# BENCHMARK WORKSHOP ON SELECTED MEGRIM STOCKS (WKMEGRIM; outputs from 2022 meeting)

VOLUME 5 | ISSUE 61

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

**ICES** INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
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ISSN number: 2618-1371

# ICES Scientific Reports

Volume 5 | Issue 61


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### Recommended format for purpose of citation:


ICES. 2023. Benchmark workshop on selected megrim stocks (WKMEGRIM; outputs from 2022 meeting). ICES Scientific Reports. 5:61. 240 pp. https://doi.org/10.17895/ices.pub.21769325



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# Contents

# i Executive summary

The main aim of the ICES WKMEGRIM benchmark was to standardize, increase transparency, and review the input data of the assessment for three megrim stocks; namely two *Lepidorhombus whiffiagonis* stocks in divisions 7.b–k, 8.a–b, and 8.d (meg.27.7b-k8abd) and divisions 8.c and 9.a (meg.27.8c9a), as well as *L. boscii* in divisions 8.c and 9.a (ldb.27.8c9a).

For all three stocks, the data collection methods were reviewed, the biological data (maturity and length-weight relationships) were updated based on newly available data, a variety of tuning indices were considered, and new assessment frameworks were employed and configured.

Scrutiny applied to historic data lead to re-assessing how discard data and catches of recruits were treated in the assessment, where catches of recruits reported from old monitoring programmes were removed and set to be estimated in the assessment model. New maturity ogives based on best-practice histological methods were adopted and the use of female-only ogives were selected. Fisheries independent surveys were available, sufficient, and often better (without inexplicable deviations) for all stocks. Therefore, only fisheries independent surveys were utilized as tuning fleets in all assessments. Recent improvements to standardizing the commercial tuning fleets for the southern stocks means these may remain valuable as an independent data source for consideration during assessment working groups. Bespoke and out-dated mechanistic assessment model frameworks were abandoned and statistical catch-at-age models were adopted, using the a4a framework for all stocks. This results in more reproducible, transparent and easier to run assessments.

Future research should focus on differentiating between the sexes in both megrim and four-spot megrim stocks (e.g. growth, maturity, fishery selectivity, habitat and spatial distribution). Preliminary evidence from a new Irish anglerfish and megrim survey points towards substantial differences between the sexes that may warrant sex-specific assessments.

# ii Expert group information

| | |
|---|---|
| **Expert group name** | Benchmark workshop on selected megrim stocks (WKMEGRIM) |
| **Expert group cycle** | Annual |
| **Year cycle started** | 2021 |
| **Reporting year in cycle** | 1/1 |
| **Chair** | Elliot John Brown, Denmark |
| **Meeting venues and dates** | 24–27 January 2022, online meeting |
| | 21–25 February 2022, online meeting (14 participants) |

# 1 Megrim west and southwest of Ireland and in the Bay of Biscay

meg.27.7b-k8abd – *Lepidorhombus whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d

## 1.1 Background

Megrim in divisions 7.b–k, 8.a–b, and 8.d is assessed using a customized Bayesian statistical catch-at-age model implemented since 2012 to resolve the issue with the limited availability of data from the discarded component of the total catch and different levels of temporal aggregation across the time-series, a mix of quarterly and annual time-steps. With the resolution of this issue in 2016 benchmark (ICES, 2016) the complex and the length of time the model needed to run, WGBIE proposed that a more standardized method could be used.

## 1.2 General stock information

### 1.2.1 Previous assessment method

Megrim (*L. whiffiagonis*) was assessed with a Bayesian catch-at-age model considered as a full analytical assessment since 2012.

- It was ad-hoc implemented to solve the lack of discard data from France.
- After the interbenchmark on megrim in 2016, discard from France where provided, so the problem disappeared.
- The Bayesian final assessment run takes 10 h to run, so it is not manageable to do different analysis.
- Therefore, a change to a more standardized model is proposed to ease the implementation and shorten the iteration times from the previous Bayesian model and a4a model is proposed.
- The a4a model is a statistical catch-at-age model with five submodels form, for initial age structure, recruitment, fishing mortality, catchability-at-age for abundance indices and observation variance of catch-at-age and abundance indices (Jardim *et al.*, 2017).

### 1.2.2 Previous assessment status

Based on the advice sheet presented for meg.27.7b-k8abd, published 30 June 2021, ICES advised catches for 2022 should be no more than 22 964 tonnes and that fishing pressure on the stock is below $F_{MSY}$ and spawning-stock size is above MSY $B_{trigger}$, $B_{pa}$, and $B_{lim}$.

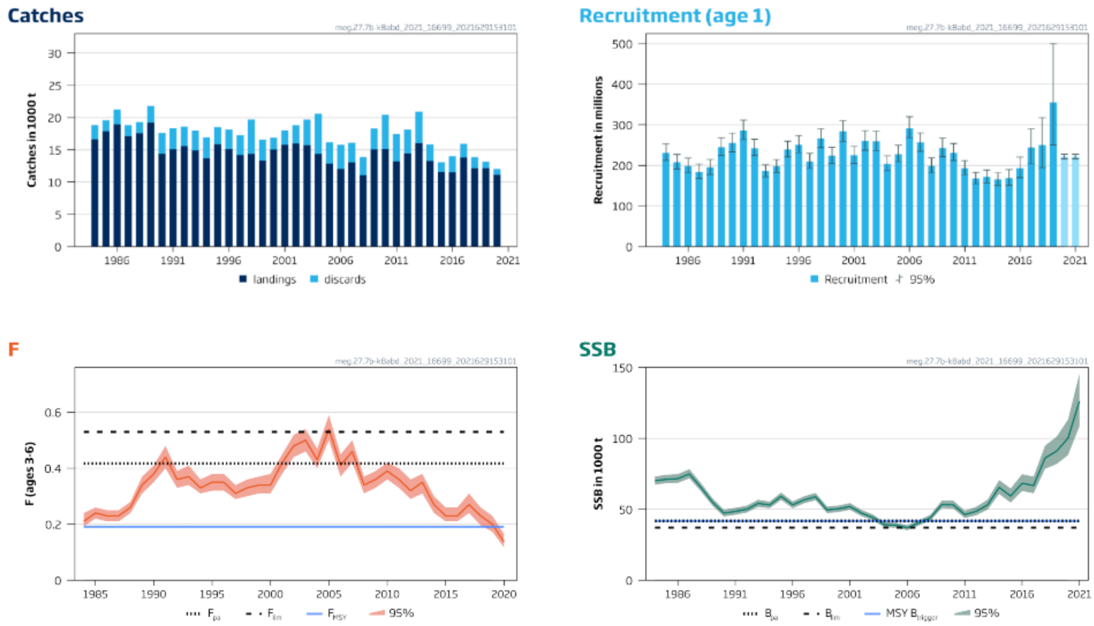


**Figure 1. Megrim in divisions 7.b–k, 8.a–b, and 8.d. Summary of the stock assessment. The assumed recruitment values for 2021 and 2022 are shaded in a lighter colour.**

## 1.2.3 Fisheries drivers of stock development

Megrim in the Celtic Sea, west of Ireland, and in the Bay of Biscay are caught in a mixed fishery predominantly by French followed by Spanish, UK and Irish demersal vessels. In 2020, the four countries together have reported around 94% of the total landings (Table 1).

**Table 1. Megrim (*L. whiffiagonis*) in divisions 7.b–k, 8.a–b, and 8.d. Nominal landings and catches (t) by country provided by the Working Group.**

| | Landings | | | | | | | | | Discards | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | France | Spain | U.K. (England & Wales) | U.K. (Scotland) | Ireland | Northern Ireland | Belgium | Unallocated | Total landings | France | Spain | U.K. | Ireland | Northern Ireland | Belgium | Others | Total discards | Total catches | TAC |
| **1984** | | | | | | | | | **16659** | | | | | | | 2169 | **2169** | **18828** | |
| **1985** | | | | | | | | | **17865** | | | | | | | 1732 | **1732** | **19597** | |
| **1986** | 4896 | 10242 | 2048 | | 1563 | | 178 | | **18927** | | | | | | | 2321 | **2321** | **21248** | |
| **1987** | 5056 | 8772 | 1600 | | 1561 | | 125 | | **17114** | | | | | | | 1705 | **1705** | **18819** | 16460 |
| **1988** | 5206 | 9247 | 1956 | | 995 | | 173 | | **17577** | | | | | | | 1725 | **1725** | **19302** | 18100 |
| **1989** | 5452 | 9482 | 1451 | | 2548 | | 300 | | **19233** | | | | | | | 2582 | **2582** | **21815** | 18100 |
| **1990** | 4336 | 7127 | 1380 | | 1381 | | 147 | | **14370** | | | | | | | 3284 | **3284** | **17654** | 18100 |
| **1991** | 3709 | 7780 | 1617 | | 1956 | | 32 | | **15094** | | | | | | | 3282 | **3282** | **18376** | 18100 |
| **1992** | 4104 | 7349 | 1982 | | 2113 | | 52 | | **15600** | | | | | | | 2988 | **2988** | **18588** | 18100 |
| **1993** | 3640 | 6526 | 2131 | | 2592 | | 40 | | **14929** | | | | | | | 3108 | **3108** | **18037** | 21460 |
| **1994** | 3214 | 5624 | 2309 | | 2420 | | 117 | | **13684** | | | | | | | 2700 | **3284** | **16968** | 20330 |
| **1995** | 3945 | 6129 | 2658 | | 2927 | | 203 | | **15862** | | | | 422 | | | 2230 | **2652** | **18514** | 22590 |
| **1996** | 4146 | 5572 | 2493 | | 2699 | | 199 | | **15109** | | | | 410 | | | 2616 | **3026** | **18135** | 21200 |
| **1997** | 4333 | 5472 | 2875 | | 1420 | | 130 | | **14230** | | 414 | | 568 | | | 2083 | **3066** | **17296** | 25000 |
| **1998** | 4232 | 4870 | 2492 | | 2621 | | 129 | | **14345** | | 381 | | 681 | | | 4309 | **5371** | **19716** | 25000 |
| **1999** | 3751 | 4615 | 2193 | | 2597 | | 149 | | **13305** | | 3135 | | 162 | | | | **3297** | **16601** | 20000 |
| **2000** | 4173 | 6047 | 2185 | | 2512 | | 115 | | **15031** | | 1033 | 208 | 630 | | | | **1870** | **16901** | 20000 |
| **2001** | 3645 | 7575 | 1710 | | 2767 | | 80 | | **15778** | | 1275 | 250 | 736 | | | | **2262** | **18040** | 16800 |
| **2002** | 2929 | 8797 | 1787 | | 2413 | | 62 | | **15987** | | 1466 | 435 | 912 | | | | **2813** | **18800** | 14900 |
| **2003** | 3227 | 8340 | 1732 | | 2249 | | 163 | | **15711** | | 3147 | 279 | 582 | | | | **4008** | **19719** | 16000 |
| **2004** | 2817 | 7526 | 1622 | | 2288 | | 106 | | **14358** | 1003 | 4511 | 257 | 472 | | | | **6243** | **20602** | 20200 |
| **2005** | 2972 | 5841 | 1764 | | 2155 | | 156 | | **12888** | 697 | 1831 | 289 | 458 | | | | **3275** | **16163** | 21500 |
| **2006** | 2763 | 5916 | 1509 | | 1751 | | 99 | | **12037** | 382 | 2568 | 271 | 529 | | | | **3751** | **15788** | 20400 |
| **2007** | 2745 | 6895 | 1462 | | 1763 | | 195 | | **13060** | 330 | 2114 | 272 | 317 | | | | **3033** | **16092** | 20400 |
| **2008** | 2578 | 5402 | 1387 | | 1514 | | 167 | | **11048** | 329 | 1479 | 289 | 764 | | | | **2860** | **13908** | 20400 |
| **2009** | 3032 | 8062 | 1840 | | 1918 | 2 | 209 | | **15064** | 674 | 1761 | 389 | 454 | | | | **3278** | **18342** | 20400 |
| **2010** | 3651 | 7095 | 1805 | | 2283 | 5 | 261 | | **15101** | 937 | 3489 | 463 | 453 | | | | **5343** | **20444** | 20106 |
| **2011** | 3235 | 3500 | 1845 | | 2227 | | 330 | 2089 | **13226** | 847 | 2097 | 898 | 344 | | | | **4187** | **17413** | 20106 |
| **2012** | 4012 | 4055 | 1744 | | 3047 | | 609 | 966 | **14433** | 796 | 2668 | 88 | 152 | | | | **3704** | **18137** | 19101 |
| **2013** | 4549 | 4982 | 2918 | | 3038 | | 538 | | **16025** | 748 | 3792 | 53 | 286 | | 5 | | **4885** | **20910** | 19101 |
| **2014** | 4311 | 3318 | 2753 | 176 | 2391 | | 179 | 150 | **13277** | 795 | 1337 | 72 | 360 | | 5 | | **2569** | **15846** | 19101 |
| **2015** | 3073 | 2863 | 2804 | 147 | 2436 | | 246 | 1 | **11569** | 634 | 513 | 47 | 308 | | 4 | | **1507** | **13076** | 19101 |
| **2016** | 3141 | 2672 | 2694 | 145 | 2593 | | 302 | 1 | **11548** | 1276 | 649 | 74 | 404 | | 42 | | **2445** | **13992** | 20056 |
| **2017** | 5101 | 3178 | 2512 | 176 | 2458 | | 360 | | **13784** | 783 | 706 | 265 | 378 | | 40 | | **2173** | **15957** | 15043 |
| **2018** | 4680 | 2276 | 2337 | 112 | 2128 | 6 | 347 | 261 | **12147** | 610 | 483 | 85 | 495 | | 66 | | **1738** | **13885** | 13528 |
| **2019** | 4332 | 2617 | 2150 | 129 | 2454 | 1 | 481 | | **12164** | 424 | 130 | 63 | 252 | | 120 | | **989** | **13153** | 19836 |
| **2020** | 4387 | 2420 | 1883 | 5 | 1797 | 1 | 649 | | **11141** | 398 | 253 | 53 | 64 | | 117 | | **885** | **12026** | 20526 |

At the beginning of the time-series in 1984 the total catches were around 20 000 t. The main contributor was Spain followed by France. The total catches have remained quite stable in the time-series with a slight decreasing trend from year-to-year and important decrease in the last four years. TAC was set for this stock in 1987 and it has fluctuated from years where catches were constraint by the TAC to years that TAC was not reached. In the last two years, the imposed TAC is not reached.

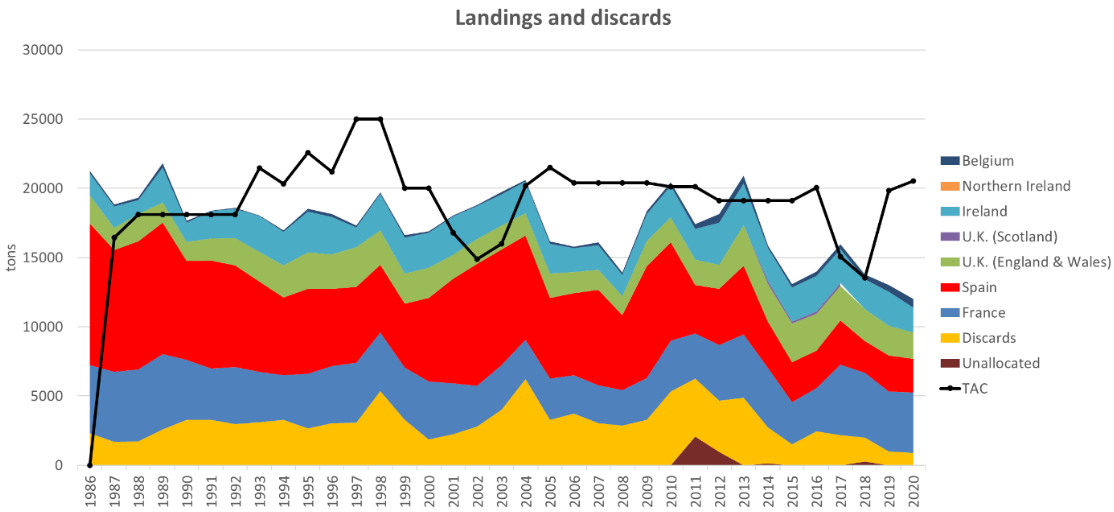


**Figure 2. Megrim (*L. whiffiagonis*) in divisions 7.b–k, 8.a–b, and 8.d. Total landings and discards in the time-series from year 1984 to 2020.**

### 1.2.4 Environmental drivers of stock development

See Stock annex for ecosystem aspects related to megrim assessment.

## 1.3 Conclusions from other expert groups relevant to this stock

As described above, the assessment working group WGBIE recommended that assessment model for this stock be upgraded in a benchmark (ICES, 2021b), based on the ground work for the shift from XSA to a4a was undertaken in WKTaDSA (ICES, 2021c)

## 1.4 Ambitions for benchmark process

The main ambition is to change to a more standardized and transparent model to ease the implementation by moving away from the bespoke Bayesian model to the a4a model framework. In addition, a revision of all the input data used for assessment including biological parameters, tuning fleets and maturity was planned.

## 1.5 Data in support of benchmark process

### 1.5.1 Discard data

A request was made during the WKMEGRIM in 2022 data compilation concerning the discard raising procedure followed by each country in the data compilation process.

A query was sent to each country's data providers confirming whether discard raising occurs before submission to Intercatch or if this should be applied by the coordinator after submission. The outcomes of the investigation into raising of discards at national vs. stock-coordinator level are presented in the WD "Investigation into raising of discards at national vs. stock-coordinator level of megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b–k, 8.a–b, and 8.d from most countries involved in the fishery".

### 1.5.2 Survey data and tuning indices

#### Western IBTS Q4 Porcupine Survey (Spain) – SP_Porc

The Spanish Groundfish Survey in the Porcupine bank (SpGFS -WIBTS-Q3, G5768) covers ICES divisions 27.7.c-k and a small portion of 27.7.b corresponding to the Porcupine Bank and the adjacent area in western Irish waters from longitude 12°W to 15°W and from latitude 51°N to 54°N, covering depths between 180 and 800 m. The survey takes place at the end of the third quarter (September), and the beginning of fourth quarter.

The available survey index consists of catch numbers-at-age per 30 minutes fished for the years 2001 onwards.

#### Western IBTS Q4 EVHOE and IGFS surveys (France/Ireland) – FR_IE_IGFS

The Irish IBTS Q4 groundfish survey (IGFS-WIBTS-Q4, G7212) covers areas 27.7bgjk. The French EVHOE-WIBTS-Q4 (G9527) survey covers areas 27.7j8ab. Both surveys are coordinated and largely standardized under WGIBTS, and both use a GOV trawl. Together the two surveys cover the majority of the stock area up to depths of 200–300 m. This is where most of the young fish occur. Older fish migrate to deeper waters and are not fully available to these surveys.

Data for Irish and French IBTS Q4 groundfish surveys (IGFS-WIBTS-Q4, G7212 and EVHOE-WIBTS-Q4, G9527) were obtained from DATRAS, quality checked and cleaned. The two surveys were combined by weighting their average catches by the area covered by each survey series (IGFS gets a weight of approximately 45% and EVHOE 55%). The combined survey appears to give a more coherent recruitment signal than the two separate surveys.

#### Irish Anglerfish and Megrim Survey (Ireland) – IE_Monksurvey

Ireland has carried out the Irish Anglerfish and Megrim survey every year in Q1 since 2016.

The survey covers ICES areas 7bcjk and the western part of 7gh; the depth range is from around 50 m to 1000 m. The survey covers the main distribution area of megrim in area 7 and although area 8abd is not covered by the survey, this area only contributes around 10% of the landings. Therefore, the survey can be considered to cover most of the stock distribution.

The survey uses a relatively large mesh gear and the catchability of small megrim is relatively low. Because female megrim grows to a larger size than males, the catchability is expected to be different for the sexes. Therefore, a sex-specific index is provided as well as a combined-sex index.

**Table 2. Available fisheries independent surveys available for use as tuning fleets.**

| Type | Name | Year range | Age range | Used in the assessment |
|---|---|---|---|---|
| Spanish Porcupine groundfish survey | SPGFS-WIBST-Q3 (G5768)) | 2001–present | 0–10+ | Yes |
| Combined French and Irish survey | EVHOE-IRL IBTS Q4 | 2003-present | 0–10+ | Yes |
| French EVHOE groundfish survey | EVHOE-WIBTS-Q4 (G9527) | 1997–present | 1–9 | No |
| Irish groundfish survey | IGFS-WIBTS-Q4 (G7212) | 2003–present | 0–10+ | No |
| Irish Anglerfish and Megrim survey | IAMS 2016–2021 (Q1) | 2016-present | 0–10+ | No |

Commercial CPUE

WKMEGRIM (2022) rejected the use of commercial CPUE data due to concerns about changes in efficiency, targeting behaviour, quota restrictions, technical measures, discarding and compliance. However, trends in effort, landings and LPUE or CPUE may be used by WGBIE as supplementary information.

## 1.5.3 Biological data

### 1.5.3.1 Maturity

In WKMEGRIM, a new histologically derived maturity ogives for assessment was presented by Domínguez-Petit *et al*. (2021). Based on precedent and that females are the main fishery and are the main limiting factor for reproductive output, the use of only female maturity ogive was accepted from year 2022 onwards assessments:

**Table 3. New female only maturity ogive for *L. whiffiagonis*, adopted for the new assessment.**

| Age | 0 | 1 | 2 | 3 | 4 | 5 | 6+ |
|---|---|---|---|---|---|---|---|
| Maturity | 0.00 | 0.00 | 0.02 | 0.36 | 0.94 | 1.00 | 1.00 |

### 1.5.3.2 Length-weight relationships

In the case of Spanish data, the following parameter values were used in the length-weight relationship (BIOSDEF, 1998):

**Table 4. Pre-existing length-weight relationship parameters for *L. whiffiagonis.***

| | *L. whiffiagonis* |
|---|---|
| A | 0.004 |
| B | 3.17 |

Mean weight-at-length are estimated from a fixed length–weight relationship (W(g)= 0.004*L(cm)^3.17; BIOSDEF, 1998).

These data were revised for WKMEGRIM and the new values for the parameters were estimated for use on data for the year 2021 and onwards (Landa *et al*., 2021).

**Table 5. Newly adopted length-weight relationship parameters for *L. whiffiagonis*.**

| | *L. whiffiagonis* |
|---|---|
| A | 0.005 |
| B | 3.10 |

### 1.5.3.3 Natural mortality

Natural mortality is likely to vary with age (smaller fish are more likely to suffer predation while mature fish may suffer from spawning mortality and older fish may also be more likely to succumb to parasites). WKMEGRIM considered that there is currently insufficient information to quantify age-varying (or time-varying) M. Therefore, a fixed natural mortality of 0.2 is used for all age groups and all years both in the assessment and the forecast.

### 1.5.4 Catch data

Catch data time-series for this stock are available from year 1984 to 2020, where at the beginning of the time-series only total catch data were available and then landings and discards data were disagregated.

In the catch-at-age data, there are data from year 1984 to 2020 and ages 1 to 10. Three data periods could be observed, the first from year 1984 to 1989 where catch data by country were available. The second period from 1990 to 1998 where landings data were provided by country but for the discard data, a total discards were estimated. And the third period from year 1999 onwards, since 2000, where an EU framework for the collection and management of fisheries data were put in place, so all countries started to provide discard information by country which could be the reason to the increase of small ages in catch data.

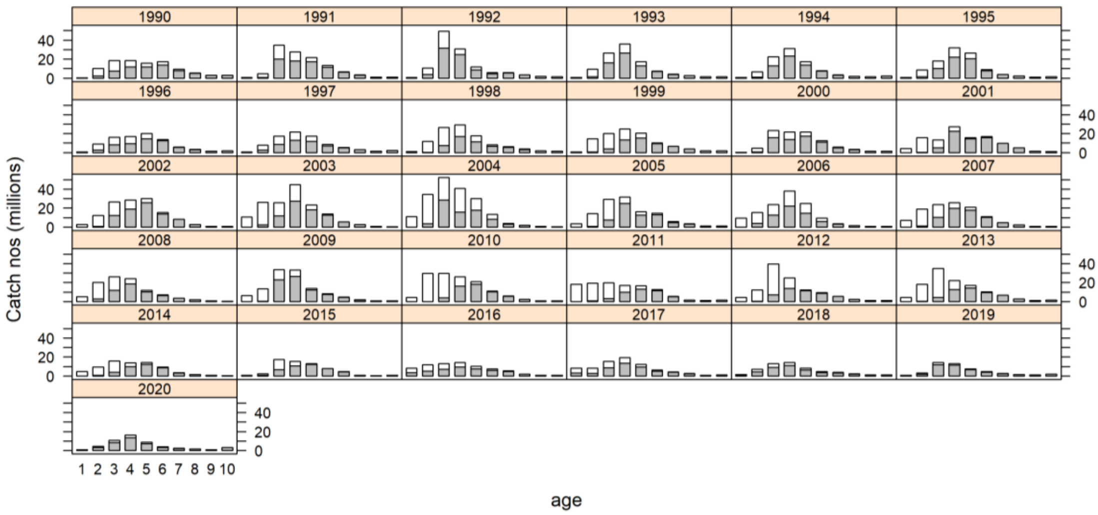


**Figure 3. Catch numbers-at-age for *L. whiffiagonis* by year. Landings in grey, discards in white.**

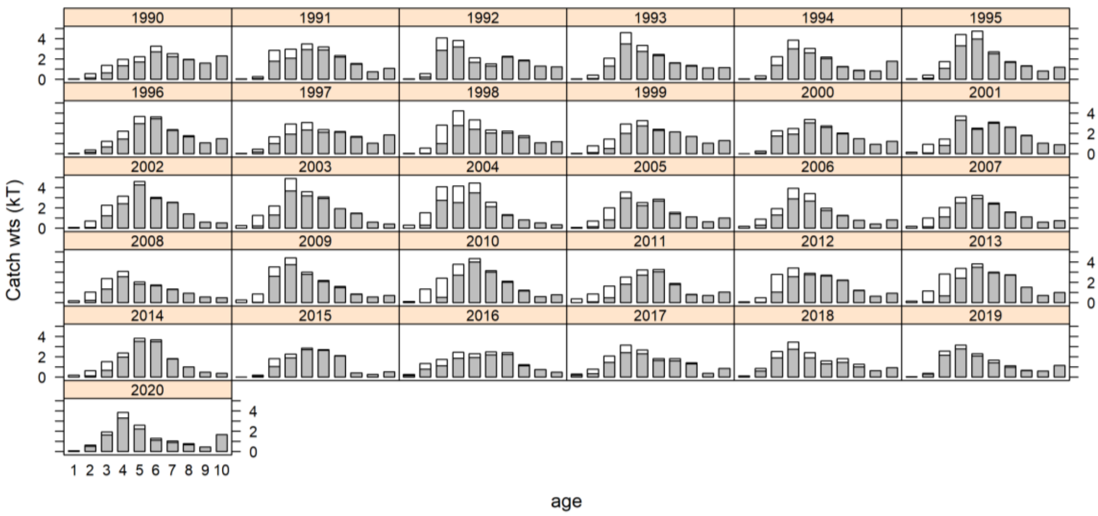


**Figure 4. Catch weight-at-age for *L. whiffiagonis* by year. Landings in grey, discards in white.**

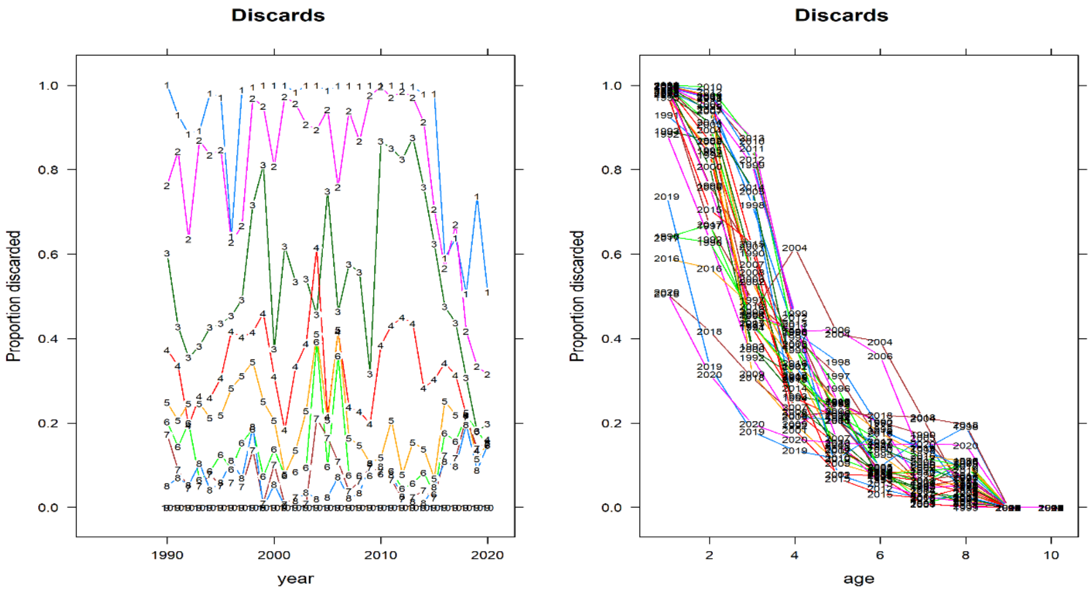


**Figure 5. Discard proportions by age and year (x-axis and coloured lines swapped between panels).**

# 1.6 Stock assessment model

## 1.6.1 New model configuration

### 1.6.1.1 Framework

A statistical catch-at-age stock assessment model developed as part of the Assessment For All (a4a) initiative of the European Commission Joint Research Centre is used[1]. The stock assessment model framework is a non-linear catch-at-age model implemented in R and FLR, and using ADMB that can be applied rapidly to a wide range of situations with low parameterization requirements. The model structure is defined by submodels, which are the different parts that require structural assumptions. There are 5 submodels in operation: a model for F-at-age, a model for the initial age structure, a model for recruitment, a (list) of model(s) for abundance indices catchability-at-age, and a list of models for the observation variance of catch-at-age and abundance indices. The submodels form use linear models.

### 1.6.1.2 Model specification

Some preliminary assessments were done to analyse different options of parameterization. These runs are summarized in the WD "Exploratory scenarios in a4a for northern megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b–k, 8.a–b, and 8.d using available abundance indices. The following sections are based on the final selected model.

The model structure is defined by submodels, which are the different parts that require structural assumptions. There are 5 submodels in operation:

- model for F-at-age,
- model for the initial age structure,
- model for recruitment,
- (list) of model(s) for abundance indices catchability-at-age,
- list of models for the observation variance of catch-at-age and abundance indices.

[1] See https://github.com/flr/FLa4a/blob/master/docs/articles/sca.pdf/ for details on the a4a framework

These submodels were defined as:

fmodel: ~factor(replace(age, age > 7, 7)) + factor(year)

srmodel: ~factor(year)

n1model: ~s(age, k = 3)

qmodel:

SP_PORC: ~I(1/(1 + exp(-age)))

CPUE.IRLFRsurvey: ~I(1/(1 + exp(-age)))

vmodel:

catch: ~s(age, k = 3)

SP_PORC: ~1

CPUE.IRLFRsurvey: ~1

The F model is a separable model. The shape of the F-at-age pattern is independently estimated for each age except ages 7 and older, which are assumed to have the same F. This pattern in F is then scaled up and down in-dependently for each year.

Stock–recruit model: Freely estimated for each year.

Catchability models:

For both surveys, catchability is assumed to increase asymptotically.

N1 model (population in the first year of the time-series): default value a4aSCA function (independently estimated for each age).

Vmodel (the shape of the observation variances): default value a4aSCA function: smooth function for the catch numbers-at-age and 'flat' for the in-dices

### 1.6.1.3 Model settings

$F_{bar}$ is set to ages 3–6.

After some exploratory analysis, the following changes were done to the initial input data

Age 1 in 2011 was removed from IRLFR survey as the value was not considered credible.

Explored the catch-at-age matrix due to doubts about age 1 data at the beginning of the historical series in total catches arised. The increase in age 1 from year 2000 onwards was not reasonable and it was considered that it was due to the bad quality of discard data at the beginning of the time-series. Therefore, the catch.n of 1 year-olds is set to NA for the early years (1984: 2000).

Ages modelled and annual variability for different components are given in tabulated form be-low.

**Table 6. Age ranges and variability settings for different model components for *L. whiffiagonis.***

| Type | Name | Year range | Age range | Variable from year-to-year |
|---|---|---|---|---|
| landings | Landings in tonnes | 1984–present | All | Yes |
| discards | Discards in tonnes | 1984–present | All | Yes |
| landings.n | Landings-at-age in numbers | 1984–present | 0–10+ | Yes |

| Type | Name | Year range | Age range | Variable from year-to-year |
|---|---|---|---|---|
| discards.n | Discards-at-age in numbers | 1984–present | 0–10+ | Yes |
| catch.wt | Weight-at-age in the commercial catch | 1984–present | 0–10+ | Yes |
| stock.wt | Weight-at-age of the spawning stock at spawning | 1984–present | 0–10+ | Yes |
| m.spwn | Proportion of natural mortality before spawning | 1984–present | 0 all ages | No |
| f.spwn | Proportion of fishing mortality before spawning | 1984–present | 0 all ages | No |
| mat | Proportion mature at age | 1984–present | All | No |
| M | Natural mortality | 1984–present | 0.2 all ages | No |
| Index1 | Spanish Porcupine Survey | 2001–present | 1–8 | Yes |
| Index1 | Combined Irish/French IBTS | 2003–present | 1–10 | Yes |

### 1.6.1.4 Assessment

Below are the results of the selected final assessment model. This model was selected based on a thorough investigation and selection of the input data (as described above) and optional model settings selected to reduce model residuals (visual inspection), improve model parsimony (AIC), and improve model predictive capability (Mohn's rho and retrospective analyses visual inspection).

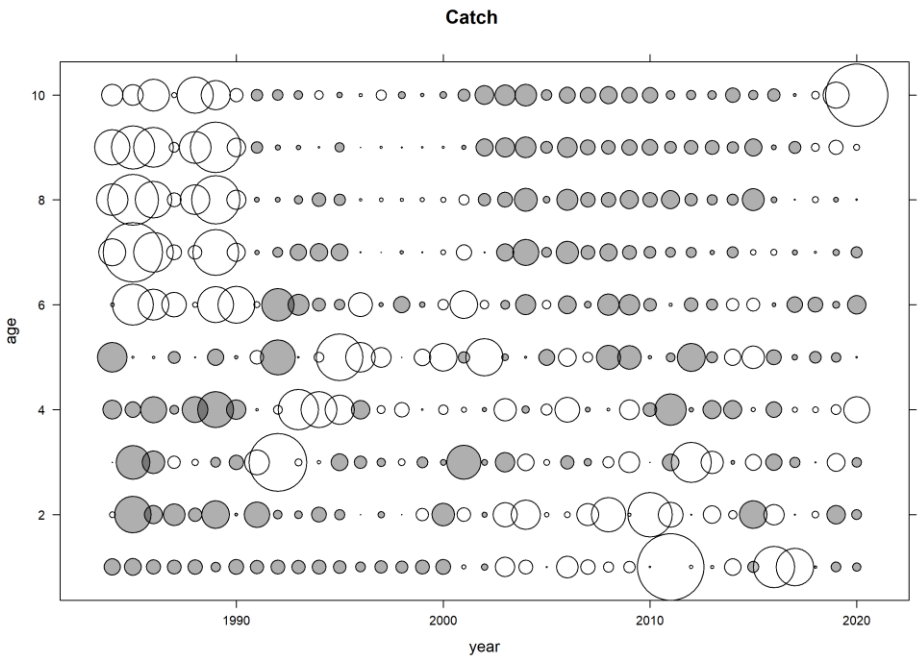


**Figure 6. Catch residuals by age over years for *L. whiffiagonis* from commercial fleet. Bubble size is proportional to difference from average; grey below average and white above.**

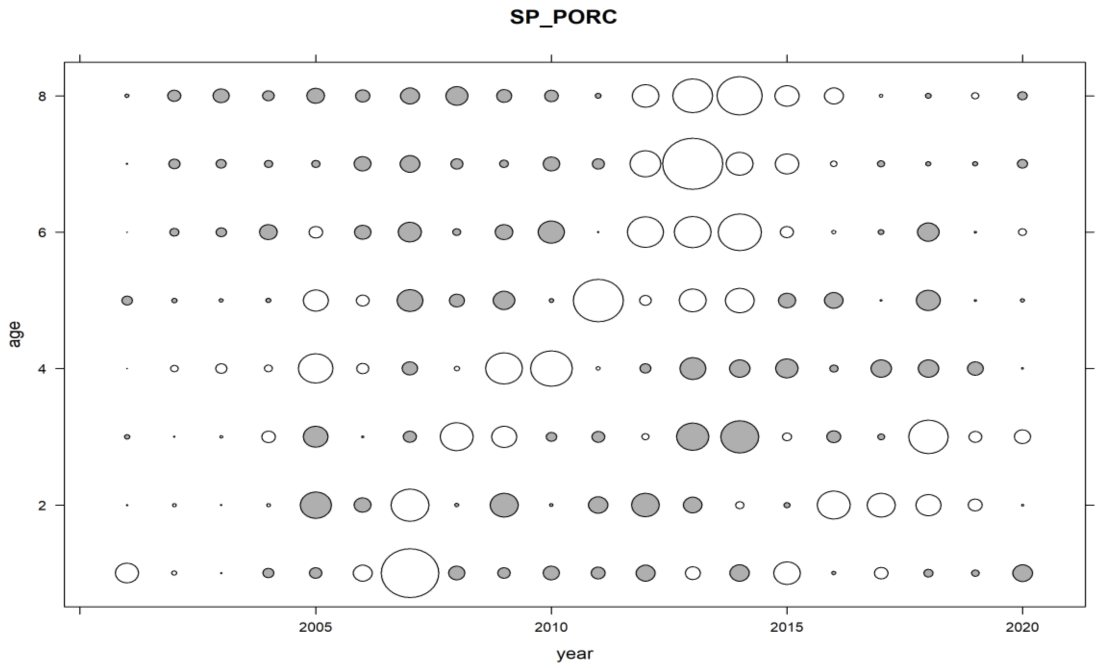


**Figure 7. Catch residuals by age over years for *L. whiffiagonis* from the selected survey (SPGFS-WIBST-Q3 (G5768)). Bubble size is proportional to difference from average; grey below average and white above.**

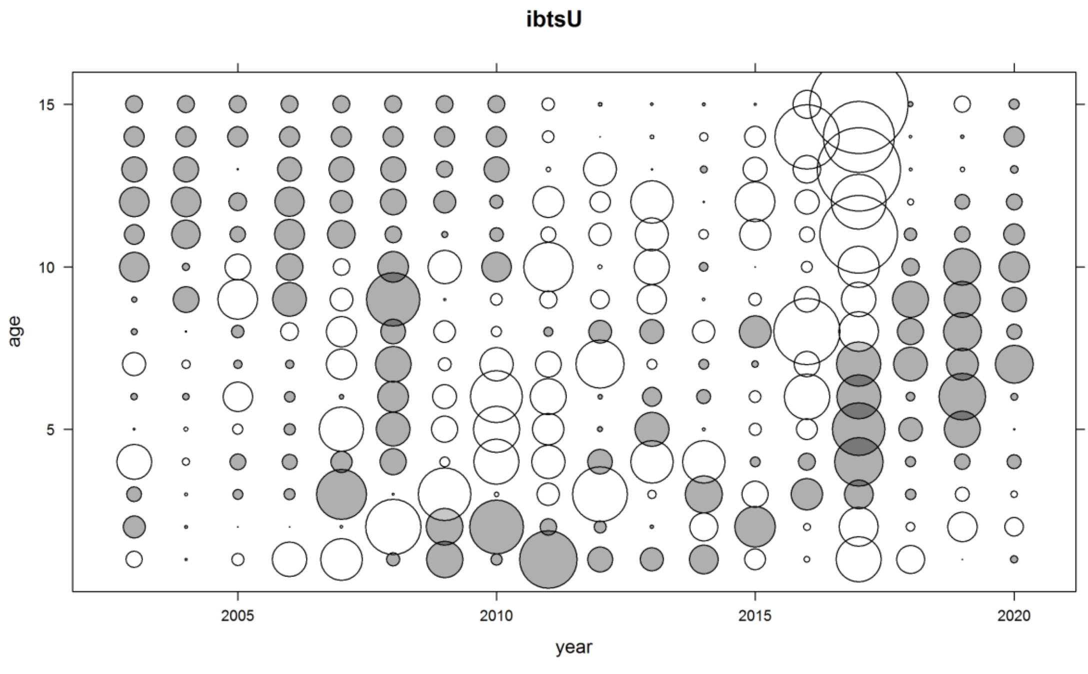


**Figure 8. Catch residuals by age over years for *L. whiffiagonis* from the selected survey (EVHOE-IRL IBTS Q4 (G9527 and G7212)). Bubble size is proportional to difference from average; grey below average and white above.**

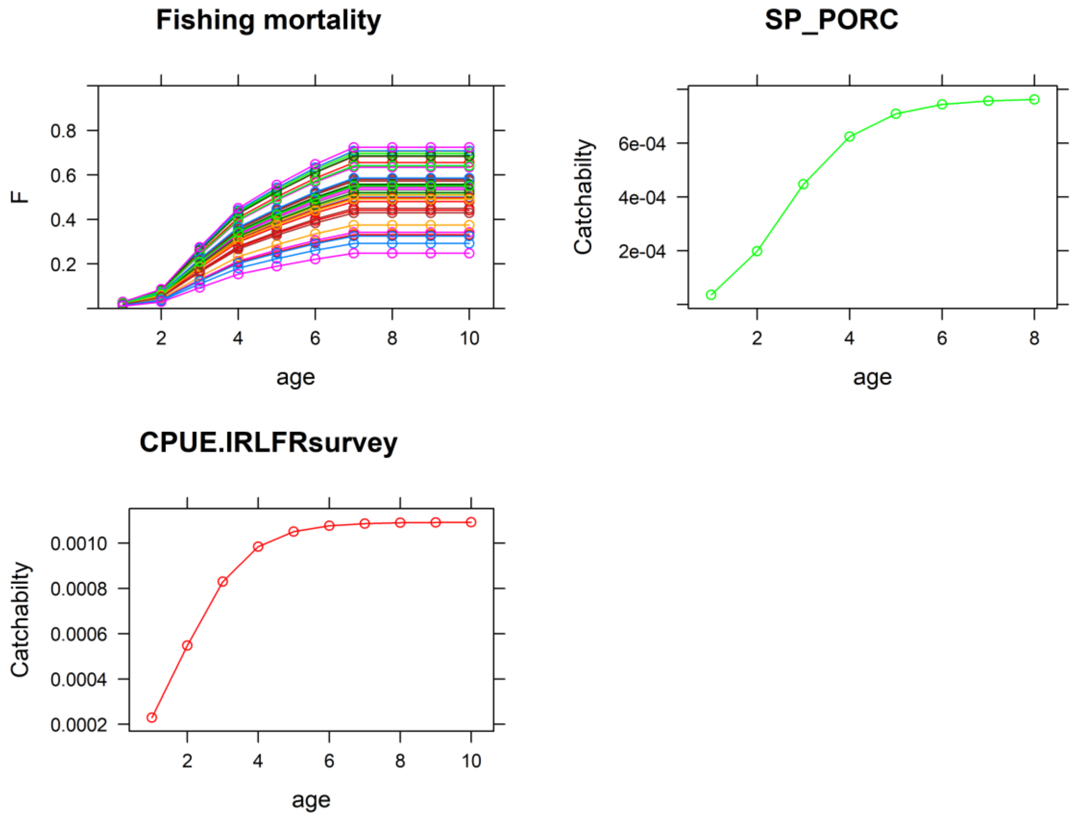


**Figure 9. Fishing mortality and catchability of tuning surveys.**

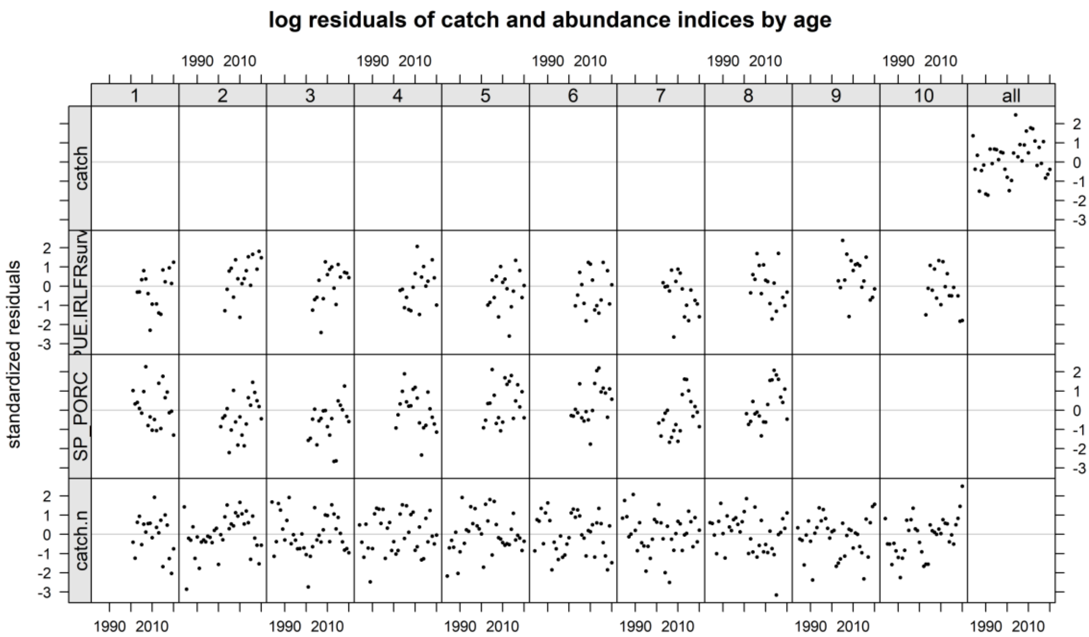


**Figure 10. Log residuals of catch and abundance indices by age for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d.**

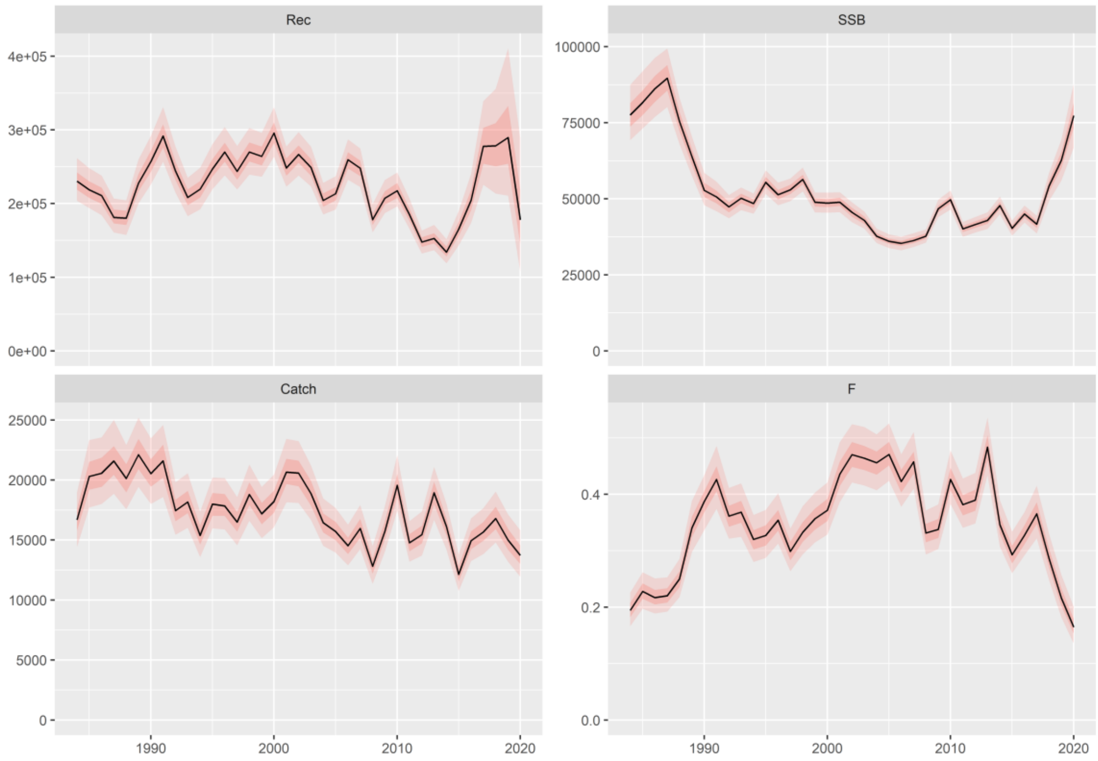


**Figure 11. Outputs of the assessment; Recruitment, SSB and F, for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d**

## 1.6.2 Validation

### 1.6.2.1 Retrospective analyses

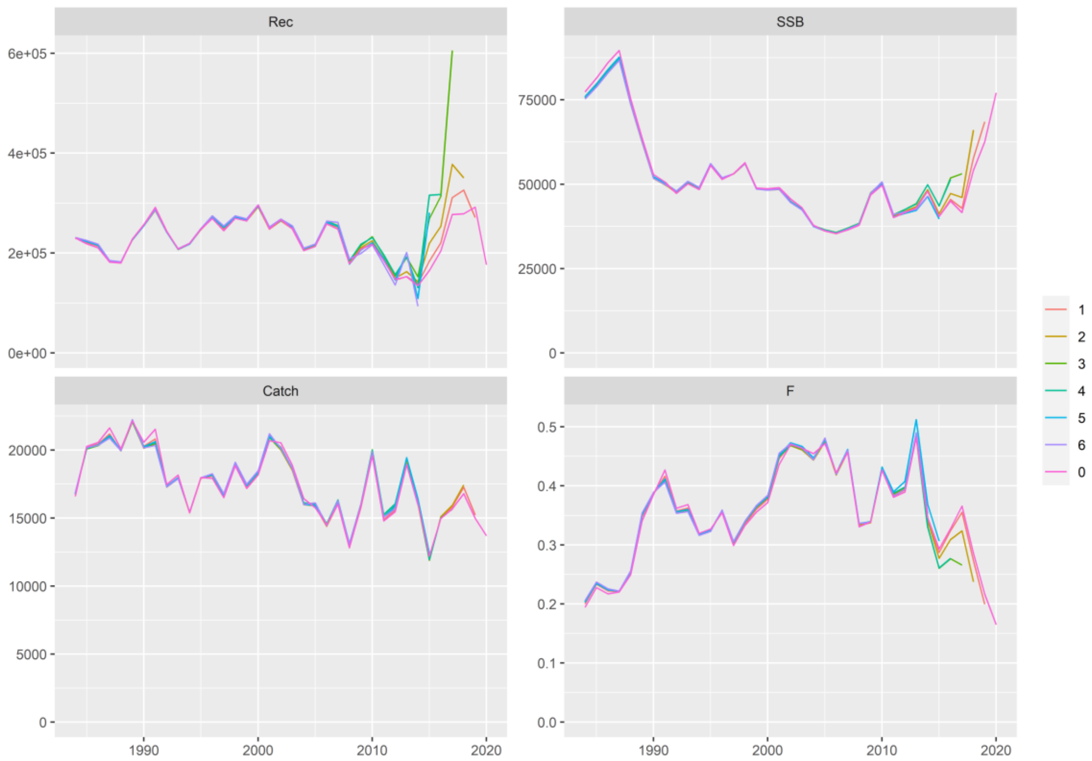


**Figure 12. Retrospective pattern plots over the last 6 years for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d.**

**Table 7. Model diagnostic statistics for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d.**

| FIT | AIC | BIC | Mohn´s rho F | Mohn´s rho SSB | Mohn´s rho R |
|---|---|---|---|---|---|
| FINAL RUN | 719.6211 | 1135.924 | −0.0876 | 0.0928 | 0.3333 |

#### 1.6.2.2 Other concerns

There are apparent differences in both growth/size and behaviour of the sexes in *L. whiffiagonis*. Due to a new, deeper, Irish megrim and anglerfish survey there is evidence of sexual dimorphism (L-W, maturity and growth) but also of differentiated habitat use, where males are more likely to be caught much deeper. Due to this spatial segregation, there is potential for differential fishing pressure on the sexes, namely higher pressure on females. During this workshop, maturity ogives were updated so that the assessment only uses female ogives derived from histological sampling. Further work is warranted to investigate the appropriateness of sex-differentiated assessments. Furthermore, as the new Irish anglerfish and megrim survey develops a longer time-series, future benchmarks should seriously consider including this survey as a tuning index to improve the spatial coverage and that of the male fraction of the population.

## 1.7 Reference point re-calculation

### 1.7.1 Data utilized

Input data were derived from the final selected assessment model from WKMEGRIM, as presented above.

### 1.7.2 Assumptions and decisions

#### 1.7.2.1 Stock–recruitment relationship

The stock–recruit relationship is a type 5 (segmented regression) according to the technical guidelines (ICES 2021a) i.e. with no evidence that recruitment has been impaired or no apparent relation between stock and recruitment.

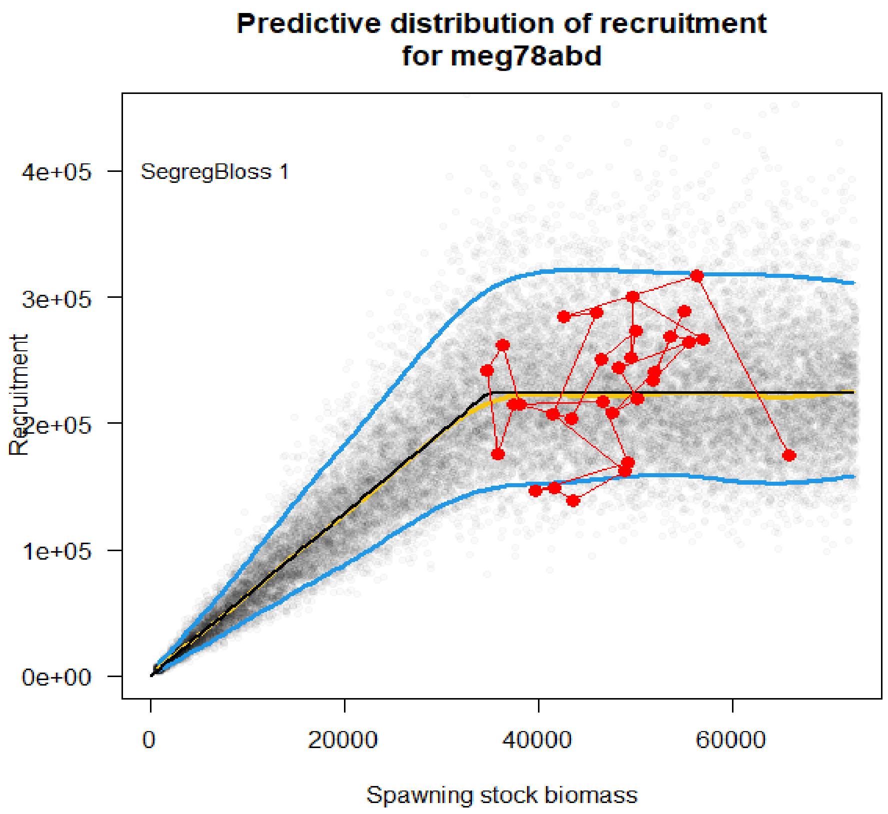


**Figure 13. Stock–recruitment model for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d. Determined to be ICES "Type 5" with a breakpoint at $B_{loss}$.**

### 1.7.2.2 $B_{lim}$

$B_{lim}$ was set at $B_{loss}$ (35 398 t), the lowest observed biomass in the time-series.

### 1.7.2.3 Variation in SSB and F

- $F_{cv}$ = 0.118 (values from summary table SSBcv and FbarCV of last year)
- $SSB_{cv}$ = 0.081 (values from summary table SSBcv and FbarCV of last year)
- $B_{pa}$ = $B_{loss}$ with assessment error = 40 444 t
- $F_{phi}$ = 0.423 (default value WKMSYREF4)

### 1.7.2.4 Autocorrelation

FALSE. Alternate runs with and without auto-regression determined no significant impact, nor any detectable autocorrelation.

## 1.7.3 Methods

Model used: *Eqsim*

Software used*:* *R* packages msy (version 0.1.18), *FLCore* (version 2.6.18) in *R* (version 4.1.2) and *icesAdvice* (version 2.1.1)

Reference points were estimated after 5000 iterations in EQsim.

### 1.7.4 Results and reference points

**Table 8. Resultant estimated biological reference points for *L. whiffiagonis* in divisions 7.b–k, 8.a–b, and 8.d.**

| | Type | Value | Technical basis |
|---|---|---|---|
| MSY Approach | MSY $B_{trigger}$ | 40 444 t | $B_{pa,}$ because the fishery has not been at $F_{MSY}$ in the last 10 years. |
| | $F_{MSY}$ | 0.233 | F giving maximum yield at equilibrium. Median *Eqsim* estimate for landings. |
| | $F_{MSY}$ range | 0.140–0.414 | |
| Precautionary Approach | $B_{lim}$ | 35 398 t | $B_{loss,}$ which is the lowest biomass observed. |
| | $B_{pa}$ | 40 444 t | $B_{lim}$ * exp(1.645* $\sigma$), where $\sigma = 0.081$ is the $SSB_{CV}$ of the year 2020. |
| | $F_{lim}$ | 0.591 | F with 5% probability of SSB <$B_{lim.}$ |
| | $F_{pa}$ | 0.430 | $F_{p.05}$ (F that gives 5% probability of SSB below $B_{lim}$). |
| EU MANAGEMENT PLAN (MAP); EU (2019) | MAP MSY $B_{trigger}$ | 40 444 t | MSY $B_{trigger.}$ |
| | MAP $F_{MSY}$ | 0.233 | $F_{MSY.}$ |
| | MAP range $F_{lower}$ | 0.140 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY. |
| | MAP range $F_{upper}$ | 0.414 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY. |

## 1.8 Short-term forecasts

#### 1.8.1.1 Assumptions for interim year

- Initial stock size: Taken from the a4a survivors.
- Weight-at-age in the stock: average of the last five years.
- Weight-at-age in the catch: average of the last five years.
- Proportion discards-at-age in the catch: average of the last three years.
- GM recruitment: full time-series excluding the last two years.
- Recruitment assumptions: Recruitment in last year of assessment is not replaced with GM unless the estimate is highly uncertain or there appears to be a retrospective bias.
- Exploitation pattern: If there is a decreasing trend of F in the results of the assessment time-series, $F_{status\ quo}$ should be scaled to $F_{bar}$ of the final assessment year (default option). If not, $F_{status\ quo}$ should be replaced by the average F of the last three years.
- Stock–recruitment model used: None.
- No medium-term projections are proposed for this stock.

#### 1.8.1.2 Assumptions for forecast

Same as for the interim year.

### 1.8.1.3 Methods

Model used: `stf()` and `fwd()` functions in *R* packages *FLasher* and *FLCore*.

Software used*:* *R* packages *FLasher* (version 0.6.7) and *FLCore* (version 2.6.18) in R (version 4.1.2)

### 1.8.1.4 Forecast results

**Table 9. Catch options table for *L. whiffiagonis* from divisions 7.b–k, 8.a–b, and 8.d. All weights are in tonnes.**

| Basis | Total catch (2022) | Wanted catch (2022) | Un-wanted catch (2022) | F[total] (ages 3–6; 2022) | F[wanted] (ages 3–6; 2022) | F[un-wanted] (ages 1–2; 2022) | SSB (2023) | % SSB change | % TAC change | % Advice change |
|---|---|---|---|---|---|---|---|---|---|---|
| MSY approach: F[MSY] | 25 118 | 21 637 | 3480 | 0.230 | 0.188 | 0.011 | 101 805 | −3.4 | 31 | 31 |
| F=MAP F[MSY lower] | 16 040 | 13 824 | 2215 | 0.140 | 0.115 | 0.007 | 111 520 | 5.8 | −16.4 | −16.4 |
| F=MAP F[MSY upper] | 40 820 | 35 129 | 5 691 | 0.410 | 0.34 | 0.02 | 85 155 | −19.2 | 113 | 113 |
| F=0 | 0 | 0 | 0 | 0 | 0 | 0 | 128 813 | 22 | −100 | −100 |
| F[pa] | 42 385 | 36 472 | 5913 | 0.430 | 0.35 | 0.021 | 83 508 | −21 | 121 | 121 |
| F[lim] | 53 874 | 46 318 | 7557 | 0.590 | 0.48 | 0.029 | 71 501 | −32 | 181 | 181 |
| SSB (2023)=B[pa] | 84 627 | 72 516 | 12 110 | 1.230 | 1.01 | 0.061 | 40 444 | −62 | 340 | 340 |
| SSB(2023)=B[lim] | 89 868 | 76 947 | 12 922 | 1.390 | 1.14 | 0.069 | 35 398 | −66 | 370 | 370 |
| SSB(2023)=MSY B[trigger] | 84 627 | 72 516 | 12 110 | 1.230 | 1.01 | 0.061 | 40 444 | −62 | 340 | 340 |
| F[2021] | 18 646 | 16 068 | 2578 | 0.165 | 0.135 | 0.008 | 108 726 | 3.2 | −2.8 | −2.8 |
| Roll-over TAC | 19 184 | 16 531 | 2653 | 0.170 | 0.139 | 0.008 | 108 149 | 2.6 | 0.00 | 0.00 |

# 2 Cantabrian Sea and Atlantic Iberian waters megrim

meg.27.8c9a – *Lepidorhombus whiffiagonis* in divisions 8.c and 9.a

## 2.1 Background

Megrim (*L. whiffiagonis*) in divisions 8.c and 9.a is assessed in ICES Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE). The model used in the assessment is Extended Survivors Analysis (XSA).

The XSA is a deterministic model. In recent years, WGBIE considered that it would be much more appropriate to use a model that incorporates uncertainty, especially since discards were included in the assessment.

A WGBIE recommendation was to update the assessment model using a4a (Assessment For All; statistical catch-at-age model[2]) following the preliminary assessment presented for megrim in divisions 7.b–k, 8.a–b, and 8.d. in 2020. The model was tested for southern megrims in the workshop on Training and Development of Stock Assessment Models Using a4a and Stock Synthesis) in November 2020 and January 2021 during the WKTaDSA (ICES, 2021b). Because of this, preliminary and promising results were presented in the last WGBIE (ICES, 2021a) where this benchmark was proposed.

## 2.2 General stock information

### 2.2.1 Previous assessment method

The catch-at-age model used in the assessment is Extended Survivors Analysis (XSA; Shepherd, 1992), software VPA95 Lowestoft suite. A VPA based approaches that estimates fishing mortality and numbers-at-age in a stock using data on international catches-at-age and estimates (or assumed values) of natural mortality. Fleet-disaggregated catch-at-age data are used to calibrate the fishing mortality and stock number estimates to observed trends in effort or in abundance indices (Darby and Flatman, 1994).

### 2.2.2 Previous assessment status

Based on the last ICES advice for this stock, the fishing pressure on the stock is below $F_{MSY}$ and the spawning stock size is above MSY $B_{trigger}$, $B_{pa}$, and $B_{lim}$.

[2] https://flr-project.org/FLa4a/authors.html

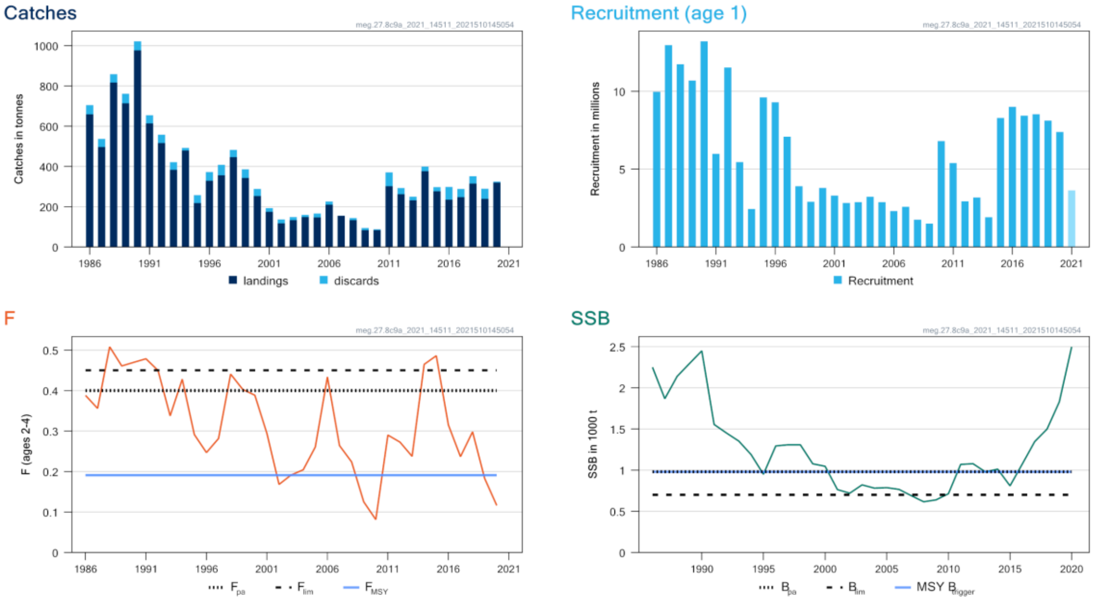


**Figure 14. Megrim in divisions 8.c and 9.a. Summary of the existing stock assessment used for advice. Assumed recruitment value is shaded in a lighter colour.**

ICES advises that when the EU multiannual plan (MAP; EU, 2019) for Western Waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the MAP are between 371 tonnes and 672 tonnes. According to the MAP, catches higher than those corresponding to $F_{MSY}$ (553 tonnes) can only be taken under conditions specified in the MAP, whereas the entire range is considered precautionary when applying the ICES advice rule (ICES Advice, 2021).

Management of catches of the two megrim species, *Lepidorhombus whiffiagonis* and *L. boscii*, under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to overexploitation of either species.

### 2.2.3 Fisheries Drivers of Stock Development

Megrims are taken as bycatch in the mixed bottom-trawl fisheries targeting “white fish” by Spanish and Portuguese fleets, and in small quantities by the Portuguese artisanal fleet. Most of the catches are taken by Spanish trawlers in the métier OTB_DEF_>=55_0_0, otter bottom trawl directed to demersal fish (at least 55 mm), with around 85%. Discards are important in Spanish fleets, particularly for younger ages, but megrims are not frequently discarded in Portuguese fisheries (Fernandes *et al.*, 2021). Portuguese discards are thus assumed to be negligible and are not reported. Minimum landing size for the two species changed from 25 to 20 cm in year 2000 (Council Regulation EC 850/98).

**Table 10. Megrim (*L. whiffiagonis*) in Divisions 8.c and 9.a. Landings, discards and catches (t) by country and division.**

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 1986 | 508 | 98 | 606 | 53 | | 659 | 46 | 705 |
| 1987 | 404 | 46 | 450 | 47 | | 497 | 40 | 537 |
| 1988 | 657 | 59 | 716 | 101 | | 817 | 42 | 859 |

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 1989 | 533 | 45 | 578 | 136 | | 714 | 47 | 761 |
| 1990 | 841 | 25 | 866 | 111 | | 977 | 45 | 1022 |
| 1991 | 494 | 16 | 510 | 104 | | 614 | 41 | 655 |
| 1992 | 474 | 5 | 479 | 37 | | 516 | 42 | 558 |
| 1993 | 338 | 7 | 345 | 38 | | 383 | 38 | 421 |
| 1994 | 440 | 8 | 448 | 31 | | 479 | 13 | 492 |
| 1995 | 173 | 20 | 193 | 25 | | 218 | 40 | 258 |
| 1996 | 283 | 21 | 305 | 24 | | 329 | 44 | 373 |
| 1997 | 298 | 12 | 310 | 46 | | 356 | 52 | 408 |
| 1998 | 372 | 8 | 380 | 66 | | 446 | 36 | 482 |
| 1999 | 332 | 4 | 336 | 7 | | 343 | 43 | 386 |
| 2000 | 238 | 5 | 243 | 10 | | 253 | 35 | 288 |
| 2001 | 167 | 2 | 169 | 5 | | 175 | 19 | 193 |
| 2002 | 112 | 3 | 115 | 3 | | 117 | 19 | 137 |
| 2003 | 113 | 3 | 116 | 17 | | 134 | 15 | 148 |
| 2004 | 142 | 1 | 144 | 5 | | 149 | 11 | 159 |
| 2005 | 120 | 1 | 121 | 26 | | 147 | 19 | 166 |
| 2006 | 173 | 2 | 175 | 35 | | 210 | 16 | 226 |
| 2007 | 139 | 2 | 141 | 14 | | 155 | 0.4 | 155 |
| 2008 | 114 | 2 | 116 | 17 | | 133 | 11 | 144 |
| 2009 | 74 | 2 | 77 | 7 | | 84 | 11 | 94 |
| 2010 | 66 | 8 | 74 | 10 | | 83 | 5 | 88 |
| 2011 | 242 | 0 | 242 | 34 | 26 | 302 | 69 | 371 |
| 2012 | 151 | 11 | 161 | 18 | 83 | 262 | 31 | 293 |
| 2013 | 128 | 3 | 131 | 11 | 90 | 231 | 18 | 250 |
| 2014 | 225 | 5 | 231 | 30 | 116 | 377 | 23 | 399 |
| 2015 | 188 | 2 | 190 | 23 | 63 | 276 | 21 | 297 |
| 2016 | 171 | 1 | 172 | 15 | 48 | 235 | 63 | 298 |

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 2017 | 189 | 4 | 193 | 16 | 39 | 247 | 41 | 288 |
| 2018 | 227 | 8 | 234 | 7 | 74 | 315 | 37 | 352 |
| 2019 | 226 | 7 | 233 | 6 | | 239 | 51 | 289 |
| 2020 | 278 | 26 | 305 | 10 | | 315 | 5 | 320 |

The maximum catch of 1022 t was reached in 1990. There is a decreasing trend from late 1980s although in recent years, 2011–2020, catches are increased in relation to the previous period. Landings are mainly from Spain in the whole time-series.

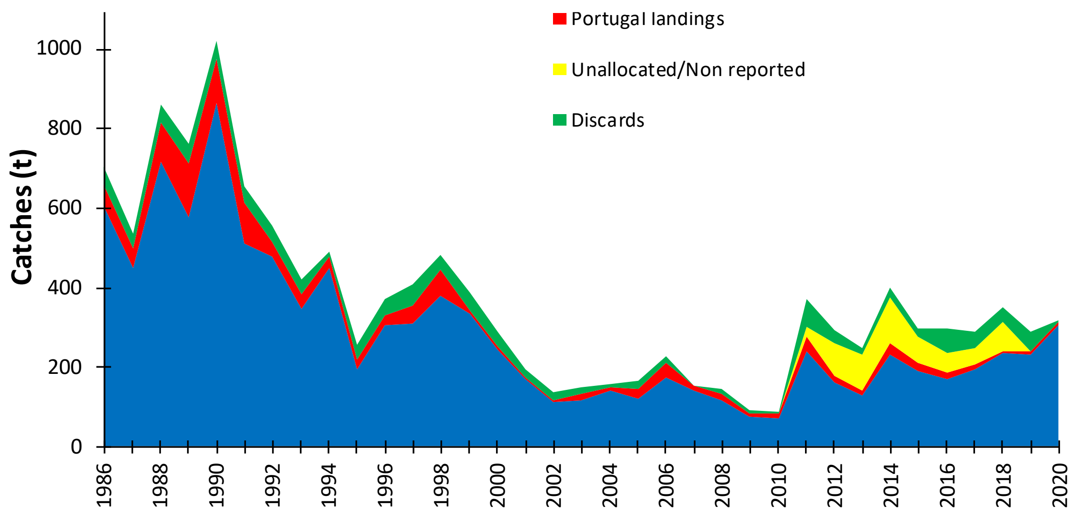


**Figure 15. Megrim (*L. whiffiagonis*) in divisions 8.c and 9.a. Catches (landings, discards and non-reported) in the time-series.**

### 2.2.4 Environmental drivers of stock development

See Stock annex for ecosystem aspects.

## 2.3 Conclusions from other expert groups relevant to this stock

As described above, the assessment working group WGBIE recommended that assessment model for this stock be upgraded in a benchmark (ICES, 2021a), based on the ground work for the shift from XSA to a4a was undertaken in WKTaDSA (ICES, 2021b).

## 2.4 Ambitions for benchmark process

The ambitions for this benchmark workshop were to address issues identified across the assessment process, from knowledge of the species biology, through the appropriateness of different fisheries based and fisheries independent tuning indices, to the fundamental assessment model framework to use. Overall the aim was to improve the transparency and reliability of the whole assessment procedure. These are specified in the below table of the issues list.

**Table 11. Issues list for the southern megrim (*Lepidorhombus whiffiagonis*), prior to the benchmark workshop.**

| Type | Problem/Aim | Work Required | Data Required |
|---|---|---|---|
| Biological parameters | Old maturity ogive and old L-W relationship (1996) | Update the maturity ogive and L-W relationship. | Maturity data obtained by species and sex and for both sexes combined based on a more robust microscopic methodology and recent Length-weight data from sampling program. |
| Tuning series | LPUE - Commercial abundance indices have to be standardized. | Standardization of reference fleets. Métier OTB_DEF_>=55_0_0 in Spanish fishing ports. | Time-series of logbooks, daily landings d and VMS records for métier OTB_DEF_>=55_0_0 in selected Spanish fishing ports. |
| Assessment method | Need to be updated. From the deterministic XSA to another model | During WKTaDSA (ICES, 2021b) some work were developed in the preparation for the WKMEGRIM benchmark in 2022. This stock has been presented as a case study to be assessed with a4a (assessment for all) model. The assessment model has been successfully implemented to this stock and different configurations have been presented. The work is fully in good progress. | Data and model scripts are available. |

# 2.5 Data in support of benchmark process

## 2.5.1 Survey data and tuning indices

### 2.5.1.1 Surveys

The Portuguese October groundfish survey (PtGFS-WIBTS-Q4, G8899) and the Portuguese Crustacean survey (PT-CTS -UWTV -FU 28–29, G2913) and one Spanish groundfish survey (SpGFS-WIBTS-Q4, G2784) series are available since 1990, 1997, and 1983, respectively.

Only the Spanish survey (SpGFS-WIBTS-Q4, G2784) is used in the assessment of this species. The survey covers the distribution area and depth strata of megrim in Spanish waters (covering both 8c and 9a). The survey appears to be quite good at tracking cohorts through time *for L. whiffiagonis* and gives good information for younger ages.

