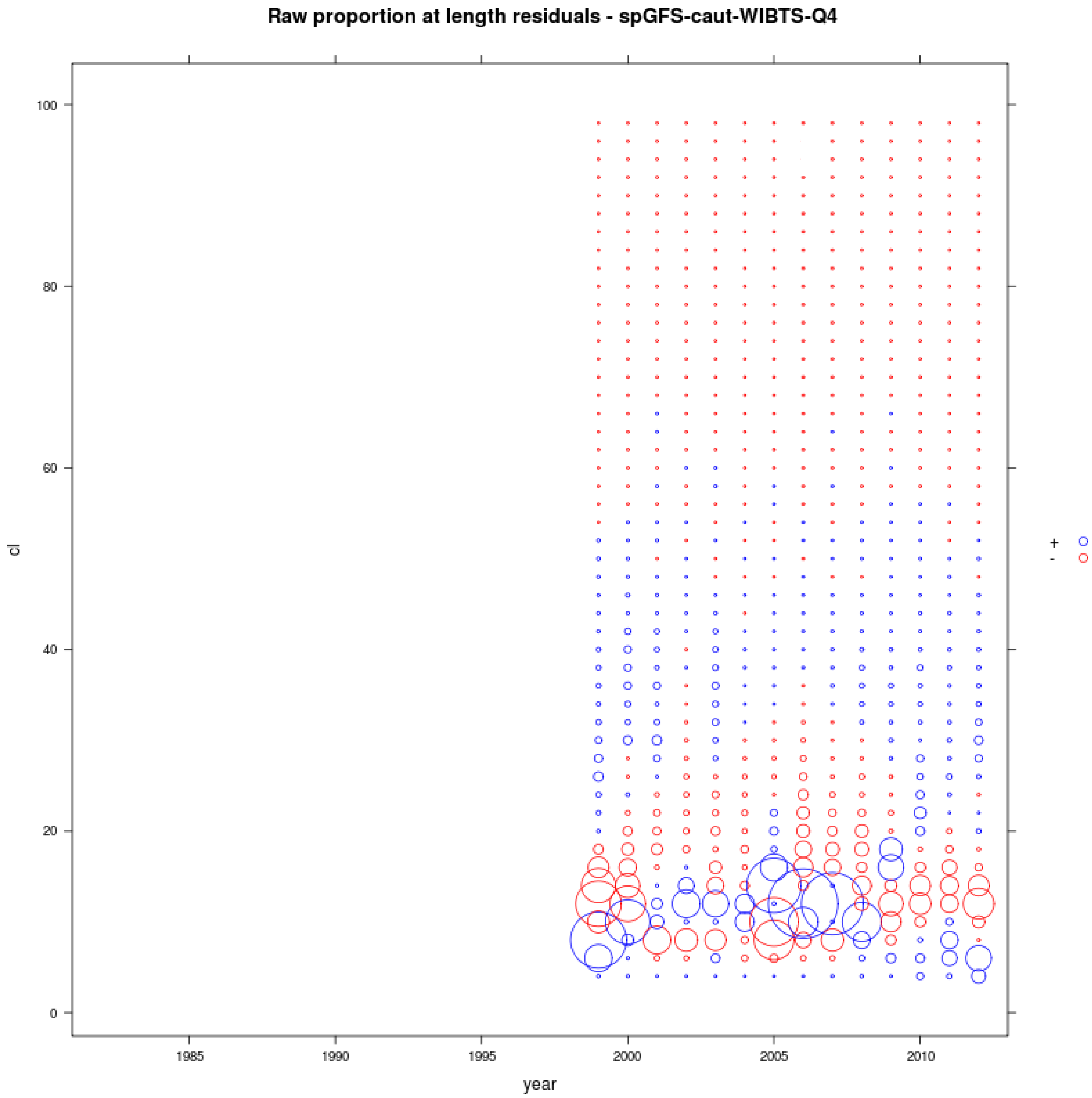
(4.5.6 e). Bubble plot for Cadiz landings length distribution from 1982 to 2004.



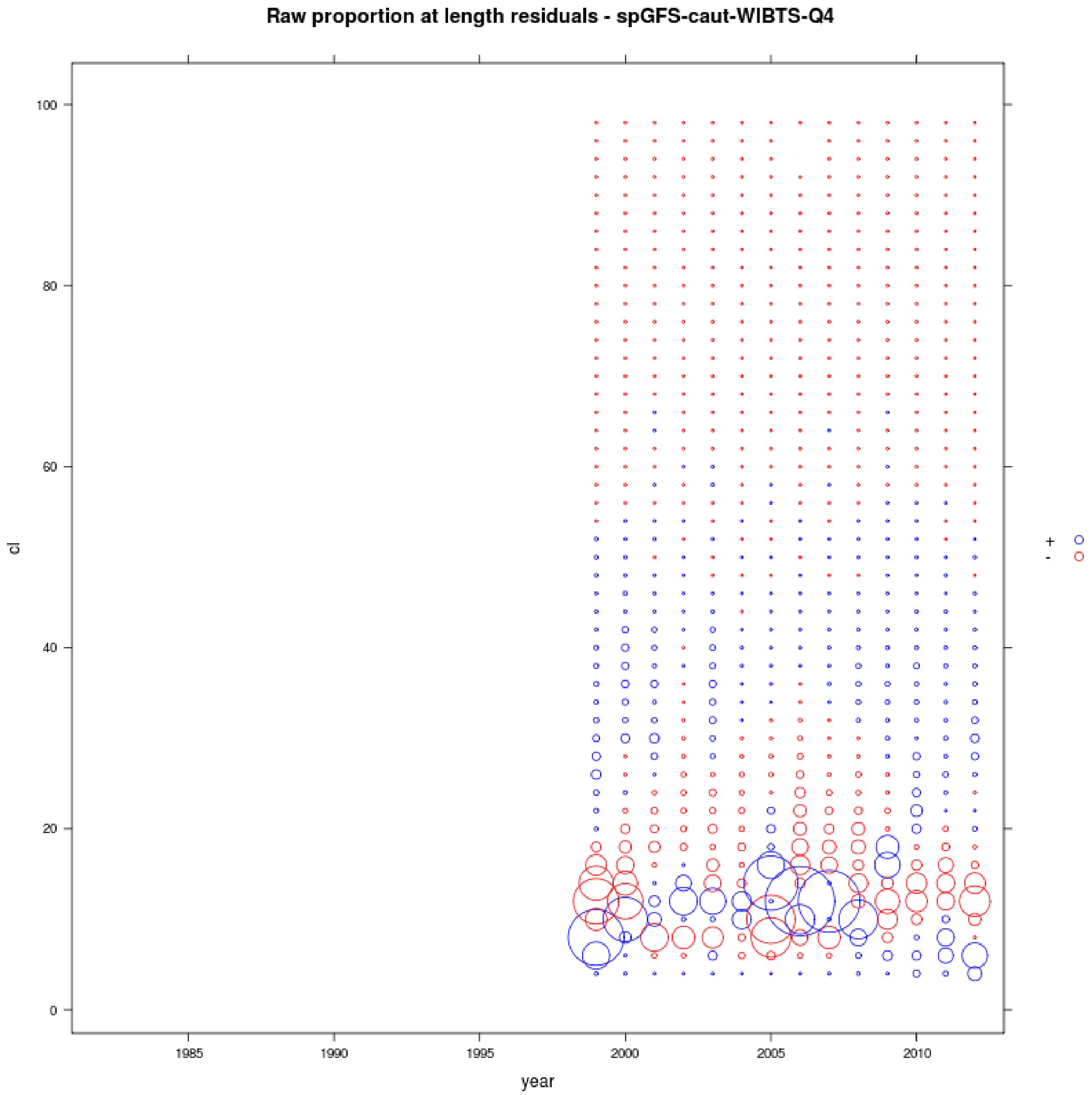
(4.5.6 f). Bubble plot for Discards length distribution for years 1993,97,99, 2004-2012



(4.5.6 g) Bubble plot for Portuguese demersal survey (ptGFS-WIBTS-Q4)



(4.5.6 h) Bubble plot for North Spain demersal survey (spGFS-WIBTS-Q4)



(4.5.6 i) Bubble plot for South Spain (Cadiz) demersal survey (spGFS-caut-WIBTS-Q4)

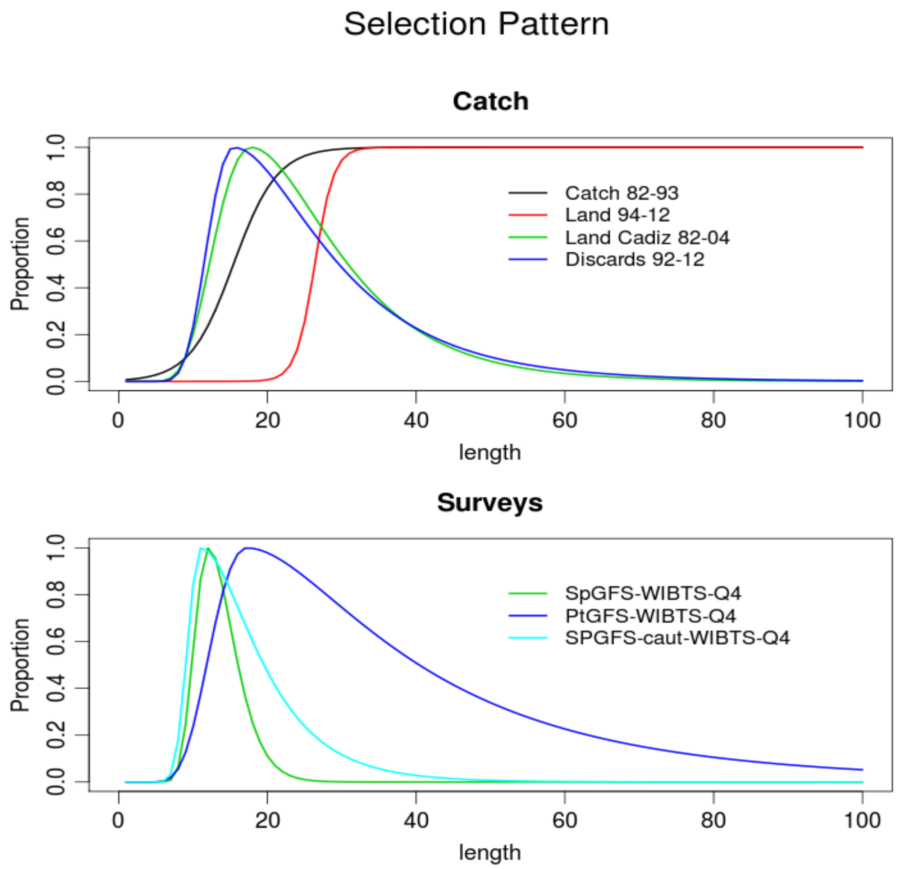


Figure 4.5.7. Selection pattern (upper panel) and von Bertalanffy growth with k parameter estimated by the model (lower panel)

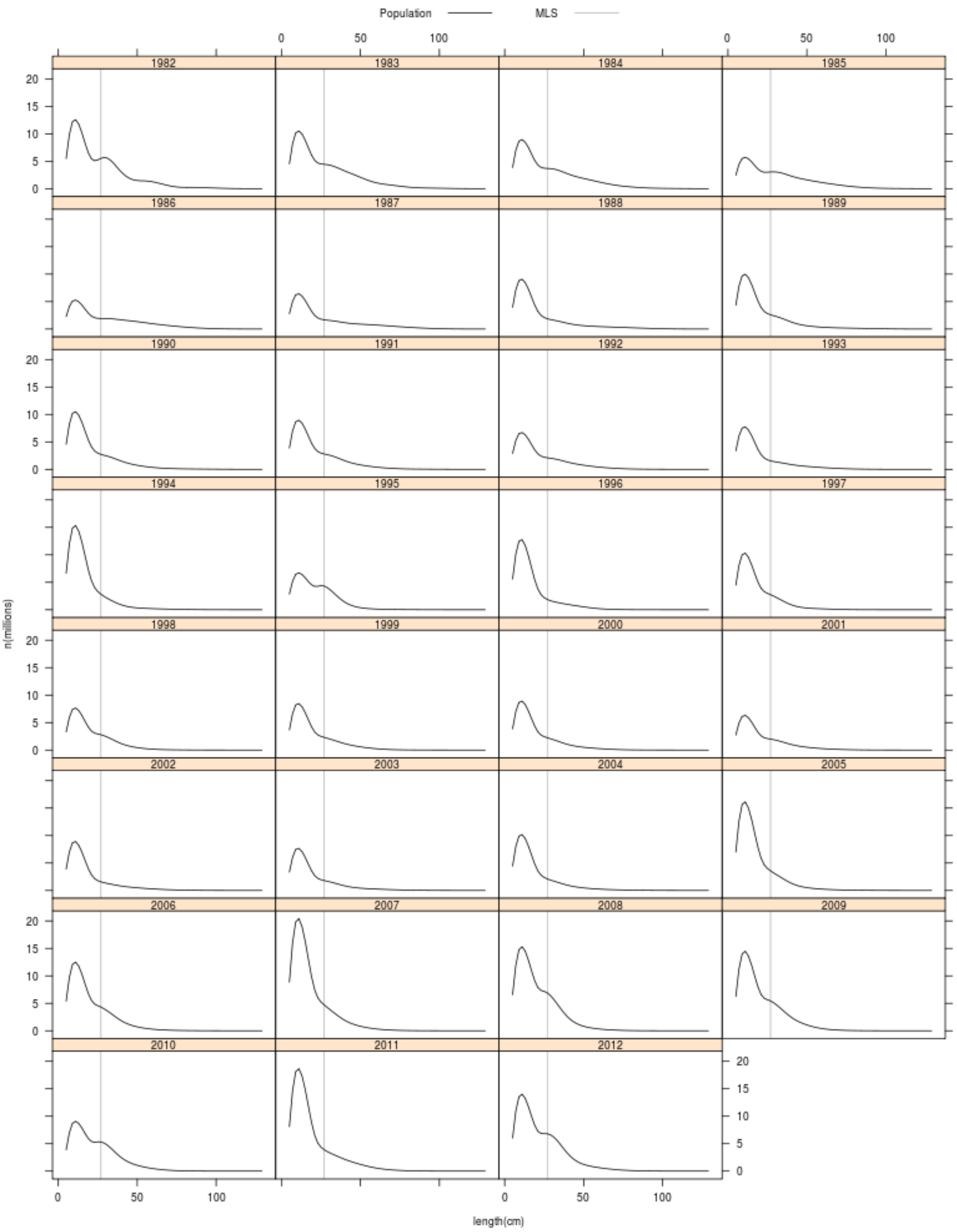


Figure 4.5.8. Population length distribution at beginning of 4rd quarter (MLS=27cm).

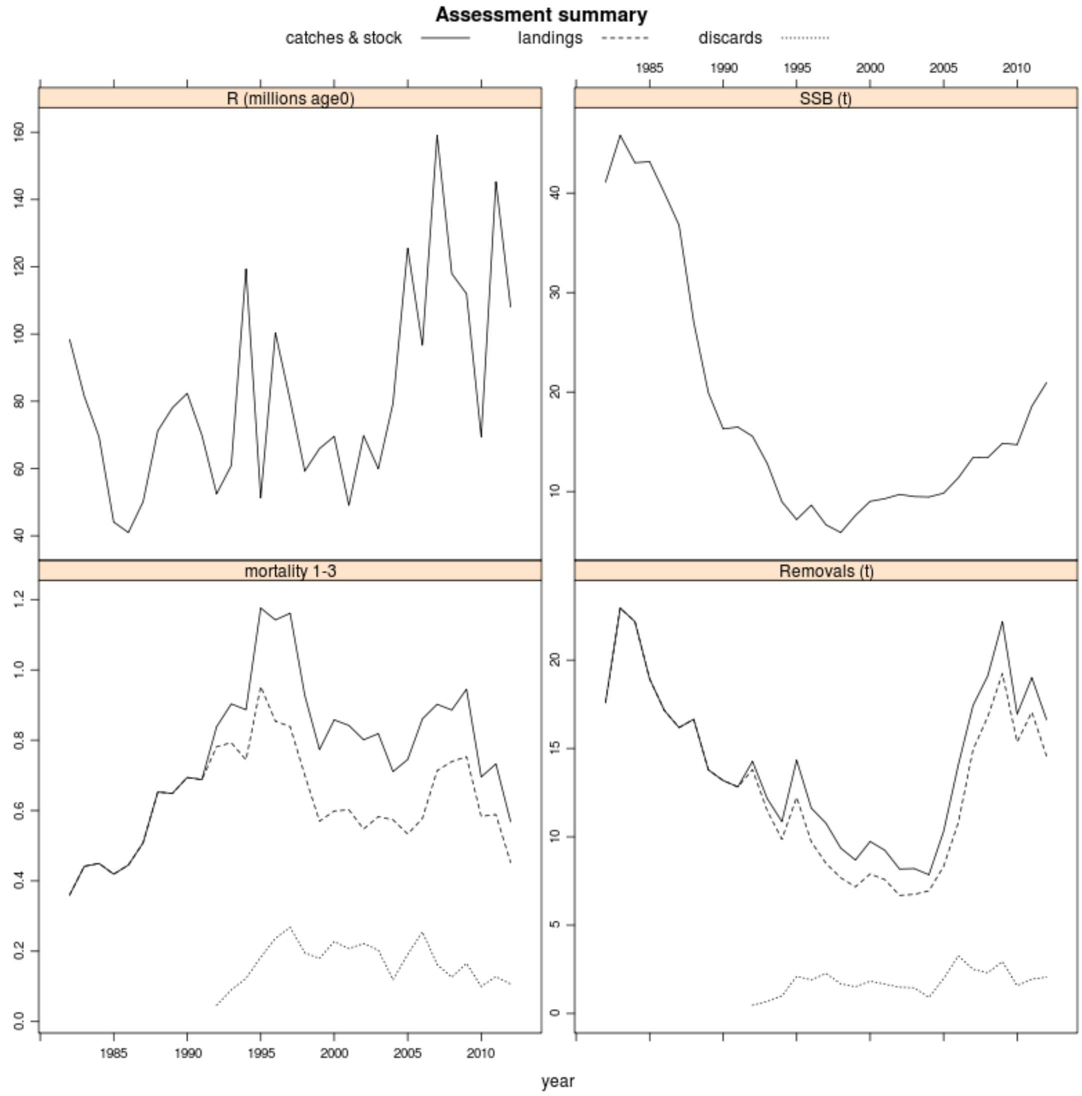


Figure 4.5.9. Summary plot. SSB and removals (catch, landings and discards) in '000 t. Recruitment in '000000 individuals.

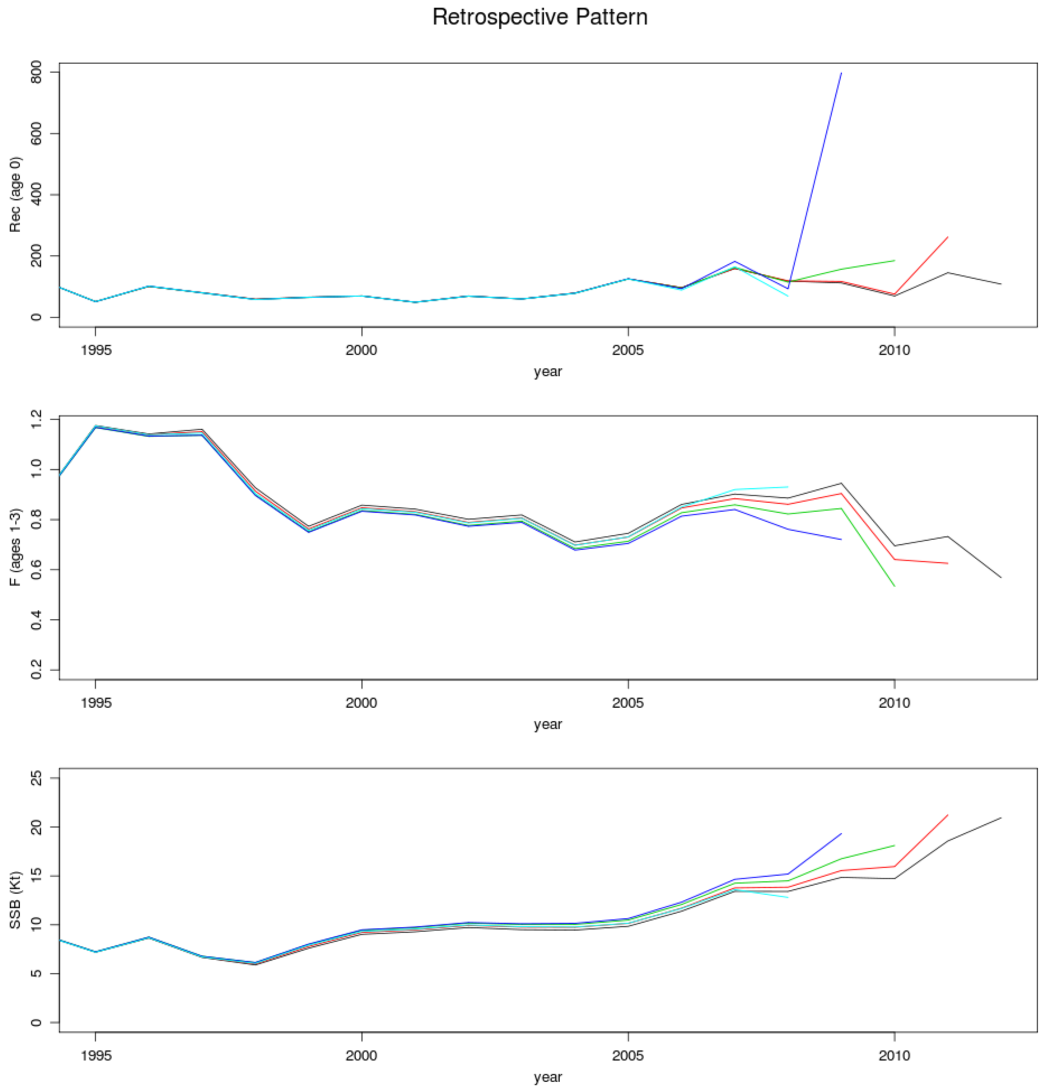


Figure 4.5.10. Retrospective plot

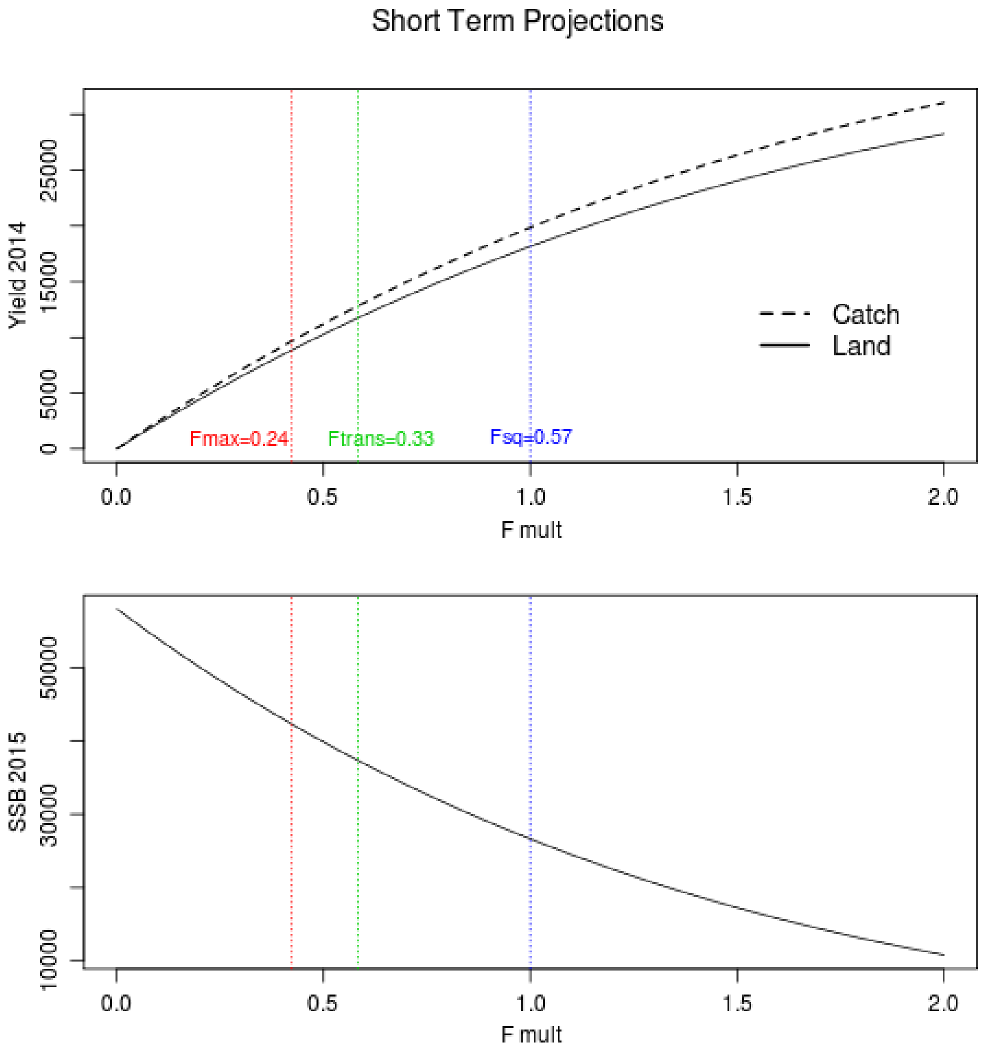


Figure 4.5. 11. Short-term advice

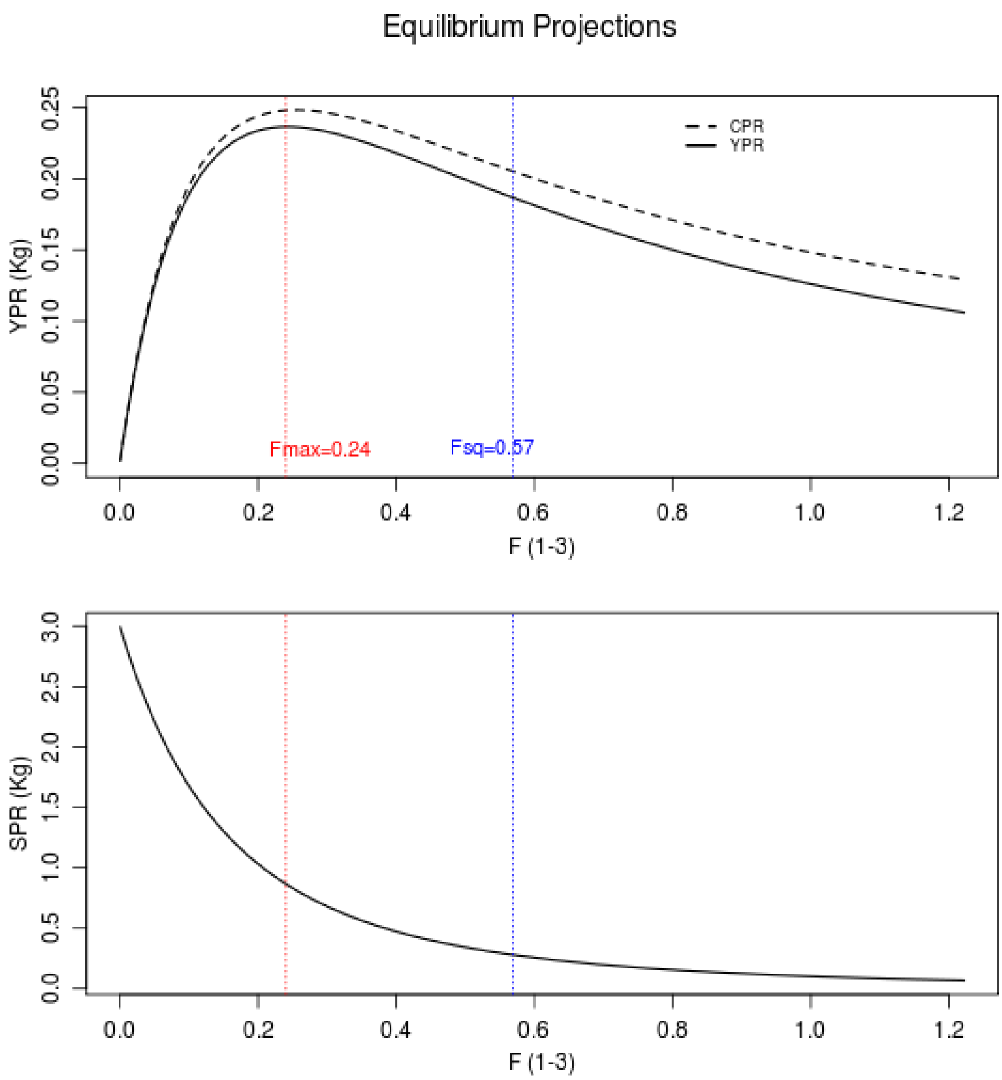


Figure 4.5.12. Yield and SSB per recruit

5 Megrim

5.1 Stock ID and substock structure

The genus Lepidorhombus is represented in eastern Atlantic waters by two species, megrim (*L. whiffiagonis*) and four-spot megrim (*L. boscii*). Three stocks of megrim are assessed by ICES: megrim in ICES Subareas IV and VI, megrim in Divisions VIIb-k and VIIIa,b,d and megrim in Divisions VIIIc and IXa. Although the boundaries of the stocks were established only for management purposes, recent genetic studies have proven the existence of at least two populations within the Atlantic Ocean for both species. While *L. boscii* populations match the stocks defined, *L. whiffiagonis* needs more detailed studies to refine the boundaries because conclusions from some studies were limited (Danancher and García-Vázquez, 2009) and another recent study suggests that there is no clear differentiation between the northern and southern stocks considered by ICES (García-Vázquez *et al.*, 2006).

The stocks considered in this benchmark are called Southern Megrims and include both megrim species in Divisions VIIIc and IXa. Megrim (*L. whiffiagonis*) is in both ICES Divisions (VIIIc and IXa), with its highest abundance in Division VIIIc. Four-spot megrim (*L. boscii*) is distributed in both ICES Divisions (VIIIc and IXa), with a more southerly distribution than megrim (Sánchez *et al.*, 2002). There is a certain bathymetric segregation between the two species of megrim. L. boscii has a preferential depth range of 100 to 450 m and L. whiffiagonis of 50 to 300 m (Sanchez *et al.*, 1998).

5.2 Multispecies and mixed fisheries issues

It should be taken into account that megrim, *L. whiffiagonis*, is caught in mixed fisheries. There is a common TAC for both species of megrim (*L. whiffiagonis* and *L. boscii*), so the joint status of the two species should be taken into consideration when formulating management advice. Megrims are a bycatch species in mixed fisheries generally directed to white fish. Therefore, fishing mortality of megrims could be influenced by restrictions imposed on demersal mixed fisheries, aimed at preserving and rebuilding the overexploited stocks of southern hake and Nephrops.

5.3 Ecosystem drivers

The Iberian Region along the eastern Atlantic shelf (Divisions VIIIc and IXa) is an upwelling area with high productivity, especially along the Portuguese and Galician coasts; upwelling takes place during late spring and summer (Álvarez-Salgado *et al.*, 2002; Serrano *et al.*, 2008). The region is characterized by a large number of commercial and non-commercial fish species caught for human consumption.

Many flatfish species show a gradual offshore movement of juveniles as they grow. This might indicate that habitat quality for flatfish is size-dependent. Another common pattern is the annual micro- and macroscale movements and migrations between spawning, feeding and wintering areas (Gibson 1994). Also, most flatfish are associated with finer sediments, rather than with hard substrata because burying themselves provides some protection from predators and reduces the use of energy (van der Veer *et al.*, 1990, 2000; Beverton and Iles 1992; Bailey 1994; Wennhage and Pihl 2001).

Previous studies on megrim species show that they generally occurred outside zones with hydrographical instabilities that foster the vertical interchange of organic matter

(Sánchez and Gil, 1995) and disappear at the mouth of the most important rivers (Sánchez *et al.*, 2001). Both species appear to show a gradual expansion in their bathymetric distribution throughout their lifetimes, with the larger individuals tending to occupy shallower waters than the juveniles. Bearing in mind that the two species have similar characteristics, a certain degree of interspecific competition may be assumed (Sanchez *et al.*, 1998).

Juveniles of these species feed mostly on detritivore crustaceans inhabiting deep-lying muddy bottoms. Adult *L. boscii* feeds mainly on crustaceans inhabiting muddy surfaces (Rodriguez-Marín and Olaso, 1993; Rodriguez-Marín, 2002) as opposed to *L. whiffiagonis*, which are more ichthyophagous and where rates of crustacean in diet decrease with fish size (Rodriguez-Marín, 2002). None of the two species represent an important part of the diet for the main fish predators in the area. However, Velasco (IEO, Santander, Spain, pers. comm.) observed that they are occasionally present in stomach contents of hake, anglerfish and rays.

The spawning period of these species is short. Mature males can be found from November to March and mature females from December to March, but spawning peaks in March. In southern areas megrims spawn from January to April (BIOSDEF, 1998; study contract 95/038).

The growth rate also varies (Landa *et al.*, 1996; Landa, 1999), growth is quicker in the southern area for both species but the maximum length attained is smaller than in the north. The maximum age for megrim also varies with latitude. In Subarea VII the maximum age of megrim is 14 years, this age decreases to 12 years in Divisions VIIIc and IXa (BIOSDEF, 1998; Landa et. al, 2000). The maximum age for four-spot megrim in Divisions VIIIc and IXa is 11 years (Landa *et al.*, 2002, Landa, pers. com.).

5.4 Megrim

5.4.1 Issue list

The following list of issues had been identified to be addressed at this benchmark:

Model

XSA convergence problems

To help with automation, transfer the analysis to the FLR-XSA environment.

Data

Potential selectivity change in recent years with new minimum landing size imposed.

Include discards in the assessment. The variability of the discards ranges between 10-45% .

Commercial tuning fleets do not cover the full time-series due to issues with obtaining full information on effort and landings and changes in the fleet over time.

Spanish ALK used to raise all countries data.

Other work required

Biological and precautionary reference points

5.4.2 Scorecard on data quality

Similar to the hake stocks a scorecard on the quality of the data used in the benchmark process was discussed during the benchmark meeting. No analysis was performed to provide scores, which were only based on qualitative judgment from national stock coordinators. Many doubts appeared whilst completing the table and it should be considered as tentative; meanwhile more clarifications, analysis and expert contributions are provided.

5.4.3 Stock Assessment data

5.4.3.1 Catch – quality, misreporting, discards

Working Group estimates of landings are available for the period 1986 to 2012 and official landings figures from Spain for 2011 and 2012 (Table 5.4.3.1.1). The discrepancy between official and scientific estimates is included in a column "Unallocated". The total estimated international landings in Divisions VIIIc and IXa for 2012 was 288 t. Landings reached a peak of 977 t in 1990, followed by a steady decline to 117 t in 2002. Some increase in landings has been observed since then, but landings have again decreased annually since 2007. The landings in 2010 were the lowest value of the entire series. 2011 and 2012 values represent important increments in the landings of the stock.

The Spanish estimates of discards have been available for an incomplete time-series: 1994, 1997, 1999-2000 and 2003-2012. So, following recommendations described in the advice sheets for both stocks, different methodologies were applied trying to reconstruct the discards time-series. An effort was made to complete the time-series back until 1986 in order to analyse and use during the benchmark. For L. whiffiagonis, different procedures were applied to estimate discards in years without sampling: arithmetic mean from years with real data, Generalized Linear Models (GLM), but replacing age 1 with results from a linear regression between abundance data from the survey and discards data, and GLM to impute missing recent discards and prior to 1994, using total catch and then removing landings to obtain discards. There were some inconsistencies in the first GLM model and the second GLM resulted in negative discard estimates. Given the dissatisfaction with these more advanced methods, discard estimates from the average by period have been selected for filling in missing data. For the first period (1986-1999), the average of available years 1994, 1997 and 1999 were used and for the second period (2000-2012) the absence of data in 2001 and 2002 was replaced by the average of the closest years. The reason for using these two periods is the change in the Minimum landing size (MLS) in 2000 that has the potential to bring about a shift in the discarding behaviour.

Table 5.4.3.1.1. Megrim (*L. Whiffiagonis*) in Divisions VIIc, IXa. Total landings (t).

	Spain			Portugal	Unallocated	Total
Year	VIIIc	IXa***	Total	IXa		
1986	508	98	606	53		659
1987	404	46	450	47		497
1988	657	59	716	101		817
1989	533	45	578	136		714
1990	841	25	866	111		977
1991	494	16	510	104		614
1992	474	5	479	37		516
1993	338	7	345	38		383
1994	440	8	448	31		479
1995	173	20	193	25		218
1996	283	21	305	24		329
1997	298	12	310	46		356
1998	372	8	380	66		446
1999	332	4	336	7		343
2000	238	5	243	10		253
2001	167	2	169	5		175
2002	112	3	115	3		117
2003	113	3	116	17		134
2004	142	1	144	5		149
2005	120	1	121	26		147
2006	173	2	175	35		210
2007	139	2	141	14		155
**2008	114	2	116	17		133
2009	74	2	77	7		84
2010	66	8	74	10		83
*2011	109	3	111	34	14	159
*2012	164	3	167	18	103	288

***IXa is without Gulf of Cádiz

** Data revised in WG2010

* Official data by country and unallocated landings

5.4.3.2 Surveys

The Portuguese October groundfish survey (PtGFS-WIBTS-Q4) and the Portuguese Crustacean survey (PT-CTS (UWTV (FU 28-29))) and one Spanish groundfish survey (SpGFS-WIBTS-Q4) series are available since 1990, 1997 and 1983, respectively.

It should be taken into consideration that during years 1996, 1999, 2003 and 2004 the October Portuguese survey was carried out with a different vessel and gear from the one used in the rest of the time-series. The Crustacean survey was performed with different vessels in different years and covers only a partial area; in 2004 it had many operational problems.

For these reasons and because indices from these surveys are not considered to be representative of megrim abundance, due to the very low catch rates, only the Spanish survey (SpGFS-WIBTS-Q4) is used in the assessment of the two species. The survey covers the distribution area and depth strata of these species in Spanish waters (covering both VIIIc and IXa). The survey appears to be quite good at tracking cohorts through time for L. whiffiagonis.

5.4.3.3 Tuning fleets

The last assessments had been calibrated by using two bottom otter trawl tuning fleets: A Coruña trawl (SP-CORUTR8c) for the period 1990-2012 and Avilés trawl (SP-AVILESTR) for the period 1990-2003. It is known that the Northern Spanish coastal bottom otter trawl fleet is a fleet deploying a variety of fishing strategies with different target species (Punzon *et al.*, 2010). In fact, these fishing strategies are identified under the current DCF sampling programme, so that they can be then re-aggregated under two DFC métiers: bottom otter trawl targeting demersal species (OB_DEF_>=55_0_0) and OTB targeting pelagic stocks accompanied by some demersal species (OTB_MPD_>55_0_0). Therefore, the LPUE of these métiers was recovered backwards (until 1986) and two new time-series of bottom otter trawl targeting demersal species, one per port (A Coruña and Avilés), were provided to be tested during this benchmark (WD 04, Castro *et al.*, 2014).

5.4.3.4 Age, weights, maturities, growth

Additional biological information used in the Benchmark include:

Age compositions of landings were calculated using annual Spanish ALKs since 1990, whereas a survey ALK from 1986 combined with an annual ALK from 1990 was applied to the years 1986-1989.

Catch weights-at-age are also used as the weights-at-age in the stock.

The following parameter values were used in the length-weight relationship. This relationship was externally calculated in an international project with sampling that spatially covered a large proportion of the stock (BIOSDEF, 1998):

	L. whiffiagonis
a	0.006488
b	3.0114

Natural mortality is set to 0.2 and assumed constant over all ages and years. This is the same value used for L. whiffiagonis in Divisions VIIb-k and VIIIabd.

The sex combined maturity ogive (BIOSDEF, 1998) is assumed constant over time, with the following proportions of fish mature at each age:

Age	0	1	2	3	4	5+
L. whiffiagonis	0	0.34	0.90	1	1	1

5.4.4 Assessment model

Extended Survivors Analysis (XSA) model was selected for use in this assessment. Model description is detailed in the Stock Annex.

The new input data tried during the Benchmark are described below:

- Spanish discards time-series, included in the catch-at-age matrix.
- New SP-CORUTR8c and SP-AVILESTR for the entire time-series.

A series of different model specifications were tried in various runs to refine the assessment. The most representative in the selection process of final model are presented here as sensitivity analysis.

Sensitivity analysis

Sensitivity to discards estimates procedures

Assessment results using discards estimates from the average by the two periods previous explained (using discards data from available years) and using discards estimates from modelled data with a GLM were examined by two runs.

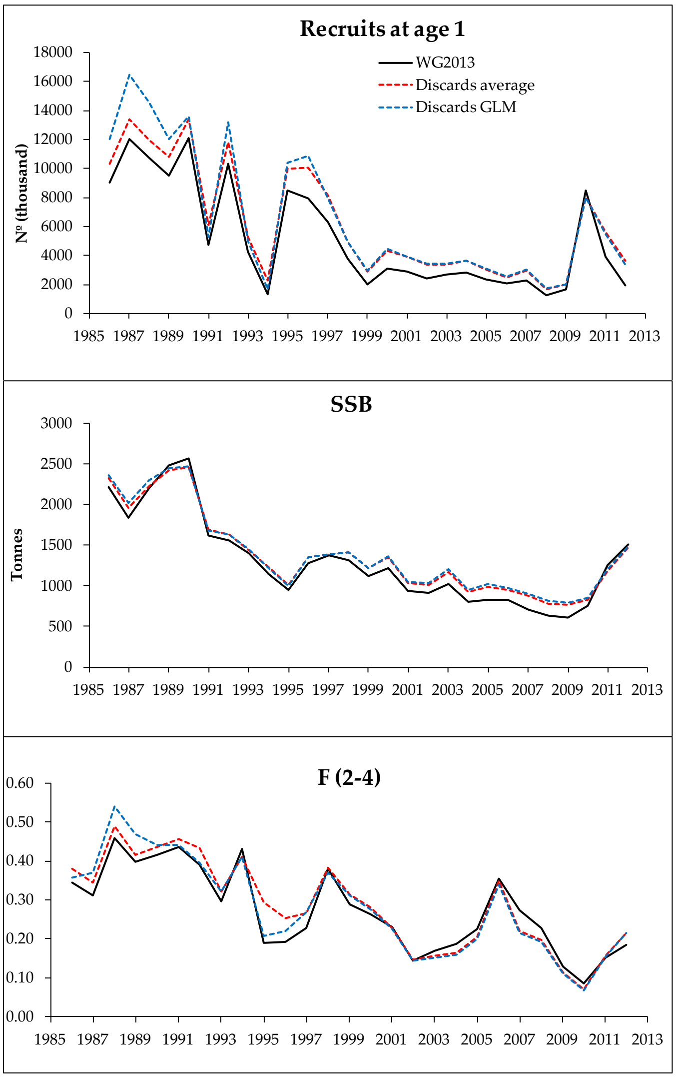


Figure 5.4.4.1. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Sensitivity analysis to different discards estimates.

Due to some inconsistencies in the GLM results and, as the figures show, in the absence of significant differences in the runs results, the Benchmark decided to use the simpler discards average for further analysis.

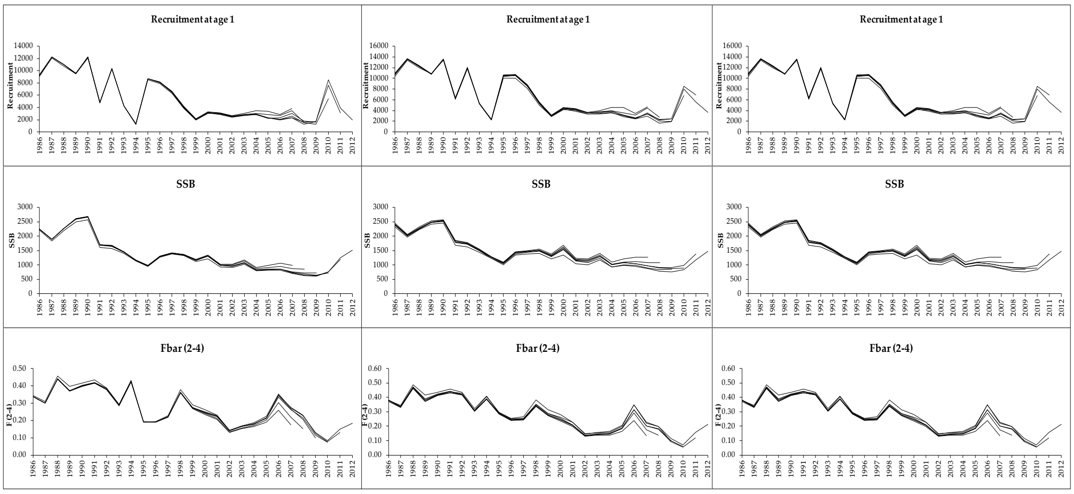


Figure 5.4.4.2. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Retrospective patterns of WG2013 assessment (left panels), discards average sensitivity run (middle panels) and discards GLM sensitivity run (right panels).

The retrospective patterns are shown in Figure 5.4.4.2, and those from the sensitivity runs are quite similar between them and in relation to the retrospective pattern of the working group assessment (WGHMM 2013).

Sensitivity to tuning fleets and surveys

The impact of the tuning fleets and the surveys on the assessment results was also tested. Four possible model configurations were considered:

- Tuning: survey (SpGFS-WIBTS-Q4)
- Tuning: survey (SpGFS-WIBTS-Q4) and Coruña (SP-CORUTR8c)
- Tuning: survey (SpGFS-WIBTS-Q4) and Avilés (SP-AVILESTR)
- Tuning: all (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR)

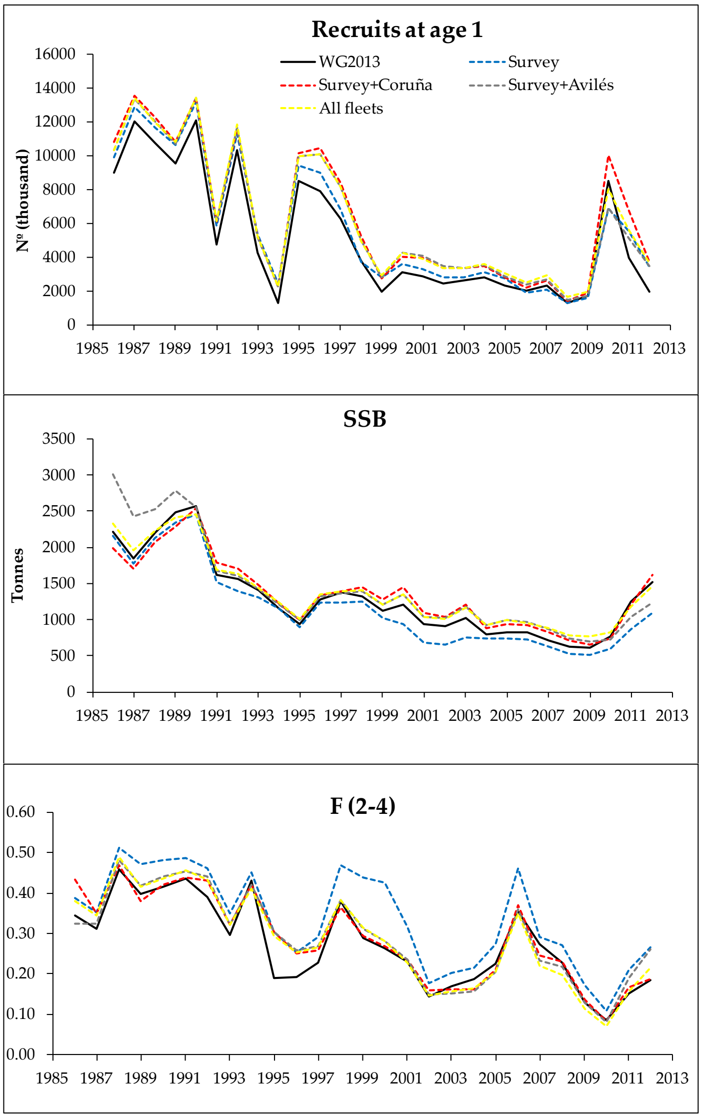


Figure 5.4.4.3. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Sensitivity analysis to different tuning fleets.

Results indicate a clear difference between the results using only the survey and the results using the commercial tuning fleets. The main differences can be observed in the F values of the entire series and the last period of SSB. Results using the survey and one of the commercial tuning fleets or the survey and both commercial tuning fleets only show differences in the first years for SSB and last years for Recruitment. Using both commercial tuning fleets together with the survey stabilizes the F and SSB estimates over time.

