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Report of the Benchmark Workshop on Anglerfish Stocks in the ICES Area (WKANGLER)

12–16 February 2018

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International Council for the Exploration of the Sea

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Contents

Executive summary

WKAnglerfish is a two-part benchmark workshop aimed at improving the scientific advice on anglerfish (*Lophius* spp.) stocks in the Northeast Atlantic. The report covers both workshops with the first workshop focused on the compilation and evaluation of data available for use by the assessment workshop. The data evaluation workshop, at IPMA in Portugal, was attended both physically and remotely by eleven scientists from Portugal, Spain, France, Ireland, UK and the Netherlands.

Landings, discards, survey data and commercial catch and effort data for all anglerfish stocks were reviewed and collated during the data workshop. Data on proportion of each species in the catch, weight, natural mortality, maturity and growth were also reviewed. Stock structure remains a major source of uncertainty. Given the spatial extent of the species and potential overlap of each unit, further investigation would be recommended to identify unique biological stock units with associated mixing rates. Other areas which require further investigation is the need for survey data on the larger fish and sampling levels to fully cover sex and species-specific data.

All the terms of reference were covered during the data workshop and an agreement was reached on the data for to use for an assessment, projections and reference points of each stock reviewed.

The second workshop, attended by 16 scientists and three reviewers, focused on the assessment, reference points and forecasts methods of the six stock units. For the two southern units in ICES divisions 8.c and 9.a, the assessments remained as category 1 where *Lophius budegassa* included a change of method used and *Lophius piscatorius* remained in an SS3 framework with a number of refinements to the model structure. For the two northern shelf stocks in ICES area 7 and divisions 8.abde, *Lophius piscatorius* had an agreed category 1 assessment with reference points and forecast. The stock unit *Lophius budegassa*, remained a category 3 with a change to the data used for assessing the status of the stock and subsequent advice. For the two most northerly stocks there was no change to the assessments or category.

For those stocks with category 1 assessments, the workshop reviewed and agreed on the methods used to calculate reference points and forecasts. Those with category 3 assessment methods, proxy reference points were not available and future work is recommended.

1 Introduction

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

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

The Stock Annex describes the methodology agreed by the benchmark workshop and the assumptions on which this is based. If an expert group finds that assumptions are no longer valid, or that new data or methods available might improve the assessment, experts are asked to put forward proposals for changes in the methodology and a renewed benchmark.

WKAnglerfish is a two-part benchmark workshop aimed at improving the scientific advice on anglerfish (*Lophius* spp.) stocks in in the Northeast Atlantic. This report covers both workshops with the first workshop focused on the compilation and evaluation of data available and the second workshop focusing on the assessment methodology described above.

The WKAnglerfish team included several external expert reviewers appointed to help in developing the stock assessments, to provide an expert review of the process and outcomes and to provide advice on future development needs. Section 2 of this report includes their comments on the work done and recommendations made by the data evaluation team in Sections 3 and 4 of the report.

This benchmark considered anglerfish in the following areas:

Lophius piscatorius in ICES divisions 8.c and 9.a;

Lophius budegassa in ICES divisions 8.c and 9.a;

Lophius piscatorius in ICES divisions 7.b–k and 8.abd;

Lophius budegassa in ICES divisions 7.b–k and 8.abd;

Anglerfish in ICES Division 3.a, ICES subareas 4 and 6; and

Anglerfish in ICES subareas 1 and 2.

The Northern Shelf stock (Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in subareas 4 and 6 and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat; anf.27.3a46) last underwent two benchmarks in quick succession at WKROUND (ICES, 2013) and WKFLAT (ICES, 2012). Alongside the typical data evaluation and updates to the stock annex, the focus of these benchmarks was the consideration of a preliminary survey-at-age-based assessment model, using data from the dedicated industry–science anglerfish surveys in Subarea 6 and Division 4.a SCO-IV-VI-AMISS-Q2 survey and reported catches from 2005–2011. Concerns about the sensitivity of the model to assumptions about age were raised, and there has been no further work towards development of the q1 model. WKAnglerfish compiled and reviewed all available information and data relevant to the assessment, including: stock identity; the history of fishery management measures; biological parameters (growth, natural mortality and age determination); commercial fisheries catch and length compositions; fishery selectivity patterns and relative abundance indices. Data quality indicators, where available, were tabulated. WKAnglerfish identified the most appropriate data and began compilation of these in a form suitable for use in assessment models. Candidate values for age and length-dependent natural mortality (M) were reviewed using published life-history based methods, including using e Then *et al*., (2015) updated Hoenig t_{max} based estimator and the updated Pauly growth-based method among others. A main focus of WKAnglerfish for the Northern Shelf stock is the identification and evaluation of suitable survey indices that predate the SCO-IV-VI-AMISS-Q2 survey which is still considered a relatively short time-series (2005–2017). Whilst some datasets for this stock have been reviewed in previous benchmarks (ICES, 2012; ICES, 2013) the absence of an analytical assessment for this stock (anf.27.3a46) since 2003 has meant that many parameters have not been revisited for some time.

Table 1.1. History of benchmark and update assessments for anglerfish.

Stocks	Meeting	Year	Assessment	Changes made to data and assessment procedure
anf.27.3a.46	WKANGLER	2018	Current report	New NS-IBTS-Q1 and NS-IBTS-Q3 survey indices, Update of historical landings volume and LFD 2002–2016 and discard volume and LFD 2008–2016.
	WGCSE	2012–2017	Precautionary approach. ICES approach to data-limited stocks (Category 3.2).	Updates to SCO-IV-VI-AMISS-Q2 survey data and updates to catch data where available. ICES Division 2.a removed from WGCSE ToR in 2013.
	WKROUND	2013	Precautionary approach. ICES approach to data-limited stocks (Category 3.2).	WKROUND evaluated an updated survey-at-age based version of the assessment model developed at WKFLAT & sensitivities to alternative assumptions about age given length.
	WKFLAT	2012	No assessment.	Benchmark concluded that an age-based assessment could be considered if internal consistency was examined and sensitivities to growth assumptions considered.
mon.27.8c.9a	WKANGLER	2018	Current report	
	WGBIE	2012–2017	Analytical assessment (Stock Synthesis model) (Category 1)	Annual update of landing data and abundances indices (assessment model and settings were approved in the benchmark WKFLAT-2012)
	WKFLAT	2012	Analytical assessment	Stock synthesis model was approved. New data: Length composition of landings and abundance indices. Two commercial abundance indices (SP-CORTR8c, SP-CEDGN8c) and 1 scientific survey (SpGFS-WIBTS-Q4) The growth pattern used in the assessment follows a von Bertalanffy model with fixed k=0.11 and Linf estimated by the model. Length–weight relationship and maturity ogive.
ank.27.8c.9a	WKANGLER	2018	Current report	
	WGBIE	2012–2017	Analytical assessment (ASPIC production model) (Category 1)	Annual update of landing data and biomass indices (assessment model and settings were approved in the benchmark WKFLAT-2012). B1/K fixed at 0.6 since the WGBIE2014, after recommendation of ADGBBI (June 2013)

Stocks	Meeting	Year	Assessment	Changes made to data and assessment procedure
	WKFLAT	2012	Analytical assessment (ASPIC production model) (Category 1)	The previous ASPIC production model was approved with the following data and settings: Catch data range: Since 1980 Cpue Series 1 (years): PT-TRC9a (since 1989) Cpue Series 2 (years): PT-TRF9a (since 1989) Index of Biomass (years): **(New data)** SPCORTR8c (1982-2012) Error Type: Condition on yield Number of bootstrap: 1000 Maximum F: 8.0 (y-1) Statistical weight B1/K: 1 Statistical weight for fisheries: 8.59E-01; 1.20E+00; 9.81E-01 B1-ratio (starting guess): 0.6 MSY (starting guess): 1.81126E+03 t K (starting guess): 1.81126E+04 t q1 (starting guess): 8.2523E-04 q2 (starting guess): 1.1196E-07 q3 (starting guess): 2.7279E-07 Estimated parameter: All Min and Max allowable MSY: 1.81126E+02 (t); 3.62252E+03 (t) Min and Max K: 1.81126E+03 (t); 3.62252E+05 (t) Random Number Seed: 1025957
mon78abd	WKAngler	2018	A4a	New statistical catch-at-age model Update of 2012–2016 time-series of landings and discards volume and LFD New combined FR/IE IGFS survey index New IE Monkfish index
	WKFLAT	2012	None	Update of historical landings volume and LFD
Ank78abd	WKAngler	2018	No assessment (survey trends)	New combined FR/IE IGFS survey index. Biomass to be used as basis for the advice Update of 2012–2016 time-series of landings and discards volume and LFD New IE Monkfish index

1.1 Issue lists

1.1.1 Black-bellied anglerfish (*Lophius budegassa*) in divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay) (ank.27.78abd) and White anglerfish (*Lophius piscatorius*) in divisions 7.b–k, 8.a–b, and 8.d (southern Celtic Seas, Bay of Biscay) (mon.27.78abd)

Landings

1) Problem: Landings (tonnage) data available to the WKBIE are inconsistent in terms of fleets and temporal aggregation (annual/quarterly) (high priority)

Progress made: a data call was issued for the landings and discard volume and length distribution from 2002 to 2016. The data were uploaded to InterCatch by the major countries involved in the fishery. Belgian data were only submitted from 2011 onwards (~3% of total landings). Germany and Netherlands did not submit data but these countries landed <20 t per year. There were some issues with data submitted annually, rather than by quarter. WD06 describes the quality checks and procedures for estimating missing data in detail, see Annex 3.

WKFLAT 2012 compiled landings data for the years 1996 to 2010; however, the fleet groupings of WKFLAT did not match those available from the most recent data call.

Conclusion: the only remaining problem with the landings data is that the mismatch between the fleet groupings.

2) Problem: Landings (tonnage) data before 1996, only annual official landings, all fleets combined. (low priority)

Progress made: Historic landings data were compiled from 1903 onwards but no data by fleet or quarter or length distributions were available

Conclusion: landings data from 1903–1986 are available but of unknown quality.

3) Problem: landings length data are of poor quality with different levels of aggregation in terms of length class bins. (high priority).

Progress made: length distributions were compiled from the data submitted to InterCatch following the data call (see WD06 for details).

The length data compiled by WKFLAT 2012 was combined with the latest set of data to form a time-series from 1986 to present. All fleets were combined as the WKFLAT fleet groupings did not match those available from the most recent data call. The data show consistent cohort tracking and no remaining quality issues were identified (WDXXX).

Conclusion: The time-series of length data from 1986 (all fleets combined) seems of sufficient quality to be used in an assessment.

4) Problem: Historic underreporting is poorly documented. (low priority)

Progress made: There is no available documentation of Spanish landings correction. Other countries also applied some corrections to the landings data but these are generally minor.

Discards

1) Problem: Discard (tonnage) is unknown and may have changed over time (medium priority)

Progress made: discard data were submitted to InterCatch following the data call. Data for the main countries were available for 2003 onwards (only Spain submitted data prior to 2003). See WD06 for details.

Conclusion: Discard data from 2003 onwards appear to be of reasonable quality. The discard rates are somewhat variable, but generally low (<10% of the catch). Discard data prior to 2003 will need to be estimated.

2) Problem: Discard length data are unavailable. (medium priority)

Progress made: length distributions were compiled from the data submitted to InterCatch following the data call (see WD06 for details). The data appear to be of consistent quality.

Conclusion: The time-series of length data from 2003 (all fleets combined) seems of sufficient quality to be used in an assessment.

Species split

Problem: Quality of species allocation of mixed landings to *L pis* and *L bud* is unknown (medium/high priority)

Progress made: descriptions of the methods used for splitting unspeciated landings were made available by: Ireland, France, Spain and the UK. For 2002–2016 the species proportions by country, fleet, area, etc. were also available in InterCatch. The data showed consistent trends over time between countries.

Conclusion: the assignment of the landings to the two species appears to be of reasonable quality although this will add some uncertainty to the landings figures.

Commercial tuning data

Problem: lack of reliable effort and lpue data (medium priority)

Progress made: The quality of the Spanish Vigo lpue dataset was reviewed. While there are no indications of changes in targeting behaviour, the number of vessels fleet has been severely reduced. This increases the risk of bias.

A new Irish otter trawl tuning fleet was developed (see WD 01). This fleet is available from 1995 and is therefore the longest available time-series. The trends of the Irish fleet are similar to those of other countries in years for which international data are available.

Conclusion: While commercial tuning fleets have a risk of bias, they may be valuable for the years where no survey data are available

Survey data

Problem: Not all survey data are available to WGBIE. Many surveys only cover part of the stock (high priority)

Progress made:

- The Spanish porcupine survey (2001–) catches mainly larger fish and only covers part of the stock. Data are only available for *L pis* due to low catches of *L bud*.
- The Irish and French IBTS surveys (IGFS and IBTS; 2003–) together cover most of the juvenile on the continental shelf. A combined index was produced. (see WD 08)
- The Irish monkfish survey has a short time-series (2007, 2008 and 2016, 2017). However this survey is specifically designed for monkfish and has a good coverage of the stock. (see WD 09)
- TBB-SW-Q1-ICOS – UK will work on
- French *Nephrops* surveys may have useful information
- Irish beam trawl survey 20016–2017 may have some information

Conclusion: there are a number of surveys available that may be suitable for use in an assessment.

Growth parameters

Problem: No reliable growth parameters available (medium priority)

Progress made: The strong contrast in recruitment strength and fast growth allows strong and weak cohorts to be tracked for many years. A number of approaches have been developed to exploit this in order to estimate reasonable growth parameters. See WD04, etc. for more details.

One of the main remaining problems is the difference in growth between males and females.

Conclusion: A number of different sets of growth parameters will be used for splitting the length distributions into cohorts.

Age data

Problem: No agreed method for ageing monkfish (low priority)

Progress made: none

Conclusion: length-splits, based on estimated growth parameters will be more reliable than using unvalidated age data.

Stock identity

Problem: Stock identity is unknown (medium/low priority)

Progress made: Literature review (genetics / morphometrics / tagging); analysis of species distribution at different life stages from survey data; spatial analysis of lpue data. See WD 13

Conclusion: Although there is some evidence of structure, there appears to be significant mixing across current stock boundaries. However there was not sufficient information to change these stock definitions. Genetic work is ongoing.

Biological data

1) Problem: Natural mortality unknown

Progress made: review of available methods for estimating M. A plausible range was identified. See WD 12

2) Problem: Maturity unknown

Progress made: review of literature and data from labs. A plausible range was identified (both species, both sexes). See WD 11

3) Problem: Growth of males and females is quite different. However, landings data are not available by sex.

Progress made: review of sex ratio data from surveys confirmed that males are more abundant at medium sizes and the females dominate the larger sizes; indicating that they grow to a larger size. It is unknown whether males suffer different natural of fishing mortality.

Conclusion: the survey data are of insufficient quality to apply these data to the catches for a separate-sex assessment.

1.1.2 Black-bellied anglerfish (*Lophius budegassa*) in divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters) (ank.27.8c9a and White anglerfish (*Lophius piscatorius*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters) (mon.27.8c9a)

Stock structure

Problem: Stock structure is not perfectly known.

Progress: The available literature (including parasite studies, genetic analysis, tagging studies and morphometric analysis) was reviewed. Some evidences of population mixing across stocks were found. The current boundaries of these stocks could not be redefined based on the available information.

Conclusion: There was not sufficient information to change the current stock areas.

Landings

1) Problem: check historical stock landings

Progress: A data call was made for landings and discard volume and length compositions from 2002 to 2016. The data were uploaded to InterCatch by métier and quarter for Portugal and Spain. New French data were also submitted from 2002 onwards (<1% of total landings).

Conclusion: Landings have been updated with the incorporation of French dataseries.

2) Problem: Length compositions of landings for Portuguese fleets is of low quality since 2009.

Progress: Sampling scheme was reviewed and improvements were recommended but, it was not possible to recover the data for previous years.

Conclusion: Length composition of Portuguese fleets will not be included in the assessment from 2009 or alternatively use the appropriate effective sample size within the modelling framework.

Discards

Discards are negligible for Portuguese fleets and the available time-series for Spanish fleets indicates that are <5% of total catch.

Conclusion: No discard data will be considered in the assessment model.

Species split

Problem: Possible misallocation of landings between *Lophius piscatorius* and *L. budegassa*.

Progress: The method used for splitting landings by species was reviewed for Portugal. Some problems were detected in ports with low level of sampling. A new method for assigning species is being developed but it is not ready yet.

Conclusion: The species split of landings are good enough to consider the current landings by species in the assessment.

Commercial tuning indices

Problem: Lack of continuity in the commercial indices used in the assessment. SP-CORTR8c series stops in 2012 and SP-CEDGN8c series stops in 2011.

Progress: None. SP-CEDGN8c index corresponds to a fleet that has been reduced to two vessels since 2011 and SP-CORTR8c information is not reliable since 2012. No reliable and representative information for these series could be recovered for recent years.

Conclusion: These two commercial abundance indices are good indices for medium and large individuals in the assessment. The available time-series will be used in the assessments. SP-CORTR8c and SP-CEDGN8c in the mon.27.8c9a assessment. SP-CORTR8c with both PT-TRF9A and PT-TRC9A in the ank.27.8c9a assessment.

Survey data

Problem: To explore alternative survey information.

Progress: A new Spanish survey was identified: SP-ARSA survey. It is carried out in Division 9a-Gulf of Cadiz in spring and in autumn.

Conclusion: The low survey coverage of the stock distribution and low catches made in this survey suggest that the survey index from the survey is not a representative index of abundance for the stock.

Biological data

1) Problem: No agreed method for ageing monkfish.

Progress: none.

Conclusion: length-based or production assessment models are considered for assessing these stocks and will be more reliable than applying unvalidated ages.

2) Growth parameters

Mon.27.8c9a growth parameters, available in Landa *et al*. (2008a), will be used in the assessment. K (0.11) is fixed and Linf will be estimated by the model.

Ank.27.8c9a growth parameters are not available. The following proposal was presented at data preparation workshop for divisions 7.b–k, 8.a–b and 8.d for sexes combined (classical VBG parameters): k=0.816, Linf=119.84 (Batts *et al.*, 2017 WD). These estimates were based in length–frequency analysis.

3) Problem: For monkfish, natural mortality is assumed at 0.20 for all ages.

Progress: A range of empirical M values was calculated following different methods based on growth parameters and maximum age. For mon27.8c9a the M range estimated was: 0.15–0.26.

Conclusion: The range for M values will be tested in a sensitivity analysis.

4) Problem: Length–weight relationship update.

Progress: New L–W relationships were provided by labs.

Conclusion: Current used parameters (BIOSDEF-Project; Pereda, 1998) and new L–W relationship parameters (Landa and Antolinez, 2017) will be tested in a sensitivity analysis.

5) Problem: Maturity data

Progress: Maturity literature and data were provided by labs. The new maturity information is based on macroscopic identification which has some errors identifying maturity stages.

Conclusion: The maturity ogive parameters currently used in the assessment (Quincoces, 2002), are based on microscopic identification of the maturity stages. This methodology is considered more precise and therefore the maturity parameters for both sexes combined from Quincoces, 2002 will be used in the assessment. The *Lophius piscatorius* parameters of maturity ogive are 50% maturity at 61.84 cm and a slope at 0.1001.

Different estimates of maturity ogive-at-length are available for *Lophius budegassa* (Duarte *et al.*, 2001; Quincoces, 2002; Landa *et al.*, 2008). The last study (Landa *et al.*, 2012) indicates, for ICES divisions 8.c–9.a, a sex ratio of 1:1.01 (50.30% of females) and L50 values of 46.95 cm for combined sexes, 40.97 cm for males and 62.44 cm for females. These values of sex ratio and L50 are within the range given for this species in previous studies.

1.1.3 Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (anf.27.3.a.4-6)

Catch, landings and discard data

1) Problem: Historical data gaps in ICES estimated landings and length compositions (landings and discards).

Progress: The WKANGLER data call led to data submissions by the majority of fleets for the period 2002–2016. The data gaps still to be filled for the most important fleets include Norway which only uploaded landings data for 2016 and no discard data. Scotland was unable to provide discard estimates before 2007. France only uploaded discard data for a handful of years. Norway was able to provide length compositions for the gillnet fleet at the WKANGLER benchmark meeting.

Conclusion: There is now a full time-series of ICES estimated landings since 2002 for all countries except Norway. Due to the absence of Scottish discard estimates prior to 2007 and the proportion of landings that Scotland represents it is not recommended to use uploaded discard estimates from some of the smaller fleets to obtain an estimate of total discards for the years preceding 2007. Efforts will be made to incorporate the Norwegian length data into raised length compositions for future assessment.

2) Problem: During the period of 1998–2006 restrictive quotas are suspected to have led to significant underreporting by the Scottish fleet.

Progress: The scale of underreporting remains unknown, there have been discussions with industry to provide some rough estimates of the magnitude of underreporting if possible.

3) Problem: The absence of a TAC in the North Sea prior to 1999 led to area misreporting into the region from Subarea 6. This is an ongoing issue and may affect the raised length compositions.

Progress: Recent data were examined to check the status of suspected area misreporting and using previously developed methods outlined in the SA, area misreporting for the Scottish fleets was estimated for the years 2002–2016.

Conclusion: As the stock is currently assessed using ICES category 3.2 survey trends method catches by area and length composition data are not used. Were they to be considered for a length-based assessment then these estimates of misreporting should be corrected for to accurately assign biological and catch data.

Species split

1) Problem: Currently the stock is assessed for the two anglerfish species *L. piscatorius* and *L. budegassa* combined despite differing life-history characteristics and distributions.

Progress: the possibility of splitting this assessment in the future was discussed at the WKANGLER data evaluation workshop. The data call for this meeting did not request species disaggregated data; some preliminary survey data by species was presented.

Conclusion: The contribution of *L. budegassa* to the stock remains small (<10%) (or negligible <5% in divisions 4a and 6b). However species-specific survey data are available (SCO-IV-Vi-AMISS-Q2) estimates of abundance should be calculated by species if possible. A full evaluation has yet to be completed at this time.

Growth parameters

1) Problem: There is no validated age readings for this stock based on the current otolith reading programme.

Progress: Some developmental mixed distribution modelling was performed on the combined North Sea and West of Scotland IBTS length–frequency data and presented at the WKANGLER data evaluation workshop.

Conclusion: The expert group considered that the modelled age distributions showed poor cohort tracking and had very variable mean growth increments between ages. This work could be further developed looking at disaggregating data by species and sex and fixing different growth parameters.

Survey data

1) Problem: SCO-IV-VI-AMISS-Q2 time-series is still relatively short and is not a measure of absolute abundance. Assessment of the stock may benefit from additional longer term tuning series, if available.

   Progress: New cpue indices have been developed for NS-IBTS-Q1 and NS-IBTS-Q3 and explored at the data evaluation workshop. Similar indices for the SCOWCGFS-Q1, SCOWCGFS-Q4 and SCOROC-Q3 surveys are also in development but were not ready for the WKANGLER meeting.

   Conclusion: WKANGLER were happy with the spatial coverage, selectivity and observed trends of the IBTS indices for use in future assessment. It was suggested to look at using the SCOROC-Q3 as an index of larger fish.

1.1.4 Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in subareas 1 and 2 (Northeast Arctic) (anf.27.1–2)

The issues list for this stock was not fully reviewed with in the benchmark time frame and further work is recommended to review the use of ICES agreed methods for assessing the status of category 4 stocks.

2 Reviewers comments

2.1 Background

The benchmark workshop for WKANGLER met in Copenhagen, Denmark at the ICES headquarters during 12th–16th of February, 2018 to review the scientific methods for the stock assessment of six anglerfish stocks in the Northeast Atlantic. The review panel (here in called the "Panel") acknowledges the significant work that the expert group had undertaken to prepare for the benchmark review. It also appreciates the professionalism and cooperation exhibited not only by the expert group, but also by the ICES staff from the secretariat who provided significantly support and assisted with the peer review process.

The panel was able to generally reach consensus on all Terms of Reference for each stock with the exception of the reference points ToR for *L. piscatorius* in divisions 8c9a due to time constraints during the meeting.

Following the benchmark meeting, a WebEx meeting was scheduled for March 2nd, 2018 to review the reference points for *L. piscatorius* in division 8c9a. It should be noted that only two of the three external reviewers were able to participate to complete the review via WebEx. The reviewers were able to reach consensus on the reference points ToR for *L. piscatorius* in division 8c9a and deemed the approach consistent with the ICES framework for deriving reference points.

While the external reviewers did an exceptional job with a difficult agenda, the panel felt that the number of stocks reviewed for the benchmark was a bit overambitious. Such level of compressed workload within a limited time frame and resource availability could potentially undermine the ICES review process. While the panel recognizes the rationale for the scheduling six stocks for the benchmark, it will be useful that future planning to consider the possibility of reducing the number of stocks for the benchmark or consider expanding the pool of external reviewers to effectively level the workload during the review process.

It was evident that the expert group had spent considerable time preparing the documents and presentations for the benchmark. However, there was unevenness in the relative content prepared for each stock. In many cases, greater detail of information was summarized in the presentations that were not summarized in the working papers. It would assist future peer reviews if the evidence supporting conclusions from the expert group be both presented in the assessment report and the presentation ahead of time to enhance the efficiency of the review process.

The terms of reference for each of the six stocks of anglerfish required a review of their stock definitions. These were conducted during the Data evaluation workshop and the results were brought forward to the benchmark review workshop. Changes in stock definition have consequences throughout the management system and should not be undertaken without significant consideration of all sources of information. One could expect that there would be considerable reluctance to change stock definition without substantial evidence to the contrary. Hence, the panel envisages that review of stock definition would likely be more productively taken outside the normal operating benchmark process and on a schedule which will allow significant changes if these were felt warranted.

Other than these issues, the panel considers the assessments for each of the stocks under review were generally viewed to be appropriate to obtaining management advice. Further, the reference points computed for each of the stocks were considered to be conducted in a manner consistent with ICES guidelines. However, the only exception during the review was Anglerfish in subareas 1 and 2. This is the first time this stock is being assessed and a great deal of information was presented relative to each of the ToRs, but the information provided was not considered sufficient enough to provide scientific advice. Hence, the panel recommended that further evaluation and development of appropriate assessment methods should be explored for future consideration.

2.2 Summary of Main points

Uncertainties remain around maturity, sex ratio, species ratio, growth and length frequencies of the catch and improvement in these data are still needed.

Area misreporting was reviewed and there was evidence of misreporting between subareas 4 and 6 and subareas 6 and 7. It is also known that misreporting occurs between species. While misreporting for areas 6 and 7 has been addressed, this has yet to be resolved for areas 4 and 6, and this area mismatch implications for sampling and catch. That is, although both areas are the same stock unit, this could be an issue for raising of length samples if length-based models are considered in future.

Discards are shown to be variable with low precision likely due to low sampling rates. Sampling differs considerably between countries for landings and discards. Sampling CV should be evaluated with the aim of including uncertainty with the selected modelling framework.

Review of literature suggests that there is some evidence of subpopulations with mixing, however information provided is too limited to reject the management and assessment units as they are now. Tagging experiments, genetic studies and other stock structure studies are ongoing to determine the movements and migratory and mixing rates between areas.

For anglerfish in ICES subareas 27.1 and 2, it was considered that recruitment in to this area is from the more southerly stock unit. This would require further R&D work looking at egg and larval dispersion and transportation as well as tagging and genetic studies.

The use of illicia and otolith-based ageing remains an issue and other methods of estimating growth of the two species by latitude of anglerfish were examined as it was suggested that growth slows the more northerly the stock unit is located. Growth for males and females of both species also differs with males growing much slower and reaching a maximum length at much smaller lengths.

For *Lophius piscatorius* the studies of growth by Landa *et al*. (2012) has been used as the basis for length-based assessments (*L. piscatorius* (divisions 8.c and 9.a)). For anglerfish in Division 3.a, Subarea 4 and Subarea 6, age has been determined using otoliths but there is uncertainty around the use of age-based assessments.

2.3 ICES divisions 8.c and 9.a

Lpue indices for both black and white anglerfish in 8c9a were not standardized for use in the assessment. When quarterly indices are used then, standardization for season is not necessary, but this is an issue when annual indices are used in models. In addition, standardization for spatial and depth effects may be useful and should be explored.

In some years the percent discarded for both black and white anglerfish in 8c9a were large and could potentially reflect a number of things including large number of young fish discarded in the fishery. However, there was very limited sampling of the discards, making it difficult to assess this.

2.3.1 *Lophius piscatorius* (ICES divisions 8.c and 9.a)

Basic settings for the SS3 model were presented and discussed. The length binning of data and derivation of quarterly lpue indices seemed sensible. The choice of von Bertalanffy (von B) growth parameters seemed reasonable, but the panel felt that some likelihood profiling based on various values of k will be useful. The assessment is based on an average maturity ogive for males and females. However, the panel felt that if the goal is to derive SSB as a proxy for egg production, then it is better to derive female SSB for the assessment model output using information on sex ratios and a female maturity ogive.

The first SS3 run presented had strong domes for all fleets and tuning indices. This results in a cryptic biomass problem. It was recommended to make the selectivity of the Spanish Artisan fleet in Division 8c (SPART8c) asymptotic, because there is evidence that the fleet has the most overlap with the larger sizes in the stock. After a final formulation was selected, it was requested that reweighting of data sources be performed in SS3. Profiles for the natural mortality rate (M) and the von B k parameters were also requested.

The change in the SPART8c fleet selectivity resulted in small changes in selectivity, but not much difference in average F and recruitment, but some difference in SSB.

All SS3 model formulations did not fit the Spanish A Coruña fleet quarterly cpue indices very well early that the time-series. It was not clear why this is, but this lack-of-fit based on pure speculation, may be related to the temporal resolution for the Spanish cpue fleets which may not support the very limited sampling for the fleet.

After reweighting the SS3 model formulation, and the examination of sensitivity rums for M (0.15, 0.25) and K (0.06,0.16), the SS3 model formulation with M=0.2 and K=0.11 was considered to be appropriate to provide harvest advice for this stock. An M profile analysis indicated that unrealistically small M values for the data were a better fit for the model, and the panel concluded that this was probably due to a confounding with some other model misspecification. The major difference in assessment model results was only in scale and it was considered that status evaluations ($B_{current}$ vs. B_{ref} and $F_{current}$ vs. F_{ref}) were relatively similar. The von B K sensitivity analysis indicated that K=0.06 was less consistent with the data than K=0.11 or K=0.16. The latter choices fit the data well but K=0.16 resulted in an unrealistically low estimate of Linf. Hence, the benchmark concluded that M=0.2 and K=0.11 were the best choice of parameters for the SS3 assessment model. Noteworthy in the K=0.06 run was a much improved fit to the SPGFS "recruitment" length compositions. This may indicate a potentially better growth model formulation, but this is a subject for future research.

2.3.2 *Lophius budegassa* (ICES divisions 8.c and 9.a)

Length compositions were presented for the Portuguese trawl fleet, but lpues were presented for the trawl fleet directed towards groundfish and the trawl fleet directed towards crustacean separately. It may be useful to derive the length compositions for these two gear-types separately because it is thought that the gear types have different selectivity patterns.

Some of the early length compositions were available only for biannual periods. This information could be used within SS3 using "super periods". However, this may not make much difference to the stock assessment.

The SS3 model in progress for this stock had not advanced far enough to be considered as a candidate assessment model for this stock. Hence, the previous surplus production model (ASPIC) was presented. That model fixed Bo/K = 0.6 and the model estimates had unrealistically narrow confidence intervals on exploitable biomass. As a solution, A SPiCT model was requested by the panel. The first run of this model presented included a vague prior on the generalized production model parameter (i.e. n). Diagnostics revealed that the data were uninformative about this parameter (as is often the case) so it was decided to fix the n parameter at 2.0, which results in a Schaefer-type symmetric production function. The rationale for this decision was to reduce potential future assessment model variability of stock size estimates and reference points due to changes in the poorly determined n parameter. There is also some literature on ASPIC that suggests this parameter is difficult to estimates and that estimates are often not robust. The SPiCT model with Schaefer production formulation was considered to be suitable for the assessment of this stock. It fit almost as well as the generalized formulation, it had acceptable retrospective patterns, and it fit the tuning indices reasonable well and substantially better than ASPIC did. There were some curious autocorrelated residual patterns in the tuning indices that differed across series, which may reflect spatio-temporal changes in distribution but could also simply indicate transitory changes in catchability.

The reference points and projection procedures were reviewed for this stock. It is important to note that the estimates of current F relative to F_{MSY} are low, and the estimate of current biomass relative to B_{MSY} is high. This results in short-term catch advice that greatly exceeds the range of landings in the assessment series. The benchmark meeting recommended caution be applied in setting quotas outside historical ranges, and that a stepwise procedure be applied to gradually change quotas and monitor the impacts of these management actions on the stock.

2.4 ICES divisions 7.b–k and 8.abd

Species proportion information from mixed catches of black and white anglerfish information in this area was considered to be more challenging in this region. Each country implements their own algorithm for disaggregating species commercial catch and getting a combined evaluation will be difficult. However, the meeting felt that some evaluation of this issue will be useful.

The methods to assign length frequencies to landings and discards were presented. For White anglerfish, the L50 of discards has been increasing. Therefore, it is not practical to assume a constant selectivity function for discards since 2002, and there is no discard information prior to 2002. For Black anglerfish there is much less discarding information available.

Estimation of growth curves from tagging and length–frequency analyses was presented. This was used to select a range of von B growth-rate parameters. More information was available for White anglerfish which suggested a K=0.11 was a reasonable choice. Less information was available for Black Anglerfish but K=0.08 seemed reasonable.

Partially based on the growth-rate analysis and also on information on T_{max}, a value of M=0.25 was proposed. The benchmark concluded this was a reasonable choice but other values are also reasonable and a sensitivity analysis with respect to the choice of M was required. This sensitivity analysis will be based on M=0.2 and M=0.3.

It was proposed to combine the Irish bottom-trawl survey in the north and the French bottom-trawl survey in the south to provide a more comprehensive survey index of the stock. It was suggested that these surveys should have similar catchabilities, and the potential problems with combining surveys with small differences in catchabilities is less than the problems of using two indices that survey different parts of the stock especially when the survey and catch information suggests that there have been changes in the spatial distribution of the stock over time. An Irish lpue series was presented, but not proposed to be used as a tuning index in the assessment. However, a Spanish survey on the Porcupine Bank which catches larger anglerfish was proposed for use in the assessment. An anglerfish industry survey in two-year periods with good precision was also proposed. The benchmark agreed with these choices.

The time-series for catches was 1986 onwards because of the lack of information on species prior to this time.

SS3 models for these stocks were reviewed but the models had convergence and other fitting issues, including somewhat unrealistic selectivity patterns. The models did not progress far enough to be considered as a candidate assessment models for the White and Black Anglerfish stocks.

2.4.1 *Lophius piscatorius* (ICES divisions 7.b-k and 8.abd)

The assessment model approach was a combination of model-assisted cohort-slicing and then a more standard age-based stock assessment using the a4a package. The Benchmark greatly appreciated the insights into age-structured catch-at-length models that this approach provided. It also helped with understanding SS3 models presented. The cohort model formulation included a separable fishing mortality function.

Several options to model fishery selectivity and survey catchability in the a4a cohort model were described. Fits to catches and indices were examined using various residual plots. The configurations for selectivity and catchability agreed at this benchmark meeting and are described in the stock annex.

Sensitivity analyses for M (0.2, 0.3) and growth rates (high/low) were requested. The M sensitivity analyses resulted in different scaling of biomass and harvest rates, but less variation in current biomass and F relative to reference points (see Kobe plot in Section 5.4.1.1). The growth sensitivity analysis were a bit more complicated in that assessment model biomass estimates were lower for both scenarios compared to the base model formulation, and harvest rates were higher. However, the status evaluations relative to MSY references points were more stable. Both the low- and high-growth scenarios resulted in somewhat lower catches on average at ages 3–4, and possibly different catch curve slopes which seemed to be the source of these results. Nonetheless, the meeting concluded that the assessment model approach for this stock was sufficiently reliable and robust to be used as a basis for harvest advice for this stock.

2.4.2 *Lophius budegassa* (ICES divisions 7.b-k and 8.abd)

A similar assessment model approach of cohort slicing and a standard a4a age-based stock assessment was presented. The sampling of age information for this stock was much poorer than the White anglerfish stock. The derived indices-at-age do not track cohorts well in the fishery and, to a lesser extent in survey indices. Growth and M sensitivity analyses produced large and unexpected differences that were difficult to understand. The issues with species identification may affect the reliability of catch data for this stock compared to white anglerfish. This assessment model approach was not considered to be suitable for the assessment of this stock.

The SS3 model for this stock was reviewed but the model had convergence and other fitting issues, including strange selectivities. The panel concluded that the SS3 formulation could not be considered as a candidate assessment model for this stock. Hence, the benchmark concluded that the status of this stock should be based on the combined Irish–French survey index.

2.5 Anglerfish-ICES Division 3.a, ICES subareas 4 and 6

Species split was not addressed in benchmark, and it was recommended by the panel that this issue be reviewed in more detail with the intention of developing an appropriate species split (if possible) for a future benchmark. Issues with the mixing between *L. piscatorius* and *L .budegassa* appears to be variable over the time-series, ranging from 10% for *L. budegassa* in some years and can be up to 30%.

Important biological information (i.e. growth and natural mortality) are needed to improve future modelling efforts. Current biological information suggests growth is linear but the analyses suffer from the lack of older ages in samples to inform growth dynamics. Further, aging validation issues also needs to be resolved to support possible age-structured assessments in the future.

It was presented at the benchmark that there are problems with the historical catch data since there is no discard information prior to 2002 and no discard data from one of the major fleets (Scottish fleet) prior to 2007. Post-2007, fishery-dependent data were considered more reliable since it now includes both the Scottish fleet landings and discards.

Area misreporting is also an issue for this stock and evident in the landings due to cap in the quotas. There is evidence that up to 20% caught in area 4 were landed in area 6, but the data are not being used. The panel recommended that this issue be resolved as it becomes important when raising length samples to reflect the size compositions for each of the areas.

Several model frameworks were considered but after several challenges with the data, the SPiCT model was brought forward for review at the benchmark workshop. Due to unreliable model diagnostics and the lack of production relationship between the survey and catch inputs in the model, the panel recommended that the index approach should be continued and adopted for this stock. Data considered included the SIAMISS (Scottish and Irish Anglerfish and Megrim Industry Science Survey), the reinitiated SIAMISS, now referred to as IAMS (Irish Angler and Megrim Survey in area 7 since 2016) and the IBTS.

Additional analyses exploring the mean size between catch and survey length frequencies showed a mismatch of lengths supporting the source of problem with a production model. This could be a result of the uncertain catch data; misreporting of catch, location and length frequencies

2.6 Anglerfish (ICES subareas 1 and 2)

This is a stock unit that was classified in 2012 as category 4 (ICES CM 2012/ACOM:68), see decision tree below. However, this stock unit has not been assessed and no advice has been provided.

Within the arctic fisheries working group, area 1 and 2 is usually considered with area 5 but for this benchmark only areas 1 and 2 are presented.

Length comps are available from bycatch fishery in area 2.a and black angler is <1% of Norwegian fishery and therefore splitting of the species is considered not necessary.

Catches have between 1043–5515 tonnes increasing as the fishery developed, decreasing sharply since 2009. Information suggests that there was a sharp decline in landings due to reduction in available resource.

Norwegian fishery consists of coastal gillnetters with maximum allowable soak time of 72 hours for this fishery. The fishery is closed for the spawning season from January to May.

There is a reference fleet which started in 2005, with some changes with incoming and out coming vessels. The reference fleet of around 25 vessels reports around 8–9% discards mainly due to spoiling of fish from long soak times during bad weather events.

The reference fleet provides a mean cpue catch per 100 gillnet days from area 2a, 2007–present, catch rates vary spatially and temporally with no standardisation.

Although there are surveys they are considered not appropriate to anglerfish.

Presented landings, cpue and inputs to untuned VPA/YPR models and catch curve analysis.

- Data are age-based using otoliths/illicia;
- Natural mortality set at 0.15;
- Maturity knife-edge set from age 7 = 1;
- Selectivity of two fleets (Norwegian gillnets, other gears) estimated from catch curves.

$F_{0.1}$ was presented as a proxy for F_{MSY} and it was agreed that using $F_{0.1}$ of the yield-per-recruit seems sensible to use as F_{MSY} proxy rather than F_{MAX}. **However, methods to derive this proxy reference point are considered no longer appropriate and the ICES accepted HCR and proxy reference points methods should be explored for a category 4 stock.**

The four methods approved by ICES for calculation of MSY reference points for category 3 and 4 stocks are:

- Length-based indicators (LBI);
- Mean length Z (MLZ);
- Length-based spawner per recruit (LBSPR);
- Surplus Production model in Continuous Time (SPiCT).

The panel concluded the following:

- Information on Stock ID-based on tagging and effort data was provided but there was no strong evidence to support population structuring for areas 1 and 2;
- A cpue estimate was presented but was not fully evaluated as basis for stock status determination. The panel recommended further evaluation of the survey for consideration by the Arctic Working Group;
- Reference points presented were not considered to be in line with ICES guidelines and therefore not considered for this benchmark;
- The following research recommendations for future work by the panel is as follows:
    - Continue exploring SS3 to provide an assessment model;
    - Explore all available data, i.e. Norwegian gillnet landings and discard length compositions;
    - Investigate potential utility of commercial fleets as a tuning indices e.g. the Norwegian gillnet and Basque fleet;
    - Recommend reallocating correct length frequencies to correct areas, (VI, IV);
    - Recommend splitting landings data by species (Splitting not done).

3 Recommendations

3.1 General, All Stocks

- There is some duplication of commercial length comps data particularly for SS3 models where length frequencies for both the commercial tuning indices and catch data were derived from the same fleet and applied in the model. This duplication of information may produce false statistical inferences and it is desirable to remove this problem.
- There were a number of approaches used in modelling SSB. SSB should reflect egg production. Investigate and apply appropriate sex ratio and female Maturity to estimate female SSB.
- Consideration of the maturity stages for derivation of the maturity ogive.
- Need improved information on stock identities.
- Consider stage-based assessment models (e.g. recruits+adults; males+females; White+black):
    - Consider applying different growth rates and different natural mortality rates to three life stages: Juvenile stage, mature age, late maturing stage considering sex specific growth rates (Hernández *et al*., 2015; Landa *et al*., 2013; Laurenson *et al*., 2005; Ofstad *et al*., 2013).
- Given the many uncertainties, in the input data, biological and environmental processes, it is recommended that these uncertainties be further explored and reviewed for potential use in a model. For example, Rate of growth may not be linear and VBF may not be an appropriate model, further work needed to validate the growth rates.
- CVs for sampling data in particularly around the splitting between species in the catch data would be useful.
- Length at first capture shows a change over time, possibly due to the implementation of the 500 g minimum market size. There is added uncertainty due to the weight limitation being either tails or whole fish with the implementation of weight restriction regulation around 1998. Recommendation to evaluate the impact of this uncertainty on weight conversion in the commercial data.
- To address, stock structure, mixing rates, and growth estimates, we recommend a tagging programme coordinated between all countries harvesting *Lophius*. Align tagging methods, measurement protocols and outreach to industry. Recommend a shared site for *Lophius* tagging data and other applicable research projects concerning *Lophius*.
- Investigate discard mortality studies by gear type, if possible.
- Investigate different length–weight relationship in spring and fall surveys.

3.2 ICES divisions 8.c and 9.a

1) Although there is a tuning fleet from 1982 to present, the change in how the data are reported has affected the time-series and it was deemed that the period 2013 to present was no longer consistent due change in the reporting protocol and quota allocations. It is recommended that the time-series 2013 to present be explored for possible development of a new tuning series to be included in the SS3 model.

2) Spanish/Portuguese lpues are raw and not standardized. They are quarterly indices so season effects may not be important but standardization for other changes (i.e. space x depth) maybe useful.

3) Discards are not included in the models as considered negligible by weight. However it is recommended that this be re-examined to look at the numbers discarded as this could relate to the recruitments and therefore contribute a larger proportion of the total catch when there is a good incoming year class. There is potential that this could help inform recruitment.

3.3 *Lophius piscatorius* (ICES divisions 8c9a)

1) Investigate if the input CV=0.4 for recruitment deviations in SS3 is the source of the lack-of-fit to the early SPCORT8Cs1 indices.

2) A weakness of the assessment is that there is only a recruitment index of abundance available in the last five years. See point one section W+B angler 8c9a.

3.4 *Lophius budegassa* (ICES divisions 8c9a)

1) Derive length compositions for POR-OTB-fish and POR-OTB–crust separately.

2) Consider the spatial coverage of the fisheries independent surveys and potential utility as a tuning index. (PT_WIBTS-Q1, PT_WIBTS_Q4, PT_GFS (Summer), PT_Deep-water Survey).

3.5 *L. piscatorius* and *budegassa* (ICES divisions 7b-k8abd)

1) Landings prior to 1986 are available but for the two species combined. The quality of these data is unknown and would require further exploration before including in any model.

2) Commercial tuning series - additional standardisation of the Irish tuning fleet is needed to take account of season and depth. etc.

3) Further investigate the Spanish Vigo fleet for potential utility as a tuning index.

3.6 Anglerfish (ICES Division 3.a, ICES subareas 4 and 6)

1) Continue exploring SS3 to provide an assessment model.

2) Explore all available data sources, i.e. Norwegian gillnet landings and discard length compositions.

3) Investigate potential utility of commercial fleets as a tuning indices e.g. the Norwegian gillnet and Basque fleet.

4) Recommend reallocating correct length frequencies to correct areas, for subareas 4 and 6.

5) Recommend splitting landings data by species (Splitting not done).

3.7 Anglerfish (ICES subareas 1 and 2)

1) Investigate standardization of the commercial cpue index. There has been a reduction in effort and change in the spatial distribution of effort and the cpue index may need to be further standardized to control for vessel and

spatial effects. There is evidence of a spatio-temporal changes in distribution that should be accounted for in index standardization.

2) Investigate using a more formal assessment model for this stock (component). Validate age determination using tagging study data.

3) It was considered that recruitment in to this area is from the more southerly stock unit, this would require further R&D work in collaboration with 3a46 looking at egg and larval dispersion and transportation as well as tagging and genetic studies.

4) Gillnet discard mortality study.

3.8 References

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4 Data evaluation for anglerfish (*Lophius piscatorius*) in Northeast Atlantic

4.1 ToR 1: Review anglerfish stock structure and mixing rates if applicable between stock areas based on tagging, genetics and other studies if available

This ToR addresses all of the stocks considered by WKAnglerfish (ank mon anf ….).

4.1.1 Literature review

In 2008 Farina *et al*. published a review paper synthesising the current knowledge of features and life strategies of *Lophius*. This paper concluded that there is evidence of limited genetic structure in *L. piscatorius* and *L. budegassa*, suggesting considerable gene flow over large areas. A number of tagging studies confirmed that ability of *Lophius* to migrate across considerable distances, deep troughs (like the one between 8c and 8b; Landa, 2004) or even between the Shetlands and Iceland (Laurenson, 2004). Additionally there is the potential for considerable dispersion during the pelagic phase. Morphometric analysis (Duarte, 2004) provided reasonable discrimination between 7cj, 8abd and 8c for *L. piscatorius*. For *L. budegassa* 9a and 8abd were different but other areas less clearly so.

Since Farina's paper, limited work has been published on genetics. Blanco *et al*. (2012) found no genetic boundary between 8c and 8abd for either species but found some differences with the Mediterranean and between Spain and Portugal for *L. piscatorius*. Otolith shape analysis by Canas (2012) found no differences between areas 7, 8c and 9.

Data storage tags have shown that *Lophius* regularly migrate vertically to the 0–50 m from the surface and after a number of hours settle at a different bottom depth (Thangstad, 2006). This suggests that they do not swim along the bottom when they migrate (which explains how they can migrate across oceanic depths).

Present knowledge of anglerfish (*Lophius* spp.) in ICES subareas 1 and 2 is based on two master theses (Staalesen, 1995; and Dyb, 2003), a report from a Nordic project (Thangstad *et al*., 2006), working documents to the ICES ASC, WGNSDS and WGCSE, and more recent catch data collected by the Norwegian Reference Fleet since 2006 (Anon., 2013). A PhD thesis by Ofstad (2013) about life history, ecological importance and stock status of *L. piscatorius* in Faroese waters has contributed to more knowledge that is also relevant to ICES areas 1 and 2. All relevant knowledge has in recent years annually been compiled and updated by the ICES Arctic Fisheries WG (latest in ICES, 2017). ICES has hitherto suggested that this stock is considered as a Category 4 stock, since the only data available to assess stock status are catch data which include a time-series of catch and catch rates (cpue) from the contracted Norwegian Reference Fleet (ICES CM 2012/ACOM:68) that can be used to approximate MSY (ICES Advice 2016, Book 1).

4.1.1.1 Species composition

Lophius budegassa are rarely caught in Nordic waters. In Norwegian waters, recent information shows that about one out of 300 anglerfish are *L. budegassa*. Although very few *L. budegassa* specimens, this is an increase compared to one out of about 2600 anglerfish landed from the Møre coast north of 62°N (2.a) and one out of about 1000 from the North Sea reported by Dyb (2003).

4.1.1.2 Stock description and management units

Dispersal of eggs and larvae and migration of young anglerfish

The WGNSDS (Northern Shelf Demersal Stocks) considered the stock structure on a wider European scale in 2004, and found no conclusive evidence to indicate an extension of the stock area northwards to include Division 2a. Anglerfish in 2a has therefore been left out of the Celtic Sea Ecoregion Working Group (WGCSE) who is now assessing the anglerfish on the Northern Shelf. Hislop *et al.* (2001) simulated the dispersal of *Lophius* eggs and larvae using a particle tracking model. Their results show the likelihood for *Lophius* at both Iceland (ICES 5a; Solmundsson *et al.*, 2007), Faroe Islands (ICES 5b; Ofstad, 2013) and Norwegian waters north of 62°N (ICES 2a and 1) to be recruited from the area west of Scotland including Rockall. This is also supported by research survey data as a migration east-/northeastwards with larger size as seen in the Scottish survey, the IBTS- and other survey.

Comparison of length modes (recruitment) across areas

Figure 4.1.1.1 shows a possible connection between the length mode at about 40 cm seen in the Scottish survey in the northern North Sea and the pulse of young anglerfish of similar size recruiting to the smaller-meshed gillnets north of 62N. For 2016, length data from anglerfish caught as bycatch in smaller meshed gillnets and longline are presented in Figure 4.1.1.1-C. This shows some promising recruitment of small anglerfish (40–50 cm) not yet big enough for the large-mesh gillnets used in the directed anglerfish fishery. These recruits correspond to the promising year classes seen further south in the North Sea (Figure 4.1.1.1-A). Note that there is no strong cohort tracking in the survey and the link between the survey recruitment and catch in the fishery, is based on one year of data.

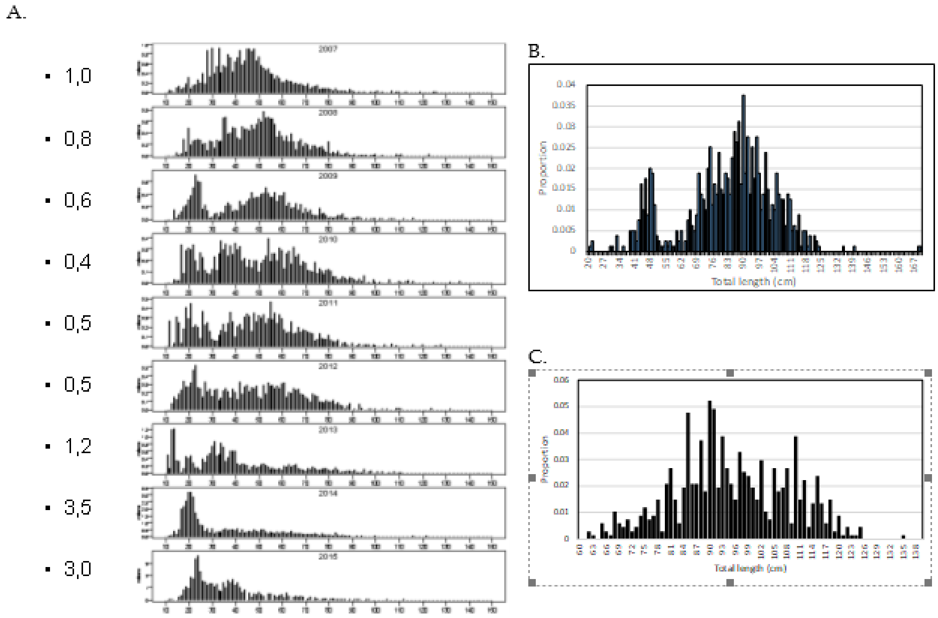


Figure 4.1.1.1 A. Length distributions of anglerfish from the Scottish survey which provides the basis for the advice in ICES 4, i.e. south of 62N. Note that the scale is different year after year (marked with maximum y-axis value to the left of each year panel). B. *Lophius piscatorius* in ICES 2a 2016. Length distribution of bycatches in smaller meshed gillnets and longlines not targeting anglerfish. C. *Lophius piscatorius* in ICES 2a 2016. Length distribution of catches from large-meshed (360 mm) gillnets targeting anglerfish.

Development of mean length in the large-meshed (360 mm) gillnets targeting anglerfish

Figure 4.1.1.2 indicates recruitment into Subarea 2a during 1997–2001 which has not happened since to a similar degree. This recruitment was observed in the large-meshed gillnets as (on average) 70 cm fish (about age 7) in about year 2000, and has thus been the main contributor to the fishery in Division 2a for about 15 years. Hence, 25 years may at least for practical management of *L. piscatorius* north of 62N be a reasonable proxy for T_{max}.

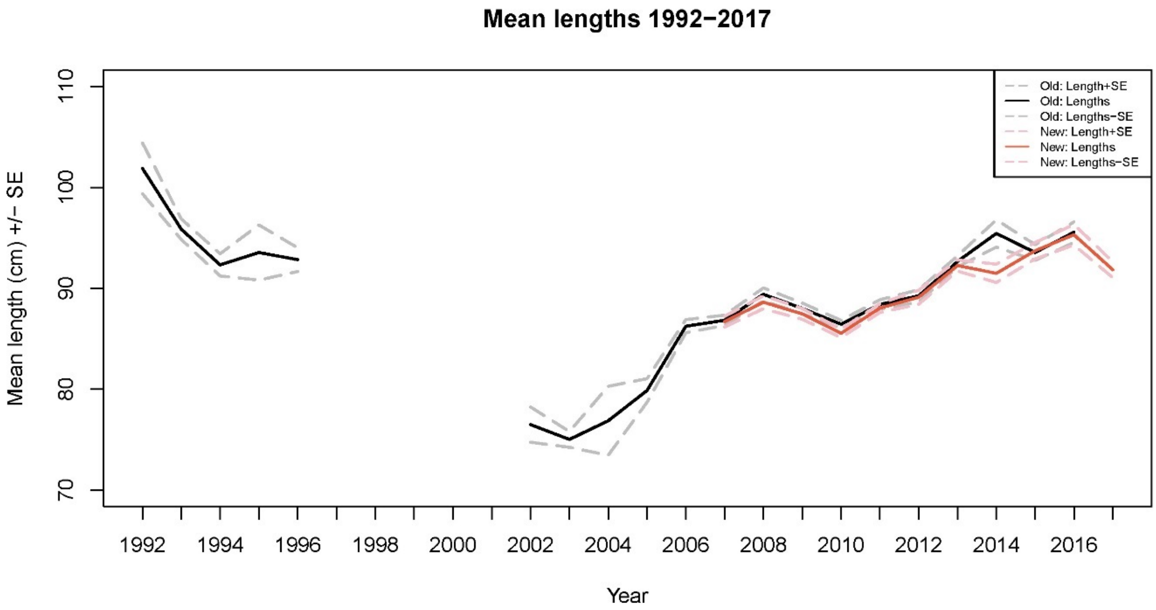


Figure 4.1.1.2. Mean lengths for *Lophius piscatorius* caught in the directed coastal gillnetting in Division 2a during 1992–2017, dotted lines represent ± 2SE of the mean. Note that data are lacking for 1997–2001.

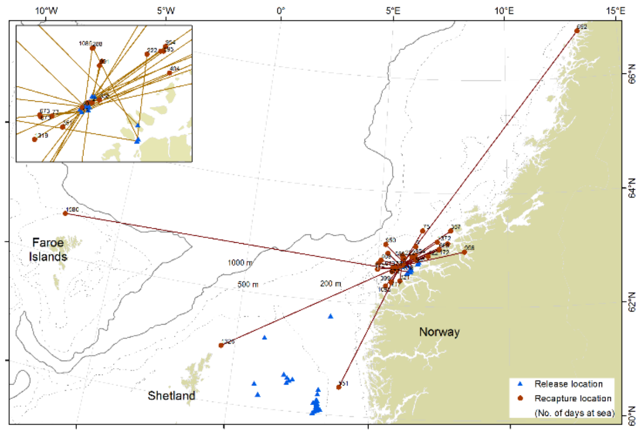
Otolith shape analysis

Recent results from the use of otolith shape analysis in stock identification of anglerfish (*L. piscatorius*) in the Northeast Atlantic (Cañás *et al*., 2012) and previous references on *L. piscatorius* stock identification find no biological evidence to support the current separation of *Lophius* stocks in the Northeast Atlantic, but find substructures within the area.