Indices from Portuguese surveys are not considered to be representative of megrim abundance, due to the very low catch rates.

**Table 12. Available fisheries independent surveys available for use as tuning fleets.**

| Type | Name | Year range | Age range | Used in the assessment |
|---|---|---|---|---|
| Spanish groundfish survey | SpGFS-WIBTS-Q4 (G2784) | 1983–present | 1–6 | Yes |

| Type | Name | Year range | Age range | Used in the assessment |
|---|---|---|---|---|
| Portuguese October groundfish survey | PtGFS-WIBTS-Q4 (G8899 | 1990-present | Biomass index+ | No |
| Portuguese Crustacean survey | PT-CTS -UWTV -FU 28–29 (G2913) | 1997–present | Biomass index | No |

#### 2.5.1.2 Commercial CPUE

LPUE and fishing effort data are available for the following fleets: Spanish trawlers targeting demersal fish based in A Coruña port (SP-LCGOTBDEF) and in Avilés port (SP-AVSOTBDEF) fishing in Division 8.c since 1986 and Portuguese trawlers fishing in Division 9.a since 1988 (non-standardized index). Effort from the Portuguese fleet is estimated from a sample of logbooks from sea trips where megrim occurred in the catch. Furthermore, a standardized CPUE based on fishery-dependent data collected from fishery observers' on-board commercial vessels in métier OTB_DEF_>=55_0_0 was presented in WKMEGRIM as a relative biomass index since 2003 (Pennino *et al*., 2022, see working document).

**Table 13. Available fisheries dependent sampling for deriving tuning fleets. These were explored but, ultimately, not used in the final assessment model.**

| Type | Name | Year range | Used in the assessment |
|---|---|---|---|
| Spanish Coruña bottom otter trawl | SP-LCGOTBDEF | 1986–present | No |
| Spanish Avilés bottom otter trawl | SP-AVSOTBDEF | 1986–present | No |
| Portuguese trawlers | PT-trawl | 1988–present | No |
| Spanish observers standardized CPUE | SP-OABCPUE | 2003-present | No |

As a decision of the WKMEGRIM group during the selection of tuning fleets for the model, the use of commercial CPUE data was rejected due to concerns about changes in efficiency, targeting behaviour, quota restrictions, technical measures, discarding and compliance. However, trends in effort, landings and LPUE or CPUE may be used by the WGBIE as supplementary information.

### 2.5.2 Biological Data

#### 2.5.2.1 Maturity

A new and updated female maturity ogive based on histology applying a robust microscopic methodology has been presented. The female maturity ogive (Domínguez *et al*., 2021, see working document) is assumed constant over time, with the following proportions of fish mature at each age:

**Table 14. New female only maturity ogive for *L. whiffiagonis*, adopted for the new assessment.**

| Age | 0 | 1 | 2 | 3 | 4 | 5+ |
|---|---|---|---|---|---|---|
| *L. whiffiagonis* | 0 | 0.06 | 0.55 | 0.96 | 1 | 1 |

This female only maturity ogive has been accepted based primarily the fact that females are the main limiting factor for reproductive output but also based on precedent, where using female only ogives is not uncommon.

### 2.5.2.2 Length-weight relationships

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 (BIOSDEF, 1998). In 2022, after a revision and update with a time-series data of the last years (Landa *et al*., 2021, see working document), new parameter values of the length-weight relationship were derived, presented to the benchmark workshop, and accepted for use in the updated assessment procedure.

**Table 15. The parameters for the age–length keys of *L. whiffiagonis* applied in the previous assessment procedure (Old Parameters) and those that were presented to and accepted by the benchmark meeting for use in the updated assessment (New Parameters).**

| | Old Parameters | New Parameters |
|---|---|---|
| a | 0.006488 | 0.0040976 |
| b | 3.0114 | 3.16823 |

### 2.5.2.3 Natural Mortality

Natural mortality was set to 0.2 and assumed constant over all ages and years as in the previous assessment method and this was retained for the new assessment procedure.

Although it is assumed that natural mortality is likely to vary with age, no new or relevant data were presented to quantify age-varying (or time-varying) M for this species and thus there was no basis upon which this assumption could be changed.

## 2.5.3 Catch Data

Catch data were available from 1986–2020 with discards sampled by on-board observer programmes.

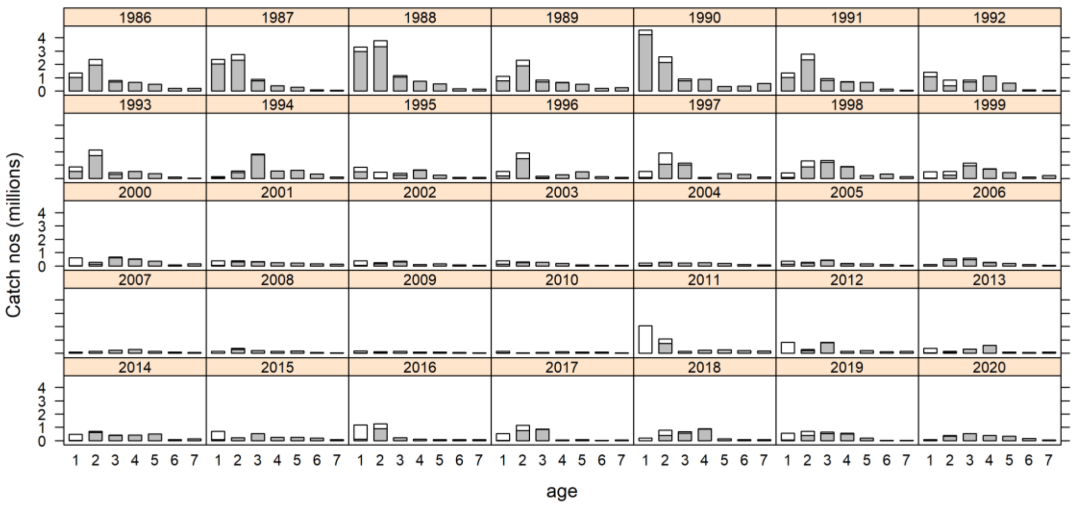


**Figure 16. Catch numbers-at-age for *L. whiffiagonis* by year. Landings in grey, discards in white.**

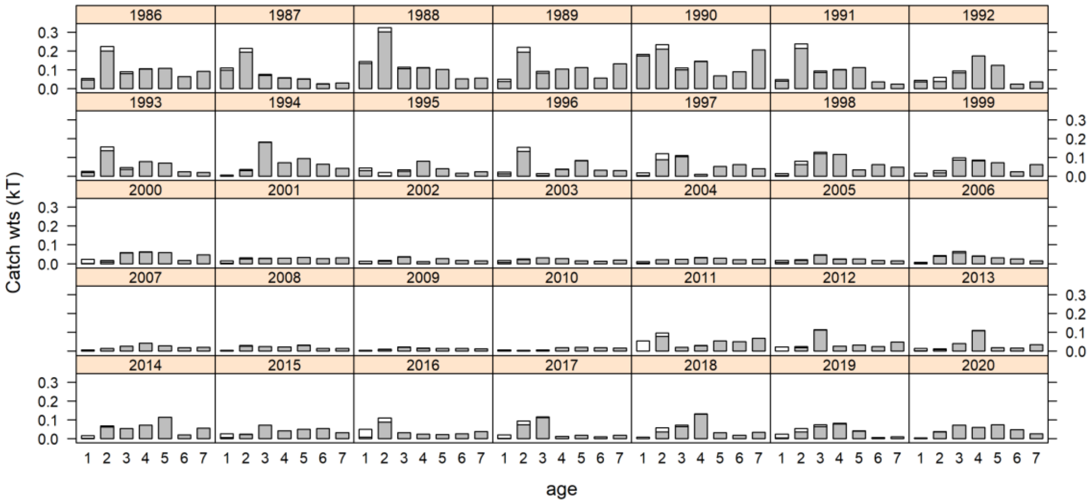


**Figure 17. Catch weight-at-age for *L. whiffiagonis* by year. Landings in grey, discards in white.**

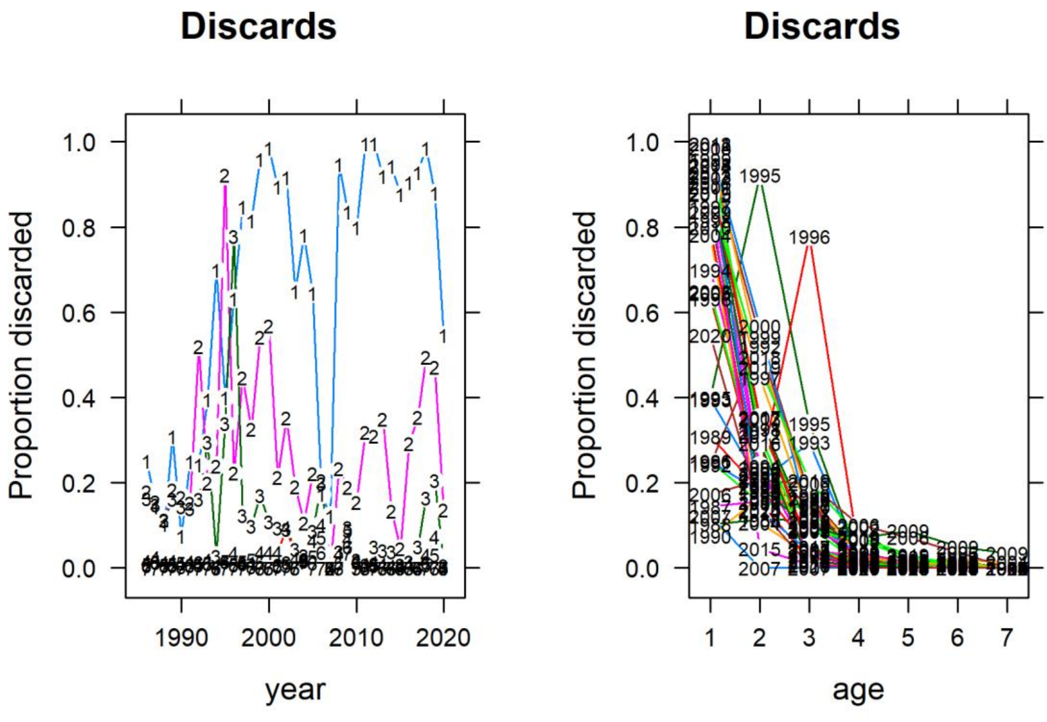


**Figure 18. Discard proportions by age and year (x-axis and coloured lines swapped between panels).**

# 2.6 Stock assessment model

## 2.6.1 New model configuration

### 2.6.1.1 Framework

The stock assessment model newly implemented for *L. whiffiagonis* in 8c and 9a is a4a (assessment for all). It is a non-linear catch-at-age model implemented in R and FLR, and using ADMB, that can be applied rapidly to a wide range of situations with low parameterization requirements[3].

#### 2.6.1.2 Model Specification

The model structure is defined by submodels, which are the different parts that require structural assumptions. There are 5 submodels in operation:

- model for F-at-age,
- model for the initial age structure,
- model for recruitment,
- (list) of model(s) for abundance indices catchability-at-age,
- list of models for the observation variance of catch-at-age and abundance indices.

These submodels were defined as:

```
fmodel: ~factor(replace(age, age > 6, 6)) + factor(year)
srmodel: ~factor(year)
n1model: ~factor(age)
qmodel: list(~I(1/(1 + exp(-age))))
vmodel:
  catch:        ~s(age, k = 3)
  SpGFS-WIBTS-Q4:    ~1
```

- The F model is a separable model. The shape of the F-at-age pattern is independently estimated for each age except ages 6 and 7+, which are assumed to have the same F. This pattern in F is then scaled up and down independently for each year.
- Stock–recruit model: Freely estimated for each year.

Catchability models:

- For the SpGFS-WIBTS-Q4 survey, catchability is assumed to increase asymptotically.
- N1 model (population in the first year of the time-series): default value a4aSCA function (independently estimated for each age)
- Vmodel (the shape of the observation variances): default value a4aSCA function: smooth function for the catch numbers-at-age and 'flat' for the index.

An FLStock object is needed and it was adapted from XSA input data. This object includes catches, landings, discards, weights-at-age, natural mortality, maturity, harvest before spawning and mortality before spawning all derived from the data introduced in section 2.5.

#### 2.6.1.3 Model Settings

$F_{bar}$ is set to ages 2–4. Ages modelled and annual variability for different components are given in tabulated form below.

**Table 16. Age ranges and variability settings for different model components for *L. whiffiagonis*.**

| Type | Name | Year range | Age range | Variable from year-to-year |
|---|---|---|---|---|
| Landings | Landings in tonnes | 1986–present | 1–7+ | Yes |
| Discards | Discards in tonnes | 1986–present | 1–7+ | Yes |
| landings.n | Landings-at-age in numbers | 1986–present | 1–7+ | Yes |

[3] http://www.flr-project.org/doc/Statistical_catch_at_age_models_in_FLa4a.html

| Type | Name | Year range | Age range | Variable from year-to-year |
|---|---|---|---|---|
| discards.n | Discards-at-age in numbers | 1986–present | 1–7+ | Yes |
| catch.wt | Weight-at-age in the commercial catch | 1986–present | 1–7+ | Yes |
| stock.wt | Weight-at-age of the spawning stock at spawning time. | 1986–present | 1–7+ | Yes |
| m.spwn | Proportion of natural mortality before spawning | 1986–present | 1–7+ | No |
| f.spwn | Proportion of fishing mortality before spawning | 1986–present | 1–7+ | No |
| Mat | Proportion mature at age | 1986–present | 1–7+ | No |
| M | Natural mortality | 1986–present | 1–7+ | No |
| Index1 | SpGFS-WIBTS-Q4 (G2784) | 1990–present | 1–6 | Yes |

#### 2.6.1.4 Assessment

Below are the results of the selected final assessment model. This model was selected based on a thorough investigation and selection of the input data (as described above) and optional model settings selected to reduce model residuals (visual inspection), improve model parsimony (AIC), and improve model predictive capability (Mohn's rho and retrospective analyses visual inspection).

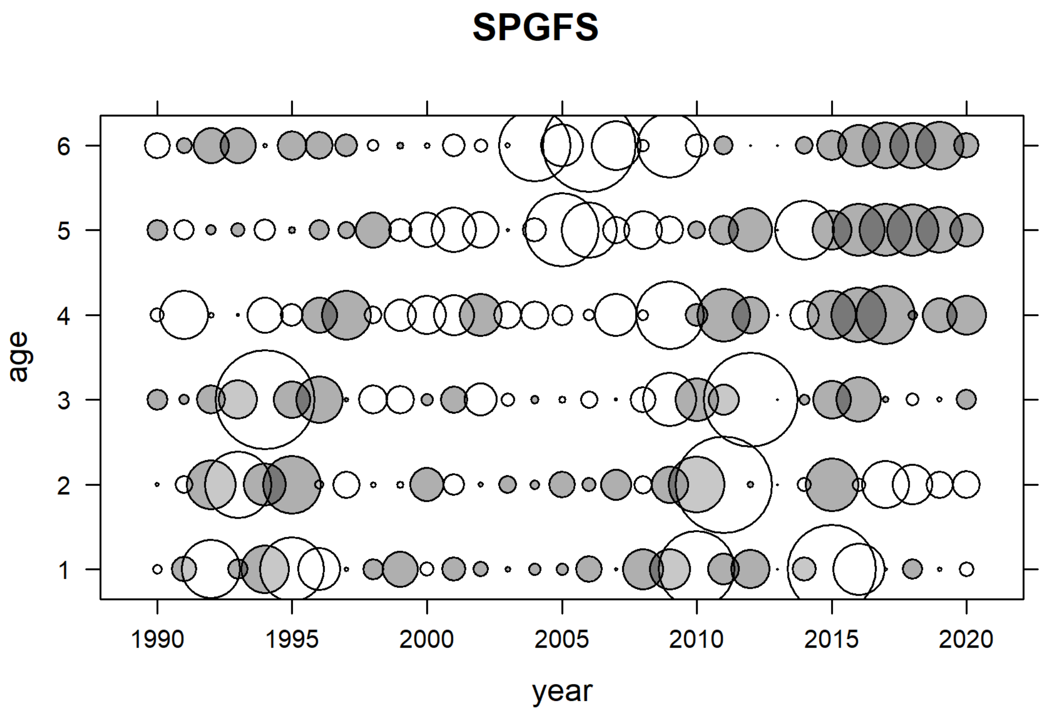


**Figure 19. Catch residuals by age over years for *L. whiffiagonis* from the selected survey. Bubble size is proportional to difference from average; grey below average and white above.**

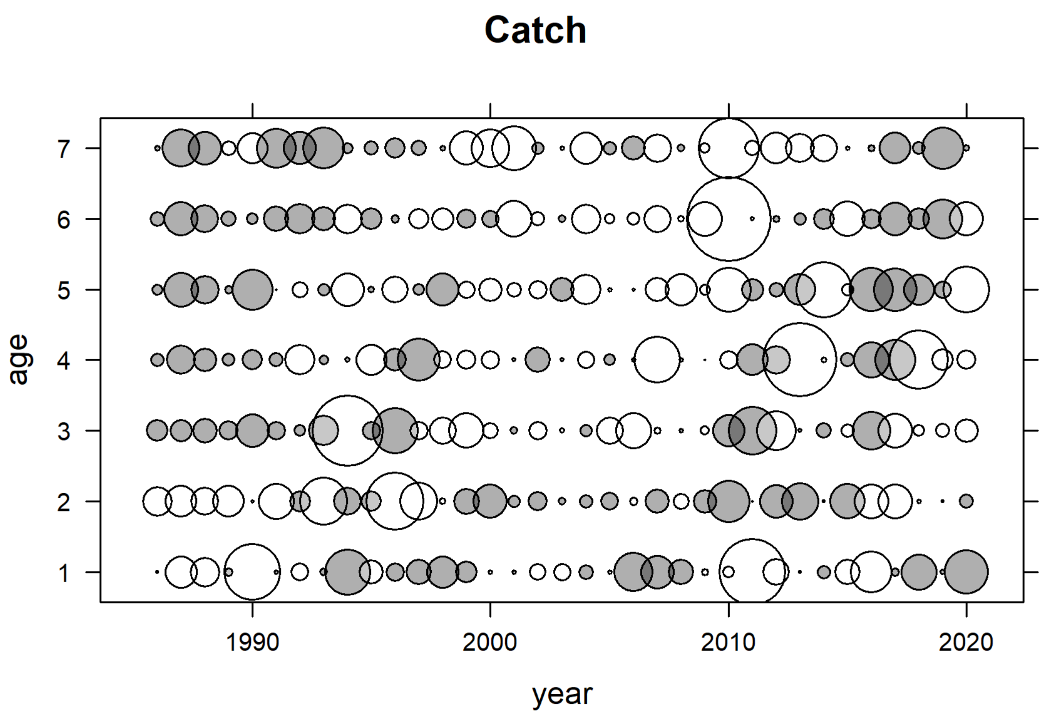


**Figure 20. Catch residuals by age over years for *L. whiffiagonis* from commercial fleet. Bubble size is proportional to difference from average; grey below average and white above.**

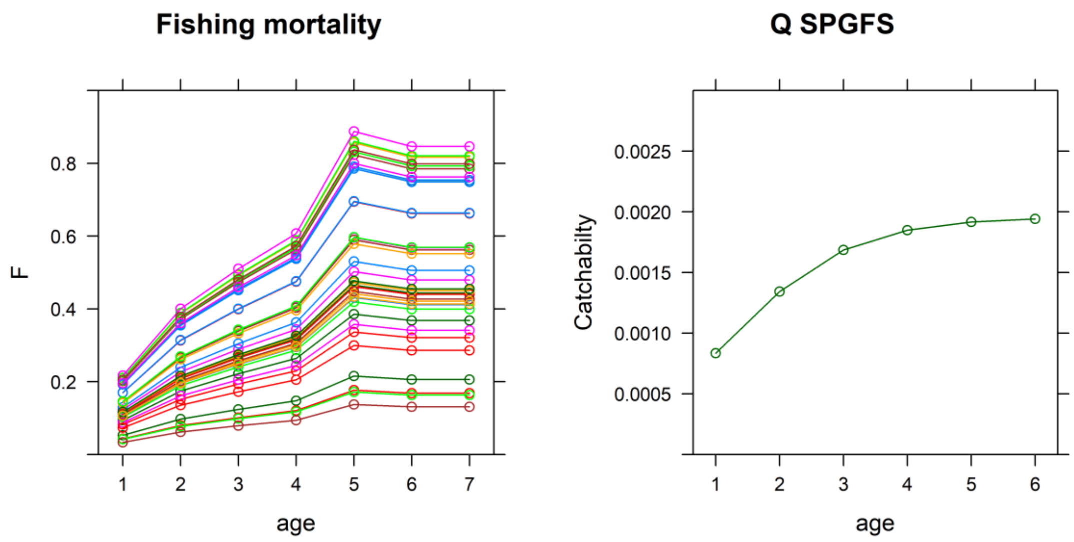


**Figure 21. Fishing mortality and catchability of tuning fleet.**

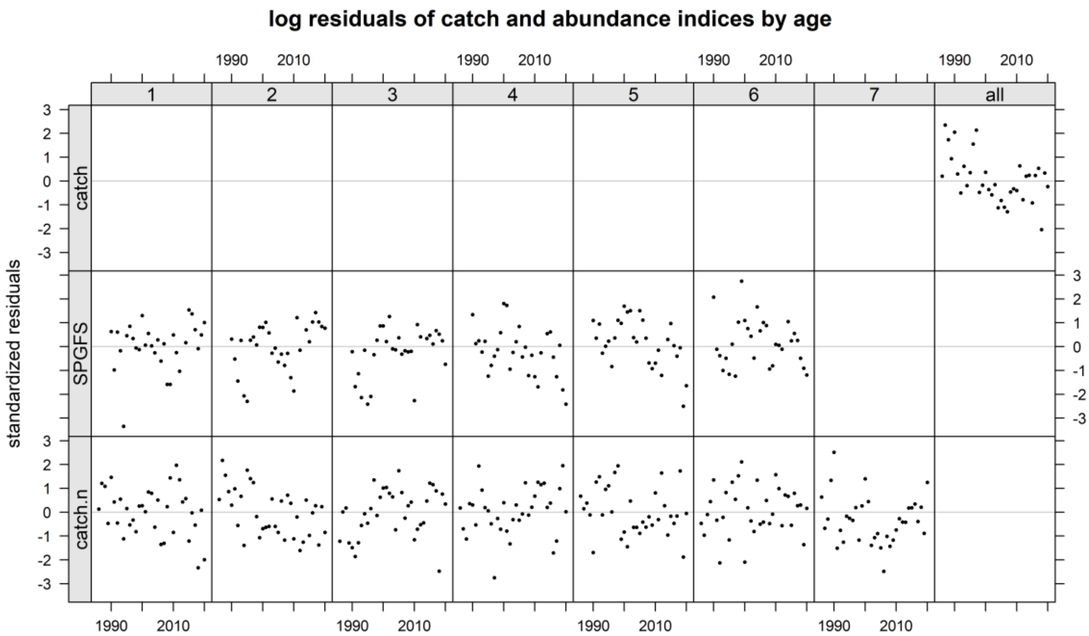


**Figure 22. Log residuals of catch and abundance indices by age.**

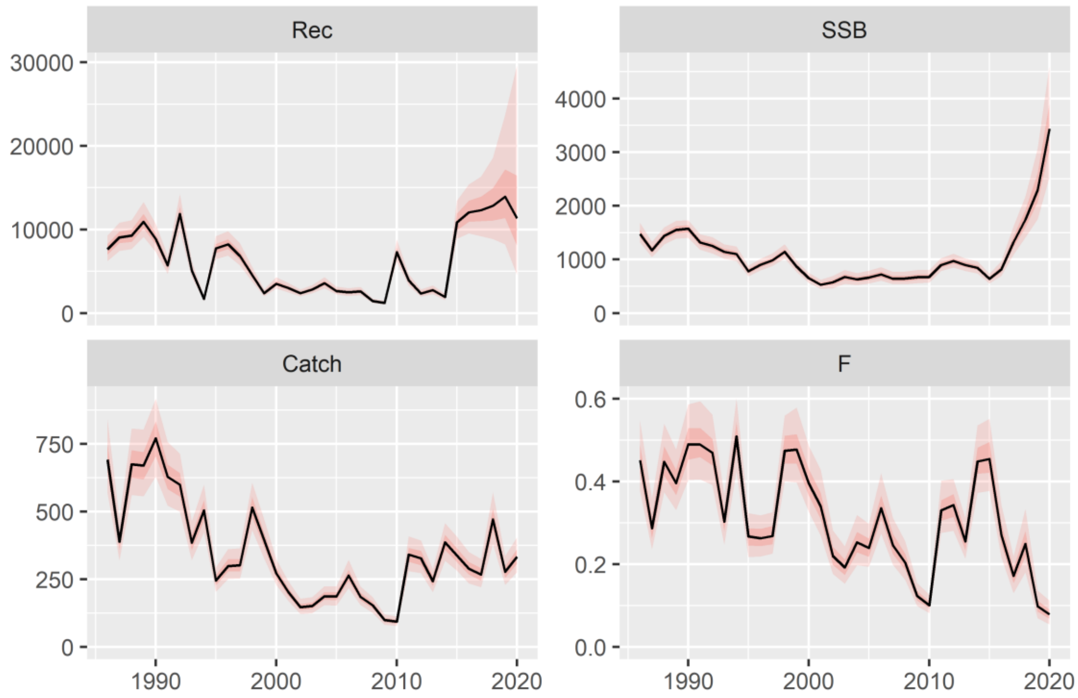


**Figure 23. Outputs of the assessment; Recruitment, SSB and F.**

## 2.6.2 Validation

### 2.6.2.1 Retrospective analyses

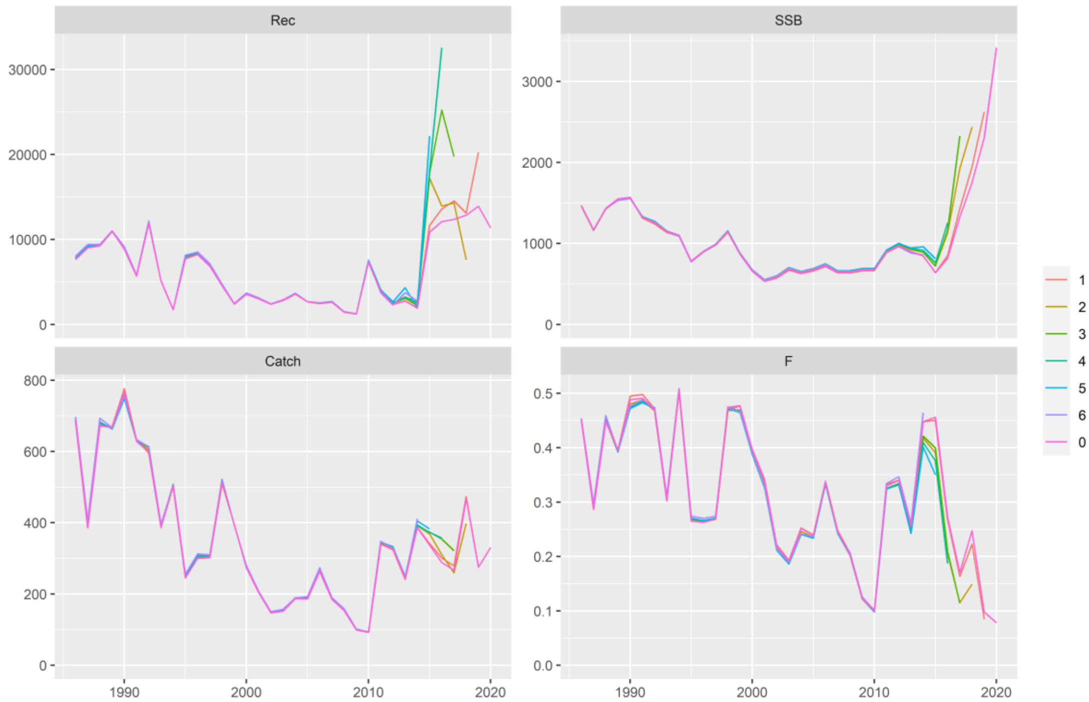


**Figure 24. Retrospective pattern plots over the last 6 years.**

**Table 17. Model diagnostic statistics.**

| AIC | BIC | Mohn's Rho (Retro_F) | Mohn's Rho (Retro_SSB) | Mohn's Rho (Retro_R) |
|---|---|---|---|---|
| 703.7 | 1044.1 | -0.223 | 0.328 | 0.531 |

Although Mohn's Rho values are bigger than it's expected, these are the lowest ones of the tested fits and similar of those that were obtained with the XSA model in previous years.

#### 2.6.2.2 Leave-one-out analyses

These analyses were done during the selection of which tuning indices to include, earlier in the benchmark, and the subsequent selection of only one tuning index makes this step redundant.

#### 2.6.2.3 Other concerns

There are apparent differences in both growth/size and behaviour of the sexes in *L. whiffiagonis*. Due to a new, deeper, Irish megrim and anglerfish survey there is evidence of sexual dimorphism (L-W, maturity and growth) but also of differentiated habitat use, where males are more likely to be caught much deeper. Due to this spatial segregation, there is potential for differential fishing pressure on the sexes, namely higher pressure on females. During this workshop, maturity ogives were updated so that the assessment only uses female ogives derived from histological sampling. Further work is warranted to investigate the appropriateness of sex differentiated assessments. Furthermore, new fisheries independent sampling of deeper habitats should be investigated because the new Irish anglerfish and megrim survey has shown (in the northern stock) that a significant portion of the male fraction of the population may be found in greater depths than the existing survey.

## 2.7 Reference point re-calculation

### 2.7.1 Data utilized

Input data were derived from the final selected assessment model from WKMEGRIM, as presented above.

### 2.7.2 Assumptions and decisions

#### 2.7.2.1 Stock–recruitmentrelationship

A stock–recruitment model was estimated using segmented-regression with the breakpoint fixed at $B_{loss}$. The stock–recruit relationship was considered to be type 5 according to the technical guidelines (ICES, 2021) i.e. with no evidence that recruitment has been impaired or no apparent relation between stock and recruitment.

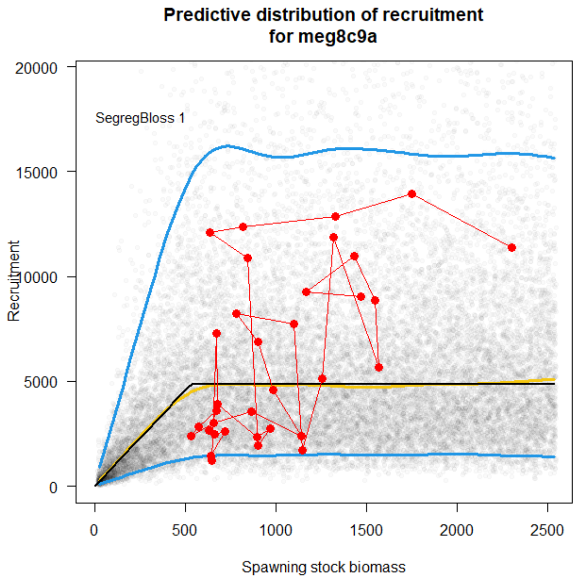


**Figure 25. Stock–recruitment model for *L. whiffiagonis* from divisions 8.c and 9.a. Determined to be ICES "Type 5" with a breakpoint at $B_{loss}$.**

### 2.7.2.2 Blim

$B_{lim}$ was set at $B_{loss}$ (532 t).

### 2.7.2.3 Variation in SSB and F

$F_{cv}$ = 0.225 (real value from the assessment)

$SSB_{cv}$ = 0.188 (real value from the assessment)

### 2.7.2.4 Autocorrelation

FALSE. Alternate runs with and without auto-regression determined no significant impact, nor any detectable autocorrelation.

## 2.7.3 Methods

Model used: *Eqsim*

Software used: *R* packages *msy* (version 0.1.19), *FLCore* (version 2.6.18) in *R* (version 4.1.2) and *icesAdvice* (version 2.0.0)

## 2.7.4 Results and reference points

**Table 18. Resultant estimated biological reference points for *L. whiffiagonis* from divisions 8.c and 9.a.**

| | Type | Value | Technical basis |
|---|---|---|---|
| MSY approach | MSY $B_{trigger}$ | 725 t | $B_{pa}$ |
| | $F_{MSY}$ | 0.173 | Stochastic simulations (*EqSim*) based on the recruitment period 1986–2020 |
| | $B_{lim}$ | 532 t | $B_{loss}$, biomass in 2001 as estimated in 2022 |
| | $B_{pa}$ | 725 t | $B_{lim}$ × exp(1.645 × 0.142) |

| | Type | Value | Technical basis |
|---|---|---|---|
| Precautionary approach | $F_{lim}$ | 0.619 | The F that results in long-term probability (SSB < $B_{lim}$) = 50%; calculated by stochastic simulation (*EqSim*) using a segmented regression with $B_{lim}$ as the breakpoint and no error |
| | $F_{pa}$ | 0.45 | $F_{p.05}$ with AR: The F that provides a 95% probability for SSB to be above $B_{lim}$. |
| EU Management plan (MAP); EU (2019) | MAP MSY $B_{trigger}$ | 725 t | MSY $B_{trigger}$ |
| | MAP $B_{lim}$ | 532 t | $B_{lim}$ |
| | MAP $F_{MSY}$ | 0.173 | $F_{MSY}$ |
| | MAP range $F_{lower}$ | 0.112 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY |
| | MAP range $F_{upper}$ | 0.284 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY |

## 2.8 Short-term forecasts

#### 2.8.1.1 Assumptions for interim year

Initial stock size: Taken from the a4a survivors.

Recruitment-at-age 1 assumed equal in intermediate year (Geometric Mean from 1998 to final assessment year minus 2). Recruitment in last year of assessment is not replaced with GM unless the estimate is highly uncertain or there appears to be a retrospective bias.

#### 2.8.1.2 Assumptions for forecast

Recruitment-at-age 1 assumed equal in all projection years (GM from 1998 to final assessment year minus 2).

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.

Proportion discards-at-age in the catch: average of the last five years

Exploitation pattern: Average of the last five years.

#### 2.8.1.3 Methods

Model used: `stf()` and `fwd()` functions in R packages *FLasher* and *FLCore*.

Software used: *R* packages *icesTAF* (version 3.6.0) and *FLasher* (version 0.6.7) in *R* (version 4.1.2)

#### 2.8.1.4 Forecast results

Various catch options were calculated according to previous advice.

**Table 19. Catch options table for *L. whiffiagonis* from divisions 8.c and 9.a.**

| Basis | Total catch (2022) | Wanted catch (2022) | Unwanted catch (2022) | F[total] (ages 2–4) (2022) | F[wanted] (ages 2–4) (2022) | F[unwanted] (ages 1–2) (2022) | SSB (2023) | % SSB change | % Advice change |
|---|---|---|---|---|---|---|---|---|---|
| MSY approach: F[MSY] | 902 | 892 | 10 | 0.172 | 0.15 | 0.055 | 3683 | −17.6 | 63 |
| F=MAP F[MSY lower] | 627 | 621 | 7 | 0.115 | 0.1 | 0.037 | 3997 | −10.5 | 13.5 |
| F=MAP F[MSY upper] | 1323 | 1309 | 14 | 0.27 | 0.23 | 0.087 | 3203 | −28 | 139 |
| MSY approach: F[MSY] | 902 | 892 | 10 | 0.172 | 0.15 | 0.055 | 3683 | −17.6 | 63 |
| F[2020] | 553 | 547 | 6 | 0.1 | 0.087 | 0.032 | 4082 | −8.6 | 0.00 |
| F=0 | 0 | 0 | 0 | 0 | 0 | 0 | 4717 | 5.6 | −100 |
| F[pa] | 1590 | 1573 | 17 | 0.34 | 0.3 | 0.109 | 2900 | −35 | 188 |
| F[lim] | 2155 | 2131 | 24 | 0.52 | 0.45 | 0.165 | 2265 | −49 | 290 |
| SSB (2023)=B[pa] | 3566 | 3522 | 44 | 1.35 | 1.18 | 0.43 | 725 | −84 | 540 |
| SSB(2023)=B[lim] | 3753 | 3706 | 48 | 1.59 | 1.38 | 0.51 | 532 | −88 | 580 |
| SSB(2023)=MSY B[trigger] | 3566 | 3522 | 44 | 1.35 | 1.18 | 0.43 | 725 | −84 | 540 |
| SSB(2023)=SSB(2022) | 588 | 581 | 6 | 0.107 | 0.093 | 0.034 | 4042 | −9.5 | 6.3 |
| Roll-over TAC | 217 | 214 | 2 | 0.038 | 0.033 | 0.012 | 4468 | 0.00 | −61 |

# 3 Four-spot megrim in southern Bay of Biscay and Atlantic Iberian waters East

### ldb.27.8c9a – *Lepidorhombus boscii* in divisions 8.c and 9.a

## 3.1 Background

Four-spot megrim *(L. boscii)* in divisions 8.c and 9.a is assessed in ICES Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE). The current model used in the assessment is Extended Survivors Analysis (XSA).

The XSA is a deterministic model. In recent years, the working group considered that it would be much more appropriate to use a model that incorporates uncertainty, especially since discards were included in the assessment.

A WGBIE recommendation was to update the assessment model using a4a (Assessment For All - statistical catch-at-age model) following the preliminary assessment presented for megrim in divisions 7.b–k, 8.a–b, and 8.d in 2020. The model was tested for southern megrims in the workshop on Training and Development of Stock Assessment Models Using a4a and Stock Synthesis in November 2020 and January 2021 during the WKTaDSA (ICES, 2021b). As a consequence of this, preliminary and promising results were presented in the last WGBIE (ICES, 2021a) where this benchmark was proposed.

## 3.2 General stock information

### 3.2.1 Previous assessment method

The catch-at-age model used in the assessment is Extended Survivors Analysis (XSA; Shepherd, 1992), software VPA95 Lowestoft suite. A VPA based approaches that estimates fishing mortality and numbers-at-age in a stock using data on international catches-at-age and estimates (or assumed values) of natural mortality. Fleet-disaggregated catch-at-age data are used to calibrate the fishing mortality and stock number estimates to observed trends in effort or in abundance indices (Darby and Flatman, 1994).

### 3.2.2 Previous assessment status

Based on the last ICES advice for this stock, fishing pressure on the stock is below $F_{MSY}$; spawning-stock size is above MSY $B_{trigger}$, $B_{pa}$, and $B_{lim}$.

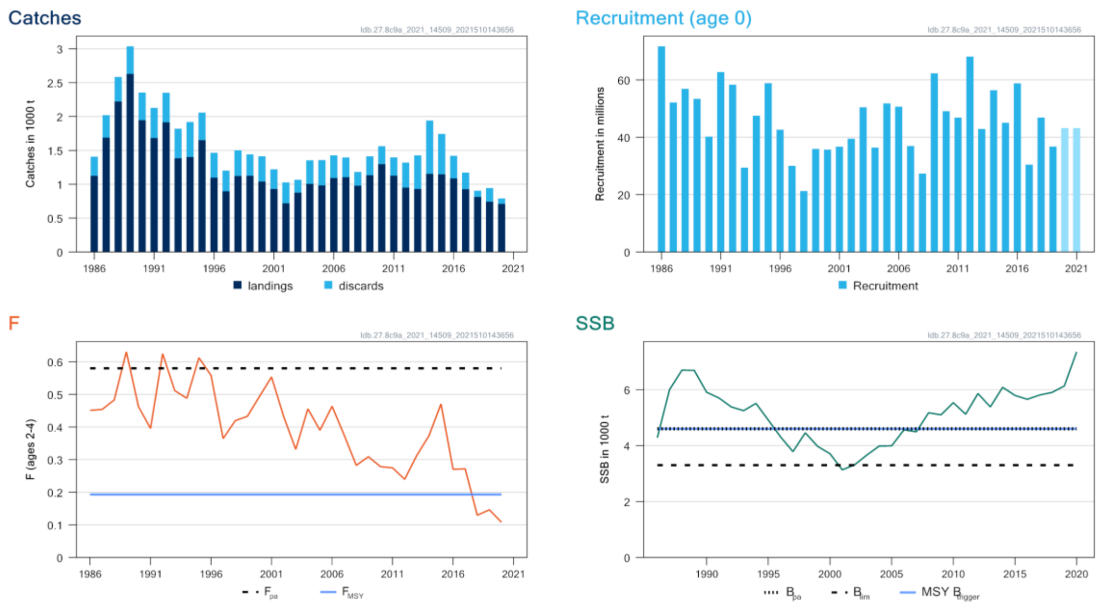


**Figure 26. Four-spot megrim in divisions 8.c and 9.a. Summary of the existing stock assessment used for advice. Assumed recruitment value is shaded in a lighter colour.**

The model has a tendency to underestimate F and an overestimate SSB in the last years.

ICES advise that when the EU multiannual plan (MAP; EU, 2019) for Western Waters and adjacent waters is applied, catches in 2022 that correspond to the F ranges in the MAP are between 1283 tonnes and 2724 tonnes. According to the MAP, catches higher than those corresponding to $F_{MSY}$ (1892 tonnes) can only be taken under conditions specified in the MAP, whilst the entire range is considered precautionary when applying the ICES advice rule (ICES Advice, 2021).

Management of catches of the two megrim species, *Lepidorhombus whiffiagonis* and *L. boscii*, under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to overexploitation of either species.

### 3.2.3 Fisheries drivers of stock development

Four-spot megrims are taken as bycatch in the mixed bottom-trawl fisheries targeting “white fish” by Spanish and Portuguese fleets, and also in small quantities by the Portuguese artisanal fleet. The majority of the catches are taken by Spanish trawlers in the métier OTB_DEF_>=55_0_0, otter bottom trawl directed to demersal fish (at least 55 mm), with around 70%. Discards are important in Spanish fleets, particularly for younger ages, but four-spot megrims are not frequently discarded in Portuguese fisheries (Fernandes *et al.*, 2021). Portuguese discards are thus assumed to be negligible and are not reported. Minimum landing size for the two species changed from 25 to 20 cm in year 2000 (Council Regulation EC 850/98).

**Table 20. Four-spot megrim (L. boscii) in Divisions 8.c and 9.a. Landings, discards and catches (t) by country and division.**

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 1986 | 799 | 197 | 996 | 128 | | 1124 | 284 | 1408 |
| 1987 | 995 | 586 | 1581 | 107 | | 1688 | 333 | 2021 |

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 1988 | 917 | 1099 | 2016 | 207 | | 2223 | 363 | 2586 |
| 1989 | 805 | 1548 | 2353 | 276 | | 2629 | 408 | 3037 |
| 1990 | 927 | 798 | 1725 | 220 | | 1945 | 409 | 2354 |
| 1991 | 841 | 634 | 1475 | 207 | | 1682 | 447 | 2129 |
| 1992 | 654 | 938 | 1592 | 324 | | 1916 | 437 | 2353 |
| 1993 | 744 | 419 | 1163 | 221 | | 1384 | 438 | 1822 |
| 1994 | 665 | 561 | 1227 | 176 | | 1403 | 517 | 1920 |
| 1995 | 685 | 826 | 1512 | 141 | | 1652 | 406 | 2058 |
| 1996 | 480 | 448 | 928 | 170 | | 1098 | 368 | 1466 |
| 1997 | 505 | 289 | 794 | 101 | | 896 | 308 | 1204 |
| 1998 | 725 | 284 | 1010 | 113 | | 1123 | 378 | 1501 |
| 1999 | 713 | 298 | 1011 | 114 | | 1125 | 317 | 1442 |
| 2000 | 674 | 225 | 899 | 142 | | 1041 | 373 | 1414 |
| 2001 | 629 | 177 | 807 | 124 | | 931 | 290 | 1221 |
| 2002 | 343 | 247 | 590 | 130 | | 720 | 308 | 1028 |
| 2003 | 393 | 314 | 707 | 169 | | 876 | 191 | 1067 |
| 2004 | 534 | 295 | 829 | 177 | | 1006 | 348 | 1354 |
| 2005 | 473 | 321 | 794 | 189 | | 983 | 375 | 1358 |
| 2006 | 542 | 348 | 891 | 201 | | 1092 | 335 | 1427 |
| 2007 | 591 | 295 | 886 | 218 | | 1104 | 292 | 1396 |
| 2008 | 546 | 262 | 808 | 172 | | 980 | 202 | 1182 |
| 2009 | 577 | 342 | 919 | 215 | | 1134 | 279 | 1413 |
| 2010 | 616 | 484 | 1100 | 197 | | 1297 | 265 | 1562 |
| 2011 | 390 | 384 | 774 | 181 | 172 | 1128 | 269 | 1397 |
| 2012 | 240 | 239 | 479 | 98 | 374 | 952 | 369 | 1321 |
| 2013 | 338 | 283 | 621 | 80 | 230 | 931 | 496 | 1427 |
| 2014 | 427 | 313 | 739 | 142 | 273 | 1154 | 788 | 1942 |
| 2015 | 460 | 255 | 715 | 137 | 296 | 1148 | 597 | 1745 |

| | | Spain landings | | Portugal landings | Non reported | Total landings | Spain Discards | Total catch |
|---|---|---|---|---|---|---|---|---|
| Year | 8.c | 9.a | Total | 9.a | | | | |
| 2016 | 403 | 276 | 679 | 105 | 303 | 1087 | 332 | 1419 |
| 2017 | 346 | 265 | 611 | 144 | 172 | 926 | 246 | 1173 |
| 2018 | 381 | 231 | 612 | 130 | 72 | 814 | 92 | 906 |
| 2019 | 385 | 240 | 625 | 118 | | 742 | 201 | 943 |
| 2020 | 346 | 224 | 569 | 141 | | 711 | 81 | 792 |

The maximum catch of 3037 t was reached in 1989. There is a decreasing trend from late 1980s more pronounced in recent years. Landings are mainly from Spain in the whole time-series.

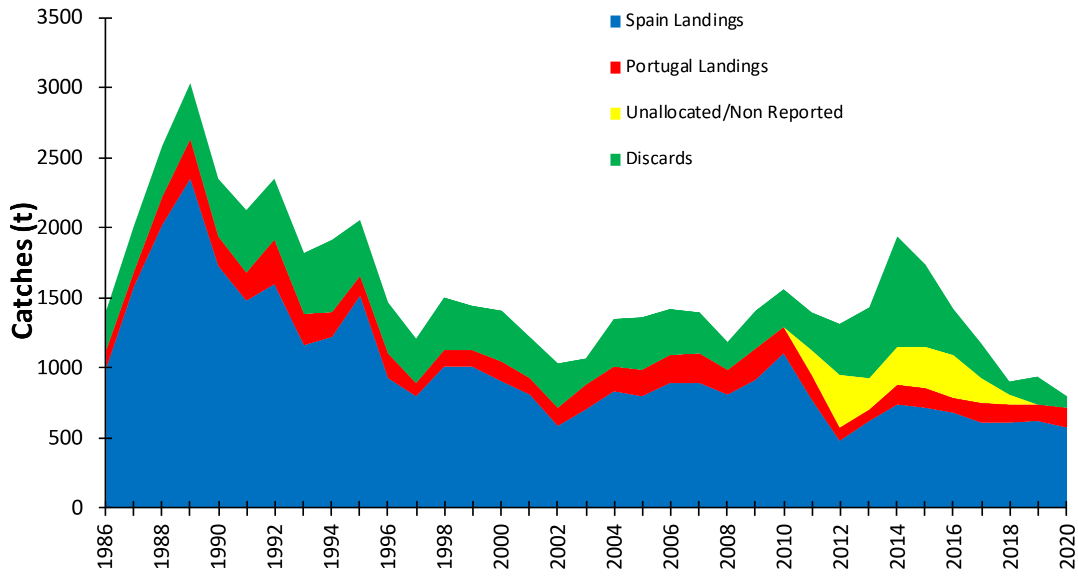


**Figure 27 Four-spot megrim (*L. boscii*) in Divisions 8.c and 9.a. Catches (landings, discards and non-reported) in the time-series.**

### 3.2.4 Environmental drivers of stock development

See stock annex for ecosystem aspects.

## 3.3 Conclusions from other expert groups relevant to this stock

As described above, the assessment working group WGBIE recommended that assessment model for this stock be upgraded in a benchmark (ICES, 2021a), based on the ground work for the shift from XSA to a4a was undertaken in WKTaDSA (ICES, 2021b).

## 3.4 Ambitions for benchmark process

The ambitions for this benchmark workshop were to address issues identified across the assessment process, from knowledge of the species biology, through the appropriateness of different fisheries based and fisheries independent tuning indices, to the fundamental assessment model framework to use. The overall aim was to improve the transparency and reliability of the whole assessment procedure. The specific issues that were addressed are in the below table of the stock's issues list.

Summarized in the Issue list:

**Table 21. Issues list for the southern megrim (*L. boscii*), prior to the benchmark workshop.**

| Type | Problem/Aim | Work Required | Data Required |
|---|---|---|---|
| Biological parameters | Old maturity ogive and old L-W relationship (1996) | Update the maturity ogive and L-W relationship. | Maturity data obtained by species and sex and for both sexes combined based on a more robust microscopic methodology and recent Length-weight data from sampling program. |
| Tuning series | LPUE - Commercial abundance indices have to be standardized. | Standardization of reference fleets. Métier OTB_DEF_>=55_0_0 in Spanish fishing ports. | Time-series of logbooks, daily landings d and VMS records for métier OTB_DEF_>=55_0_0 in selected Spanish fishing ports. |
| Assessment method | Need to be updated. From the deterministic XSA to another model | During WKTaDSA (ICES, 2021b) some work was developed in preparation for the WGMEGRIM benchmark in 2022. This stock has been presented as case study to be assessed with a4a (assessment for all) model. The assessment model has been successfully implemented to this stock and different configurations have been presented. The work is fully in good progress. | Data and model script are available. |

## 3.5 Data in support of benchmark process

### 3.5.1 Survey data and tuning indices

#### 3.5.1.1 Surveys

The Portuguese October groundfish survey (PtGFS-WIBTS-Q4, G8899) and the Portuguese Crustacean survey (PT-CTS (UWTV (FU 28–29, G2913))) and one Spanish groundfish survey (SpGFS-WIBTS-Q4, G2784) series are available since 1990, 1997 and 1983, respectively.

The Spanish survey (SpGFS-WIBTS-Q4, G2784) and the Portuguese Crustacean survey (PT-CTS-UWTV-FU 28–29, G2913) are used in the assessment of this species. The Spanish survey covers the distribution area and depth strata of this species in Spanish waters (covering both 8.c and

9.a). The survey appears to be quite good at tracking some cohorts through time and gives good information for younger ages. The Portuguese survey covers part of the distribution of four-spot megrim in Portuguese waters in the South of Division 9.a and was proposed to WKMEGRIM 2022 (Moura *et al*., 2022, see working document).

Portuguese October index is not considered to be representative of four-spot megrim abundance, due to the very low catch rates.

**Table 22. Available fisheries independent surveys available for use as tuning fleets.**

| Type | Name | Year range | Age range | Used in the assessment |
|---|---|---|---|---|
| Spanish groundfish survey | SpGFS-WIBTS-Q4 (G2784) | 1983–present | 1–6 | Yes |
| Portuguese October groundfish survey | PtGFS-WIBTS-Q4 (G8899) | 1990-present | Biomass index | No |
| Portuguese Crustacean survey | PT-CTS -UWTV -FU 28–29 (G2913) | 1997–present | 1–6 | Yes |

#### 3.5.1.2 Commercial CPUE

LPUE and Fishing Effort data are available for the following fleets: Spanish trawlers targeting demersal fish based in A Coruña port (SP-LCGOTBDEF, ?) since 1986 and Portuguese trawlers fishing in Division 9a since 1988. Effort from the Portuguese fleet is estimated from a sample of logbooks from sea trips where megrim occurred in the catch. Furthermore, a standardized CPUE based on fishery-dependent data collected from fishery observers' on-board commercial vessels in métier OTB_DEF_>=55_0_0 was presented in WKMEGRIM 2022 as a relative biomass index since 2003 (Pennino *et al*., 2022, see working document).

**Table 23. . Available fisheries dependent sampling for deriving tuning fleets. These were explored but, ultimately, not used in the final assessment model.**

| Type | Name | Year range | Used in the assessment |
|---|---|---|---|
| Spanish Coruña bottom otter trawl | SP-LCGOTBDEF1 | 1986–1999 | No |
| Spanish Avilés bottom otter trawl | SP-AVSOTBDEF2 | 2000–present | No |
| Portuguese trawlers | PT-trawl | 1988–present | No |
| Spanish observers standardized CPUE | SP-OABCPUE | 2003-present | No |

As a decision of the group, the use of commercial CPUE data was rejected due to concerns about changes in efficiency, targeting behaviour, quota restrictions, technical measures, discarding and compliance. However, trends in effort, landings and LPUE or CPUE may be used by the assessment working group as supplementary information.

### 3.5.2 Biological data

#### 3.5.2.1 Maturity

A new and updated female maturity ogive based on histology applying a robust microscopic methodology has been presented. The female maturity ogive (Domínguez *et al*., 2021, see working document) is assumed constant over time, with the following proportions of fish mature at each age:

**Table 24. New female only maturity ogive for *L. boscii*, adopted for the new assessment.**

| Age | 0 | 1 | 2 | 3 | 4 | 5+ |
|---|---|---|---|---|---|---|
| *L. boscii* | 0 | 0.05 | 0.32 | 0.83 | 0.98 | 1 |

This female only maturity ogive has been accepted based primarily on the fact that females are the main limiting factor for reproductive output but also based on precedent, where using female only ogives is not uncommon.

#### 3.5.2.2 Age-length keys and length-weight relationships

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 (BIOSDEF, 1998). In 2022, after a revision and update with a time-series data of the last years (Landa *et al*., 2021, see working document), new parameter values of the length-weight relationship were derived, presented to the benchmark workshop, and accepted for use in the updated assessment procedure.

ALKs from Spanish surveys were applied to the Portuguese Crustacean survey data, for which ages are not available.

**Table 25. The parameters for the age–length keys of *L. boscii* applied in the previous assessment procedure (Previous and those that were presented to and accepted by the benchmark meeting for use in the updated assessment (Updated).**

| | *Previous* | *Updated* |
|---|---|---|
| a | 0.00431 | 0.0043427 |
| b | 3.1904 | 3.2008 |

#### 3.5.2.3 Natural Mortality

Natural mortality was set to 0.2 and assumed constant over all ages and years as in the previous assessment method and this was retained for the new assessment procedure.

Although it is assumed that natural mortality is likely to vary with age, no new or relevant data were presented to quantify age-varying (or time-varying) M for this species and thus there was no basis upon which this assumption could be changed.

## 3.6 Stock assessment model

### 3.6.1 Data exploration

Data exploration of data used in the assessment is presented in next figures.

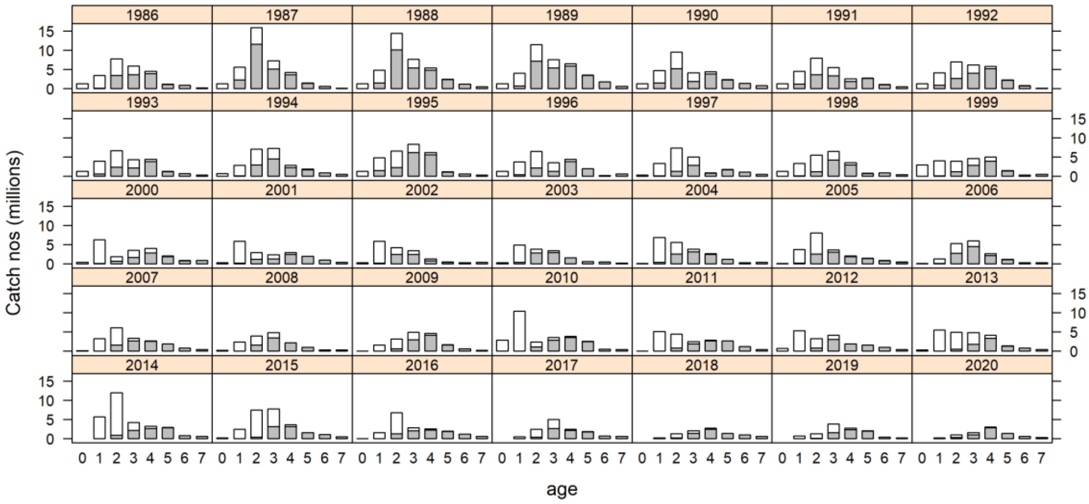


**Figure 28. . Catch numbers-at-age for *L. boscii*: landings are in grey, discards in white.**

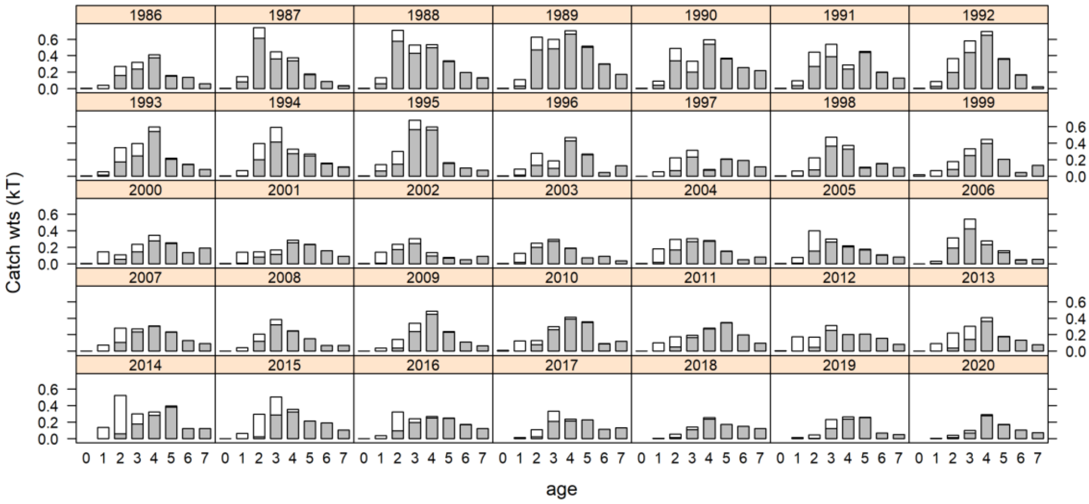


**Figure 29. Catch weight-at-age for *L. boscii*: landings are in grey, discards in white.**

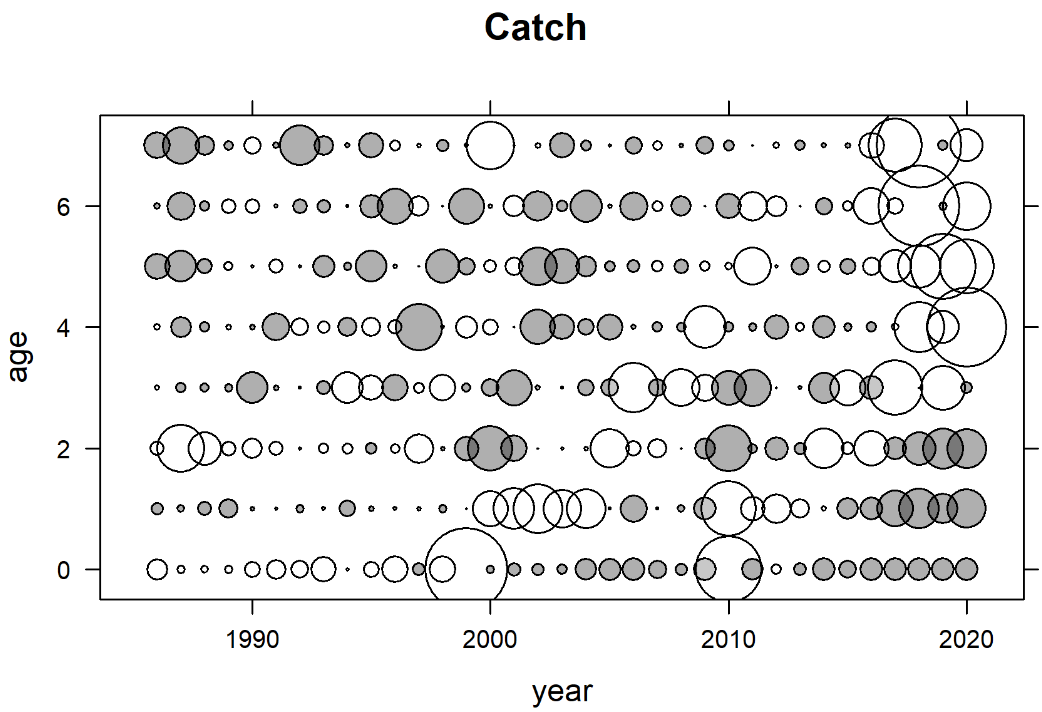


**Figure 30. Catch residuals by age over years for *L. boscii* from commercial fleet. Bubble size is proportional to difference from average; grey below average and white above.**

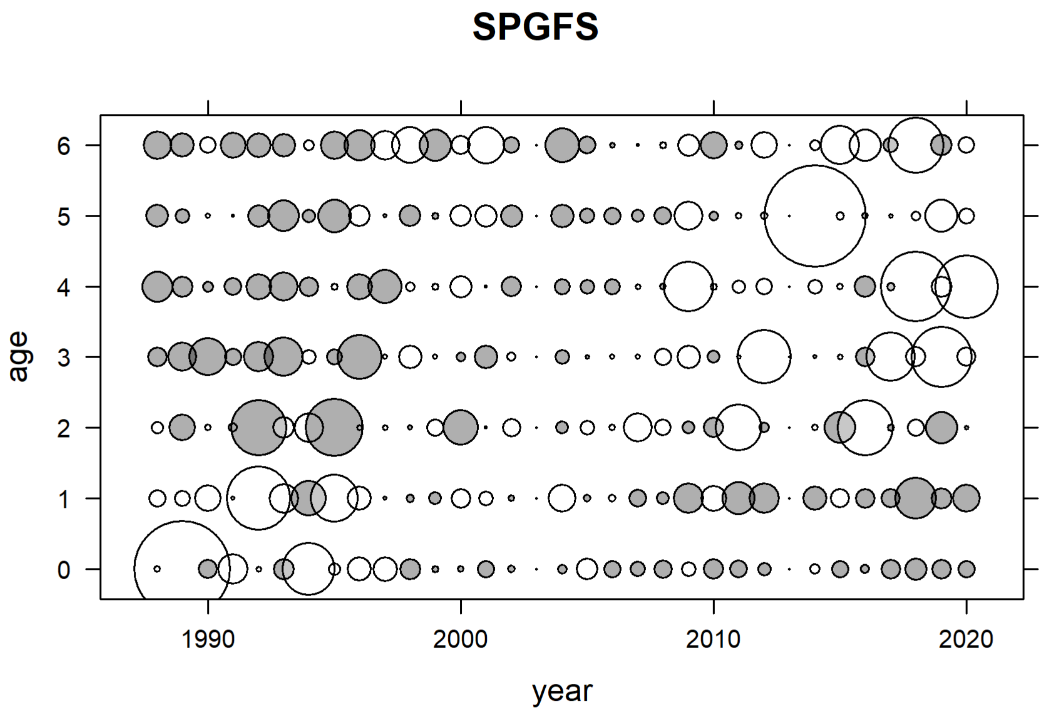


**Figure 31. Catch residuals by age over years for *L. boscii* from the selected survey, SpGFS-WIBTS-Q4 (G2784). Bubble size is proportional to difference from average; grey below average and white above.**

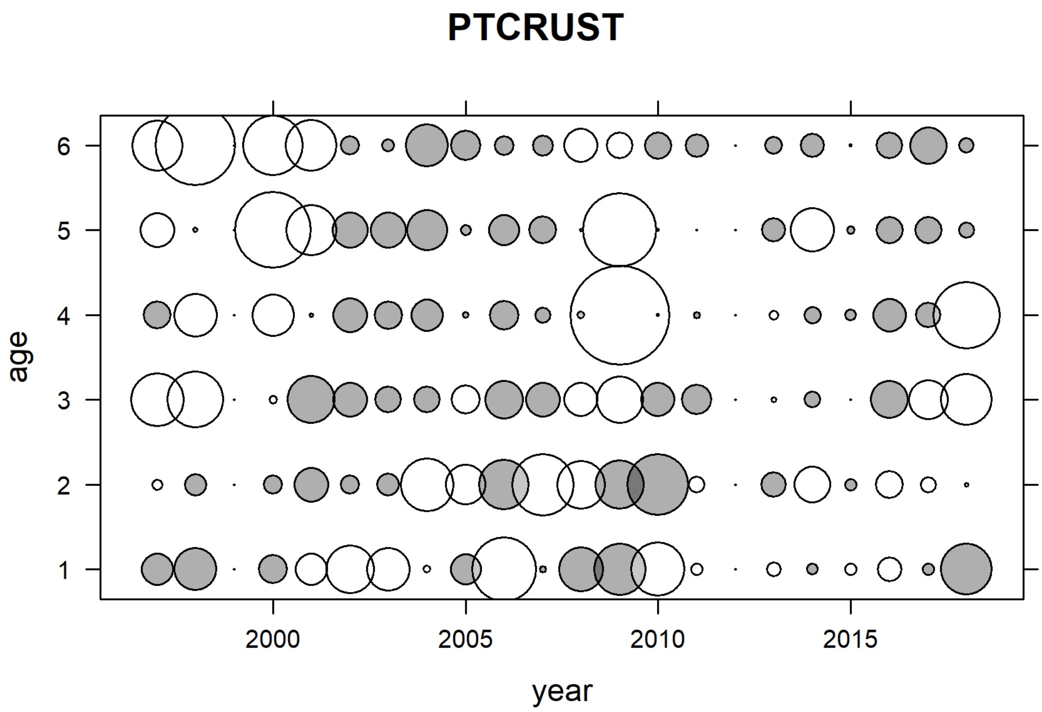


**Figure 32. Catch residuals by age over years for L. *boscii* from the selected survey, PT-CTS -UWTV -FU 28–29 (G2913). Bubble size is proportional to difference from average; grey below average and white above.**

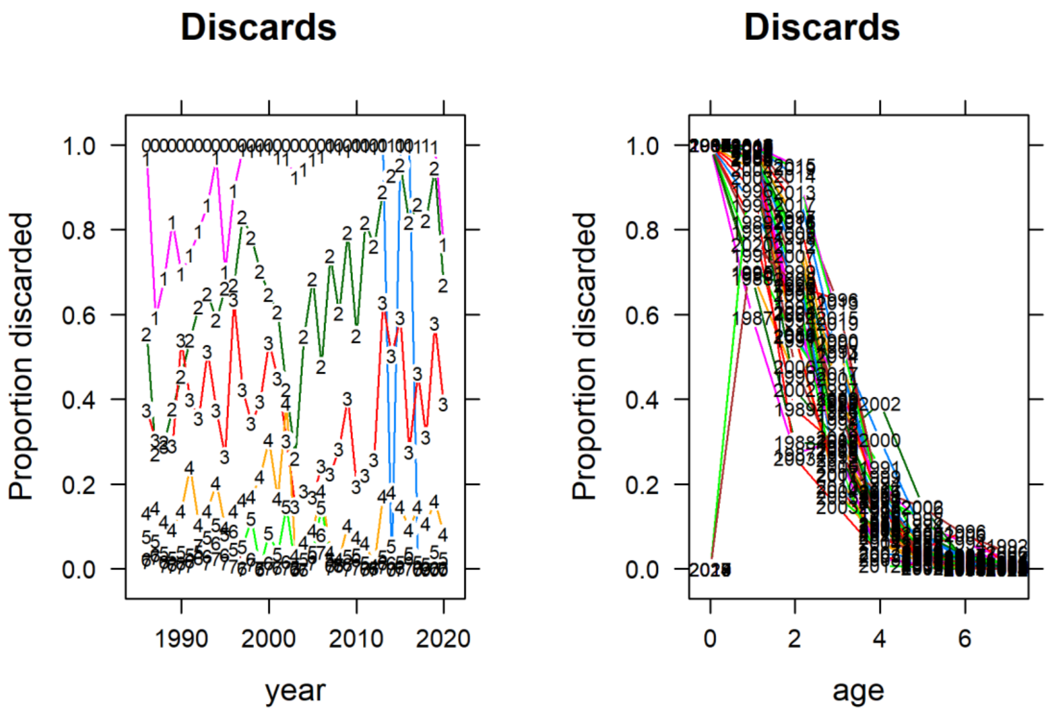


**Figure 33. Discard proportions by age and year (x-axis and coloured lines swapped between panels).**

## 3.6.2 New Model Configuration

### 3.6.2.1 Framework

The stock assessment model selected was a4a (assessment for all) is implemented for assessment of the stock. It is a non-linear catch-at-age model implemented in R and FLR, and using ADMB, that can be applied rapidly to a wide range of situations with low parameterization requirements (http://www.flr-project.org/doc/Statistical_catch_at_age_models_in_FLa4a.html).

### 3.6.2.2 Model Specification

The model structure is defined by submodels, which are the different parts that require structural assumptions. There are 5 submodels in operation:

- model for F-at-age,
- model for the initial age structure,
- model for recruitment,
- (list) of model(s) for abundance indices catchability-at-age,
- list of models for the observation variance of catch-at-age and abundance indices.

These submodels were defined as:

```
fmodel: ~factor(replace(age, age > 6, 6)) + factor(year)
srmodel: ~factor(year)
n1model: ~factor(age)
qmodel: list(~I(1/(1 + exp(-age)))+s(replace(age, age > 5, 5), k = 5),
        ~I(1/(1 + exp(-age))))
vmodel:
  catch:         ~s(age, k = 3)
  SpGFS-WIBTS-Q4:    ~1
  PT-CTS-UWTV -FU 28–29:    ~1
```

- The F model is a separable model. The shape of the F-at-age pattern is independently estimated for each age except ages 6 and 7+, which are assumed to have the same F. This pattern in F is then scaled up and down independently for each year.
- Stock–recruit model: Freely estimated for each year.

Catchability models:

  - For the SpGFS-WIBTS-Q4 (G2784) survey, catchability is assumed to increase asymptotically but ages 5 and 6 are bound (i.e. same catchability for these two ages). This configuration was selected in order to solve a residuals issue in this survey.
  - For the PT-CTS-UWTV-FU 28–29 (G2913) survey, catchability is assumed to increase asymptotically.
- N1 model (population in the first year of the time-series): default value a4aSCA function (independently estimated for each age)
- Vmodel (the shape of the observation variances): default value a4aSCA function: smooth function for the catch numbers-at-age and 'flat' for the indices

An FLStock object is needed and it was adapted from XSA input data. This object includes catches, landings, discards, weights-at-age, natural mortality, maturity, harvest before spawning and mortality before spawning all derived from the data introduced in section 2.5.

#### 3.6.2.3 Model Settings

**Table 26. Age ranges and variability settings for different model components for *L. boscii*.**

| Type | Name | Year range | Age range | Variable from year-to-year |
|---|---|---|---|---|
| landings | Landings in tonnes | 1986–present | 0–7+ | Yes |
| discards | Discards in tonnes | 1986–present | 0–7+ | Yes |
| landings.n | Landings-at-age in numbers | 1986–present | 0–7+ | Yes |
| discards.n | Discards-at-age in numbers | 1986–present | 0–7+ | Yes |
| catch.wt | Weight-at-age in the commercial catch | 1986–present | 0–7+ | Yes |
| stock.wt | Weight-at-age of the spawning stock at spawning time. | 1986–present | 0–7+ | Yes |
| m.spwn | Proportion of natural mortality before spawning | 1986–present | 0–7+ | No |
| f.spwn | Proportion of fishing mortality before spawning | 1986–present | 0–7+ | No |
| mat | Proportion mature at age | 1986–present | 0–7+ | No |
| M | Natural mortality | 1986–present | 0–7+ | No |
| Index1 | SpGFS-WIBTS-Q4 (G2784) | 1990–present | 0–6 | Yes |
| Index2 | PT-CTS-UWTV-FU 28–29 (G2913) | 1997–2018 | 1–6 | Yes |

Exploratory analysis based in the preliminary results obtained in WKTaDSA (ICES, 2021b) where developed in order to select the appropriate indices for the assessment (Abad, 2022, see working document).

The preliminary runs showed a trend in the residuals of age 0 in catch. As the first period of the discards time-series was estimated, it was decided to set to NA age 0 in the catch for the early years.

stock@catch.n['0',as.character(1986:1998)] <- NA

#### 3.6.2.4 Assessment

Below are the results of the selected final assessment model. This model was selected based on a thorough investigation and selection of the input data (as described above) and optional model settings selected to reduce model residuals (visual inspection), improve model parsimony (AIC), and improve model predictive capability (Mohn's rho and retrospective analyses visual inspection).

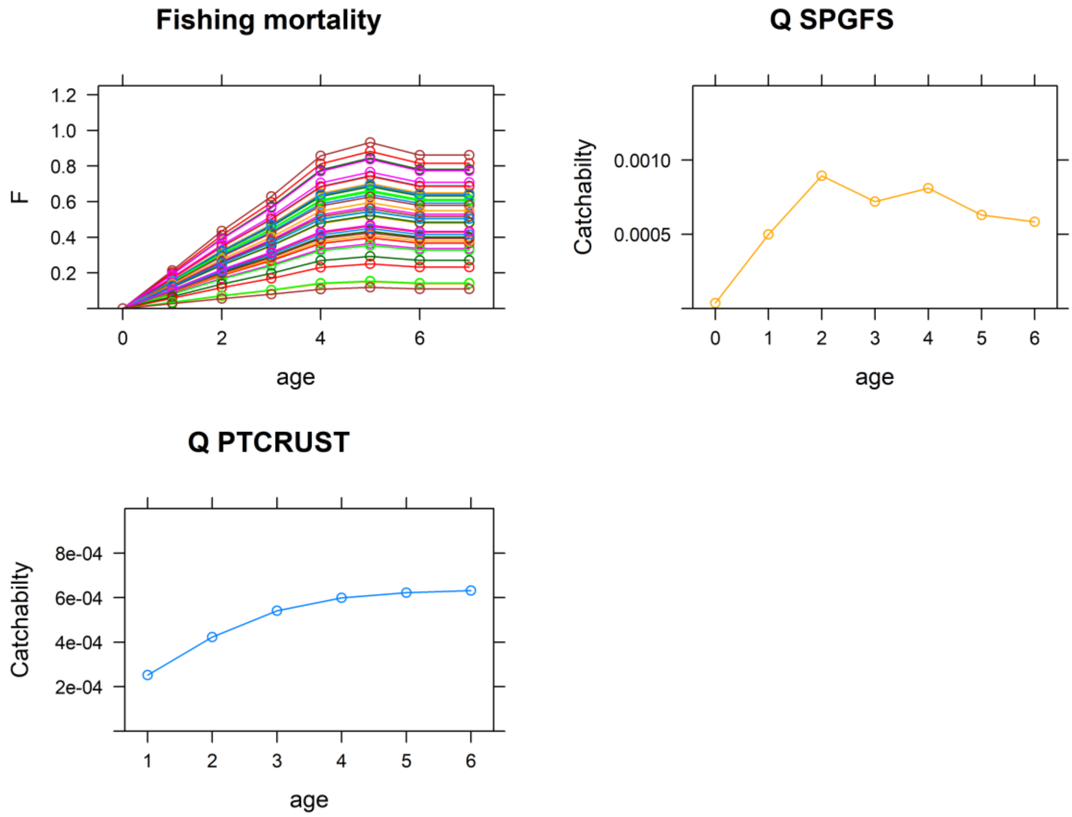


Figure 34. Fishing mortality and catchability of tuning surveys.