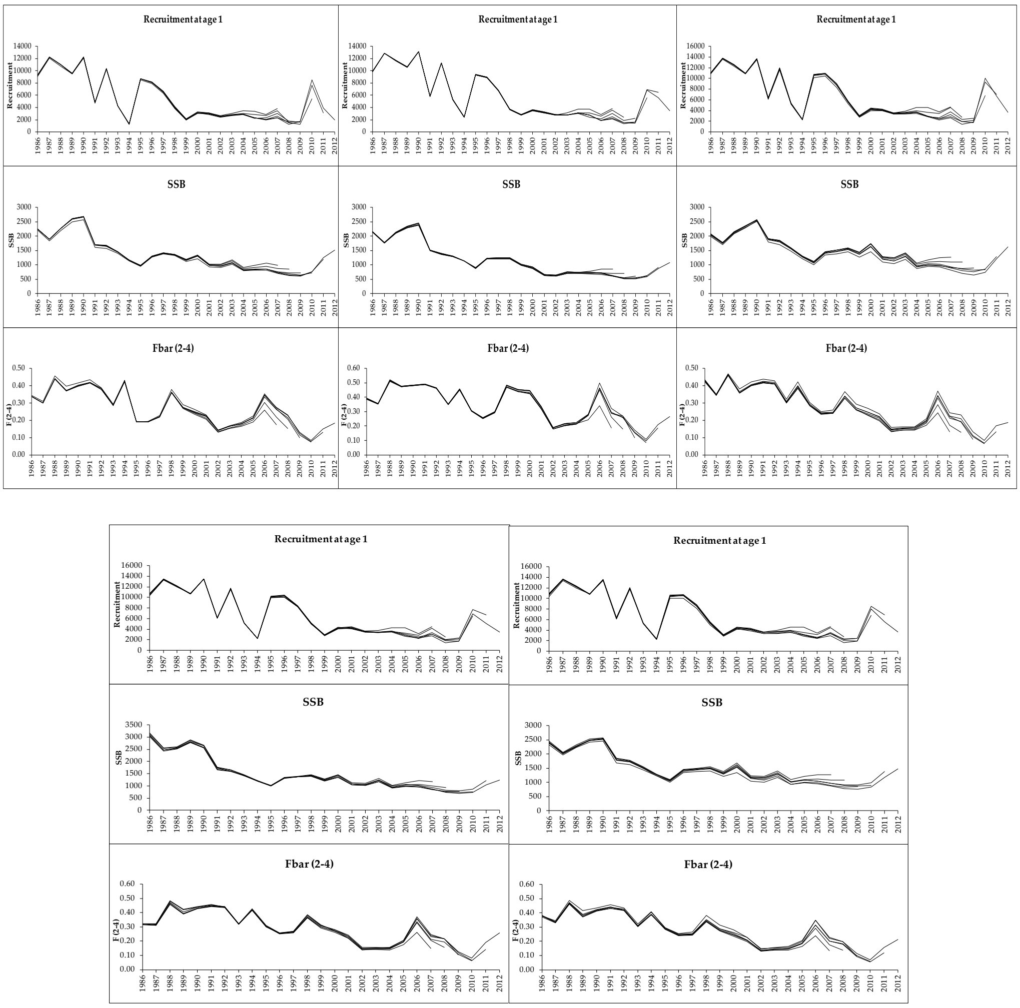
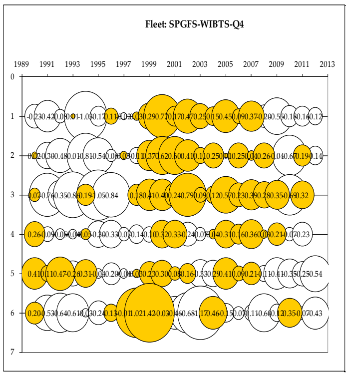
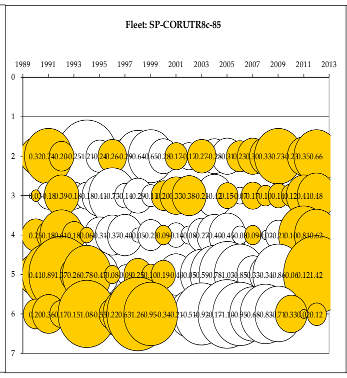
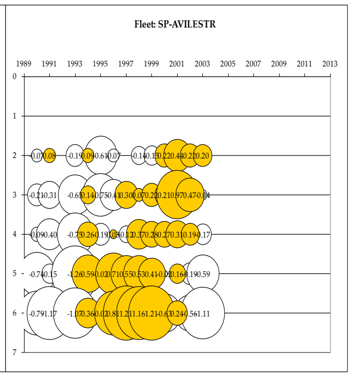
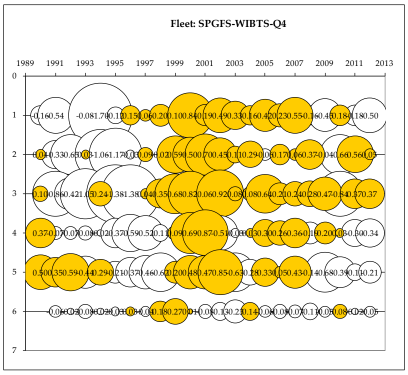


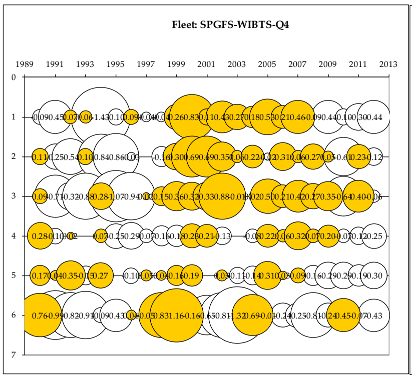
Figure 5.4.4.4. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis for XSA assessments tuning with: survey (SpGFS-WIBTS-Q4), survey and Coruña (SpGFS-WIBTS-Q4, SP-CORUTR8c), survey and Avilés (SpGFS-WIBTS-Q4, SP-AVILESTR) and all fleets (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR).


Fleet: SPGFS-WIBTS-Q4
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7


Fleet: SP-CORUTR8c-85
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7


Fleet: SP-AVILESTR
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7


Fleet: SPGFS-WIBTS-Q4
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7


Fleet: SPGFS-WIBTS-Q4
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7

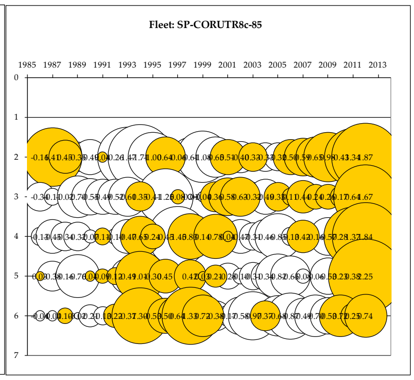

Fleet: SP-CORUTR8c-85
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
0
1
2
3
4
5
6
7

Figure 5.4.4.5. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Log catchability residual plots of WGHMM2013 assessment and sensitivity analysis for XSA assessments tuning with: survey (SpGFS-WIBTS-Q4), survey and Coruña (SpGFS-WIBTS-Q4, SP-CORUTR8c), survey and Avilés (SpGFS-WIBTS-Q4, SP-AVILESTR) and all fleets (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR).

Residual plots show minor differences and the last option including all tuning fleets minimizes residual values that are greater if fleets are not combined in the same model.

The quality of the survey is much better than the quality of the commercial fleets, but using only one dataseries can be problematic, especially given the likelihood for surveys of obtaining poor observations in certain years. In addition, there is no strong reason to exclude the commercial tuning series.

These considerations led the Benchmark to accept the configuration that includes the survey and both commercial tuning fleets.

Sensitivity to change catchability settings

Catchability dependent on stock size is especially of use for younger ages. Using XSA, it is possible to test the need to make the catchability dependent on stock size. In case the power model parameter does not differ significantly from one, the catchability should be independent on run size. If not, the opposite is the case. The sensitivity to the catchability-age-dependence assumptions has been tested in two model configurations:

- setting catchability independent of stock size for all ages
- setting catchability dependent on stock size for ages < 3

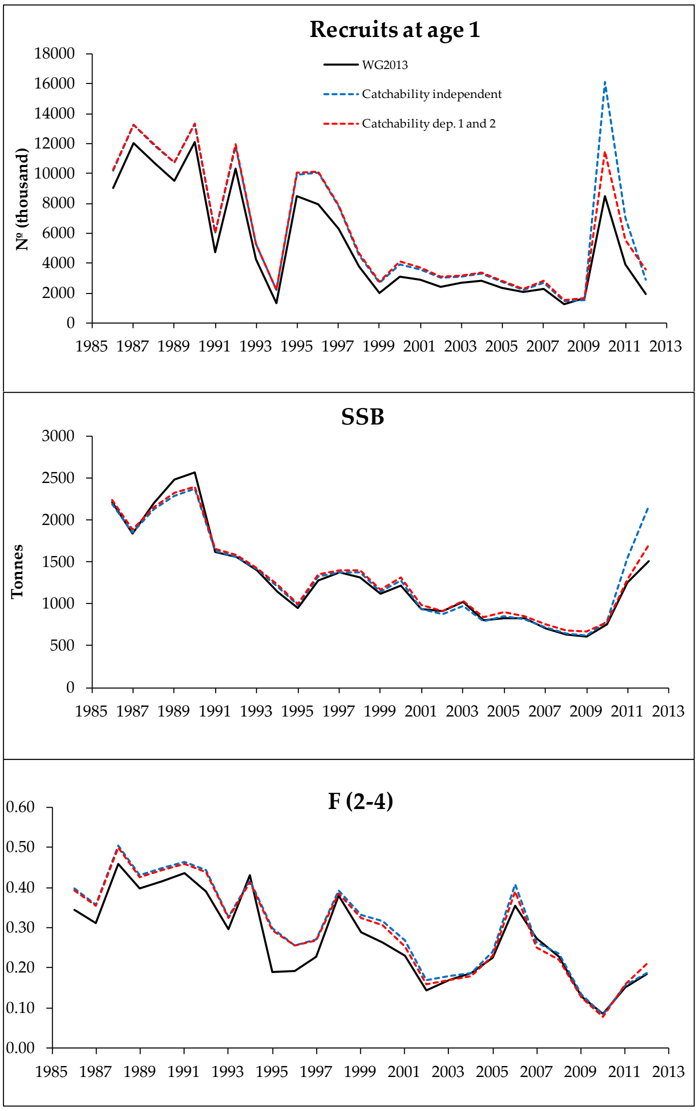


Figure 5.4.4.6. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Sensitivity analysis to different catchability options.

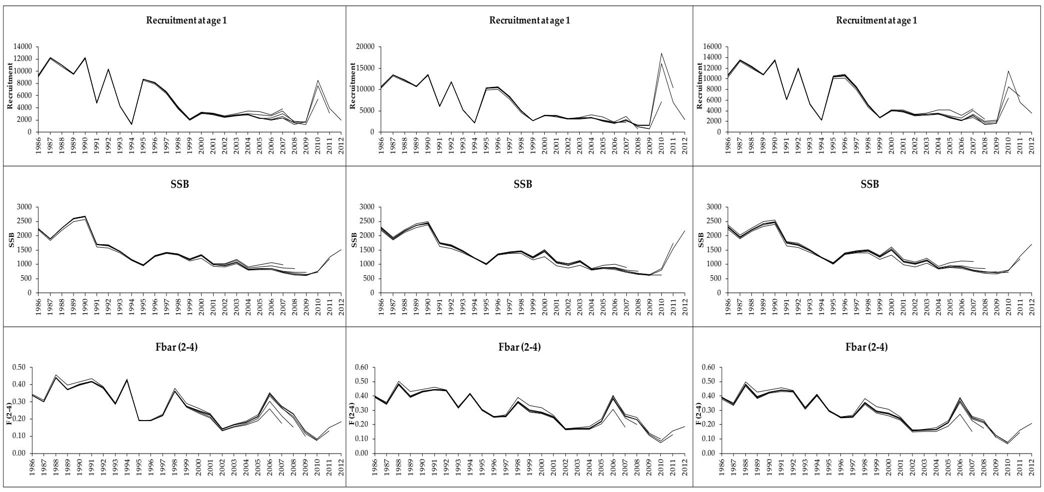


Figure 5.4.4.7. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis to catchability independent of stock size and catchability dependent on stock size for ages <3.

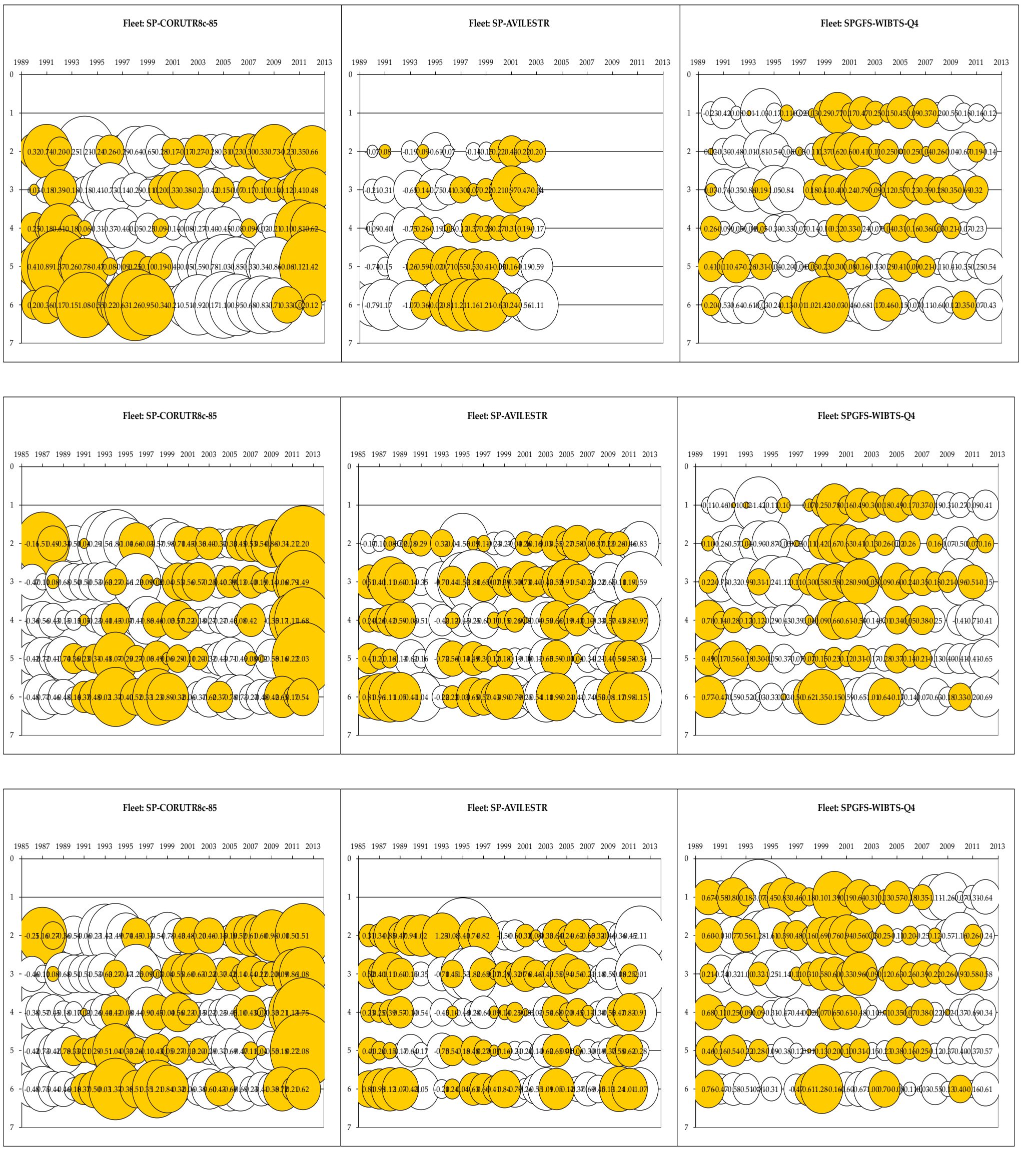


Figure 5.4.4.8. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and sensitivity analysis to catchability independent of stock size and catchability dependent on stock size for ages <3.

Sensitivity to tuning fleets and surveys: removing ages 1 and 2 from the commercial tuning fleets

The commercial tuning fleet data, which is based on landings information, included ages which were highly variable and subject to high discarding. The Benchmark recommended removing the younger ages with lots of discarding from these tuning fleets, to remove the potential noise and extreme variability of the index that these age groups were causing.

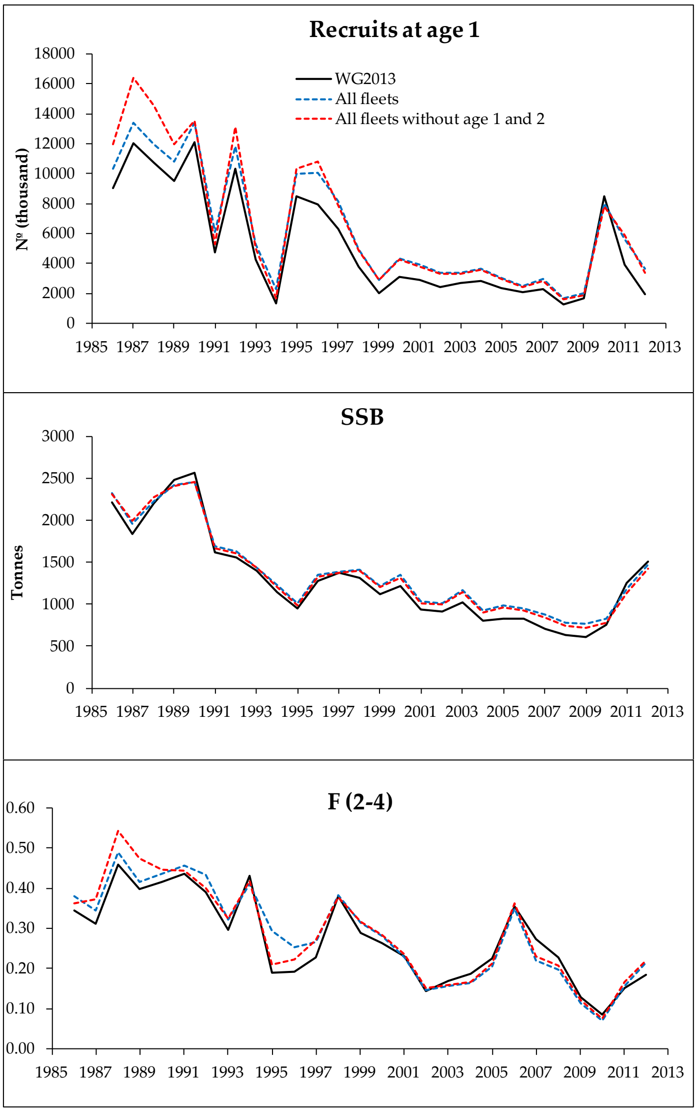


Figure 5.4.4.9. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Sensitivity analysis to different tuning fleet options.

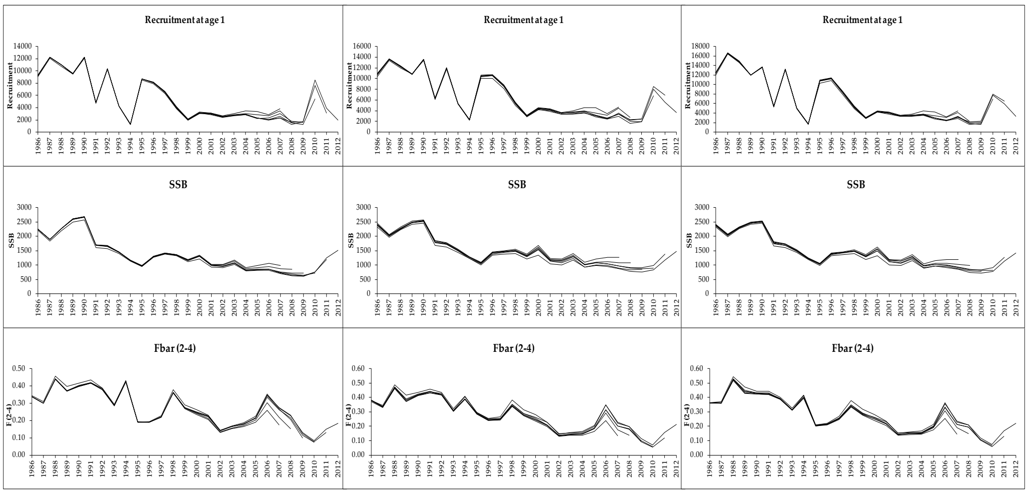


Figure 5.4.4.10. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis to XSA settings for tuning fleets and removing age 1 and 2 from commercial tuning fleets.

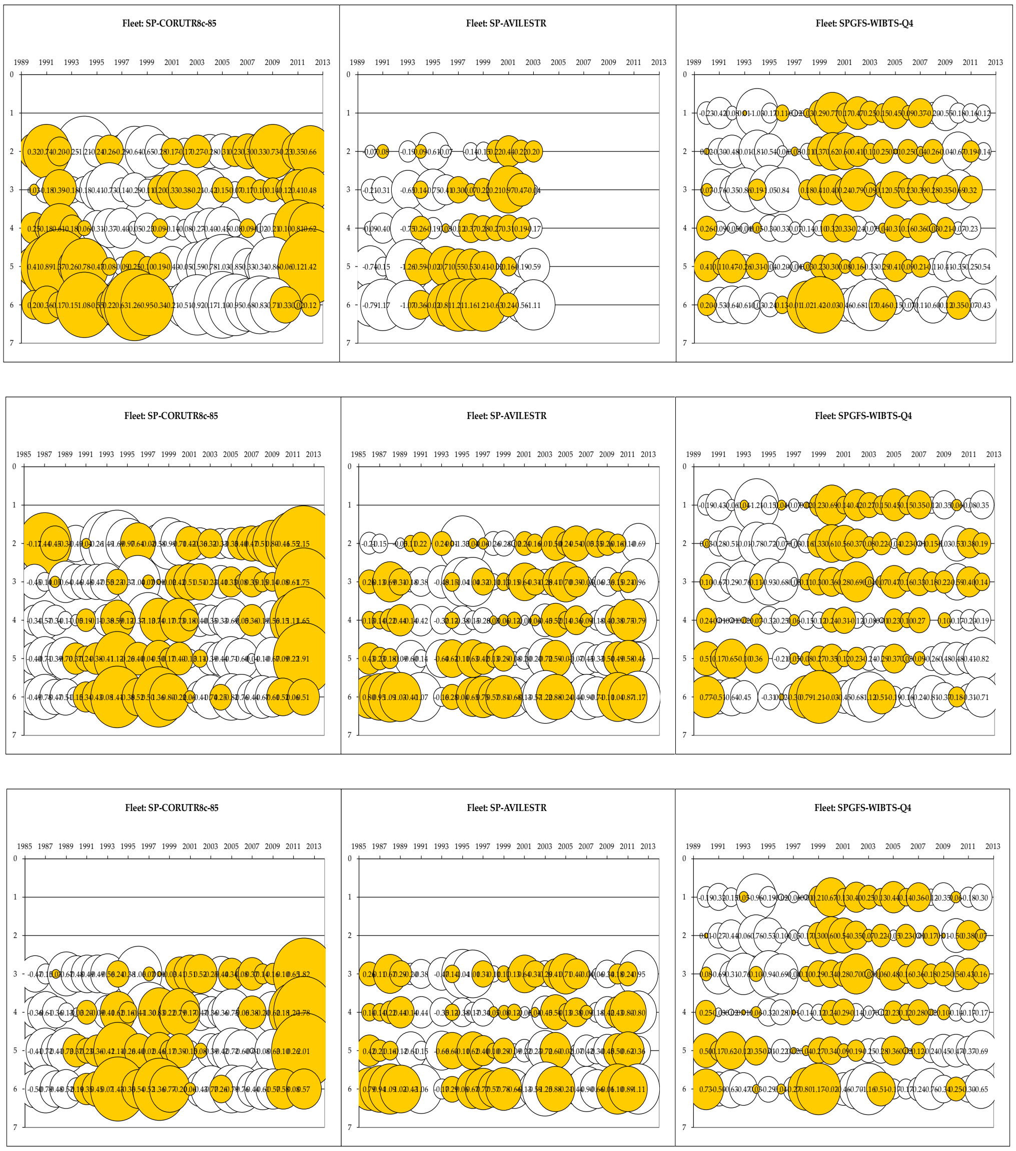


Figure 5.4.4.11. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and sensitivity analysis to XSA settings for tuning fleets and removing age 1 and 2 from commercial tuning fleets.

Final accepted assessment

Based on the sensitivity analysis, retrospective patterns and the residual plots, the final accepted model has the following specifications:

- Discards average by period. First period from 1986 to 1999 and second period from 2000 to 2012, because the change of MLS in 2000.
- All tuning fleets (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR).
- Catchability dependent of stock size age 1 and 2.
- Age 1 and 2 removed from commercial tuning fleets.

The Benchmark agreed that the final model configuration, presented in the Stock Annex, is the most appropriate and shows an improvement in the assessment.

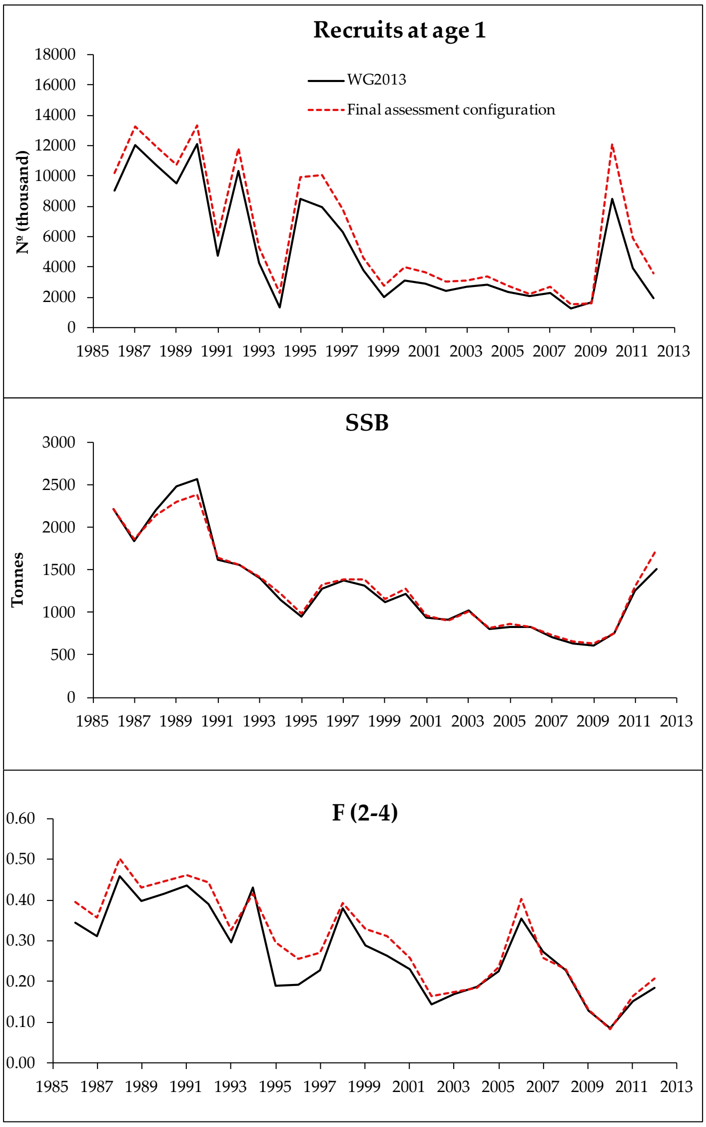


Figure 5.4.4.12. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Final assessment configuration (in red).

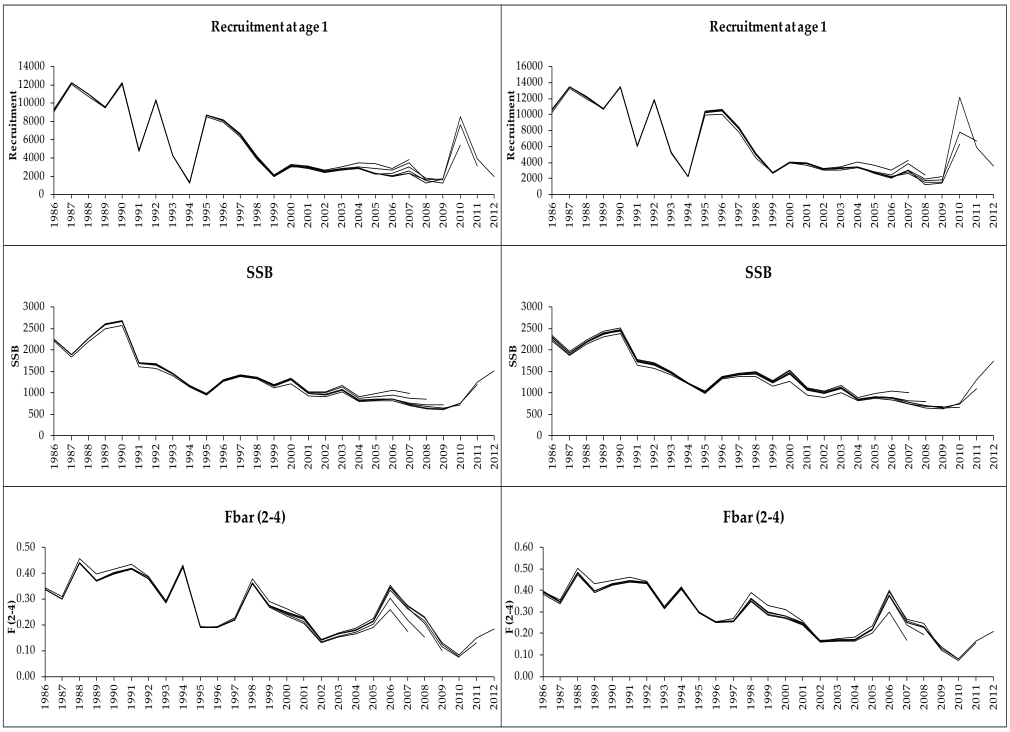


Figure 5.4.4.13. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and final assessment configuration.

Figure 5.4.4.14. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and final assessment configuration.

5.4.5 Short-term projections

The software used for the short-term projections was MFDP with management option table and yield-per-recruit routines, according to the Stock annex. Because of the variability of the recent discard data, some settings have been changed from those used previously for this stock. The average of 5 years has been used for (at age) weight in catch, weights in the stock and the exploitation pattern. Flexibility should be allowed to choose the range of years depending on the data. To calculate the exploitation pattern at age (F-at-age/Fbar), each year is first standardized and then averaged (using a 5 years average, as noted above). Fbar for the intermediate year is usually taken as a 3-year average, but it could be scaled to the final assessment year if the assessment WG considers this a more realistic option for Fbar in the intermediate year. Forecast catch numbers-at-age are divided into landings and discards (at age) based on the proportions given as inputs to the projection software; the software does it automatically. These proportions were taken (for each age) to be those corresponding to the observed average of the most recent 5 years.

Table 5.4.5.1. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Input data for deterministic short-term predictions.

MFDP version 1a
Run: whiff5
Time and date: 23:34 06/02/2014
Fbar age range (Total) : 2-4
Fbar age range Fleet 1 : 2-4

Age 2013	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
1	3130	0.2	0.34	0	0	0.031	0.015	0.060	0.164	0.028
2	2179	0.2	0.9	0	0	0.087	0.078	0.097	0.027	0.064
3	2172	0.2	1	0	0	0.127	0.126	0.128	0.005	0.099
4	5099	0.2	1	0	0	0.152	0.211	0.153	0.006	0.115
5	375	0.2	1	0	0	0.188	0.351	0.188	0.007	0.162
6	124	0.2	1	0	0	0.236	0.329	0.237	0.005	0.165
7	650	0.2	1	0	0	0.379	0.332	0.380	0.002	0.127

Age 2014	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
1	3130	0.2	0.34	0	0	0.031	0.015	0.060	0.164	0.028
2	.	0.2	0.9	0	0	0.087	0.078	0.097	0.027	0.064
3	.	0.2	1	0	0	0.127	0.126	0.128	0.005	0.099
4	.	0.2	1	0	0	0.152	0.211	0.153	0.006	0.115
5	.	0.2	1	0	0	0.188	0.351	0.188	0.007	0.162
6	.	0.2	1	0	0	0.236	0.329	0.237	0.005	0.165
7	.	0.2	1	0	0	0.379	0.332	0.380	0.002	0.127

Age 2015	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
1	3130	0.2	0.34	0	0	0.031	0.015	0.060	0.164	0.028
2	.	0.2	0.9	0	0	0.087	0.078	0.097	0.027	0.064
3	.	0.2	1	0	0	0.127	0.126	0.128	0.005	0.099
4	.	0.2	1	0	0	0.152	0.211	0.153	0.006	0.115
5	.	0.2	1	0	0	0.188	0.351	0.188	0.007	0.162
6	.	0.2	1	0	0	0.236	0.329	0.237	0.005	0.165
7	.	0.2	1	0	0	0.379	0.332	0.380	0.002	0.127

Input units are thousands and kg - output in tonnes

Table 5.4.5.2. Megrim (*L. whiffiagonis*) (Divisions VIIIc and IXa). Management options for catch predictions.

MFDP version 1a
Run: whiff5
Time and date: 23:34 06/02/2014
Fbar age range (Total) : 2-4
Fbar age range Fleet 1 : 2-4

2013		Total	Landings		Discards	
Biomass	SSB	FMult	FBar	Yield	FBar	Yield
1686	1603	1	0.1383	271	0.0127	20

2014		Total	Landings		Discards		2015	
Biomass	SSB	FMult	FBar	Yield	FBar	Yield	Biomass	SSB
1578	1496	0	0.0000	0	0.0000	0	1840	1754
.	1496	0.1	0.0138	35	0.0013	2	1796	1711
.	1496	0.2	0.0277	69	0.0025	4	1754	1669
.	1496	0.3	0.0415	102	0.0038	6	1713	1628
.	1496	0.4	0.0553	134	0.0051	8	1673	1588
.	1496	0.5	0.0692	165	0.0063	10	1634	1550
.	1496	0.6	0.0830	195	0.0076	12	1596	1512
.	1496	0.7	0.0968	224	0.0089	14	1559	1476
.	1496	0.8	0.1107	252	0.0101	16	1524	1441
.	1496	0.9	0.1245	280	0.0114	18	1489	1406
.	1496	1	0.1383	307	0.0127	20	1455	1373
.	1496	1.1	0.1522	333	0.0139	22	1423	1341
.	1496	1.2	0.1660	358	0.0152	23	1391	1309
.	1496	1.3	0.1798	383	0.0165	25	1360	1279
.	1496	1.4	0.1937	406	0.0177	27	1330	1249
.	1496	1.5	0.2075	430	0.0190	29	1301	1220
.	1496	1.6	0.2213	452	0.0203	30	1272	1192
.	1496	1.7	0.2352	474	0.0215	32	1245	1165
.	1496	1.8	0.2490	495	0.0228	33	1218	1138
.	1496	1.9	0.2628	516	0.0241	35	1192	1112
.	1496	2	0.2767	536	0.0253	36	1167	1087

Input units are thousands and kg - output in tonnes

5.4.6 Appropriate Reference Points (MSY)

The work during the benchmark and the writing of this report concentrated first on four-spot megrim, followed by work and report writing on megrim. It is therefore important to read the reference points section for four-spot megrim before reading this one (as the one for four-spot megrim provides considerable more detail of the analysis conducted).

The reference points analysis conducted for megrim mirrored the one conducted for four-spot megrim, and used the same PlotMSY software.

While conducting the analysis for megrim it was noticed that the selection-at-age pattern (originally based on an arithmetic mean of the 5 most recent years) resulted in very high values at age 1 (higher than for ages 2 and 3), and that this was strongly driven by the high value of discards at age 1 in 2011 (which resulted in a very high estimate of F at age 1 for 2011 in the assessment). After discussion at the benchmark, it was felt that this selection pattern was not appropriate to the calculation of reference points, as it was too dependent on interannual variability, and a geometric mean was considered preferable because it puts less weight on high values that occur occasionally (see Figure 5.4.6.1). The analysis presented in this section is, therefore, based on a (5-year) geometric mean for the selection-at-age pattern.

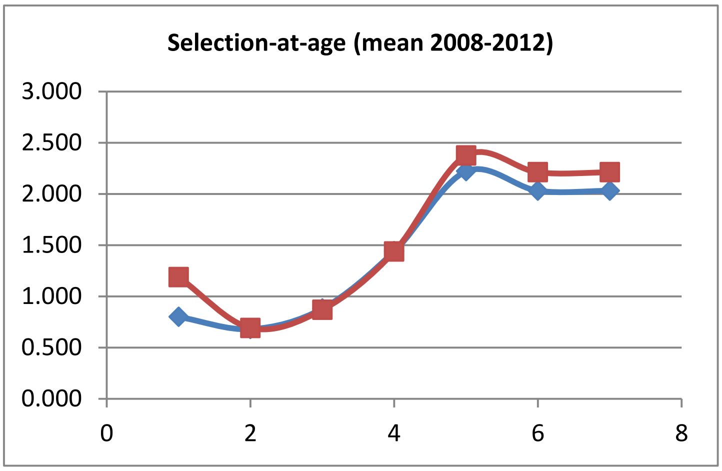


Figure 5.4.6.1. Megrim: selection-at-age (F(a)/F(2-4)) of total catch, obtained as an arithmetic (red) or geometric (blue) mean of 2008-2012

All other parameters are based on 5-year arithmetic means, as also done for four-spot megrim (Figure 5.4.6.2 shows the weight-at-age for the calculation of SSB and for converting total catch from numbers-at-age to weight). CVs were, as for four-spot megrim, based on the North Sea cod example provided with the PlotMSY software. As noted for four-spot megrim, uncertainties and risks should be based on values carefully thought about and considered appropriate to the megrim stock, but there was no time to explore this aspect at the benchmark.

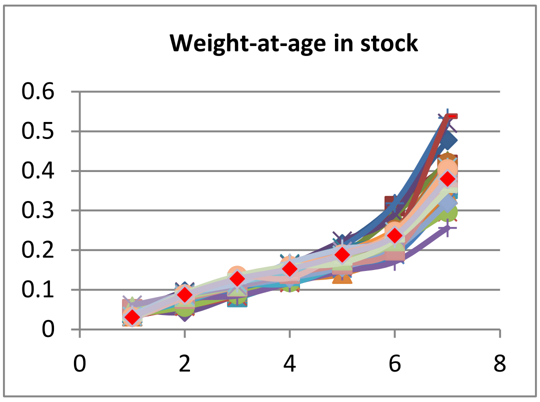


Figure 5.4.6.2. Megrim: weight-at-age (for calculation of SSB and total catch in weight) for each historic year and average of 2008-2012 (red dots)

The two input files used for PlotMSY were:

“Megw_srmsymc.dat”, with the following format:

#stkname, filname // stkname=stock dealing with; filname=name of 2nd file

Megw Megw.dat

#ybeg, yend, r, A, Ropt, simopt, senopt,penopt // ybeg=1st yr; yend=last yr; r=recr age; A=plusgroup; Ropt=S-R function type, simopt (0=no sim, 1=do sim); senopt (0=error only in recr, 1=error in recr & steady-state vectors); penopt (0=no SR constraints, 1=apply SR constraints)

1986 2012 1 7 1 1 1 1

#R, Bssb // R=recr; Bssb=SSB

10205	2210
13232	1866
11931	2140
10731	2302
13324	2388
6027	1638
11853	1564
5293	1414
2248	1216
9927	989
10030	1332
7822	1385
4614	1384
2727	1159
3998	1278
3663	957
3053	896
3101	1010
3339	815
2786	867
2225	832
2686	734
1497	656
1574	636
12103	753
5924	1308
3559	1746

“Megw.dat”, with the following format:

#fno, sno, f, m // fno=nr fleets; sno=fleet for ypr stats; f=F before spwn; m=M before spwn

2 1 0 0

Selection pattern: selection-at-age of F_catch (Fbar=1), split into F_landings (1st col) + F_disc (2nd col)

0.067 0.718

0.497 0.171

0.829 0.035

1.372 0.041

2.135 0.045

1.966 0.029

1.981 0.014

cv Selection pattern

0.175 0.175

0.097 0.097

0.076 0.076

0.079 0.079

0.085 0.085

0.109 0.109

0.109 0.109

Weight at age

0.060 0.028

0.097 0.064

0.128 0.099

0.153 0.115

0.188 0.162

0.237 0.165

0.380 0.127

cv Weight at age

0.112 0.255

0.143 0.282

0.137 0.419

0.097 0.542

0.062 0.480

0.050 0.345

0.040 0.792

Biological data

M, mat, wSSB

0.2 0.34 0.031

0.2 0.9 0.087

0.2 1 0.127

0.2	1	0.152
0.2	1	0.188
0.2	1	0.236
0.2	1	0.379

cv Biological data

cvM, cvmat, cvwSSB

0.1 0.0 0.112

0.1 0.1 0.143

0.1 0.1 0.137

0.1 0.1 0.097

0.1 0.0 0.062

0.1 0.0 0.050

0.1 0.0 0.040

From the values in the "Megw.dat" file, it is clear that megrim shares several of the characteristics noted for four-spot megrim, and which will have an impact on the reference points values. In particular, a significant proportion of fish are assumed to mature at age 1 (34%), at a rather low weight (31 g for megrim). As for four-spot megrim, it is recommended that this maturity assumption is checked by the appropriate scientists with their colleagues in their home institutes.

It can be also be seen that there is high selection of fish at ages 1 and 2; those caught at age 1 are mainly discarded. This selection of small fish, which are subsequently mainly discarded, is expected to have an impact on the calculated F_{MSY} values (obtained by maximizing long-term yield = landings) resulting in lower F_{MSY} values.

Results

The "plotMSY" function from the R "msy" library was run with 1000 iterations. The three stock–recruitment relationships provided in the software (Ricker, Beverton–Holt, Hockey-stick) were tried. The software produces results for each of them separately. It also allows to combine them (in a bootstrap-type way) assigning user-selected weights to each of them (based on biological/ecosystem knowledge of what is more appropriate to the stock in question) or automatic weights based on their respective likelihood fits to the stock–recruitment "data". In the automatic weighting option, some trimming is often required to get stable weights (no trimming was applied for the megrim stock after an initial run based on the result of the exploratory procedure suggested in Annex 7 of the WGMG 2013 report).

Figures 5.4.6.3-7 show the results for each of the stock–recruitment functions and a per-recruit analysis.

Figure 5.4.6.3 shows what are probably convergence difficulties with some of the deterministic fits (blue lines), and this distorts some of the long-term yield and SSB graphs in subsequent figures (particularly in Figure 5.4.6.4, corresponding to the Ricker model).

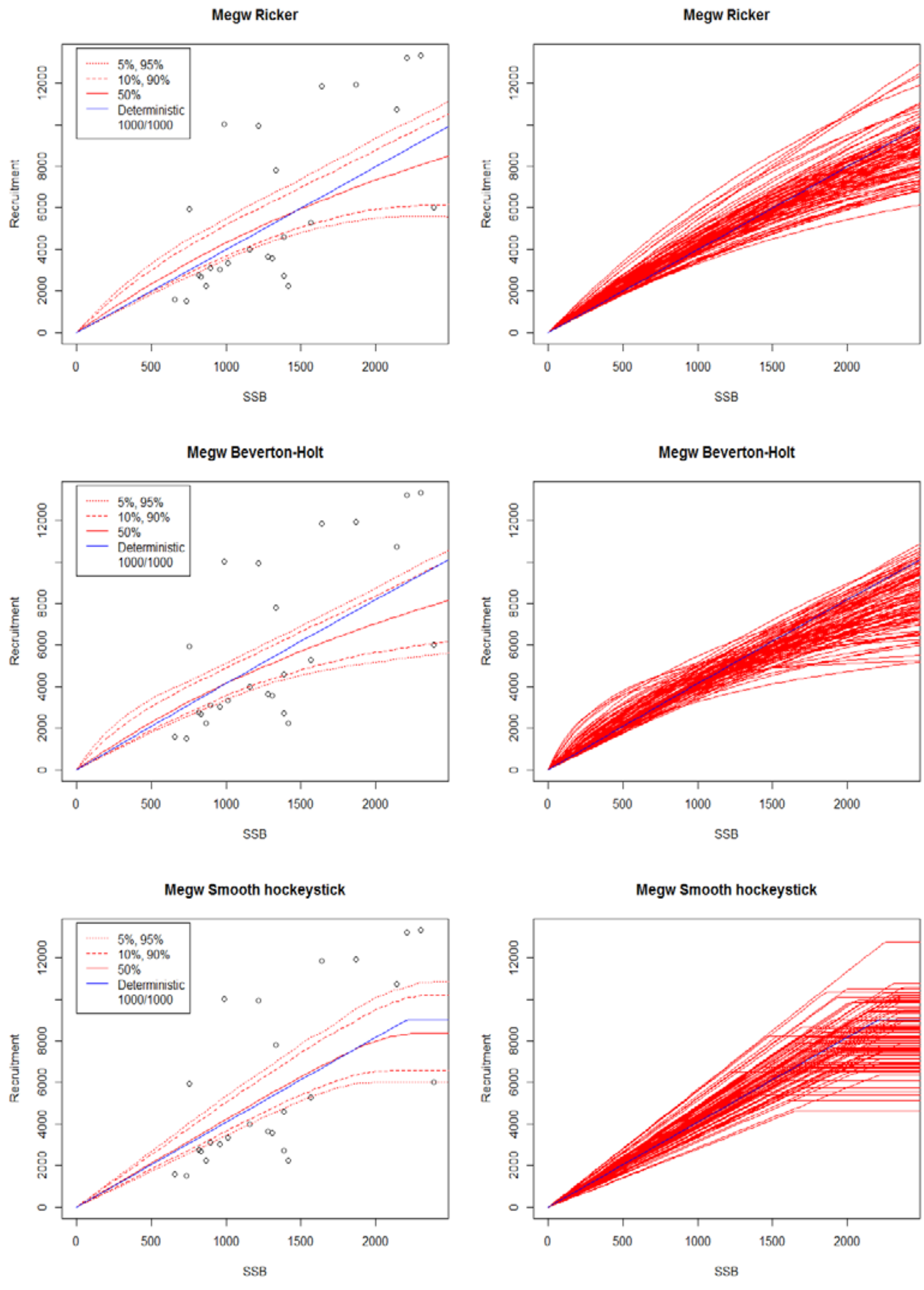


Figure 5.4.6.3. Megrim: stock-recruitment pairs from assessment (open circles) and fits from Ricker, Beverton–Holt and Hockey-stick functions. The stock-recruitment value corresponding to (SSB_{2009}, R_{2010}) is hidden under the legend on the top left corner of the graphs (Figure 4.4.6.8 shows all stock-recruitment pairs).

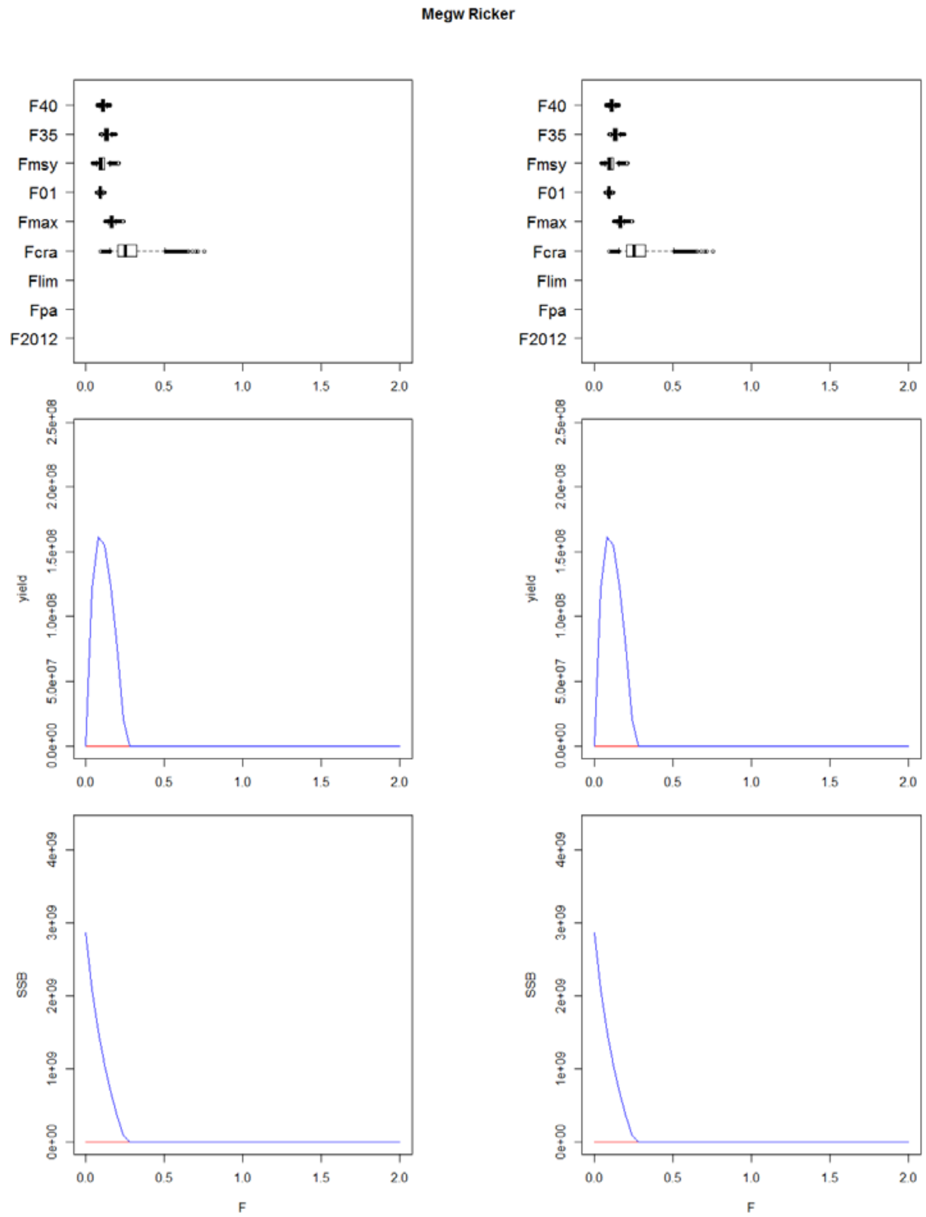


Figure 5.4.6.4. Megrim: results for Ricker stock-recruitment function (the deterministic fit, blue line, may not have converged and distorts the graphs).

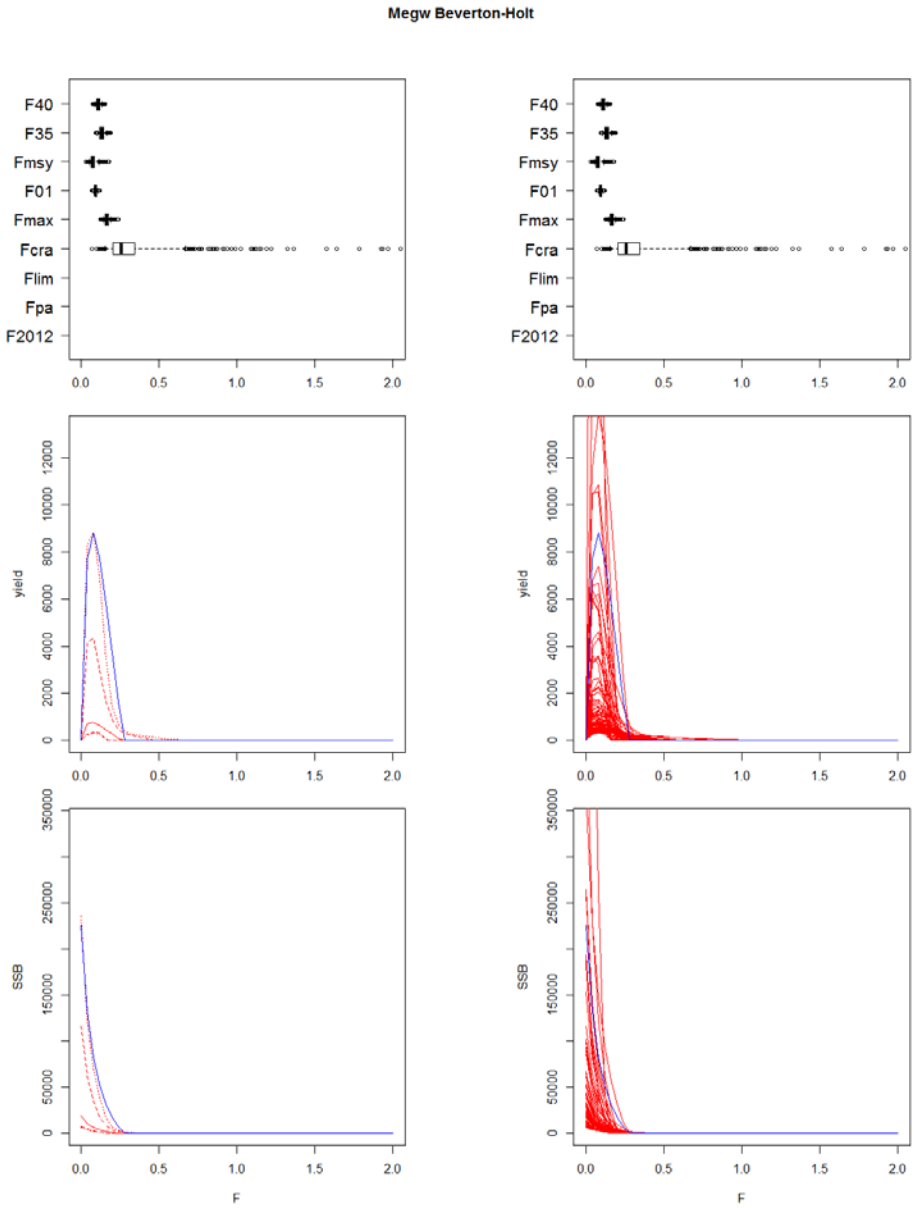


Figure 5.4.6.5. Megrim: results for Beverton–Holt stock-recruitment function (the deterministic fit, blue line, may not have converged).

