ICES WKFLAT REPORT 2012

ICES ADVISORY COMMITTEE

ICES CM 2012/ACOM:46

Report of the Benchmark Workshop on Flat-fish Species and Anglerfish (WKFLAT)

1–8 March 2012

Bilbao, Spain

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

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

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

Recommended format for purposes of citation:

ICES. 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.

Contents

Executive Summary

WKFLAT 2012 met from 1st to 8th March 2010 at AZTI Derio (Bilbao) Spain. The meeting was chaired by Joanne Morgan (Canada) and ICES co-ordinator was Rob Scott (UK). Rick Methot (USA) and Paul Nitschke (USA) participated in the meeting as invited external experts. A total of 25 participants from nine countries were in attendance. Stakeholder representatives were in attendance for part of the meeting.

The main goals and objectives of the meeting were to compile and evaluate data sources for stock assessment, investigate assessment models suitable to provide information on stocks status and to update the relevant stock annexes of seven stocks as necessary. These included a number of anglerfish stocks (Anglerfish *(Lophius piscatorius*) (Divisions VIIb–k and VIIIabd), Anglerfish (*Lophius budegassa*) (Divisions VIIb–k and VIIIabd), Anglerfish (Divisions IIa and IIIa, Subarea IV and Subarea VI), Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa), Anglerfish (*L. budegassa*) (Divisions VIIIc and IXa)), Sole in Division VIIe and Megrim in Divisions VIIb–k and VIIIabd. For each stock the preferred stock assessment method was determined and the stock annexes updated with the agreed procedures for generating and collating the input data to the stock assessment and the methods for estimating and forecasting stock status. In addition issues related to ageing and stock structure of anglerfish were discussed.

Part of the problem with producing acceptable assessment models for anglerfish was data quality and a lack of knowledge of some of the basic biological processes for these species. There is a lot of uncertainty about maturity, sex ratio, growth, and length frequencies of the catch and there needs to be an improvement in these data.

The main results of the meeting stock were:

Use of ageing in anglerfish assessments: The use of *illicia* based ageing was not warranted for either species. For *Lophius piscatorius* the studies of growth of Landa *et al.* (2012) should be used as the basis for length based assessments. For anglerfish in Divisions IIa and IIIa, Subarea IV and Subarea VI, ageing based on otoliths exists and age based assessments could be considered for this stock if the internal consistency of the age composition of the data were examined in more detail and sensitivity to growth assumptions considered. Further growth and (ageing) age validation studies taking sex into account are required.

Anglerfish stock structure: There is no clear biological evidence to support the management and assessment units as they are now. Tagging experiments and other stock structure studies are encouraged to determine if the migratory rate between areas is low enough not to impair the assessment models that consider the current stocks as isolated populations with little movement.

Anglerfish (*L. piscatorius and L. budegassa*) in Divisions VIIb–k and VIIIabd

Various formulations of SS3, ASPIC and a custom surplus production model were applied to the data for these species both separately and combined. Although the SS3 model shows some promise and should be pursued further, it was not ready at this time to be used as an assessment. ASPIC fits appeared to be unstable. There was no basis at this time to change from the current trends based assessment. For *L. piscatorius* a new standardization of the Basque fleet was presented, however there were some concerns about the model formulation and this requires further exploration before it can be used as an index of stock abundance.

Anglerfish (Divisions IIa and IIIa, Subarea IV and Subarea VI)

For this stock ageing based on otoliths exists. These age readings have been carried out by a single reader and have been very consistent over time. The benchmark concluded that an age based assessment could be considered for this stock if the internal consistency of the age composition data was examined in more detail and sensitivity to growth assumptions considered. Work should continue on the proposed survey based model and preliminary results should be presented to the WGCSE. A benchmark should be considered once the work as identified in Section 4.11 is ready for review.

Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa)

Analyses of the retention ogive of Spanish trawlers (landings vs. discards) were available for this stock and the Spanish 'A Coruña' trawler index was reviewed and updated. A maturity ogive was uncertain for this stock and the ogive for the species in VIIIabd, based on histology, was used. Various formulations of SS3 were applied to the data with the final accepted model having recruitment in quarter 3 and K for the von Bertalanffy growth curve fixed and Linfinity estimated. The unsexed nature of the model for a sexually dimorphic species and the fixing of the steepness of the stock–recruit model at 0.99 make the use of stock–recruit based reference points questionable. Therefore it was decided to propose YPR based reference points as proxies for F_{MSY}. A retrospective analysis showed that these reference points were relatively stable but there was no clear basis on which to choose between the candidate reference points. The WGHMM should examine this issue in May 2012 following further exploration of the results of the reference point analysis and evaluation of the implications for the stock of fishing at the various candidate reference point levels. There is no proposal for MSY $B_{trigger}$ at this time but it should be explored along with the evaluation of F based reference points, preferably by simulation.

Stock forecasts should use the average of the last three years fishing mortality-at-length with the possibility of rescaling to the final year. Recruitment should be based on a geometric mean with the range of years included in the mean chosen by the WG depending on trends in recruitment.

Anglerfish (*L. budegassa*) (Divisions VIIIc and IXa)

A revised series from the Spanish fleet 'A Coruña' was available at this meeting, historical survey-series, along with new discard data and revisions to lpue series. The 'A Coruña' series is the longest of the potential tuning-series and represents the bulk of the fishery and it was concluded that this series should be included in the modelling. Three potential models were applied to the data: a Bayesian surplus production model, SS3, and numerous formulations of ASPIC. The SS3 showed promise but it was determined that more exploration would be required before the model could be accepted as the basis for advice. A new formulation of ASPIC which included three tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to groundfish) was presented which tracks the central trend in the indices and is more stable than the previous ASPIC assessment. In addition the three models showed similar trends, adding support to the final ASPIC result which was accepted as the basis for advice. Further development of the application of SS3 to this stock is recommended.

Stock forecasts should use the average of the last three years fishing mortality with the possibility of projecting with fishing mortality estimated in the final year depending on trends.

Reference points are F_{MSY} based from the ASPIC and 50% B_{MSY} is considered to be a proxy for MSY $B_{trigger}$.

Megrim (Divisions VIIbce–k and VIIIabd)

Tuning-series were revised and new indices provided (cpue Vigo reviewed, France number-at-age cpue provided, Ireland lpue provided,). Discard data for some countries (UK, Ireland and Spain) were available for recent years and included in the models. Several formulations of a Bayesian statistical catch-at-age model were applied to the data. The model accounted for missing discards-at-age. The model appeared to fit the data well but the benchmark had concerns about the underlying data. The model showed sharp changes in selection pattern to match unexpected changes in the proportion of younger and older ages over time in the catch data. It was decided that this model should be accepted as a trends based assessment illustrative of trends in the population and fishing mortality. It should be presented for evaluation of stock status along with indices of abundance in total and by age or length group. The determination of possible reference points was not considered appropriate at this time.

Sole in Division VIIe

Various formulations of an XSA model were explored. The most important changes were to include two new survey-series and to split the commercial beam trawl tuning index series (UK-CBT) in 2002–2003 (the longest index series). Shrinkage on fishing mortality was also explored. With low shrinkage a retrospective pattern was evident. Higher (0.5) shrinkage s.e. makes the retrospective pattern much smaller. The benchmark decided to use the XSA formulation with this higher shrinkage, but to allow the option of using shrinkage s.e. of 1.5 in future. This should be re-examined in 2013 when the survey indices are longer and make a retrospective comparison more appropriate. In 2013, a five year retrospective should be run and the model with the best retrospective pattern chosen. Stock forecasts should use the same basis of assumptions as the assessment in 2011.

F_{MAX} is proposed as an appropriate proxy for F_{MSY} for this stock. The fishing mortality on the population has been above this value for most years apparently without causing serious harm to the stock. Stochastic simulations were conducted at this level to determine MSY $B_{trigger}$. The preferred set up of the simulations indicated that MSY $B_{trigger}$ (defined as the lower 95% CI on the SSB) is close to 2800 t, intermediate between other simulations assumptions. Based on a meta-analysis presented at WKFRAME2 reasonable B_{PA} and B_{lim} for this stock are 1800 t and 1300 t respectively.

1 Introduction

The Benchmark Workshop on Flatfish and Anglerfish 2012 was convened in accordance with the advisory structure established by ACOM in 2007. Draft terms of reference were outlined in the document 2011/2/ACOM47 (Annex 1). The main goal of the meeting was to evaluate the appropriateness of stock assessment data and methods for the stocks of anglerfish in the ICES area, megrim in Division VIIb–k and VIIIabd and sole in Division VIIe. Five anglerfish stocks were considered: i) *Lophius. piscatorius* in Divisions IIa and IIIa, Subarea IV and Subarea VI; ii) *L. piscatorius* in Divisions VIIb–k and VIIIabd; iii) *L. budegassa* in Divisions VIIb–k and VIIIabd; iv) *L. piscatorius* in Divisions VIIIc and IXa; and v) *L. budegassa* in Divisions VIIIc and IXa.

The key aspects of the terms of reference were:

- To compile and evaluate data sources for stock assessment.
- Investigate assessment models suitable to provide information on the stocks status.
- To update the relevant stock annexes to provide a comprehensive description of the agreed procedure for generating assessment input data and for conducting the assessment according to the agreed method.

The initial work of the benchmark workshop was devoted to exploratory analyses of the available data with subsequent work focusing on addressing a number of assessment issues. Because all anglerfish stocks of the ICES area were being benchmarked and, to allow a consistent decision on stock definition and age estimation across all anglerfish stocks, some time was devoted on the examination of scientific studies of anglerfish stock identity and age estimation.

The workshop was chaired by Joanne Morgan (Canada), with ICES co-ordinator, Robert Scott (UK). Richard Methot (USA) and Paul Nitschke (USA) attended as invited experts. Other participants included members of the ICES stock assessment working groups (WGHMME and WGCSE), industry representatives and members of the ICES secretariat. A full list of participants is provided in Annex 2.

The results of the workshop for each stock are given in Sections 4–10. Recommendations to other ICES Exerts groups are available on Annex 3. Several working documents with auxiliary information were presented/available at the meeting (Annex 4). Working documents containing data and/or methods used at this meeting are available on Annex 4. A summary of the main data issues are presented on Annex 5.

Annex 6 contain the "stock annex" of each stock, where data and methodology to assessment the stock statues in the incoming years is described.

2 Stock identity and migration for *Lophius* spp.

2.1 Introduction

Both black (*Lophius budegassa*) and white anglerfish (*L. piscatorius*) are bottom-living species that occur from shallow, inshore waters to 800 m and deeper than 1000 m, respectively (Whitehead *et al*., 1986; Quero and Vayne, 1997). The black anglerfish is distributed far to the south (Mediterranean and eastern North Atlantic from the British Isles, 60°N, to Senegal, 12°N) while the white anglerfish has a more northern distribution (Mediterranean, Black Sea and Eastern North Atlantic from Barents Sea, 75°N, to Mauritania, 20°N), although the occurrence of both species overlaps considerably (Whitehead *et al*., 1986; Quero and Vayne, 1997).

In the Northeast Atlantic, the International Council for the Exploration of the Sea (ICES) considers three stocks of *L. piscatorius* and *L. budegassa*, with boundaries that were established for assessment and management purposes rather than on biological population data.

The Northern Shelf stock extends over ICES Divisions IIa and IIIa and Subareas IV and VI. Two stocks are defined in the Southern Shelf area, the Northern stock in Divisions VIIb–k and VIIIa, b, and d and the Southern stock in Divisions VIIIc and IXa (ICES, 2010). Three management units are currently distinguished within the Northern Shelf stock (ICES, 2009), and there are indications of metapopulations in the Southern Shelf area (Duarte *et al*., 2004; Blanco *et al*., 2008).

A review of the literature was made about the biological basis for the three current stocks of *L. piscatorius* and *L. budegassa*.

2.2 Literature review

Traditionally there have been some useful techniques to elucidate the stock structure of fish populations; from all of them some has been used for European Anglers.

GESSAN (**G**enetic characterization and **S**tock **S**tructure of the two Species of **AN**glerfish (*Lophius piscatorius* and *L. budegassa*) of the Northeast Atlantic. EU Study Contract 99/013) was a project funded by the VI European Research Framework with the aim of studying the stock structure of both European Anglers by mean of morphometric, meristic, genetic and tagging-recapture studies. The conclusion of the project was that no biological evidence was found for supporting the segregation of the population neither in the current stocks used by ICES nor in the management units used by the European Commission. The study analysed data from morphometrics, meristics, genetics and tag-recapture experiments not being able to found differences between the current stocks by any of the mentioned methods.

Phylogeographical studies published by Charrier *et al.* (2006) did not allowed to discriminate the stocks currently considered for management purposes of both European Lophiids.

In case of tag-recapture experiments Laurenson *et al*. (2005) reported for *L. piscatorius* that adults and juveniles are able to cover significant distances until ~900 km in ~three years, and this mobility would strengthen the dispersion potential of anglerfish. Landa *et al.* (2008) calculated a mean displacement of 381 m per day for white anglerfish, with a maximum value of 6 km per day, concluding that his results pointed out the need for revising the assessment and management of anglerfish in the Bay of Biscay and the Celtic Sea.

The study based on otoliths shape analysis conducted by Cañas *et al.* (2012) concluded that no biological reason for the current separation between stocks was found and recommended that a holistic revision may give a conclusive basis for the reconsideration of the current management units in the area.

2.3 Conclusion

There is no clear evidence of the current stock or population definition of European anglerfish since there is a lack of information concerning their biology, specially their movements and possible migratory patterns.

Currently anglerfish in Division VIIa are not included in any stock assessment. There are commercial landings from that area and there is also a survey on that area, but these data were not available for WKFLAT 2012. The fish in this area should be included in an assessment unit but there is no evidence at present to determine in which stock they should be included. It may be possible to determine this by a comparison of distribution in surveys, fishery distribution and length frequencies.

It was noted that a similar situation exists for megrim in Divisions VIIa and VIIId.

This information is fundamental to reduce uncertainties regarding stock boundary, for an enhanced fisheries assessment and management and for the adoption of alternative management measures, such as closed areas. In order to have a better understanding of the population, mark-recapture experiments are advisable to determine if the migratory rate is low enough not to impair the assessment models that examine the current stocks as closed and isolated populations. The problem should be referred to SIMWG for advice on methods to examine stock structure in these species.

2.4 Bibliography

Blanco, G., Borrell, Y. J., Cagigas, M. E., Vázquez, E., and Sánchez Prado, J. A. 2008. Microsatellites-based genetic analysis of the Lophiidae fish in Europe. Marine and Freshwater Research, 59: 865–875.

Cañás, L., Stransky, C., Schlickeisen, J., Sampedro, M. P., and Fariña, A. C. 2012. Use of the otolith shape analysis in stock identification of anglerfish (*Lophius piscatorius*) in the Northeast Atlantic. ICES Journal of Marine Science, 69: 250–256.

Charrier G., Chenel T., Durand J.D., Girard M., Quiniou L. and Laroche J. 2006. Discrepancies in phylogeographical patterns of two European anglerfishes (*Lophius budegassa* and *Lophius piscatorius*). Molecular phylogenetics and evolution 38, 742–754.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A. C., and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the southwest of Ireland to the southwestern Mediterranean. ICES Document CM 2004/EE: 22. 19 pp.

ICES. 2009. Report of the Workshop on Anglerfish and Megrim. ICES Document CM 2009/ACOM: 28. 110 pp.

ICES. 2010. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim. ICES Document CM 2010/ACOM: 11. 599 pp.

Landa J., Quincoces I., Duarte R., Fariña a. C. and Dupouy H. 2008. Movements of black and white anglerfish (*Lophius budegassa* and *L. piscatorius*) in the Northeast Atlantic. Fisheries Research 94, 1–12.

Laurenson C., Johnson A. and Priede I. 2005. Movements and growth of monkfish tagged at the Shetland Islands, Northeastern Atlantic. Fisheries Research 71, 185–195.

Quero, J.C., Vayne, J.J. 1997. Les poissons de mer des Pêches Françaises. Delachaux et Niestlé SA, Lausanne-París, 304 pp.

Whitehead, P.J., Bauchot, M.L., Hureau, J.C., Nielsen, J., Tortonesse, E. 1986. Fishes of the Northeastern Atlantic and the Mediterranean. UNESCO, París, 1362 pp.

3 Anglerfish ageing

3.1 Results of the Anglerfish (*Lophius piscatorius*) illicia and otoliths exchange 2011

The age estimation for stock assessment of white anglerfish (*Lophius piscatorius*) in the ICES area has been traditionally based on two different calcified structures, the *illicium* (used in most of the European countries) and the *sagitta* otolith (used in two countries). The otoliths from *Lophius* have confusing secondary structures (Woodroffe *et al*., 2003), and an increase in the opacity of the otoliths with age, makes them more difficult for age estimating. The growth pattern is easier to distinguish in the *illicia*, which exhibit fewer secondary structures (Dupouy *et al*., 1986).

Growth studies alternative to the age estimates on calcified structures (CS) of white anglerfish, such as tagging-recapture (Laurenson *et al*., 2005; Landa *et al.,* 2008), daily growth (Wright *et al*., 2002) and length–frequency distributions of catches (Dupouy *et al*., 1986; Thangstad *et al*., 2002; Jónsson, 2007), showed that the growth pattern estimated using the traditional standardized age estimation criterion based on *illicia* (Duarte *et al*., 2002) was underestimated and that criterion was not accurate, although it was standardized and used in several age estimation anglerfish workshops. The last anglerfish *illicia* exchange and workshop using that criterion took place in 2004 (Duarte *et al*., 2005). The ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) (ICES, 2011) recommended an exchange of *illicia* and otoliths for 2011, when a new age estimation criterion on *illicia* was expected. Modifications in the methodology of *illicia* preparation and in the traditional standardized age estimation criterion have allowed a new age estimation criterion on *illicia* to be obtained. Using this new criterion, the catches-at-age have been tracked more successfully (Landa *et al*., 2012). Therefore this criterion seems to be more accurate and it was presented in the protocol of the present exchange.

A white anglerfish exchange of 200 images (100 *illicia* and 100 otoliths) from the same specimen took place during the third quarter of 2011. Each reader was asked to mark the annual rings on the images, using an image analysis software program (GIMP). The exchange was carried out through the European Age Readers Forum (EARF). Fourteen readers (including two Mediterranean readers) from ten institutes from eight European countries participated.