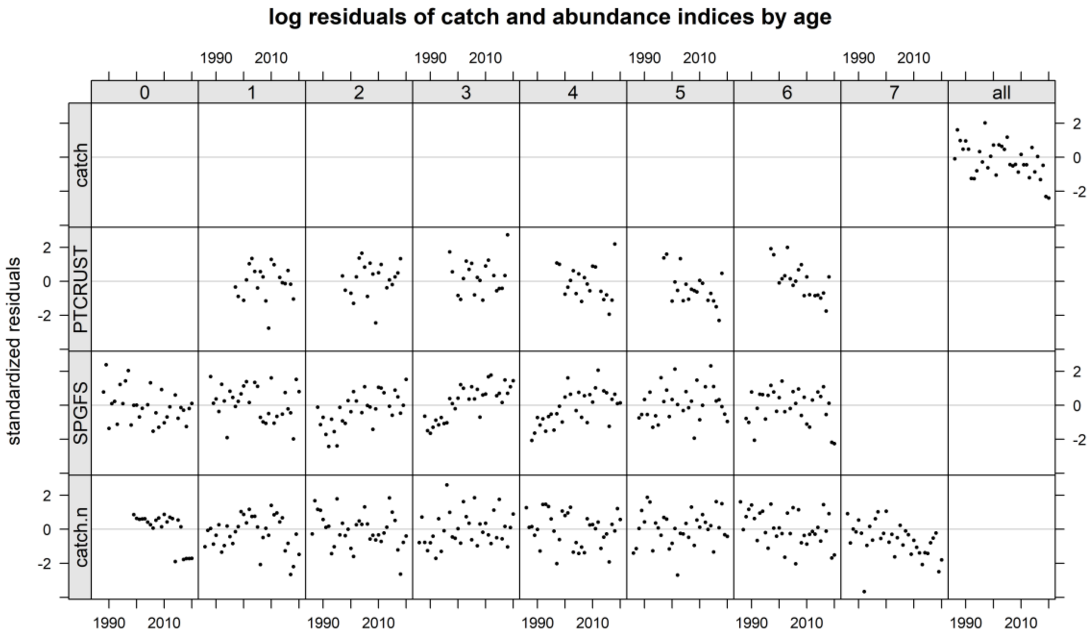


Figure 35. Log residuals of catch and abundance indices by age.

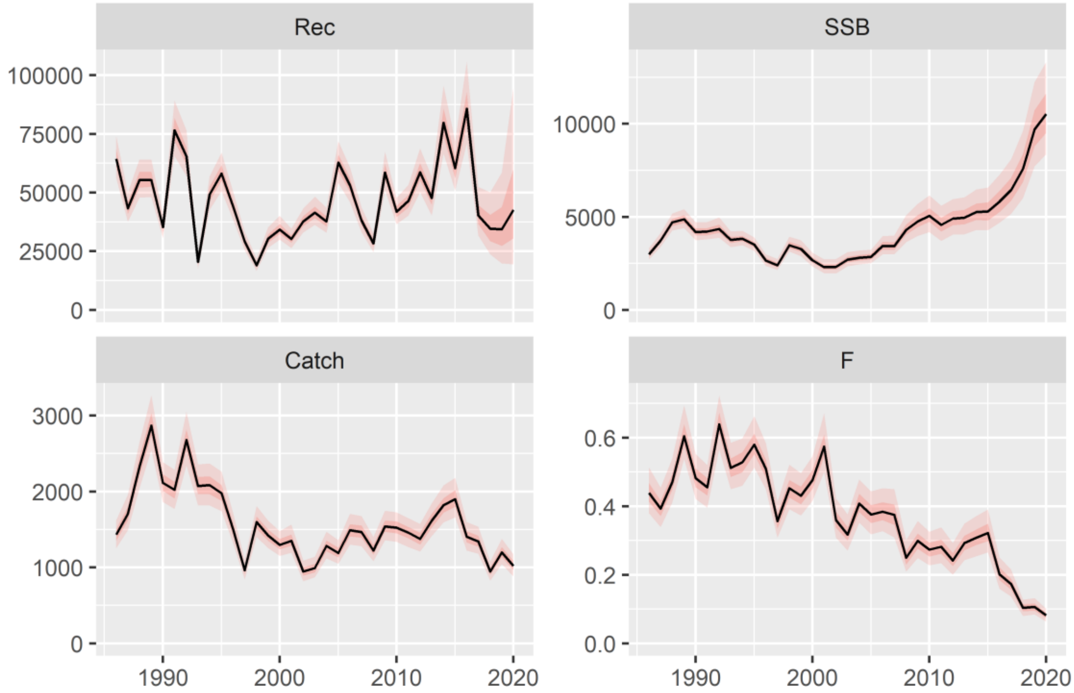


**Figure 36. Outputs of the assessment; Recruitment, SSB and F.**

## 3.6.3 Validation

### 3.6.3.1 Retrospective Analyses

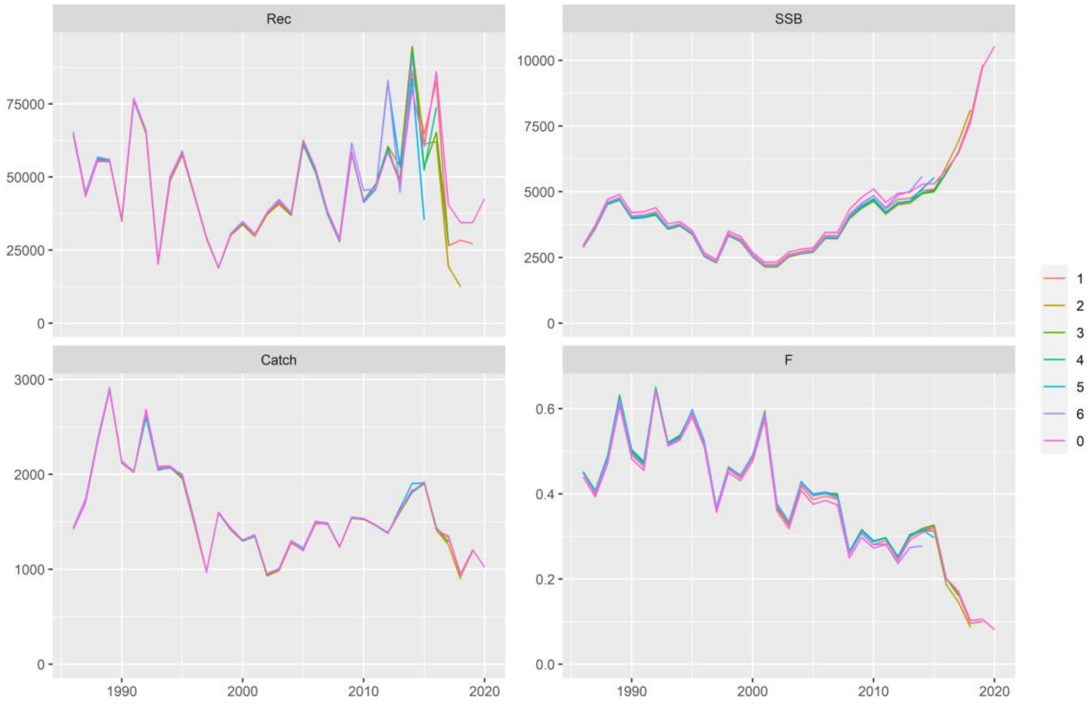


**Figure 37. Retrospective pattern plots over the last 6 years.**

**Table 27. Model diagnostic statistics.**

| AIC | BIC | Mohn's Rho (Retro_F) | Mohn's Rho (Retro_SSB) | Mohn's Rho (Retro_R) |
|---|---|---|---|---|
| 1038.1 | 1443.2 | −0.07 | 0.05 | −0.21 |

#### 3.6.3.2 Leave-one-out analyses

These analyses were done during the selection of which tuning indices to include, earlier in the benchmark, and the subsequent selection of only one tuning index makes this step redundant. Other concerns

There are no outstanding concerns for this assessment. However, the reliability of the Portuguese survey is uncertain and may require an interbenchmark to ensure the assessment continues to run smoothly, should this survey cease to operate.

## 3.7 Reference point re-calculation

### 3.7.1 Data utilized

Input data were derived from the final selected assessment model from WKMEGRIM, as presented above.

### 3.7.2 Assumptions and decisions

#### 3.7.2.1 Stock–recruitment relationship

A stock–recruitment model was estimated using segmented-regression with the breakpoint fixed at $B_{loss}$. The stock–recruit relationship is considered to be type 5 according to the technical guidelines (ICES, 2021) i.e. with no evidence that recruitment has been impaired or no apparent relation between stock and recruitment.

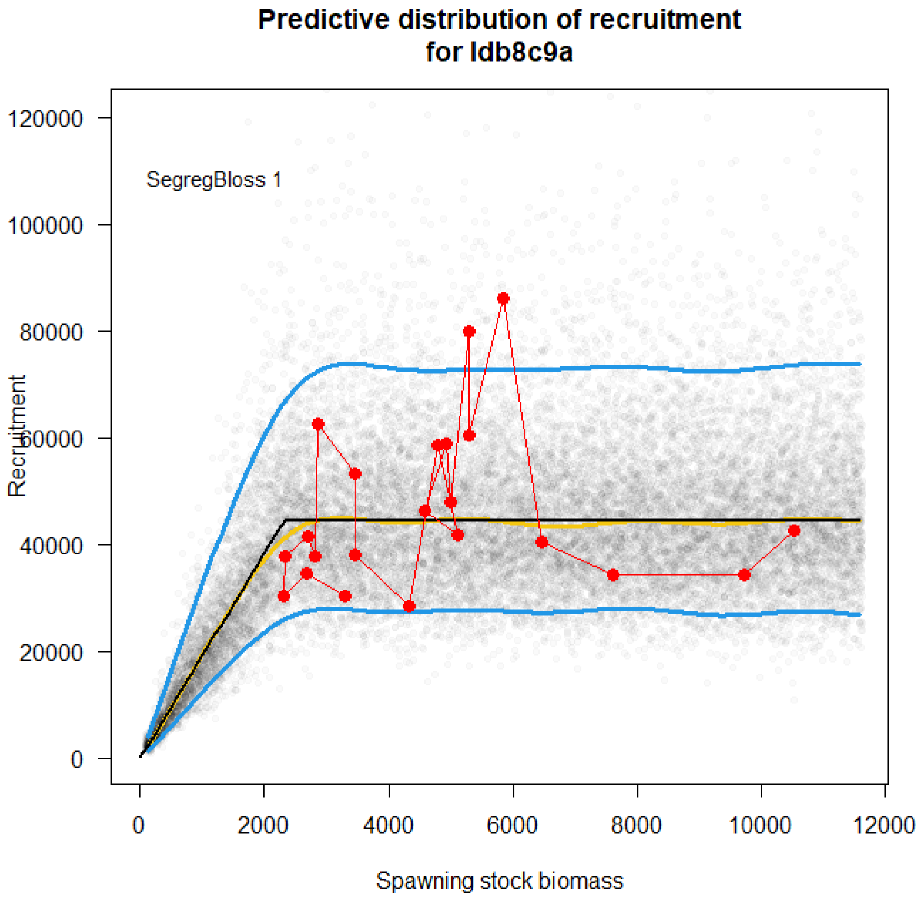


**Figure 38. Stock–recruitment model for *L. boscii* in divisions 8.c and 9.a. Determined to be ICES "Type 5" with a break-point at $B_{loss}$.**

### 3.7.2.2 $B_{lim}$

$B_{lim}$ was set at $B_{loss}$ (2321 t)

### 3.7.2.3 Variation in SSB and F

$F_{cv}$ = 0.142 (real value from the assessment)
$SSB_{cv}$ = 0.142 (real value from the assessment)

### 3.7.2.4 Autocorrelation

FALSE. Alternate runs with and without auto-regression determined no significant impact, nor any detectable autocorrelation.

## 3.7.3 Methods

Model used: *Eqsim*

Software used: *R* packages msy (version 0.1.19), *FLCore* (version 2.6.18) in *R* (version 4.1.2) and *icesAdvice* (version 2.0.0)

### 3.7.4 Results and reference points

**Table 28. Resultant estimated biological reference points for *L. boscii* in divisions 8.c and 9.a.**

| | Type | Value | Technical basis |
|---|---|---|---|
| MSY Approach | MSY $B_{trigger}$ | 2932 t | $B_{pa}$ |
| | $F_{MSY}$ | 0.176 | Stochastic simulations (*EqSim*) based on the recruitment period 1986–2020. |
| Precautionary Approach | $B_{lim}$ | 2321 t | $B_{loss}$, biomass in 2001 as estimated in 2022. |
| | $B_{pa}$ | 2932 t | $B_{lim} \times \exp(1.645 \times 0.142)$. |
| | $F_{lim}$ | 0.56 | The F that results in long-term probability (SSB < $B_{lim}$) = 50%; calculated by stochastic simulation (*EqSim*) using a segmented regression with $B_{lim}$ as the breakpoint and no error. |
| | $F_{pa}$ | 0.46 | $F_{p.05}$ with AR: The F that provides a 95% probability for SSB to be above $B_{lim}$. |
| EU Management plan (MAP); EU (2019) | MAP MSY $B_{trigger}$ | 2932 t | MSY $B_{trigger}$ |
| | MAP $B_{lim}$ | 2321 t | $B_{lim}$ |
| | MAP $F_{MSY}$ | 0.176 | $F_{MSY}$ |
| | MAP range $F_{lower}$ | 0.119 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY. |
| | MAP range $F_{upper}$ | 0.28 | Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY. |

## 3.8 Short-term forecasts

#### 3.8.1.1 Assumptions for interim year

Initial stock size: Taken from the a4a survivors.

Recruitment-at-age 0 assumed equal in intermediate year (GM from 1990 to final assessment year minus 2). Recruitment in last year of assessment is not replaced with GM unless the estimate is highly uncertain or there appears to be a retrospective bias.

#### 3.8.1.2 Assumptions for forecast

Recruitment-at-age 0 assumed equal in all projection years (GM from 1998 to final assessment year minus 2). Recruitment in last year of assessment is not replaced with GM unless the estimate is highly uncertain or there appears to be a retrospective bias.

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.

Proportion discards-at-age in the catch: average last five years

Exploitation pattern: Average the last five years.

### 3.8.1.3 Methods

Model used: `stf()` and `fwd()` functions in *R* packages *FLasher* and *FLCore*.

Software used: *R* packages *icesTAF* (version 3.6.0) and *FLasher* (version 0.6.7) in *R* (version 4.1.2)

### 3.8.1.4 Forecast Results

**Table 29. Catch options table for *L. boscii* divisions 8.c and 9.a.**

| Basis | Total catch (2022) | Wanted catch (2022) | Un-wanted catch (2022) | F[total] (ages 2–4)(2022) | F[wanted] (ages 2–4) (2022) | F[un-wanted] (ages 1–2) (2022) | SSB (2023) | % SSB chnge | % Advice chnge |
|---|---|---|---|---|---|---|---|---|---|
| MSY approach: F[MSY] | 2210 | 2040 | 170 | 0.176 | 0.111 | 0.077 | 9917 | −11.7 | 16.8 |
| F=MAP F[MSY lower] | 1546 | 1429 | 117 | 0.119 | 0.075 | 0.052 | 10643 | −5.2 | −18.3 |
| F=MAP F[MSY upper] | 3305 | 3046 | 259 | 0.28 | 0.176 | 0.122 | 8722 | −22 | 75 |
| MSY approach: F[MSY] | 2210 | 2040 | 170 | 0.176 | 0.111 | 0.077 | 9917 | −11.7 | 16.8 |
| F[2020] | 1892 | 1748 | 144 | 0.148 | 0.093 | 0.065 | 10265 | −8.6 | 0.00 |
| F=0 | 0 | 0 | 0 | 0 | 0 | 0 | 12342 | 9.9 | −100 |
| F[pa] | 4899 | 4503 | 395 | 0.46 | 0.29 | 0.2 | 6994 | −38 | 159 |
| F[lim] | 5628 | 5166 | 462 | 0.56 | 0.35 | 0.24 | 6209 | −45 | 197 |
| SSB (2023)=B[pa] | 8728 | 7945 | 783 | 1.19 | 0.75 | 0.52 | 2932 | −74 | 360 |
| SSB(2023)=B[lim] | 9324 | 8468 | 856 | 1.39 | 0.87 | 0.61 | 2321 | −79 | 390 |
| SSB(2023)=MSY B[trigger] | 8728 | 7945 | 783 | 1.19 | 0.75 | 0.52 | 2932 | −74 | 360 |
| SSB(2023)=SSB(2022) | 1272 | 1176 | 96 | 0.097 | 0.061 | 0.042 | 10944 | −2.5 | −33 |
| Roll-over TAC | 1013 | 937 | 76 | 0.076 | 0.048 | 0.033 | 11228 | 0.00 | −46 |

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# Annex 1: List of participants

| Name | Institute | Country (of institute) |
|---|---|---|
| Ane Iriondo | AZTI | Spain |
| Esther Abad | IEO | Spain |
| Hans Gerritsen | MI | Ireland |
| Teresa Moura | IPMA | Portugal |
| Ching Villanueva | Ifremer | France |
| Josefina Teruel | IEO | Spain |
| Jorge Landa | IEO | Spain |
| Maria Grazia Pennino | IEO | Spain |
| Maria Korta | AZTI | Spain |
| María Pan Añón | IEO | Spain |
| Rosario Dominguez | IEO | Spain |
| Elliot John Brown (chair) | DTU Aqua | Denmark |

| WKMEGRIM reviewers | | |
|---|---|---|
| Paul Dolder | Cefas | UK |
| Christopher Legault | NOAA | United States of America |

# Annex 2: Resolutions

**WKMEGRIM – Benchmark Workshop for selected Megrim Stocks**

2021/2/FRSG28 A **Benchmark Workshop for selected Megrim Stocks**, chaired by ICES chair Elliot Brown, and attended by two invited external experts Paul Dolder and Christopher Legault, will be established and will meet online for a five-day data compilation workshop 24-27 January 2022 and online/hybrid (tbd) for a five-day Benchmark workshop 21-25 February 2022 to:

a) Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short term outlook taking agreed or proposed management plans into account for the stocks listed in the text table below. The evaluation shall include consideration of:
   i. Stock identity and migration issues;
   ii. Life-history data.
   iii. Review current sampling levels and adjust stratification levels for landings and discards accordingly;
   iv. Inclusion of recent scientific fishing surveys not yet considered in the assessment;
   v. Examine alternative assessment models to the current model;
   vi. Explore impact of all tuning fleets on assessment estimates;
   vii. Further considerations of environmental drivers, multi-species information, and ecosystem impacts for stock dynamics in the assessments and outlook;
   viii. Examine mixed fisheries interaction;
b) Agree and document the most appropriate method for evaluating stock status and (where applicable) short term forecast and update the stock annex as appropriate. Knowledge about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology where possible. If no analytical assessment method can be agreed, then an alternative method for providing advice (ideally one of the WKLIFE X (https://doi.org/10.17895/ices.pub.5985) methods) should be put forward;
c) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);
d) Develop recommendations for future improvements of the assessment methodology and data collection;
e) As part of the evaluation:
   i) Conduct a data evaluation workshop. Stakeholders are invited to contribute data (including data from non-traditional sources) and to contribute to data preparation and evaluation of data quality. As part of the data compilation workshop, consider the quality of data including discard and estimates of misreporting of landings;
   ii) Following the Data evaluation, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting.

The Benchmark Workshop will report by 1 April 2022 for the attention of ACOM.

| Stock | Assessment Lead |
|---|---|
| ldb.27.8c9a: Four-spot megrim (*Lepidorhombus boscii*) in divisions 8.c and 9.a (southern Bay of Biscay and Atlantic Iberian waters East) | Esther Abad, Spain |

| | |
|---|---|
| meg.27.8c9a: Megrim (*Lepidorhombus whiffiagonis*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters) | Esther Abad, Spain |
| meg.27.7b-k8abd: Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k, 8.a-b, and 8.d (west and southwest of Ireland, Bay of Biscay) | Ane Iriondo, Spain |

# Annex 3: Decisions made at WKMEGRIM benchmark workshop

| Stock | Component | Decision | Proposed By | Consensus | Dissenting Opinions | Reviewers Present |
|---|---|---|---|---|---|---|
| Megrim 7.b-k, 8.a-b and d: | Commercial Tuning Index | Use kilogramme per fishing day, as opposed to kg/fd*100hp | Josefine and Ane | NA | NA | NA |
| Megrim 7.b-k, 8.a-b and d: | Commercial Tuning Index | Remove commercial tuning index from assessment | Hans and Chris | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d: | Maturity Ogives | Use Histologically derived Maturity Ogives for Assessment | Rosario and Chris | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d: | Maturity Ogives | Use Female only maturity ogive. Based on precedent and that Females are the main fishery and are the main limiting factor for reproductive output. | Hans and Chris | Yes | No | Yes |
| Megrim 8.c and 9.a | Maturity Ogives | Use Histologically derived Maturity Ogives for Assessment | Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Maturity Ogives | Use Histologically derived Maturity Ogives for Assessment | Esther | Yes | No | Yes |
| Megrim 8.c and 9.a | Maturity Ogives | Use Female only maturity ogive. Based on precedent and that Females are the main fishery and are the main limiting factor for reproductive output. | Rosario and Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Maturity Ogives | Use Female only maturity ogive. Based on precedent and that Females are the main fishery and are the main limiting factor for reproductive output. | Rosario and Esther | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d | Natural Mortality | Retain fixed natural mortality across all ages as it is currently close to the estimated NM based on the work presented by Hans and falls well within the error of the different methods he presented. There were no other | Ane and Esther | Yes | No | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | data or knowledge shared to indicate that one could expect a change in NM. | | | | |
| Megrim 7.b-k, 8.a-b and d | Catch and Discards | If no national level raising is undertaken by data providers before submission to intercatch, stock coordinator needs to establish a raising procedure to apply rates across countries / areas / quarters. The success of the benchmark does not depend on the outcome of this exercise. | Ane | Yes | No | Yes |
| Megrim 8.c and 9.a | Catch and Discards | Current Policy of only accounting for Spanish discards retained (due to low catches and insignificant discards in Portugal) | Esther and Teresa | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Catch and Discards | Current Policy of only accounting for Spanish discards retained (due to low catches and insignificant discards in Portugal) | Esther and Teresa | Yes | No | Yes |
| Megrim 8.c and 9.a | Natural Mortality | Retain fixed natural mortality across all ages, using the same logic as applied to the Northern Stock. | Ane and Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Natural Mortality | Retain fixed natural mortality across all ages as there is no indication to expect this to have changed. | Ane and Esther | Yes | No | Yes |
| All | Assessment | Run assessments with different combinations of tuning/survey indices according to the agreed tables uploaded to SharePoint | Ane and Esther | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d | Catch and Discards | Use the new raising procedure (WKMEGRIM2022 approach) for the years 2016 - 2020. (Inlcude 2015 if we can get an answer from Henrik on reason for it not working in InterCatch) | Ane | Yes | No | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| Megrim 7.b-k, 8.a-b and d | Reference points | Use a segmented regression with breakpoint at Bloss to model Stock–recruitment relationship. | Ane | Yes | No | Yes |
| Megrim 8.c and 9.a | Reference points | Use a segmented regression with breakpoint at Bloss to model Stock–recruitment relationship. | Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Reference points | Use a segmented regression with breakpoint at Bloss to model Stock–recruitment relationship. | Esther | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d | Assessment | Use the assessment model configuration known as "Tweaked fit 2". | Ane | Yes | No | Yes |
| Megrim 8.c and 9.a | Assessment | Use the assessment model configuration known as "Fit 4: only survey without smoother" | Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Assessment | Use the assessment model configuration known as "Fit4: without smoother" | Esther | Yes | No | Yes |
| Megrim 7.b-k, 8.a-b and d | Forecasts | Accept the input assumptions as presented in forecast procedure | Ane | | | |
| Megrim 7.b-k, 8.a-b and d | Reference points | Do not use autocorrelation in the reference point estimation | Ane (by correspondence) | Yes | No | Yes |
| Megrim 8.c and 9.a | Reference points | Do not use autocorrelation in the reference point estimation | Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Reference points | Do not use autocorrelation in the reference point estimation | Esther | Yes | No | Yes |
| Megrim 8.c and 9.a | Forecasts | Accept the forecast procedure and default settings as presented (conditional on increased number of simulations in reference point estimation. | Esther | Yes | No | Yes |
| Four Spot Megrim 8.c and 9.a | Forecasts | Accept the forecast procedure and default settings as presented (conditional on increased number of | Esther | Yes | No | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | simulations in reference point estimation. | | | | |
| All Stocks | Forecasts | Default average periods for F, recruitment, discard ratios should be consistent with the methods used for reference point estimation (as described in the updated stock annex) unless stock developments indicate shorter periods would be more relevant (respond to changes). | David and Hans | Yes | No | Yes |

# Annex 4: Working documents

**Working Document to the ICES Benchmark workshop for selected Megrim stocks (WKMegrim2022) –**

**UK Cefas data submission.**

Not to be cited without prior reference to the authors

# UK (Cefas) data submission for WKMegrim2022 benchmark for Megrim *Lepidorhombus whiffiagonis*

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**Abstract**

This document describes the methods for data extraction and subsequent data collation of the maturity at length at age dataset required for this benchmark workshop.

**Megrim 27.7b-k8abd data**

Data was extracted from the Cefas database the 'Fishing survey system' (FSS) for current surveys operating in the required sea area. Four existing surveys operate in this area, the 'Data Collection Regulations (DCR) Data Collection survey (DCRDC)' which ran from 2005 to 2010, the 'Quarter 1 South-west Otter Trawl survey' (Q1SWOTTER), which ran between 2018 and 2020, the 'Western Channel Ground Fish Survey (WCGFS), which ran between 1982 and 2004, and the 'Quarter 1 South-west Beam trawl survey (Q1SWBEAM) which has been operating in this sea area since 2013. These surveys provide data mainly for the month of March but due to schedule flexibility some data was also collected in February and April.

Data has been provided as unsexed. Over the year range provided, three different maturity stage keys have been in use as follows:

**Maturity keys used (inc year ranges)**

| 1988 - 2001 | | 2002 - 2011 | | 2012-2021 | |
|---|---|---|---|---|---|
| 1 | Immature | I | Immature | 1 | Immature/Juvenile |
| 2 | Maturing | M | Maturing | 2 | Developing |
| 3 | Mature | H | Hyaline (female only) | 3 | spawning |
| 4 | Spawning | R | Running | 4a | regressing |
| 5 | Hyaline (female only) | S | Spent | 4b | regenerating |
| 6 | Running | | | 5 | omitted spawning |
| 13 | First time maturing | | | 6 | abnormal |
| | | | | u | undetermined |

In order to amalgamate the data into 'all years ogives' (1988-2021) these keys have been aligned as per colour scheme above with all stages in green being deemed as immature fish and all stage in orange being deemed as mature fish.

Proportions of fish at each maturity stage were calculated then combined as above to provide proportions of fish deemed both immature and mature by age.

Working document presented to the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim)

Data revision workshop – 24th to 27th January 2022

**Portuguese survey data for *Lepidorhombus boscii* (ICES division 9a)**

Teresa Moura[1], Corina Chaves[1], Jorge Landa[2], Esther Abad[2]

[1] Instituto Português do Mar e da Atmosfera (IPMA)

[2] Instituto Español de Oceanografía (IEO)

## 1. Introduction

The four-spotted megrim *Lepidorhombus* boscii and the megrim *Lepidorhombus whiffiagonis* are important fisheries resources in mainland Portugal. Both species are taken as bycatch in several fisheries but more frequently in bottom trawl fisheries. Megrims are misidentified in landings but sampling data shows that *L. boscii* is more abundant, representing, in the last decade, 82 to 95% of the estimated national landings (in weight) of both megrims (ICES, 2021).

Data from the Portuguese waters have been submitted to WGBIE annually, including survey biomass and abundance indices for both species. However, catchability of these species in the Portuguese surveys has been considered low and the surveys have not been used in the assessment. The present working document provides an insight into the data available, exploring in detail data from the crustacean survey which can potentially be used to assess the four-spotted megrim stock, ldb.27.8c9a.

### *Summary of the data available*

Both the Portuguese Autumn Groundfish Survey and the Crustacean Survey are likely to catch megrims (Table 1).

Table 1. Summary of the surveys catching megrims (*L. whiffiagonis* and *L. boscii*).

| Survey | Quarter | Area surveyed | Period | Notes |
|---|---|---|---|---|
| Portuguese International Bottom Trawl Survey (Portuguese Autumn Groundfish Survey) Code: G8899 | 4 | All coast, 20-500 m deep | 1981-2018 | Survey was not conducted in 1984, 2012, 2019 and 2020; different vessel/net in 1996, 1999, 2003 and 2004; doubts in the continuity of the series due to vessel change in 2021. |
| Nephrops Survey Offshore (Crustacean survey) Code: G2913 | 2/3 | Southwest and southern coast, 150- 750 m deep | 1997-2018 | Survey was not conducted in 2012, 2019 and 2020; different vessels were used in 1999 and in 2004; doubts in the continuity of the series due to vessel change in 2021. |

The Portuguese Autumn Groundfish Survey (PtGFS-WIBTS-Q4) has been carried out annually in Portuguese continental waters since 1979 in the 4th quarter. The survey covers the whole Portuguese continental waters (ICES Division 9.a) from 20 to 500 m depth (Figure 1). The main objectives of the survey are to monitor the abundance and distribution of hake and horse mackerel recruitment (more information in ICES, 2017). Both *L. boscii* and *L. whiffiagonis* are caught in these surveys but their catchability is low, which might be related to the gear configuration (Figure 2). Both species seem to co-occur in the same areas and depths (Annex, Figures A1-A3), but *L. whiffiagonis* is less frequent, being mostly caught in the southwest coast. *Lepidorhombus boscii* occurs along the whole coast being more frequent in the western waters. The low occurrence of *Lepidorhombus* spp. in these surveys makes this series unsuitable to assess their abundance or biomass trends.

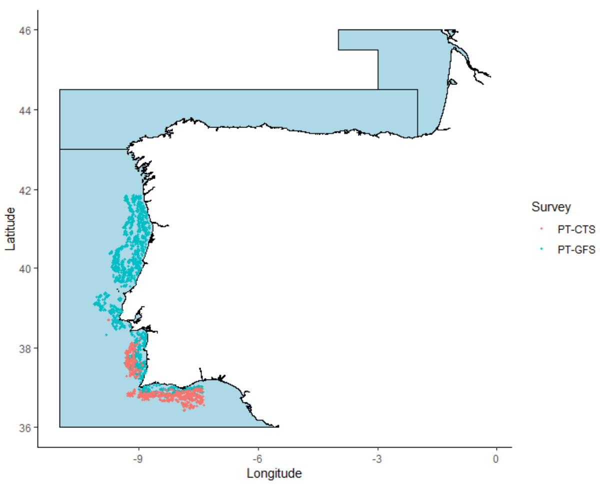



Figure 1. Location of fishing hauls conducted by the Portuguese Autumn Groundfish Survey and the Crustacean Survey between 1981-2018.

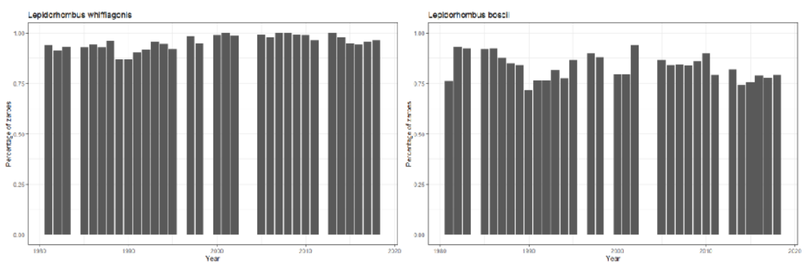



Figure 2. Percentage of zeros of a) *Lepidorhombus whiffiagonis* and b) *Lepidorhombus boscii* in demersal surveys (1981-2018).

The Crustacean Survey (PT-CTS (UWTV (FU 28–29))) is carried out in May–July and covers the southwest coast (Alentejo or FU 28) and the south coast (Algarve or FU 29). The main objectives are to estimate the abundance of the main crustacean species, Norway lobster, rose shrimp and red shrimp (2016). Both megrims *(L. boscii* and *L. whiffiagonis*) occur in these surveys, with *L. whiffiagonis* occurring in 5% to 15% of the hauls, depending on the year (Figure 3). The species is more frequent in the south-western coast, where relatively few high catches were registered (Annex, Figure A4). *Lepidorhombus boscii* occurs in 13 – 51% of the hauls. The data for this survey is presented and discussed below for further use in the assessment of the stock ldb.27.8c9a.

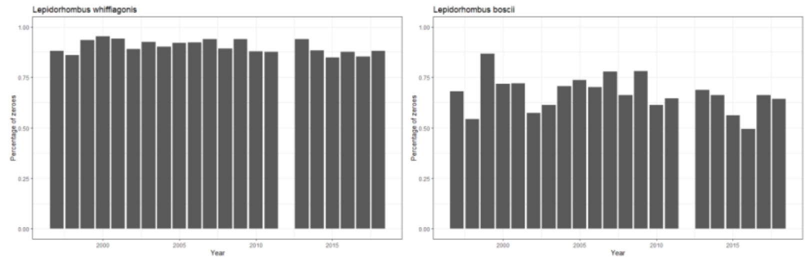



Figure 3. Percentage of zeros of a) *Lepidorhombus whiffiagonis* and b) *Lepidorhombus boscii* in crustacean surveys (1997-2018).

## 2. Methods

Data for *L. boscii* were recorded from the PT-CTS (UWTV (FU 28–29)) from 1997 to 2018. This survey was based on a stratified random sampling, with at least two stations by strata, for the period 1997-2004. The sector and depth strata were the same used for the PT-WIBTS-Q4 survey, from 200 to 750 meters in southwest and from 100 to 750 m in the south. The number of hauls was set to a minimum of two hauls per strata. Since 2005, sampling is based on a regular grid superimposed on the area of *Nephrops norvegicus* distribution, as it is the target species for this survey. The regular grid is composed by 77 rectangles with 6.6 minutes of latitude by 5.5 minutes of longitude for the southwestern coast and vice-versa for the South coast. In each rectangle, one haul is performed and the abundance observed will reflect the relative abundance of the resource in that area and be assigned at the center of the rectangle. The stations may be grouped *a posteriori* in the strata used previously and the results compared with the former surveys.

No surveys were conducted in 2012, 2019 and 2020 and a different vessel was used in 1999 and 2004 (but using the same net). The survey conducted in 1999 only covered the southern area, where the species is less abundant. This year should thus not be considered in the biomass and abundance indices. In addition, a new vessel started to operate in 2021 and the continuity of the series is still under study.

All catch (or a subsample) is sorted by species, counted and weighted. Length distributions are recorded for all fish, crustaceans and cephalopods and target species are weighted by length class. *Lepidorhombus* spp. are a target species for both Crustaceans and GroundFish surveys. A subsample of 10 individuals by length class is also sampled for length and for maturity assessment following an adaptation of the maturity scale described in ICES (2007).

Abundance (number per hour) and biomass (kg per hour) estimation and their standard deviations are computed for the surveyed area based on the methodology presented by Cochran (1977) for calculation of estimators for the stratified random sampling.

Age estimates of *L. boscii* from Portuguese waters corresponding to the time series studied are not available. However, age-length-keys (ALK) for combined sexes of *L. boscii* from otolith direct age estimations are available for each annual IBTS Spanish bottom survey (SP-WIBTS-Q4) from 1997–2018, performed in September-October. The estimated age range in this survey was 0–12 years and the length range of these ALKs (mainly 5-36 cm) represented the vast majority of the lengths caught in the Portuguese crustacean surveys (mainly based on 9-40 cm). However, some lengths from the length distribution (LD) of the Portuguese surveys corresponding to large individuals (generally lengths between 36 and 42 cm) did not have age composition in their corresponding ALK from SP-WIBTS-Q4. To complete the age composition in those length ranges, a usual procedure was carried out, which is to take the corresponding age composition from the combined ALK of several years, and apply it in those lengths with lacks, always taking into account the distribution and strength of the cohorts of each specific year in those lengths. This process had to be performed each year in only 3 lengths.

## 3. Results and discussion

### 3.1. Catch distribution

High catch rates ($kg.h^{-1}$) are consistently attributed to the south-western coast and at depths ranging from 300 to 500 m deep (Figures 4 and 5). Despite not frequently caught, individuals <10 cm were found both in the south-western and in the southern coasts (Figure 6). *Lepidorhombus boscii* co-occur with *L. whiffiagonis* in same areas and depths, suggesting that no segregation occurs between species.

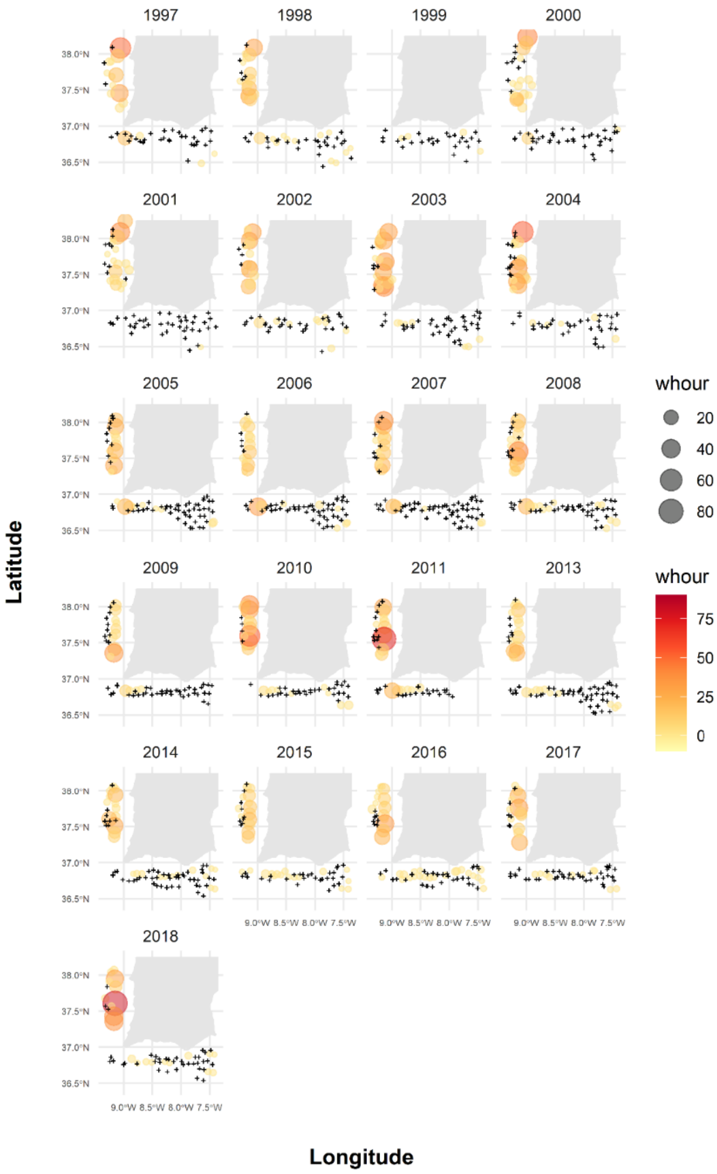



Figure 4. Occurrences and catch distribution (kg.h$^{-1}$) of *Lepidorhombus boscii* in the PT Crustacean Survey from 1997 to 2018. Surveys were not conducted in 2012, 2019 and 2020. Black crosses represent hauls with zero catch of *L. boscii*.

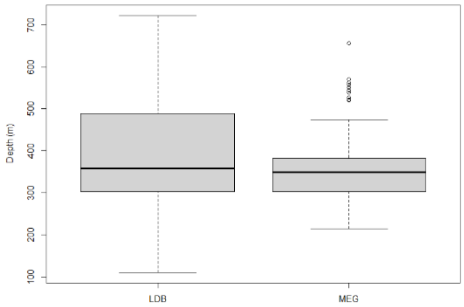



Figure 5. Boxplot of the depth distribution of both *Lepidorhombus boscii* (LDB) and *Lepidorhombus whiffiagonis* (MEG).

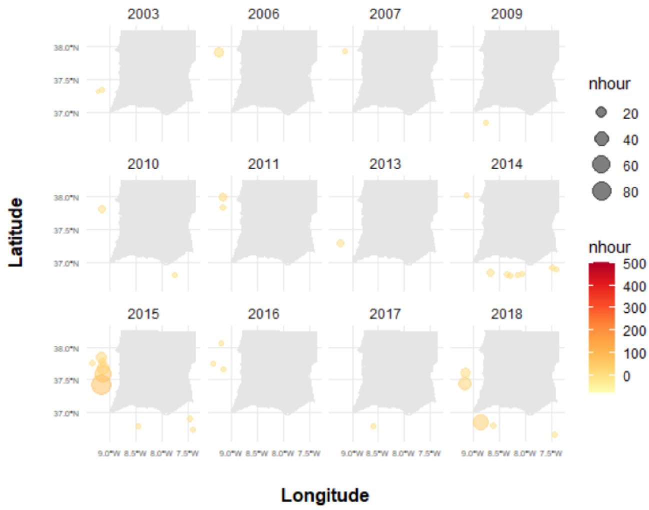



Figure 6. Catch distribution (n.h$^{-1}$) of *Lepidorhombus boscii* < 10 cm in the PT Crustacean Survey from 1997 to 2018. Surveys were not conducted in 2012, 2019 and 2020.

### ***3.1.1. Biomass and abundance indices***

Stratified biomass and abundance indices are presented in Table 2 and Figures 7 and 8 for *L. boscii*. From 1997 to 2017 both series show no major trends, varying around the long-term mean. The highest value was observed in 2018, which is associated to very high catches (>500 kg) in 4 hauls, which also explains the large variance. This extreme value is in line with the value obtained in the commercial LPUE index for the same year. Despite not standardized a large increase was also observed from 2017 to 2018 (Figure 9).

Table 2. Stratified biomass index for *Lepidorhombus boscii* caught in the Portuguese Crustacean survey

| | Biomass (kg.h$^{-1}$) | | Abundance (n.h$^{-1}$) | |
|---|---|---|---|---|
| **Year** | **Index** | **variance** | **Index** | **variance** |
| 1997 | 4.04 | 3.19 | 41.77 | 251.67 |
| 1998 | 2.62 | 0.28 | 28.05 | 72.57 |
| 1999 | --- | --- | --- | --- |
| 2000 | 1.15 | 0.11 | 11.10 | 11.72 |
| 2001 | 1.35 | 0.14 | 14.22 | 13.01 |
| 2002 | 2.63 | 0.30 | 38.90 | 43.23 |
| 2003 | 3.71 | 0.34 | 60.82 | 98.16 |
| 2004 | 2.79 | 0.35 | 42.59 | 90.21 |
| 2005 | 2.62 | 0.41 | 31.72 | 71.08 |
| 2006 | 1.82 | 0.07 | 32.81 | 35.01 |
| 2007 | 3.08 | 0.37 | 46.74 | 69.87 |
| 2008 | 3.08 | 0.25 | 32.86 | 34.41 |
| 2009 | 1.77 | 0.16 | 14.68 | 14.68 |
| 2010 | 4.91 | 0.93 | 80.59 | 360.69 |
| 2011 | 4.24 | 0.89 | 65.44 | 182.87 |
| 2013 | 2.37 | 0.47 | 36.91 | 96.36 |
| 2014 | 2.15 | 0.44 | 32.40 | 123.72 |
| 2015 | 2.22 | 0.06 | 37.35 | 32.35 |
| 2016 | 2.65 | 0.10 | 53.47 | 19.96 |
| 2017 | 2.82 | 0.67 | 54.03 | 215.08 |
| 2018 | 8.98 | 22.83 | 146.28 | 6409.79 |

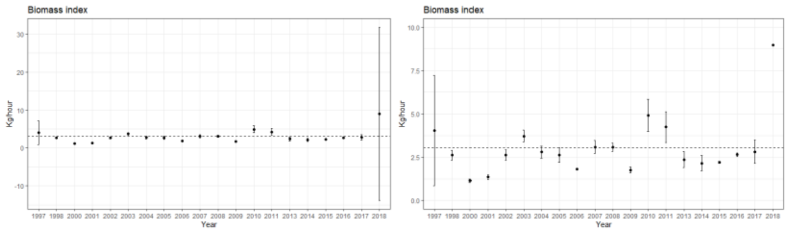



Figure 7. Biomass index (kg.h$^{-1}$) for *Lepidorhombus boscii* in the PT Crustacean survey (1997-2018; no data for 1999, 2012, 2019 and 2020). Right plot is similar to the left one but excluding the error bar in 2018.

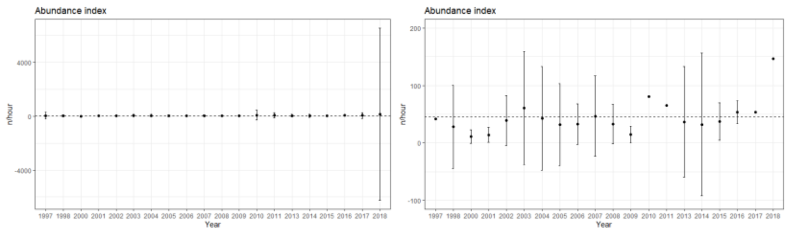



Figure 8. Abundance index (n.h$^{-1}$) for *Lepidorhombus boscii* in the PT Crustacean survey (1997-2018; no data for 1999, 2012, 2019 and 2020). Right plot is similar to the left one but excluding the error bars in 1997, 2010, 2011 and 2018.

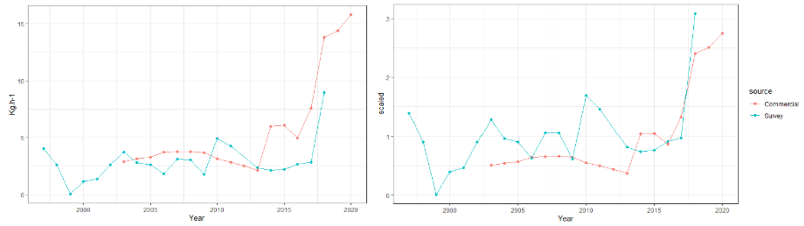



Figure 9. Comparison between stratified biomass survey index and commercial biomass index (kg.h-1) from the PT OTB fleet for *Lepidorhombus boscii* (in the right, values scaled to mean of the time series).

#### *3.1.2. Length composition*

Stratified mean length is presented in Figure 10, by year. During the whole time series, the crustacean survey caught specimens from 3 to 45 cm (but mostly between 10 and 30 cm). Individuals <10 cm were rarely caught.

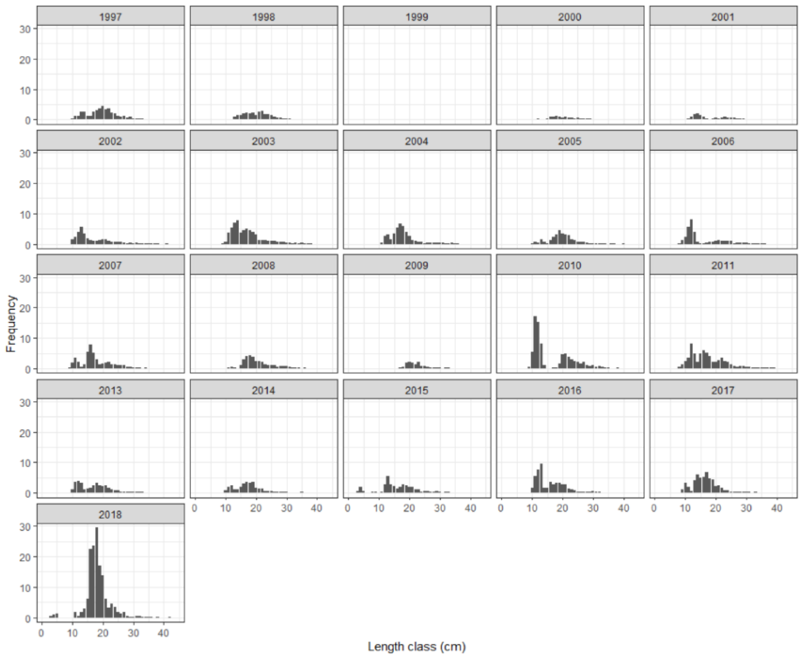



Figure 10. Length frequency distribution of *Lepidorhombus boscii* in the PT Crustacean Survey (1997-2018).

### *3.1.3. Age-length keys*

A matrix of abundance indices at Age and year (AaA) was obtained (Table 3) after applying the age-length-key obtained from direct age estimation in each Spanish bottom survey (1997–2018) to their respective length distribution from the Portuguese crustacean surveys.

The ALKs from SP-WIBTS-Q4 come from September-October, while the LDs from the Portuguese crustacean surveys were performed annually three months before (June-July). That means that the growth applied to the Portuguese LDs is slightly biased, slightly overestimating the mean lengths at age thus obtained. However, when this procedure is applied to the whole time series, all the years are similarly biased and distinguishing trends in cohort dynamics is not seriously influenced.

The mean age composition of the time series in the AaA matrix indicates that ages 1, 2 and 3 are the mainly captured in these surveys (78%) (Table 3). The range up to 4 years constitutes 90% of the catch, and up to age 6 it represents 97% of it. Specimens <8 cm are not usually collected in these crustacean surveys (there are only any individuals <8 cm in some recent years of the time series) and in several years there are no specimens <12 cm. So those Portuguese crustacean surveys are not representative for estimating age class 0, and age class 1 is therefore the best indicator of cohort strength in those surveys. Thus the main range of ages (1-8) well represented in the AaA matrix is shown between lines in Table 3.

Two years of the time series could not be taken into account: 2012 without survey information, and 1999 due to the very low representation of individuals in the LD (only individuals in 6 length ranges, between 12 and 25 cm).

A high variability is also observed in the abundance indices between the years of the Portuguese crustacean surveys, with extremely low values in 2000, 2001 and 2009 and extremely high values in 2010, 2011 and 2018 (Table 3). These extreme years are not due to the emergence of an extreme recruitment, since the frequency values increase in all lengths in the LD and logically in all age classes (Table 3). It seems rather that it is due to a "year effect" probably caused to an extremely higher or lower catchability in those aforementioned years.

Several cohorts of *L. boscii* can be preliminary tracked in the first ages in the AaA matrix, from age 1 and, in several of them, up to age 8, although they are really well tracked in the most abundant age classes (1 to 4) (Table 3, Figure 11).

To analyze in more detail, the cohort tracking avoiding that bias due to the "year effect", the AaA matrix (in % for each surveys) was estimated, so that the annual indices were comparable (Table 4). Thus, in addition to those abundant cohorts (2002,2003,2005, 2006,2009,2014,2015) which are more clearly detectable in Table 4 and Figure 12, other scarce cohorts can also be observed (1998, 1999, 2007, 2008), which were not so clearly observable in Table 3.

As in any other species, it is more appropriate to apply ALKs from age estimates of *L. boscii* collected in the same surveys, than ALKs from another area or stock. However, one of the most remarkable results presented here can be considered that despite that, applying the estimates of the northern (Spanish) area of the stock, it is possible to analyze and obtain a preliminary view of the cohort dynamics of this southern (Portuguese) area of the stock.

Table 3. Abundance at age matrix (in number) of *L.boscii* after applying the age-length-key obtained from direct age estimation in each Spanish bottom survey (1997–2018) to their respective length distribution from the Portuguese crustacean surveys. The mean value and % of the abundance of each age group is showed on the right. The main range of ages (1-8) well represented in the catch-at-age matrix is shown between lines. Diagonal lines encompass clear some strong cohorts.

| | | | NA (only 8 ind.) | | | | | | | | | | | | | NA | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | | mean | % | % aggregated |
| 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 3 | 0 | 0 | 3 | | 0 | 1 | 1 |
| 1 | 5 | 2 | | 1 | 6 | 17 | 31 | 14 | 4 | 20 | 12 | 2 | 0 | 45 | 22 | | 13 | 7 | 12 | 22 | 12 | 2 | | 12 | 28 | 29 |
| 2 | 13 | 6 | | 2 | 2 | 7 | 13 | 18 | 12 | 4 | 22 | 13 | 2 | 8 | 21 | | 8 | 12 | 8 | 19 | 17 | 42 | | 13 | 28 | 57 |
| 3 | 15 | 10 | | 2 | 1 | 4 | 9 | 6 | 9 | 4 | 6 | 10 | 5 | 10 | 9 | | 8 | 6 | 7 | 6 | 18 | 52 | | 10 | 22 | 79 |
| 4 | 2 | 6 | | 2 | 1 | 1 | 3 | 2 | 3 | 2 | 4 | 3 | 5 | 9 | 6 | | 5 | 2 | 3 | 2 | 3 | 37 | | 5 | 11 | 90 |
| 5 | 3 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 3 | | 1 | 3 | 1 | 1 | 1 | 5 | | 2 | 4 | 94 |
| 6 | 2 | 2 | | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 3 | | 1 | 3 | 97 |
| 7 | 1 | 1 | | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | | 1 | 0 | 0 | 1 | 1 | 0 | | 1 | 1 | 98 |
| 8 | 0 | 0 | | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | | 0 | 0 | 0 | 0 | 0 | 1 | | 0 | 1 | 99 |
| 9 | 0 | 0 | | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | | 0 | 0 | 0 | 0 | 0 | 1 | | 0 | 1 | 100 |
| 10 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 100 |
| 11 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 100 |
| 12 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 100 |
| Total | 42 | 28 | | 11 | 14 | 33 | 61 | 43 | 32 | 33 | 47 | 33 | 15 | 80 | 65 | | 37 | 32 | 37 | 53 | 54 | 146 | | 45 | 100 | |

Table 4. Abundance at age matrix (in % for each year) of *L.boscii* after applying the age-length-key obtained from direct age estimation in each Spanish bottom survey (1997–2018) to their respective length distribution from the Portuguese crustacean surveys. Solid diagonal green lines encompass clear strong cohorts and diagonal red lines encompass clear weak ones.

| Age | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 9 | 0 | 0 | 2 |
| 1 | 12 | 6 | | 12 | 43 | 52 | 50 | 32 | 13 | 62 | 26 | 5 | 1 | 56 | 34 | | 36 | 23 | 31 | 41 | 23 | 1 |
| 2 | 30 | 22 | | 20 | 17 | 22 | 21 | 43 | 39 | 13 | 46 | 41 | 13 | 10 | 32 | | 21 | 38 | 23 | 36 | 32 | 29 |
| 3 | 36 | 37 | | 21 | 9 | 12 | 15 | 15 | 29 | 12 | 13 | 30 | 33 | 13 | 14 | | 23 | 18 | 20 | 12 | 33 | 35 |
| 4 | 5 | 20 | | 18 | 10 | 4 | 5 | 4 | 10 | 5 | 8 | 10 | 31 | 11 | 10 | | 13 | 8 | 8 | 4 | 6 | 26 |
| 5 | 7 | 4 | | 10 | 8 | 2 | 2 | 2 | 4 | 2 | 3 | 4 | 10 | 5 | 5 | | 3 | 8 | 4 | 3 | 3 | 4 |
| 6 | 6 | 7 | | 6 | 6 | 2 | 2 | 1 | 1 | 2 | 2 | 5 | 4 | 2 | 2 | | 2 | 2 | 3 | 2 | 1 | 2 |
| 7 | 2 | 2 | | 5 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | | 2 | 1 | 1 | 1 | 1 | 0 |
| 8 | 1 | 1 | | 4 | 2 | 2 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 0 |
| 9 | 0 | 1 | | 2 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 100 | 100 | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | 100 | 100 | 100 | 100 | 100 | 100 |

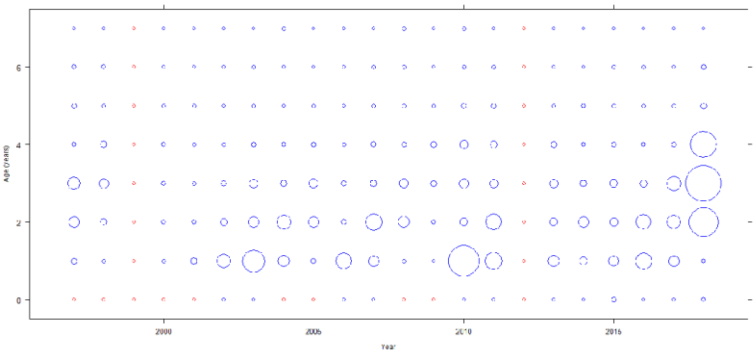



Figure 11. Bubble plots of abundance at age (in number) of *L.boscii* after applying the age-length-key obtained from direct age estimation in each Spanish bottom survey (1997–2018) to their respective length distribution from the Portuguese crustacean surveys. The size of the bubble is proportional to abundance at that year's age.

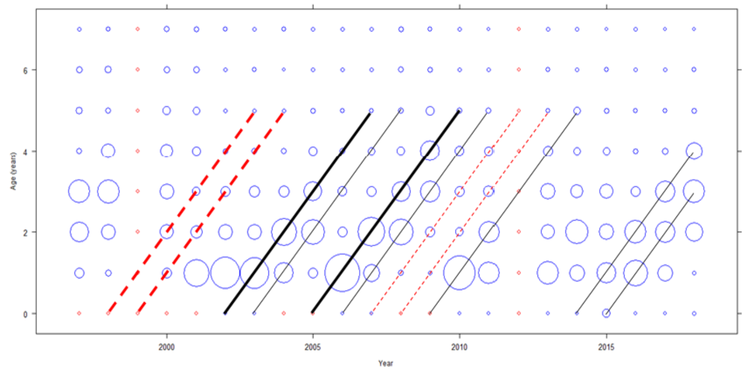


Figure 12. Bubble plots of abundance at age (in % for each year) of *L.boscii* after applying the age-length-key obtained from direct age estimation in each Spanish bottom survey (1997–2018) to their respective length distribution from the Portuguese crustacean surveys. The size of the bubble is proportional to abundance at that year's age. Solid diagonal black lines encompass clear strong cohorts and diagonal red lines encompass clear weak ones

### *3.1.4. Biological information*

In general, the crustacean survey catches more males than females and, regardless of the sex, immature specimens (Figure 13). No segregation by depth with maturity stage seems to occur but larger females seem to distribute at deeper depth strata (Figures 14 and 15).

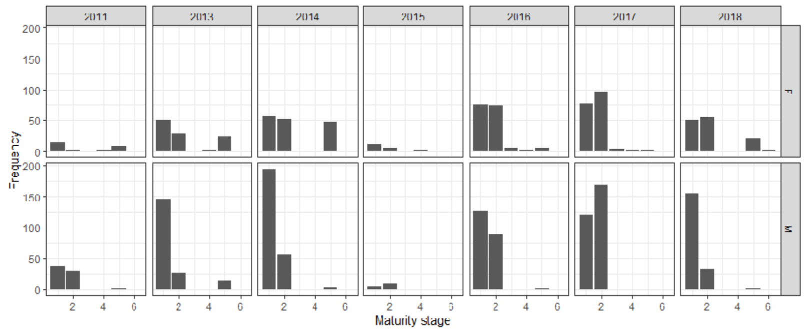


Figure 13. Frequency of males and females by maturity stage and by year in PT Crustacean Survey (2011-2018).

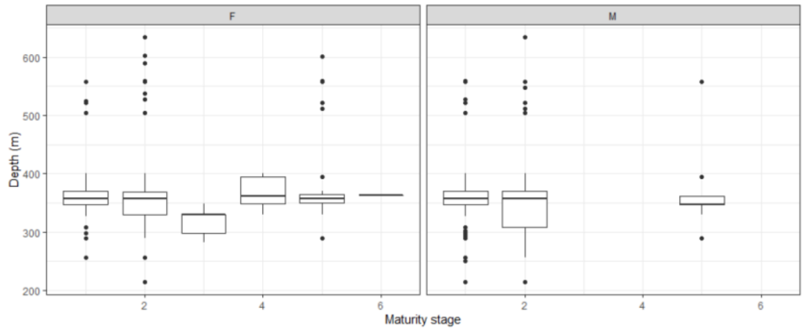



Figure 14. Boxplot of the depth distribution by maturity stage and sex of *Lepidorhombus boscii* in the PT Crustacean Survey (2011-2018).

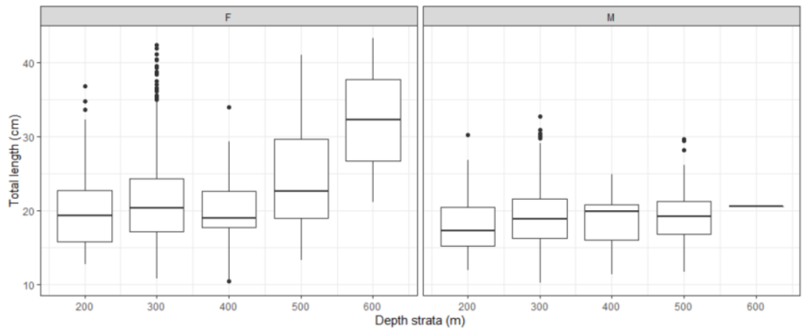



Figure 15. Boxplot of the total length by sex and depth strata of *Lepidorhombus boscii* in the PT Crustacean Survey (2011-2018).

**References**

Cochran, 1977. Sampling Techniques. John Wiley and Sons, New York, third edition. 428pp

ICES (2007). Report of the Workshop on Sexual Maturity Sampling (WKMAT), 15–19 January 2007, Lisbon, Portugal. ICES CM 2007/ACFM:03. 85 pp.

ICES (2016). Final report of the Working Group on *Nephrops* Surveys (WGNEPS), 10-13 November 2015, Cadiz, Spain. ICES CM 2015/SSGIEOM:30. 56 pp.

ICES (2017). Manual of the IBTS North Eastern Atlantic Surveys. Series of ICES Survey Protocols SISP 15. 92 pp. http://doi.org/10.17895/ices.pub.3519

ICES (2021). Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE). ICES Scientific Reports. 3:48. 1101 pp. https://doi.org/10.17895/ices.pub.8212

**ANNEX**

**Portuguese Autumn Groundfish Survey**

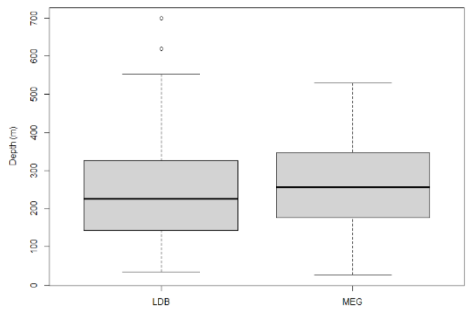



Figure A1. Boxplot of the depth distribution of both *Lepidorhombus boscii* (LDB) and *Lepidorhombus whiffiagonis* (MEG) in the Portuguese Autumn Groundfish Survey.

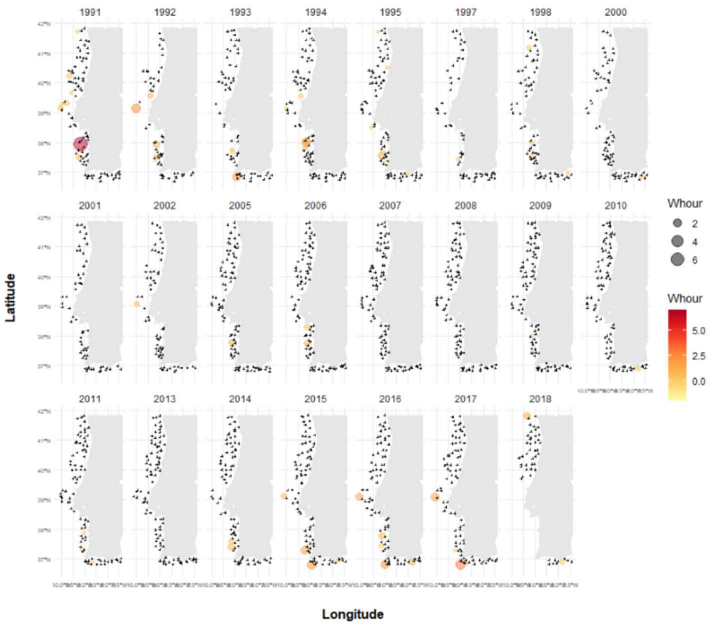



Figure A2. Occurrences and distribution of *Lepidorhombus whiffiagonis* in the Portuguese Autumn Groundfish Survey from 1991 to 2018. Surveys were not conducted in 2012, 2019 and 2020. Black crosses represent hauls with zero catch of *L. whiffiagonis*.

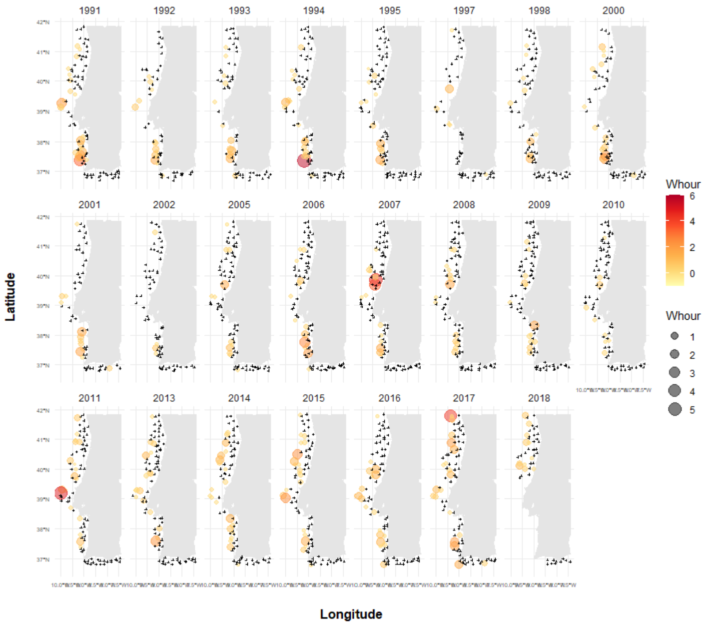



Figure A3. Occurrences and distribution of *Lepidorhombus boscii* in the Portuguese Autumn Groundfish Survey from 1991 to 2018. Surveys were not conducted in 2012, 2019 and 2020. Black crosses represent hauls with zero catch of *L. boscii*.

**Portuguese Crustacean Survey**

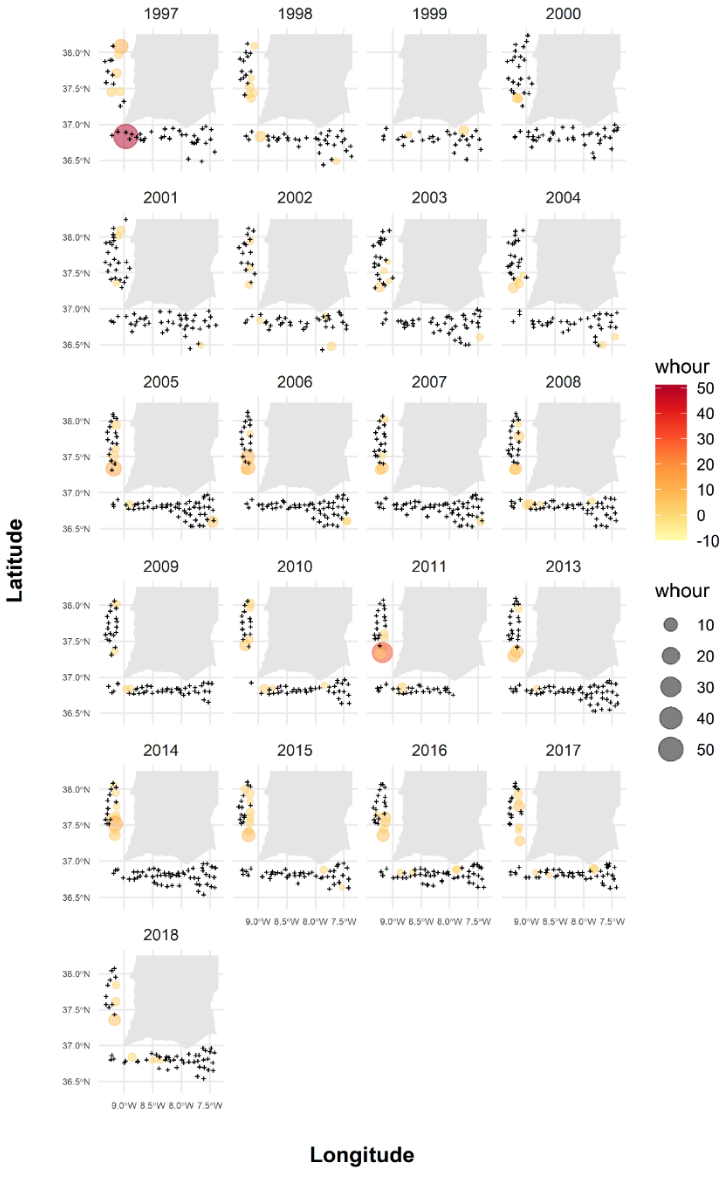



Figure A4. Occurrences and distribution of *Lepidorhombus whiffiagonis* in the PT Crustacean Survey from 1997 to 2018. Surveys were not conducted in 2012, 2019 and 2020. Black crosses represent hauls with zero catch of *L. whiffiagonis*.

**Investigation into raising of discards at national vs stock-coordinator level of megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k, 8.a-b, and 8.d from most countries involved in the fishery**

Ane Iriondo[1]

[1] email: airiondo@azti.es

In this document the work done to response to the request done during WKMegrim 2022 Data Compilation is presented:

The tasks were:

| | | |
|---|---|---|
| Contact Data providers from each country to query whether discard raising occurs before submission to intercatch or if this should be applied by the coordinator after submission. | Megrim 7.b-k, 8.a-b & d: | Ane |
| Prepare presentation on the outcome of investigation into raising of discards at national vs stock-coordinator level | Megrim 7.b-k, 8.a-b & d: | Ane |

## 1 Contact Data providers from each country to query whether discard raising occurs before submission to intercatch or if this should be applied by the coordinator after submission.

Data providers from the mains countries involved in the megrim fishery were contacted: Belgium, France, Ireland, Spain and UK.

**¿Discard raising occurs before submission to intercatch or the raising should be applied by the coordinator after the Intercatch data extraction?**

BELGIUM (Sofie Nimmegeers Sofie.Nimmegeers@ilvo.vlaanderen.be)

Before we upload a discard estimate to InterCatch, the discard samples are raised based on the landings as auxiliary variable (we use the COST package). So, it is our national estimate for the TBB_DEF_70-99 fleet that is uploaded to InterCatch. Then, the stock coordinator has to raise the empty strata of the stock in InterCatch to have the discard estimate for the assessment.

Most stock coordinators assume the discard rate pattern from the different métiers from different countries are similar. For instance, for my stocks I take all available information on discards provided to InterCatch for one gear group e.g. 'OTB' and fill the blanks for all OTB strata.

IRELAND Hans Gerritsen <hans.Gerritsen@Marine.ie>

For each combination of metier area, and quarter (i.e. each sampling stratum), the discards are raised. However there are strata that have landings but no discard data. For those strata, the discards should be imputed in intercatch. We try to make sure that the main strata have discard data associated with them so there should be a fairly small amount of 'missing' discards each year.

UK (Stephen Shaw stephen.shaw@cefas.co.uk)

Each member country provide discards estimates at the national level, i.e. the sampled discards are raised to the national fleets and provided to IC. And then the stock coordinator has to compile data from all countries and raise it to stock level, by filling the gaps using the most appropriate method.

SPAIN (Josefina Teruel Gómez josefina.teruel@ieo.es & Lucia Zarauz <lzarauz@azti.es>)

For The Spanish Discards Sampling Program (DSP) both DSP's (IEO and AZTI), the sampling strategy and the estimation methodology are in accordance with the "Workshop on Discard Sampling Methodology and Raising Procedures" (ICES, 2003), "Working Group on Discard Raising Procedures" (ICES, 2007) and "Study Group on Practical Implementation on Discard Sampling Plans" (ICES, 2012) guidelines.

Until 2009, discards estimates were provided annually, as it was asked by DCR (Data Collection Regulation). However, since the DCF implementation (2009), the raising procedure is done disaggregated by quarter, and also provided to InterCatch by ICES Division.

These are the main metiers for discard sampling in megrim fisheries. In the rest of metiers the megrim discard are considered negligible.

- GNS_DEF_>=100_0_0
- GNS_DEF_80-99_0_0
- OTB_DEF_>=55_0_0
- OTB_MCD_>=55_0_0
- OTB_MPD_>=55_0_0
- PS_SPF_0_0_0
- PTB_MPD_>=55_0_0

When data are uploaded to Intercatch (IC), if a metier is sampled and there are no discards, a 0 is uploaded to IC, and it is a real zero. If there is no sampling from a metier, no data is provided to IC and a blank field is presented.

ICES data call

**According to the ICES data call the following applies: When a country uploads a blank field for discards, then it means that the discards are unknown (not monitored). When a country**

**uploads a zero for discards, this means that that métier was monitored, but no discarding took place (= true zero).**

## 2 Prepare presentation on the outcome of investigation into raising of discards at national vs stock-coordinator level

According to the answers obtained, a revision of discards data for available years was realized and Intercatch tool discards raising procedure was used.

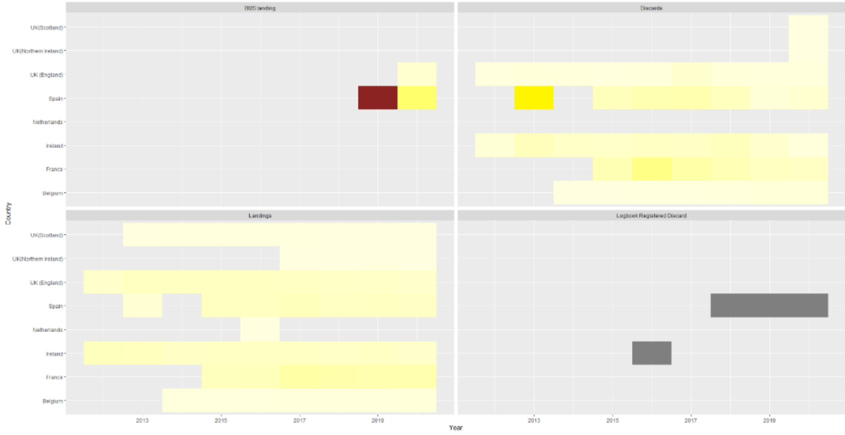
First a revision of all data uploaded to Intercatch by each member state for landings and discards is done.