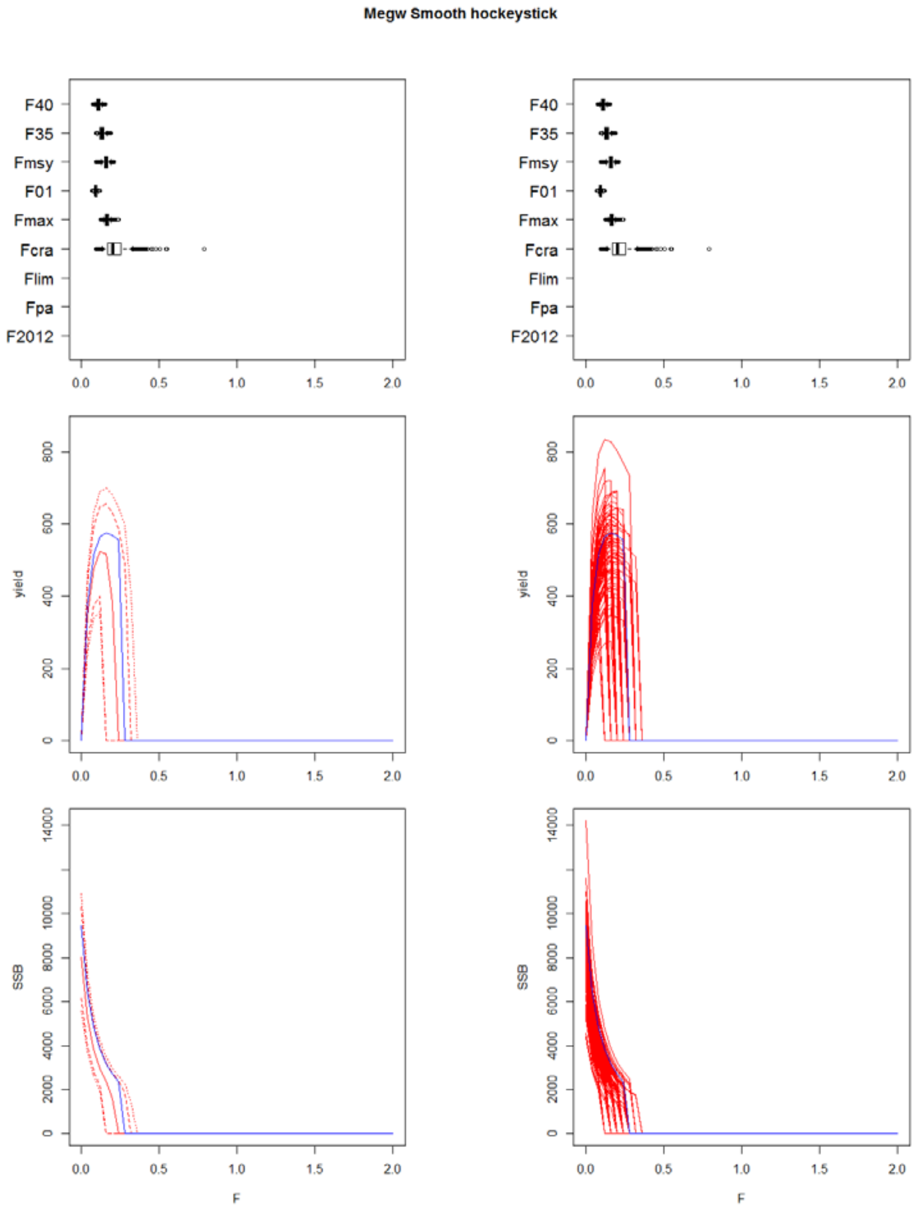


Figure 5.4.6.6. Megrim: results for Hockey-stick stock-recruitment function.

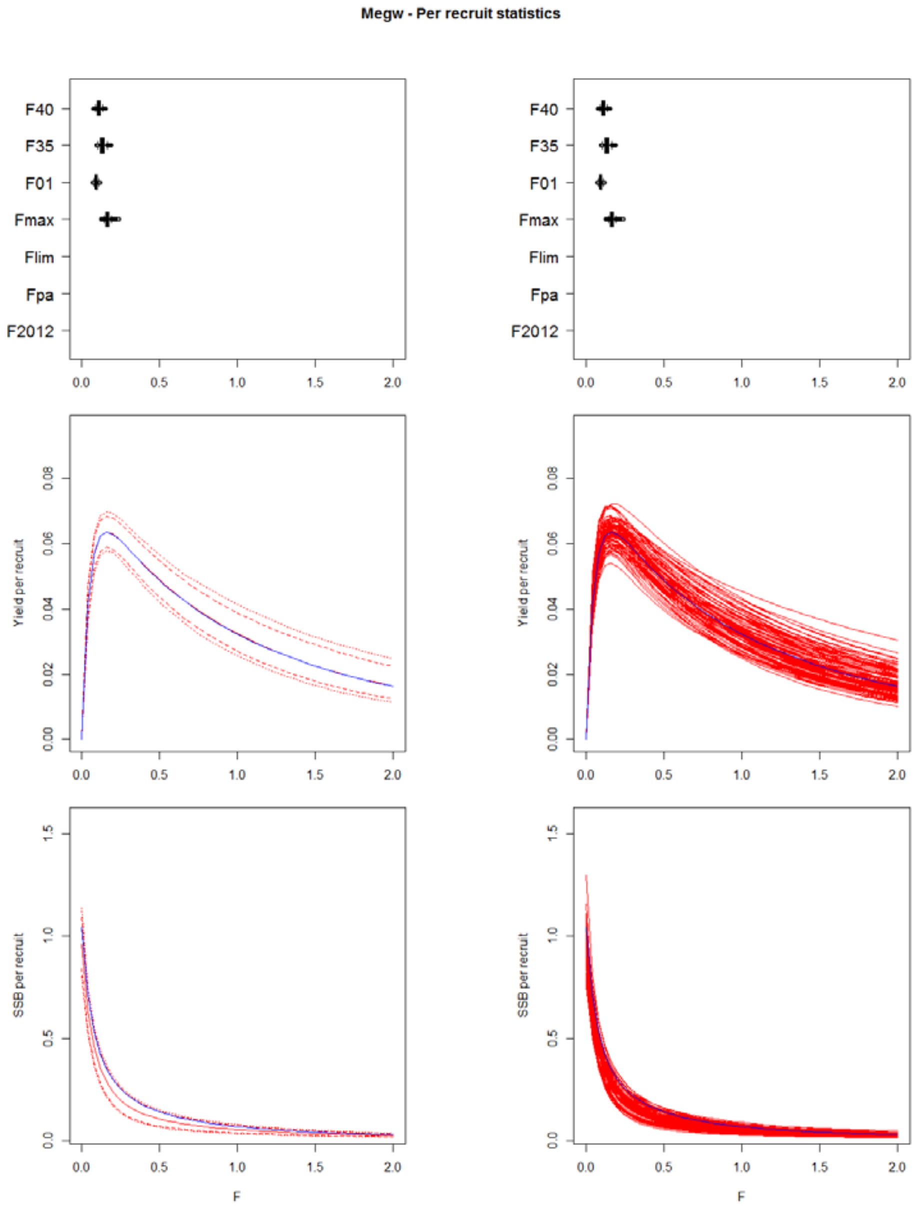


Figure 5.4.6.7. Megrim: results for per-recruit analysis.

Results in table form were also obtained for each stock-recruit function considered, per-recruit, and with automatic (likelihood-based) weighting of the three stock-recruitment functions (weights in the table are given in the order Ricker, Beverton–Holt, Hockey-stick).

Table 5.4.6.1. Megrim: results per-recruit, for each stock-recruitment function separately, and with equal (first 4 columns of final rows) automatic (last 4 columns of final rows) weighting.

Stock name									
Megw									
Sen filename									
NA									
index filename									
NA									
Number of iterations									
1000									
Simulate variation in Biological parameters									
TRUE									
SR relationship constrained									
TRUE									
Ricker									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.25	0.09	1365300000	163506000	0.84	0.00	3.99	0.00	51.29
Mean	0.28	0.10	15062	1976	0.74	0.40	5.36	0.00	53.72
5%ile	0.15	0.07	1869	343	0.53	0.03	3.78	0.00	51.41

25%ile	0.20	0.08	3155	489	0.66	0.15	4.41	0.00	51.97
50%ile	0.25	0.10	5107	722	0.74	0.31	5.02	0.00	52.94
75%ile	0.32	0.12	10018	1312	0.83	0.57	5.93	0.00	54.76
95%ile	0.50	0.15	53084	6592	0.96	1.05	8.16	0.00	58.58
CV	0.39	0.26	3	3	0.17	0.80	0.25	0.80	0.04
N	1000	1000	1000	1000	1000	1000	1000	1000	1000
Beverton–Holt									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.27	0.07	89440	8853	0.04	1.17	279243.00	66160.20	51.31
Mean	0.32	0.08	70795	6955	0.53	1.44	266120.20	67097.17	53.64
5%ile	0.15	0.05	2166	320	0.03	1.10	7572.56	676.73	51.41
25%ile	0.20	0.06	3958	502	0.19	1.26	13681.03	2237.65	51.94
50%ile	0.26	0.07	7148	804	0.42	1.40	25116.45	5185.84	52.91
75%ile	0.34	0.08	16166	1670	0.77	1.58	55948.15	13002.43	54.58
95%ile	0.67	0.11	96165	9209	1.39	1.96	314413.80	84127.80	58.45
CV	0.76	0.24	13	13	0.83	0.18	14.32	14.79	0.04
N	998	1000	1000	1000	1000	1000	1000	1000	1000
Smooth hockeystick									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.26	0.16	3171	575	0.43	1.68	2.04	2211.41	51.15
Mean	0.22	0.16	2469	537	0.45	1.50	2.16	1970.61	53.28
5%ile	0.13	0.13	1663	379	0.36	1.03	1.73	1354.52	51.23
25%ile	0.17	0.15	2083	471	0.41	1.37	1.96	1797.82	51.65

50%ile	0.20	0.16	2381	536	0.44	1.54	2.11	2028.05	52.49		
75%ile	0.25	0.17	2790	599	0.49	1.68	2.32	2213.42	54.10		
95%ile	0.33	0.19	3534	703	0.56	1.79	2.68	2348.97	58.00		
CV	0.30	0.11	0.23	0.18	0.15	0.16	0.15	0.16	0.04		
N	1000	1000	1000	1000	1000	1000	1000	1000	1000		
Per recruit											
	F20	F25	F30	F35	F40	F01	Fmax	Bmsypr	MSYpr	Fpa	Flim
Deterministic	0.32	0.24	0.19	0.15	0.12	0.09	0.16	0.35	0.06		
Mean	0.26	0.20	0.16	0.13	0.11	0.09	0.16	0.29	0.06		
5%ile	0.19	0.15	0.13	0.10	0.09	0.08	0.14	0.22	0.06		
25%ile	0.23	0.18	0.14	0.12	0.10	0.09	0.15	0.26	0.06		
50%ile	0.26	0.20	0.16	0.13	0.11	0.09	0.16	0.29	0.06		
75%ile	0.30	0.23	0.18	0.14	0.12	0.10	0.17	0.32	0.07		
95%ile	0.35	0.26	0.20	0.16	0.13	0.11	0.19	0.37	0.07		
CV	0.18	0.16	0.15	0.14	0.13	0.09	0.09	0.16	0.06		
N	1000	1000	1000	1000	1000	1000	1000	1000	1000		
Combining all SRRs											
Automatically specified weights											
	0.34	0.36	0.30								
Percentage	Fmsy	Fcrash	MSY	Bmsy	Fmsy_w	Fcrash_w	MSY_w	Bmsy_w			
5%	0.06	0.14	345	1826	0.06	0.15	321	1773			
25%	0.08	0.19	480	2395	0.08	0.19	444	2225			
50%	0.10	0.24	600	3606	0.11	0.25	558	3218			
75%	0.15	0.30	994	8019	0.15	0.32	826	6690			
95%	0.18	0.50	5021	46352	0.18	0.56	3622	34023			

The stock-recruitment values obtained from the assessment are shown in Figure 5.4.6.8. The lowest biomass observed in the stock (SSB$_{2009}$ = 640 t) produced one of the highest recruitment values in history (age 1 Recruitment in 2010). This is the point in the top left corner of Figure 5.4.6.7, which is hidden by the legend in Figure 5.4.6.3.

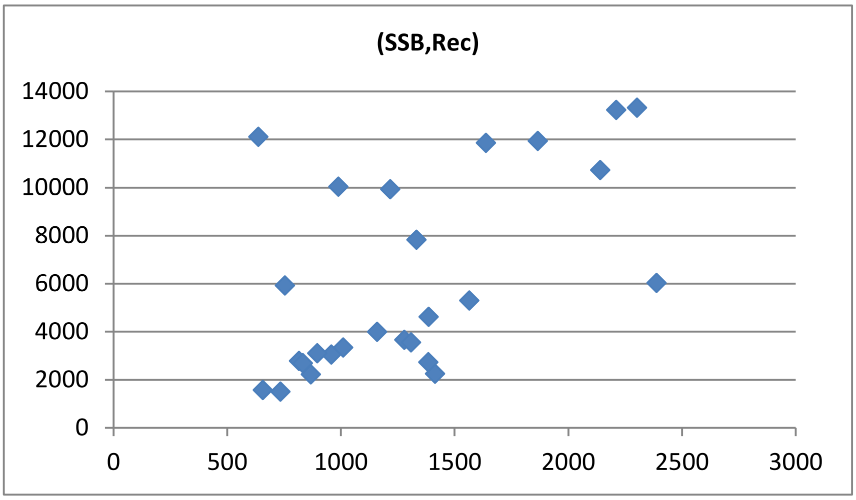
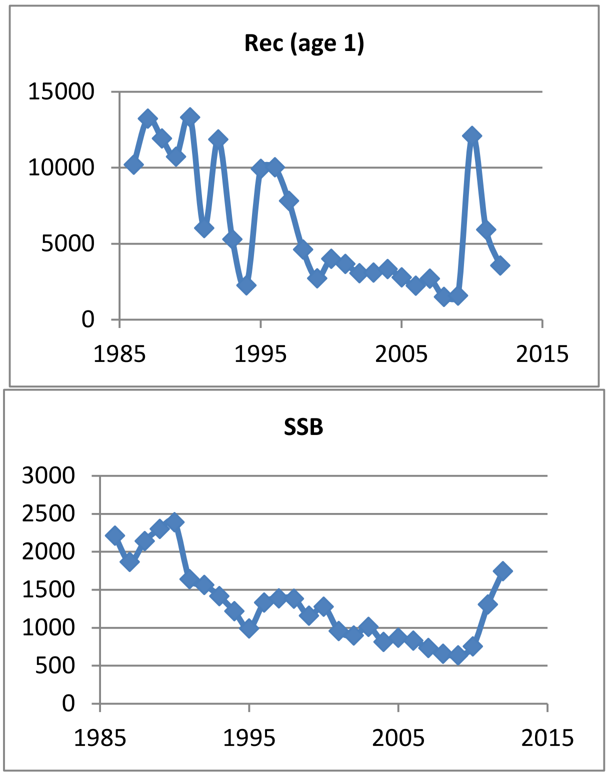


Figure 5.4.6.8. Megrim: stock-recruitment values from assessment (the top left point is hidden under the legend in Figure 4.4.6.3)

Assessment results for the stock are shown in Figure 5.4.6.9.



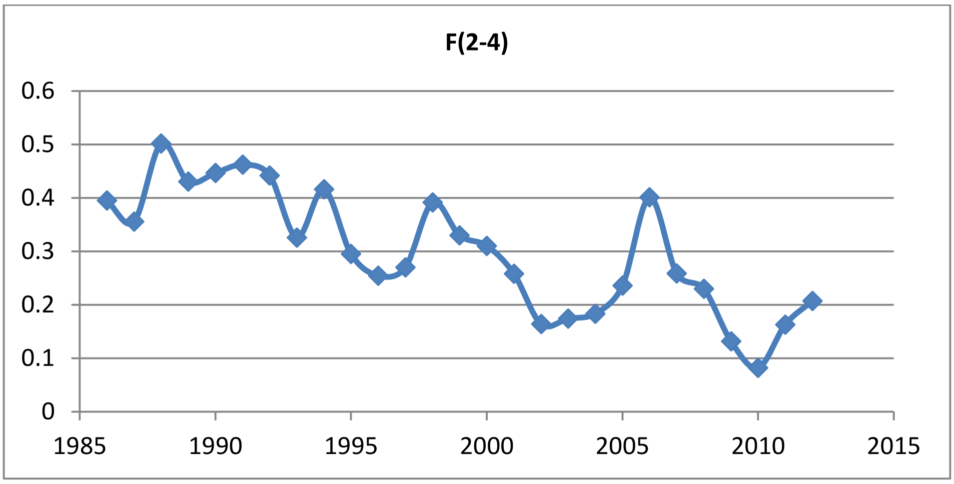


Figure 5.4.6.9. Megrim: results from assessment

These results were only available on the last afternoon of the benchmark meeting, and there was not enough time to analyse them or considered them properly. After the meeting, a WebEx meeting took place to discuss further analysis and draw conclusions. The conclusions of this WebEx are presented in a following section.

Some preliminary comments based on the benchmark discussion are noted here:

Similar to the situation for four-spot megrim, the megrim yield-per-recruit curve peaks at a rather low F value (Figure 5.4.6.7), with F_{max} = 0.16. F=0.16 also corresponds to $F_{30\%SPR}$ (Table 5.4.6.1).

From Figure 4.4.6.9, SSB shows a continuous decreasing trend from the start of the assessment (mid 1980s) until 2009. After 2009, SSB has sharply increased, and it is now estimated to be at the highest value since 1990. The average F of 2009-2011 is 0.13, and corresponds to $F_{35\%SPR}$ (Table 5.4.6.1).

This suggests F_{MSY} proxies in the range of around 0.13 - 0.16. However, lower F_{MSY} values are obtained when Ricker or Beverton–Holt curves are employed in the calculation of F_{MSY} (F_{MSY} = 0.11 based on the automatic likelihood weighting of the three stock-recruitment functions), which is believed to be related to the low slope at the origin of the estimated stock-recruitment curves. This raises the question of whether F values in the range 0.13 - 0.16 might be non-precautionary for the stock. The concern arises because when computing the long-term probability of SSB being < 650 t (just above the lowest observed SSB) with PlotMSY, this probability is > 5% for any F > 0.13 (as for four-spot megrim, it must be stressed that these probabilities were calculated using the example CVs from North Sea cod, so they do not necessarily constitute appropriate settings for the megrim stock).

The following considerations were made during the benchmark discussion:

Recruitment in years 1986-1989 has always been considered unreliable by the assessment WG (see Stock Annex in WGHMM 2013 report) because the age structure assumed for those years is based on a survey ALK from 1986 and a commercial catch ALK from 1990, with no year-specific ALKs. Consequently, the assessment WG has always excluded these years from the GM-recruitment calculation for short-term forecasts. The years 1986-1989 correspond to high SSB and recruitment; there was no time to check a possible impact of these years in the stock-recruitment fits.

This is a small stock (average stock SSB since 1986 is 1300 t) which is always caught in mixed fisheries and has a single TAC together with four-spot megrim. Managing according to a very low F for megrim could cause serious difficulties for the exploitation of other stocks in the mixed fishery (choke species effect). Of course, any F to be applied for the management of megrim must be in conformity with the precautionary approach.

The fact that both SSB and F show a decreasing trend over a long period of years could have different possible explanations and this was also discussed at the benchmark meeting. It could mean that the F's applied historically have been too high in many of the years (even if they showed a decreasing trend over time) and that these Fs caused a prolonged decline of the SSB. In that scenario, only F values in the range of those observed since 2009 would be expected to be sustainable. Another idea that has been suggested in the past is that this stock could be just "the tail" of the much larger stock of megrim in ICES Subarea VII and Divisions VIIIabd. Genetic studies on 16S rDNA gene from several samples from the Atlantic area show that there is not a clear differentiation between the northern and southern stocks considered by ICES (García-Vázquez *et al.*, 2006). This could also explain why a prolonged decrease in F was not reflected in stock increases.

Conclusions and recommendations

- More consideration of the issues identified is required and will take place at the scheduled WebEx.

Work conducted after benchmark meeting

The work presented here used the latest version of the "msy" package available on the GITHUB site on February 13, 2014. This is msy package version 0.1.12.

The analysis was expanded after the benchmark meeting ended, in three ways as follows:

First, the same analysis presented in the section above was rerun because a small mistake had been made in the calculation of the geometric mean selection-at-age pattern at the benchmark meeting. Additionally, the CV of the proportion mature-at-age was set to 0.1 for ages 1-3 (which seemed more logical than for ages 2-4, as had been done in the benchmark meeting). These changes produced very slightly higher (median) values of the potential reference points: F_{max}=0.17 (equal to $F_{30\%}$), whereas F_{MSY} was 0.11, 0.08, and 0.16, under Ricker, Beverton–Holt and Hockey-stick, respectively. Values of F below 0.14 gave less than 5% long-term probability of SSB being below 650 t (just above the lowest observed SSB), based on the likelihood weighting of the three stock-recruitment functions automatically done by the PlotMSY software.

Second, the analysis just explained was redone, changing the CVs to those corresponding to the megrim assessment assumptions (in the case of weight, M and proportion mature at age) or assessment results (in the case of selection at age) for the last 5 years (2008-2012). Based on these CVs, there are, once again, some slight changes to the (median) values of potential reference points: F_{max}=0.17 (between $F_{35\%}$=0.15 and $F_{30\%}$=0.19), whereas F_{MSY} was 0.11, 0.08, and 0.17, under Ricker, Beverton–Holt and Hockey-stick, respectively. There was, however, some increase in the value of F giving 5% long-term probability of SSB being below 650 t, based on the likelihood weighting of the three stock-recruitment functions; this F value increased to 0.19.

Third, the EqSim software (also developed at the 2014 ICES workshop WKMSYREF2 and included in the "msy" package) was also applied. Inputs for (at age) fishery selection, proportion landed and discarded, weight, M and proportion mature were randomly drawn from the four-spot megrim assessment assumptions (in the case of weight, M and proportion mature at age) or assessment results (in the case of selection at age) for the last 5 years (2008-2012). The Ricker, Beverton–Holt and Hockey-stick SR relationships were considered; it must be noted that the EqSim software estimated different weights for each of these SR relationships than the PlotMSY software. Long-term projections, including the randomly drawn parameters noted above and annual stochastic variability of recruitment, were conducted for different F values. A graphical display of results is presented in Figure 5.4.6.10. The figure shows a fairly flat yield (long-term landings) curve, with a maximum at F=0.12, whereas values of F below 0.21 give less than 5% long-term probability of SSB being below 650 t (just above B_{loss}), which could be considered a candidate for B_{lim}. Following the guidelines in Section 4.3 of the WKMSYREF2 report, a test was then conducted incorporating assessment and implementation error in the long-term projections (this was done simply, assuming that the real F in each projection year varied stochastically around the intended F with the errors having CV=0.25 and 0.3 correlation between consecutive years). By introducing these errors in the real F, the "intended" F value giving 5% probability of SSB being less than 650 t decreased to F=0.19 (from the previous 0.21, calculated without errors in F). Finally, repeating the latter exercise for the ICES MSY HCR (which, when SSB < MSY $B_{trigger}$, reduces F linearly from the target F), assuming MSY $B_{trigger}$ = 1.4*650 t, the target F value giving 5% probability of SSB being less than 650 t increased to F=0.24; it is also noted that the target F value giving 5% probability of SSB being less than 1000 t is F=0.20.

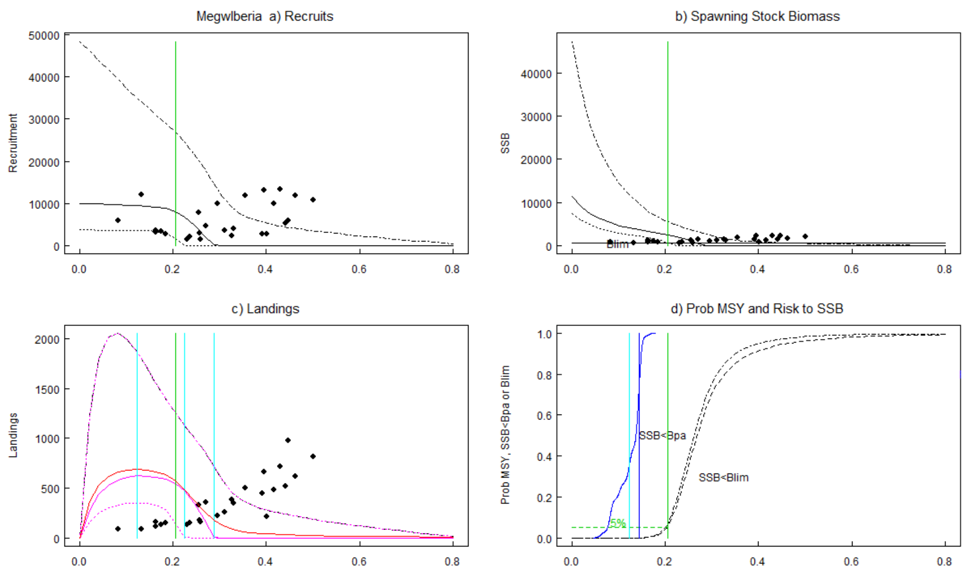


Figure 5.4.6.10. Megrim, long-term projections from EqSim including stochastic annual recruitment: (a) recruitment vs. F, (b) SSB vs. F, (c) yield (i.e. landings) vs. F, (d) probability of SSB < B_{lim} and B_{pa} vs. F (for this plot it is assumed B_{lim}=650 t, and B_{pa}=1.4 B_{lim}). In all panels, the green vertical line is at F=0.21 (the F value that gives 5% probability of SSB < B_{lim}). The left-most vertical line in panel (c) is at F=0.12 (the F value that maximizes long-term average landings). Historical estimates from the benchmark assessment are represented as dots in panels (a), (b), (c).

Taking all the above information into account, as well as the historic stock development as estimated by the benchmark assessment, and the comments on recruitment uncertainty, mixed fishery issues and stock identity made earlier in this report section, the following reference points are proposed:

B_{lim} = 650 t (provisional reference point; just above B_{loss} in the 2014 benchmark assessment),

B_{pa} = 910 t (default option; 1.4 B_{lim}),

MSY $B_{trigger}$ = 910 t (default option; B_{pa}),

F_{MSY}=0.17 (F_{max} as F_{MSY} proxy; a check for precautionary considerations has been conducted).

Given the uncertainties surrounding the recruitment estimates (due to uncertain discards estimates) and the stock identity noted earlier in this report section, these reference points should be considered provisional. They represent pragmatic choices given the current state of knowledge.

It is recommended that the assessment working group WGBIE gives further consideration to these proposals. Additionally, WGBIE should keep a close check on stock development and appropriateness of these reference points, and provide alternatives if any problems or issues are detected.

5.4.7 Future Research and data requirements

Develop more appropriate tuning fleets which cover the full spatial extent of the stock.

Gather and evaluate additional commercial information such as the Coruña and Avilés time-series and combine these time-series into appropriate tuning indices.

Migrate the assessment models from XSA to the SAM statistical catch-at-age model. This increases the flexibility of the modelling approach (e.g. it removes the assumption of exact catches) and is in line with many other stocks within ICES

The reference point model for megrim and four spot megrim needs further exploration.

Given the issues highlighted at this benchmark, work should be conducted towards a better method of incorporating discarding into the assessment

Evaluate the validity of the maturity-at-age 1 value (for both stocks, but particularly for four-spot megrim)

Consider truncating the survey to remove years prior to 1997, to avoid the identified strange residual patterns suggesting a misfit between this survey and the population in the early years

5.5 Four spot megrim (as above)

5.5.1 Issue list

The following issues had been identified to be addressed at this benchmark:

Model

XSA convergence problems

To help with automation, transfer to analysis to the FLR-XSA environment.

Data

Potential selectivity change in recent years with new minimum landing size imposed.

Include discards in the assessment. The variability of the discards ranges between 39-63% .

Commercial tuning fleets do not cover the full time-series due to issues with obtaining full information on effort and landings and changes in the fleet over time.

Spanish ALK used to raise all countries data.

Other work required

Biological and precautionary reference point

5.5.2 Scorecard on data quality

Similar to the previous three stocks a scorecard on the quality of the data used in the benchmark process was discussed during the benchmark meeting. No analysis was performed to provide scores, which were only based on qualitative judgment from national stock coordinators. Many doubts appeared whilst completing the table and it should be considered as tentative; meanwhile more clarifications, analysis and expert contributions are provided.

5.5.3 Stock Assessment data

5.5.3.1 Catch – quality, misreporting, discards

Working Group estimates of four-spot megrim international landings for the period 1986 to 2012 and official landings figures from Spain for 2011 and 2012 were available to the group (Table 5.5.3.1.1). The discrepancy between official and scientific estimates is included in the column "Unallocated". Landings reached a peak of 2 629 t in 1989 and have generally declined since then to their lowest value of 720 t in 2002. There has been some increase again in the last few years. Landings in 2010 are 1 297 t, the highest value after 1995. After a similar value in 2011, landings in 2012 are 806 t, a significant drop.

Discards series available for four spot megrim is the same as described in the previous stock. Different methodologies have been applied trying to reconstruct the discards time-series. The procedures used in L. boscii started also with an arithmetic mean from years with real data, the second procedure was a Generalized Linear Models (GLM) and the third procedure, a combined method, estimation of ages 0 and 1 from linear regression with survey indices, and ages 2 to 7 by applying a GLM.

Table 5.5.3.1.1. Four-spot megrim (*L. Boscii*) in Divisions VIIIc, and IXa. Total landings (t).

	Spain			Portugal	Unallocated	Total
Year	VIIIc	IXa***	Total	IXa		
1986	799	197	996	128		1124
1987	995	586	1581	107		1688
1988	917	1099	2016	207		2223
1989	805	1548	2353	276		2629
1990	927	798	1725	220		1945
1991	841	634	1475	207		1682
1992	654	938	1592	324		1916
1993	744	419	1163	221		1384
1994	665	561	1227	176		1403
1995	685	826	1512	141		1652
1996	480	448	928	170		1098
1997	505	289	794	101		896
1998	725	284	1010	113		1123
1999	713	298	1011	114		1125
2000	674	225	899	142		1041
2001	629	177	807	124		931
2002	343	247	590	130		720
2003	393	314	707	169		876
2004	534	295	829	177		1006
2005	473	321	794	189		983
2006	542	348	891	201		1092
2007	591	295	886	218		1104
**2008	546	262	808	172		980
2009	577	342	919	215		1134
2010	616	484	1100	197		1297
2011	499	368	867	181	212	1260
2012	245	231	476	98	231	806

***IXa is without Gulf of Cádiz

** Data revised in WG2010

* Official data by country and unallocated landings

5.5.3.2 Surveys

The Portuguese October groundfish survey (PtGFS-WIBTS-Q4) and the Portuguese Crustacean survey (PT-CTS (UWTV (FU 28-29))) and one Spanish groundfish survey (SpGFS-WIBTS-Q4) series are available since 1990, 1997 and 1983, respectively.

It should be taken into consideration that during years 1996, 1999, 2003 and 2004 the October Portuguese survey was carried out with a different vessel and gear from the one used in the rest of the series. The Crustacean survey was performed with different vessels in different years and covers a partial area; in 2004 it had many operational problems.

For these reasons and because indices from these surveys are not considered to be representative of megrim abundance, due to the very low catch rates, only the Spanish survey (SpGFS-WIBTS-Q4) is used in the assessment of the two species. The survey covers the distribution area and depth strata of these species in Spanish waters (covering both VIIIc and IXa). For L. boscii, the survey signal is clear until 2002, whereas it seems more blurred in recent years.

5.5.3.3 Commercial tuning fleets

Last assessments have been calibrated by using the A Coruña bottom otter trawl tuning fleet (SP-CORUTR8c) just for the period 1990-1999. Intersessional work was developed in order to recover backwards (until 1986) this time-series. Besides, as it is known that this trawl fleet has been deploying a combination of different fishing strategies through these last years (Punzon *et al.*, 2010), the respective métiers were also disaggregated: bottom otter trawl targeting demersal species (OB_DEF_>=55_0_0) and OTB targeting pelagic stocks accompanied by some demersal species (OTB_MPD_>55_0_0). Therefore, the LPUE of these métiers was recovered backwards (until 1986) and two new time-series of bottom otter trawl targeting demersal species, one per port (A Coruña and Avilés), were provided to be tested during this benchmark (WD 04, Castro *et al.*, 2014).

5.5.3.4 Weights, maturities, growth

The following biological information is used in the Benchmark:

Age compositions of landings are based on annual Spanish ALKs since 1990, whereas a survey ALK from 1986 combined with an annual ALK from 1990 was applied to years 1986-1989.

Landings weights-at-age are also used as the weights-at-age in the stock. The following parameter values were used in the length-weight relationship. This relationship was externally calculated in an international project with a sampling that spatially covered a large proportion of the stock (BIOSDEF, 1998):

	L. boscii
a	0.00431
b	3.1904

Natural mortality is set to 0.2 and assumed constant over all ages and years. This is the same value used for L. boscii in Divisions VIIb-k and VIIIabd.

The sex combined maturity ogive (BIOSDEF, 1998) is assumed constant over time, with the following proportions of fish mature at each age:

Age	0	1	2	3	4	5+
L. boscii	0	0.55	0.86	0.97	0.99	1

5.5.4 Assessment model

Extended Survivors Analysis (XSA) model was selected for use in this assessment. Model description is detailed in the Stock Annex.

The new input data tried during the Benchmark has been the same as for the other megrim stock:

- Spanish discards time-series, included in the catch-at-age matrix.
- New SP-CORUTR8c and SP-AVILESTR for the entire time-series.

The same procedure described in *L. whiffiagonis* has been applied to *L. boscii*. A series of different model specifications were tried in various runs to refine the assessment. The most representative in the selection process of final model are presented here as a sensitivity analysis.

Sensitivity analysis

Sensitivity to discards estimates procedures

In this stock, three different approaches for discards estimation have been tested. First estimation is derived from an average by period using discards data from available years. For the first period (1986-1999), the average of available years 1994, 1997 and 1999 were used and for the second period (2000-2012) the absence of data in 2001 and 2002 was replaced by the average of the closest years. The reason of using these two periods is the change in the Minimum landing size (MLS) in 2000 that has the potential to bring about a shift in the discarding behaviour. Second set of estimates has been calculated using a GLM depending on several variables. The third one is a combination of two different estimation procedures: age 1 and age 2 are obtained from a linear regression between abundance data from a survey and discards data, and age 2 to 7 from a GLM. These three options have been examined in the following runs:

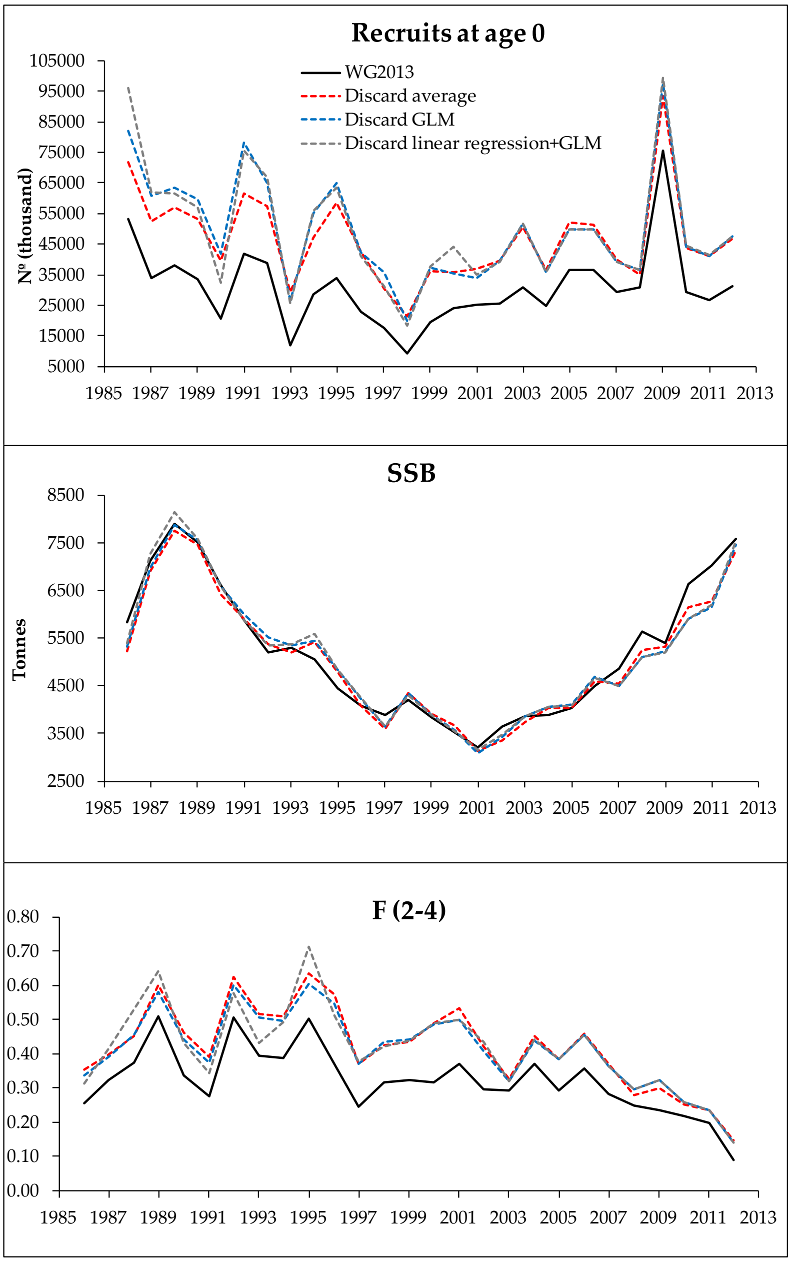


Figure 5.5.4.1. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Sensitivity analysis to different discards estimates.

In the absence of significant differences in the run results, and to be coherent with the other stock, the Benchmark decided to use the discards average for further analysis.

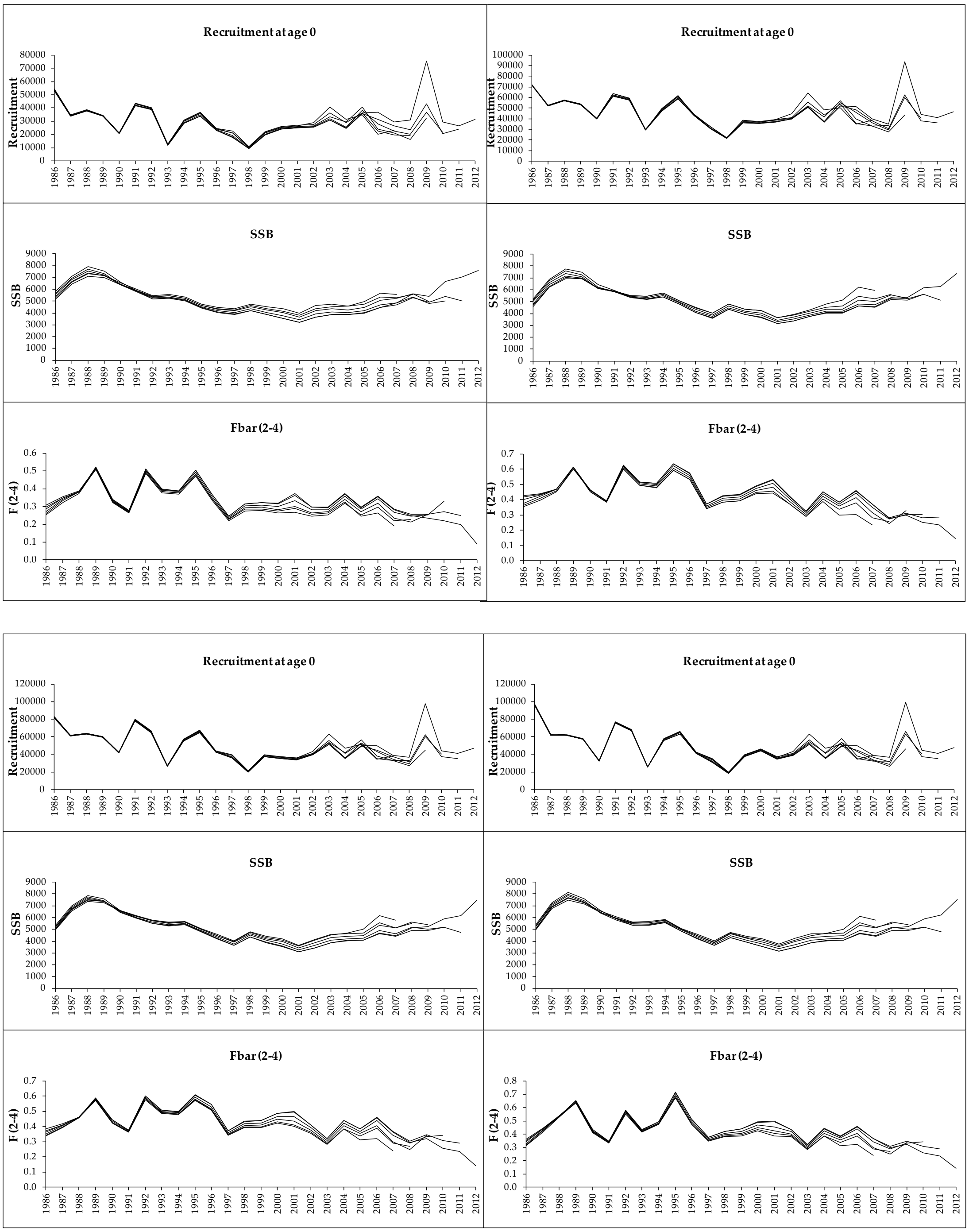


Figure 5.5.4.2. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment, discards average sensitivity run, discards GLM sensitivity run, and discard linear regression and GLM sensitivity run.

The retrospective patterns are shown in Figure 5.5.4.2, and are all very similar.

Sensitivity to tuning fleets and surveys

The impact of the commercial tuning fleets and the surveys was also tested. Four possible model configurations were considered:

- Tuning: survey (SpGFS-WIBTS-Q4)
- Tuning: survey (SpGFS-WIBTS-Q4) and Coruña (SP-CORUTR8c)

- Tuning: survey (SpGFS-WIBTS-Q4) and Avilés (SP-AVILESTR)
- Tuning: all (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR)

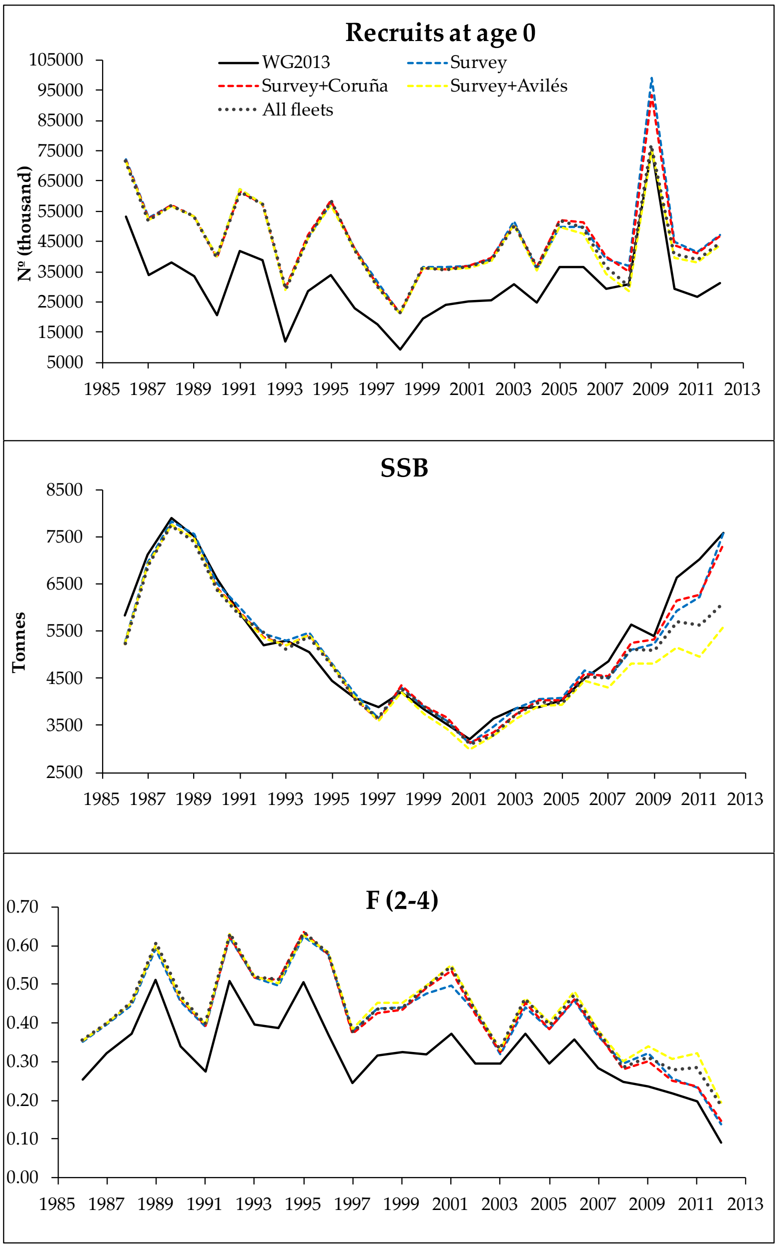


Figure 5.5.4.3. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Sensitivity analysis to different tuning fleets.

The first period of the time-series is very similar for all the options. The results from the survey only and survey plus Coruña configurations are almost the same during the time-series, with the exception of minor differences around 2000 in values of F. The results from the configurations with survey plus Avilés and all fleets differ from the other two configurations in the last years, especially for SSB and F. Visual inspection of the survey data as well as the tuning data indicated that there are diverging signals between Coruña and Avilés. The Avilés tuning fleet (SP-AVILESTR) was not used in the past for this stock, and this index presents big year effects and it is difficult to follow cohorts in the time-series. Given that year effects seem to dominate the Avilés dataset, this tuning fleet failed the consistency test, while Coruña data seems to show internal consistency. These reasons led the Benchmark to accept the configuration of survey and Coruña trawl (SP-CORUTR8c) as tuning fleets.

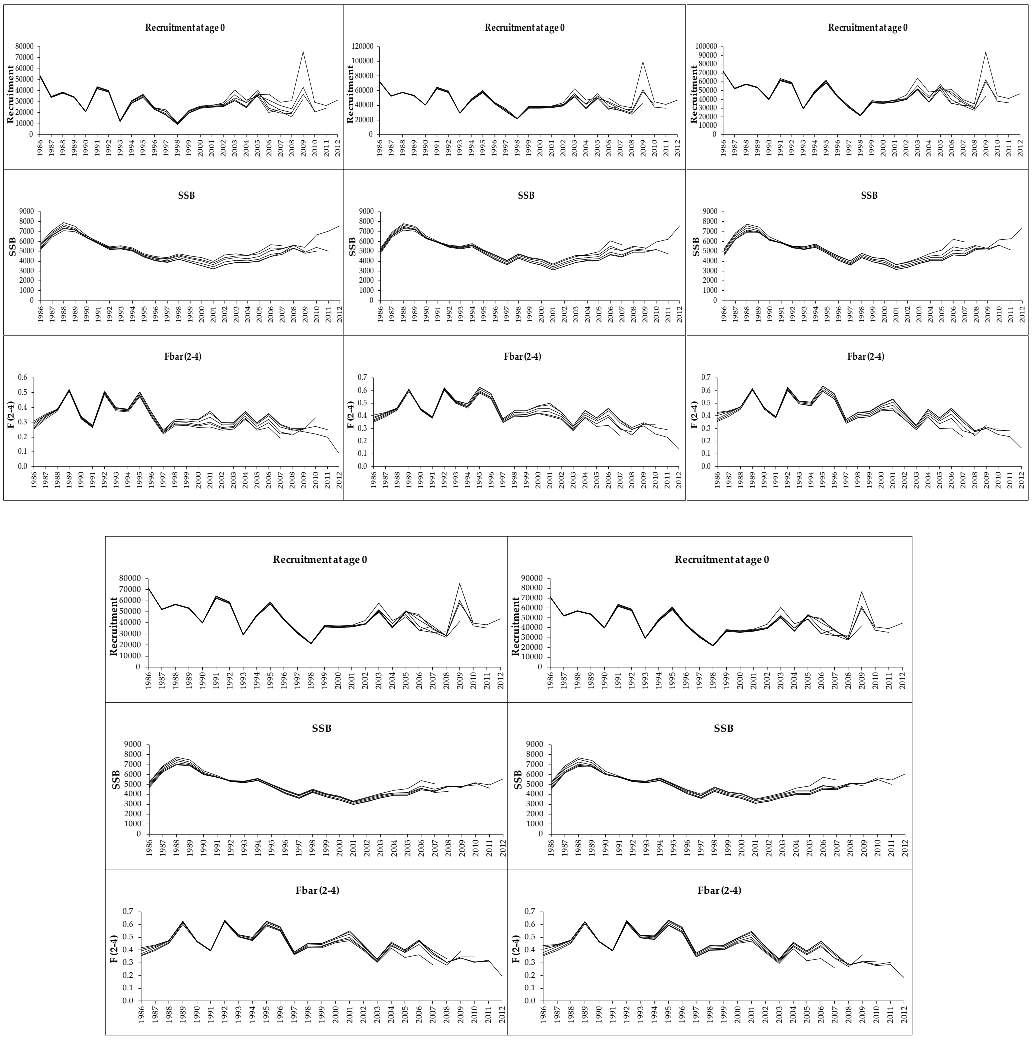
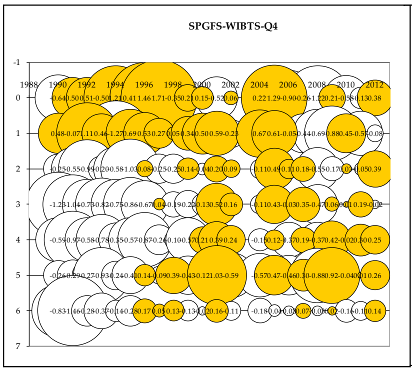
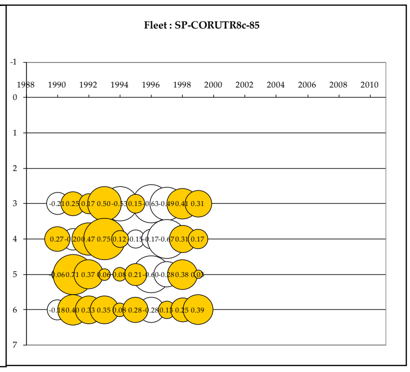
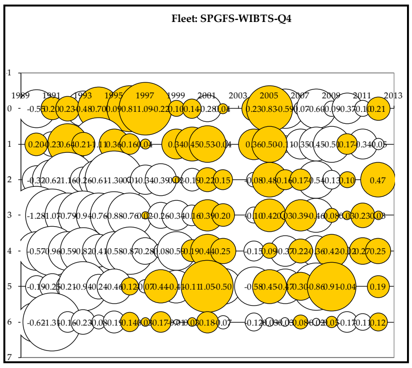
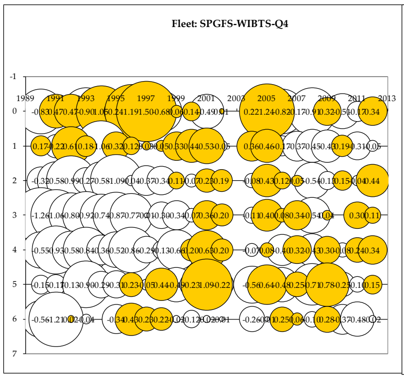


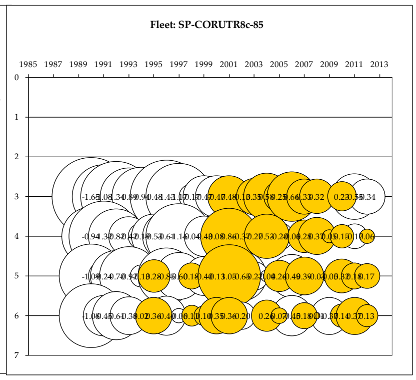
Figure 5.5.4.4. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis for XSA assessments tuning with: survey (SpGFS-WIBTS-Q4), survey and Coruña (SpGFS-WIBTS-Q4, SP-CORUTR8c), survey and Avilés (SpGFS-WIBTS-Q4, SP-AVILESTR) and all fleets (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR).