Mark-recapture studies

Anglerfish have been tagged during two IBTS surveys in the North Sea and five one-day trips using a small (15 m) Danish seiner off the Norwegian coast at around 62°40'N (Møre) during 2003–2006 (Thangstad *et al*., 2006; Otte Bjelland, IMR, Norway, pers. comm.). A total of 872 individuals were tagged with conventional Floy dart type tags, 123 in the North Sea (25–78 cm) and 749 at Møre (30–102 cm). Some of this is further described in Thangstad *et al*. (2006). Figure 4.1.1.3 shows the tagging locations and the hitherto recaptures. There are migrations in all directions, i.e. recaptures from the North Sea, at Shetland and the Faroes, and northwards to Lofoten. Most of the recaptures were done at Møre, where most of the fish were tagged. The recaptured fish had been at liberty for 2–1896 days, on average 641 days and up to more than five years, and will hence provide useful information to the understanding of growth. From the tagging in the North Sea during the IBTS surveys, only two tagged fish (46 and 48 cm) have so far been recaptured after 587 and 112 days in liberty after tagging (Otte Bjelland, IMR, Norway, pers. comm.). The two IBTS tagged fish were recaptured south of 62N on the western slope of the Norwegian trench somewhere between 58N and 61N (exact position not reported). The results from these tagging experiments show migration of adult *L. piscatorius* back to the North Sea (ICES 4a) and to the Faroes (ICES 5b). Similar tagging experiments on the Faroes and in Iceland have hitherto only shown a certain exchange between these two ICES divisions, i.e. one of 49 recaptures from the

Faroes experiments had migrated to Iceland, and two of 24 recaptures from the Icelandic experiments had migrated to or towards the Faroes (Ofstad, 2013; Magnús Thorlacius, MFRI, Iceland, pers.comm.).



In 2000–2001 a total of 1768 trawl caught *L. piscatorius* was tagged using conventional dart tags and released on inshore fishing grounds at Shetland (Laurenson *et al*., 2005). Anglerfish of between 25 and 83 cm total length were tagged. The overall recapture rate was 4.5% and times at liberty ranged from five to 1078 days. Recapture positions of 35% of individuals were less than 25 km from the release positions, with some recaptures close to release positions after periods of more than one year. The largest displacement recorded (by the time of publication) was 876 km with movement being from the release location at Shetland to a fishing ground at the southeast of Iceland, another recapture occurred close to Faroe. This suggests that these individuals had crossed the Faroe–Shetland Channel. Growth of recaptured fish averaged 9.4 cm year−1. After this publication, Dr Laurenson reported to Fishupdate.com about a 104 cm anglerfish caught off the Norwegian coast near Ålesund in 2006. The fish had been tagged and released in the Scalloway Deeps on 13 September 2000 when it was 45 cm long, and had hence been at liberty for five years and nine months. This is of particular importance as it may indicate a wider mixing of stocks and validate the growth rate of anglerfish.

4.1.2 Working documents presented to WKAnglerfish regarding the distribution of recruits and adults

Working documents summarising the available data from DATRAS (WD08 and WD09) indicate that there are nursery areas for *L. piscatorius* to the west and southwest of Ireland, in Biscay and the Cantabrian Sea. The abundance of recruits (<24 cm) varies between these areas in different years. This could indicate that there are separate spawning areas, or it could simply be the result of differences in survival due to environmental or biological factors. The same data also suggest that medium sized *L. piscatorius* (24–45 cm) migrate inshore and possibly from the west of Ireland to the west of Scotland and even into the North Sea. However it is possible that this is an artefact of the groundgear used in the different areas and that there is also considerable recruitment in areas 4 and 6 which is not seen by the surveys there. For *L. budegassa*, the nursery area appears to be more confined to the southwest of Ireland and to a lesser extent, Biscay. The abundance of recruits shows less annual variation between areas.

Another working document (WD10), indicated that LPUE trends were remarkably consistent between countries within areas (lpue of both species combined). The trends in lpue in area 4 were quite different from those in area 7; area 6a had trends that were intermediate between those of 4 and 7. This indicates that there may be differences between the stock abundance, which could result from the existence of subpopulations. However these trends varied smoothly in space; there were no sudden changes from one area to the next. It should be noted as well that in areas 4 and 6 the landings consist nearly exclusively of *L. piscatorius*, while the proportion of *L. budegassa* increases further south.

4.1.3 Conclusion

The overall impression is that while there may be some structure within the NE Atlantic area, there is also some degree of mixing. **WKAnglerfish concluded that there is not sufficient information to change the current stock areas.**

4.2 ToR 2: Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length

4.2.1 Growth, maturity and length-weight

The growth parameters and maturity ogive

Farina (2008) notes that growth studies based on illicia and vertebrae show a linear relation between age and total length. They state that this is not consistent with the von Bertalanffy growth model. However, they also note that the reading criteria applied to illicia may be biased which might underpin the apparently linear growth pattern.

There is no biological reason why growth should not be linear and a von Bertalanffy growth curve (VBGC) can fit to a linear pattern (with very high Linf). However, if growth is initially linear, followed by a reduction in growth rate at older ages, this cannot be modelled by a VBGC. However, there is no evidence of this.

4.2.1.1 A review of the recent available growth parameters

Landa *et al*. (2008a) compared the growth rates estimated from the tagging study that they carried out with the previous estimates with illicia and otoliths. They concluded that the growth rates were underestimated in the previous studies. Thus, we reviewed the estimated von Bertalanffy growth parameters after Landa *et al*. (2008a) for White anglerfish (*L. piscatorius*) and for the Black anglerfish (*L. budegassa*).

SPECIES	REFERENCE	AREA	SEX	LINF	K	T0	N	SIZE-RANGE
White anglerfish (*L.piscatorius*)	WD04WKANGLER	7	Comb	244.31	0.072	-0.979	11010	3–137
	Landa *et al*., 2012	7	Comb	162.31	0.088	-0.894	979	5–125
	Landa *et al*., 2008a	78	Comb	140	0.11	-0.7		
	Holah WKANGLER	46	female	300	0.034	-0.987		11–136
Black anglerfish (*L.budegassa*)	WD04 WKANGLER	7	Comb	119.84	0.118	-0.816	6720	4–90

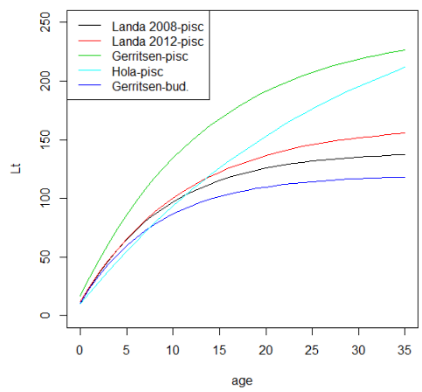


Figure 4.2.1.1. The figure shows the different growth estimates mentioned in the table for (L. *piscatorius*) and (L. *budegassa*).

The parameters estimated by Landa *et al*., 2008a (from a tagging study) and Landa *et al*., 2012 (validated with cohort tracking analysis) show the most similar pattern. The estimates of Gerritsen for L. *budegassa* are not possible to compare, since for the moment is the only available study after Landa *et al*. (2008a).

Some age readings exist for anglerfish in Division 2a, and comparative analyses of different structures, preparations and methods used for age readings were done by Staalesen (1995) and Dyb (2003). The Norwegian Institute of Marine Research adopted the ICES age-reading criteria using the first dorsal fin ray (illicium) as its routine method, but few fish have been aged since the above-mentioned projects. Recent information from the mark–recapture experiments in Norway, Faroes and Iceland provides useful information about fish growth during the time between tagging and recapture (Ofstad, 2013; Laurenson *et al*., 2005; Thangstad *et al*., 2006; Bjelland, Laurenson and Thorlacius, pers comm.). This should be included in future work.

4.2.1.2 Length-weight relationship

L. piscatorius

A review of the different length–weight relationships available was done for white anglerfish.

REFERENCE	AREA	SEX	A	B	N	SIZE-RANGE
Olaso & Pereda, 1983	8c–9a	Comb	0.021	2.885	235	-
BIOSDEF-Proj.,Pereda 1998	8c–9a	Comb	0.027	2.839	1011	14–121
Landa & Antolinez,2017	8c–9ª	Comb	0.025	2.853	3596	11–165
Pereda and Villamor,1991	8	Comb	0.024	2.85	239	-
Quincoces, 2002	8abcd	Comb	0.019	2.915	565	12.5–111.5
		Male	0.039	2.738	281	24.5–86.5
		Femalea	0.015	2.963	219	12.5–111.5
Pereda *et al.*, 1998	8abd	Comb	0.026	2.841	563	12–111
Landa and Antolinez, 2017	7bchjk	Comb	0.027	2.826	3623	5–135
Gerritsen, WKANGLER 2017*	7	Comb	0.03	2.82	3897	
Silva *et al.*, 2013	4,7	Comb	0.0266	2.8614	2101	5–111
Silva *et al.*, 2013	4	Comb	0.0297	2.8410	84	5–91

*** These parameters were used for the 78abd stock.**

The length–weight relationships available for the southern stock (left Figure 4.2.1.2) are very similar. In the case of the northern stocks however, at 100 cm the length–weight relationship starts to diverge. The relationship estimated by Silva (WKAnglerfish) gives 2.1 kg higher weight than that estimated by Landa *et al*. (2017) at 100 cm, this difference increases to 7.1 kg at 150 cm.

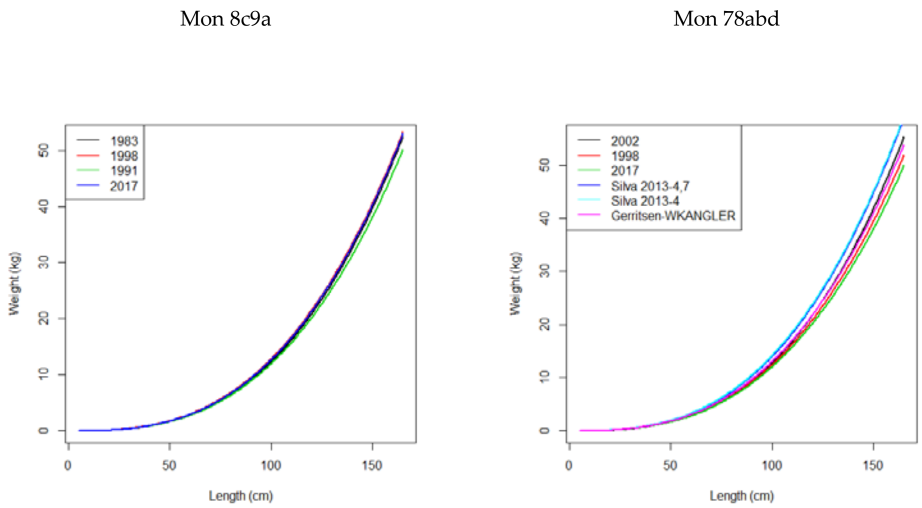


Figure 4.2.1.2. The length–weight relationships estimated for L. *piscatorius* described in the previous table for left) the southern stock and right) for the northern stock.

L. budegassa

A review of the different length–weight relationship available was done for black anglerfish.

REFERENCE	AREA	SEX	A	B	N	SIZE RANGE
Pereda *et al.*, 1998	8c–9a	Comb	0.021	2.92	1030	5–99
Olaso and Pereda, 1983	8c–9a	Comb	0.02	2.896	143	-
Pereda and Villamor,1991	8	Comb	0.021	2.882	234	-
Landa and Antolinez 2017	8c–9a	Comb	0.02	2.916	2035	5–99
Quincoces, 2002	8abd	Comb	0.021	2.915	592	14–84
Pereda, 1998	8abd	Comb	0.015	3.004	590	14–84
Landa and Antolinez, 2017	7bchjk	Comb	0.025	2.841	1263	4–91
Gerritsen, WKANGLER 2017*	7	Comb	0.0195	2.93	3897	-
Silva *et al.*, 2013	7	Comb	0.0259	2.8575	285	10–81

*** These parameters were used for the 78abd stock.**

The length–weight relationships of black anglerfish for the south (left Figure 4.2.1.3) and for the northern stocks starts to be different at 60 cm. For the southern stock the maximum difference is between the estimated by Pereda and Villamor (1991) and Pereda (1998) with a difference of 0.5 kg at 60 cm and 2.3 kg at 100 cm and for the northern stocks the maximum difference is between the relationship estimated by Landa and Antolinez (2017) and (1998) with a difference of 0.4 kg at 60 cm and 3.2 kg at 100 cm.

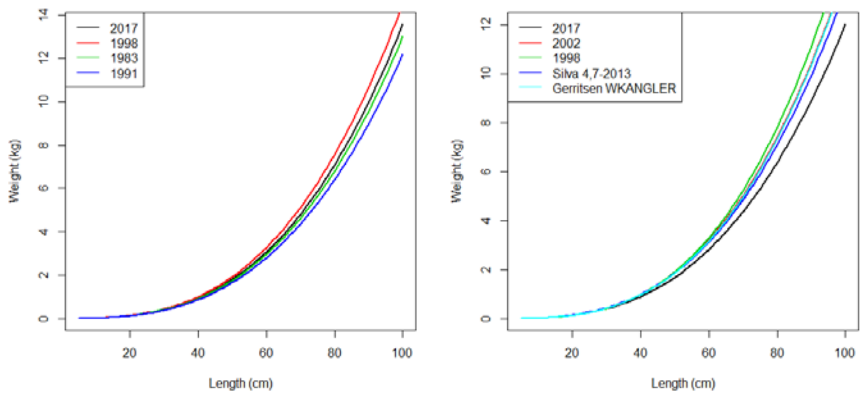


Figure 4.2.1.3. The length–weight relationships estimated for *L. budegassa* described in the previous table for left) the southern stock and right) for the northern stock.

4.2.1.3 Growth in area 7,8

Length-frequency analysis

Working document WD04 (WKANGLER_mon.27.78ab_2018_IRL_growth) outlines a new method for fitting mixed distribution to identify cohorts in length–frequency data. The means of the normal distributions are constrained to fit along a von Bertalanffy growth curve. The optimisation routine estimates growth parameters as well as the standard deviation around the means and the mixing proportions (i.e. the abundance of each cohort in each year). The procedure was applied to length–frequency data from the EVHOE, IGFS and SP-PORC surveys.

The preliminary growth parameters estimated for *L. piscatorius* in area 7 were as follows:

Stock	Linf(cm)	K	T0	SD
Mon.27.78	244.31	0.072665	-0.979066	4.796
Ank.27.78	119.84	0.118635	-0.816986	3.165

The method is currently still being developed to deal with standard deviations that change with length or age; to cope with data from different seasons; and to fit separate curves for the two sexes.

Tagging

Tagging data can provide an alternative way of estimating the growth rate. There is a reasonable amount of tagging data available for *L. piscatorius* in areas 4a and 5, but less for area 7 and 8. Nevertheless this can help to resolve the shape of the growth curve for larger fish; something that is difficult to do with length–frequency analysis.

The figure below shows that the growth rate estimated from tagged *L. piscatorius* (that were recaptured after a sufficient time period) is in the order of 8 cm/year. This is considerably lower than the growth rate estimated from length–frequency analysis.

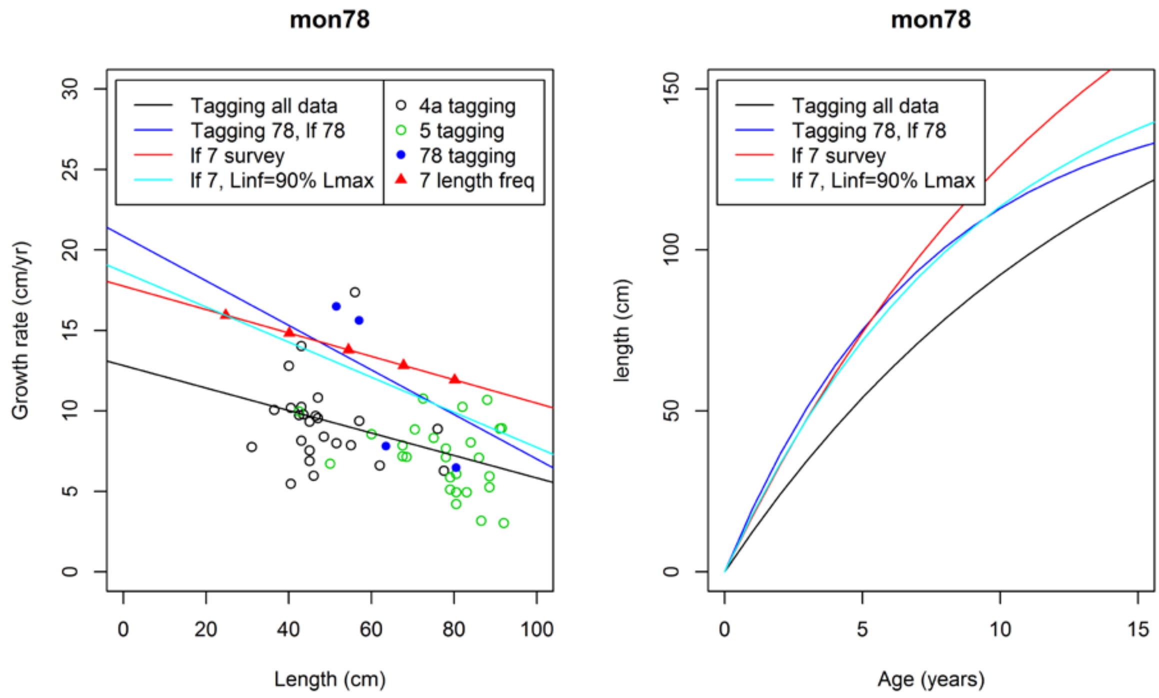


Figure 4.2.1.4. Left: Circles represent growth-rate estimates from tagged individuals (black: area 4a-Laurensen, 2005; green: area 5-Ofstad, 2013; blue: area 78-working document 04). Red triangles are growth-rate estimates from survey data length–frequency analysis (working document 02). Lines represent the estimated VBGC models (black; regression though all tagging data; blue regression through tagging data from area 7 and 8 and the growth rate between the first two cohorts of the length–frequency analysis; red: length–frequency analysis only; light blue: growth rate between the first two cohorts of the length–frequency analysis with an Linf of 90% of Lmax). Right: corresponding growth curves (assuming t0=0).

data	Linf	K
"Tagging all data"	183.5508	0.06986885
"Tagging 78, lf 78"	150.6840	0.13831692
"lf 7 survey"	244.3100	0.07266500
"lf 7, Linf=90% Lmax"	171.0000	0.10900000

The first two cohorts can be clearly identified in the length distributions, even without analytical tools (approximately 17 and 33 cm). Therefore, the estimate of a growth rate of 16 cm/year for young/small fish is considered to be reliable. The tagging data are nearly exclusively from larger fish and suggests a much lower growth rate of around 8 cm/year. Fitting a growth curve through the tagging data alone gives an unrealistically slow growth for small fish. It should be noted that most tagging data are from more northerly stocks. The other three growth curves appear more realistic and can be used for further exploration.

For *L. budegassa* there is only one datapoint for a fish tagged in area 6. Again, first two cohorts can be clearly identified in the length distributions, even without analytical tools (approximately 11 and 23 cm). Therefore, the estimate of a growth rate of 12 cm/year for young/small fish is considered to be reliable. However, the growth rate of the larger fish is more difficult to estimate. Two alternatives to the survey estimates are provided for further analysis.

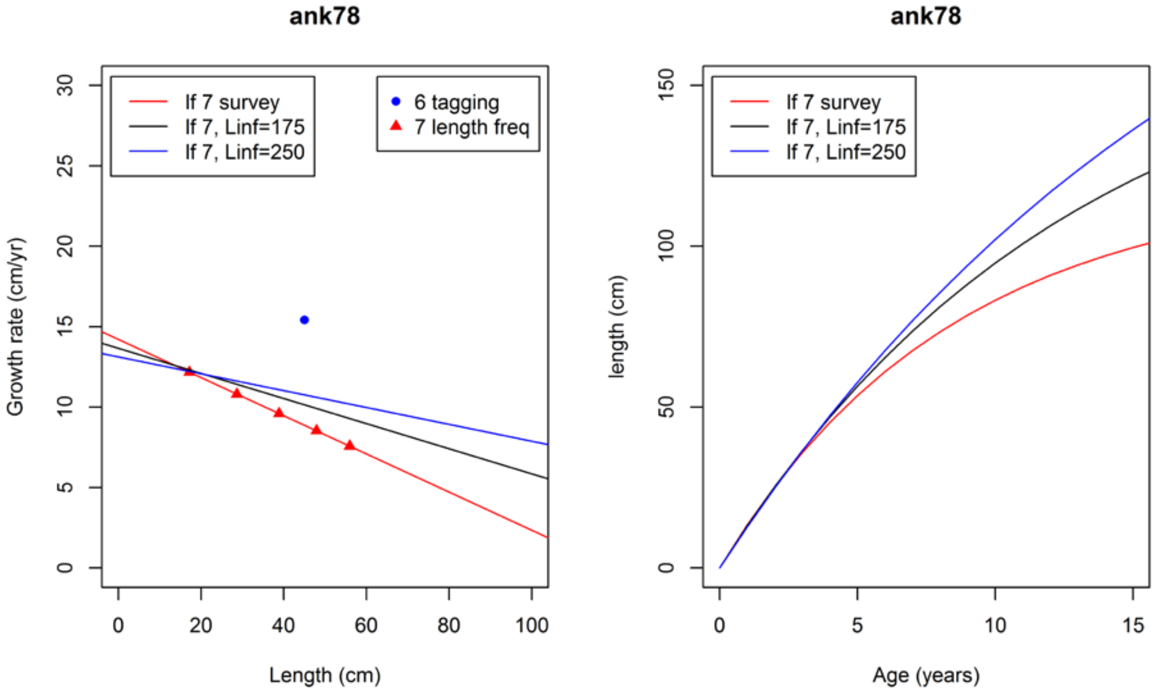


Figure 4.2.1.5. Left: the blue represents the single growth-rate estimates from tagged fish (area 6-working document 04). Red triangles are growth-rate estimates from survey data length–frequency analysis (working document 02). Lines represent the estimated VBGC models (red: length–frequency analysis of the survey data; black: growth rate between the first two cohorts of the length–frequency analysis with a Linf 175 cm and blue: like previous but Linf of 250 cm). Right: corresponding growth curves (assuming t0=0).

Data	Linf	K
"lf 7 survey"	119.84	0.118635
"lf 7, Linf=175"	175.00	0.078000
"lf 7, Linf=250"	250.00	0.052500

Conclusion: WKAnglerfish concludes that the method for fitting mixed distributions along means constrained by growth curves appears to provide realistic VBGC parameters. An alternative approach using the mean lengths of the first two cohorts provides a range of VBGC parameters that can be used in sensitivity analysis.

4.2.1.4 Growth in areas 3.a, 4 and 6

As the current assessment method for the Northern Shelf stock is based on survey trends alone, no agreed growth parameters or maturity ogive are required. At WKFlat model sensitivity analysis was run based on the parameters of the von Bertalanffy growth models of Landa *et al*. (2008) and Quincoces *et al*. (1998). Von Bertalanffy growth implies an asymptotic length. However, consideration of biological data taken from 14 285 fish caught in the SCO-IV-VI-AMISS-Q2 surveys found that when fitting growth models to age information as read from otolith structures the models of best fit for both male and female *L. piscatorius* and female *L. budegassa,* were linear (Figure 4.2.1.6). For male *L. budegassa* an allometric model produced the best fit.

As larger fish are rarely caught, it is difficult to accurately estimate asymptotic length ($L\infty$). The approach most commonly taken in growth literature is to use the highest observed length in the dataset. However, when applied to these data, such an approach resulted in an underestimation of length for both the youngest and the oldest observed fish and an overestimation of length for the ages in between. This approach also gives significant influence to the largest observed fish. The von Bertalanffy parameters estimated for male and female *L. piscatorius* separately, (with an L_∞ equal to the largest observed fish in the SCO-IV-VI-AMISS-Q2 survey), are similar to the values found in the literature (Figure 4.2.1.6).However they have a poor fit to the data (Figure 4.2.1.7). The von Bertalanffy $L\infty$ and growth-rate (*K*) parameters can be manipulated to achieve an acceptable fit to the observed data and model residuals however this requires significantly larger $L\infty$ estimates which are unlikely to be observed in either the survey or catch data.

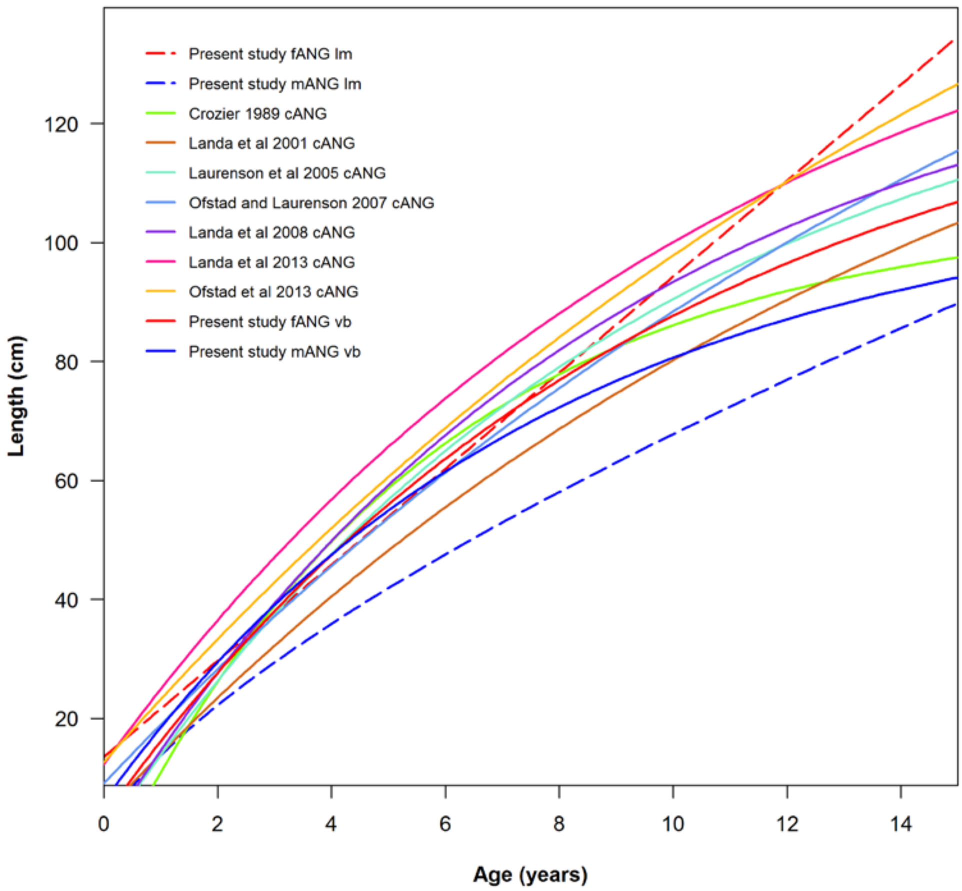


Figure 4.2.1.6. Comparison of length curves found in literature for cANG = "combined" male and female *L. piscatorius*, fANG = female *L. piscatorius* and mANG = male *L. piscatorius* compared to the growth curves from the present study lm = linear model, vb = von Bertalanffy model.

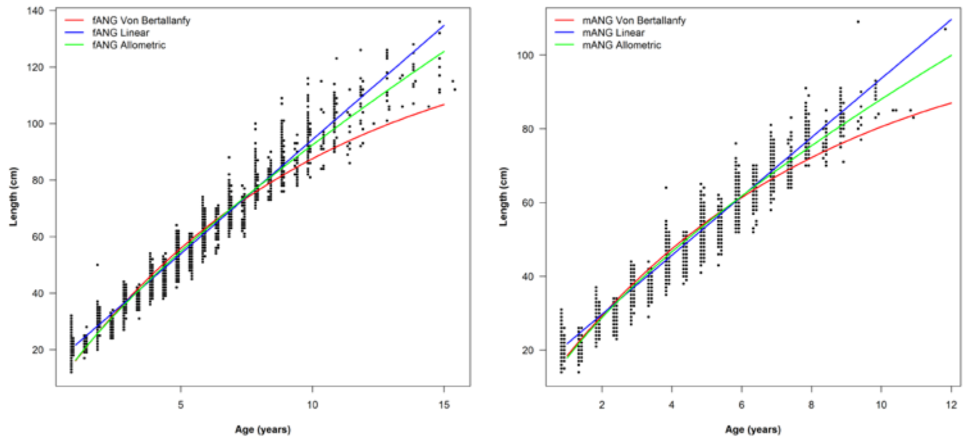


Figure 4.2.1.7. Length-at-age data from SCO-IV-VI-AMISS-Q2 otolith readings from 2005–2016 left = female *L. piscatorius* right = male *L. piscatorius*.

4.2.1.5 Maturity

Maturity data from the literature were compiled (Table 4.2.1.1). The approximate latitude was estimated from the description of the sample areas.

Reference	Area	Latitude	Species	Sex	L50
Azevedo, 1996	Portugal	40	*Lbud*	F	56
Azevedo, 1996	Portugal	40	*Lbud*	M	37.6
Duarte, 2001	Iberian coast	40	*Lbud*	F	53.6
Duarte, 2001	Iberian coast	40	*Lbud*	M	38.6
Landa, 2014	8c,9a	42	*Lbud*	F	53
Landa, 2014	8c,9a	42	*Lbud*	M	36
Quincoces, 1998a	Biscay	45	*Lbud*	F	64.5
Quincoces, 1998a	Biscay	45	*Lbud*	M	34.5
Ireland working doc	W Ire	54	*Lbud*	F	65
Ireland working doc	W Ire	54	*Lbud*	M	50
Colmenero, 2017	NW med	40	*Lpis*	F	60
Colmenero, 2017	NW med	40	*Lpis*	M	49
Duarte, 2001	Iberian coast	40	*Lpis*	F	93.9
Duarte, 2001	Iberian coast	40	*Lpis*	M	50.3
Quincoces, 1998b	Biscay	45	*Lpis*	F	73.2
Quincoces, 1998b	Biscay	45	*Lpis*	M	52.7
Ireland working doc	W Ire	54	*Lpis*	F	85
Ireland working doc	W Ire	54	*Lpis*	M	60
Alfonso-Dias, 1996	W Scot	56	*Lpis*	F	73.5
Alfonso-Dias, 1996	W Scot	56	*Lpis*	M	48.9
Larensen, 2007	W Scot	56	*Lpis*	F	93.8
Larensen, 2007	W Scot	56	*Lpis*	M	57.1
Larensen, 2007	Rockall	56	*Lpis*	F	104.4
Larensen, 2007	Rockall	56	*Lpis*	M	57.3
Gordon, 2001	W Scot	56	*Lpis*	F	92

Reference	Area	Latitude	Species	Sex	L50
Gordon, 2001	W Scot	56	*Lpis*	M	56
Dyb, unpub in Thangstad, 2006	Nsea	58	*Lpis*	F	83
Dyb, unpub in Thangstad, 2006	Nsea	58	*Lpis*	M	57
Larensen, 2007	Shetland	60	*Lpis*	F	96.7
Larensen, 2007	Shetland	60	*Lpis*	M	60.6
Dyb, unpub in Thangstad, 2006	W Norway	62	*Lpis*	F	61
Dyb, unpub in Thangstad, 2006	W Norway	62	*Lpis*	M	57
Offstad, 2017	Faroe	62	*Lpis*	F	84
Offstad, 2017	Faroe	62	*Lpis*	M	58

Figure 4.2.1.8 shows the trend for maturity at higher latitudes to occur at larger lengths.

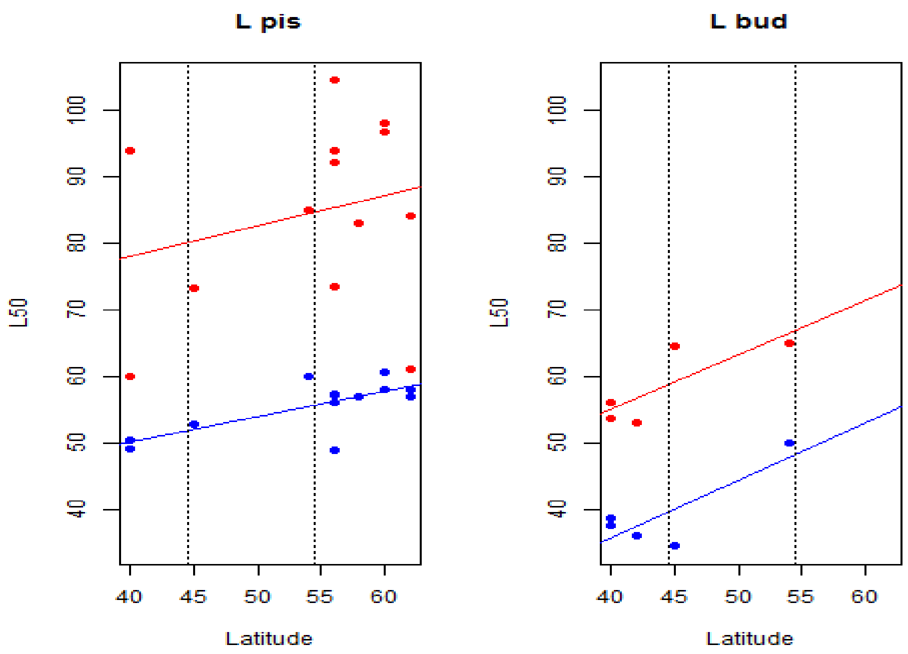


Figure 4.2.1.8. L50 (length at 50% maturity) from the literature, plotted against latitude. This information can be used to establish a range of plausible lengths at maturity for sensitivity analysis.

Spawning has been documented to occur in ICES Division 2a in spring. The estimation of GSI (gonad-somatic index) for females in Division IIa, indicated developing ovaries from January to June. The highest values of GSI were found in June when some of the ovaries were 20–30% of the round weight. Only females bigger than 90 cm had elevated GSI values indicating developing ovaries. The Nordic project (Thangstad *et al*., 2006) developed a five-stage maturity scale that have since been used by the Nordic countries and UK; (I) virgin/immature, (II) developing, (III) maturing, (IV) ripe or spawning and (V) spent or resting, and where maturity stage I and II were classified as immature and stage III, IV and V as mature. Thangstad *et al*. (2006) also describes the gonad differences between the sexes, and presents macroscopic images of the different stages of maturation relative to the five-stage scale (Figures 4.2.1.9 and 4.2.1.10).

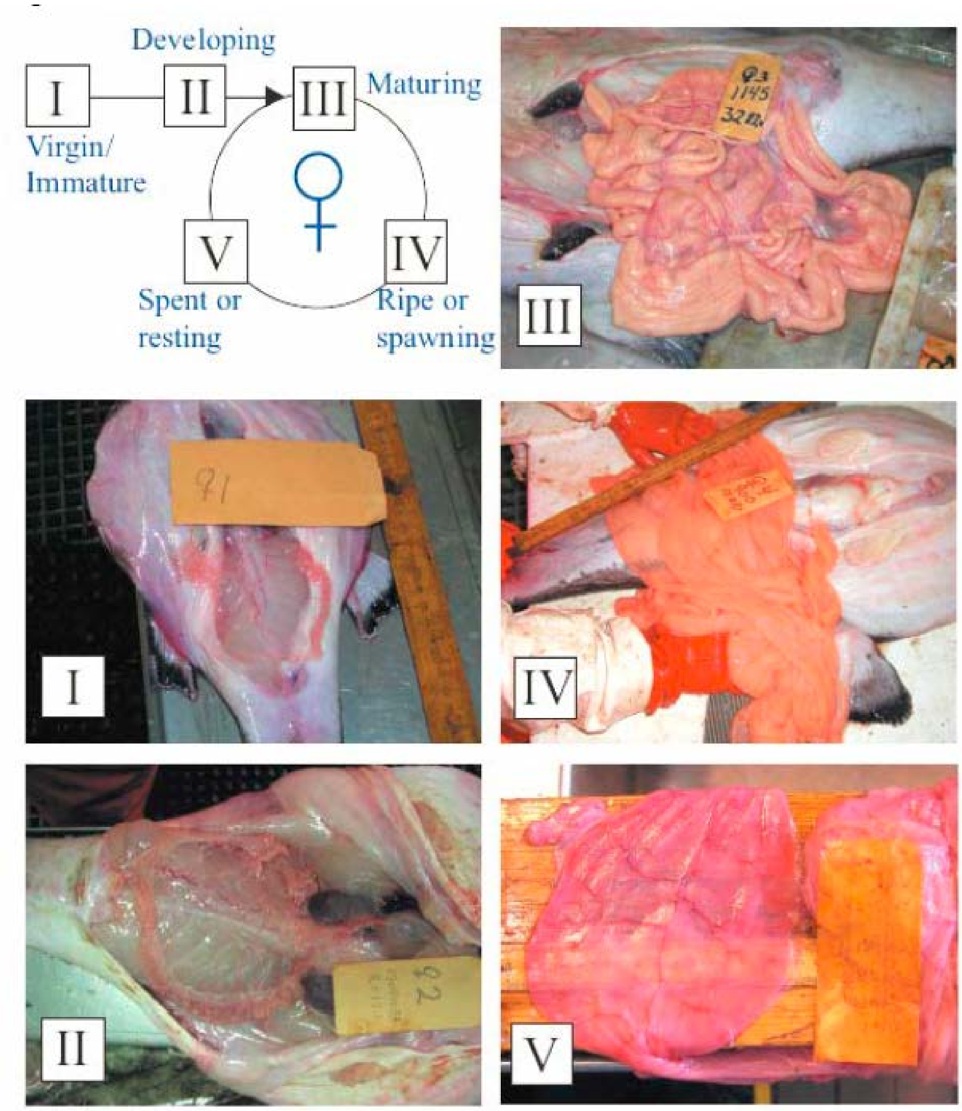


Figure 4.2.1.9: Maturation stages in female *Lophius piscatorius* according to scale described in Table 4.2.1.2 (Photos: L.H. Ofstad; Thangstad *et al.,* 2006).

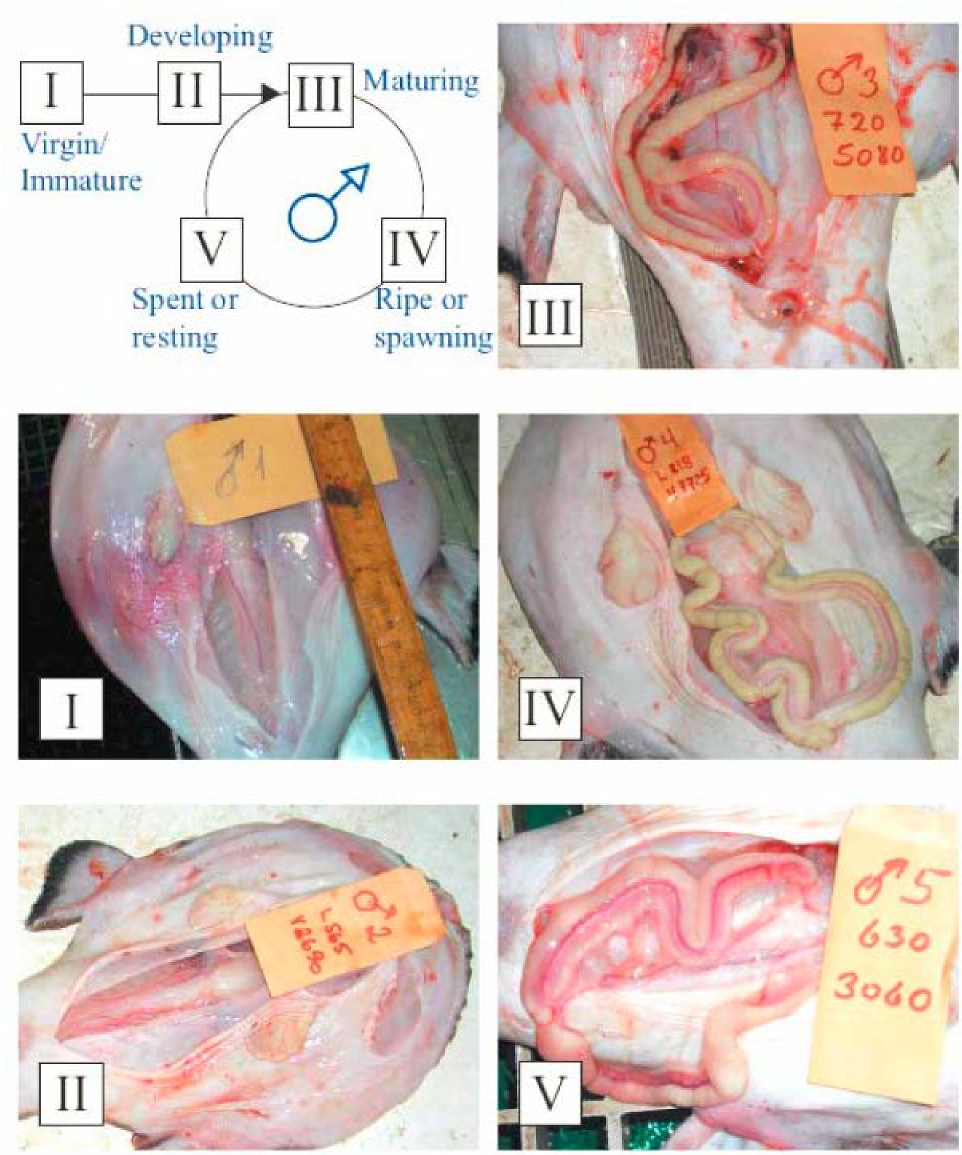


Figure 4.2.1.10. Maturation stages in male *Lophius piscatorius* according to scale described in Table 4.2.1.2 (Photos: L.H. Ofstad; Thangstad *et al.*, 2006).

Table 4.2.1.2 Macroscopic maturity scale for *Lophius piscatorius*, as agreed on by the Nordic project group to be used as standard (Thangstad *et al.*, 2006). The scale is based on previously used scales shown in Thangstad op. cit.

Maturity stage		Females	Males
I	Virgin/ immature	The ovaries are very narrow (< 2cm broad), thin and ribbon-like. They are translucent and no individual oocyte-clusters (eggs) and vascularization can be seen. Veins can though be seen in the connecting tissue/membrane running to the ovaries. The volume of the ovaries is negligible compared with that of the other internal organs.	The testes are long, narrow (<5 mm broad) and have a tube-like structure. The medial seminiferous duct is distinct, being very pale with no visible vascularization. Their volume is negligible compared with that of the other internal organs.
II	Developing	The ovaries increase in length and, particularly, in width (~2 – 4 cm broad). They become less translucent and there is visible vascularization. There are still no visible individual oocyte clusters (eggs), but the texture is almost grainy when rubbed. The volume occupied by the ovaries is roughly the same as that occupied by the intestine.	The flattened tubular shaped testes increase in length and, especially, in width. Blood vessels become visible around the medial seminiferous duct. The volume is roughly half that occupied by the intestine. Milt not visible when cutting the gonad.
III	Maturing	The ovaries increase considerably in width (>4cm) and, particularly, in length. They are highly vascularised. Individual opaque oocyte clusters (eggs) are visible, and at the end of the stage embedded in a gelatinous matrix. The ovaries occupy most of the abdominal cavity.	The testes have a very firm texture and moderate to large amounts of milt are produced when they are dissected, but no milt extrudes when pressure is applied. The seminiferous duct is now highly vascularised.
IV	Ripe or spawning	The ovaries are extremely long (>6m) and wide (20-30 cm) and occupy most of the body cavity. The bright orange oocyte clusters (1-2mm eggs) have darker centres, and are embedded in a transparent gelatinous matrix. The ovaries are highly vascularised.	Milt runs from the genital pore on slight pressure. The testes appear swollen and large amounts of milt are produced when dissected.
V	Spent or resting	The ovaries are shrunk and flaccid, with longitudinal striations. They are still wide (6-15cm) and highly vascularised when newly spent. When resting the ovaries are opaque and less vascularised. When newly spent, a few remaining oocytes (eggs) may occur.	The testes are very flaccid, and look bruised red or blotchy. In newly spent males, milt may be present in the seminiferous duct when dissected, but no milt extrudes when pressure is applied. The posterior edge is sometimes narrower than the anterior part of the gonad. At this stage, the testes are still highly vascularised in the vicinity of the seminiferous duct, and the edges of the testes are sometimes transparent.

WKAnglerfish concluded that the values from the literature provide a range of plausible lengths at 50% maturity that can be used for sensitivity analyses.

4.2.2 Natural mortality

The currently used value of 0.2 reflected the results of Hoenig's (1983) method-based only on a maximum observed age.

Then *et al*. (2015) validated a range of methods for estimating natural mortality against a database of >200 direct estimates of M for a broad range of species. They concluded that the best predictor of M is the oldest observed age. This information is lacking for anglerfish in absence of agreed ageing criteria. However, when the proposed growth parameters are applied to the catch data; an estimate can be made of how frequently each age class would be encountered. One could then select a sufficiently 'rare' age class as the maximum observed age. For mon78 it is estimated that one in a million fish in the catch would be aged 15 or over; in other words, if a million fish had been aged, it is very unlikely that any would be older than age 15. For ank78 this age is 12. These ages can now be applied to Then's method (see figure below). The estimate for M is then 0.41 for mon78 and 0.5 for ank78. However, there is considerable variability around this estimate; 95% of the observations are expected to lie between 0.27 and 0.94 at age 12 (ank) and between 0.22 and 0.77 at age 15 (mon).

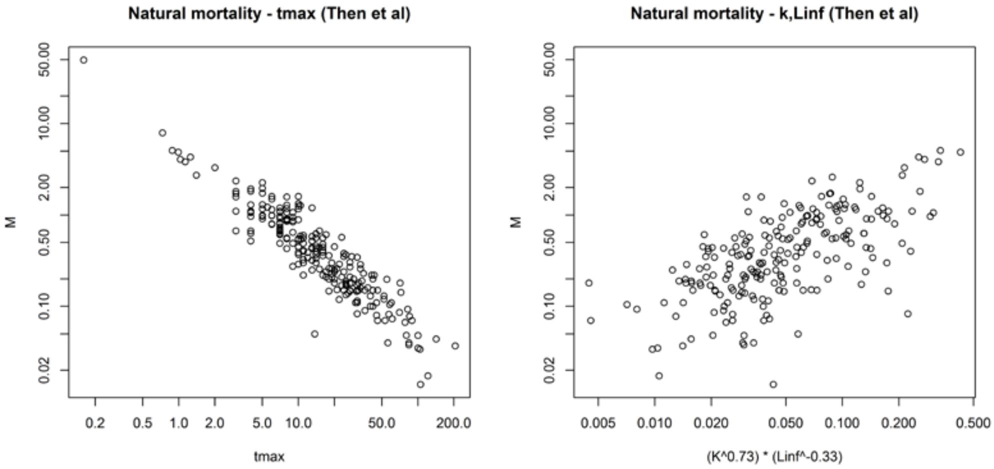


Figure 4.2.2.1. Dataset of >200 independent, direct estimates of M vs. the maximum observed age (tmax) which forms the basis of the paper by Then *et al*.

Other methods (available for the function M.empirical in the fishmethods package) include those by Roff which use growth parameters and age at maturity; Gundersun – using GSI; Lorenzen – weight-at-age; Gislason – growth parameters (length); Then – oldest age and Then – growth parameters (Figure 4.2.2.2). The parameters used to estimate these values were for *L. piscatorius*: Linf=244; Kl=0.0727; tmax=20; tm=7; GSI=0.50; Wwet (from Linf, Kl and t0=-0.104 and a=0.0303, b=2.80); Bl (from Linf, Kl and t0). For *L. budegassa* the parameter values were: Linf=120; Kl=0.1186; tmax=25; tm=7; GSI=0.50; Wwet (from Linf, Kl and t0=-058 and a=0.0195, b=2.93); Bl (from Linf, Kl and t0).

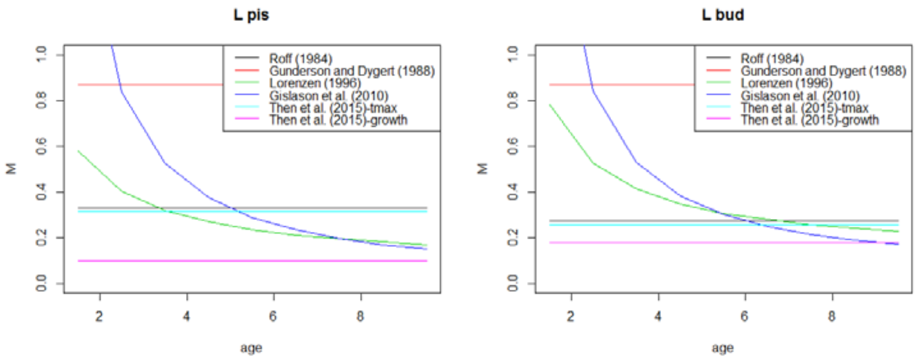


Figure 4.2.2.2. Range of M estimates.

4.2.2.1 Range of M considering the specific biology of *Lophius*

The different methods for estimating M give wide-ranging estimates. Additional uncertainty results from lack of direct ageing confound this further. There are some additional considerations that can help narrow down the credible range for M:

- *Lophius* are ambush predators that are well camouflaged, suggesting they are less likely to be preyed on than species that are more exposed.
- *Lophius* species are fast growing so within a few years they are so large that there are few predators able to eat them.
- *Lophius* are late maturing, which is a life-history strategy which can only be successful for species with relatively low natural mortality.
- *Lophius* seem to be particularly susceptible to parasites, however it is very rare to encounter anglerfish in particularly poor condition, so parasite infection does not appear to harm them excessively.
- Females have a high GSI, which might result in spawning mortality; this will obviously only affect the older, mature fish. Males have relatively low GSI.

Overall there is limited information to suggest that natural mortality decreases with age or length, in fact it may increase for mature females. Therefore, the group concluded that a fixed M value over all ages was more appropriate. Also, there is certainly insufficient information to estimate a time-varying M.

WKAnglerfish conclused that the biology of the species suggests a relatively low M therefore the most appropriate value might be around the lower range of the Then - tmax method.

- For *L. piscatorius* in 78abd, M = 0.25 was assumed and sensitivity between 0.2 and 0.35 was explored.
- For *L. budegassa* in 78abd, M = 0.30 was assumed and sensitivity between 0.2 and 0.35 was explored.

4.3 ToR 3: Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of

relevance for the scientific assessment of the stocks and provision of advice

4.3.1 Fishery management regulations

No TAC is given for ICES subareas 1 and 2, Norwegian waters. Catches of anglerfish in Division 2a, EC waters, are taken as a part of the EC anglerfish quota for ICES areas 3, 4 and 6, or as part of the Norwegian 'Others' quota in EC waters. The most important and relevant fishery management regulations in the Norwegian fishery is:

- A discard ban on anglerfish regardless of size;
- A prohibition against targeting anglerfish with other fishing gear than 360 mm (stretched mesh) gillnets;
- A minimum catch size of 60 cm in all gillnet fisheries, and a maximum permission of 5% anglerfish (in numbers) below 60 cm when fishing with gillnets;
- 72 hours maximum soak time in the gillnet fishery;
- A maximum of 500 gillnets (each net being maximum 27.5 m long) per vessel;
- A closure of the gillnet fishery from 1 March to 20 May. This closure period was expanded to 20 December-20 May in the areas north of N 65° in 2008 and north of N 64° since 2009;
- A maximum of 15% bycatch of anglerfish in the trawl- and Danish seine fisheries, and maximum 10% bycatch of anglerfish in the shrimp trawl fishery. When fishing for argentines and Norway pout/sandeel a maximum of 0.5% bycatch is allowed within a maximum limit of 500 kg anglerfish per trip;
- A maximum of 5% bycatch of anglerfish in gillnets targeting other species;

During the directed gillnet fishery in 2012 and 2013, not landed anglerfish accounted on average for 8.6% and 8.9%, respectively, of the total anglerfish catch caught by the large-meshed gillnet fishery. This discarding is likely to be representative for this fishery, and is mainly composed of damaged fish due to long soaking time of the gillnets and/or areas with a lot of amphipods/isopods and bad weather over time.

For ICES subareas 4 and 6 and Division 3a:

- The TAC for the anf.3a46 stock (and Division 2a) is currently based on a survey trends assessment method (category 3.2) which estimates biomass for the whole stock area. The current TAC split is 64% to Subarea 4 and 36% to Subarea 6 (since 2011), a downward revision from 67% to Subarea 4 in 2005–2010.
- There is no TAC for Division 3a.
- The stock assessment is carried out for the combined white and black anglerfish species, which are caught and landed together as "monkfish" thus the advice is given for the combined species.
- There is no minimum landing size for anglerfish, but in order to ensure marketing standards a minimum landing weight of 500 g was fixed in 1996 by the Council Regulation (EC) No.2406/96.

For ICES subareas 8c and 9a:

- Although the stock assessment is carried out separately for each species, white and black anglerfish are caught and landed together, due to that, the advice is given for individual and the combined species. There is a unique TAC for both species, set annually by the European Union.
- There is no minimum landing size for anglerfish, but in order to ensure marketing standards a minimum landing weight of 500 g was fixed in 1996 by the Council Regulation (EC) No.2406/96.
- As part of the Recovery Plan for the Southern hake and Iberian *Nephrops* stocks (Council Regulation (EC) No.2166/2005), in force since January of 2006, the fishing effort regulations are affecting the Spanish and Portuguese mixed trawl fisheries. As anglerfish are taken in these mixed trawl fisheries, these stocks are also affected by the recovery plan effort limitation.
- Since 2012 that Portuguese vessels cannot land *Lophius* specimens in January and February. This national regulation was set to avoid target fisheries to these species during the reproductive season.

4.4 ToR 4: Develop time-series of fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision

4.4.1 Catch Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in Subareas 1 and 2 (Northeast Arctic)

4.4.1.1 Commercial fishery landings

Landings in tonnes are available in electronic format since 1950, and by gear categories, months and subareas since 1977.

4.4.1.2 Commercial fishery discards

Estimation of discards, including length composition of the discards, has hitherto only been done for the large-meshed gillnet fishery in 2012–2013. Unwanted catch of anglerfish accounted for on average around 8.6% and 8.9%, respectively, of the total anglerfish catch caught by the large-meshed gillnet fishery. This discarding is likely to be representative for this fishery, and is mainly composed of damaged fish due to long soaking time of the gillnets and/or areas with a lot of amphipods/isopods and bad weather over time.

4.4.2 Catch Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in Subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)

4.4.2.1 Commercial fishery landings

Landings from commercial catches for this stock are reported annually to the Working Group for the Celtic Sea Ecoregion (WGCSE). In addition to this the data call for WKANGLER resulted in the submission of all catches into InterCatch from 2002–2016 under a specified species code and métier list. Landings data prior to this are described and evaluated in previous benchmarks (WKROUND, WKFLAT) and were not subject to any additional evaluation at WKANGLERFISH.

The absence of a TAC for Subarea 4 prior to 1999 means that before 1999, landings in excess of the TAC in Subarea 6 were likely to be misreported into the North Sea. In 1999, a precautionary TAC was introduced for North Sea anglerfish, but was set in accord with recent catch levels from the North Sea which included a substantial amount misreported from Subarea 6. The area misreporting practices thus became institutionalised and the statistical rectangles immediately east of the 4°W boundary (E6 squares) account for a disproportionate part of the combined 6.a/North Sea catches of anglerfish. A procedure to reallocate Scottish misreported landings in Division 4.a back into divisions 6.a and 6.b was developed, the full details can be found in the stock annex and the working document to this report "Scottish misreporting from West of Scotland ICES divisions 27.6.a–b into the North Sea ICES Subarea 4" (see Working Document 17). The landings adjusted for area misreporting are reported below. There were minor differences to the landings data submitted to InterCatch compared with the landings data by ICES statistical rectangle from the UK (Scottish) FMD database. To estimate the WG landings by area the percentage change to landings for Division 4.a (see table below) was applied to the Subarea 4 landings reported to InterCatch with the remainder allocated to divisions 6.a and 6.b in proportion to their landings.

	Reported landings							Post-reallocation			
ICES Division	3.a	4.a	4.b	4.c	6.a	6.b	Total	4.a	6.a	6.b	p
2002	0	9516471	234521	164	1185266	280426	11216848	7437639	2866362	678162.1	-0.22
2003	0	6441603	244701	257	745304	190229	7622094	5077585	1831966	467585	-0.21
2004	0	6420732	141435	6859	882386	309691	7761103	5316913	1699443	596453.3	-0.17
2005	0	7869560	124101	51	993426	436618	9423756	6274724	2101330	923549.9	-0.20
2006	0	7448417	98195	86	869191	420131	8836020	6121176	1763945	852618.2	-0.18
2007	0	8066071	152431	85	955522	482521	9656630	6581137	1942201	980775.7	-0.18
2008	0	8658353	142476	0	1096380	622696	10519905	7003399	2151865	1222165	-0.19
2009	0	7781782	105771	0	866478	1187585	9941616	6312192	1486404	2037249	-0.19
2010	0	5995651	121331	0	1019660	1189794	8326436	4779112	1581091	1844902	-0.20
2011	0	6230803	117998	0	1014707	1016728	8380236	4965370	1646794	1650074	-0.20
2012	0	4820761	83897	0	1188064	894694	6987416	3998382	1657172	1247965	-0.17
2013	0	4546597	48076	0	1042088	812605	6449366	3484157	1639036	1278097	-0.23
2014	0	5929920	68268	0	956348	1214558	8169094	4303733	1672731	2124362	-0.27
2015	0	7973333	109169	0	1634297	863968	10580767	5543492	3223833	1704273	-0.30
2016	17	9244680	95167	0	1946440	822688	12108992	7152924	3416751	1444134	-0.23

Reported landings (kg) of Scottish trawl fleets by ICES division before and after area misreporting reallocation from Subarea 27.4 back to 27.6. p indicates the percentage change to landings for Division 4.a.

Reported catches during the period 1998–2006 may still be underestimated due to significant suspected underreporting and previous WGs highlighted 2003–2005 as being particularly problematic. The introduction of the buyers and sellers regulation in the UK and Ireland is considered to have resolved this with reported landings post-2006 representative of actual total landings into the UK and Ireland. The scale of this underreporting remains unknown.

The WG landings estimates (adjusted for area misreporting) for 2002–2015 in (Tables in Section 4.4.2.1) do not include Norwegian landings as these were only submitted to the WKANGLER data call for 2016.