**INTERCATCH DATA**

| | **BEL** | | **FR** | | **IRL** | | **UK** | | **SP** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Catch cat.** | **Landings** | **Discards** | **Landings** | **Discards** | **Landings** | **Discards** | **Landings** | **Discards** | **Landings** | **Discards** |
| 2007 | X | X | | | | X | X | X | | |
| 2008 | X | X | | | | X | X | X | | |
| 2009 | No data in intercatch | | | | | | | | | |
| 2010 | No data in intercatch | | | | | | | | | |
| 2011 | No data in intercatch | | | | | | | | | |
| 2012 | | | | | X | X | X | X | | |
| 2013 | | | | | X | X | X | X | X | X |
| 2014 | X | X | | | X | X | X | X | | |
| **2015** | X | X | X | X | X | X | X | X | X | X |
| **2016** | X | X | X | X | X | X | X | X | X | X |
| **2017** | X | X | X | X | X | X | X | X | X | X |
| **2018** | X | X | X | X | X | X | X | X | X | X |
| **2019** | X | X | X | X | X | X | X | X | X | X |
| **2020** | X | X | X | X | X | X | X | X | X | X |

In the table above it is observed that from year 2015 onwards, data of landing and discards is available in intercatch for the main countries in the megrim fishery, therefore a revision of discards data and raising procedure is applied to data from 2015 to 2020.

**Which countries submitted data in which years?**




**# Landing data by division for all countries and all season 2012-2020**


**#Discard data by division for all countries and all season 2012-2020**


<u>Intercatch tool was used for discard raising from year 2016 to 2020.</u>

Discarding in this stock, based on discards imported and raised data is around 19% in the last five years.

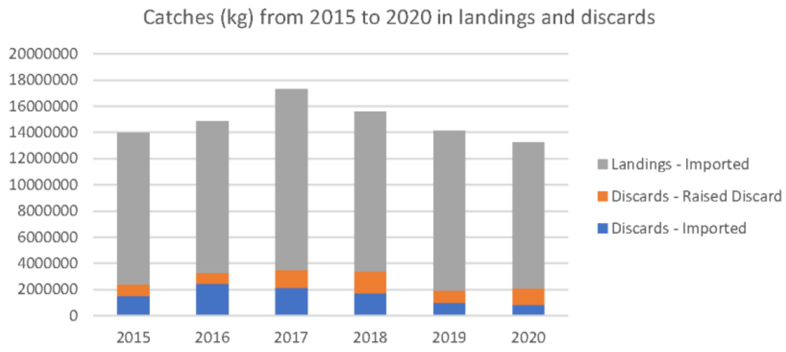
Allocations scheme for discard raising:

For landings strata with missing discards, the discard volume was estimated using the proportions of the catch that were discarded for similar strata using the following hierarchy:

1. If discard data were available for the same country, gear group and year, these discard proportions were applied to the landings of the strata with missing discards;
2. If discard data were only available for the same gear group and year, these discard proportions were applied;
3. If discard data were only available for the year, these discard proportions were applied.

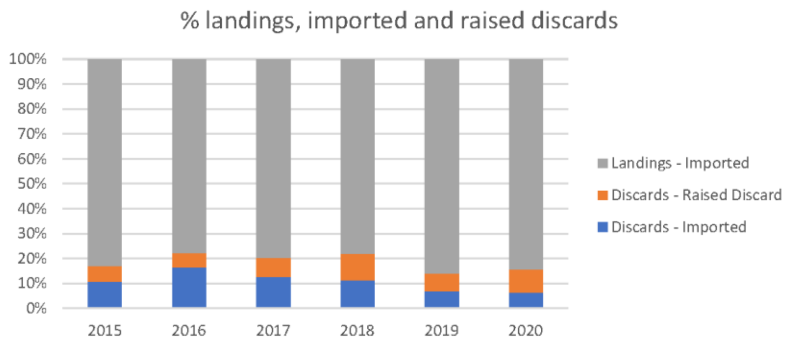
Ones all discards allocations for all the years are implemented, the following results are observed:

| Year | Imported Discard (t) | Raised Discard (t) | Total Discards (t) | Landings (t) | Catches (t) |
|---|---|---|---|---|---|
| 2015 | 1507 | 887 | 2393 | 11569 | 13962 |
| 2016 | 2445 | 870 | 3315 | 11566 | 14881 |
| 2017 | 2173 | 1345 | 3518 | 13784 | 17303 |
| 2018 | 1738 | 1677 | 3415 | 12147 | 15562 |
| 2019 | 989 | 977 | 1966 | 12161 | 14127 |
| 2020 | 856 | 1228 | 2085 | 11141 | 13225 |

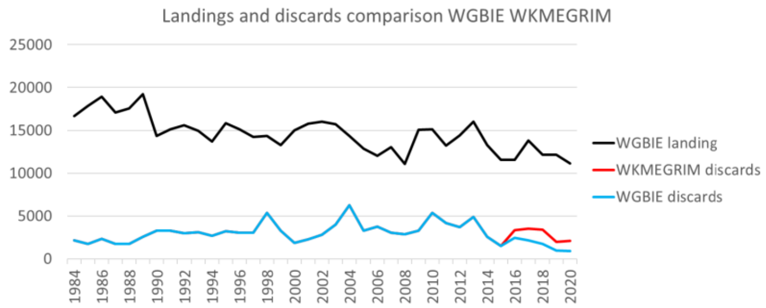



Discard imported, discard raised and landings % in total catches.

| Year | Discards Imported | Raised Discard | Total Discards | Landings | Catches |
|---|---|---|---|---|---|
| 2015 | 11% | 6% | 17% | 83% | 100% |
| 2016 | 16% | 6% | 22% | 78% | 100% |
| 2017 | 13% | 8% | 20% | 80% | 100% |
| 2018 | 11% | 11% | 22% | 78% | 100% |
| 2019 | 7% | 7% | 14% | 86% | 100% |
| 2020 | 6% | 9% | 16% | 84% | 100% |
| **Total general** | **11%** | **8%** | **19%** | **81%** | **100%** |



The updated data in the time series of landings and discards comparison between WGBIE and WKMEGRIM 2022.




**New allocation for numbers at age**

Ones the total catches are defined for years 2015-2020 including the raised discards, new allocations should be done to obtain numbers at age for the new values.

Therefore, Intercatch tool was used to make allocations of the new raised discards to the total catches of the stock, to obtain the new numbers at age by year. The allocations were possible for years 2016 to 2020 but for year 2015, due to the lack of sampling data included in Intercatch, it was not possible to obtain the new numbers at age for year 2015.

**In conclusion, new data for discards in tons and numbers at age for years 2016 to 2020 are updated in the input data for the stock assessment.**


2016 Discards numbers at age
2016 New data
2016 Old data
2017 Discards numbers at age
2017 New data
2017 Old data
years
2018 Discards numbers at age
2018 New data
2018 Old data
years
2019 Discards numbers at age
2019 New data
2019 Old data
years
2020 Discards numbers at age
2020 New data
2020 Old data
years

**Exploratory scenarios in a4a for northern megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k, 8.a-b, and 8.d using available abundance indices**

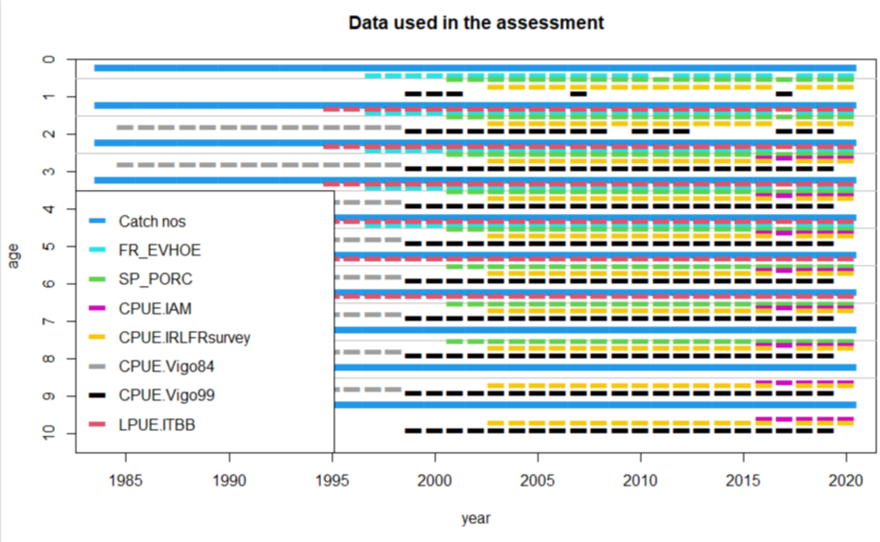
Ane Iriondo[1]

[1] email: airiondo@azti.es

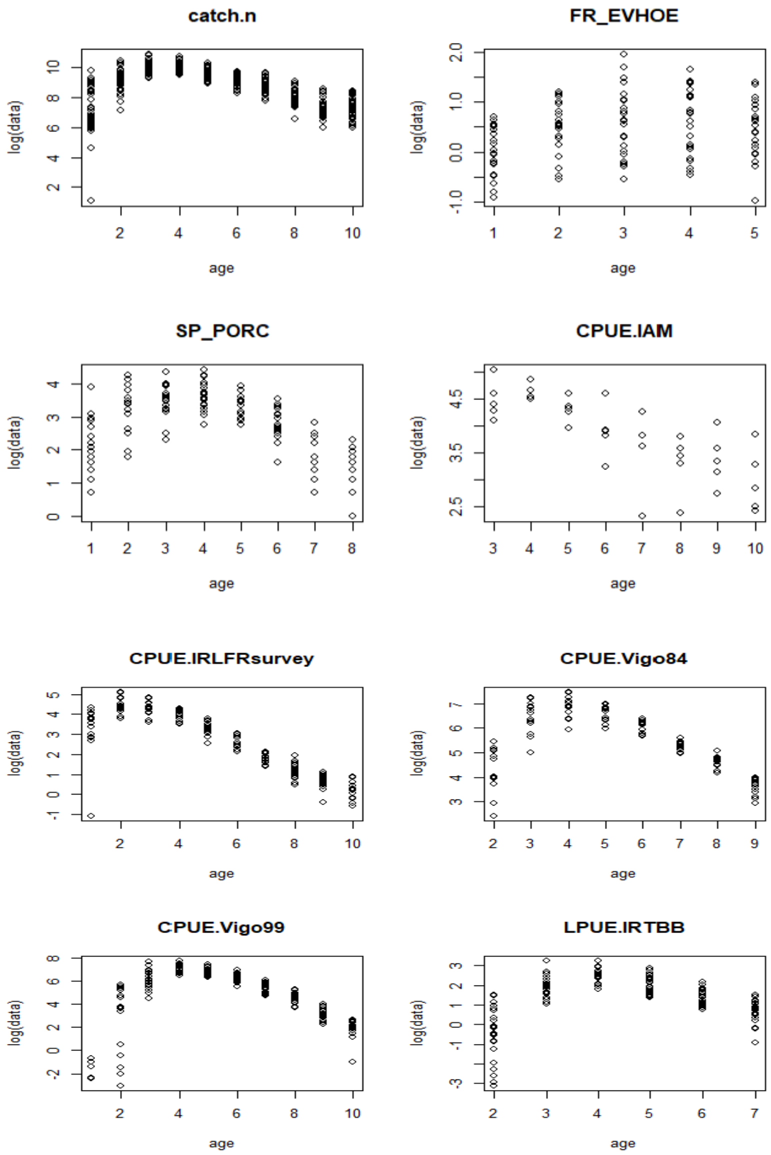
In this document the intersessional work deployed to response the WKMEGRIM 2022 Data Compilation from 24-27 January is shown. This information will be presented in WKMEGRIM Benchmark meeting in 21-25 February 2022.

First, a data exploration analysis was done with the updated raised discard data, new data provided for tuning fleets and maturity ogive. Then, the scenarios decided in the WKMegrim Data Compilation were run, including some other scenarios. Finally, a summary table with the values for AIC, BIC and Mohn index is also presented and some comments and issues observed to be analized during the WKMEGRIM Benchmark.

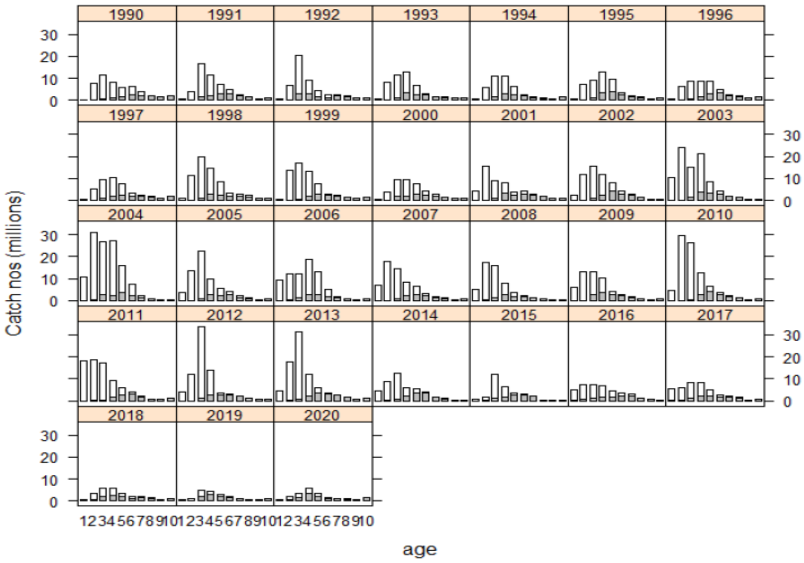
## 1 Data exploration



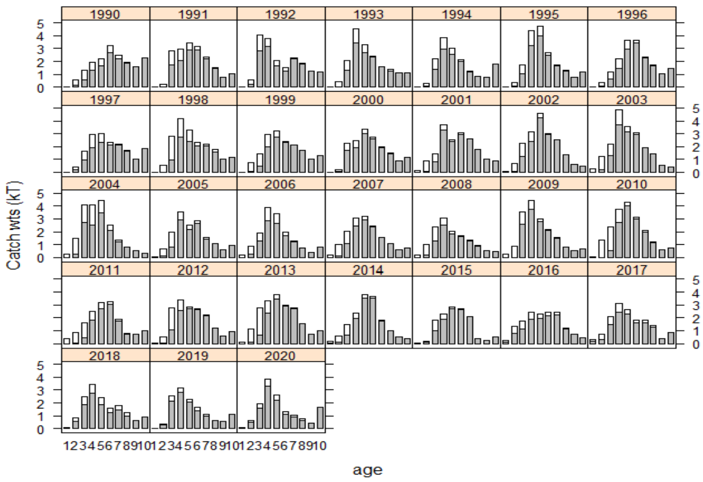
Catch numbers at age log(data)



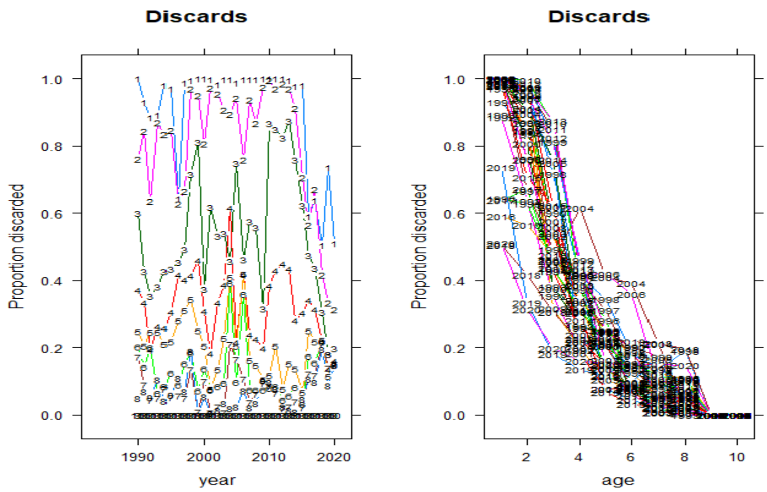
Catch number at age, landings (grey) and discards (white).




Catch weight at age

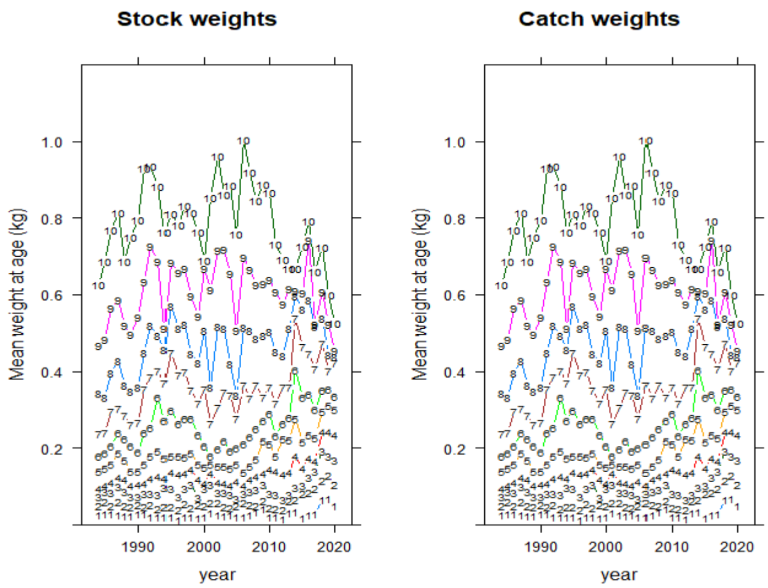


Proportion of discards at age by year



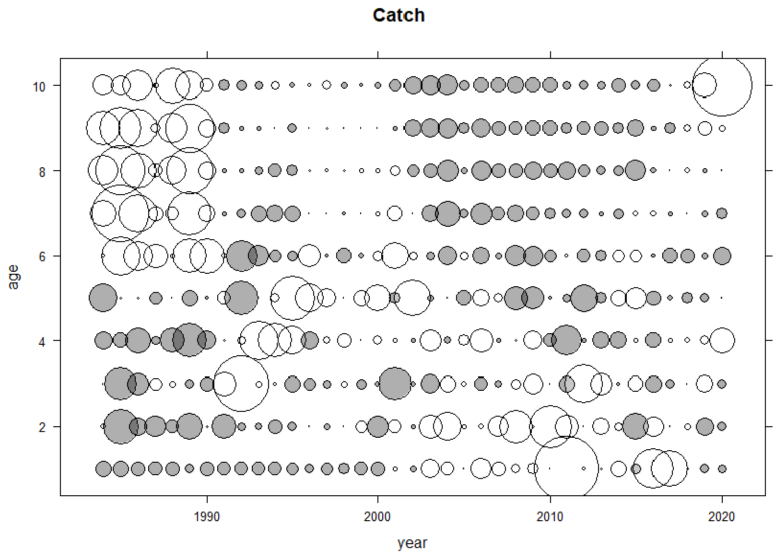

Discard data are available from 1990 onwards. Discards occur mainly from years 1 to 3.

Catch weight at age

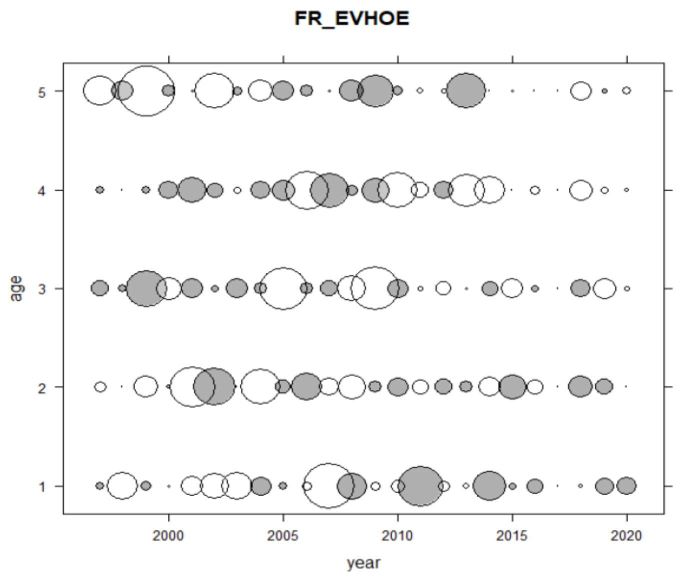


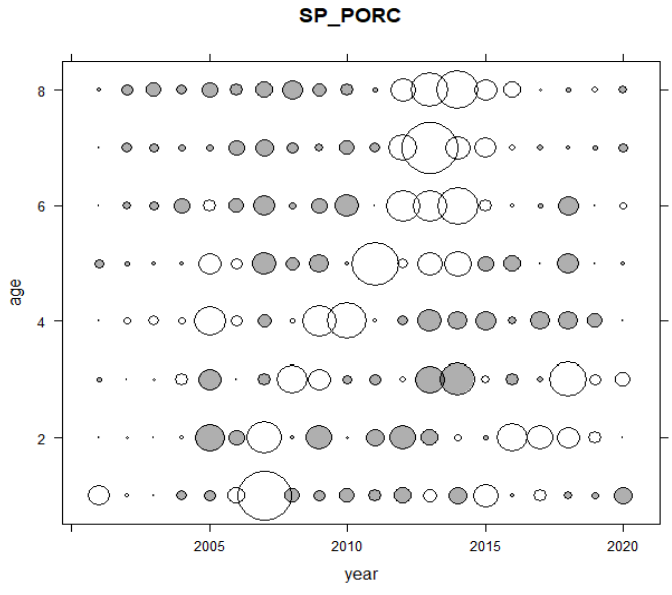

BUBBLE PLOT OF STANDARDISED CATCHES NUMBERS AT AGE

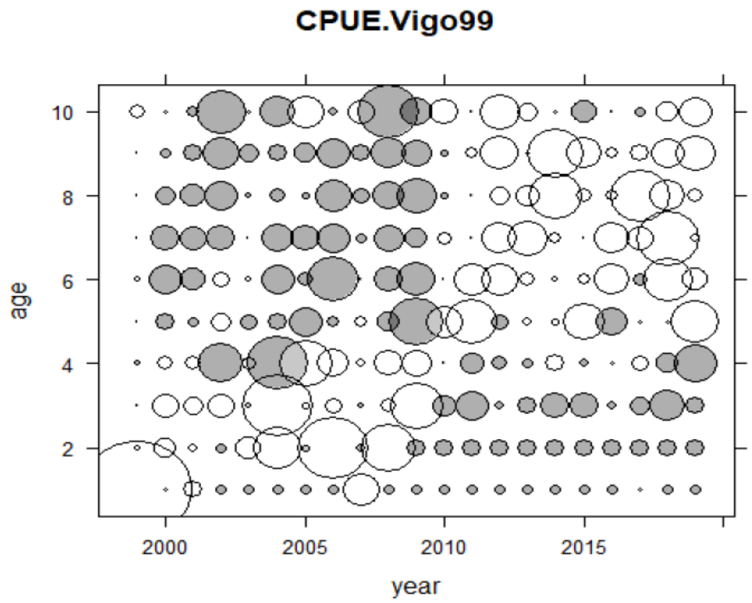
Buble plots, grey is below average, white is above average

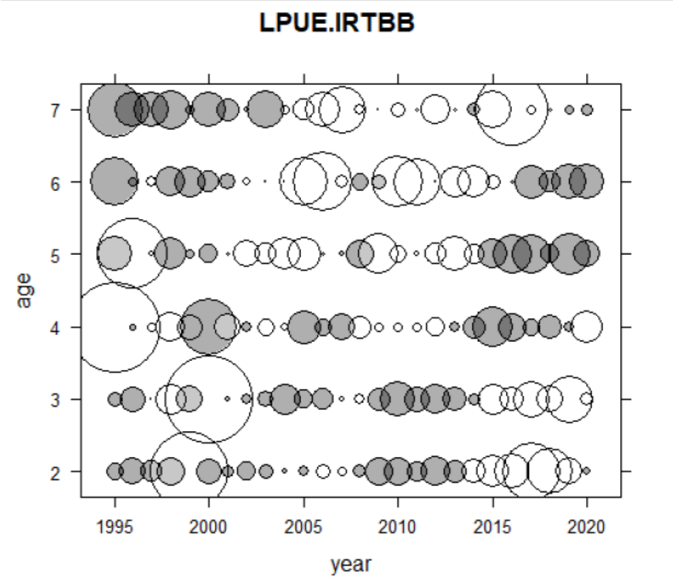


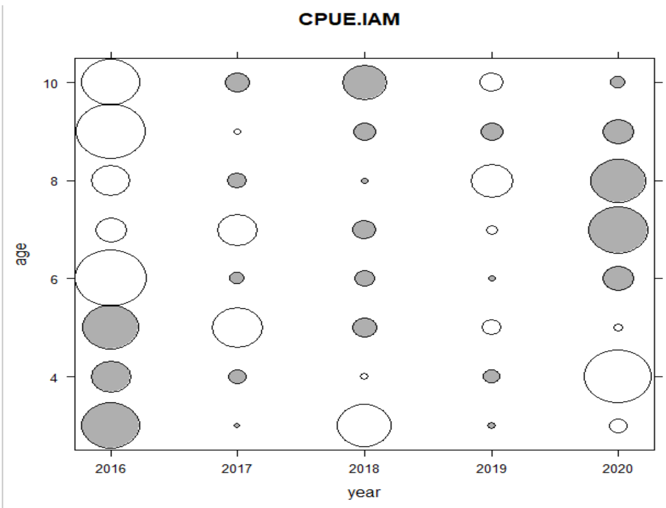

Cohort tracking in the tuning fleets




SP_PORC
age
year
2005
2010
2015
2020
2
4
6
8

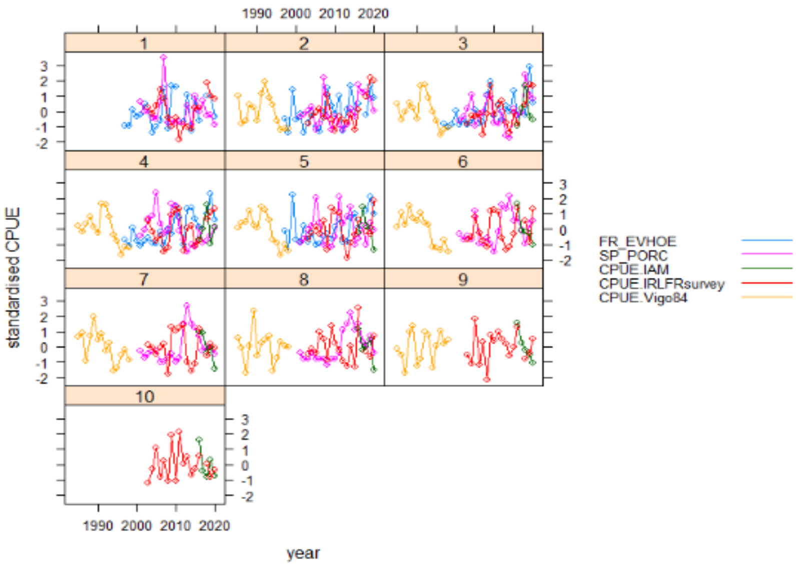

CPUE.Vigo99
age
year
2000
2005
2010
2015
2
4
6
8
10

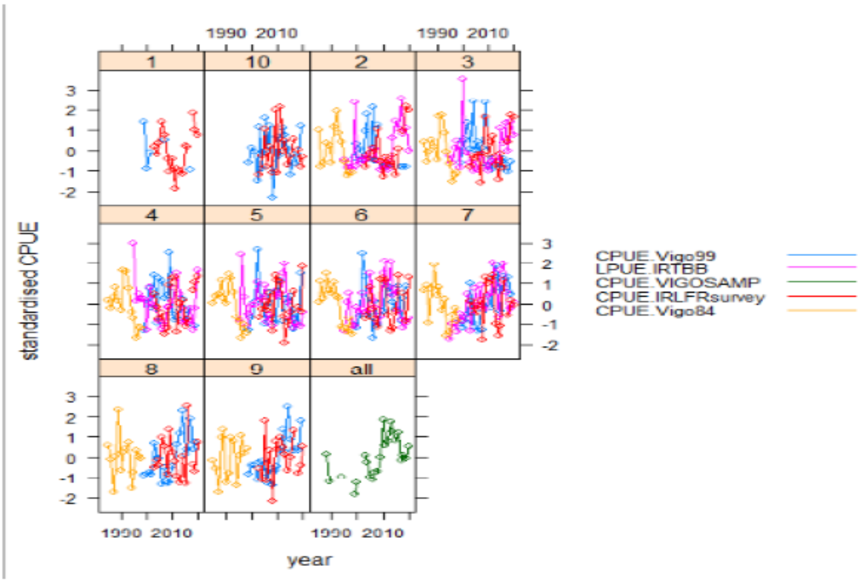


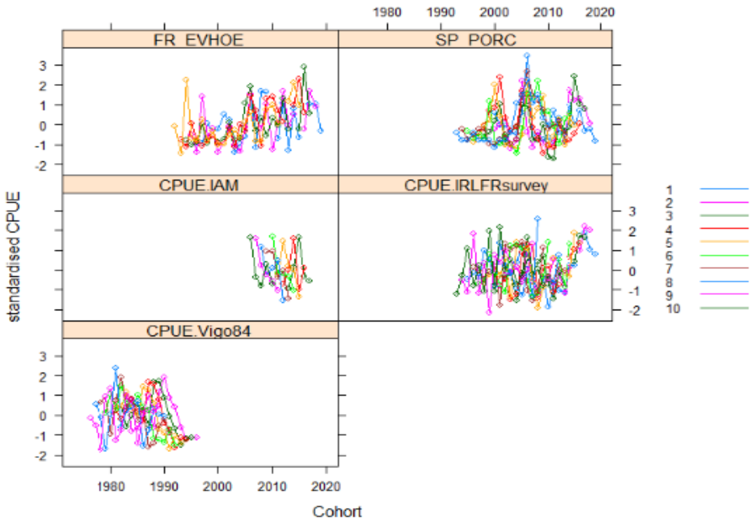

- bubbles_tun_IRLFRSurvey-> ERROR “Error using packet 1 mixture of missing and non-missing values for cex”.
- bubbles_VIgo84 ->ERROR “Error using packet 1 mixture of missing and non-missing values for cex.

Standardised CPUE by cohort of the tuning fleets to analyse the internal consistency of **tuning fleets**, in general all are a bit noisy.



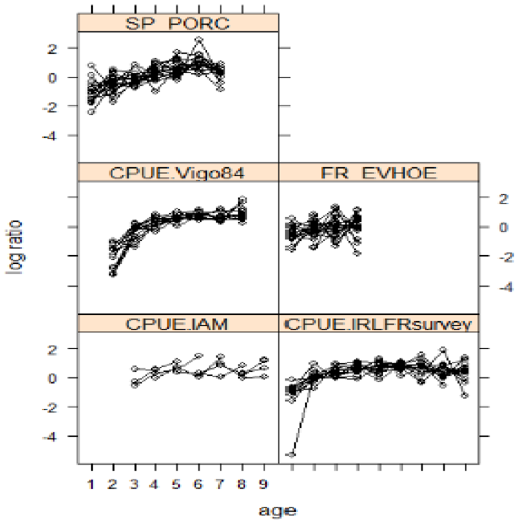



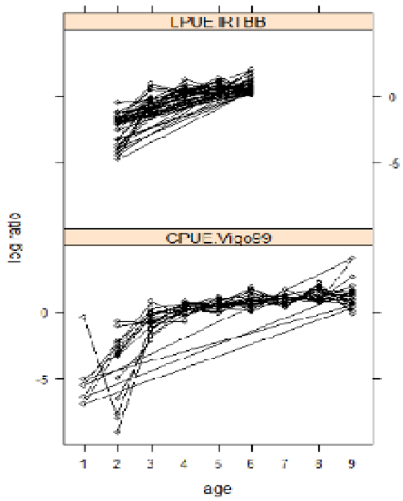
Standardised CPUE by cohort of the tuning fleets to analyse the internal consistency of **ages**. Despite SP-Porcu survey shows a bit of consistency, in general all are a bit noisy.



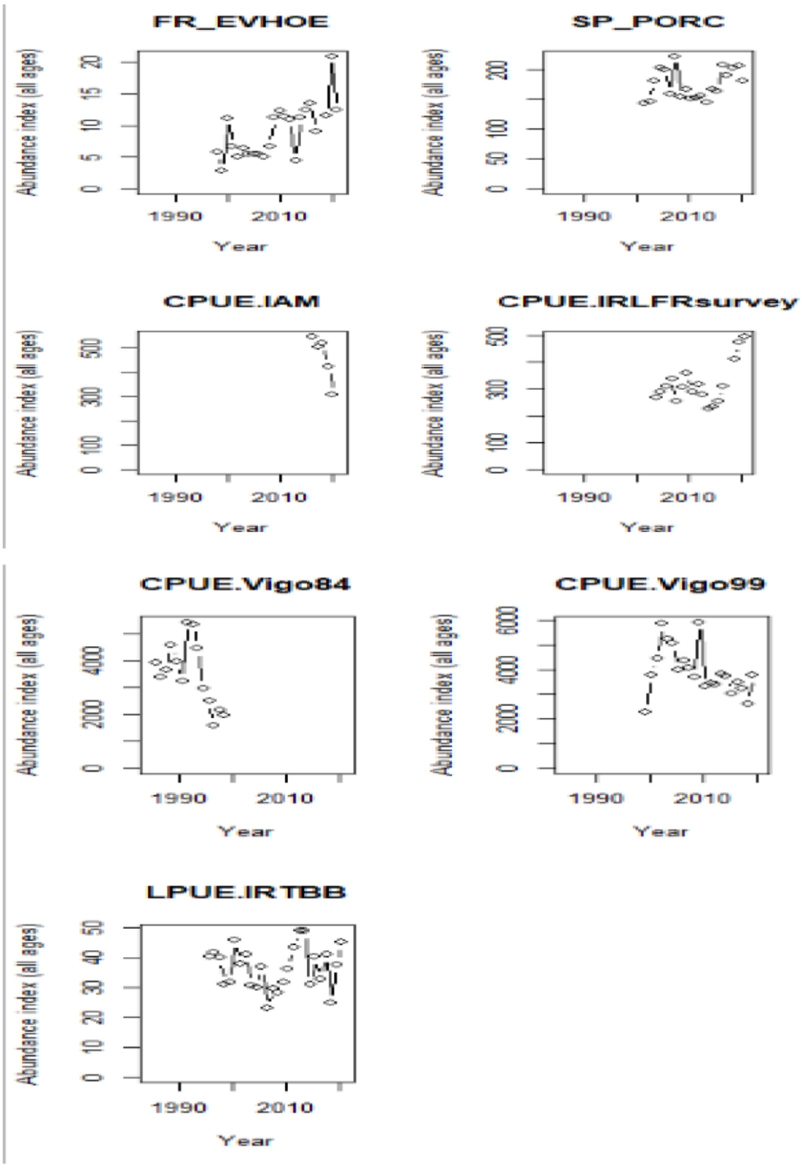
The log-ratios of the catch and tuning data can give an indication of the selectivity pattern of the fleets and surveys.

Log ratio of the tuning fleets suggest a relatively flat-topped selection for FR EVHOE, CPUE.IAM and CPUE.IRFLSurvey. A logistic selectivity may be appropriate for SP PORCU, CPUE.Vigo84.



Abundance indices for all ages.



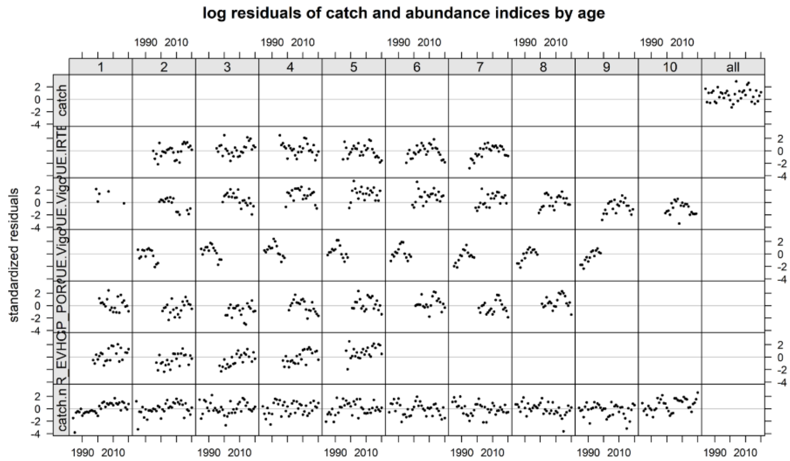
## 2 Scenarios

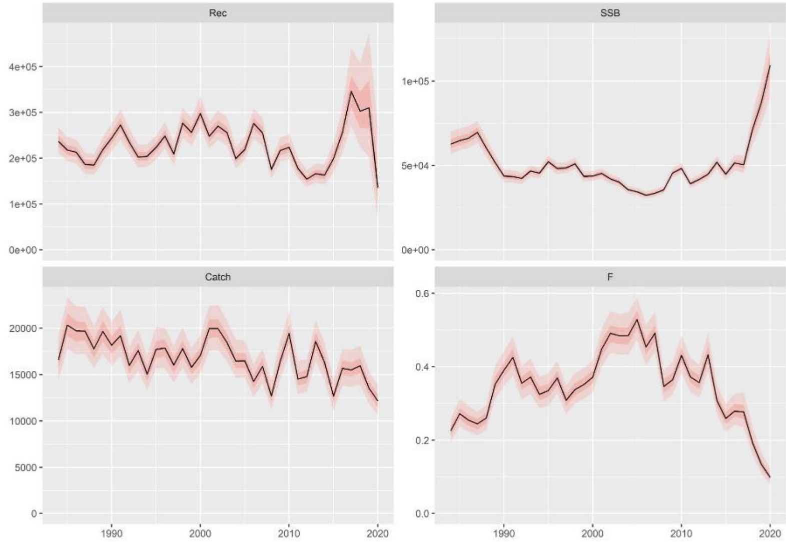
| | FIT 1 | FIT 2 | FIT 3 | FIT 4 | FIT 5 | FIT 6 |
|---|---|---|---|---|---|---|
| | Same tuning fleet as WGBIE 2021 | **Only surveys** | Only with surveys starting in 1997 | The same as Fit 2 but starting time series in 2001 | Including new standarized biomass index | Including new LPUE Vigo |
| Commercial indices | | | | | | |
| ESP LPUE Vigo7 kg/(FD*100hp) | X | | | | | |
| NEW ESP LPUE Vigo7 kg/(FD*100hp) | | | | | | |
| NEW ESP LPUE Vigo 7 kg/FD | | | | | | X |
| NEW Standardized CPUE index (Kg/haul duration) | | | | | X | |
| IRL Beam Trawler TBB | X | | | | | |
| Survey indices | | | | | | |
| ESP Porcupine (2001-2020 (Q3). Subarea: 7c, 7k.) | X | **X** | X | X | X | X |
| FR EVHOE 1997-2020 (Q4). Subarea: Celtic and bay of Biscay. | X | | X | | | |
| NEW Combined EVHOE-IRL IBTS. 2003-2020 (Q4). Subarea: 7j8ab-7bgjk. | | **X** | | X | X | X |
| NEW IR IAMS 2016-2021 (Q1). Subarea: 7bcjk | | **X** | X | X | X | X |
| Maturity ogive | | | | | | |
| BIOSDEF Macro Ogive | X | | | | | |
| NEW Histology Female Ogive | | **X** | X | X | X | X |

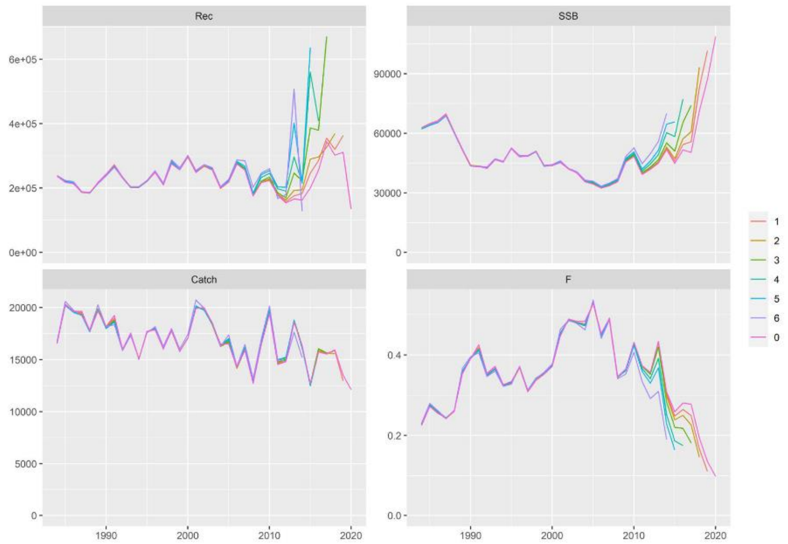
## 2.1. FIT 1

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 1 | 5 tuning fleets as WGBIE 21 | 2038.1 | 2553.5 | -0.289 | 0.328 | 0.553 |

The same 5 tuning fleets as WGBIE 21.



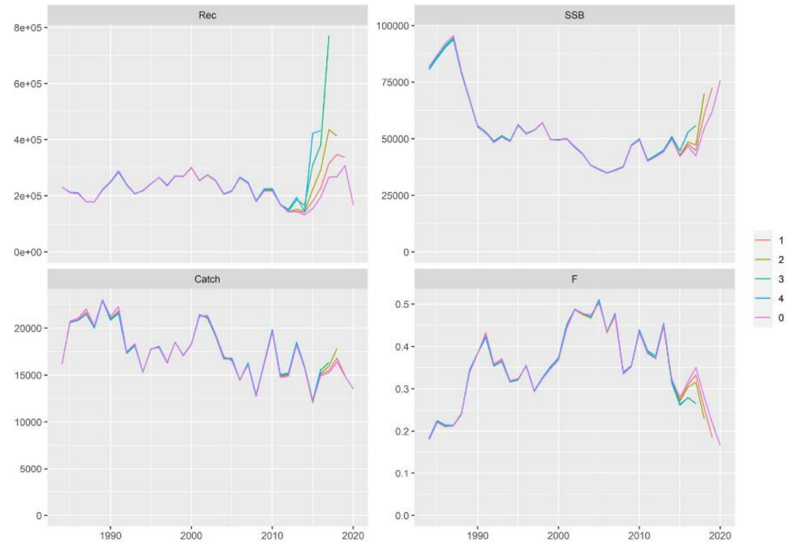

Rec
4e+05
3e+05
2e+05
1e+05
0e+00
SSB
1e+05
5e+04
0e+00
Catch
20000
15000
10000
5000
0
F
0.6
0.4
0.2
0.0
1990
2000
2010
2020


Rec
6e+05
4e+05
2e+05
0e+00
SSB
90000
60000
30000
0
Catch
20000
15000
10000
5000
0
F
0.4
0.2
0.0
1990
2000
2010
2020
1
2
3
4
5
6
0

## 2.2. FIT 2 a

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 2a | only_3surveys<br>"SP_PORC","CPUE.IRLFRsurvey", "CPUE.IAM" | 1007.9 | 1454.7 | We get the plot for retro 4 but not the values, due to error in CPUE-IAM | | |

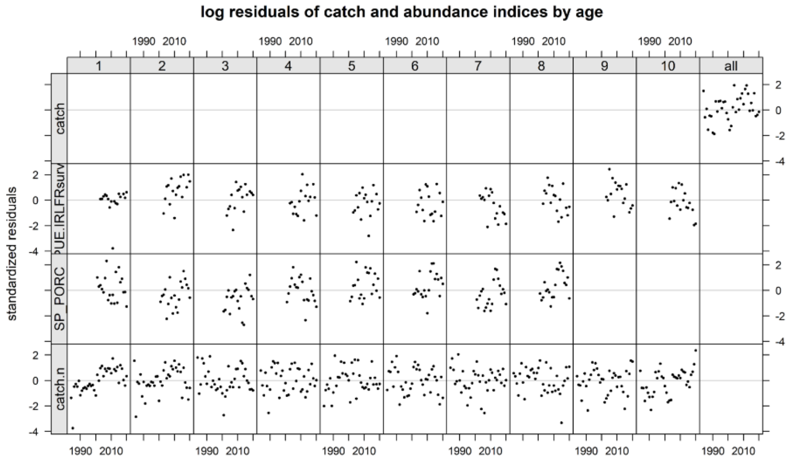
Only 3 surveys: "SP_PORC","CPUE.IRLFRsurvey", "CPUE.IAM"

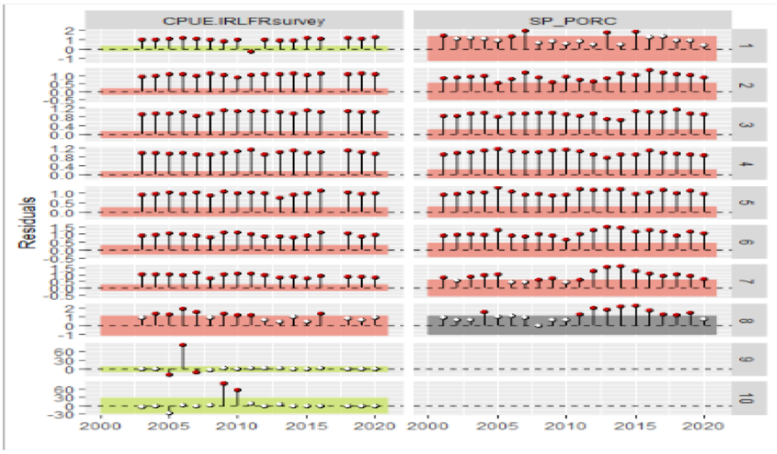


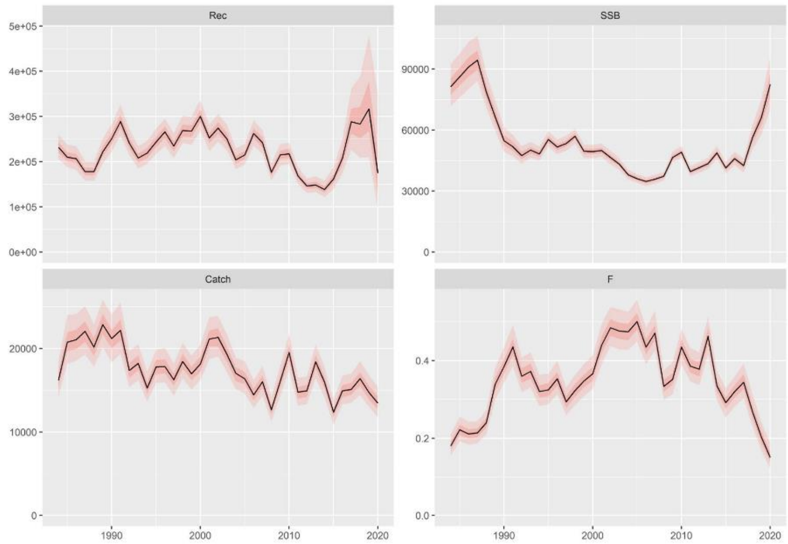
## 2.3. FIT 2 b

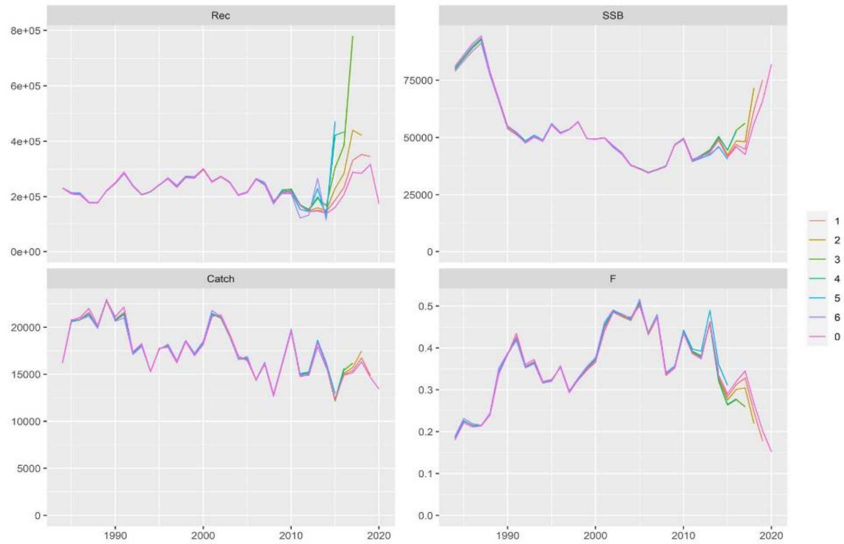
| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 2b | Only _2surveys.R "SP_PORC","CPUE.IRLFRsurvey", | 919.3 | 1347.1 | -0.060 | 0.0876 | 0.739 |

Only _2surveys: "SP_PORC","CPUE.IRLFRsurvey",



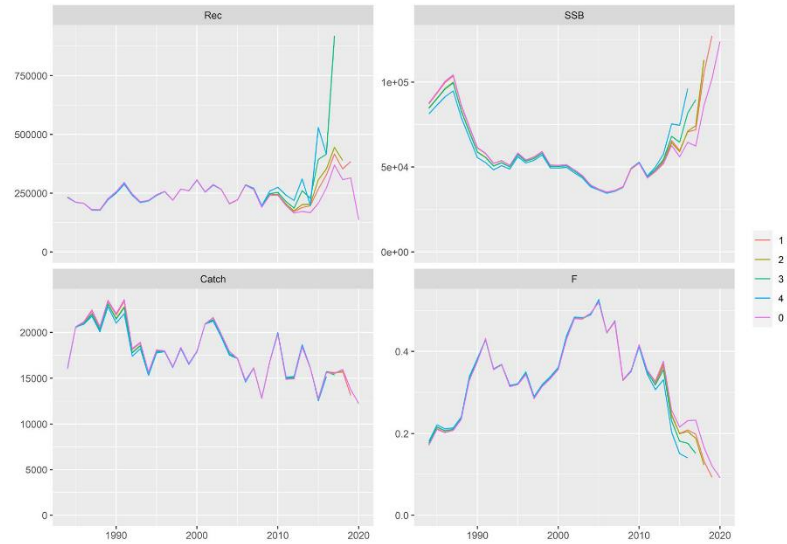




Rec
SSB
Catch
F


Rec
SSB
Catch
F
1
2
3
4
5
6
0

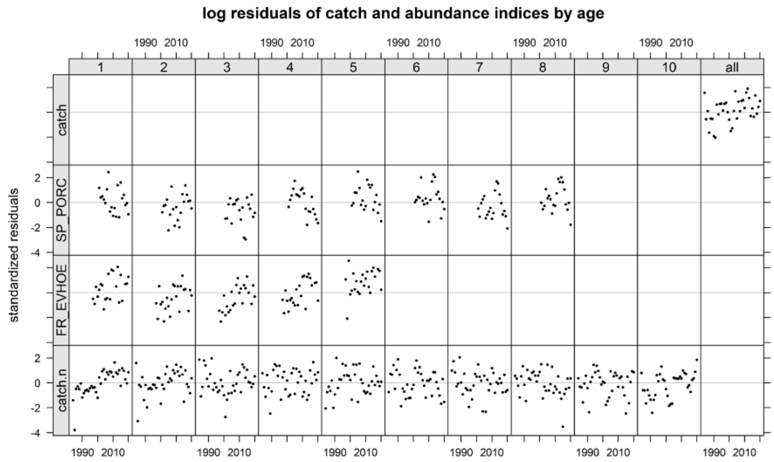
## 2.4. FIT 3 a

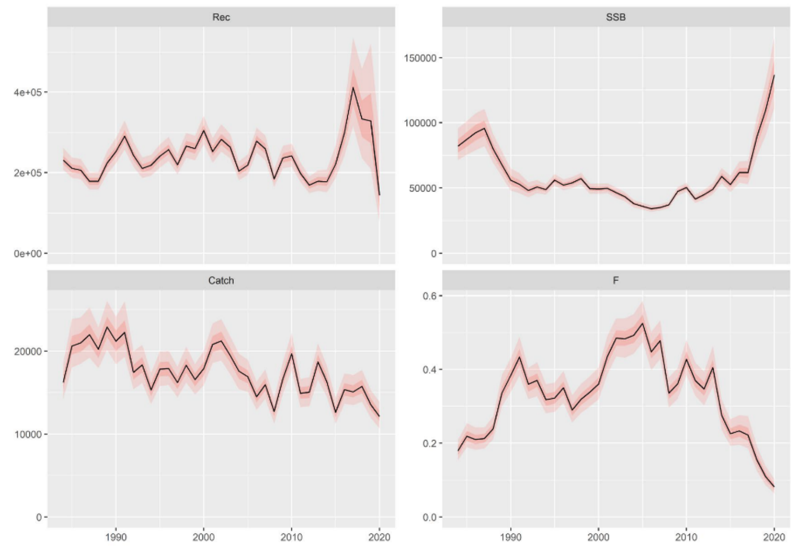
| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 3a | only_3surveys_from1997.R<br>"FR_EVHOE", "SP_PORC", "CPUE.IAM" | 958.3 | 1397.5 | We get the plot for retro 4 but not the values, due to error in CPUE-IAM | | |

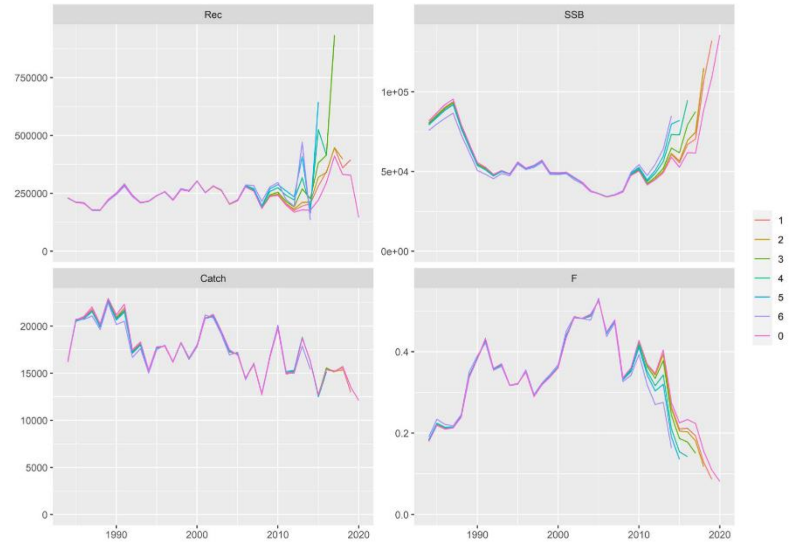


## 2.5. FIT 3 b

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 3b | only_2surveys_from1997.R "FR_EVHOE", "SP_PORC " | 867.5 | 1287.4 | -0.273 | 0.321 | 0.469 |

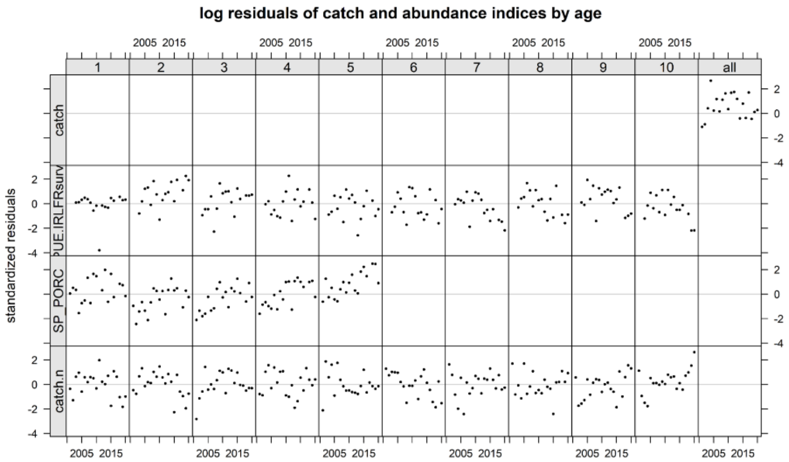


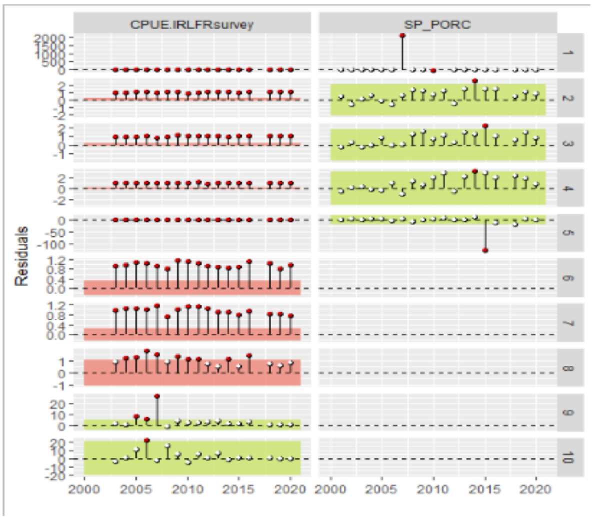



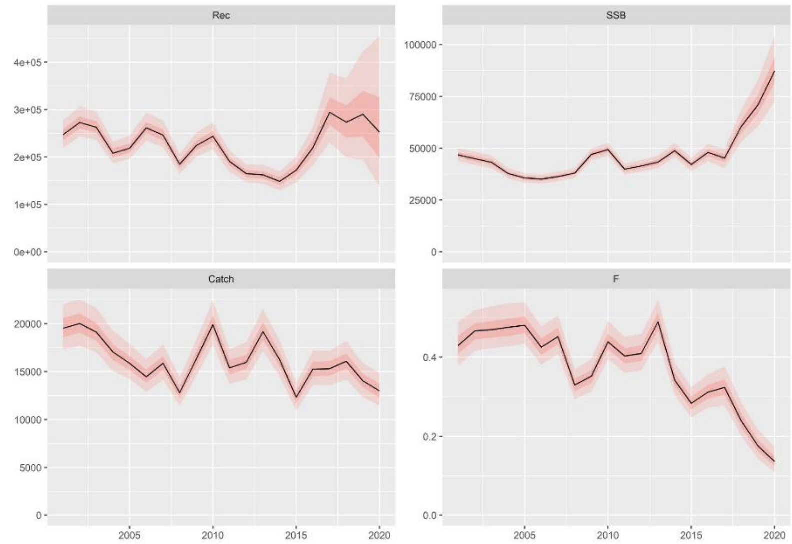

Rec
SSB
Catch
F
750000
500000
250000
0
1e+05
5e+04
0e+00
20000
15000
10000
5000
0
0.4
0.2
0.0
1990
2000
2010
2020
1
2
3
4
5
6
0

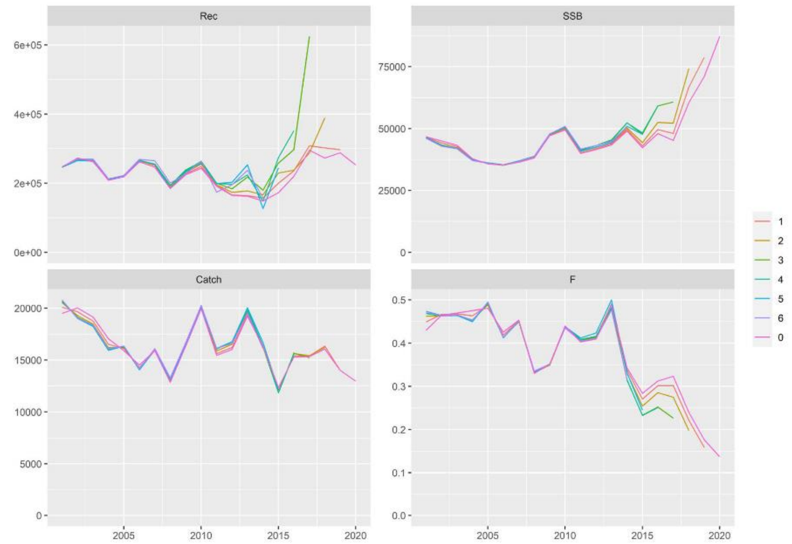
## 2.6. FIT 4

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 4 | only_2surveys_with time series from2001 | 615.3 | 863.7 | -0.137 | 0.141 | 0.405 |




Rec
SSB
Catch
F


Rec
SSB
Catch
F
1
2
3
4
5
6
0

## 2.7. FIT 5

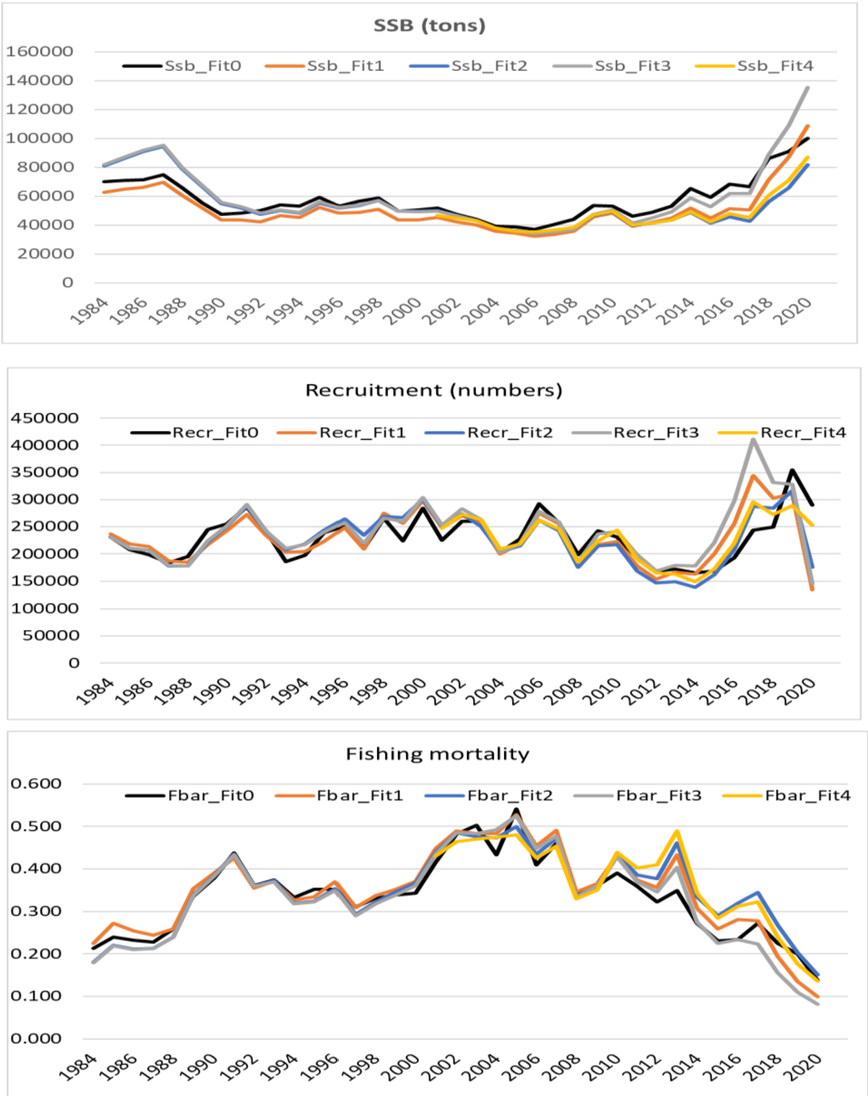
| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 5 | CPUE biomass index | 1014.9 | 1478.7 | Error in retro<br>Error in seq.default(start, end, by = frequency) : wrong sign in 'by' argument | | |

## 2.8. FIT 6

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 6 | Including new LPUE Vigo<br>SP_PORC","CPUE.IAM","CPUE.IRLFRsurvey","CPUE.Vigo99" | 1621.8 | 2105.2 | Error in retro<br>Error in seq.default(start, end, by = frequency) : wrong sign in 'by' argument | | |

## 3 Pre-benchmark Summary and conclusions

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| FIT 0 | Bayesian model Results from WGBIE2021 | | | -0.24 | 0.329 | 0.670 |
| FIT 1 | 5 tuning fleets as WGBIE 21 using a4a | 2038.1 | 2553.5 | -0.289 | 0.328 | 0.553 |
| FIT 2a | only_3surveys<br>"SP_PORC","CPUE.IRLFRsurvey", "CPUE.IAM" | 1007.9 | 1454.7 | We get the plot for retro 4 but not the values, due to error in CPUE-IAM | | |
| **FIT 2b** | **Only _2surveys.R "SP_PORC","CPUE.IRLFR survey"** | **919.3** | **1347.1** | **-0.060** | **0.0876** | **0.739** |
| FIT 3a | only_3surveys_from1997.R<br>"FR_EVHOE", "SP_PORC", "CPUE.IAM" | 958.3 | 1397.5 | We get the plot for retro 4 but not the values, due to error in CPUE-IAM | | |
| FIT 3b | only_2surveys_from1997.R<br>"FR_EVHOE", "SP_PORC " | 867.5 | 1287.4 | -0.273 | 0.321 | 0.469 |
| **FIT 4** | **Only_2surveys_with time series from2001 "SP_PORC","CPUE.IRLFR survey"** | **615.3** | **863.7** | **-0.137** | **0.141** | **0.405** |
| FIT 5 | CPUE biomass index | 1014.9 | 1478.7 | Error in retro<br>Error in seq.default(start, end, by = frequency) : wrong sign in 'by' argument | | |
| FIT 6 | SP_PORC","CPUE.IAM","CPUE.IRLFRsurvey","CPUE.Vigo99" | 1621.8 | 2105.2 | Error in retro<br>Error in seq.default(start, end, by = frequency) : wrong sign in 'by' argument | | |


SSB (tons)
Ssb_Fit0
Ssb_Fit1
Ssb_Fit2
Ssb_Fit3
Ssb_Fit4
Recruitment (numbers)
Recr_Fit0
Recr_Fit1
Recr_Fit2
Recr_Fit3
Recr_Fit4
Fishing mortality
Fbar_Fit0
Fbar_Fit1
Fbar_Fit2
Fbar_Fit3
Fbar_Fit4

**Conclusions**

- In the figure above the comparison of SSB, F and R estimates show similar trends for all scenarios. The results obtained seems to be in line with the output from the Bayesian Statistical catch at age model used in WGBIE 2021.

- Results show that in the fits where LPUE data from commercial fleets are included, the AIC, BIC and Mohr' values are worse. Therefore, the fits using only survey data are considered the most appropriate.

- The Fit 2 and Fit 4 are considered the best ones. In both of them, only two surveys are considered: "SP_PORC survey" and "CPUE.IRLFR survey". The difference between the two fits is that Fit 4 starts the data times series for catches and tuning fleets in 2001. The reason of doing that is because "SP_PORC survey" survey starts in 2001 and "CPUE.IRLFR survey" starts at 2003. Therefore, starting the assessment in 2001 we have all the times series covered by a tuning fleet.

Next steps:

- The model scenarios with the selected fleets presented should be refined and reviewed by an expert to solve the problems and error that different scenarios have presented.

- Ones the input data regarding tuning fleets are decided, the a4a model parametrization and catchability options should be decided. For doing so, the support of an a4a expert is needed.

- When the final scenarios regarding input data and parametrization are decided in the Benchmark, the reference points calculation should be done.

# 4 Benchmark Selected tuning indices and alternative runs

The surveys below are selected as the ones to be used in the final assessment.

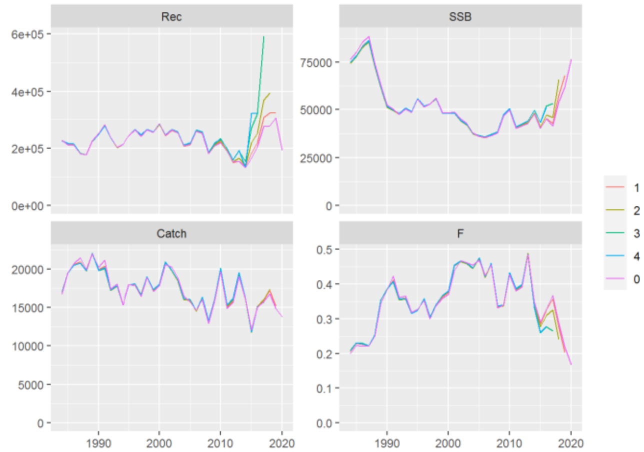
| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| **FIT 2b** | **Only _2surveys.R "SP_PORC","CPUE.IRLFR survey"** | **919.3** | **1347.1** | **-0.060** | **0.0876** | **0.739** |

Now, different parametrization options and alternatives will be analysed for this fit.

| FIT | Comments | AIC | BIC | Mohr´ rho F | Mohr´ rho SSB | Mohr´ rho R |
|---|---|---|---|---|---|---|
| Tweaked fit 2 | -SP_PORC, CPUE.IRLFR surveys<br>-remove age 1 in 2011 | 790.4 | 1295.5 | -0.088 | 0.095 | 0.416 |
| minus porc | CPUE.IRLFR surveys<br>-remove age 1 in 2011<br>-remove SP_PORC survey | 491.59 | 954.85 | -0.063 | 0.081 | 0.034 |
| Plus Iams | CPUE.IAM, CPUE.IRLFR surveys<br>-remove age 1 in 2011 | 562.53 | 1059.78 | -0.083 | 0.087 | 0.738 |
| Tweaked fit 2 (3 SURVEYS) | SP_PORC, CPUE.IRLFR CPUE.IAM surveys<br>-remove age 1 in 2011 | 862.24 | 1401.054 | -0.196 | 0.167 | 0.634 |

Fit 2


Tweaked fit 2




minus porc


Rec
SSB
Catch
F
4e+05
3e+05
2e+05
1e+05
0e+00
75000
50000
25000
0
20000
15000
10000
5000
0
0.5
0.4
0.3
0.2
0.1
0.0
1990
2000
2010
2020
1
2
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4
0

Plus lams


Rec
SSB
Catch
F
4e+05
3e+05
2e+05
1e+05
0e+00
75000
50000
25000
0
20000
15000
10000
5000
0
0.5
0.4
0.3
0.2
0.1
0.0
1990
2000
2010
2020
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0

*Working Document to the Benchmark Workshop for selected Megrim Stocks (WKMEGRIM). Data evaluation meeting, 24-27 January 2022*

**Spatial standardization of Catch Per Unit Effort (CPUE) indices for the megrim (*Lepidorhombus whiffiagonis*) and the four-spot megrim (*L. boscii*) in North Atlantic Iberian waters (ICES divisions 8c and 9a).**

Maria Grazia Pennino[1], Esther Abad[1] & Jaime Otero[1].

[1]Instituto Español de Oceanografía (IEO). Centro Oceanográfico de Vigo, Subida a Radio Faro, 50-52, 36390 Vigo (Pontevedra), Spain.

**Background**

Fishery-dependent data collected from fishery observers' on-board commercial vessels or logbooks can be used to construct standardized indices of relative biomass for stock assessment models.
Several standardization techniques have been used for fishery-dependent data of many species, and most of them highlight the inclusion of environmental variables and spatio-temporal effects (Thorson et al., 2016). Overall these methods have been proved to be a useful tool to address ecological and stock assessment issues.
Within this context here we present a spatial standardization of Catch Per Unit Effort (CPUE) indices for the megrim (*Lepidorhombus whiffiagonis*) and the four-spot megrim (*L. boscii*) using a time series (2003-2020) of observers on board data of the bottom otter trawl fleet that operate in the in North Atlantic Iberian waters (ICES divisions 8c and 9a).

**Study Region**

The region of interest for this study is the northern continental shelf of the Iberian Peninsula, a narrow area (10–60 km) of almost 18,000 km$^2$ that is characterized by important and marked hydro dynamism (Abad et al., 2019). Over the shelf, currents are driven by regional factors, such as tides and wind. In the winter, a warm and saline poleward current moves eastward along the Cantabrian coast and enters the Bay of Biscay (Izquierdo et al., 2021). In addition, the coastal upwelling off the Galician and Portuguese coasts appears during spring and summer which, combined with hydrographic mesoscale activities, has a strong influence on the primary production of the area (Sánchez and Olaso, 2004).

**Input data**

A dataset was compiled from the observers on board programme of the Northern Spanish coastal bottom otter trawl fleet developed by the Instituto Español de Oceanografía (IEO). These reference fleet includes trawlers that usually operate in waters from the continental shelf (from 100 to 350 m depth) with European hake (*Merluccius merluccius*) and anglerfish (*Lophius budegassa, L. piscatorius*), megrims (*Lepidorhombus boscii* and *L. whiffiagonis*), horse mackerel (*Trachurus sp.*), blue whiting (*Micromesistius poutassou*) and Norway lobster (*Nephrops norvegicus*) as target species. They make hauls of about 2–4 h, comprising about 4-5 fishing hauls per trip. At each haul, observers record all basic operational data (i.e., date and geographical position and time duration of the fishing haul), the number and weight of all retained and discarded taxa and environmental variables as the bathymetry of the seabed. Additionally, information about the fishing vessel are recorded as its total length (in meters). The time period considered in the present study extends from 2003 to 2020.

**Methods**

For the four-spot megrim the relationship between the catches and predictors was modelled using a Gamma distribution as no zeros were recorded. On the contrary for the megrim, a hurdle model was implemented as the percentage of zeros was higher than 30%. For this reason, two different response variables were analysed for the megrim: (1) a presence/absence variable to measure the occurrence probability of the species; (2) positive catches (in kg) as an indicator of the conditional-to-presence biomass of the species. The occurrence was modelled using a Binomial distribution with a logit link function and the catches with a Gamma distribution with a log link, to capture the overdispersion of the data.

In each model the response variable was modelled as a function of explanatory variables assumed to influence catchability including: fishing haul duration (in hours), total vessel length (in m), depth (in m) of the fishing haul, and two variables that assess the interannual (years, 2003-2010) and seasonal (quarter: 1,2,3,4) variability.

Prior to the analysis, the explanatory variables were standardized (i.e., difference from the mean divided by the corresponding standard deviation) (Gelman et al., 2014) to better interpret both the direction (positive or negative) and magnitude (effect sizes) of the parameter estimates.

As it is known that gear saturation can exert a significant nonlinear effect on catchability exploratory analysis were performed to verify the linear relationship between the response variables and the continuous predictors. For this reason, second order random walk (RW2) functions were applied to the haul duration and the bathymetry.