Three **age estimation analyses** were performed within each CS: (i) *illicia* age readings, (ii) otoliths age readings, and (iii) a comparison between *illicia* and otoliths age readings. The analyses within each CS (i and ii) were performed for all readers and also for the readers contributing to the stock assessment. For both analyses, the between reader agreement was higher in *illicia* compared to otoliths. The *illicia* readings were less relatively biased than otolith readings, although had slightly lower precision. However the overall values of the mean CV were strongly influenced by the high CV values at first ages, especially at age 0. More specimens were aged 0 years using *illicia* than otoliths, and therefore the slightly lower precision in *illicia* was influenced by that.

i) ***Illicia*.** Analysing <u>all *illicia* readers</u>, the overall percentage **agreement** was **45.0%**, the CV was 26.7%, and the relative bias was 0.39. The first annulus was located by most of readers between 300 and 350 µm. When analysing the <u>*illicia* readers that contribute to the stock assessment</u>, the agreement, precision and especially the relative accuracy increased: the overall percentage **agreement** was **49.3%**, the CV was 22.4%, and the relative bias was 0.11.

ii) **Otoliths.** Similar to the last anglerfish *illicia*/otoliths ageing workshop in 2004, two different analyses had to be performed when the readings were analysed, using R8 and R9 as reference readers, due to the low agreement between both experienced otolith readers. Analysing all otoliths readers, the overall percentage **agreements** were **19.5%** and **19.5%** when R8 and R9 were, respectively, the reference readers; the CV were 23.7% and 24.0%; and the relative biases were -0.96 and 0.47, respectively. There were discrepancies among the readers in the location of the first annulus. Analysing only the otolith readers contributing to the stock assessment, the overall percentage **agreements** were **18.3%** and **25.4%** when R8 and R9 were, respectively, the reference readers; the CV were 13.3% and 16.6%; and the relative biases were -1.23 and 0.52, respectively.

iii) ***Illicia* and otoliths age readings comparison.** Results indicate strong discrepancies between *illicia* and otoliths readings, there are similar to the conclusions in the last anglerfish exchange and workshop in 2004 (Duarte *et al*., 2005). Comparing the expert otoliths readers vs. the expert *illicia* readers, the overall percentage **agreement** were **4.7%** and **16.5%,** when R8 and R9 were compared, respectively, to the modal *illicia* readings; and the relative bias were 2.67 and 0.92, respectively. The 86% and 71% specimens were aged older using otoliths than using *illicia* when the readings of the experienced *illicia* readers and experienced otoliths readers R8 and R9 were compared.

Considering the above there are **implications** regarding the stock assessment of this species, given that the stock is undergoing a benchmark assessment at ICES WKFLAT in 2012, the following should be considered:

i) ***Illicia* vs. otoliths.** Considering the low levels of agreement between both CS (5–16%) it is not possible to use the age estimations of both *illicia* and otoliths together for stock assessment purposes.

ii) ***Illicia*.** Although the relative bias values (0.11) among the assessment readers can be considered good, the agreement values (49%) and precision (CV: 22%, APE: 16) suggest that they are not still sufficiently acceptable for building since now a valid ALK for stock assessment, using the readings of several readers. If the new age estimation criterion is validated in other geographical areas by cohorts tracking, and the agreement among readers is increased, then the age estimation using *illicia* could be used for stock assessment in future.

iii) **Otoliths.** The age estimation of white anglerfish, based on otoliths, is difficult, mainly due to the occurrence of confusing false annuli and to the increasing of opacity with age. The location of the first annulus is also a problem, even among expert readers, both in the last and present exchanges. There have been advances in daily growth studies that can help locate the first annulus more precisely. It is not possible to use otoliths of white anglerfish for stock assessment without a validated growth pattern and further research in that issue is needed.

3.2 Benchmark conclusion on the use of anglerfish ageing in assessments

The benchmark considered these conclusions of the otolith exchange in determining whether age based assessments should be attempted. The group agreed that the use of illicia based ageing was not warranted and that for *Lophius piscatorius* the growth curve of Landa *et al*. (2012) should be the basis for length based assessments. For anglerfish in Divisions IIa and IIIa, Subarea IV and Subarea VI, ageing based on otoliths exists. These age readings have been carried out by a single reader and have been very consistent over time. The benchmark agreed that an age based assessment could be considered for this stock if the internal consistency of the data were examined in more detail and sensitivity to growth assumptions considered (see Section 4.2). The benchmark agreed with the conclusion of the otolith exchange that further growth and (ageing) age validation studies are required and that such studies should take sex into account.

3.3 References

Duarte, R., Landa, J., Quincoces, I., Dupouy, H., Bilbao, E., Dimeet, J., Marçal, A., McCormick, H. and Ni Chonchuir, G. 2002. Anglerfish Ageing Guide. In "Report of the 4th International Ageing Workshop on European Anglerfish". IPIMAR, Lisbon (Portugal). 40 pp.

Duarte, R., Landa, J., Morgado, C., Marçal, A., Warne, S., Barcala, E., Bilbao, E., Dimeet, J., Djurhuus, H., Jónsson, E., McCormick, H., Ofstad, L., Quincoces, I., Rasmussen, H., Thaarup, A., Vidarsson, T. and Walmsley, S. 2005. Report of the Anglerfish Illicia/Otoliths Ageing Workshop. IPIMAR, Lisbon (Portugal). 47pp.

Dupouy, H., Pajot, R., and Kergoat, B. 1986. Etude de la croissance des baudroies, *Lophius piscatorius* et *L. budegassa*, de L'Atlantique Nord-Est obtenue a` partir de l'illicium. Revue des Travaux de l'Institut des Pêches Maritimes, 48: 107–131.

Jónsson, E. 2007. Verification of anglerfish (*Lophius piscatorius*) age estimation through comparison of length modes of age read fish (illicia) to length modes of large year classes appearing in the Icelandic stock. ICES CM 2007/K:03.

Landa, J., Barrado, J. and Velasco, F. 2012. Age and growth of anglerfish (*Lophius piscatorius*) on the Porcupine Bank (west of Ireland) based on illicia age estimation. Working document to the Benchmark Workshop on Flatfish (WKFLAT). Bilbao, Spain, 1–8 March 2012.

Landa, J., Duarte, R., and Quincoces, I. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. ICES Journal of Marine Science, 65: 72–80.

Laurenson, C.H., Johnson, A., and Priede, I.G. 2005. Movements and growth of monkfish *Lophius piscatorius* tagged at the Shetland Islands, northeastern Atlantic. Fisheries Research, 71: 185–195.

Thangstad, T., Dyb, J.E., Jonsson, E., Chevonne, L., Ofstad, L.H. and Reeves, S.A. 2002. Anglerfish (*Lophius* spp.) in Nordic European Waters. Status of current knowledge an ongoing research. Insitute of Marine Research, Bergen, Norway.

Woodroffe, D.A., Wright, P.J., and Gordon, J.D.M. 2003. Verification of annual increment formation in the white anglerfish, *Lophius piscatorius* using the illicia and sagitta otoliths. Fisheries Research, 60: 345–356.

Wright, P.J., Woodroffe, D.A., Gibb, F.M., and Gordon, J.D.M. 2002. Verification of the first annulus formation in the illicia and otoliths of white anglerfish, *Lophius piscatorius* using otolith microstructure. ICES Journal of Marine Science, 59: 587–593.

4 Anglerfish (Divisions IIa and IIIa, Subarea IV and Subarea VI)

4.1 Current assessment and issues with data and assessment

The anglerfish stock on the Northern Shelf is considered to occur in Divisions IIa, IIIa (Skagerrak and Kattegat), Subarea IV (the North Sea) and Subarea VI (West of Scotland plus Rockall). Management of Northern Shelf anglerfish is based on separate TACs for the North Sea area (Subarea IV) and West of Scotland area (Subarea VI): no TAC is given for Division IIa, but the fishery is regulated with a variety of technical measures; catches in Division IIIa are not regulated. There are two species of anglerfish which are taken in these areas: the anglerfish (*Lophius piscatorius*) and the black anglerfish (*Lophius budegassa*). Although the distributions of *L. piscatorius* and *L. budegassa* overlap, catches of *L. budegassa* are negligible in Area IV (<1%), and generally low in Area VI (<10%).

UK (Scottish) vessels account for most of the reported anglerfish landings from the Northern Shelf area and the stock is one of the most commercially important demersal fishery resources to that country. In 2010, for example, landings into Scotland alone were worth £27 million (~€32 million) placing it as the fourth most valuable fishery resource in the country after mackerel, *Nephrops* and haddock (Anon, 2011). The Danish and Norwegian fleets are the next most important exploiters of this stock in the North Sea, while Irish and French vessels take a significant proportion of the landings from the West of Scotland; a Norwegian coastal gillnet fishery operates in Division IIa.

There has been no assessment of the anglerfish stock on the northern shelf since 2003. Previous analytical assessments of the Northern shelf anglerfish stock were made using a length-based model taking account of the difference in growth patterns between males and females (ICES 2004). Indices of recruitment were provided by the Scottish March West Coast survey. The model used a catch-at-length analysis (modified CASA - Sullivan *et al.*, 1990; Dobby, 2002). Input data covered the periods from 1993 to 2002. This analytical assessment also provided the technical basis for optional catch predictions. However, these assessments were discontinued due to the lack of reliable fishery catch-at-length data, and insufficient survey information. There was also some doubt concerning the geographical coverage of the input data. The previous assessment approach was length-based due to ongoing problems associated with ageing anglerfish (see Section 3).

ICES have highlighted the generally poor data for this stock and the need to continue with the recently instigated data collection schemes (both survey and commercial data) in order to obtain time-series of sufficient length. Since 2005, a new annual survey has been conducted by the Scottish, and in some years, Irish institutes, which is dedicated and specifically designed for anglerfish. These surveys, known as the Scottish Anglerfish and Megrim Industry Science Surveys (SCO-IV-VI-AMISS-Q2), include several considerations to account for various components of survey catchability in an attempt to deliver absolute estimates of abundance and biomass. Estimates of minimum absolute abundance and biomass from the SCO-IV-VI-AMISS-Q2 surveys have been presented each year since 2005, to the ICES WGCSE. The group also provides updates to catch and effort data where available.

In 2009, the ICES workshop on anglerfish and megrim (ICES 2009) reviewed these surveys and also considered self-sampling programmes, catch and effort data, and issues associated with ageing. The workshop concluded that the surveys could deliver minimum estimates of abundance and biomass at age, largely because there was evidence of [whole gear] selectivity-at-ages less than four, and that fact that large areas in Subarea IV and all of Division IIIa are not surveyed. In addition to some additional improvements to the survey, WKAGME also recommended that a sounder stock assessment should be developed to: (a) estimate fishing mortality-at-age and (b) establish a baseline population to parameterise the biological operating model for management simulations so that biological reference points can be determined. The concerns over the ageing of anglerfish, particularly the doubts over the comparability of readings using the otoliths and illicia, also led to a recommendation to conduct an ageing exchange. The latter exercise took place in 2011 (see Section 3) and concluded that anglerfish ages could not determined accurately enough for the purposes of producing an international catch-at-age dataset for stock assessment purposes.

4.2 Compilation of available data

4.2.1 Catch and landings data

Table 1 indicates the most important nations fishing this stock. Data for WKFLAT was requested from UK (Scotland, EW&NI), France, Denmark, Norway, Ireland, Germany, Spain, Belgium, Sweden and the Netherlands. Data were requested for as many years as possible, of the following type, in order of priority:

1) total landings by year;
2) landings disaggregated by length;
3) landings disaggregated by age if possible (with an indication of how they were aged).

Data were received from all of these nations with the exception of Norway.

Table 1. Landings of northern shelf anglerfish by nation from 2008–2010 (as reported to ICES for Divisions IIIa, Subareas IV and VI) with an indication of which data were supplied to WKFLAT 2012, numbered as per the priorities identified in Section 4.2.1 (above).

	Landings (t)					Supplied		
	2008	2009	2010	Average (2008–2010)	Rank of landings based on average (2008–2010)	1	2	3
UK (total)	11 120	10 089	8528	9912	1	✓	✓	
France	2086	2249	1196	1844	2	✓	✓	
Denmark	1595	1726	1607	1643	3	✓		
Norway	1026	1024	916	989	4			
Ireland	370.6	419	617	469	5	✓	✓	✓
Germany	421	445	0	289	6	✓		
Spain	259	246	0	253	7	✓		
Belgium	184.6	140	131	152	8	✓	✓	
Sweden	127	0	52	60	9	✓		
Netherlands	74	41	61	59	10	✓	✓	
Russia	35	0	0	12	11			
Faroe Is.	2	10	12	8	12			
Total	17 300	16 389	13 120					

As a result of discussions at WKFLAT it was concluded that every effort should be made to obtain an international catch-at-length dataset. Despite reservations about the quality of these data, these will provide information which could be used in the development of the survey based model discussed below, particularly to assist in the determination of the fishing selectivity pattern.

4.2.2 Biological data

The SCO-IV-VI-AMISS-Q2 surveys make biological measurements for every fish that is caught: these include length, weight, sex, maturity (visual inspection of maturity stage), gutted weight, and stomach contents. Since 2005 this amounts to a sample of over 10 700 fish. Results of the biological analysis of these data are in preparation for a publication.

The key issue regarding the biological data from the SCO-IV-VI-AMISS-Q2 surveys is the estimation of age, which is carried out by reading otoliths, particularly given the findings of the recent exchange (Section 3). The WG considered this at some length. The abundance-at-age matrix from the surveys has some evidence of cohort tracking (Figure 1), but this is not easy to follow due to the selectivity issues in the younger ages (ages four and younger). Tracking cohorts with data of ages five and older (Figure 2) indicates that the fish may be read consistently (at worst) and perhaps accurately (at best). This is possible because these ages have all been read by a single, very experienced reader. The data on length-at-age and mean length-at-age from SCO-IV-VI-AMISS-Q2 indicate linear growth (Figure 3). This is in accordance with some published results (e.g. Figure 6 in Landa *et al.*, 2008), and several published growth models fit reasonably well to the intermediate ages (see Figure 3).

The WG concluded on the basis of these results that the estimates of abundance and biomass at age from the SCO-IV-VI-AMISS-Q2 data could be used in a survey-based and age-based assessment model, provided that some sensitivity analysis could be performed, such as converting the survey fish lengths to age using published growth parameters and comparing results.

4.2.3 Survey tuning data

In 2005, Fisheries Research Services (FRS, now Marine Scotland Science, MSS) initiated a new project to estimate the abundance and distribution of anglerfish on the Northern Shelf. The project was unique in two aspects: the aim was to produce an absolute abundance estimate (i.e. a total number and biomass of anglerfish), as opposed to an index of relative abundance which is normally produced from surveys; and, crucially, the project aimed to involve the fishing industry throughout, from planning through to the execution of the surveys.

Seven surveys have been carried out to date, in November 2005, 2006, 2007 and April 2008, 2009, 2010 and 2011: these covered much of the area of the known distribution of Northern Shelf anglerfish (ICES Divisions IVa, VIa and VIb at Rockall), with the exception of the central and southern parts of Area IV and the Skagerrak and Kattegat (Division IIIa). As the area is so large, these are multi-vessel surveys, incorporating the research vessel FRV Scotia, and up to three commercial fishing vessels. In 2006, 2007 and 2009, the survey was extended south into Irish waters with the participation of the Irish Marine Institute (MI) in association with Bord Iascaigh Mhara (BIM). In 2008 and 2010, however, the Irish were not able to participate. In 2011 the Scottish survey was extended into Irish waters to include the whole of ICES Division VIa.

The survey, now known as the Scottish Anglerfish and Megrim Industry Science Surveys (SCO-IV-VI-AMISS-Q2) is described in Fernandes *et al.* (2007) and ICES (2009). ICES WKAGME made a number of recommendations to improve the survey estimates. These include improvements to the model of net retention, the separation into the two species, and the consideration of other survey data (e.g. IBTS). Some of these have since been carried out and will be published in due course. The latest results of the survey are reported annually to ICES WGCSE.

4.2.4 Commercial tuning data

Reliable effort data (in terms of hours fished) are not available from the Scottish trawl fleets due to changes in the practices of effort recording and non-mandatory recording of hours fished in recent years. Further details can be found in Section B4 of the Stock Annex and the Report of the 2000 WGNSSK (ICES, 2001). Trends in Catch per unit of effort are provided for the Irish otter trawl fleet and two Danish fleets: these are reported annually to WGCSE.

4.2.5 Industry/stakeholder data inputs

The Scottish Anglerfish and Megrim Industry Science Surveys (SCO-IV-VI-AMISS-Q2) are conducted in liaison with the Scottish fishing industry. An industry–science group meet regularly to discuss survey gear, survey design, survey protocols and results. In 2006, Marine Scotland Science (in consultation with the fishing industry) established a monkfish tallybook project. This has since been discontinued but a fuller description and analysis of these data can be found in the WGNSDS 2008 Report and Dobby *et al.* (2008).

Discussions with industry representatives at WKFLAT concluded with a number of recommendations for data which could be supplied by the fishing industry. There is some uncertainty concerning the status of large old anglerfish. The numbers of (large) mature females sampled either by the national sample programmes or by the survey(s) are small. It would, therefore, be useful for the fishing industry to make biological measurements of any large anglerfish that are caught prior to any market processing. Such measurements include length, weight, sex, maturity stage and, if possible, the collection of the otolith and illicium for any individual greater than 100 cm. Some form of guidance will be required, perhaps in the form of an information leaflet, video or training course. Information leaflets could also highlight the need to be vigilant in identifying (and returning) anglerfish that have been tagged. As with any stock, the accurate recording of catch and logbook entry is always advantageous: apart from the obvious direct use in stock assessment, these data also help to understand the nature of the fishery and can assist in examining the distribution of the fished component of the stock.

4.2.6 Environmental data

The SCO-IV-VI-AMISS-Q2 survey includes a component which samples anglerfish visually by means of a video camera mounted in a deep-towed body: the system is described in McIntyre *et al.*, 2012 (in prep). The system is deployed in areas which are closed to trawling which have been identified as areas to protect the deep-water coral of the *Lophelia* genus. The system can, therefore, provide information on the location and extent of coral in these areas. This information is the subject of a PhD studentship at the University of Aberdeen and methods are in development to process the video data for both counts of anglerfish, but also counts of other fauna, including the deep-water coral.

4.3 Stock identity, distribution and migration issues

Anglerfish are widely distributed over the Northern Shelf, and occur in a wide range of depths, from quite shallow inshore waters down to at least 1000 m. Small anglerfish occur over most of the northern North Sea and Division VIa, but large fish, the potential spawners, are rarely caught. Little is known about when and where anglerfishes spawn in northern European waters. This lack of knowledge is due to the unusual spawning habits of anglerfish. The eggs and larvae are pelagic, but whereas most marine fish produce individual free-floating eggs, anglerfish eggs are spawned in a large, buoyant, gelatinous ribbon which may contain more than a million eggs. Due to this strange behaviour, anglerfish eggs and larvae are rarely caught in conventional surveys.

An EU-funded research project entitled 'Distribution and biology of anglerfish and megrim in the waters to the West of Scotland' (Anon, 2001) did however, improve our understanding. A particle tracking model was use to predict the origins of young fish and indicated that post-larval anglerfish may be transported over considerable distances before settling to the seabed (Hislop *et al.*, 2001). Anglerfish in deeper waters to the west of Scotland and at Rockall could, therefore, be supplying recruits to the western shelf and the North Sea. Furthermore, results of micro-satellite DNA analysis carried out as part of this project showed no structuring of the anglerfish stock into multiple genetic populations within or among samples from Divisions IVa, Division VIa and Rockall. In fact, this project also suggested that anglerfish from further south (Subarea VII) could also be part of the same stock.