YEAR	3.A	4.A	4.B	4.C	6.A	6.B	4	6	TOTAL (3.A,4,6)	WG LANDINGS	WG DISCARDS
2002	667	11048	1244	21	2280	718	12313	2998	15978	15067	
2003	478	8523	847	20	2493	643	9390	3136	13004	11847	
2004	519	8987	851	15	2453	671	9853	3124	13496	11857	
2005	458	8424	688	5	3019	958	9117	3982	13557	13540	
2006	425	10339	683	3	2785	915	11026	3700	15151	13071	
2007	433	10632	749	4	3353	1260	11384	4613	16430	14288	524
2008	486	11038	769	5	3373	1247	11812	4620	16918	15739	717
2009	479	10067	652	9	2983	1821	10729	4804	16012	15158	88
2010	434	8134	614	11	3040	1606	8759	4646	13839	11819	185
2011	406	7759	764	9	2871	1871	8532	4741	13679	12532	76
2012	422	6460	714	3	2835	1831	7177	4666	12265	10849	367
2013	407	6392	546	4	2666	2124	6943	4789	12139	11056	343
2014	439	7629	823	27	2610	1755	8482	4366	13287	14078	410
2015*	480	9668	961	9	3365	1559	10639	4924	16043	15450	367
2016*	586	11671	1194	12	4676	1368	12877	6042	19505	19118	873

Official landings by division of the stock anf 27.3.a4–6 (all countries combined) and the total (all divisions) landings and discards estimated by ICES, WGCSE anf.27.3.a.4–6.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
BE	0	0	0	0	0	0	0	0	0	0	135	138	220	132	254
DK	1527	1710	1746	1612	1574	1152	1339	1413	1369	1159	1150	1077	1165	1378	2109
FR	8	8	7	5	6	13	37	43	13	24	17	15	30	26	36
DE	112	76	31	93	187	198	367	233	145	63	274	283	338	309	226
NL	64	44	46	36	43	68	70	42	53	57	63	25	83	93	153
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	623
SW	0	0	0	0	0	0	0	27	10	16	15	9	6	9	10
UK (EN)	296	255	173	130	207	174	118	134	194	253	164	162	122	220	134
UK (NI)	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
UK (SC)	7585	5219	5399	6236	6202	6706	7119	6398	4876	5059	3811	3521	4500	5615	7203
Total	9592	7312	7402	8112	8219	8311	9050	8293	6660	6631	5629	5230	6464	7782	10748

ICES estimates of landings of anf.3.a.4–6 in Subarea 27.4 adjusted for Scottish area misreporting.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
FR	727	1177	1157	1452	1254	1748	1989	1564	1250	1167	1167	1115	1084	1107	1734
DE	38	92	105	115	73	222	146	211	166	149	142	136	85	63	81
IE	394	173	106	180	198	233	184	161	241	133	133	117	163	288	351
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
SP	115	139	90	82	102	85	174	193	157	137	102	150	72	99	227
UK (EN)	8	25	20	17	21	15	4	9	0	0	1	1	1	1	2
UK (NI)	0	0	0	0	0	0	0	1	1	1	1	1	5	8	10
UK (SC)	2917	1869	1730	2212	1776	1961	2169	1495	2261	1659	1696	1647	3706	3244	3424
Total	4199	3475	3208	4058	3424	4264	4666	3634	4076	3246	3242	3167	5116	4810	5830

ICES estimates of landings of anf.3.a.4–6 in Subarea 27.6.a adjusted for Scottish area misreporting.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
FR	42	192	288	291	223	327	339	675	636	524	456	663	148	219	0
DE	0	0	0	0	0	0	0	0	0	0	0	0	66	139	177
IE	0	14	6	12	27	36	47	44	51	16	71	54	54	101	96
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
SP	68	43	28	25	38	31	104	64	71	50	41	0	0	55	19
UK (EN)	132	133	54	93	46	65	1	1	2	113	131	315	133	112	110
UK (NI)	0	0	0	0	0	0	0	0	0	0	0	0	0	104	86
UK (SC)	654	453	548	664	858	990	1232	2049	0	1662	920	1283	1735	1715	1449
Total	896	835	924	1085	1192	1449	1723	2833	760	2365	1619	2315	2136	2445	1948

ICES estimates of landings of anf.3.a.4–6 in Subarea 27.6 adjusted for Scottish area misreporting.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
DK	378	222	317	279	232	261	296	357	275	260	315	307	315	346	390
FR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DE	1	0	1	1	2	1	1	0	1	2	1	2	1	1	2
NL	0	3	5	4	3	2	2	0	5	1	0	1	5	22	24
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123
SE	0	0	0	0	0	0	0	41	43	26	43	33	41	42	52
UK (EN)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UK (SC)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	379	226	322	284	237	265	299	399	324	289	360	342	362	412	591

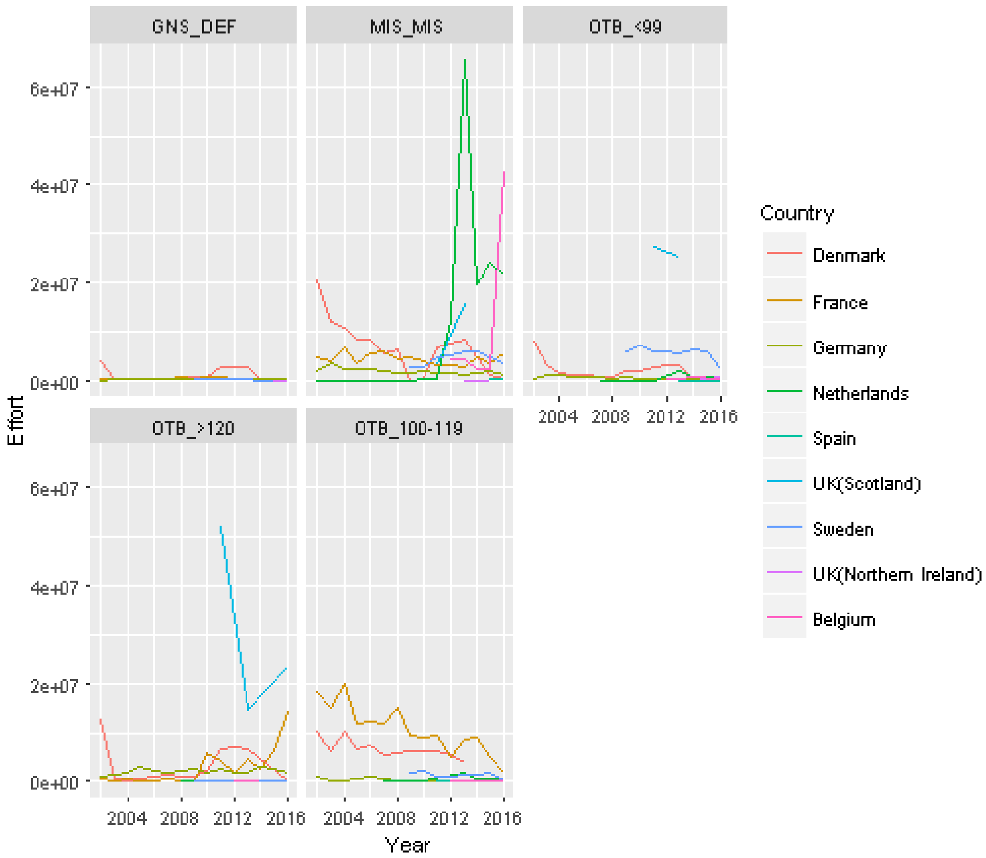
ICES estimates of landings of anf.3.a.4–6 in Subarea 27.3.a adjusted for Scottish area misreporting.

4.4.2.2 Commercial fishery discards

Prior to this benchmark workshop, discard data for the key countries exploiting the Northern Shelf stock were available in InterCatch for 2012 onwards. Total discard rates are relatively low (<5% of total international commercial catch weight) although with the strong 2014 year class now fully selected in the fishery and quota limited in some fleets, this may be expected to increase. The data call associated with the benchmark requested discard data for 2002 onwards. Data for each year (for at least some fleets) were provided by Denmark, Germany, and UK (England). France submitted discard data for some, but not all years since 2002, Ireland submitted no data for 2002 and Scotland only provided discard estimates from 2007 onwards. Discard rates available for other nation's fleets prior to 2007 were high and not considered to be representative of the discarding by the Scottish demersal fleet which accounts for over 60% of landings (based on consideration of trip level data from a number of research projects, Laurenson (2006). For this reason there are no estimates of total discards provided for the stock prior to 2007 (Table in Section 4.4.2.1).

4.4.2.3 Effort

Some effort data as measured in kW days were submitted to the InterCatch WKANGLER data call by several countries however there are few discernible trends due to high variability and the relatively short time-series in some instances. These data were not considered to be used in an assessment.



A Spanish Basque trawl fleet lpue for Subarea 6 and Norwegian gillnet reference fleet lpue indices for Subarea 4 and Division 3.a were presented to the WKANGLER benchmark (see Working Documents 14 and ?) and may be considered for future use in an analytical assessment. These are discussed in ToR8 and in the respective WDs.

4.4.3 Catch White anglerfish (*Lophius piscatorius*) in divisions 7.b-k, 8.a-b, and 8.d (southern Celtic Seas, Bay of Biscay) and Black-bellied anglerfish (*Lophius budegassa*) in divisions 7.b-k, 8.a-b, and 8.d (west and southwest of Ireland, Bay of Biscay)

4.4.3.1 Commercial fishery landings and discards

Table x. Official (EUROSTAT) and ICES estimates of the landings of mon.27.78abd and ank.27.78abd combined. A number of countries applied misreporting corrections, which account for the majority of the unallocated landings.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Official 7b-k	18,339	21,303	21,232	21,319	21,397	23,864	21,310	19,498	21,685	23,918	26,131	28,405	28,295	28,088	30,380
ICES 7b-k	22,608	28,235	27,837	27,096	26,623	30,281	27,136	23,623	24,367	26,725	28,965	33,056	29,390	29,387	30,963
Official 8ab	4,457	6,390	7,390	6,825	6,856	6,794	5,893	6,541	6,569	7,154	6,842	7,773	8,386	7,815	7,982
ICES 8ab	5,308	7,231	8,124	7,471	6,743	7,112	7,026	6,282	6,297	7,046	7,358	7,760	8,663	7,886	8,011
Official total	22,796	27,693	28,622	28,144	28,253	30,658	27,203	26,040	28,253	31,072	32,973	36,178	36,681	35,902	38,362
ICES total	27,916	35,466	35,961	34,567	33,365	37,392	34,162	29,905	30,664	33,771	36,323	40,816	38,054	37,274	38,974
Unallocated	5,120	7,773	7,339	6,423	5,112	6,734	6,959	3,865	2,411	2,699	3,350	4,639	1,372	1,372	612
Discards	654	2,690	3,087	2,837	1,596	1,229	2,579	4,191	4,107	2,802	3,789	3,970	4,428	3,784	6,026

4.4.3.2 Species split

Figure x shows the species split applied by each country to the landings of mon.27.78abd and ank.27.78abd. The UK, France and Ireland show very similar trends over time but different absolute values. The Spanish species-split in area 7 is also shows a similar trend but the proportion of *L. piscatorius* is much lower. The Spanish data for area 8 are quite different but these represent only 6% of the total landings.

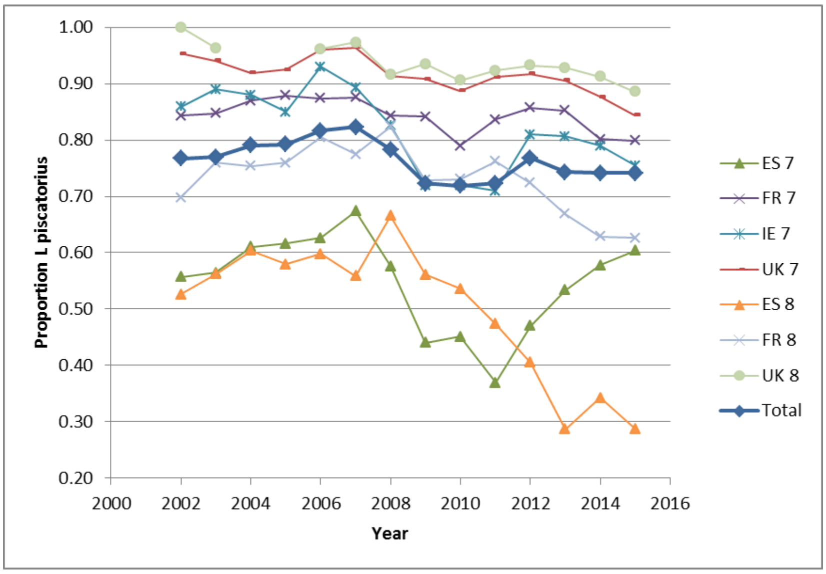


Figure x. Proportion of *L. piscatorius* in the landings of the combined *Lophius* species by country and ICES subarea.

4.4.3.3 Landings by species and country

ICES estimates of annual landings of mon.27.78abd by country and subarea.

Row Labels	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
27.7	**17,874**	**21,980**	**22,479**	**21,882**	**21,947**	**25,424**	**21,097**	**17,145**	**17,555**	**19,309**	**23,007**	**25,782**	**23,276**	**23,103**	**24,836**
BE											1,321	1,100	524	769	981
ES	3,084	4,662	4,507	4,663	4,589	5,065	4,107	2,754	2,353	2,232	2,565	4,465	2,228	2,107	2,105
FR	9,195	12,081	12,281	11,137	10,607	12,253	10,871	8,691	8,188	9,546	12,225	12,775	11,410	11,721	12,667
IE	1,884	1,456	1,646	2,071	2,656	2,902	2,419	2,048	2,523	2,304	2,648	2,557	2,707	2,582	2,761
NL															1
OTH	725	930	1,139	980	957	1,168	772	639	816	939	220	256	278	281	268
UK	2,985	2,850	2,906	3,032	3,137	4,036	2,928	3,013	3,675	4,287	4,028	4,629	6,129	5,644	6,052
27.8	**3,537**	**5,315**	**5,945**	**5,498**	**5,287**	**5,361**	**5,666**	**4,472**	**4,483**	**5,114**	**4,887**	**4,560**	**4,945**	**4,521**	**3,919**
BE											45				
DE	0														
ES	514	508	718	571	420	401	527	374	367	452	472	318	492	303	288
FR	3,023	4,806	5,227	4,927	4,819	4,935	5,132	4,065	4,043	4,569	4,221	4,105	4,279	4,153	3,561
IE		0	0												
UK	0	0			48	25	7	33	73	93	149	137	174	65	69
Grand Total	21,411	27,294	28,424	27,380	27,234	30,785	26,763	21,617	22,038	24,423	27,893	30,342	28,222	27,624	28,755

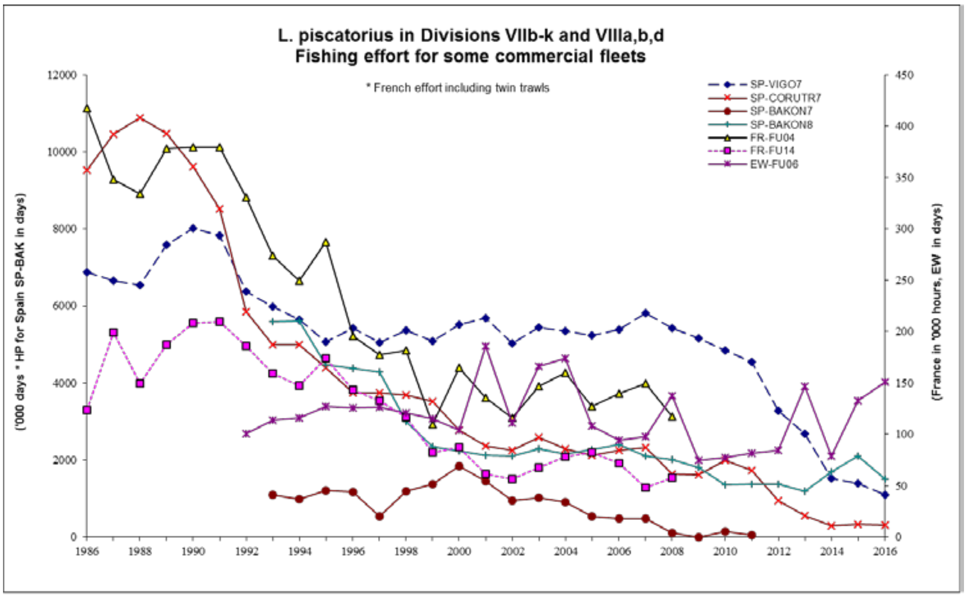
ICES estimates of annual landings of ank.27.78abd by country and subarea.

Row Labels	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
27.7	**4,734**	**6,256**	**5,358**	**5,214**	**4,675**	**4,857**	**6,039**	**6,478**	**6,812**	**7,416**	**5,959**	**7,274**	**6,114**	**6,284**	**6,127**
ES	2,451	3,600	2,875	2,902	2,737	2,451	3,017	3,498	2,866	3,812	2,888	3,896	1,629	1,384	1,118
FR	1,710	2,175	1,845	1,530	1,536	1,747	2,030	1,635	2,179	1,863	2,032	2,211	2,829	2,945	2,881
IE	309	180	224	365	200	348	508	797	981	941	621	615	720	839	970
OTH	119	119	157	167	71	162	205	244	316	382	53	68	74	69	94
UK	146	181	256	248	131	150	279	304	469	418	365	484	862	1,046	1,063
27.8	**1,771**	**1,916**	**2,178**	**1,974**	**1,456**	**1,751**	**1,360**	**1,809**	**1,815**	**1,933**	**2,471**	**3,200**	**3,718**	**3,365**	**4,093**
BE											156	368	230	128	193
DE	0														
ES	463	396	471	415	282	316	265	293	317	503	692	790	945	749	918
FR	1,309	1,520	1,708	1,559	1,171	1,434	1,095	1,515	1,490	1,423	1,612	2,032	2,526	2,480	2,968
IE		0	0												
UK	0	0			2	1	1	2	8	8	11	11	17	8	13
Grand Total	6,505	8,171	7,537	7,187	6,131	6,608	7,399	8,287	8,626	9,348	8,429	10,475	9,832	9,649	10,220

4.4.3.4 Commercial fishery discards

The assessment currently excludes discards, which have been considered to be relatively low. Discard data are now available from 2003 onwards. In that period the proportion of the catch that was discarded varied between 3 and 11% for mon.27.78abd and 2 and 20% for ank.27.78abd. See also table in 3.4.3.1.

4.4.3.5 Effort



Effort in nearly all fleets has declined substantially over the last 20 years.

4.4.4 Catch White anglerfish (*Lophius piscatorius*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

4.4.4.1 Commercial fishery landings

The commercial fishery landings for this stock are reported annually by Spain and Portugal segregated by métier/fleet and quarter (Figure 4.4.4.1.1). The ICES data call for WKANGLER resulted in the submission of French landings from 2002–2016, that represent less than 1% of total landings of the stock. Besides official landings, there is a series of unreported landings for the period 2011–2016. This series represents an average of 14% of total landings. The unreported landings are considered realistic and are included in the stock assessment. No quality indicators for landings series are available. The methodology for estimating species-specific landings, to separate landings by *Lophius* species, has been revised, but not revised data were provided. There are not suspicions of relevant inaccuracy in the landings figures.

Figure 4.4.4.1.1. Mon.27.8c.9a Official quarterly landings by country, area, and fleet for the period 2003–2016.

4.4.4.2 Commercial fishery discards

The assessment currently excludes discards, which have been considered negligible for Portugal fleets and low for Spanish fleets. Spain provides an annual estimate of discards in weight for trawl since 1994 (with gaps for years 1995, 1996, 1998, 2001 and 2002) and for gillnets fleet since 2013 (Table 4.4.4.2.1).

Table 4.4.4.2.1. Mon.27.8c.9a. Weight and percentage of discards for Spanish fleets.

	Trawl			Gillnet	
Year	Weight (t)	CV	% Catches	Weight (t)	% Catches
1994	20.9	34.05	2.4		
1995	n/a	n/a	n/a		
1996	n/a	n/a	n/a		
1997	5.4	68.13	0.3		
1998	n/a	n/a	n/a		
1999	0.7	n/a	0.1		
2000	6.2	n/a	1.6		
2001	n/a	n/a	n/a		
2002	n/a	n/a	n/a		
2003	26.2	n/a	2.1		
2004	64.9	n/a	4.1		
2005	56.2	n/a	3.1		
2006	99.3	n/a	6.5		
2007	17.2	n/a	1.5		
2008	5.1	n/a	0.5		
2009	24.5	n/a	3.6		
2010	12.5	n/a	2.3		
2011	30.1	n/a	9.1		
2012	66.7	n/a	11.4		
2013	65.8	n/a	17.0	143.8	16.1
2014	24.4	n/a	5.2	0.0	0.0
2015	20.8	n/a	4.4	7.6	0.8
2016	0.03	n/a	0.0	24.2	2.8

n/a: not available
CV: coefficient of variation

4.4.4.3 Effort

Although there are effort series available for Spanish and Portuguese fleets, they were not considered to be used in the assessment.

4.4.5 Catch Black-bellied anglerfish (*Lophius budegassa*) in divisions 8c and 9a (West and Cantabrian Sea, Atlantic Iberian Waters)

4.4.5.1 Commercial fishery landings

The commercial fishery landings for this stock are reported annually by Spain and Portugal segregated by métier/fleet and quarter (Figure 4.4.5.1.1). Portuguese landings were TAC constrained since 2005 and low landings can be registered during the 4th quarters since then. Since 2012 that Portuguese landings in the 1st quarter may also be lower given the prohibition to land *Lophius* species in January and February (to protect these species during the reproductive season).

This species is usually landed with the white anglerfish and is being recorded together in the ports' statistics. Therefore, estimates of each species in Spanish landings from divisions 8.c and 9.a and Portuguese landings of Division 9.a are derived from their relative proportions in market samples.

French landings from 2002–2016 were available to WKANGLER. These represent less than 1% of total landings of the stock. Besides official landings, there is a series of unreported landings for the period 2011–2016 allocated to Spain, which represents 3% of total landings. The unreported landings are considered realistic and are included in the stock assessment. No quality indicators for landings series are available. The methodology for estimating species-specific landings at the Portuguese landing ports has been revised and a new approach was presented. The objective was to handle with the gap of sampling information detected for some years in some landing ports which can bias the proportion estimates. Given the latitudinal gradient observed in the proportion of these species, with *L. budegassa* proportions increasing remarkably from the northern to the southern landing ports, sampling information along the coast is mandatory. However, the potential new method to split landings needs further studies and was not used for the Benchmark 2018.

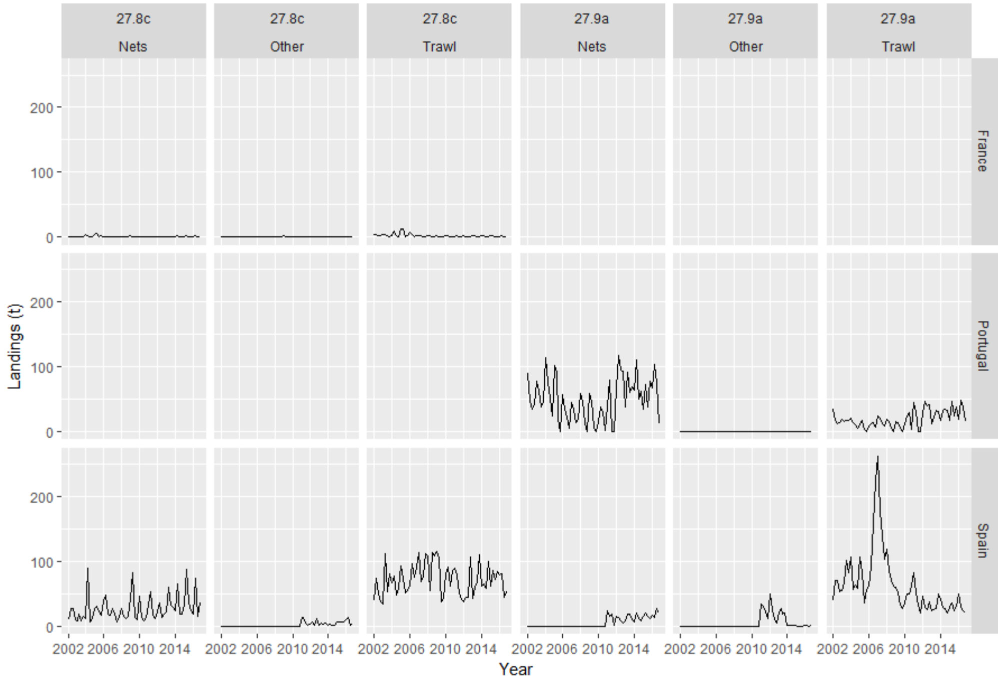


Figure 4.4.5.1.1. Ank.27.8c.9a. Official quarterly landings by country, area, and fleet for the period 2003–2016. French landings were combined to OTB (trawl métiers) and ART (nets and other fleets).

4.4.5.2 Commercial fishery discards

The assessment currently excludes discards, which have been considered negligible for Portugal fleets and low for Spanish fleets. Spain provides an annual estimate of discards in weight for trawl since 1994 (with gaps for years 1995, 1996, 1998, 2001 and 2002) and for gillnets fleet since 2013 (Table 4.4.5.2.1).

Table 4.4.5.2.1. Ank.27.8c.9a. Weight and percentage of discards for Spanish trawl and gillnet fleets.

TRAWL

Year	Weight (t)	CV	% Trawl Catches	% Total Catches
1994	6.1	24.4	0.6	0.4
1995	n/a	n/a	n/a	n/a
1996	n/a	n/a	n/a	n/a
1997	21.3	35.2	1.6	1.2
1998	n/a	n/a	n/a	n/a
1999	19.7	43.7	1.6	1.0
2000	8.7	35.1	1.1	0.6
2001	n/a	n/a	n/a	n/a
2002	n/a	n/a	n/a	n/a
2003	1.4	n/a	0.2	0.1
2004	10.9	n/a	2.0	1.1
2005	9.3	n/a	1.7	1.0
2006	114.0	n/a	11.7	9.8
2007	4.2	n/a	0.4	0.3
2008	4.9	n/a	0.7	0.5
2009	23.3	n/a	4.7	3.0
2010	63.5	n/a	11.0	8.4
2011	19.7	n/a	4.2	1.9
2012	5.9	n/a	1.6	0.5
2013	22.3	n/a	5.2	1.9
2014	27.8	n/a	6.4	2.5
2015	0.5	n/a	0.1	0.0
2016	0.4	n/a	0.1	0.0

GILLNETS

Year	Weight (t)	CV	% Gillnets Catches	% Total Catches
2011	10.6	n/a		
2012	14.3	n/a		
2013	0	n/a		
2014	0.1	n/a	0.03	0.00
2015	0.4	n/a	0.15	0.03
2016	5.0	n/a	2.20	0.44

n/a: not available

CV: coefficient of variation

4.4.5.3 Effort

Although there are effort series available for Spanish and Portuguese fleets, they were not considered to be used in the assessment.

4.5 ToR 5: Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision

Data on landings and discards length frequencies have been evaluated by WKAnglerfish.

4.5.1 Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in Subareas 1 and 2 (Northeast Arctic)

4.5.1.1 Landings length compositions

Landings in numbers-at-length are available for three gear groups, "large-meshed gillnets", "other gillnets", and "other gears" for the years 2010–2017. An age–length key is available based on illicium readings from 970 specimens of *L. piscatorius* collected during North Sea surveys (ICES Subarea 4) and port sampling of landings in ICES Division 2a during 1994–1998 (Dyb, 2003).

4.5.1.2 Discards length compositions

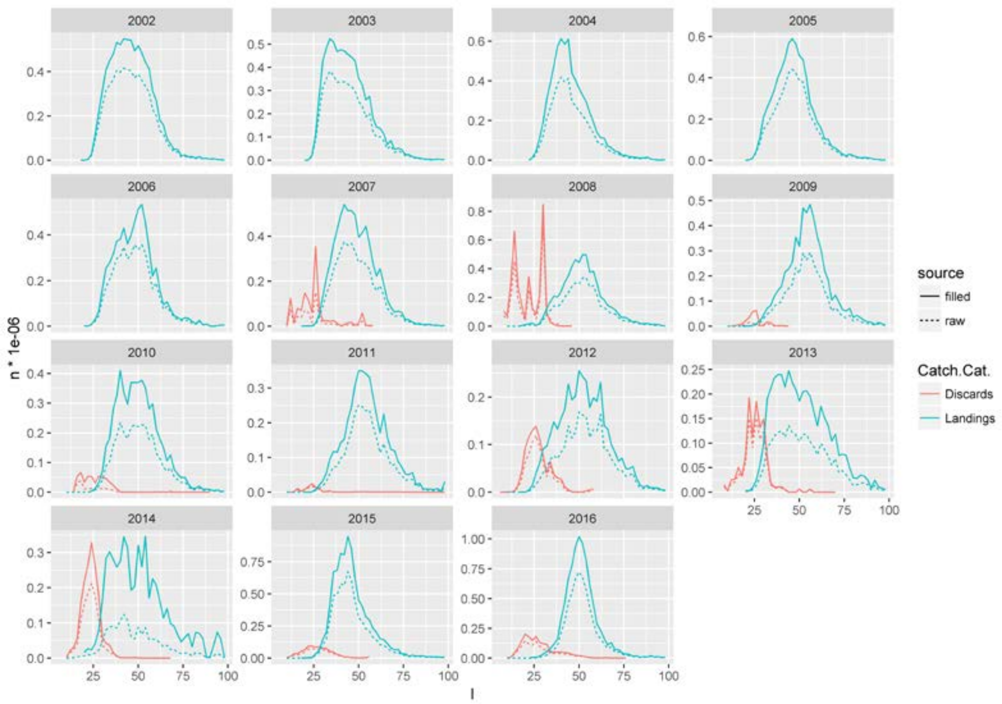
Raised length compositions are given for the

4.5.2 Anglerfish (*Lophius budegassa, Lophius piscatorius*) in Subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)

4.5.2.1 Catch length compositions

Length compositions of landings were submitted to InterCatch for the main métiers/fleets from UK (Scotland), UK (England), Denmark, Ireland and France. The stratification is by ICES division and quarter. In addition to this, landings compositions were submitted to the stock coordinator at WKANGLER for the Spanish Basque trawl fleet fishing in Subarea 6 and the Norwegian gillnet fleet fishing in Subarea 4 and Division 3.a. The number of samples and fish measured are also provided as indicative of quality of the length composition. Estimates of precision are not available. A full break down of the length composition data available for landings and discards can be found in the stock annex.

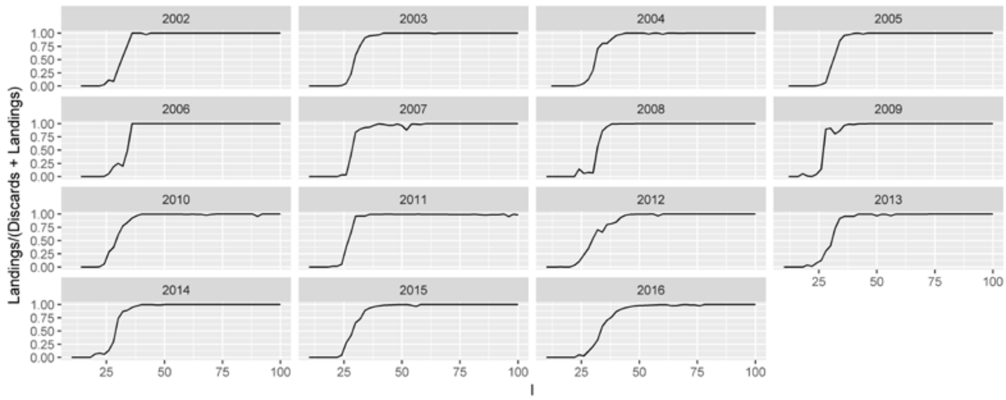
The figure below shows landings and discard length compositions of the data uploaded to InterCatch for the WKANGLER data call, they do not include the length composition data from Spain and Norway received at the benchmark meeting out with the InterCatch system nor do they take account of the area misreporting in the raising process. Whilst discard length compositions were provided by some countries they were considered to be unrepresentative in the absence of any samples from UK (Scotland), the largest exploiter of the stock.



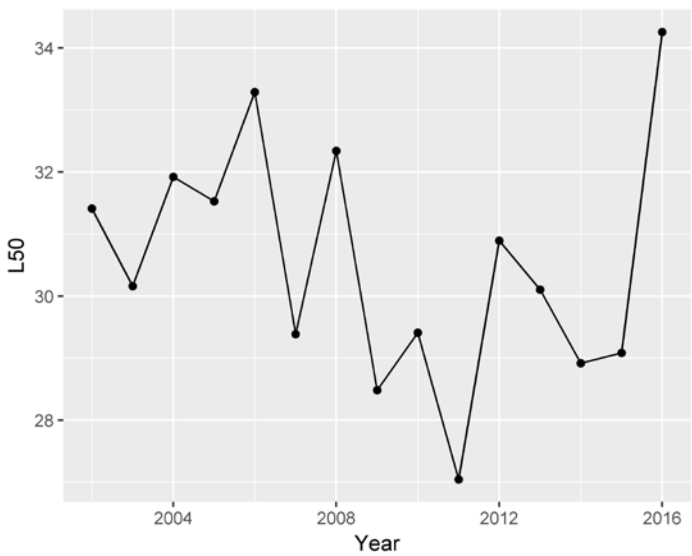
Annual catch length–frequency distributions for InterCatch data anf.27.3a, 4 and 6.

4.5.2.2 Discards length compositions

There is no minimum landing size for anglerfish but the EU Council Regulation (No. 2406/96), stipulates a minimum marketable weight of 500 g for anglerfish which is approximately a length of 32 cm. The discard ogive indicates that larger fish are rarely discarded. From the surveys (NS-IBTS-Q3, SCO-IV-VI-AMISS-Q2), strong incoming year classes with modes between 5–15 cm for the first age group were observed in 2002, 2005, 2008, 2013 and 2017. There is often a decrease in the L50 in the catch in the following year when recruitment may start to be observed in the commercial catches. There has been a marked increase in the L50 in 2016.



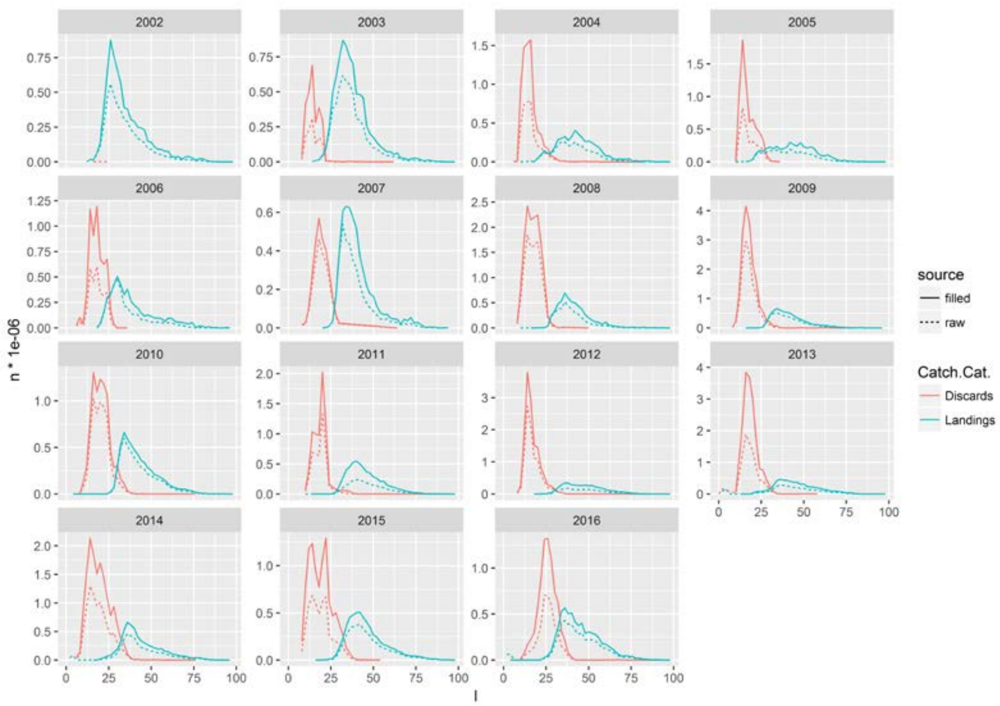
Discard ogives anf 27.3.a.4–6.



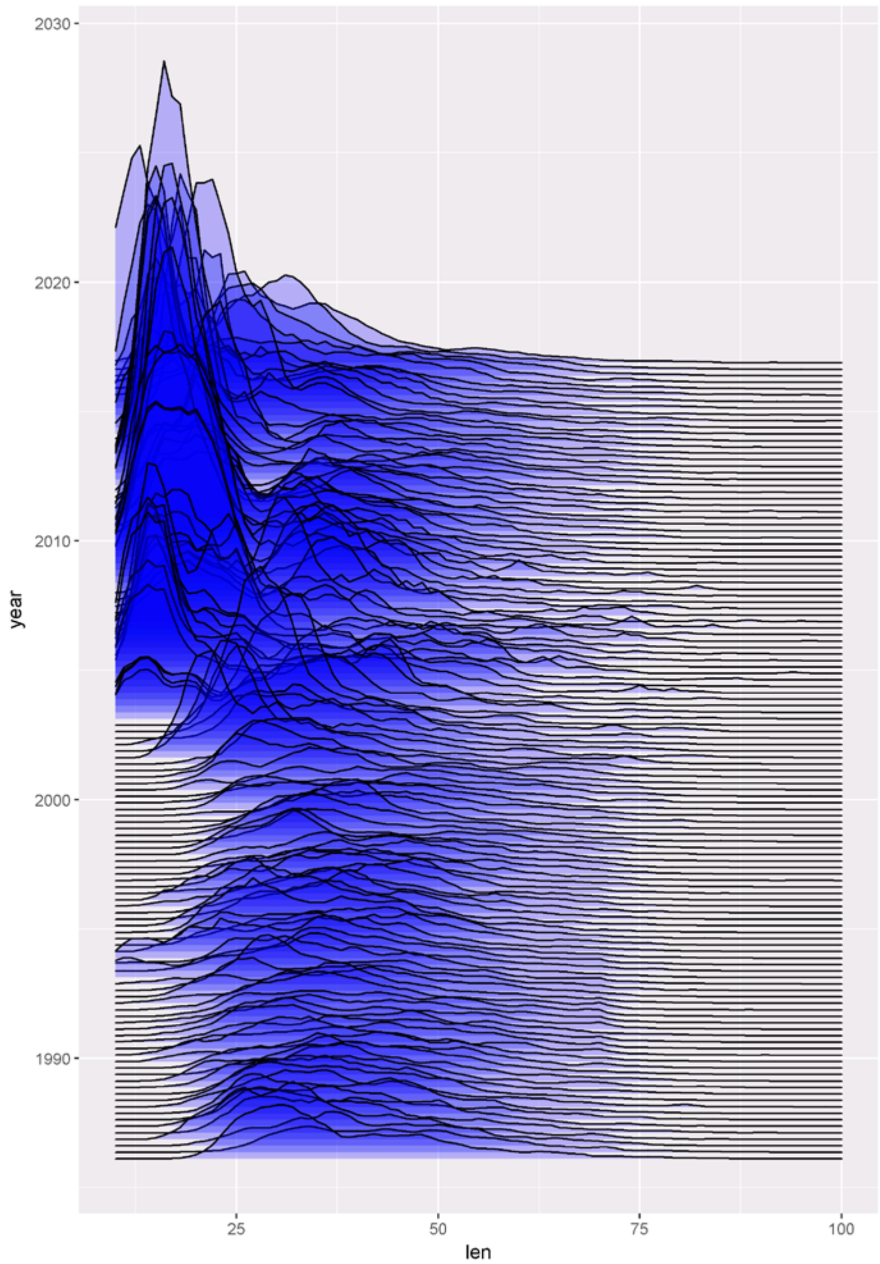
Length at 50% discards over time anf 27.3.a.4-6. Fish of 32 cm have an average weight of 500 g.

4.5.3 Black-bellied anglerfish (*Lophius budegassa*) in divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay)

4.5.3.1 Catch length compositions



Annual catch length–frequency distributions for mon.27.78ab.

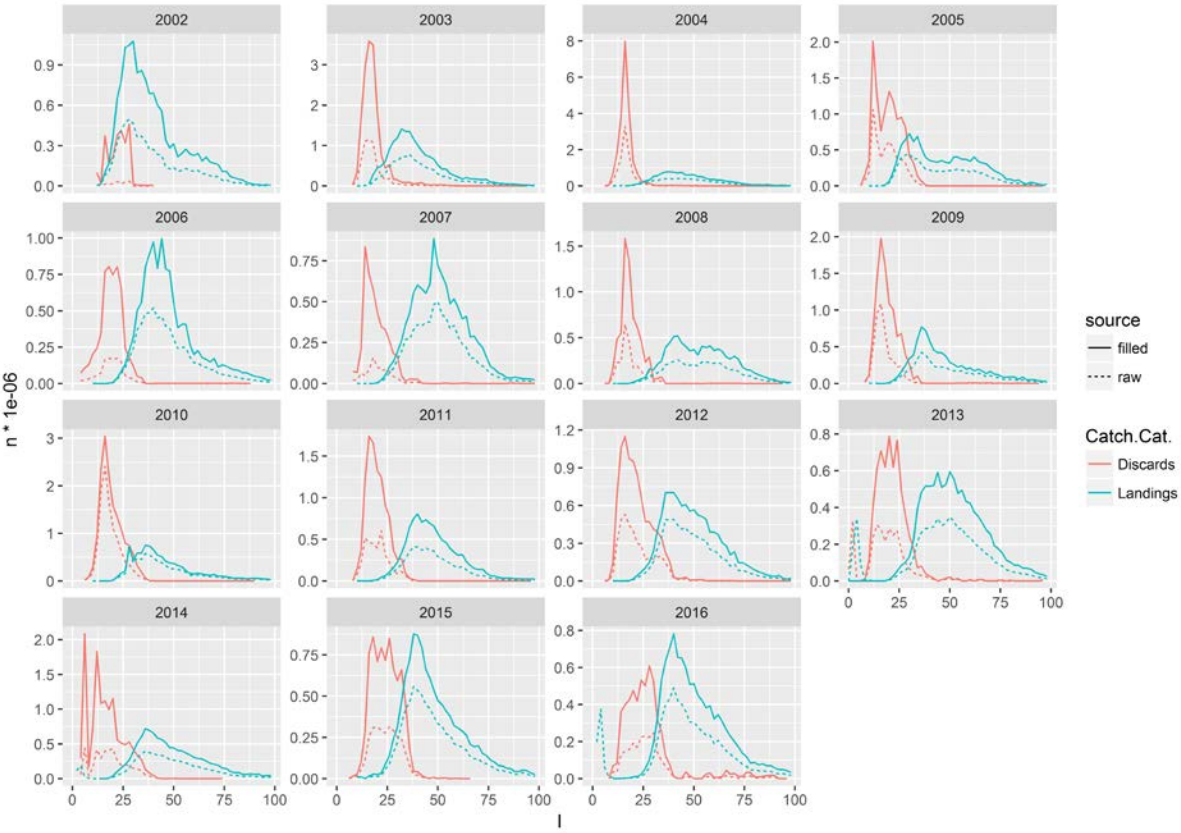


Quarterly length distributions of the catch data. Cohort tracking is not as clear as in the *L piscatorius* catch data.

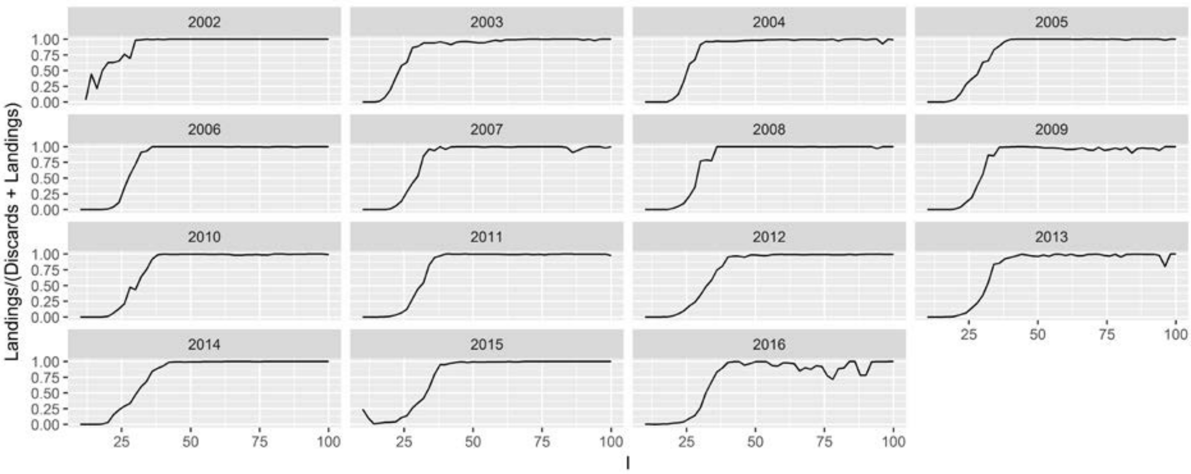
4.5.4 White anglerfish (*Lophius piscatorius*) in divisions 7.b–k, 8.a–b, and 8.d (southern Celtic Seas, Bay of Biscay)

4.5.4.1 Catch length compositions

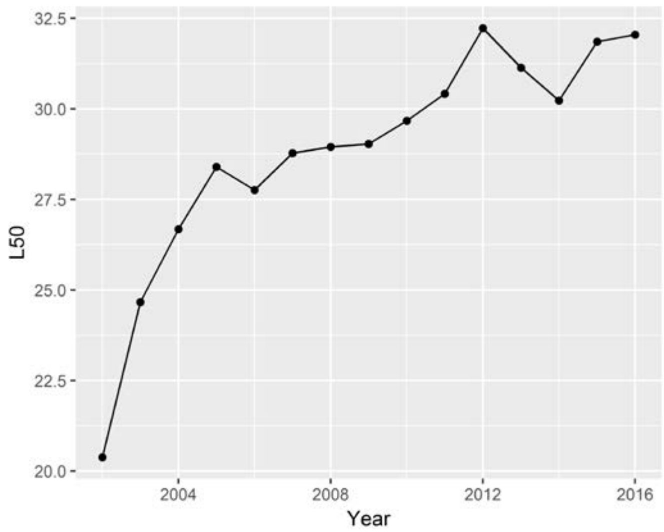
There is no minimal landing size for anglerfish but an EU Council Regulation (No. 2406/96), laying down common marketing standards for certain fishery products fixes a minimum weight of 500 g for anglerfish. When the minimum landing size does not fit with the selective properties of the gears, this is expected to lead to discarding of undersized fish. The estimates of discards are mainly between 12.5 and 37 cm, or between 33 and 744 g (following the length–weight relationship estimated by Landa *et al*. (2017)). From the surveys (WGBIE), strong incoming year classes with modes between 10–25 cm for the first age group were observed in 2002, 2004, 2008, 2009, 2010 , 2011 and 2014; 25–45 for the second age group in 2002, 2003, 2005, 2009, 2010, 2011; and those are the years with the highest discards numbers.



Discards



Discard ogives. Only in 2016 was there significant discarding of marketable fish.



Length at 50% discards over time. Fish of 32 cm have an average weight of 500 g; L50 is close to this value in recent years.

4.5.5 White anglerfish (*Lophius piscatorius*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

4.5.5.1 Landings and discards length compositions

Length compositions of landings are available for the main métiers/fleets from Portugal and Spain (Table 4.5.5.1.1). The stratification is by ICES division and quarter. The number of samples and fish measured are also provided as indicative of quality of the length composition. Estimates of precision are not available. The quality of length compositions was consistent through the years. Since 2009, when the métier-based sampling was implemented in the DCR, the length compositions of Portuguese fleets are estimated with a small number of fish measured. These length compositions have a low quality and will not be used in the stock assessment or with a very low effective sample size.

Table 4.5.5.1.1. Mon.27.8c.9a. Length composition of landings. Stratification and quality checks.

Country	Metier	Division	Fleet	Subarea	Quality	Q_check	For assessment
SP	**GNS_DEF_>=100_0_0** GNS_DEF_60-79_0_0 GTR_DEF_60-79_0_0 GNS_DEF_80-99_0_0	8c	Gillnet	8c9a	nsamples, nfish	high sampling level good coverage	Effective Sample size=125
SP	**OTB_DEF_>=55_0_0** OTB_MPD_>=55_0_0 PTB_MPD_>=55_0_0	8c	Trawl	8c9a	nsamples, nfish	high sampling level good coverage	Effective Sample size=125
SP	**OTB_DEF_>=55_0_0** OTB_MPD_>=55_0_0 OTB_MCD_>=55_0_0 PTB_MPD_>=55_0_0	9a					
PT	MIS_MIS_0_0_0	9a	Artisanal	9a	nsamples, nfish	Since 2009: low sampling level	No used for the assessment or effective sample size=25
PT	OTB	9a	Trawl	9a	nsamples, nfish	Since 2009: low sampling level	No used for the assessment or effective sample size=25

4.5.5.2 Discards length compositions

Discards are considered negligible or low (<5% total catch) and discard length composition are not regularly provided by countries.

4.5.6 Black-bellied anglerfish (*Lophius budegassa*) in divisions 8.c and 9.a (Cantabrian Sea, Atlantic Iberian waters)

4.5.6.1 Landings length compositions

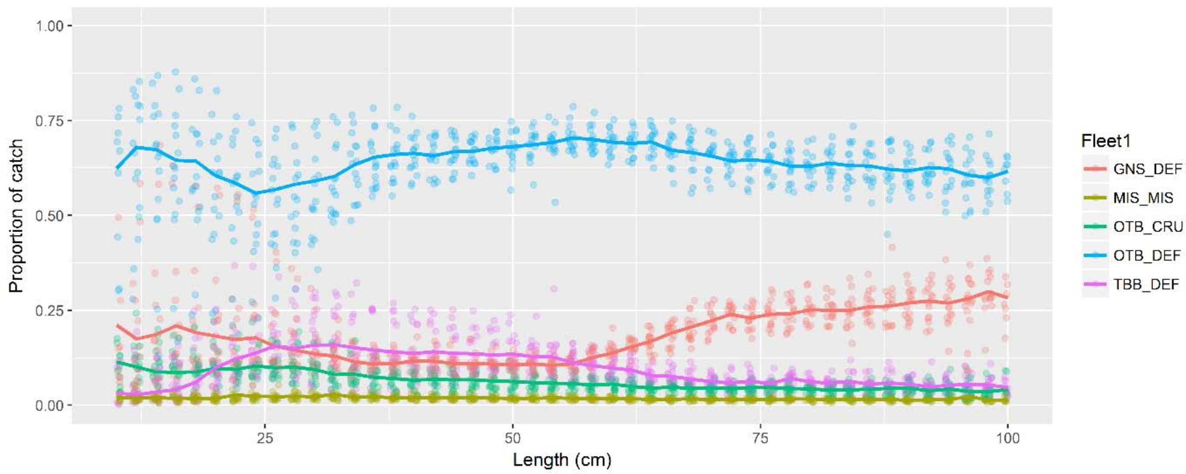
Length compositions of landings are available for the main métiers/fleets from Portugal and Spain. The stratification is by ICES division and quarter. Estimates of precision are not available. The quality of length compositions was consistent through the years.

4.5.6.2 Discards length compositions

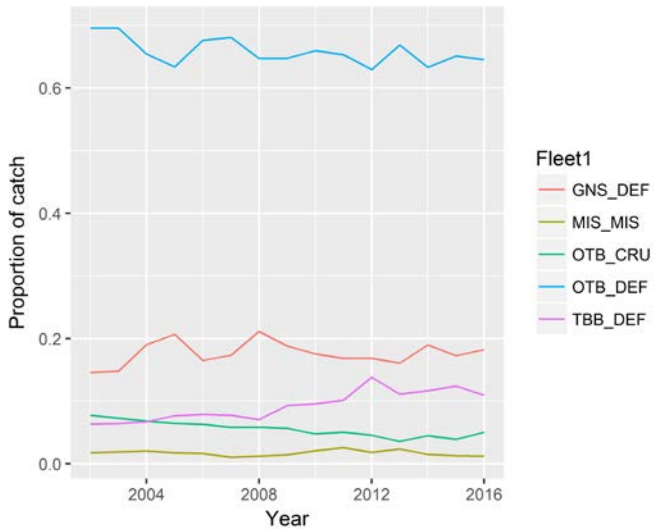
Discards are considered negligible or low (<5% total catch) and discard length composition are not regularly provided.

4.6 ToR 6: Develop recommendations for addressing fishery selectivity (pattern of catchability at length or age) in the assessment model

4.6.1 White anglerfish (*Lophius piscatorius*) in divisions 7.b-k, 8.a-b, and 8.d (southern Celtic Seas, Bay of Biscay)

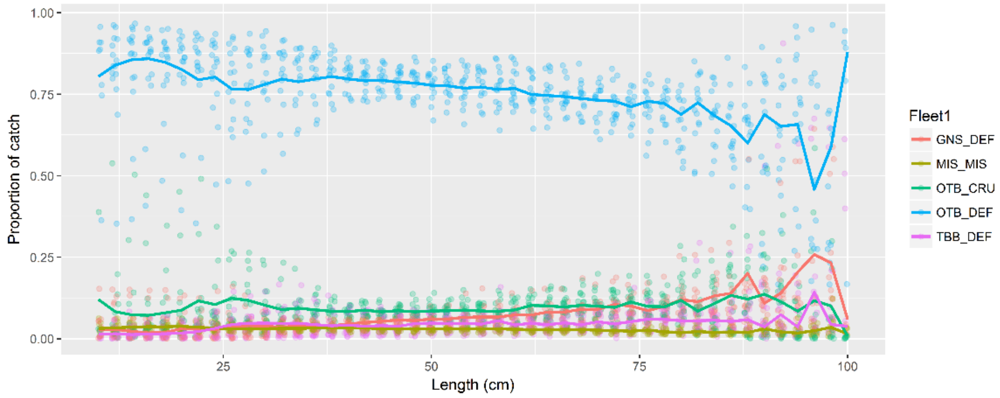


The proportion of the catch in each length class that was caught by each fleet. The lines are the average over all years, the points represent individual years. Gillnets catch relatively more of the large (>60 cm) fish. Beam trawls catch relatively more of the medium sized (20–60 cm) fish.

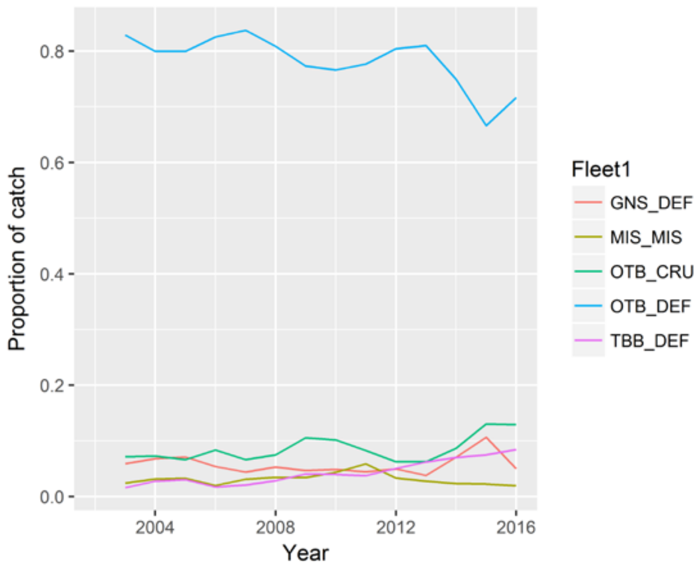


The contribution of each of the fleets to the catches is relatively constant over time, so differences in selectivity between the fleets are probably not of major importance.

4.6.2 Black-bellied anglerfish (*Lophius budegassa*) in divisions 7.b-k, 8.a-b, and 8.d (west and southwest of Ireland, Bay of Biscay)

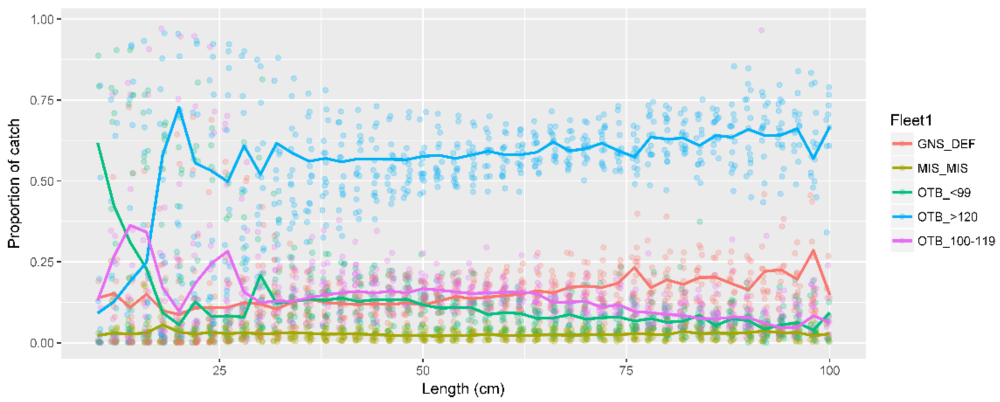


The proportion of the catch in each length class that was caught by each fleet. The lines are the average over all years, the points represent individual years. Gillnets catch relatively more of the large (>60 cm) fish. Beam trawls catch relatively more of the medium sized (20–60 cm) fish.