We further accounted for spatial autocorrelation by including a numeric vector with a mean of 0 and a Matern covariance function linking each observation to a spatial location (i.e., latitude and longitude). Thus, our model accounts for independent and region-specific noise not explained by the available covariates. For the parameters involved in the fixed effects, vague Gaussian priors with a mean of 0 and a variance of 100 were used. The random spatial effect only depends on two hyperparameters: the range and the variance of the spatial effect. Penalized complexity priors (Fuglstad et al., 2018) were used to describe prior knowledge on these hyperparameters. We set a prior range of 50 km with a probability of 0.001 for it to be lower and a prior variance of 2 with a probability of 0.001 for it to be higher. We performed a sensitivity analysis of the choice of priors for the spatial effect by testing different priors and verifying that the posterior distributions were consistent and concentrated well within the support of the priors.

Bayesian inference was performed using the Integrated Nested Laplace Approximations (INLA) approach (Rue et al., 2009) with its corresponding package. INLA uses the so-called Stochastic Partial Differential Equation approach to approximate the Gaussian field with the Matern covariance function by a Gaussian Markov random field (Rue et al., 2009).
We selected the most parsimonious model, starting with all, based on the goodness-of-fit using the deviance information criterion (DIC) (Spiegelhalter et al., 2002) and Watanabe–Akaike information criterion (WAIC) (Watanabe, 2010).
The final model was evaluated with the log-conditional predictive ordinate (log-CPO) (Roos and Held, 2011), which is a "leave-one-out" cross-validation index to assess the predictive power of the model (Pennino et al., 2019).
INLA has built-in functions allowing for a linear interpolation of the spatial effect within each triangle into a finer regular grid. The resulting high-resolution map of the spatial effect can be seen as a proxy for the species' relative biomass.
All analyses and graphics were performed in R (R Core Team, 2020).

**Results**
**Four-spot megrim (*L. boscii*)**

Overall 3092 fishing hauls were analysed in which the *L. boscii* was caught, with values ranging from 1 and 370 kg by haul. The seasonal distribution of the catches seems overall homogeneous (Figure 1). However, it worth to be mentioned that in the 2020, due to the COVID pandemic the observers' onboard program was performed only in the two last quarters of the year.
Overall catches showed a decreasing temporal trend along the time series 2003-2020, (Figure 1), recording the highest catches in the 2015, while the lowest value was recorded in the 2020 one (Figure 1).
The final Bayesian model, selected on the basis of the lowest DIC, WAIC and LCPO values, retained as predictors, the fishing haul time duration, depth, vessel total length, year, quarter and the spatial effect (Table 1). Finally, the depth variable required a smoothing spline, showing a negative relationship with the catches of the *L. boscii* (Figure 2).

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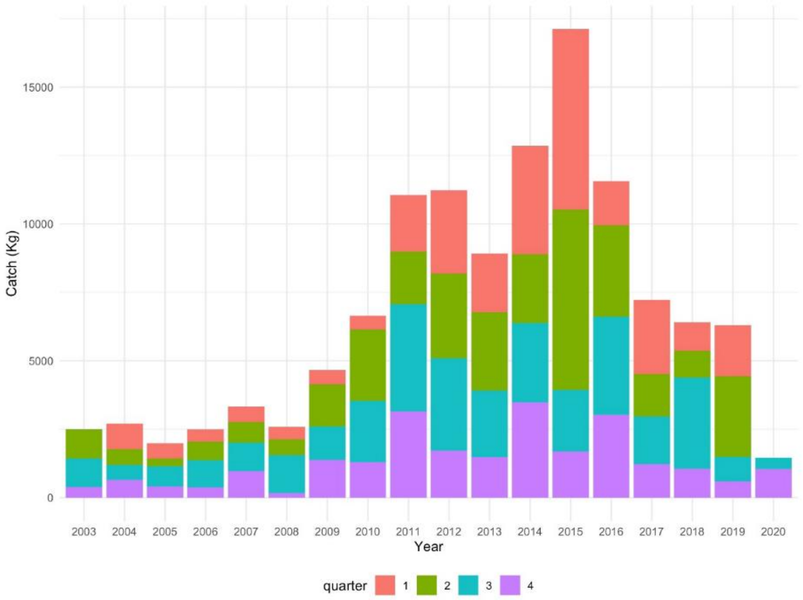


Figure 1: Temporal distribution (by quarter and year) of the megrim (*Lepidorhombus boscii*) catches (in Kg).

Fourth main hot-spots were identified in the area studied (Figure 3). Specifically, from south to north, the first was located off the Ria of Pontevedra and Vigo, the second one off the Costa de la Muerte, the third and largest of these covered most of the Artabrian gulf off La Coruña, and the fourth (a small one) was located off Gijon.

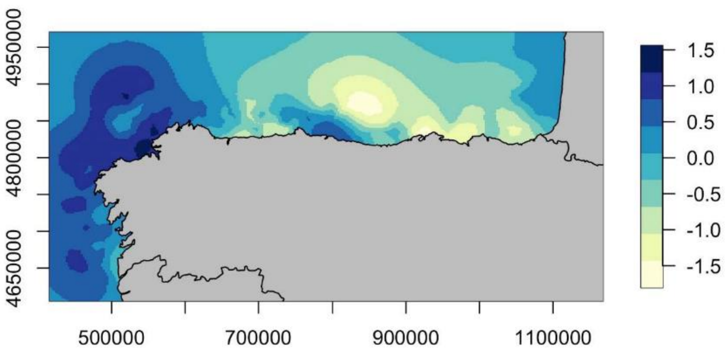


Figure 3: Posterior mean of the spatial effect for the four-spot megrim (*L. boscii*) model.

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The fishing haul duration showed a positive relationship with the four-spot megrim catches, meaning that higher values of catches were in longer hauls. On the contrary, the vessel length showed a negative relationship with the catches (i.e., longer boats catch less quantity). Regarding the seasonal trend, there was a bit of heterogeneity between the different four-month periods, the first being the one with the highest catches (Figure 4). The annual trend showed a decreasing pattern in the last years of the time series, as also showed for the final standardized CPUE index (Figure 5).

Table 1. Model comparison for the occurrence and conditional-to-presence catch of the four-spot megrim (*L.boscii)*. Acronyms are deviance information criterion (DIC), Watanabe–Akaike information criterion (WAIC) and log-conditional predictive ordinate (log-CPO), Y = year, Q = quarter of the year, D = depth of the fishing haul, HD = haul duration, VL = vessel length, S = spatial effect, f = smoothing function. The final selected mode is highlighted in bold.

| Model | DIC | WAIC | LCPO |
|---|---|---|---|
| 1 + Y + Q + D + HD + VL | 13755.97 | 13760.06 | 4.62 |
| 1 + Y + Q + D + HD + VL + S | 13389.88 | 13428.34 | 4.45 |
| **1 + Y + Q + f(D) + HD + VL + S** | 13345.53 | 13378.56 | 4.41 |
| 1 + Y + Q +F(D) + f(HD) + VL + S | 13348.21 | 13379.5 | 4.41 |

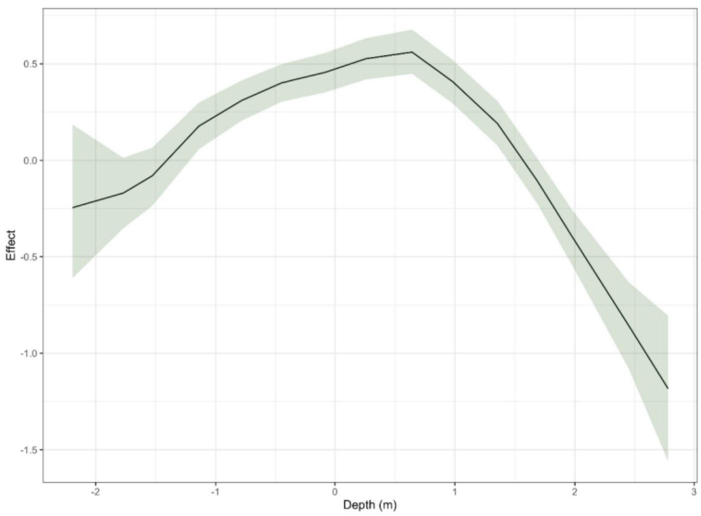


Figure 2: Smooth functions of the standardized bathymetry effect for the four-spot megrim (*L.boscii*) model. The solid line is the smooth function estimate, and shaded regions represent the approximate 95% credibility interval.

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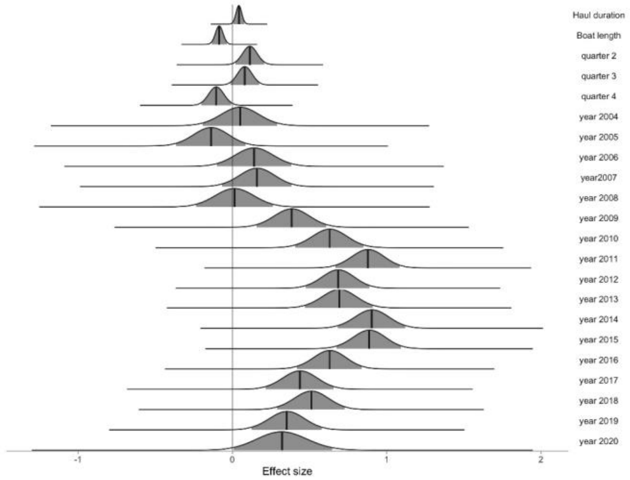


Figure 4: Posterior marginal distribution of the fixed effects of the catches four-spot megrim (*L. boscii)* model.

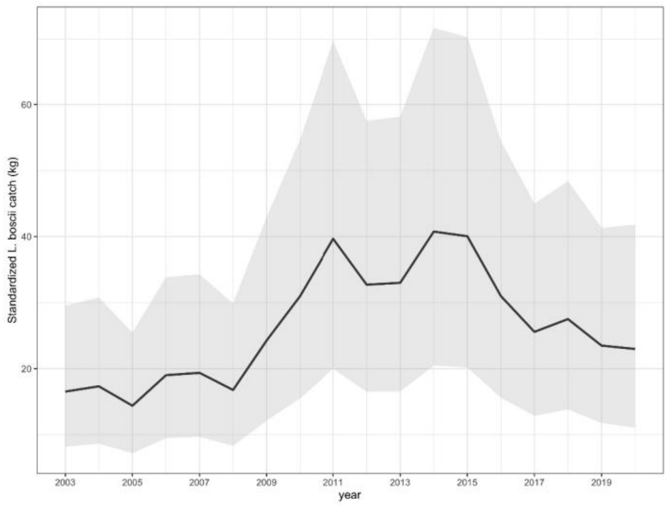


Figure 5: Standardized CPUE combined index for the four-spot megrim (*L. boscii*).

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**Megrim *(Lepidorhombus whiffiagonis)***

Among 3093 fishing hauls recorded, 1852 have positive catches ranging from 1 to 170 kg by haul. The seasonal distribution of the catches seems overall homogeneous (Figure 6).

No clear temporal trend can be observed in the catches along the time series 2003-2020, although in the last decade catches were higher than in the first one (Figure 6). The year with the highest catches was the 2011 while the lowest value was recorded in the 2008 one (Figure 6).

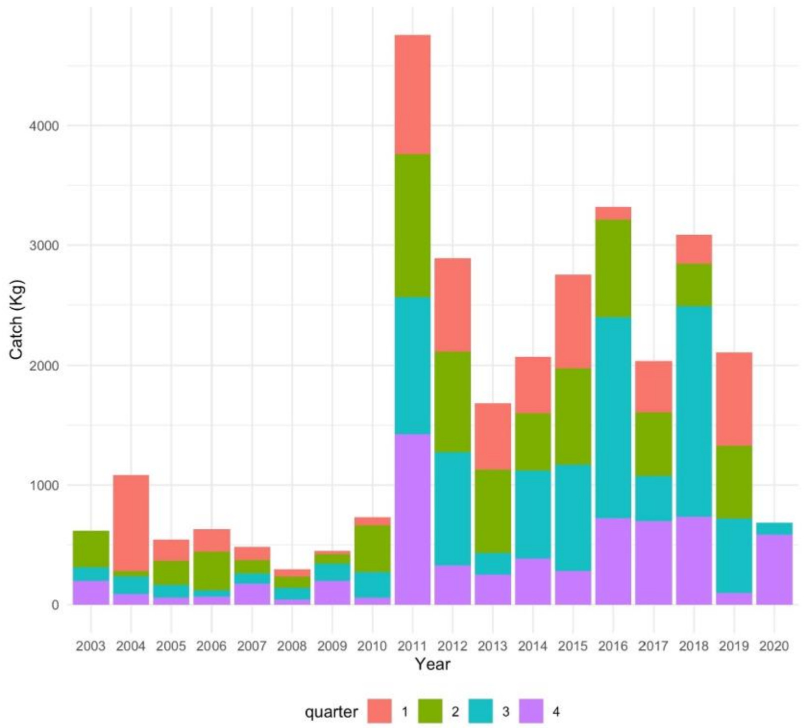


Figure 6: Temporal distribution (by quarter and year) of the megrim (*Lepidorhombus whiffiagonis*) catches (in Kg).

In the final Bayesian hurdle model for both occurrence and conditional-to-presence-catch retained as predictors, the fishing haul time duration, depth, vessel total length, year, quarter and the spatial effect (Table 2). In both models only, the depth variable required smoothing splines, showing a negative relationship with the probability of occurrence and the catches of the *L. whiffiagonis* (Figure 7).

Table 2. Model comparison for the occurrence and conditional-to-presence catch of the megrim (*L. whiffiagonis*). Acronyms are deviance information criterion (DIC), Watanabe–Akaike information criterion (WAIC) and log-conditional predictive ordinate (log-CPO), Y = year, Q = quarter of the year, D = depth of the fishing haul, HD = haul duration, VL = vessel length, S = spatial effect, f = smoothing function. The final selected mode is highlighted in bold.

| Model | DIC | WAIC | LCPO |
|---|---|---|---|
| **Occurrence** | | | |
| 1 + Y + Q + D + HD + VL | 3811.705 | 3812.281 | 0.62 |
| 1 + Y + Q + D + HD + VL + S | 2902.212 | 2901.01 | 0.47 |
| **1 + Y + Q + f(D) + HD + VL + S** | 2876.866 | 2875.622 | 0.47 |
| 1 + Y + Q +F(D) + f(HD) + VL + S | 2877.437 | 2876.036 | 0.47 |
| **Conditional-to-presence-catch** | | | |
| 1 + Y + Q + D + HD + VL | 13755.97 | 13760.06 | 3.71 |
| 1 + Y + Q + D + HD + VL + S | 13389.88 | 13428.34 | 3.67 |
| **1 + Y + Q + f(D) + HD + VL + S** | 13345.53 | 13378.56 | 3.62 |
| 1 + Y + Q +F(D) + f(HD) + VL + S | 13348.21 | 13379.50 | 3.62 |

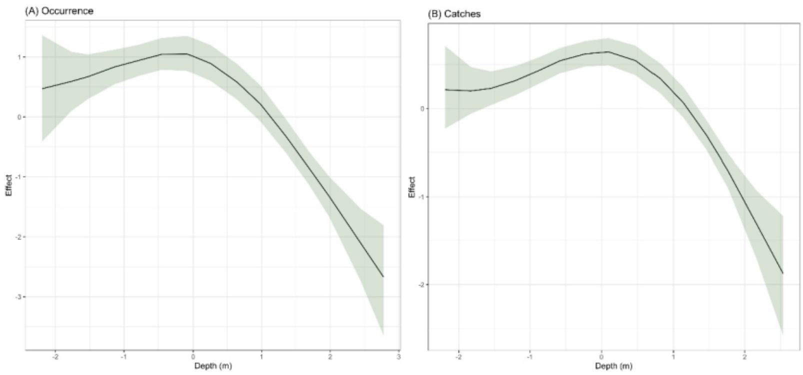


Figure 7: Smooth functions of the standardized bathymetry effects for the occurrence (A) and conditional-to-presence-catches (B) of the megrim (*L. whiffiagonis*) models. The solid line is the smooth function estimate, and shaded regions represent the approximate 95% credibility interval.

The spatial effect pattern was similar in both occurrence and conditional-to-presence-catches models (Figure 8), highlighting three main hotspots, the largest one covered most

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of the Artabrian gulf off La Coruña, the second one was located off Santander and the last one in more deeper waters in the Bay of Biscay.

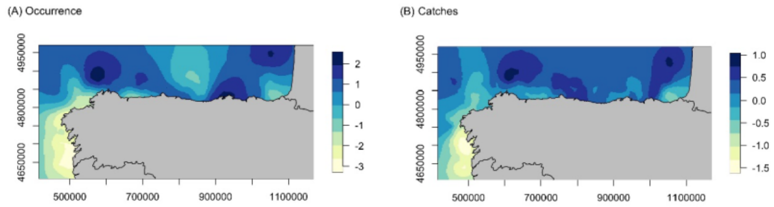


Figure 8: Posterior mean of the spatial effect for the (A) occurrence and (B) conditional-to-presence-catches for the megrim (*L. whiffiagonis*) models.

The fishing haul duration showed a positive relationship, i.e., higher values catches are recorded when the duration of the haul is longer. On the contrary the vessel length presented a negative relationship with the occurrence and the conditional-to-presence catches meaning the larger vessel caught lower quantity of megrim. However, looking at the magnitude of the estimated parameters for these two variables we can see that are not the most relevant in explaining the occurrence and catches variability (Figure 9). With respect the seasonal pattern, for the occurrence the quarter with higher probability of presence is the fourth of the year, while for the catches is the first one (Figure 9). For both models if we analysed the estimated parameters of the years we can see that overall there is an increasing trend in both occurrence and conditional-to presence-catches variables. This increasing trend is also reflected in the final standardized combined CPUE index (i.e., probability of occurrence * conditional-to presence-catches) (Figure 10).

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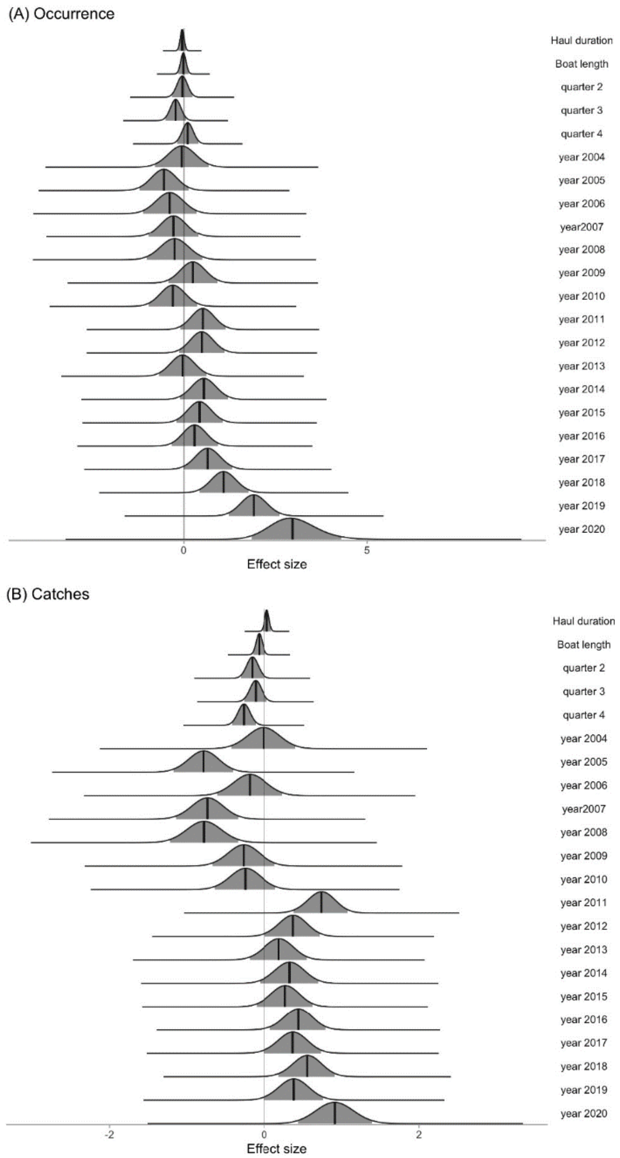


Figure 9: Posterior marginal distribution of the fixed effects of the occurrence (A) and conditional-to-presence-catches (B) megrim (*L. whiffiagonis)* models.

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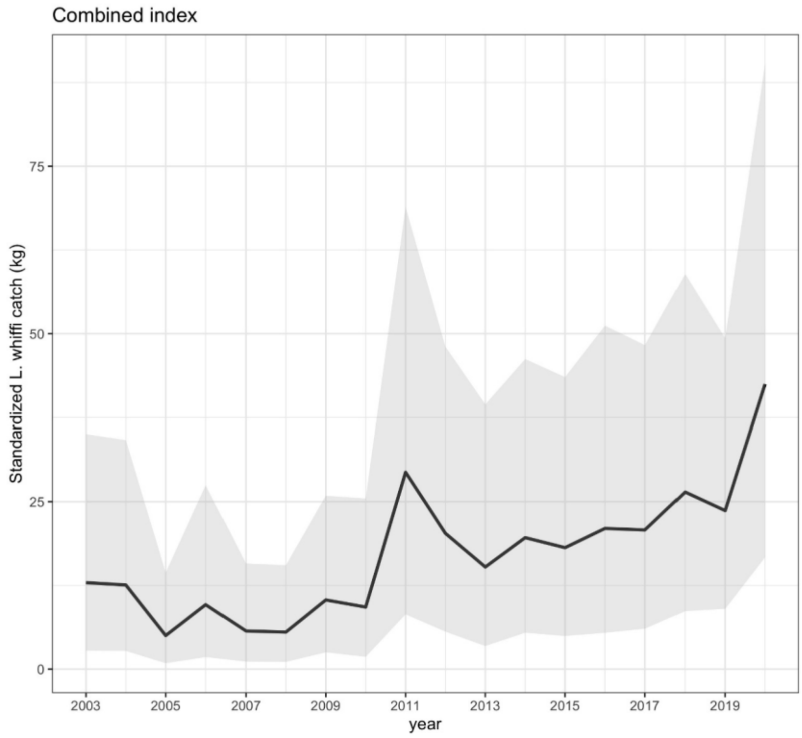


Figure 10: Standardized CPUE combined index for the megrim (*L. whiffiagonis*).

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*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

**Review of the Spanish commercial tuning index used in the assessment of Megrim (*Lepidorhombus whiffiagonis*) in ICES Divisions 7b-k and 8a,b,d (meg.27.7b-k8abd)**

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***SUMMARY***

*In response to the WKMegrim 2022 Data call, the original values of the SP-VIGOTR7 tuning fleet have been retrieved from the IEO database. On the other hand, given the uncertainty of the horsepower declared per vessel, the LPUE values are provided in both kg/fd*100HP and kg/fd, in order to show their differences. Progress towards standardization applying multivariate methodologies is not appropriate in such a long time series in which different data sources occur with few common explanatory variables.*

## INTRODUCTION

The SP-VIGOTR7 tuning fleet, used in the current assessment of the megrim (*Lepidorhombus whiffiagonis*) stock in ICES Divisions 7b-k and 8abd, is elaborated by IEO from scientific and official fishing data. This tuning fleet index consists of the weight of megrim landed in the port of Vigo by unit of effort of the Spanish trawling fleet directed at this stock in waters of ICES Subarea 7 (Castro *et al*, 2012). The configuration of this time series can be described as follows:

- Duration: 1984-2019 (35 years).
- Catch category: landings.
- Unit: Kg/(fishing day*100 HP).
- Temporal stratification: quarter.

This index was analyzed for the last time in Fernandez *et al.* (2008), where it was decided to split the series in two periods: 1984–1998 (VIGO84) and 1999–present (VIGO99). No updated data was provided for year 2020 for these fleet due to the COVID-19 disruption coupled with administrative problems, which prevented the execution of the IEO on-shore sampling programme throughout the four quarters of 2020.

*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

The Data call for the ICES WKMegrim 2022[1], launched on 20/10/2021, requested standardized LPUE time series data for this tuning fleet with a deadline of November 19th. In response to this request, an effort has been made to compile and review the original time series from the IEO's institutional database, in order to validate the values used by the ICES WGBIE (ICES, 2021). The objective of this working document is to detail the revision process of the SP-VIGOTR7 tuning index, so that reasoned decisions can be made during the WKMegrim 2022.

**REVIEW**

The SP-VIGOTR7 tuning index is made from raw data of two types of sources:

- Scientific data:
    - Length frequency distributions (LFD) from the IEO on-shore sampling programme, whose design has remained stable throughout the entire time series. The sampling unit is the fishing trip, where landings are classified by the fishermen in commercial categories, which are sampled as separate strata. At this step we also proceed to the taxonomic separation of both species, *L. whiffiagonis* [MEG] and *L. boscii* [LDB], which are landed together.
    - Scientific estimation of landings from the LPUE indices obtained by sampling in the port of Vigo, weighted to the total number of trips landed by the target fleet in this port, taken from their respective logbooks. Implemented from 2014 onwards.
- Official data:
    - Landings: total landings of the SP-VIGOTR7 trips were collected from the official sales notes until 2013. The sales notes do not differentiate species since the TAC is set for the Genus *Lepidorhombus* spp. (Alpha-3 code: LEZ), so that both species must be separated by applying the ratio obtained by sampling.
    - Effort: the number of total trips, taken from the official sales notes, is transformed into fishing days applying the mean value of 12.9 fd/trip, until 2013. Since 2014, the actual number of fishing days per trip recorded in the respective logbooks began to be used.
    - Technical features: fishing days are standardized by the fishing power of the vessels applying the horsepower value declared in the census of the operational fishing fleet.

The compilation process carried out specifically to answer the WKMegrim 2022 Data call has revealed some discrepancies with the series published by ICES (Table 1, Figure 1):

- Start date: the time series published by ICES begins in 1984, while the IEO series starts one year later. The 1984 data was submitted prior to the creation of the IEO database, therefore its validation is currently not possible.
- Discrepancies in the values prior to the year 2013: these differences, especially high between the years 1999-2012, seem to be due to the inclusion of discard estimates. It must be considered that the SP-VIGOTR7 tuning index comes from on-shore

[1] "ICES Benchmark Workshop for selected Megrim Stocks". Data call available from the ICES website at: https://www.ices.dk/data/tools/Pages/Data-calls.aspx

sampling, so that it is based exclusively on landings. The addition of discard estimates is surely done later during the respective WG meetings.

- Discrepancy in the 2013 value: this is the result of a transmission error, verified after consulting our minutes of transmission of the 2014 Data call.

As stated above, the Spanish on-shore sampling programme had to be suspended in 2020 due to an unfortunate coincidence of the COVID-19 pandemic and administrative and logistical problems. For this reason, it is not possible to update the time series by adding the year 2020, having to wait until the value of the year 2021 is available.

**THE EFFECT OF FISHING POWER**

The SP-VIGOTR7 tuning fleet used by ICES in the assessment of the meg.27.7b-k8abd stock is calculated as kilograms by fishing day * 100 horse power. The fishing power data are obtained from the official census of the Spanish fishing fleet, which is provided by the Spanish Ministry of Agriculture, Fisheries and Food.

On the other hand, the IEO develops an at-sea sampling programme which, among others, also includes the fleet that concerns us here. Although its main objective is the sampling of discards, the observers also collect the technical characteristics of the vessel. The comparison of the figures for the year 2019, the last coincident of both sampling programmes (on-shore and at-sea), indicates that the official fishing power could represent only 60% of the real one (collected by observers). Unfortunately, the at-sea sampling programme does not provide data for all vessels throughout the time series and the discrepancies between matching vessels are not regular, ranging from 0% to 60% depending on the vessel.

Since an adequate correction of the official fishing powers values is not possible, we also present here the SP-VIGOTR7 LPUE index in kg/fishing day, with the objective of better illustrating the effect caused by the inclusion of fishing power (Table 1; Figure 1).

**DISCUSSION**

The discrepancies between the series published in the Table 5.7. of the 2021 WGBIE report ("ICES") and the one retrieved from the IEO database ("IEO1") are concentrated in the first decade of the current century, and they seem to be due to the inclusion of discard estimates. It is advised that WGBIE must clarify this ambiguity in future reports by providing only LPUE (Landings per unit of effort) or only CPUE (Catch per unit of effort), but not both at different year periods in the same series.

The LPUE standardization by applying technical measures of power has been a common practice in the development of commercial tuning indices. This is due to the belief that effective effort can be greatly affected by the power of the vessel, especially for active fishing gears such as trawling. However, this thesis is supported by the assumption that the correct data for said variable is available, which is not always the case. The use of power in the calculation of the SP-VIGOTR7 series began in the 80s of the last century and continued to date under express request of the WGBIE. However, the quality of this information had never been checked before.

The discrepancy found between the "IEO1" series, in kg/(fishing day*100HP), with the "IEO2" series, in kg/fd, calls into question the accuracy of the fishing power values used in the calculation of the SP-VIGOTR7 tuning index. The comparison of both series shows the largest differences at the beginning (1985-1993) and end (2014-2019) of the time series. The first ones could be related to possible adaptations of the fleet register after the inclusion of Spain in the EU in 1986, while the last ones may be related to a better declaration of the fishing power of the new vessels built to replace the older ones.

Regarding the decision to split the SP-VIGOTR7 LPUE time series into two periods (VIGO84 and VIGO99), this was based on the pattern detected in the log-catchability residuals for this series (Fernández *et al.*, 2008). That working document pointed out two possible sources of bias: the inclusion of discards and the standardization of effort. In fact, Fernández *et al.* (2008) considers the first cause more likely, since the problem was attenuated with the elimination of discards. However, they ultimately dismiss this possibility since the discards estimates are part of the international commercial catch matrix for this stock, so it would be inconsistent not to include discards in the SP-VIGOTR7 tuning series.

In terms of progress towards standardization applying multivariate methodologies, it does not seem appropriate in such a long time series in which different data sources occur with very few common explanatory variables. The first twenty years of the time series are supported by sales notes, since the logbooks began to present sufficient quality only 15 years ago. As is known, the sales notes record a commercial transaction by trip with little biological-fishery information, while logbooks provide georeferenced information per fishing day. However, standardization could be more appropriate on scientific catch data obtained from the at-sea sampling programme which, although shorter in time, provides a larger number of variables collected with the same scientific criteria throughout the entire time series. The results of this work are presented to the WKMegrim 2022 in a separate working document. In this way, two independent indices could be available: a longer one with only landings (LPUE) and a shorter one with total catches (CPUE).

*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

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*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

| Year | ICES | IEO1 | IEO2 |
|---|---|---|---|
| 1984 | 99.1 | NA | NA |
| 1985 | 108.9 | 107.8 | 654.1 |
| 1986 | 105.1 | 105.1 | 637.8 |
| 1987 | 96.2 | 95.2 | 570.5 |
| 1988 | 106.1 | 106.1 | 771.6 |
| 1989 | 92.1 | 92.1 | 733.6 |
| 1990 | 73.8 | 74.0 | 614.6 |
| 1991 | 85.4 | 86.3 | 806.1 |
| 1992 | 105.6 | 95.7 | 747.6 |
| 1993 | 92.3 | 87.6 | 679.9 |
| 1994 | 78.7 | 82.7 | 439.3 |
| 1995 | 94.3 | 84.6 | 456.1 |
| 1996 | 79.3 | 72.3 | 409.2 |
| 1997 | 96.0 | 85.2 | 458.8 |
| 1998 | 82.4 | 77.2 | 420.8 |
| 1999 | 137.0 | 76.8 | 391.5 |
| 2000 | 128.9 | 88.7 | 497.1 |
| 2001 | 131.2 | 109.2 | 604.5 |
| 2002 | 185.3 | 156.3 | 820.6 |
| 2003 | 192.1 | 140.4 | 728.4 |
| 2004 | 210.0 | 127.3 | 647.3 |
| 2005 | 135.3 | 100.0 | 506.4 |
| 2006 | 146.1 | 100.5 | 535.2 |
| 2007 | 144.3 | 108.1 | 575.7 |
| 2008 | 114.0 | 90.7 | 497.1 |
| 2009 | 173.2 | 157.2 | 849.9 |
| 2010 | 198.3 | 119.6 | 648.9 |
| 2011 | 151.2 | 121.1 | 669.7 |
| 2012 | 135.3 | 110.6 | 680.1 |
| 2013 | 210.2 | 124.0 | 766.2 |
| 2014 | 116.7 | 116.7 | 806.8 |
| 2015 | 89.7 | 89.7 | 647.4 |
| 2016 | 96.6 | 96.6 | 769.5 |
| 2017 | 85.5 | 85.5 | 719.0 |
| 2018 | 65.5 | 65.5 | 569.3 |
| 2019 | 78.2 | 78.2 | 682.7 |
| 2020 | NA | NA | NA |

**Table 1.** LPUE of the SP-VIGOTR7 tuning fleet for Northern megrim. "ICES": series published by ICES (WGBIE 2021; CPUE and LPUE in different years); "IEO1": original values recovered from the IEO data base, in landed kg/fd*100HP; and "IEO2": original values recovered by IEO in kg by fishing day.

*WD presented at WKMegrim 2022*
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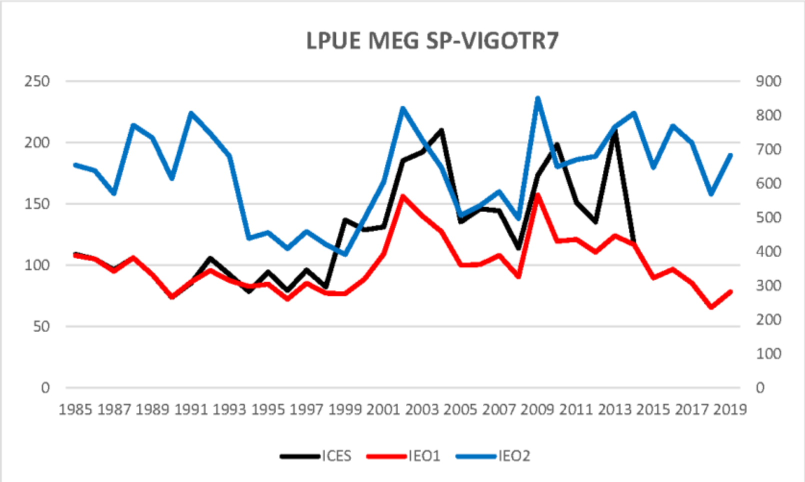


**Figure 1.** LPUE of the SP-VIGOTR7 tuning fleet for Northern megrim. Black line (WGBIE 2021; CPUE and LPUE in different years); red line (original LPUE data recovered from the IEO data base, in kg/fd*100HP); and blue line (original LPUE data recovered by IEO, in kg/fd).

# Exploratory scenarios in a4a for southern megrims (*Lepidorhombus whiffiagonis* and *L.boscii*) in divisions 8.c and 9.a using available abundance indices

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The objective of this working document is to present different configurations of the assessment model combining the available abundance indices as decided in the data compilation meeting. The indices that were already part of the previous model and some new indices developed for this benchmark have been used.

Once the indices were selected, different options were studied during the benchmark to choose the most appropriate one with the best fit. All the considered configurations are listed in this document.

## Scenarios to consider the different abundance indices

*Lepidorhombus boscii* 8c9a a4a scenarios (in red new indices):

| *L. boscii* | Commercial indices | | | Survey indices | |
|---|---|---|---|---|---|
| | SP-LCGOTBDEF1 LPUE 1986-1999 | SP-LCGOTBDEF2 LPUE 2000-2020 | OAB_INDEX CPUE (biomass) 2003-2020 | ESP Demersales 1988-2020 | PT Crustacean 1997-2018 |
| FIT 1: Base Case as WGBIE 2021 (old maturity ogive) | X | X | | X | |
| FIT 2: Commercial indices from bottom trawl fleets and surveys | X | X | | X | X |
| FIT 3: Commercial indices based on-board data and surveys | | | X | X | X |
| FIT 4: Only Surveys | | | | X | X |
| FIT 5: All indices overlapping commercial LPUEs and commercial CPUE | X | X | X | X | X |
| FIT 6: All indices with no overlapping | X | | X | X | X |

Table with AIC, BIC and Mohn's Rho values of the different fits:

| | AIC | BIC | Mohn's Rho (Retro_F) | Mohn's Rho (Retro_SSB) | Mohn's Rho (Retro_R) |
|---|---|---|---|---|---|
| FIT 1: Base Case as WGBIE 2021 (old maturity ogive) | 904.0 | 1384.6 | -0.14 | 0.13 | -0.18 |
| FIT 2: Commercial indices from bottom trawl fleets and surveys | 1193.0 | 1710.9 | -0.04 | 0.02 | -0.15 |
| FIT 3: Commercial indices based on-board data and surveys | 1089.9 | 1562.0 | -0.10 | 0.06 | -0.09 |
| FIT 4: Only Surveys | 1073.5 | 1533.7 | -0.04 | 0.01 | -0.16 |
| FIT 5 All indices overlapping commercial LPUEs and commercial CPUE | 1211.4 | 1750.5 | -0.12 | 0.09 | -0.08 |
| FIT 6 All indices with no overlapping | 1157.9 | 1661.7 | -0.10 | 0.06 | -0.10 |

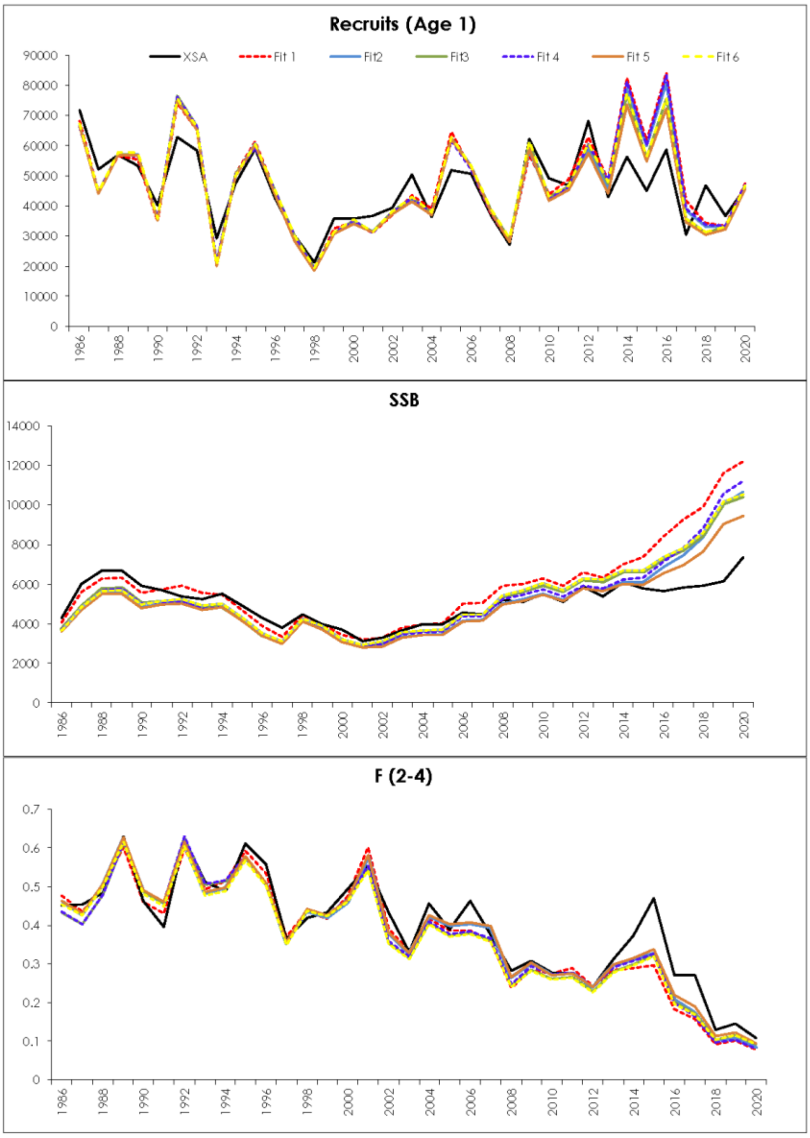


Figure 1. XSA (WGBIE2021) results and a4a fits results comparison.

Fit 1

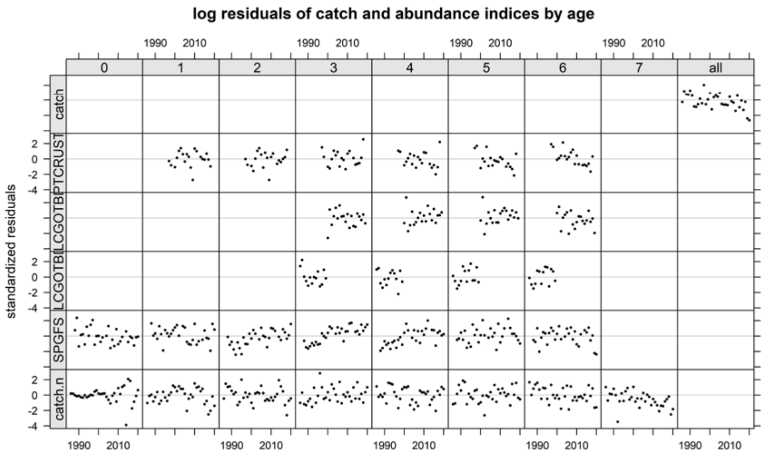


Figure 2. Log residuals of catch and abundance indices by age

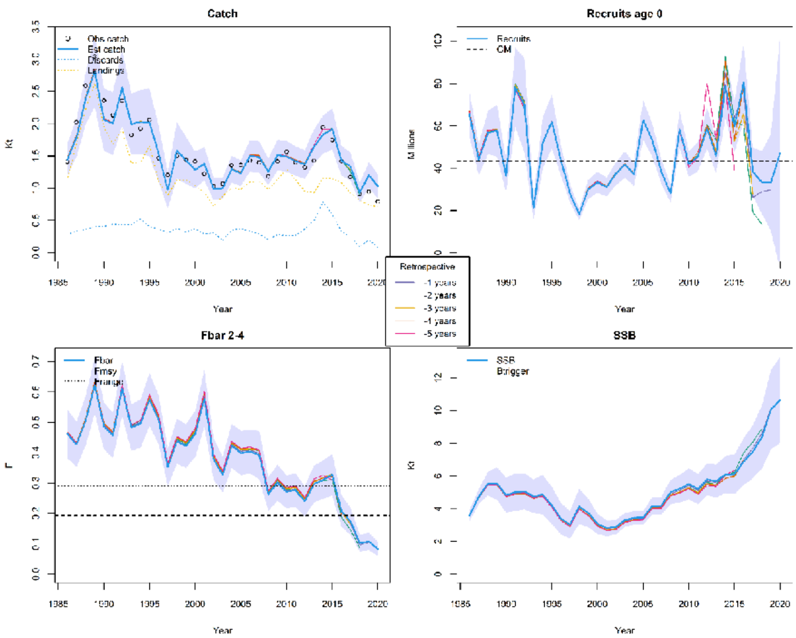


Figure 3. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 2

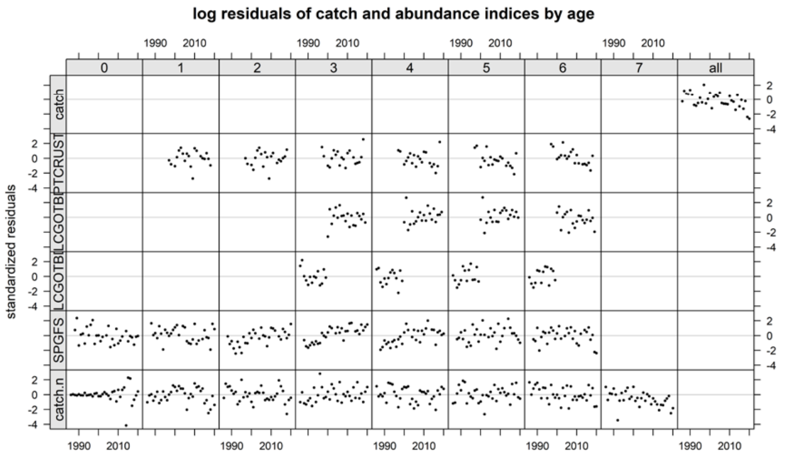


Figure 4. Log residuals of catch and abundance indices by age

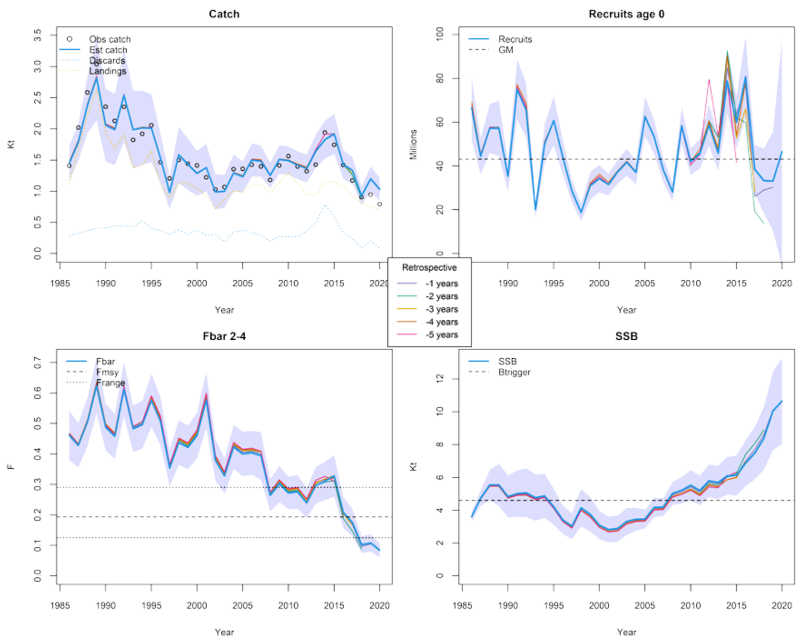


Figure 5. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 3

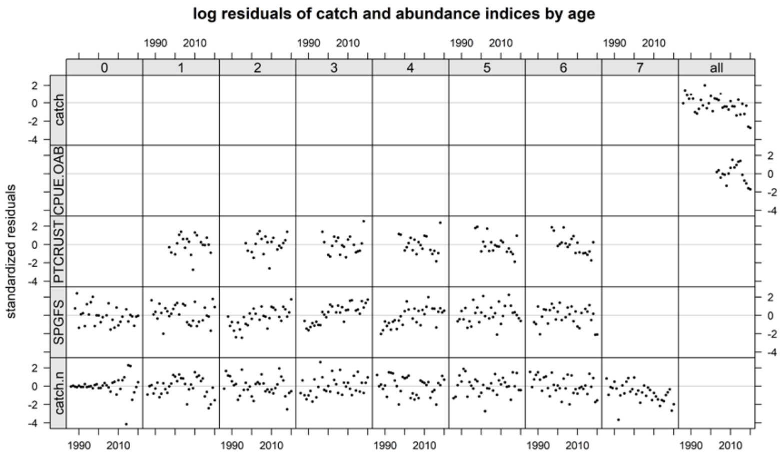


Figure 6. Log residuals of catch and abundance indices by age

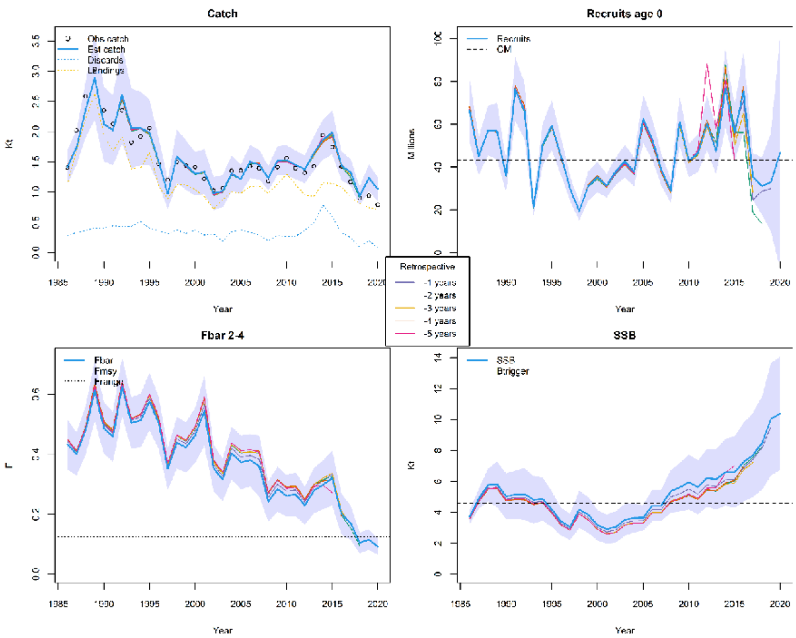


Figure 7. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 4

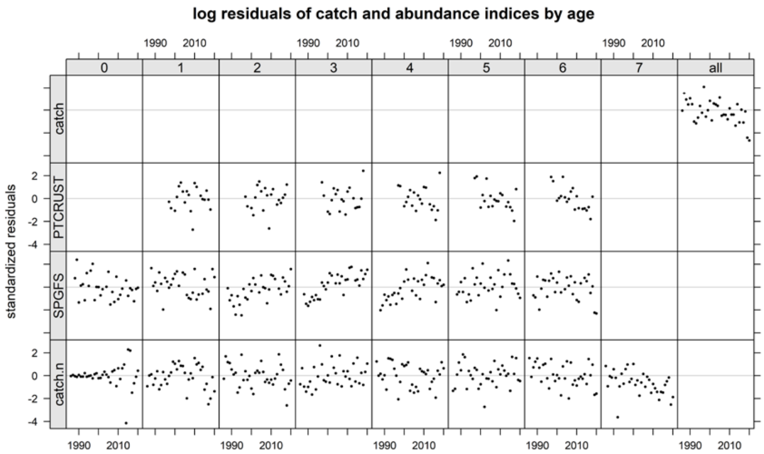


Figure 8. Log residuals of catch and abundance indices by age

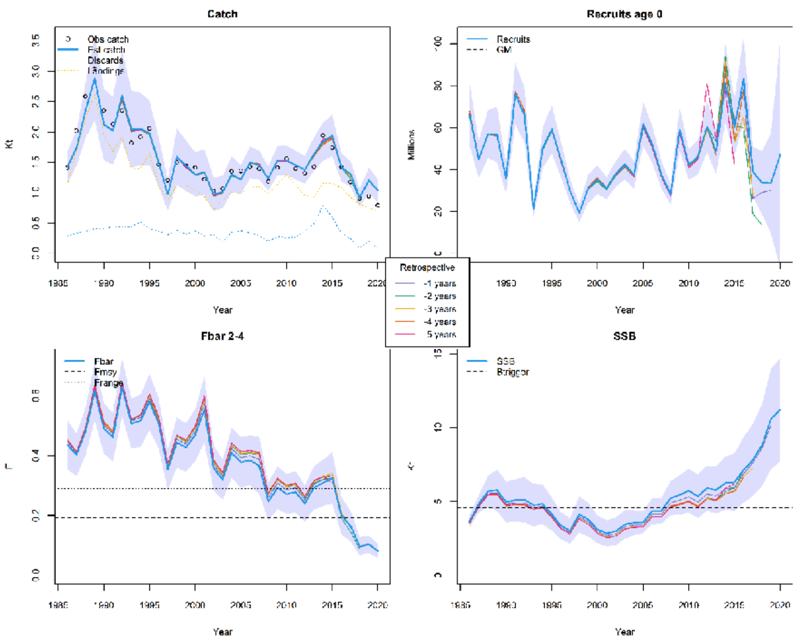


Figure 9. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 5

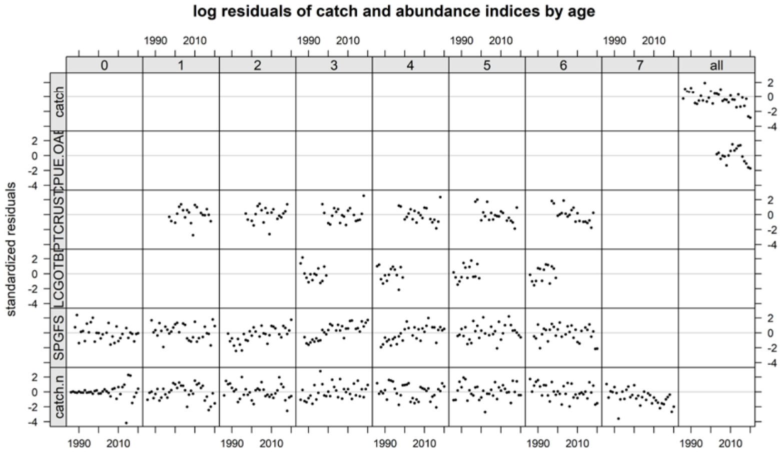


Figure 10. Log residuals of catch and abundance indices by age

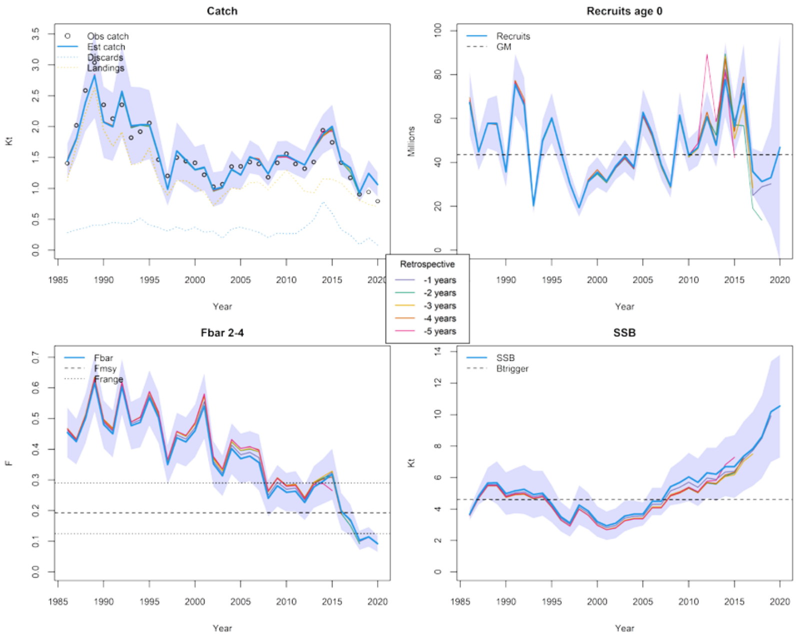


Figure 11. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 6

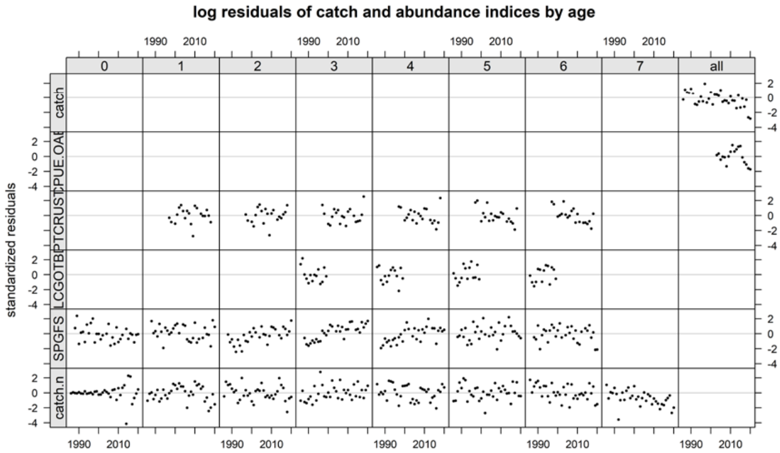


Figure 12. Log residuals of catch and abundance indices by age

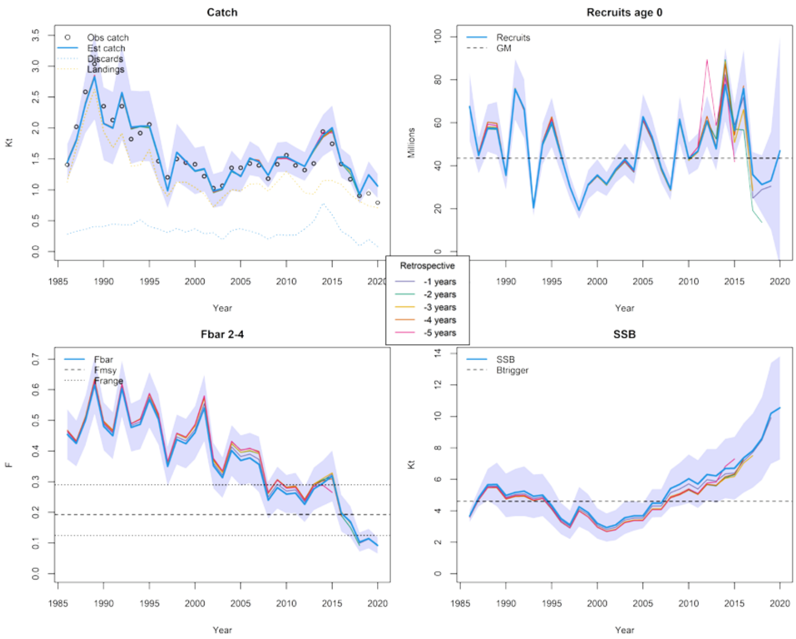


Figure 13. Summary of assessment outputs and retrospective pattern plots over the last 6 years

*Lepidorhombus whiffiagonis* 8c9a a4a scenarios (in red new indices):

| *L. whiffiagonis* | Commercial indices | | | Survey index |
|---|---|---|---|---|
| | SP-LCGOTBDEF LPUE 1986-2020 | SP-AVSOTBDEF LPUE 1986-2020 | OAB_INDEX CPUE (biomass) 2003-2020 | ESP Demersales 1990-2020 |
| FIT 1: Base Case as WGBIE 2021 (old maturity ogive) | X | X | | X |
| FIT 2: Commercial indices from bottom trawl fleets and survey | X | X | | X |
| FIT 3: Commercial indices based on-board data and survey | | | X | X |
| FIT 4: Only Survey | | | | X |
| FIT 5 All indices overlapping commercial LPUEs and commercial CPUE | X | X | X | X |
| FIT 6 All indices with no overlapping | X | X | X | X |

Table with AIC, BIC and Mohn's Rho values of the different fits:

| | AIC | BIC | Mohn's Rho (Retro_F) | Mohn's Rho (Retro_SSB) | Mohn's Rho (Retro_R) |
|---|---|---|---|---|---|
| XSA WG2021 | | | -0.02 | -0.32 | 0.34 |
| FIT 1: Base Case as WGBIE 2021 (old maturity ogive) | 1162.6 | 1598.6 | -0.212 | 0.434 | 0.844 |
| FIT 2: Commercial indices from bottom trawl fleets and survey | 1185.8 | 1621.8 | -0.233 | 0.404 | 0.759 |
| FIT 3: Commercial indices based on-board data and survey | 736.2 | 1096.5 | -0.287 | 0.448 | 0.678 |
| FIT 4: Only Survey | 705.3 | 1053.7 | -0.234 | 0.357 | 0.522 |
| FIT 5 All indices overlapping commercial LPUEs and commercial CPUE | 1205.2 | 1652.7 | -0.275 | 0.408 | 0.906 |
| FIT 6 All indices with no overlapping | 943.3 | 1370.0 | -0.295 | 0.412 | 0.729 |

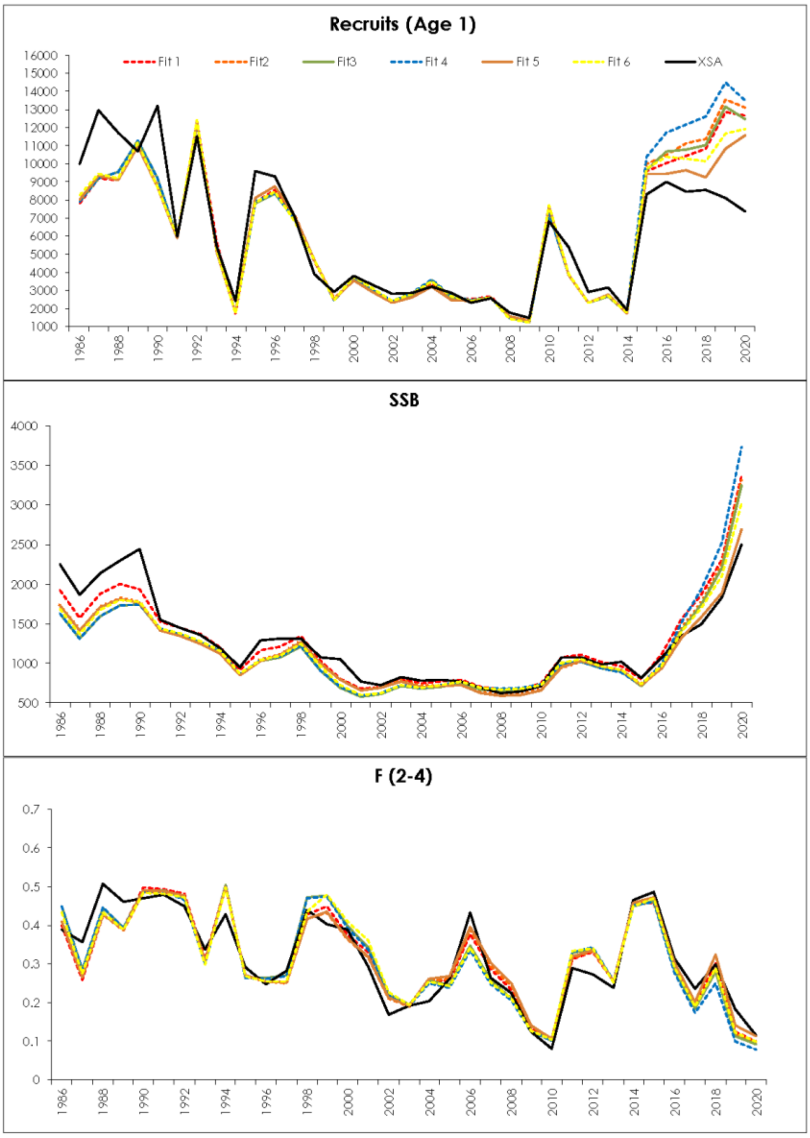


Figure 14. XSA (WGBIE2021) results and a4a fits results comparison.

Fit 1

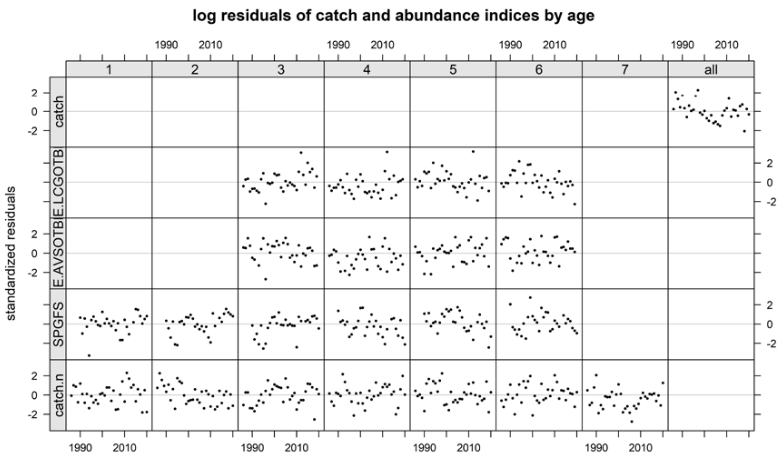


Figure 15. Log residuals of catch and abundance indices by age

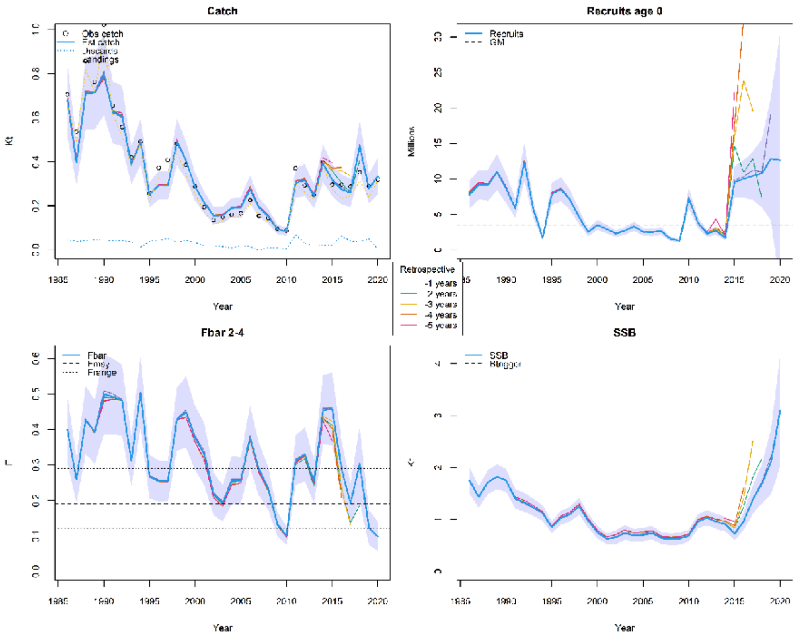


Figure 16. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 2

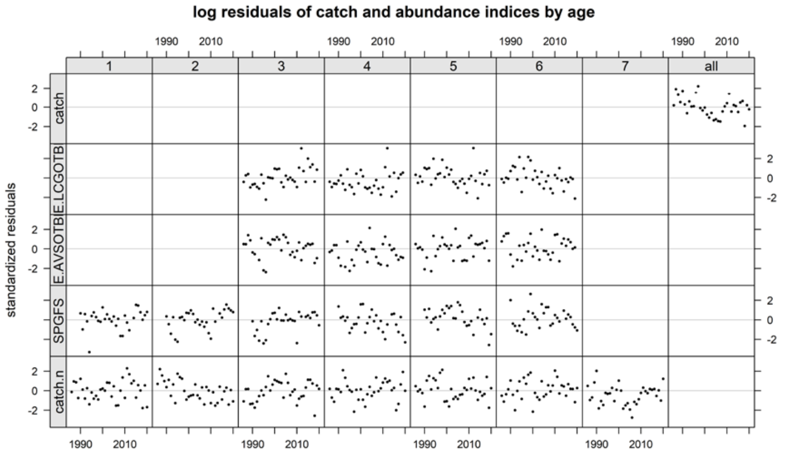


Figure 17. Log residuals of catch and abundance indices by age

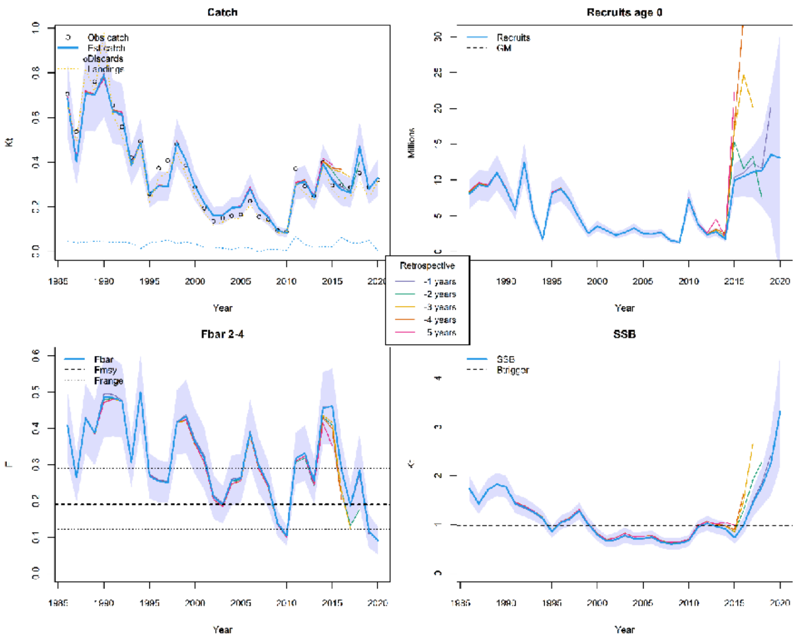


Figure 18. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit3

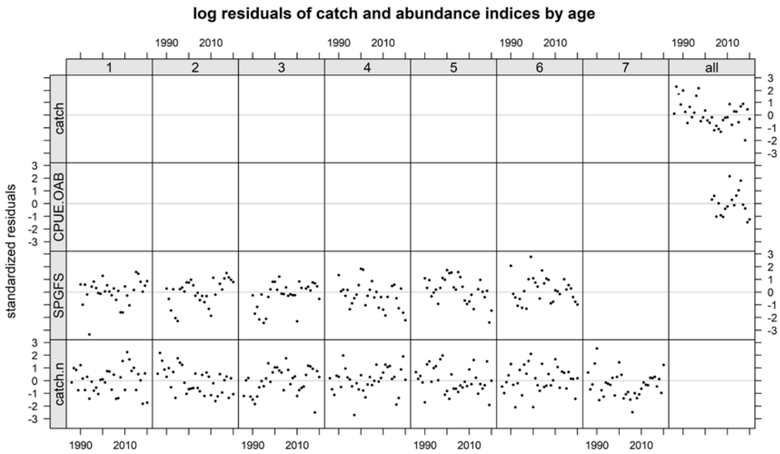


Figure 19. Log residuals of catch and abundance indices by age

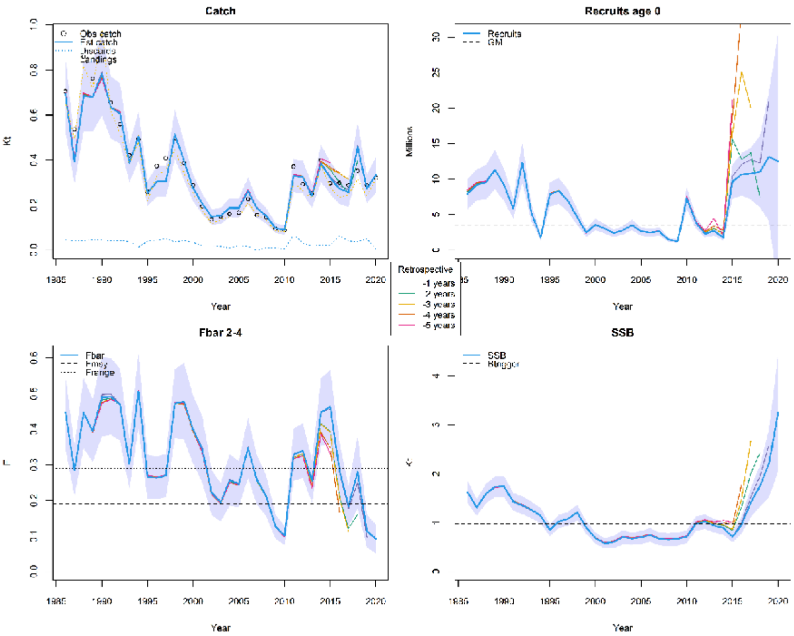


Figure 20. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 4

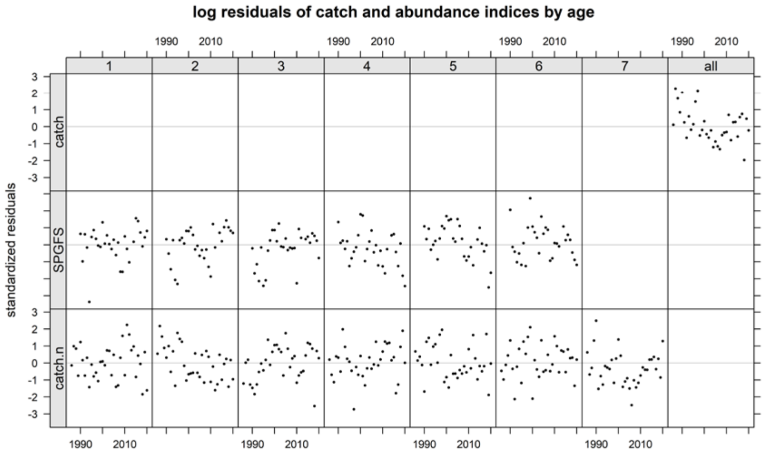


Figure 21. Log residuals of catch and abundance indices by age

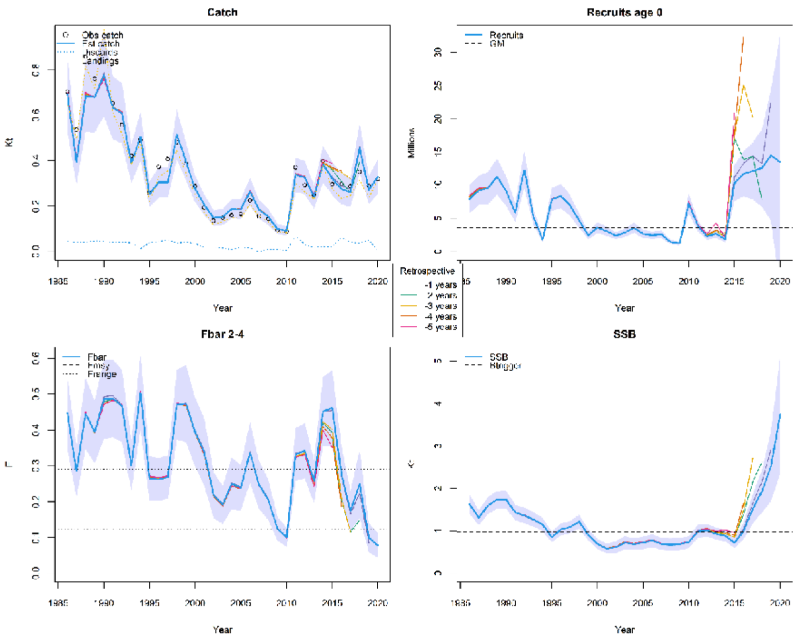


Figure 22. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 5

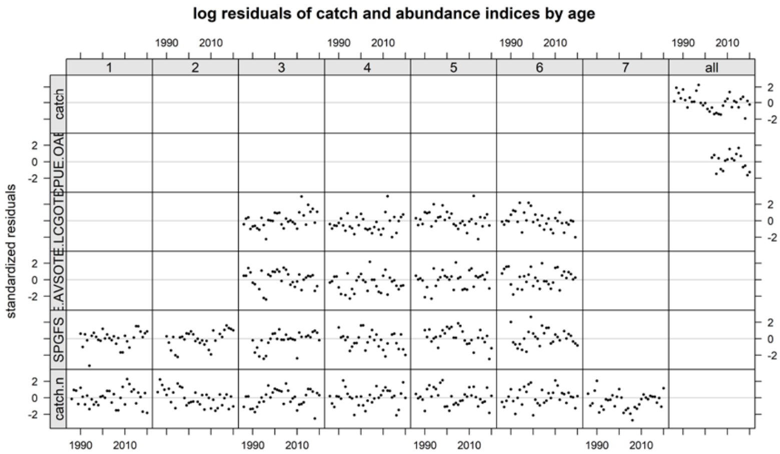


Figure 23. Log residuals of catch and abundance indices by age

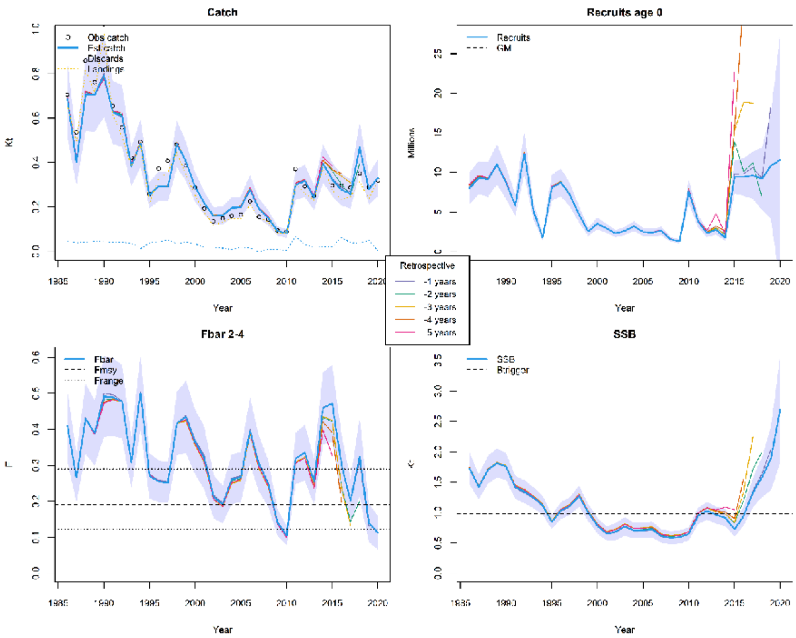


Figure 24. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Fit 6

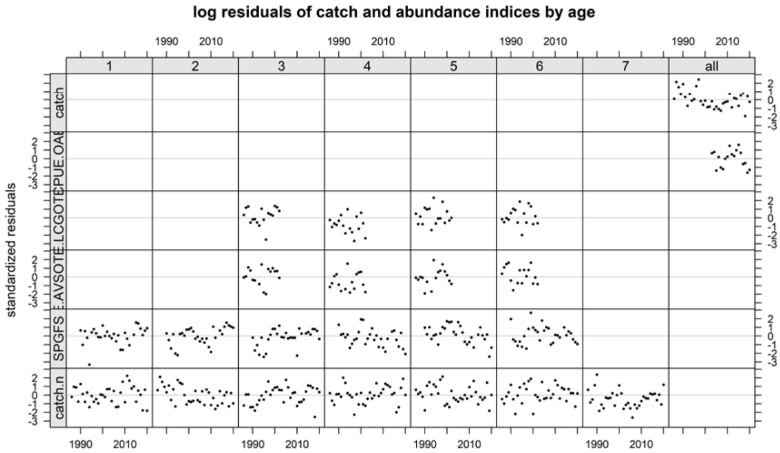


Figure 25. Log residuals of catch and abundance indices by age

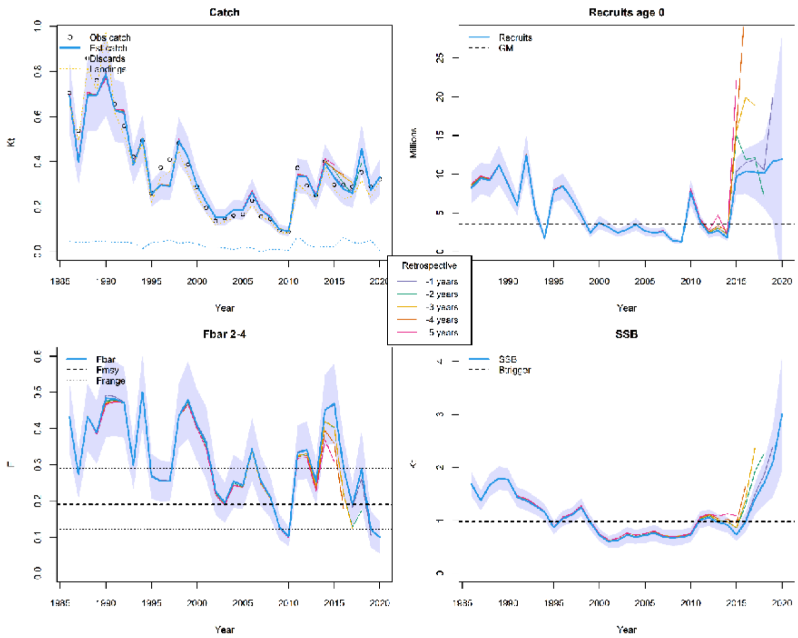


Figure 26. Summary of assessment outputs and retrospective pattern plots over the last 6 years

Comments about the exploratory scenarios in a4a for southern megrims using available abundance indices:

Figure 1 and 14 show all a4a fits have similar results and all of them do not much differ from XSA results. All a4a fits have been done with the new maturity ogive except fi1 and also the XSA model was run with the old one.