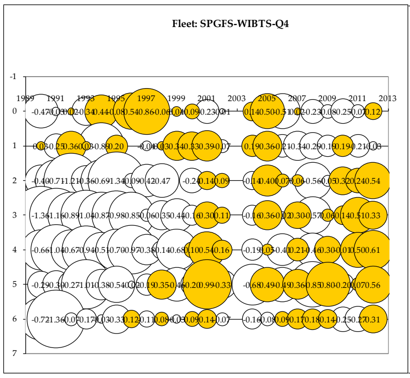

SPGFS-WIBTS-Q4

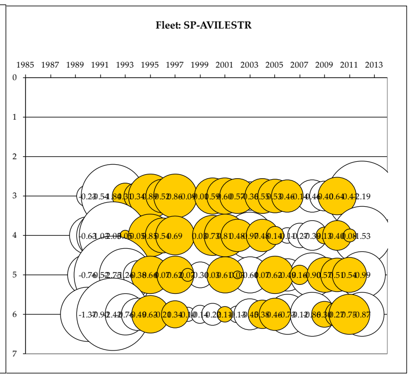

Fleet : SP-CORUTR8c-85


Fleet: SPGFS-WIBTS-Q4


Fleet: SPGFS-WIBTS-Q4


Fleet: SP-CORUTR8c-85


Fleet: SPGFS-WIBTS-Q4


Fleet: SP-AVILESTR

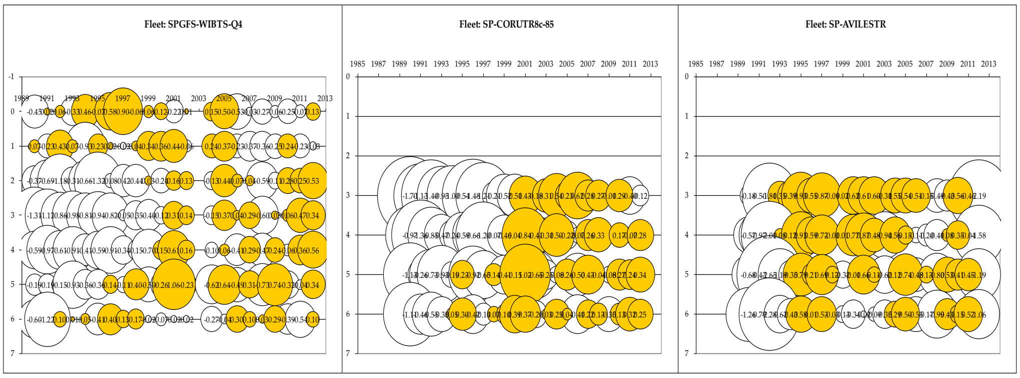


Figure 5.5.4.5. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and sensitivity analysis for XSA assessments tuning with: survey (SpGFS-WIBTS-Q4), survey and Coruña (SpGFS-WIBTS-Q4, SP-CORUTR8c), survey and Avilés (SpGFS-WIBTS-Q4, SP-AVILESTR) and all fleets (SpGFS-WIBTS-Q4, SP-CORUTR8c and SP-AVILESTR).

Including or not Avilés tuning fleet (SP-AVILESTR) does not seem to have a big effect in residual plots. The Benchmark ratifies the use of the Survey (SpGFS-WIBTS-Q4) and Coruña commercial fleet (SP-CORUTR8c) for tuning the four-spot megrim assessment.

Sensitivity to change catchability and taper settings

The sensitivity to the catchability assumptions has been tested through a configuration where catchability is independent of stock size for all ages, following the t-test results that there is no indication that catchability should be dependent on stock size. Also, sensitivity to the taper weighting has been analysed. The taper would reduce the impact of earlier parts of the time-series data. Given the effort made to improve the data in the early part of the time-series, there is, in principle, no reason to use taper weighting. These two options have been studied:

- catchability independent of stock size for all ages
- weighting (catchbility dependent on stock size for ages < 3)

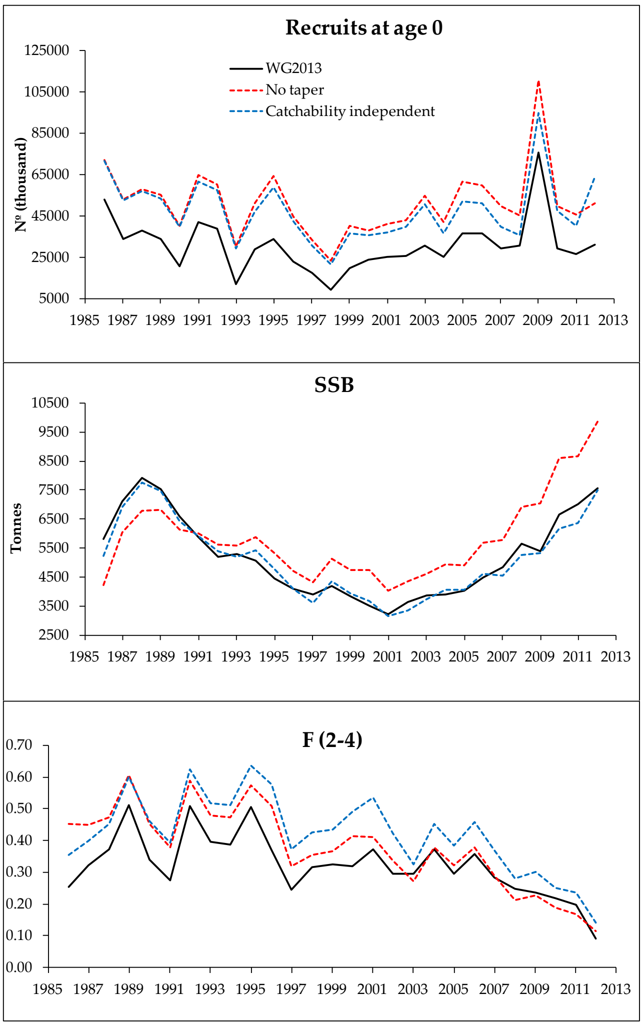


Figure 5.5.4.6. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Sensitivity analysis to catchability-independent-on-stock size and no-taper options.

Due to the reasons previously mentioned, the Benchmark decided to use options combined, no taper and catchability independent of stock size.

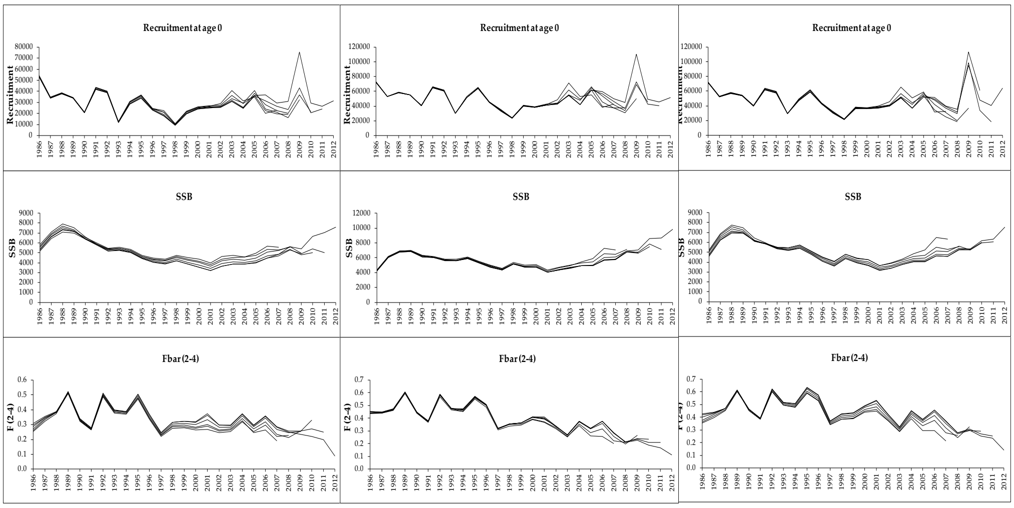


Figure 5.5.4.7. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis to no taper option and catchability independent of stock size.

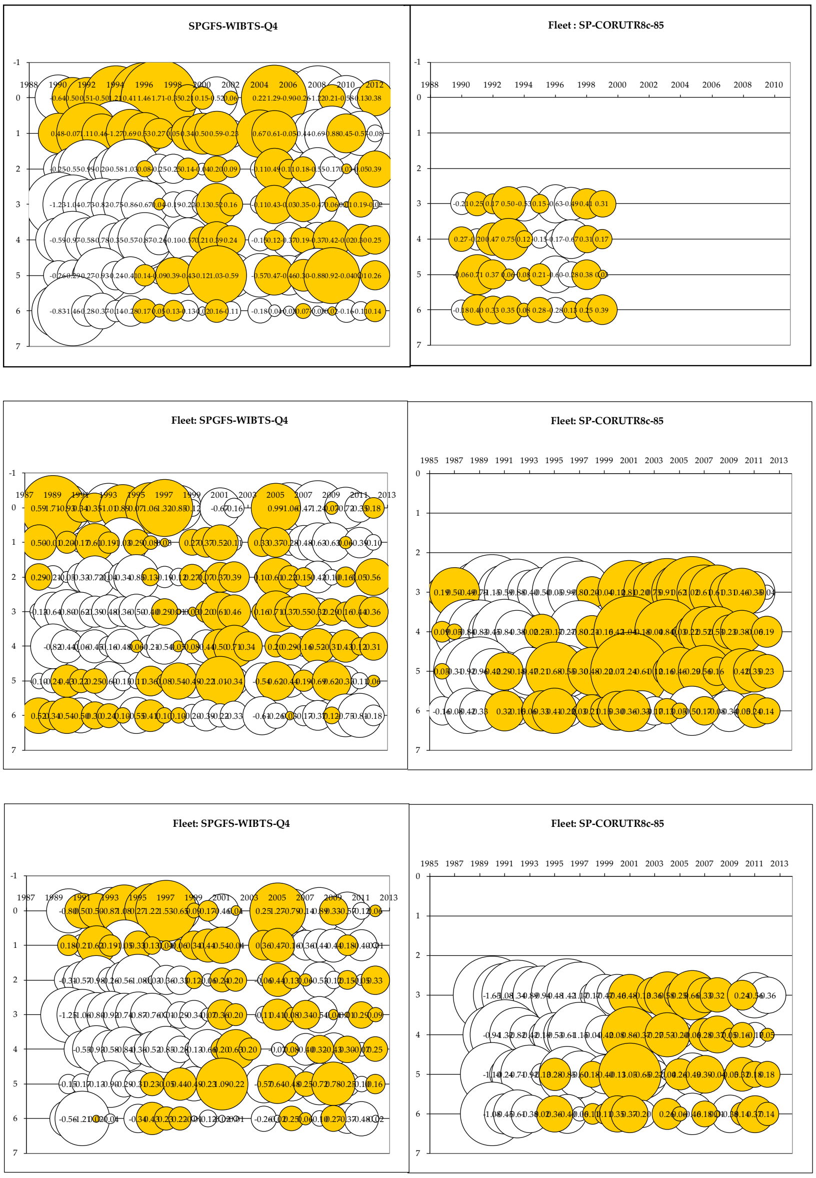


Figure 5.5.4.8. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and sensitivity analysis to no taper option and catchability independent on stock size.

Sensitivity to tuning fleet: splitting Coruña in to two time-series

Because of trends in the residuals, the tuning time-series from Coruña has been split in two, one from 1986 to 1999 and the other from 2000 to 2012, and additional sensitivity analysis has been run:

- Including the latter part of the Coruña time-series.
- Including the Coruña time-series split in two parts.

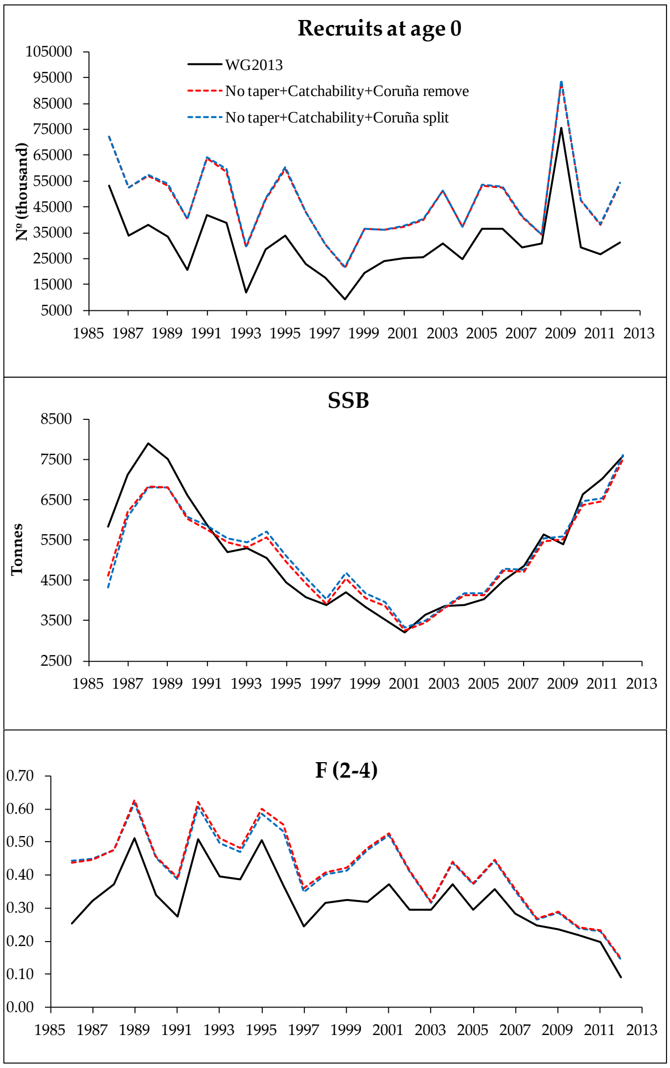


Figure 5.5.4.9. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Sensitivity analysis to different tuning fleet options.

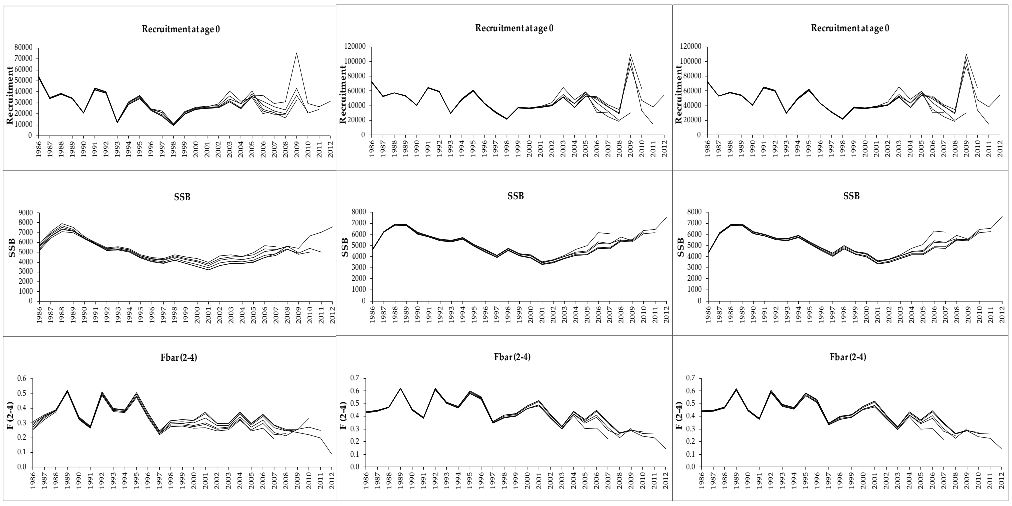


Figure 5.5.4.10. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and sensitivity analysis to tuning fleets removing first part of Coruña time-series and splitting Coruña time-series in two parts.

Figure 5.5.4.11. Four spot megrim (*L.boscii*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and sensitivity analysis to tuning fleets removing first part of Coruña time-series and splitting Coruña time-series in two parts.

Final accepted assessment

Based on the sensitivity analysis, retrospective patterns and the residual plots, the final accepted model has the following specifications:

- Discards average by period. First period from 1986 to 1999 and second period from 2000 to 2012, because of the change in MLS in 2000.
- Tuning fleets: Spanish survey (SpGFS-WIBTS-Q4) and Coruña trawl (SP-CORUTR8c) split in two periods.
- Catchability independent of stock size.
- No taper time weighting.

The Benchmark agreed that the final model configuration, that it is presented in the Stock Annex, is the most appropriate and shows an improvement in the assessment. Model convergence is reached with this configuration.

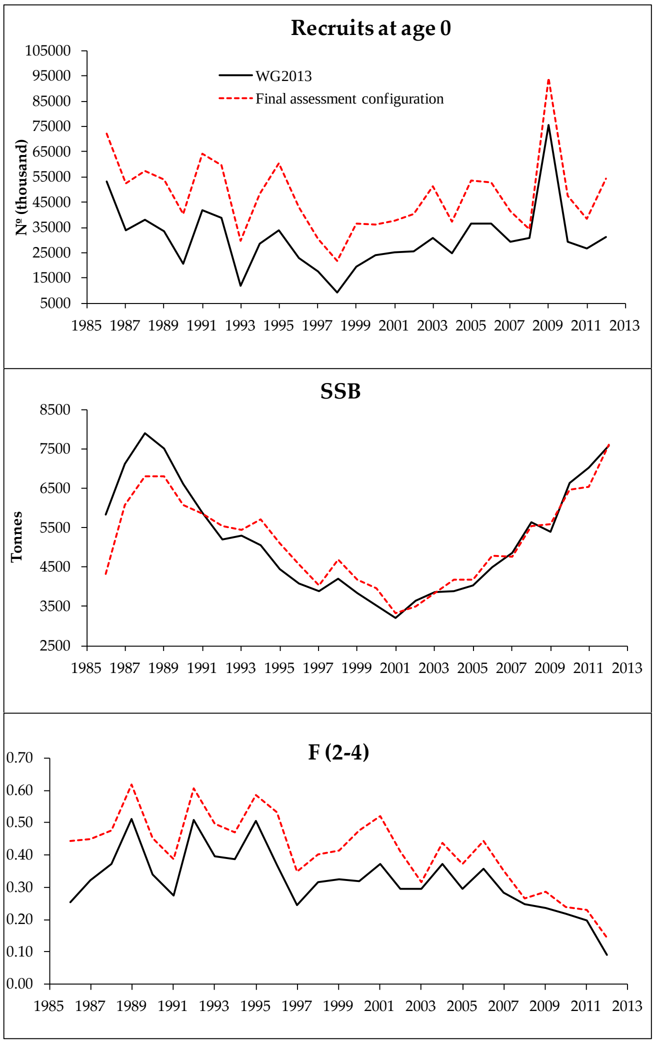


Figure 5.5.4.12. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Final assessment configuration (in red).

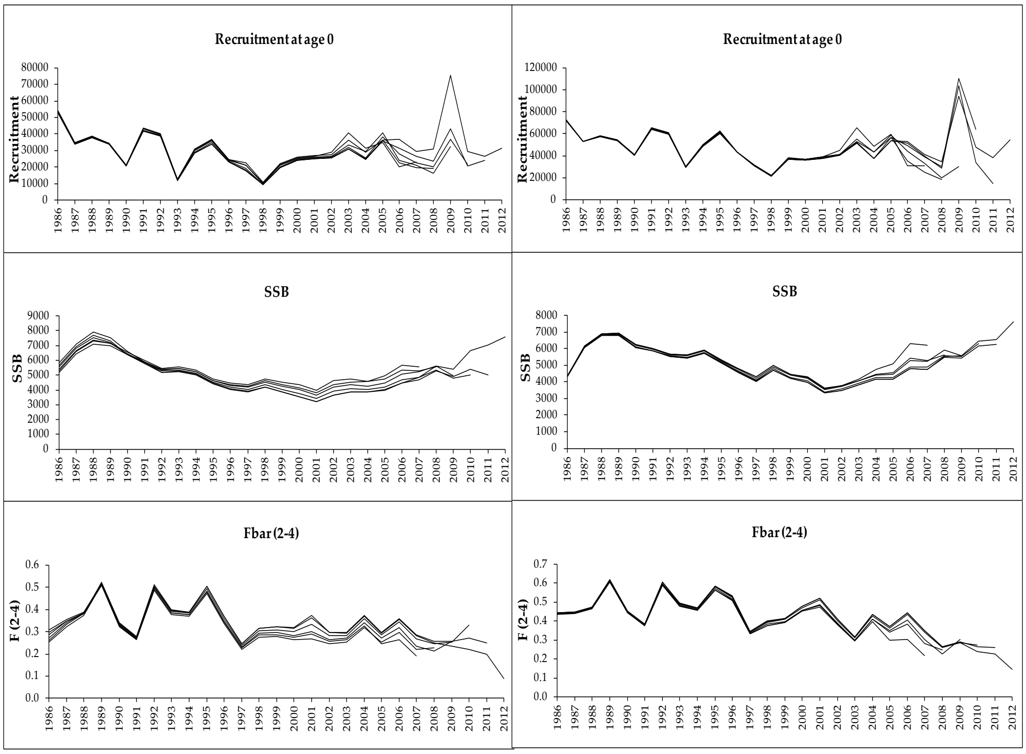


Figure 5.5.4.13. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Retrospective patterns of WGHMM2013 assessment and final assessment configuration.

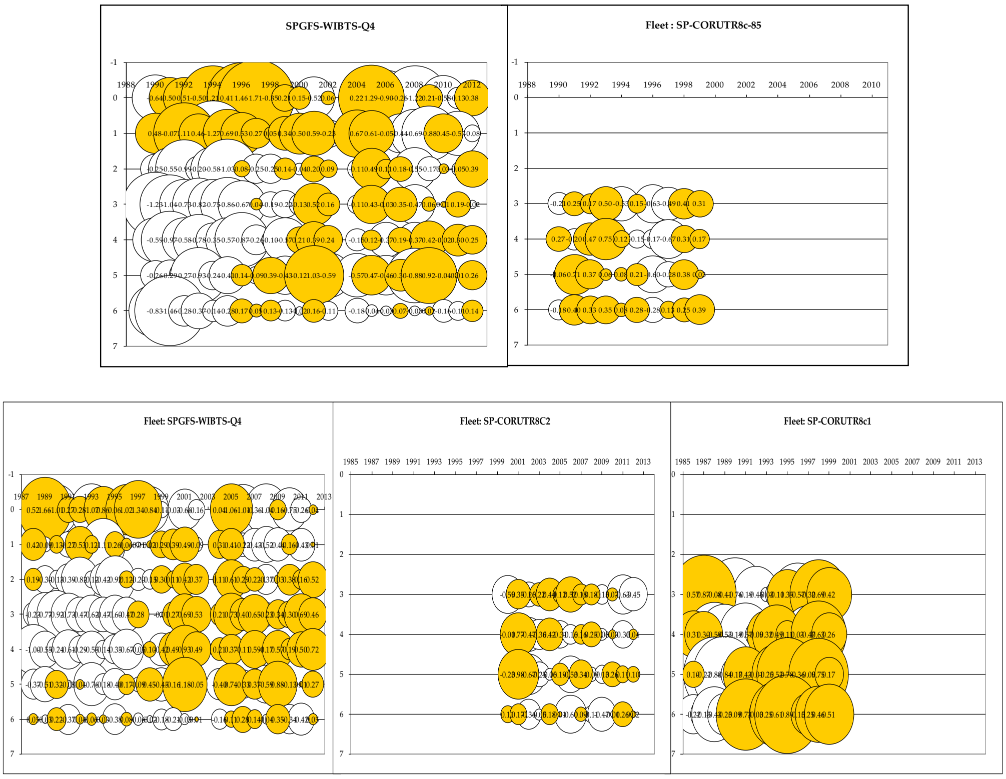


Figure 5.5.4.14. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Log-catchability residual plots of WGHMM2013 assessment and final assessment configuration.

5.5.5 Short-term projections

The software used for the short-term projections was MFDP with management option table and yield-per-recruit routines, according to the Stock annex. Because of the variability of the recent discard data, some settings have been changed from those used previously for this stock. The average of 5 years has been used for (at age) weight in catch, weights in the stock and the exploitation pattern. Flexibility should be allowed to choose the range of years depending on the data. To calculate the exploitation pattern at age (F-at-age/Fbar), each year is first standardized and then averaged (using a 5 years average, as noted above). Fbar for the intermediate year is usually taken as a 3-year average, but it could be scaled to the final assessment year if the assessment WG considers this a more realistic option for Fbar in the intermediate year. Forecast catch numbers-at-age are divided into landings and discards (at age) based on the proportions given as inputs to the projection software; the software does it automatically. These proportions were taken (for each age) to be those corresponding to the observed average of the most recent 5 years.

Table 5.5.5.1. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Input data for deterministic short-term predictions.

Table 9.2.13 Four-spot megrim (*L. boscii*) in Divisions VIIIc and IXa.
Prediction with management option table: Input data

MFDP version 1a
Run: boscii2
Time and date: 16:22 06/02/2014
Fbar age range (Total) : 2-4
Fbar age range Fleet 1 : 2-4

2013 Age	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
0	43617	0.2	0	0	0	0.005	0.000	0.003	0.017	0.005
1	43942	0.2	0.55	0	0	0.022	0.001	0.036	0.137	0.022
2	20951	0.2	0.86	0	0	0.049	0.036	0.066	0.087	0.041
3	17821	0.2	0.97	0	0	0.079	0.138	0.086	0.052	0.056
4	29377	0.2	0.99	0	0	0.104	0.281	0.105	0.018	0.087
5	6854	0.2	1	0	0	0.132	0.364	0.133	0.008	0.112
6	4190	0.2	1	0	0	0.171	0.307	0.171	0.003	0.134
7	3906	0.2	1	0	0	0.237	0.309	0.237	0.001	0.128

2014 Age	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
0	43617	0.2	0	0	0	0.005	0.000	0.003	0.017	0.005
1	.	0.2	0.55	0	0	0.022	0.001	0.036	0.137	0.022
2	.	0.2	0.86	0	0	0.049	0.036	0.066	0.087	0.041
3	.	0.2	0.97	0	0	0.079	0.138	0.086	0.052	0.056
4	.	0.2	0.99	0	0	0.104	0.281	0.105	0.018	0.087
5	.	0.2	1	0	0	0.132	0.364	0.133	0.008	0.112
6	.	0.2	1	0	0	0.171	0.307	0.171	0.003	0.134
7	.	0.2	1	0	0	0.237	0.309	0.237	0.001	0.128

2015 Age	Stock size	Natural mortality	Maturity ogive	Prop. of F bef. Spaw.	Prop. of M bef. Spaw.	Weight in Stock	Exploit pattern	Weight CWt	Exploit pattern	Weight DWt
0	43617	0.2	0	0	0	0.005	0.000	0.003	0.017	0.005
1	.	0.2	0.55	0	0	0.022	0.001	0.036	0.137	0.022
2	.	0.2	0.86	0	0	0.049	0.036	0.066	0.087	0.041
3	.	0.2	0.97	0	0	0.079	0.138	0.086	0.052	0.056
4	.	0.2	0.99	0	0	0.104	0.281	0.105	0.018	0.087
5	.	0.2	1	0	0	0.132	0.364	0.133	0.008	0.112
6	.	0.2	1	0	0	0.171	0.307	0.171	0.003	0.134
7	.	0.2	1	0	0	0.237	0.309	0.237	0.001	0.128

Input units are thousands and kg - output in tonnes

Table 5.5.5.2. Four spot megrim (*L. boscii*) (Divisions VIIIc and IXa). Management options for catch predictions.

MFDP version 1a
Run: boscii2
Time and date: 16:22 06/02/2014
Fbar age range (Total) : 2-4
Fbar age range Fleet 1 : 2-4

2013		Total	Landings		Discards	
Biomass	**SSB**	**FMult**	**FBar**	**Yield**	**FBar**	**Yield**
9222	8345	1	0.1561	1572	0.0481	250

2014		Total	Landings		Discards		2015	
Biomass	**SSB**	**FMult**	**FBar**	**Yield**	**FBar**	**Yield**	**Biomass**	**SSB**
9156	8317	0	0.0000	0	0.0000	0	11228	10376
.	8317	0.1	0.0156	183	0.0048	26	10977	10129
.	8317	0.2	0.0312	361	0.0096	52	10733	9890
.	8317	0.3	0.0468	534	0.0145	77	10496	9657
.	8317	0.4	0.0624	701	0.0193	102	10266	9431
.	8317	0.5	0.0780	863	0.0241	126	10042	9211
.	8317	0.6	0.0936	1021	0.0289	150	9824	8997
.	8317	0.7	0.1092	1174	0.0337	174	9612	8789
.	8317	0.8	0.1249	1322	0.0385	197	9406	8587
.	8317	0.9	0.1405	1466	0.0434	220	9206	8391
.	8317	1	0.1561	1606	0.0482	243	9011	8200
.	8317	1.1	0.1717	1741	0.0530	265	8822	8015
.	8317	1.2	0.1873	1873	0.0578	287	8638	7834
.	8317	1.3	0.2029	2001	0.0626	309	8459	7659
.	8317	1.4	0.2185	2125	0.0674	330	8284	7488
.	8317	1.5	0.2341	2245	0.0723	351	8115	7322
.	8317	1.6	0.2497	2362	0.0771	372	7950	7160
.	8317	1.7	0.2653	2475	0.0819	392	7789	7003
.	8317	1.8	0.2809	2585	0.0867	413	7633	6850
.	8317	1.9	0.2965	2692	0.0915	432	7480	6702
.	8317	2	0.3121	2796	0.0963	452	7332	6557

5.5.6 Appropriate Reference Points (MSY)

The benchmark workshop conducted a preliminary examination of potential MSY reference points for the four-spot megrim stock. A draft version of the WKMSYREF2 report (an ICES workshop conducted in January 2014 to consider the basis for reference points) was available and the guidelines proposed in Section 4 of that report were followed as much as practically possible. Of the two suggested softwares in WKMSYREF2 (PlotMSY and EqSim), PlotMSY was employed for the exploration, as it was considered easier to use given the limited time available for this task during the benchmark.

The time available for reference points derivation during the workshop was rather limited, but it was felt important to progress with the issue as much as possible. All suggestions for potential reference points made in this section must be considered as provisional, and it is recommended that they are given further consideration by the assessment working group WGBIE when it next meets in May 2014.

It is also noted that a final version of the PlotMSY software described below was not available during the benchmark. The version in the "msy" library still requires some development and the values obtained in the analysis in this section must be checked (by re-running the analysis when a final version of PlotMSY is available in the "msy" library – this finalization of PlotMSY for the "msy" library is expected to take place very soon) to ensure no bugs in the library may have affected the numbers obtained here.

Method and software used

The PlotMSY software was run from R (R version 3.0.2) using the library "msy", available on GITHUB https://github.com/wgmg/msy. The "msy" version used was:

> packageVersion("msy")

[1] '0.1.11'

> packageDescription("msy")

Package: msy

Type: Package

Title: Estimation of equilibrium reference points for fisheries

Version: 0.1.11

Date: 2014-02-02

Author: Colin Millar, Noel Cadigan, Timothy Earl, Jose D'Oliviera

Maintainer: Colin Millar <colinpmillar@gmail.com>

Description: Estimation of equilibrium reference points for fisheries

License: GPL (>= 2)

VignetteBuilder: knitr

Depends: FLCore, MASS, mgcv, scam, reshape2, plyr, ggplot2, gridExtra,

R2admb

Suggests: knitr

LazyData: yes

Collate: 'myMH.R' 'SimulateRefPts.R' 'cod-data.R' 'ModelAverage.R'

.....

GithubRepo: msy

GithubUsername: wgmg

GithubRef: master

GithubSHA1: 4dae3e5887367528289bb08c7af1b971851a024d

Built: R 3.0.2; ; 2014-02-06 12:25:57 UTC; windows

-- File: C:/Program Files/R/R-3.0.2/library/msy/Meta/package.rds

While running PlotMSY software during the benchmark it was noted that the R "msy" library only works properly if the two executable files "srmsymc.exe" and "srmsymc2.exe" (provided as part of the "msy" library) are also copied into the same working directory from which R is being run. This minor bug was reported to the library developers, who were already aware of it and are working to correct this problem. Other than this, PlotMSY was run without apparent difficulties using the "msy" R library (note however the need to re-run the analysis with a final version of the software, as already said). The "plotMSY" function from this library was used in the exploration of potential reference points (see Annex 7 of WGMG 2013 report for a clear explanation of how to use this function as well as the format of the required input files).

Settings and input files

The biological information needed to run this model was obtained from the assessment model (final XSA run agreed during the benchmark).

- Similarly to the short-term projections conducted during the benchmark, 5-year averages were used for the following settings: mean weight-at-age of the landings, of the discards, and of the stock; selection-at-age (i.e. F(a)/F(2-4)) for the total catch, subsequently split into selection-at-age of landings and discards based on the (5-year average) proportion landed-at-age. Natural mortality and proportion mature-at-age were assumed constant over time. Figures 4.5.6.1 and 4.5.6.2 show the selection-at-age of the total catch and the weight-at-age for the calculation of SSB and for converting total catch from numbers-at-age to weight.
- *Note:* As discussed in the reference point section for megrim, the benchmark considered that the selection-at-age pattern should possibly be computed based on a geometric mean instead of an arithmetic mean. This is in order to reduce the effect of large spikes that occur occasionally in the selection-at-age estimates, due to the variability of the discards data, and which would distort the results of the reference points computation. This fact, however, was only realized after this report section for four-spot megrim had been completed, so the analysis presented in this section is based on an arithmetic mean (instead of a geometric mean, as finally suggested in the benchmark, and already implemented in the megrim reference points computation).
- A CV was set around each of the quantities noted in the previous bullet points. There was no information readily available at the benchmark to set these CVs, so they were provisionally taken from an example provided with the package (North Sea cod) noting that the values did not seem too unreasonable at first sight.

Two input files were required in order to run PlotMSY:

"Megb_srmsymc.dat", with the following format:

#stkname, filname // stkname=stock dealing with; filname=name of 2nd file

Megb Megb.dat

#ybeg, yend, r, A, Ropt, simopt, senopt,penopt // ybeg=1st yr; yend=last yr; r=recr age; A=plusgroup; Ropt=S-R function type, simopt (0=no sim, 1=do sim); senopt (0=error only in recr, 1=error in recr & steady-state vectors); penopt (0=no SR constraints, 1=apply SR constraints)

1986 2012 0 7 1 1 1 1

#R, Bssb // R=recr; Bssb=SSB

72216	4325
52595	6080
57532	6809
53929	6812
40549	6075
64233	5850
59606	5532
29714	5437
48518	5721
60288	5116
43059	4566
30612	4041
21623	4701
36773	4191
36231	3956
37638	3332
40205	3506
51433	3844
37404	4174
53597	4183
53006	4800
41464	4759
34438	5541
94013	5596
47605	6468
38481	6545
54424	7606

"Megb.dat", with the following format:

#fno, sno, f, m // fno=nr fleets; sno=fleet for ypr stats; f=F before spwn; m=M before spwn

2 1 0 0

Selection pattern: selection-at-age of F_catch (Fbar=1), split into F_landings (1st col) + F_disc (2nd col)

0.000	0.083
0.004	0.672
0.178	0.428

0.674 0.257

1.385 0.078

1.787 0.033

1.503 0.014

1.513 0.004

cv Selection pattern

0.175 0.175

0.175 0.175

0.097 0.097

0.076 0.076

0.079 0.079

0.085 0.085

0.109 0.109

0.109 0.109

Weight at age

0.003 0.005

0.037 0.021

0.067 0.040

0.086 0.053

0.107 0.083

0.139 0.120

0.178 0.148

0.247 0.114

cv Weight at age

0.112 0.255

0.112 0.255

0.143 0.282

0.137 0.419

0.097 0.542

0.062 0.480

0.050 0.345

0.040 0.792

Biological data

M, mat, wSSB

0.2 0 0.005

0.2 0.55 0.021

0.2 0.86 0.049

0.2 0.97 0.077

0.2	0.99	0.106
0.2	1	0.138
0.2	1	0.178
0.2	1	0.247

cv Biological data

cvM, cvmat, cvwSSB

0.1 0.0 0.112

0.1 0.1 0.112

0.1 0.1 0.143

0.1 0.1 0.137

0.1 0.1 0.097

0.1 0.0 0.062

0.1 0.0 0.050

0.1 0.0 0.040

While preparing the "Megb.dat" file, it was noted that the fish are assumed to mature really young: 55% of the fish mature at age 1. Given that the mean weight of the age 1 fish is only 21 g, this seems a very low age and weight of maturation. This maturity assumption is also made in the assessment. It is recommended that it is checked by the appropriate scientists with their colleagues in their home institutes.

From the "Megb.dat" file, it can be also be seen that there is high selection of fish at ages 1 and 2, which are then largely discarded. This selection of small fish, which are subsequently mainly discarded, is expected to have a clear impact on calculated F_{MSY} values (obtained by maximizing long-term yield = landings) resulting in lower F_{MSY} values.

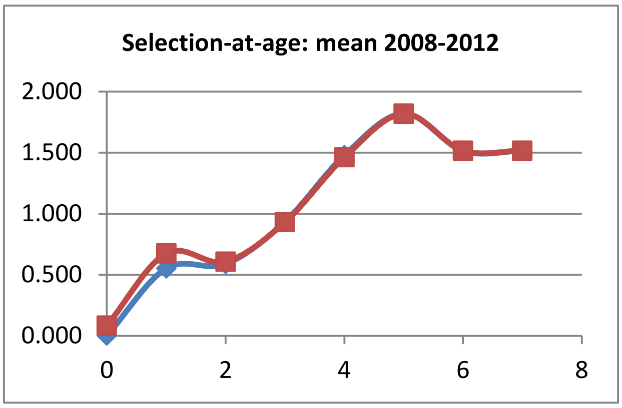


Figure 5.5.6.1. Four-spot megrim: selection-at-age (F(a)/F(2-4)) of total catch, obtained as an arithmetic (red) or geometric (blue) mean of 2008-2012.

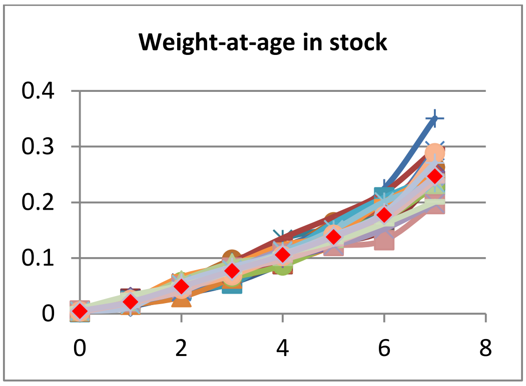


Figure 5.5.6.2. Four-spot megrim: weight-at-age (for calculation of SSB and total catch in weight) for each historic year and average of 2008-2012 (red dots)

Results

The "plotMSY" function from the R "msy" library was run with 1000 iterations. The three stock–recruitment relationships provided in the software (Ricker, Beverton–Holt, Hockey-stick) were tried. The software produces results for each of them separately. It also allows to combine them (in a bootstrap-type way) assigning user-selected weights to each of them (based on biological/ecosystem knowledge of what is more appropriate to the stock in question) or automatic weights based on their respective likelihood fits to the stock-recruitment "data". In the automatic weighting option, some trimming is required to get stable weights (0.5% trimming was applied for the four-stock megrim stock after an initial run with no trimming and following the exploratory procedure suggested in Annex 7 of the WGMG 2013 report).

Figures 5.5.6.3-7 show the results for each of the stock-recruitment functions and a per-recruit analysis.

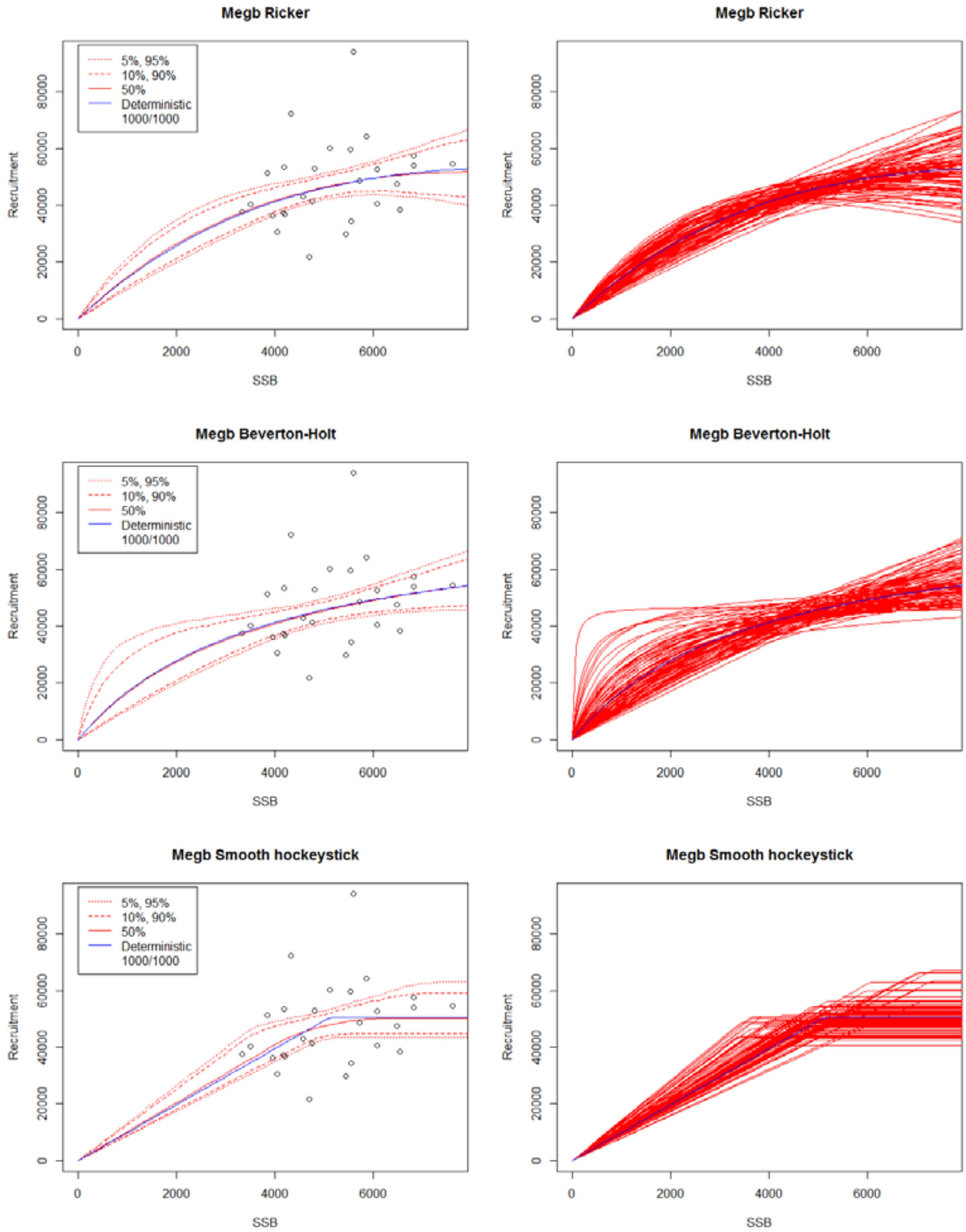


Figure 5.5.6.3. Four-spot megrim: stock-recruitment pairs from assessment (open circles) and fits from Ricker, Beverton–Holt and Hockey-stick functions.

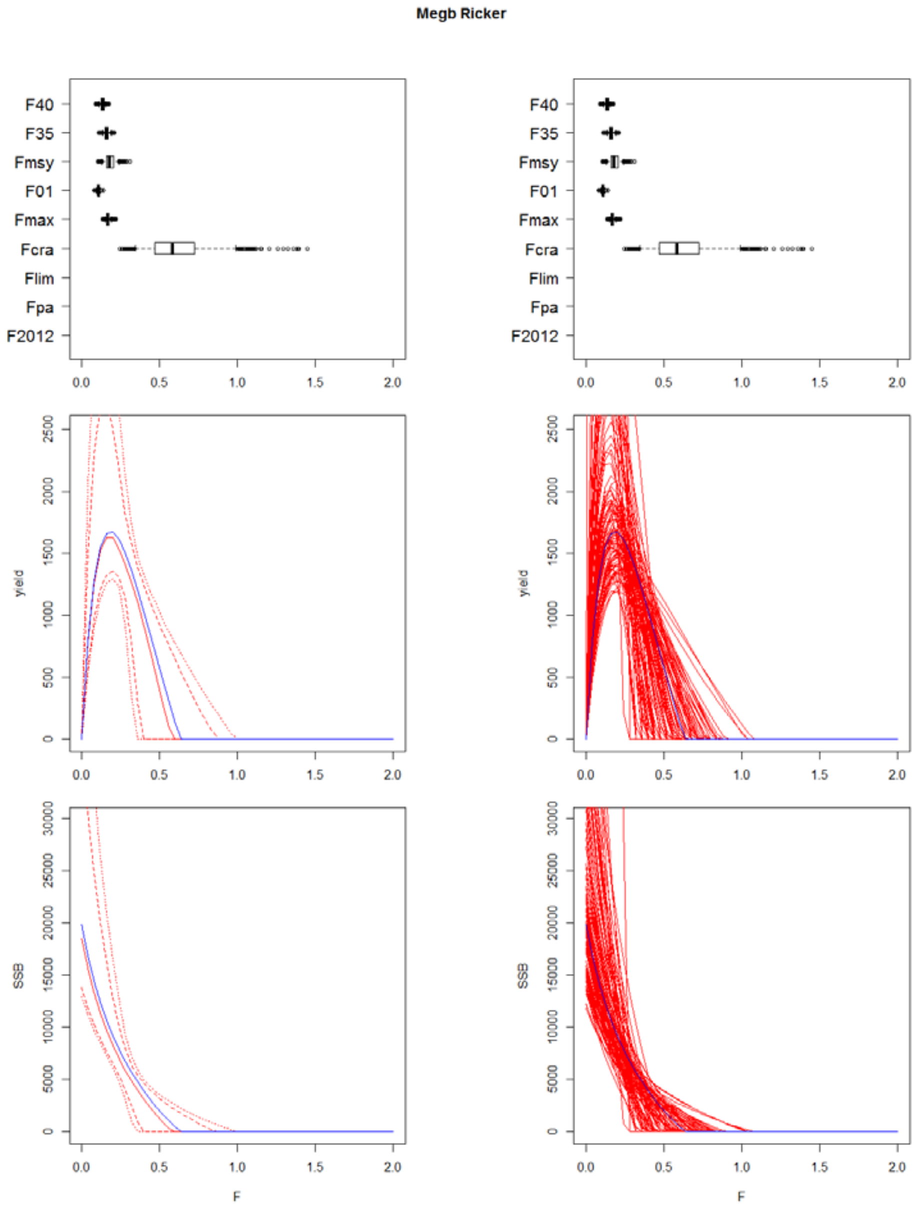


Figure 5.5.6.4. Four-spot megrim: results for Ricker stock-recruitment function.

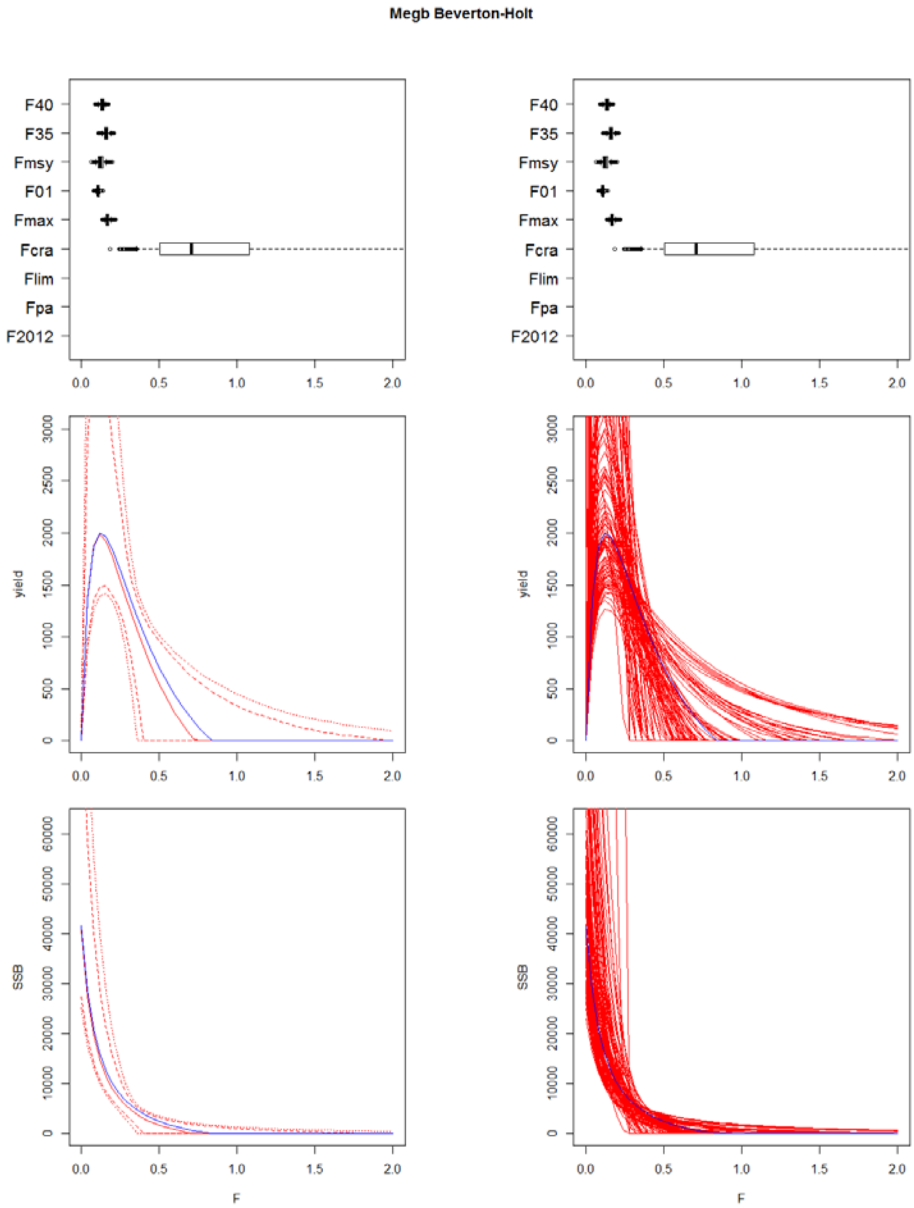


Figure 5.5.6.5. Four-spot megrim: results for Beverton–Holt stock-recruitment function.