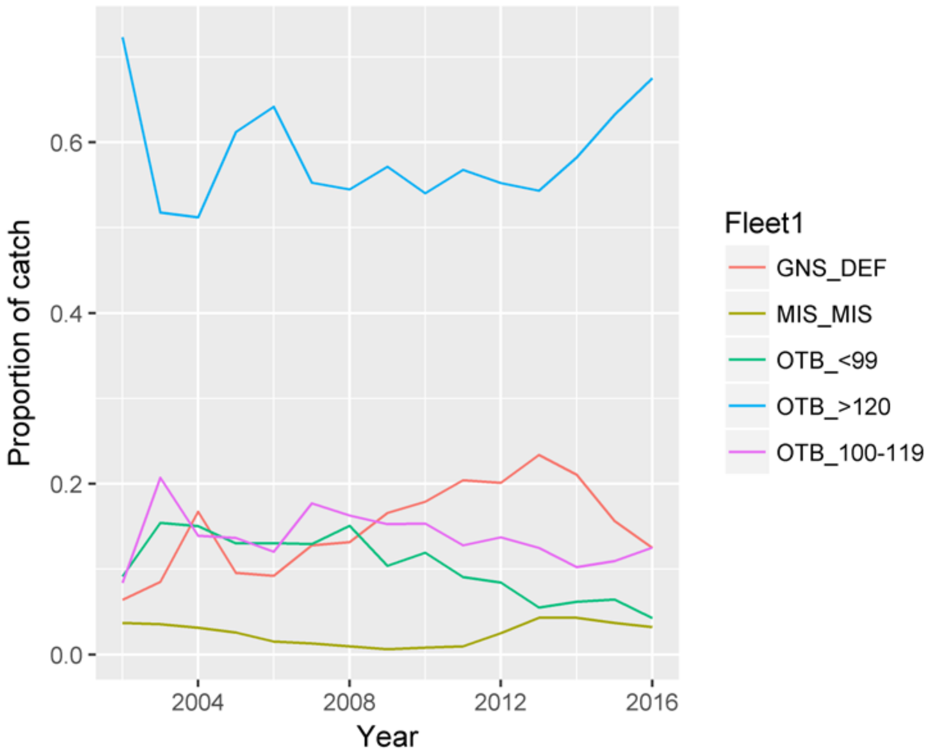


The contribution of each of the fleets to the catches is relatively constant over time, so differences in selectivity between the fleets are probably not of major importance.

4.6.3 Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)



The proportion of the catch in each length class that was caught by each fleet. The lines are the average over all years, the points represent individual years. Gillnets catch relatively more of the larger (>60 cm) fish. Small mesh otter trawls catch more of the medium sized fish (25–60 cm) fish. However large mesh otter trawls (OTB_>120) take the majority of the catch.



The relative contribution of each of the fleets to catches over time has been relatively consistent. There has been a small decline in the proportion of catch attributed to OTB_99 while the GNS_DEF proportion of catches increased to 2013 but has declined since then.

4.7 ToR 7: Recommend values for discard mortality rates for commercial fisheries, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values

4.7.1 Commercial discard mortality

No discard mortality studies for anglerfish were identified during a recent workshop. Anecdotal evidence from tagging suggests low survival of trawl-caught anglerfish, even when the trawl was hauled slowly and the fish were handled with extreme care.

WKAnglerfish data WK proposes that studies are developed to understand the discard survival of anglerfish in commercial fisheries and should focus initially on bottom trawls as these produce the largest amounts of discards. Future changes in quantities discarded from trawls and other gears such as gillnets must be monitored so that removals from dead discards can be reliably estimated.

4.8 ToR 8: Review all available and relevant fishery dependent and independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision

Anglerfish appears in demersal trawl surveys along the Norwegian shelf, but in very small numbers. The trawl survey gears are comparable with those used with greater success in other ICES areas, so that is unlikely to be the reason for catching so small numbers. The reason is rather lack of small and young anglerfish inhabiting the ICES subareas 1 and 2, both coastal and in the Barents Sea. Pelagic trawl surveys and small-meshed trammel-/fykenet surveys shallower than 30 m depth neither catch/observe young anglerfish to any noteworthy degree. Therefore, no time-series from surveys in Division 2a yields reliable information on the abundance of anglerfish.

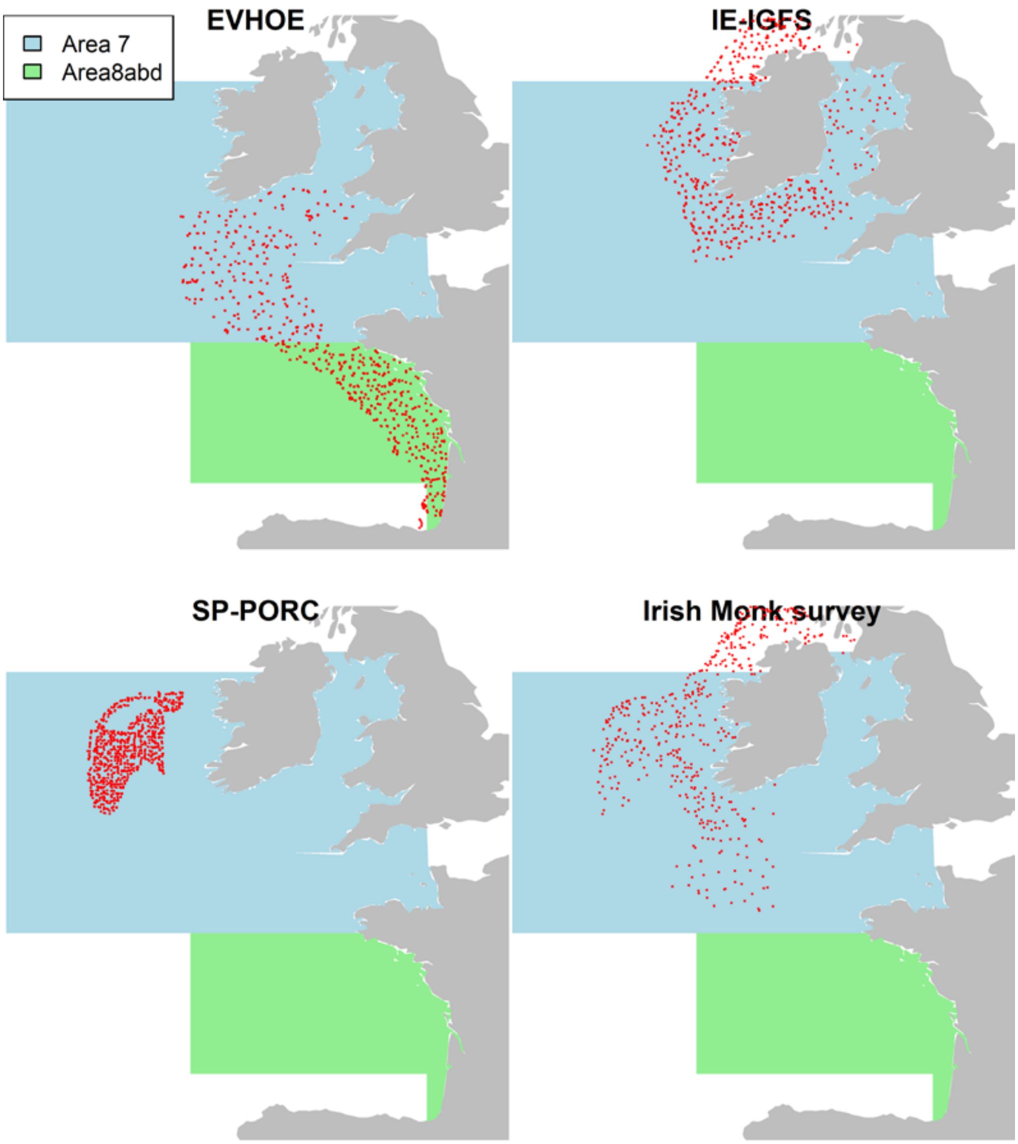


Figure 4.8.1. Overview of the spatial distribution of the surveys available for areas 7 and 8abd. The EVHOE and IE-IGFS surveys were combined into a single 'Irish-French IBTS Q4 survey index' SP-PORC is the Spanish porcupine survey.

4.8.1 Irish-French IBTS Q4 surveys

See working document WKANGLER_mon.27.78ab_2018_IRL_FRA_national surveys for full details.

The Irish IBTS Q4 groundfish survey (IGFS) covers areas 7b,g,j,k. The French EVHOE survey covers areas 7j,8a,b. Therefore, together these surveys cover the majority of the stock area up to depths of 200–300 m. This is where most of the recruitment appears to occur for both species.

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. Because the main recruitment area appears to change over time and sometimes occurs in the Irish survey area, sometimes in the French area and sometimes in both; the combined survey gives a more coherent recruitment signal.

The surveys are not expected to provide a useful index for mature fish, which migrate to deeper waters, not covered by the two surveys. An index of catch numbers-at-length was calculated for both species in areas 78ab.

4.8.2 Irish monkfish survey

See working document WKANGLER_mon.27.78ab_2018_IRL_national_surveys for full details.

Irish anglerfish survey data in area 27.7 are available for the years 2007, 2008 (under the acronym SIAMISS), 2016 and 17 (IAMS). These surveys were designed to estimate the biomass of anglerfish and they cover a significant part of the stock. The estimated indices suggest that the biomass of both *Lophius piscatorius* and *L. budegassa* is around twice as high in the period 2016/2017 compared to 2007/2008. This trend is also apparent in commercial lpue and, to some extent, in IBTS surveys.

The survey index of abundance may be informative for an assessment model that can deal with gaps in survey series. The survey index includes catch numbers-at-length for both species in area 78ab.

4.8.3 Spanish porcupine survey

The Spanish Groundfish Survey in the Porcupine bank (SP-Porc) covers ICES Division 7c,k and a small portion of 7b 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 at the end of the third quarter (September), and the beginning of 4th quarter.

This survey catches larger anglerfish than the French and Irish IBTS surveys, however the catches of *L. budegassa* are so low that no meaningful index could be produced for this species. The available survey index consists of catch numbers-at-length for *L. piscatorius*.

4.8.4 French Groundfish Survey in the Celtic Sea and Bay of Biscay (divisions 7.fghj; 8.ab; EVHOE)

The EVHOE survey covers the Celtic Sea with ICES divisions 7fghj, and the French part of the Bay of Biscay in divisions 8ab. The surveys are conducted from 15 to 600 m depths, usually it is conducted in the fourth quarter, starting at the end of the October.

4.8.5 North Sea International Bottom Trawl Survey (NS-IBTS-Q1 and NS-IBTS-Q3) (divisions 4.a-c and 3.a)

See working document WKANGLER_anf.27.3.a.4-6_2018_NS-IBTS-Q1 and NS-IBTS-Q3 cpue indices for full details.

The multination IBTS Q1 (1987–2017) and Q3 (1991–2016) groundfish survey covers divisions 3.a and 4.a–c. The surveys cover the whole North Sea and Skagerrak components of the 27.3.a.4–6 stock area up to depths of 250 m.

Catches of *L. piscatorius* from all countries participating in the North Sea IBTS quarters 1 and 3 were obtained from DATRAS, quality checked and cleaned. A standard 'anglerfish area' was drawn up to include all ICES statistical rectangles with mean catches of ≥0.1 per haul per hour. The cpue index was calculated, separately for each survey, by summing numbers of fish per size per haul and per hour for each statistical rectangle within the 'anglerfish area', and by dividing this sum by the total number of rectangles within the area (119 rectangles). In addition to mean fish numbers (npue), mean catch weights (wpue) using the same method.

The survey indices show consistent trends between the quarters and significant correlations with the SCO-IV-VI-AMISS-Q2 and may provide useful indices for abundance. The strong year classes are seen earliest in the NS-IBTS-Q3 which could provide a useful index for recruitment.

4.8.6 Scottish Irish Anglerfish and Megrim Industry Science Survey (SCO-IV-VI-AMISS-Q2) (subareas 4-6 and Division 3.a).

See working document to WGCSE for the latest survey report and estimates (Barreto and Clarke, 2017) and Fernandes *et al*., 2007 for survey design and methodology.

The Scottish anglerfish survey covers a significant part of the stock area (subareas 4 and 6) and data are available from 2005 to present (under the acronym SCO-IV-VI-AMISS-Q2). The survey is conducted annually and the results are provided ahead of the advice drafting of WGCSE in October. The survey estimated biomass (for *L. piscatorius* and *L. budegassa* combined) has been used as the basis for advice under the ICES data-limited approach for category 3.2 stocks since 2012. In addition to a biomass index, the survey also provides indices of catch numbers- and weights-at-length. Estimates of abundance are corrected for herding of anglerfish by trawl door, escapes under the footrope (Reid *et al*., 2007a and b) and for fish abundance in regions not covered in specific years (Southern Division 6.a in 2005, 2008 and 2010). This survey will continue to be used as the basis for the assessment of the stock.

4.8.7 Northern Spanish Shelf Groundfish Survey in the Cantabrian Sea and Off Galicia (SP-NSGFS)

The Spanish survey SP-NSGFS covers the northern Spanish shelf comprised in ICES Division 8c and the northern part of 9a, including the Cantabrian Sea and off Galicia waters. The surveys are conducted from 30 to 800 m depth, usually starting at the end of the third quarter. Abundance index data (in number and in weight) and their associated standard deviation and length compositions are available for the period 1983–2016 with the exception of year 1987. The series is annually updated and provided to the WGBIE.

This survey index may be a good indicator for smaller individuals (<20 cm) abundance but will not be used in the stock assessment.

4.8.8 Southern Spanish Groundfish Survey on the Gulf of Cádiz (Southern part of Division 9a) (SP-ARSA)

The Southern Spanish Groundfish Survey on the Gulf of Cádiz is conducted in the southern part of ICES Division 9a, the Gulf of Cádiz. The covered area extends from

15 m to 800 m depth, during spring and autumn. This survey was identified during the WKANGLER-Data Evaluation meeting as a potential abundance index for monkfish in divisions 8c9a. The time-series data were requested to Spain. The series covers the period 1993–2017, two surveys by year, and the abundance index (in number and in weight) and their associated variance, and length compositions are available. The abundance values of *L. piscatorius* in this survey are very low, being zero in some cases and it is not recommended to use this survey index in its assessment. The abundance values of *L. budegassa* in this survey are regular and its usefulness is promising. A survey index for *L. budegassa* was estimated for future use in the assessment, but the low spatial coverage of the stock is a concern.

4.8.9 Portuguese Autumn Groundfish Survey (PtGFS-WIBTS-Q4)

Portuguese Autumn Groundfish Survey has been carried out in Portuguese continental waters since 1979 in the fourth quarter of the years. The survey extends from latitude 41°20' N to 36°30' N (ICES Division 9.a) and from 20–500 m depth. Abundance indices are available from 1989 to 2016. The main objectives of the survey is to estimate the abundance and study the distribution of the most important commercial species in the Portuguese trawl fishery, mainly to monitor the abundance and distribution of hake and horse mackerel recruitment. The low catchability of *Lophius* on these surveys, possibly related to the gear configuration, makes this series unsuitable to assess the abundance or biomass trends of these species.

This survey is not used in the assessment of both white and black anglerfish.

4.8.10 Portuguese Crustacean Survey (PT-CTS (UWTV (FU 28-29)))

The 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, to study the distribution and the biological characteristics of the main crustacean species, namely Norway lobster, rose shrimp and red shrimp. In addition, the survey provides data for other species that have been used for stock assessment purposes.

Biomass and abundance indices for both *L. piscatorius* and *L. budegassa* are available since 1997. This survey is not used in the assessments.

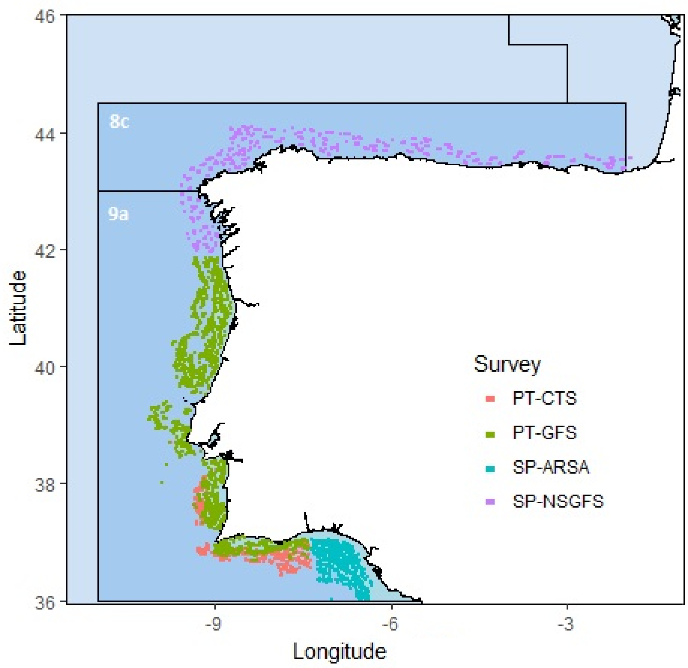


Figure 4.8.2. Overview of the spatial distribution of the surveys available for areas 8c and 9a. Points represent the surveyed locations and not the presence of *Lophius* spp. PT-CTS –Portuguese Crustacean Survey, PT-GFS –Portuguese Ground Fish Survey, SP-ARSA –Spanish Cadiz Survey SP-NSGFS –Spanish Ground Fish Survey.

4.8.11 Fishery-dependent lpue series

4.8.11.1 Norwegian gillnet reference fleet in Division 2a (NO-GNF2a)

Since late 2005, 10–13 gillnetters have been included in a self-sampling scheme established along the Norwegian coast within Division 2a. Detailed information about effort and catch is provided through this scheme. The standardised cpue has been estimated in the following way: a cpue series has been estimated for each vessel, and then an average of the two relative cpues was estimated each year resulting in a standardised cpue time-series. Norwegian reference fleet fish directly for anglerfish using large-meshed gillnets (360 mm), with and without precision measures.

4.8.11.2 Norwegian gillnet reference fleet fishing in Subarea 4 and Division 3.a (NO-GNF4.3a)

A standardized lpue index for a Norwegian reference fleet of gillnetters targeting mainly 70–120 cm anglerfish is available. The lpue was estimated for each vessels seasonal fisheries (three subareas, with at least two vessels in each) and was then averaged annually for the two ICES areas. The fishing effort is measured as number of gillnet soaking days per year giving a catch (landing) rate in kg per gillnet soaking day, with associated precision measures. This lpue series could be standardised further to take into account spatial distribution of effort and may be suitable for use in a future stock assessment.

4.8.11.3 Basque Trawl fleet fishing in Subarea 6.a (SP-TRF6)

See working document WKANGLER_Basque Angler 6 lpue for full details.

A Basque lpue series for the traditional demersal fishing fleet targeting hake, anglerfish and megrim in Subarea 6 is available. The lpue index is standardised using a generalised linear model and is available for both *L. piscatorius* and *L. budegassa* from the fleet from 2004 to 2016. Fishing effort is calculated as fishing days = trips*(days/trip) with the inclusion of only trips where anglerfish were landed. The lpue index is based on 2–4 demersal otter trawls fishing a mesh size between 100–120 mm. The lpue series show consistent trends with the results of SCO-IV-VI-AMISS-Q2 and could be used in a future assessment.

4.8.11.4 Vigo-marine bottom-trawl fleet operating in ICES Division 7

Vigo trawl fleet fishing in Division 7 is available for years 1986–2016. Data provided for Vigo trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet was previously used for tuning XSA assessment of three stocks, as a cpue index (i.e. including discards) for megrim and as an lpue index (without incorporating discards) for anglerfish. However, WKFLAT2012 concluded that it was very difficult to standardise the cpues due to the renovation of the fleet during the 1990s. Therefore, the cpue was split in two series: 1986–1998 and 1999–2010 because changes in fishing power related to technical improvement in the fleet are suspected as cpues have drastically increased for all species caught in the late 1990s;

4.8.11.5 A Coruña Trawl Fleet in Division 8c (SP-CORTR8c)

A Coruña trawl fleet fishing in Division 8.c is available for years 1982–2012. Data provided for A Coruña trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This is a mixed-fishery targeting various demersal (hake, megrims, anglerfish) and pelagic species (mackerel, horse mackerel). The length composition of white anglerfish catches ranged from 30 to 80 cm. This fleet represents an average of 15% and 18% of international catches of white and black anglerfish, respectively, along the available time-series. A standardized series from 1994–2006 is also available for this fleet with annual effort data (in fishing days) and annual lpue. Data from this commercial lpue series are provided annually but, since 2012 the information is not considered adequate for the assessment. The change in the source of the information and the methodology used to estimate the lpue prevent the use of the information since then. This abundance index together with its length composition by quarter and for the period 1982–2012 is used in the assessments.

4.8.11.6 Cedeira Gillnet Fleet in Division 8.c (SP-CEDGN8c)

Cedeira gillnet fleet fishing in Division 8.c is available for years 1999–2011. Data provided for Cedeira gillnets comprise quarterly standardized effort (in soaking days), landings and length composition of landings. This fleet represents an average of 11% and 1% of international catches of white and black anglerfish respectively since 1999. The fishery is directed to white anglerfish (92% of catches) and larger individuals (lengths over 60 cm). Due to the reduction in the number of vessels of Cedeira fleet, this tuning series could not be considered as a representative abundance index of the white anglerfish stock and since 2012, it is no longer recorded. This abundance index and its length composition by quarter for the period 1999–2011 are only used in the white anglerfish assessment.

4.8.11.7 Santander trawl fleet fishing in Division 8.c (SP-SANTR8c)

Santander trawl fleet fishing in Division 8.c is available for the years 1986–2010. Data provided comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents on average of 7% and 3% of international catches of white and black anglerfish, respectively, along the available time-series. Problems with the consistency of the information and the sampling level through the years prevent the use this index in the assessments.

4.8.11.8 Avilés trawl fleet in Division 8.c (SP-AVITR8c)

Avilés trawl fleet fishing in Division 8.c is available for years 1986–2003. Data provided for comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 6% and 3% of international catches of white and black anglerfish, respectively along the available time-series. Problems with the consistency of the information and the sampling level through the years prevent to use this index in the assessments.

4.8.11.9 Portuguese trawlers targeting fish in Division 9.a (PT-TRF9a)

Portuguese trawlers targeting fish: years 1989–2016. Data provided for Portuguese trawlers targeting fish comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet represents an average of 1% and 5% of international catches of white and black anglerfish, respectively, along the time-series. Due to its low representativeness of the white anglerfish, it is only used in the black anglerfish assessment. A standardized series from 1989–2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue, but was not updated since then.

4.8.11.10 Portuguese trawlers targeting crustacean (PT-TRC9a)

Data from the Portuguese trawlers targeting crustacean are available since 1989. Data provided comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet represents an average of 1% and 3% of international catches of white and black anglerfish respectively, along the time-series. Due to its low representativeness of the white anglerfish, it is only used in the black anglerfish assessment. A standardized series from 1989–2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue, but was not updated since then.

4.8.11.11 Portuguese artisanal fleet in Division 9.a

Portuguese landings for both black and white anglerfish are mainly attributed to the artisanal fleet, particularly to vessels targeting these species with trammelnets. However, these vessels can deploy different gears during the same trip (according to the target species), which difficult the collection of accurate data for cpue estimates. Despite the efforts to develop a cpue series using logbook data from a reference fleet, the approach needs further developments and will not be available for the Benchmark 2018. The main issue is the definition of an adequate effort unit.

4.9 ToR 9: Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts

No information available during the benchmark to support this ToR.

4.10 ToR 10: Review progress on existing recommendations for research to develop and improve the input data and parameters for assessments, and develop and prioritise new proposals

4.10.1 Recommendation for Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in subareas 1 and 2 (Northeast Arctic)

This stock management unit was last benchmarked in 2012 and it was decided that anglerfish in Division 2.a was separate from the Northern Shelf, so from 2013 the 'stock unit' 2.a was combined with Subarea 1 and assessed with in the ICES expert working group for arctic fisheries (AFWG). In 2013 AFWG initially assessed the stock to be a Category 3 stock, using the cpue indices from the Norwegian fleet, however since 2014 they have re-evaluated it to be a category 4.

Stock units classified as a category 4 include stocks for which only reliable catch data are available, and includes stocks for which a time-series of catch and catch rates can be used to approximate MSY.

The WKAnglerfish EG agreed with the AFWG that the 'stock unit' is a category 4 stock and recommended that the ICES approved methods should be explored and evaluated by the ICES AFWG for this anglerfish stock unit.

4.11 ToR 11: For each stock, develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the data evaluation workshop

The data inputs and R scripts used by WKAnglerfish for the raising and update assessment is located in the WKAnglerfish SharePoint site in the data folder.

4.12 ToR 12: Prepare the data evaluation workshop report providing complete documentation of workshop actions, decisions, list of working documents, other information used by the workshop, and a list of any additional tasks to be completed following the workshop with dates and responsibilities for completion

This report fulfils this ToR.

All Working Documents supplied to the WKAnglerfish data workshop are located in the Working Document folder on SharePoint. These are mostly drafts of text, tables and figures for the report prepared in advance of the meeting. Also see Annex 3 of this report.

All objectives of the Data Workshop were met at the meeting, and subsequent work focuses on completion of the report. Tasks were allocated to WK members for this purpose on the final day of the meeting.

5 Assessment of the preferred method for evaluation stock status, short-term forecast and MSY and PA reference points

5.1 Black-bellied anglerfish in divisions 8.c and 9.a

In the previous Ank.27.8c.9a benchmark (ICES, 2012), it was concluded that three assessment models could potentially be applied to the data: a Bayesian surplus production model, SS3, and ASPIC. The SS3 seemed promising but more exploration was required before the model could be accepted as the basis for advice. ASPIC, which included three tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to groundfish), was tracking the central trend in the indices and was accepted as the basis for advice. Nevertheless, in the following years ASPIC revealed to be unstable; in 2014 the B1/K needed to be fixed to stabilize the model.

During this benchmark (2018), when reviewing the ASPIC model, it was suggested to explore the SPiCT model (Stochastic Surplus Production model in Continuous Time (Pedersen and Berg, 2016). The SS3 model was also reconsidered.

5.1.1 Model development

5.1.1.1 Configuration of stock synthesis (SS3)

The models were run considering the following data:

- Four series of landing data, by quarter, from the Portuguese and Spanish artisanal and trawl fleets (Spanish data with French data included).
- Three quarterly lpue indices, from the Portuguese crustacean and fish fleets (PT-TRC9A and PT-TRF9A, respectively) and from the A Coruña trawl fleet (SP-CORTR8c).
- Four survey biomass indices, from SP-NSGFS, PT-CTS, SP-ARSA Q1 and SP-ARSA Q4.
- Length data from the: i) Portuguese and Spanish artisanal and trawl fleets, by quarter; ii) from the Portuguese crustacean and fish fleets and from the A Coruña trawl fleet, by quarter; and from research surveys.

Length data from the Portuguese trawl commercial fleets were not available. The tests were performed assuming a quarterly set-up and three different data arrangements:

Test	Landings	LPUE	Survey indices	Length
1	All	All	All	All
2	All	All	---	Landings and SP-CORTR8c
3	All	PT-TRC9A	---	Landings

Recruitment was assumed to follow a Beverton–Holt stock–recruitment relationship and was modelled in a quarterly basis, with prevalence in the third quarter (but tests were also run to determine quarters with highest recruitment). Steepness was fixed at 0.999 and sigmaR at 0.4 or 0.6 whereas R0 was estimated. Selectivities were modelled using a logistic or a double normal distribution function (dome-shaped). Depending on the model configuration, one of the growth parameters was estimated.

Despite the fishing mortality and biomass trends being in accordance with results obtained using ASPIC and SPiCT models, most of the runs performed were not successful due to the poor model convergence. More work and sensitivity analysis are needed to develop a more robust model for this stock.

5.1.1.2 Configuration of SPiCT (Software: SPiCT R package)

The model was set in order to mimic the ASPIC, so the same input data were used:

- Total landings since 1980–2016 (discards are considered negligible).
- Commercial fleets lpues:
    - SPN A Coruña trawl (1982–2012) (Index1);
    - PRT Bottom-trawl crustacean (1989–2016) (Index2);
    - PRT Bottom-trawl fish (1989–2016) (Index3).

SPiCT settings:

- Euler time-step (years): 1/16 (default);
- Production curve shape: assume Schaefer (n=2);
- Alpha (Biomass observation and process errors ratio): estimated by the model (default priors);
- Beta Catch observation and process errors ratio): estimated by the model (default priors);
- Other parameters: default (estimated by the model).

Data

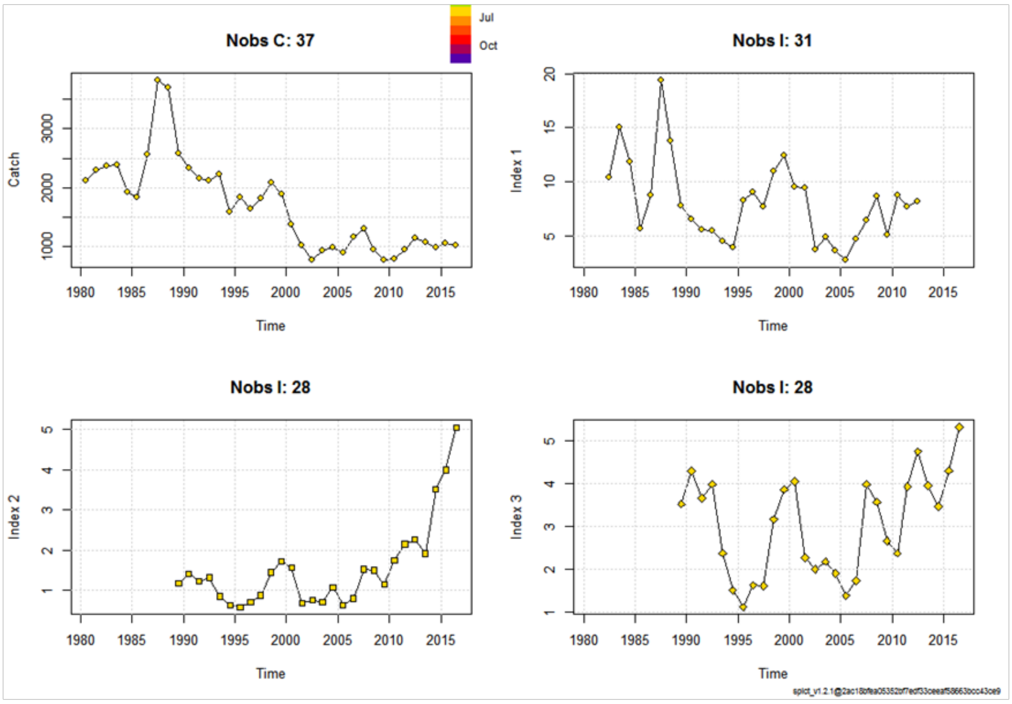


Figure 5.1.1.2.1. Catch; Index 1 - SPN A Coruña trawl (1982–2012); Index 2 - PRT Bottom-trawl crustacean (1989–2016); Index 3 - PRT Bottom-trawl fish (1989–2017).

Diagnostics

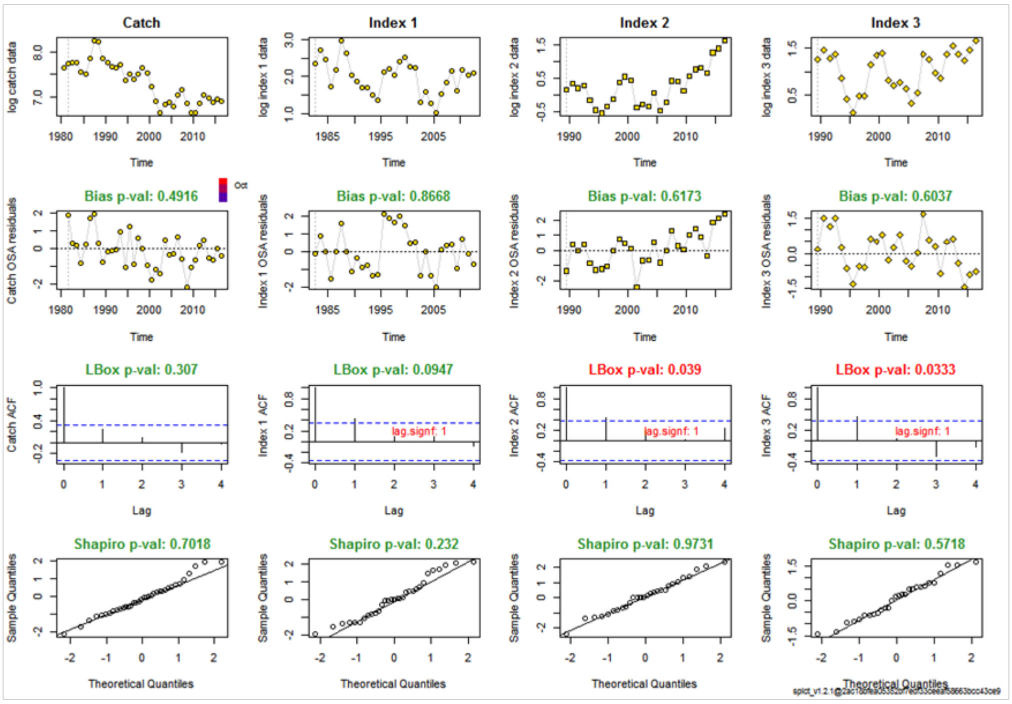


Figure 5.1.1.2.2. Ank.27.8c.9a SPiCT diagnostics. Row1. Log of the input dataseries. Row 2. OSA residuals with the p-value of a test for bias. Row 3. Empirical autocorrelation of the residuals with tests for significant autocorrelation. Row 4. Tests for normality of the residuals, QQ-plot and Shapiro test.

No significant bias (the mean of the residuals different from zero) is observed in the OSA (one-step-ahead) residuals. The diagnostics show some autocorrelation for index 2 and for index 3 (the Portuguese trawl series) but were considered not meaningful. Both QQ-plot and the Shapiro test shows normality in the residuals.

Retrospective analysis

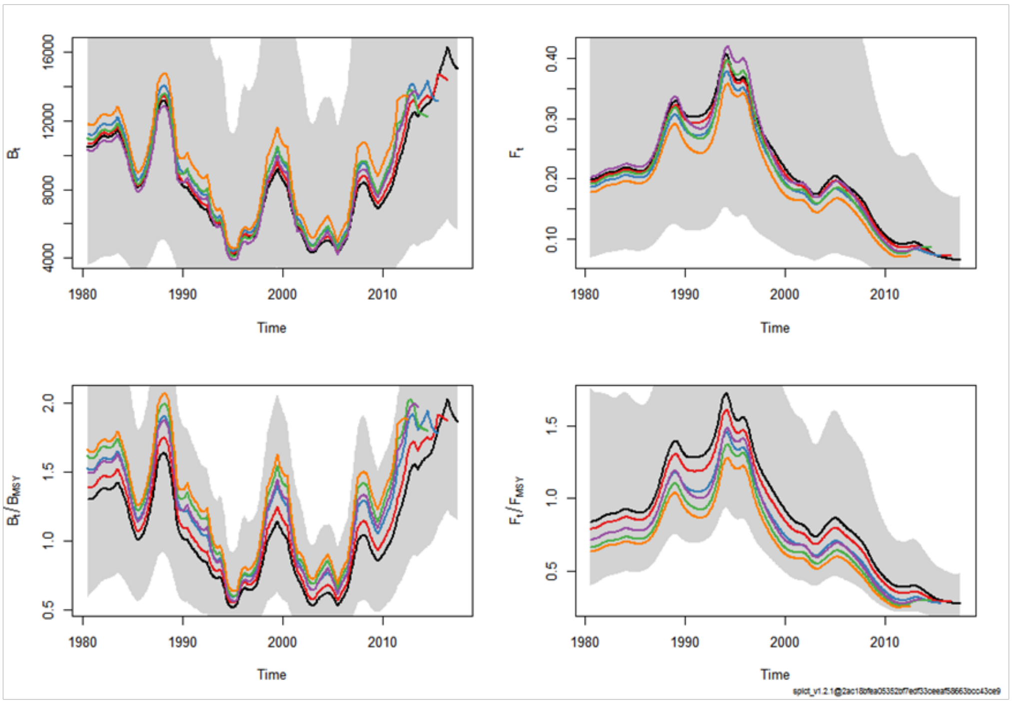


Figure 5.1.1.2.3. Ank.27.8c.9a. Five years retrospective analysis. Upper panels absolute biomass and fishing mortality. Under panels relative biomass and fishing mortality.

Some retrospective pattern is observed, suggesting some past underestimation of fishing mortality and over overestimation of biomass, but this pattern is inside the confidence intervals, being not significant.

Results

The issues found in the diagnostics and in the retrospective analysis were not considered meaningful to reject the model.

Figure 5.1.1.2.4 and Table 5.1.1.2.1 shows the main results.

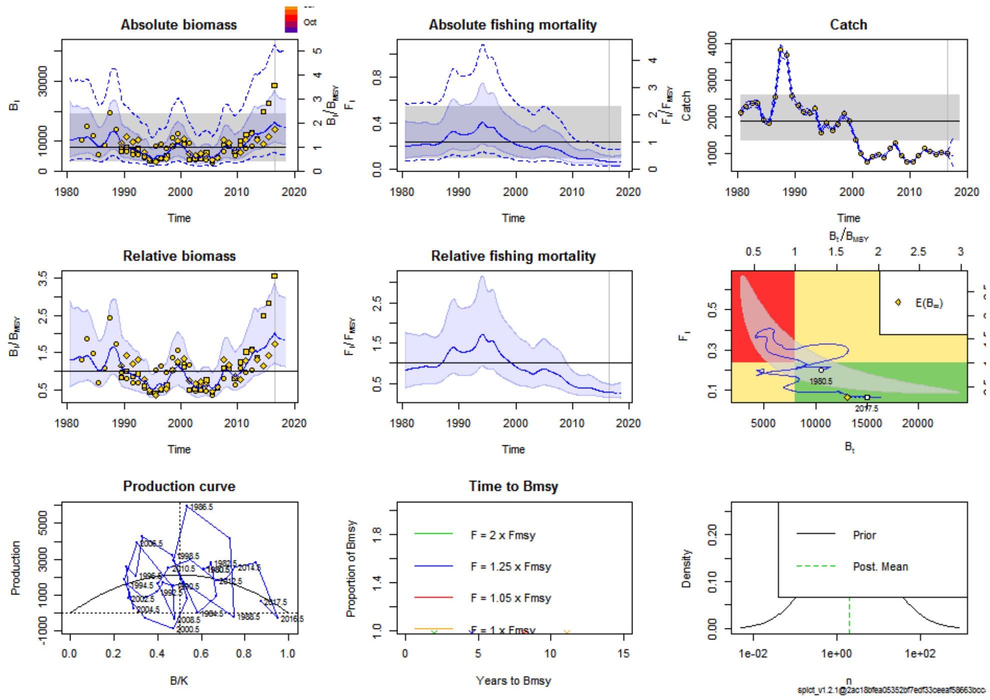


Figure 5.1.1.2.4. Ank.27.8c.9a. SPiCT results.

Table 5.1.1.2.1. Ank.27.8c.9a. SPiCT results.

```
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 [5] ""
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[10] " I2   0.9731 0.6173 0.0184 0.0390       -    -   *    *  "
[11] " I3   0.5718 0.6037 0.0142 0.0333       -    -   *    *  "
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[49] "          estimate       cilow        ciupp   log.est rel.diff.Drp  "
[50] " Bmsys 8047.398927 3362.856162 1.925763e+04  8.993104  -0.06662296  "
[51] " Fmsys     0.236561    0.102698 5.449096e-01 -1.441549  -0.04927131  "
[52] " MSYs  1897.451799 1378.430203 2.611901e+03  7.548267  -0.12286269  "
[53] ""
[54] "States w 95% CI (inp$msytype: s)"
[55] "                    estimate        cilow        ciupp    log.est  "
[56] " B_2016.50       1.634228e+04 6311.4574427 4.231514e+04  9.7015111  "
[57] " F_2016.50       6.604870e-02    0.0254654 1.713078e-01 -2.7173632  "
[58] " B_2016.50/Bmsy 2.030753e+00    1.2287687 3.356172e+00  0.7084069  "
[59] " F_2016.50/Fmsy 2.792036e-01    0.1607968 4.848023e-01 -1.2758141  "
[60] ""
[61] "Predictions w 95% CI (inp$msytype: s)"
[62] "                  prediction        cilow        ciupp    log.est  "
[63] " B_2017.50       1.501989e+04 5646.2460582 3.995522e+04  9.6171303  "
[64] " F_2017.50       6.454610e-02    0.0243642 1.709971e-01 -2.7403753  "
[65] " B_2017.50/Bmsy 1.866427e+00    1.1532734 3.020577e+00  0.6240261  "
[66] " F_2017.50/Fmsy 2.728519e-01    0.1532719 4.857259e-01 -1.2988262  "
[67] " Catch_2017.50   9.590054e+02  654.8407203 1.404451e+03  6.8658967  "
[68] " E(B_inf)       1.309869e+04           NA           NA  9.4802678  "
```
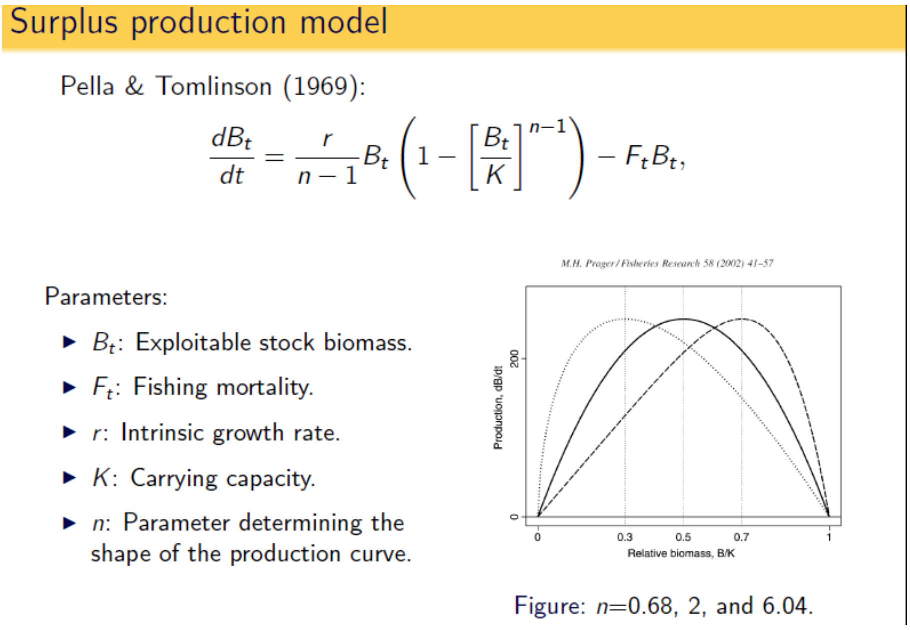

Conclusions

The SPiCT model was considered more reliable than ASPIC since it does not require the fixation of parameters, such as B1/k, to be stable. The SPiCT model with these settings was accepted as the basis for advice. Nevertheless, it was recognised that further sensitive analyses should be done, those analyses may change the settings if better fit is evident.

5.1.2 Sensitivities

The SPiCT model is based on the Pella and Tomlinson (1969) surplus production model.



Quantities that are traditionally difficult to estimate are *logn*, and the noise ratios *logalpha* and *logbeta* where *logalpha* = *logsdi* - *logsdb* and *logbeta* = *logsdc* - *logsdf*, respectively. Therefore, to generally stabilise estimation, default semi-informative priors are imposed on these quantities that inhibit them from taking extreme and unrealistic values. If informative data are available these priors should have limited effect on results, if informative data are not available estimates will reduce to the priors (Perderson, 2016).

Some different model settings were explored. All the tests showed no convergence problems and diagnostics were always acceptable.

Test	n	sdi	sdc
1	Model	Model	Model
2	Model	0.15	0.10
3	Fixed at 2	0.15	0.10
4	Fixed at 2	Model	Model

No major differences were detected among tests but tests 1 and 4 fitted the data better. Since *n* is very difficult to estimate, the group approved fixing *n* at 2, reducing the Pella and Tomlinson model to the Schaefer (1954) model.

Other possible changes in settings were not explored, the default assumptions were used.

5.1.3 Reference points

Table 5.1.3. Black-bellied anglerfish in divisions 8.c and 9.a. Reference points, values, and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	0.5 x B_{MSY} = 0.25 x K*	Relative value. B_{MSY} is estimated directly from the assessment model and changes when the assessment is updated.	ICES (2012)
	F_{MSY}	1 x F_{MSY} = r/2*	Relative value. F_{MSY} is estimated directly from the assessment model and changes when the assessment is updated.	ICES (2012)
Precautionary approach	B_{lim}	0.3 x B_{MSY}*	Relative value (equilibrium yield at this biomass is 50% of MSY).	ICES (2016a)
	B_{pa}	Not defined		
	F_{lim}	1.7 x F_{MSY}*	Relative value (the F that drives the stock to B_{lim}).	ICES (2016a)
	F_{pa}	Not defined		
Management plan	SSB_{mgt}	Not applicable		
	F_{mgt}	Not applicable		

*** Fishing mortality is estimated only in relation to F_{MSY} and total-stock biomass is estimated only in relation to B_{MSY}. K is the carrying capacity and r is the intrinsic biomass growth rate.**

5.1.4 Forecast

Due to time constraints this point was not deeply explored. Since the model is not adequate for medium or long-term projections, the same relative reference points used for ASPIC were approved to be used with SPiCT. Regarding short-time projections, forecasts for F_{MSY} result in a large increase in the catches in the first projected year, values never observed in the fishery. Therefore, a stepwise increase in fishing opportunities advice should be considered.

5.2 White anglerfish in divisions 8.c and 9.a

5.2.1 Model development

The SS3 model is described in Methot (2000; 2011). A length-based model using SS3 was formulated for Iberian white anglerfish stock in previous benchmark (WKFLAT) (ICES, 2012).

5.2.1.1 Base Run

During WKAnglerfish, all exploratory runs were based on the model accepted at the latest working group meeting (ICES, 2017). This assessment used landings-at-length data from 1980 until 2016. During the benchmark meeting, the effect of the change or addition of different data and settings was investigated. Changes were done one step at a time and a consistent set of diagnostics was used to assess the differences between each exploratory run and the base case assessment. Once a decision was made to a given data/setting source, the base case run was updated on the basis of the decision.

The exploratory assessments were judged on the basis of goodness-of-fit criteria, model parameter estimates, and residual plots. Retrospective analyses were also used to explore the stability of the assessments.

Incorporating French landings

A new series of landings data from France was provided to the Benchmark for the period 2002–2016 (Figure x.1). The average representative of total stock landings is <2%, and it was decided to include these values in the assessment. For assessment purposes, data by quarter were included in SPTR8C9A (trawl landings) and SPART8C9A (gillnet landings).

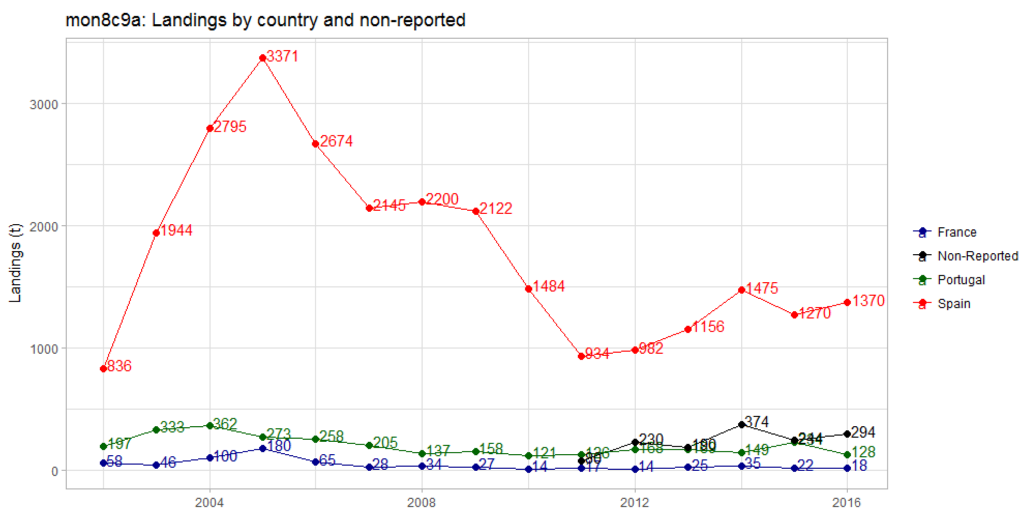


Figure x.1. Annual landings of mon.27.8C9A by country and non-reported landings (in black) for the period 2002-2016.

Change the length-weight relationship

The L–W parameters included in the assessment model were changed to those provided by Landa and Antolínez (2017) (a = 0.000025; b = 2.85) (Figure x.1). The assessment model was fitted using the updated L–W parameters and compared to the basecase.

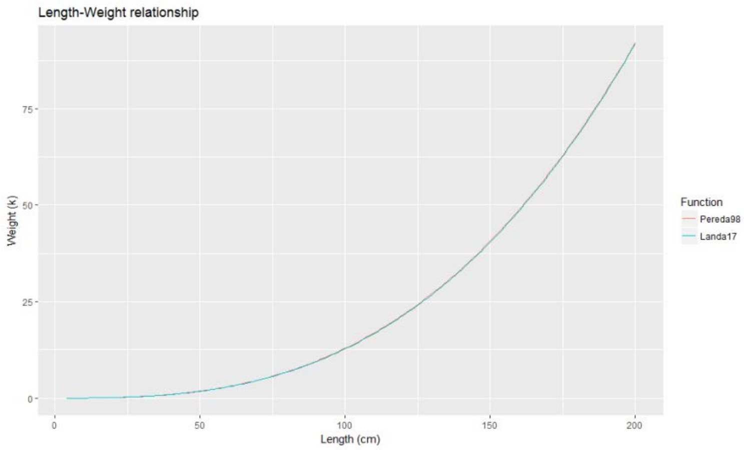


Figure x.2. Comparison of the currently used Length–Weight relationship (Pereda, 1998) and the new proposed by Landa and Antolínez (2017).

Results

The inclusion of the new series of French landings and the update of L–W relationship parameters resulted in, practically, the same values of -log-likelihood (New: 19 954, RunBase: 19 953) and in small impact in the parameter estimates.

Conclusion

The changes realized were considered appropriate and they didn't have an impact on the population estimates neither in the model fit. The run base was updated with these changes.

5.2.1.2 Fishery selectivity for fishery PTART9A (Portuguese Artisanal in Division 9A): from dome-shaped to flat-topped

Data and model configuration

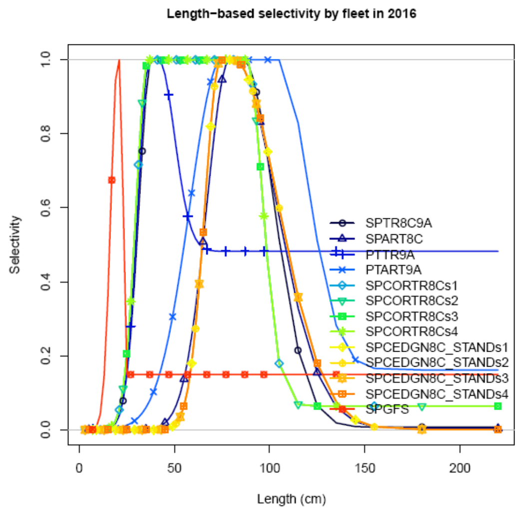
Assumptions about fisheries selectivity have great impact on biomass estimates, particularly in SSB. The selectivity of the four fisheries is modelled as a double normal function and all parameters are estimated by the model. The model fitted dome shaped selectivity for the main fisheries of mon.27.8C9A. In SS3, selectivity is a proxy of availability of the species and gear selectivity and for white anglerfish there is a relationship between size and depth. Larger fish (>140 cm) are associated with deeper areas, where fleets don't work. Nevertheless, in order to avoid that the assessment models a population with "cryptic biomass" of older individuals, at least one fishery must have a flat top selectivity. Maintaining settings from previous RunBase, an alternative was proposed to model selectivity for the fishery PTART9A with double-normal with flat-topped (model parameter-4 was fixed to the maximum length). The selectivity was set at S=1 for lengths larger than first length reached S=1.

Results

Both model configurations produced invertible Hessian matrices. The lowest -log-likelihood score (19 954) was for the RunBase, being "flat-top" configuration –log-likelihood=20 012. The *flat-topped* configuration leaded that for PTART9A, lengths >72 cm was set at selectivity=1. The resulting pattern also caused the rise of selectivity at larger lengths in the other three fisheries with respect to RunBase (Figure x.3). The model was sensitive to the change of selectivity pattern. The stock estimates of Recruitment didn't show important differences between runs (Figure x.4); F estimates were slightly higher for the "flat-topped" configuration. As it was expected, the major changes were observed for SSB. The RunBase overestimated the SSB through the time-series, being the higher differences in years with higher values of SSB.

Conclusion

This sensitivity run of the choice of selectivity pattern used highlighted the risk of dome-shaped for all fisheries of a stock. A common practice, for precautionary reasons, in stock assessment is to include at least one fishery with flat-top selectivity. The change in the selectivity pattern for PTART9A was considered correct and the RunBase was modified to include the change.



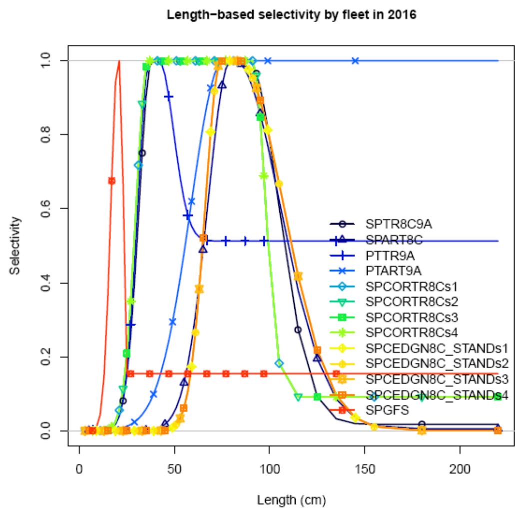


Figure x.3. Selectivity patterns for fisheries and surveys for the RunBase (left plot) and run with flat-topped selectivity PTART9A (right plot).

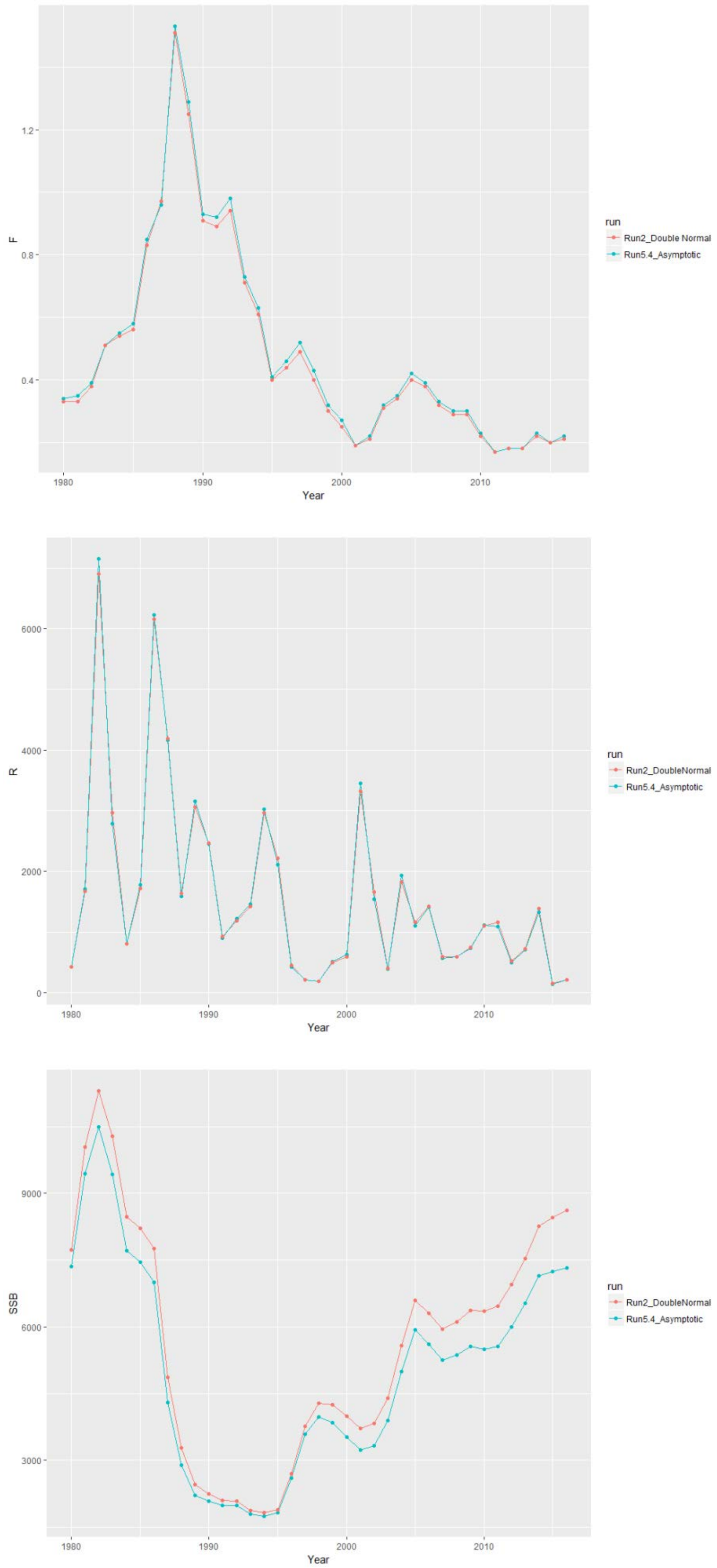


Figure x.4. Selectivity patterns for model and Run Base for the fisheries.

5.2.1.3 Weighting of length compositions and relative abundance indices

Data and model configuration

Model fitting sensitivity to data weighting was evaluated for mon.27.8C9A. The RunBase assumed a standard error for each cpue series. A default value of 0.15 was selected for the commercial cpues and yearly value derived from its uncertainty in the case of scientific survey. The sample size of the length compositions was set to 125 for all fisheries and relative abundance indices. Since 2009, the sample size for length composition of the two Portuguese fisheries has been reduced to 25. The weighting approach followed one of the options provided by SS3. The model estimates internally a variance adjustment factor, fleet-specific, that is applied to relative abundance indices. On the other hand, the effective sample sizes for length structured landings and abundance surveys were changed to get the convergence to the harmonic mean of yearly effective sample size reported in the fitting of the SS3 run. This "weighting factor" for the fishery length composition data used during parameter estimation.