On the other hand, following the development of fisheries for anglerfish in ICES Divisions IIa and Vb1 (Faroese waters), ICES (2004) considered the stock structure on a wider North Atlantic scale, and it was concluded that there was insufficient information at that time to conclusively define new stock areas for assessment and further coordinated work is still required. Therefore, since no conclusive evidence was found to indicate an extension of the stock area northwards to include Division IIa, Anglerfish in IIa is currently treated as a separate stock. This also holds for anglerfish in Faroese and Icelandic waters. Thus, at present the anglerfish in IIa, Va and Vb1 (the Norwegian Sea, Iceland and Faroese waters) are considered separate stocks/units separated from the "Northern Shelf stock". Given the request to ICES to assess anglerfish in Division IIa and that there may be an extension to include ICES Division V (including Icelandic waters) in the near future, the likely spatial disaggregation of the Northern Shelf stock(s)/units (drift of larvae and possible migration of mature fish back into deeper water) means that any assessment model would need to be spatially structured, possibly supported by assessments for each of the stock units separately.

For management purposes, anglerfish on the Northern Shelf are currently, split into three management units: 1) Subarea VI (including Vb (EC), XII and XIV), 2) the North Sea (including IIIa and the EU waters of IIa), and 3) IIa, Norwegian waters.

There is however, no management of anglerfish fisheries in Division IIIa. It is not clear, therefore, how any catch-based forecast would apply to this area. Furthermore, data from this area is restricted to catch at length information and it is unclear if this will be used to assess the status of the stock in this area. ICES should consider what needs to be done in relation to anglerfish in this subarea given the lack of management and data.

From the above it appears that questions still remain as to the overall stock structure of anglerfish on the northern shelf, and the current stock delineation(s) are based partly on implications of larval drift, partly on lack of other conclusive scientific stock identification data, and in a rather large part on the basis of the current units for TAC based management (see Section 3.3 below). This is, however, no different from stocks of other demersal species which occur in the same area (e.g. cod and haddock, which are separated at a stock level by the 4° line of longitude to the north of Scotland).

4.4 Influence of the fishery on the stock dynamic

The fishery for anglerfish in Subarea VI occurs largely in Division VIa with the UK and France being the most important exploiters, followed by Ireland. Landings from Rockall (Division VIb) are generally been less than 1000 t with the UK taking on average around 50% of the total.

The Scottish fishery for anglerfish in Division VIa comprises two main fleets targeting mixed roundfish. The Scottish TR1 Fleet (trawlers with mesh sizes greater than 100 mm) takes around 70% of landings and the Scottish TR2 Fleet (trawlers with mesh sizes greater than 70 mm but less than 100 mm) over 15%. Just over 10% of landings are taken from gillnet fisheries. The development of a directed fishery for anglerfish has led to considerable changes in the way the Scottish fleet operates. Part of this is a change in the distribution of fishing effort; the development of a directed fishery having led to effort shifting away from traditional roundfish fisheries in inshore areas to more offshore areas and deeper waters. The expansion in area and depth range fished has been accompanied by the development of specific trawls and vessels to exploit the stock. There was an almost linear increase in landings from Division VIa since the start of the directed fishery until 1996 which has since been followed by a very severe decline, indicating the previous increase was almost certainly due to the expansion and increase in efficiency of the fishery.

There is no minimum landing size for anglerfish and discarding is known to occur at very low levels in the targeted fishery for anglerfish, but also in other fisheries, for example for scallops. However, discard data are not routinely collated.

The Irish fleet which takes around 15–20% of the total Division VIa landings is a light trawl fleet targeting anglerfish, hake, megrim and other gadoids on the Stanton Bank and on the slope northwest of Ireland. This fleet uses a mesh size of 80 mm or greater. Since 1996 there has been an increase in the number of vessels using twin rigs in this fleet. There have also been changes to the fleet composition since 2000, with around ten vessels decommissioned and four new vessels joining the fleet. The activity of this fleet is not thought to have been significantly affected by the recent hake and cod recovery plans.

The Irish fleet otter trawl in Division VIb take anglerfish as a bycatch in the haddock fishery on the Rockall Bank. The fleet targeting haddock uses 100 mm mesh and twin rig trawls. Occasionally Spanish vessels target anglerfish, witch and megrim with 80 mm mesh on the slope in VIb. Discarding practices of these vessels are not known. Discarding of anglerfish from the fleet targeting haddock in Division VIb is not thought to be significant (Anon, 2001). The fleet composition changed in 2001. Four vessels have recently been decommissioned and two new vessels have joined the fleet that target haddock.

French demersal trawlers also take a considerable proportion of the total landings from this area. The vessels catching anglerfish may be targeting saithe and other demersal species, or fishing in deep water for roundnose grenadier, blue ling or orange roughy.

Since the mid-1990s, a deep-water gillnet fishery targeting anglerfish has operated on the continental slopes to the West of the British Isles, North of Shetland, at Rockall and the Hatton Bank. These vessels, though mostly based in Spain are registered in the UK, Germany and other countries outside the EU such as Panama. Gear loss and discarding of damaged catch are thought to be substantial in this fishery. Until now these fisheries have not been well documented or understood and they seem to be largely unregulated, with little or no information on catch composition, discards and a high degree of suspected misreporting. In 2005 around 16 vessels participated in the fishery, 12 UK registered and four German registered.

UK landings of anglerfish from the North Sea show a similar trend to those in Division VIa: a rapid increase in the late 1980s followed by a decline since 1996. Around 90% of the landings are taken in the northern North Sea and the fishery is dominated by the Scottish fleet which takes around 80% of the total landings in this area. As in Division VIa, the fishery in this region has moved into deeper more offshore areas.

The majority of Danish anglerfish landings are taken in the northeastern North Sea (IVa). Demersal trawl fisheries account for more than 90% of total Danish landings, the vessels being in the size range 20–40 m. Most of the Danish trawl fishery in the North Sea takes place in the Norwegian Deep, and the mesh size in the trawls is 120 mm. In the Skagerrak (IIIa) the two main Danish fisheries taking anglerfish are the (mixed) *Nephrops* fishery and the demersal trawl fishery. In both areas minor landings are taken in gillnets and Danish seines and as bycatch in fisheries for shrimp (*Pandalus*). The Danish fishery has in recent years accounted for around 10% of the total landings from the North Sea. Only minor anglerfish landings are reported from IVb.

A Norwegian directed gillnet fishery (360 mm mesh size), targeting large anglerfish, carried out by small vessels in coastal waters in the eastern part of the Northern North Sea started in the early 1990s. The landings from this fishery have comprised around 6% of the total landings from Division IVa since 1999.

Landings from Division Skagerrak (IIIa) are low, accounting for less than 5% of the total Northern Shelf landings, with Denmark and Norway responsible for the bulk of the landings. Most of the Norwegian landings are taken in a directed gillnet fishery. Until the end of the 1990s the Danish landings were taken mainly as bycatches in fisheries for shrimp (*Pandalus*), Norway lobster (*Nephrops*) and mixed roundfish, but in recent years some Danish demersal trawlers and gillnetters have been targeting Anglerfish in IIIa.

4.5 Influence of environmental drivers on the stock dynamic

Sea temperature limits the distribution of anglerfish to the north of the Northern shelf particularly at depths where cold-water currents of polar descent occur. *Lophius piscatorius* is predominant throughout the area, with *Lophius budegassa* occurring in greater density towards the southern part of the area as befits the more general distribution of these two species (Fariña *et al.*, 2008).

4.6 Role of multispecies interactions

4.6.1 Trophic interactions

Anglerfish are opportunistic, non-selective-feeders, with a common feeding strategy: they are sit-and-wait predators, luring their prey by raising and moving the illicium

(Fariña *et al.*, 2008). Young fish consume a variety of prey including many invertebrates, and switch to a largely ichthyophagous habit as they grow older.

4.6.2 Fishery interactions

See Section 4.4 above.

4.7 Impacts of the fishery on the ecosystem

The main impacts on the fishery are undoubtedly the impact of heavy trawling gear on the seabed. In certain areas, such as Rockall, this activity is banned to protect deep-water coral and the associated communities.

4.8 Stock assessment methods

A survey-based abundance-at-age model is in development, which treats the estimates of abundance at age five and older from the SCO-IV-VI-AMISS-Q2 survey, described above, as absolute estimates (with a survey catchability approximately equal to one). The model, therefore, primarily attempts to estimate the numbers-at-ages zero to four. A fishing selectivity pattern will be estimated as well as a survey catchability function. To assist in the estimation of the former it may be necessary to tune the model to catch-at-length data: the initial prototype of the model has a separability constraint and tunes to the total catch.

Discussions during WKFLAT concluded that this idea should be pursued with specific consideration of sensitivities to ageing and differentiation by species and sex. The model is currently formulated under the FLR framework, but it may be necessary to transpose it to a more effective minimisation code such as ADModelBuilder.

The value of natural mortality will be critical to any assessment. Previous assessments of this stock used the natural mortality rate applied to anglerfish in Division VI adopted by an earlier Hake Assessment Working Group of 0.15 yr-1. This value was adopted for all ages and lengths in the last length based assessments (ICES 2004). Other options will be explored in the development of the survey based model. At WKFLAT 2012 for example, the natural mortality-at-age curves of (Lorenzen, 1996) were estimated by sex, based on the mean weight-at-age averaged over the 2005 to 2011 SCO-IV-VI-AMISS-Q2 survey time-series. The estimated natural mortality-at-age from Lorenzen's curves was rescaled to result in five percent of the population age structure at the oldest age assuming no fishing. The oldest age for females was 15 and for males 10 based on the survey age distributions.

4.8.1 Conclusions

The benchmark concluded that an age based assessment could be considered for this stock if the internal consistency of the age composition data was examined in more detail and sensitivity to growth assumptions considered. Work should continue on the proposed survey based model and preliminary results should be presented to the WGCSE. No changes to the stock annex were proposed by WKFLAT.

4.9 Short-term and medium-term forecasts

There are no forecasts for this stock, although once the assessment model, described above, has been prepared, a management strategy evaluation is also in preparation to determine suitable catch options in relation to reference points.

4.10 Biological reference points

In terms of the status of F in relation to F_{msy} there are two major uncertainties. The first is the value of F_{msy}. Previous WG have considered that the fishing mortality corresponding to 35% of the unfished SSB/R could be an approximation of $\mathbf{F_{MSY}}$: this is what F_{pa} was set to ($\mathbf{F_{35\%SPR}}$ = F_{pa} = 0.30). Another suitable proxy might be $F_{0.1}$, which like $\mathbf{F_{35\%SPR}}$, would be derived from a yield-per-recruit analysis. The last time a yield-per-recruit was carried out (ICES 2004), $F_{0.1}$ was estimated at 0.12 and $F_{35\%SPR}$ was 0.12. However, as yet no assessment is available to determine the fishing mortality [selection] pattern which is required for a Y/R analysis. The second uncertainty is the current level of fishing mortality, where, in the absence of an assessment, this is also unknown.

Biological reference points

	Type	Value	Technical basis
Precautionary approach	B_{lim}	Not defined	There is currently no biological basis for defining B_{lim}
	B_{pa}	Not defined	
	F_{lim}	Not defined	There is currently no biological basis for defining F_{lim}
	F_{pa}	0.30	$F_{35\%SPR}$ = 0.30. This fishing mortality corresponds to 35% of the unfished SSB/R. It is considered to be an approximation of F_{MSY}.
Targets	F_y	Not defined	

(unchanged since 1998).

4.11 Recommendations on the procedure for assessment updates and further work

Recommendation	For follow up by:
Develop an assessment model using the abundance at species, age and sex from the SCO-IV-VI-AMISS-Q2 survey.	P. Fernandes, UNIABDN
Determine the sensitivity to age readings in the above model, by investigating alternative estimates of age based on existing growth functions.	P. Fernandes, UNIABDN
Investigate alternative estimates of natural mortality for use in the above model.	P. Fernandes, UNIABDN
Generate an international catch-at-length dataset from 1998–present to tune the above model.	Liz Clarke, MSS
Investigate spatial structure of northern shelf anglerfish stock by sex and age.	P. Fernandes, UNIABDN
Develop a management strategy evaluation for the northern shelf anglerfish stock to determine suitable reference points.	P. Fernandes, UNIABDN
Investigate the potential for using IBTS data for estimates of recruits (index) and spatial extrapolation of absolute surveys estimates into Area IV.	P. Fernandes, UNIABDN & Liz Clarke, MSS
Consider the inclusion of Area IIIa in this stock.	ICES ?

4.12 Implications for management (plans)

There are no management plans available for this stock, although a management strategy evaluation is in preparation and will be carried out once a suitable stock assessment has been devised.

4.13 References

Anon. 2011. *Scottish Sea Fisheries Statistics 2010*. Scottish Government, Edinburgh, 86 pp.

Dobby, H., Allan, L., Harding, M., Laurenson, C.H. and McLay, H.A. 2008. Improving the quality of information on Scottish anglerfish fisheries: making use of fishers' data. *ICES J. Mar. Sci.* **65**: 1334–1345.

Fariña, A.C., Azevedo, M., Landa, J., Duarte, R., Sampedro, P., Costas, G., Torres, M.A. and Cañás, L. 2008. *Lophius* in the world: a synthesis on the common features and life strategies. **65**(7): 1272–1280.

Fernandes, P.G., Armstrong, F., Burns, F., Copland, P., Davis, C., Graham, N., Harlay, X., O'Cuaig, M., Penny, I., Pout, A.C. and Clarke, E.D. 2007. Progress in estimating the absolute abundance of anglerfish on the European northern shelf from a trawl survey. *ICES CM 2007/**K:**12.* 16 pp.

ICES. 2004. Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNSDS). *ICES CM 2004/**ACFM:**04.* 561 pp.

ICES. 2009. Report of the Workshop on Anglerfish and Megrim (WKAGME). *ICES CM 2009/**ACOM:**28.* 112 pp.

Landa, J., Duarte, R. and Quincoces, I. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. *ICES J. Mar. Sci.* **65**: 72–80.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. *Journal of Fish Biology* **49**: 627–647.

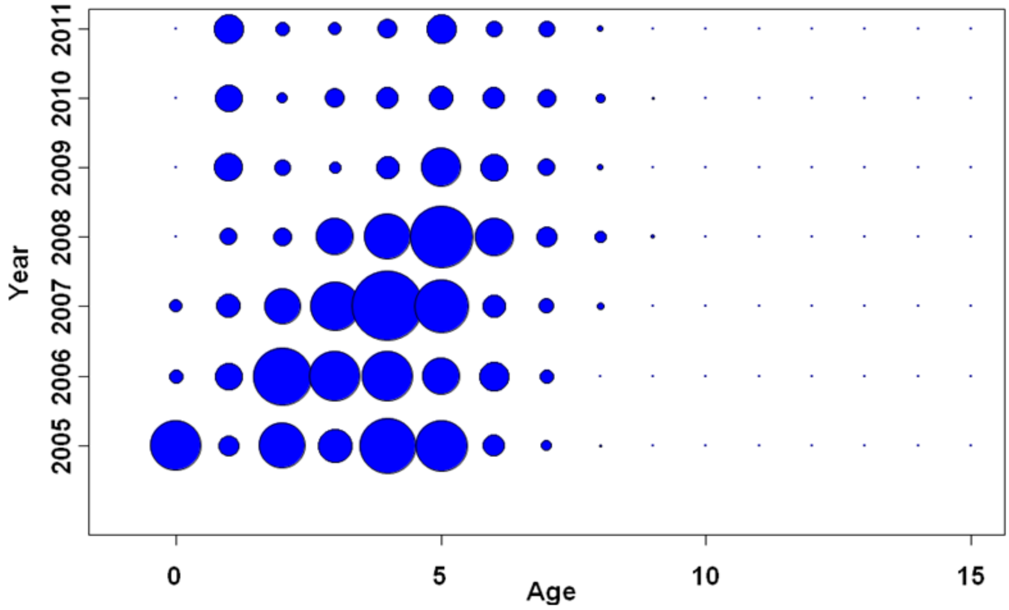


Figure 1. Abundance (blue circles, with abundance proportional to circle size) at age (x-axis) and year (y-axis) for *Lophis piscatorius* as estimated from the Scottish Anglerfish and Megrim Industry-Science Surveys in Areas IV and VI (SCO-IV-VI-AMISS-Q2).

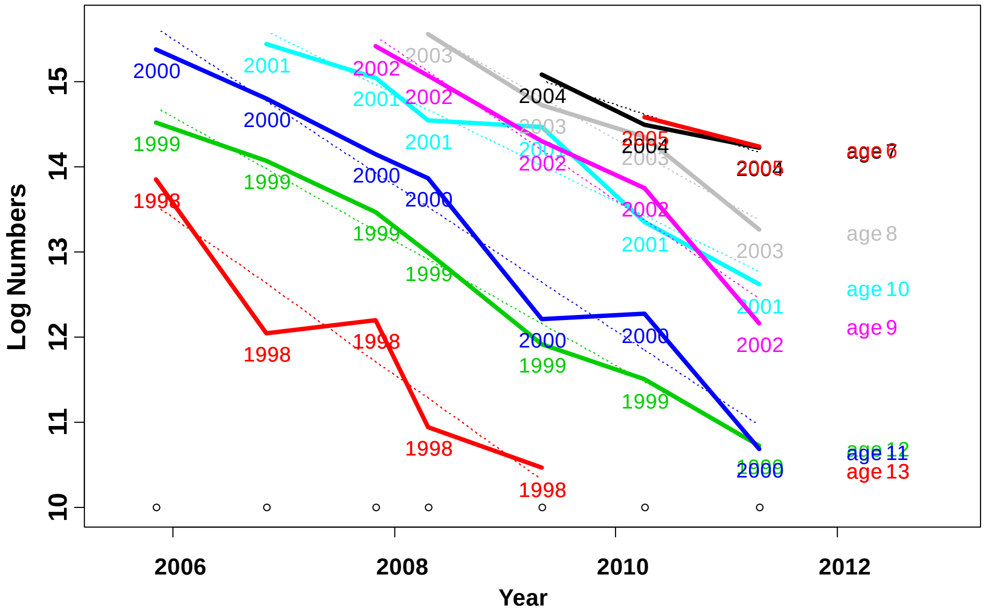


Figure 2. Curves of (log_e) abundance of anglerfish (*Lophius piscatorius*) plotted as lines tracking individual cohorts (cohort age class labelled along the lines; age in 2011 indicated on the right hand size of the figure), for those fish aged 5 and older as estimated from the Scottish Anglerfish and Megrim Industry-Science Surveys in Areas IV and VI (SCO-IV-VI-AMISS-Q2). The dotted lines are generalised linear model fits. The points along the bottom of the figure indicate the exact timing of the surveys from 2005–2011.