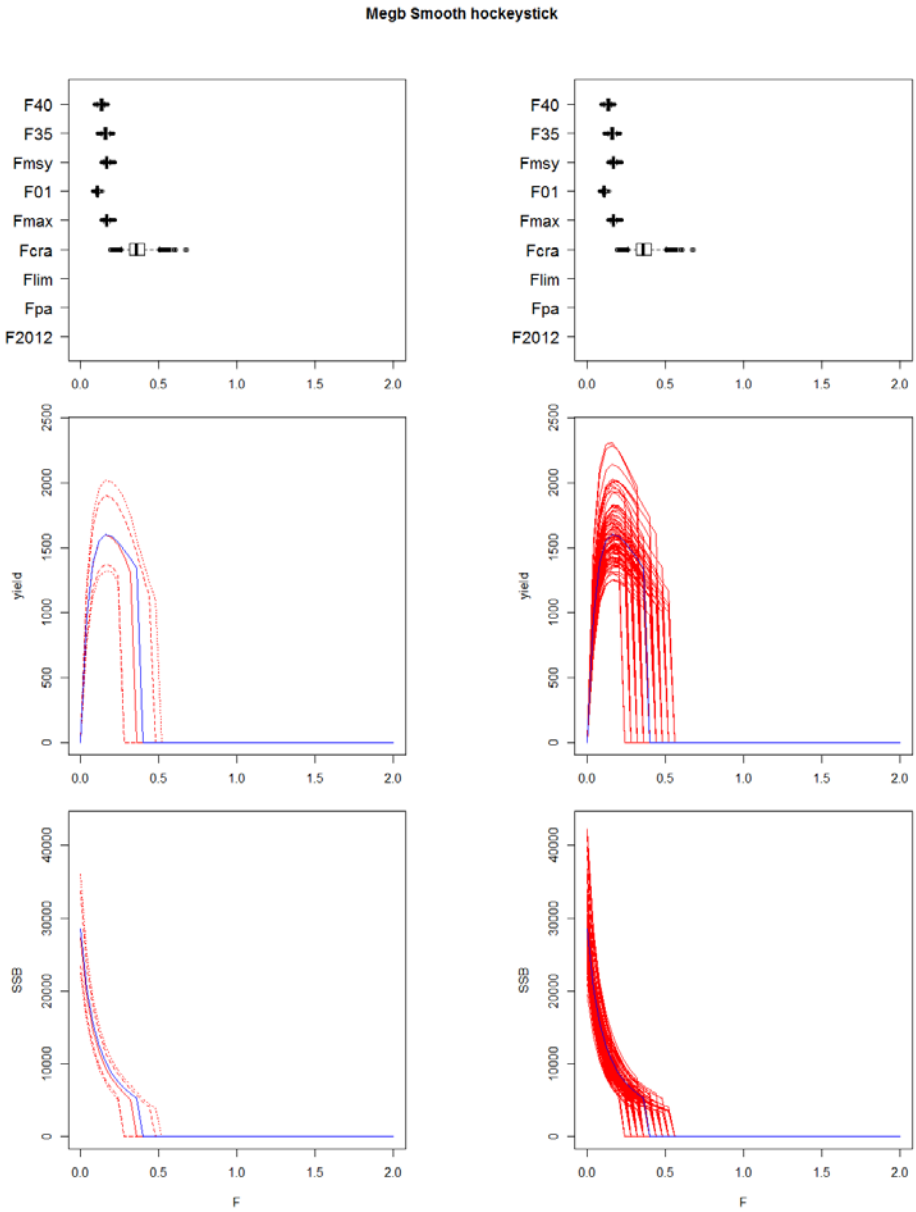


Figure 5.5.6.6. Four-spot megrim: results for Hockey-stick stock-recruitment function.

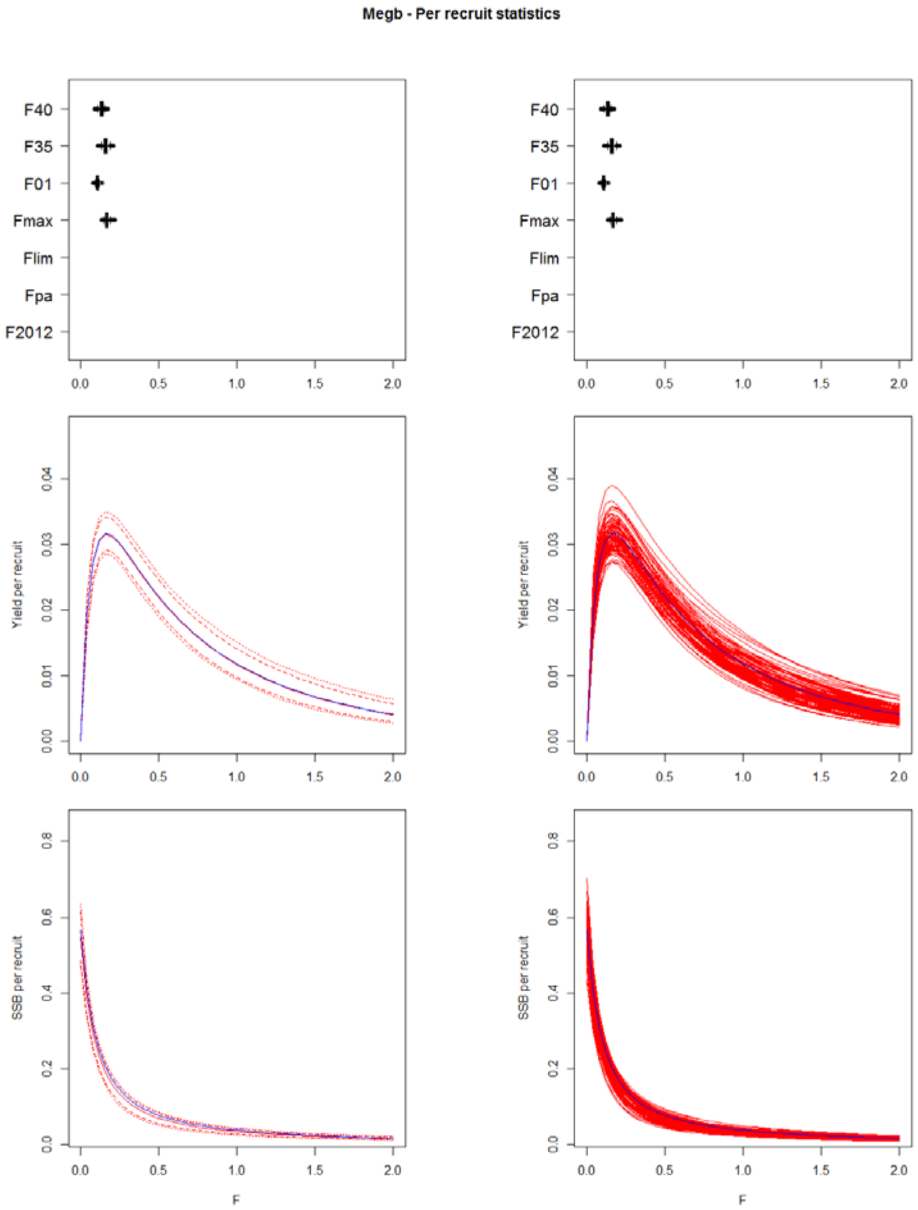


Figure 5.5.6.7. Four-spot megrim: results for per-recruit analysis.

Results in table form were also obtained for each stock-recruit function considered, per-recruit, and with automatic (likelihood-based) weighting of the three stock-recruitment functions (weights in table given in the order Ricker, Beverton–Holt, Hockey-stick).

Table 5.5.6.1. Four-spot megrim: results per-recruit, for each stock-recruitment function separately, and with equal (first 4 columns of final rows) automatic (last 4 columns of final rows) weighting.

Stock name									
Megb									
Sen filename									
NA									
index filename									
NA									
Number of iterations									
1000									
Simulate variation in Biological parameters									
TRUE									
SR relationship constrained									
TRUE									
Ricker									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.63	0.18	9770	1679	1.07	0.48	16.08	0.00	15.98
Mean	0.61	0.18	13337	2184	1.09	0.51	17.33	0.00	18.05
5%ile	0.34	0.13	6263	1330	0.97	0.15	10.84	0.00	16.09
25%ile	0.47	0.16	7545	1486	1.03	0.36	13.96	0.00	16.63
50%ile	0.58	0.18	8966	1660	1.08	0.51	16.58	0.00	17.53

75%ile	0.72	0.20	12155	1992	1.14	0.66	20.08	0.00	18.90
95%ile	0.99	0.24	25142	3731	1.21	0.90	26.16	0.00	21.82
CV	0.32	0.19	2.21	1.56	0.07	0.43	0.28	0.43	0.11
N	1000	1000	1000	1000	1000	1000	1000	1000	1000
Beverton–Holt									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.84	0.13	15416	2002	0.50	0.93	80083.50	3744.93	15.95
Mean	0.93	0.12	34681	3884	0.49	0.95	195641.52	17386.61	17.78
5%ile	0.35	0.09	8603	1422	0.14	0.85	49310.20	444.38	16.08
25%ile	0.50	0.11	11421	1674	0.34	0.90	62746.23	1939.17	16.50
50%ile	0.71	0.12	14773	1985	0.50	0.94	80622.60	3883.65	17.27
75%ile	1.08	0.14	21213	2561	0.64	0.99	118881.25	8185.11	18.44
95%ile	2.38	0.16	48623	5376	0.81	1.06	284914.25	26284.52	21.15
CV	0.74	0.17	9.57	8.12	0.42	0.07	9.72	13.38	0.10
N	962	1000	1000	1000	1000	1000	1000	1000	1000
Smooth hockeystick									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AICc
Deterministic	0.38	0.17	10020	1603	0.53	0.99	4.94	5111.63	16.89
Mean	0.36	0.17	9390	1623	0.57	0.96	5.28	4951.88	18.97
5%ile	0.26	0.15	7129	1327	0.47	0.69	4.36	3556.35	17.16
25%ile	0.31	0.16	8366	1477	0.51	0.81	4.76	4195.76	17.66
50%ile	0.36	0.17	9224	1601	0.55	0.94	5.12	4877.13	18.43
75%ile	0.41	0.17	10326	1738	0.62	1.07	5.69	5553.60	19.68

95%ile	0.50	0.19	12168	2021	0.72	1.34	6.63	6908.86	22.35
CV	0.21	0.07	0.16	0.13	0.13	0.20	0.13	0.20	0.10
N	1000	1000	1000	1000	1000	1000	1000	1000	1000
Per recruit									
	F20	F25	F30	F35	F40	F01	Fmax	Bmsypr	MSYpr
Deterministic	0.33	0.26	0.21	0.17	0.14	0.11	0.17	0.20	0.03
Mean	0.31	0.24	0.19	0.16	0.13	0.11	0.17	0.18	0.03
5%ile	0.25	0.20	0.16	0.13	0.11	0.09	0.15	0.15	0.03
25%ile	0.28	0.22	0.18	0.15	0.12	0.10	0.16	0.17	0.03
50%ile	0.31	0.24	0.19	0.16	0.13	0.11	0.17	0.18	0.03
75%ile	0.34	0.26	0.21	0.17	0.14	0.11	0.17	0.20	0.03
95%ile	0.38	0.29	0.23	0.19	0.15	0.12	0.19	0.22	0.04
CV	0.12	0.11	0.11	0.11	0.10	0.08	0.07	0.12	0.06
N	1000	1000	1000	1000	1000	1000	1000	1000	1000
Combining all SRRs									
Automatically specified weights									
	0.34	0.42	0.24						
Percentage	Fmsy	Fcrash	MSY	Bmsy	Fmsy_w	Fcrash_w	MSY_w	Bmsy_w	
5%	0.10	0.28	1343	6790	0.10	0.28	1355	6877	
25%	0.13	0.37	1514	8505	0.12	0.39	1513	8592	
50%	0.16	0.50	1692	10088	0.15	0.53	1724	10592	
75%	0.18	0.71	2037	13754	0.17	0.74	2133	15320	
95%	0.22	1.37	3792	31545	0.21	1.52	3976	33452	

The stock-recruitment values obtained from the assessment do not show any clear stock-recruitment signal to allow a clear estimation of a stock-recruitment curve (Figure 5.5.6.3). The time-series is relatively short and there are no data sufficiently close to the origin to allow an understanding of what may happen at lower stock biomasses. Based on the available data, there is no indication that recruitment might decrease at high stock sizes (which would be typical of a Ricker curve).

It is noted that the estimated recruitment (age 0) is strongly dependent on the time-series of discards (introduced for the first time in the assessment at this benchmark). The discard time-series is highly uncertain before 1994, as there are no discard observations from that early period (discards each year were reconstructed using the observed mean values, from the years with discard sampling, during 1995-1999); this also results in high uncertainty in recruitment estimates.

Despite all these issues, the range of values that were generally found to be consistent with high long-term yield is not very wide, as can be seen from Table 5.5.6.1. F_{MSY} would be 0.12 based on Beverton–Holt, 0.17 based on Hockey-stick, and 0.18 based on Ricker. During the last decade, the SSB has been continuously increasing, and it is now estimated to be at its historical maximum. During the same period, F has shown a clear decreasing trend, from about 0.4 at the start of the period to 0.23 in 2011, and then dropping to 0.14 in 2012. The historical stock development suggests that F values not exceeding approximately 0.3 are sustainable and allow clear stock increases. At the same time, the high fishery selection and discarding at ages 1 and 2 causes the yield-per-recruit curve to peak at a low F value (F_{max} = 0.17).

Based on all of the above, F_{max} = 0.17 is considered an appropriate F_{MSY} proxy for the stock.

The WKMSYREF2 report notes that if F_{max} is chosen as a proxy for F_{MSY}, a test for precautionary considerations should be made. The arguments provided in the paragraph above indicate that fishing at F=0.17 should be precautionary for this stock. An additional test was done with PlotMSY as follows:

As part of the PlotMSY output, a plot of the estimated long-term probability of SSB<B_{lim}, when fishing at a constant F is produced. Either 3300 t (B_{loss}=SSB_{2001}) or 3800 t (excluding the two lowest SSB values, for which recruitment was a bit below the long-term historic average), could be considered as B_{lim} candidates. Based on the CVs specified in the "Megb.dat" file and the automatic weighting of the three stock-recruitment functions, long-term fishing at a constant F=0.26 gives a 5% probability of long-term SSB < 3300 t (Figure 5.5.6.8), whereas long-term fishing at a constant F=0.25 gives a 5% probability of long-term SSB < 3800 t (no figure shown). This provides another indication that fishing at F=0.17 should be precautionary for this stock. It must be stressed that the CVs used in this analysis were simply taken from the example provided with PlotMSY (corresponding to North Sea cod). This probability plot should be done with CVs that are carefully thought about and considered appropriate to the four-spot megrim stock. There was no time to consider this at the benchmark, but at least the analysis at the benchmark shows some robustness of the F=0.17 against some degree of uncertainty.

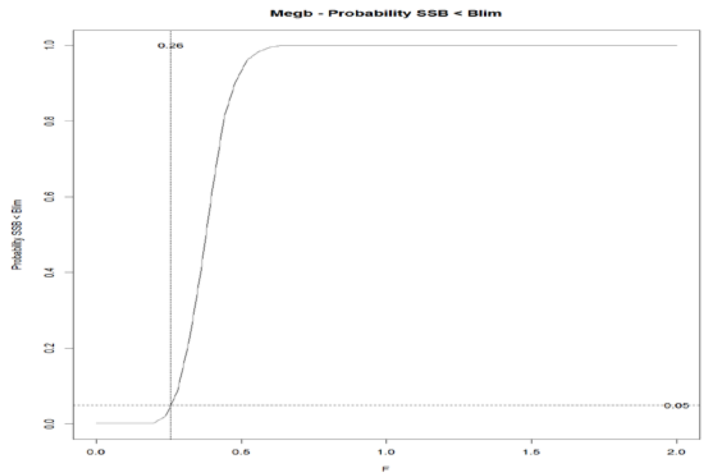


Figure 5.5.6.8. Four-spot megrim: long-term probability of SSB < B_{lim} (for this plot, B_{lim} is taken as 3300 t)

The ICES MSY harvest control rule is based on fishing at F_{MSY} if SSB ≥ MSY $B_{trigger}$ and applying a linear reduction in F when SSB < MSY $B_{trigger}$. For most stocks, MSY $B_{trigger}$ has been initially set at B_{pa}. For the four-spot megrim stock, a provisional choice of biomass reference points could thus be: B_{lim}=3300 t (=B_{loss}, based on no signal of impaired recruitment during the historical time-series); B_{pa} = 4600 t (default choice B_{pa} = 1.4 B_{lim}); MSY $B_{trigger}$ = 4600 t (default choice = B_{pa}). It must be stressed once more that the short time available during the benchmark did not permit a careful consideration of these potential biomass reference points. Therefore, they are simply noted here as potential values that should merit further consideration by the assessment working group (WGBIE).

Conclusions and recommendations

- The little time available during the benchmark did not permit very careful consideration of reference points, so the results derived during the benchmark should be further considered during the assessment working group (WGBIE). This is particularly the case for the biomass reference points.

  F_{max} (= 0.17 with the settings used in this report section) is suggested as F_{MSY} proxy for the stock (to be further considered by WGBIE). A preliminary run with geometric mean (of 2008-2012) instead of arithmetic mean for selection-at-age gives F_{max} as 0.18. When WGBIE carefully reconsiders the analysis in this section, it is suggested that the geometric mean is used for selection-at-age, as discussed during the benchmark meeting (and already incorporated in the reference points section for megrim).
- Potential biomass reference points were also suggested at the benchmark (to be further considered by WGBIE)
- It is recommended that additional exploration of model settings and sensitivities (e.g. CVs used in the "Megb.dat" file; the high uncertainty in recruitment before 1994 because of the discard estimates used for that early period) is conducted.
- Check the maturity assumption at age 1 used in the assessment and reference points analysis.
- Before making final decisions on reference points for four-spot megrim, the potential reference points for megrim also need to be considered, as there is a single TAC for

both species. The benchmark did not have time to consider any aspect in relation to this. There was almost no time at the benchmark to consider potential reference points for megrim.

Work conducted after benchmark meeting

The work presented here used the latest version of the "msy" package available on the GITHUB site on February 13, 2014. This is msy package version 0.1.12.

The analysis was expanded after the benchmark meeting ended, in three ways as follows:

First, the same analysis presented here was rerun using the geometric mean (instead of the arithmetic mean) of years 2008-2012 for the selection-at-age of the catch. This was agreed during the benchmark meeting, as recommended and done as well for megrim (*L. whiffiagonis*). This change produced very slightly higher (median) values of the potential reference points: F_{max}=0.18 (close to $F_{35\%}$=0.17), whereas F_{MSY} was 0.19, 0.13, and 0.18, under Ricker, Beverton–Holt and Hockey-stick, respectively. Values of F below 0.27 correspond to less than 5% long-term probability of SSB being below 3300 t (B_{loss}), based on the likelihood weighting of the three stock-recruitment functions automatically done by the PlotMSY software.

Second, the analysis just explained (based on geometric mean) was redone, changing the CVs to those corresponding to the four-spot megrim assessment assumptions (in the case of weight, M and proportion mature at age) or assessment results (in the case of selection at age) for the last 5 years (2008-2012). Based on these CVs, there are, once again, some slight changes to the (median) values of potential reference points: F_{max}=0.18 (equal to $F_{35\%}$=0.18), whereas F_{MSY} was 0.20, 0.13, and 0.18, under Ricker, Beverton–Holt and Hockey-stick, respectively. Values of F below 0.33 correspond to less than 5% long-term probability of SSB being below 3300 t (B_{loss}), based on the likelihood weighting of the three stock-recruitment functions.

Third, the EqSim software (also developed at the 2014 ICES workshop WKMSYREF2 and included in the "msy" package) was also applied. Inputs for (at age) fishery selection, proportion landed and discarded, weight, M and proportion mature were randomly drawn from the four-spot megrim assessment assumptions (in the case of weight, M and proportion mature at age) or assessment results (in the case of selection at age) for the last 5 years (2008-2012). The Ricker, Beverton–Holt and Hockey-stick SR relationships were considered; it must be noted that the EqSim software estimated different weights for each of these SR relationships than the PlotMSY software. Long-term projections, including the randomly drawn parameters noted above and annual stochastic variability of recruitment, were conducted for different F values. A graphical display of results is presented in Figure 5.5.6.9. The figure shows a fairly flat yield (long-term landings) curve, with a maximum at F=0.16, whereas values of F below 0.36 give less than 5% long-term probability of SSB being below 3300 t (B_{loss}, which could be considered a candidate for B_{lim}). Following the guidelines in Section 4.3 of the WKMSYREF2 report, a test was then conducted incorporating assessment and implementation error in the long-term projections (this was done simply, assuming that the real F in each projection year varied stochastically around the intended F with the errors having CV=0.25 and 0.3 correlation between consecutive years). By introducing these errors in the realized F, the "intended" F value giving 5% probability of SSB being less than 3300 t decreased to F=0.34 (from the previous 0.36, calculated without errors in realized F). Finally, repeating the latter exercise for the ICES MSY HCR (which, when SSB < MSY $B_{trigger}$, reduces F linearly from the target F), assuming MSY $B_{trigger}$ = 1.4*3300 t, the target F value giving 5% probability of SSB being less than 3300 t increased to F=0.41.

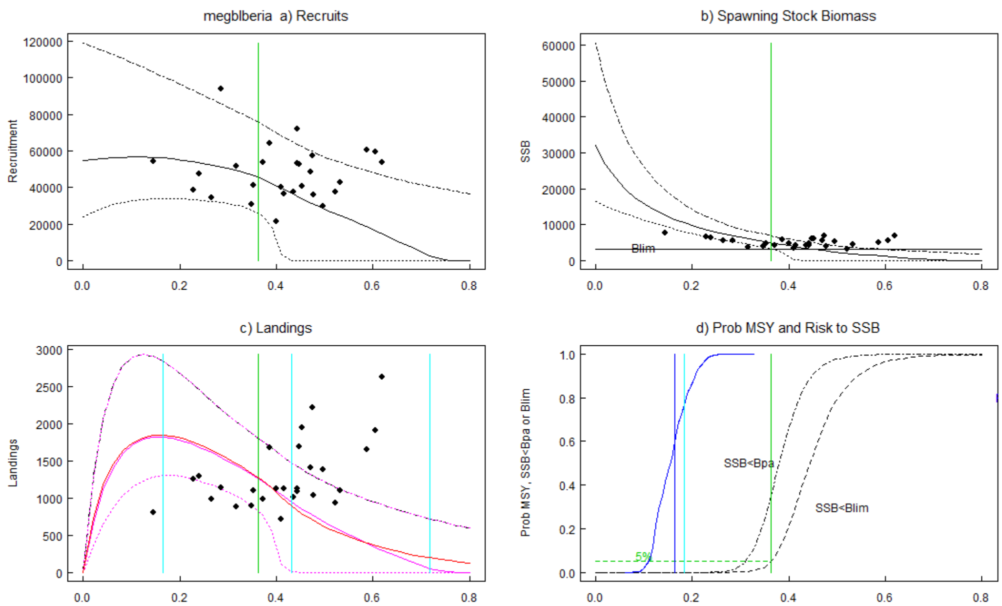


Figure 5.5.6.9. Four-spot megrim, long-term projections from EqSim including stochastic annual recruitment: (a) recruitment vs. F, (b) SSB vs. F, (c) yield (i.e. landings) vs. F, (d) probability of SSB < B_{lim} and B_{pa} vs. F (for this plot it is assumed B_{lim}=3300 t, and B_{pa}=1.4 B_{lim}). In all panels, the green vertical line is at F=0.36 (the F value that gives 5% probability of SSB < B_{lim}). The left-most vertical line in panel (c) is at F=0.16 (the F value that maximizes long-term average landings). Historical estimates from the benchmark assessment are represented as dots in panels (a), (b), (c).

Taking all the above information into account, as well as the historic stock development as estimated by the benchmark assessment, the following reference points are proposed:

B_{lim} = 3300 t (provisional reference point; B_{loss} in the 2014 benchmark assessment),

B_{pa} = 4600 t (default option;1.4 B_{lim}),

MSY $B_{trigger}$ = 4600 t (default option; B_{pa}),

F_{MSY}=0.18 (F_{max} as F_{MSY} proxy; a check for precautionary considerations has been conducted).

Given the uncertainties surrounding the recruitment estimates (due to uncertain discards estimates), these reference points should be considered provisional. They represent pragmatic choices given the current state of knowledge.

It is recommended that the assessment working group WGBIE gives further consideration to these proposals.

5.5.7 Future Research and data requirements

Develop more appropriate tuning fleets which cover the full spatial extent of the stock.

Gather and evaluate additional commercial information such as the Coruña and Avilés time-series and combine these time-series into appropriate tuning indices.

Migrate the assessment models from XSA to the SAM statistical catch-at-age model. This increases the flexibility of the modelling approach (e.g. it removes the assumption of exact catches) and is in line with many other stocks within ICES

The reference point model for megrim and four spot megrim needs further exploration.

Given the issues highlighted at this benchmark, work should be conducted towards a better method of incorporating discarding into the assessment

Evaluate the validity of the maturity-at-age 1 value (for both stocks, but particularly for four-spot megrim)

Explore removal of age 0 from the assessment and evaluate the impact on catch recommendations

6 References

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Annex 1: New stock annexes

Stock Annex Northern Stock of Hake

Stock specific documentation of standard assessment procedures used by ICES.

Stock Northern Stock of Hake (Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d)

Working Group:	Working Group for the Bay of Biscay and Iberic Waters Ecoregion (WGBIE)
Date:	1 April 2014
Revised by	WKSOUTH2014

A. General

A.1. Stock definition

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

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

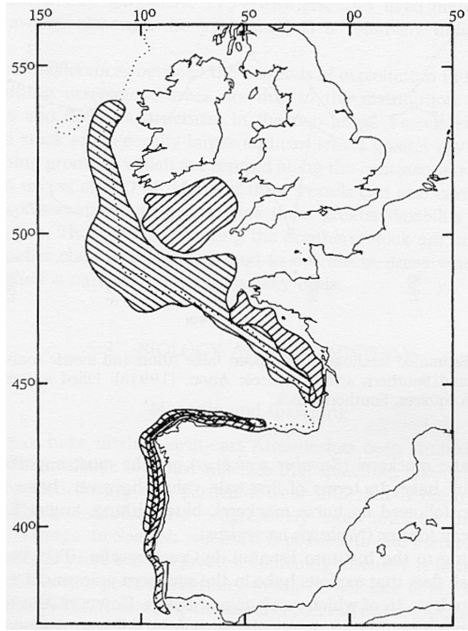

Figure 1. Main spawning and nursery areas. Spawning areas sloping downwards from left to right; Nursery areas sloping downwards from right to left. (from Casey and Pereiro, 1995)

A.2. Fishery

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

Fishery Unit	Description	Sub-area
FU1	Longline in medium to deep water	VII
FU2	Longline in shallow water	VII
FU3	Gillnets	VII
FU4	Non-Nephrops trawling in medium to deep water	VII
FU5	Non-Nephrops trawling in shallow water	VII
FU6	Beam trawling in shallow water	VII
FU8	Nephrops trawling in medium to deep water	VII
FU9	Nephrops trawling in shallow to medium water	VIII
FU10	Trawling in shallow to medium water	VIII
FU12	Longline in medium to deep water	VIII
FU13	Gillnets in shallow to medium water	VIII
FU14	Trawling in medium to deep water	VIII
FU15	Miscellaneous	VII & VIII
FU16	Outsiders	IIIa, IV, V & VI
FU00	French unknown	

The main part of the fishery is currently conducted in six Fishery Units, three of them from Subarea VII: FU 4, FU 1 and FU 3, two from Subarea VIII: FU 13 and FU 14 and one in Subareas IIIa, IV, V and VI : FU16.

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

The minimum landing size for fish caught in Subareas IV, VI, VII and VIII is set at 27 cm total length (30 cm in Division IIIa).

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

A 100 mm minimum mesh size has been implemented for otter trawlers when hake comprises more than 20% of the total weight of marine organisms retained on board. This measure did not apply to vessels less than 12 m in length and which return to port within 24 hours of their most recent departure.

Two areas have been defined, one in Subarea VII and the other in Subarea VIII, where a 100 mm minimum mesh size is required for all otter trawlers, whatever the amount of hake caught.

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

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

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

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

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

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

A.3. Ecosystem aspects

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

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

Ecological factors or environmental conditions impacting on hake population dynamics are not taken into account at present in the assessment or in the management. However, synchronous changes have been observed in hake recruitment success and several global, regional and local parameters, which suggest that environmental conditions may be influential for hake (Goikoetxea and Irigoien, 2013). An ecological regime shift occurred in the Northeast Atlantic shelf system in 1988/89, which was detected at global scale (NAO, Gulf Stream and northern hemisphere temperature anomaly), as well as regionally (climatology of the Northeast Atlantic and copepod variability of the Celtic Sea). The region went from a period of cool temperatures and relatively weak wind (1978-1989) to a period of warmer temperatures and stronger westerly winds (1900-2006). Given the synchronous stepwise increase in hake recruitment success, it was concluded that the environment shifted to a regime that was favourable for northern hake. Early life stages of hake were found to benefit from a warming trend (either through the widening of the optimal environmental window or/and higher growth rates). In addition, coastward transport avoided vulnerable stages from their dispersion to oceanic areas and helped in their transport from spawning areas to nursery grounds (Goikoetxea, 2011). Other previous studies also highlighted the influence of environmental parameters such as water temperature and wind-driven transport on northern hake stock (Fernandes *et al.*, 2010; Álvarez *et al.*, 2001).

B. Data

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

B.1. Commercial catch B.1.1. Landings

Until 2010, the Spanish landings data were based on sales notes and Owners Associations records compiled by the National laboratories (IEO and AZTI). From 2011, the Spanish data are derived from official statistics provided by the Spanish Fishery Administration. French landings data are based on logbook and auction hall sales.

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

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

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

*** For Spain only**

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

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

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

In the 2014 benchmark, the length frequency distribution, from 2003 to 2012, of the landings outside areas VII and VIII (i.e. the landings of OTHERS fleet in SS3) was recalculated using the data in InterCatch. The allocation schemes to disaggregate unsampled data (data without length information) in InterCatch were defined by year, taking into account the area, season and gear.

B.1.2. Discards

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

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

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

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

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

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

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

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

* sampled but not raised

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

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

B.2. Biological

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

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

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

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

B.3. Surveys

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

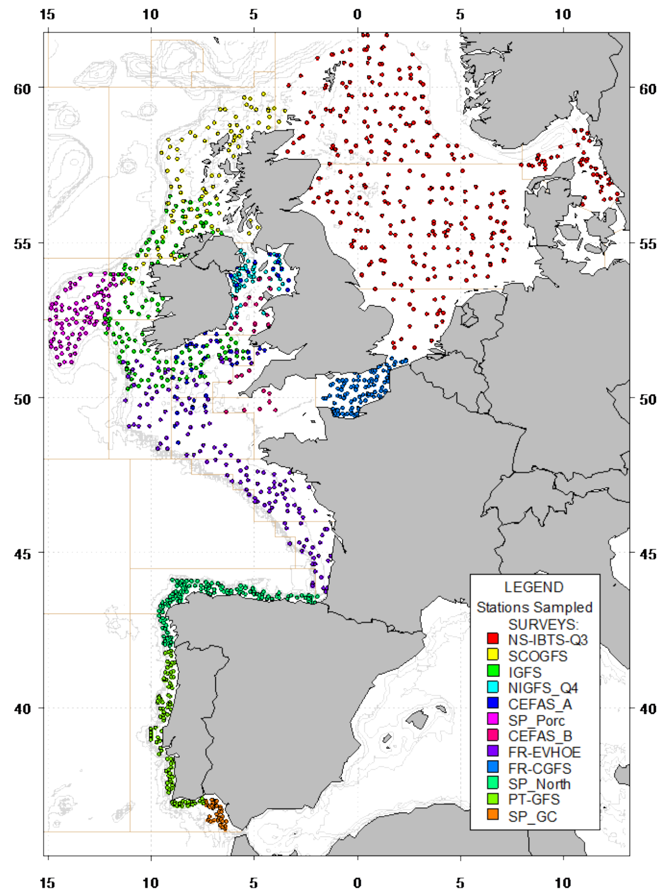

Figure 2. Map of East Atlantic groundfish surveys: stratification and trawling positions. FR-EVHOE correspond to EVHOE-WIBTS-Q4, SP Porc corresponds to SPPGFS-WIBTS-Q4 and IGFS corresponds to IGFS-WIBTS-Q4.

Abundance indices used in the SS3 assessment:

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

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

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

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

Abundance indices not used in the SS3 assessment:

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

B.4. Commercial cpue

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

a) Trawlers from A Coruña and Vigo fishing in Sub-area VII (SP-CORUTR7 and SP-VIGOTR7), pairtrawlers from Ondarroa and Pasajes fishing in Sub-area VIII (SP-PAIRT-ON8 and SP-PAIRT-PA8)

b) The A Coruña trawler fleet, targeting mainly hake, operates in deeper waters close to the slope in Division VIIb-c, j–k, while the trawler fleet from Vigo, targeting megrim, works in shallower waters in Division VIIj–h and catch hake as bycatch. Both pairtrawler fleets from Ondarroa and Pasajes are targeting hake in the Bay of Biscay.

c) Ondarroa “Baka” trawlers fishing in Subareas VI, VII and Division VIIIa,b,d, Pasajes “Bou” trawlers fishing in Subarea VIII, longliners from A Coruña, Celeiro and Burela fishing in VII, longliners from Avilés in VIIIa,b,d and trawlers from Santander in VIIIa,b,d.

d) Lpue values of Spanish gillnetters that started to fish hake in Subareas VII and VIII in 1998 are also provided. It is to be noted that only a small number of ships are involved in the gillnet fishery which makes lpues very sensitive to small changes in the number of trips. It is also noted that for gillnetters and longliners, lpues expressed in kg/day may not be the most appropriate.

e) Lpue data from two French fleets (Les Sables and Lesconil) fishing in Divisions VIIIa,b,d are also available from Logbooks. Due to important reductions in the availability of logbook information in recent years for both fleets, lpue values for the years 1996 onwards have low reliability. No data have been provided for those two fleets after 2003.

f) Lpue from Spanish Longliners is available since the 2014 Benchmark. This LPUE corresponds to the most important Spanish longline fleet operating in ICES Subarea VII (A Coruña, Celeiro and Burela ports) and it provides an abundance index for large individuals. The time-series starts in 1995, first year with sampling for quarterly length frequency distributions (LFD). Although effort is measured in number of days it is considered appropriate because the fishing tactic of the fleet have been quite homogeneous over the period covered, without changes due to technological improvements or new management measures. Its use as a tuning index was tested in the assessment during 2014 benchmark; however it was considered that a deeper analysis of its suitability was necessary in order to use it as an abundance index.

C. Assessment: data and method

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

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

Recent assessments and sensitivity analysis carried out.

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

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

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

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

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

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

Current assessment

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

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

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

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

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

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

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

Input data for SS3

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

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

Fleets	Description	FU	Landings (quarterly)	Discards (quarterly)
SPTRAWL7*	Spanish trawl in VII	04	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	1994, 1999, 2000, 2003–2008 (LFD + Weight)
FRNEP8	French trawl targeting Nephrops in VIII	09	Yearly : 1978-1989 (tonnage) Yearly : 1985-1989 (LFD) Quarterly : 1990-2012 (LFD+tonnage)	2003–2008 (LFD + Weight)

SPTRAWL8	Spanish trawl in VIII	14	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	2005–2008 (LFD + Weight)
TRAWLOTH	All other trawl	05 + 06 + 08 + 10	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
GILLNET	Gillnet all countries	03 + 13	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
LONGLINE	Longline all countries	01 + 02 + 12	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	
OTHERS	Everything else all countries	15 + 16 + 00	Yearly : 1978-1989 (LFD+tonnage) Quarterly: 1990-2012 (LFD+tonnage)	2003-2012 (Weight) 2003-2008 (Weight+LFD)

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

For the two Spanish trawl fisheries, it is thought that discarding became much more substantial starting from 1998. For the French *Nephrops* fishery, discarding is thought to have occurred already in earlier years. For the OTHERS fleet, since 2009 the discards are mainly formed by Scottish discards for which LFD are not available. The retention and selection of OTHERS fleet is thought to vary yearly because it is formed by a mixed of gears and countries. The remaining 3 fisheries (TRAWLOTH, GILLNET, LONGLINE) are assumed not to discard any fish, whereas this will not be strictly true in all cases, but given the present data and information is the most appropriate assumption for assessment purposes.

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

Table 5. List of surveys used in SS3.

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

No commercial fleet tuning data are used in the assessment.

SS3 settings (input data and control files):

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

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

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

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

Landings (tonnes): 10% variability

Discards (tonnes): 50% variability

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

Length compositions were assigned the following sampling sizes in the SS3 input data file, on the basis of how representative they were felt to be[1]:

Landings: 125 for all fleets, except SPTRAWL7 for which 50 was used for 1978-1997 and 200 was used from 1998 onwards

Discards: 50 for SPTRAWL7 and SPTRAWL8, 80 for FRNEP8

Surveys: 125

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

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

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

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

M=0.4.

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

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

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

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

Recruitment deviations starting in 1970.

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

Surveys catchabilities constant over time.

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

Selectivity only length-based (no age selectivity considered)

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

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

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

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

D. Short-Term Projection

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

E. Medium-Term Projections

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

F. Long-Term Projections

- Model used: yield and biomass-per-recruit over a range of F values.
- Software used: bespoke R script based on SS3 hake stock dynamics.
- Selectivity pattern: Average of final 3 assessment years.

Stock and catch weights-at-length: Same length–weight relationship as in the assessment model

- Maturity: Fixed maturity ogive as used in assessment

G. Biological Reference Points

	WG 1998	ACFM 1998	ACFM 2003	ACOM 2010
MSY Btrigger				not defined
FMSY				0.24
Flim	No proposal	0.28 (= Floss WG 98)	0.35 (= Floss WG 03)	not defined
Fpa	No proposal	0.20 (= Flim*e-1.645*0.2)	0.25 (= Flim*e-1.645*0.2)	not defined
Blim	No proposal	120 000 t (~ Bloss= B94)	100 000 t (~ Bloss= B94)	not defined
Bpa	119 000 t (=Bloss= B94)	165 000 t (= Blim*e1.645*0.2)	140 000 t (= Blim*e1.645*0.2)	not defined

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Stock Annex	Southern Stock of Hake

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Southern Stock of Hake (Division VIIIc and IXa)
Working Group: (WGBIE)	Working Group for the Bay of Biscay and Iberic Waters Ecoregion
Date:	1 April 2014
Revised by	WKSOUTH2014

A. General

A.1. Stock definition

Southern hake stock comprises the Atlantic coast of Iberian Peninsula corresponding to the ICES divisions VIIIc and IXa. The Northern limit is in the Spanish – French boundary and the Southern one in Gibraltar Strait. These boundaries were defined based on management considerations without biological basis.

Atlantic and Mediterranean European hake are usually considered as different stocks due to the differences in biology (i.e. growth rate or spawning season) of the populations in both areas. In the Northeastern Atlantic, there is no clear evidence of the existence of multiple hake populations, although Roldán *et al.* (1998) based on genetic studies states that "*the data (…) indicate that the population structure within the Atlantic is more complex than the discrete northern and southern stocks proposed by ICES*". It is likely that there is a degree of transfer between the Southern and Northern hake stocks, and recent studies on population genetics support that (Balado *et al.*, 2003; Pita *et al.*, 2010; Pita *et al.*, 2011), however there is at present a lack of data to quantify the amount of migrations between stocks.

A.2. Fishery

Hake in divisions VIIIc and IXa is caught in a mixed fishery by the Spanish and Portuguese fleets (trawls, gillnetters, longliners and artisanal fleets).

The Spanish trawl fleet is quite homogeneous and uses mainly two gears, pair trawl and bottom trawl. The percentage of hake present in the landings is small as there are other important target species (i.e. anglerfish, megrims, Norway lobster, blue whiting, horse mackerel and mackerel). During recent years there has been an increase in Spanish trawlers using a new High Vertical Opening gear towed by single vessels and targeting the pelagic species listed above. In contrast, the artisanal fleet is very heterogeneous and uses a wide variety of gears; traps, large and small gillnet, longlines, etc. The trawl fleet landings length composition, since the implementation of the minimum landing size in 1991, has a mode around 29-31 cm depending on the year. Artisanal fleets target different components of the stock depending on the gear used. Small gillnets catch smaller fish than gillnets and longlines, which target mainly large fish and have length composition with a mode above 50 cm. Hake is an important component of the catch for these fleets mainly due to the high prices that reaches in the Iberian markets.

Hake is caught by the Portuguese fleet in the trawl and artisanal mixed fisheries together with other fish species and crustaceans. These include horse mackerel, anglerfish, megrim, mackerel, Spanish mackerel, blue whiting, red shrimp (*Aristeus antennatus*), rose shrimp (*Parapenaeus longirostris*) and Norway lobster. The trawl fleet comprises two distinct components - the trawl fleet catching demersal fish (70 mm mesh size) and the trawl fleet targeting crustaceans (55 mm mesh size). The fleet targeting fish species operates along the entire Portuguese coast at depths between 100 and 200 m. The trawl fleet targeting crustaceans operates mainly in the southwest and south in deeper waters, from 100 to 750 m. The most important fishing harbours from Northern Portugal are: Matosinhos, Aveiro and Figueira Foz, from Central Portugal are: Nazaré, Lisboa and Sines and Southern Portugal are: Portimão and Vila Real Santo António. The artisanal fleet lands hake mainly in the fishing harbours of the Centre. The main fishing harbours are Póvoa do Varzim (North), Sesimbra (Centre) and Olhão (South). Landings recorded by month show that the majority of the hake landings occur from May until October for both fleets.

A.3. Ecosystem aspects

European hake presents indeterminate fecundity and asynchronous development of the oocytes (Andreu, 1956; Murua *et al.*, 1998; Domínguez-Petit, 2007). It is a serial or batch spawner (Murua *et al.*, 1996). Duration of spawning season at the population level may differ between areas (Pérez and Pereiro, 1985; Alheit and Pitcher, 1995; Ungaro *et al.*, 2001; Domínguez-Petit, 2007); but a latitudinal gradient exists such that the latest peaks of spawning occur in higher latitudes. In general, adults breed when water temperatures reach 10º or 12ºC, changing their bathymetric distribution depending on the region they are in and the local current pattern, releasing eggs at depths from 50 to 150m (Murua *et al.*, 1996; 1998; Alheit and Pitcher, 1995). In general males mature earlier than females. Size at maturity is determined by density-dependent factors like abundance or age/length population structure and density independent factors like environmental conditions or fishing pressure (Domínguez *et al.*, 2008). L50 varies between areas; in the Atlantic populations is between 40-47 cm (Lucio *et al.*, 2002; Piñeiro and Saínza, 2003; Domínguez-Petit, 2007). Besides, temporal fluctuations in size at maturity within the population have been also observed what could reflect changes in growth rate (Domínguez *et al.*, 2008). Changes in maturity parameters affect stock reproductive potential, because smaller and younger females have different reproductive attributes than larger and older individuals (Trippel *et al.*, 1997; Mehault *et al.*, 2010). Maternal physiological status, spawning experience (recruit or repeat spawners) or food rations during gametogenesis are all known to alter fecundity, egg and larval quality, as well as duration of the spawning season (Hislop *et al.*, 1978; Kjesbu *et al.*, 1991; Trippel, 1999; Marteinsdottir and Begg, 2002). Change in stock structure entails a compensatory response of age/size at maturity because depletion of large fish can be compensated by increased egg production by young fish (Trippel, 1995).

Hake recruitment indices have been related to environmental factors (Sanchez and Gil, 2000). High recruitments occur during intermediate oceanographic scenarios and decreasing recruitment is observed in extreme situations. In Galicia and the Cantabrian Sea, generally moderate environmental factors such as weak Poleward Currents, moderate upwelling and good mesoscale activity close to the shelf lead to strong recruitments. Hake recruitment leads to well-defined patches of juveniles, found in localized areas of the continental shelf. These concentrations vary in density according to the strength of the year class, although they remain generally stable in size and spatial location. These authors have related the year-on-year repetition of the spatial patterns to environmental conditions. In the eastern, progressively narrowing, shelf of the Cantabrian Sea, years during which there is massive inflow of the eastward shelf edge current produce low recruitment indices, due to larvae and pre-recruits being transported away from spawning areas to the open ocean.

In Portuguese continental waters the abundance of small individuals is higher between autumn and early spring. In the Southwest main concentrations occur at 200-300 m depth, while in the South they are mainly distributed at coastal waters. In the North of Portugal recruits are more abundant between 100-200 m water depths. These different depth-areas associations may be related with the feeding habits of the recruits, since the zooplankton biomass is relatively higher at those areas.

Hake is a highly ichthyophagous species with euphausiids although decapod prawns are an important part of its diet for smaller hake (> 20 cm). In Galicia and the Cantabrian Sea hake is one of the apex predators in the demersal community, occupying together with anglerfish one of the highest trophic levels (Velasco *et al.*, 2003). Its diet at >30 cm is mainly composed of blue whiting, while other species such as horse mackerel and clupeids are only important in shallow waters and in smaller individuals that also feed on other small fish. Along the Portuguese coast the diet of hake is mainly composed of crustaceans (particularly decapods) and fish. The main food items include blue whiting, sardine, snipefish, decapods and mysids. Cannibalism in the diet of hake is highly variable depending on predator size, alternative prey abundance, year or season. Cannibalism in stomach content observations ranged from 0 to 30% of total volume, with mean values about 5%; this produces a high natural mortality in younger ages.

B. Data

B.1. Commercial catch

Landings

The landings data used in the Southern Hake assessment are based on: (i) Portuguese sales notes compiled by the National Fisheries and Aquaculture Directorate; (ii) Spanish sales notes and owners associations data compiled by IEO; and (iii) Basque Country sales notes and Ship Owners data compiled by AZTI. Since 2011 Spanish landings are submitted by the national authority, which is a different procedure from the past scientific estimations. Scientific landings estimates are presented as UNALLOCATED

From 1982 to 1993 only annual landings for Spain were available. The length distributions of landings were computed by quarter after 1994. Raising procedures are performed at the national labs before submitting the data. For the period before 1994, it was assumed that the existing annual length distribution was caught in the middle of the year.

Discards

A Spanish Discard Sampling Programme is being carried out in Divisions VIIIc and IXa North since 1993. The series provides information on discarded catch in weight and number and length distributions for Southern hake. Spanish sampling was carried out in 1994, 1997, 1999-2000 and from 2003 onwards. The number of trips sampled by the Spanish program was distributed by three trawl fleets: Baca otter trawl, Pair trawl and HVO (High Vertical Opening) trawl. Total discards were estimated raising sampling with effort. This series was revised and computed by quarter from 2004 onwards.

The Portuguese Discard Sampling Programme started in 2003 (second semester) and is based on a quasi-random sampling of co-operative commercial vessels. Two trawl fleets are sampled in this programme: Crustacean Trawl and Fish Trawl fleets. The discards estimation method was revised to take into account fishing hours as auxiliary variable and include outlier analysis.

Both series of discarded weights were rebuilt back to 1992 based on the relationships between discards and surveys, and discards and landings (ICES, 2010), with the aim of integrating them in assessment models.

B.2. Biological

A full revision of hake ecology was performed by Murua (2010). The sampling of commercial landings is carried out by the Fisheries Institutes involved in the fishery assessment (AZTI, IEO and IPMA) since 1982, except in the Gulf of Cadiz were length distribution are available only since 1994. The length composition sampling design follows a multistage stratified random scheme by quarter, harbour and gear.

After 2010, the gear sampling was substituted by a métier sampling. Raising procedure in every sampled vessel is performed by weight category and then extended to total catch in every month, harbour and gear (or métier after 2010). If there was any gap in the sampling procedure this was covered with the available information from the same quarter. Previous to 1994, only annual length distributions were available.

An international length-weight relationship for combined sexes for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Age information (otoliths) are collected by IEO, AZTI and IPMA. However, due to doubts on growth patterns and unstable ageing criteria, a von Bertalanffy growth model with t0=0, Linf=130 cm and k~0.16 (where k is re-estimated by the stock assessment model every year) is used. The Linf parameter value was chosen based on tagging data collected for the northern stock on the French coast and k estimates by the assessment models carried out during the Benchmark (ICES, 2010)

Natural mortality was assumed to be 0.4 year-1, instead of the past 0.2. The rationale is that if hake growths about two times faster, the hake longevity is reduced around half (from age ~20 to ~10). Hewit and Hoening (2005) estimate a relationship among longevity and M that produces a figure around 0.4. This value was set equal for all ages and years.

Maturity proportions-at-length was estimated with sexes combined from IEO sampling. Data available from IPMA and AZTI since 2004 were not considered due to inconsistencies with the IEO data. Maturity at length used to estimate population mature biomass was estimated with a logistic function (outside GADGET model) for all the years.

Hake is a dimorphic species where males mature at smaller size than females and also attain smaller asymptotic size (Cerviño, in press, Murua, 2010).

B.3. Surveys

The **Spanish October** groundfish (spGFS-WIBTS-Q4) survey uses a stratified random sampling design with half hour hauls and covers the northwest area of Spain from Portugal to France during September/October since 1983 (except 1987).