Results

Results were compared with RunBase, where old effective sample sizes and default SE for cpues had been used. It turned out that the best option now, in terms of log-likelihood, it is the weighted configuration, with LogLikelihood = 8304. Most of the model estimates are now included in the confidence intervals of the relative abundance indices (Figure x.5) that in the RunBase. The model fit to length compositions has also improved (Figure x.6). This weighting was considered appropriate and therefore it was recommended to adopt this last model.

Conclusion

The results obtained after the weighting process provided a better fit of the model to the observational data. More abundance indices estimates are included in the confidence intervals and an important decrease in the total Log-Likelihood was obtained. The meeting considered that the weighting data process was useful to improve the model assessment and weighting factors must be incorporated into the model assessment.

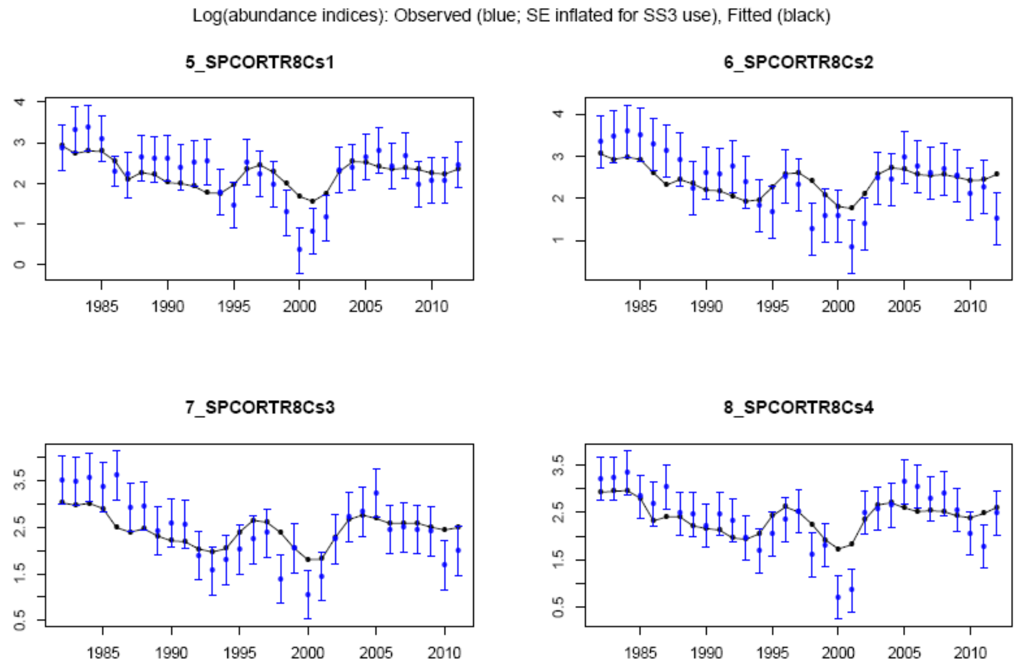


Figure x.5. Abundance indices (in log scale) for SPCORTR. Blue points are the observational data, and blue bars are SE model-modified. Black line represents the model estimate.

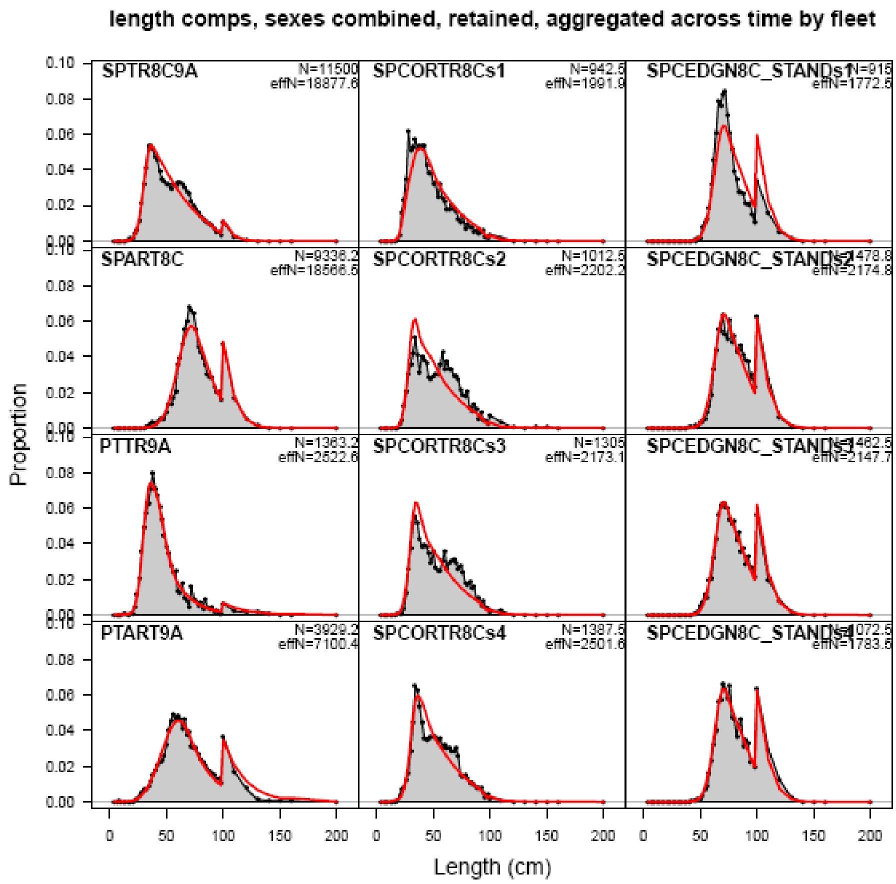


Figure x.6. Model fit (red line) to the length composition across quarters and years for the 4 fisheries and 8 commercial abundance indices.

5.2.1.4 Final Assessment

During the Benchmark, a number of changes have been proposed and explored for mon.27.8C9A. The final accepted assessment includes the French landings series (2002–2016), updates the length–weight relationship parameters, sets a flat top selectivity for fishery PTART9A, makes a weighting process for the length composition of all fisheries and surveys and for the abundance indices, and it uses the current version of SS3 (3.30.10). No other changes to the model configuration or to the input data were carried out compared with previous assessment.

The likelihood components for FinalRun are represented in Table x.5. A summary of the input data is shown in Figure 10. A number of model outputs are shown in Figure x.11 to 14. The stock trends are represented in Figure 15 and Table x.6. The retrospective analysis, carried for five years, is represented in Figure 16. There is no evidence of bias for Recruitment and Fishing mortality. A moderate retrospective pattern is observed for SSB. The SSB is corrected upwards from year to year.

Table x.5. Likelihood components for the FinalRun.

	Log-Likelihood
TOTAL	8313
Catch	6.82
Equil_catch	11.12
Survey	10.91
Recruitment	59.97
Length_comp	8223
Converge, final gradient	0.00004

Table x.6. Summary results for the FinalRun.

Year	Rec (thousands)	B total Jan1 (t)	SSB Jan1 (t)	F (30-130 cm)
1980	711	15140	9469	0.3
1981	1965	16238	11090	0.33
1982	7351	15376	11689	0.38
1983	1961	14236	10499	0.49
1984	785	13965	8737	0.51
1985	1820	12988	8388	0.53
1986	6535	10777	7776	0.8
1987	3746	7419	4821	0.92
1988	1072	7313	3165	1.38
1989	3332	5970	2499	1.08
1990	2232	4953	2430	0.81
1991	1066	4818	2234	0.83
1992	1319	4523	2134	0.86
1993	1696	3805	1993	0.62
1994	3120	3848	2089	0.49
1995	1829	4657	2360	0.33
1996	338	6606	3327	0.38
1997	283	7574	4402	0.45
1998	224	6872	4803	0.38
1999	741	5858	4656	0.29
2000	645	5174	4326	0.23
2001	3702	5020	4071	0.16
2002	1626	5901	4276	0.19
2003	350	8037	4899	0.29
2004	2157	9455	5975	0.33
2005	1367	9681	6924	0.38
2006	1277	9120	6645	0.34
2007	705	8917	6425	0.28
2008	766	9188	6779	0.26
2009	854	9229	7146	0.25
2010	1457	9001	7227	0.18
2011	1110	9373	7525	0.13
2012	502	10491	8248	0.14
2013	773	11535	9114	0.14
2014	1320	12285	10079	0.18
2015	220	12372	10397	0.16
2016	424	12621	10591	0.17

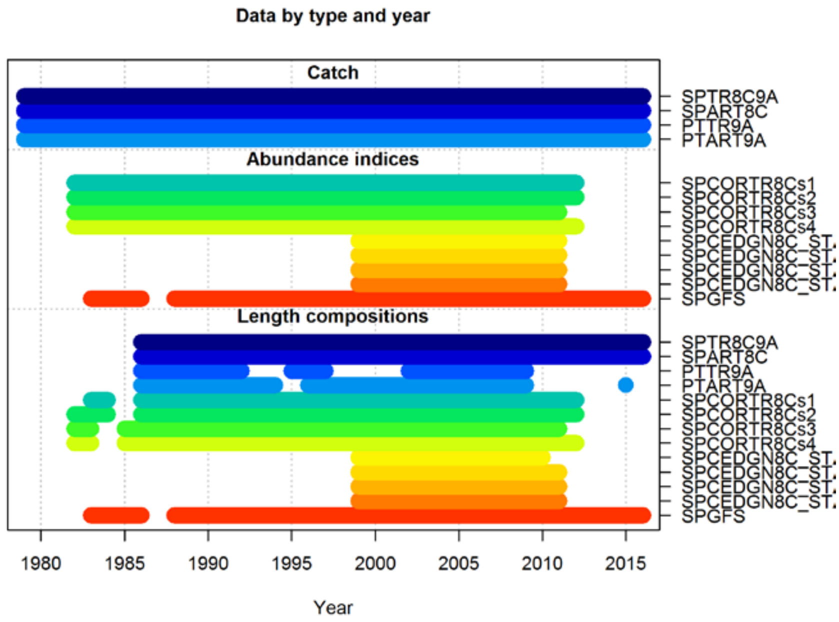


Figure x.10. Dataset used in the final mon27.8C9A assessment.

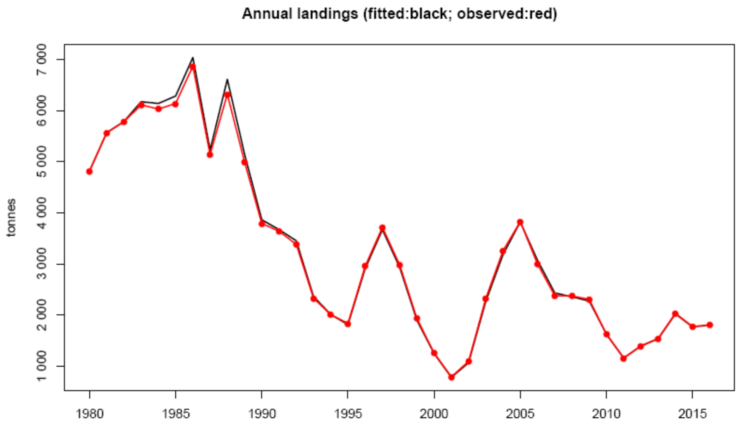


Figure x.11. Annual landings estimated by the model and observed.

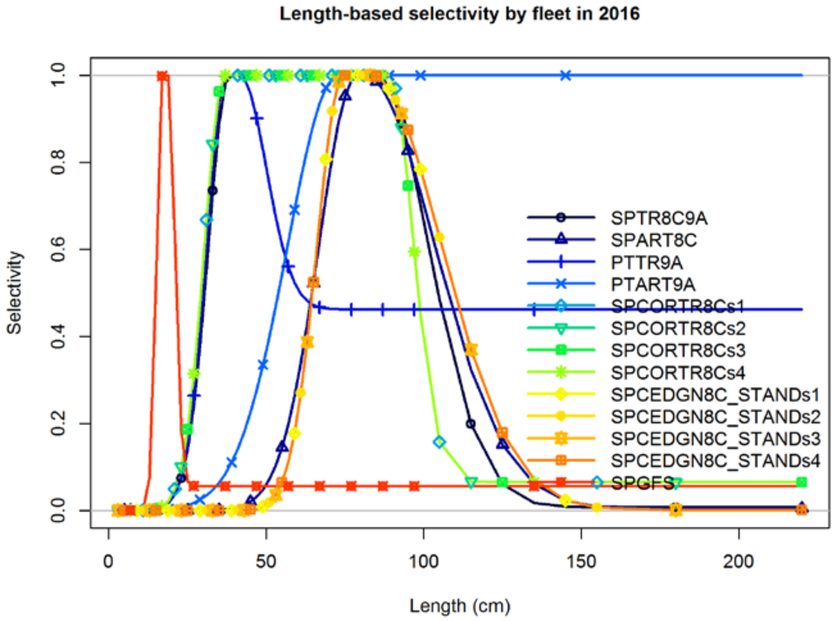


Figure x.12. Selectivity models for four fisheries and 8 surveys.

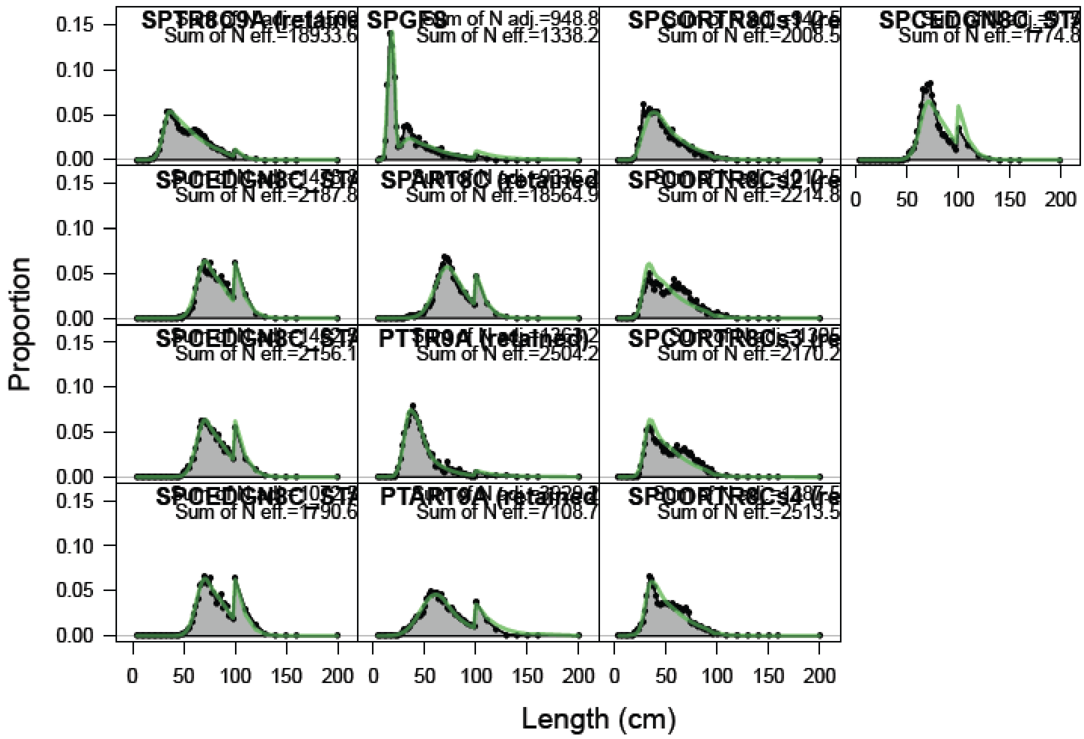


Figure x.13. Model fit to length compositions, for fisheries and surveys.

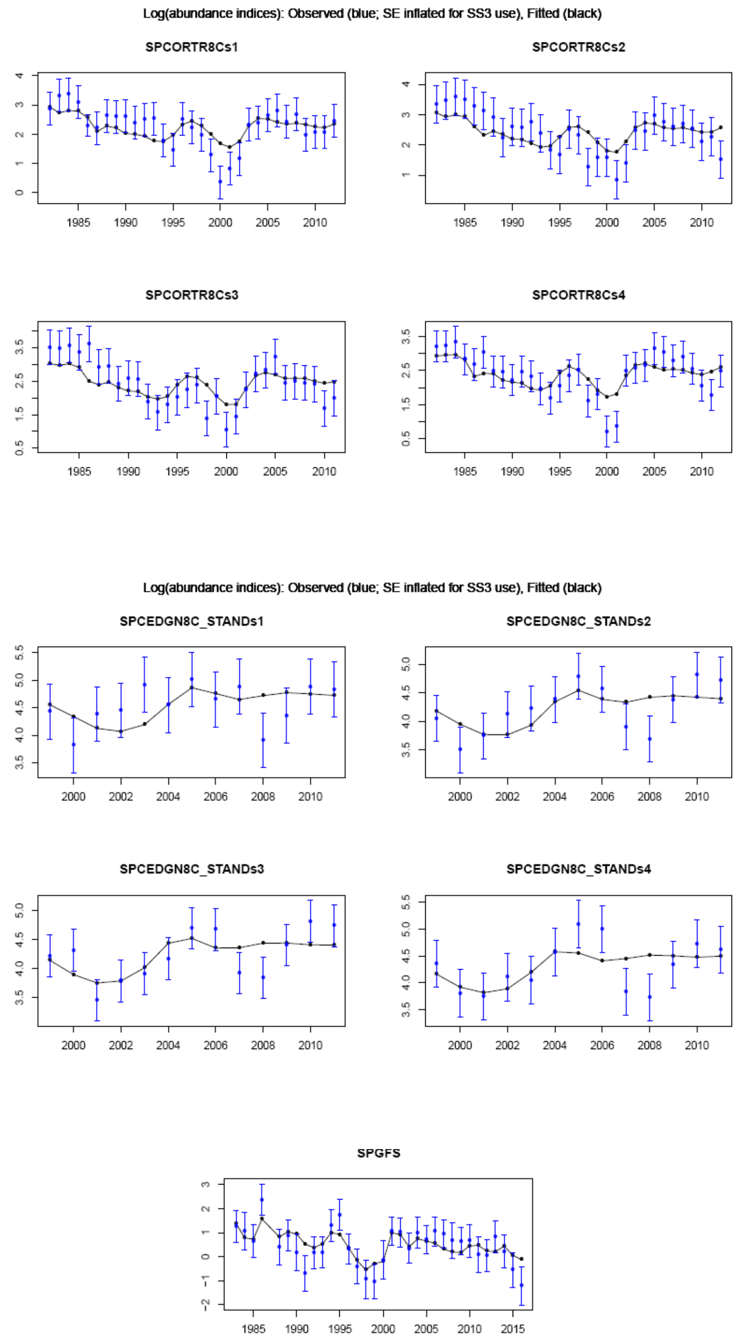


Figure x.14. Abundance indices in log sale. Blue points: observations; blue bars: SE-model; black line: model fit.

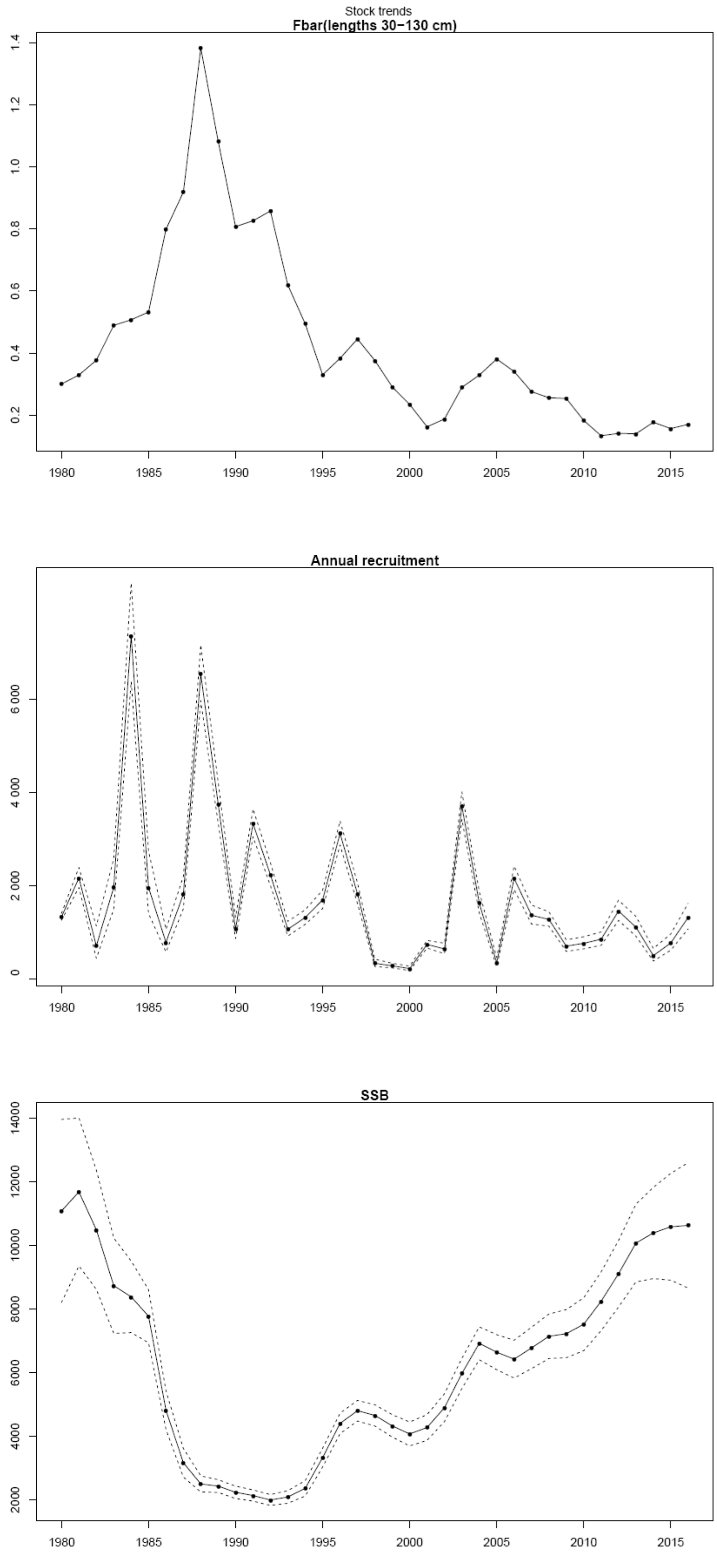


Figure x.15. Stock trends for the mon.27.8C9A FinalRun. For Recruitment and SSB, 90% asymptotic intervals are shown.

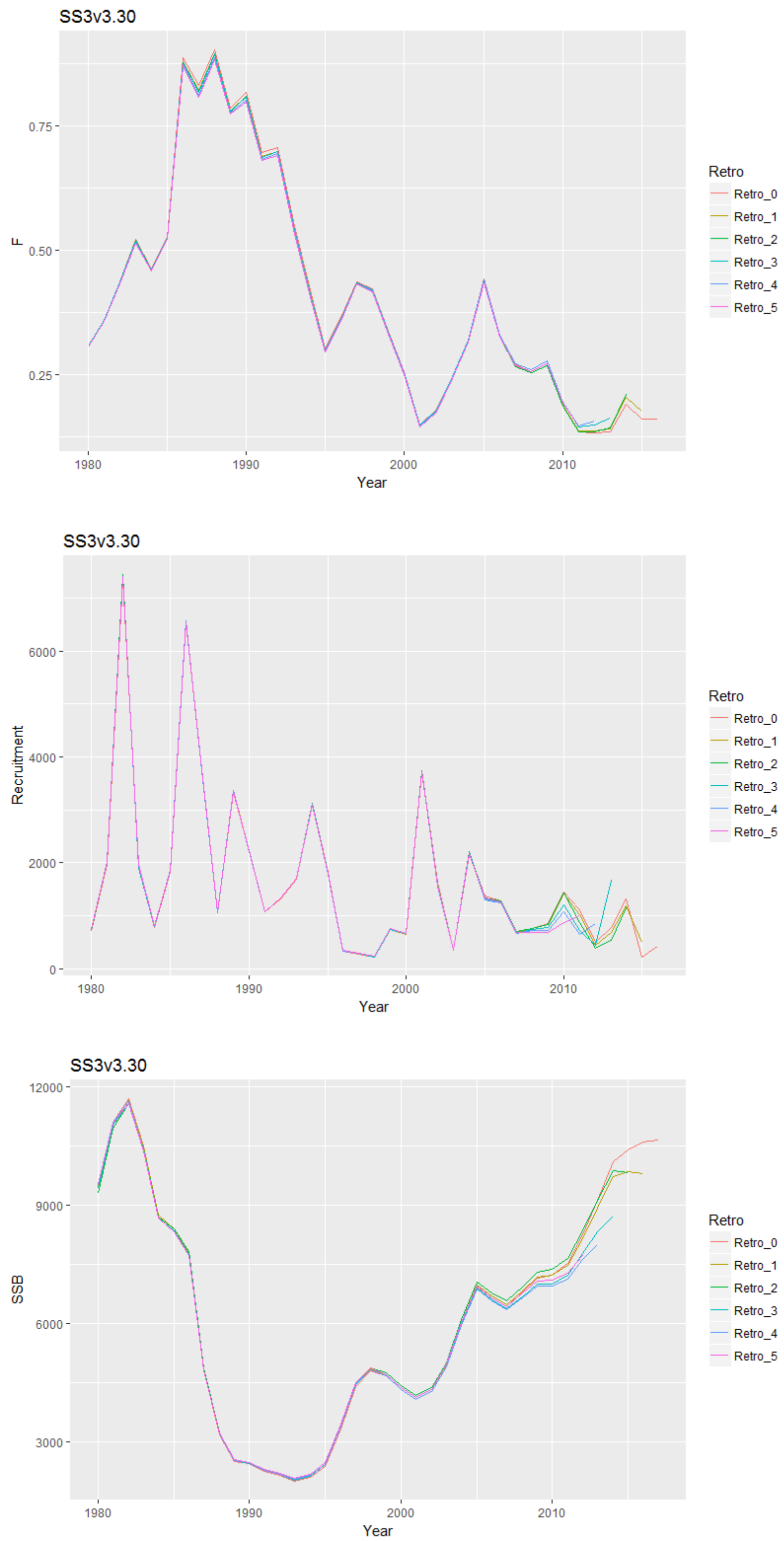


Figure x.16. Five-year retrospective analysis for mon.27.8C9A FinalRun.

5.2.1.5 Short-term projections

The settings and methodology for short-term projections have not been revisited during the WKANGLER2018 and remain unchanged from the previous benchmark.

5.2.2 Sensitivities

5.2.2.1 Sensitivity to Natural Mortality (M)

Data and model configuration

In the RunBase assessment, natural mortality is assumed at 0.2 for all ages and years. This value was selected based on the life-history knowledge of the species in the previous benchmark (ICES, 2012). During the DEM, it was suggested to perform a sensitivity analysis for a range of M values. Indirect estimates of M were calculated based on life-history parameters (growth-rate coefficient= 0.11 (Landa *et al.*, 2008); Linf=180 cm; Maximum age=25) and Temperature=14ºC, following different methodologies (Table x.1). The range of indirect estimates was 0.15–0.26. A sensitivity analysis for M values between 0.15 and 0.26, with a 0.01 step, was carried out.

Results

Table x.2 presents the log-likelihood profile for runs with different assumptions of natural mortality. The increase in the value of M leads to an increase in total log-likelihood that is driven by the increase in log-likelihood of the length composition. Except for runs with M=0.21 and M=0.22, likelihood value increases with M. In trials realized with lower M values (until 0.01), not presented in this analysis, log-likelihood kept decreasing. The expected U-shaped of the M-profile was not found and the minimum log-likelihood value could not be identified. It should be considered that the lowest log-likelihood value is not a suitable indicator to select the most appropriate M rate.

Conclusion

For this stock assessment, the log-likelihood seems not to be a useful indicator of the optimum value of M. The expected U-shape of the M-profile was not found making no possible to identify a minimum log-likelihood. The M-profile analysis indicated that unrealistically small M values provided a better fit and, it was concluded that this could be due to some other model misspecification. It was suggested to explore the interaction between natural mortality (M) and growth-rate coefficient (K) in a sensitivity analysis.

Table x.1. Indirect estimates of M for mon.27.8C9A.

Model	M	K	Linf (cm)	T^a	tmax	Equation
Pauly (1980) - Length Equation	0.19	0.11	180	14		log M = - 0.0066 - 0.279 x log Linf+ 0.6543 x log K + 0.4634 x log T^a
Hoenig (1983) - Joint Equation	0.18				25	M = 4.22/(tmax$^{0.982}$)
Hoenig (1983) - Fish Equation	0.17				25	M = exp(1.46 - 1.01 * log(tmax))
Alverson and Carney (1975)	0.18	0.11			25	M = (3 x K)/(exp(K * (0.38 * tmax)) - 1)
Then et al. (2015)-tmax	0.26				25	M = 4.899 tmax$^{-0.916}$
Then et al. (2015)-growth	0.15	0.11	180			M = 4.118 K$^{0.73}$x Linf$^{-0.33}$

Table x.2. M-profile for mon.27.8C9A.

-Log-Likelihood	M=0.15	M=0.16	M=0.17	M=0.18	M=0.19	M=0.20	M=0.21	M=0.22	M=0.23	M=0.24	M=0.25	M=0.26
TOTAL	8296	8297	8298	8300	8301	8310	8306	8309	8311	8315	8319	8322
Catch	6	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9
Equil_catch	18.4	16.7	15	13.4	12	10.6	9.4	8.2	7.2	6.3	5.5	4.7
Survey	1.3	3.2	5.1	7.2	9.4	12.9	14.1	16.7	19.3	22	24.7	27.6
Length_comp	8210	8210	8211	8212	8213	8219	8215	8217	8219	8221	8224	8226
Converge, final gradient	0.0002	0.0003	0.0003	0.1711	0.033	0.0031	0.119	0.00018	0.00047	0.00026	0.0006	0.004
Parameter												
L_at_Amax	172.8	173.2	173.6	174	174.4	174.5	175.1	175.8	176.3	176.7	177.3	177.8
SR_LN (R0)	7.04	7.07	7.1	7.13	7.16	7.2	7.23	7.26	7.29	7.32	7.35	7.38
SPB_Virgin	102842	92320	83394	75765	69203	62913	58584	54265	50475	47310	44168	41533
SPB_2017	12040	11803	11561	11315	11067	10315	10570	10414	10322	9846	9611	9911
F_2016	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.15	0.15	0.17	0.18

5.2.2.2 Sensitivity to Natural Mortality (M) and growth-rate coefficient (K)

Data and model configuration

Sensitivity runs for a range of M values (0.15, 0.20, 0.25) and a range of K values (0.06, 0.11, 0.16) were carried out to identify the best fit among scenarios created by these two parameters.

Results

The M-K sensitivity analysis indicated that K=0.06 was less consistent with the data than K=0.11 or K=0.16. The latter choice offers a better fir (lower LogLikelihood), but K=0.16 resulted in an unrealistically low estimate of Linf. The major difference in assessment model results was only in scale and it was considered that status evaluations ($B_{current}$/ B_{ref} and $F_{current}$/F_{ref}) will be more similar.

Conclusion

The benchmark concluded that M=0.2 and K=0.11 were the best choice of parameters for the SS3 assessment model. Noteworthy in the K=0.06 run was a much improved fit to the SPGFS "recruitment" length compositions. This may indicate a potentially better growth model formulation, but this is a subject for future research.

Table x.3. M&K profile for mon.27.8C9A

	M=0.15			M=0.20			M=0.25		
-LogLikelihood	K=0.06	K=0.11	K=0.16	K=0.06	K=0.11	K=0.16	K=0.06	K=0.11	K=0.16
TOTAL	8621	8296	8251	8651	8310	8255	8702	8319	8268
Catch	6.8	6.0	5.8	6.7	5.8	5.6	7.1	5.9	5.5
Equil_catch	23.4	18.4	16.8	11.9	10.6	9.8	5.2	5.5	4.9
Survey	67.6	1.3	2.7	94.8	12.9	10.8	125.9	24.8	28.0
Length_comp	8456	8210	8166	8469	8219	8169	8496	8224	8175
Convergence, final gradient	0.0005	0.00022	0.0010	0.0004	0.00310	0.0010	0.0067	0.00060	0.0015
Parameter									
L_at_Amax	200.0	172.8	139.0	200.0	174.5	140.0	200.0	177.3	139.3
SR_LN(R0)	7.17	7.05	7.03	7.37	7.20	7.37	7.60	7.35	7.33
SPB_Virgin	85097	102842	78906	50317	62913	51540	34440	44168	36519
SPB_2017	14214	11268	9399	12474	10315	9351	12002	10050	8876
F_2016	0.12	0.14	0.15	0.13	0.16	0.16	0.14	0.17	0.17

Due to the lack of time during the Benchmark, the change of version of the model assessment and the estimation of the Reference Points were presented and discussed during a WebEx meeting (2nd of March 2018).

5.2.2.3 Update version of Stock Synthesis: from version 3.23b to 3.30.10

The last assessment for mon.27.8C9A, accepted during the WKANGLER, was run with the latest version of the software. After the automatic conversion of 3.23b files to 3.30 files, using the available tool *ss_trans.exe*, the model was run with SS3 3.30.10. No setting modifications have been made in the input files with respect to input files 3.23b.

Results

The values of log-likelihood were very similar for both runs. The estimates of Linf and SR_Ln(R0) are also analogous (Table x.4). Figure x.7 shows the comparison of stock trends obtained from runs with both versions of SS3.The fishing mortality and recruitment estimates have very small differences through the time-series. For SSB time-series, some differences are observed at the beginning of the series, the first three years, and at the ending (last two years) of the time-series. The 3.30 version seems to be underestimating the SSB values for these five years. The retrospective analysis indicates the same conclusion for both runs (Figure x.8, x.9). There are not relevant trends in F and Recruitment and, in the case of SSB, both models show a moderate upwards revision from 2005. The SS3 3.30.10 calculates the SSB at the beginning of the next year, so one more year is included in the plot for SSB.

Conclusion

Some minor differences were detected in the results obtained with different model assessment versions. Nevertheless, the run performed with the SS3 version 3.30.10 was accepted to carry out to the assessment for mon.27.8C9A, and it is considered as the FinalRun.

Table x.4. Likelihood values and some estimates for runs with different versions of SS3.

-LogLikelihood	v3.23b	v3.30
TOTAL	8304	8313
Catch	5.8	6.8
Equil_catch	10.6	11.1
Survey	11.7	10.9
Length_comp	8214	8224
Convergence, final gradient	0.0002	0.00004
Parameter		
L_at_Amax	174.9	175.1
SR_LN(R0)	7.20	7.19
SPB_Virgin	63525	63377
SPB_2016	10715	10590
F_2016	0.1573	0.1610

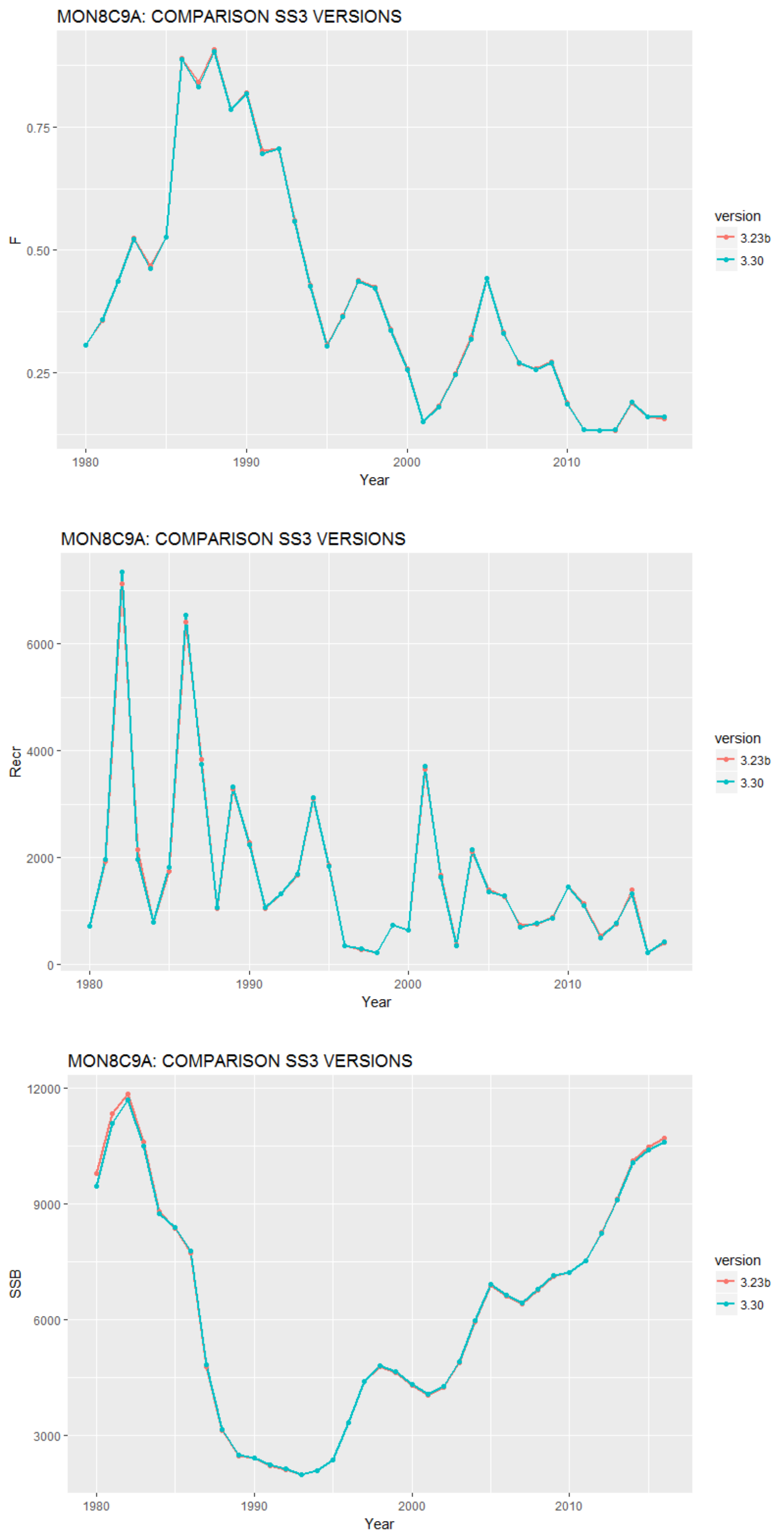


Figure x.7. Comparison of stock trends obtained with the current version used (3.23b) and the latest version of the Stock Synthesis (3.30.10).

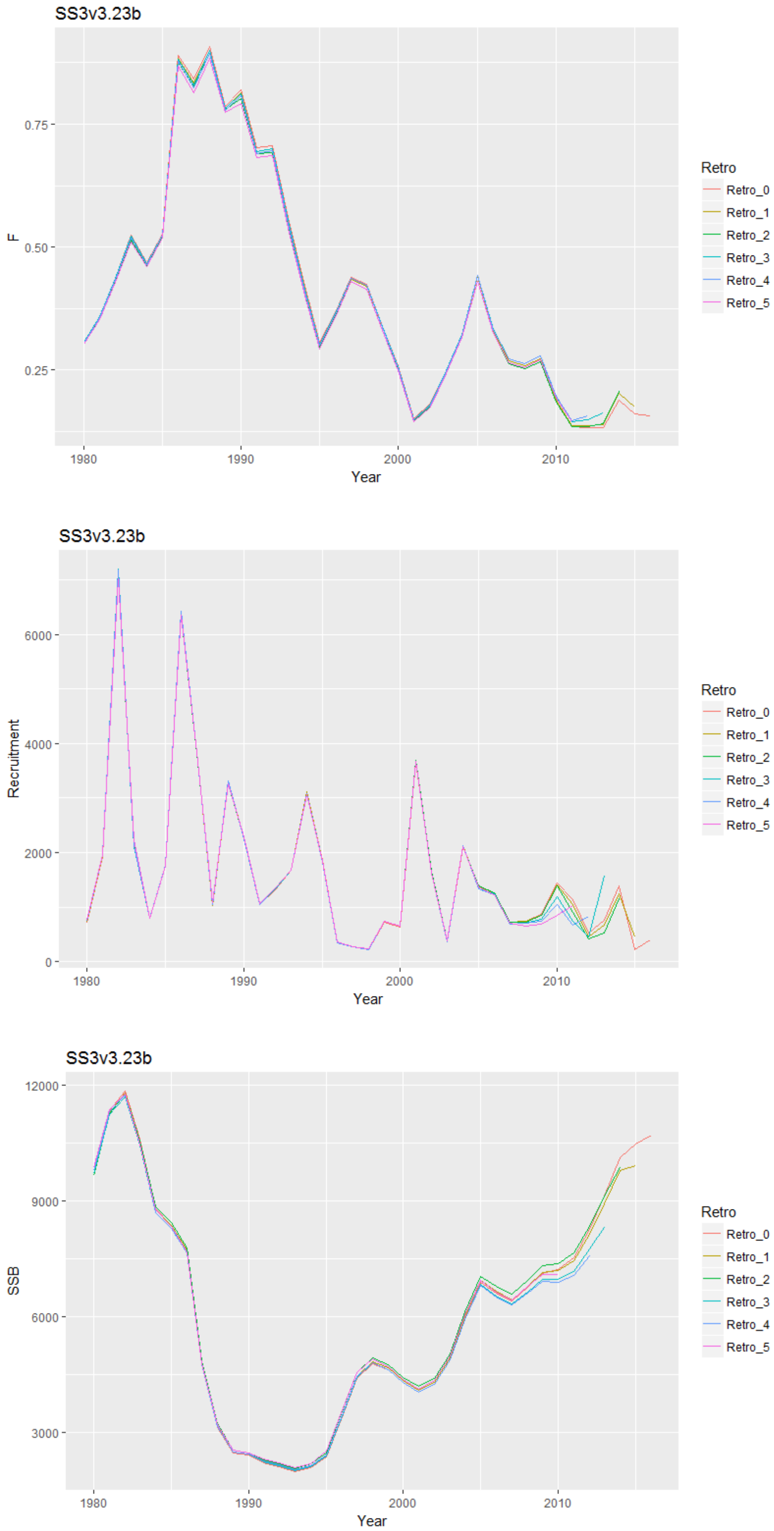


Figure x.8. Retrospective analysis for run using SS3 3.23b.

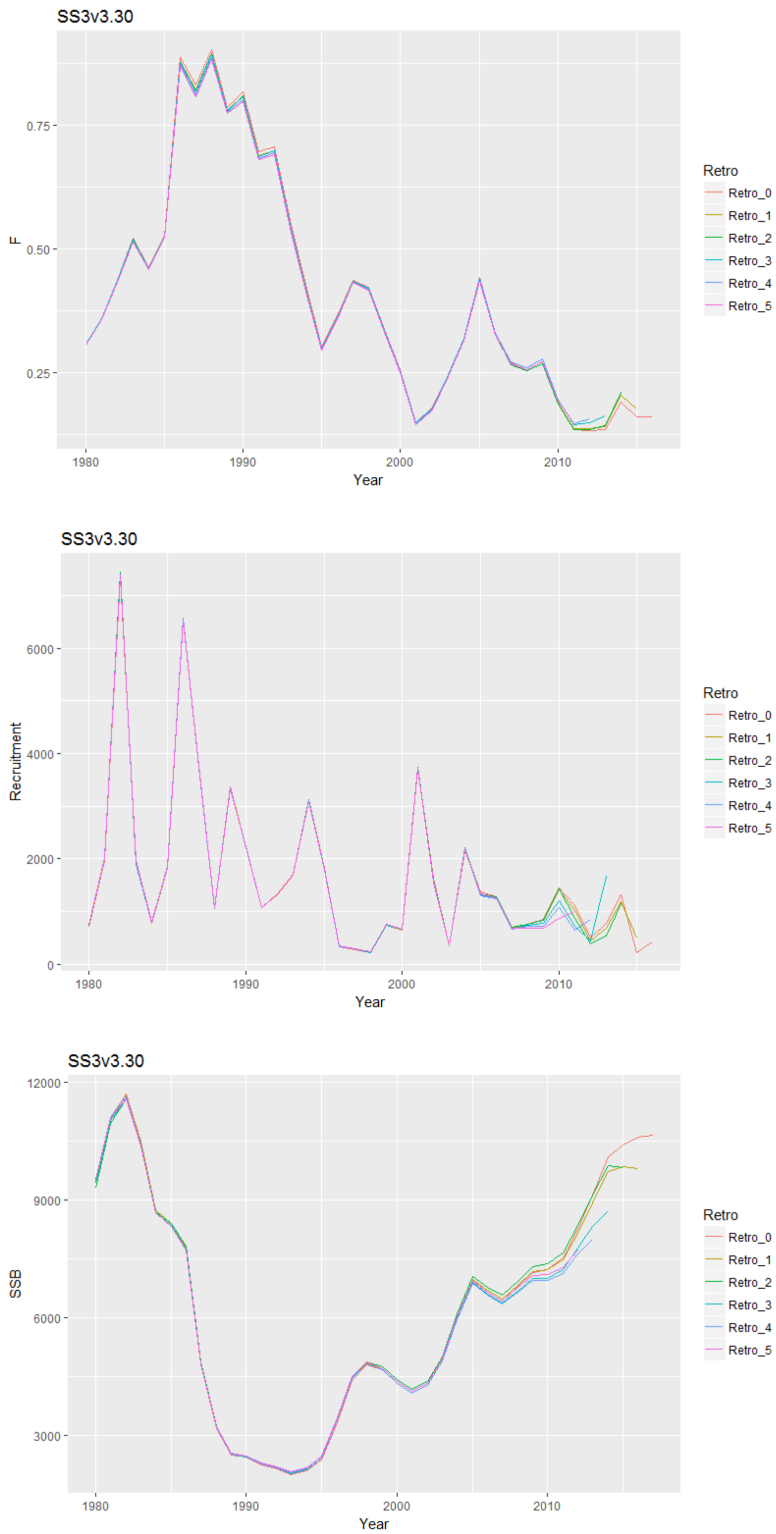


Figure x.9. Retrospective analysis for run using SS3 3.30.10.

5.2.3 Reference points

5.2.3.1 Introduction

The reference points previously evaluated for white anglerfish stock were defined during the WKMSYREF4 (ICES, 2016) (Table x1). The reference points were reviewed again during WKANGLER 2018 following the latest ICES Advice technical guidelines on reference point estimation for category 1 and 2 stocks (http://ices.dk/sites/pub/Publication%20Reports/Advice/2017/2017/12.04.03.01_Reference_points_for_category_1_and_2.pdf). The estimation of reference points was based on assessment data and stock–recruitment plots using the data from the Final Run for mon.27.8c9a. The full time-series of stock and recruitment was used. The uncertainty in the SS3 estimates of SSB, F and Recruitment were not used in the calculations of the reference points. As an internal calculation of the model, it may only represent a part of the uncertainty of the value. In all cases, it was substituted by the default value calculated at the WKMSYREF4.

5.2.3.2 Definition of the stock–recruitment model

There is no clear evidence of stock–recruitment relationship for Iberian white anglerfish stock, hence it has been considered as a Type 5 in ICES guidelines. A segmented regression S–R was used and the breakpoint was set at B_{lim} (Figure x2). *EqSim* software is available in the library *msy* at github repository *ices-tools-prod*.

5.2.3.3 Precautionary reference points

B_{lim}: there is no a clear relation between stock and recruitment (Figure x1). It is considered a stock Type 5 and the previous basis for B_{lim} is retained. B_{lim} is taken as B_{loss}, the lowest estimate of spawning-stock biomass from the accepted WKANGLER 2018 assessment. This was estimated to have occurred in 1993 with B_{loss} = 1993 t.

B_{pa}: the ICES basis for advice requires that the assessment uncertainty in the estimate of spawning–stock biomass is taken into consideration. This leads to a precautionary reference point B_{pa}, which is a biomass reference point designed to avoid reaching B_{lim}. Consequently, B_{pa} was calculated from:

$$B_{lim}*\exp(1.645*\sigma)$$

where σ (0.20) was taken as the default value for uncertainty. This results in a B_{pa} value of 2769 t.

F_{lim}: F_{lim} is derived from B_{lim} and is determined as the fishing mortality that, on average would bring the stock biomass to B_{lim}. Simulating a stock with a segmented regression S–R relationship with the point of inflection at B_{lim}, thus determining the F = F_{lim} that, at equilibrium, gives a 50% probability of SSB >B_{lim}. This simulation was conducted based on a fixed F (without inclusion of $B_{trigger}$) and without inclusion of assessment errors (F_{cv} and F_{phi} were set to zero). F_{lim} was estimated at 0.56 (Table x2).

F_{pa}: the value of the estimated fishing mortality which ensures that the true F has a less than 5% probability of being above the reference point F_{lim}. F_{pa} is calculated from:

$$F_{lim}*\exp(-1.645*\sigma)$$

σ (=0.20) is used as default value. This leads to an estimate for F_{pa} of 0.40.

5.2.3.4 Long-term stochastic simulations for the estimation of MSY

The long-term stochastic simulations were performed using an *ad hoc* code developed for length based SS3 assessments with quarter time-step (WKMSYREF4). After fitting the stock–recruitment models, a long-term stochastic projection can be performed based on the quarterly step population dynamics and length-based selection and retention used in the SS3 assessment. Recruitment is stochastically drawn on a quarterly basis (for the quarters assumed to have recruitment) and growth is according to the von Bertalanffy based models used in the SS3 assessments. Fishery parameters are randomly drawn from a selected number of recent years. The procedure to calculate reference points from the results of the stochastic simulation is the same as used in *EqSim*. The long-term stochastic projection methodology is coded in R and the script is available at the SharePoint of WKANGLER 2018.

Biological parameters (mean weights-at-age, maturity and natural mortality) and exploitation pattern were as in the last ten years (2007–2016) of the stock assessment. The assessment error in the advice year and the autocorrelation of the assessment error, in estimation of the MSY reference points were fixed as the default value used during the WKMSYREF4 (F_{cv}=0.233; F_{phi} =0.423). The simulations were based on 1000 replicates of the stock, used the values of B_{lim} and B_{pa} defined above.

5.2.3.5 Maximum sustainable yield (MSY) reference points

F_{MSY}: the median of the yield across iterations reached a maximum for an F value of 0.24 (Figure x3). This F value appeared to be precautionary as it was lower than $F_{.05}$ (= 0.35), the fishing mortality above which the probability of SSB falling below B_{lim} is larger than 5%. The range for F_{MSY} was 0.16–0.33.

MSY $B_{trigger}$: based on these simulations, the lower SSB value (5th percentile for the distribution across iterations) observed when fishing constantly at the candidate F_{MSY} value of 0.24 was 6283 tonnes. Following ICES flowchart, this value was a candidate value for MSY $B_{trigger}$ (five or more years F <F_{MSY}, MSY$B_{trigger}$ >B_{pa}, MSY $B_{trigger}$ >previous MSY $B_{trigger}$, MSY $B_{trigger}$ <SSB2017/1.4).

When applying the ICES MSY harvest control rule with MSY $B_{trigger}$ at 6283 t, median F_{MSY} was estimated at 0.30 and $F_{.05}$ increased to 0.87.

Table x1. Current mon.27.8C9A reference points.

FRAMEWORK	REFERENCE POINT	VALUE	RATIONAL	SOURCE
Precautionary approach	Blim	1900 t	Bloss	WKMSYREF4 (2016)
	Bpa	2600 t	Blim*exp (1.645*0.2)	"
	Flim	0.6	Stochastic simulation of recruitment with Blim as the breakpoint	"
	Fpa	0.43	Flim*exp (-0.2*1.645)	"
MSY approach	FMSY	0.31	Stochastic simulation, F maximises median equilibrium yield	"
	MSY Btrigger	5400 t	5th percentile of SSB2015 (WGBIE2015)	"
	FMSY ranges [Flower, Fupper]	0.18, 0.41	Stochastic simulation, 5% reduction in long-term yield compared with MSY	"

Table x2. Revised reference points for mon.27.8C9A after Benchmark WKANGLER 2018.

FRAMEWORK	REFERENCE POINT	VALUE	RATIONAL	SOURCE
Precautionary approach	Blim	1993 t	Bloss	WKANGLER2018
	Bpa	2769 t	Blim*exp (1.645*0.2)	"
	Flim	0.56	Stochastic simulation of recruitment with Blim as the breakpoint	"
	Fpa	0.4	Flim*exp (-0.2*1.645)	"
MSY approach	FMSY	0.24	Stochastic simulation, F maximises median equilibrium yield	"
	MSY Btrigger	6283 t	5th percentile of SSB when fishing at F_{MSY}	"
	FMSY ranges [Flower, Fupper]	0.16, 0.33	Stochastic simulation, 5% reduction in long-term yield compared with MSY	"

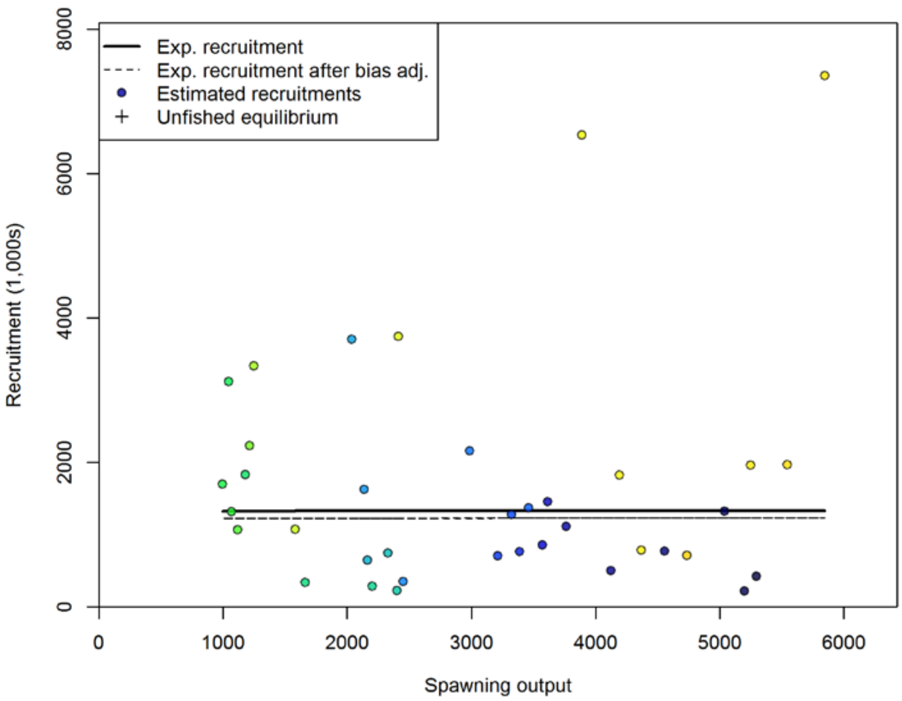


Figure x1. SSB-recruitment pairs for mon.27.8c9a estimated in SS3 assessment.

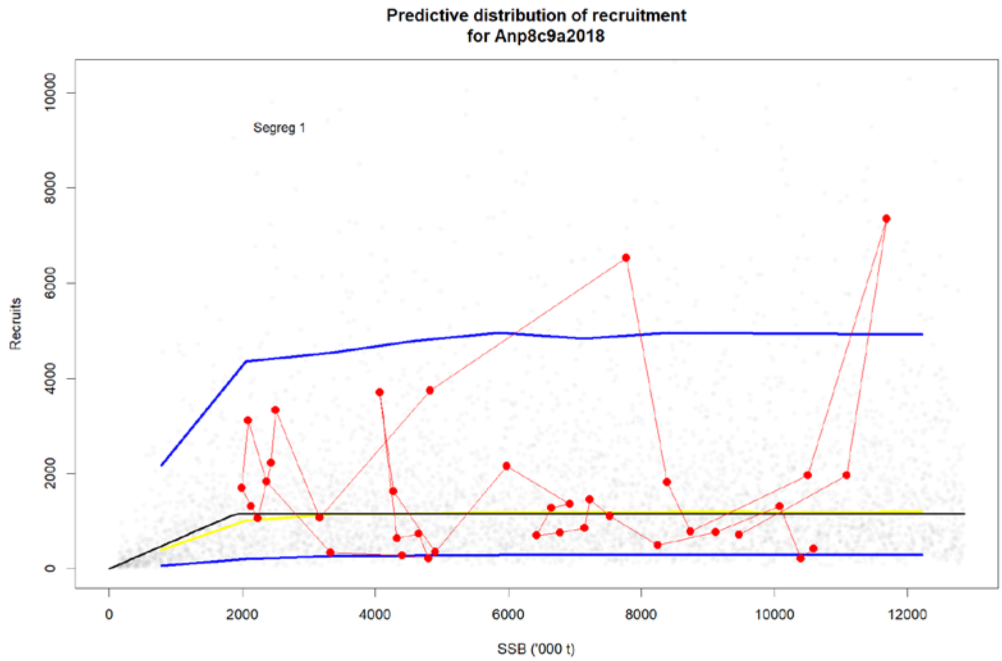


Figure x2. *EqSim* S–R model used for the stochastic simulations. SS3 estimates of the stock–recruitment pairs used for model fitting are represented in red (1980–2016). Black line shows the average Segmented Regression. The grey dots represent simulated values; the yellow line represents the median and the blue lines the 5% and 95% percentiles for the simulated values.