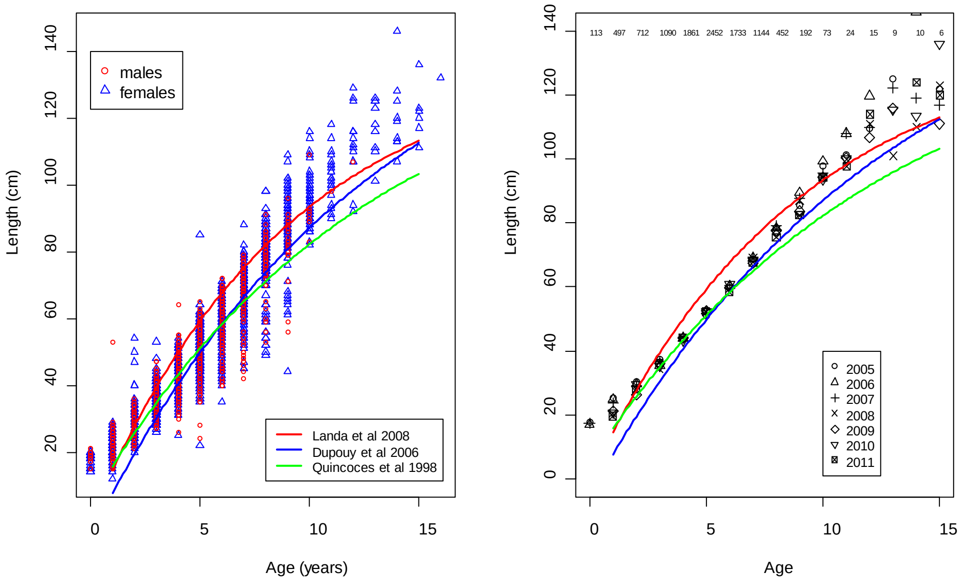


Figure 3. Length-at-age (left) and mean length-at-age (right) from the Scottish Anglerfish and Megrim Industry-Science Surveys in Areas IV and VI (SCO-IV-VI-AMISS-Q2) plotted as points (males are red circles and females are blue triangles on the left panel; mean length-at-age is plotted by year according to the legend on the right panel). The lines overlaid on the data are von Bertalanffy growth curves with parameters estimated by the respective authors as indicated on the legend on the left panel. The numbers along the top of the figure on the right panel indicate the sample size for all years at each age which contributed to the average value (both sexes combined).

5 Anglerfish (*L. piscatorius*) (Divisions VIIb–k and VIIIabd)

5.1 Current assessment and issues with data and assessment

There was no accepted assessment for *L. piscatorius* in 2007. The Working Group in 2007 found that the input data showed deficiencies, especially as discarding was known to be increasing and that ageing problems had become more obvious. No new analytical assessment has been proposed since then.

5.2 Compilation of available data

5.2.1 Catch and landings data

The particularity of the data gathering processes for anglerfish species is that, except in Spain, anglerfishes are sold without any species distinction. The overall catch per species is estimated from the species ratio observed in the biological sampling.

Biological sampling is carried out by the countries contributing most catches, but assumptions about species proportion have to be made for countries reporting raw tonnages for species combined. The amount of tonnage with no biological sampling for species composition has been much reduced since the early 2000s and in 2007 these represented less than 8% of the total *Lophius* landings. In some countries however, anglerfish are landed as tails only and conversion factors have to be used to estimate total length, which still may introduce errors.

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

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

5.2.2 Biological data

In 2007, WGHMM rejected the XSA age based assessments of both species because of data quality (increased discards not incorporated) and ageing problems clearly identified (ICES, 2007). Therefore there is no age based data used to assess the stocks. Only length distributions of landings and survey indices are used.

5.2.3 Survey tuning data

For the first three surveys presented, a full description can be found on the ICES DATRAS website: http://datras.ices.dk/Home/Descriptions.aspx.

The French FR-EVHOE-WIBTS-Q4 survey

This survey covers the largest proportion of the area of stock distribution. It started in 1997.

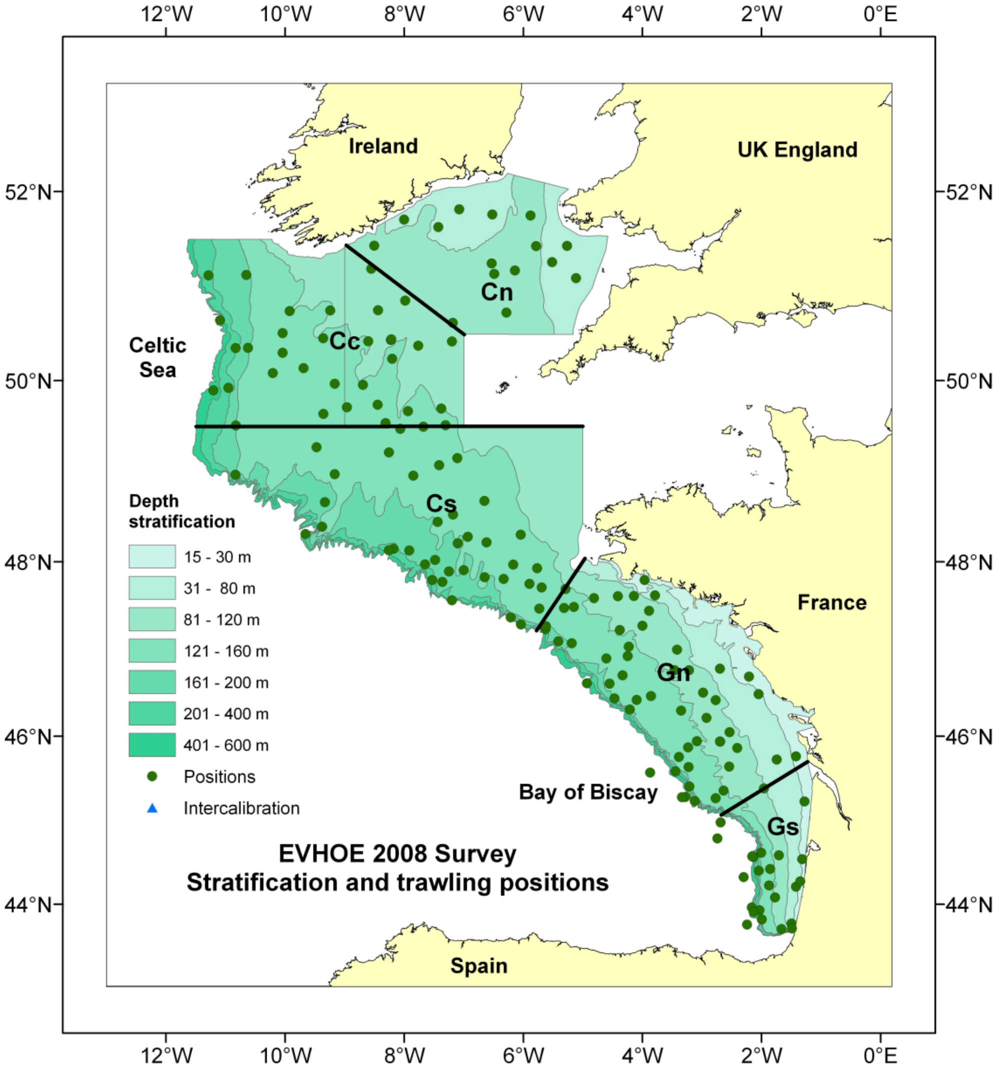


Figure 5.2.3.1. Map of Survey Stations completed by the EVHOE-WIBTS-Q4 Survey in 2008.

The Spanish Porcupine Groundfish Survey (SPGFS-WBTS-Q4)

This survey was initiated in 2001 and covers the Porcupine Bank.

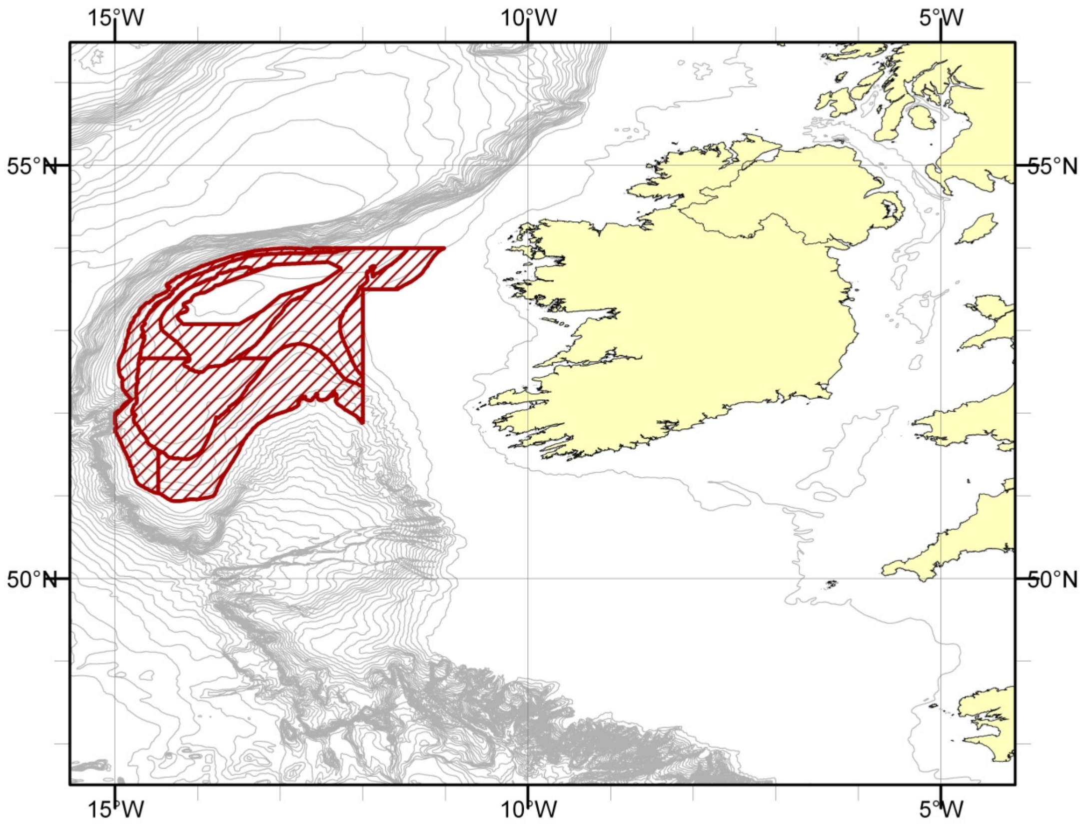


Figure 5.2.3.2. Map of area covered by the Porcupine Groundfish Survey (SPGFS-WIBTS-Q4).

The Irish Groundfish Survey (IGFS-WIBTS-Q4)

This survey was initiated in 2003 and covers areas around Ireland.

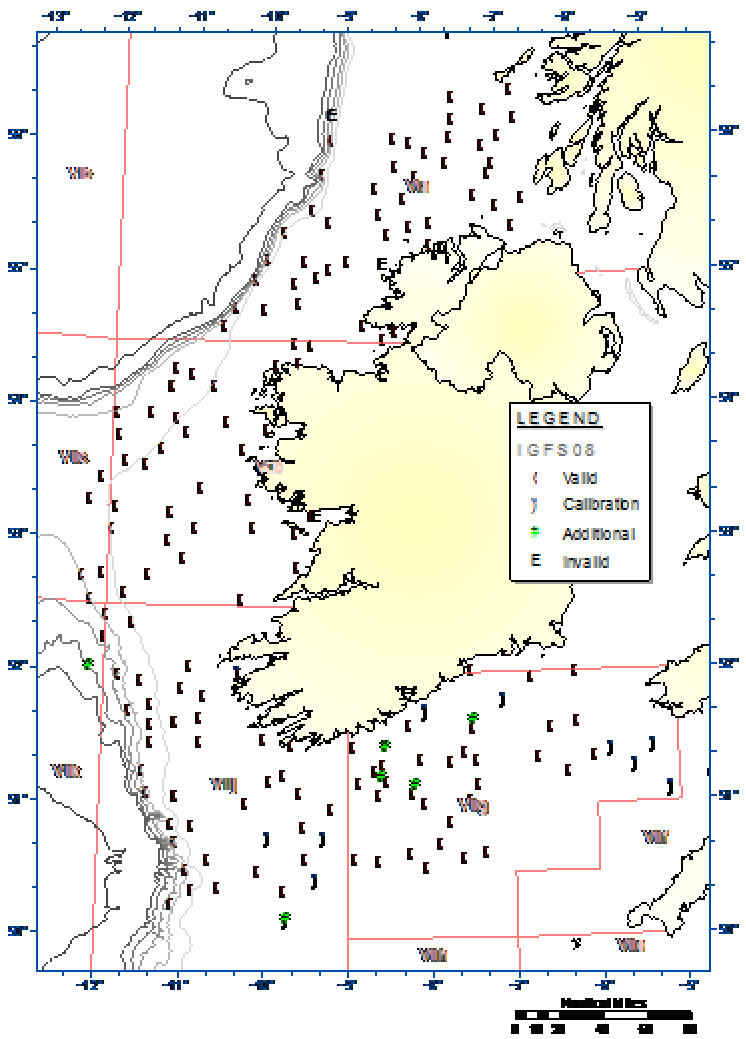


Figure 5.2.3.3. Map of Survey Stations completed by the Irish Groundfish Survey (IGFS-WIBTS-Q4) in 2008. Valid = red circles; Invalid = crosses; Intercalibration = blue squares; intercalibration and additional stations not valid for IBTS survey indices = green triangles.

The English Fisheries Science Partnership survey (EW–FSP)

This survey traverses Areas VIIe–h and started in 2003.

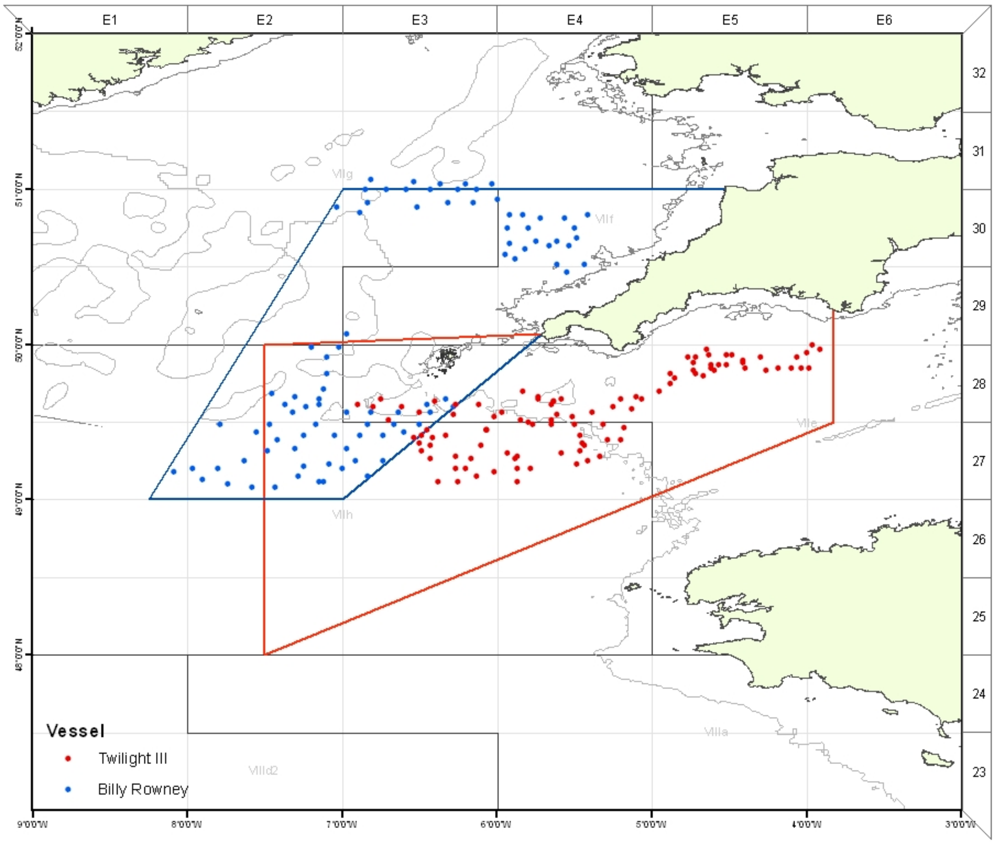


Figure 5.2.3.4. Map of Survey Stations completed by the EW-FSP Survey in 2011.

A description of the survey can be found in Section 2.2.12 of the WGHMM 2011 report (ICES, 2011).

5.2.4 Commercial tuning data

Effort and lpue data were available for four Spanish trawl fleets (SP-VIGO7, SP-CORUTR7, SP-BAKON7 and SP_BAKON8), the French FR-FU04 and FR-FU14 and the UK EW-FU06. However, the tuning indices do not give sufficient information to enable the production model to converge. There is future potential to produce a further commercial tuning index from the French fleets.

5.3 Stock identity, distribution and migration issues

ICES assumes since the end of the 1970s three different stocks for assessment and management purposes: Anglerfish in Division IIa (Norwegian Sea), Division IIIa (Kattegat and Skagerrak), Subarea IV (North Sea), and Subarea VI (West of Scotland and Rockall) (*Lophius piscatorius* and *L. budegassa*); Anglerfish in Divisions VIIb–k and VIIIa,b,d (*L. piscatorius* and *L. budegassa*) and Anglerfish in Divisions VIIIc and IXa (*L. piscatorius* and *L. budegassa*). These stock definitions apply for both anglerfish species White anglerfish (*L. piscatorius*) and Black anglerfish (*L. budegassa*). In Divisions VIIb–k and VIIIa,b,d, the two species are assessed separately but advised as a single stock since the EU gives a unique TAC for both species.

For concerns about current stock definition see Section 2 of the report.

5.4 Influence of the fishery on the stock dynamic

Anglerfish are an important component of mixed fisheries taking hake, megrim, sole, cod, plaice, and *Nephrops*. A trawl fishery by Spanish and French vessels developed in the Celtic Sea and Bay of Biscay in the 1970s, and overall annual landings may have attained 35 000–40 000 t by the early 1980s. Landings decreased between 1981 and 1993 and since 2000, landings show an increasing trend. France and Spain together still report more than 75% of the total landings of both species combined. The remainder is taken by the UK and Ireland (around 10% each) and Belgium (less than 5%). Otter trawls (the main gear used by French, Spanish, and Irish vessels) currently take about 80% of the total landings of *L. piscatorius*, while around 60% of UK landings are by beam trawlers and gillnetters. Over 95% of total international landings of *L. budegassa* are taken by otter trawlers. There has been an expansion of the French gillnet fishery since the early 1990s in the Celtic Sea and in the north of the Bay of Biscay, mainly by vessels landing in Spain and fishing in medium to deep waters. Otter trawling in medium and deep water in ICES Subarea VII appears to have declined, although the increasing use of twin trawls by French vessels may have increased significantly the overall efficiency of the French fleet.

5.5 Influence of environmental drivers on the stock dynamic

Lophius piscatorius is a Northeastern Atlantic species, with a distribution area from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea). *Lophius budegassa* has a more southern distribution from the British islands and Ireland to Senegal (including the Mediterranean and the Black Sea). Though the Working Group assesses two different stocks for each species (VIIIc, IXa stock and VIIb–k, VIIIabd), the boundaries are not based on biological criteria. Recent studies were carried out in genetic and morphometric analysis (GESSAN, 2002; Duarte *et al*., 2004; Fariña *et al*., 2004).

The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m (Afonso-Dias and Hislop, 1996; Hislop *et al*., 2001; Quincoces *et al*., 2002). This particular spawning results in a highly clumped distribution of eggs and newly emerged larvae (Hislop *et al*., 2001) and favourable or unfavourable ecosystem conditions can therefore have important impacts on the recruitment.