In *Lepidorhombus boscii*, all the fits continue presenting improvable residuals for age 0 in catch. In *L. whiffiagonis* this issue is not observed.

Commercial LPUEs from Spanish fishing ports have been calculated with the effort in fishing days, to avoid the possible inexact HP data. They cover all the time series, give information for the whole year and have been used in the XSA model.

The scientific surveys indices are good. The Spanish survey covers all the time series, is a good index for the recruitment and has been used in the XSA model. The Portuguese survey for *L. boscii* (this survey is not useful for *L. whiffiagonis* due to its distribution) is shorter and its continuity is being considered. They are giving information of only a part f the year.

The on-board observer biomass stardardized index is based on scientific data from fishing trips in the metier where these species are caught. The time series is shorter. The information is for the whole year. This index is new for this benchmark.

To select the appropriate indices, we must take into account what information we can lose by choosing one or the other. It is also necessary to consider if the possible information also has associated errors or if it is redundant. On the other hand, choosing only one can be risky, if a year fails the model would be without a tuning index.

In any case, the configuration of the model has to be refined and reviewed by an expert to solve the minor problems that the different scenarios have presented, regardless of which ones are selected for the assessment of these stocks.

## Benchmark Selected tuning indices and alternative runs

Studied configurations for the selected option of using only the survey abundance index are presented.

*Lerpidorhombus whiffiagonis*

| | AIC | BIC | Mohn's Rho (Retro_F) | Mohn's Rho (Retro_SSB) | Mohn's Rho (Retro_R) |
|---|---|---|---|---|---|
| **Only Survey** | 705.3 | 1053.7 | -0.234 | 0.357 | 0.522 |
| **Only Survey without smoother at age 1** | 703.7 | 1044.1 | -0.223 | 0.328 | 0.531 |

Only surveys

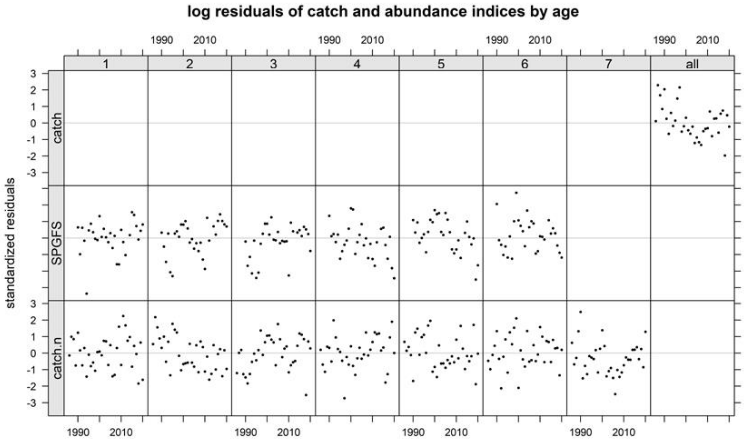


Figure 27. Log residuals of catch and abundance indices by age

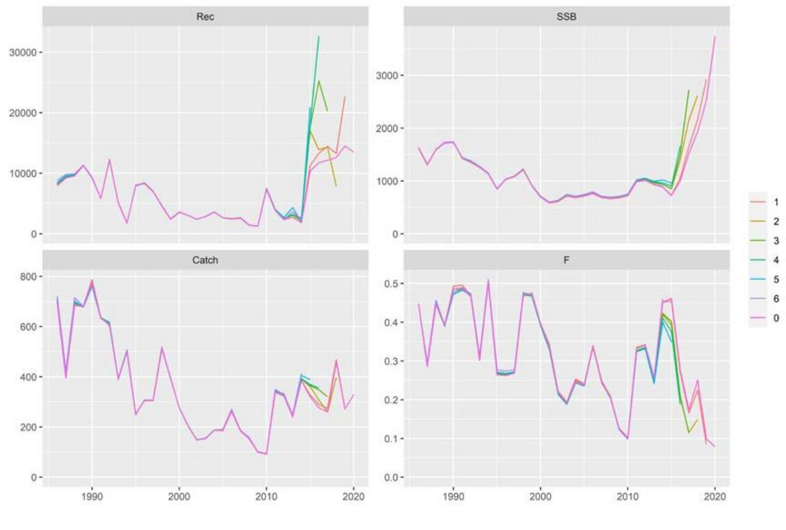


Figure 28. Retrospective pattern plots over the last 6 years

**Only surveys without smoother at age 1 (selected one)**

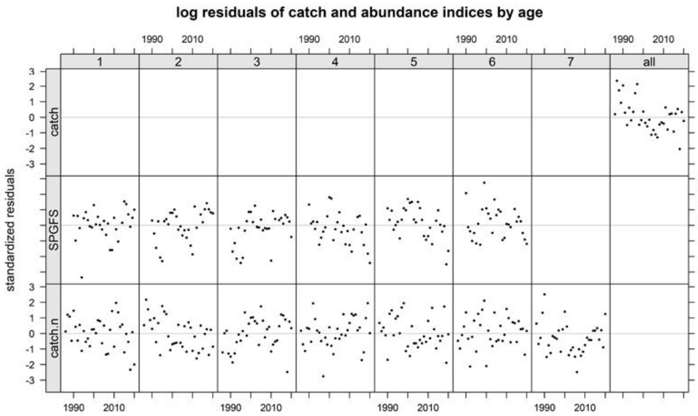


Figure 29. Log residuals of catch and abundance indices by age

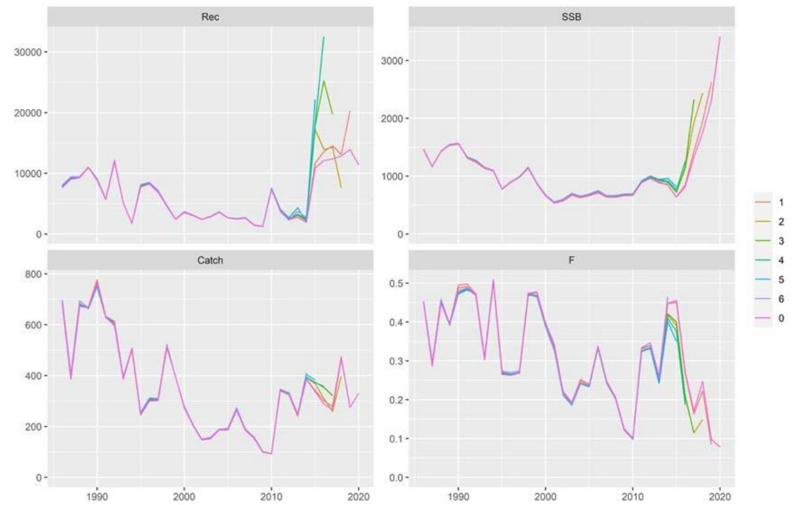


Figure 30. Retrospective pattern plots over the last 6 years

*Lerpidorhombus boscii*

| | AIC | BIC | Mohn's Rho | Mohn's Rho | Mohn's Rho |
|---|---|---|---|---|---|
| | | | (Retro_F) | (Retro_SSB) | (Retro_R) |
| **Only Surveys** | 1122.9 | 1530.0 | -0.07 | 0.05 | -0.24 |
| **Only Surveys increasing knots** | 1065.7 | 1596.7 | -0.06 | 0.02 | -0.08 |
| **Only Surveys without smoother in age 0** | 1127.4 | 1552.1 | -0.04 | 0.01 | -0.25 |
| **Only Surveys without smoother in age 0 and NA in a period in age 0** | 1038.1 | 1443.2 | -0.07 | 0.05 | -0.21 |

Only Surveys

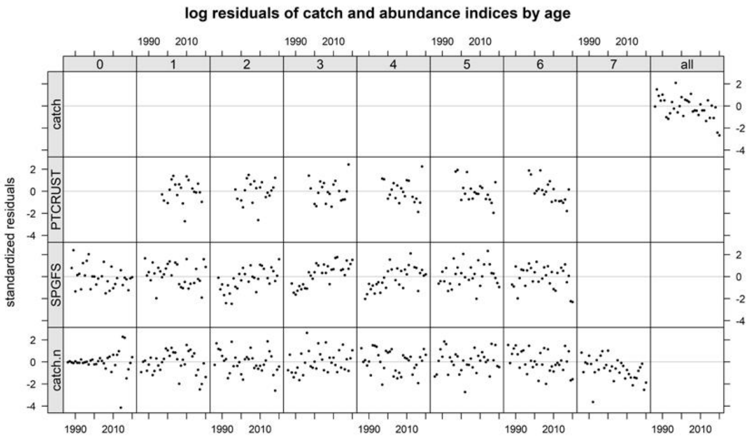


Figure 31. Log residuals of catch and abundance indices by age

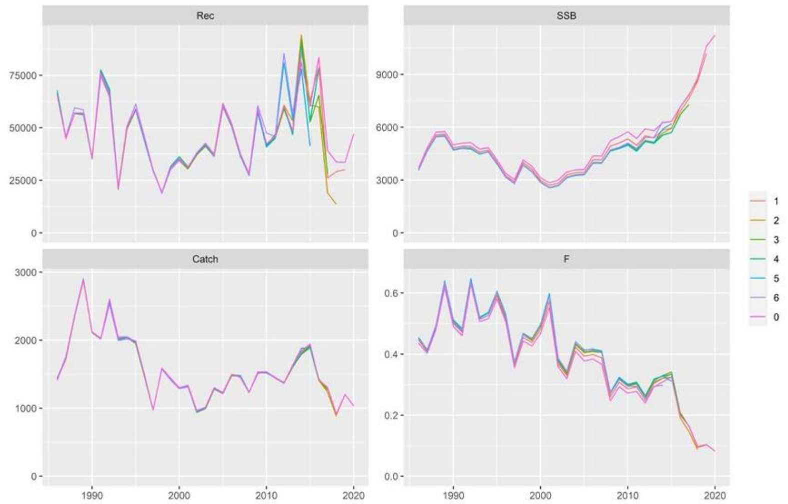


Figure 32. Retrospective pattern plots over the last 6 years

Only Surveys increasing knots

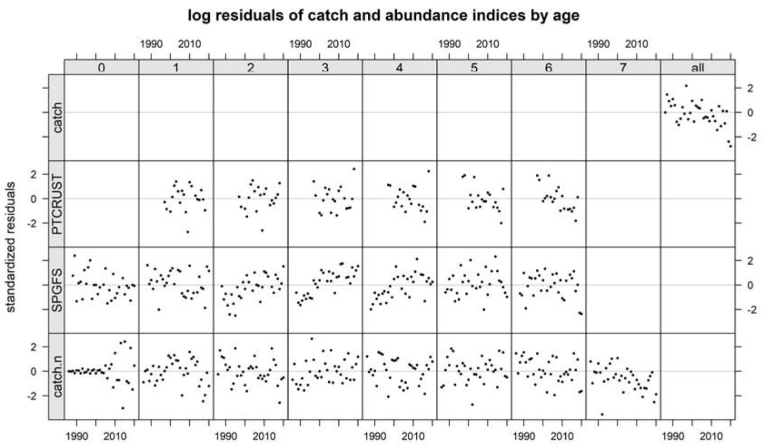


Figure 33. Log residuals of catch and abundance indices by age

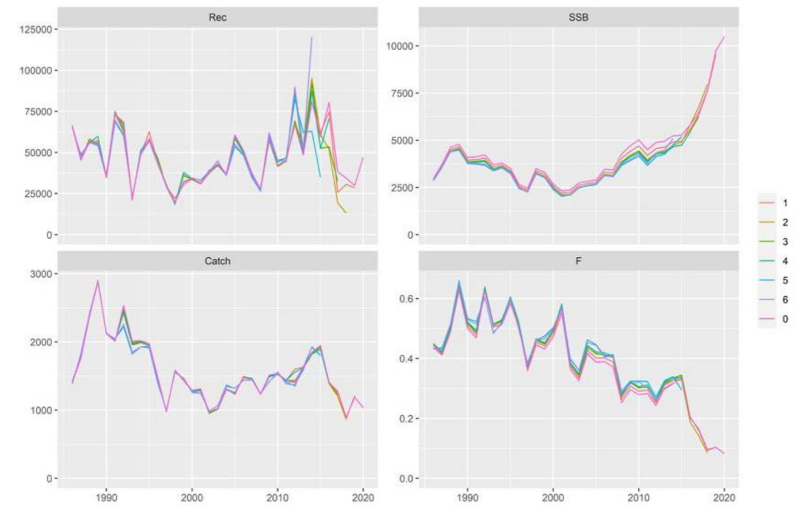


Figure 34. Retrospective pattern plots over the last 6 years

Only Surveys without smoother in age 0

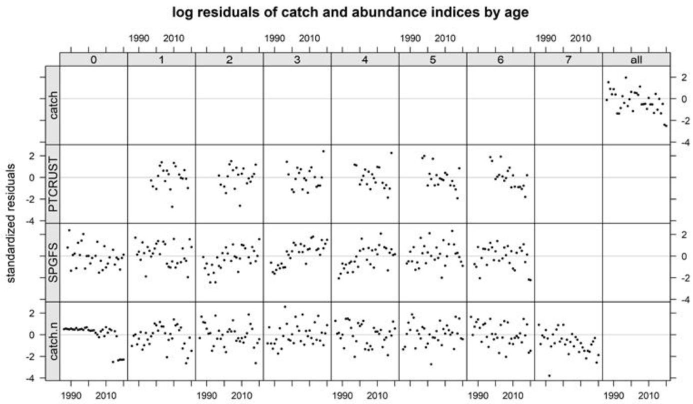


Figure 35. Log residuals of catch and abundance indices by age

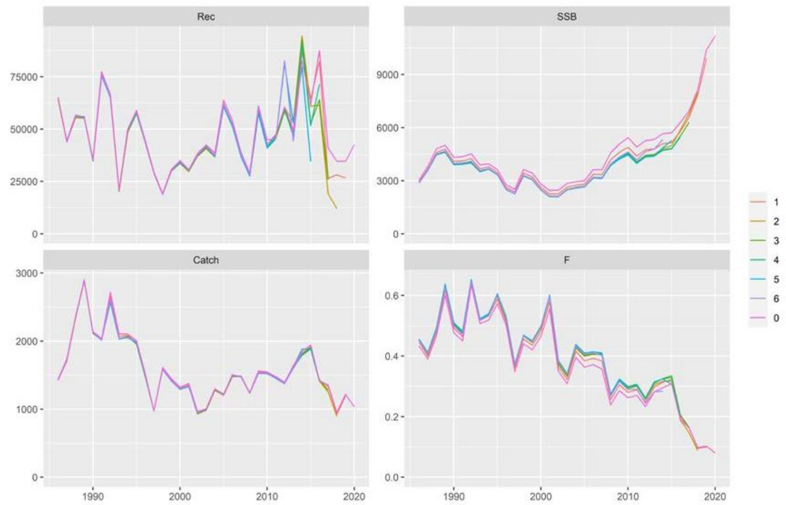


Figure 36. Retrospective pattern plots over the last 6 years

**Only Surveys without smoother in age 0 and NA in a period in age 0 (selected one)**

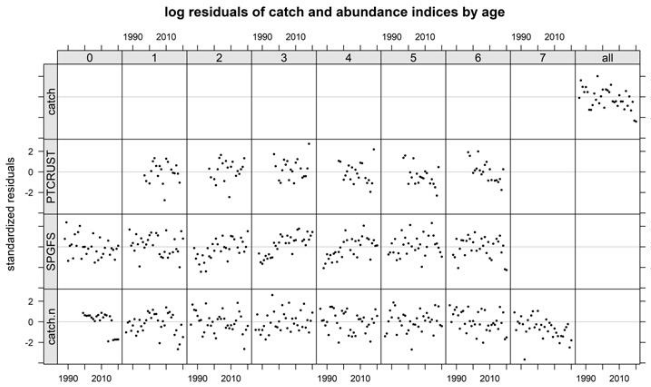


Figure 37. Log residuals of catch and abundance indices by age

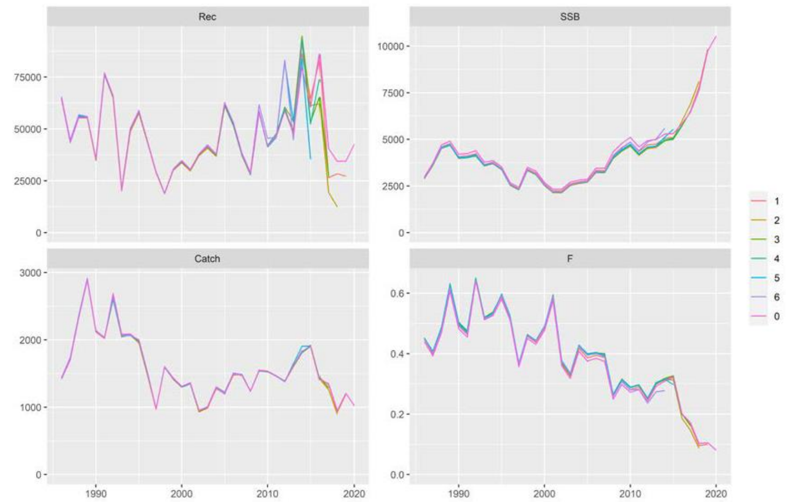


Figure 38. Retrospective pattern plots over the last 6 years

*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

**Standardization of the CPUE of the Spanish trawl fleet targeting megrim in ICES Subarea 7 from at-sea sampling data**

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***SUMMARY***

*Data collected by scientific observers on board fishing vessels of the Spanish bottom otter trawl fleet operating in ICES Divisions 7b-k has been employed to provide a possible standardization of the CPUE of megrim in order to explore an updated independent source of information. The results of the analyses do not support the high increase recorded in the SP-VIGOTR7 series from 1999 to 2008.*

1. INTRODUCTION

Data collected by scientific observers on board fishing vessels of the Spanish bottom otter trawl fleet operating in ICES Divisions 7b-k and 8abd was employed in order to provide a preliminary standardization of the CPUE (catch per unit of effort) of megrim (*Lepidorhombus whiffiagonis*). Yearly data from 2003 to August 2021 has been obtained through the Spanish at-sea sampling programme established in 2003 following the European Data Collection Regulation (DCR) (Council Regulation (EC) No 1543/2000). Discontinuous previous data from 1988 to 2000 were compiled from several pilot programmes and projects carried out by IEO.

The purpose of this working document is to explore the data collected by scientific observers on board providing a possible CPUE standardization as a complement to the revision of the SP-VIGOTR7 LPUE requested by the WKMegrim 2022 Data call. It is also an attempt to provide an updated review of the at-sea data analysed by Fernández et al. 2008, where it was decided to split the SP-VIGOTR7 tuning series into two, from 1984 to 1998 (VIGO84) and from 1999 onwards (VIGO99).

*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

## 2. METHODS

### 2.1. Sampling at sea

The objective of the IEO at-sea sampling programme is to collect discard volume and length samples from commercial catches on board the Spanish (non-Basque) fleet, particularly the métiers most likely to produce discards, such as trawls and gillnets. Among its sampling strata is the Spanish (non-Basque) bottom otter trawl fleet targeting megrim in the ICES Subarea 7 waters. In this case, the vessel represents the Primary Sampling Unit (PSU), which are systematically selected from the official lists of target boats belonging to the fishery association "ANASOL" (currently 19 vessels), which is located in the port of Vigo.

The sampling protocol includes the collection of technical data of the vessel (power, length...), the trip (start date, end date, fishing days...) and the haul (type of gear, mesh size, pingers...), as well as biological sampling data (taxonomic identification of species, volume of the discarded catch fraction, length distributions...).

### 2.2. Data

A summary of the data employed in the CPUE standardization can be found in Table 1.

| Year | Total Nº trips | Nº trips sampled | % sampled | Kg/trip sampled/year | Mean fishing days/trip | Total Nº hauls | Nº hauls sampled | Mean hauls sampled/Year | Mean haul duration (h) |
|---|---|---|---|---|---|---|---|---|---|
| 1988 | 884 | 6 | 0.7 | 7133.19 | 11.3 | 281 | 190 | 31.7 | 4.2 |
| 1989 | 1022 | 5 | 0.5 | 4130.04 | 10.0 | 187 | 136 | 27.2 | 4.2 |
| 1994 | 806 | 10 | 1.2 | 5471.52 | 11.9 | 511 | 367 | 36.7 | 4.4 |
| 1999 | 765 | 4 | 0.5 | 5158.33 | 13.5 | 280 | 176 | 44.0 | 3.9 |
| 2000 | 781 | 7 | 0.9 | 7285.25 | 13.4 | 485 | 302 | 43.1 | 3.9 |
| 2003 | 808 | 7 | 0.9 | 8627.12 | 13.1 | 505 | 315 | 45.0 | 3.6 |
| 2004 | 814 | 8 | 1.0 | 6750.08 | 13.8 | 575 | 335 | 41.9 | 3.6 |
| 2005 | 806 | 7 | 0.9 | 5055.25 | 13.7 | 558 | 275 | 39.3 | 3.4 |
| 2006 | 785 | 9 | 1.1 | 4775.99 | 13.3 | 659 | 301 | 33.4 | 3.3 |
| 2007 | 830 | 9 | 1.1 | 4065.98 | 12.9 | 624 | 296 | 32.9 | 3.5 |
| 2008 | 764 | 7 | 0.9 | 5341.84 | 12.4 | 495 | 246 | 35.1 | 3.3 |
| 2009 | 770 | 9 | 1.2 | 5636.20 | 11.8 | 583 | 285 | 31.7 | 3.4 |
| 2010 | 668 | 9 | 1.3 | 7416.12 | 11.3 | 590 | 297 | 33.0 | 3.2 |
| 2011 | 616 | 9 | 1.5 | 5412.26 | 10.2 | 506 | 253 | 28.1 | 3.4 |
| 2012 | 562 | 9 | 1.6 | 6958.94 | 12.1 | 635 | 314 | 34.9 | 3.3 |
| 2013 | 533 | 9 | 1.7 | 9585.67 | 11.2 | 602 | 307 | 34.1 | 3.1 |
| 2014 | 390 | 12 | 3.1 | 5565.26 | 8.9 | 640 | 292 | 24.3 | 3.3 |
| 2015 | 353 | 9 | 2.5 | 5084.02 | 9.4 | 518 | 261 | 29.0 | 3.2 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 312 | 13 | 4.2 | 5447.14 | 9.2 | 705 | 373 | 28.7 | 3.0 |
| 2017 | 333 | 12 | 3.6 | 4211.11 | 9.8 | 725 | 350 | 29.2 | 3.0 |
| 2018 | 320 | 11 | 3.4 | 4391.62 | 10.5 | 688 | 335 | 30.5 | 3.1 |
| 2019 | 300 | 6 | 2.0 | 3768.48 | 8.3 | 317 | 140 | 23.3 | 3.1 |
| 2020 | 309 | 3 | 1.0 | 2142.47 | 6.7 | 122 | 47 | 15.7 | 3.4 |
| 2021(*) | NA | 7 | NA | 3946.96 | 8.7 | 344 | 166 | 23.7 | 3.2 |

Table 1. Summary of the data. All columns refer to the data obtained from the sampled trips except "Total Nº trips" which refers to the number of trips performed by the fleet in that year. From 1988 to 2008, the "Total Nº trips" was obtained from on-shore sampling; from 2009 to 2021 from official data recorded in the logbooks. (*)Data available until August 2021.

Variables available for the analysis are shown in Table 2.

| | Type(*) | Summary | Remarks |
|---|---|---|---|
| Year | N | 1988, 1989, 1994, 1999, 2000, 2003 - Aug 2021 | 2019, 2020 few observations<br>2021 incomplete |
| Trip | N | 197 levels | |
| Haul | N | | |
| Vessel code | N | 68 levels | |
| Metier DCF | N | OTB_DEF_70-99_0_0 | |
| ICES subdivision | N | 9 levels: 27.6.a/ 27.6.b.2/ 27.7.b / 27.7.c.2 / 27.7.g / 27.7.h / 27.7.j.2 / 27.7.k.2 / 27.8.ab | Unbalanced.<br>Re-grouped in 3 levels: Celtic Sea: 27.7.h., 27.7.g. Great Sole: 27.7.j.2, 27.7.k.2. Porcupine: 27.7.b, 27.7.c2<br>Subdivisions: 27.6.a/ 27.6.b.2/ 27.8.ab removed |
| Statistical rectangle | N | 70 levels | Unbalanced |
| Day | N | Day of capture | |
| Month | N | 12 levels | |
| Quarter | N | 4 levels | |
| Landing harbour | N | 7 levels: Castletown, unknown GB, Douarnenez, Celeiro, Marín, Vigo, unknown | Unbalanced.<br>Re-grouped in 2 levels: Spain vs. abroad. Still unbalanced |
| Vessel size<br>(vessel category) | C (N) | Continuous variable, from 23 m to 39.10 m | Nominal variable created<br>3 levels: 1: 23-31.25 m; 2: 32-35.10 m; 3: 36-39.10 m |
| Gross tons | C | 131-349.5 gt | |
| Power HP | C | 275-1450 hp | |
| Fishing time | C | Hours per haul | |
| Kg captured | N | Total kg captured including discards | |
| kg retained | N | Kg retained onboard | |
| Net mesh size | N | 5 levels: 70-80-90-100 mm | Unbalanced.<br>Re-grouped in 2 levels: from 70 to 80mm; from 90 to 100mm |
| Depth | C | 99.5-611.5 m depth | |

Table 2. Explanatory variables available (*)N: Nominal; C: Continuous

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Only ICES divisions 27.7 were taken into account in the analysis since the rest of subdivisions (27.6.a, 27.6.b.2 and 27.8.ab) correspond to other management units.

During this WD we employed the same at-sea sampling data analysed by Fernández et al. 2008, updated up to August 2021, with the exception of the two trips from 2001 included by those authors. We decided to exclude them from the data analyses since they were part of a pilot survey directed to cephalopods, with different sampling design.

During preliminary analysis it was observed a strong bias in some of the nominal variables due to the different number of observations per category (landing harbour, ICES subdivision, mesh size), which led to regroup their levels in order to avoid subsequent possible model misspecification (Table 2). Vessel size was converted into a categorical variable, testing different number of levels. Despite the small range in vessel size (23 m to 39.10 m) which approximately correspond to one of the Length Over All (LOA) categories considered in the DCF (24-<40 m) (Commission Delegated Decision (EU) 2019/910), 3 balanced levels were employed.

Data regarding fishing power (HP) has been obtained from the records directly collected by the observers on board. These data do not always match with the data of power registered in the official Census of vessels and important discrepancies have been observed in some cases. Total catches (i.e. discards plus retained) were always positive in the hauls sampled during the trips. CPUE was calculated as total kg captured/haul duration (hours).

In order to select the best subset of explanatory variables for the fixed effects part, an initial series of models fitted by Generalised Linear Models (GLM) employing reasonable combinations and interactions between variables were compared based on lowest AIC and highest percentage of deviance explained. This procedure allowed to select the most influential variables to be tested in a subsequent series of models fitted by GLMM where interactions were included as random effects. CPUE was modelled with a Gamma distribution with log link function. A summary of the models performed is available in Table 3.

All preliminary and statistical analyses were performed using R software, version 4.0.4 (R Development Core Team, 2021)

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3. RESULTS

3.1. Data

The haul duration in hours was employed as a measure of effort to calculate the nominal CPUE. Two periods were observed, up to 2000 with a median haul duration above 3.9 hours and after 2003, with a decreasing median haul duration (Figure 1, Table 1). Years 2003 and 2004 appeared to be a transitional period, with a median similar to the next years but higher variability.

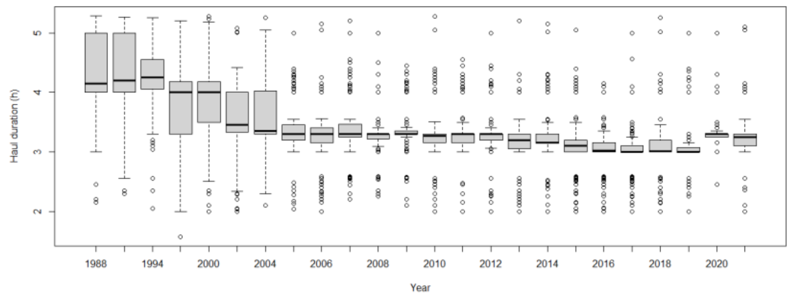
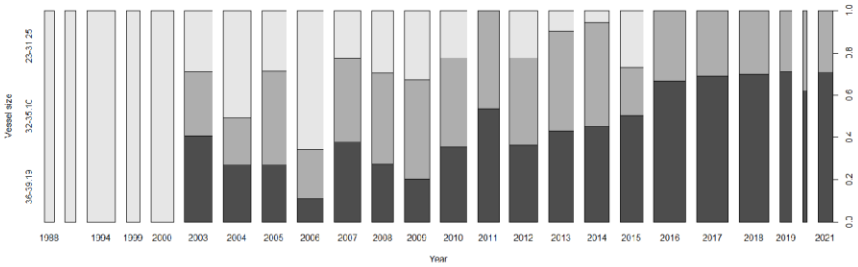



Figure 1. Haul duration through the time series

When considering the size of the vessels, two periods are also evident: until 2000 and from 2003 onwards, being smaller vessels present in the first period while disappearing progressively through the years. The proportion of the biggest vessels increases through the time series (Figure *2*). Regarding the power engine (HP) of the vessels, there is an evident increase from 2013.



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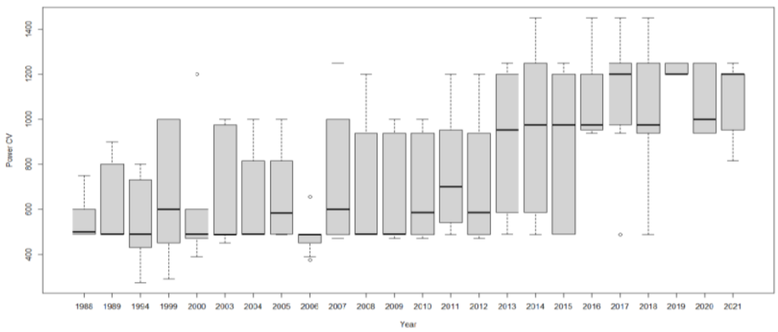


Figure 2. Proportion of vessel sizes through the years (upper panel) and power engine (HP) (lower panel).

The density distribution and the boxplot of the nominal CPUE (total kg captured/h) of *L. whiffiagonis* per year are presented in Figure 3.

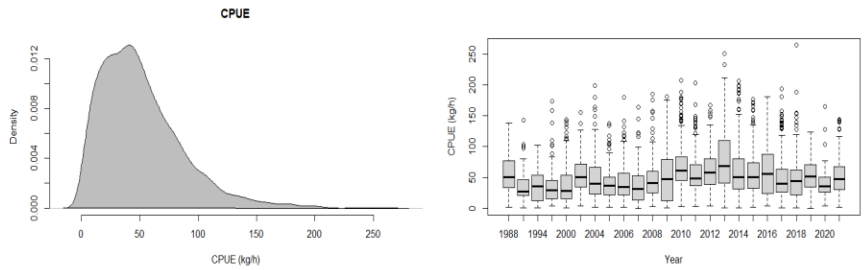


Figure 3 Nominal CPUE (retained plus discards) of *L. whiffiagonis*. Left: density distribution; Right: distribution by year

The CPUE for the total catches registered versus each explanatory variable considered in the final models through the time series is presented in Figure 4. A clear seasonality was observed in the nominal CPUE data, being December and January the months with lowest CPUE values, while March appeared to present the highest captures. Regarding the size of the vessels, biggest vessels and more powerful engines appear to show highest CPUE values and biggest mesh sizes higher CPUE levels. Highest captures were observed in ICES subdivisions 27.7.j2 and 27.7.k2 (grouped as Great Sole Bank), also with highest number of observations. Regarding fishing

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depths, the highest CPUE values were obtained when operating in shallow depths (between 100-200m depth).

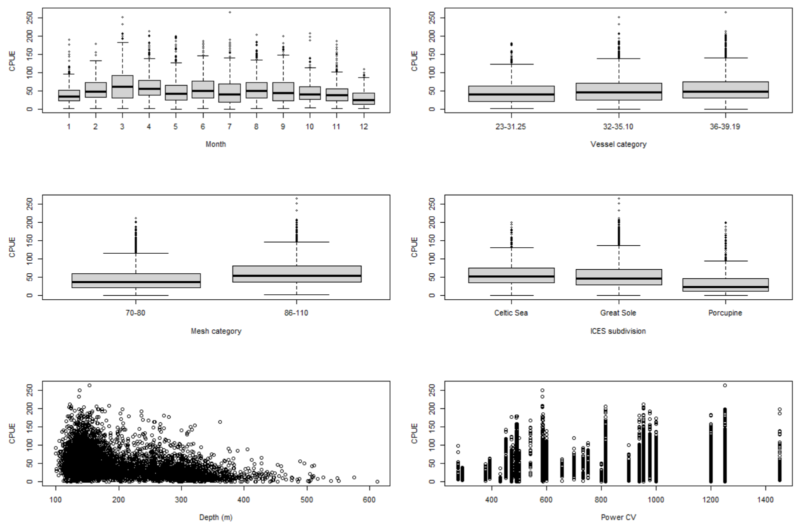


Figure 4. CPUE for the total catches vs. each explanatory variable selected for the final models (1988-Aug 2021)

During the whole time series considered, 4 different mesh sizes were employed, being the most prevalent the 80 mm (present every year except in 2020) and 100 mm (employed from 2003). Sizes were re-grouped in 2 levels: 70-80 mm and 90-100 mm. (Figure 5). In figure 6 can be seen the proportion of both groups of mesh sizes. Again, as observed with the vessel size, power engine and the haul duration, there is a change in the mesh employed through the time series. Until 2003, 80 mm mesh size was mainly used while from 2011 onwards, 100 mm mesh size was predominant in the hauls sampled by the observers.

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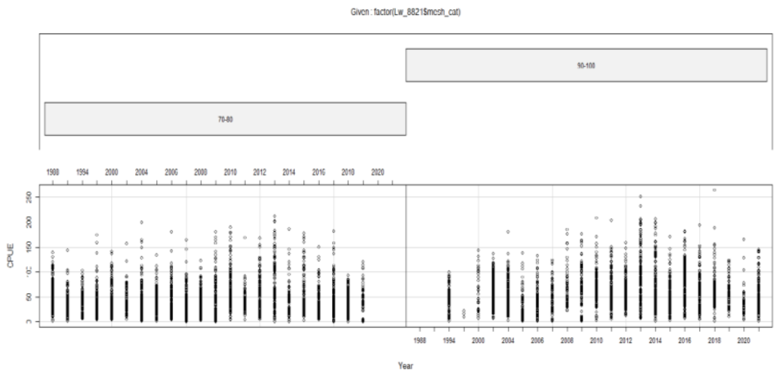


Figure 5. Mesh size employed through the time series

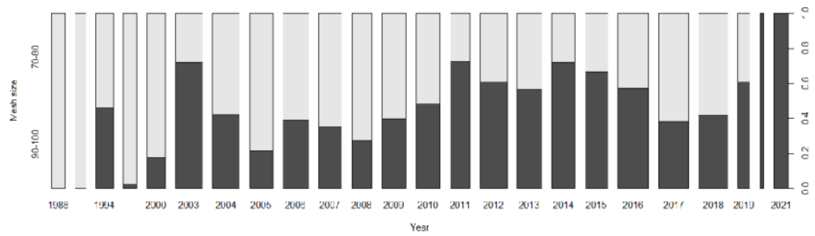


Figure 6. Grouped mesh sizes through the time series considered.

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3.2. CPUE standardization

A summary of the models tested is shown in Table 3. The final model selected included the explanatory variables in Table 4.

| Model name | df | AIC | Dev. Expl. | Gamma distribution, log link function | |
|---|---|---|---|---|---|
| Lw_8821_glm9 | 275 | 52422.68 | 0.45 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+landingcountry+ year:month+year:power_hp+year:mesh_cat+year:region+ year:landingcountry+power_hp:mesh_cat+power_hp:region+ power_hp:landingcountry |
| Lw_8821_glm11 | 265 | 52427.27 | 0.45 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+landingcountry+ year:month+year:power_hp+year:mesh_cat+year:region+power_hp:region |
| Lw_8821_glm10 | 266 | 52428.19 | 0.45 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+year:month+year:power_hp+year:mesh_cat+ year:region+power_hp:mesh_cat+power_hp:region |
| Lw_8821_glm12 | 263 | 52446.35 | 0.44 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+ year:month+year:power_hp+year:mesh_cat+year:region |
| Lw_8821_glm16 | 246 | 52547.74 | 0.43 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+year:month+year:power_hp+year:region |
| Lw_8821_glm13 | 224 | 52571.02 | 0.42 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+year:month+year:power_hp+year:mesh_cat |
| Lw_8821_glm18 | 226 | 52598.42 | 0.42 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ year:month+year:region |
| Lw_8821_glm17 | 227 | 52600.18 | 0.42 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+year:month+year:region |
| Lw_8821_glm20 | 206 | 52669.8 | 0.41 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ year:month+year:power_hp |
| Lw_8821_glm14 | 207 | 52670.97 | 0.41 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+ year:month+year:power_hp |
| Lw_8821_glm18.2 | 187 | 52727.15 | 0.40 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+year:month |
| Lw_8821_glm15 | 188 | 52728.38 | 0.40 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry+year:month |
| Lw_8821_glmm18 | 43 | 52799.2 | | GLMM | CPUE~year+month+depth+power_hp+mesh_cat+region+ (1\|year:month)+(1\|year:region) |
| Lw_8821_glmm18.2 | 42 | 52895.6 | | GLMM | CPUE~year+month+depth+power_hp+mesh_cat+region+(1\|year:month) |
| Lw_8821_glm0 | 100 | 53234.75 | 0.33 | GLM | CPUE~year+month+depth+power_hp+meshsize+statistical_r+ landingharbour |
| Lw_8821_glm5 | 100 | 53234.75 | 0.33 | GLM | CPUE~year+month+depth+power_hp+meshsize+statistical_r+ landingharbour |
| Lw_8821_glm6 | 97 | 53240.14 | 0.33 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+statistical_r+ landingharbour |
| Lw_8821_glm19 | 133 | 53322.97 | 0.33 | GLM | CPUE~year+quarter+depth+power_hp+mesh_cat+region+ year:quarter+year:region |
| Lw_8821_glm7 | 93 | 53345.76 | 0.32 | GLM | CPUE~year+month+depth+power_hp+meshsize+statistical_r+ landingcountry |
| Lw_8821_glmm22 | 35 | 53440.05 | | GLMM | CPUE~year+quarter+depth+power_hp+mesh_cat+region+ (1\|year:quarter)+(1\|year:region) |
| Lw_8821_glm4 | 92 | 53440.27 | 0.31 | GLM | CPUE~year+quarter+depth+power_hp+meshsize+statistical_r+l andingharbour |
| Lw_8821_glm3 | 52 | 53531.88 | 0.29 | GLM | CPUE~year+month+depth+power_hp+meshsize+region+ landingharbour |
| Lw_8821_glm8.1 | 41 | 53648.99 | 0.27 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region |
| Lw_8821_glm1 | 42 | 53650.74 | 0.27 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry |
| Lw_8821_glm8 | 42 | 53650.74 | 0.27 | GLM | CPUE~year+month+depth+power_hp+mesh_cat+region+ landingcountry |
| Lw_8821_glm2 | 34 | 53818.64 | 0.25 | GLM | CPUE~year+quarter+depth+power_hp+mesh_cat+region+ landingcountry |

Table 3. Summary of the models tested. In grey, final model selected for the whole time series (1988-Aug 2021)

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| Explanatory variable | Type(*) | Remarks |
|---|---|---|
| Year | N | 1988-August 2021 |
| Month | N | 1-12 |
| Depth | C | 99.5 m - 611.5 m |
| Region | N | 3 levels<br>Celtic Sea: 27.7.h., 27.7.g. Great Sole: 27.7.j.2, 27.7.k.2. Porcupine: 27.7.b, 27.7.c2 |
| Power HP | C | 275-1450 hp |
| Net mesh size | N | 2 levels<br>70-80mm; 90-100mm |

Table 4. Variables included in the final model (*)N: nominal; C: continuous

The fixed component of the final model selected included: "year", "month", "depth", "region", "power engine" and "net mesh size". As a random effect it was included the interaction "year:month", being the final model of the form:

CPUE~ year + month + depth + region + power hp+ net mesh size + (1|year:month),
family=Gamma

Even though the GLMM model including as a random effect the interactions "year:month" and "year:region" (Lw_8821_glmm18) showed a slightly lowest AIC value than the final model selected (with only the interaction "year:month" as random effect), the fact that the region variable was still unbalanced despite re-grouping levels, the simplicity of the model, the degrees of freedom and that both models showed a similar output, we decided to choose the model mentioned above. Estimated effects of each explanatory variable and residuals of the final model are presented below in Figure 7. Standardized CPUE index is plotted in Figure 8 and presented in Table 5.

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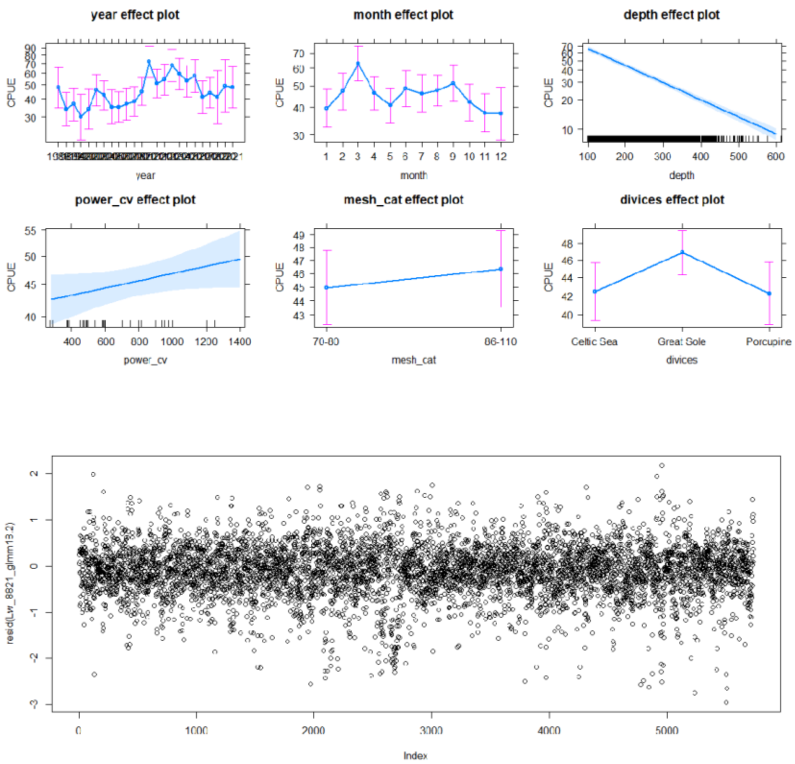


Figure 7. Upper panel: estimated effects of explanatory variables included in the model. Lower panel residuals from the model

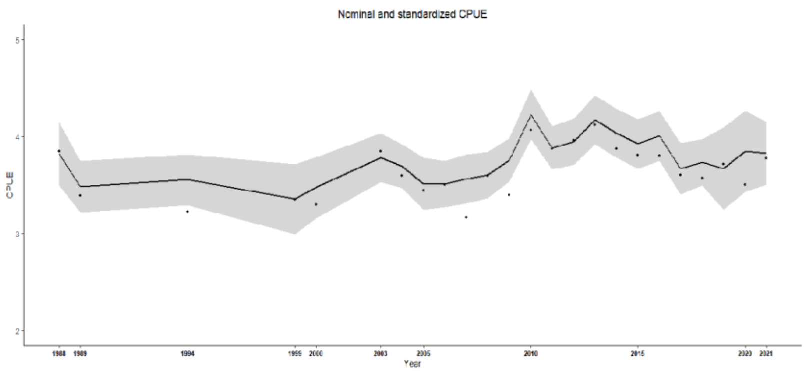


Figure 8. Nominal (dots) and standardized CPUE index (black line)

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*Data evaluation meeting, January 24-27*

| Year | CPUE index | Lower se | Upper se |
|---|---|---|---|
| 1988 | 3.820215 | 3.497923 | 4.142507 |
| 1989 | 3.483388 | 3.216912 | 3.749864 |
| 1994 | 3.555233 | 3.294605 | 3.81586 |
| 1999 | 3.355038 | 2.991759 | 3.718318 |
| 2000 | 3.475389 | 3.1612 | 3.789577 |
| 2003 | 3.78099 | 3.52849 | 4.033491 |
| 2004 | 3.697519 | 3.473458 | 3.92158 |
| 2005 | 3.513122 | 3.24315 | 3.783093 |
| 2006 | 3.510578 | 3.271073 | 3.750082 |
| 2007 | 3.561297 | 3.309477 | 3.813117 |
| 2008 | 3.601023 | 3.363603 | 3.838443 |
| 2009 | 3.75796 | 3.534104 | 3.981817 |
| 2010 | 4.22754 | 3.975478 | 4.479602 |
| 2011 | 3.883626 | 3.661135 | 4.106117 |
| 2012 | 3.946728 | 3.707427 | 4.186028 |
| 2013 | 4.170257 | 3.919236 | 4.421278 |
| 2014 | 4.035443 | 3.783545 | 4.28734 |
| 2015 | 3.924292 | 3.67185 | 4.176735 |
| 2016 | 4.003015 | 3.74577 | 4.260259 |
| 2017 | 3.669754 | 3.406677 | 3.932831 |
| 2018 | 3.737755 | 3.499075 | 3.976435 |
| 2019 | 3.669626 | 3.247445 | 4.091807 |
| 2020 | 3.845391 | 3.429339 | 4.261442 |
| 2021 | 3.825433 | 3.500885 | 4.149981 |

Table 5. Standardized CPUE index (Kg/haul duration) and respective standard error

4. DISCUSSION

When performing standardization of abundance indices of fisheries data, GLMs have been commonly applied, but the problems regarding correlation among observations (e.g. consecutive hauls of the same fishing trip) and the fact that fisheries data are often unbalanced and methodologies and protocols can change in a long time series, led to use random terms, being GLMMs a powerful extension of GLMs in those situations (Venables and Dichmont, 2004) and therefore appropriate in this case.

The year effect appears to be the main driver in the CPUE index obtained. It appears to be a stable series with two periods, up to 2009 with lower CPUE values and from 2010 onwards, when the CPUE shows slightly higher levels than before, at least up to 2016. In the first period can also be noted 2 subperiods, before and after 2003, maybe related with the changes introduced in 2002 in the review of the Common Fisheries Policy (Council regulation 2371/2002) and the changes observed in the data in the fleet characteristics regarding haul duration, vessel size,

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power engine (figures 1, 2 and 6) and in general, the renovation of the fleet that happened between 1994 and 2003. During those years, major renewal plans affected to the vessels operating in 27.7.j2, changing drastically the working practices on board. From our data, the peak observed in 2003 would be related with changes in the haul duration, vessel size and net mesh size, while we do not see a clear explanation of 2010 peak. The secondary increase in 2013 is probably linked with the change recorded in power engine which shows an evident increase from that year (figure 2, lower panel).

When comparing our series with the LPUE from the revision of the Vigo-Marín tuning index (SP-VIGOTR7) carried out for this WKMegrim 2022 (Castro et al. 2022) (figure 9, IEO1 series) we see a similar general trend, with a first stable period up to the end of nineteens and an increase in 2003. Nevertheless, the peak recorded in the SP-VIGOTR7 in 2009 is not present in this time series but in 2010. After that year, both trends seems to follow a similar pattern.

Even though the time series analysed here is shorter than the LPUE available from SP-VIGOTR7 (1984-2019), here we provide the analysis of the longest time series available at this point from scientific at-sea sampling data, employing trawling hours as a measure of effort, performing the revision of the power engine from observers on board records and the use of total catches data (retained plus discards) for the whole time series. This working document along with the review of the SP-VIGOTR7 LPUE (Castro et al. 2022), provide an overview of the status of the data available compiled from different sources for megrim in ICES Divisions 7b-k and 8abd.

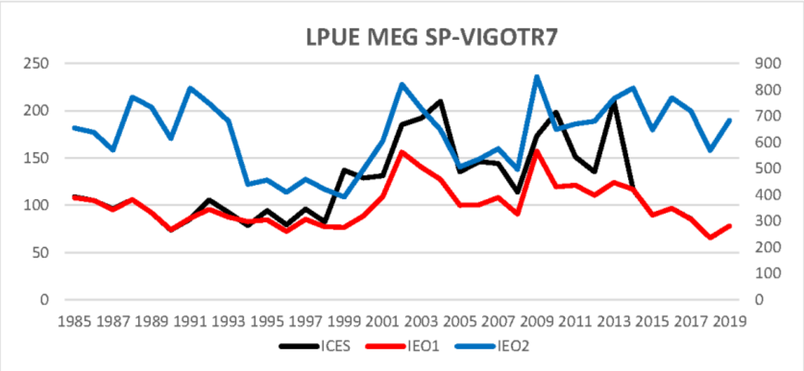


Figure 9. LPUE of the SP-VIGOTR7 tuning fleet for Northern megrim. Black line (WGBIE 2021; CPUE and LPUE in different years); red line (original LPUE data recovered from the IEO data base, in kg/fd*100HP); and blue line (original LPUE data recovered by IEO, in kg/fd) (Source: Castro et al. 2022)

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*Data evaluation meeting, January 24-27*

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Castro, J., Teruel J., Patiño B., Marín M., Salinas I., Cebrián J.L. and Pan M. 2022. Review of the Spanish commercial tuning index used in the assessment of Megrim (Lepidorhombus whiffiagonis) in ICES Divisions 7b-k and 8a,b,d (meg.27.7b-k8abd). WD presented at WKMegrim 2022.

Council Regulation (EC) No 1543/2000 of 29 June 2000 establishing a Community framework for the collection and management of the data needed to conduct the common fisheries policy.

Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy

Commission Delegated Decision (EU) 2019/910 of 13 March 2019 establishing the multiannual Union programme for the collection and management of biological, environmental, technical and socioeconomic data in the fisheries and aquaculture sectors.

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R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Venables, W.N. and Dichmont, C.M., 2004. GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. Fisheries Research, 70(2–3), 319-337 https://doi.org/10.1016/j.fishres.2004.08.011

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APPENDIX

During WKMegrim2022 it was asked for the possibility of performing some more trials regarding CPUE standardization, in particular removing the variables vessel size or power engine. From this request, it is provided a comparison between 1. GLMM including power engine (original selected model, figures 7 and 8), 2. GLMM including vessel size instead power engine and 3. GLMM without power engine neither vessel size.

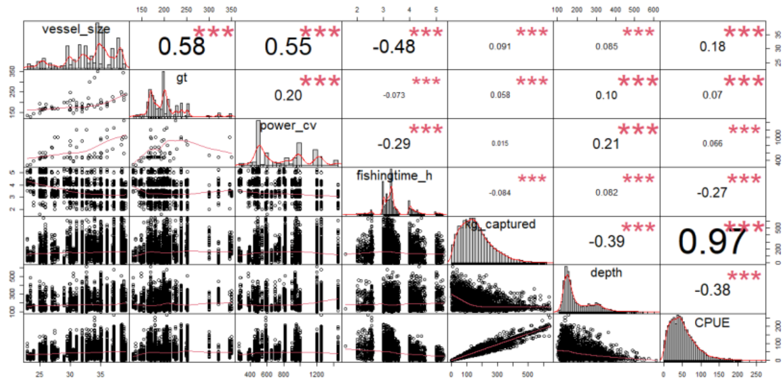


Figure 10. Correlation chart between some vessel characteristics (vessel size, gross tonnage (gt) and power engine in HP (power_cv)), haul duration (fishingtime_h), total catches (kg_captured), fishing depth (depth) and CPUE.

1. CPUE~ year + month + depth + region + power hp+ net mesh size + (1|year:month), family=Gamma

See figures 7 and 8

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*Data evaluation meeting, January 24-27*

2. CPUE~ year + month + depth + region + vessel size+ net mesh size + (1|year:month), family=Gamma

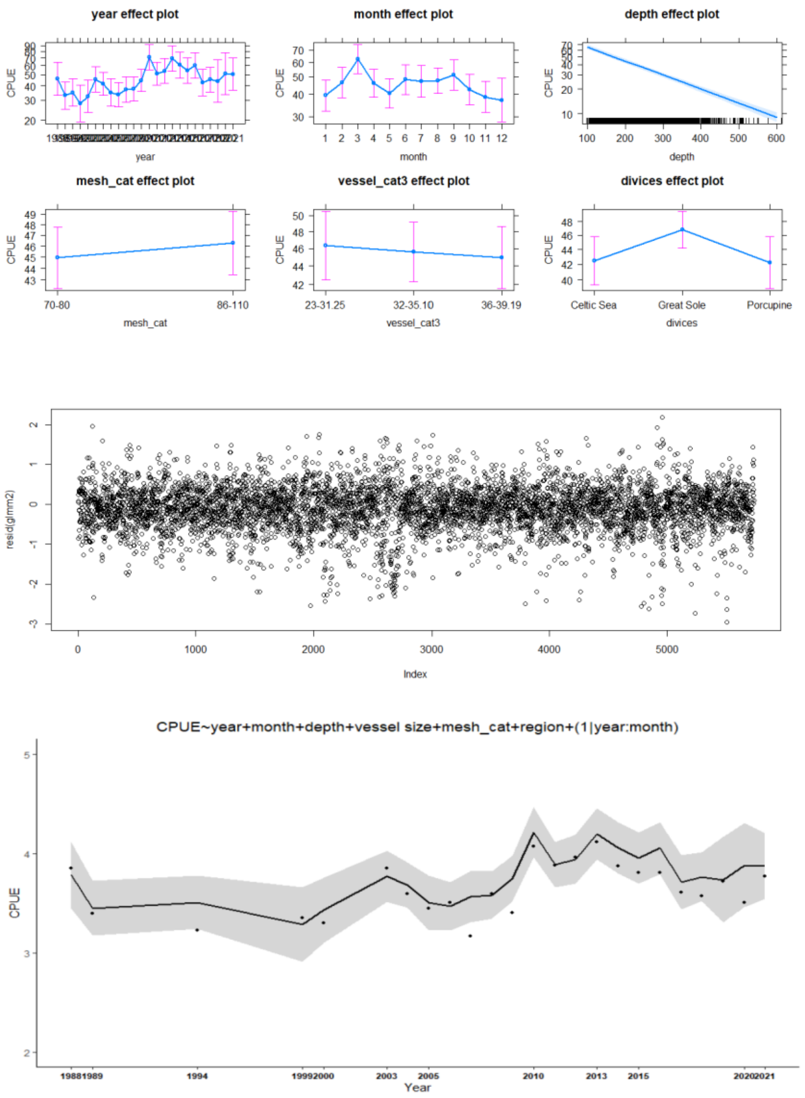


Figure 11. Upper pannel, estimated effects of explanatory variables included in the model. Middle panel, residuals from the model. Lower pannel, nominal and standardized CPUE

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*Data evaluation meeting, January 24-27*

3. CPUE~ year + month + depth + region + net mesh size + (1|year:month), family=Gamma

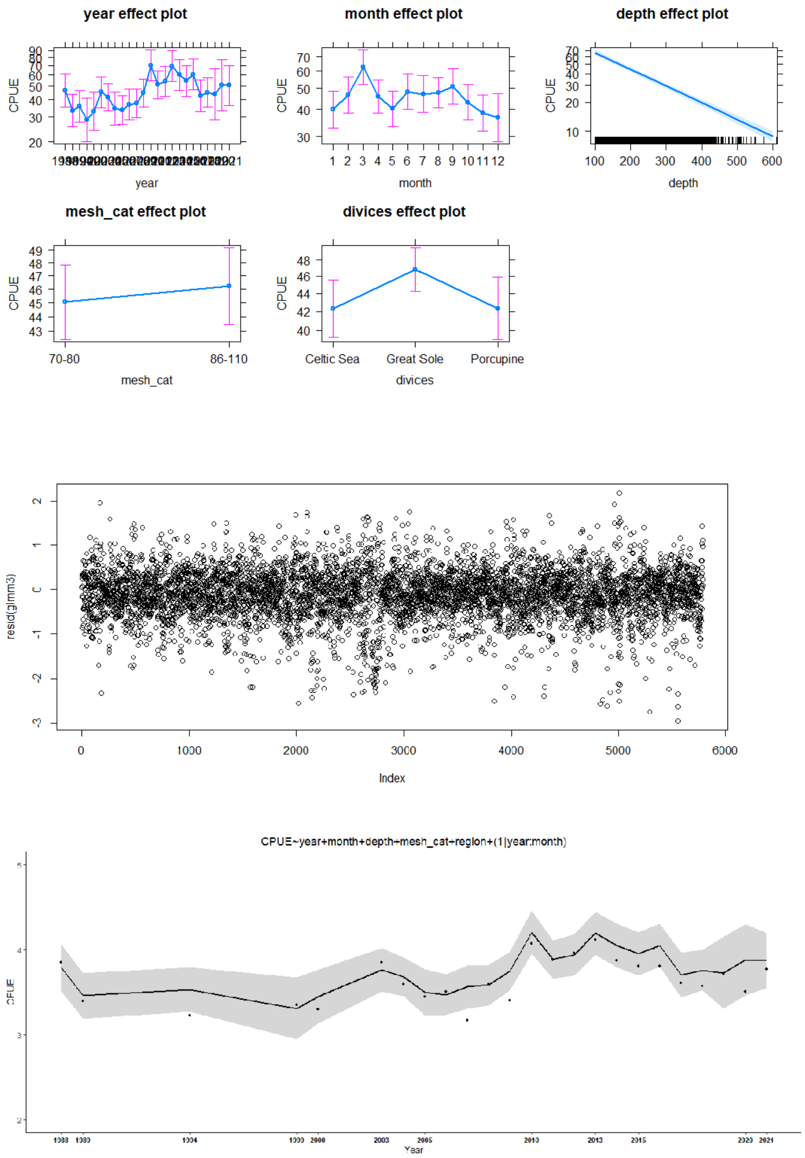


Figure 12. Upper pannel, estimated effects of explanatory variables included in the model. Middle panel, residuals from the model. Lower pannel, nominal and standardized CPUE

*WD presented at WKMegrim 2022*
*Data evaluation meeting, January 24-27*

| Model | df | AIC | Gamma distribution, log link function | |
|---|---|---|---|---|
| 1 | 42 | 52895.6 | GLMM | CPUE~year+month+depth+power_hp+mesh_cat+region+(1\|year:month) |
| 2 | 43 | 52900.66 | GLMM | CPUE~year+month+depth+vessel size+mesh_cat+region+(1\|year:month) |
| 3 | 41 | 53382.09 | GLMM | CPUE~year+month+depth+mesh_cat+region+(1\|year:month) |

Table 6. AIC values for the models. 1. Including power engine (HP). 2. Including vessel size instead power engine. 3. Without including power engine neither vessel size.

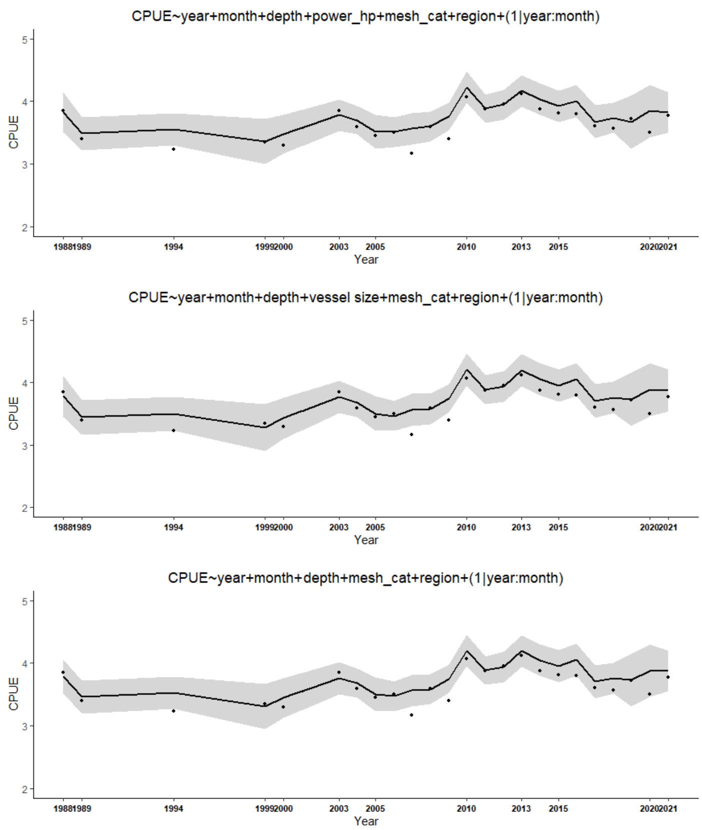


Figure 13. Nominal (dots) and standardized CPUE index (black line) from 1. original model including power engine (HP). 2. Model including vessel size instead power engine. 3. Model without including power engine neither vessel size.

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| | 1.Model including power engine (HP) | | | 2. Model including vessel size | | | 3. Model without HP or vessel size | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year** | **CPUE index** | **Lower se** | **Upper se** | **CPUE index** | **Lower se** | **Upper se** | **CPUE index** | **Lower se** | **Upper se** |
| 1988 | 3.820 | 3.498 | 4.143 | 3.780 | 3.448 | 4.112 | 3.787 | 3.514 | 4.061 |
| 1989 | 3.483 | 3.217 | 3.750 | 3.447 | 3.170 | 3.724 | 3.456 | 3.189 | 3.724 |
| 1994 | 3.555 | 3.295 | 3.816 | 3.506 | 3.236 | 3.777 | 3.528 | 3.267 | 3.790 |
| 1999 | 3.355 | 2.992 | 3.718 | 3.284 | 2.910 | 3.659 | 3.309 | 2.944 | 3.674 |
| 2000 | 3.475 | 3.161 | 3.790 | 3.430 | 3.103 | 3.757 | 3.445 | 3.129 | 3.762 |
| 2003 | 3.781 | 3.528 | 4.033 | 3.767 | 3.509 | 4.024 | 3.761 | 3.507 | 4.016 |
| 2004 | 3.698 | 3.473 | 3.922 | 3.679 | 3.450 | 3.907 | 3.681 | 3.455 | 3.907 |
| 2005 | 3.513 | 3.243 | 3.783 | 3.502 | 3.226 | 3.778 | 3.498 | 3.225 | 3.771 |
| 2006 | 3.511 | 3.271 | 3.750 | 3.466 | 3.224 | 3.709 | 3.470 | 3.232 | 3.709 |
| 2007 | 3.561 | 3.309 | 3.813 | 3.563 | 3.305 | 3.821 | 3.560 | 3.305 | 3.815 |
| 2008 | 3.601 | 3.364 | 3.838 | 3.580 | 3.339 | 3.822 | 3.582 | 3.342 | 3.821 |
| 2009 | 3.758 | 3.534 | 3.982 | 3.749 | 3.521 | 3.978 | 3.748 | 3.522 | 3.974 |
| 2010 | 4.228 | 3.975 | 4.480 | 4.213 | 3.956 | 4.470 | 4.203 | 3.949 | 4.457 |
| 2011 | 3.884 | 3.661 | 4.106 | 3.887 | 3.657 | 4.117 | 3.884 | 3.659 | 4.109 |
| 2012 | 3.947 | 3.707 | 4.186 | 3.940 | 3.695 | 4.185 | 3.939 | 3.697 | 4.181 |
| 2013 | 4.170 | 3.919 | 4.421 | 4.192 | 3.935 | 4.449 | 4.191 | 3.938 | 4.445 |
| 2014 | 4.035 | 3.784 | 4.287 | 4.057 | 3.798 | 4.316 | 4.049 | 3.794 | 4.303 |
| 2015 | 3.924 | 3.672 | 4.177 | 3.949 | 3.692 | 4.207 | 3.950 | 3.696 | 4.205 |
| 2016 | 4.003 | 3.746 | 4.260 | 4.052 | 3.791 | 4.313 | 4.051 | 3.796 | 4.307 |
| 2017 | 3.670 | 3.407 | 3.933 | 3.709 | 3.440 | 3.979 | 3.701 | 3.437 | 3.966 |
| 2018 | 3.738 | 3.499 | 3.976 | 3.764 | 3.516 | 4.012 | 3.756 | 3.515 | 3.997 |
| 2019 | 3.670 | 3.247 | 4.092 | 3.734 | 3.305 | 4.164 | 3.727 | 3.304 | 4.150 |
| 2020 | 3.845 | 3.429 | 4.261 | 3.882 | 3.457 | 4.307 | 3.877 | 3.457 | 4.296 |
| 2021 | 3.825 | 3.501 | 4.150 | 3.875 | 3.544 | 4.206 | 3.871 | 3.546 | 4.196 |

Table 7. Standardized CPUE index and respective standard error for 1. original model including power engine (HP). 2. Model including vessel size instead power engine. 3. Model without including power engine neither vessel size.

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*Data evaluation meeting, January 24-27*

*Working Document to the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim). Datacall October 2021*

# Four spot megrim (*Lepidorhombus boscii*) weight-length and weight-weight relationships in northern Iberian waters (stock 8.c, 9.a)

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## Abstract

Total weight-length, gutted weight-length and total weight-gutted weight relationships were fitted for the Iberian Atlantic stock of four spot megrim (*Lepidorhombus boscii*) and their temporal variations were analyzed. The large sample size, size range and time-series available allowed obtaining robust somatic parameters of combined sexes for the total weight-length relationships (a=0.0043, b=3.2008), for the gutted weight-length relationships (a=0.0055, b=3.1139), and the weight conversion factors (1.062). They are considered to best fit the current biometric relationships and most appropriate to be used in the stock assessment of the status of the stock and they contribute to a deeper knowledge of the life history traits of this species.

## Keywords
Iberian; condition factor; weight-length relationships; weight conversion factor; *Lepidorhombus boscii*; Four spot megrim;

## 1. Introduction

*Lepidorhombus boscii* is a relevant commercial flatfish in southern European waters. The Iberian Atlantic stock (Div. 8.c and 9.a) is the main of the four spot megrim stocks for the Spanish and Portuguese fleets (ICES, 2020a; ICES, 2020b). The stock assessment procedures of this species in ICES utilize the biological knowledge available to predict variations in the population parameters. Weight-length relationships as well as the weights conversion factors (total-gutted weight relationship) are commonly used in those procedures, and allow predicting weights of individuals from measurements of length or of other weights, and for estimation of the stock biomass. Understanding the biological parameters of the stocks is of great importance. However, there are scarce studies on condition and weight-length relationships of megrim in Iberian Atlantic waters (Fuertes, 1978; Costa, 1986; Alperi, 1992; Pérez, 1998; Azevedo in Pereda et al., 1998) although these studies are mostly working documents or project reports. In fact, the estimates currently in use in assessment (Pérez, 1998) were obtained in an European Union study project (BIOSDEF) (Pereda et al., 1998), more than twenty years ago. It is quite evident the need research on biological traits of this species and for a robust and updated information on these biological parameters before their incorporation into the assessment process of megrim stocks, that will lead to a more adequate management of them.

This aim of this study is to provide robust and updated weight-length relationships and weight conversion parameters of this species in Iberian Atlantic waters, that can be incorporated in the oncoming stock assessment process and fishery management.

## 2. Materials and methods

### 2.1. Sampling

The studied area, the northern Iberian Atlantic waters (Div. 8.c, 9.a.2) belongs to the stock 8.c, 9.a and it is the main Atlantic area for the Spanish commercial fleet catching four spot megrim.

A total of 2099 individuals were sampled from a time-series of 22 years, from 1998 to 2019 were obtained by Instituto Español de Oceanografía (IEO, CSIC). The 97% of the specimens came from the landings of the commercial fleet and only a small sample (194 individuals <32 cm in length) came from two research fishing surveys "Cormol I", carried out by IEO in northern Iberian Atlantic waters, during May 2012.

The temporal variation of the parameters in the time-series for periods of 5 years (quinquennium): 2000-04, 2005-09, 2010-14, 2015-19, and the previous period of 1998-99, was analyzed. For gutted weight, the periods 2000-04, 2005-09 only had 8 and 1 specimens respectively with weight information, so they were not included in the analysis of the gutted weight–length and total weight–gutted weight relationships.

Total length [Lt (cm), length class of 1 cm], total weight [Wt (g)], gutted weight [Wg (g)], sex and maturity were collected from each specimen. The numbers of specimens studied are shown in detail in Table 1, Table 2 and Table 3.

## 2.2. Data analysis

Weight-length relationships for combined sexes were calculated for the total weight and gutted weight. Regression functions were tested and the power function showed the best coefficient of determination ($r^2$) for the two weight-length relationships studied (Wt-Lt; Wg-Lt):

$W = a(Lt)^b$

*where: W= total weight [Wt (g)], or gutted weight [Wg (g)]; Lt = total length (cm); a, b = parameters of the regression.*

Weight conversion factor for combined sexes was estimated by the linear function that relate the total and gutted weights with values "0" to intercept with the x-axis:

$Wt = aWg$

*where: Wt = total weight (g); Wg = gutted weight (g); a = parameter of the regression.*

The temporal factor, year and quinquennium, relevant for stock assessment process, was considered in the weight-length and in the weight-weight models. The "five-year period (quinquennium)" showed a more adequate sample representativeness than the "year". The role of the quinquennium was analyzed in each stock using the following Linear Models (LMs):

*log(Wt) ~ log(Lt) * quinquennium*

*log(Wg) ~ log(Lt) * quinquennium*

*Wt ~ Wg * quinquennium*

LMs were performed using the stats library in the R statistical software version 4.0.5 (R Foundation for Statistical Computing, 2021).

# 3. Results

## 3.1. Weight-length relationships

The parameters of the total weight-length relationship and gutted weight-length relationship are shown in Table 1 and Table 2. Significant differences ($p<0.001$) also were found among quinquennia in the total weight-length relationship. In the gutted weight-length relationship, only the two quinquennia with a relevant sample size (2010-14; 2015-19) are shown in Figure 1. Quinquennium slopes showed differences up to 8% between the most different quinquennia.