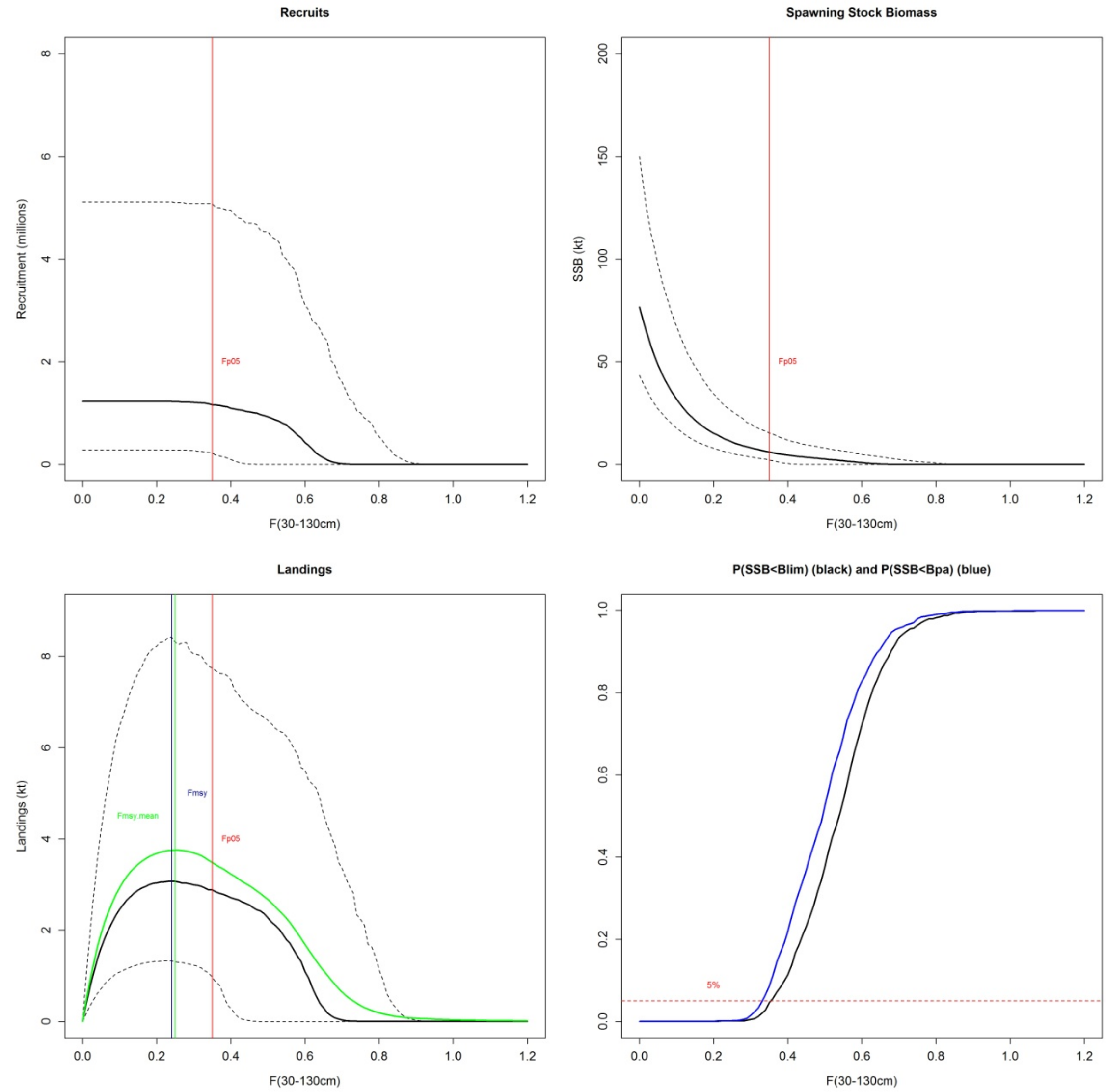


Figure x3. Results of applying the hockey-stick assumption for recruitment for mon.27.8C9A. Median (solid black) and 90% intervals (dotted black) for recruitment (upper-left), SSB (upper-right) and landings (bottom-left) for exploitation at fixed values of F. Panel bottom-right also shows mean landings (green solid line). Probability of SSB<B_{lim} (black) and SSB<B_{pa} (blue) are also represented (bottom-right).

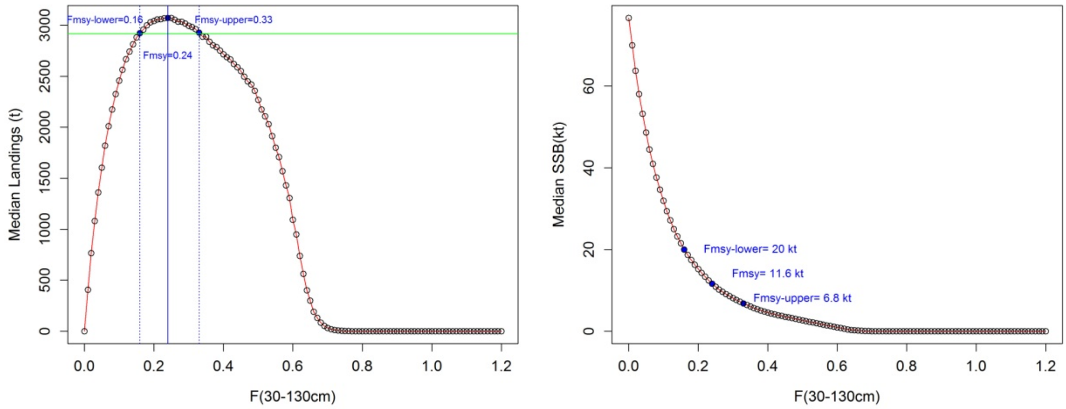


Figure x4. Mon.27.8C9A with fixed F exploitation. Median landings yield curve with estimated reference points (left) and median SSB with estimated reference points (right).

5.2.4 Forecast

5.3 Black-bellied anglerfish in divisions 7.b-k and 8.a,b,d

5.3.1 4a4 model exploration

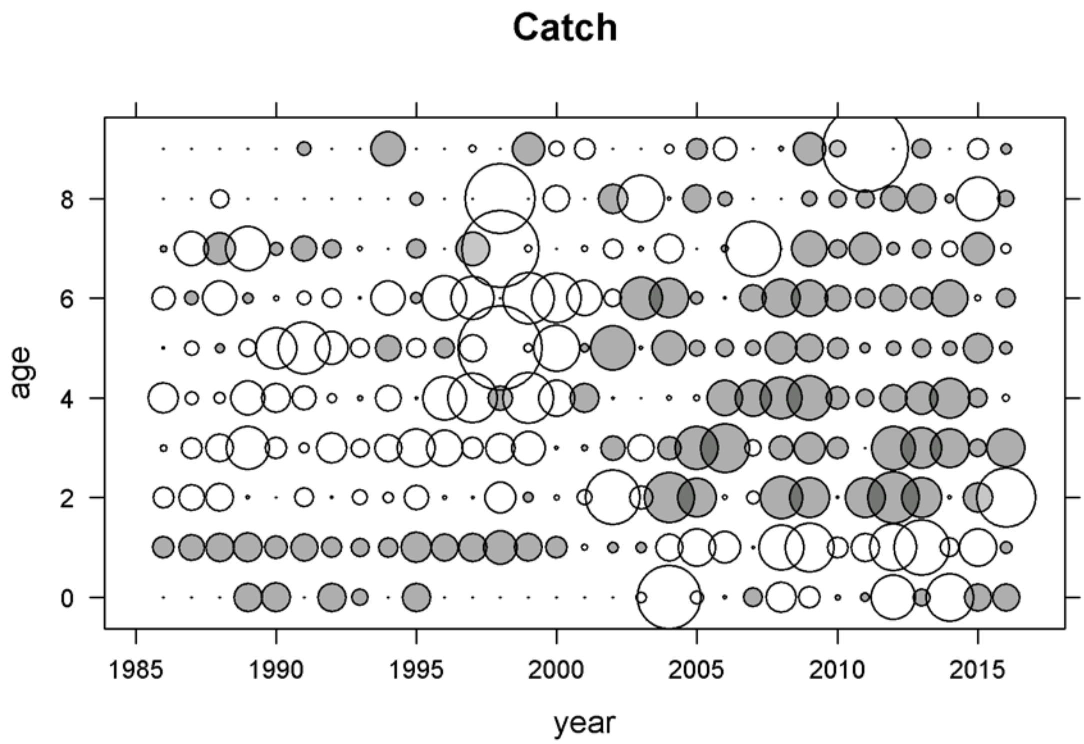
Length data of the catches and surveys were converted to pseudo-ages a von Bertallanfy growth curve with the following parameters: Linf = 175; K = 0.078; t0 = 0. The parameters are based on the growth rate in the first two cohorts estimated by length–frequency analysis of the survey data; Linf was estimated by trial-and-error, based on the value that gave the best cohort tracking in the catch and survey data.

The growth curve was used to estimate the mean length-at-age in each quarter and the standard deviation was assumed to increase from 3 cm at age 0 to 10 cm at age 10. The abundance in each age class was then estimated for each length–frequency distribution. These mixture distributions were then used as an age–length key to estimate the final numbers-at-age for the catch and tuning data.

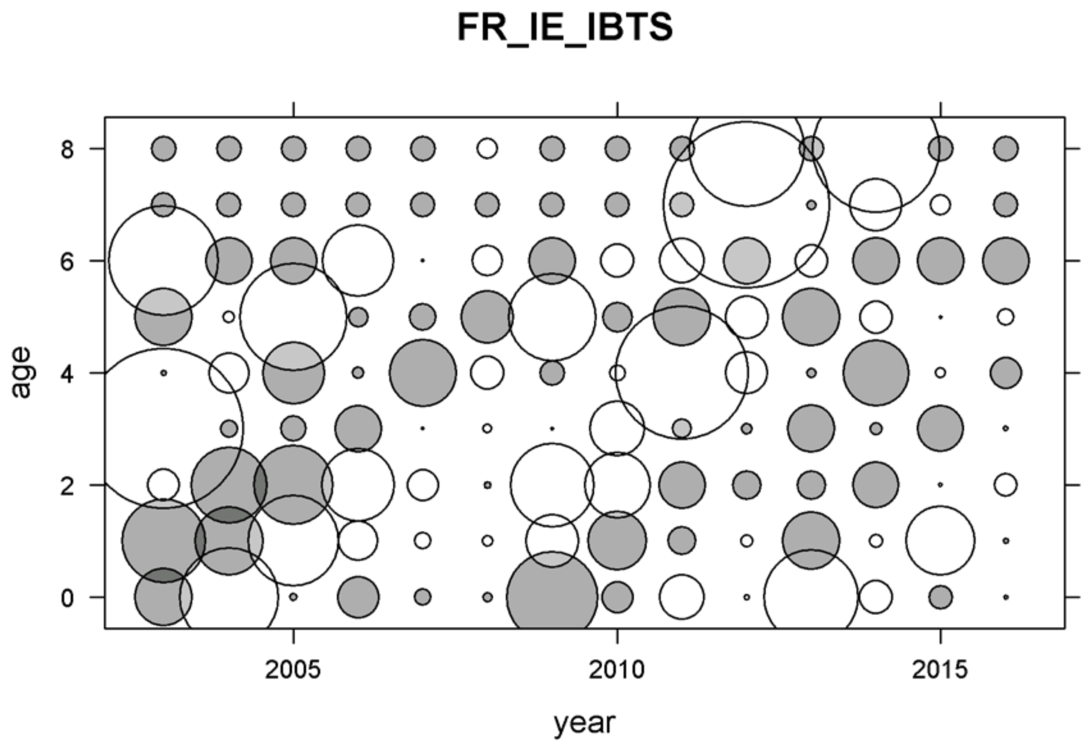
5.3.1.1 Indicators of bias; Cohort tracking

An inappropriate growth model will show a pattern in cohort tracking where strong or weak cohorts do not progress though the catch-at-age matrix as expected. For example one may see a strong cohort of 4-year-olds in one year followed by a strong cohort of 6-year-olds in the next year.

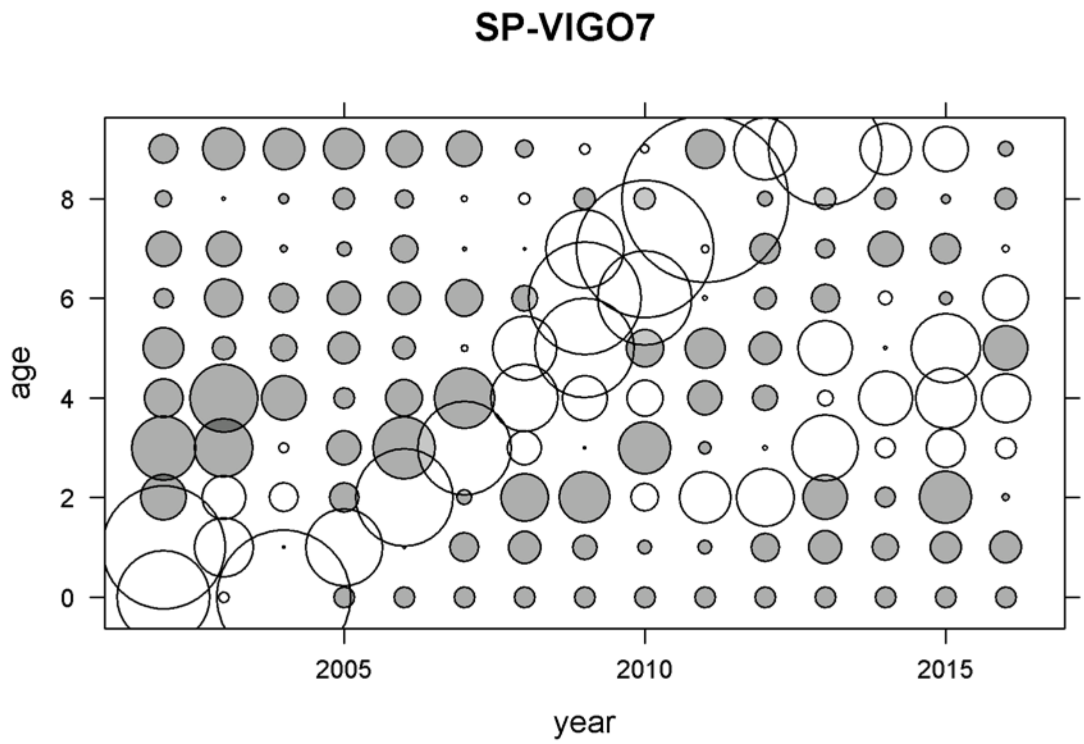
Cohort tracking for ank78 is not particularly strong in the catch but quite good in the tuning indices, suggesting the growth model is not strongly biased.



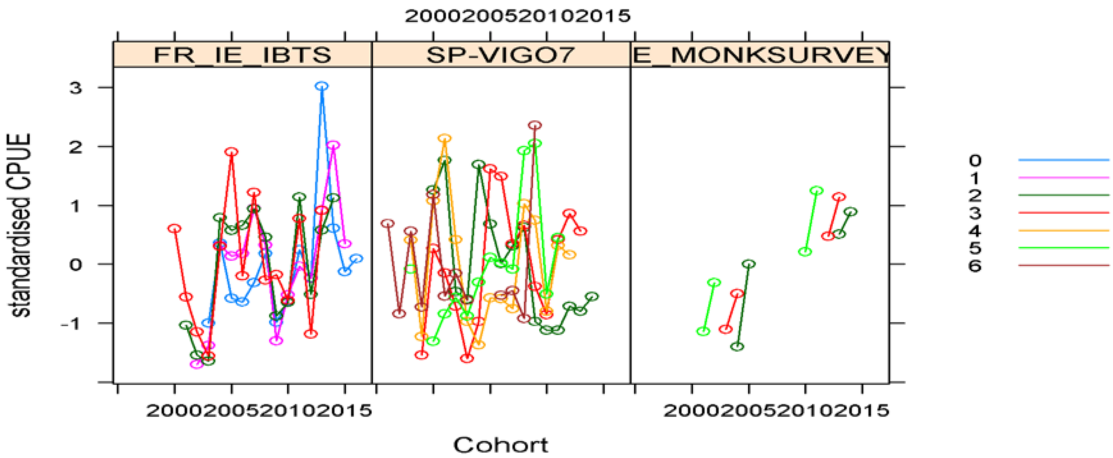
The white bubbles indicate above-average cohorts; grey is below-average. Some cohorts can be tracked for up to six years or more in the catch data. However cohort tracking is not as clear in the catch data as it is for the tuning data (see below).



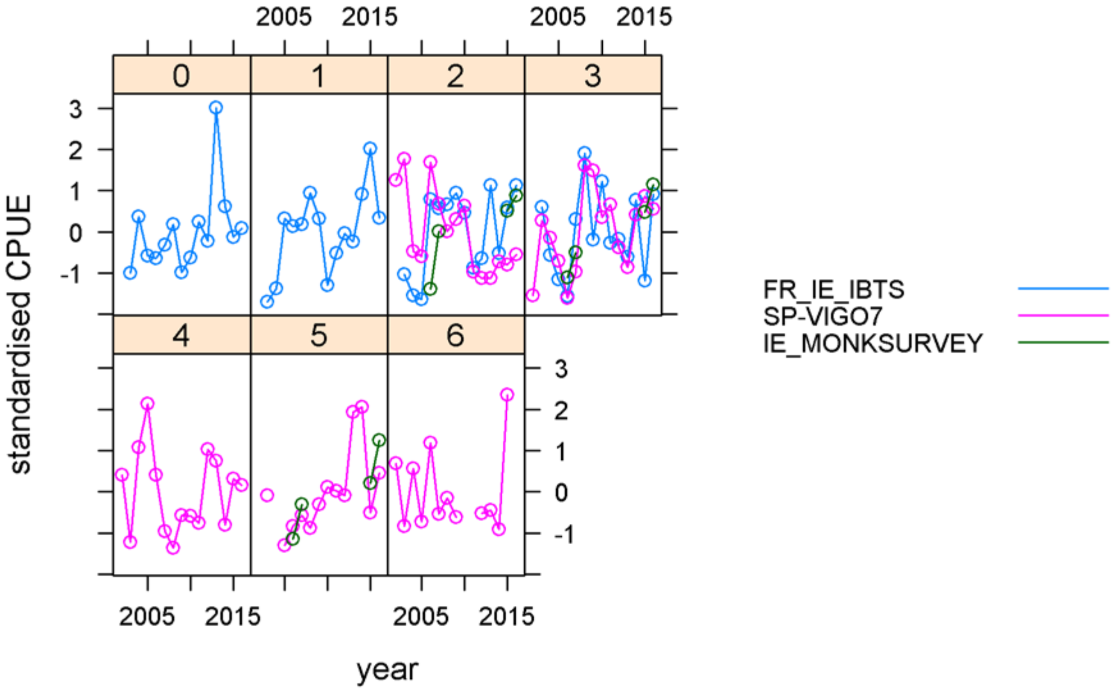
Cohort tracking in the IBTS fleet.



Cohort tracking in the Spanish porcupine survey.



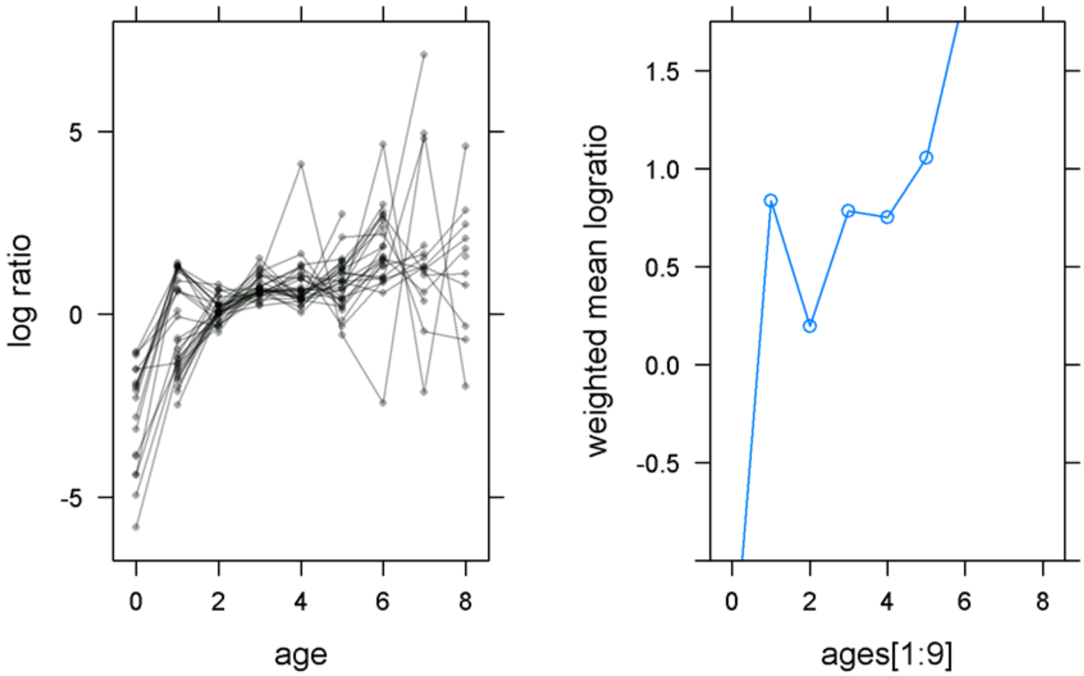
Standardised cpue by cohort of the tuning fleets. The IBTS survey shows very good internal consistency for ages 1 to 3; age 0 does not appear to be well estimated. The Vigo fleet is quite noisy. The monk survey has insufficient data to judge its consistency.



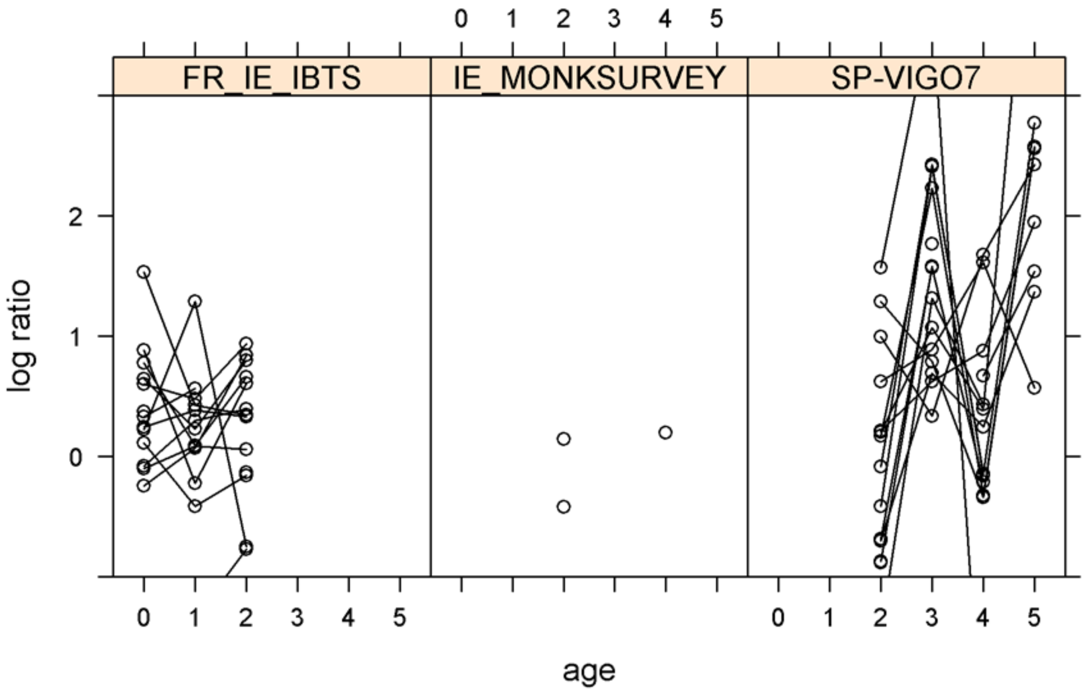
Consistency between indices is reasonably good.

5.3.1.2 Log-ratios; basis for selectivity / catchability model

The log-ratios of the catch and tuning data can give an indication of the selectivity pattern of the fleet/survey.

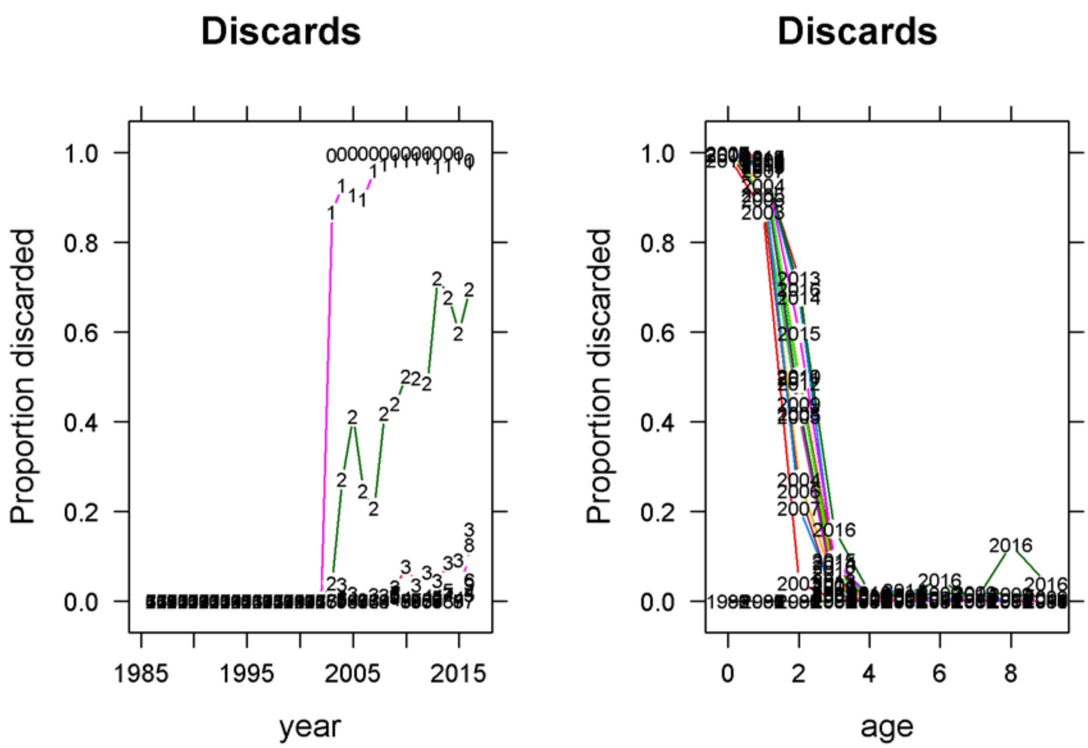


Log-ratios of the catch data. This pattern suggests a relatively flat-topped selection. A logistic selectivity may be appropriate



Log ratios of the tuning data. For the IBTS fleet a 'flat' catchability model may be appropriate (i.e. same q for all ages). For the Vigo fleet a logistic curve may be more appropriate considering this fleet does not include discards. The Irish monk survey does not have enough data to evaluate the log-ratios but either a flat or logistic catchability may be appropriate.

5.3.1.3 Dealing with missing discard data



Catches of ages zero and one are nearly 100% discarded. Discards of age-2 fish appear to have been increasing, but may have been quite low before 2003. In order to deal with missing discards prior to 2003, the catch numbers-at-ages 0 and 1 in those years were replaced with NA. This allows the model to estimate the pattern in F for those ages from the years where discard data are available and apply this to the stock numbers of the full time-series. Discards of age 2 and older were assumed to be zero.

5.3.1.4 Exploratory assessments

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

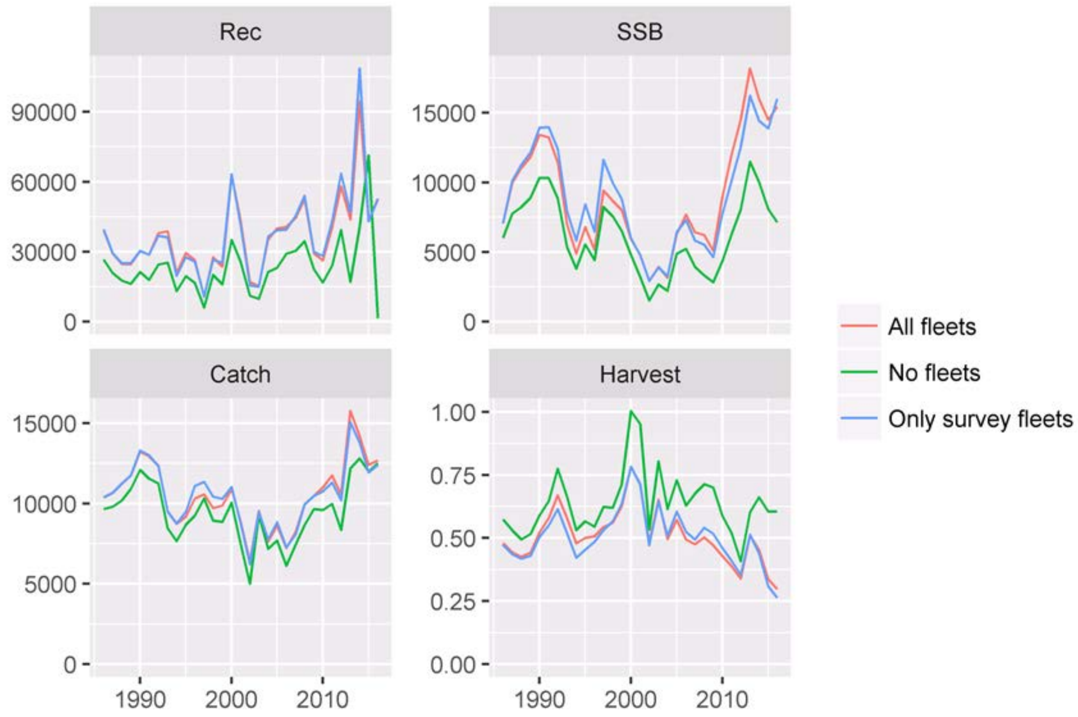
An initial assessment was conducted using all fleets. The submodels were defined as follows:

```
fmod <- ~factor(replace(replace(age, age<2, 2), age>3, 3)) + factor(year)

srmod <- ~factor(year)

qmod <- list(~factor(replace(age,age<2,2)),~I(1/(1 + exp(-age))),~1,~1)
```

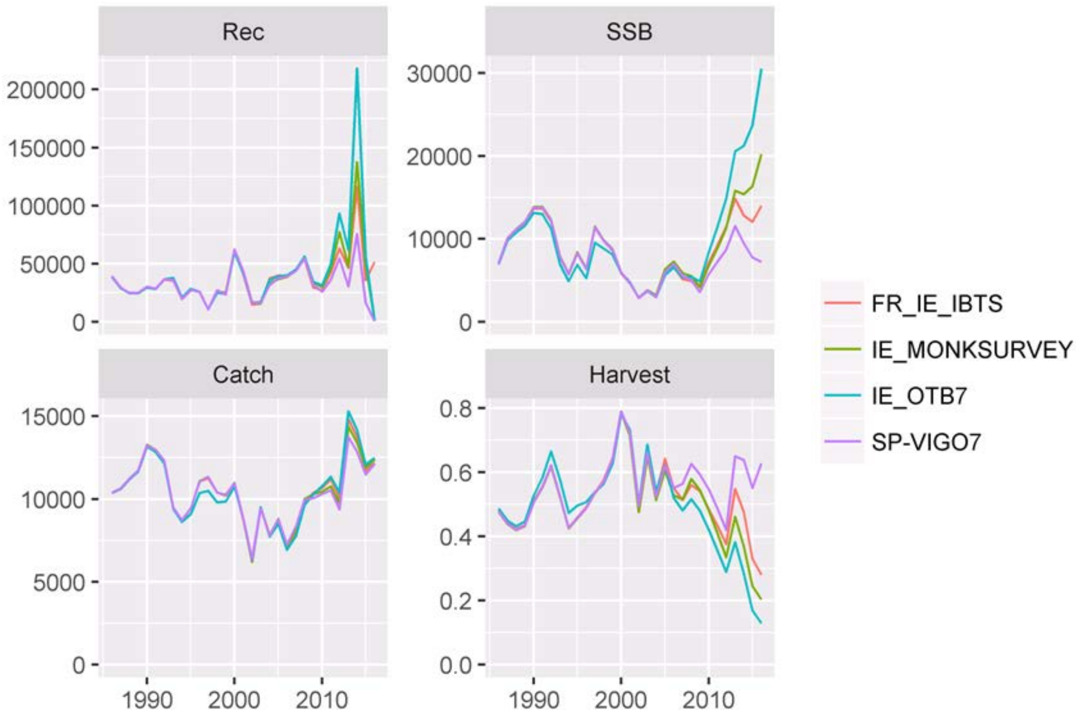
The F model (fmod) is a stepped function; f is assumed to be the same for ages 1 and 2 and also the same for ages 3–7, resulting in a stepped pattern. The level F can vary freely between years; but the shape of the F-pattern is fixed, i.e. a separable model.

The stock–recruitment model (srmod) is ‘free’; i.e. there is no restriction on the estimated recruitment, based on the SSB.

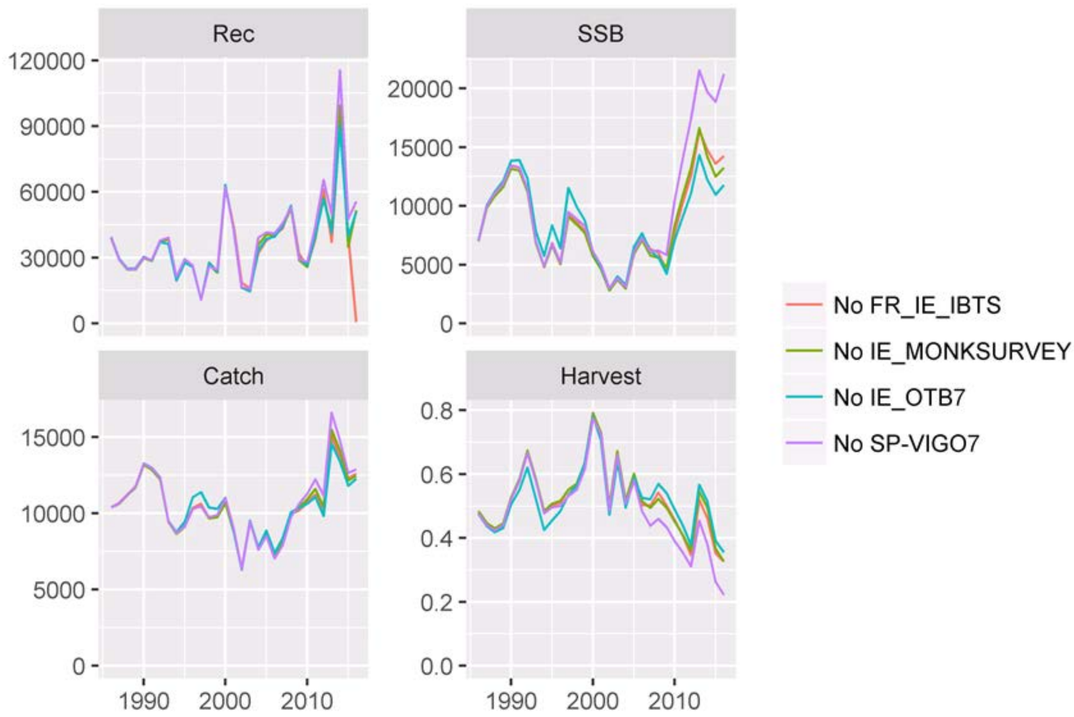
The tuning fleet catchability is the same for ages 0,1,2 and freely estimated for age 3; logistic function for the Vigo fleet and 'flat; (~1) for the Irish Monkfish survey. The Irish OTB fleet is a biomass fleet and does not have an age composition so the catchability is model is simply ~1.



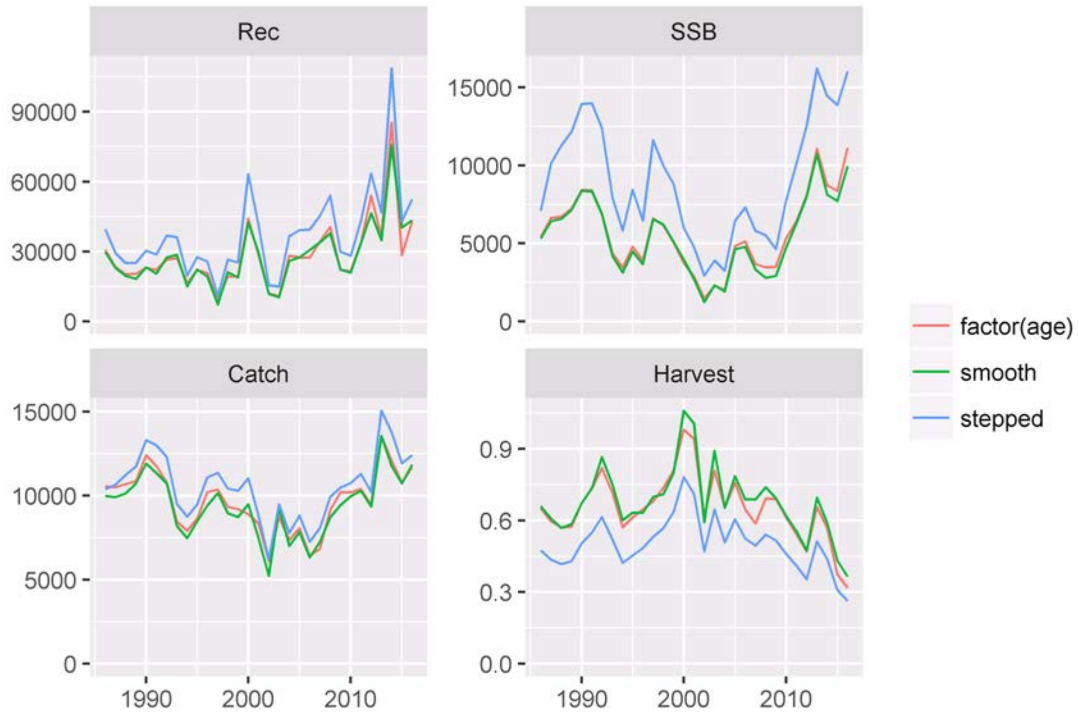
Initial exploratory runs included a run with no tuning data (very similar to a separable VPA); a run with all fleets and a run with only survey fleets. Trends were very similar; including tuning data resulted in a small reduction in F and increase in SSB.



Single fleet runs were also performed. Trends were similar but estimates for recent years varied considerably, depending on the index used.

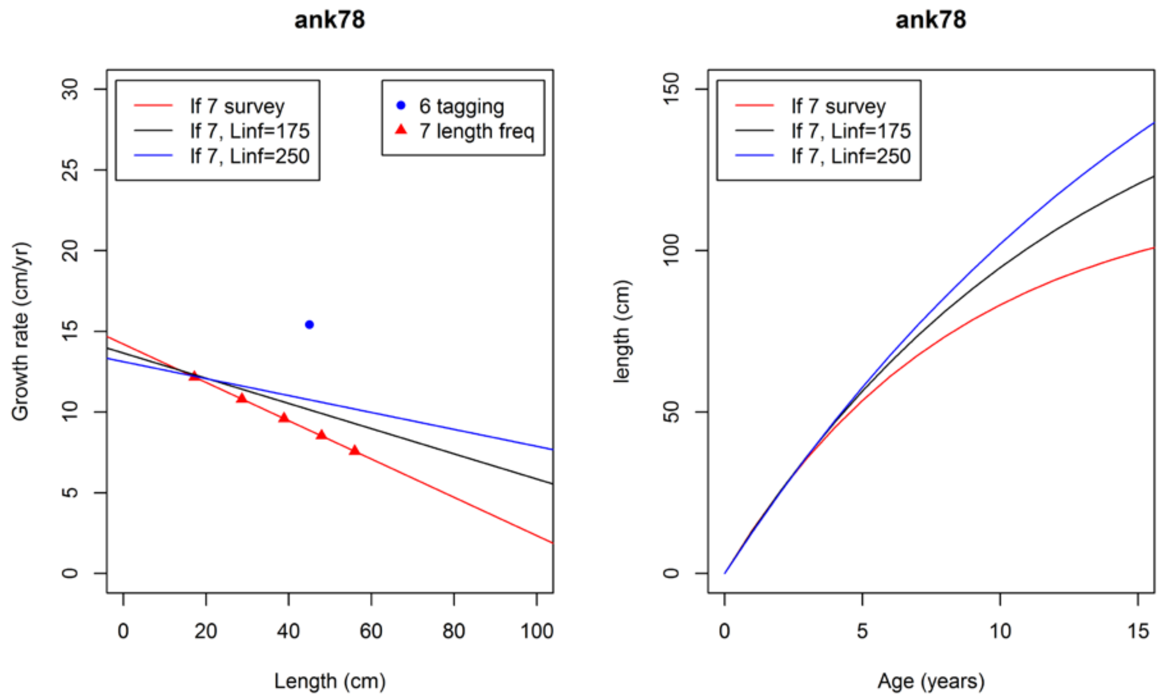


Removing one fleet and keeping the others gives an impression of the effect this fleet has.

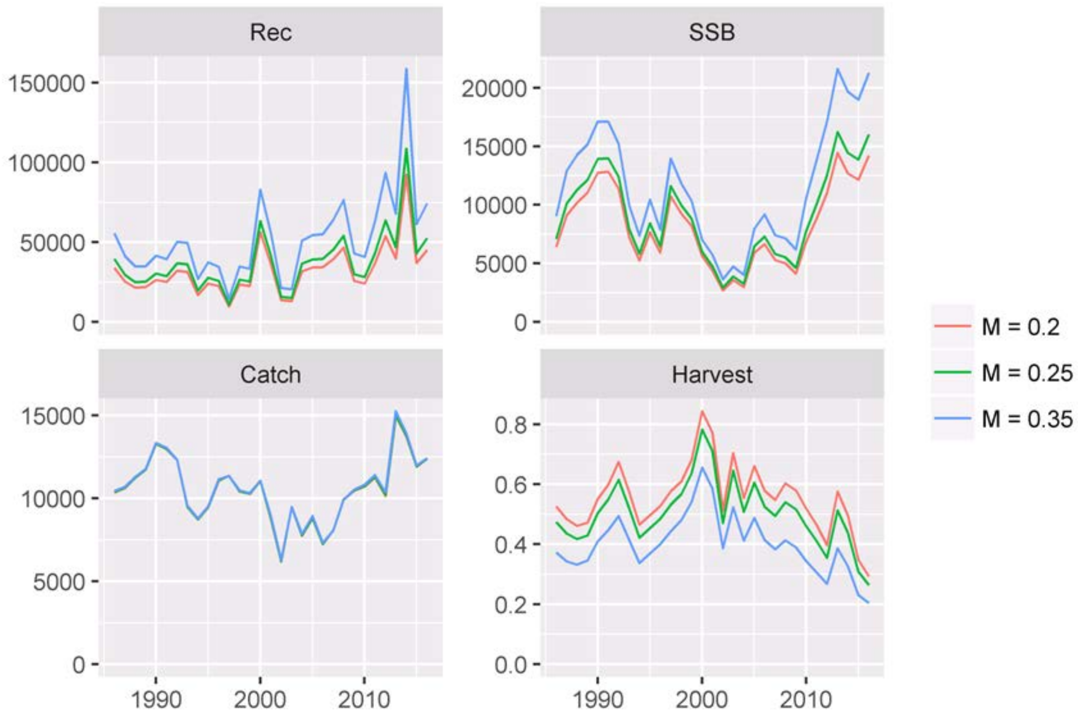


Different F-submodels (freely estimated: factor(age) + year; smooth and stepped.

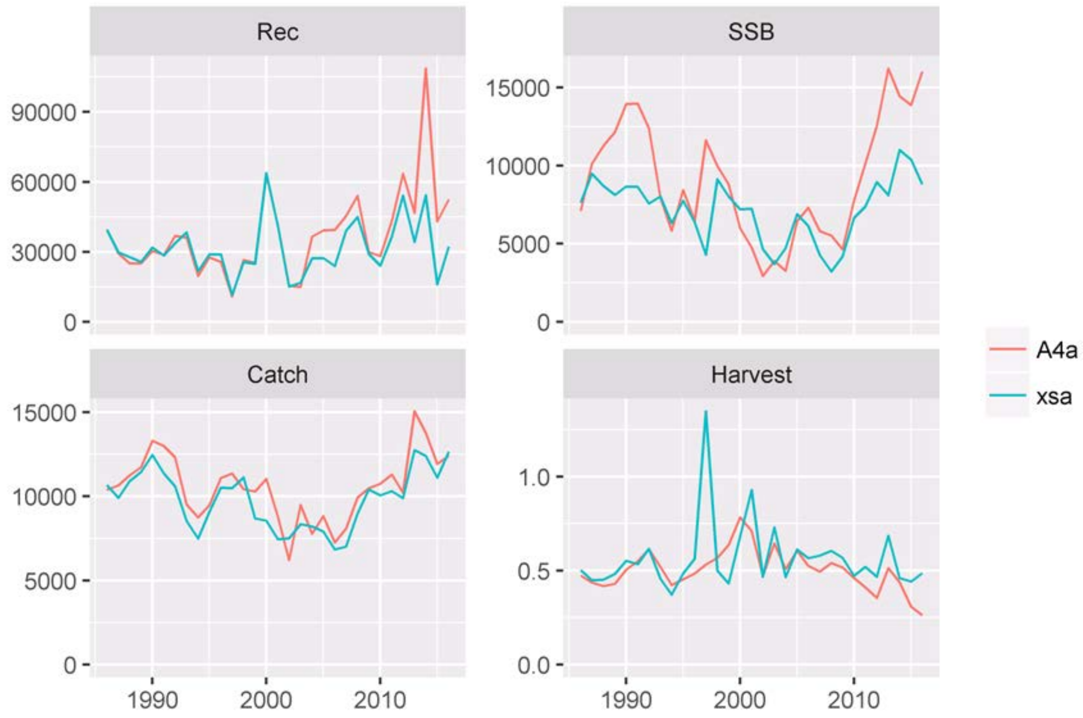
The effect of the assumption of the growth model.



The three growth models explored above.



Changing M simply scales the trends but will influence the reference points.



Comparison of the proposed a4a model with an XSA using default settings on the same data results in very similar trends and absolute estimates. XSA F estimates are a bit more volatile.

5.3.1.5 Conclusion

The assessment trends were quite robust to the inclusion of various tuning indices, natural mortality assumptions and specification of the F-pattern. However, the outcomes were highly sensitive to the growth parameters used to split the length data into (pseudo-) age classes. WKAnglerfish concluded that this undermined the credibility of the assessment and it was not accepted.

5.3.2 SPiCT analysis

SPiCT was explored and while the model converged, the uncertainty was so large that no useful information could be obtained from the model. The most likely explanation is that the catch data did not have enough contrast to be informative.

5.4 White anglerfish in divisions 7.b-k and 8.a,b,d

5.4.1 A4a model

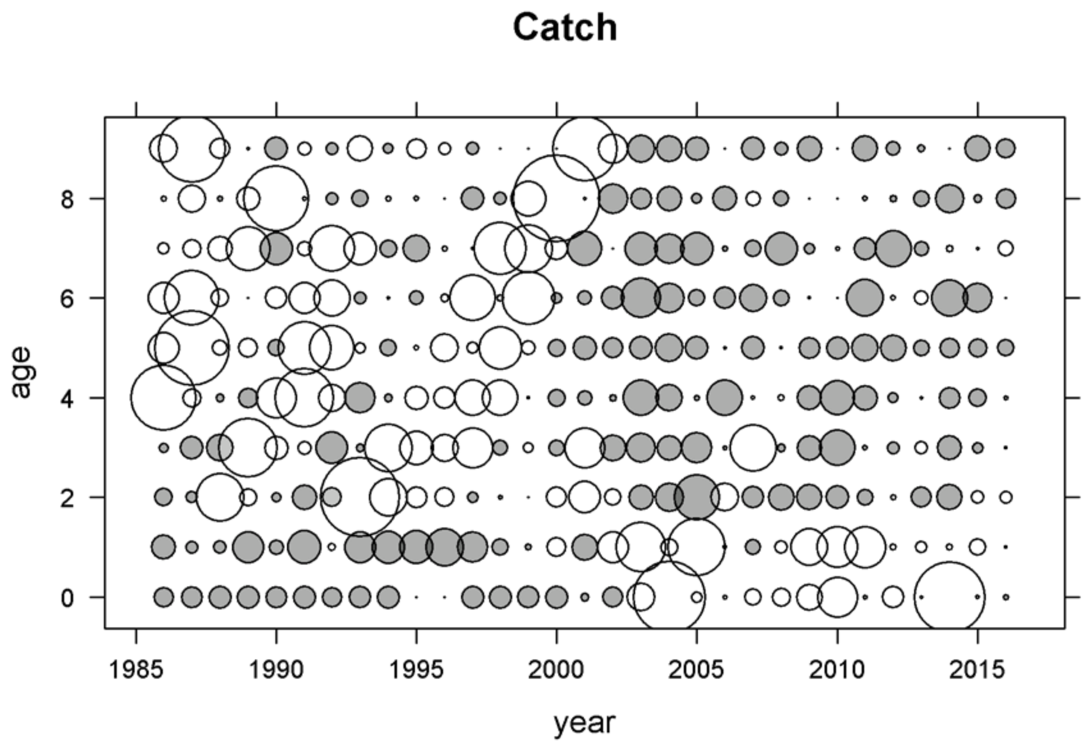
Length data of the catches and surveys were converted to pseudo-ages a von Bertallanfy growth curve with the following parameters: Linf = 171; K = 0.1075; t0 = 0. The parameters are based on the growth rate in the first two cohorts estimated by length–frequency analysis of the survey data; Linf was estimated as 90% of the largest observed individual.

The growth curve was used to estimate the mean length-at-age in each quarter and the standard deviation was assumed to increase from 3 cm at age 0 to 10 cm at age 10. The abundance in each age class was then estimated for each length–frequency distribution. These mixture distributions were then used as an age–length key to estimate the final numbers-at-age for the catch and tuning data.

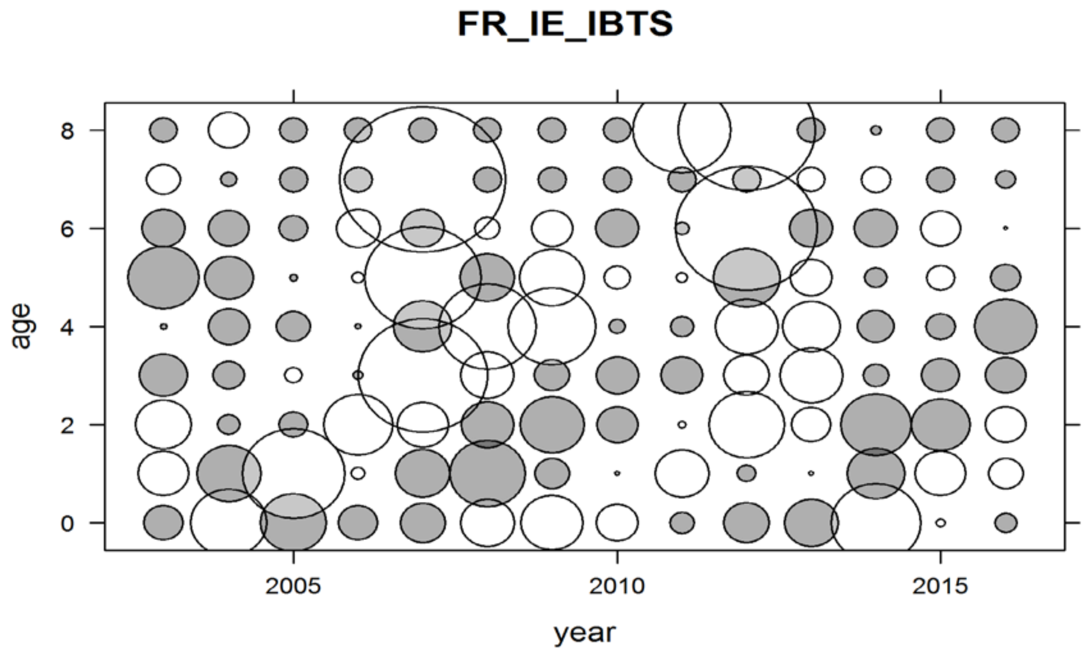
5.4.1.1 Indicators of bias; Cohort tracking

An inappropriate growth model will show a pattern in cohort tracking where strong or weak cohorts do not progress though the catch-at-age matrix as expected. For example one may see a strong cohort of 4-year-olds in one year followed by a strong cohort of 6-year-olds in the next year.

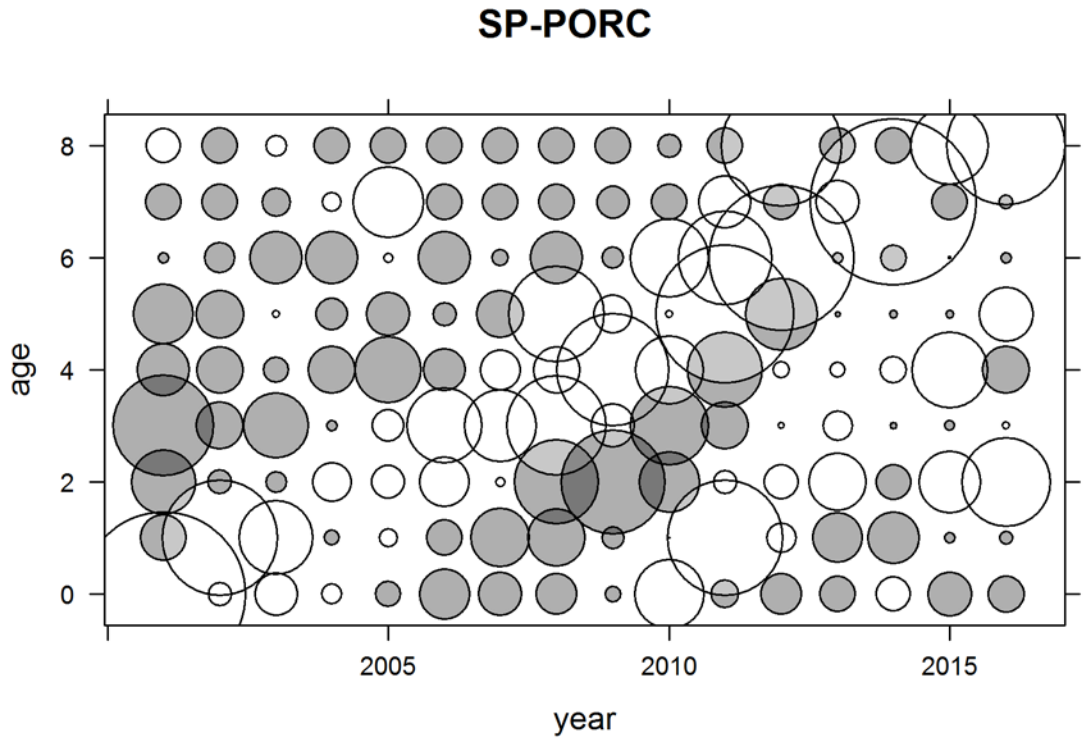
Cohort tracking is quite good in the catch data and tuning indices, suggesting the growth model is not strongly biased.



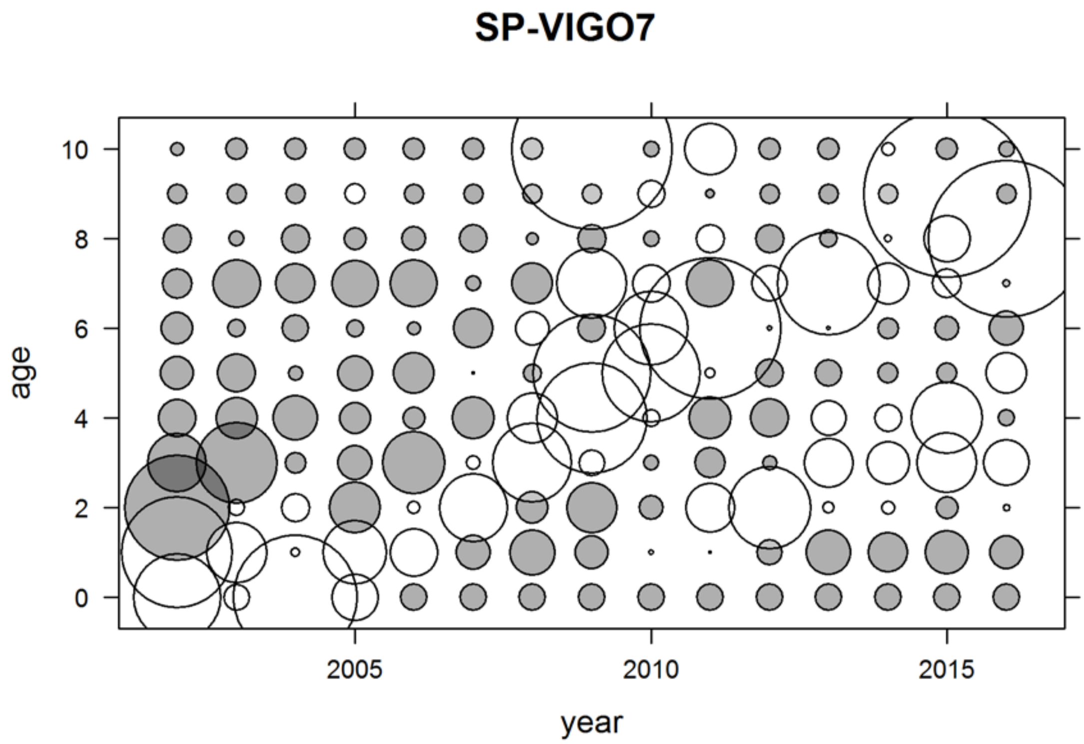
The white bubbles indicate above-average cohorts; grey is below-average. The cohorts can be tracked for six years or more in the catch data.