5.6 Stock assessment methods

5.6.1 Models

A Schaeffer type model (ASPIC, Prager, 1994) was used on the following dataset:

- Landings from 1984 to 2010;
- Cpues from the Vigo fleet split in two series: 1986–1998 and 1999–2010 (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);
- Cpues from the French benthic fleet in the Celtic Sea (FR-FU04) from 1986 to 2010;
- Biomass index from the French EVHOE survey from 1997 to 2010.

The indices were selected on the basis of their correlation and their coverage of the distribution area.

The other available indices were rejected for the following reasons:

- EW-Cirolana survey (1984–2004): This survey covering the Celtic Sea showed very high interannual variations;
- SP-PGFS : This survey covers only the Porcupine Bank, a small area of the stock distribution and was designed to target large hakes;
- Standardized Basque fleet cpues: Concerns were raised by WKFLAT 2012 about the model used to standardize this index.

The indices used are positively correlated but they follow the landings (Figure 5.1).

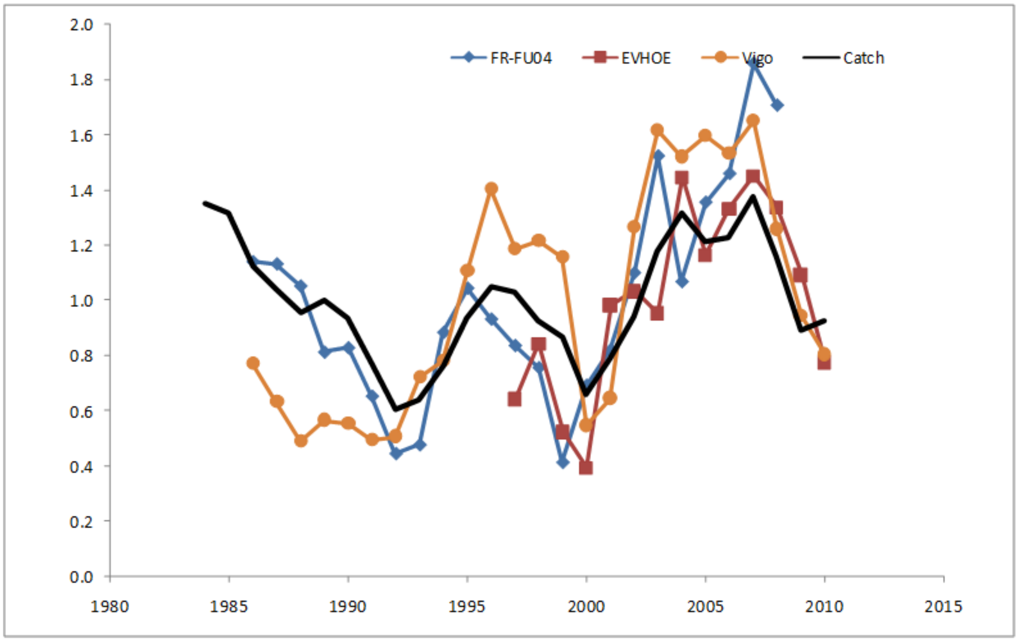


Figure 5.1. Indices of cpue and landings used in the ASPIC formulation for both species combined assessment (The indices are standardized to their mean in the graph).

Results of the fit are given in Table 5.1 and Figure 5.2. They do not show any major problem except a lack of contrast.

Table 5.1. Goodness-of-fit parameters.

	Weighted SSE	N	Weighted MSE	Inv. var. weight	R-squared in cpue
Vigo1	1.180	12	0.118	0.819	0.246
FRFU04	1.633	23	0.078	1.243	0.509
EVHOE	1.365	14	0.114	0.850	0.233
Vigo 2	1.184	13	0.011	0.900	0.221
Total Obj. Funct.	5.363		Contrast index	0.13	
MSE	0.098		Nearness index	0.74	
RMSE	0.312				

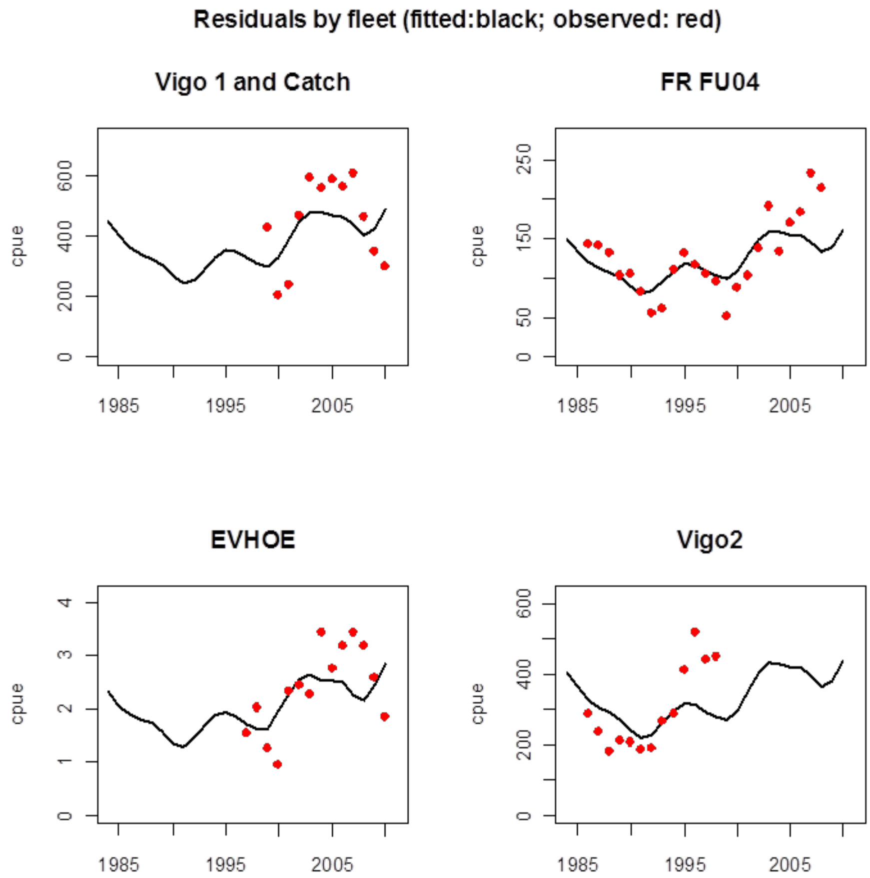


Figure 5.2. Observed and estimated cpues for the four indices used in the ASPIC formulation.

Output from the model (Figure 5.3) would indicate that the species has been harvested over MSY over all the time-series and that the biomass has remained at around 40% of B_{MSY}.

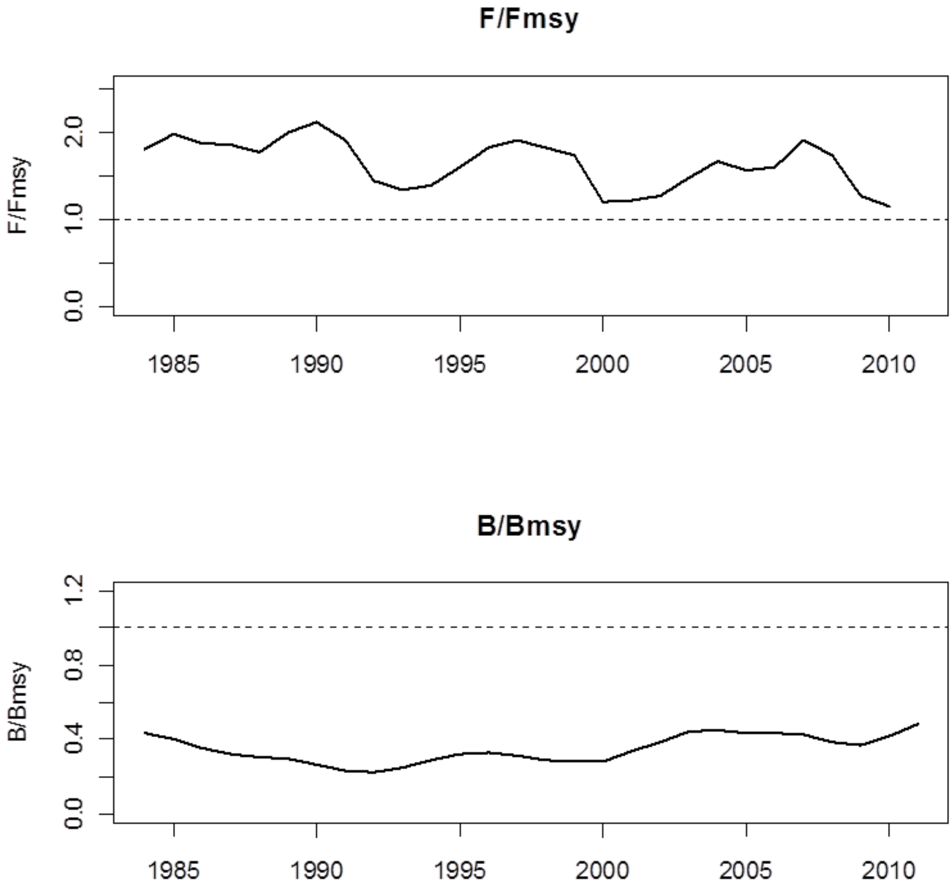


Figure 5.3. Results from the ASPIC formulation on *Lophius* in VII and VIII both species combined.

5.6.2 Retrospective patterns

A retrospective analysis (Figure 5.4) showed a strong pattern in underestimating F/F_{MSY} and overestimating B/B_{MSY}.

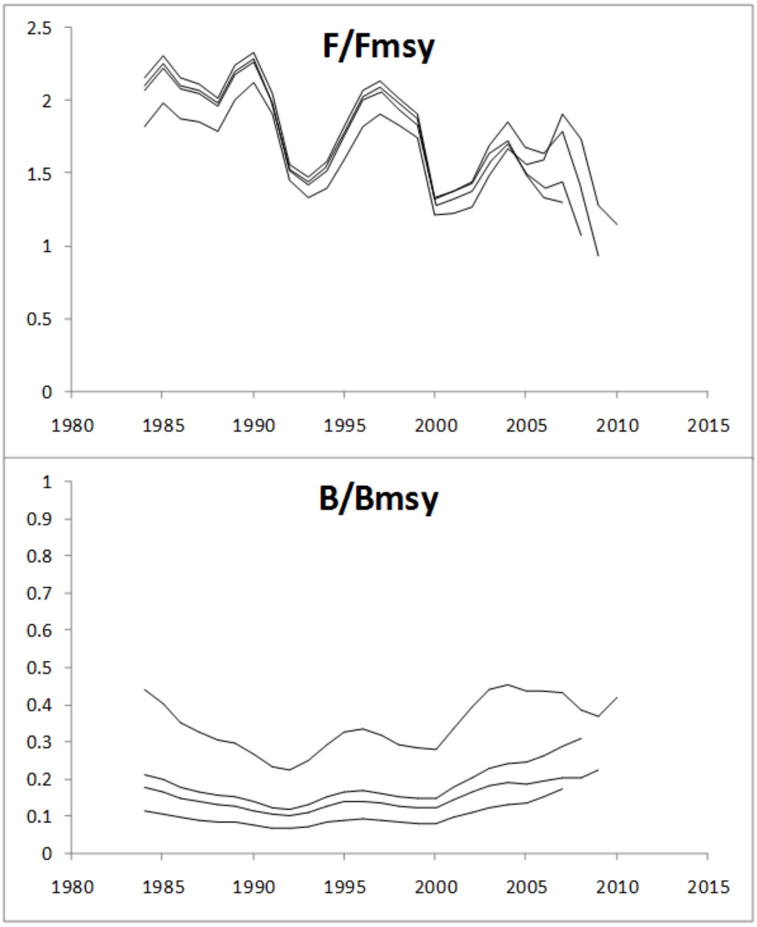


Figure 5.4. Retrospective analysis from the ASPIC formulation on *Lophius* in VII and VIII both species combined.

5.6.3 Evaluation of the models

The strong pattern shown by the retrospective analysis can be explained by the lack of contrast of the data. In the absence of a response from the biomass to either an increase or a decrease in catch, the parameters cannot be estimated precisely. This is shown in Figure 5.4 where the indices follow the trends in the landings.

5.6.4 Conclusion

In view of the instability of the model, it was decided that it could not be used as a basis for management advice.

5.7 Recommendations on the procedure for assessment updates and further work

Continue using a trend based assessment until new or better data are available for producing an analytical assessment.

5.8 References

Afonso-Dias, I.P. and J.R.G. Hislop. 1996. The reproduction of anglerfish *Lophius piscatorius* Linnaeus from the northwest coast of Scotland. Journal of Fish Biology 49: 18–39.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

Gessan. 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the North Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

Hislop, J. R. G., Gallego, A., Heath, M. R., Kennedy, F.M., Reeves, S.A. and Wright., P.J. 2001. A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus, 1758) in northern British waters. ICES Journal of Marine Science 58: 70–86.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8–17 May 2007, Vigo, Spain. ICES CM2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.

Prager, M. H. 1994. A suite of extensions to a non equilibrium surplus–production model. Fishery Bulletin 92: 374–389.

6 Anglerfish (*L. budegassa*) (Divisions VIIb–k and VIIIabd)

6.1 Current assessment and issues with data and assessment

There was no accepted assessment for *L. budegassa* in 2007. The Working Group in 2007 found that the input data showed deficiencies, especially as discarding was known to be increasing and that ageing problems had become more obvious. No new analytical assessment has been proposed since then.

6.2 Compilation of available data

6.2.1 Catch and landings data

The particularity of the data gathering processes for anglerfish species is that, except in Spain, anglerfishes are sold without any species distinction. The overall catch per species is estimated from the species ratio observed in the biological sampling.

Biological sampling is carried out by the countries contributing most catches, but assumptions about species proportion have to be made for countries reporting raw tonnages for species combined. The amount of tonnage with no biological sampling for species composition has been much reduced since the early 2000s and in 2007 these represented less than 8% of the total *Lophius* landings. In some countries however, anglerfish are landed as tails only and conversion factors have to be used to estimate total length, which still may introduce errors.

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

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

6.2.2 Biological data

In 2007, WGHMM rejected the XSA age based assessments of both species because of data quality (increased discards not incorporated) and ageing problems clearly identified (ICES, 2007). Therefore there is no age based data used to assess the stocks. Only length distributions of landings and survey indices are used.

6.2.3 Survey tuning data

For the first three surveys presented, a full description can be found on the ICES DATRAS website: http://datras.ices.dk/Home/Descriptions.aspx.

The French FR-EVHOE survey (EVHOE-WIBTS-Q4)

This survey covers the largest proportion of the area of stock distribution. It started in 1997.

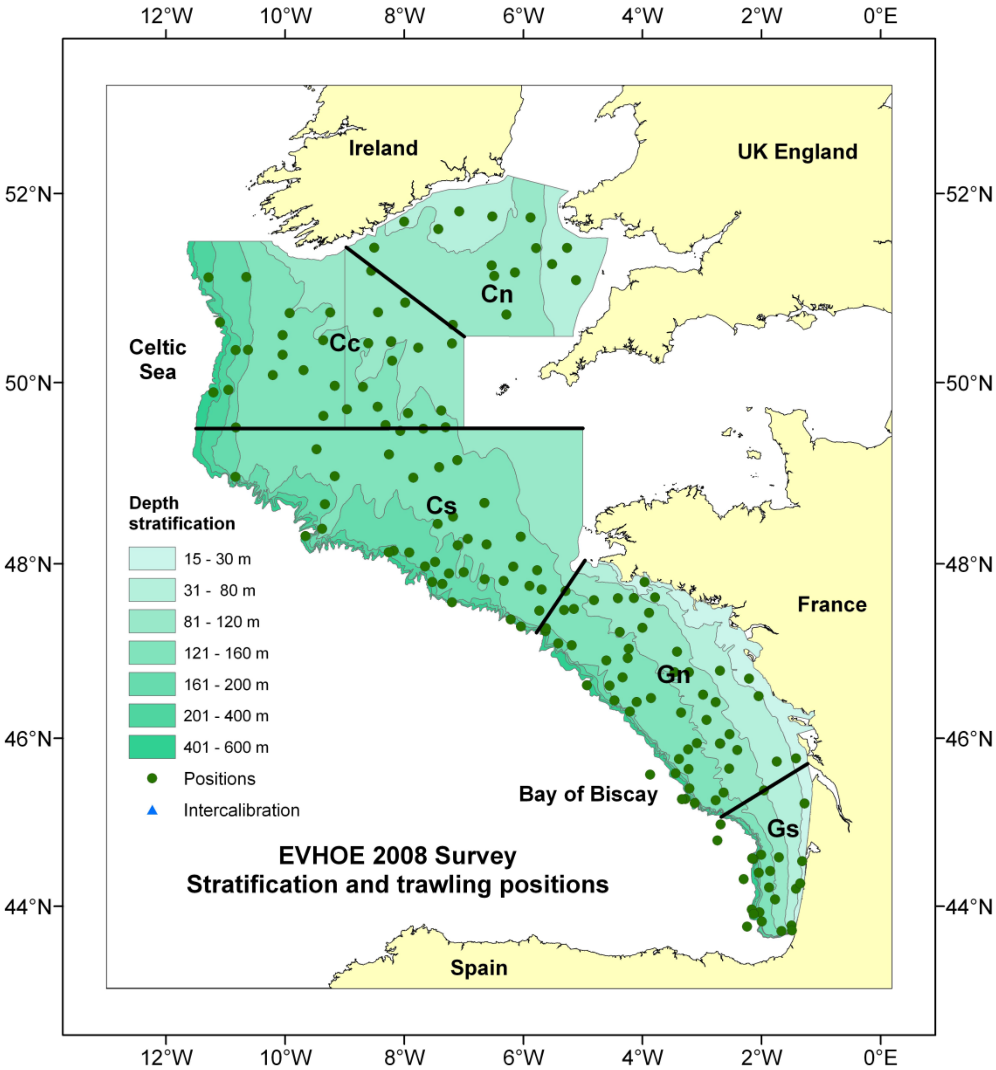


Figure 6.2.3.1. Map of Survey Stations completed by the EVHOE-WIBTS-Q4 Survey in 2008.

The Spanish Porcupine Groundfish Survey (SPGFS-WIBTS-Q$)

This survey was initiated in 2001 and covers the Porcupine Bank.