### 3.2. Weight conversion factors

Weight conversion factors are shown in Table 3. Only the two quinquennia with a relevant sample size (2010-14; 2015-19) are shown in Figure 1. Quinquennium slopes showed differences of 4% between both quinquennia.

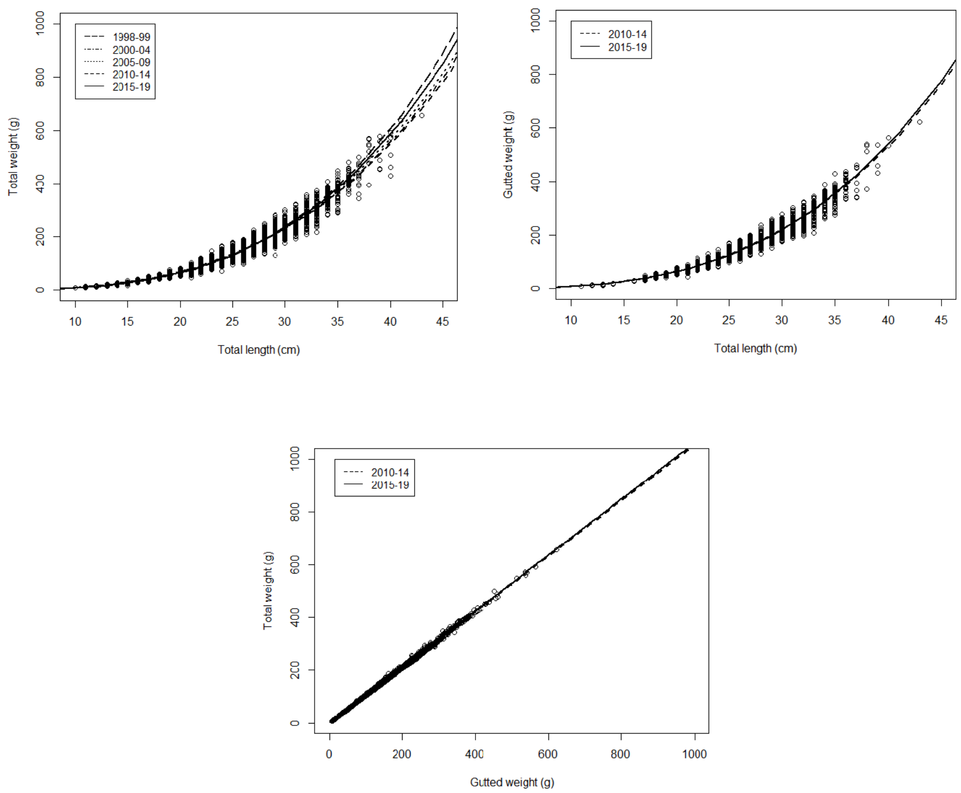


**Figure 1**. Relationships estimated for *L.boscii* in northern Iberian water (stock 8.c, 9.a): total weight–total length, gutted weight–total length and total weight–gutted weight.

## 4. Discussion

The large sample size and time-series have allowed obtaining robust weight-length relationships and weight conversion factors, and analyze the temporal variation of the total weight–total length relationship. A more accurate and reliable assessment of the stock status will be possible having the updated information her presented, allowing a better management of this population.

### 4.1. Weight-length relationships

The parameters of the total weight-length relationship and gutted weight-length relationship from the most recent quinquennium (2015-19) are underlined in Table 1 and Table 2. They show a complete representation of the commercially exploited size range of four spot megrim (4-43 cm and 17-40 cm in total weight-length and gutted weight-length relationships respectively) and are based on the large sample size (1921 and 1833 individuals in total weight-length and gutted weight-length relationships respectively) studied so far in this stock. The estimated parameters of combined sexes of four spot megrim for the total weight-length relationships (a=0.0043, b=3.2008) and for the gutted weight-length relationships (a=0.0055, b=3.1139) are considered to best fit the current biometric relationships and most appropriate to be used in the stock assessment process of the status of the stocks, replacing the old values from 1998 currently used (Table 1, Table 2). The differences between the relationships currently proposed for stock assessment and the current ones are small (0.3% and 4%, in the slopes of total weight-length and gutted weight-length relationships respectively) are shown in Figure 2.

### 4.2. Weight conversion factors

The weight conversion factor (1.062) from the most recent quinquennium (2015-19) are underlined in Table 3, based on a complete size range of four spot megrim (32-592 g in total weight), representative of the commercially exploited weight range, and also based on the largest sample size studied so far in this stock. This value would replace that old value (1.042) currently used (Pereda et al.(1998); Pérez, 1998). The small differences between the conversion factor currently proposed for stock assessment and the old ones (2%) are shown in Figure 2.

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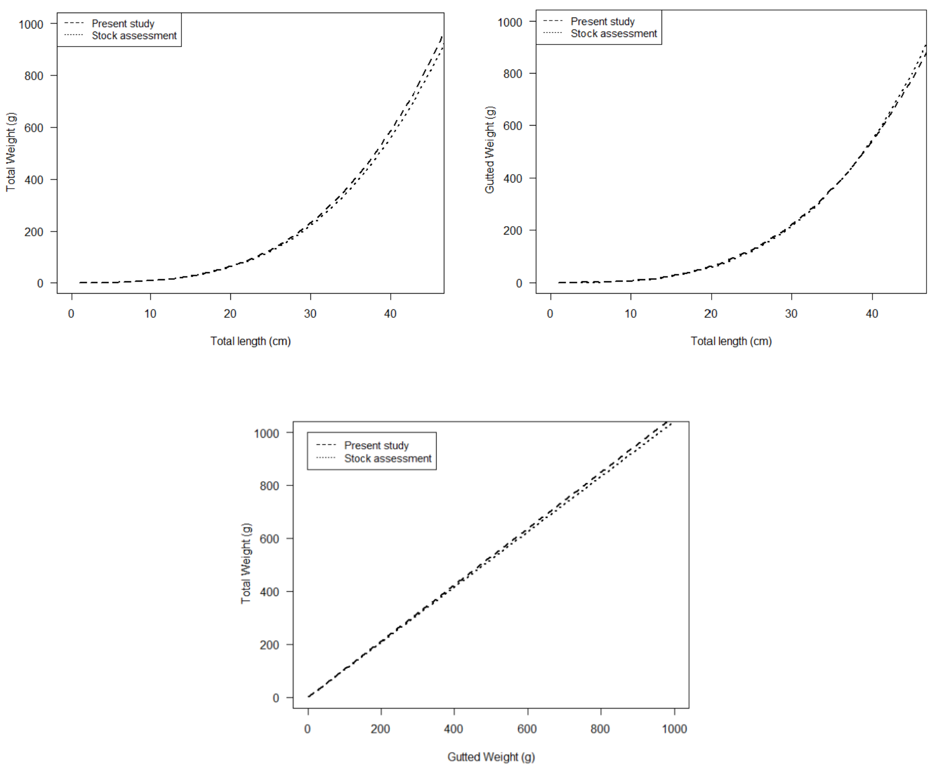


**Figure 2**. Differences between the relationships from the present study proposed for stock assessment and those currently used from 1998, for *L. boscii* in Iberian Atlantic stock (ICES Div. 8.c, 9.a).

A complete study covering a relevant area of distribution of the species and a wide period, thus allowing the analysis of its temporal variability, was not available until now. The parameters estimated here are in the range of those obtained in previous works, mostly grey literature (Table 1, Table 2, Table 3) and are considered the most appropriate to be used in the upcoming stock assessment.

Regarding the total weight-length relationship, the parameter b (slope) in the studies performed in the Iberian Atlantic stock varies between 3.03 and 3.29 (Table 1).

The slopes of the gutted weight-length relationship compared between studies vary from 3.07 to 3.55, and the value of the slope of the study of Pereda et al.(1998) and Pérez (1998) was the same than that estimated here in the later period 1998-99 (Table 2).

In relation to the total weight- gutted weight relationship, the slopes of the studies showed values between 1.042 and 1.062 (Table 3).

This study provides new biological parameters in the main fishing stock of four spot megrim and the main Atlantic fishery areas for the fleets catching this species, necessary for its accurate annual stock assessment process and stock management. The new somatic parameters from weight-length relationships and weight conversion factor are available to be used in the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim) and it is recommended that they replace the ones used so far, which are outdated. The continue monitoring of these parameters is essential to detect possible long-term shifts due to the fisheries pressure or environmental variations and to deeper understanding of the specific causes of these variations.

| Author | ICES Div. | Area | Period | Sex | Coefficients | | n | $r^2$ | Length (cm) | | Weight (g) | | Stock assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | a | b | | | min | max | min | max | |
| **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2015-19** | **combined** | **0.004** | **3.201** | **1921** | **0.98** | **4** | **43** | **0** | **657** | **new proposed** |
| | | | **2010-14** | **combined** | **0.008** | **3.027** | **2552** | **0.97** | **6** | **39** | **3** | **570** | |
| | | | **2005-09** | **combined** | **0.007** | **3.068** | **1283** | **0.96** | **15** | **37** | **23** | **440** | |
| | | | **2000-04** | **combined** | **0.007** | **3.068** | **370** | **0.96** | **19** | **41** | **48** | **638** | |
| | | | **1998-99** | **combined** | **0.003** | **3.293** | **30** | **0.97** | **21** | **36** | **74** | **428** | |
| Pereda et al.(1998); Pérez | 8.c, 9.a2 | Southern Bay of Biscay & | 1997 | combined | 0.004 | 3.190 | 631 | 0.99 | 8 | 39 | | | currently used |
| Alperi (1992) | 8.c2 | Cantabrian Sea | 1989 | combined | 0.007 | 3.027 | 54 | 0.98 | 13 | 38 | | | |
| Fuertes (1978) | 8.c1, 9.a2 | Galician waters | 1975 | females | 0.000 | 3.120 | 1118 | | | | | | |
| Pereda et al.(1998) (Azevedo) | 9.a | Portuguese waters | 1997 | combined | 0.004 | 3.230 | 631 | 0.99 | 5 | 40 | 1 | 639 | |
| Costa (1986) | 9.a | Portuguese waters | | females | 0.003 | 3.200 | 251 | | | | | | |

**Table 1**. Parameters of the total weight - total length relationship for *L. boscii* estimated in the present study and previous studies in Iberian Atlantic stock (ICES Div. 8.c, 9.a). The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.

| Author | ICES Div. | Area | Period | Sex | Coefficients | | n | $r^2$ | Length (cm) | | Weight (g) | | Stock assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | a | b | | | min | max | min | max | |
| **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2015-19** | **combined** | **0.006** | **3.114** | **1833** | **0.98** | **17** | **40** | **30** | **565** | **new proposed** |
| | | | **2010-14** | **combined** | **0.006** | **3.067** | **227** | **0.96** | **17** | **39** | **39** | **541** | |
| | | | **1998-99** | **combined** | **0.004** | **3.245** | **30** | **0.97** | **21** | **36** | **72** | **408** | |
| Pereda et al.(1998); Pérez (1998) | 8.c, 9.a2 | Southern Bay of Biscay & Galician waters | 1997 | combined | 0.003 | 3.245 | 624 | 0.99 | 8 | 39 | - | - | currently used |

**Table 2**. Parameters of the gutted weight - total length relationship for *L. boscii* estimated in the present study and previous studies in Iberian Atlantic stock (ICES Div. 8.c, 9.a). The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.

| Author | ICES Div. | Area | Period | Sex | Coefficient | n | $r^2$ | Total weight (g) | | Gutted weight (g) | | Stock assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | a | | | min | max | min | max | |
| **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2015-19** | **combined** | **1.062** | **1833** | **0.999** | **32** | **592** | **30** | **565** | **new proposed** |
| | | | **2010-14** | **combined** | **1.054** | **227** | **0.999** | **40** | **570** | **39** | **541** | |
| | | | **1998-99** | **combined** | **1.057** | **30** | **0.999** | **74** | **428** | **72** | **408** | |
| Pereda et al.(1998); Pérez (1998) | 8.c, 9.a2 | Southern Bay of Biscay & Galician waters | 1997 | combined | 1.042 | - | - | - | - | - | - | currently used |
| Alperi (1992) | 8.c2 | Cantabrian Sea | 1989 | combined | 1.044 | - | - | - | - | - | - | |

**Table 3**. Parameters of the total weight - gutted weight relationship for *L. boscii* estimated in the present study and previous studies in Iberian Atlantic stock (ICES Div. 8.c, 9.a). The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.

## Acknowledgements

This study has been co-funded by the European Union through the European Maritime and Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy and IEO. We would like to express our gratitude to M. Ámez, P. Quelle, J. Conde del Rio and D.

Garabana for their collaboration in the samplings in the laboratory and on board of IEO research surveys "Cormol I". Also, acknowledgment to the survey coordinators F. Velasco, A. Punzón.

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*Working Document to the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim). Datacall October 2021*

# Updated maturity parameters based on histology of megrim (*Lepidorhombus whiffiagonis*) and four spot megrim (*L. boscii*) stocks in Atlantic Iberian waters (Div. 8.c, 9.a) and in Celtic Seas (Div. 7.b-k)

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## Abstract

The maturity ogives of megrim (*L whiffiagonis*) and four spot megrim (*L. boscii*) stocks in Atlantic Iberian waters (ICES Div. 8.c, 9.a) and Celtic Seas and northern Bay of Biscay (ICES Div. 7.b-k, 8.abd) currently used in the stock assessment are based on macroscopic observations and were estimated in 1998. This study presents updated maturity ogives and parameters by length and age in Div. 8.c,9.a2 (Galician waters and Cantabrian Sea), and in Div. 7.b-k (Celtic Sea, West and South of Ireland) by specie for both sexes combined based on a more robust microscopic methodology.

A total of 1708 individuals were sampled between 2017 and 2020 on board the commercial vessels and research surveys, 876 *L. whiffiagonis* of which 538 in Div. 7.b-k and 338 in 8.c, 9.a2, and a total of 832 *L. boscii*, 435 in Div. 7.b-k and 397 in 8.c, 9.a2.

*L. whiffiagonis* in 8.c, 9.a2 showed a $L_{50}$ for both sexes combined of 18.9 cm and an $A_{50}$ of 1.6 years, while in 7.b-k were 17.8 cm and 2.4 years, respectively. On the other hand, *L. boscii* in 8.c, 9.a2 showed a $L_{50}$ and an $A_{50}$ for both sexes combined of 14.7 cm and 1.6 years, respectively, while in 7.b-k were 16.7 cm and 2.3 years respectively.

*Keywords*: reproduction; maturity ogive; histology; L50; A50; flatfish, Northeast Atlantic.

## 1. Introduction

The state of the megrim (*Lepidorhombus whiffiagonis*) and the four spot megrim (*L. boscii*) stocks in Atlantic Iberian waters (ICES Div. 8.c, 9.a) and that of the megrim stock in Celtic Seas and northern Bay of Biscay (ICES Div. 7.b-k, 8.abd) is annually assessed in ICES since more than two decades ago. The catches of the Spanish fleet, mainly Galician, represent a very significant percentage of the total landings of these stocks. Analytical models (XSA-VPA) have always been used in the assessment of the three stocks, but 2016 was the first year in which a Bayesian (analytical) assessment model was used for the *L. whiffiagonis* stock in 7.b-k, 8.abd. The *L. boscii* stock in ICES Div. 7.b-k, 8.abd has now also been included in the assessment process in 2017 but still without analytical model (ICES, 2017). The Spawning Stock Biomass (SSB) is one of the parameters estimated in the assessment process, basic information needed for the calculation of recruitment projections and the biological reference points (Blim, Bpa, Bloss, etc).

SSB is estimated based on the percentage of mature individuals by age or size (maturity ogive). The maturity ogives used by the ICES working group for the assessment of the *L. whiffiagonis* stock in 7.b-k, 8.abd, and for both Atlantic Iberian stocks, were estimated in 1998 based on macroscopic maturity data (BIOSDEF project, Pereda et al., 1998). The maturity parameters of *L. whiffiagonis* in 7.b-k, also estimated based on macroscopic information, were updated in the Benchmark Workshop on Flatfish (WKFLAT) (Landa et al., 2012) although they were not incorporated into the stock assessment process. Maturity parameters need to be updated periodically and, as far as possible, validated by microscopic (histological) methods.

Maturity and growth are two of the most plastic features of the life history of exploited fish. The maturity ogive can vary over time, and with it, the SSB. These shifts can be phenotypic, in response to environmental variations and, therefore, reversible, or they can be genotypic, due to genetic changes in the population and hardly reversible. Gerritsen (2016) observed some variability in the length at first maturity ($L_{50}$) of the *L. whiffiagonis* stock in 6.a and 7.abgj between 2004 and 2015, in addition to significant differences with respect to the maturity ogive used in the assessment process. However, these differences and variations could be due to sampling limitations (insufficient spatial coverage) and methodological errors, because the maturity stages were assigned based on macroscopic observations that have a higher error than the microscopic ones.

Taking into account the need to obtain updated information on the main biological parameters of these two species for a better assessment of the state of these stocks, the objective of the present study is to estimate, in a robust way (histological), the maturity ogive of the four stocks of interest to the Spanish fleet: *L. whiffiagonis* and *L. boscii* in Div. 7.b-k, 8.abd, and in Div. 8.c, 9.a.

## 2. Materials and methods

A total of 1708 individuals were sampled between 2017 and 2020, 973 in ICES Div. 7.b-k (Celtic Sea, West and South of Ireland) and 735 in Div. 8.c, 9.a2 (Galician waters and Cantabrian Sea). A total of 876 *L. whiffiagonis* were sampled, 538 in Div. 7.b-k and 338 in 8.c, 9.a2, and a total of 832 *L. boscii*, 435 in Div. 7.b-k and 397 in 8.c, 9.a2. The composition of the sample according to species and sex is shown in Table 1.

The sampling of individuals larger than 20 cm in total length was performed in March and April 2017 on board the commercial vessels "Manuel Laura", "Pescasar" and "Skellig Light II". Because the minimum landing size for both *Lepidorhombus* species is 20 cm, fish between 5 and 20 cm were obtained from the Instituto Español de Oceanografía (IEO, CSIC) research surveys, “Demersales” (in Div. 8c-9a2) and “Porcupine” (in Div. 7b,c,k) that took place in September-October 2017 on board of the research vessels “Miguel Oliver” and “Vizconde de Eza”, respectively. In all cases, bottom trawling was the fishing gear used.

The total length (mm), weight (g), sex and macroscopic maturity stage from each individual were taken on board and the sagitta otoliths were removed for age estimation in the lab. In addition, gonads were collected and immediately fixed in 4% buffered formaldehyde. In the laboratory, the gonads were weighed (to the nearest 0.01 g) and a histological study was performed. For this, a sub-sample was extracted from the central zone of each gonad. The histological processing consisted in the inclusion in paraffin of the sub-samples, the cutting using a microtome to sections of 3.5 microns and the staining with hematoxylin-eosine. The observation methodology and the age estimation criterion followed the protocol of Anon (1997) described for *L. whiffiagonis*, and that is similar for both *Lepidorhombus* species. The age interpretation in these species is based on the count of the translucent rings (hyaline) that are considered as annual in whole otoliths.

The histological sections of the gonads were examined to determine the maturity stage of each individual. In males, individuals were classified as mature or immature, while a scale of 6 maturity stages was used for females (Table 2). The percentage of mature individuals was estimated by length and age for each species, sex and study area. The maturity ogives and the length and age at first maturity ($L_{50}$ and $A_{50}$) were estimated, fitting the data to the logistic model of Ashton (1972).

The maturity ogives at age were performed fitting the data of each individual, using its "absolute age". This "absolute age" was estimated as a function of the capture season, adding to the age estimated the proportional part of the year (month) in which it was caught. Thus, in the specimens collected in the period of February-March, which coincides with the spawning season and, therefore, close to the theoretical month of birth, their "absolute ages" were the same as the estimated ages (i.e. ages 1, 2, 3, etc.). However, in the specimens caught in the research surveys (performed in September-October) the aforementioned fit was incorporated, and the "absolute age" for those specimens was approximately half a year older (i.e. ages 1.5, 2.5, 3.5, etc.) than those captured in March-April.

The maturity ogives at age and length was estimated by using the sizeMat R package (Torrejón-Magallanes, 2020).

## 3. Results and Discussion

Table 3 summarizes the parameters of the maturity ogives for each stock. Results showed that the length and age at maturity was larger in the northern stock than in the southern one for both species of *Lepidorhombus*.

***L. whiffiagonis*** in **7.b-k** showed a length at first maturity ($L_{50}$) for both sexes combined of **17.8** cm, which corresponded to an age at first maturity ($A_{50}$) of **2.4** years; while in **8.c, 9.a2** showed a $L_{50}$ of **18.9** cm and a $A_{50}$ of **1.6** years. The maturity ogive by length and age is shown in Table 4 and 5 respectively.

***L. boscii*** in **7.b-k** showed a length at first maturity ($L_{50}$) for both sexes combined of **16.7** cm which corresponded to an age at first maturity ($A_{50}$) of **2.3** years; while in **8.c, 9.a2** showed a $L_{50}$ of **14.7** cm and a $A_{50}$ of **1.6** years. The maturity ogive by length and age is shown in Table 4 and 5 respectively.

The observed differences between the maturity ogives currently used in the assessment and those estimated in the present study could be due to wrong macroscopic assignation of maturity stages (Pereda et al., 1998) (Table 4). As previously mentioned, and especially in the case of males, maturation occurs very early in these species and it is not possible to macroscopically identify the maturity stage of the small gonads of the youngest mature individuals. On the other hand, the maturity ogives estimated by Pereda et al. (1998) were obtained from individuals larger than 16 cm, while in the present study individuals larger than 4 cm were sampled, thus covering a wider length range of small individuals. It is also relevant to consider the difference of 20 years between the study of Pereda et al. (1998) and the current study. It is known that the fish stocks maturity in parameters are very plastic features that can present high interannual variability since they are influenced not only by environmental factors, but also by density-dependent factors (Cardinale and Modin, 1999, Domínguez-Petit et al. al., 2007; Pérez-Rodríguez et al., 2013). Considering this plasticity and our results, it is recommended a regular update of the maturity ogives to be taken into account by the relevant stock assessment group (WGBIE), on which the estimation of the spawning stock biomass

(SSB) depends and, therefore the perception of the state of the stock. In that sense, it is advisable doing a special effort to obtain samples of individuals smaller than 15 cm and estimating the maturity ogives based on microscopic observations, since it is impossible to distinguish visually the true maturity stage in the smallest gonads.

## Acknowledgements

We thank Andrés Villaverde and Marisol Pérez for their help in the laboratory analyses and Lorena Rodríguez for the age estimation of the samples, as well as the scientist and crew on board the IEO research surveys "Demersales" and "Porcupine", for their collaboration in the sampling of young specimens and the crews from the fishing vessels: "Manuel Laura", "Pescasar" and "Skellig Light II", for their collaboration in the sampling of mature individuals.

This study was funded by the Fisheries Producer Organization, OPPF-4 (*Organización de Productores de Pesca Fresca del Puerto Vigo*) and by the EU through the European Maritime and Fisheries Fund (EMFF) as an action included in a Production and Marketing Plan. It also has received funds from the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

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## Tables and Figures

***Table 1.*** *Descriptive statistics of analyzed variables by specie, area and sex. Values corresponds to mean (S.D.), saving age that is presented as a range (min-max). N: nº of sampled specimens. North: ICES division 27.7.b-k-8.abd, South: ICES division 27.8.c, 9.a. n.s.: not sampled.*

| Sex | Variable | *L. boscii* | | *L. whiffiagonis* | |
|---|---|---|---|---|---|
| | | South | North | South | North |
| Females | Length (mm) | 223.9 (69.2) | 239.3 (71.4) | 238.7 (69.3) | 314.1 (120.7) |
| | Weight (g) | 71.6 (72.7) | 144.7 (136.3) | 78.2 (72.0) | 353.5 (370.5) |
| | Age | 1-9 | 1-12 | 1-7 | 1-11 |
| | N | 209 | 220 | 192 | 296 |
| Males | Length (mm) | 204.4 (53.5) | 219.9 (57.5) | 204.0 (47.5) | 227.9 (64.8) |
| | Weight (g) | 32.5 (19.4) | 58.7 (49.4) | 33.3 (13.3) | 77.8 (70.4) |
| | Age | 1-8 | 1-12 | 1-5 | 1-9 |
| | N | 158 | 191 | 146 | 217 |
| Indetermined | Length (mm) | 59.3 (13.9) | 98.6 (7.6) | n.s. | 93.0 (13.7) |
| | Weight (g) | 1.3 (1.1) | 6.1 (2.4) | n.s. | 8.8 (6.8) |
| | Age | 0-1 | 1 | n.s. | 0-1 |
| | N | 30 | 24 | n.s. | 25 |

***Table 2.*** *Histological description of maturity stages used in the present study to classify gonads. Adapted from Brown-Peterson et al. (2011).*

| STAGE | DESCRIPTION | |
|---|---|---|
| | Females | Males |
| 0 | | Immature. Only primary spermatogonias are observed in testes. |
| 1 | Immature. Ovary only presents oogonias and/or oocytes in primary growth stage, well packaged, without atresia or postovulatory follicles. Ovary tunica is thin. | Mature. Testes present secondary spermatogonia, spermatocytes, spermatids and/or sperm. |
| 1b | Regenerating. Ovary presents oogonias and/or oocytes in primary growth stage. Ovary tunica is swollen. Blood vessels are numerous; rest of atresia and postovulatory follicles in advanced degeneration stage can exist. | |
| 2 | Developing. Ovary presents oogonias and oocytes in primary growth and cortical alveoli stage. Oocytes in vitelogenic and migratory nucleous stage can be also present. No hydrated oocytes or postovulatory follicles exist. Some atretic oocytes can be present but are not abundant. | |
| 2b | Spawning capable-between batches. Equal to stage 2 but with postovulatory follicles (recents or not) and/or residuals hydrated oocytes. Atretic oocytes can be more or less abundant. | |
| 3 | Actively spawning. Equal to stage 2 but with numerous hydrated oocytes. No recent postovulatory follicles. | |
| 4 | Regressing. Rest of oocytes at different developing stage can be present. Atretic oocytes and postovulatory follicles are abundant. Numerous and prominent blodd vessels are observed. Ovary tunica is more or less swollen. | |

***Table 3.*** *Parameters of the maturity ogives at length (mm) and age (years) estimated in the present study for L. whiffiagonis and L.boscii.in each study areas,* 7.b-k (Celtic Sea) and 8.c, 9.a2 (Galician waters and Cantabrian Sea)

| Species | Stock | Studied ICES Division | Length | | | Age | | |
|---|---|---|---|---|---|---|---|---|
| | | | Intercept | Slope | $L_{50}$ | Intercept | Slope | $A_{50}$ |
| *L. whiffiagonis* | 7.b-k, 8.abd | 7b-k | -6.9178 | 0.0389 | 178 | -4.5405 | 1.8766 | 2.4 |
| | 8.c, 9.a | 8.c, 9.a2 | -6.1998 | 0.0327 | 188.5 | -3.3067 | 2.1229 | 1.6 |
| *L. boscii* | 7.b-k, 8.abd | 7b-k | -7.7134 | 0.0459 | 167.3 | -3.8478 | 1.6764 | 2.3 |
| | 8.c, 9.a | 8.c, 9.a2 | -6.4671 | 0.044 | 147 | -2.775 | 1.7315 | 1.6 |

***Table 4.*** *Maturity ogives at length (mm) estimated in the present study for L. whiffiagonis and L.boscii.in each study areas, 7.b-k (Celtic Sea) and 8.c, 9.a2 (Galician waters and Cantabrian Sea)*

| Length (mm) | 8.c, 9.a | | 7.b-k, 8.abd | |
|---|---|---|---|---|
| | *L. whiffiagonis* | *L. boscii* | *L. whiffiagonis* | *L. boscii* |
| 70 | 2% | 3% | 1% | 1% |
| 80 | 3% | 5% | 2% | 2% |
| 90 | 4% | 8% | 3% | 3% |
| 100 | 5% | 11% | 5% | 4% |
| 110 | 7% | 16% | 7% | 7% |
| 120 | 9% | 23% | 10% | 10% |
| 130 | 12% | 32% | 13% | 15% |
| 140 | 16% | 42% | 19% | 22% |
| 150 | 22% | 53% | 25% | 30% |
| 160 | 28% | 64% | 33% | 41% |
| 170 | 35% | 73% | 42% | 52% |
| 180 | 42% | 81% | 52% | 63% |
| 190 | 50% | 87% | 62% | 73% |
| 200 | 58% | 91% | 70% | 81% |
| 210 | 66% | 94% | 78% | 87% |
| 220 | 73% | 96% | 84% | 92% |
| 230 | 79% | 97% | 88% | 94% |
| 240 | 84% | 98% | 92% | 96% |
| 250 | 88% | 99% | 94% | 98% |
| 260 | 91% | 99% | 96% | 99% |
| 270 | 93% | 100% | 97% | 99% |
| 280 | 95% | 100% | 98% | 99% |
| 290 | 96% | 100% | 99% | 100% |
| 300 | 97% | 100% | 99% | 100% |
| 310 | 98% | 100% | 99% | 100% |
| 320 | 99% | 100% | 100% | 100% |
| 330 | 99% | 100% | 100% | 100% |
| 340 | 99% | 100% | 100% | 100% |
| 350 | 99% | 100% | 100% | 100% |

***Table 5.*** *Maturity ogives at age (years) estimated in the present study for L. whiffiagonis and L.boscii.in each study areas, 7.b-k (Celtic Sea) and 8.c, 9.a2 (Galician waters and Cantabrian Sea)*

| Age | 8.c, 9.a | | 7.b-k, 8.abd | |
|---|---|---|---|---|
| | *L. whiffiagonis* | *L. boscii* | *L. whiffiagonis* | *L. boscii* |
| 0 | 4% | 6% | 1% | 2% |
| 1 | 23% | 26% | 7% | 10% |
| 2 | 72% | 67% | 31% | 38% |
| 3 | 96% | 92% | 75% | 77% |
| 4 | 99% | 98% | 95% | 95% |
| 5 | 100% | 100% | 99% | 99% |
| 6 | 100% | 100% | 100% | 100% |
| 7 | 100% | 100% | 100% | 100% |

*Working Document to the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim). Datacall October 2021*

# Weight-length relationships, weight conversion factors and condition in two stocks of megrim (*Lepidorhombus whiffiagonis*): Celtic Seas - northern Bay of Biscay (7.b-k, 8.abd stock) and northern Iberian waters (8.c, 9.a stock)

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## Abstract

Somatic parameters of megrim (*Lepidorhombus whiffiagonis*), an economically important flatfish species relevant in the benthic community, are of a great interest in fish biology and required for a deeper knowledge of its life history traits and an adequate stock assessment process and fishery management.

Le Cren's condition factor (K), weight-length relationships and weight conversion factors are studied from a time-series of more than two decades (1998 to 2019) in a wide European distribution area of megrim with relevant fishing activity and belonging to two stocks: northern Bay of Biscay-nBB and Celtic Sea-CS stock, and southern Bay of Biscay-sBB and Galician waters-Gw stock. Around 30,000 specimens, mostly collected from commercial landings by IEO and AZTI, were sampled. Total fish length, total weight and commercial gutted weight were obtained and five-year periods were defined in the time-series.

The influence of several factors, as seasonality, temporality, fish sex and maturity on the megrim condition were analyzed for each stock, showing the season a more relevant effect. A clear seasonal pattern found in K is described in detail in both populations for the first time based on a multi-year period. That pattern was more prominent in females and less marked in immature, related with the needs for reproduction process. The lowest condition in May in nBB-CS and a month earlier in sBB-Gw (both after the spawning period) was observed, followed by a progressive increase (favorable feeding conditions) to the highest values in November-February, and showing the relevance of K as indicator of the nutritional/reproductive status of megrim.

Total weight-length, gutted weight-length and total weight-gutted weight relationships were fitted for each megrim stock and their temporal variations were analyzed. The large sample size, size range and time-series available allowed obtaining robust somatic parameters of combined sexes for the total weight-length relationships (a=0.0049, b=3.1012; a=0.0041, b=3.1682, respectively in nBB-CS stock and sBB-Gw stock), for the gutted weight-length relationships (a=0.0046, b=3.1033; a=0.0042, b=3.1510, respectively in nBB-CS and sBB-Gw stock), and the weight conversion factors (1.049; 1.056, respectively in nBB-CS and sBB-Gw stock). They are considered to best fit the current biometric relationships and most appropriate to be used in the stock assessment of the status of both stocks.

A historical analysis of the temporal variability of the weight-length relationships including previous studies showed different trends between stocks.

Our findings can contribute to facilitating better exploitation, management and conservation of this species.

**Keywords**
Bay of Biscay; condition factor; weight-length relationships; weight conversion factor; somatic growth; *Lepidorhombus whiffiagonis*; megrim;

# 1. Introduction

The megrim, *Lepidorhombus whiffiagonis*, is a common benthic flatfish and an important commercial species in the European multispecific bottom trawl fisheries. Its catches rose to ~16000t in Atlantic waters in 2019 (ICES, 2020a; ICES, 2020b). It is mainly found on fine sand bottoms from 50 m to 700 m depth and distributed from the Iceland to Cape Bojador and in the Mediterranean (Whitehead et al., 1986; Sánchez et al., 1998; Fenández-Zapico et al, 2017; Abad et al, 2020). The International Council for the Exploration of the Sea (ICES) identifies four megrim stocks in European Atlantic waters for assessment and management purposes, i.e., megrim in Div. 8.c and 9.a (Iberian Atlantic waters), megrim in Div. 7.b–k and 8.a,b,d (Celtic Seas and northern Bay of Biscay), megrim in Div. 4.a and 6.a (northern North Sea and West of Scotland), and megrim in Div. 6.b (Rockall) (ICES, 2020a; ICES, 2020b).

The stock assessment procedures of megrim in ICES utilize the biological knowledge available to predict variations in the population parameters. Weight-length relationships as well as the weights conversion factors (total-gutted weight relationship) are commonly used in those procedures, and allow predicting weights of individuals from measurements of length or of other weights, and for estimation of the stock biomass. Besides, the condition factor, indicator of the well-being of a species, is a somatic index whose seasonal variation over the year is widely considered an index for the reproduction timing and the nutritional variation in a species. Thus, understanding the biological parameters of the stocks is of great importance. However, there are scarce studies on condition and weight-length relationships of megrim in Iberian Atlantic waters (Alperi, 1991, 1992; Pérez, 1998) and in Celtic Seas and northern Bay of Biscay (Dizerbo et al., 1946; Dwivedi, 1964; Conan et al., 1981; Aubin-Ottenheimer, 1985; Fontenla and Patiño, 1991; Pérez, 1998; Santurtún et al., 1998). Besides, these studies are mostly working documents or project reports. In fact, the estimates currently in use in assessment (Pérez, 1998; Santurtún et al., 1998) were obtained in an European Union study project (BIOSDEF) (Pereda et al., 1998), more than twenty years ago. It is quite evident the need research on biological traits of this species and for a robust and updated information on these biological parameters before their incorporation into the assessment process of megrim stocks, that will lead to a more adequate management of them.

This study pursues the following main aims:

i) to deepen the knowledge, on the one hand, of the megrim reproductive process through the analysis of the condition factor, and on the other hand, of the weight-related biological parameters of megrim, studying their seasonal, inter-annual, sexual and maturity-related variability in a wide area of its distribution, from western Irish waters to western Iberian Peninsula;

ii) to provide robust and updated weight-length relationships and weight conversion parameters of this species in relevant European fishing areas in both stocks, i.e., Celtic Seas - northern Bay of Biscay and Iberian Atlantic, that can be incorporated in the oncoming stock assessment process and fishery management.

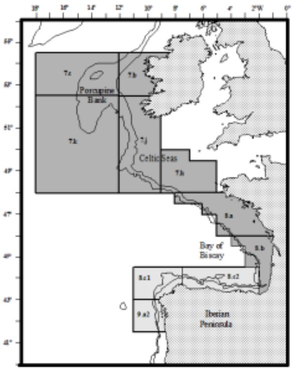



**Figure 1**. ICES Divisions of northeast Atlantic studied: i) Celtic Sea, south-western Ireland, Porcupine Bank (Div. 7.b,c,j,h,k) and northern Bay of Biscay (Div. 8.a,b) (northern stock, dark gray); ii) northern Iberian Atlantic waters corresponding to southern Bay of Biscay (Div. 8.c) and western Galician waters (Div. 9.a2) (southern stock, light gray).

## 2. Materials and methods

### 2.1. Sampling

The main megrim catching areas of the Spanish commercial fleet, Celtic Sea, south-western Ireland, Porcupine Bank (ICES Div. 7.b,c,j,h,k) and northern Bay of Biscay (Div. 8.a,b), belonging to the stock 7.b-k, 8.abd; and northern Iberian Atlantic waters, corresponding to the southern Bay of Biscay and Galician waters (ICES Div. 8.c, 9.a2), belonging to the stock 8.c, 9.a, were sampled (Fig. 1).

Sampling data were provided by Instituto Español de Oceanografía-IEO (from 7.b-k, 8.c, 9.a2) and AZTI (from 7.b-k, 8.abd). They comprise a time-series of 22 years, from 1998 to 2019. A total of 29986 individuals were sampled. The 99.7% came from the landings of the commercial fleet and only a small sample (100 individuals <20 cm in length) came from two research fishing surveys "Demersales", carried out by IEO in northern Iberian Atlantic waters, during September-October 2017 and 2019.

The available time-series allowed us to analyze the temporal variation of the parameters for periods of 5 years (quinquennium): 2000-04, 2005-09, 2010-14 and 2015-19. In northern Iberian, information was also available for the period 1998-99.

Total length [Lt (cm), length class of 1 cm], total weight [Wt (g)], gutted weight [Wg (g)], sex and maturity were collected from each specimen. The quarter was the sampling unit used to get the whole range of the length distribution of the commercially captured megrim. The sampling source influenced the type of weight data, ungutted (total) or gutted weight, that was available for each individual, which depends on the duration of the fishing trip and the landing harbour. Because the specimens landed by the Spanish fleet in some harbors are gutted, the available range of fish lengths for estimating the weight-length relationship varied according to the type of weight estimated. The numbers of specimens studied are shown in detail in Table 1, Table 2, and Table 3.

## 2.2. Data analysis

### 2.2.1 Condition factor

Le Cren's (1951) relative condition factor (K) was monthly estimated by sex and combined sexes:

$K = Wg / a\,Lt^b$

*where: K = Le Cren's condition factor; Wg = gutted weight (g); Lt = total length (cm); a, b = parameters of the regression.*

The temporal variation of the condition in each stock was related to variables associated to the stock size and the intensity of fishing exploitation, Thus, biomass, annual abundance of the stock, annual abundance indices from Spanish, French and Irish annual surveys and commercial CPUE or LPUE, abundance of age groups in the stock (i.e., age groups of 1-2 and 3-5 years-old) and fishing mortality (F) were analyzed. This information was obtained from the stock assessment information (ICES, 2020a).

### 2.2.2 Weight-length relationships

Weight-length relationships for combined sexes were calculated for the total weight and gutted weight. Regression functions were tested and the power function showed the best coefficient of determination ($r^2$) for the two weight-length relationships studied (Wt-Lt; Wg-Lt):

$W = a(Lt)^b$

*where: W= total weight [Wt (g)], or gutted weight [Wg (g)]; Lt = total length (cm); a, b = parameters of the regression.*

### 2.2.3 Weight conversion factor

Weight conversion factor for combined sexes was estimated by the linear function that relate the total and gutted weights with values "0" to intercept with the x-axis:

$Wt = aWg$

*where: Wt = total weight (g); Wg = gutted weight (g); a = parameter of the regression.*

The temporal factor, year and quinquennium, relevant for stock assessment process, was considered in the weight-length and in the weight-weight models. The "five-year period (quinquennium)" showed a more adequate sample representativeness than the "year". The role of the quinquennium was analyzed in each stock using the following Linear Models (LMs), and the and LMs were performed using the stats library in the R statistical software version 4.0.5 (R Foundation for Statistical Computing, 2021):

*log(Wt) ~ log(Lt) * quinquennium*

*log(Wg) ~ log(Lt) * quinquennium*

*Wt ~ Wg * quinquennium*

# 3. Results

## 3.1 Condition factor

### 3.1.1 Seasonal, temporal and sexual factors influencing condition

The megrim condition by month shows a clear pattern, with the lowest values in May in Celtic Seas and northern Bay of Biscay and a month earlier, in April, in northern Iberian waters (Figure 2). A sharp decrease from the maximum values of condition in November - February to the minimums values is observed in both stocks. However, the recovery of the condition increases progressively during the following seven months to reach the maximum values again.

A more detailed seasonal analysis of the condition is shown by quarter and sex, considering the sexual dimorphism in growth of megrim (Conan et al., 1981; Rodriguez and Iglesias, 1985). Mature males and females showed significant differences among quarters ($p<0.05$) with a more outstanding seasonal variability in females, which showed an increase from the smallest values in the second quarter (0.94 and 0.93, in Celtic Seas - northern Bay of Biscay and northern Iberian waters, respectively) to the highest values in the first quarter in Celtic Seas - northern Bay of Biscay (1.07) and in the fourth quarter in northern Iberian waters (1.10). The seasonal difference in the condition values between the quarters with lowest values and highest values was ~6-8% in mature males, while it was around double (~14-19%) in mature females. In immature specimens, the seasonal variability was only possible to compare in females. Immature females condition was significantly smaller ($p<0.05$) also in the second quarter, but without seasonal differences as outstanding as in mature females (Figure 2).

Temporal differences ($p<0.001$) in condition were observed among the quinquennia in both stocks. Similar values of 0.99-1.02 and 1.01-1.02, in Celtic Seas - northern Bay of Biscay and in northern Iberian waters, respectively, were obtained for the most recent three quinquennia (2005-09, 2010-14, 2015-19). They showed a more representative sampling of the population than the previous periods studied (1998-99, 200-04): the sample size in those periods was significantly smaller and a range of fish sizes was also narrower. This may prove the lower condition of about 0.99 and 0.97 obtained in those earlier periods.

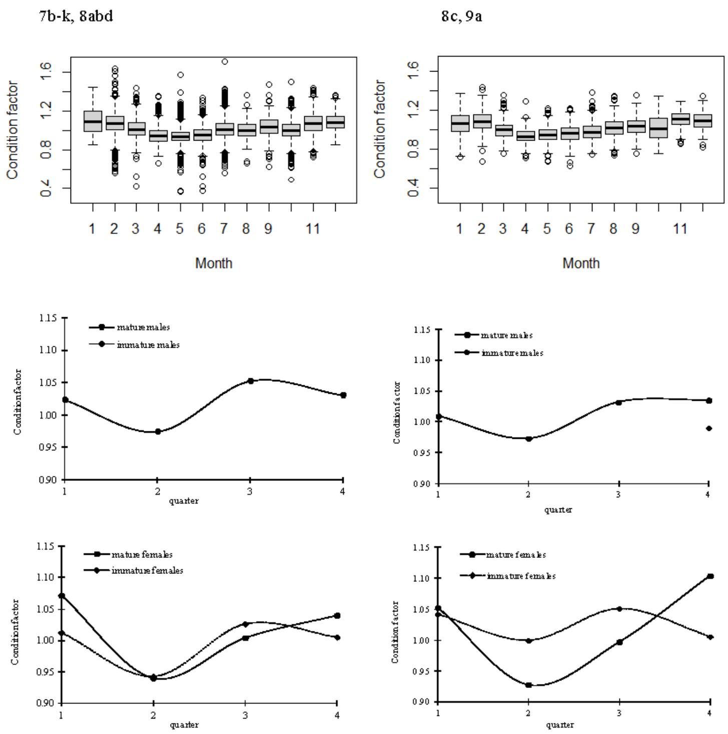



**Figure 2**. Seasonality of the Le Cren's condition factor by megrim stock: Celtic Seas and northern Bay of Biscay (left column) and northern Iberian (right column). Monthly box plot (top panel) and quarterly mean values by sex: males (central panel) and females (bottom panel), differentiating mature and immature individuals.

## 3.2. Weight-length and weight conversion factor for stock assessment

### 3.2.1. Weight-length relationships

In Celtic Seas - northern Bay of Biscay stock (7.b-k, 8.abd), the regression lines by quinquennium showed significant differences ($p<0.001$), both in the total weight-length relationship and in the gutted weight-length relationship (Figure 3). The differences among quinquennium slopes were < 3%.

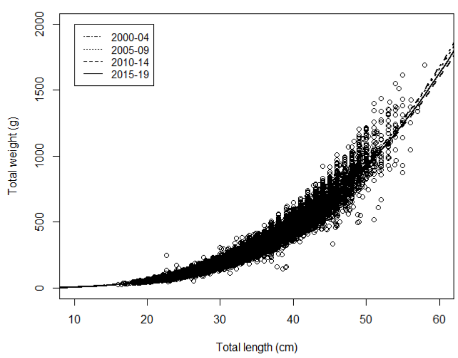
For the Iberian Atlantic stock (8.c, 9.a), significant differences ($p<0.001$) also were found among quinquennia both in the total weight-length relationship and in the gutted weight-length relationship (Figure 3). Quinquennium slopes showed differences up to 12%, being also 2000-04 the period with the highest difference. That quinquennium also was based on the smallest sample size, short range of sizes sampled and relatively smaller specimens. The distribution of the samples per quarter was notably different from the other quinquennia. In 2000-04 quinquennium, 88% of the individuals were sampled in the first semester, while that % was clearly lower (47-68%) in the other quinquennia. A significant inverse correlation (r: -0.9, $p<0.05$) was obtained between the slope of Wg-Lt per quinquennium and the number of specimens sampled in the first semester of each quinquennium, demonstrating the influence of seasonality on the overall slope value for an annual or multi-year period.

### 3.2.2. Weight conversion factors

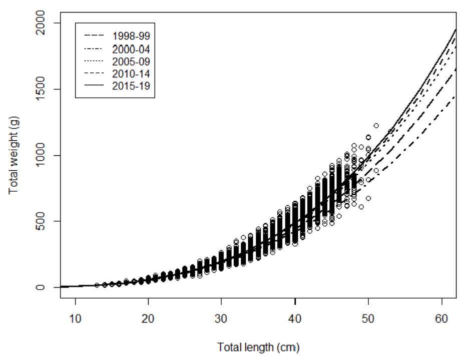
In Celtic Seas - northern Bay of Biscay stock (7.b-k, 8.abd), no significant differences among the three first quinquennia were found, but the most recent one (2015-19) showed significant differences ($p<0.05$) of only ~0.1% among slopes (Figure 3).

In Iberian Atlantic stock (8.c, 9.a), the three most recent quinquennia (2005-09, 2010-14, 2015-19), with a broad range of sampled sizes, did not show significant differences ($p>0.05$) among themselves. However, the oldest analyzed periods (1998-00, 2001-04), with a narrower range sampled, showed significant differences ($p<0.001$) with respect to the others. The differences were up to 1.7% among slopes (Figure 3).

stock 7.b-k, 8.abd




stock 8.c, 9.a



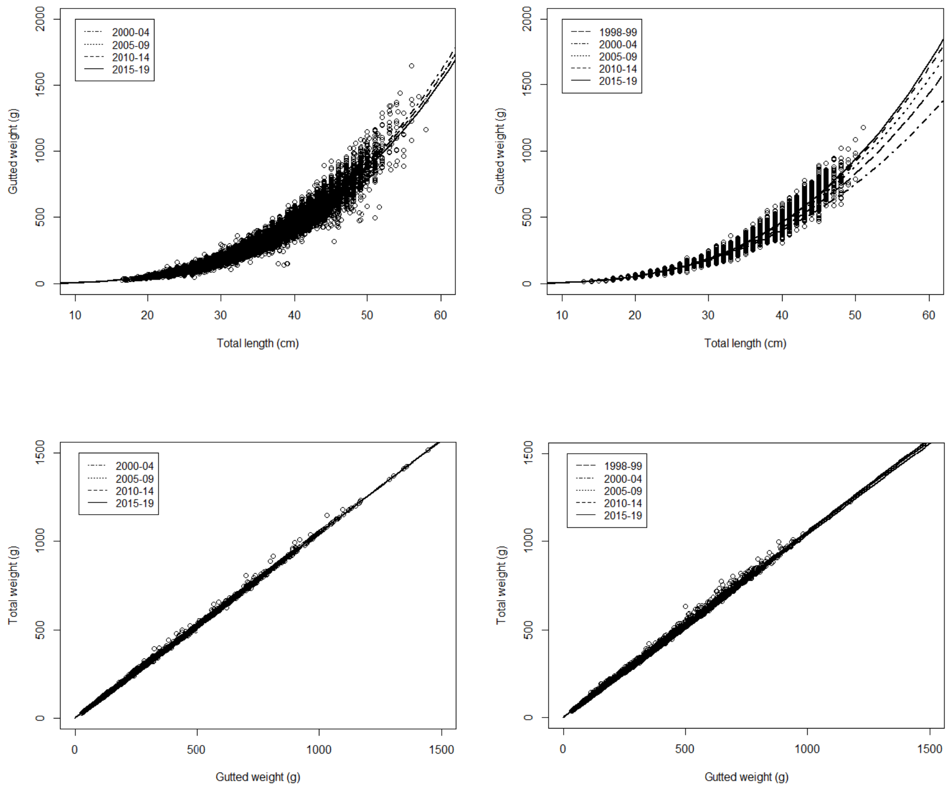



**Figure 3**. Relationships estimated for *L.whiffiagonis* stock 7.b-k, 8.abd (left column) and stock 8.c, 9.a (right column): total weight–total length (top panel); gutted weight–total length (central panel) and total weight–gutted weight (bottom panel).

## 4. Discussion

This study presents results of great interest on the one hand for a deeper knowledge of the biology of megrim in a wide area of its geographical distribution. On the other hand, it provides results of biological parameters of two important megrim stocks, one of them (Celtic Seas and northern Bay of Biscay stock) being the main one in annual landings (> 12000 t) of megrim and representing ~75% of its landings in Atlantic waters (ICES, 2020a). The large sample size and time-series, and the inter-institutional collaboration AZTI-IEO collecting complementary data, have allowed obtaining robust weight-length relationships and weight conversion factors, and analyze their temporal variation. Having that updated information in those fishing areas here studied is of primary importance for an accurate and reliable assessment of the stock status, allowing a better management of their populations.

### 4.1 Condition factor

#### 4.1.1 Seasonal, temporal and sexual factors influencing condition

The results of the present study show for the first time a clear, complete and coherent seasonal pattern of the condition in a wide European study area corresponding to two megrim stocks, with similarities between both and based on a multi-year period, which eliminate the possible effect of the year on the indices.

The spawning season of megrim is restricted to winter/spring months with a peak of spawning between February and April in southern European Atlantic waters and centered on March in northern Iberian waters (Dwivedi, 1964; Aubin-Ottenheimer, 1985, 1986; Fontenla and Patiño, 1991; Pérez, 1998; Santurtún et al., 1998; Robson, 2004) based on maturity stage frequencies and gonadosomatic index analyses. Therefore, our results on seasonal condition of mature individuals in both stocks support the findings on spawning period of aforementioned studies which were based on other indices. The results here obtained indicate a decrease in the megrim condition during one or two months after March, when spawning peaks. The condition of the megrim would be recovering in summer, with a more active metabolism favored by potentially better environmental and nutritional conditions. A better condition would be reached in autumn and winter, with a greater stored energy for spawning at the end of the first quarter. The only previous known studies where the condition factor of megrim was analyzed seasonally in these areas are those of Santurtún et al. (1998) and Pérez (1998), both based on around 1-year period. Our results agree with Santurtún et al. (1998) that show a lowest condition in the second quarter and highest in the fourth-first quarters in northern Bay of Biscay (Div. 8.abd). The study of Pérez (1998) in Div. 7.b-k based on nine months of information, shows a decrease of the condition from February-March to April-June, also in agreement with that here found.

### 4.2. Weight-length and weight conversion factor for stock assessment

#### 4.2.1. Weight-length relationships

In both stocks, Celtic Seas - northern Bay of Biscay stock (7.b-k, 8.abd) and Iberian Atlantic stock (8.c, 9.a), the parameters of the total weight-length relationship and gutted weight-length relationship from the most recent quinquennium (2015-19) are underlined in Table 1 and Table 2. They show a complete representation of the commercially exploited size range of megrim. The estimated parameters of combined sexes of megrim for the total weight-length relationships (a=0.0049, b=3.1012; a=0.0041, b=3.1682, respectively in 7.b-k, 8.abd stock and 8.c, 9.a stock) and for the gutted weight-length relationships (a=0.0046, b=3.1033; a=0.0042, b=3.1510, respectively in 7.b-k, 8.abd stock and 8.c, 9.a stock) are considered to best fit the current biometric relationships and most appropriate to be used in the stock assessment process of the status of both stocks, replacing the old values from 1998 currently used (Table 1, Table 2). The differences between the relationships currently proposed for stock assessment and the old ones are shown in Figure 4.

A remarkable aspect to consider when estimating length-weight relationships is the seasonal distribution of the samples collected. The markedly different slope in the gutted weight-length relationship for the period 2000-04 observed here (in Iberian Atlantic stock) allows to advice that when noticeable seasonal variations in length-weight relationships are detected in a species (due to the natural seasonal feeding / reproductive process), they should have taken into account in further sampling designs and relationship estimations. A poorly representative sampling in the quarters that show differences in the somatic relationships with respect to the rest of year, may lead to differences among the relationships comparing years or multi-year periods. However, that population could really have fewer differences among years or multi-year periods (or no significant differences) if the quarters had been similarly sampled among the comparing years (or multi-year periods).

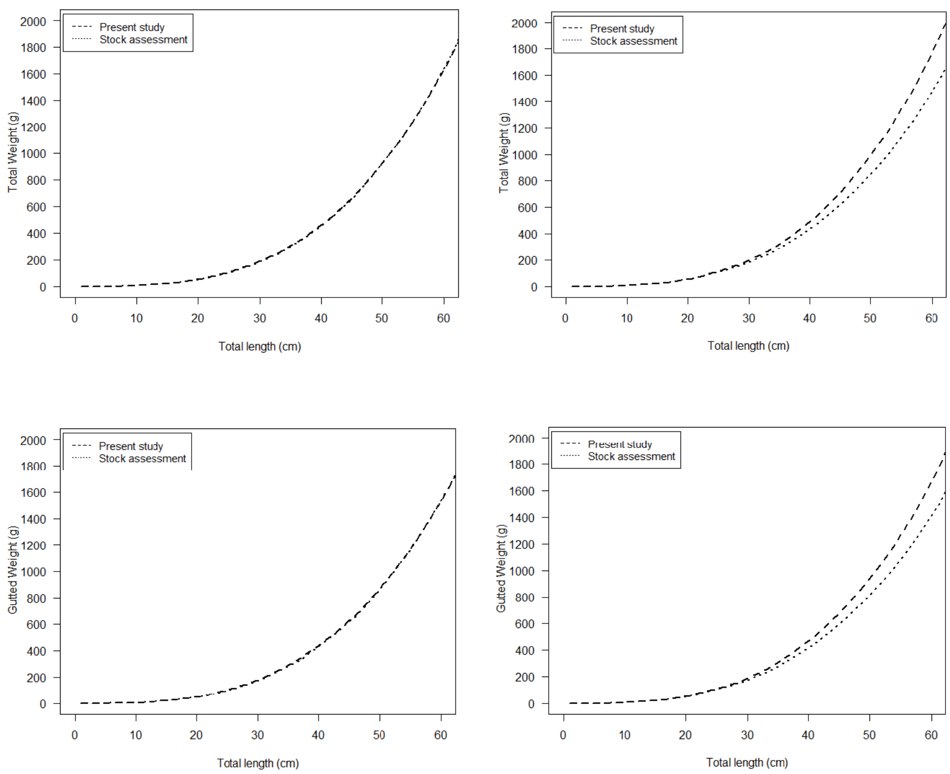
#### 4.2.2. Weight conversion factors

In Celtic Seas - northern Bay of Biscay stock (7.b-k, 8.abd), the similarity among the weight conversion factor from all quinquennia allowed to consider the value 1.049 for the overall period (2000-19) (underlined in Table 3), comprising the overall commercial range of sizes, as the most appropriate to be used in the stock assessment process, replacing that old value (1.060) from 1998 currently used (Pérez, 1998).

For the Iberian Atlantic stock (8.c, 9.a), the weight conversion factor (1.056) was selected from the period (2005-19), corresponding to the three most recent quinquennia, without differences among them (underlined in Table 3. It was that best represents the overall commercial range of sizes and considered as the most appropriate to be used in the stock assessment process, also replacing that old value (1.050) currently used (Pérez, 1998).

The small differences between the conversion factor currently proposed for stock assessment and the old ones (1 % and 0.6 % for 7.b-k, 8.abd and 8.c, 9.a stocks, respectively) are shown in Figure 4.

stock 7.b-k, 8.abd                                         stock 8.c, 9.a



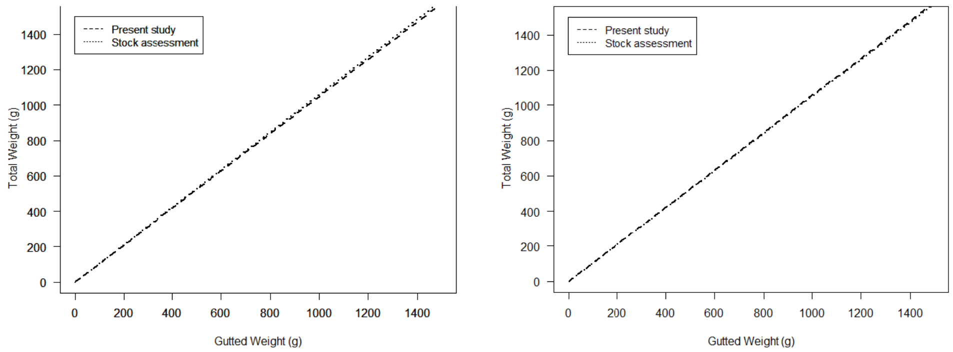



**Figure 4**. Differences between the relationships from the present study proposed for stock assessment and those currently used from 1998, for *L.whiffiagonis* stock 7.b-k, 8.abd (left column) and stock 8.c, 9.a (right column).

### 4.2.3. Historical perspective

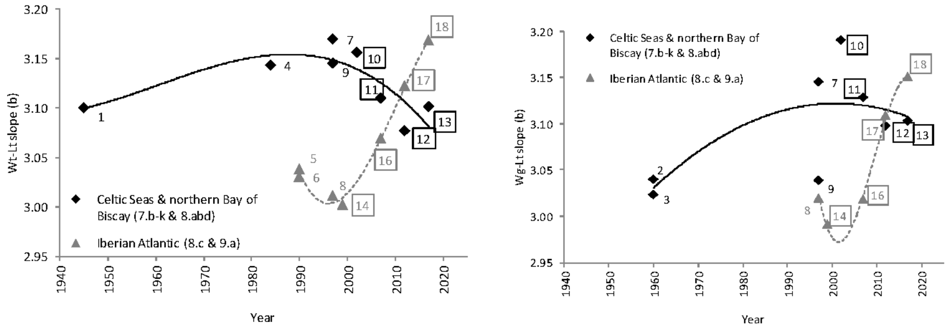



**Figure 5**. Slope (parameter b) from the total weight - total length relationship (left) and from the gutted weight - total length relationship (right) of *L. whiffiagonis* estimated in the North-eastern Atlantic in this study (number in square) and from previous studies: 1, Dizerbo, Forest and Letaconnoux (1946); 2, Dwivedi (1964) in 7.bj; 3, Dwivedi (1964) in 8.ab; 4, Aubin-Ottenheimer (1985); 5, Alperi (1991); 6, Alperi (1992); 7, Pérez (1998) in 7.b-k; 8, Pérez (1998) in 8.c,9.a; 9, Santurtún et al. (1998); 10, Present study in 7.b-k, 8.abd (2000-04); 11, Present study in 7.b-k, 8.abd (2005-09); 12, Present study in 7.b-k, 8.abd (2010-14); 13, Present study in 7.b-k, 8.abd (2015-19); 14, Present study in 8.c,9.a (1998-99); 15, Present study in 8.c,9.a (2000-04); 16, Present study in 8.c,9.a (2005-09); 17, Present study in 8.c,9.a (2010-14); 18, Present study in 8.c,9.a (2015-19).

A complete study covering a large area of distribution of the species and a wide period, thus allowing the analysis of its temporal variability, was not available until now. The parameters estimated here are in the range of those obtained in previous works, mostly grey literature (Table 1, Table 2, Table 3) and are considered the most appropriate to be used in the upcoming stock assessment in each megrim stock.

In the total weight-length relationship, the parameter b (slope) of the Atlantic studies varies between 3.01 and 3.17, with the exception of that from Conan et al (1981) which presents a lower value (2.95), probably due to being based on a narrow megrim sizes (only up to 36 cm). In the same way, the low slope of 2.84 of the present study corresponding to the five-year period 2000-

04 in the stock 8.c, 9.a (Table 1) also seems to be related to the lower sample size range (only individuals up to 39 cm) and to the aforementioned reasons. The Mediterranean studies show a greater slope (3.23-3.26) than the Atlantic ones, partly due to the lower megrim abundance and individuals reaching smaller maximum sizes in Mediterranean than in Atlantic (close to 60 and 50 cm in stock 7.bk-8.abd and 8.c, 9, a, respectively). The Mediterranean parameters of Merella et al. (1997), based on only 11 small individuals (up to 18 cm), should be considered with caution.

Regarding the gutted weight-length relationship, the slopes of the studies vary between 2.98 and 3.15, lower values than those based on total weight (Table 2). Fontenla and Patiño (1991), analyzed a smaller range of megrim sizes and smaller maximum lengths than the other studies, and estimated the lowest value of the slope (2.98).

In relation to the total weight- gutted weight relationship, the slopes of the studies, with values between 1.04 and 1.06, are more similar to each other compared to those observed in the aforementioned somatic relationships (Table 3).

In addition to the variability among quinquennia of the parameters above mentioned, a temporal variability of the slope ('b' parameter) over the decades is observed when the results of the present study and previous ones are compared (Figure 5). A rise of the slope value from those few figures available in the years '40 (in total weight) and '60 (in gutted weight) to the highest values found in the late '90 -early '00, is observed (Figure 5). From the BIOSDEF study (Pérez, 1998; Santurtún et al., 1998) and including the results of the present study, periodic parameters are available from middle '90 until now, evidencing a more detailed downward trend in 'b' parameter in Celtic Seas - northern Bay of Biscay (stock 7.bk, 8.abd) both in the total weight-length and gutted weight-length relationships (Figure 5). However a sharper opposite upward trend in the slope is observed in both relationships in southern Bay of Biscay (stock 8.c,9.a). The different time trend of the slope between both stocks in the last decades would indicate the need for more monitoring and research on this matter. In the comparison exercise (Figure 5), we consider only the parameters from the studies covering the whole size range of population and were not partially biased in this respect. Thus, the parameters of Connan et al (1981) in stock 7.b-k, 8.abd, and those of the present study corresponding to the quinquennium 2000-04 in stock 8.c, 9.a (Table 1) are not included in that figure.

In **conclusion**, the seasonality of condition factor in both stocks shows its relevance as indicator of the reproductive and nutritional status of megrim. This collaborative study AZTI-IEO provides new biological parameters in the main fishing stock of megrim and the main fishery areas for the fleets catching megrim, necessary for an accurate annual stock assessment process and stock management of megrim. The new somatic parameters from weight-length relationships and weight conversion factor are available to be used in the next stock assessment in ICES (benchmak-2021/WGBIE-2022) and it is recommended that they replace the ones used so far, which are outdated. The observed temporal variability in the somatic parameters obtained here from two decades of sampling and the information from previous studies, constitutes a solid basis for future studies that will allow to have a broader perspective of these variations found. The continue monitoring of these parameters is essential to detect possible long-term shifts due to the fisheries pressure or environmental variations and to deeper understanding of the specific causes of these variations.

| Ocean / Sea | Stock | Author | ICES Div. / GSA | Area | Period | Sex | Coefficients | | n | r² | Length range (cm) | Weight range (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | a | b | | | | |
| Atlantic | 7.b-k, 8.abd | **Present study** | **7.b-k, 8.abd** | **Celtic Seas & northern Bay of Biscay** | **2015-19** | **combined** | **<u>0.005</u>** | **<u>3.10</u>** | **5481** | **0.98** | **18-57** | **45-1342** |
| | | | | | **2010-14** | **combined** | **0.005** | **3.08** | **4383** | **0.97** | **19-59** | **47-2374** |
| | | | | | **2005-09** | **combined** | **0.005** | **3.11** | **8242** | **0.98** | **16-56** | **27-1514** |
| | | | | | **2000-04** | **combined** | **0.004** | **3.16** | **3276** | **0.98** | **16-54** | **28-1549** |
| | | Pérez (1998) | 7.b-k | Celtic Sea, southwestern Ireland | 1997 | combined | 0.004 | 3.17 | 1117 | 0.99 | 16-63 | - |
| | | Santurtún et al. (1998) | 8.abd | Northern Bay of Biscay | 1996-97 | combined | 0.004 | 3.15 | 537 | 0.99 | 16-53 | 28-1090 |
| | | Aubin-Ottenheimer (1985) | 7.efgh, 8.a | Celtic Sea & northern Bay of Biscay | 1984 | females | 0.004 | 3.14 | - | 0.99 | 12-54 | - |
| | | Conan et al (1981) | 7.ghj | Celtic Sea | 1980-81 | combined | 0.008 | 2.95 | 192 | 0.99 | 10-36 | 9-330 |
| | | Dizerbo, Forest and Letaconnoux (1946) | 8.ab | Northern Bay of Biscay | ~1945 | combined | - | 3.10 | - | - | - | - |
| | 8.c, 9.a | **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2015-19** | **combined** | **<u>0.004</u>** | **<u>3.17</u>** | **1687** | **0.98** | **13-49** | **14-1065** |
| | | | | | **2010-14** | **combined** | **0.005** | **3.12** | **3026** | **0.97** | **20-50** | **53-1153** |
| | | | | | **2005-09** | **combined** | **0.006** | **3.07** | **2104** | **0.97** | **19-53** | **48-1225** |
| | | | | | **2000-04** | **combined** | **0.012** | **2.84** | **288** | **0.97** | **20-39** | **56-399** |
| | | | | | **1998-99** | **combined** | **0.007** | **3.00** | **353** | **0.98** | **18-50** | **38-815** |
| | | Pérez (1998) | 8.c, 9.a2 | Southern Bay of Biscay & Galician waters | 1997 | combined | 0.006 | 3.01 | 663 | 0.99 | 12-52 | - |
| | | Alperi (1991) | 8.c2 | Cantabrian Sea | 1990 | combined | 0.006 | 3.04 | 189 | 0.98 | 17-45 | - |
| | | Alperi (1992) | 8.c2 | Cantabrian Sea | 1989 | combined | 0.006 | 3.03 | 87 | 0.99 | 17-45 | - |
| Mediterranean | - | Santic et al. (2012) | 17 | Northern Adriatic Sea | 2006 | females | 0.003 | 3.23 | 671 | 0.94 | 10-35 | 8-313 |
| | - | Merella et al. (1997) | 5 | Western Mediterranean | 1995-96 | combined | 0.003 | 3.26 | 11 | 1.00 | 9-18 | - |

**Table 1**. Parameters of the total weight - total length relationship for *L. whiffiagonis* estimated in the present study and previous studies. The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.

| Ocean / Sea | Stock | Author | ICES Div. | Area | Period | Sex | Coefficients | | n | r² | Length range (cm) | Weight range (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | a | b | | | | |
| Atlantic | 4.ab, 6.a | Dwivedi (1964) | 4.a | Northern North Sea | 1957-62 | females | 0.006 | 3.052 | 256 | - | - | - |
| | 7.b-k, 8.abd | **Present study** | **7.b-k, 8.abd** | **Celtic Seas & northern Bay of Biscay** | **2015-19** | **combined** | **<u>0.005</u>** | **<u>3.103</u>** | **4757** | **0.98** | **18-58** | **43-1383** |
| | | | | | **2010-14** | **combined** | **0.005** | **3.098** | **8221** | **0.969** | **19-58** | **45-1649** |
| | | | | | **2005-09** | **combined** | **0.004** | **3.129** | **7406** | **0.976** | **18-56** | **38-1444** |
| | | | | | **2000-04** | **combined** | **0.003** | **3.191** | **2140** | **0.984** | **16-51** | **27-1123** |
| | | Pérez (1998) | 7.b-k | Celtic Sea, southwestern Ireland | 1997 | combined | 0.004 | 3.145 | - | - | - | - |
| | | Santurtún et al. (1998) | 8.abd | Northern Bay of Biscay | 1996-97 | combined | 0.006 | 3.039 | 3199 | 0.992 | 16-55 | 23-1145 |
| | | Fontenla and Patiño (1990) | 7 | Celtic Sea | 1990 | combined | 0.008 | 2.980 | 507 | - | 18-47 | - |
| | | Dwivedi (1964) | 7.bj | Western Ireland | 1957-62 | females | 0.006 | 3.040 | 148 | - | - | - |
| | | Dwivedi (1964) | 8.ab | Northern Bay of Biscay | 1957-62 | females | 0.006 | 3.024 | 180 | - | - | - |
| | 8.c, 9.a | **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2015-19** | **combined** | **<u>0.004</u>** | **<u>3.151</u>** | **1611** | **0.97** | **13-49** | **13-1014** |
| | | | | | **2010-14** | **combined** | **0.005** | **3.109** | **2983** | **0.971** | **20-50** | **51-1087** |
| | | | | | **2005-09** | **combined** | **0.007** | **3.018** | **667** | **0.977** | **19-51** | **46-1176** |
| | | | | | **2000-04** | **combined** | **0.011** | **2.840** | **233** | **0.972** | **20-39** | **54-386** |
| | | | | | **1998-99** | **combined** | **0.007** | **2.991** | **353** | **0.983** | **18-50** | **36-787** |
| | | Pérez (1998) | 7.b-k | Celtic Sea, Southwestern Ireland | 1997 | combined | 0.006 | 3.020 | - | - | - | - |

**Table 2**. Parameters of the gutted weight - total length relationship for *L. whiffiagonis* estimated in the present study and previous studies. The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.

| Ocean / Sea | Stock | Author | ICES Div. | Area | Period | Sex | Coefficient | n | $r^2$ | Total weight range (g) | Gutted weight range (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Atlantic | 7.b-k, 8.abd | **Present study** | **7.b-k, 8.abd** | **Celtic Seas & northern Bay of Biscay** | **2000-19** | **combined** | **<u>1.049</u>** | **13662** | **0.999** | **27-1444** | **28-1514** |
| | | | | | **2015-19** | **combined** | **1.048** | **3725** | **0.993** | **43-1169** | **45-1232** |
| | | | | | **2010-14** | **combined** | **1.049** | **2860** | **1.000** | **45-1305** | **47-1368** |
| | | | | | **2005-09** | **combined** | **1.049** | **5183** | **1.000** | **38-1444** | **39-1514** |
| | | | | | **2000-04** | **combined** | **1.049** | **1894** | **1.000** | **27-1123** | **28-1178** |
| | | Pérez (1998) | 7.b-k | Celtic Sea, southwestern Ireland | 1997 | combined | 1.060 | - | - | - | - |
| | | Santurtún et al. (1998) | 8.abd | Northern Bay of Biscay | 1996-97 | combined | 1.043 | 532 | 0.999 | - | - |
| | | Aubin-Ottenheimer (1985) | 7.efgh, 8.a | Celtic Sea and northern Bay of Biscay | 1984 | females | 1.041 | - | - | - | - |
| | 8.c, 9.a | **Present study** | **8.c, 9.a2** | **Southern Bay of Biscay & Galician waters** | **2005-19** | **combined** | **<u>1.056</u>** | **5300** | **0.999** | **13-1176** | **14-1225** |
| | | | | | **2015-19** | **combined** | **1.056** | **1611** | **0.999** | **13-1014** | **14-1065** |
| | | | | | **2010-14** | **combined** | **1.057** | **2983** | **0.999** | **51-1087** | **53-1153** |
| | | | | | **2005-09** | **combined** | **1.055** | **667** | **0.999** | **46-1176** | **48-1225** |
| | | | | | **2000-04** | **combined** | **1.037** | **233** | **0.998** | **54-386** | **56-399** |
| | | | | | **1998-99** | **combined** | **1.048** | **353** | **0.999** | **36-787** | **38-815** |
| | | Pérez (1998) | 7.b-k | Celtic Sea, Southwestern Ireland | 1997 | combined | 1.050 | - | - | - | - |
| | | Alperi (1991) | 8.c2 | Cantabrian Sea | 1990 | combined | 1.051 | - | - | - | - |
| | | Alperi (1992) | 8.c2 | Cantabrian Sea | 1989 | combined | 1.049 | - | - | - | - |

**Table 3**. Parameters of the total weight - gutted weight relationship for *L. whiffiagonis* estimated in the present study and previous studies. The underlined parameters are considered as the most appropriate to be used in the next stock assessment process.


## Acknowledgements

This study has been co-funded by the European Union through the European Maritime and Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy, IEO and AZTI. We would like to express our gratitude to M. Ámez, P. Quelle, J. Conde del Rio and D. Garabana for their collaboration in the samplings in the laboratory and on board of IEO research surveys "Demersales", and to A. Maceira and C. Abaroa for their collaboration in the samplings in the laboratory in AZTI. Also, acknowledgment to the surveys coordinators F. Velasco, A. Punzón, I. Preciado.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*Working Document to the ICES Benchmark Workshop for selected Megrim Stocks (WKMegrim). Datacall October 2021*

# Main considerations for the stock assessment from the megrim otolith exchange in Iberian Atlantic stock

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## Abstract

An otolith exchange (EX) from the Iberian Atlantic stock (Div. 8.c, 9.a) of megrim was performed for **the first time.**

A total of 120 whole otoliths and images were analyzed, representative of the whole range of specimens commercially captured.

The "multistage modal age approach" was used, and the percentage of multiple mode cases for all readers was reduced from 13% (traditional approach) to 0% (multistage approach).

For all readers, the overall agreement (PA) was 68%, CV was 14%, APE was 9% and relative bias (RB) was -0.07.

For the readers involved in the assessment of this stock, better results were obtained: overall PA of 82%, CV of 11%, APE of 6% and RB of -0.10.

As usual, the overall PA decreases with increasing age (from age 5) but the overall CV was stable with age (from age 3). RB increases from age 7 (ages with low samples and low landings). Three readers (basic-intermediate experience) showed higher RB and lower PA, mainly in ages ≥ 6.

No noticeable general concerns related to the age estimation in that stock were found, except the usual increasing difficulty of interpretation in older megrim due to increased otolith opacity.