Two groundfish surveys are carried out annually in the **Gulf of Cadiz - in March**, from 1994, and in **November (spGFS-caut-WIBTS-Q4)**, from 1997. A stratified random sampling design with 5 bathymetric strata, covering depths between 15 and 700 m, is used in this area, with one hour hauls. Hake otoliths have been collected since 2000.

The **Portuguese October groundfish (ptGFS-WIBTS-Q4)** has been carried out in Portuguese continental waters since 1979 on board the RV "Noruega" and RV "Capricórnio". Recent work on calibration of these vessels showed a higher catchability of Capricórnio, in particular at lower sizes, as a consequence these years were calibrated. The main objective of this survey is to estimate hake's abundance indices to be used in stock assessment (Anon., 2008). A stratified sampling design was used from 1989 until 2004. In 2005 a new hybrid random-systematic sampling design was introduced, composed by a regular grid with a set of additional random locations (Jardim and Ribeiro Jr., 2007; Jardim and Ribeiro Jr., 2008). The tow duration was 60 minutes until 2001 and reduced to 30 minutes for the subsequent years, based on results of an experiment showing no significant differences in the mean abundance and length distribution between the two tow durations (Cardador personal communication, 2007)..

B.4. Commercial cpue

Effort series are collected from Portuguese logbooks and compiled by IPMA, and from Spanish sales notes and Owners Associations data and compiled by IEO.

Landings, LPUE and effort are available for A Coruña trawl (SP-CORUTR) and Portuguese trawl (P-TR) fleets.

The cpue series (1989-2008) of Portuguese trawlers is standardized using a GLM model with Gamma residuals, a "log" link function and explanatory variables year, zone, engine power, métier, percentage of hake in the catch, level of total catch and level of fishing effort.

Tuning data table (Table 1) shows details about these surveys and LPUEs as well as their use in the assessment model.

C. Historical Stock Development

Until 2008 this stock was assessed with XSA models based on ages estimated from ALK. In 2009 a Bayesian VPA was introduced. Since 2010, based on the decisions of the Benchmark a length based model with GADGET was introduced.

C.1. Description of gadget

Gadget is a shorthand for the "Globally applicable Area Disaggregated General Ecosystem Toolbox", which is a statistical model of marine ecosystems. Gadget (previously known as BORMICON and Fleksibest). Gadget is an age–length structured forward-simulation model, coupled with an extensive set of data comparison and optimization routines. Processes are generally modelled as dependent on length, but age is tracked in the models, and data can be compared on either a length and/or age scale. The model is designed as a multi-area, multi-area, multifleet model, capable of including predation and mixed fisheries issues; however it can also be used on a single species basis. Gadget models can be both very data- and computationally intensive, with optimization in particular taking a large amount of time. Worked examples, a detailed manual and further information on Gadget can be found on www.hafro.is/gadget. In addition the structure of the model is described in Begley and Howell (2004), and a formal mathematical description is given in Frøysa *et al.* (2002).

Gadget is distinguished from many stock assessment models used within ICES (such as XSA) in that Gadget is a forward simulation model, and is structured be both age and length. It therefore requires direct modelling of growth within the model. An important consequence of using a forward simulation model is that the plus groups (in both age and length) should be chosen to be large enough that they contain few fish, and the exact choice of plus group does not have a significant impact on the model.

Setup of a gadget run

There is a separation of model and data within Gadget. The simulation model runs with defined functional forms and parameter values, and produces a modelled population, with modelled surveys and catches. These surveys and catches are compared against the available data to produce a weighted likelihood score. Optimization routines then attempt to find the best set of parameter values Growth is modelled by calculating the mean growth for fish in each length group for each time-step, using a parametric growth function. In the hake model a Von Bertanlanffy function has been employed to calculate this mean growth. The actual growth of fish in a given length cell is then modelled by imposing a beta-binomial distribution around this mean growth. This allows for the fish to grow by varying amounts, while preserving the calculated mean. The beta-binomial is described in Stefansson (2001). The beta-binomial distribution is constrained by the mean (which comes from the calculated mean growth), the maximum number of length cells a fish can grow in a given time-step (which is set based on expert judgement about the maximum plausible growth), and a parameter β, which is estimated within the model. In addition to the spread of growth from the beta-binomial distribution, there is a minimum to this spread due by discretization of the length distribution.

Catches

All catches within the model are calculated on length, with the fleets having size-based catchability. This imposes a size-based mortality, which can affect mean weight and length-at-age in the population (Kvamme 2005). A fleet (or other predictor) is modelled so that either the total catch in each area and time interval is specified, or this catch per time-step is estimated. In the hake assessment described here the commercial catch and the discards are set (in kg per quarter), and the surveys are modelled as fleets with small total landings. The total catch for each fleet for each quarter is then allocated among the different length categories of the stock according to their abundance and the catchability of that size class in that fleet.

Likelihood Data

A significant advantage of using an age–length structured model is that the modelled output can be compared directly against a wide variety of different data sources. It is not necessary to convert length into age data before comparisons. Gadget can use various types of data that can be included in the objective function. Length distributions, age length keys, survey indices by length or age, cpue data, mean length and/or weight at age, tagging data and stomach content data can all be used. Importantly this ability to handle length date directly means that the model can be used for stocks such as hake where age data are sparse or considered unreliable. Length data can be used directly for model comparison. The model is able to combine a wide selection of the available data by using a maximum likelihood approach to find the best fit to a weighted sum of the datsets.

Optimization

The model has two alternative optimizing algorithims linked to it, a wide area search simulated annealing Corona *et al.* (1987) and a local search Hooke and Jeeves algorithim HookeJeeves1961. Simulated annealing is more robust than Hooke and Jeeves and can find a global optima where there are multiple optima but needs about 2-3 times the order of magnitude number of iterations than the Hooke and Jeeves algorithim. The model is able to use both in a single run optimization, attempting to utilize the strengths of both. Simulated annealing is used first to attempt to reach the general area of a solution, followed by Hooke and Jeeves to rapidly home in on the local solution. This procedure is repeated several times to attempt to avoid converging to a local optimum. The algorithms are not gradient-based, and there is therefore no requirement on the likelihood surface being smooth. Consequently neither of the two algorithms returns estimates of the Hessian.

Likelihood weighting

The total objective function to be minimized is a weighted sum of the different components. Selection of the weights is based on expert knowledge of the quality of the data and the space-time coverage of each dataset, and the internal variance of the dataset. An internal weight based on individual adjustments of the model (var) is used to reflect the variability of the dataset. This was done by optimizing the model to each dataset in turn, and inverting the resulting objective score to use as a weight for that dataset. This has the effect of assigning high weights to low variance datasets, and low weights to low variance ones. It also normalizes the weighted contribution of the different datasets. These weights were then adjusted to account for the length of the dataseries, the coverage of the area inhabited by the stock, and an expert judgement about the relative quality of the different data. The final column (% weight) in the table below gives the final weighted contribution of each dataset to the optimized objective function.

Finding these weights is a lengthy procedure, but it does not generally need to be repeated for each assessment. Rather, the current weights can be used for several years. The weighted contribution of the datasets in a new assessment should be computed, and compared against the previous year. Provided the relative contributions are similar then the model results should be comparable between years.

C.2. Settings for the hake assessment

Population is defined by 1cm length groups, from 1-130 cm and the year is divided into four quarters. The age range is 0 to 15 years, with the oldest age treated as a plus group. Recruitment happens in the first and second quarter. The length at recruitment is estimated and mean growth is assumed to follow the von Bertalanffy growth function with Linf=130 and k estimated by the model.

An international length-weight relationship for the whole period has been used since 1999 (a=0.00000659, b=3.01721).

Natural mortality was assumed to be 0.4 year^{-1}

The commercial landings are modelled as two different fleets (1982-93 and 1994-present) with a selection pattern described by a logistic function. Cadiz data are modelled as an independent fleet from 1982-04 (andersen function, see gadget manual for more information) and it was added to landings fleet from 2005-08. Discards from 1992-present follows an Andersen function. The same function was used for Spanish survey, Cádiz survey and Portuguese survey. The surveys, on the other hand are modelled as fleet with constant effort and a nonparametric selection pattern that is estimated for three 15 cm length groups.

Table 1. Data used for the assessment are described below:

description	period	area	Likelihood component
Length distribution of landings	1994-lastYear	Iberia	Land1.ldist
Length distribution of landings	1982-1993	Iberia	Land.ldist
Length distribution of landings in Cadiz	1994-lastYear	Gulf of Cadiz	cdLand.ldist
Length distribution of Spanish GFS	1982-lastYear	North Spain	SpDem.ldist
Length distribution of Spanish GFS	1989-lastYear	Portugal	PtDem.ldist
Length distribution of Spanish GFS in Cadiz	1990-lastYear	Gulf of Cadiz	CdAut.ldist
Length distribution of discards	1994, 1998, 1999, 2004-lastYear	Iberia	Disc.ldist
Abundace index of Spanish GFS of 4-19 cm individuals	1982-lastYear	North Spain	SpIndex15cm.1
Abundace index of Spanish GFS of 20-35 cm individuals	1982-lastYear	North Spain	SpIndex15cm.2
Abundace index of Spanish GFS of 36-51 cm individuals	1982-lastYear	North Spain	SpIndex15cm.3
Abundace index of Portuguese GFS of 4-19 cm individuals	1989-2011	Portugal	PtIndex15cm.1
Abundace index of Portuguese GFS of 20-35 cm individuals	1989-2011	Portugal	PtIndex15cm.2
Abundace index of Portuguese GFS of 36-51 cm individuals	1989-2011	Portugal	PtIndex15cm.3
Abundace index of Spanish trawlers from A Coruña of 25-39 cm individuals	1994-lastYear	North Spain	Spcpue15cm.1
Abundace index of Spanish trawlers from A Coruña of 40-54 cm individuals	1994-lastYear	North Spain	Spcpue15cm.2
Abundace index of Spanish trawlers from A Coruña of 55-70 cm individuals	1994-lastYear	North Spain	Spcpue15cm.3
Standardized abundace index of Portuguese trawlers of 25-39 cm individuals	1989-2010	Portugal	Ptcpue15cm.1
Standardized index of Portuguese trawlers of 40-54 cm individuals	1989-2010	Portugal	Ptcpue15cm.2
Standardized index of Portuguese trawlers of 55-70 cm individuals	1989-2010	Portugal	Ptcpue15cm.3

Description of the likelihood components weighting procedure and relative contribution to the final total likelihood (Note that relative contribution may change from year to year depending on the new data used to fit the model):

Likelihood component	var	quarters	quality	area	Multiplicative Weight
Land1.ldist	0.66	44	2	1	133.2
Land.ldist	0.91	72	3	0.9	213.9

cdLand.ldist	2.5	52	2	0.1	4.2
SpDem.ldist	0.87	27	4	0.5	62.3
PtDem.ldist	0.39	24	4	0.4	99
CdAut.ldist	0.38	10	4	0.1	10.4
Disc.ldist	1.04	36	1	0.9	31.2
SpIndex15cm.1	4.84	9	4	0.5	3.7
SpIndex15cm.2	0.98	9	4	0.5	18.3
SpIndex15cm.3	1.2	9	4	0.5	15
PtIndex15cm.1	3.75	8	4	0.4	3.4
PtIndex15cm.2	1.34	8	4	0.4	9.5
PtIndex15cm.3	0.52	8	4	0.4	24.5
Spcpue15cm.1	2.37	5	2	0.5	2.1
Spcpue15cm.2	0.23	5	2	0.5	21.5
Spcpue15cm.3	1.55	5	2	0.5	3.2
Ptcpue15cm.1	0.46	6.67	2	0.4	11.6
Ptcpue15cm.2	1.39	6.67	2	0.4	3.8
Ptcpue15cm.3	0.76	6.67	2	0.4	7

The parameters estimated are:

- The number of fish by age when simulation starts. (ages 1 to 8) .
- Recruitment each year. (1982 to present).
- The growth rate (k) of the von Bertalanffy growth model.
- Parameter β of the beta-binomial distribution.
- The selection pattern of:
    - Commercial catches (1982-93). 2 params
    - Landings (1994-present). 2 params
    - Cadiz landings (1982-2004). 3 params
    - Discards (1992-present . 3 params
    - Spanish Survey . 3 params
    - Portuguese Survey . 3 params
    - Cadiz autumn Survey . 3 params
- Catchability of :
    - Spanish Survey (3 groups from 4 cm by 15 cm) .3 params
    - Portuguese Survey . (3 groups from 4 cm by 15 cm) .3 params

- Spanish cpue (3 groups from 25 cm by 15 cm) .3 params
- Portuguese cpue (3 groups from 25 cm by 15 cm) .3 params

The estimation can be difficult because of some or groups of parameters are correlated and therefore the possibility of multiple optima cannot be excluded. The optimization was started with simulated annealing to make the results less sensitive to the initial (starting) values and then the optimization was changed to Hooke and Jeeves when the 'optimum' was approached. Multiple optimization cycles were conducted to ensure that the model had converged to an optimum, and to provide opportunities to escape convergence to a local optimum.

The model fits were analysed with the following **diagnostics**:

- Profiled likelihood plots. To analyse convergence in problematic parameters.
- Plot comparing observed and modelled proportions in fleets (catches, landings or discards). To analyse how estimated population abundance and exploitation pattern fits observed proportions.
- Plot for residuals in catchability models. To analyse precision and bias in abundance trends.

D. Short-Term Projection

Model used: Age–length forward projection

Software used*:* GADGET (script: predict.st.sh)

Initial stock size: estimates at the final of the assessment period estimated by the gadget model, with recruitment replaced by geometric mean (1989-Y-1), if last year recruitment estimate rejected by the group.

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight at age in the stock: modelled in GADGET with VB parameters and length weight relationship

Weight at age in the catch: modelled in GADGET with VB parameters and length weight relationship

Exploitation pattern:

GADGET is a length-age based forward projection model, structured by quarter for southern hake. Two different "fleets" are used for projections, landings fleet with a logistic selection pattern, and discards fleet with an Andersen selection pattern. Although each fleet has a constant selection pattern function, the level of exploitation can be distinct by quarter. 8 F multipliers are required for projections (2 "fleets" (landings and discards) * 4 quarters), which are computed by averaging the last 3 years by quarter and fleet.

Intermediate year assumptions: If there is a trend in mean F of last 3 years the multipliers are scaled to last year's F bar (ages 1-3), so that a single scaling factor is applied to all quarters. Otherwise the multipliers are not scaled (script: multF.r).

Stock recruitment model used: geometric mean of years 89 to last year minus one.

Procedures used for splitting projected catches: driven by the selection patterns estimated by gadget for each “fleet” (landings and discards).

E. Medium-Term Projections

NA

F. Long-Term Projections

F multipliers are set in the way described for short-term projections.

Model used: Age–length forward projection until 2050

Software used*:* GADGET (script: predict.lt.sh)

Maturity: arithmetic mean of last 3 years

F and M before spawning: NA

Weight at age in the stock: modelled in GADGET with VB parameters and length weight relationship

Weight at age in the catch: modelled in GADGET with VB parameters and length weight relationship

Exploitation pattern:

Landings: logistic selection parameters estimated by GADGET.

Discards: Andersen (asymmetric) selection parameters estimated by GADGET.

Stock recruitment model used: geometric mean of years 89 to last year minus one.

Procedures used for splitting projected catches: driven by different selection functions (logistic for landings, Andersen for discards) and provide by GADGET.

G. Biological Reference Points

F max (= 0.24) was set as a proxy for Fmsy

No other BRPs set.

H. Other Issues and further work

It should be noted that new assessment model have been developed to avoid the reliance on age-based data. This new model is considered to be an improvement on the previous method given the problems related to age data described previously. However both are new, complex, and significantly different from the previous models. It is therefore likely that refinements and updates will be required over the coming years to both models and further consideration given to the data used. The panel (WKSOUTH, 2014) considers that ICES should be flexible in allowing model improvements during the Assessment Working Groups and on an intersessional basis. ICES should therefore ensure that resources are in place to evaluate these improvements.

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Stock Annex: Southern megrims (*L. whiffiagonis* and *L. boscii*)

Stock specific documentation of standard assessment procedures used by ICES.

Stock Southern megrims (Division VIIIc, IXa)

Working Group: Working Group for the Bay of Biscay and Iberic Waters Ecoregion (WGBIE)

Date: 1 April 2014

Revised by WKSOUTH2014

A. General

A.1. Stock definition

The genus Lepidorhombus is represented in eastern Atlantic waters by two species, megrim (*L. whiffiagonis*) and four-spot megrim (*L. boscii*). Three stocks of megrim are assessed by ICES: megrim in ICES Subareas IV and VI, megrim in Divisions VIIb-k and VIIIa,b,d and megrim in Divisions VIIIc and IXa. Although the boundaries of the stocks were established only for management purposes, recent genetic studies have proven the existence of at least two populations within the Atlantic Ocean for both species. While *L. boscii* populations match the stocks defined, *L. whiffiagonis* needs more detailed studies to refine the boundaries, although in principle would also overlap with the current structure (Danancher and García-Vázquez, 2009).

The stocks under this Annex are called Southern Megrims and include both megrim species in Divisions VIIIc and IXa. Megrim (*L. whiffiagonis*) is in both ICES Divisions (VIIIc and IXa), with its highest abundance in Division VIIIc. Four-spot megrim (*L. boscii*) is distributed in both ICES Divisions (VIIIc and IXa), being more southerly present than megrim (Sánchez *et al.*, 2002). There is a certain bathymetric segregation between the two species of megrim. *L. boscii* has a preferential depth range of 100 to 450 m and *L. whiffiagonis* of 50 to 300 m (Sanchez *et al.*, 1998).

A.2. Fishery

Management of megrim is both by TAC and technical measures. The two species (*L. whiffiagonis* and *L. boscii*) are managed under a common TAC. They are caught and recorded together in the landings statistics. It is impossible to manage each species separately under a common TAC. The spatial distribution of the two stocks shows some differences that could be utilized for separate management of the two stocks.

The minimum mesh size for towed gears ranges between 55 and 70 mm, depending on catch species composition. Minimum landing size for the two species changed from 25 to 20 cm in year 2000 (Council Regulation EC 850/98).

Both megrim species are included in the landings from ICES Divisions VIIIc and IXa. The percentage of megrim (*L. whiffiagonis*) in landings of both species by weight was between 12% and 37% over the whole period for which data are available, being mostly above 20% until year 2000 and mostly below 20% since that year.

No landings data are available for these stocks before 1986, although some Spanish harbours have longer landings series. Total international landings increased sharply from 1986 to 1989, when they reached 3340 t, and then showed a continuous declining trend until their lowest level of 840 t in 2002. There has been some increase in landings since that year, being 1380 t in 2010, the maximum value of the last decade.

Both species of megrim are taken as bycatch in the mixed bottom-trawl fisheries targeting “white fish” by Portuguese and Spanish fleets, and also in small quantities by the Portuguese artisanal fleet. The majority of the catches are taken by Spanish trawlers. Fishing practices of some Spanish trawl fleets have changed in recent years, now focusing more on species such as horse mackerel, blue whiting, or mackerel, and not taking megrim in the catch (Punzón *et al.*, 2010).

Since the early 1990´s the Spanish bottom-trawl fleet has diversified its fishing strategy, introducing a new trawl gear which targets primarily pelagic species (as horse mackerel and mackerel). This gear, named "jurelera", affects catches of *L. boscii* more than those of *L. whiffiagonis*, probably due to differences between the distribution area of both species. The increasing use of "jurelera" gear by trawlers in the last years (Castro *et al.,* 2011), has led to reduced effort of the traditional OTB vessels (using "baca" gear) on megrim species. Also, the fishing ban for all trawlers in grounds within 100 m depth (RD 1441/1999, 10 sept) may affect in the proportion of both species in catches due to their different bathymetric distribution.

The Prestige oil spill in the northwest Spanish coast (November 2002) prompted a redistribution of fishing effort, particularly in the Galician area. Some regulation measures, such as spatial and seasonal closures, were adopted in order to minimize the oil spill impact on fisheries. Some trawl fleets display lower effort in 2003 in relation to later years (Abad *et al*., 2010).

Horse mackerel, Atlantic mackerel, blue whiting, anglerfish, hake, megrim, different cephalopods and *Nephrops* account for a high percentage (around 90%) of all retained species in this multispecies trawl fishery (Castro *et al.,* 2011). A great number of species are caught as bycatch.

Discards are important, particularly for younger ages of both megrim species. Around 10-65% of the individuals caught are discarded by trawlers (Pérez *et al*., 2011). Lack of commercial interest, variations in market price, fish size (MLS or market sized, storage capacity as well as distance to home port are the main reasons for discarding. Artisanal fleets catch few megrims and discards of all species in these fleets are very low.

Megrims have been affected by the Recovery Plan for the Southern hake and Iberian *Nephrops* stocks (Council Regulation EC 2166/2005), since January of 2006, with the fishing effort limitation measurements in the Spanish and Portuguese mixed trawl fisheries.

A.3. Ecosystem aspects

The Iberian Region along the eastern Atlantic shelf (Divisions VIIIc and IXa) is an upwelling area with high productivity, especially along the Portuguese and Galician coasts; upwelling takes place during late spring and summer (Álvarez-Salgado *et al*., 2002; Serrano *et al*., 2008). The region is characterized by a large number of commercial and non-commercial fish species caught for human consumption.

Many flatfish species show a gradual offshore movement of juveniles as they grow. This might indicate that habitat quality for flatfish is size-dependent. Another common pattern is the annual micro- and macroscale movements and migrations between spawning, feeding and wintering areas (Gibson 1994). Also, most flatfish are associated with finer sediments, rather than with hard substrata because burying themselves provides some protection from predators and reduces the use of energy (van der Veer *et al*., 1990, 2000; Beverton and Iles 1992; Bailey 1994; Wennhage and Pihl 2001).

Previous studies on megrim species show that they generally occurred outside zones with hydrographical instabilities that foster the vertical interchange of organic matter (Sánchez and Gil, 1995) and disappear at the mouth of the most important rivers (Sánchez *et al*., 2001). Both species appear to show a gradual expansion in their bathymetric distribution throughout their lifetimes, with the larger individuals tending to occupy shallower waters than the juveniles. Bearing in mind that the two species have similar characteristics, a certain degree of interspecific competition may be assumed (Sanchez *et al.,* 1998).

Juveniles of these species feed mostly on detritivore crustaceans inhabiting deep-lying muddy bottoms. Adult *L. boscii* feeds mainly on crustaceans inhabiting muddy surfaces (Rodriguez-Marín and Olaso, 1993; Rodriguez-Marín, 2002) as opposed to *L. whiffiagonis*, which are more ichthyophagous and where rates of crustacean in diet decrease with fish size (Rodriguez-Marín, 2002). None of the two species represent an important part of the diet for the main fish predators in the area. However, Velasco (IEO, Santander, Spain, pers. comm.) observed that they are occasionally present in stomach contents of hake, anglerfish and rays.

The spawning period of these species is short. Mature males can be found from November to March and mature females from December to March, but spawning peaks in March. In southern areas megrims spawn from January to April (BIOSDEF, 1998; study contract 95/038).

The growth rate also varies (Landa *et al.*, 1996; Landa, 1999), growth is quicker in the southern area for both species but the maximum length attained is smaller than in the north. The maximum age for megrim also varies with latitude. In Subarea VII the maximum age of megrim is 14 years, this decreases to 12 years in Divisions VIIIc and IXa (BIOSDEF, 1998; Landa et. al, 2000). The maximum age for four-spot megrim in Divisions VIIIc and IXa is 11 years (Landa *et al.*, 2002, Landa, pers. com.).

B. Data

B.1. Commercial catch

Landings

Landings data are provided by National Government and research institutions of Spain and Portugal. The available series began in 1986.

The proportions of each megrim species in Portuguese and Spanish landings are estimated using the relative abundances of the two species of megrim in the sampled landings.

For *L. whiffiagonis*, landings present an increase for a few years at the beginning of the time-series and a general declining trend since then. In 2011 and 2002 landings are increasing. For *L. boscii,* landings present the same increase at the beginning of the time-series; after that, they have generally declined to their lowest value in 2002 and, since then, the general trend is to increase smoothly. A decrease in landings in 2012 has occurred.

Discards

Discards estimates are available for Spanish trawlers in some years and are used in this assessment. Where discards are missing, mainly in the historic data, they have been estimated using the mean of the discards time-series for each age. A discarding sampling programme runs regularly since the establishment of the European Data Collection Programme in 2003. Before this year, Spanish discards data are available only for 1994, 1997, 1999 and 2000. The raising procedure used to estimate Spanish discards for the sampled years was based on effort.

In order to include discards data in the assessment, discards estimates from the average by period have been used for imputing missing data. For the first period (1986-1999), the average of available years 1994, 1997 and 1999 were used and for the second period (2000-2012) the absence of data in 2001 and 2002 was replaced by the average of the closest years. The raison of using these two periods is the change of the Minimum landing size (MLS) in 2000 that could bring a shift in the discarding behaviour. The whole time-series of discards have been added to the landings data to calculate catch data.

B.2. Biological

Landings numbers at length

Annual length compositions of total landings for *L. whiffiagonis* and *L. boscii* are available since 1986.

For *L. whiffiagonis*, length distributions were available for both Spanish and Portuguese landings until 1998, when Portuguese length frequency data were mainly based on samples from Aveiro. Due to the uncertainties of this port since 1999, Spanish length distributions were raised to the total international landings for all subsequent years. Portuguese landings only represent 10% of the total landings on average.

For *L. boscii*, length distributions are available for Spanish and Portuguese landings since 1986 and 1998, respectively.

There has been a strong decrease in landings of fish under 15 cm in length since 1994 and under 20 cm in recent years for both species. This change probably results from stricter enforcement of the minimum landing size and a mesh size increase regulation in year 2000.

Catch numbers-at-age

Age compositions of landings are based on annual Spanish ALKs since 1990, whereas a survey ALK from 1986 combined with an annual ALK from 1990 was applied to years 1986-1989. Landings weights-at-age are also used as the weights-at-age in the stock. The following parameter values were used in the length-weight relationship (BIOSDEF, 1998):

	L. whiffiagonis	L. boscii
a	0.006488	0.00431
b	3.0114	3.1904

Natural mortality is set to 0.2 and assumed constant over all ages and years. This is the same value used for *L. whiffiagonis* in Divisions VIIb-k and VIIIabd.

The sex combined maturity ogive (BIOSDEF, 1998) is assumed constant over time, with the following proportions of fish mature at each age:

Age	0	1	2	3	4	5+
L. whiffiagonis	0	0.34	0.90	1	1	1
L. boscii	0	0.55	0.86	0.97	0.99	1

B.3. Surveys

The Portuguese October groundfish survey (PtGFS-WIBTS-Q4) and the Portuguese Crustacean survey (PT-CTS (UWTV (FU 28-29))) and one Spanish groundfish survey (SpGFS-WIBTS-Q4) series are available since 1990, 1997 and 1983, respectively.

It should be taken into consideration that during years 1996, 1999, 2003 and 2004 the October Portuguese survey was carried out with a different vessel and gear from the one used in the rest of the series. The Crustacean survey was performed with different vessels in different years and covers a partial area; in 2004 it had many operational problems.

For these reasons and because indices from these surveys are not considered to be representative of megrim abundance, due to the very low catch rates, only the Spanish survey (SpGFS-WIBTS-Q4) is used in the assessment of the two species. The survey covers the distribution area and depth strata of these species in Spanish waters (covering both VIIIc and IXa). The survey appears to be quite good at tracking cohorts through time *for L. whiffiagonis*. For *L. boscii*, the survey signal is also clear until 2002, whereas it seems more blurred in recent years.

B.4. Commercial cpue

LPUE and Fishing Effort data are available for the following fleets: Spanish trawlers based in A Coruña port (SP-CORUTR8c) and fishing in Division VIIIc and Spanish trawlers based in Avilés port (SP-AVILESTR) and fishing in Division VIIIc since 1986 and Portuguese trawlers fishing in Division IXa since 1988. Effort from the Portuguese fleet is estimated from a sample of logbooks from sea trips where megrim occurred in the catch

Commercial fleets used in the assessment of L.whiffiagonis to tune the model

SP-CORUTR8c: This fleet contributed with data of effort (fishing days per 100 horse power), LPUE (as kg per fishing day per 100 horse power) and length composition of landings. In 2003, restrictions imposed on fishing activity due to the Prestige oil spill had an influence on effort.

SP-AVILESTR: This fleet contributed with data of effort (fishing days per 100 horse power), LPUE (as kg per fishing day per 100 horse power) and length composition of landings.

Commercial fleets used in the assessment of L.boscii to tune the model

SP-CORUTR8c: This fleet contributed with data of effort (fishing days per 100 horse power), LPUE (as kg per fishing day per 100 horse power) and length composition of landings. Because of trends in the residuals and, this fleet has been split in two periods, SP-CORUTR8c1 (1986-1999) and SP-CORUTR8c2 (2000-present).

B.5. Other relevant data

C. Assessment: data and method

Model used: Extended Survivors Analysis (XSA), (Shepherd, 1992)

Software used: VPA95 Lowestoft suite.

Model Options chosen *L. whiffiagonis*:

Input data types and characteristics

Type	Name	Year range	Age range	Variable from year to year
Caton	Catch in tonnes	1986- present	1-7+	Yes
Canum	Catch-at-age in numbers	1986- present	1-7+	Yes
Weca	Weight at age in the commercial catch	1986- present	1-7+	Yes
West	Weight at age of the spawning stock at spawning time.	1986-present	1-7+	Yes
Mprop	Proportion of natural mortality before spawning	1986-present	1-7+	No
Fprop	Proportion of fishing mortality before spawning	1986-present	1-7+	No
Matprop	Proportion mature at age	1986-present	1-7+	No
Natmor	Natural mortality	1986-present	1-7+	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	SP-CORUTRc	1986-present	3-6
Tuning fleet 2	SP-AVILESTR	1986-present	3-6

Tuning survey 1	SpGFS-WIBTS-Q4	1986-present	1-6

Model options:

Type	Setting
Taper	No
Tuning range	
Ages catch dep. on stock size	1-2
Q plateau	5
F shrinkage s.e.	1.5
Shrinkage year range	5
Shrinkage age range	3
Fleet s.e.threshold	0.2
F bar range	2-4

Model Options chosen *L. boscii*:

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year
Caton	Catch in tonnes	1986- present	0-7+	Yes
Canum	Catch-at-age in numbers	1986- present	0-7+	Yes
Weca	Weight at age in the commercial catch	1986- present	0-7+	Yes
West	Weight at age of the spawning stock at spawning time.	1986-present	0-7+	Yes
Mprop	Proportion of natural mortality before spawning	1986-present	0-7+	No
Fprop	Proportion of fishing mortality before spawning	1986-present	0-7+	No
Matprop	Proportion mature at age	1986-present	0-7+	No
Natmor	Natural mortality	1986-present	0-7+	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	SP-CORUTR8c1	1986-1999	3-6
Tuning fleet 2	SP-CORUTR8c2	2000-present	3-6
Tuning survey 1	SpGFS-WIBTS-Q4	1988-present	0-6

Model options:

Type	Setting
Taper	No
Tuning range	
Ages catch dep. on stock size	Independent
Q plateau	5
F shrinkage s.e.	1.5
Shrinkage year range	5
Shrinkage age range	3
Fleet s.e.threshold	0.3
F bar range	2-4

D. Short-Term Projection

L. whiffiagonis

Model used: Age structured

Software used: MFDP prediction with management option table and yield-per-recruit routines.

Initial stock size: Taken from the XSA survivors.

Maturity: Average maturity ogive for the last three years

F and M before spawning: Set to 0 for all ages in all years.

Weight at age in the stock: Average stock weights for the last five years or an appropriate number of years selected by the assessment working group.

Weight at age in the catch: Average of the last five years or an appropriate number of years selected by the assessment working group

Exploitation pattern: Scale F-at-age within each year, then average the scaled last five years weighted to the final year or an appropriate number of years selected by the working group.

Intermediate year assumptions: Average Fbar for the last three years (normally unscaled although, when appropriately justified, it could be scaled to the final year).

Stock recruitment model used: None. Recruitment-at-age 1 assumed equal in all projection years (GM from 1998 to final assessment year minus 2)

Procedures used for splitting projected catches: Forecast catch numbers-at-age are divided into landings and discards (at age) based on the proportions given as inputs to the projection software; the software does it automatically. These proportions were taken (for each age) to be those corresponding to the observed average of the most recent 5 years.

L. boscii

Model used: Age structured

Software used: MFDP prediction with management option table and yield-per-recruit routines.

Initial stock size: Taken from the XSA survivors.

Maturity: Average maturity ogive for the last three years

F and M before spawning: Set to 0 for all ages in all years.

Weight at age in the stock: Average stock weights for the last five years or an appropriate number of years selected by the working group.

Weight at age in the catch: Average of the last five years or an appropriate number of years selected by the working group.

Exploitation pattern: Scale F-at-age within each year, then average the scaled last five years weighted to the final year or an appropriate number of years selected by the working group.

Intermediate year assumptions: Average Fbar for the last three years (normally unscaled although, when appropriately justified, it could be scaled to the final year).

Stock recruitment model used: Stock recruitment model used: None. Recruitment-at-age 0 assumed equal in all projection years (GM from 1990 to final assessment year minus 2).

Procedures used for splitting projected catches:

E. Medium-Term Projections

Medium term projections are not conducted for these stocks.

F. Long-Term Projections

Model used: yield and biomass per recruit over a range of F values.

Software used: MFYPR.

Yield-per-recruit calculations are conducted using the same input values as those used for the short-term forecasts.

G. Biological Reference Points

During the 2014 benchmark workshop, the softwares PlotMSY and EqSim were employed to explore potential biological reference points for both stocks, following the recommendations of ICES workshop WKMSYREF2.

The biological information needed to run the models was obtained from the assessment.

Weight at age in the stock: Average stock weights for the last five years.

Weight at age in the landings and in the discards: Average of the last five years.

Selection-at-age: (i.e. F(a)/F(2-4)) for the total catch was computed for each of the last 5 years and the geometric mean (by age) then taken over these years. This selection pattern was subsequently split into selection-at-age of landings and discards based on the (5-year average) proportion landed-at-age. The use of geometric mean instead of arithmetic mean for selection-at-age is in order to reduce the effect of large spikes that occur occasionally in the selection-at-age estimates, due to the variability of the discards data, and which would distort the results of the reference points computation.

Natural mortality and proportion mature-at-age were assumed constant over time (as in the assessment).

Uncertainty around each of the input variables for the reference point calculation was introduced either by calculating CVs for subsequent stochastic drawing (for the PlotMSY software) or by bootstrapping (for the EqSim software) based on the values corresponding to the assessment assumptions (in the case of weight, M and proportion mature at age) or assessment results (in the case of selection at age) for the last 5 years.

The following reference points were proposed by the 2014 Benchmark. Given the uncertainties surrounding the recruitment estimates (due to uncertain discards estimates), these reference points should be considered provisional for both megrim stocks. They represent pragmatic choices given the current state of knowledge.

The assessment working group WGBIE should keep a close check on stock development and appropriateness of these reference points, and provide alternatives if any problems or issues are detected.

L. whiffiagonis

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	Type	Value	Technical basis
MSY	MSY Btrigger	910 t	default option; Bpa
Approach	FMSY	0.17	Fmax as FMSY proxy (a check for precautionary considerations has been conducted)
	Blim	650 t	provisional reference point; just above Bloss in the 2014 benchmark assessment
Precautionary	Bpa	910 t	default option; 1.4 Blim
Approach	Flim		
	Fpa		

L. boscii

	Type	Value	Technical basis
MSY	MSY Btrigger	4600 t	default option; Bpa
Approach	FMSY	0.18	Fmax as FMSY proxy (a check for precautionary considerations has been conducted)
	Blim	3300 t	provisional reference point; Bloss in the 2014 benchmark assessment
Precautionary	Bpa	4600 t	default option;1.4 Blim
Approach	Flim		
	Fpa		

H. Other Issues

H.1. Historical overview of previous assessment methods

WG YEAR	2008		2009		2010		2011		2012		2013	
Model	XSA		XSA		XSA		XSA		XSA		XSA	
Software	VPA95 Lowestoft suite		VPA95 Lowestoft suite		VPA95 Lowestoft suite		VPA95 Lowestoft suite		VPA95 Lowestoft suite		VPA95 Lowestoft suite	
Stock	L.whiffiagonis	L.boscii	L.whiffiagonis	L.boscii	L.whiffiagonis	L.boscii	L.whiffiagonis	L.boscii	L.whiffiagonis	L.boscii	L.whiffiagonis	L.boscii
Catch data range	1986-2007	1986-2007	1986-2008	1986-2008	1986-2009	1986-2009	1986-2010	1986-2010	1986-2010	1986-2010	1986-2010	1986-2010
Age range in catch data	1-7+	0-7+	1-7+	0-7+	1-7+	0-7+	1-7+	0-7+	1-7+	0-7+	1-7+	0-7+
SP-CORUTR8c	1990-2007 Ages 2-6	1986-1999 Ages 3-6	1990-2008 Ages 2-6	1986-1999 Ages 3-6	1990-2009 Ages 2-6	1986-1999 Ages 3-6	1990-2010 Ages 2-6	1986-1999 Ages 3-6	1990-2010 Ages 2-6	1986-1999 Ages 3-6	1990-2010 Ages 2-6	1986-1999 Ages 3-6
SP-AVILESTR	1990-2003 Ages 2-6	Not used	1990-2003 Ages 2-6	Not used	1990-2003 Ages 2-6	Not used	1990-2003 Ages 2-6	Not used	1990-2003 Ages 2-6	Not used	1990-2003 Ages 2-6	Not used
SpGFS-WIBTS-Q4 survey	1990-2007 Ages 1-6	1988-2007 (2003 not included) Ages 0-6	1990-2008 Ages 1-6	1988-2008 (2003 not included) Ages 0-6	1990-2009 Ages 1-6	1988-2009 (2003 not included) Ages 0-6	1990-2010 Ages 1-6	1988-2010 (2003 not included) Ages 0-6	1990-2010 Ages 1-6	1988-2010 (2003 not included) Ages 0-6	1990-2010 Ages 1-6	1988-2010 (2003 not included) Ages 0-6
Taper	No	Tricubic over 20 years	No	Tricubic over 20 years	No	Tricubic over 20 years	No	Tricubic over 20 years	No	Tricubic over 20 years	No	Tricubic over 20 years

Tuning range	18	22	19	23	20	24	21	25	21	25	21	25
Ages catch dep. stock size	1-4	0-2	1-4	0-2	1-4	0-2	1-4	0-2	1-4	0-2	1-4	0-2
Q plateau	5	5	5	5	5	5	5	5	5	5	5	5
F shrinkage s.e.	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Shrinkage year range	5	5	5	5	5	5	5	5	5	5	5	5
Shrinkage age range	3	3	3	3	3	3	3	3	3	3	3	3
Fleet s.e. threshold	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3
F bar range	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4	2-4

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Annex 2: Working documents

WD 01 Compilation of LPUE series of the Spanish set-longline fleet targeting hake in non-Spanish European waters

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ABSTRACT

During the last WGHMM, a problem was identified in the assessment of northern hake in relation to the scarce information on abundance of large fish in the setting of the SS3 model. So, the inclusion of LPUEs from commercial fleets catching adults, i.e. *longline or gillnet, was proposed as a possible solution to be investigated. The current working document provides the compilation of LPUE series of the Spanish set-longline fleet targeting hake in ICES Subarea VII. This fleet is compounded of vessels larger than 100 gross registered tonnes (grt) which develop a homogeneous fishing strategy targeting hake alongside the slope of the European western shelf. Although the number of hooks used by trip is not available throughout the time-series, the stability of the set-longline fishing tactic makes reasonable to use fishing days as suitable effort unit.*

INTRODUCTION

The Spanish set-longline fleet operating in non-Spanish European waters is currently composed of two fleet segments whose fishing rights were established under the "*Adhesion Treaty of Spain to the European Community*" in 1985 (Castro *et al.*, 2011). The first fleet segment is formed by vessels larger than 100 gross registered tonnes (grt) which are allowed to operate in European western waters (ICES Subareas VI and VII, and Divisions VIIIabd), and whose fishing activity is mainly focused on exploiting hake (*Merlucius merluccius*). The second fleet segment includes vessels smaller than 100 grt which are restricted to operate in non-Spanish waters of the Bay of Biscay (ICES Divisions VIIIc). Besides, these vessels develop more diverse fishing tactics exploiting not only hake but also conger (*Conger conger*) or deep-water species as forkbeards (*Phycis* spp.) and lings (*Molva* spp.).

During the last WGHMM, a number of problems were identified in the assessment of northern hake in order to be analysed during the WKSOUTH benchmark (ICES, 2013). One of them makes reference to the little information on abundance of large fish in the present setting of the SS3 model. So, the incorporation of cpue from commercial fleets catching adults, *i.e.* longline or gillnet, was proposed as a possible solution to be investigated during the benchmark. IEO has been providing to ICES landings, effort and LPUE for the Spanish set-longline fleet operating in Subarea VII for three Galician ports: Burela, Celeiro and A Coruña. However, these data were presented in annual bases, with the only objective to give LPUE series to illustrate trends of hake abundance. Therefore, the compilation of length frequency distribution (LFD) of quarterly landings of the Spanish set-longline fleet targeting hake in ICES Division VII was developed as inter-seasonal work between WGHMM 2013 and WKSOUTH 2014 meetings.

MATERIAL AND METHODS

A dataset was compiled from the commercial data sampled by IEO for the Spanish set-longline fleet operating in ICES Subarea VII: length frequency distribution (LFD), landings and effort by quarter and landing port. Four were the main ports covered, three in Northern Galicia (Burela, Celeiro and A Coruña) and one in Asturias (Avilés). This last one was irregularly covered, so the respective time-series was rejected from the final compilation. Length frequency distribution could only be recovered backwards to middle 90's, so the final Spanish longline LPUE series ranges from 1995 to 2012.

RESULTS

A Coruña set-longline fleet shows a pronounced decrease in effort since the beginning of the time-series (2016 fishing days in 1995 to an average of 300 fd throughout the period 1998-2012), while Burela fleet shows a strong increase mainly since 2005 (Table 1; Figure 1). The Celeiro fleet seems to be stable throughout the time-series (around 5000 fd average). The three fleets give similar LPUE means: 0.90 t/fd in the Burela fleet, 0.95 t/fd in the Celeiro fleet, and 0.88 t/fd in the A Coruña fleet. After combining these three fleets, the average LPUE of the recovered period (1995-2012) was 0.93 tons by fishing day (Table 2).

LPUE of hake for the Spanish set-longline fleet operating in ICES Subarea VII shows three different periods in trends (Figure 2): a stable period with an average of 0.81 t/fd throughout the first fourteen years (1995-2008), a three-year period with a marked increase of 66% (2009- 2011), and a pronounced decrease (44%) in the last year (2012).

The average of quarterly landing size shows a seasonal increase: 56.3 cm, 57.1 cm, 58.4 cm and 59.8 cm from the first to the fourth quarter, respectively. The annual mean landings size also shows an increase throughout the time-series, from 55.4 cm in 1995 to 61.6 cm in 2012 (Figure 3).

DISCUSSION AND CONCLUSIONS

The decrease observed in the effort of A Coruña fleet started at the beginning of 90's, and it is directly related with the start of the longline fishery in Celeiro and Burela ports. This transference of vessels supports the idea to join the three ports in a common LPUE, a well as the similar LPUE mean observed in the three longline series.

It is known the importance of standardization of effort in a longline LPUE, which is strongly dependent of the number of hooks used by trip. Unfortunately, this information has never been collected, so that it is now unrecoverable throughout the time-series. However, interviews with skippers describe the Spanish set-longline fishery targeting hake in European western waters as a very homogeneous fishing tactic throughout the period recovered here, without changes due to technological improvements or new management measures. Therefore tons by fishing day can be an optimal candidate of LPUE for this longline fleet. Besides, the practical lack of discards observed in this logline fleet (Pérez *et al.*, 1996) makes reasonable to use landings (LPUE) as proxy of catches (cpue).

These longliners use an average of 90 hooks per set and 120 sets by haul (Fariña, 2013). Haul fishing starts hauling the lines between 2:00 and 4:00 pm, and begins to be collected in the morning (between 9:00 and 11:00 am). This process continues throughout the day and once completed, a new fishing haul starts. Thus it can be considered that Spanish longliners use around 10000 hooks by fishing day. Sardine, herring or mackerel are used as bait. A trip consists of about 5.3 fishing days in Subarea VII and the most common depth in the trips is located between 250 and 400 m deep.

Regarding the obtained LPUE series, the increase observed since 2009 may be related with the high recruitment calculated for 2007 and 2008 (ICES, 2013). Nevertheless, the 3 consecutive years of low recruitment do not seem to produce any decrease on the 2010-1011 LPUEs, which are still increasing. Probably related with this, the increase in the yearly mean size in the last two years of the time-series makes to think that older individuals from the 2008 cohort year have been coming into the fishery until 2012, when the LPUE decrease again to the historical mean.

The increase in northern hake SSB observed in the last assessment results is considered the consequence of the 2007-2008 good recruitments as well as the high growth rate estimated by SS3 model (in agreement with the growth rate estimated from tagging data: de Pontual *et al.*, 2009). Though these recent trends are consistent with increasing landings and LPUEs, it is considered that the respective rate of variation may be over-estimated, and the inclusion of tuning information about large fish may help to stabilize the SSB estimates. The time-series (1995-2012) of hake LPUE provided here for the Spanish set-longline fleet fishing in ICES Subarea VII is a good candidate to be tested in the WKSOUTH 2014.

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Table 1. Revised series of landings (t), effort (fishing days) and LPUE (t/fd) of the Spanish long-line fleet operating in ICES Subarea VII by landing port: Burela, Celeiro and A Coruña.

Landings (t)				Effort (fishing days)			LPUE (t/fd)		
Year	Burela	Celeiro	Coruña	Burela	Celeiro	Coruña	Burela	Celeiro	Coruña
1995	2273	5209	2507	2772	6420	2160	0.82	0.81	1.16
1996	3245	5988	2111	3636	6720	1668	0.89	0.89	1.27
1997	2299	4174	830	3540	5040	900	0.65	0.83	0.92
1998	1639	2817	292	3000	5184	372	0.55	0.54	0.78
1999	1982	3447	323	2964	4624	396	0.67	0.75	0.82
2000	2282	3699	281	2928	4440	276	0.78	0.83	1.02
2001	3034	3383	229	3672	3756	276	0.83	0.90	0.83
2002	2399	2841	214	3732	3984	300	0.64	0.71	0.71
2003	2514	3386	192	3612	4404	300	0.70	0.77	0.64
2004	3255	3990	280	3852	4596	312	0.85	0.87	0.90
2005	3074	4177	199	3507	3930	288	0.88	1.06	0.69
2006	3639	4372	256	5184	4572	312	0.70	0.96	0.82
2007	4367	5039	271	5796	5040	340	0.75	1.00	0.80
2008	4058	4302	233	4884	5184	324	0.83	0.83	0.72
2009	5146	4959	214	4536	4624	192	1.13	1.07	1.12
2010	9141	7630	322	5736	5556	375	1.59	1.37	0.86
2011	10908	9672	443	5988	5172	350	1.82	1.87	1.26
2012	7464	6612	218	6984	6720	363	1.07	0.98	0.60
AVERAGE		0.90			0.95			0.88	

Table 2. Landings of hake (t), effort (fishing days) and LPUE (t/fd) of the Spanish set-longline fleet which operates in ICES Subarea VII (Burela, Celeiro and A Coruña ports together).

Year	Landings	Effort	LPUE
	(tons)	(fishing days)	(t/fd)
1995	9988	11352	0.88

1996	11343	12024	0.94
1997	7303	9480	0.77
1998	4748	8556	0.55
1999	5753	7984	0.72
2000	6262	7644	0.82
2001	6647	7704	0.86
2002	5453	8016	0.68
2003	6092	8316	0.73
2004	7526	8760	0.86
2005	7450	7725	0.96
2006	8268	10068	0.82
2007	9676	11176	0.87
2008	8593	10392	0.83
2009	10319	9352	1.1
2010	17092	11667	1.46
2011	21022	11510	1.83
2012	14294	14067	1.02
AVERAGE		0.93	

Figure 1. Effort (fishing days) of the Spanish set-longline fleet operating in ICES Subarea VII: by port (Burela, Celeiro and A Coruña) and total (the three ports together).

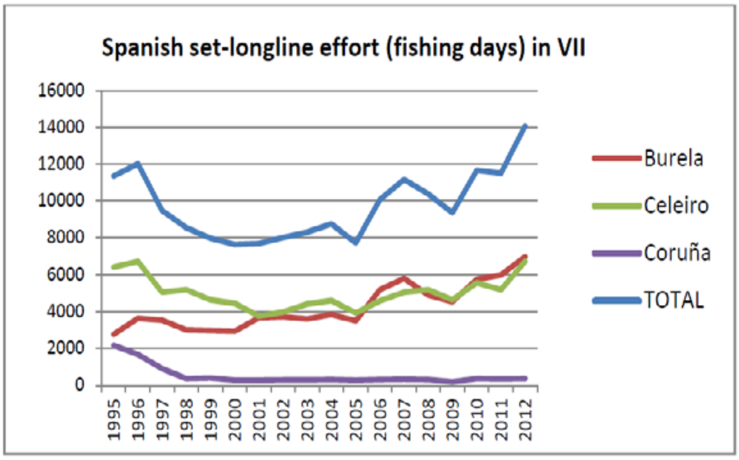


Figure 2. LPUE (tons/fishing day) time series (1995-2012) of hake for the Spanish set-longline fleet operating in ICES Subarea VII.

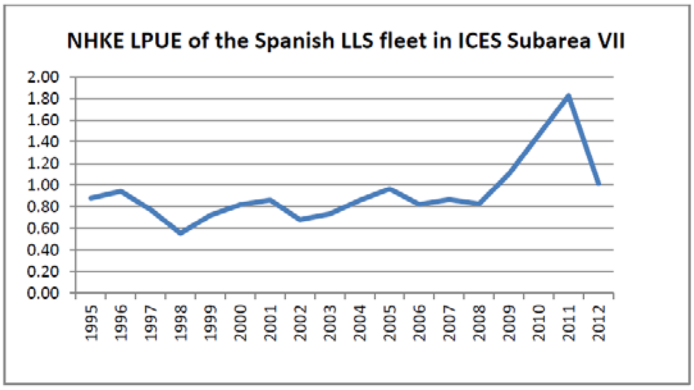
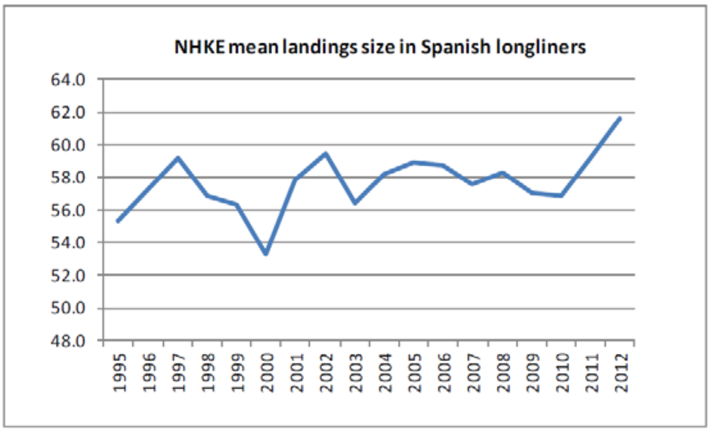


Figure 3. Evolution of the hake mean landing size (cm) in the Spanish set-longline fleet operating in ICES Subarea VII.