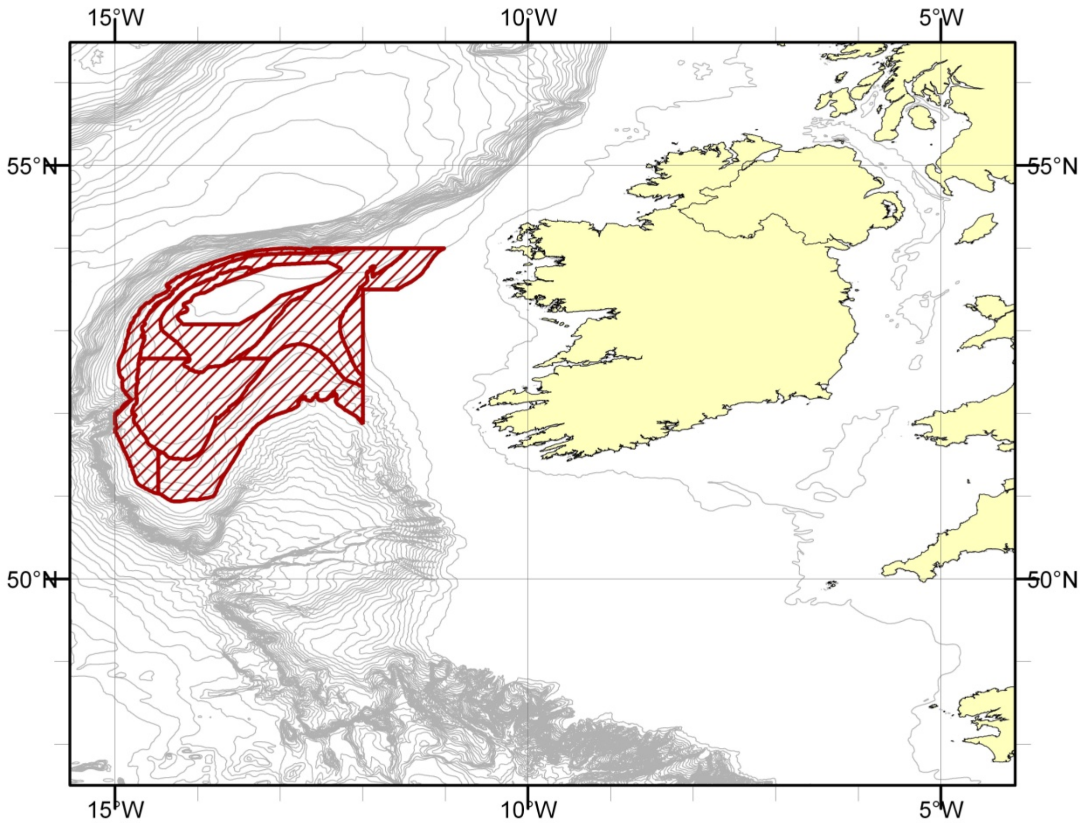


Figure 6.2.3.2. Map of area covered by the Porcupine Groundfish Survey (SPGSF-WIBTS-Q4).

The Irish Groundfish Survey (IGFS-WIBTS-Q4)

This survey was initiated in 2003 and covers areas around Ireland.

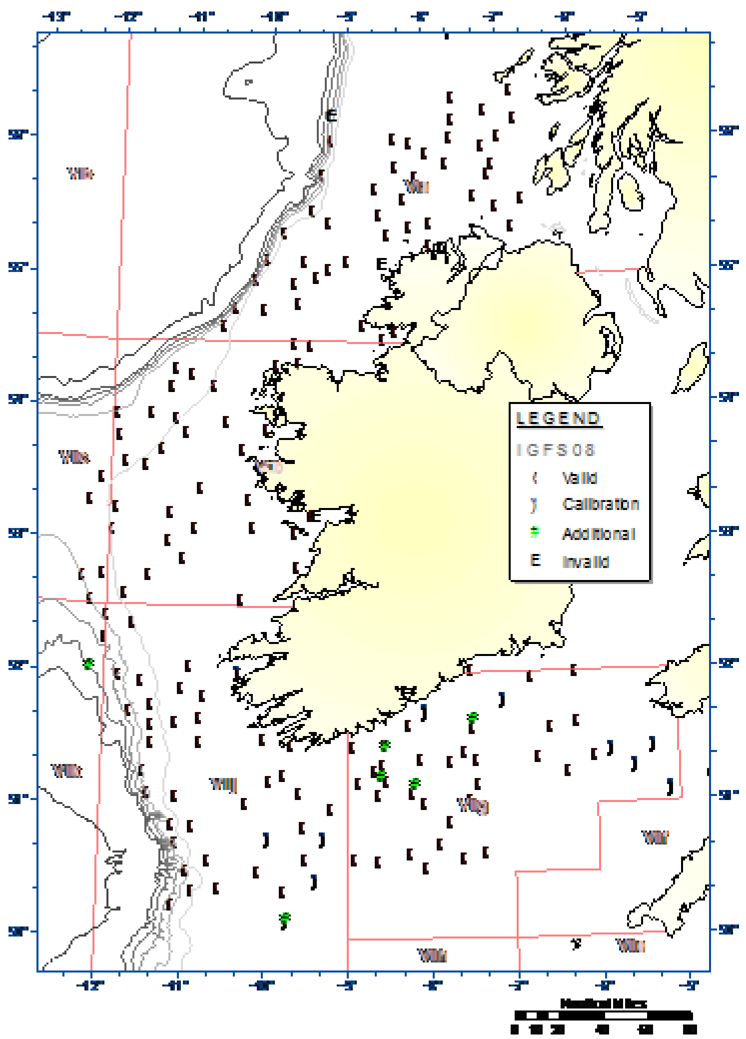


Figure 6.2.3.3. Map of Survey Stations completed by the Irish Groundfish Survey (IGFS-WIBTS-Q4) in 2008. Valid = red circles; Invalid = crosses; Intercalibration = blue squares; intercalibration and additional stations not valid for IBTS survey indices = green triangles.

The English Fisheries Science Partnership survey (EW-FSP)

This survey traverses Areas VIIe–h and started in 2003.

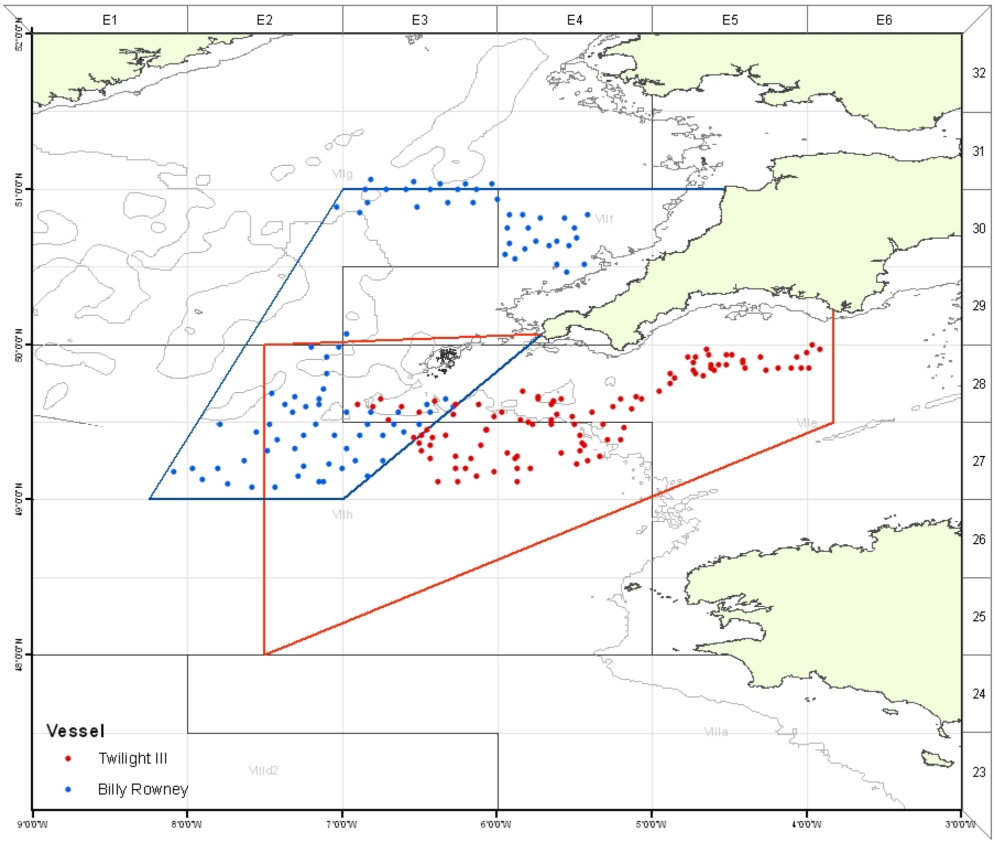


Figure 6.2.3.4. Map of Survey Stations completed by the EW-FSP Survey in 2011.

A description of the survey can be found in Section 2.2.12 of the WGHMM 2011 report (ICES, 2011).

6.3 Commercial tuning data

Effort and lpue data were available for four Spanish trawl fleets (SP-VIGO7, SP-CORUTR7, SP-BAKON7 and SP_BAKON8), the French FR-FU04 and FR-FU14 and the UK EW-FU06. However, the tuning indices do not give sufficient information to enable the production model to converge. There is future potential to produce a further commercial tuning index from the French fleets.

6.4 Stock identity, distribution and migration issues

ICES assumes since the end of the 1970s three different stocks for assessment and management purposes: Anglerfish in Division IIa (Norwegian Sea), Division IIIa (Kattegat and Skagerrak), Subarea IV (North Sea), and Subarea VI (West of Scotland and Rockall) (*Lophius piscatorius* and *L. budegassa*); Anglerfish in Divisions VIIb–k and VIIIa,b,d (*L. piscatorius* and *L. budegassa*) and Anglerfish in Divisions VIIIc and IXa (*L. piscatorius* and *L. budegassa*). These stock definitions apply for both anglerfish species White anglerfish (*L. piscatorius*) and Black anglerfish (*L. budegassa*). In Divisions VIIb–k and VIIIa,b,d, the two species are assessed separately but advised as a single stock since the EU gives a unique TAC for both species.

For concerns about current stock definition see Section 2 of the report.

6.5 Influence of the fishery on the stock dynamic

Anglerfish are an important component of mixed fisheries taking hake, megrim, sole, cod, plaice, and *Nephrops*. A trawl fishery by Spanish and French vessels developed in the Celtic Sea and Bay of Biscay in the 1970s, and overall annual landings may have attained 35 000–40 000 t by the early 1980s. Landings decreased between 1981 and 1993 and since 2000, landings show an increasing trend. France and Spain together still report more than 75% of the total landings of both species combined. The remainder is taken by the UK and Ireland (around 10% each) and Belgium (less than 5%). Otter trawls (the main gear used by French, Spanish, and Irish vessels) currently take about 80% of the total landings of *L. piscatorius*, while around 60% of UK landings are by beam trawlers and gillnetters. Over 95% of total international landings of *L. budegassa* are taken by otter trawlers. There has been an expansion of the French gillnet fishery since the early 1990s in the Celtic Sea and in the north of the Bay of Biscay, mainly by vessels landing in Spain and fishing in medium to deep waters. Otter trawling in medium and deep water in ICES Subarea VII appears to have declined, although the increasing use of twin trawls by French vessels may have increased significantly the overall efficiency of the French fleet.

6.6 Influence of environmental drivers on the stock dynamic

Lophius piscatorius is a Northeastern Atlantic species, with a distribution area from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea). *Lophius budegassa* has a more southern distribution from the British islands and Ireland to Senegal (including the Mediterranean and the Black Sea). Though the Working Group assesses two different stocks for each species (VIIIc, IXa stock and VIIb–k, VIIIabd), the boundaries are not based on biological criteria. Recent studies were carried out in genetic and morphometric analysis (GESSAN, 2002; Duarte *et al.*, 2004; Fariña *et al.*, 2004).

The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m (Afonso-Dias and Hislop, 1996; Hislop *et al.*, 2001; Quincoces *et al.*, 2002). This particular spawning results in a highly clumped distribution of eggs and newly emerged larvae (Hislop *et al.*, 2001) and favourable or unfavourable ecosystem conditions can therefore have important impacts on the recruitment.

6.7 Stock assessment methods

6.7.1 Models

Two models were explored a surplus production model and a length based stock synthesis model.

Surplus production model

A Schaeffer surplus production model (ASPIC, Prager, 1994) was used on the following dataset:

- Landings from 1984 to 2010 for the single species and both species combined.
- Cpues from Vigo fleet split in two series: 1986–1998 and 1999–2010 (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).

- Cpues from the French benthic fleet in the Celtic Sea (FR-FU04) from 1986 to 2008.
- Biomass index from the EVHOE-WIBTS-Q4 from 1997 to 2010.

The indices were selected on the basis of their correlation and their coverage of the distribution area.

The other available indices were rejected for the following reasons:

- EW-Cirolana survey (1984–2004): This survey covering the Celtic Sea showed very high interannual variations.
- SP-PGFS: This survey covers only the Porcupine Bank, a small area of the stock distribution and was designed to target large hakes.
- Standardized Basque fleet cpues: Concerns were raised by WKFLAT about the model used to standardize this index.

The indices used are positively correlated but they follow the landings (Figure 6.7.1.1)

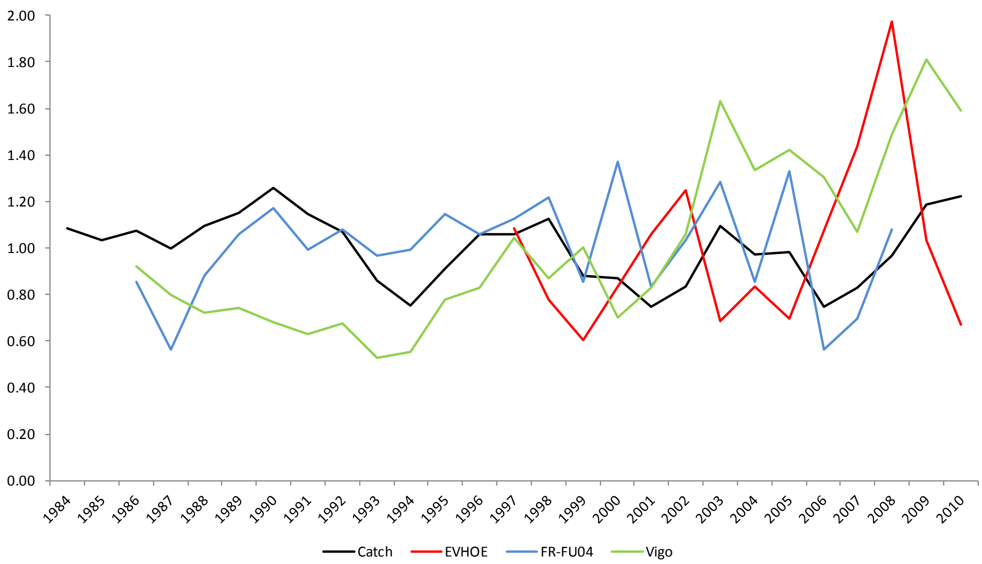


Figure 6.7.1.1. Indices of cpue and landings used in the ASPIC formulation for both species combined assessment (The indices are standardized to their mean in the graph).

As the surplus production model was unable to converge using a number of different input options, there are no results available.

Length based stock synthesis model

A stock synthesis model (NOA Fisheries Toolbox, 2011) was explored using the following datasets:

- Landings from 1984 to 2010 for *L. budegassa*.
- Biomass index from the French EVHOE survey (EVHOE-WIBTS-Q4) from 1997 to 2010.

The other available indices were not included for the following reasons:

- EW-Cirolana survey (1984–2004): This survey covering the Celtic Sea showed very high interannual variations.
- Cpues from Vigo fleet split in two series: 1986–1998 and 1999–2010 (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) data were not available by quarter.
- Cpues from the French benthic fleet in the Celtic Sea (FR-FU04) from 1986 to 2008 were not available by quarter.
- SP-PGFS: This survey covers only the Porcupine Bank, a small area of the stock distribution and was designed to target large hakes.
- Standardized Basque fleet cpues: Concerns were raised by WKFLAT about the model used to standardize this index.

A combination of different combined Fisheries units were used with the final combination being gillnets, French trawl fleet, Spanish trawl fleet, *Nephrops* trawl feet, English beam trawl fleet and a category contain those not in the previous groupings. The length compositions for the French, Spanish and *Nephrops* trawl fleets showed that there was a change in selectivity after 2005 (Figure 6.7.1.2) where the smaller fish were no longer seen in the landings due to a restriction on minimum landing weight imposed. For these three combinations a change in selectivity was introduced to the model.

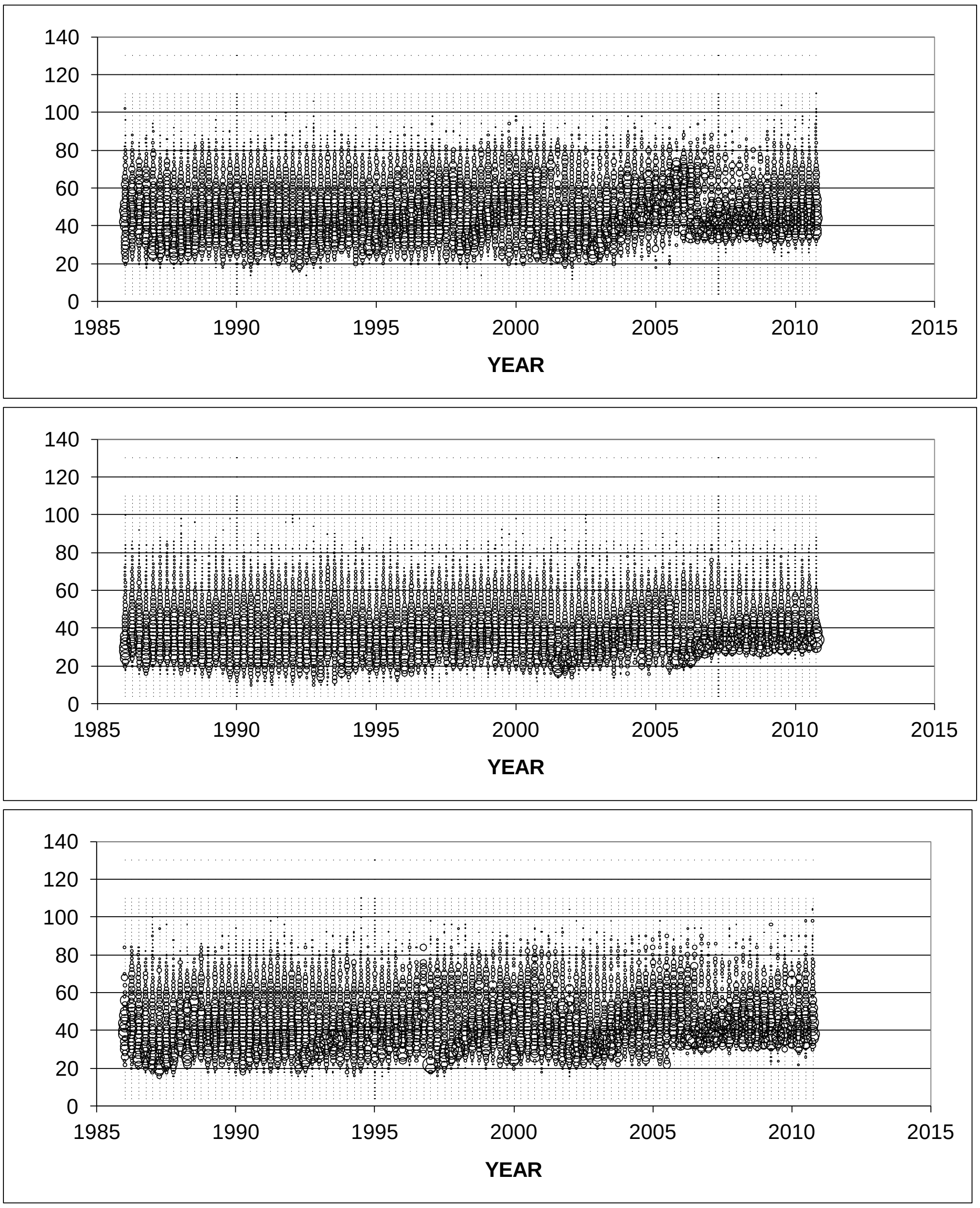


Figure 6.7.1.2. Observed length frequencies (cm) by year for the trawl fishing units a) French trawl, b) Spanish trawl, c) *Nephrops* trawl.