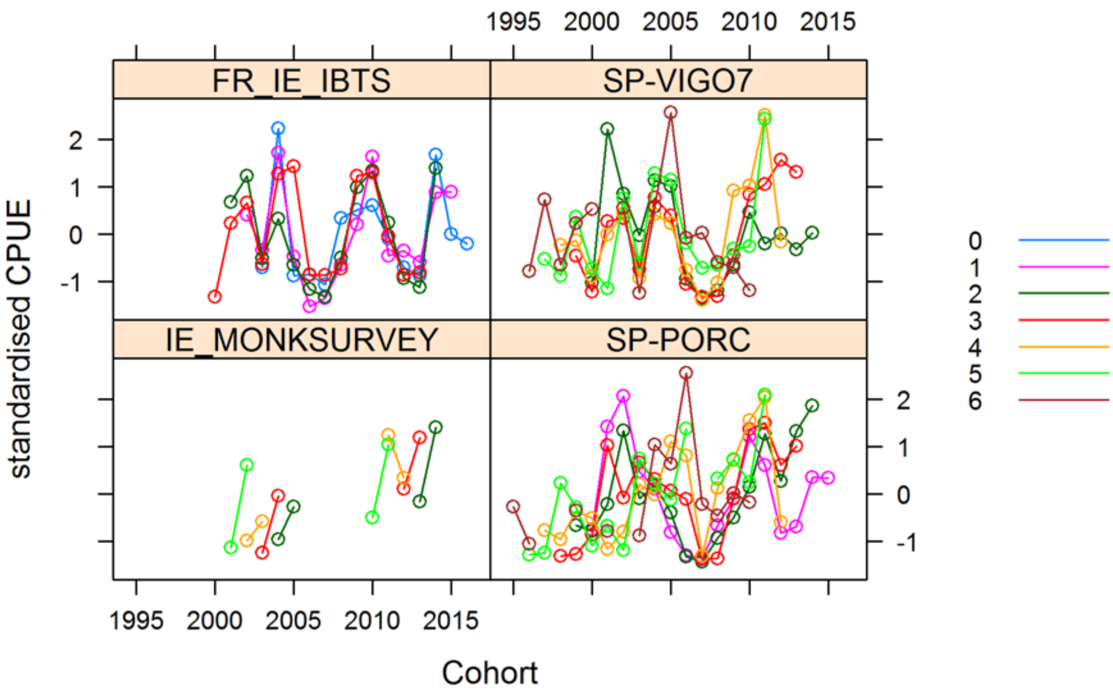
Cohort tracking in the IBTS fleet.



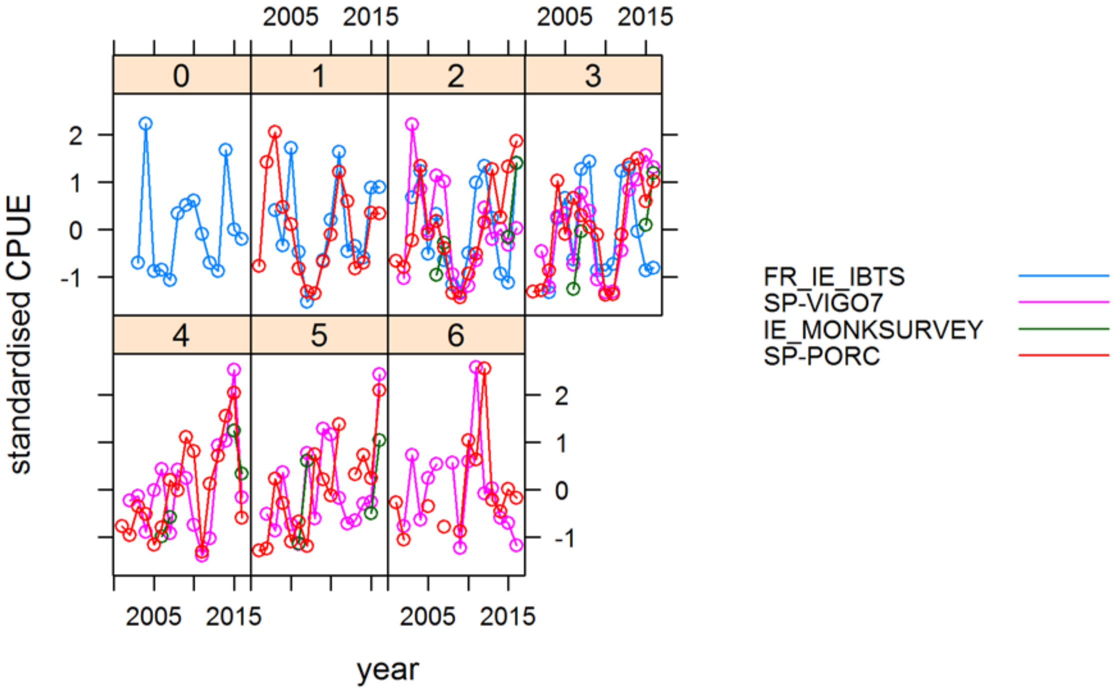
Cohort tracking in the Spanish porcupine survey.



Cohort tracking in the Vigo fleet.



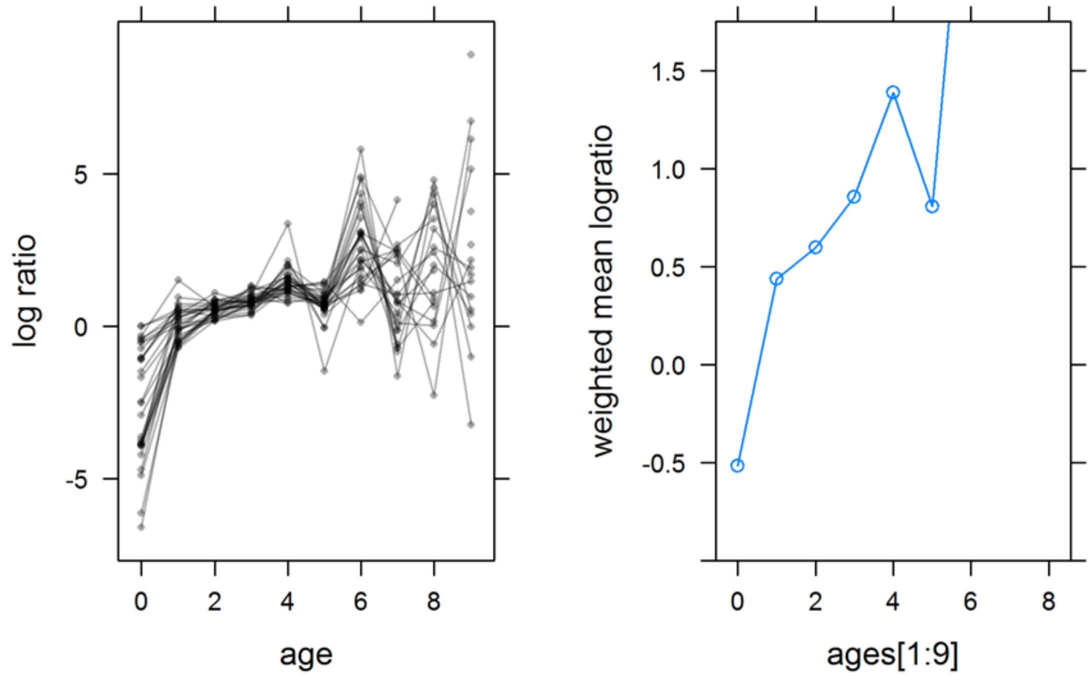
Standardised cpue by cohort of the tuning fleets. The IBTS survey shows very good internal consistency for ages 0 to 3. The Vigo fleet is reasonably consistent. The monk survey has insufficient data to judge its consistency. The Porcupine survey is a bit noisy.



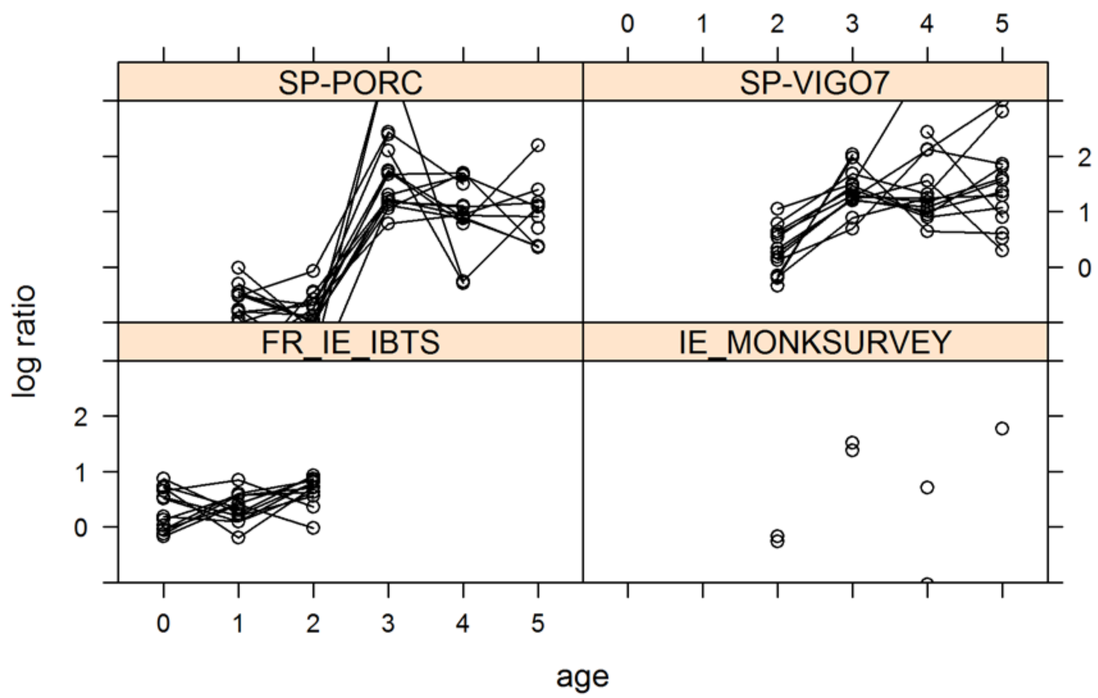
Consistency between surveys is reasonably good.

5.4.1.2 Log-ratios; basis for selectivity / catchability model

The log-ratios of the catch and tuning data can give an indication of the selectivity pattern of the fleet/survey.

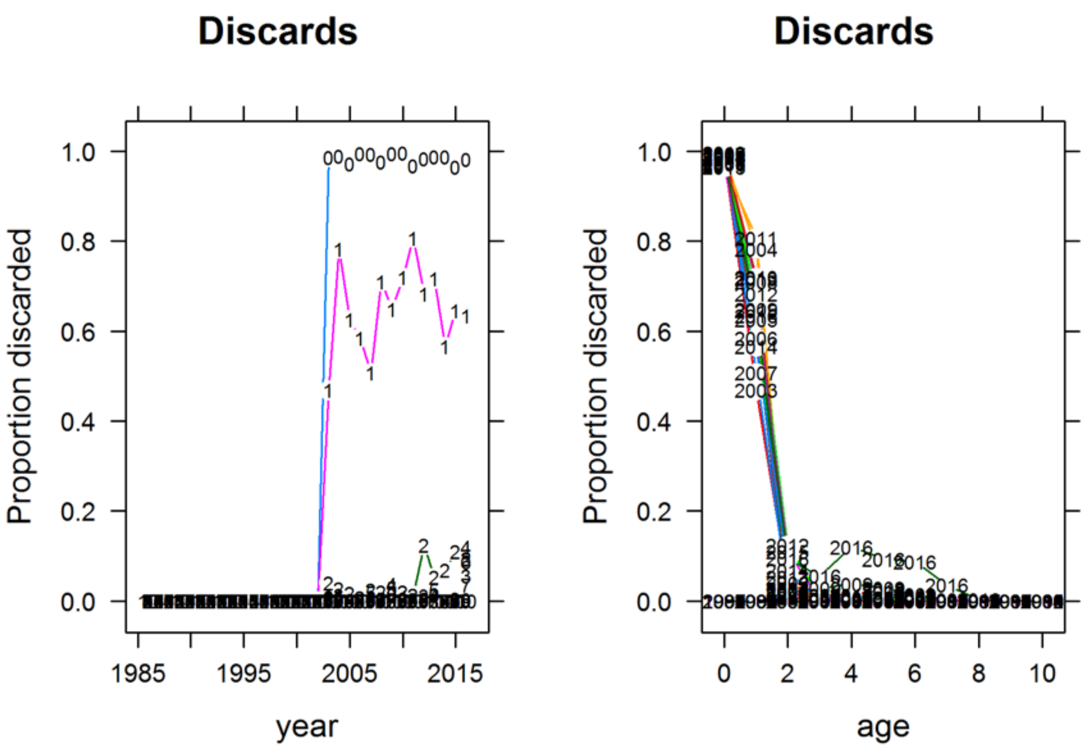


Log-ratios of the catch data. This pattern suggests a relatively flat-topped selection. A logistic selectivity may be appropriate.



Log-ratios of the tuning data. For the IBTS fleet a 'flat' catchability model may be appropriate (i.e. same q for all ages). For the Vigo fleet a logistic curve may be more appropriate considering this fleet does not include discards. The Irish monk survey does not have enough data to evaluate the log-ratios, but either a flat or logistic catchability may be appropriate. The Spanish porcupine index shows a stepwise selection pattern.

5.4.1.3 Dealing with missing discard data



Discards occur nearly exclusively at ages zero and one. In order to deal with missing discards prior to 2003, the catch numbers-at-ages 0 and 1 in those years were replaced with NA. This allows the model to estimate the pattern in F for those ages from the years where discard data are available and apply this to the stock numbers of the full time-series.

5.4.1.4 Exploratory assessments

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

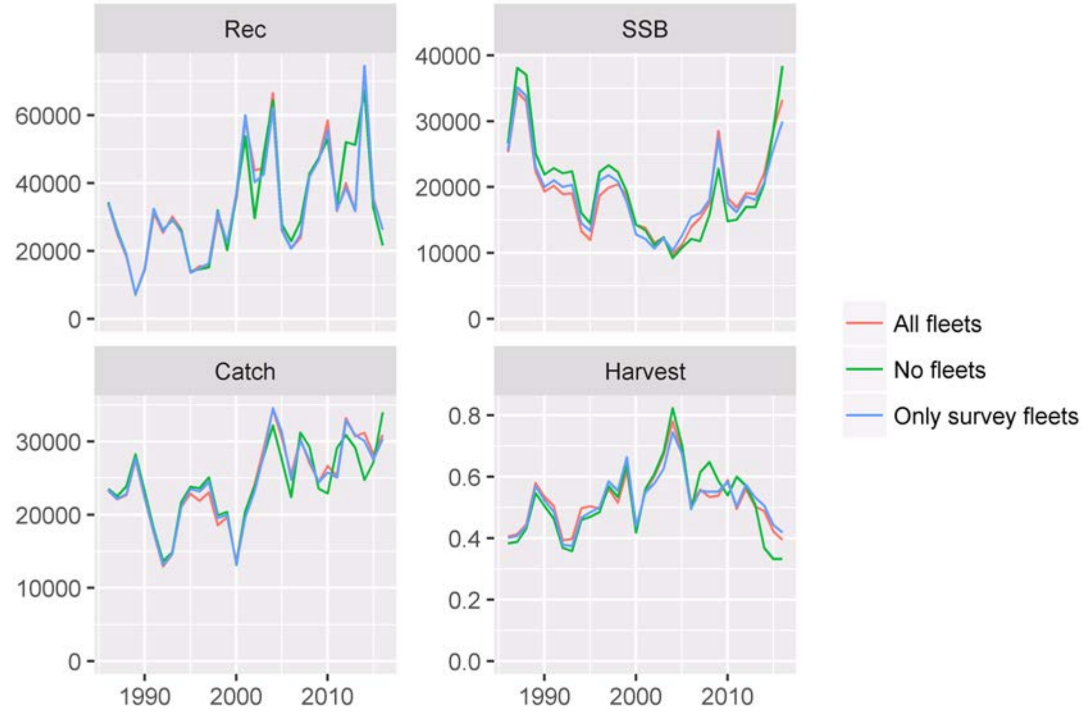
An initial assessment was conducted using all fleets. The submodels were defined as follows:

```
fmod <- ~I(1/(1 + exp(-age))) + factor(year)

srmod <- ~factor(year) # uninformative

qmod <- list(~1,~I(1/(1 + exp(-age))),~I(1/(1 + exp(-age))),~1,~factor(replace(age,age>4,4)))
```

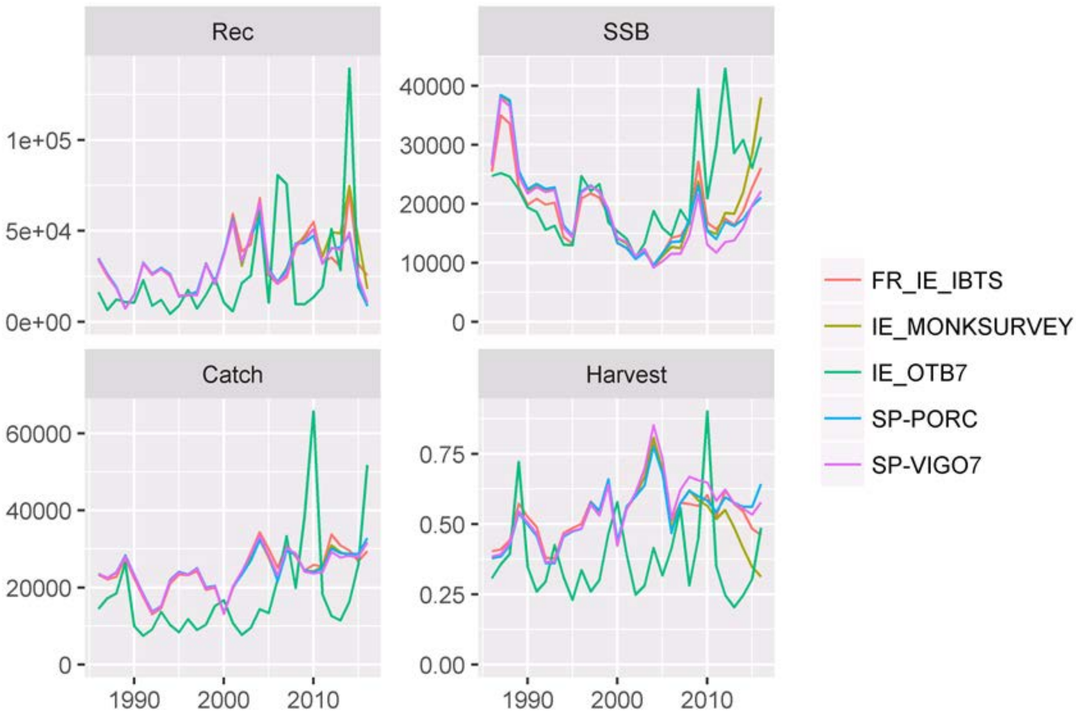
The F model (fmod) is a logistic function across the ages which can vary between years; this is the same as a separable model.

The stock–recruitment model (srmod) is ‘free’; i.e. there is no restriction on the estimated recruitment, based on the SSB.

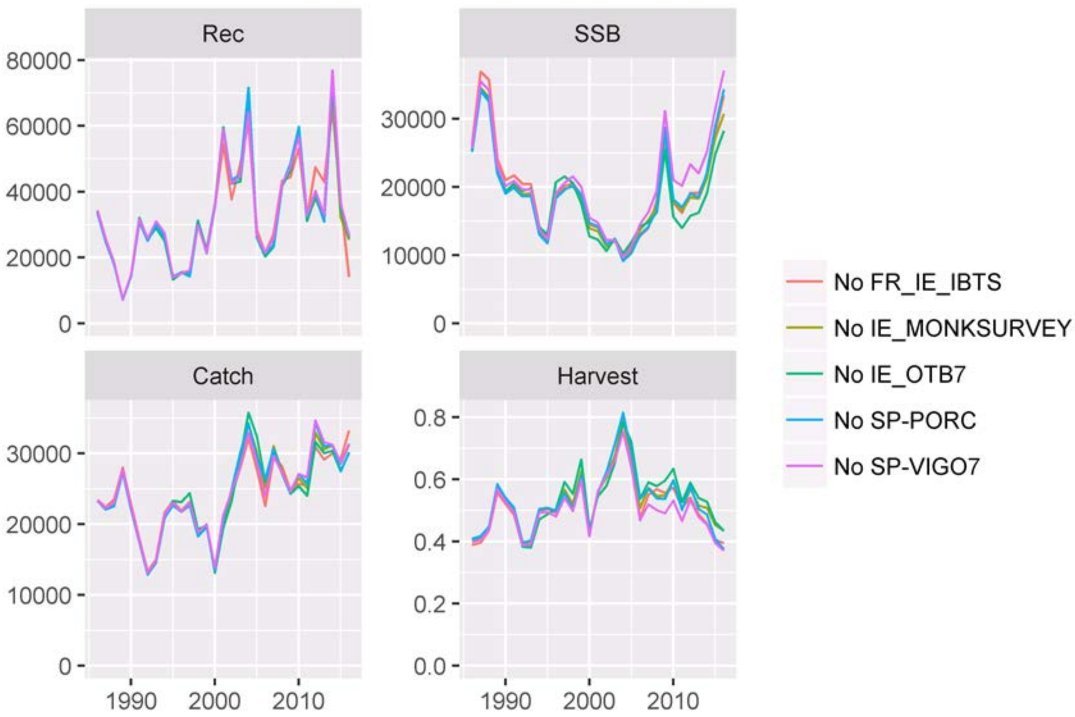
The tuning fleet catchability is 'flat' (~1) for the IBTS survey; logistic function for the Vigo fleet and monkfish survey. The Irish OTB fleet is a biomass fleet and does not have an age composition so the catchability is model is simply ~1. Finally the Porcupine survey has a freely estimated catchability at ages 1–4.



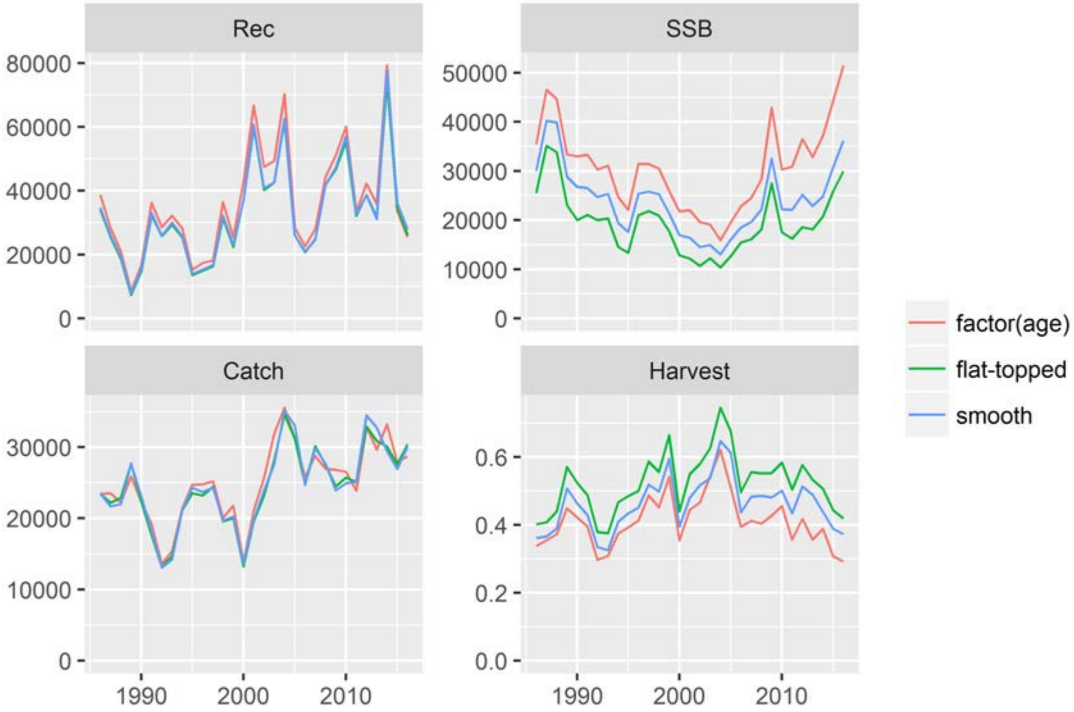
Initial exploratory runs included a run with no tuning data (very similar to a separable VPA); a run with all fleets and a run with only survey fleets. Trends were very similar; including tuning data resulted in a small difference in the most recent years.



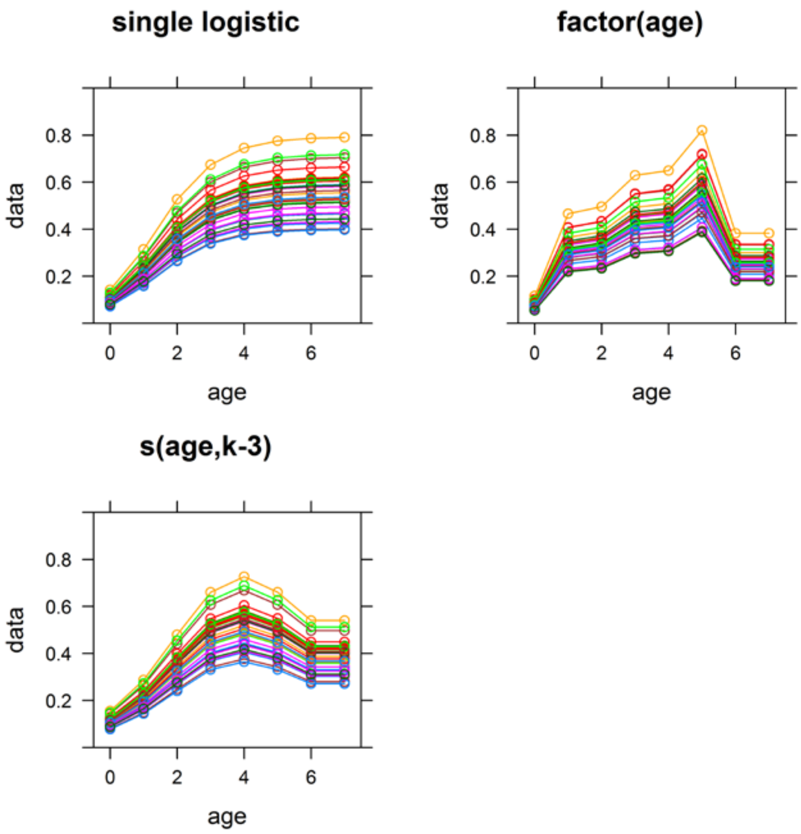
Single fleet runs were also performed. Trends were similar but estimates for recent years varied considerably, depending on the index used.



Runs with all fleets except one; this indicates the influence each fleet has.

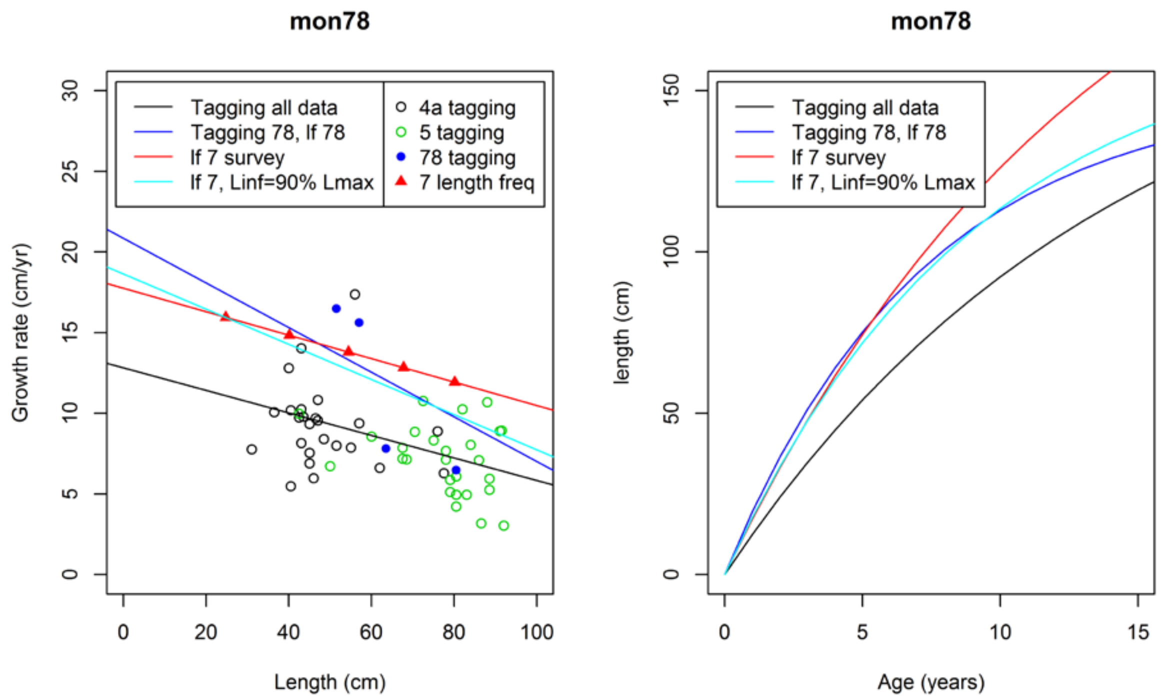


Different F submodels: freely estimated across ages (factor(age) + factor(year)); flat-topped (logistic curve) and smooth.

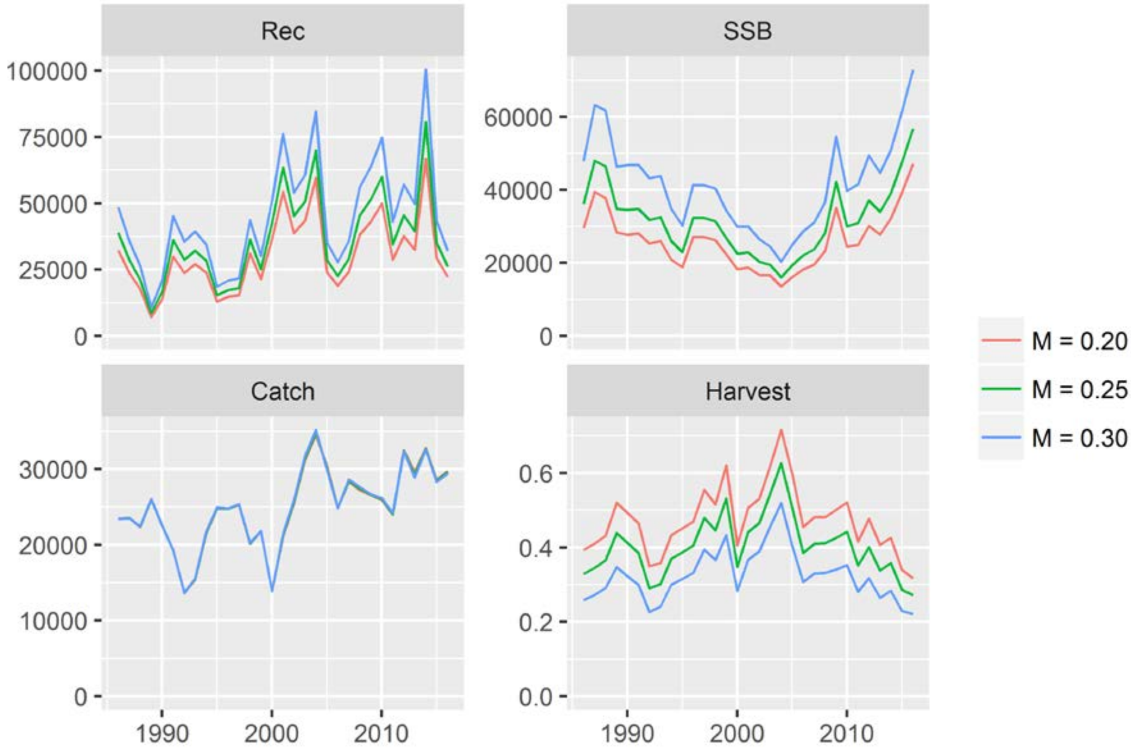


Shape of the F-submodels explored.

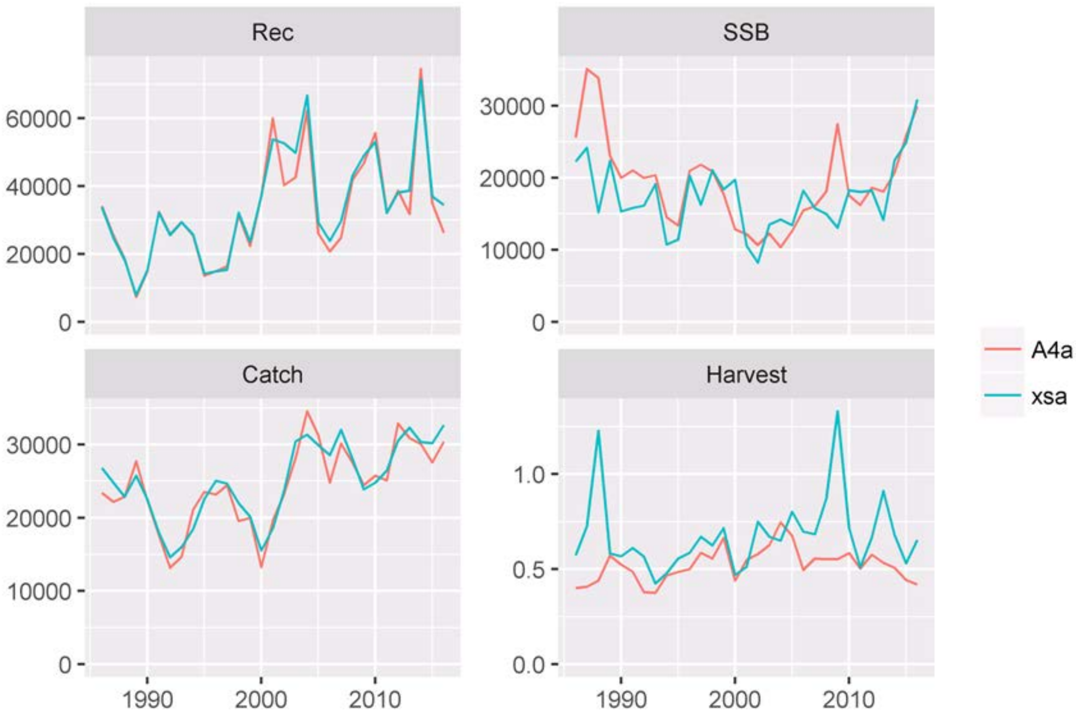
Runs with different growth models used to estimate the age composition.



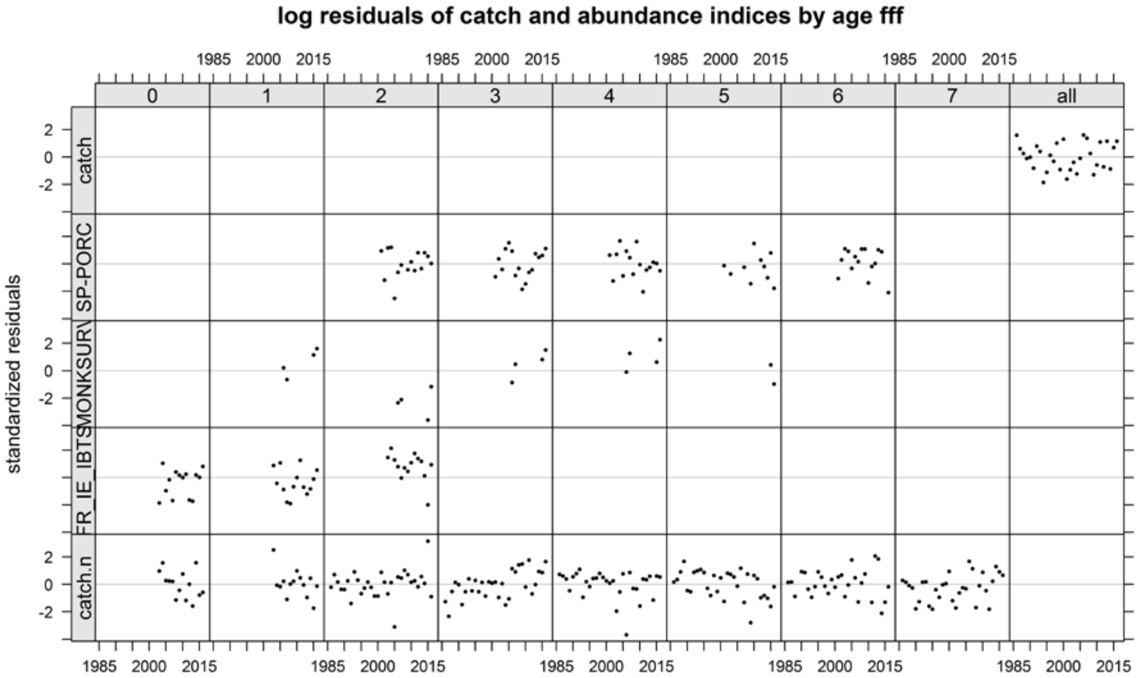
The growth models used in the runs above (the black curve was not used as this was clearly underestimating the growth rate at younger ages.



Changing M simply scales the trends but obviously will influence the reference points.



Comparison between a4a model and XSA with the same data and default settings. The two models give similar absolute estimates. XSA F estimates are noisier than those from a4a.



Residuals of the final run.

5.4.2 Reference points

Model used: eqsim

Software used: R packages msy (version 0.1.18), FLCore (version 2.6.5) in R (version 3.4.1) and icesAdvice (version 1.4.0)

Inputs: a4a assessment-final run of WKAngler 2018.

Stock–recruit model: a weighted stock–recruitment model was estimated using segmented-regression, Ricker and Beverton–Holt. The stock–recruit relationship is considered to be type 5 according to the technical guidelines (ICES, 2017). Therefore B_{lim} was set at B_{loss} (16 032 t).

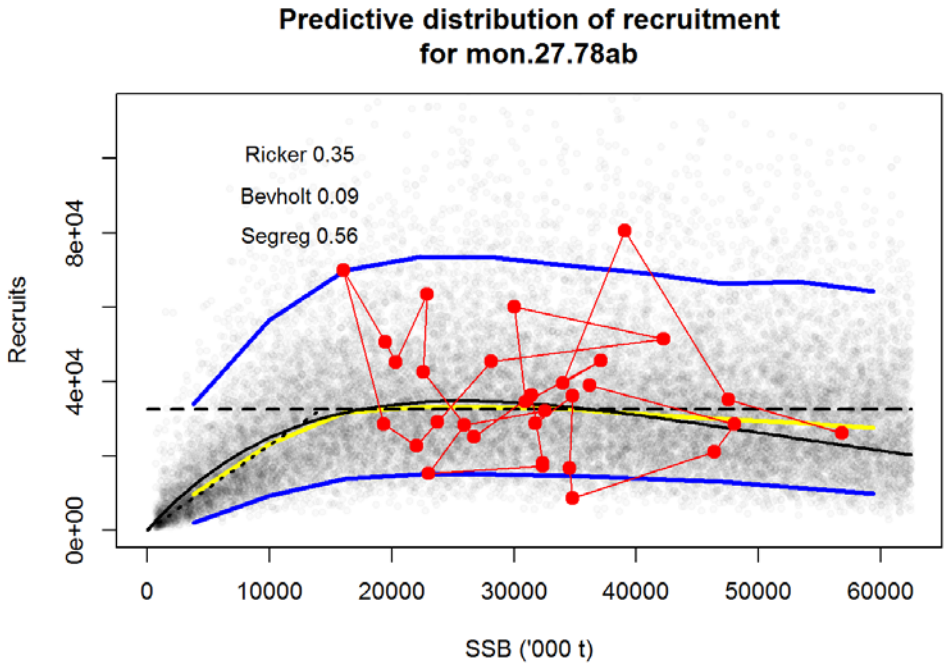


Figure E.1. Weighted stock–recruit model.

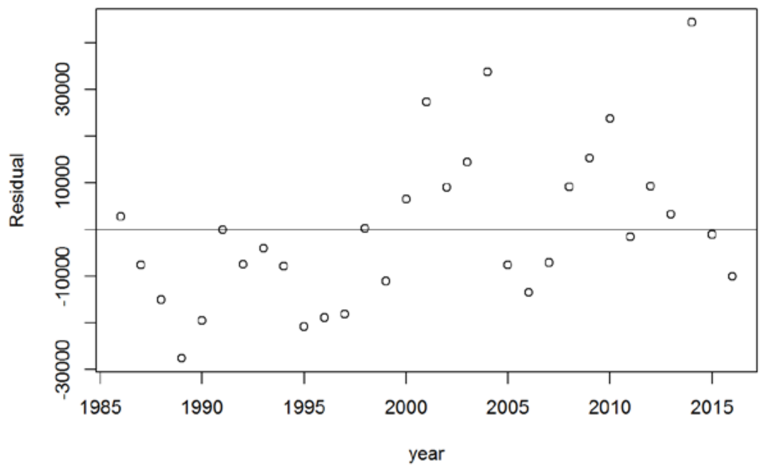


Figure E.2. Residuals in the stock–recruit relationship. In recent years the residuals are mostly positive, indicating higher recruitment than expected from the S–R relationship.

Uncertainty parameters:

- F_{cv} = 0.233 (default value WKMSYREF4)
- SSB_{cv} = 0.20 (default value technical guidelines; only used for B_{pa} estimate)
- B_{lim} = B_{loss} = 16 023 t
- B_{pa} = B_{loss} with assessment error = 22 278 t
- F_{phi} = 0.423 (default value WKMSYREF4)

Selection pattern, biological parameters time period: ten years

Step 1: Eqsim base run without $B_{trigger}$

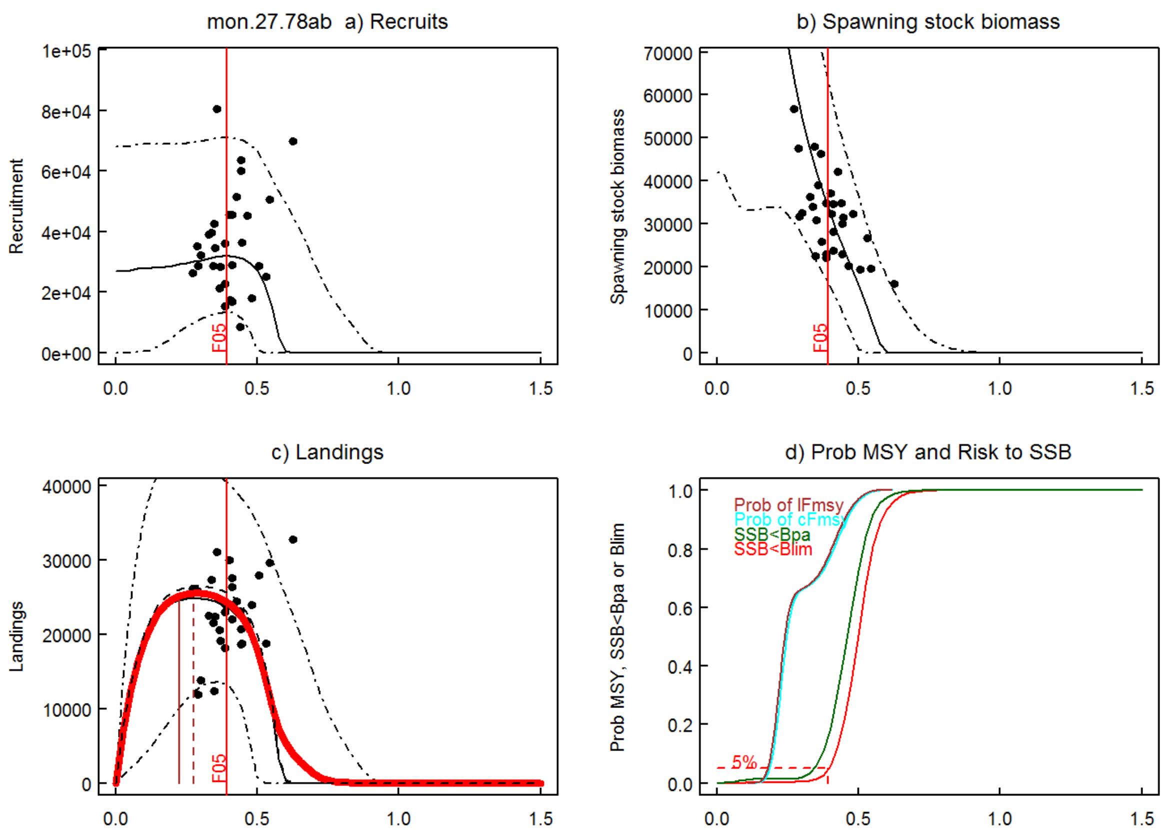


Figure E.3. Eqsim baserun outputs. Panels a–c: historic values (dots) median (solid black) and 90% intervals (dotted black) recruitment, SSB and landings for exploitation at fixed values of F. Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB less than B_{lim} (red), SSB less than BPA (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

Following the first eqsim run, F_{MSY} was estimated as 0.279 with a range of 0.181–0.392

Step 2: Eqsim run with no error to select F_{lim}, F_{pa} and $B_{trigger}$

F_{lim} = 0.526; F_{pa} = 0.359; $B_{trigger}$ = 22 278 t.

F_{pa} was estimated to be larger than F_{MSY} therefore the original estimate of 0.279 was carried forward

Step 3: Eqsim with $B_{trigger}$ to evaluate MSY advice rule

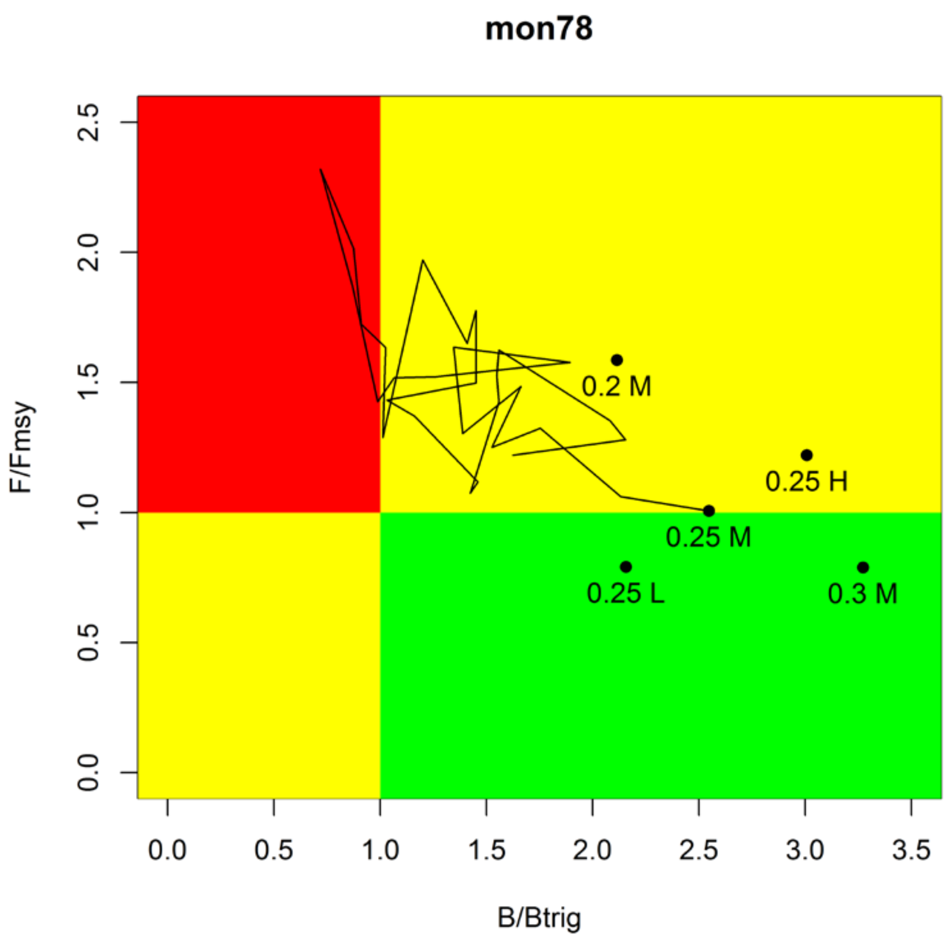
$F_{p.05}$ (F that gives 5% probability of SSB below B_{lim}) = 0.394

$F_{p.05}$ is slightly above the upper range of F_{MSY} estimate so the final choice of F_{MSY} remains 0.279 and the range remains unchanged as well.

Table E.1. Biological reference points.

	Type	Value	Technical basis
MSY	MSY $B_{trigger}$	22 278 t	B_{pa}
Approach	F_{MSY}	0.28	Median Eqsim estimate for landings
	F_{MSY} range	0.181-0.39	
	B_{lim}	16 032 t	B_{loss}
Precautionary	B_{pa}	22 278 t	B_{lim} + assessment error
Approach	F_{lim}	0.53	F with 5% probability of SSB <B_{lim}
	F_{pa}	0.36	F_{lim} + assessment error

5.4.2.1 Sensitivity of F_{MSY}



The sensitivity of the estimate of F_{MSY} to assumptions on growth and M was explored:

0.25M = medium growth; M = 0.25

0.25L = low growth, M = 0.25

0.25H = high growth, M = 0.25

0.2M = medium growth M = 0.2

0.3M = medium growth M =0.3

Conclusion: F_{MSY} is quite sensitive to the assumptions on growth and M. Using medium growth and M=0.25 appears to be a sensible compromise.

5.4.3 SPiCT analysis

SPiCT was explored and while the model converged, the uncertainty was so large that no useful information could be obtained from the model. The most likely explanation is that the catch data did not have enough contrast to be informative.

5.4.4 SS3 analysis

The Stock Synthesis assessment model (NOAA Fisheries Toolbox, 2011) is a highly flexible statistical model framework which allows the building of simple to complex models using a mix of data compositions available. The Stock Synthesis assessments were built using SS3 version SS-V3.24U-fast. This annex explores the progress made with the Stock Synthesis model for *Lophius piscatorius* species.

5.4.4.1 Development of the model

Although a Stock Synthesis model was developed during the WKANGLER 2018 benchmark, the model was very sensible to the parameterization of the selectivity of the surveys and therefore, further work is necessary in order to get a stable version. This annex presents the results from the exploration and further development of the SS3 length-based model.

For *Lophius piscatorius* model the following datasets were used:

Data available in WKFLAT 2012:

- Quarterly landings and length–frequency compositions from 1986 to 2001.

Data available in WKANGLER 2018:

- Index based in number and length–frequency compositions from the EVHOE-WIBTS-Q4 from 1997 to 2012.
- Index based in number and length–frequency compositions from the SPPGFS-WIBTS-Q4 from 2001 to 2012.
- Index based in number and length–frequency compositions from the IGFS-WIBTS-Q4 from 2003 to 2012.
- Index based in number and length–frequency composition from the monkfish Irish survey 2007–2008 and 2016.

The landings where aggregated into one common fleet; the setting for the biological parameters have been set to those used in the *Lophius piscatorius* in areas 8.c and 9.a SS3 assessment:

- K=0.11 Landa *et al*. (2008);
- M= 0.2.

Number of samples 100 for the common fleet and 125 for the survey fleets.

Recruitment is assumed in the second season following Quincoces *et al*. (2008) with a cv of 0.4.

The Std.err. of log(value) of the discards 0.5.

It was assumed asymptotic selectivity for the common fleet, to avoid that the plus group increases due to the low mortality of the largest.

Sensitivity analysis

- Two surveys: EVHOE-WIBTS-Q4 and SPPGFS-WIBTS-Q4

Doble normal selectivity (fixed last parameter) & linear growth until age 0.75

Logistic selectivity for both surveys & linear growth until age 0.75

Logistic selectivity for both surveys & linear growth until age 1.75

- Three surveys: EVHOE-WIBTS-Q4, SPPGFS-WIBTS-Q4, IGFS-WIBTS-Q4

Doble normal selec. (fixed last parameter) & linear growth until age 0.75

- Four surveys: EVHOE-WIBTS-Q4, SPPGFS-WIBTS-Q4, IGFS-WIBTS-Q4, monkfish Irish survey

Doble normal selectivity (fixed last param) & linear growth until age 0.75

Logistic selectivity surveys & linear growth until age 1.75

(Fixed logistic selectivity for the monkfish (only 3 data))

Assessment model results

The selectivity of the surveys is too flexible with the normal selectivity, therefore the last parameter which describes the selectivity in the last bin, was fixed. The retrospective pattern analysis shows that the model was very sensitive, and the selectivity was changing during the retrospective simulations when two surveys are included as well as with four surveys (Figure 1).

In the case of two surveys assuming a logistic pattern for both surveys’ selectivity then the retrospective pattern improved compared with the previous model but the retrospective pattern is still quite sensitive (Figure 2). The increase of time with linear growth was analysed and increasing to 1.75 improved considerably the retrospective pattern of the model (Figure 3). The length distribution of landings and discards were fitting very well the data (Figure 4). The model that better fit the data and with the best retrospective pattern was with two surveys, with logistic selectivity pattern and assuming a linear growth until 1.75 age. The model shows an increasing trend in the relative spawning biomass over the time-series with peaks in abundance at 1997 and with an increasing trend since 2004 (Figure 2). The increases in 1997 and 2008 could be due to the 1992 and 2001 recruitments entering the fishery and the increase since 2012 could be explained by the high recruitment years between 2006–2008. The large peak in recruitment abundance in 2001 corresponds to the length distributions found in the EVHOE-IBTS-Q4 survey for 2001.

The model fit to the EVHOE-IBTS-Q4 and SPPGFS-WIBTS-Q4 surveys, shown in Figure 4, is slightly better for the EVHOE-IBTS-Q4 in the early years than that of the SPPGFS-WIBTS-Q4. However, there are years where the model does not fit well both indices due to the contradictory signals between both indices and for example the model does not fit the highest values of both indices; 2003 and 2005 for EVHOE and 2004 for SPPGFS-WIBTS-Q4. The last year for the EVHOE-IBTS-Q4 give a fit outside the confidence intervals of the survey. The value is close to the lowest value of the series while the index SPPGFS-WIBTS-Q4 does not show any decrease. The estimated discards by the model in the start of the series is overestimated while at the end of the series underestimates (Figure 4).

Selectivity for the fleets' landings and discards and the EVHOE-IBTS-Q4 survey indices give good fits to the length–frequency distributions (Figure 4). However, the model does not fit well the two peaks of the SPPGFS-WIBTS-Q4 survey.

Recommendations

The model needs further analysis on the discards data and porcupine. The inclusion of the IGFS and Irish monkfish survey in the model gave very sensitive retrospective pattern (Figure 5) and therefore further analysis is necessary. In addition, it was not analysed the inclusion of any commercial cpue data, and the long time-series of the lpue of the fleets of Vigo could be interesting to analyse. Therefore, in summary the selectivity of the surveys should be analysed with caution and more understanding of the linear growth parameters would help to understand and improve the model.

References

ICES. 2012. Report of the Benchmark Workshop on Flatfish Species and Anglerfish (WKFLAT), 1–8 March 2012, Bilbao, Spain. ICES CM 2012/ACOM:46. 283 pp.

NOAA Fisheries Toolbox. 2011. Stock Synthesis 3, version 3.23b. [Internet address: http://nft.nefsc.noaa.gov].

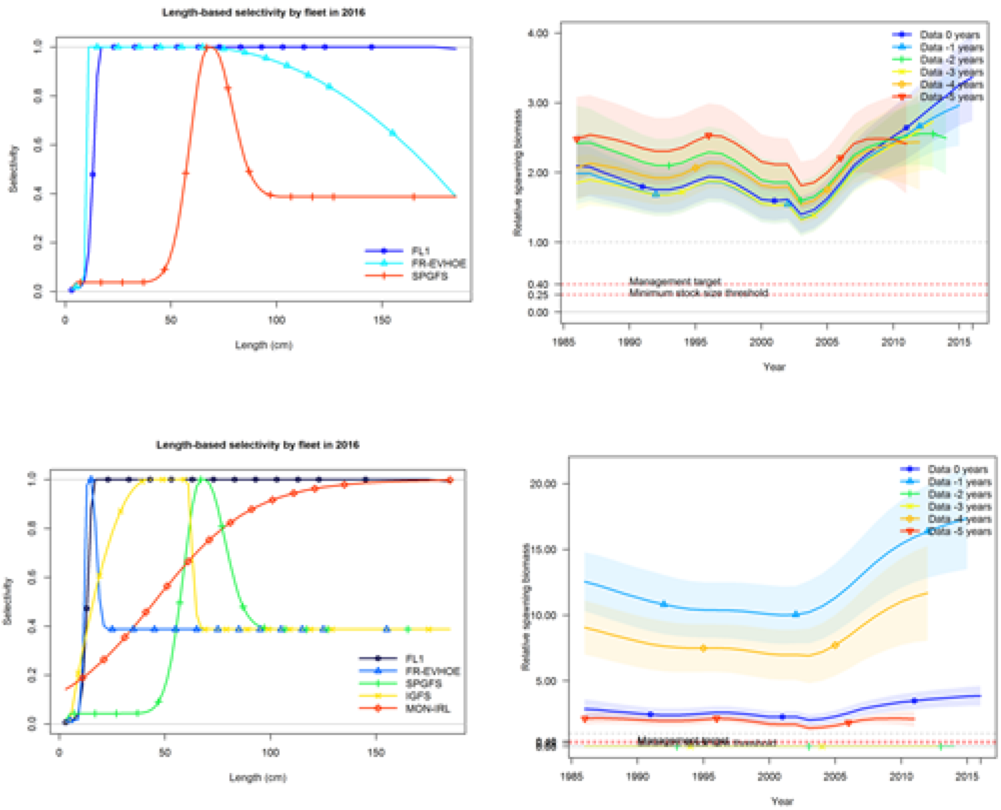


Figure 1. The estimated selectivity and retrospective analysis including two surveys (at the top) and four surveys (in the bottom).

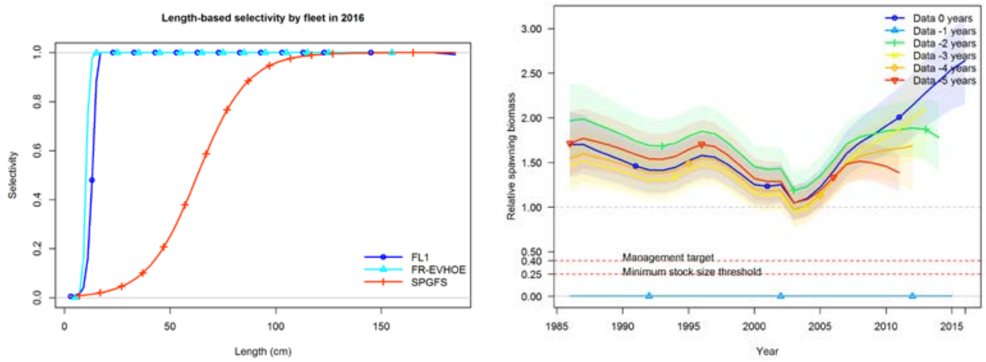


Figure 2. Assuming logistic selectivity pattern for both surveys the estimated selectivity (left) and retrospective pattern (right).