WD 02 A new calibration index for Southern hake. A Coruña cpue 1985-1993.

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Introduction

Current ICES model for Southern hake are calibrated with 3 surveys and 2 LPUE providing information mainly for the recent part of the time-series. The Spanish survey in the north of Spain (spGFS-WIBTS-Q4) is the only source of information for the period 83-88 and is mainly for small fish (Table 1)

Table 1. Summary of current calibration indices and the new suggested index (SP-CORUTR85)

name	type	year start	year end	Fish size
spGFS-WIBTS-Q4	survey	1983	2012	5-50 cm (==)
spGFS-caut-WIBTS-Q4	survey	1997	2012	5-50 cm (--)
ptGFS-WIBTS-Q4	survey	1989	2011	5-50 cm (++)
SP-CORUTR	LPUE	1994	2012	25-70 cm
PT-TR	LPUE	1989	2010	25-70 cm
SP-CORUTR85	LPUE	1985	1993	25-70 cm

Old data from A Coruña otter trawl landings (total and length distribution) and effort were recovered for the period 1985-1993 (SP-CORUTR85). This is the same fleet than those already implemented to calibrate the current model for the 1994 to 2012 period (SP-CORUTR). The reason to cut this series in two pieces is to consider the change in landings length distribution after the regulation for minimum landing size (MLS) from 1992. This regulation sets the MLS in 27 cm after 1993, although it was implemented gradually.

A Coruña bottom otter trawlers (OTB) used the gear called "BAKA", that is a gear targeting demersal species like hake (*Merluccis merluccius*), megrims (*Lepidorhombus boscii* and *L. whiffiag-onis*) and anglerfish (*Lophius piscatorius* and *L. budegassa*). It uses a codend mesh size of 65 mm with a vertical opening of 1.2-1.5 m and a wingspred of 22-25 m. The fleet is considered quite stable in this time so no standardization process was applied.

Data description

Table 2. Summary of sampling effort, landings (weight), effort and LPUE.

	1985	1986	1987	1988	1989	1990	1991	1992	1993
NºMeasured	1316	2497	1520	2167	5386	5993	3072	3219	3479
Samples	16	32	22	38	63	75	74	78	93
Land.Ung.(*)	945	842	695	698	715	749	501	589	514
Land.Gut.(*)	859	765	632	635	650	681	456	535	467
Calc.Land.(*)	941	843	691	703	715	749	502	588	513
SOP ratio	1.00	1.00	1.01	0.99	1.00	1.00	1.00	1.00	1.00
Ef(day/100cv)	45920	39810	34680	42180	44440	44430	40440	38910	44504
CPUE	20.6	21.1	20.0	16.5	16.1	16.9	12.4	15.1	11.5

Sampling effort and quality check with SOP ratio are presented in table 2. Table 2 and figure 1 show the effort and LPUE trends. The amount of samples ranges from 16 the first year of the series (1985) to 93 in the last year (1993) with a number of fish measured ranging between 1316 and 5993. Total landings (ungutted) ranges from 501 t in 1991 to 859 t in 1985. Effort shows no trends with a minimum effort of 34 680 day/100cv in 1987 and maximum effort of 45 920 in 1985. The LPUE shows a decreasing trend from 20.6 and 21.1 in 1985 and 1986 respectively to a minimum of 11.5 in 1993.

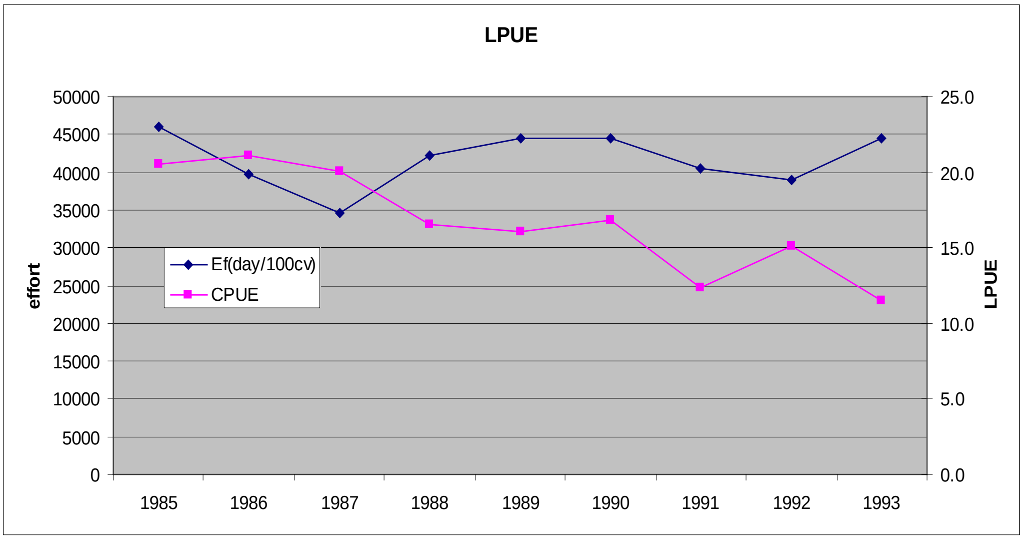


Figure 1. Effort and LPUE trend.

Length distribution

Figure 2 show the length distribution for SP-CORUTR85. It can be seen that throughout the time the landings have moved towards larger fish with many fish around 20-25 cm in years 1985-88, that eventually disappear from landings length distribution in years 1989-93.

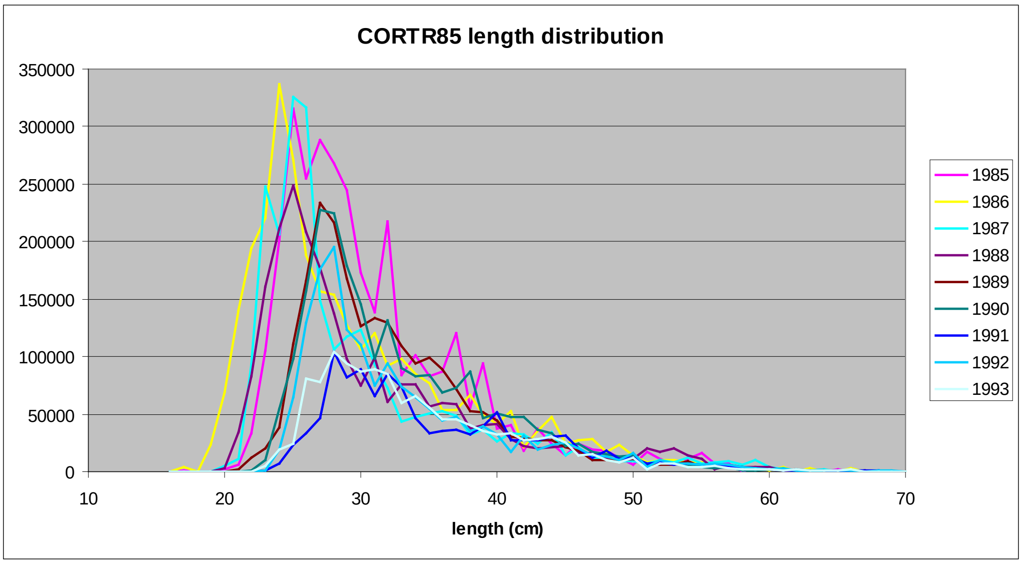


Figure 2. SP-CORTR85 length distribution from 1985 to 1993.

To evaluate the LPUE trends by length, four groups of length classes were grouped (25-40 cm; 40-55 cm; 55-70 cm and 70-85 cm) and their trends presented in figure 3. This figure shows a decreasing LPUE trend for the first length group (25-40 cm) from 55 cm in 1985 to around 20 cm in 1991-93. Larger length groups do not show similar decreasing trends, being quite stable along the time

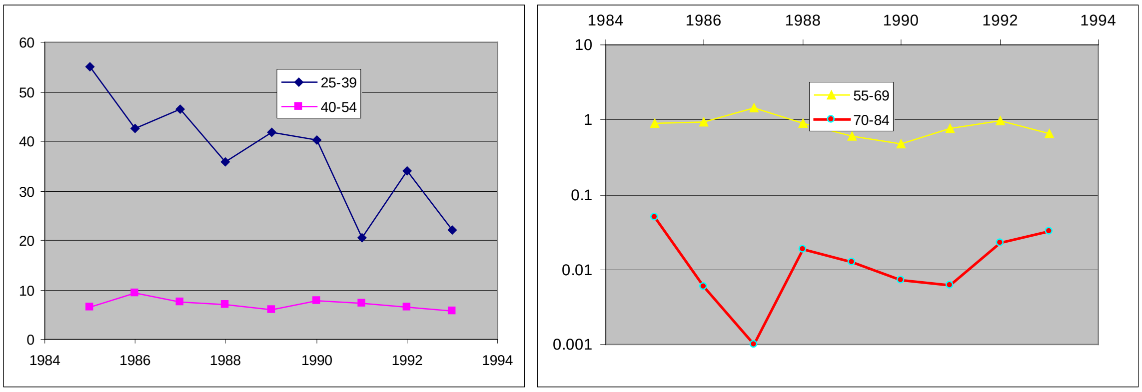


Figure 3. LPUE trends by length. Left plot shows the trends for the first two length groups (25-39 and 40-54) in normal scale, and right plot shows the trends for the larger fish groups (55-69 and 70-84 cm) in logarithm scale.

Conclusion regarding data

The SP_CORTR85 provides a new source of information to calibrate the model at the beginning of the time-series adding complementary information to the existing spGFS-WIBTS-Q4 survey index that mainly targets small fish. This new information might help to calibrate the population trends for large fish at the beginning of the time-series.

Model implementation

Beginning with the "Base" case, a new likelihood component was added to the GADGET likelihood function. The new likelihood component was built equally than those previously implemented for the same fleet for years 1994-2013. The first run implements 3 length groups (25-39 cm; 40-54 cm and 55-60 cm); each with the same weight than those assigned to the aforementioned fleet acting in period 1994-13.

Residuals for the 3 cpues are presented in figure 4

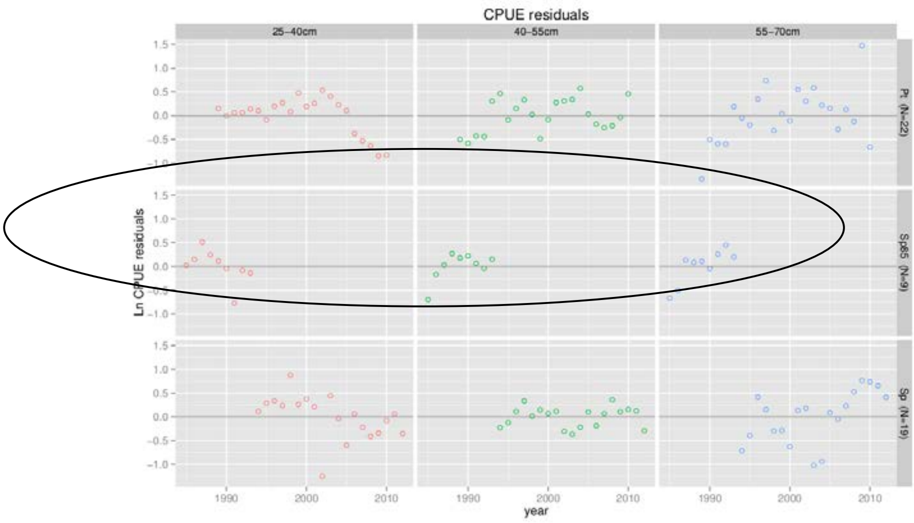


Fig 4a. Residuals with new cpue (1985-93) at 3 different length groups. New cpue likelihood weights (2.1; 21.5 and 3.2) are the same than old Spanish cpue (1994-13).

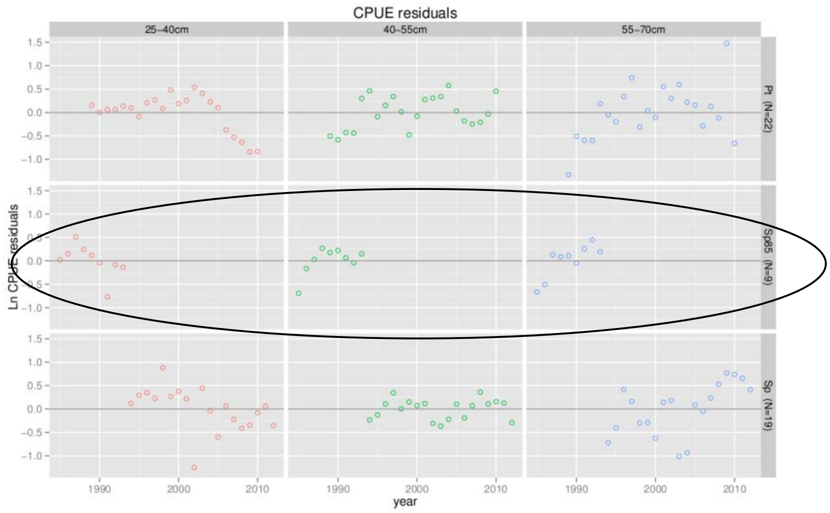


Figure 4b. Residuals with new cpue (1985-93) at 3 different length groups. New cpue likelihood weights (50, 50 and 50) have increased compared with previous run.

The implementation of ACORUÑA85 cpue with the same weights than ACORUÑA cpue than do not change the model results. Increasing the weights to 50 in all the 3 likelihood components for ACoruña85 fleet makes the final fit also unmodified even taking into account that now the sum of these 3 components reaches a 13% of total likelihood weight (see table 3). The total likelihood in the 3 runs (base, new cpue with low weight and new cpue with high weight produce the same results without changing the model results, only adding the new likelihood figures to the total likelihood.

Model configuration was checked and apparently there are not anything wrong!!

A new run with weight = 1000 will be performed to cheek if the new cpue is taken into account or not

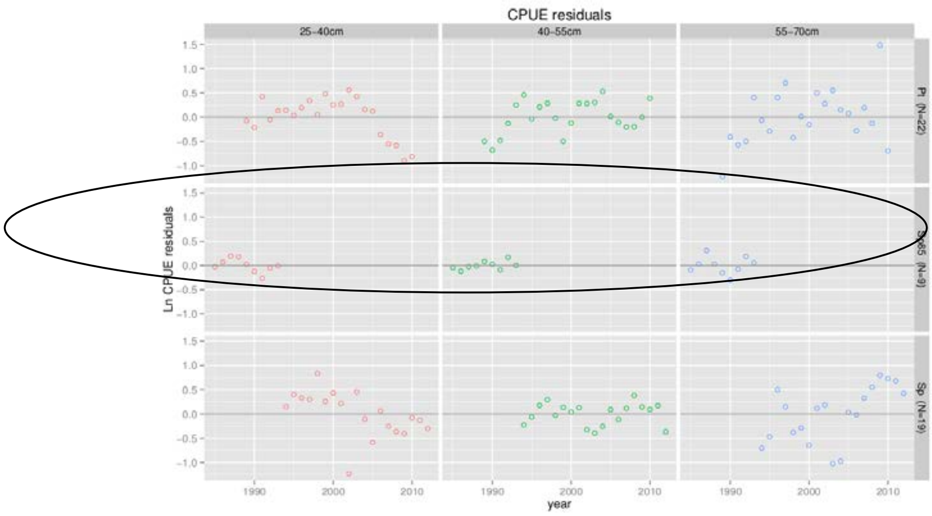
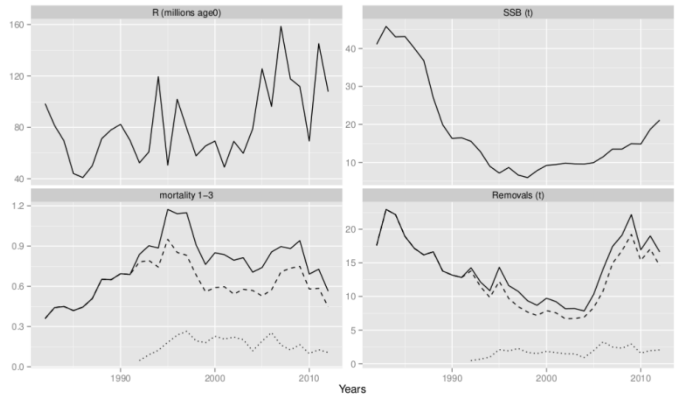
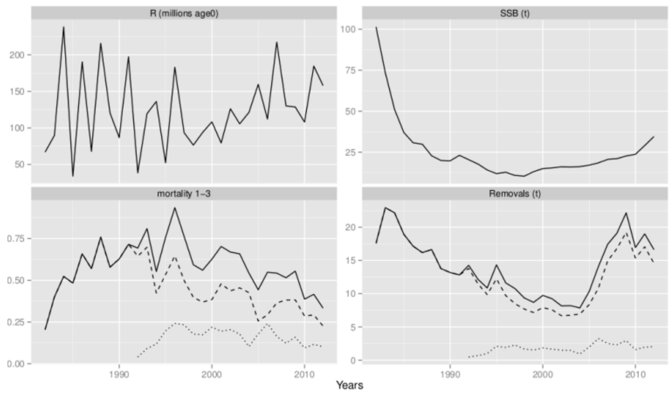


Figure 4c. Residuals with new cpue (1985-93) at 3 different length groups. New cpue likelihood weights (1000, 1000 and 1000).

Run with extremely high weights in cpue85 gives a better fit however other parameters hit boundaries. Abundance in initial conditions (ages 2 to 7 in 1982) got the lower boundary ~0 and high values for ages older than 8. This makes SSB really high at the beginning of the time-series, even having zeroes in ages 2 to 7.



Summary plot with cpue85 weights = 2.1; 21.5 and 3.2



Summary plot with cpue85 weights = 1000, 1000, 1000

An additional run with weights: 0, 50, 50 was performed to check if conflicting signals come from the 3 series at length. It seems like the first sere (25-39 cm) presents a higher decreasing trend than the other two signals (40-54 and 55-69). The results are the same as in run with weight 50, 50, 50. So, if the problem is a conflicting signal between different datasets, this conflicting signal have to come from landings length distribution or Spanish Demersal survey, which are the sources of information available to fit the beginning of the time-series.

Table 3. Likelihood scores and weights

	run base			runBase+CPUE85-1			runBase+CPUE-2			runBase+CPUE-3			runBase+CPUE-4		
Component	weight	score	like	weight	score	like	weight	score	like	weight	score	like	weight	score	like
Land1.ldist	133	0.17	23	133.2	0.17	23	133.2	0.2	23	133.2	0.3	44	133.2	0.2	23
Land.ldist	214	0.76	163	213.9	0.77	164	213.9	0.8	165	213.9	0.9	190	213.9	0.8	165
cdLand.ldist	4.2	1.94	8	4.2	1.94	8	4.2	1.9	8	4.2	2.6	11	4.2	1.9	8
Disc.ldist	31.2	1.62	50	31.2	1.62	51	31.2	1.6	51	31.2	1.6	50	31.2	1.6	51
SpDem.ldist	62.3	1.42	89	62.3	1.42	88	62.3	1.4	88	62.3	1.3	84	62.3	1.4	88
PtDem.ldist	99	0.39	38	99	0.39	38	99	0.4	38	99	0.4	44	99	0.4	38
CdAut.ldist	10.4	0.59	6	10.4	0.59	6	10.4	0.6	6	10.4	0.6	6	10.4	0.6	6
SpIndex15cm.1	3.7	14.13	52	3.7	14.07	52	3.7	14.1	52	3.7	10.9	40	3.7	14.1	52
SpIndex15cm.2	18.3	6.88	126	18.3	6.85	125	18.3	6.9	125	18.3	7.0	128	18.3	6.9	125
SpIndex15cm.3	15	4.53	68	15	4.52	68	15	4.5	68	15	4.7	70	15	4.5	68
SpIndex15cm.4	0	9.30	0	0	9.26	0	0	9.2	0	0	10.0	0	0	9.2	0
PtIndex15cm.1	3.4	17.26	59	3.4	17.28	59	3.4	17.2	59	3.4	18.1	62	3.4	17.2	59
PtIndex15cm.2	9.5	4.82	46	9.5	4.78	45	9.5	4.8	45	9.5	5.2	49	9.5	4.8	45
PtIndex15cm.3	24.5	2.40	59	24.5	2.36	58	24.5	2.4	58	24.5	3.0	73	24.5	2.4	58
PtIndex15cm.4	0	9.75	0	0	9.72	0	0	9.7	0	0	9.6	0	0	9.7	0
Sp85CPUE15cm.1	**0**	**0**	**0**	**2.1**	**0.98**	**2**	**50**	**0.98**	**49**	**1000**	**0.17**	**166**	**0**	**0.98**	**0**
Sp85CPUE15cm.2	**0**	**0**	**0**	**21.5**	**0.69**	**15**	**50**	**0.69**	**35**	**1000**	**0.06**	**61**	**50**	**0.69**	**35**
Sp85CPUE15cm.3	**0**	**0**	**0**	**3.2**	**1.05**	**3**	**50**	**1.04**	**52**	**1000**	**0.26**	**263**	**50**	**1.04**	**52**
SpCPUE15cm.1	2.1	3.90	8	2.1	3.90	8	2.1	3.9	8	2.1	4.0	8	2.1	3.9	8
SpCPUE15cm.2	21.5	0.83	18	21.5	0.83	18	21.5	0.8	18	21.5	0.9	20	21.5	0.8	18
SpCPUE15cm.3	3.2	5.42	17	3.2	5.47	18	3.2	5.5	18	3.2	5.9	19	3.2	5.5	18
PtCPUE15cm.1	11.6	3.25	38	11.6	3.26	38	11.6	3.3	38	11.6	3.6	42	11.6	3.3	38
PtCPUE15cm.2	3.8	2.62	10	3.8	2.62	10	3.8	2.6	10	3.8	2.4	9	3.8	2.6	10
PtCPUE15cm.3	7	7.17	50	7	7.13	50	7	7.1	50	7	6.8	48	7	7.1	50
Tot likelihood			928			948			1063			1490			1013.89

WD 03 Hake life History. Some ideas about biological parameters for stock assessment.

Santiago Cerviño and Catherine Michielsens

Abstract

Both hake stocks might be considered "data poor" in terms of biological information, being this one of the main difficulties to get a good model. In this work is explored the use of the biological information available (maturity) and life-history invariants to complete the missed biological information (growth and natural mortality parameters). The results show different figures than these currently used for Linf and M (k is estimated in the assessment model). However the results do aim to substitute the old parameters but to explore alternatives that may help to full the gaps.

Introduction

Biological parameters are one of the weakest areas in current ICES assessment models. Growth and M are relatively unknown and were set as constants (Linf=130 and M = 0.4) meanwhile k is estimated by the model based on the length distribution progression through quarters. There is information for maturity at length although this information is not used to fit the model. This information is used to calculate SSB after the model was fit.

The aim of this work is to provide more information regarding biological parameters for the hake models developed in ICES WKSOUTH 2014. This information will be based on life-history invariants (LHI) theory using hake biological information from literature. LHI theory predicts that the relationship between some life-history parameters is relatively constant. Most evolutionary life-history theory is developed in terms of allocation of resources to the competing ends of growth, reproduction and adult survivorship (Charnov and Barrigan, 1991). The goal of life-history theory is to understand the variation in such life-history strategies to explain the reproductive success. For instance, higher investment in current reproduction hinders growth and survivorship and reduces future reproduction, while investments in growth will pay off with higher fecundity in the future. Beverton and Holt (1959) and Beverton, (1992) provided empirical evidences that some relationships among parameters are relatively constant like Lm/Linf and k/M in different fish groups. Charnov (1993) developed the theoretical basis for this invariance relationship based on simple maths with VB growth curve, the exponential survivorship and some reproductive traits. Based on this theory, biological parameters might be built based on the expected value of these invariants and their variability estimated from other hake information.

Charnov (1993) extends the theory explaining the role of these invariants. Charnov and Berrigan (1991) present 3 patterns in life history:

1. k/M tend to be relatively constant in similar taxa (~0.6; Charnov and Berrigan, 1993)
2. Lm/Linf is relatively constant among similar taxa.

2.1. Lm/Linf=1-exp(-k*m) (where m is age of maturity); if a group of species share the same Lm/Linf value they also share the same k*m.

2.2. For species where k/M and Lm/Linf are constant, M is inversely proportional to m, i.e. M*m is constant

3. k and Linf are negatively correlated

Because of the limited information available on these biological parameters and the relationship between them for *Merluccius merluccius*, we use a meta-analysis approach whereby we rely on data from other related species to help estimate these relationships and associated parameters. In order to properly account for the variability between data from *M. merluccius* and the other species within this meta-analysis, an hierarchical modelling approach will be used whereby we estimated the parameters of interest simultaneous at the species level and at the meta-species level. In doing so, hierarchical models allow predicting the parameters for *M.*

merluccius for which we have limited data, based on the estimates from all species combined and the similarities/dissimilarity between the individual species.

Current ICES assessment models for both hakes assume that most biological parameters are constant (Lmat 50% = 43.85cm; M=0.4 year-1 and Linf=130 cm) and only k for VonBertalanffy growth are estimated by the model. Length at maturity (Lm) is the unique parameter for which there is available information directly used in the assessment process. Since Lm may be estimated out of the model it may be the basis to develop a link among priors of different biological parameters following Charnov and Berrigan (1991) and Beverton (1992) LHI theory such as:

1) Prior for Linf from ratio Lm/Linf for hakes in literature.
2) Prior for k based on negative correlation between Linf and k from hake literature.
3) Prior for M based on constant relation k/M from hake literature.

Material and methods

When doing meta-analyses, it is common to use an hierarchical approach (Liermann and Hillborn, 1997; Myers and Mertz, 1998; Myers and Mertz, 1998). Instead of using all the data from the different species combined (thereby placing larger weight on the data from species with more records), hierarchical models still allow to account for the differences between the different species, and at the same time giving higher weight to the data from *M. merluccius* depending on the amount of *M. merluccius* data available.

The analysis will be developed in 3 stages as described in figure 1. In the first stage the maturity information will be described; in the second stage the hake LHI meta-analysis based on hake information from literature will be developed and, in the third stage, the priors for Linf, k and M will be developed sequentially.

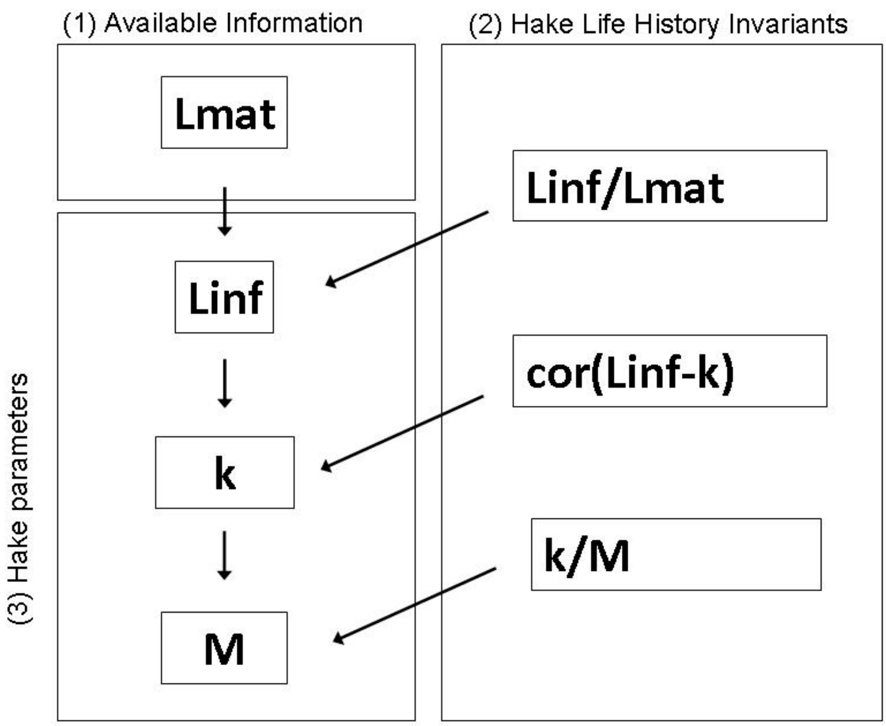


Figure 1. Hake meta-analysis

Maturity information

The first stage is having a maturity distribution for Northern and Southern hake. This distribution is built from available information. There are available maturity information from the Northern stock since 1987 (WKROUND, 2010) and from the Southern stocks since 1980 (ICES, 2013). Length of 50% of maturity for both sexes combined is presented in figure 2. L50 mean and standard deviation for both time-series were used to build the normal distributions.

For Southern Hake, there seems to be a trend in the data maturity data. Rather than deriving the distribution for L50 based on all the data whereby the earlier years indicate larger values for L50 than the later years, the time-series has been split in 3 periods and only the last period has been used to estimate the distribution of L50.

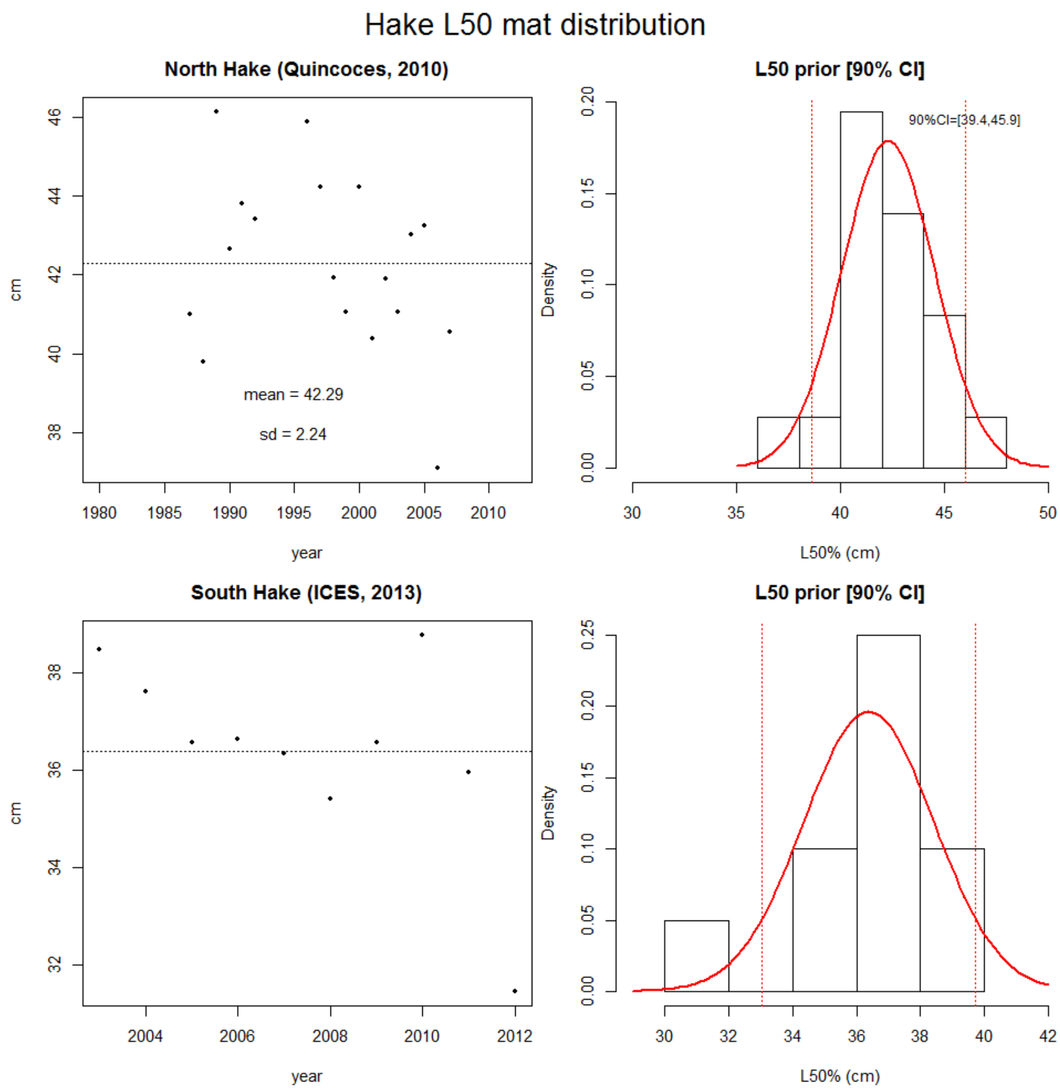


Figure 2. Maturity information from Northern and Southern hake. Time-series in the left and L50 distribution with normal fit in the right.

Figure 2 left panel shows the L50 figures for Northern and Southern hake. These figures range from 36 to 46 cm with a mean of 42.29 and s.d. of 2.24 cm (Northern hake) and 33 to 50 cm mean ot 37.95 and s.d. of 3.09cm (Southern hake). Right panel shows the resulting female normal priors based on the mean and s.d. of the L50 figures.

Data review for Life-history invariant analysis

The initial idea for hake data review was to use only information from the same species (*Merluccius merluccius*) to develop priors for Northern hake assessment. However, after the initial review of this information we realized that practically all data are based in a growth model unbelievable. Hake data for the genus *Merluccius* was downloaded from FishBase (Froese and Pauly, 2013). The total amount of records with life-history data in FishBase was 188, although not all of them have all the needed data. A literature review was extended to add new data not already collected in FishBase this review provided 125 new records from the 12 hake species all over the world. The distribution of all collected records by species after deleting unrealistic *M. Merluccius, (*Those based in old assumed slow growth*)* records are presented in next figure 3.

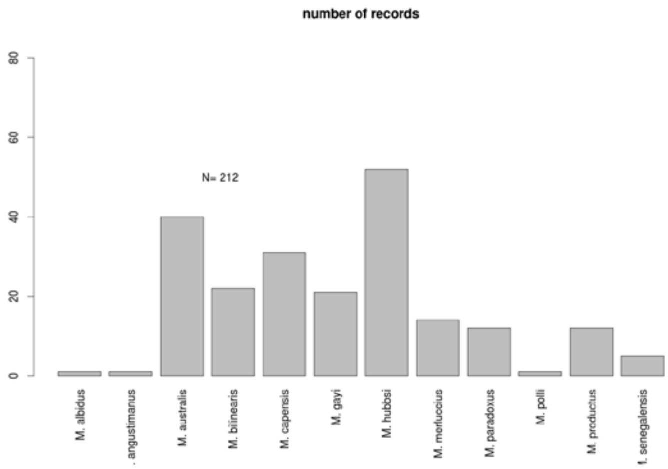


Figure 3. Distribution of records by species after deleting unrealistic records.

Linf from Linf/Lmat invariant.

Linf priors were estimated based on the life-history invariant for the ratio Linf / Lmat. The total number of records with Linf and Lmat data were 33 (Figure 4); 13 belong to *M. australis* and only one to *M. merluccius*. The other species has less than 5 records and some of them zero. The distributions of these ratios by species are presented in figure 4 (right panel) showing two different groups: those with mean figures above 2 and those with figures below 2. Among the species below 2, *M. australis* has 13 records with a mean around 1.4 and a narrow sd. The other 2 species with figures below 2 only has 3 records.

There are certain requirements that need to be met to be able to include data within a Meta-analysis. One of those requirements is that the data from the different species need to be exchangeable, i.e. there should not exist any a priori information that would allow indicate that a particular species would be different from the other ones in the meta-analysis. *M. australis* however matures between 60 and 80 cm and growths until 80- 120 cm depending on the sex, while the other hakes mature between 20 and 50 cm and grow until 40-130 cm. So the knowledge that M. *australis* behaves differently, and thereby violates the assumption of exchangeability within the hierarchical meta-analysis requires us to exclude it from the analysis.

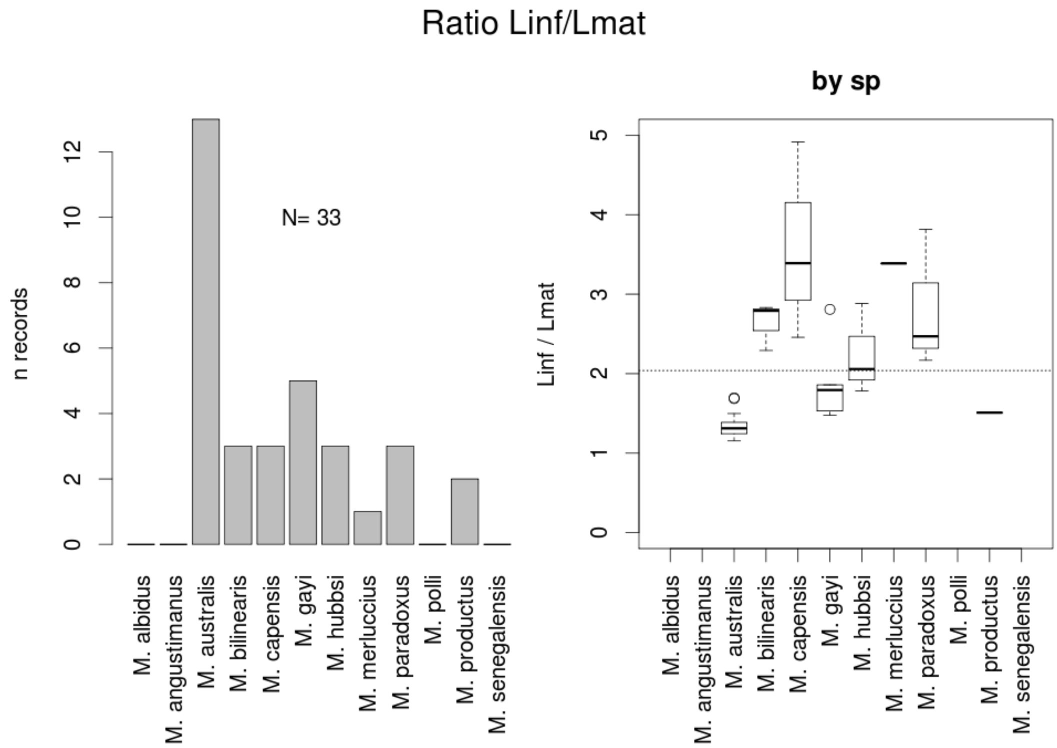


Figure 4. Number of records with Linf and Lmat data (left panel) and their boxplots (left panel)

A hierarchical Bayesian analysis was run to estimate the ratio of Linf over Lmat for *M. merluccius.* The model assumes that the species-specific ratios ($Linf/Lmat_{SP}$) are normally distributed as follows;

$Linf/Lmat_{sp}$ ~ normal(mu.sp.Linf/Lmat, var.sp.Linf/Lmat)

Whereby mu.sp.Linf/Lmat is the average ratio of Linf over Lmat for all species combined and var.sp.Linf/Lmat indication of the variance between estimates for the different species. The model predictions of $Linf/Lmat_{sp}$ have been compared against the observations (Linf/Lmat.obs) using a following normal likelihood function:

$Linf/Lmat.obs_{i,sp}$ ~ norm($Linf/Lmat_{sp}$, var.Linf/mat)

To run this analysis, uninformative priors have been placed on mu.sp.Linf/Lmat, var.sp.Linf/Lmat and var.Linf/Lmat. The resulting distribution for Linf/Lmat for *M. merluccius* can be seen in Figure 5.

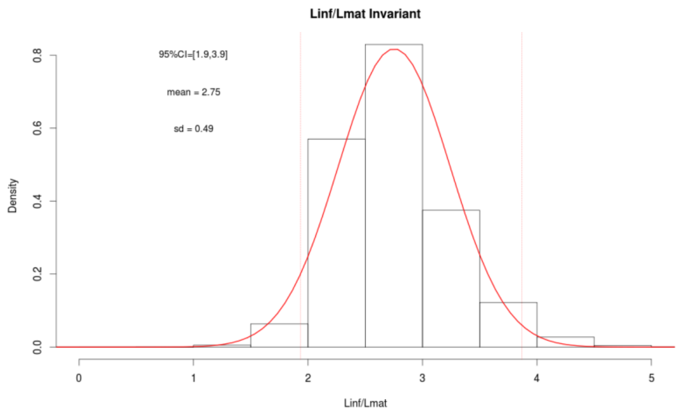


Figure 6. prior distribution for the ratio Linf/Lmat with 95% CI, mean and s.d.

Priors for Linf were developed as the product between Lmat distribution (Figure 2) and Linf/Lmat distribution (Figure 6) and are presented in Figure 7.

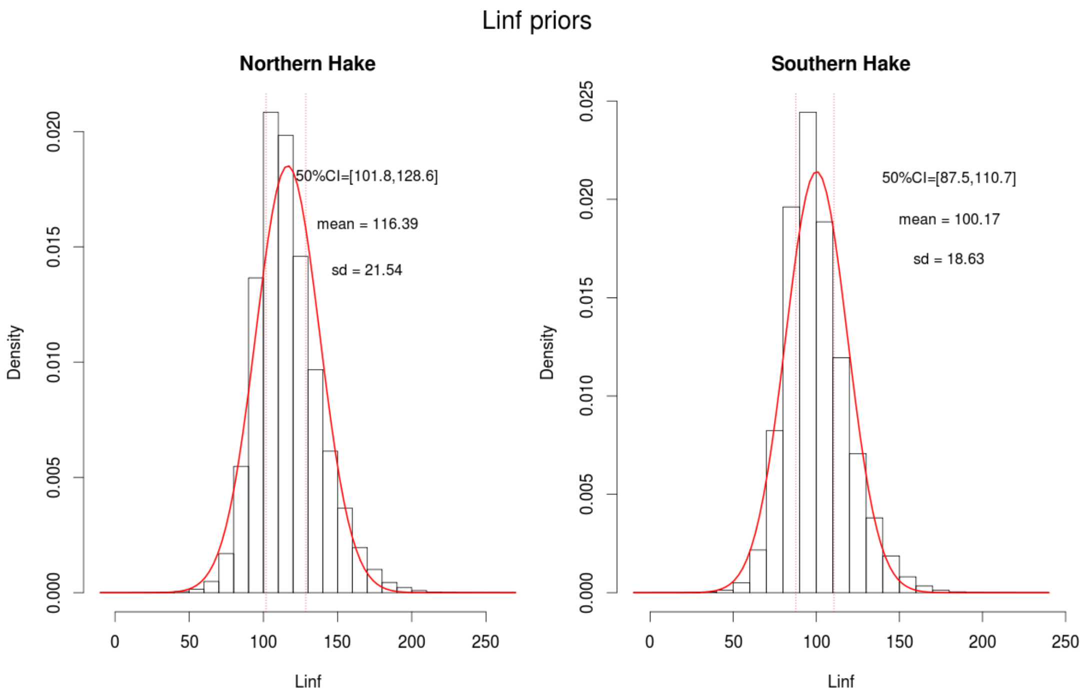


Figure 7. The probability distributions for the ratio Linf/Lmat with 50%CI, mean and s.d. for Norther hake (left panel) and Southern hake (right panel)

Mean figures and 95% CI for Linf are 100.4 cm [82.4, 19.6] for Northern hake and 90.15 [71, 110.9] for Southern hake. These numbers are belowthe current Linf used within the stock assessment model model (130 cm). Linf=130 is however well within the full probability distributions for Linf. We have to keep in mind that Linf=130 had been based on data from female hake while this analysis was performed for males and females combined.

K from Linf-k invariant

K is modelled in the ICES models (SS3 and GADGET) as a von Bertalanffy parameter. k prior estimation was based on the high negative correlation among Linf and k. Figure 8 shows the valid records with information on von Bertalanffy fits providing data for Linf and k. Most *M. merluccius* were excluded since recent tagging studies have showed that k is about two times above those previously estimated (de Puntual *et al.*, 2006; Piñeiro *et al.*, 2007). Figure 8 shows the distribution of valid data for different hake species (left panel) and the plot of kvs.Linf for all the data (central plot). This plot shows the negative correlation among both parameters which presents a banana shape. These kinds of shapes are easily linearized thorough log transformations allowing for a linear model able to predict k from Linf (right plot).

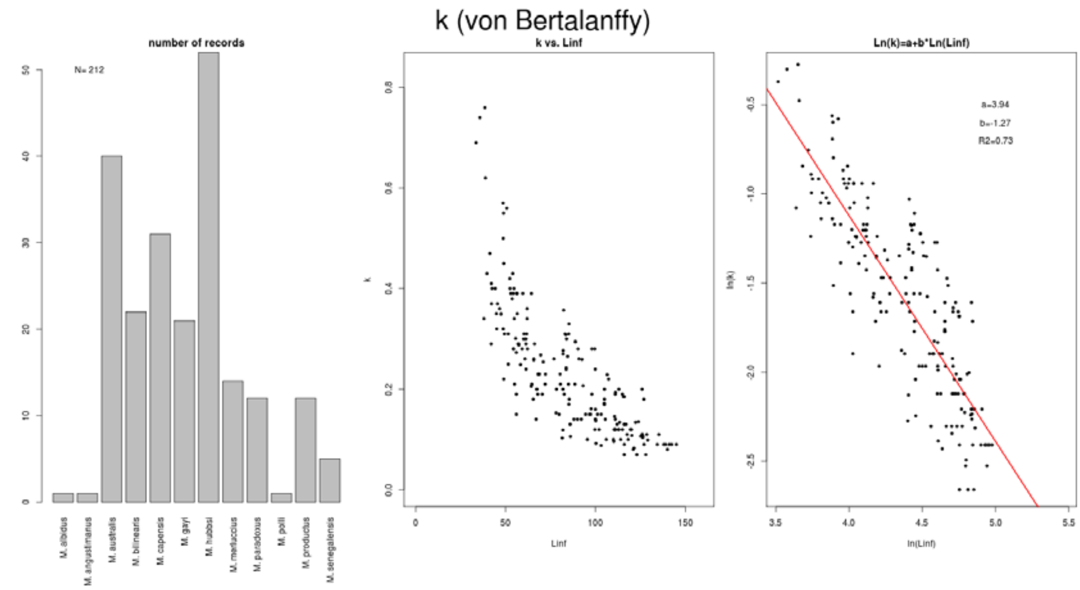


Figure 8. Number of records with information on k and Linf (left panel); kvs.Linf (central panel) and log linear model (right panel)

A Bayesian linear regression model was developed to estimate k, with the relationship between k and Linf being expressed by the following equation:

$log.k_{i,sp} = a_{sp} + b_{sp} * log(Linf.obs_{i,sp})$

whereby $Linf.obs_{i,sp}$ are observations of Linf for individual species, a_{sp} and b_{sp} are species-specific linear regression parameters. $k_{i,sp}$ are the species-specific model predicted estimate. These estimates are compared against the observations on the logscale using the following likelihood:

$log.k.obs_{i,sp} \sim norm(log.k_{i,sp}, var.k)$

The stock specific values of the intercept a_{sp} and slope b_{sp} are defined by a mean (mu.a and mu.b) and variance (var.a and var.b) across species:

$a_{sp} \sim norm(mu.a, var.a)$

$b_{sp} \sim norm(mu.b, var.b)$

whereby mu.a, mu.b, var.a and var.be have been given uninformative priors, as well as var.k.

The resulting model for M. merluccius is used to predict the distribution for k for both Northern and Southern hake by using the a and b parameters for M. merluccius in combination with the distributions for Linf obtained previously for Northern and Southern hake.

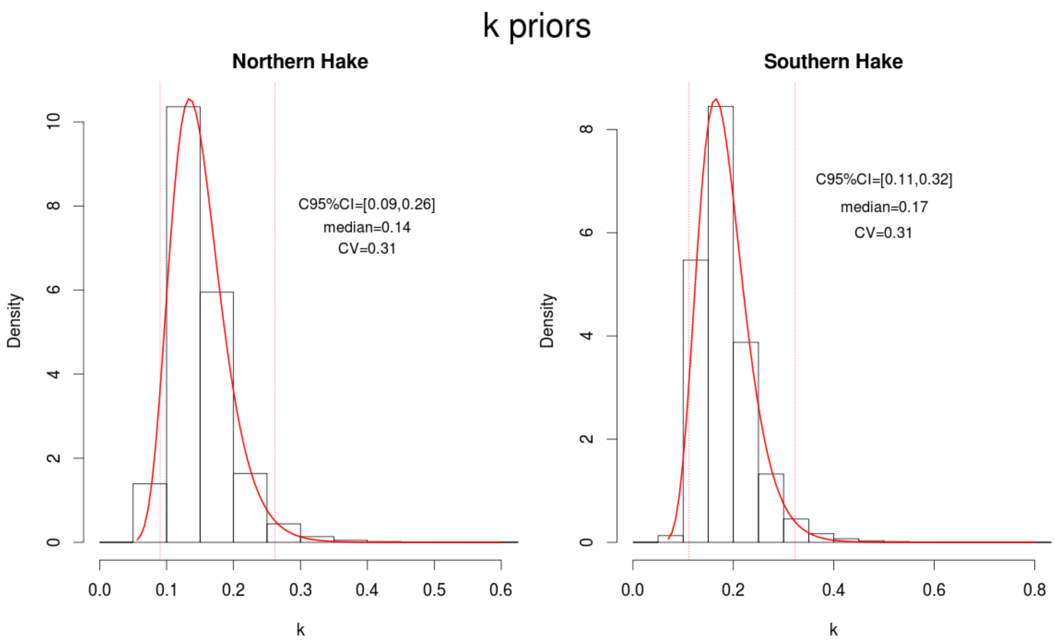


Figure 9. k priors for Northern hake (left panel) and Southern hake (right prior)

K mean and 95% CI are 0.15 [0.08, 0.28] for Northern hake and 0.17 [0.09, 0.32] for Southern hake. These figures are similar to those estimated by both ICES models (around 0.17). However we have to take into account that k is the rate at which the population raises Linf and in this exercise Linf is well below ICES Linf (90-100 vs. 130 cm).

M from k/M invariant

Natural mortality is set as a constant parameter in time and length in hake ICES models. This estimation is based on the for the assumption that the ratio of k/M, is relatively constant among similar taxa.

Figure 10 shows the hake species with records for k and M. As in the previous analysis most *M. merluccius* data were rejected because of wrong k estimation. All *M. australis* records were also eliminated. Many records with a typical 0.2 figure estimation without a justification were also eliminated. Finally only 25 records were used for this analysis. In the central panel of the same figure we can see the distribution of k/M rate for different species. In the left part of this plot we can see the total distribution with a median equal to 0.58 and CV=0.41, similar than those presented by Jensen (1996). Preliminary linear models with these data did not show a good fit and given the relatively low variability around the mean value it was decided to use the mean and s.d. of these figures to develop the informative priors for the k/M ratio.