The fit to the EVHOE-WIBTS-Q4 index and predicted biomass and recruitment of the final run produced for WKFLAT 2012 are shown in Figures 6.7.1.3 and 6.7.1.4, the prediction to the EVHOE-WIBTS-Q4 index gives a consistent fit with three of the fourteen years are outside the bounds of the confidence interval for the survey, the trends in the recruitment index appears to be consistent with the EVHOE-WIBTS-Q4 and EW-FSP. The predicted SSB, however, has scaling issues and further work on selectivity for each of the fleets, the development of a commercial tuning index and the extension to the time-series of landing needs to be done.

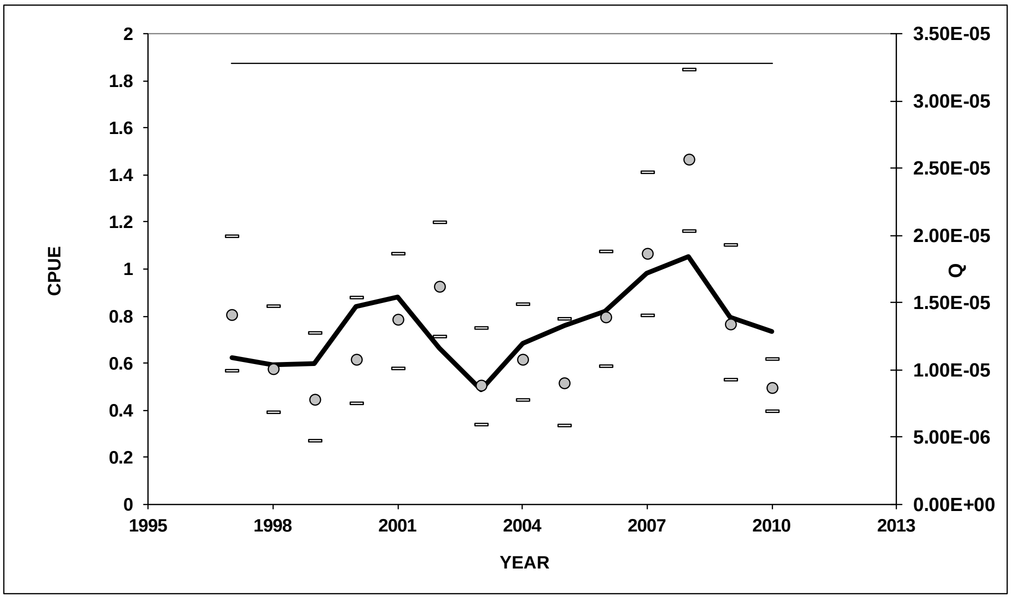


Figure 6.7.1.3. EVHOE-WIBTS-Q4 tuning index (points) with corresponding confidence intervals and the expected (black line).

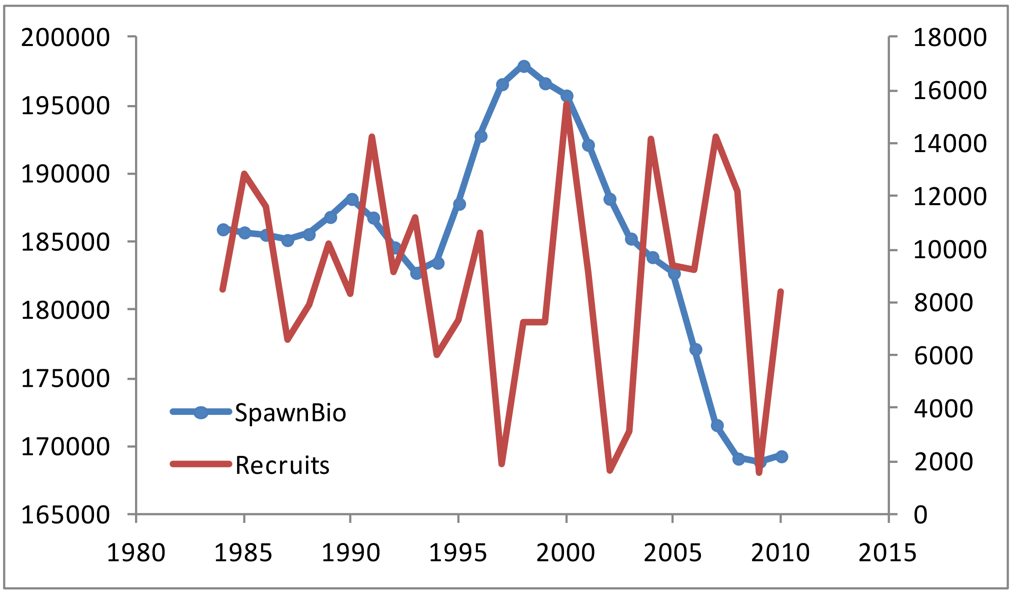


Figure 6.7.1.4. SS3.32b estimates for SSB and recruits.

6.7.2 Conclusion

In view of the instability of the surplus production model as well as the short time-series of landings, lack of commercial cpue index and biological information, it was decided that neither the surplus production nor stock synthesis could be used as a basis for management advice at this time. It was recommended to explore and develop the stock synthesis model.

6.8 References

Afonso-Dias, I.P. and J.R.G. Hislop 1996. The reproduction of anglerfish *Lophius piscatorius* Linnaeus from the northwest coast of Scotland. Journal of Fish Biology 49: 18–39.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

Gessan. 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the North Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8–17 May 2007, Vigo, Spain. ICES CM2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

Hislop, J. R. G., Gallego, A., Heath, M. R., Kennedy, F.M., Reeves, S.A. and Wright., P.J. 2001. A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus, 1758) in northern British waters. ICES Journal of Marine Science 58: 70–86.

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

Prager, M. H. 1994. A suite of extensions to a non equilibrium surplus–production model. Fishery Bulletin 92: 374–389.

Quincoces, I., Santurtún, M. and Lucio, P. 1998. Biological aspects of white anglerfish (*Lophius piscatorius*) in the Bay of Biscay (ICES Division VIIIa, b,d), in 1996–1997. ICES Doc. CM 1998/O:48: 29 pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.

7 Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa)

7.1 Current assessment and issues with data and assessment

The current assessment of this stock was accepted in 2011 (ICES, 2011). The assessment method applied on white anglerfish stock was a non-equilibrium production model using ASPIC software (Prager, 1994). The assessment model had some problems as it only used fishery-dependent data and the results were sensitive to model input settings although it was accepted. RGBBI 2010 (ICES, 2010 Annex R) made some comments to the assessment for this stock. It was pointed out the R-squared values for observed vs. fitted cpue values of the two series used were low. Besides it was declared that the assessment was completely dependent on commercial lpue data which may be biased due to targeting, local depletions, and changes in efficiency. Despite the concerns about the model fit were acknowledged it was agreed to approve the assessment because a benchmark for this stock was scheduled for beginning of 2012. The main issues addressed in the benchmark are:

- Change the model assessment to a length-based assessment model using Stock Synthesis (SS3);
- Incorporate fishery-independent information to fit the assessment model;
- Use the available length composition information and biological information about growth curve and maturity ogive of this species;
- Update and review the existing fishery-dependent information to be used in the assessment.

7.2 Compilation of available data

7.2.1 Catch and landings data

Landings

Total landings of *L. piscatorius* by country, area and gear for the period 1980–2010, as estimated by the Working Group, are available. The population is mainly exploited by two Spanish fisheries: trawlers acting in ICES Division VIIIc and Subdivision IXaN (SPTR8C9A) and an artisanal fishery using gillnets (called "rasco") (SPART8C) operating in Division VIIIc, and two Portuguese mixed fisheries operating in Division IXa: one artisanal fisheries (PTART9A) and a trawl fishery (PTTR9A) with low catches of anglerfish. The maximum landing of the available series was recorded in 1986 at 6870 t. After that, a general decline to 788 t in 2001 was observed, reaching the minimum of the available series. From 2002 to 2005 landings increased reaching 3644 t. Since 2005 landings have slowly decreased to 1547 t in 2011. Landed numbers-at-length are also available for these main four fisheries.

Discards

Discards for this stock are considered low. Some discards estimates are available for the fishery SPTR8C9A (1994–2010, except for years 1995, 1996, 1998, 2001 and 2002) but the raising procedure and the sampling protocol used are considered not appropriate to determine total discard of this species. For this available time-series anglerfish discards represent less than 1.5% of total catches of the stock.

Retention function to separate total catch into discard and retained portions for SPTR8C9A was estimated from a two parameter logistic curve (WKFLAT 2012 WD06, see Annex 4). The parameters of the curves for SPTR8C9A were allowed to change (shift to larger size at retention) beginning in 2000 due to changes in enforcement of minimum marketable weight.

New information about discards of Portuguese trawl fleet is presented in WKFLAT WD07 (Annex 4):

The sampling effort and percentage of occurrence of *L. piscatorius* discards in the trawl Portuguese fisheries were presented for the 2004–2010 period. The maximum occurrence of discard was 3% and 7% in the trawl targeting fish and trawl fleet targeting crustaceans respectively. Due to its low abundance and low frequency of occurrence anglerfish is considered a rare species in the discard samples. Because the estimation algorithm may be sensitive to a large frequency of zeros in the samples and a reasonable number of observations are required for accurate length–frequency estimation of annual fleet discards, estimates of discards have not been calculated for the moment. *L. piscatorius* discards in the Portuguese trawl fisheries seem to be negligible.

7.2.2 Biological data

The further biological information is used in the Benchmark:

Growth curve

The most recent study about white anglerfish growth in Atlantic integrates results for different growth researches (tag–recapture study, length–frequency of catches, and microstructure analysis of hard parts) (Landa *et al*., 2008). A von Bertalanffy growth curve fitted to all data provided the parameter values L*inf* = 140 cm and *K* = 0.11. This growth rate is faster than estimated recently using *illicia* for age estimation. In the assessment *K* was fixed at 0.11 and L*max* was estimated.

Maturity-at-length

Maturity was modelled as a logistic function of length. Different estimates of maturity ogive based on macroscopic maturity staging are available for this stock (Duarte *et al*., 2001; WKFLAT 2012 WD08). In these studies the difficulty of finding mature females in the field resulted in samplings with low coverage of mature individuals. Besides, the inadequacy in same instances of the macroscopic examination to determine maturity stage, let it to consider a maturity ogive of white anglerfish from other areas. The available study was carried out in ICES Divisions VIIIabd and determined microscopically the maturity stage (Quincoces, 2002). The parameters of maturity ogive are 50% maturity at 61.84 cm and a slope at 0.1001. Both values were fixed in the model.

Natural mortality

No specific studies about natural mortality of this species were available. However, taking into consideration its growth rate and the high size that can attain, a constant annual instantaneous natural mortality rate (*M*) of 0.2 yr^{-1} was used in the assessment. The rate of natural mortality was assumed to be independent of age and time.

Length-weight relationship

The weight-at-length relationship was externally calculated (BIOSDEF 1998), using data from an international project with a sampling that spatially covered a high proportion of the stock and which number of samples, even for larger fish, was high:

$W = 2.7 \times 10^{-5} \cdot L^{2.839}$

where W = weight in kilograms and L = length in centimetres. The parameters were fixed in the model.

7.2.3 Survey tuning data

Two surveys, SpGFS-WIBTS-Q4 and PtGFS-WIBTS-Q4, have been regularly provided to be used in the assessment.

SpGFS-WIBTS-Q4 aims to collect data on the distribution and relative abundance, and biological information of commercial fish in ICES Divisions VIIIc and Northern IXa. It is annually carried out in fourth quarter of the years. Data of abundance (in weight and numbers) and length information is available for anglerfish from 1983 to 2010 except for 1987.

PtGFS-WIBTS-Q4 covers the area of Portugal coast (ICES Subdivisions IXaC and part of IXaS). A time-series of relative abundance is available from 1989 to 2010 but the low abundance of the species in the area let it to not be considered to the assessment.

7.2.4 Commercial tuning data

Six commercial lpue series were available to be used as abundance indices. New information about the tuning fleet SPCORTR8C was provided to the Benchmark (WKFLAT 2012 WD05). Based on this new information four new years, at the beginning of the time-series, were included and some values were reviewed.

The selection of abundance indices to be used in the assessment was carried out using two criteria: their representativeness (in terms of proportion of total landings) and the quality of the data. The next abundance indices were used in the assessment:

A Coruña trawlers (SPCORTR8C). It is a mixed fisheries that catches anglerfish together with other demersal (hake, megrim, *Nephrops*) and pelagic species (mackerel and horse mackerel). This fleet represents an average of 13% of international catches of *L. piscatorius* along the time-series. It is a not standardized lpue (in weight) series, quarterly basis, from 1982 to 2010. Length information of this commercial tuning fleet is also available.

Cedeira gillnetters (SPCEDGN8C). It is an artisanal gillnet fishery targeting anglerfish. This fleet represents an average of 10% of total catches of *L. piscatorius.* A standardized quarterly lpue (in weight) series is available from 1999 to 2010. The standardization methodology was described in Costas *et al*. (2007). Length information of this commercial tuning fleet is also available.

7.2.5 Industry/stakeholder data inputs

Part of the information regarding to tuning fleets was provided by Ports Authorities and Fishermen's Associations.

7.2.6 Environmental data

No environmental data were presented to WKFLAT or used in the assessment.

7.3 Stock identity, distribution and migration issues

Some concerns about the structure of this stock structure were examined during the benchmark workshop (See Section 2 of this report).

7.4 Influence of the fishery on the stock dynamic

Not investigated during the Benchmark Workshop.

7.5 Influence of environmental drivers on the stock dynamic

Not investigated during the Benchmark Workshop.

7.6 Role of multispecies interactions

Not investigated during the Benchmark Workshop.

7.6.1 Trophic interactions

7.6.2 Fishery interactions

7.7 Impacts of the fishery on the ecosystem

Not investigated during the Benchmark Workshop.

7.8 Stock assessment methods

7.8.1 Models

The Stock Synthesis (SS) assessment model (Methot, 1990) was selected for use in this assessment. Stock Synthesis is a highly flexible statistical model framework that allows building from simple to complex models based on the data available. This model is written in ADMB (www.admb-project.org) and is forward simulating.

For white anglerfish southern stock a length-based stock assessment was conducted using the most recent version of Stock Synthesis 3, SS3 v3.23b (Methot, 2011; available at NOAA toolbox: http://nft.nefsc.noaa.gov/SS3.html). The assessment attempts to integrate the available fisheries data (landings in weight from four fishing fleets, size composition data from four fishing fleets and three abundance indices) and biological data from recent researches (growth rate and maturity ogive). A series of different model specifications were tried in various runs to refine the model. The input data and the model specifications tried during the Benchmark are described below:

- A quarterly time-step model from 1980–2010.
- Four fishing fleets and three abundance indices.
- Recruitment was assumed to follow a Beverton–Holt stock–recruitment relationship. The recruitment was modelled in a quarterly basis, and mostly occurs in second and third quarter with annual variations. There was no evidence that recruitment was related to spawning stock size for white anglerfish so steepness was fixed at 0.999 and also was sigmaR at 0.4, R0 was estimated.
- Selectivities were modelled as length-based not age-based. Selectivity varies among fleets, but is assumed to be time-invariant. For all fishing fleets, selectivities were estimated using a double normal distribution function which allows a dome-shaped.
- Retention functions enable size-specific modelling of the discarded portion of the catch for fleet SPTR8C9A. Retention functions were defined as logistic curves.

From this preliminary model configuration some specifications were tested before selecting the final run. They are presented here as sensitivity analysis.

7.8.2 Sensitivity analysis

Growth assumptions

Growth assumptions were examined by conducting five sensitivity runs varying the von Bertalanffy *K* parameter. Sensitivities were conducted at *K* fixed at values from 0.09 to 0.13. It was noted that SSB scaling is quite sensitive to different values of *K* (Figure 7.8.2.1). Exploitation rates showed less effect and recruitment was not affected.

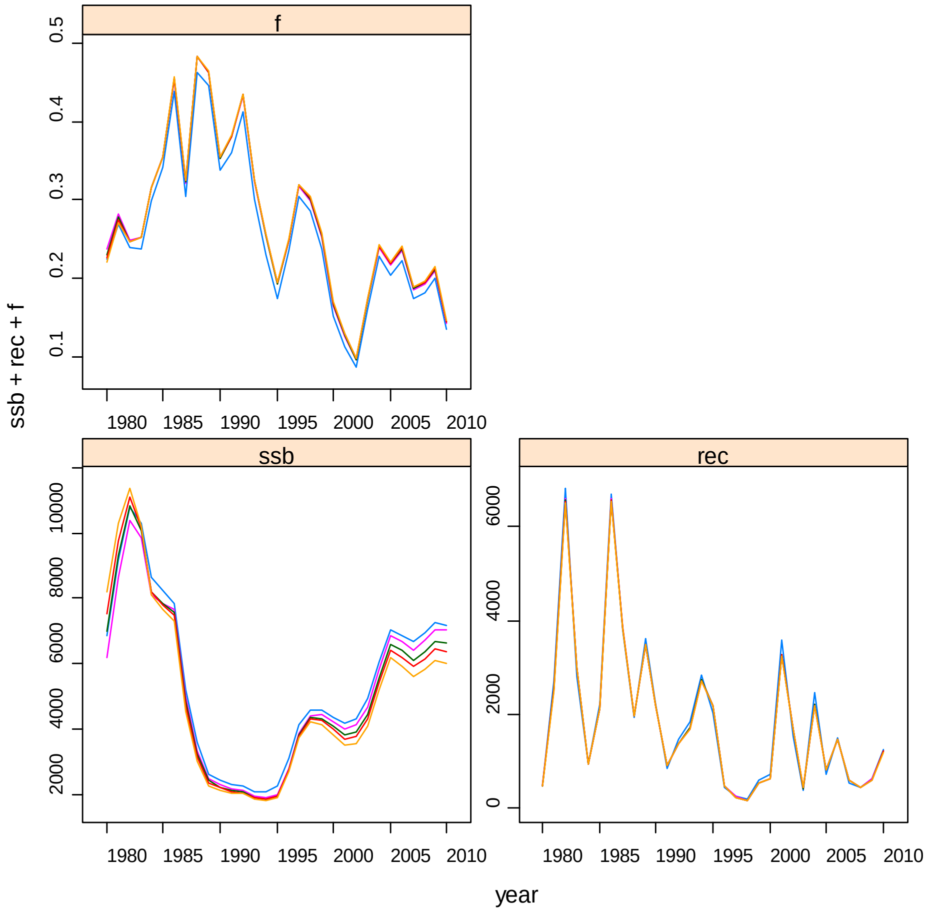


Figure 7.8.2.1. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). Sensitivity analysis to different values of growth parameter *K* (0.09–0.13).