Similar or better results in present EX than in previous megrim EXs and workshops (almost all based on stock 7.b-k, 8.abd).

A reference collection, training in older ages and continue calibration EXs for all readers are recommended. **Considering the good results of the readers providing readings for stock assessment, no specific recommendation are suggested for them**.

## Keywords

Megrim; age estimation; otolith; *Lepidorhombus whiffiagonis*; Iberian

## 1. Introduction

The megrim Iberian Atlantic stock (Div. 8.c, 9.a) is captured by the Spanish and Portuguese fleets, with annual catches between 250 to 400 t since 2011 (ICES, 2020).

Several age calibration exchanges and workshops on megrim have taken place in 1997, 2004 and 2010, most analyzing samples from the 7.b-k, 8.a,b,d stock (Anon, 1997; Egan et al, 2004; Etherton, 2011) and one based on samples of the 4.a, 6.a stock in 2018-19 (Gault and Craig, 2019). The present exchange will therefore be the first based on the 8.c, 9.a stock of megrim.

The sagitta otolith is the common calcified structure used for the age estimation in megrim.

The ICES Working Group on Biological Parameters (WGBIOP) in 2019 (ICES, 2019) established the need to perform an age calibration exchange of megrim (*Lepidorhombus whiffiagonis*) from ICES Div. 8.c, 9.a. in 2020, coordinated by Jorge Landa (IEO, Spain).

The **objective** was to estimate the agreement, precision and relative bias in the age estimations from age readers of the different age reading laboratories, to check that these parameters are within acceptable level (ICES, 2019).

## 2. Materials and methods

### 2.1. Material

The fish length range (20-47 cm) of the collection analyzed represented the **whole range of specimens commercially captured** by the Spanish fleet in the ICES Div. 8.c, 9.a.

Including samples from both semesters, in which a different type of border is generally shown, and including samples of the fish size range used in the stock assessments, are considered important considerations in the otolith exchanges and recommended in the WGBIOP Guidelines for Otolith Exchanges and Workshops (ICES, 2019b).

Information on sex was available in all the specimens for the exchange, but not the fish length.

Both whole saggital otoliths were available in most samples of the exchange collection, although for a few specimens, broken otoliths or only one otolith were included. The representation of this type of otoliths in the collection is proportional to that usually is read by the age readers in the age estimation monitoring for the stock assessment in the area.

The otoliths from each specimen were immersed in water and the pictures were taken by IEO. Those digitized images have been uploaded to Smartdots.

Therefore the collection was based on:

- The whole **otolith set**
- The **image set** of those otoliths, available on **Smartdots**

### 2.2. Methods

#### 2.2.1. Modal age: a multistage approach to define the modal age by sampled fish

In this event, the multistage approach to calculate the modal age has been used. When summarizing the output and reporting the results of the exchange events developed within the SmarDots framework, the modal age (the most common age decided by the age readers for every fish sample) is the most relevant measurement. It is a key statistic by itself, but it is also fundamental for the estimation of some other relevant statistics to assess the performance of the techniques assessed in the exchange event, like the Percentage Agreement (PA), or input for stock assessments like the Age Error Matrix (AEM) (see below). However, the standard approach of calculating the mode (each reader has the same weight=1) the mode is taken as the lowest age of the multiple modal ages. This way renders multiple cases (fish samples) with multiple modal ages (i.e. different ages got the same highest number of readers). Accordingly, this imply a wrong perception of the age by fish individual and introduction of bias in the calculation of the PA and AEM. As a solution, in this report a multistage approach to select the modal age is used. This multistage approach is based in the different weight given to the age readers according to their experience. Two different weight scores scales were assigned, a weight score decreasing linearly with the experience and another decreasing with a negative exponential

shape. The modal age by fish individual is decided following the next approach:
1.-If there is a single mode estimated with the standard approach (equal weight for all readers) this value is used as the modal age, if not
2.-Adding up, for each age category, the score assigned with the linear weighting for all the readers that decided that age for that fish. Next, the modal age is selected as the age category that obtains the highest score sum. If, despite this approach, there were still multiple ages with the same score (and hence multiple modes), the next step is applied:
3.-Adding up, for each age category, the score assigned with the negative exponential weighting for all the readers that decided that age for that fish. Select as the modal age the age with the highest score sum.
During the WGBIOP 2019 meeting it was found that the combination of the modes decided using these three methods (so called 'multistage approach'), allows assigning a single modal age to each fish individual.
It is important checking the table that indicates the percentage of multimodal cases (in the results section) and the table with the fishID and sampleID that obtained multiple modes (included in annex 3).

### 2.2.2. Pecentage Agreement (PA)

The percentage agreement per reader per modal age tells how large is the part of readings that are equal to the modal age. The percentage agreement is estimated by modal age and reader as the proportion (as percentage) of times that the lectures of that reader agreed with the resulting modal age.This percentage is estimated as the number of times that a reader agreed with the modal age divided by the total number of otoliths read by a reader for each modal age.

$$PA = \frac{nmodalage}{ntotal} * 100$$

### 2.2.3. Coefficient of Variation (CV)

The table presents the Coefficient of Variation (CV) per modal age and reader. The CV's are calculated as the ratio between the standard deviation (σ) and mean value (μ) per reader and modal age:

$$CV = \frac{\sigma}{\mu} \cdot 100\%$$

To the table is also added the CV of all readers combined per modal age and a weighted mean of the CV per reader.

### 2.2.4. Relative bias

The relative bias is calculated as the difference between the mean and the modal age. This statistic is presented in first place by modal age and reader, but it is also calculated as an average value by modal age for all readers together (or only advanced readers).

### 2.2.5. Average Percentage Error (APE)

The Average Percentage Error (APE) was calculated based on the method outlined by Beamish & Fournier (1981). This method is dependent of fish age and thus provides a better estimate of precision than percentage agreement. As the calculations of both CV and APE pose problems if the mean age is close to 0, all observations for which modal age was 0 were omitted from the CV and APE calculations.
The average percentage error is calculated per image as:

$$APE = \frac{100\%}{n} \sum_{i=1}^{n} \left| \frac{a_i - \bar{a}}{\bar{a}} \right|$$

where $a_i$ is the age reading of reader i and $\bar{a}$ is the mean of all readings from 1 to n.

### 2.2.6. Age error matrix (AEM)

Age error matrices (AEM) were produced following procedures outlined by WKSABCAL (ICES, 2014) where the matrix shows the proportion of each modal age mis-aged as other ages. The sum of each row is 1, which equals 100%. The age data was analysed twice, the first time all readers were included and the second time only the "advanced" readers were included. If a reader is "advanced" then they are considered well trained and they provide ages for stock assessment or similar purposes. When the AEM is compiled for assessment purposes it uses only those readers who provide age data for the stock assessment in that specific area.

#### 2.2.7. Otolith Growth Analysis

SmartDots provides a measure of distance between the annotations made by the readers and thus provides a measure of growth increment width. This data is used to establish growth curves for each otolith (fish) and for each reader.

#### 2.2.8. Overview of samples and readers

A total of 8 readers participated, of which two (R01 and R03) contribute their readings to the assessment process of the Iberian Atlantic stock.

## 3. Results

### 3.1.Stock assessment readers (called advanced readers in the Tables and Figures)

The new multistage approach considered here to weight the experience of the reader which will be considered when defining the fish age mode, was a substantial improvement by reducing the percentage of samples with multiple modes from 36% obtained with the traditional approach to 0% using the new approach (**Table 1**).

The mean CV, APE and Relative bias by modal age for the stock assessment readers are shown in **Table 2.** Good results in relative accuracy (age bias plot) are obtained (**Figure 1**). The overall relative bias of the assessment readers, with values between 0 and -0.02 in all ages except age 10, is lower than the obtained for all readers. Age 10 is only represented by two samples in the EX and its contribution to commercial catches is minimal. Considering that the plus group for the stock assessment is age 7, the impact that those differences have on the readers participating in the stock assessment process are minimal (**Figure 1**). **Table 3** shows the Age Error Matrix. Practically equal mean distances from the otolith center to each winter annulus are obtained for the stock assessment readers (**Figure 2**).

### Multimodal cases

**Table 1:** Summary of statistics; Total number of samples (NSample), a percentage of cases (fish samples) with multiple modes depending on the approach to weight the experience of the reader which will be considered when defining the fish age mode. PercMM_traditional shows the percentage of the total samples for which multiple modes are obtained when all the readers are equally weighted. PercMM_linear_weight shows the percentage of the total samples for which multiple modes are obtained when the weight assigned to the different readers decreases linearly with the experience, while in the PercMM_negexp the weight applied decreases with a negative exponential shape with the experience. The PercMM_multistage shows the percentage of multiple mode cases when a combination of the different methodologies is used, as explained in the material and methods section

| NSample | PercMM_traditional | PercMM_linear_weight | PercMM_negexp_weight | PercMM_multistage |
|---|---|---|---|---|
| 120 | 36% | 0% | 0% | 0% |

## Age readings, CV, PA, APE and Relative Bias

**Table 2:** The number of age readings, and the mean CV, PA, APE and Relative bias by modal age are presented for all advanced readers combined. The last row shows the total number of readings and the weighted mean CV, PA, APE and relative bias for all modal ages.

| Modal age | Num_read | CV | PA | APE | Relat.Bias |
|---|---|---|---|---|---|
| 2 | 18 | 34% | 61% | 25% | -0.2 |
| 3 | 42 | 14% | 83% | 8% | -0.1 |
| 4 | 36 | 7% | 92% | 3% | 0.0 |
| 5 | 42 | 7% | 88% | 4% | -0.1 |
| 6 | 33 | 9% | 79% | 4% | 0.0 |
| 7 | 43 | 8% | 79% | 4% | -0.1 |
| 8 | 13 | 5% | 85% | 3% | -0.1 |
| 9 | 6 | 5% | 83% | 3% | -0.2 |
| 10 | 4 | 13% | 50% | 11% | -1.0 |
| **Total/Weighted mean** | **237** | **11 %** | **82 %** | **6 %** | -0.1 |

## Bias plot

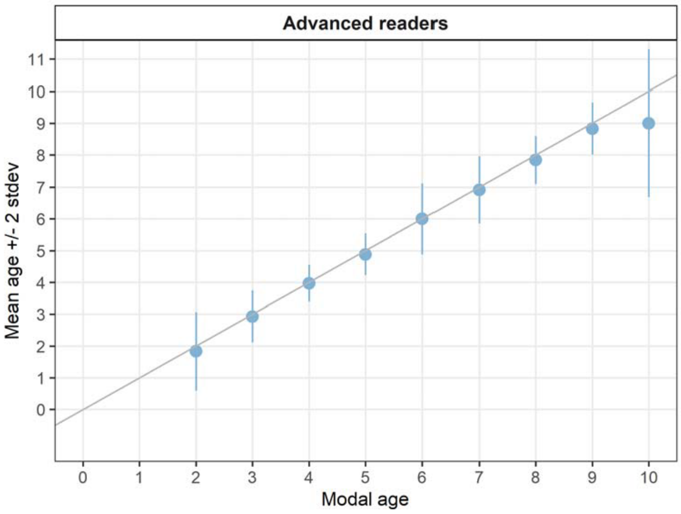


**Figure 1:** Age bias plot for advanced readers.

## Growth analysis

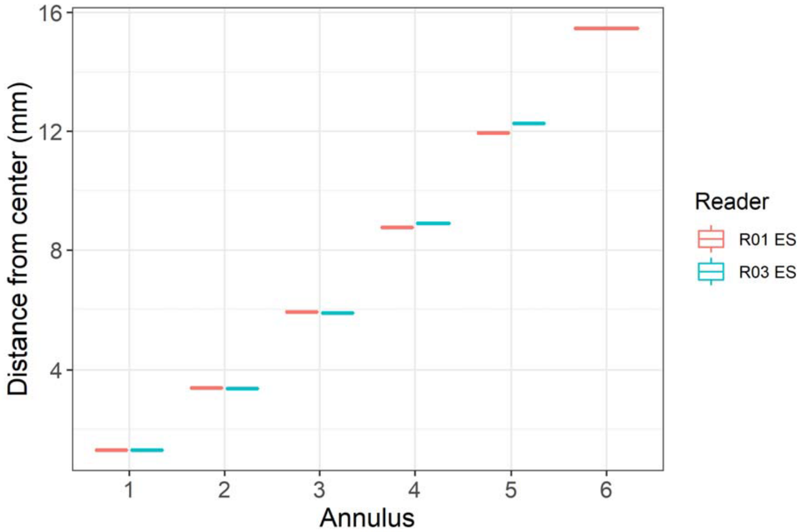


**Figure 2:** Plot of average distance from the centre to the winter rings for advanced readers. The boxes represent the median, upper and lower box boundaries of the interquartile range, whiskers extend no further than 1.5 * IQR (where IQR is the inter-quartile range) from the box boundary. Data beyond the end of the whiskers are represent outlers and are plotted individually.

## Age error matrices AEM

**Table 3:** General Age error matrix (AEM)

| Modal age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| **Age 1** | 0.3 | - | - | - | - | - | - | - | - |
| **Age 2** | 0.6 | 0.1 | - | - | - | - | - | - | - |
| **Age 3** | 0.1 | 0.8 | 0.1 | - | - | - | - | - | - |
| **Age 4** | - | 0.0 | 0.9 | 0.1 | - | - | - | - | - |
| **Age 5** | - | - | 0.0 | 0.9 | 0.1 | - | - | - | - |
| **Age 6** | - | - | - | - | 0.8 | 0.2 | - | - | - |
| **Age 7** | - | - | - | - | 0.1 | 0.8 | 0.2 | - | - |
| **Age 8** | - | - | - | - | 0.0 | 0.0 | 0.8 | 0.2 | 0.5 |
| **Age 9** | - | - | - | - | - | 0.0 | - | 0.8 | - |
| **Age 10** | - | - | - | - | - | - | - | - | 0.5 |

## 3.2. All readers

The new multistage approach considered here supposed reducing the percentage of samples with multiple modes from 13% obtained with the traditional approach to 0% using the new approach (**Table 4**).

The mean CV, APE and Relative bias by modal age for the stock assessment readers are shown in **Table 5**, highlighting the good results in relative accuracy. The overall bias of all readers is low, with values lower than ± 0.1 (between -0.08 and +0.06) up to age 6 (which represents approximately 93 samples, that is 77% of the otoliths read). The bias increases from age 7 (which represents only 27 samples, that is approx. 23% of the total) with values between -0.2 and -0.5. Considering that the analyzed samples are representative of commercial catches, the overall impact of this relative older age bias is small (**Figure 3**).

Similar mean distance from the center to each winter annulus for all readers (**Figure 4**), except for R05, although the low values of that reader in that figure is a methodological error in the generation of it by the program that does not correspond to the reality of distances of R05. R06 and R08 present lower values than the rest in rings 4, 5 and 6, which is related to the negative bias they have in those ages.

## Multimodal cases

**Table 4:** Summary of statistics; Total number of samples (NSample), a percentage of cases (fish samples) with multiple modes depending on the approach to weight the experience of the reader which will be considered when defining the fish age mode. PercMM_traditional shows the percentage of the total samples for which multiple modes are obtained when all the readers are equally weighted. PercMM_linear_weight shows the percentage of the total samples for which multiple modes are obtained when the weight assigned to the different readers decreases linearly with the experience, while in the PercMM_negexp the weight applied decreases with a negative exponential shape with the experience. The PercMM_multistage shows the percentage of multiple mode cases when a combination of the different methodologies is used, as explained in the material and methods section

| NSample | PercMM_traditional | PercMM_linear_weight | PercMM_negexp_weight | PercMM_multistage |
|---|---|---|---|---|
| 120 | 13 % | 0 % | 0 % | 0 % |

## Age readings, CV, PA, APE and Relative Bias

**Table 5:** The number of age readings, and the mean CV, PA, APE and Relative bias by modal age are presented for all advanced readers combined. The last row shows the total number of readings and the weighted mean CV, PA, APE and relative bias for all modal ages.

| Modal age | Num_read | CV | PA | APE | Relat.Bias |
|---|---|---|---|---|---|
| 2 | 33 | 24 % | 79 % | 12 % | **-0.03** |
| 3 | 60 | 10 % | 92 % | 4 % | **-0.05** |
| 4 | 52 | 8 % | 90 % | 4 % | **0.05** |
| 5 | 62 | 9 % | 89 % | 5 % | **-0.14** |
| 6 | 59 | 12 % | 68 % | 6 % | **-0.01** |
| 7 | 56 | 12 % | 68 % | 8 % | **-0.24** |
| 8 | 15 | 13 % | 60 % | 10 % | **-0.47** |
| 9 | 9 | 12 % | 56 % | 9 % | **-0.22** |
| 10 | 3 | 27 % | 67 % | 21 % | - |
| **Total/Weighted mean** | **349** | **12 %** | **79 %** | **7 %** | **-0.10** |

## Bias plot

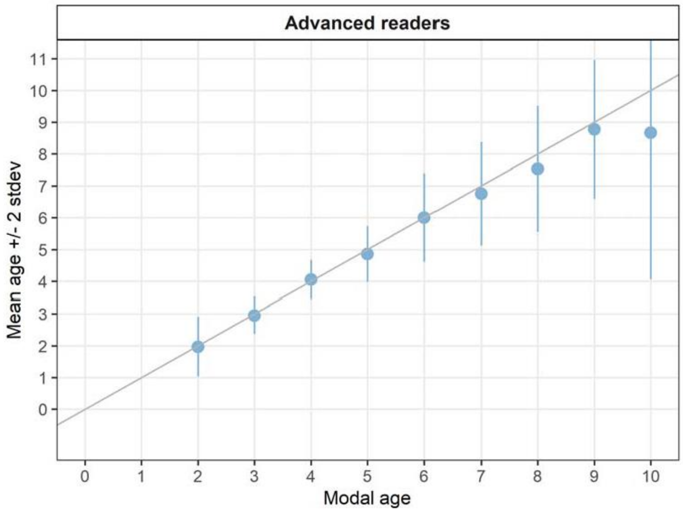


**Figure 3:** Age bias plot for advanced readers.

## Growth analysis

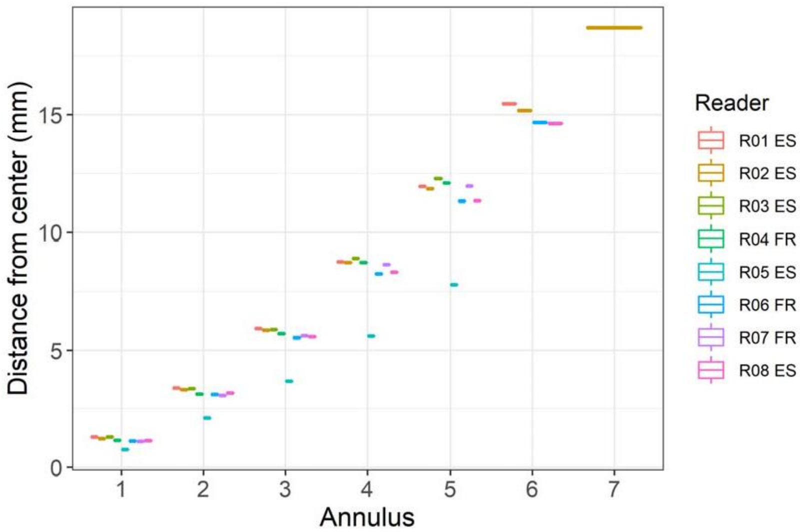


**Figure 4:** Plot of average distance from the centre to the winter rings for advanced readers. The boxes represent the median, upper and lower box boundaries of the interquartile range, whiskers extend no further than 1.5 * IQR (where

IQR is the inter-quartile range) from the box boundary. Data beyond the end of the whiskers are represent outlers and are plotted individually.

## Age error matrices AEM

**Table 6:** General Age error matrix (AEM)

| Modal age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| **Age 1** | 0.12121 | - | - | - | - | - | - | - | - |
| **Age 2** | 0.78788 | 0.06667 | - | - | - | - | - | - | - |
| **Age 3** | 0.09091 | 0.91667 | 0.01923 | 0.03226 | - | - | - | - | - |
| **Age 4** | - | 0.01667 | 0.90385 | 0.08065 | 0.03390 | 0.03571 | - | - | - |
| **Age 5** | - | - | 0.07692 | 0.88710 | 0.11864 | 0.03571 | 0.06667 | - | - |
| **Age 6** | - | - | - | - | 0.67797 | 0.16071 | 0.06667 | - | 0.3333 |
| **Age 7** | - | - | - | - | 0.15254 | 0.67857 | 0.20000 | 0.2222 | - |
| **Age 8** | - | - | - | - | 0.01695 | 0.08929 | 0.60000 | - | - |
| **Age 9** | - | - | - | - | - | - | 0.06667 | 0.5556 | - |
| **Age 10** | - | - | - | - | - | - | - | 0.2222 | 0.6667 |

# 4. Recomendaciones

### Stock assessment readers

Taking into account the good results of the readers which age readings contribute to the assessment process in Iberian Atlantic stock of megrim, no specific recommendation is considered for them.

### All readers

Readers R04 and R08 should analyze the underestimation of age that is detected in their readings, especially in otoliths older than 6. Reader R06 should analyze their overestimation of age, especially also in otoliths older than 6.

Those R04, R06 and R08 are readers with not extensive experience in megrim age estimation (experience in megrim from 2017-2019). Reviewing the images of this exchange of those ages older than 6 can help them improve their age interpretation criteria.

A reference collection, training in older ages and continue calibration EXs for all readers are recommended.

## Acknowledgements

Thanks to L. Rodríguez for preparing the images of the otolith collection for this exchange. Thanks to all the participants for contributing this exchange to perform properly.

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## Meg.27.7b-k8abd – Three proposed tuning indices

*Working document to WKMegrim – Hans Gerritsen – Marine Institute – 21/10/2021 – version 1*

### Introduction

This document describes three tuning indices that are made available to WKMegrim 2022:

1. A slight revision of the existing commercial TBB index
2. A new index based on the Irish Anglerfish and Megrim Survey
3. A new index based on the combined Irish and French IBTS surveys (IGFS and EVHOE)

### Irish Commercial TBB index

Ireland has historically provided a commercial TBB index for the 7b-k8abd megrim assessment. A minor change in the way this index is calculated is proposed here. This index is currently calculated by taking the average annual LPUE of Irish beam trawlers operating in the Celtic Sea and applying the age distribution of all Irish 7g landings to this.

The Irish beam trawl fleet operates mainly in area 7g (Figure 1). There are two more or less distinct patches and Figure 1 shows that the LPUE in the northern, inshore area (rectangles 32E2 and 31E1) is considerably lower than in the more southern offshore area (rectangles 31E3, 31E3, 30E2 and 30E3). Changes in the relative effort between the northern and southern area could lead to bias in the index, therefore, the revised index is only calculated for the rectangles 31E3, 31E3, 30E2 and 30E3 where the LPUE is consistently high and does not vary much in space. Figure 2 shows that the difference in the original and revised indices is relatively small; the revised index shows a slightly stronger increase in biomass in recent years. Table 2 provides the new index.

Because this is a commercial index, it is subject to biases caused by restrictive quota, discarding, market conditions and other changes in fleet behaviour over time. It is difficult to account for these factors and create an unbiased, fully standardised, index. Therefore, commercial indices are generally only used when no fishery-independent data is available. It is therefore not recommended to include the index in the assessment model unless it is absolutely necessary.

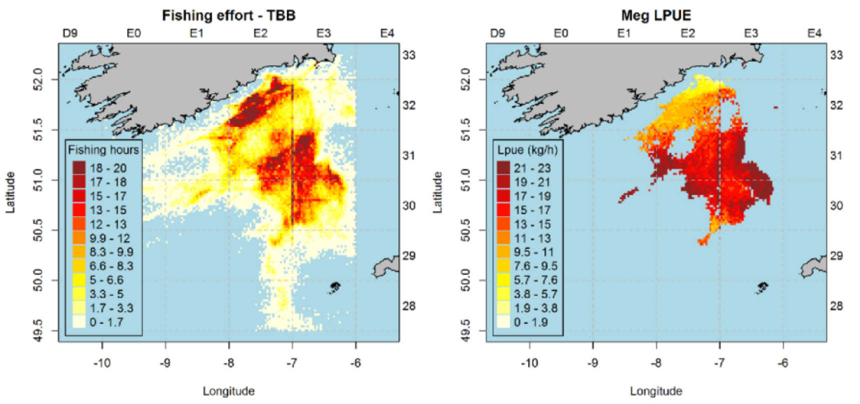



*Figure 1. Average annual beam trawl fishing effort and megrim LPUE during the period 2006-2020.*

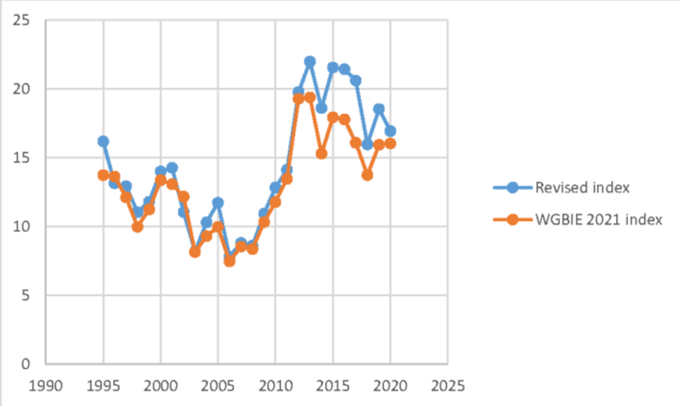



*Figure 2. The revised index and the index used at WGBIE 2021 (LPUE in kg/hour).*

*Table 1. Revised Irish TBB index (effort in fishing hours; numbers-at-age in thousands and landings in tonnes). Note that the numbers here are not standardised, to calculate an index, they need to be divided by the effort. The table is presented like this to match the 'lowestoft' format. Also note that the landings are provided; these could be used to calculate a biomass index, if required.*

| Effort | age2 | age3 | age4 | age5 | age6 | age7 | age8 | age9 | age0 | age11 | age12 | Landings (t) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25014 | 16 | 163 | 633 | 134 | 53 | 10 | 4 | 4 | 1 | 1 | 0 | #1995 | 343.8 t |
| 36146 | 5 | 177 | 451 | 645 | 177 | 45 | 30 | 9 | 2 | 0 | 0 | #1996 | 493.2 t |
| 35696 | 15 | 309 | 500 | 347 | 207 | 44 | 16 | 2 | 0 | 0 | 0 | #1997 | 432.8 t |
| 45484 | 2 | 465 | 584 | 196 | 116 | 37 | 19 | 3 | 0 | 0 | 0 | #1998 | 454.1 t |
| 51771 | 220 | 184 | 666 | 342 | 135 | 93 | 28 | 14 | 2 | 0 | 0 | #1999 | 582.6 t |
| 50327 | 14 | 1275 | 300 | 418 | 224 | 71 | 18 | 4 | 0 | 0 | 0 | #2000 | 673.4 t |
| 51561 | 43 | 389 | 795 | 430 | 206 | 84 | 25 | 5 | 2 | 0 | 0 | #2001 | 674.1 t |
| 31765 | 19 | 231 | 371 | 398 | 184 | 91 | 33 | 7 | 4 | 2 | 0 | #2002 | 386.4 t |
| 35167 | 20 | 166 | 406 | 311 | 139 | 30 | 7 | 4 | 0 | 0 | 0 | #2003 | 286.7 t |
| 32071 | 30 | 92 | 334 | 308 | 127 | 71 | 35 | 29 | 7 | 0 | 2 | #2004 | 298.3 t |
| 43438 | 38 | 229 | 338 | 520 | 333 | 139 | 31 | 9 | 1 | 1 | 0 | #2005 | 433.4 t |
| 61513 | 75 | 188 | 372 | 310 | 316 | 142 | 48 | 20 | 6 | 4 | 0 | #2006 | 459.7 t |
| 57995 | 81 | 401 | 405 | 378 | 258 | 195 | 92 | 29 | 7 | 1 | 1 | #2007 | 495.4 t |
| 38743 | 22 | 276 | 432 | 165 | 113 | 82 | 41 | 14 | 2 | 0 | 0 | #2008 | 324.2 t |
| 41813 | 3 | 168 | 465 | 457 | 144 | 87 | 31 | 18 | 15 | 0 | 10 | #2009 | 431.4 t |
| 38559 | 4 | 111 | 483 | 384 | 294 | 110 | 52 | 29 | 19 | 14 | 5 | #2010 | 453.9 t |
| 35186 | 20 | 180 | 535 | 368 | 312 | 104 | 36 | 15 | 12 | 9 | 4 | #2011 | 473.4 t |
| 38322 | 2 | 190 | 715 | 546 | 241 | 177 | 145 | 79 | 60 | 48 | 67 | #2012 | 739.1 t |
| 30325 | 13 | 185 | 423 | 488 | 265 | 102 | 67 | 21 | 38 | 23 | 33 | #2013 | 588 t |
| 33325 | 68 | 175 | 254 | 297 | 187 | 54 | 92 | 48 | 42 | 7 | 36 | #2014 | 509.5 t |
| 33218 | 102 | 443 | 250 | 198 | 203 | 139 | 115 | 91 | 56 | 48 | 26 | #2015 | 595.8 t |
| 34235 | 89 | 338 | 255 | 137 | 141 | 156 | 106 | 85 | 97 | 80 | 47 | #2016 | 608.7 t |
| 30864 | 137 | 447 | 337 | 151 | 98 | 93 | 106 | 87 | 76 | 46 | 60 | #2017 | 496.5 t |
| 32552 | 74 | 254 | 193 | 145 | 78 | 55 | 50 | 47 | 39 | 34 | 37 | #2018 | 447 t |
| 29257 | 77 | 434 | 318 | 123 | 83 | 63 | 54 | 53 | 50 | 42 | 37 | #2019 | 466.1 t |
| 23559 | 29 | 276 | 451 | 165 | 79 | 58 | 42 | 50 | 43 | 48 | 39 | #2020 | 377.8 t |

## Irish Anglerfish and Megrim Survey index.

Ireland has carried out the Irish Anglerfish and Megrim survey every year in Q1 since 2016. The time series is now long enough to construct an index.

The survey covers ICES areas 7bcjk and the western part of 7gh; station positions are random-stratified (Figure 3); the depth range is from around 50m to 1000m. The survey covers the main distribution area of megrim in area 7 and although area 8abd is not covered by the survey, this area only contributes around 10% of the landings. Therefore, the survey can be considered to cover the vast majority of the stock distribution.

The survey uses a relatively large mesh gear and the catchability of small megrim is relatively low. Because female megrim grow to a larger size than males, the catchability is expected to be different for the sexes. Therefore, a sex-specific index is provided as well as a combined-sex index.

Catches in numbers and weight were standardised by swept area (the mean wing spread multiplied by the distance over ground for each haul). A biomass index was calculated (Table 2). Sex-specific age-length keys were applied at the haul level and mean numbers per 10km2 swept area were estimated (Table 3). Either or both of these indices could be included into the stock assessment model.

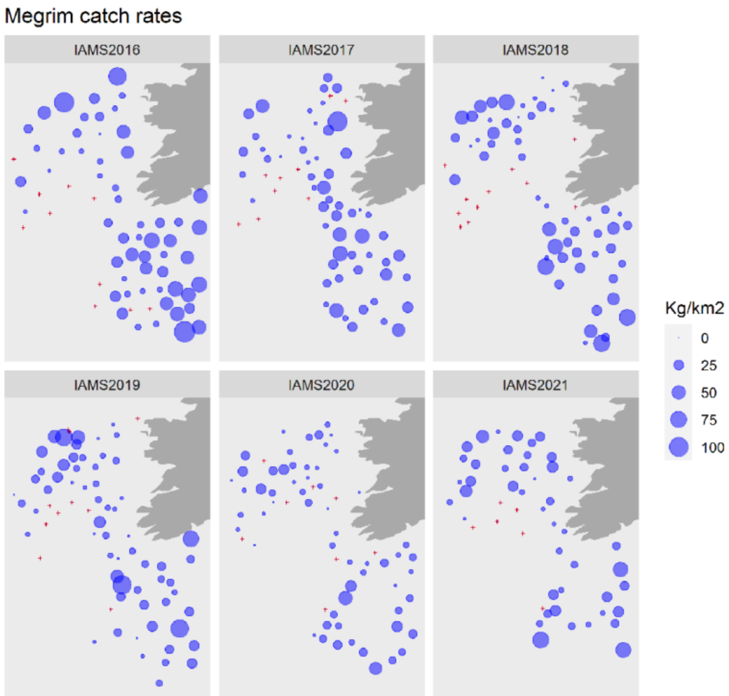



*Figure 3. Catch rates of megrim on the IAMS surveys (kg per swept area). Red symbols denote hauls with zero megrim catch.*

*Table 2. IAMS megrim biomass index.*

| CruiseName | Year | Season | NumHauls | WtKgMegKm2 | se |
|---|---|---|---|---|---|
| IAMS2016 | 2016 | Q1 | 66 | 21.73423 | 4.243139 |
| IAMS2017 | 2017 | Q1 | 67 | 16.64465 | 3.226559 |
| IAMS2018 | 2018 | Q1 | 67 | 17.74072 | 3.244777 |
| IAMS2019 | 2019 | Q1 | 72 | 14.68066 | 2.696829 |
| IAMS2020 | 2020 | Q1 | 67 | 9.255525 | 1.755685 |
| IAMS2021 | 2021 | Q1 | 51 | 14.81196 | 2.91474 |

*Table 3. IAMS megrim numbers at age per 10km2 swept area. Depending on the model a female-only, combined-sex or sex-specific index could be used.*

| | Female | | | | | Male | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Age** | **2016** | **2017** | **2018** | **2019** | **2020** | **2016** | **2017** | **2018** | **2019** | **2020** |
| 2 | 5.68 | 10.52 | 33.28 | 10.46 | 17.77 | 3.21 | 12.58 | 37.19 | 9.70 | 14.96 |
| 3 | 39.81 | 63.85 | 119.68 | 50.59 | 60.23 | 20.91 | 36.08 | 35.04 | 32.05 | 12.74 |
| 4 | 67.98 | 76.66 | 103.24 | 61.79 | 87.91 | 26.47 | 28.84 | 27.49 | 28.12 | 19.48 |
| 5 | 56.30 | 67.91 | 51.84 | 64.17 | 40.66 | 15.48 | 31.42 | 26.66 | 11.12 | 11.82 |
| 6 | 82.42 | 33.15 | 35.15 | 34.58 | 21.90 | 17.06 | 17.14 | 14.08 | 11.05 | 3.83 |
| 7 | 47.77 | 52.54 | 18.28 | 38.41 | 9.19 | 23.79 | 18.33 | 19.08 | 7.72 | 1.08 |
| 8 | 37.32 | 22.24 | 21.74 | 24.28 | 7.85 | 7.84 | 5.05 | 9.49 | 11.67 | 3.02 |
| 9 | 57.41 | 25.18 | 24.48 | 20.82 | 10.08 | 0.97 | 11.04 | 4.07 | 2.48 | 5.34 |
| 10 | 43.25 | 13.46 | 10.88 | 25.00 | 9.01 | 3.29 | 3.63 | 0.45 | 1.92 | 3.28 |
| 11 | 41.26 | 31.58 | 17.26 | 17.59 | 8.89 | 0.70 | 1.46 | 0.00 | 0.00 | 0.00 |
| 12 | 25.30 | 29.16 | 18.70 | 15.36 | 9.96 | 0.00 | 0.50 | 1.11 | 0.00 | 2.26 |
| 13 | 8.74 | 3.85 | 19.79 | 9.62 | 5.89 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 |
| 14 | 6.04 | 2.96 | 15.40 | 18.90 | 7.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 4.81 | 9.18 | 5.92 | 5.35 | 4.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 2.32 | 5.34 | 9.22 | 2.70 | 4.86 | 0.00 | 0.00 | 0.00 | 0.97 | 0.00 |
| 17 | 3.23 | 6.14 | 5.77 | 7.96 | 0.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18 | 0.85 | 4.14 | 1.88 | 1.91 | 3.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 0.00 | 1.02 | 0.00 | 1.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20+ | 0.00 | 3.75 | 3.63 | 3.45 | 1.92 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 |

### Combined Irish and French IBTS survey index

The Irish IBTS Q4 groundfish survey (IGFS-WIBTS-Q4) covers areas 27.7bgjk. The French EVHOE-WIBTS-Q4 survey covers areas 27.7j8ab (Figure 5). Both surveys are coordinated and largely standardised under WGIBTS and both use a GOV trawl. Together the two surveys cover the majority of the stock area up to depths of 200–300 m.

Data for Irish and French IBTS Q4 groundfish surveys (IGFS and EVHOE) were obtained from DATRAS, quality checked and cleaned. The two surveys were combined by weighting their average catches by the area covered by each survey series (IGFS gets a weight of approximately 45% and EVHOE 55%). The combined survey appears to give a more coherent recruitment signal than the two separate surveys (Figure 6; Table 4).

Sex-specific age-length keys were applied at the haul level and mean numbers per hour fished were estimated (Table 5). Either or both of these indices could be included into the stock assessment model.


*Figure 5. Megrim catch rates (kg/h) on the two surveys. The French survey was largely incomplete and the index could not be calculated for that year.*

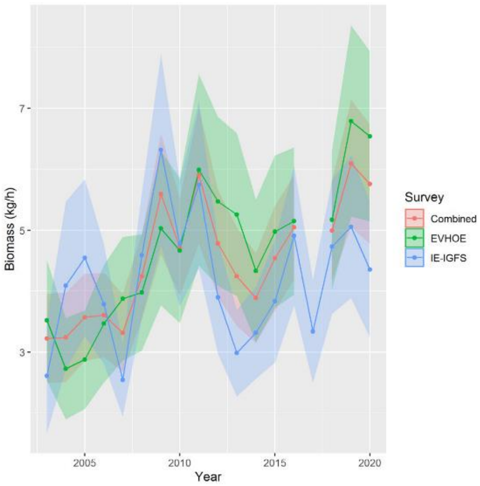



*Figure 6. Biomass index of the two surveys and the combined estimate.*

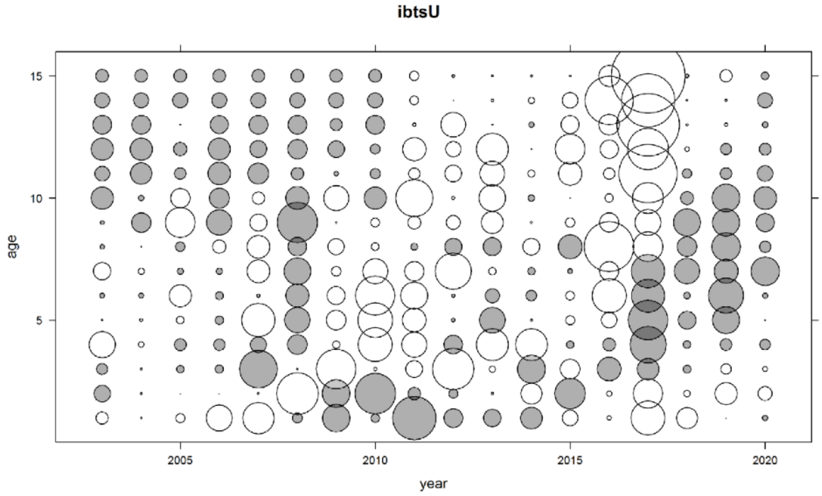
*Table 4. IBTS Megrim biomass index.*

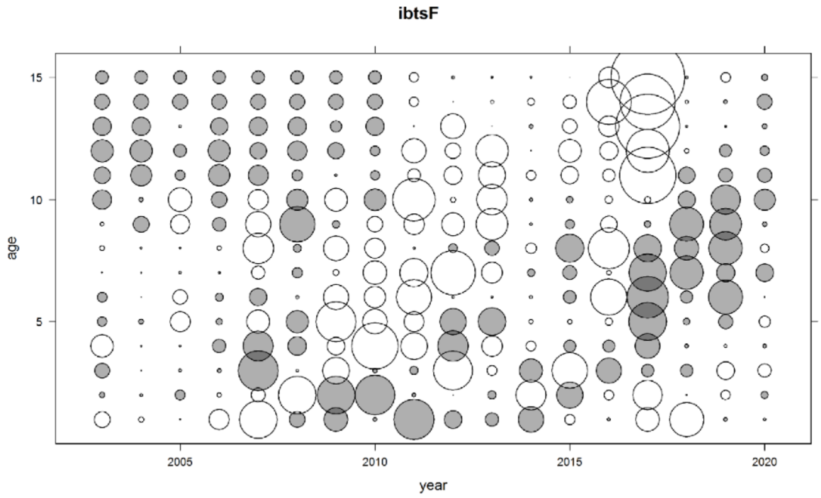
| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Kg/h | 3.23 | 3.24 | 3.57 | 3.61 | 3.32 | 4.24 | 5.59 | 4.72 | 5.90 |
| se | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 |
| **Year** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
| Kg/h | 4.78 | 4.24 | 3.89 | 4.54 | 5.05 | NA | 4.99 | 6.09 | 5.76 |
| se | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | NA | 0.51 | 0.52 | 0.52 |

*Table 5. IBTS Megrim numbers-at-age index (numbers per 10 hours fished).*

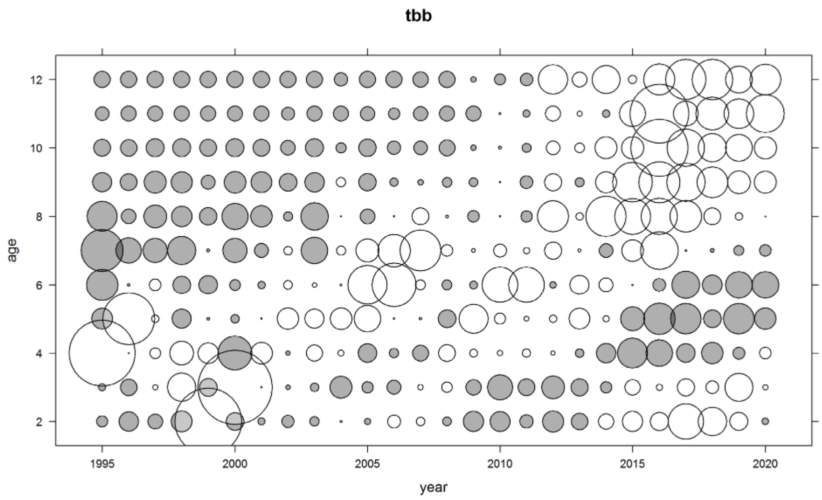
| Year | Sex | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | Female | 0.85 | 20.16 | 34.81 | 26.40 | 26.91 | 9.41 | 6.10 | 3.68 | 2.40 | 1.46 | 0.57 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004 | Female | 1.30 | 19.75 | 46.64 | 39.28 | 24.61 | 12.43 | 8.61 | 4.49 | 2.59 | 1.19 | 1.07 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2005 | Female | 1.28 | 17.77 | 39.59 | 37.50 | 25.43 | 17.48 | 10.43 | 4.26 | 2.62 | 2.24 | 1.74 | 0.48 | 0.25 | 0.41 | 0.00 | 0.00 |
| 2006 | Female | 1.09 | 26.67 | 48.11 | 37.79 | 20.75 | 12.29 | 7.72 | 4.35 | 2.94 | 1.27 | 0.79 | 0.18 | 0.01 | 0.02 | 0.00 | 0.00 |
| 2007 | Female | 0.12 | 27.59 | 42.99 | 16.51 | 12.01 | 14.78 | 5.22 | 4.44 | 3.55 | 1.98 | 1.35 | 0.18 | 0.12 | 0.00 | 0.00 | 0.00 |
| 2008 | Female | 0.44 | 10.89 | 65.97 | 39.85 | 18.53 | 8.67 | 8.19 | 3.65 | 2.24 | 0.58 | 0.64 | 0.46 | 0.08 | 0.00 | 0.00 | 0.00 |
| 2009 | Female | 3.34 | 8.89 | 28.40 | 60.77 | 36.65 | 25.78 | 14.03 | 5.77 | 4.79 | 1.72 | 2.03 | 0.82 | 0.18 | 0.17 | 0.00 | 0.00 |
| 2010 | Female | 2.66 | 15.92 | 22.53 | 36.23 | 40.19 | 18.17 | 11.13 | 6.14 | 3.71 | 2.10 | 0.62 | 0.50 | 0.32 | 0.00 | 0.00 | 0.00 |
| 2011 | Female | 1.44 | 0.30 | 46.97 | 38.17 | 37.06 | 18.97 | 14.27 | 7.18 | 3.02 | 2.48 | 2.40 | 1.20 | 1.28 | 0.40 | 0.40 | 0.20 |
| 2012 | Female | 1.81 | 9.66 | 43.45 | 54.88 | 13.92 | 7.58 | 8.54 | 7.59 | 2.13 | 2.26 | 1.23 | 1.20 | 0.92 | 0.83 | 0.22 | 0.08 |
| 2013 | Female | 0.86 | 9.39 | 31.86 | 33.97 | 25.02 | 5.91 | 6.90 | 4.73 | 1.48 | 2.06 | 1.50 | 1.16 | 1.09 | 0.28 | 0.21 | 0.07 |
| 2014 | Female | 1.81 | 5.22 | 48.23 | 21.98 | 22.04 | 11.05 | 6.99 | 3.03 | 2.54 | 1.35 | 0.84 | 0.78 | 0.45 | 0.23 | 0.26 | 0.07 |
| 2015 | Female | 1.45 | 21.32 | 29.63 | 53.89 | 20.38 | 13.80 | 6.79 | 3.27 | 1.10 | 1.36 | 0.98 | 1.18 | 1.11 | 0.63 | 0.42 | 0.10 |
| 2016 | Female | 3.01 | 17.94 | 54.85 | 29.59 | 22.77 | 16.12 | 14.47 | 5.17 | 5.36 | 2.35 | 1.46 | 1.18 | 1.12 | 0.85 | 1.01 | 0.30 |
| 2017 | Female | | | | | | | | | | | | | | | | |
| 2018 | Female | 1.45 | 43.14 | 60.84 | 44.15 | 31.74 | 16.00 | 9.41 | 2.44 | 1.80 | 0.84 | 0.99 | 0.41 | 0.89 | 0.44 | 0.37 | 0.11 |
| 2019 | Female | 1.25 | 29.64 | 91.78 | 85.80 | 47.15 | 18.97 | 7.74 | 5.51 | 1.56 | 1.28 | 0.79 | 0.68 | 0.47 | 0.72 | 0.32 | 0.34 |
| 2020 | Female | 1.95 | 23.16 | 57.26 | 62.26 | 33.01 | 21.70 | 11.86 | 4.27 | 4.32 | 2.13 | 0.89 | 0.51 | 0.46 | 0.38 | 0.00 | 0.08 |
| 2003 | Male | 2.09 | 21.68 | 27.20 | 31.33 | 33.21 | 13.73 | 5.13 | 2.84 | 0.43 | 0.20 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004 | Male | 1.34 | 14.81 | 34.28 | 33.44 | 26.77 | 14.03 | 3.57 | 1.76 | 0.71 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2005 | Male | 3.81 | 27.77 | 48.53 | 32.35 | 17.86 | 12.55 | 7.93 | 1.46 | 0.33 | 0.82 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2006 | Male | 4.08 | 39.19 | 48.11 | 37.80 | 26.74 | 13.85 | 5.73 | 1.89 | 1.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2007 | Male | 0.47 | 26.13 | 31.45 | 19.40 | 21.47 | 18.28 | 5.77 | 2.17 | 0.66 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2008 | Male | 0.86 | 18.47 | 63.75 | 36.56 | 19.06 | 8.63 | 1.02 | 0.38 | 0.08 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2009 | Male | 3.49 | 7.89 | 41.60 | 67.66 | 28.63 | 14.57 | 6.26 | 2.31 | 0.59 | 0.70 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | Male | 2.59 | 13.14 | 21.62 | 37.63 | 30.07 | 19.94 | 9.33 | 1.54 | 0.10 | 0.09 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2011 | Male | 0.98 | 0.04 | 31.29 | 55.13 | 33.69 | 18.45 | 5.65 | 0.78 | 0.21 | 0.07 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| 2012 | Male | 1.97 | 10.11 | 28.47 | 46.58 | 21.08 | 15.81 | 3.49 | 0.62 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2013 | Male | 1.20 | 7.72 | 31.97 | 26.08 | 29.31 | 6.84 | 1.29 | 0.27 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2014 | Male | 4.45 | 9.59 | 35.16 | 17.51 | 33.92 | 10.14 | 2.03 | 1.25 | 1.01 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2015 | Male | 3.58 | 21.60 | 18.41 | 23.67 | 18.33 | 11.71 | 6.26 | 1.60 | 0.54 | 0.60 | 0.10 | 0.09 | 0.08 | 0.01 | 0.00 | 0.00 |
| 2016 | Male | 3.34 | 24.29 | 40.14 | 27.16 | 20.74 | 17.64 | 6.72 | 2.67 | 1.70 | 0.39 | 0.08 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 |
| 2017 | Male | | | | | | | | | | | | | | | | |
| 2018 | Male | 5.53 | 32.28 | 66.04 | 49.08 | 30.39 | 11.32 | 7.58 | 3.15 | 1.22 | 0.65 | 0.26 | 0.33 | 0.08 | 0.15 | 0.00 | 0.00 |
| 2019 | Male | 5.98 | 29.04 | 79.26 | 45.30 | 19.98 | 6.84 | 2.80 | 1.09 | 1.00 | 0.44 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2020 | Male | 3.78 | 30.64 | 106.74 | 66.22 | 38.10 | 22.29 | 8.86 | 2.01 | 0.18 | 0.14 | 0.15 | 0.08 | 0.00 | 0.07 | 0.00 | 0.00 |

## Data exploration of the three indices

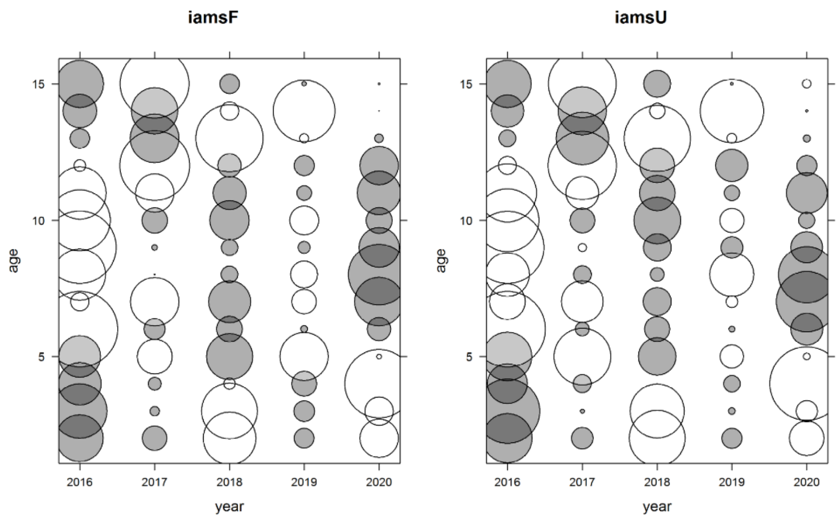


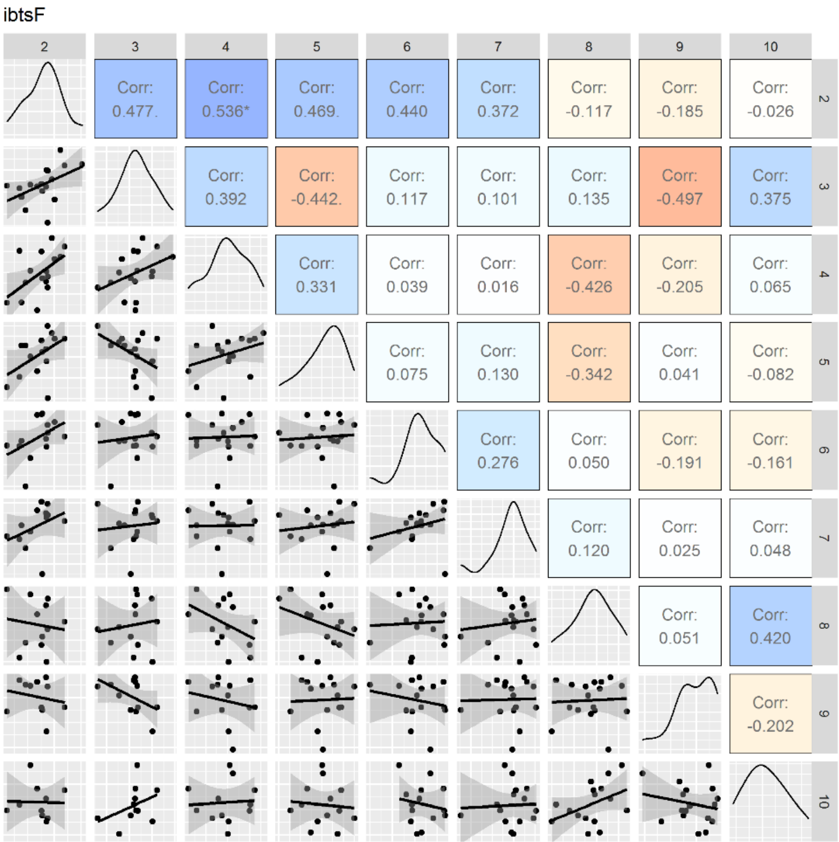

The combined Irish French IBTS index is able to track weak (white) and strong (grey) cohorts reasonably well from age 1 up to around age 5 or 6. At older ages the cohorts appear to blend into each other, which may indicate a problem with age determination; alternatively, this could be due to low sample sizes. The female-only index (ibtsF) appears to have slightly better cohort tracking than the combined-sex index (ibtsU).



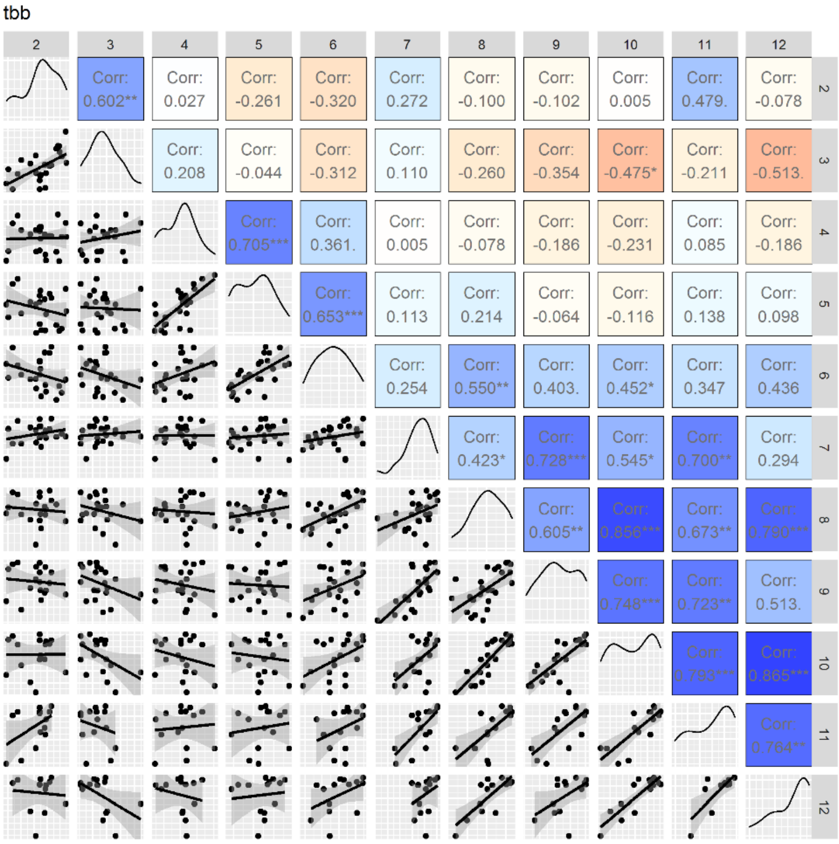

The beam trawl index tracks weak (white) and strong (grey) cohorts quite well up to age 7 or 8.




The IAMS index does not appear to track weak (white) and strong (grey) cohorts very well but the time series is quite short and recruitment variability is quite limited in this stock.



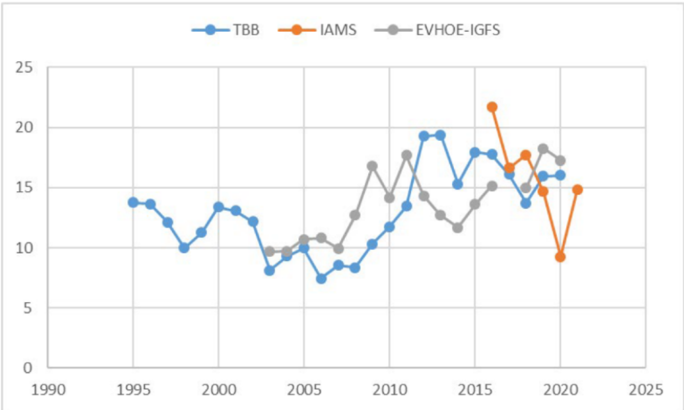

The IBTS female-only index has reasonable internal consistency (log index vs log index) for ages 2-5



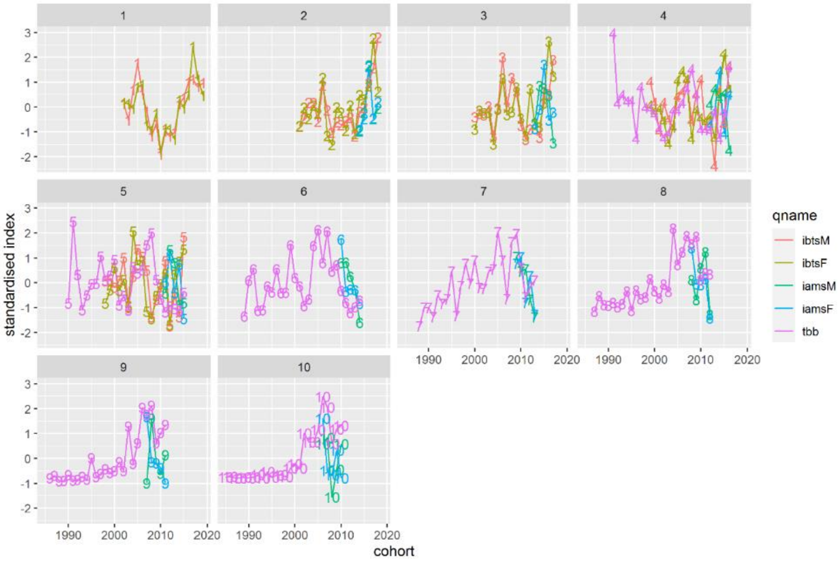

The TBB index has good internal consistency (log index vs log index) for nearly all age classes. This is not immediately apparent in the bubble plots. It may be an artefact of having a block of low values for older ages at the start and a block of high values at the end of the time series.

The IAMS index is too short to produce meaningful internal consistency plots

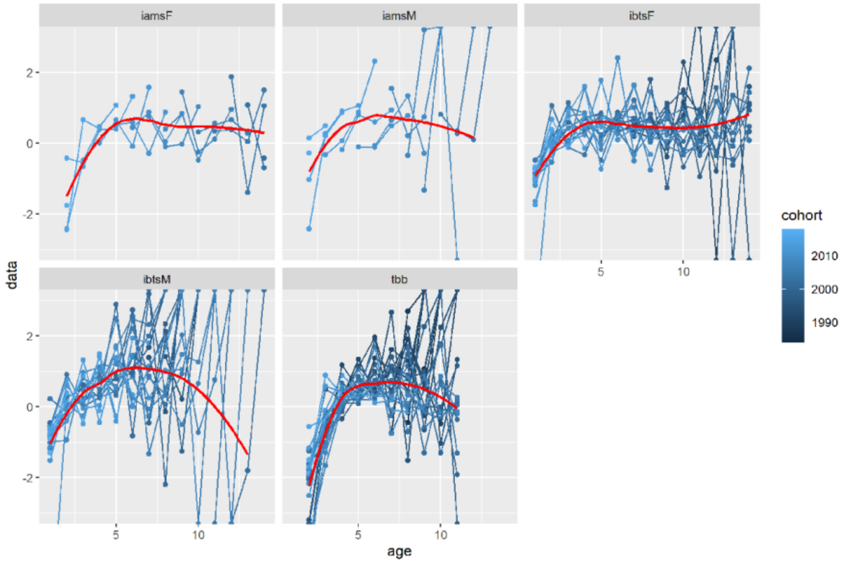

The plot above shows the standardised indices by cohort. The IBTS survey indices are fairly consistent: recent cohorts are relatively strong as well as the 2006 cohort. The IAMS survey is too short to show clear patterns. The TBB index also shows reasonably consistent in recent years but in the earlier years the older age classes did not show the same contrast as the younger age classes.




(bonus plot) The three irish biomass indices (kg/h; EVHOE-IGFS rescaled to kg/1/5h)




The three proposed indices agree reasonably closely with each other. The male and female IBTS indices show very similar trends as do the male and female IAMS indices. The IBTS, IAMS and TBB indices also agree fairly closely between them.




The catch curves of the survey indices (log index at age a+1 minus log index at age a for each cohort) can give an indication of selectivity at age as well as show how noisy the data are. The IAMS survey appears to have fairly flat selectivity from age 4 onwards; for IAMS males the data get quite noisy after age 8. The IBTS female index appears to have flat selectivity from age 2 onwards and gets noisy after age 10, the male index gets quite noisy from age 5 onwards. The TBB index only fully selects fish from age 5 onwards (discards are not included in the index) and the data get noisy after age 7.

## Conclusion

The commercial TBB index has a reasonably long time series and appears to be have relatively good internal consistency for some age classes. However, it is not recommended that this index is included in the assessment model as it is not possible to standardise a commercial index to the extent that it is unbiased. However, if the index is included, it is recommended to only include age classes 4-7 as young fish are more subject to (variable) discarding practices and older fish show poor consistency. A flat catchability could be assumed.

The combined French Irish IBTS survey also performs reasonably well. A choice would have to be made to use the combined-sex index, or the female-only. As there was no great difference between the female-only and combined-sex indices, the latter may be the most sensible. It is recommended to include age classes 1 to 10, although the very low value of 1-year-olds in 2011 may cause problems. Selectivity appears to be quite flat after age 2.

The IAMS survey time series is still quite short, which makes it difficult to evaluate the consistency of the data. However, this survey covers the majority of the stock, including the deeper water where the IBTS surveys do not fish. It is therefore recommended that this index is included in the assessment model. The survey does not have very good catchability for small fish so an age range of 3-12 might be most appropriate. Perhaps even older age classes can be included. Selectivity appears to be flat after age 3.

| Index | Suggested age range | Suggested Q model |
|---|---|---|
| TBB (not recommended) | 4-7 | ~1 |
| IBTS combined sexes | 2-10 | Logistic: ~I(1/(1 + exp(-age))) or ~factor(replace(age,age>3,3)) |
| IAMS combined sexes | 3-12 | Logistic: ~I(1/(1 + exp(-age))) or ~factor(replace(age,age>4,4)) |

## Meg.27.7b-k8abd – Maturity data from Irish groundfish surveys.

Working document to WKMegrim – Hans Gerritsen – Marine Institute – 21/10/2021 – version 1

### Introduction

This document describes the estimation of maturity parameters from Irish survey data.

The Marine Institute, Ireland, has conducted an annual Q4 groundfish survey (IE-IGFS) since 2003. This survey mainly covers areas 7bgj (Figure 1). Since 2016, Ireland has also carried out an annual Q1 anglerfish and megrim survey (Q1 IAMS), this survey mainly covers areas 7bcjk (Figure 1). Additionally, a number of Q1 groundfish surveys (Biological Sampling Survey; BSS) were undertaken during 2004-9 with the aim to collect maturity data during the main spawning season for most demersal fish species. The spatial coverage of the BSS varied from year to year (Figure 1). Age data from all these surveys are available in DATRAS. Maturity data is currently not uploaded to DATRAS; the raw maturity data can be made available if required by contacting hans.gerritsen@marine.ie

### Analysis

Biological data (age, maturity) is generally collected on a length-stratified basis, therefore the data need to be weighted by the numbers-at-length in the catches to avoid bias. This weighting is generally done through the use of age-length keys. Sex-specific age-length keys were constructed and applied to the length frequency distribution of the catches. Age length-keys were applied initially at the haul level and any remaining gaps were filled in by applying ALKs for the combined hauls on the survey.

Megrim spawn in winter and early spring and during the Q4 surveys many fish that will spawn in the following season can be distinguished from immature fish that will not spawn (by visual inspection of the gonads). However, there may be some fish for which it is difficult to determine whether they will spawn. The Q1 surveys generally took place after the peak of spawning but it is believed that these data are slightly more reliable in distinguishing mature and immature fish.

Initial data explorations indicated that length is the main predictor of maturity. For some species age is also an important factor after length has been taken into account (e.g. a 2-year old fish of 25cm may less likely to be mature than a 3-year old of the same length), however this does not seem to be the case for megrim. There were only small differences in maturity-at-length between the sexes but because there is considerable sexual dimorphism in other life-history parameters, estimates were produced separately for the two sexes. Figure 1 shows the proportions of mature fish at length. Up to around 30cm the proportions increase in approximately logistic curve. Larger fish often have lower proportions mature than expected from the initial shape of the curve. This could indicate skipped spawning or an inability to identify some fish as being mature at the time of sampling. Because of the poor fit of the logistic curve for older fish, it was assumed that these were incorrectly assigned as immature and fish under 30cm were excluded from the model fit.

A glm with a binomial link function was fitted as follows:

Mature ~ Length * Sex * SurveySeries

This model was applied to the length-frequency-at-age data to predict proportions mature-at-age (model predictions were extended beyond 30cm to cover all size classes).

For fish sampled in Q4, the age classes were corrected for the age the fish would be during the spawning season; i.e. a 2-year old fish that is ripening in Q4 is assumed to spawn as a 3-year-old fish in Q1 of the next year. Figure 3 and Table 1 show the resulting estimates. The estimates for the IAMS are consistently higher than those of the other two surveys. For Q4 IGFS this could be due to an inability to identify which fish will spawn in the coming season. The geographic distribution of the samples may also play a role. The IAMS has the broadest coverage of the 7b-k area and is therefore likely to be the most representative of the stock. For this reason, only the IAMS estimates are included in Table 1.

Figure 4 shows that no clear trends could be identified in the proportions mature over time.

*Table 1. Proportions mature at age from the Q1 IAMS survey only.*

| Sex\Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ |
|---|---|---|---|---|---|---|---|---|---|---|
| F | 0.12 | 0.42 | 0.63 | 0.76 | 0.85 | 0.90 | 0.93 | 0.95 | 0.97 | 0.99 |
| M | | 0.38 | 0.52 | 0.64 | 0.74 | 0.82 | 0.82 | 0.90 | 0.92 | 0.97 |

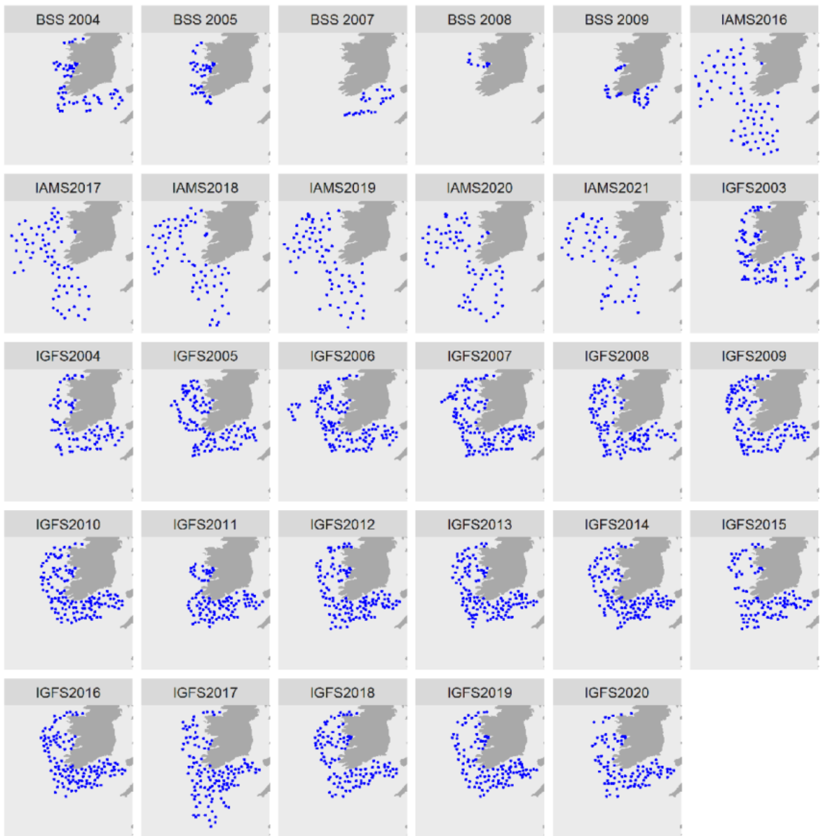



*Figure 1. Spatial coverage of the Q1 Biological Sampling Survey (BSS), Q1 Irish Anglerfish and Megrim Survey (IAMS) and the Q4 Irish GroundFish Survey (IGFS).*

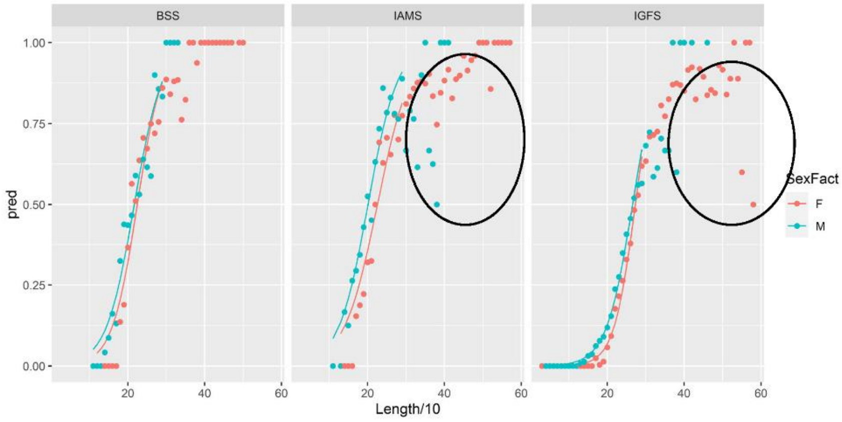



*Figure 2. Proportion of mature megrim at length. The colours correspond to the age classes and the panels correspond to the survey series and sex. Points are observations and lines are the modelled estimates.*

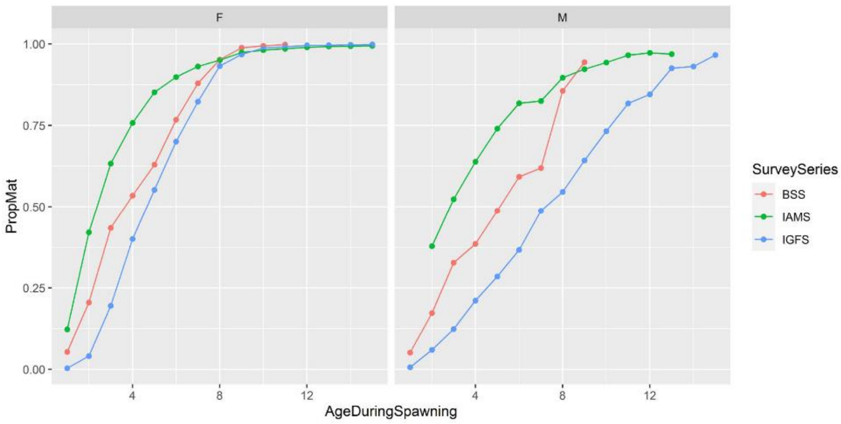



*Figure 3. Proportions of mature megrim at age.*

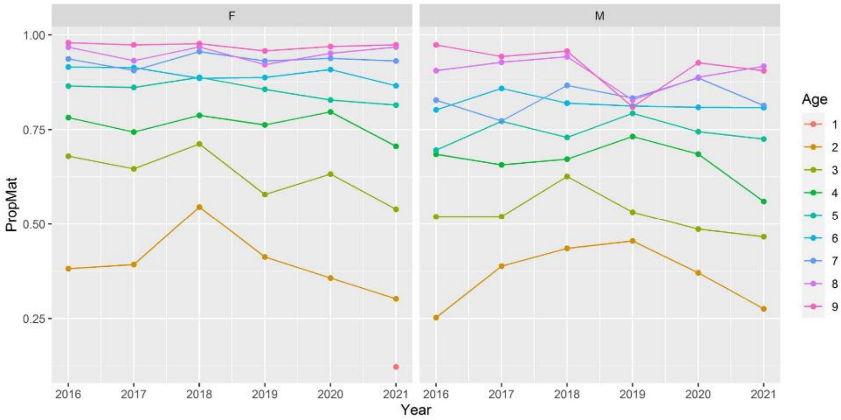



*Figure 4. Proportions of mature megrim at age over time.*

## meg.27.7b-k8abd - Ireland

### Fisheries dependent data

Ireland reviewed the IRL TBB tuning index and proposes a slight revision to the way the index is calculated. See working document: WKMegrim_2022_meg.27.7b-k8abd_indices.docx which was submitted to data.call@ices.dk

### Scientific survey data

The same working document also provides a proposal for a new index, based on the Irish Anglerfish and Megrim Survey and a combined IGFS-EVOE index, which is similar to the combined index used for anglerfish.

These survey indices were not requested in the data call but it is recommended that they are included in the new in the assessment.

### Life-history data

Ireland submitted a working document to data.call@ices.dk: WKMegrim_2022_meg.27.7b-k8abd_maturity.docx. This document provides updated maturity ogives, based on Irish sampling data. The raw data was also made available (WKMegrim_2022_meg.27.7b-k8abd_maturity_bio.csv and WKMegrim_2022_meg.27.7b-k8abd_maturity_lfd.csv)

# Annex 5: Reviewer report

To be attached.

# Annex 6: Stock annex edits

- ICES. 2023. Stock Annex: Four-spot megrim (*Lepidorhombus boscii*) in divisions 8.c and 9.a (southern Bay of Biscay and Atlantic Iberian waters East). ICES Stock Annexes. Report. https://doi.org/10.17895/ices.pub.23261030
- ICES. 2023. Stock Annex: Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b-k, 8.a-b, and 8.d (west and southwest of Ireland, Bay of Biscay. ICES Stock Annexes. Report. https://doi.org/10.17895/ices.pub.23261078
- ICES. 2023. Stock Annex: Megrim (*Lepidorhombus whiffiagonis*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters). ICES Stock Annexes. Report. https://doi.org/10.17895/ices.pub.23261081