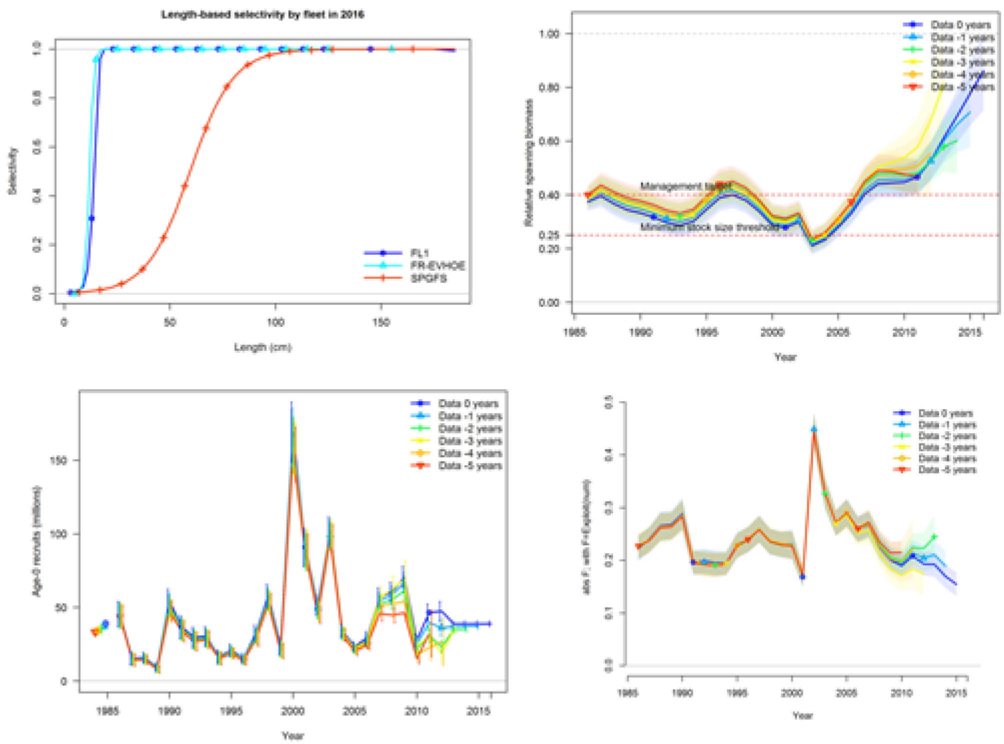


Figure 3. Estimated logistic selectivity pattern for both surveys and the retrospective analysis.

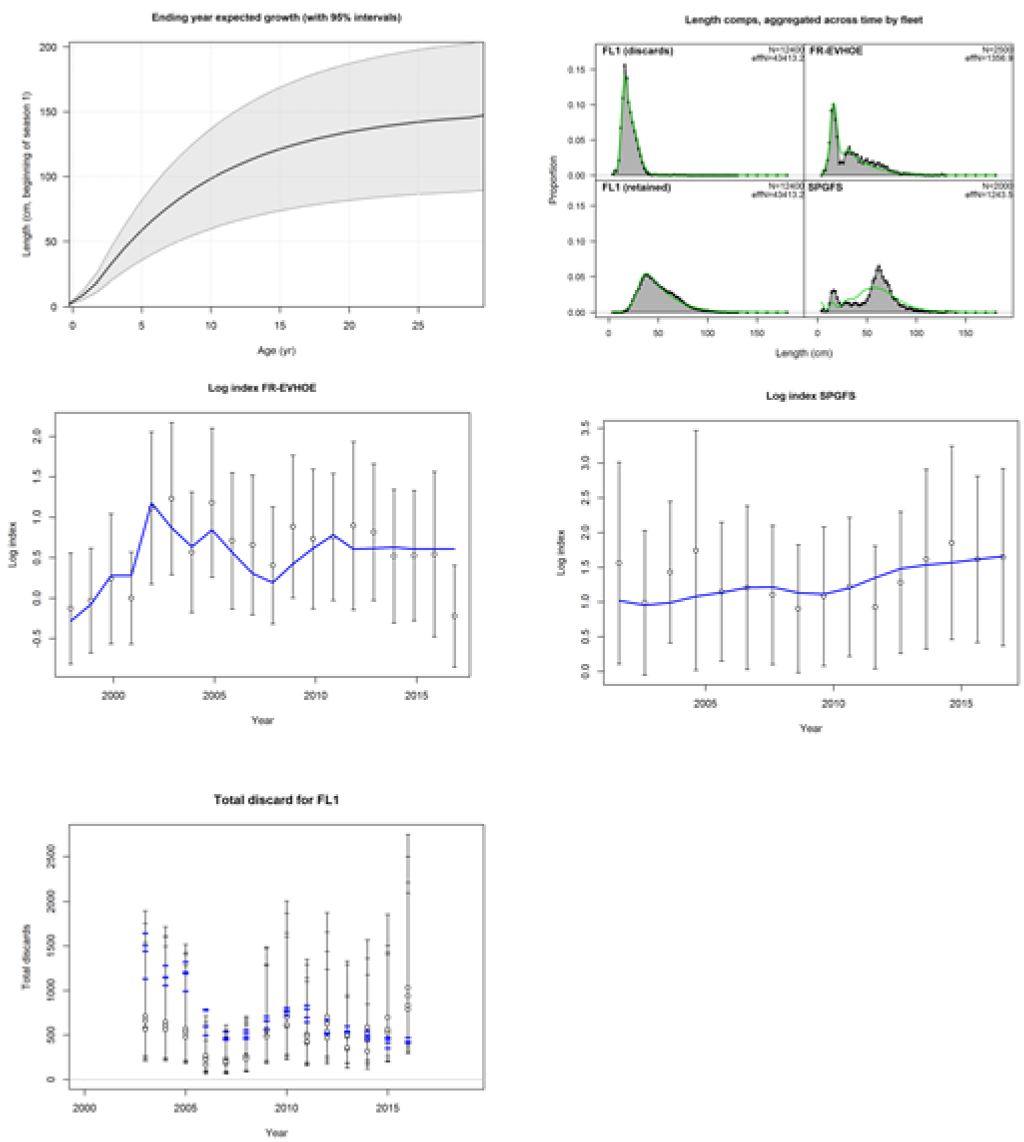


Figure 4. Results of the case study with two surveys, with logistic selectivity pattern and linear growth until 1.75. The estimated length–age relationship, the model fits to the quarterly length distributions aggregated for the combined fleets and survey indices, discards and survey index.

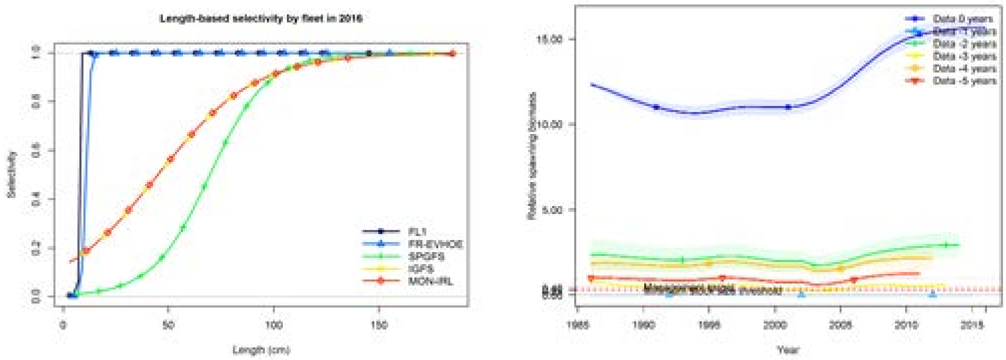


Figure 5. The results of the model including four surveys and linear growth until 1.75 age. The figures show the estimated selectivity pattern for the surveys and fleets and the retrospective analysis.

5.5 Anglerfish in subareas 4 and 6 and Divisions 3.a

In the previous anf.3a46 benchmark (WKROUND 2013) three options for the assessment of anglerfish were recommended. Firstly the existing procedure using the SCO-IV-VI-AMISS-Q2 survey to provide advice on catches by applying method 3.2.0 of ICES Implementation of RGLIFE advice on Data-Limited Stocks (DLS) (ICES, 2012). Secondly a simple harvest ratio approach used in e.g. *Nephrops*. Finally, the q1 model approach explored at both WKFLAT (2012) and WKROUND (2013) although the latter option may be used just to determine certain parameters for the former two simpler approaches, if it were deemed unacceptable for use. It was concluded that further work was required on all three options if any were to be presented as to the way forward for the anglerfish assessment.

During this benchmark (2018), both the ASPIC and SPiCT (Stochastic Surplus Production model in Continuous Time (Pedersen and Berg, 2016) models were explored. Whilst it was the intention to also consider the SS3 model, length data for years prior to 2009 were unavailable for Scottish catches in advance of the meeting. As Scotland takes the majority of catches of this stock the available data before 2009 were of limited use and it was not feasible to develop a length-based model with so few years of data.

5.5.1 Model development SPiCT

The SPiCT model has previously been explored at WGCSE 2017 for the purpose of attempting to set MSY reference points for category 3 & 4 stocks with update assessments in 2017 (see Holah, 2017 for full report) in accordance with the methods outlined in 'ICES technical guidance for providing reference points for stocks in categories 3–4'. The working document was also reviewed by John Hoenig's proxy reference review group who agreed that the uncertainties associated with the catches between 1998–2006, due to the introduction of a restrictive TAC, impacts the results of the SPiCT models. In addition the sensitivity of the models, visible in the retrospective patterns and diagnostics were a concern.

5.5.2 Configuration of SPiCT

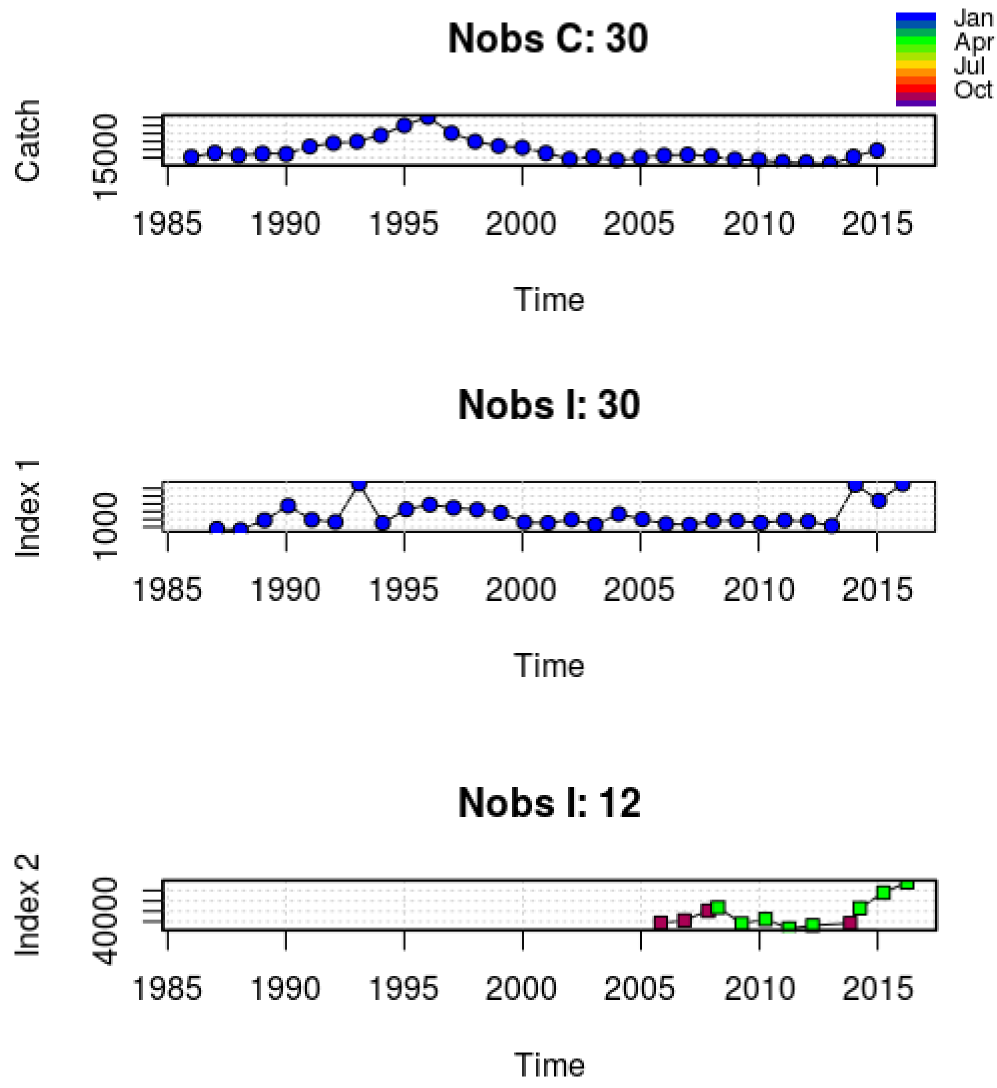
The models were run considering the following data:

- International official landings (1993–2016) (Unquantified uncertainty around suspected under reported landings during the years 1998–2005).
- Scottish Anglerfish Megrim Industry Science Survey (SCO-IV-VI-AMISS-Q2) estimated abundance (biomass) index (2005–2016).
- North Sea International Bottom Trawl Survey (IBTS-Q1) cpue index (1987–2016).

SPiCT settings

- Euler time-step (years): 1/16 (default) (fixed);
- Production curve shape: assume Schaefer (n=2) (a range tested);
- Alpha (Biomass observation and process errors ratio): estimated by the model (default priors) (a range tested);
- Beta Catch observation and process errors ratio): estimated by the model (default priors) (a range tested);
- Other parameters: default (estimated by the model).

Data



Summary of model runs attempted

run	data	settings
1	NS-IBTS-Q1 from 1987 Official landings from 1987 SCO-IV-VI-AMISS-Q2 from 2005	none
2		Alpha prior set to 0.65
3		Alpha prior set to 0.65 N prior set to 0.5
4		Alpha prior set to 0.65 N prior set to 1.5
5	Official landings from 1987 SCO-IV-VI-AMISS-Q2 from 2005	Alpha prior set to 0.65
6		Alpha prior set to 0.65 Q prior set to 0.8
7		Alpha prior set to 0.65 Q prior set to 0.4

5.5.3 Diagnostics and Retrospective analysis

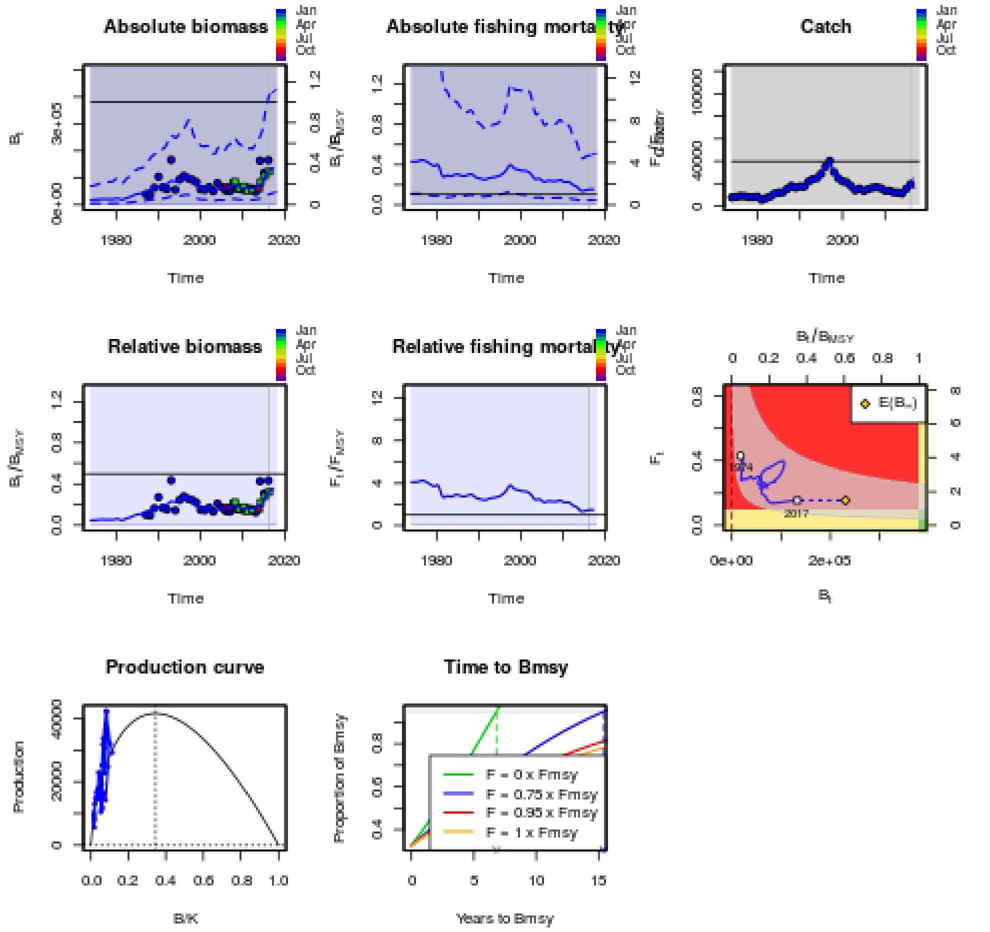


Figure 2. SPiCT model graphical outputs for run1.

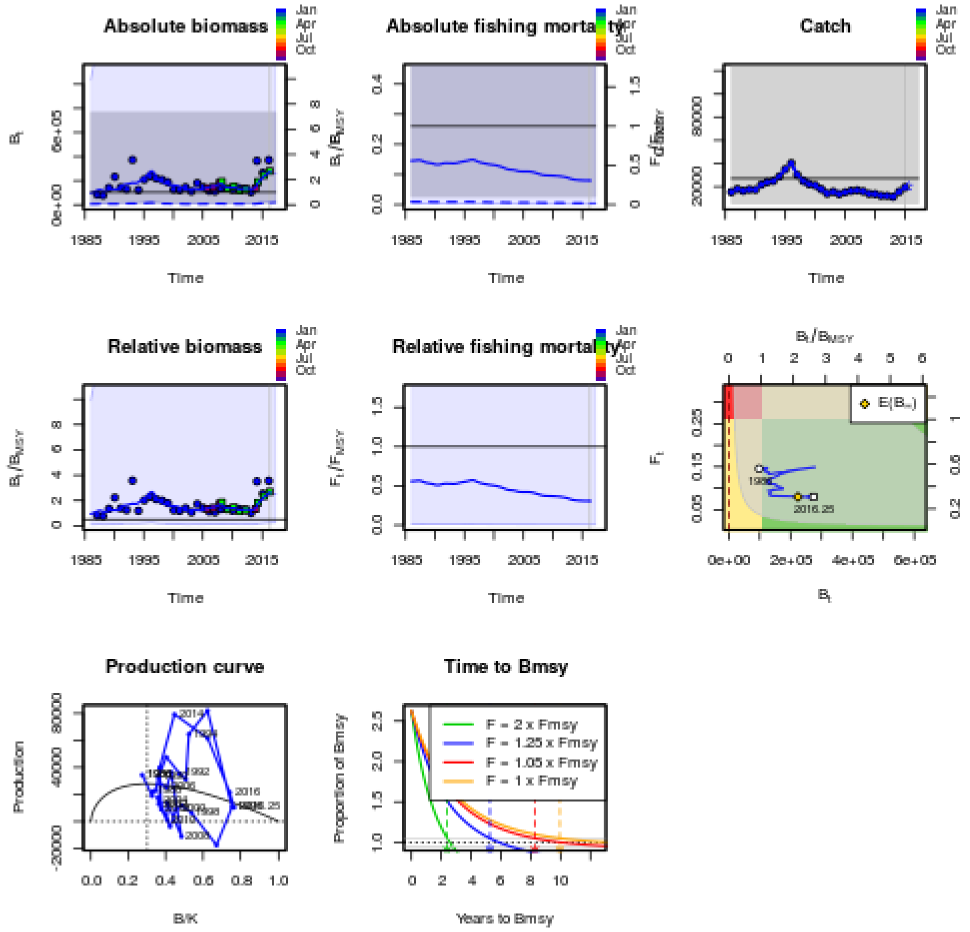


Figure 3. SPiCT model graphical outputs for run2.

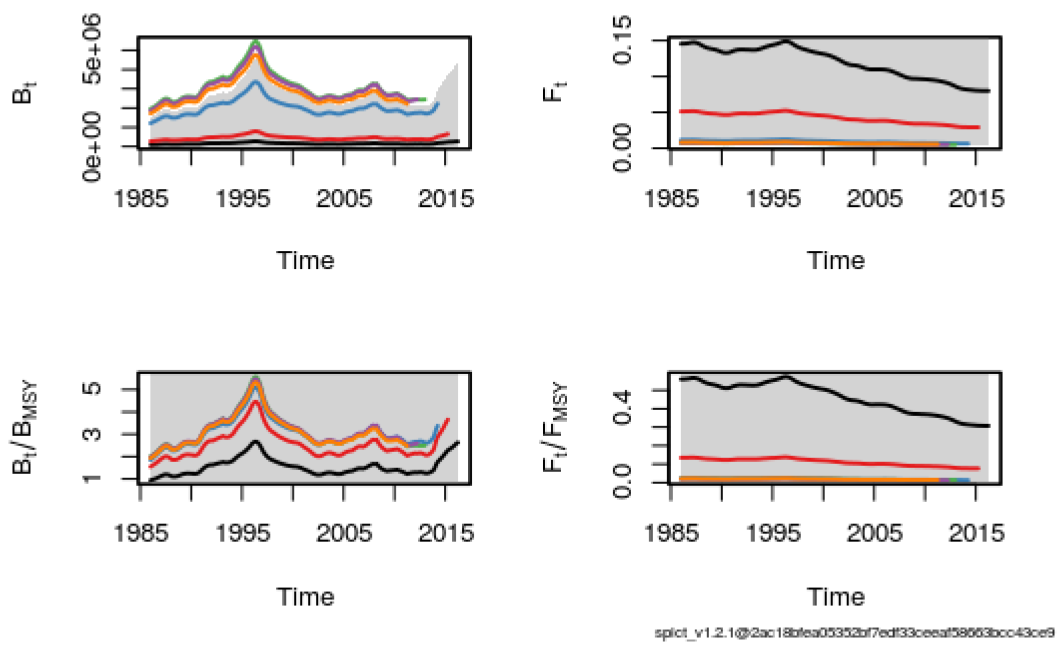


Figure 4. SPiCT model retrospective fits for run2.

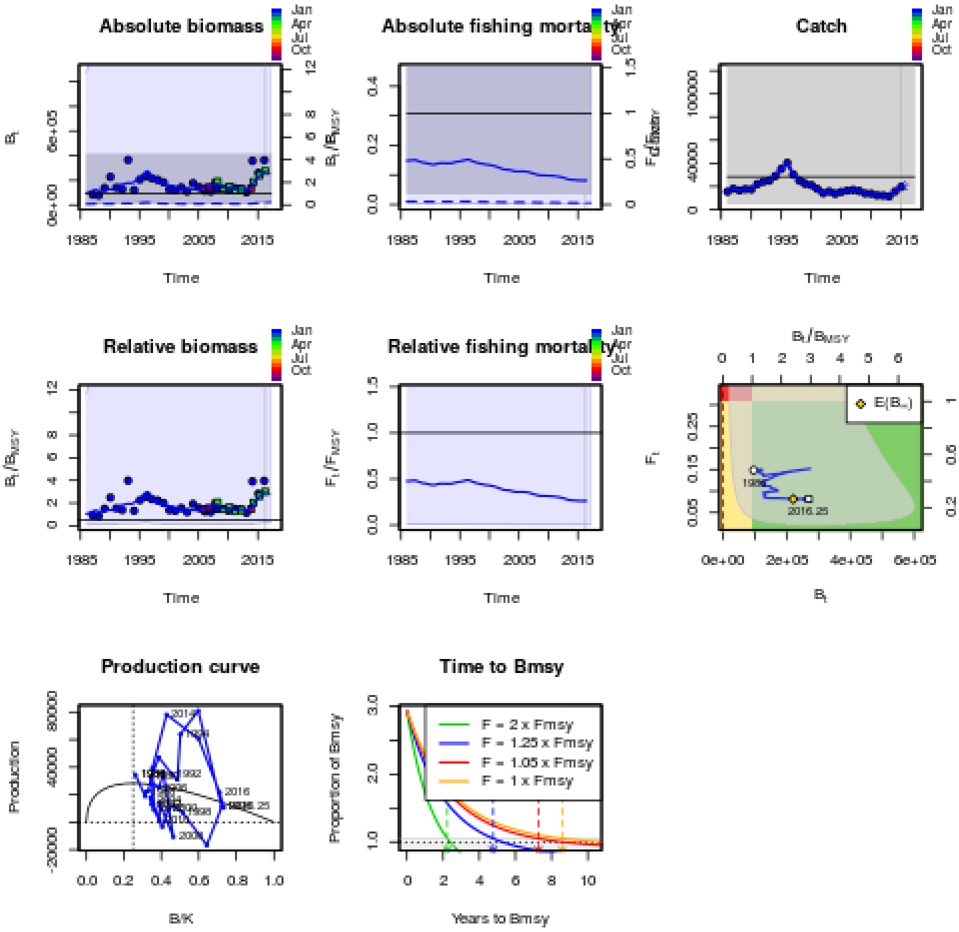


Figure 5. SPiCT model graphical outputs for run3.

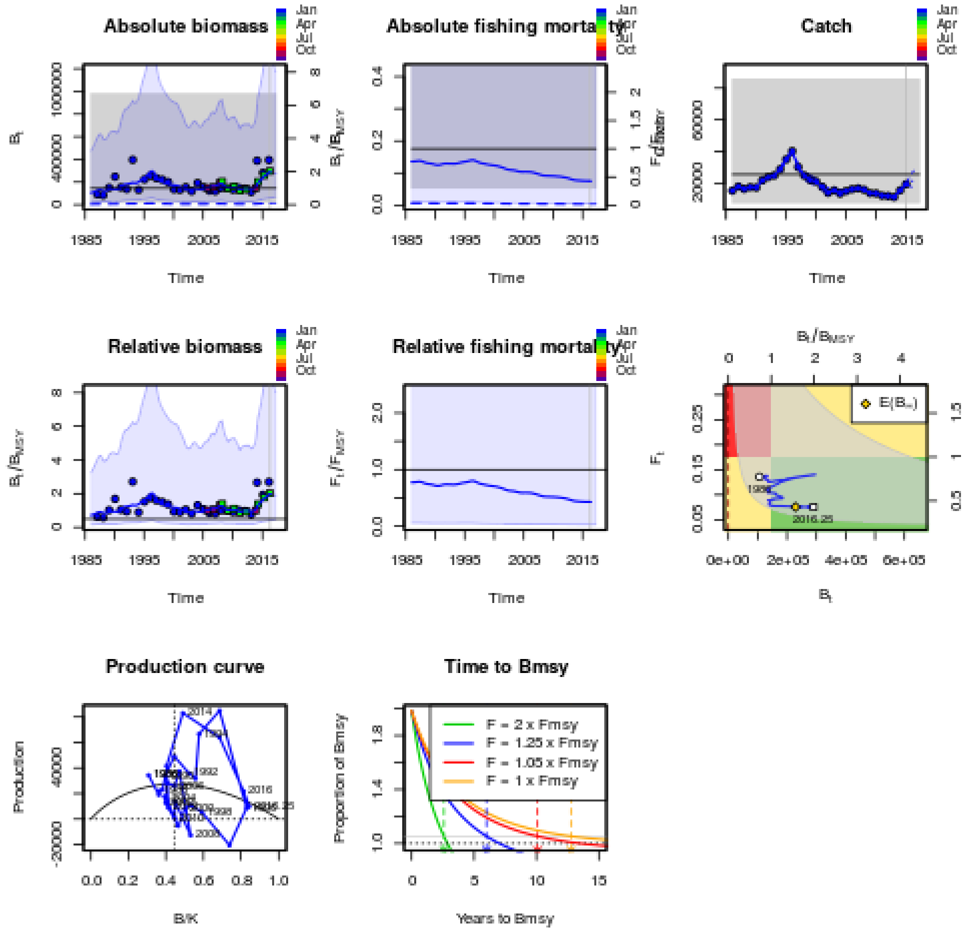


Figure 6. SPiCT model graphical outputs for run4.

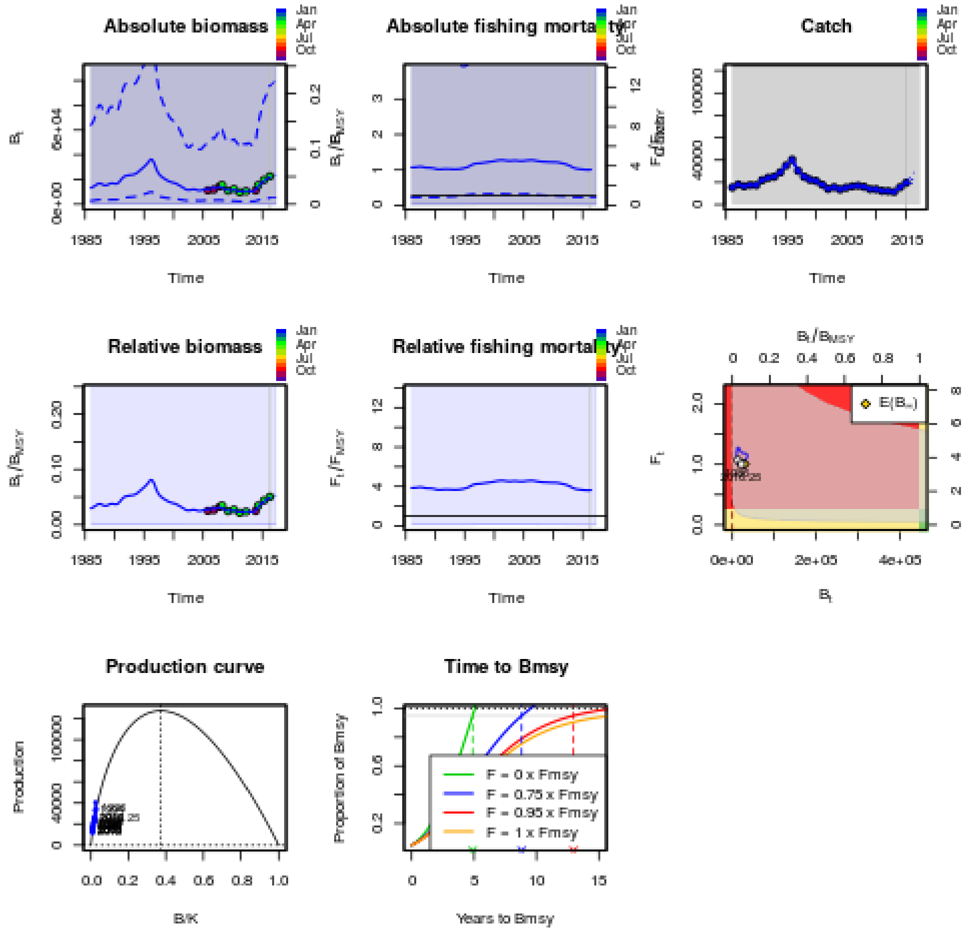


Figure 7. SPiCT model graphical outputs for run5.

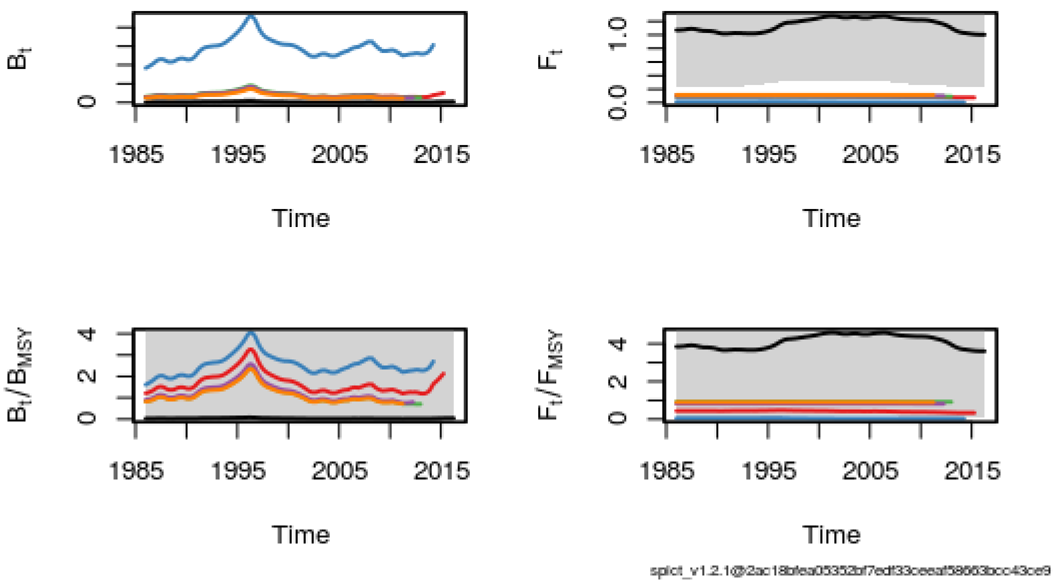


Figure 8. SPiCT model retrospective fits for run5.

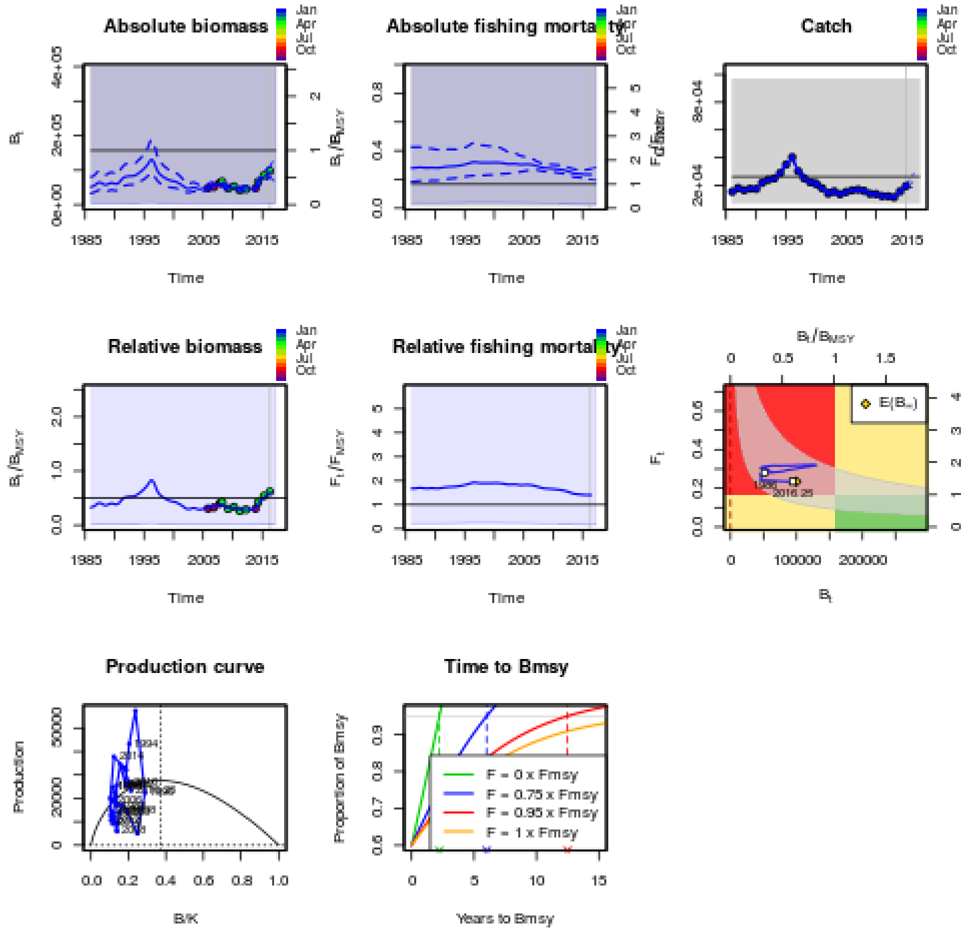


Figure 9. SPiCT model graphical outputs for run6.

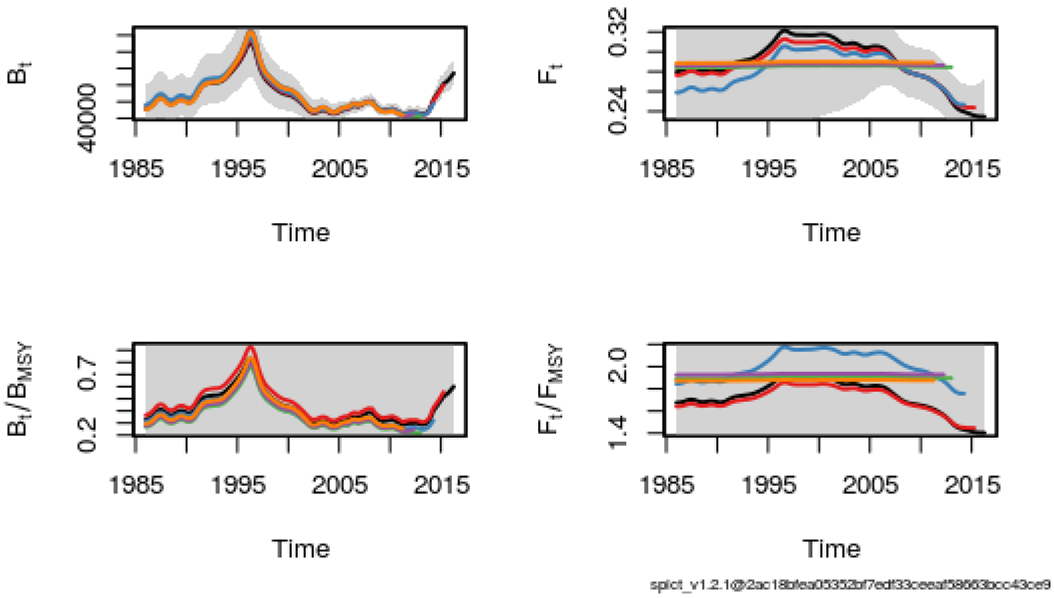


Figure 10. SPiCT model retrospective fits for run6.

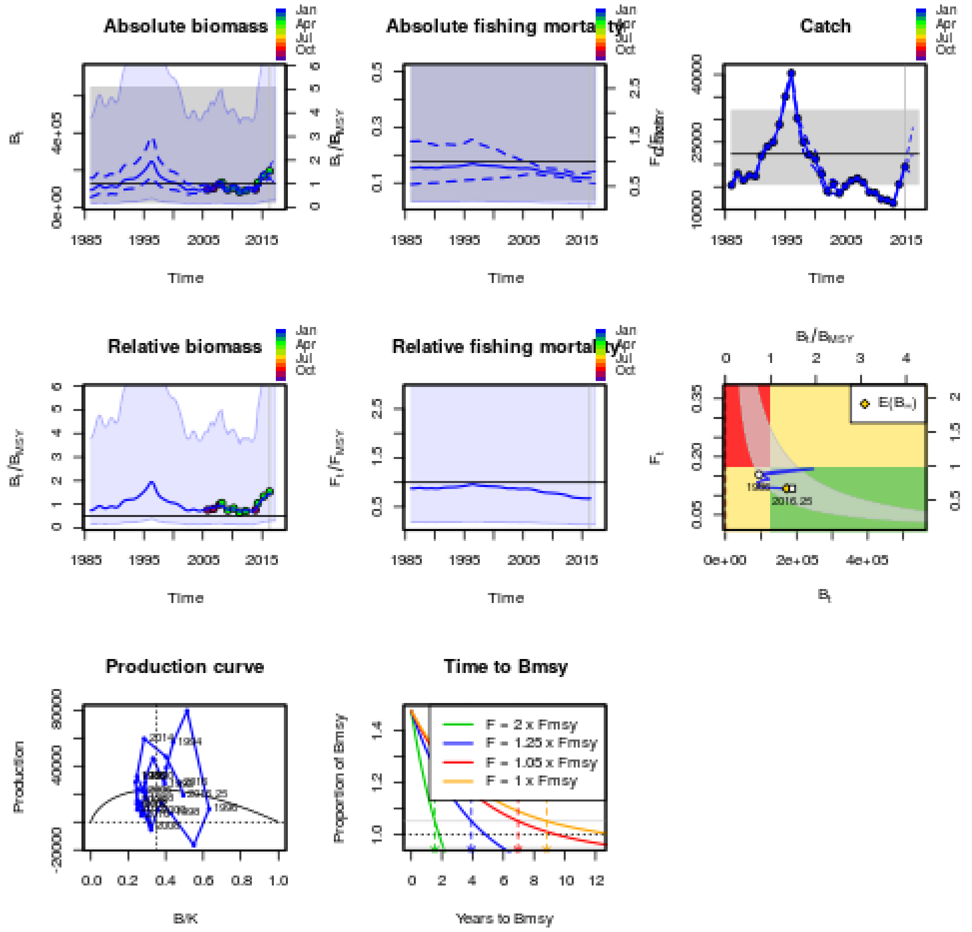


Figure 11. SPiCT model graphical outputs for run7.

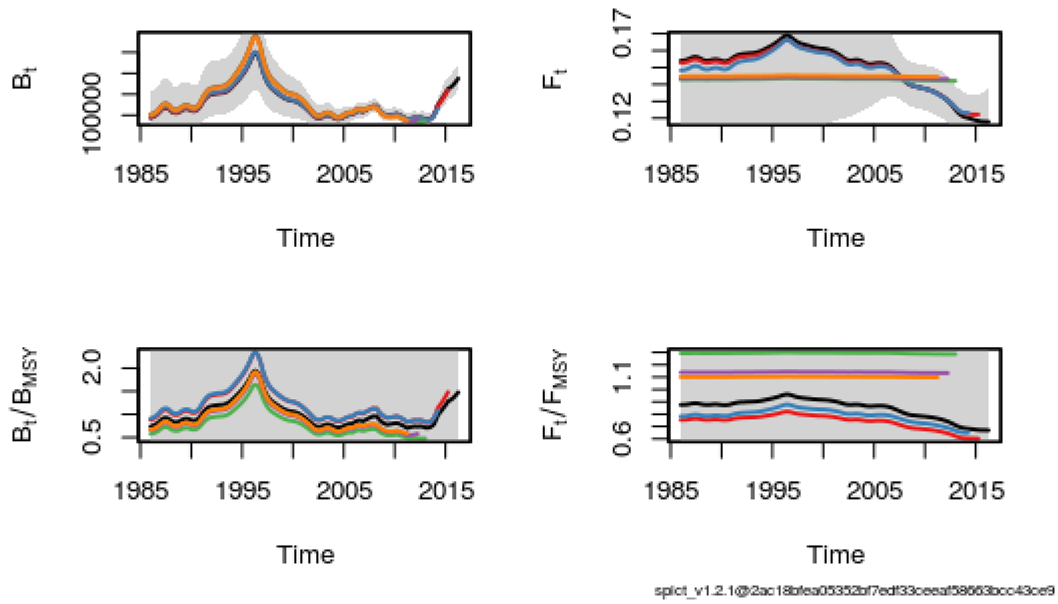


Figure 12. SPiCT model retrospective fits for run7.

5.5.4 Results

Seven SPiCT runs were explored to test the suitability of the SPiCT surplus production model for use as an assessment model for this stock (anf.27.3.a46). Initially the first model to be run used the full available time-series of data for the NS-IBTS-Q1 and SCO-IV-VI-AMISS-Q2 surveys and the catch data from 1987 to match with the start of the first abundance (cpue) index. It was run with no informative priors set. The uncertainties surrounding the estimation of the reference points were large and the perceived state of stock poor (Figure 2) with biomass well below B_{MSY} and F above F_{MSY} for the full time-series. This is not in line with the knowledge of the stock history; that biomass is at its highest in the SCO-IV-VI-AMISS-Q2 series and that fishing mortality reduced significantly in the early 2000s. For the second trial an informative prior on alpha (the ratio between observation and process error for the biomass indices) was set at 0.65 as was used in the WKLife 2016 report. This appears to transform the stock status into a healthy state (Figure 3) where B has always been above B_{MSY} and likewise F always below F_{MSY}. Experimenting with lower estimates of alpha continue to give lower estimated values of B_{MSY}, F_{MSY} and MSY. For the model to be so sensitive to the setting of the alpha prior indicates the instability of the model based on the available input data, this is reflected in both the production curve (Figure 3) and the retrospective model fits (Figure 4). Experimental model runs were also done using various values of a fixed beta prior (0.2 in the WKLife 2016 report) however the output estimates (not shown here) for parameters and reference points are almost identical with the model runs without a beta prior fix so the model was allowed to estimate the beta prior freely in subsequent runs. Model runs 3 and 4 were run using a fixed value of 'logn' which determines the shape of the production curve. Typically with no prior for n the model was estimating it to be ~0.88 when using default parameters and ~0.69 when using a fixed alpha of 0.65. Run 4 using a 'logn' value of 1.5 appears to reduce the uncertainties around the abundance indices series and gives a slightly more symmetrical shape to the production curve (Figure 6). This run produces slightly higher estimates of B_{MSY}, lower F_{MSY} and a similar MSY compared with run 2 which is the same as run 6 only with the default logn prior. It was decided not to fix logn five the small difference produced. Attempts to fix the 'logq' catchability parameter in subsequent runs led to a failure in the model fitting.

Model runs 5–7 used only the SCO-IV-VI-AMISS-Q2 survey biomass estimates as well as landings data from 1987 and the same fixed alpha 0.65. Run 5 produces unrealistic estimates of MSY ~126 381 as well as B_{MSY}. Runs 6 and 7 use fixed 'logq' parameters (0.8 and 0.4) respectively, this appears to improve the model stability with this input data although it led to model failure with the addition of the NS-IBTS-Q1 series. The higher value for logq gives a more pessimistic outlook on stock state and a biomass series below B_{MSY}.

5.5.5 Conclusions

Thorough explorations of the SPiCT surplus production model as well as ASPIC (not shown in this report) have led to the conclusion that a production model is not suitable for this stock given the available data. Whilst the model converged in most instances, the uncertainty was so large that no useful information could be obtained from the model. The lack of noise/variation in the catch data and no apparent response in the biomass indices after the significant reduction in catches in the early 2000s suggests that there is not a production relationship to be modelled. This can be seen in the large variability of predicted productions of the models run production curves. The model is unable to predict stock productions consistently.

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5.6 Anglerfish in subareas 1 and 2

6 Recommendation for future work to improve the assessments, data collection and processing

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Annex 1: Terms of reference for the WKAnglerfish

Overall Terms of Reference for WKAnglerfish

A Benchmark of Anglerfish (WKAnglerfish), chaired by Larry Alade, US and ICES Chair Lisa Readdy, UK, and attended by Crista Bank, US and Noel Cadigan, Canada will be established and meet for a five-day data evaluation meeting in Lisbon, 27 November–1 December 2017 and at ICES Headquarters for a Benchmark meeting, 12–16 February 2018 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) Fishery-dependent and fishery-independent data;

iv) Further inclusion of environmental drivers, multispecies information, and ecosystem impacts for stock dynamics in the assessments and outlook.

b) Agree and document the preferred method for evaluating stock status and (where applicable) short-term forecast and update the stock annex as appropriate. Knowledge of environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology.

If no analytical assessment method can be agreed, then an alternative method (the former method, or following the ICES data-limited stock approach) should be put forward;

c) Re-examine and update if appropriate MSY and PA reference points according to ICES guidelines (see Technical document on reference points);

d) Develop recommendations for future work to improve the assessment and data collection and processing;

e) As part of the evaluation:

i) Conduct a 3 day data evaluation workshop (DEWK). 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 DEWK, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting

The Benchmark Workshop will report by 2 March 2018 for the attention of ACOM.

Detailed Terms of reference for the data evaluation workshop

DEWKAnglerfish ToRs

The DEWKAnglerfish, chaired by Lisa Readdy, UK, will meet in Lisbon, 27 November–1 December 2018, to carry out the following tasks for anglerfish stocks to provide input data and parameters for the WKAnglerfish benchmark assessment meeting:

1) Review anglerfish stock structure and mixing rates if applicable between stock areas based on tagging, genetics and other studies if available.

2) Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length.

3) Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of relevance for the scientific assessment of the stocks and provision of advice.

4) Develop time-series of fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision.

5) Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision.

6) Develop recommendations for addressing fishery selectivity (pattern of catchability at length or age) in the assessment model.

7) Recommend values for discard mortality rates, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values.

8) Review all available and relevant fishery-dependent and -independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision.

9) Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts.

10) Review progress on existing recommendations for research to develop and improve the input data and parameters for assessments, and develop and prioritise new proposals.

11) For each stock, develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the data evaluation workshop.

12) Prepare the workshop report providing complete documentation of workshop actions, decisions, list of working documents, other information used by the workshop, and a list of any additional tasks to be completed following the workshop with dates and responsibilities for completion.

Annex 2: List of participants

Benchmark Workshop on Anglerfish Stocks in the ICES Area [WKAnglerfish] 12–16 February 2018.

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Annex 3: Working documents

WD01 Irish fleet landings per Unit of effort for *Lophius piscatorius* in ICES Area 7

Hans Gerritsen

The majority of the Irish otter trawl fleet targets *Nephrops*, another sizable part of the fleet targets gadoids and a relatively small part of the fleet targets anglerfish along the edge of the continental shelf. In order to avoid bias; two spatial strata were created: an area along the shelf edge where with high historic anglerfish lpue and the remaining area (mainly on the continental shelf) where the anglerfish lpue is lower (but where most of the fishing effort takes place).

Data were available by ICES rectangle from 1995 onwards. Landings were for both *Lophius* species combined, so the national species split (based on port and observer sampling) was used to estimate the landings by species.

As there is a minor trend showing an increase in vessel power, the lpue was calculated in kg per kWh.

WD02 Irish tagging studies for *Lophius piscatorius* in areas 7 and 8abd

Hans Gerritsen and Macdara Ó Cuaig

Between November 2006 and January 2008, 863 *Lophius piscatorius* and 416 *L. budegassa* were tagged in the waters off the north, west and southwest of Ireland. Only four tags were returned. It is more likely that the low return rate for anglerfish was due to either tag loss or tagging-induced mortality. For two fish a credible length at the time of re-capture was available. Both fish grew at a rate of 15 cm per year in the period between tagging and recapture.

WD03 Anglerfish stock structure

Helen Dobby and Helen Holah

An introduction to European anglerfish stock structure and existing management with reference to recent information on tagging and genetic developments from relevant literature looking in particular at the Northern Shelf anglerfish stock.

WD04 Anglerfish growth

Luke Batts and Hans Gerritsen

Method for fitting mixture models constrained by VBGF parameters to identify appropriate growth curves.

WD05 Irish landings correction between areas

Hans Gerritsen

Description of the methods used to estimate area misreporting between 7 and 6.

WD06 InterCatch quality checks for *Lophius budegassa* in ICES areas 7 and 8abd

Hans Gerritsen

Quality checks, data visualisations, estimation of missing data for data stored in InterCatch. InterCatch itself is designed for managing international catch data, but it lacks data visualisation tools and is extremely labour intensive if used for a time-series of data.

WD07 InterCatch extractions for *Lophius piscatorius* in ICES areas 7 and 8abd

Hans Gerritsen

Quality checks, data visualisations, estimation of missing data for data stored in InterCatch. InterCatch itself is designed for managing international catch data, but it lacks data visualisation tools and is extremely labour intensive if used for a time-series of data.

WD08 French and Irish national surveys in ICES areas 7 and 8abd

Hans Gerritsen

A combined survey index was produced for the Irish IGFS and French EVHOE surveys for the years 2003–2016. The combined survey area covers most of the juvenile stock. The spatial distribution of the first cohort (0-group) varies between years and is sometimes only in the Irish survey area, sometimes only in the French area and sometimes in both areas. The combined index is more consistent than the separate survey indices.

WD09 Irish national surveys in ICES areas 7 and 8abd

Hans Gerritsen

Irish anglerfish survey data in area 27.7 are available for the years 2007, 2008, 2016 and 17. These surveys were designed to estimate the biomass of anglerfish and they cover a significant part of the stock. The estimated indices suggest that the biomass of both *Lophius piscatorius* and *L. budegassa* is around twice as high in the period 2016/2017 compared to 2007/2008. This trend is also apparent in commercial lpue and, to some extent, in IBTS surveys.

The survey index of abundance may be informative for an assessment model that can deal with gaps in survey series.

WD10 Anglerfish lpue and stock structure

Hans Gerritsen

JRC landings and effort data by rectangle showed remarkably consistent otter trawl lpue trends between countries. In all areas (27.4, 6a, 6b, 7 and 8) there has been a strong increasing trend in lpue. Spatial patterns in lpue show a continuous distribution of the stock along the shelf edge however spatial patterns in the trends in lpue suggest that the northern stock(s) (>54°N) increased in abundance before the southern stock(s). This gives some support to the notion that these may be separate stocks.

WD11 Maturity

Hans Gerritsen

Literature review of maturity-at-length as well as unpublished data. L50 varies with latitude. A plausible range of L50 values is identified for both species and both sexes.

WD12 Natural mortality

Hans Gerritsen

Review of available methods for estimating M. A plausible range is proposed.

WD13 Population structure of *Lophius*

Hans Gerritsen

Review of available data from literature and unpublished sources, including genetics, morphometrics, microchemistry, tagging, lpue and survey data. Conclusions:

- Genetics – very little structure
- Otolith microchemistry – only shows limited exchange during early life, not evidence of isolated stocks
- Morphometrics – possibly strongest argument for stock structure but how to distinguish this from phenotypical adaptation to local environment?
- Lpue – possible argument for difference between 4 and 6 but not conclusive
- Survey catches of juveniles and medium sized fish –recruitment from area 7 spills over into area 6 (Lpis) or is this a catchability issue?

WD14 Standardized lpue for white and black anglerfish of Basque otter trawler fisheries in the ICES Subarea 6 during the period 2004-2016

Agurtzane Urtizberea, Ane Iriondo, Marina Santurtún, Estanis Mugerza

The Basque otter trawlers are mainly demersal fisheries, targeting hake, anglerfish and megrim and more than other 30 species until some years ago. These demersal fisheries operate in different sea areas, ICES subareas 6, 7, divisions 8a,b,d (Bay of Biscay) and 8c (eastern Cantabrian Sea).

Anglerfish fisheries in the ICES Subarea 6 are a traditional fishery for the Basque trawlers in the last decade. This métier is targeting mainly hake, megrim and anglerfish. Considering that anglerfish is a target species for this fleet, an analysis of its lpue will be presented to analyse if it could be used as tuning fleet in the anglerfish assessment in ICES Subarea 6.

WD15 InterCatch quality checks for *Lophius piscatorius* and *Lophius budegassa* in ICES Division 3a and subareas 4 and 6

Helen Holah and Hans Gerritsen

Quality checks, data visualisations, estimation of missing data for data stored in InterCatch. InterCatch itself is designed for managing international catch data, but it lacks data visualisation tools and is extremely labour intensive if used for a time-series of data.

WD16 Multinational North Sea IBTS-Q1 and Q3 survey indices for anf 27.3a46 in ICES Subarea 4

Helen Holah and Andrzej Jaworksi

Information on catches of *Lophius piscatorius* in ICES Subarea 27.4 from the North Sea International Bottom Trawl Surveys (NS-IBTS) have been recorded since 1987 for Q1 and 1992 for Q3 and are available within the DATRAS database. An ‘anglerfish area’ of ICES statistical rectangles was delineated using a threshold density of ≥0.1 mean fish per haul per hour over the whole time-series. An annual cpue index (per cm) was calculated, separately for each survey. Whilst the IBTS surveys are not specifically designed to target anglerfish it appears that there are strong correlations with the biomass trends observed in the SCO-IV-VI-IAMISS-Q2 and in the length–frequency data. The Q1 and Q3 survey cpue indices may be informative for future assessment models.

WD17 Scottish area misreporting corrections to anf 27.3a46 reported landings

Helen Holah

The absence of a TAC for the North Sea prior to 1999 resulted in apparent area-misreporting by the Scottish demersal fleet into 27.4 from 27.6 where quota was considered restrictive. Due to this the historic reported landings in 27.4 are inflated. This working document provides corrected estimates for landings in 27.4 and 27.6. These corrections have not been applied to the data submitted by Scotland to InterCatch thus far, but may be used in future analytical assessments of the stock.

Annex 4: Stock Annexes

The table below provides an overview of the stock annexes updated at WKAngler 2018. Stock annexes for other stocks are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species*, and *acronym* of the relevant ICES expert group.

Stock ID	Stock name	Last updated	Link
anf.27.1–2	Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in Subareas 1 and 2 (Northeast Arctic)	February 2018	*Lophius* 1 and 2
anf.27.3.a46	Anglerfish (*Lophius budegassa*, *Lophius piscatorius*) in Subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)	February 2018	*Lophius* 3a and 46
ank.27.78abd	Black-bellied anglerfish (*Lophius budegassa*) in divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay)	May 2018	*L. budegassa* 7bk, 8abd
mon.27.78abd	White anglerfish (*Lophius piscatorius*) in divisions 7.b–k, 8.a–b, and 8.d (southern Celtic Seas, Bay of Biscay)	May 2018	*L. piscatorius* 7bk,8abd
mon.27.8c9a	White anglerfish (*Lophius piscatorius*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	March 2018	*L. piscatorius* 8c9a
ank.27.8c9a (old anb.8c9a)	Black-bellied anglerfish (*Lophius budegassa*) in divisions 8c and 9a (West and Cantabrian Sea, Atlantic Iberian Waters)	November 2016	*L. budegassa* 8c9a