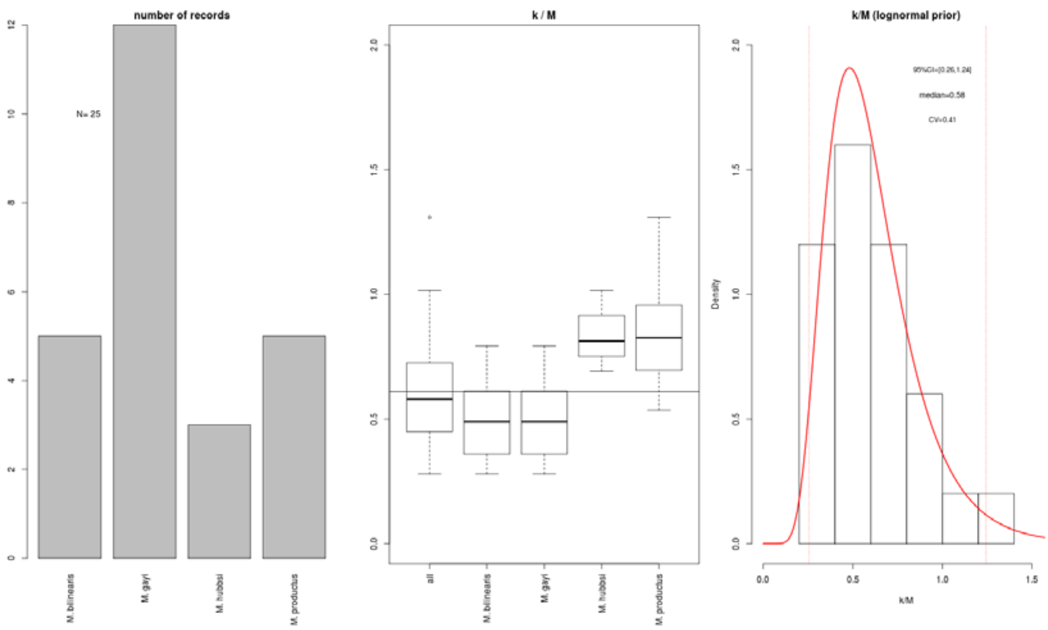


Figure 10. Records with information on M and k (left panel); a boxplot for this ratio k/M in every species (central panel) and k/M distribution (right panel)

Priors for M were built based on the k/M distribution (Fig 10) and using a Bayesian model very similar to the model used to estimate Linf/Lmat. The model assumes that the species-specific ratios are normally distributed as follows;

k/M_{sp} ~normal(mu.sp.k/M, var.sp.k/M)

Whereby mu.sp.k/M is the average ratio of k over M for all species combined and var.sp.k/M indicates the variance between estimates for the different species. The model predictions of k/M have been compared against the observations (k/M.obs) using a following normal likelihood function:

$k/M.obs_{i,sp}$ ~ norm(k/M_{sp}, var.k/M)

To run this analysis, uninformative priors have been placed on mu.sp.k/M, var.sp.k/M and var.k/M. The resulting distribution for k/M has been used in combination with the distributions for k for both Northern and Southern Hake to calculate the distribution of M as seen in Figure 11. The M estimated following Life-history Invariants theory represents the expected M after maturity, that has median = 0.23 for Northern hake and 0.28 for Southern hake. In both cases the variability is very high because the sequential process from Lmat to M through Linf and k, accumulates the variability of all relationships.

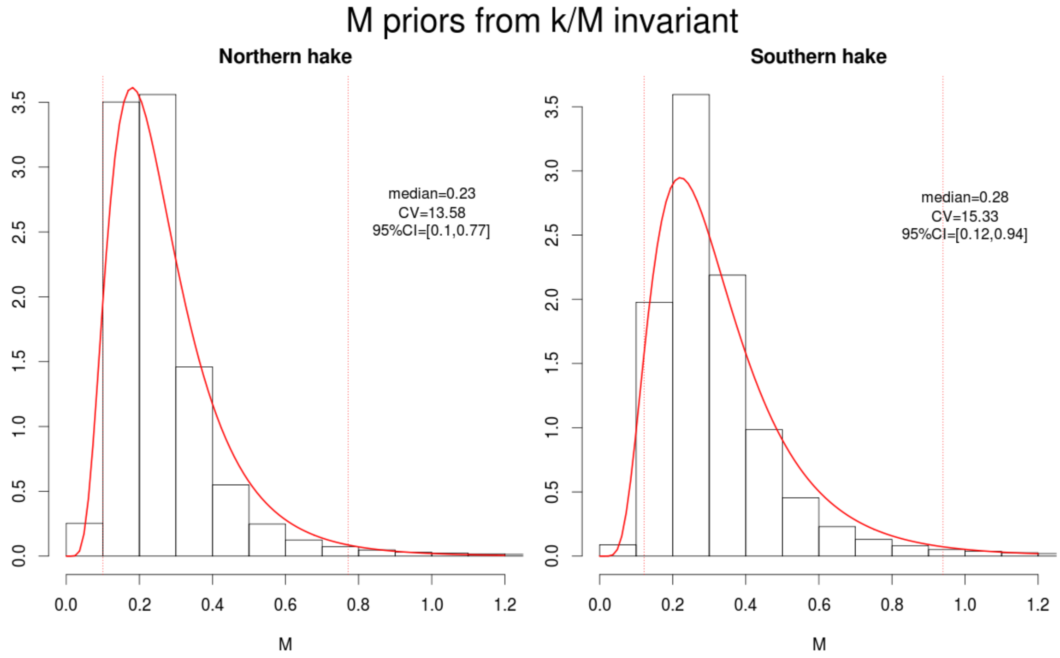


Figure 11. M prior distribution for Northern hake (left panel) and Southern hake (right panel)

Lorenzen (1996) point to the existence of an allometric relationship between natural

mortality and body weight, in fish, of the form M = *a* + W ^ *b* where is natural mortality at weight W, *a* is mortality at unit weight, and *b* is the allometric exponent. Based on empirical studies with different populations Lorenzen found out the following parameters: b=−0.288 (90% CL[−0.315, −0.261]) and a=3.00 (90% CL[2.70, 3.30]) year−1. More recently Cook (2013) uses this equation in an assessment model for haddock getting the following parameters: a=3.69 and b=-0.305 and confirming the Lorenzen assertion that *b* is relatively constant among different species. Figure 12 shows the M estimated for Southern hake based on Lorenzen figures and hake parameters. The model produces high M at length figures for small hake (e.g. M= 1.8 for age 0 and M=3.5 for length 1cm) that decreases until 0.18 at length 130 cm or age 15.

An ulterior development of the natural mortality model will aim to the introduction of higher values for small hake based on the high predation mainly caused by cannibalism. Literature review and preliminary analysis of Southern hake will provide the information for the M for this small hake. This model will include two parameters plus the usual constant M. At this time only the prior for the constant M was estimated.

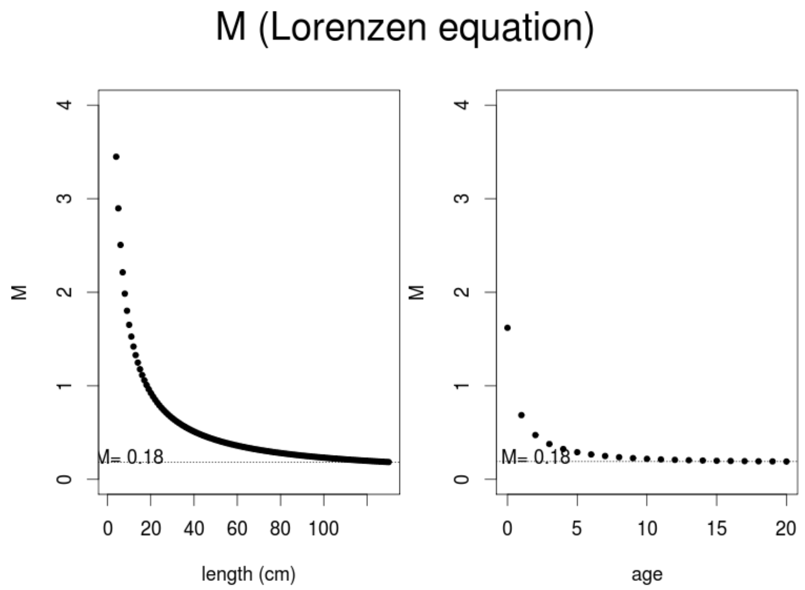


Figure 12. Lorenzen estimates of M at length and M at age.

Table 3. Summary of the developed priors for Lmat, Linf, k and M and Linf/Lmat and k/M.

parameter	function	Northern Parameters	Southern Parameters
L 50% maturity	normal	mean=42.29; sd=2.24	mean=37.95; sd=3.09
Linf (von Bertalanffy)	normal	mean=100.42; sd=9.48	mean=90.15; sd=10.17
k (von Bertalanffy)	lognormal	median=0.15; CV=0.31	median=0.17; CV=0.33
M	lognormal	median=0.27; CV=0.54	median=0.31; CV=0.55
Linf/Lmat	normal	mean=2.37; sd=0.19	
k/M	lognormal	median=0.58; CV=0.41	

GADGET runs

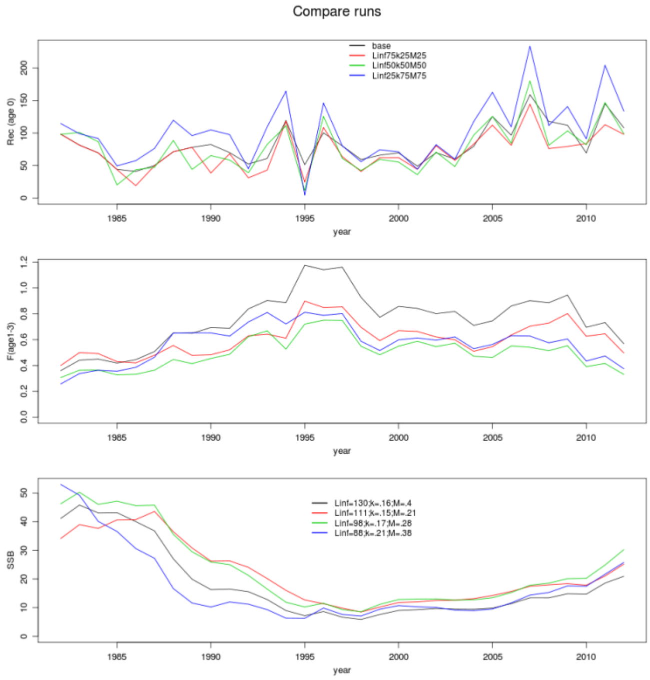
To analyse the sensitivity of current GADGET model to the results of the life-history invariants analysis it was decided to perform 3 runs: 1 with the medians of Linf, k and M and 2 more runs with the 25 and 75 percentiles. To be consistent with the relationship between these correlated parameters, these two runs used the following percentiles: first with 75%-Linf, 25%-k and 25%-M and second with 25% Linf, 75%-k and 75%-M. The parameters for these 3 runs are described in the following table. These parameters were set as constant and the model was fit estimating recruitment from1982 to 2012, abundance at age in 1982 (ages 1-8) and fleets selection.

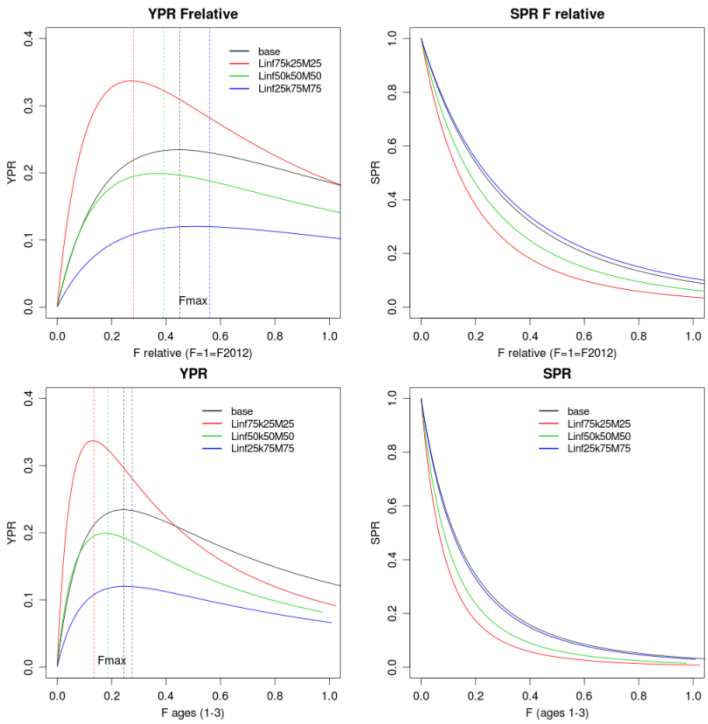
Nº	Run name	Life-history values (constants)	Lik result
1	Base (WGHMM2013)	Linf = 130; k = 0.164; M=0.4	Lik= 928.26
2	LHLinf75k25M25	Linf = 110.690; k = 0.147; M=0.212	Lik= 1037.88
3	LHLinf50k50M50	Linf = 97.778; k = 0.173; M=0.279	Lik=970.76
4	LHLinf25k75M75	Linf = 87.547; k = 0.208; M=0.378	Lik=908.55

Compare GADGET likelihoods

Compare GADGET parameters

Compare results





Discussion

Hake is a sex dimorphic species with different size at maturity and different growth in both sexes. Females mature larger than males and have larger sizes than males. The exercise performed here was done to estimate parameters for a model with sexes combined. So, the initial information for this sequential estimation was Lmat, which is the yearly L50% maturity for both sexes combined. And then, the estimated parameters for growth (k and Linf) and M correspond also to both sexes combined.

An assessment model like those performed for both hakes with SS3 or GADGET with sexes combined always have to make some assumptions. In this case, that Linf is equal to 130 cm and M=0.4. With these constant figures k is estimated by the model explaining the observed catches. The Linf estimated here showed figures around 100 cm, well below 130 cm set for ICES models. This is because Linf is estimated from a sex combined Lmat. Meanwhile in ICES Linf was mainly based on the higher observed hakes, which are females. Both approaches make different assumptions: (1) the ICES approach assumes that all hakes in the population might reach 130 cm. However we know that approximately half of the population, the males, rarely achieves 75 cm. However, since k (and also recruitment) was estimated to fit the past population productivity, it is expected that the final combination of model parameters for growth and mortality be able also to predict the future productivity. (2) On the other side, the approach presented here based on LHI would assume that all population achieves a Linf around 100 cm. In this case we lost the option of half of the population (females) growing larger and the other half growing shorter (See Cerviño, *in press* for comparisons among hake male and female growth and M parameters). Since fishing selection is mainly based on fish length this assumption might also have an impact on the productivity. Furthermore, there are a lot of catch data with figures well overestimated Linf that will be difficult to implement in the model with a short Linf. Which approach in better? ANY MODEL APPROACH BASED ON SEXES COMBINED WILL LOST AN IMPORTANT PART OF THE REALITY. In any case 130 cm seems to be an extremely large Linf, even for females, where mean historic northern hake Lmat is about 48 cm (Dominguez *et al.*, 2008) and the mean Linf based on LHI would be around 114 cm. An impact analysis of both approaches on assessment results and reference points may be seen on annex I.

The approach also provides information for k and M. k is conditioned to Linf so it cannot be used as a prior if Linf is different. However the prior for the correlation among k and Linf might be used if required.

M presents figures around 0.3 with a high CV (~0.5). This seems to be below current M (0.4) used in ICES models. The approach used by ICES follows the Hewitt and Hoenig (2005) approach based on longevity and assuming that hake lives around 10 years. This approach provides a mean M for all ages. However we have to consider that LHI approach provides M figures only for mature fish (above 40 cm aprox). M for immature fish should be estimated following other methods like Lorenzen's (1996). These approaches might be complementary predicting that immature hake (<40 cm) M should be higher than 0.4 in order to get the mean 0.4 predicted by Hewitt and Hoenig (2005). This is in agreement with other studies based on hake that predict a high M for small hakes because of cannibalism (Jurado-Molina *et al.*, 2006), limited food or predation, including cannibalism (Smith, 1995).

In summary, the ICES models cannot be able to estimate growth and M (apart of other parameters like recruitment, selection, etc), and is required to fix two of these parameters (Linf and M) allowing to estimate k. The approach presented here provide information to explore figures for this parameters that might be directly input in the model (M or Linf means); ranges to explore (e.g. inside a confident interval of 90%) or using the invariants distribution to set one of them once that other have been set.

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Annex I. Comparison between Southern hake GADGET results with Linf=130 and Linf=105 cm.

Two model for Southern hake have been fit with M=0.4, k estimated and Linf set as 130 (model 1) or 105 (model 2). The quality of the fit is better for model 1 (Table 1)

Table 1. summary results

Model	Linf	K (estimated)	Likelihood
Model 1	130	0.168	928
Model 2	105	0.189	979

Reference points

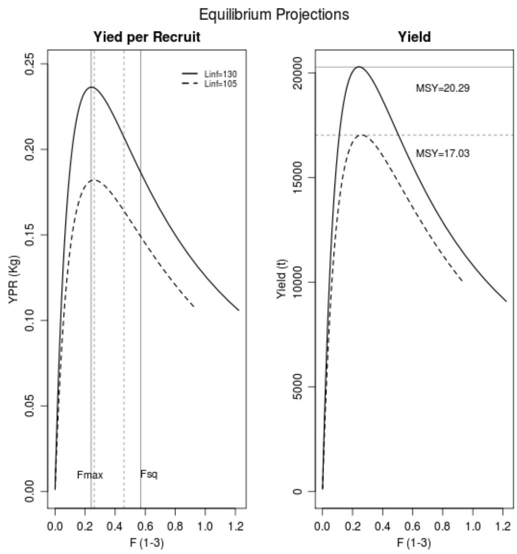

Figure 1. Yield-per-recruit (left) and absolute yield (right). Fsq is the F estimated for the last year in the model (2012). YPR and Yield are higher at all levels of F for model 1 compared to model 2. Model 1 presents a MSY a 15% higher than model 2. Fmax is quite similar in both models however the stock status (current F regarding Fmax) is better for model 2

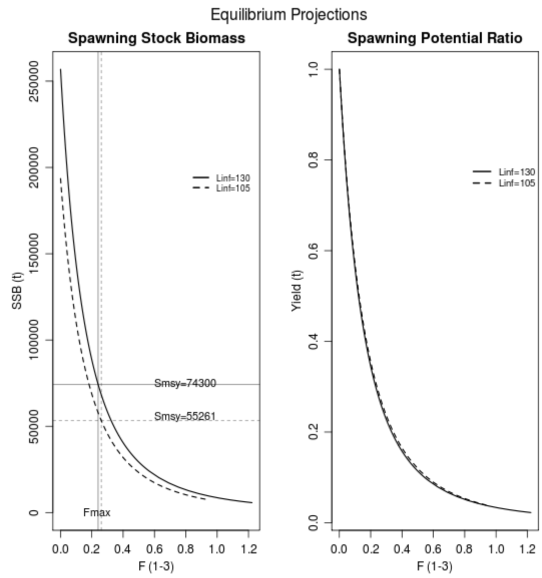

Figure 2. Spawning-stock biomass (left) and SPR (right) against F. SSB size at Fmax (Smsy) is a 50% higher for model 1, however the similarity in SPR for both model tell us that F SPR reference points are quite similar.

Conclusion.

Setting Linf at different values produces fits of different quality with populations of quite different productivity (yield), different size (SSB) and different status (Fcurrent/Fref). However reference F reference points based on YPR or SPR remains relatively similar.

WD 04 Standardization of the LPUE series of the Northern Spanish coastal bottom otter trawl fleet to tune the assessment of the Iberian megrims stocks

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ABSTRACT

There are two tuning fleets which have been used in the assessment of Iberian stocks of megrim: Northern Spanish coastal bottom otter trawlers landing in A Coruña port ("SP-CORUTR8c") and Avilés port ("SP-AVILESTR"). However, it is known the existence of changes in the fishing strategy of this fleet in recent years, which has diversified into demersal and pelagic fishing activities. As consequence, these tuning fleets show noisy behaviour through the time-series, and they are partially used in the assessment of megrims (1990-1999 for "SP-CORUTR8c" tuning fleet in the assessment of four-spot megrim and 1990-2003 for "SP-AVILESTR" in the megrim assessment). In the present work the disaggregation in métiers of the whole time-series available (1986-2012) is provided for landings and effort of the Northern Spanish coastal bottom otter trawlers landing in both harbours (A Coruña and Avilés): métier targeting demersal fish (OTB_DEF_>=55_0_0) and métier targeting a mixed of demersal and pelagic fish (OTB_MPD_>=55_0_0). The first métier is considered the most appropriate to assess benthic fish as megrims.

INTRODUCTION

Administrative control is achieved through a common fishing license for the whole Northern Spanish coastal trawl fleet, the size of which has decreased from 279 vessels in the early 1990s (STECF, 1994) to 99 vessels registered in 2012 (64.5% of reduction). During the last two decades, the Northern Spanish coastal trawl fleet has been made up of boats using two main gear types, the bottom otter trawl and the bottom pair trawl. The pairtrawlers have been traditionally defined as a highly mono-specific fleet, targeting blue whiting (*Micromesistius poutassou*) and hake (*Merluccius merluccius*) by using a characteristic gear which permits a vertical opening up to 25 m. However, another fishing strategy targeting mackerel (*Scomber scombrus*) has been recently identified (Castro *et al.*, 2010).

Regarding bottom otter trawlers, they use different type of trawl gears depending on the target species (Lema *et al.*, 2006): traditional trawl gear to catch demersal species ("*baca*") and a Vertical High Opening (VHO) trawl gear ("*jurelera*") directed to pelagic fish. They can be alternatively used during the same trip, complicating the precise separation of both activities. Therefore, it was determined that the more accurate disaggregation protocol is to apply multivariate methodologies to the landing matrix by trip and species in percentage. Punzon *et al.* (2010) found four different fishing strategies by using the multivariate technique CLARA (Kaufman and Rousseeuw, 1990) to a time-series of landings by trip (1983-2004): 1) trips with mixed of demersal species as hake, monkfish (*Lophius piscatorius* and *L. budegassa*), and megrim (*Lepidorhombus boscii* and *L. whifiagonis*) (each one around 10% in weight of landings), 2) trips targeting horse mackerel (*Trachurus trachurus*) (63%) 3) trips targeting mackerel (76%), and 4) trips targeting blue whiting (62%).

This methodology has been routinely applied to the Spanish logbooks since 2009, when the DCF regulation was implemented, in order to split the Northern Spanish coastal bottom otter trawl activity into the following two DCF métiers:

- **OTB_DEF_>=55_0_0**: bottom otter trawl targeting demersal species by using 70 mm mesh size (Spanish regulation: Real Decreto 1441/1999). This métier is developed by around 60 vessels (mainly between 24-40 m of length) operating in the Spanish waters of ICES Divisions VIIIc and IXa (Castro *et al.*, 2011). In the Northern Portuguese waters of Division IXa a smaller number of vessels (around 5 vessels) develop a similar fishing strategy (Map 1). Main ports of landings are in Galicia: A Coruña (30% of total ladings), Vigo (18%), Marín (13%) and Burela (11%).

- **OTB_MPD_>=55_0_0**: bottom otter trawl targeting a mixed of pelagic and demersal species by using 55 mm mesh size (Spanish regulation: APA/16/2002). This DCF métier cover the two fishing tactics identified by Punzon *et al.* (2010) targeting horse mackerel and mackerel (accompanied by some demersal species, mainly hake). This métier is developed by a large number of the same vessels developing the previous métier, but exclusively operating in Spanish waters (mainly VIIIc). Main ports of landings are also in Galicia: A Coruña (39%), Burela (23%) and Ribeira (16%). Trips targeting mackerel show a clear seasonality concentrating in February and March.

A decline in the importance of the fourth fishing tactic targeting blue whiting started to be evident from the late 1990s, probably due to competition with pair trawling (Lema *et al.*, 2006). Since 2009, when DCF métier disaggregation started to be routinely applied to Spanish logbooks, this fishing tactic never again was detected.

During the last WGHMM, a number of problems were identified in the megrims assessment in order to be analysed during the WKSOUTH benchmark (ICES, 2013). Regarding commercial data, the "SP-CORUTR8c" tuning fleet (Northern Spanish coastal bottom otter trawlers landing in A Coruña port) was partially used in the assessment of four-spot megrim (only time-series 1990-1999) due to the increasing use of the "*jurelera*" trawl gear targeting other species than megrim in the last decade.

Therefore, the métier disaggregation of the SP-CORUTR8c tuning fleet was developed as inter-seasonal work between WGHMM 2013 and WKSOUTH 2014. Moreover, the "SP-AVILESTR" tuning fleet (Northern Spanish coastal bottom otter trawlers landing in Avilés port), used as tuning fleet in the assessment of megrim just to 2003, was also split in DCF métiers and updated (until 2012). To develop both tasks it was necessary to compile and analyse the commercial data of the period 2004-2008, which was missed between the periods available: 1983-20031 (Punzon *et al.*, 2010) and 2009-2012 (DCF period).

1 2004 data from Punzón *et al.* (2010) was based in partial sampling.

MATERIAL AND METHODS

A dataset was compiled from the official logbooks of the Northern Spanish coastal bottom otter trawl fleet for the period 2004–2008, which has been facilitated by the Spanish ministry responsible for fisheries (MAGRAMA: "*Ministerio de Agricultura, Alimentacion y Medio Ambiente*"). This dataset contains information on fishing area, date of landing, landing port, base port, and landed weight of species by trip, fishing day and ICES rectangle. This dataset was used to develop the analytical work which is here shown.

Moreover, the original data from Punzon *et al.* (2010) was also available in order to split landings and effort by fishing tactic and port (A Coruña and Avilés) for the old time-series (1983-2003). Landings and effort data by DCF métier was also taken from the IEO databases for the recent period (2009-2012). Finally, the time-series provided to ICES (1983-2012) for the whole Northern Spanish coastal bottom otter trawl fleet was taken for raising (ICES, 2013). This last process was needed due to the low sampling level detected in some years of the old time-series (Table 1): years 1999 and 2000 in A Coruña port and years 1994-2003 for Avilés.

To classify trips, a non-hierarchical cluster technique was applied to the landings matrix by trip and species, the same methodology used by Punzón *et al.* (2010) and currently applied by the IEO fishery data programme. Five multivariate analyses were developed, one per year of the time-series (2004-2008). The "*Clustering Large Applications*" method (CLARA) is a partitioning clustering method specifically designed for clustering large datasets (Kaufman and Rousseeuw, 1990). Its algorithm works by applying a "*Partitioning Around Medoids*" method (PAM) to data subsets of fixed size, allowing the user to try different levels of sampling. One valuable advantage of CLARA and PAM methods is that they provide a quality index which facilitates a more objective selection of the most appropriate number of clusters. This "*silhouette coefficient*" is calculated for each cluster (*s*) and the whole clustering procedure (ASW: "*average* *silhouette width*"). An interpretation proposed by Kaufman and Rousseeuw (1990) identifies a reasonable structure when ASW is higher than 0.5.

Computations were performed using the R statistical language (R Development Core Team, 2008). Cluster analysis was performed using R package cluster (Maecheler *et al.*, 2005).

RESULTS

After testing different number of groups, the highest ASW values were obtained by splitting into 4 groups for years 2004 and 2005, and by splitting into 3 clusters for years 2006-2008 (Table 2). Except for year 2004, all the ASW coefficients obtained are significant (>0.5). Table 3 shows the specific characterization for each cluster, each of them with different catch profile:

- Cluster k1: mixed landings profile where, in addition of blue whiting and horse mackerel, demersal stocks stand by their higher presence compared to the other métiers: anglerfish (12.5%), hake (8.7%), megrim (7%)…
- Cluster k2: the main species by weight is horse mackerel (80.4%).
- Cluster k3: the main species by weight is mackerel (83.1%).
- Cluster k4: the main species by weight is blue whiting (52.3%).

The cluster disaggregation obtained for the period analysed (2004-2008) was linked to the periods 1983-2003 (Punzon *et al.*, 2010) and 2009-2012 (DCF period): landings (t) and effort (fishing days standardized by power: fd/1000*HP/100). However, due to the low sampling level in particular years of the old period, the ICES landings and effort time-series of the whole Spanish trawl activity was used in order to raise the values (Figures 1 and 2).

Due that cluster 4 has disappeared in this last decade, the first three clusters were re-aggregated into the current DCF métiers: OTB_DEF_>=55_0_0 (cluster k1 targeting demersal fish) and OTB_MPD_>=55_0_0 (integrating clusters k2 and k3 directed to horse mackerel and mackerel, respectively). Finally, as the species of megrims are not properly identified in log-books (both recorded at genus level), the ratio of species obtained by yearly sampling (IEO data) was applied to split landings by species, four-spot megrim (*L. boscii*) and megrim (*L. whiffiagonis*). Therefore, LPUE are provided by species (four-spot megrim and megrim), DCF métier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and landing port (A Coruña and Avilés) in Tables 4-5 and Figures 3-4.

DISCUSSION

The same methodology has been applied to the three time-series available trying to establish a consistent link: 1983-2003 (obtained from Punzón *et al.*, 2010), 2004-2008 (period recovered here) and 2009-2012 (DCF period). The results obtained show the evolution of four fishing tactics with different target species: demersal fish, horse mackerel, mackerel and blue whiting. This last fishing tactic shows a decreasing from the late 1990s, probably as a consequence of the increasing of the pair trawl fishing activity, which obtains higher yields per trip (Lema *et al.*, 2006). The OTB fishing activity targeting blue whiting completely disappears in the Avilés and A Coruña fleets in 2001 and 2006, respectively.

The fishing tactic targeting horse mackerel seems to be important from the beginning of the series (Figures 1 and 2). However, it keeps being important for the A Coruña fleet while it has been practically disappeared in Avilés from the late 1990s. The other pelagic fishing tactic, the one targeting mackerel, shows lower levels of effort due to its seasonal character, mainly concentrated in February and March. It takes advantage of the spawning migration of mackerel to the north coast of Spain at the beginning of the year (Sola *et al.*, 1990), as do other fleets targeting mackerel in the same areas, such as purse-seiners (Villamor *et al.*, 1997) and handlines (Punzón and Villamor, 2009). However, an increase, more evident in Avilés, can be observed from 2000, probably in response to improved market conditions for mackerel (Punzón *et al.*, 2004). The fishing tactic targeting demersal fish shows a moderate decreasing through the time-series, and results the more important fishing tactic in Avilés compared with the remained trawl fishing tactics.

Since 2009, these three fishing tactics are re-aggregated in two DCF métiers following the pan-European "*Data Collection Framework*" for fishery data: OTB_DEF_>=55_0_0 (corresponds to fishing tactic targeting demersal fish) and OTB_MPD_>=55_0_0 (integrates both fishing tactics targeting horse mackerel and mackerel). This procedure was applied backwards to the recovered time-series in order to obtain a robust index (LPUE) feasible to be used as tuning fleet. Due to benthic species are target objective of OTB_DEF_>=55_0_0, it is recommended to use the LPUE of this métier as tuning fleet in the assessment of megrims.

LPUE of A Coruña OTB_DEF_>=55_0_0 shows different levels and trends between megrim species, being higher (average of 13.7 and 2.4 t by standardize effort unit for four-spot megrim and megrim, respectively) and with a remarkable increasing trend for four-spot megrim since middle 90's (Figure 3). However, Avilés OTB_DEF_>=55_0_0 gives similar indices (13.7 and 13.8 t by standardize effort unit for four-spot megrim and megrim, respectively), showing a more balanced abundance of both species in Cantabrian waters than was observed in North-western Iberian waters (Figure 4).

The changes detected in the fishing strategy of a fleet may have led to variations in trends of the tuning indices used in stock assessment which are not related to species abundance. Therefore, LPUE series should be computed by métier in order to provide more homogeneous yielding indices which can improve the knowledge of the stock evolution.

CONCLUSIONS

Eight new LPUE time-series can be obtained by DCF métier, landing port and megrim stock. However, the four time-series of the métier targeting demersal fish are recommended to be tested in the assessment of megrims:

- LPUE of métier OTB_DEF_>=55_0_0 in A Coruña port for four-spot megrim (LDB).
- LPUE of métier OTB_DEF_>=55_0_0 in A Coruña port for megrim (MEG).
- LPUE of métier OTB_DEF_>=55_0_0 in Avilés port for four-spot megrim (LDB).
- LPUE of métier OTB_DEF_>=55_0_0 in Avilés port for megrim (MEG).

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Table 1. Available databases of the Northern Spanish coastal bottom otter trawl fleet used in the time-series compilation: number of trips by year and port (A Coruña and Avilés). [Numbers between brackets are based in partial samplings; "*na*": not available].

	A Coruña		Avilés	
Year	Punzón et al (2010)	LOGBOOKS	Punzón et al (2010)	LOGBOOKS
1983	na	na	2698	na
1984	na	na	2331	na
1985	na	na	2195	na
1986	4446	na	2390	na
1987	4010	na	1858	na
1988	4873	na	2069	na
1989	5295	na	na	na
1990	5542	na	1992	na
1991	5089	na	1786	na
1992	5055	na	1107	na
1993	5694	na	1070	na
1994	5169	na	na	na
1995	5470	na	[144]	na
1996	4858	na	na	na
1997	4789	na	na	na
1998	3494	na	[110]	na
1999	[263]	na	[427]	na
2000	[504]	na	[378]	na
2001	3532	na	[246]	na
2002	3211	na	[314]	na
2003	2690	na	[269]	na
2004	[489]	3351	[374]	538
2005	na	3542	na	855
2006	na	3326	na	881
2007	na	3412	na	631

2008	na	3216	na	579
2009	na	3161	na	666
2010	na	3054	na	527
2011	na	2312	na	488
2012	na	2366	na	680

Table 2. Results of CLARA clustering (*k*: number of clusters; *ASW*: average silhouette width; and *s*: silhouette coefficient by cluster).

Year	k	ASW	S(k1)	S(K2)	S(K3)	S(k4)
2004	4	0.45	0.05	0.68	0.59	0.47
2005	4	0.50	0.22	0.71	0.75	0.36
2006	3	0.56	0.25	0.69	0.77	--
2007	3	0.58	0.36	0.74	0.70	--
2008	3	0.54	0.40	0.70	0.73	--

Table 3. Mean landing profile (%) by cluster (mean of the analysed period 2004-2008).

SPECIES	AL3	K1	K2	K3	K4
Atherinidae	SIL	0.3	0	0	0
Boops boops	BOG	0.4	0.3	0	0.1
Eledone spp	OCM	4.0	0.2	0.2	0.5
Galeorhinus galeus	GAG	0.4	0	0	0
Galeus melastomus	SHO	0.4	0	0	0
Illex illecebrosus	SQI	2.4	0.1	0	0.9
Lepidorhombus spp	LEZ	7.0	1.0	0.2	4.4
Loligo spp	SQC	1.3	0.2	0	1.4
Lophiidae	ANF	12.5	1.4	0.4	5.6
Merluccius merluccius	HKE	8.7	2.4	0.7	5.2
Micromesistius poutassou	WHB	24.7	1.8	0.7	52.3
Mullus spp	MUX	0.6	0	0	0
Nephrops norvegicus	NEP	1.0	0	0	0.5
Octopus vulgaris	OCC	1.8	0.1	0.1	0.4
OTHERS	OTH	8.5	2	4.6	4.3
Pagellus acarne	SBA	0.3	0.1	0	0.2
Phycis blennoides	GFB	0.3	0	0	0
Raja spp	SKA	1.5	0.4	0.1	0.4
Scomber scombrus	MAC	8.0	8.8	83.1	5.4
Scyliorhinidae	SYX	0.4	0	0	0
Trachurus spp	JAX	10.8	80.4	9.5	17.3
Triglidae	GUX	1.3	0.1	0.1	0.4
Trisopterus luscus	BIB	3.9	0.5	0.2	0.7

Table 4. LPUE (t/fd/1000*HP/100) of four-spot megrim (*L. boscii*) by DCF métier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and port (A Coruña and Avilés).

	A Coruña		Avilés	
Year	OTB_DEF_>-55_0_0	OTB_MPD_>-55_0_0	OTB_DEF_>-55_0_0	OTB_MPD_>-55_0_0
1986	9.8	8.8	6.8	4.5
1987	14.9	11.7	10.4	8.2
1988	7.0	6.3	14.0	12.5
1989	6.2	4.1	10.9	9.3
1990	7.8	4.2	19.7	17.6
1991	9.8	4.2	12.2	10.1
1992	6.6	3.5	15.5	12.5
1993	7.8	4.2	16.1	13.0
1994	10.6	6.6	14.0	11.0
1995	11.0	7.6	24.7	15.3
1996	7.2	6.2	16.4	12.4
1997	7.9	5.4	18.7	13.9
1998	14.4	11.6	11.0	13.3
1999	11.7	13.2	11.3	9.7
2000	16.4	12.7	13.8	10.1
2001	20.2	9.8	12.5	9.6
2002	13.0	8.0	11.3	4.6
2003	11.6	5.7	5.7	1.9
2004	18.2	8.7	14.8	5.0

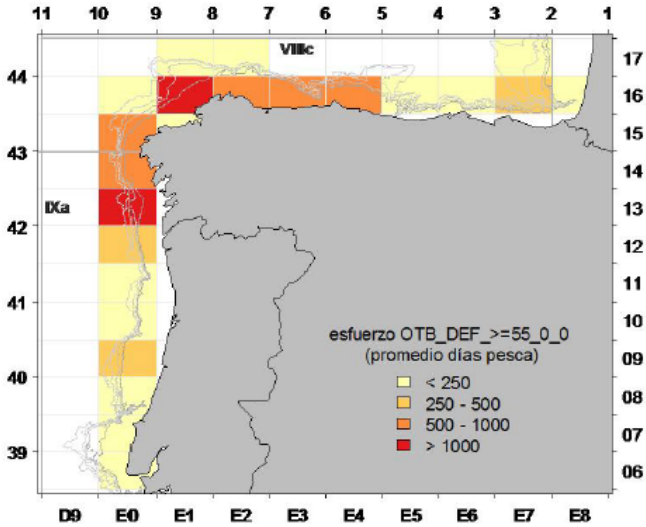
2005	13.6	6.0	15.2	1.9
2006	15.9	6.5	11.6	1.5
2007	17.9	7.3	8.9	1.8
2008	22.0	8.1	7.2	0.6
2009	17.3	6.9	18.5	2.2
2010	29.3	13.3	25.4	3.1
2011	24.8	11.9	19.6	4.2
2012	16.7	10.1	4.3	0.8
AVERAGE	13.7	7.9	13.7	7.8

Table 5. LPUE (t/fd/1000*HP/100) of megrim (*L. whiffiagonis*) by DCF métier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and port (A Coruña and Avilés).

	A Coruña		Avilés	
Year	OTB_DEF_>-55_0_0	OTB_MPD_>-55_0_0	OTB_DEF_>-55_0_0	OTB_MPD_>-55_0_0
1986	2.2	2.0	21.2	14.2
1987	2.9	2.2	17.6	13.9
1988	2.6	2.3	24.6	22.0
1989	2.0	1.4	19.8	16.9
1990	3.1	1.7	36.9	32.9
1991	3.1	1.3	15.0	12.4
1992	3.1	1.6	15.5	12.5
1993	1.5	0.8	18.5	15.0
1994	3.8	2.3	11.4	8.9
1995	0.9	0.6	9.7	6.0

1996	2.4	2.1	17.1	13.0
1997	2.4	1.6	19.2	14.2
1998	3.6	2.9	12.2	14.7
1999	2.6	3.0	12.7	10.9
2000	3.3	2.6	10.5	7.6
2001	2.3	1.1	11.2	8.5
2002	2.0	1.2	9.1	3.7
2003	1.7	0.8	5.7	1.9
2004	1.7	0.8	14.8	5.0
2005	1.3	0.6	11.1	1.4
2006	1.4	0.6	9.6	1.2
2007	1.8	0.7	4.8	1.0
2008	1.3	0.5	5.3	0.4
2009	1.1	0.4	5.1	0.6
2010	2.0	0.9	11.7	1.4
2011	3.4	1.6	18.7	4.0
2012	5.6	3.5	4.4	0.8
AVERAGE	2.4	1.5	13.8	9.1

Map 1. Geographical effort distribution of the two DCF metiers of the Northern Spanish coastal bottom otter trawl fleet: OTB_DEF_>=55_0_0 (bottom otter trawl targeting demersal fish) and OTB_MPD_>=55_0_0 (bottom otter trawl targeting a mixed of pelagic and demersal fish).



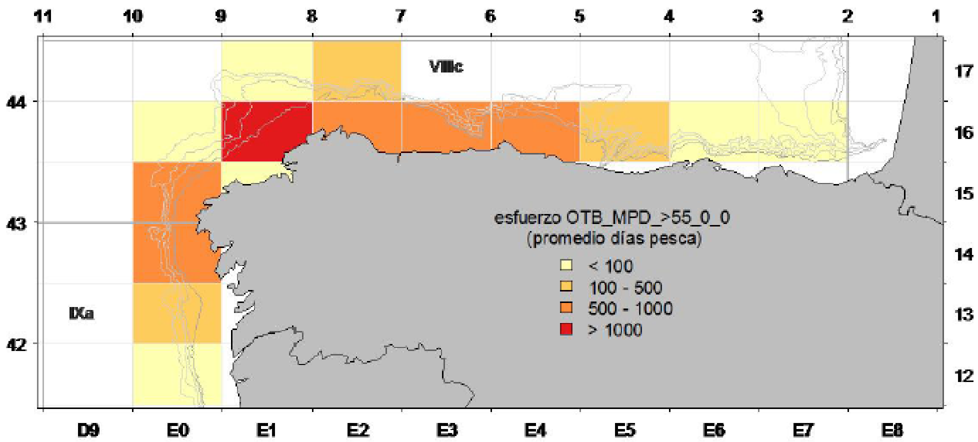


Figure 1. Effort (fd/1000*HP/100) by cluster of the Northern Spanish coastal bottom otter trawl fleet landing in A Coruña port: k1 (fishing tactic exploiting demersal fish), k2 (horse mackerel), k3 (mackerel), and k4 (blue whiting).

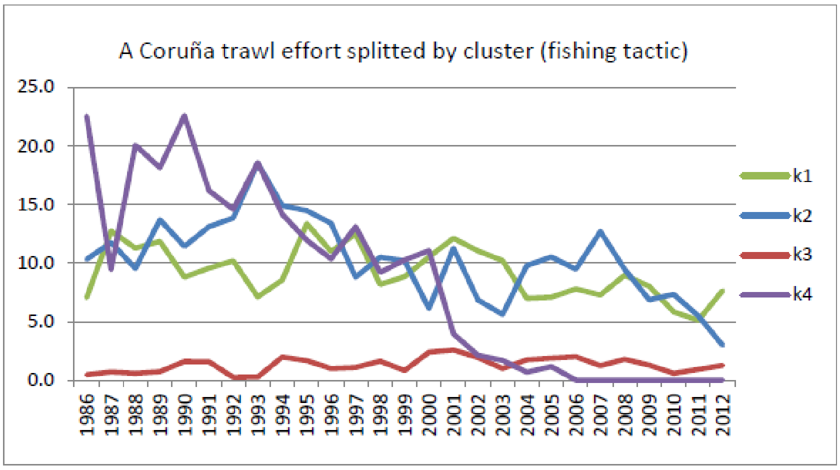


Figure 2. Effort (fd/1000*HP/100) by cluster of the Northern Spanish coastal bottom otter trawl fleet landing in Avilés port: k1 (fishing tactic exploiting demersal fish), k2 (horse mackerel), k3 (mackerel), and k4 (blue whiting).

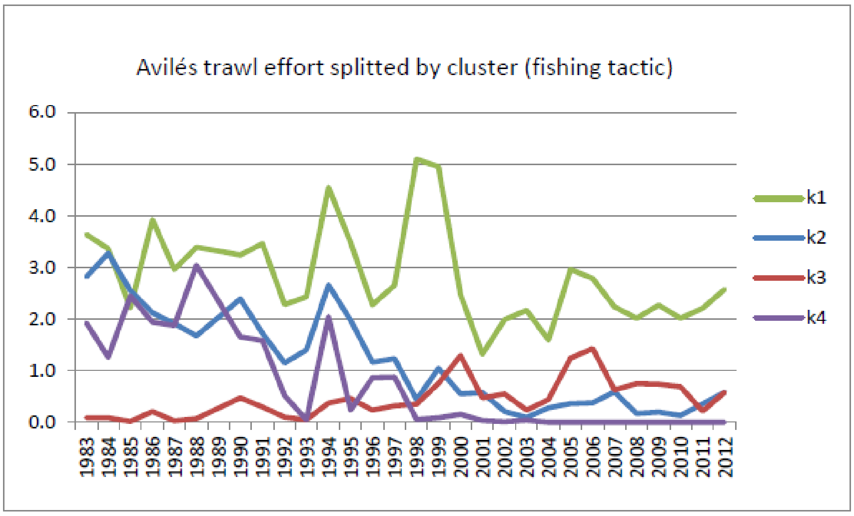


Figure 3. LPUE (t/fd/1000*HP/100) of A Coruña OTB_ DEF_>=55_0_0 metier for four-spot megrim (LDB) and megrim (MEG).

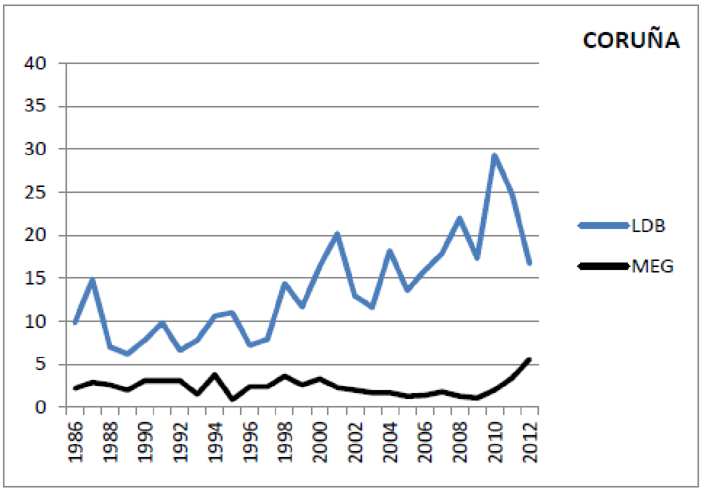
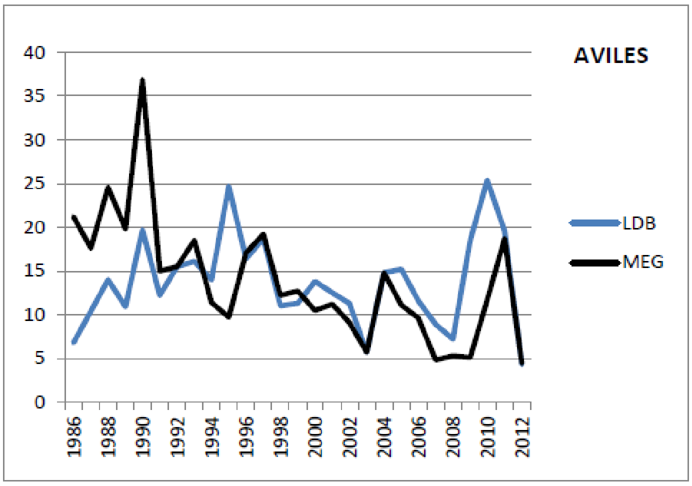


Figure 4. LPUE (t/fd/1000*HP/100) of Avilés OTB_DEF_>=55_0_0 metier for four-spot megrim (LDB) and megrim (MEG).



Annex 3: Participants list

Data Compilation Workshop on Southern Megrim and Hake Stocks (DCWKSOUTH)

30 October–1 November 2013

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Benchmark Workshop on Southern Megrim and Hake Stocks (WKSOUTH)

3 February–7 February 2014

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Annex 4: WKSOUTH review of biological reference point for Southern and Northern hake.

Participants: Catherine Michielsens (External Chair), Lisa Readdy (Chair), Carmen Fernandez, Daniel Howell, Santiago Cervino, Esther Abad, Joao Figueiredo Pereira, Anne Cooper (ICES secretariat).

WKSOUTH members met, via WebEx, to discuss proposed biological reference points for two stocks of hake put forward by the expert working group for the Bay of Biscay and Iberic Waters Ecoregion (WGBIE)

Hake in Divisions VIIIc and IXa (Southern stock)

During the expert working group meeting, WGBIE in 2014, it was discussed that the B_{lim} value originally set (35 000 tonnes) should no longer be considered an appropriate recovery target, due to the fact that this estimate was based on an earlier stock assessment model, whereas the current assessment model indicates that 35 000 tonnes is no longer in the range of historic SSBs produced by the model. Therefore, B_{lim} would need updating, taking into account the current stock assessment. WKSOUTH members agreed with this conclusion.

The diagnostics from stock recruit relationship showed no real trend in recruitment within the range of historically observed SSBs. WKSOUTH agreed that the justification used by the expert working group, WGBIE, for selecting the new proposed B_{lim} value was appropriate.

WKSOUTH also agreed that because the lowest SSB showed (slightly) below average recruitment, it would be more appropriate and more precautionary to select the lowest SSB which produced average or above average recruitment. This leads to choosing B_{lim} close to the 5th lowest value in the historical series

WKSOUTH recommended that WGBIE should also consider a B_{pa} and an MSY $B_{trigger}$ for this stock in the near future.

Hake in Divisions IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d (Northern stock)

Using the new accepted benchmarked assessment, WGBIE produced the following new reference points: B_{lim}, B_{pa}, MSY $B_{trigger}$ and F_{msy}.

As with Southern hake, B_{lim} for Northern hake was selected based on the Bloss approach due to the fact that the Hockey Stick relationship produced a potential B_{lim} (at the breakpoint of the hockey-stick) which was higher than a large number of the historical SSB values. Considering that the stock has shown considerable increases in SSB from low SSB levels, even under fishing mortalities substantially above the F_{msy} value proposed by WGBIE, while taking into account a more precautionary approach (hence, avoiding to choose Bloss as B_{lim}), WKSOUTH agreed with WGBIE that the SSB in 2006, 25% higher than the lowest observed SSB, was an appropriate value to use given the justification outlined in Annex R of the WGBIE 2014 report.

WKSOUTH agreed with the application of the default approach (used by many ICES stocks) to produce B_{pa} and MSY $B_{trigger}$ to the northern hake stock.

WKSOUTH agreed that the methodology used to derive F_{msy} and to evaluate the ICES MSY harvest control rule followed the guidelines set out by ICES within the expert workshop WKMSYREF2 (ICES 2014/ACOM:47). Because of the features of the northern hake assessment, the software put forward by WKMSYREF2 (PlotMSY and EqSim) could not be applied to northern hake. It was noted that the R program developed specifically for northern hake is similar to the software available (in particular, EqSim), but takes into account the differing data structure of the Hake model. Having viewed all the available diagnostics from the northern hake results and considering the consistency between the methods, WKSOUTH were happy with the outcomes from this software and accepted all the biological reference point proposed by WGBIE for this stock.

References

ICES. 2014. Report of the Workshop to consider reference points for all stocks(WKMSYREF2), 8-10 January 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014/ACOM:47. 91 pp.