While this analysis demonstrated the potential influence of *K* parameter in determining stock status, the workshop recommended to fix the L*max* at 190 cm and to allow the model to estimate the *K* from the input data. This option was included in a next run.

Period of recruitment

The impact on the stock status of the period of recruitment set in the model configuration was tested. Two possible model configurations were considered: recruitment was allowed in one quarter (third quarter) and recruitment was allowed in two quarters (second and third quarter) with annual variations (Figure 7.8.2.2). Although minor differences can be observed in recruitment estimates, the period of recruitment appears to have very little effect on the estimation of stock status in terms of SSB and F. As the best index of recruitment, the survey index, was indicating that recruitment probably occurs in third quarter, the workshop decided to assume that the recruitment takes place only in third quarter. Assuming that the recruitment takes place in a single quarter will also reduce the number of parameters to be estimated by the model helping to avoid an *over-parametrization of the model.*

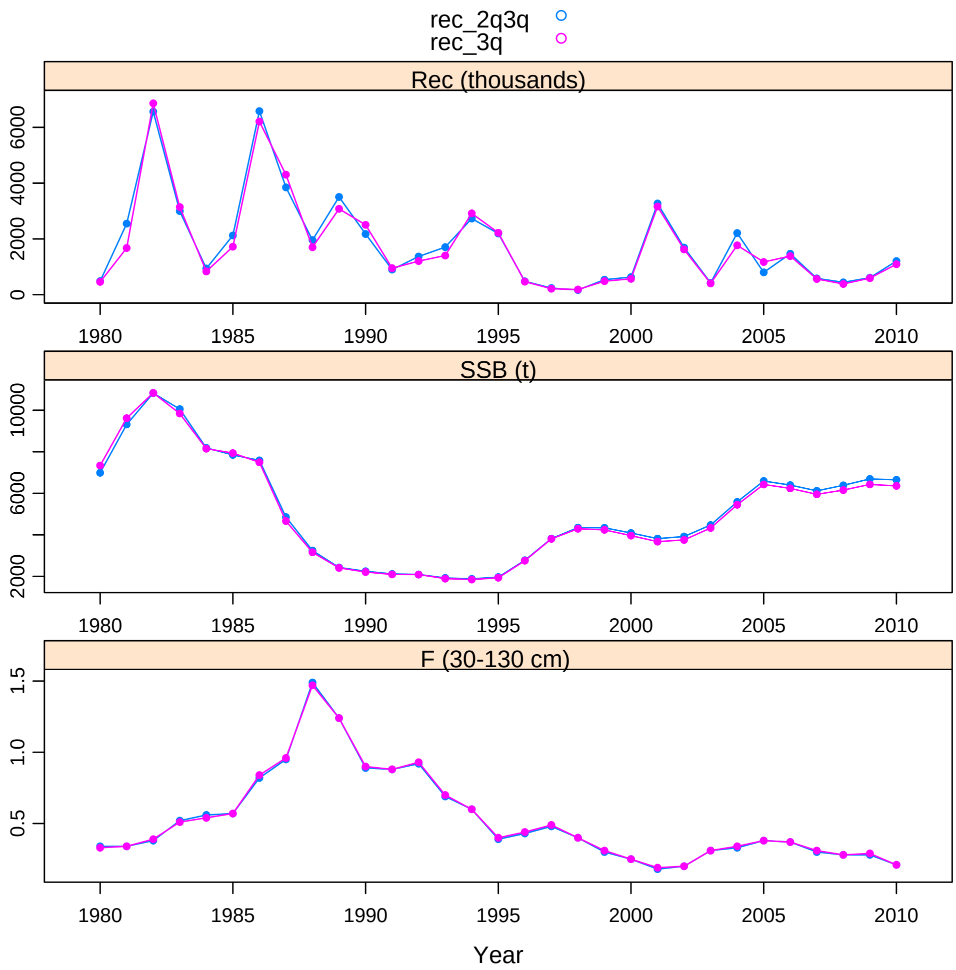


Figure 7.8.2.2. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). Sensitivity to recruitment period configuration showing the effects on estimates of stock status.

Discard information

A sensitivity analysis was carried out to explore the effect of including the available discard information on the assessment. There was discard information only for fleet SPTR8C9A. The further model configurations were tried:

- include two retention ogives for periods 1980–1999/2000–2010, externally estimated, without discard data. (run20);
- not to include discard information in the assessment. (run23);
- include two retention ogives for periods 1980–1999/2000–2010, externally estimated, and discard data in weight. (run24);

- include two retention ogives for periods 1980–1999/2000–2010, externally estimated, discard data in weight and length composition of discards. (run25).

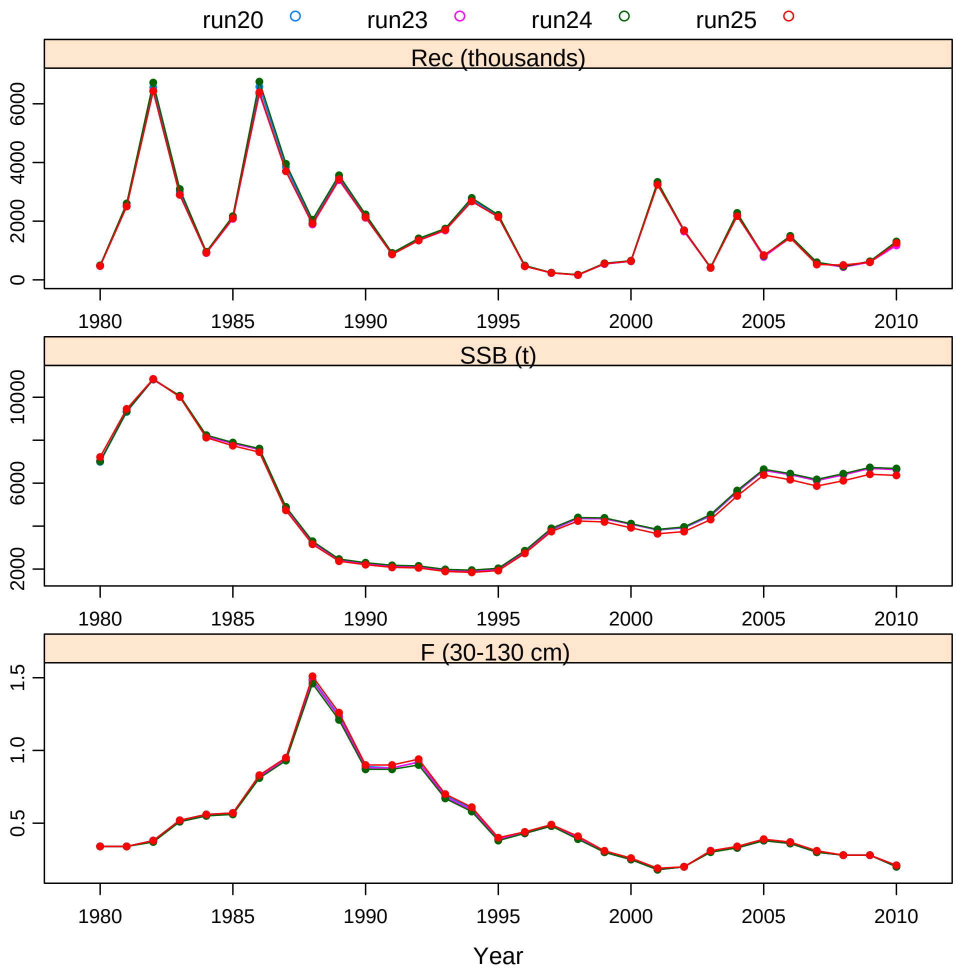


Figure 7.8.2.3. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). Sensitivity to discard configuration showing the effects on estimates of stock status.

The discard model fits were very similar among runs with discards information (run20, 24, 25). Only in run 25 the use of length composition had a slight effect on SSB affecting to the final years (1999–2010). The no inclusion of information of discards had no a significant effect on the estimates of stock status. Important differences between discard model fits and discard observations were observed in runs with discard information. In all cases model fits were lower than discard observations that could be indicating a poor discard fit.

The Benchmark decided not to include any discard information in the assessment as discard ratios are lower than the present uncertainty on landings and the available discard estimates can be considered negligible.

7.8.3 Retrospective patterns

Retrospective analysis to assess the level of bias and uncertainty in terminal year estimates of SSB, recruitment and fishing mortality was conducted for two model configurations. The two runs differ in the growth assumptions, in one configuration

K is fixed at 0.11 and LMAX is estimated by the model and in the other configuration K is estimated by the model and LMAX is fixed at 190 cm. The other model specifications are common for both runs and include the Benchmark decisions regarding recruitment period and discards information. The examination of the retrospective patterns will help to check the consistency of model fit between these two model configurations. In these analyses, it was removed up to four years of data and examined changes in SSB, F for lengths from 30 to 130 cm, and recruitment as more data are removed from the model. The retrospective analysis of first model configuration (Figures 7.8.3.1) indicates that current estimates have very low uncertainty and do not exhibit a directional pattern that would indicate a bias. However in the second configuration some uncertainty is present in terminal year point estimates of SSB (Figures 7.8.3.2). The process of estimating K by the model seems to increase the uncertainty of the fit and it could be affecting the consistency of the assessment from year to year.

The better retrospective pattern showed by the first model configuration, that supports a consistent assessment, was the reason to select this configuration as final model configuration of the assessment.

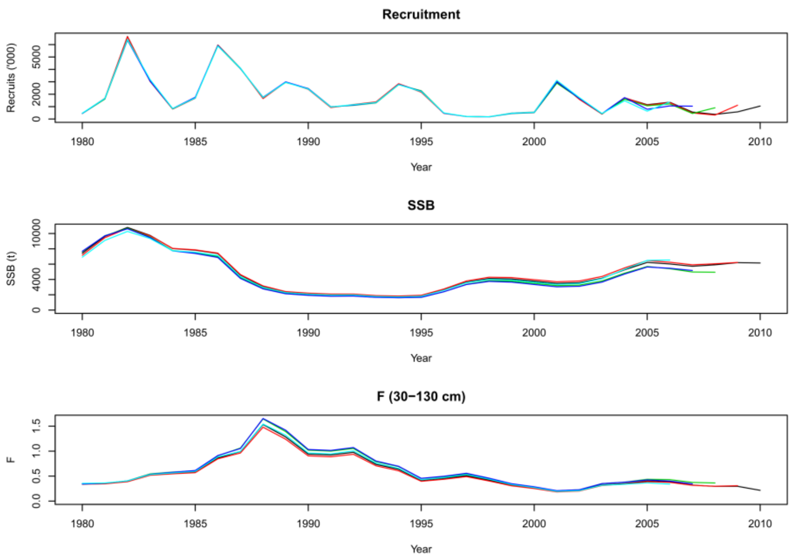


Figure 7.8.3.1. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). 5-year retrospective analysis from the model run with a *K* fixed at 0.11 and L*max* estimated by the model.

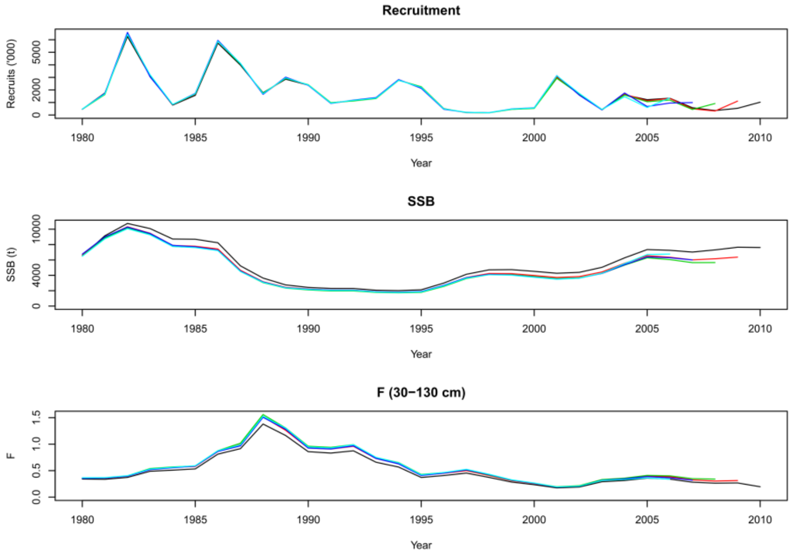


Figure 7.8.3.2. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). 5-year retrospective analysis from a model run with a *K* estimated by the model and L*max* fixed at 190 cm.

7.8.4 Evaluation of models

Based on the sensitivity analysis and retrospective pattern results it was selected a final model with the following specifications: the *K* is fixed at 0.11 and LMAX is estimated by the model, the recruitment occurs in third quarter and no discard information is included in the model. The Benchmark concluded that the final model configuration, documented in the Stock Annex, is appropriate to the assessment of white anglerfish southern stock.

7.8.5 Conclusion

The main reason to propose a new assessment model for this stock was that previous assessment methodology was quite sensitive to input settings. The new assessment model has been tested for different model assumptions and only small changes have been observed in the stock status estimates. Besides the retrospective analysis of the final configuration does not show different trends or bias indicating a consistent model fit. The inclusion of fishery-independent information, a survey index, and of biological information of the species in the assessment are indicators that the model is representative of the stock dynamics. A quite different approach from the last assessment, in methods and information used, was presented and the results of the assessment seem to be consistent and representative of population dynamics.

The Benchmark considered that the final configuration of the proposed model is suitable to be the basis of advice management.

7.9 Short-term and medium-term forecasts

7.9.1 Input data

Although no forecast was presented during the Benchmark, input data for short-time forecast were proposed:

Initial stock size: the SS3 outputs in the last assessment year.

Exploitation pattern: average of the final three assessment years with the possibility of scaling to final year F.

Intermediate year assumptions: *status quo* F.

Recruitment in the projection years: geometric mean of estimated recruitment from 1980 until the final assessment year. It could be modify in function of recruitment trends along the time-series.

Natural mortality: set to 0.2 for all ages in all years.

Growth model: von Bertalanffy model, with parameters estimated in the assessment model.

Maturity-at-length: the same ogive as in the assessment is used for all years.

Weight-at-length: the same length–weight relationship as in the assessment model.

7.9.2 Model and software

The software proposed to perform short-time forecast is an *ad hoc* R code that reproduces the population dynamics of SS3 model. The code performs deterministic forecast and takes SS3 outputs in the last assessment year. The code is available in the Benchmark SharePoint site.

7.9.3 Conclusion

The exploitation pattern for the short-term forecast should take into account trends in fishing mortality by scaling the three year average F's to the last year or not. No work was done by WKFLAT 2012 in relation to medium-term forecasts.

7.10 Biological reference points

The accepted Benchmark model constitutes a radical change in the assessment of this stock. In previous assessment the only biological reference point available was a F_{MSY} that was directly provided by ASPIC model.

The biological reference points based on yield-per-recruitment (F_{max} and $F_{0.1}$) and spawning per recruit ($F_{30\%}$ and $F_{35\%}$) were estimated based on the final model assessment (Table 7.10.1). These reference points refer to an F_{bar} from length 30 to 130 cm.

Table 7.10.1. Preliminary estimates of Biological Reference Points for white anglerfish southern stock.

	F(30-130cm)
Fmax	0.28
F0.1	0.19
F35%	0.13
F30%	0.15

In order to explore the consistency of BRPs a retrospective analysis of BRPs derived from final model configuration was carried out (Table 7.10.2). Only minimum variations in F_{MAX} and $F_{0.1}$ values were observed in the retro3 and retro4. $F_{35\%}$ and $F_{30\%}$ were the most robust BRPs.

Table 7.10.2. Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa). 5 year retrospective analysis of preliminary estimates of Biological Reference Points.

			F(30-130cm)		
BRP	retro-4	retro-3	retro-2	retro-1	Assessment
Fmax	0.27	0.27	0.28	0.28	0.28
F0.1	0.18	0.18	0.19	0.19	0.19
F35%	0.13	0.13	0.13	0.13	0.13
F30%	0.15	0.15	0.15	0.15	0.15

Benchmark did not have enough time to thoroughly evaluate the implications of the potential BRP values in the management advice. A more detailed study will be done before the selection of a MSY reference and implementation of a management target for the anglerfish fishery.

7.11 Recommendations on the procedure for assessment updates and further work

In order to improve the assessment of this stock some recommendations were made during the Benchmark. Due to the differential sexual growth, females achieve larger sizes than males, the possibility of performing the assessment by sex should be explored. The model assumption of an almost null stock–recruitment relationship should be analysed in more detail means a sensitivity analysis of steepness values assumed by the model. The implications of new BRP value in the stock management should be analysed in the next working group by a simulation study.

7.12 Implications for management (plans)

Lophius piscatorius is managed together with *L. budegassa* by a common TAC so the joint status of these species should be taken into account when formulating management advice.

It should be noted that anglerfish are essentially caught in mixed fisheries. Hence, management measures applied to this species may have implications for other stocks and vice versa. Besides it is necessary to take into account that a recovery plan for hake and *Nephrops* is taking place in the same area.

7.13 References

BIOSDEF. 1998. Biological studies of demersal fish. Ref.: EU, DG XIV, Study Contract 95/038.

Costas, G., Fariña, C., Sampedro, P., Landa, J., Morlán, R., Azevedo, M., and Duarte, R. 2007. CPUE standardization of artisanal gillnet fishery targeting anglerfish in Northwest of Iberian Peninsula. Working Document in WGHMM2009 ICES CM/2007 K:27.

Duarte, R., Azevedo, M. Landa, J., and Pereda, P. 2001. Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. Fisheries Research, 51: 2–3 349–361.

ICES. 2010. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2010, Bilbao, Spain. ICES CM 2010/ACOM:11. 571 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM). ICES CM 2011/ACOM:11. 625 pp.

Landa, J., Duarte, R., and Quincoces, I. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. ICES Journal of Marine Science, 65: 72–80.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. International North Pacific Fisheries Commission Bulletin (50): 259–277.

Methot, R.D. 2011. User Manual for Stock Synthesi, Model Version 3.23b. NOAA Fisheries Service, Seattle. 167 pp.

Prager, M.H. 1994. A suite of extension to a non-equilibrium surplus-production model. Fish. Bull. 92: 374–389.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola 1807 y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD. Thesis. Departamento de Zoología y Dinámica Celular Animal. Universidad del País Vasco, Spain. 258 pp.

8 Anglerfish (*L. budegassa*) (Divisions VIIIc and IXa)

8.1 Current assessment and issues with data and assessment

In WGHMM2011 the ASPIC (Prager, 1994; Prager, 2004) model, which implements the Schaeffer population growth model, was used for the assessment of the anglerfish (*L. budegassa*) Divisions VIIIc and IXa stock (ICES, 2011). Runs were performed conditioning on yield rather than on effort. The model options were the same ones used in previous assessments.

Input data

The input data, comprising the lpues for the Portuguese trawl crustacean fleet (PT-TRC9a), the lpues for the Portuguese trawl fish fleet (PT-TRF9a) and the landings. The lpue series of PT-TRC9a was introduced as cpue and the PT-TRF9a as a biomass index.

Assessment results

The correlation coefficient between input fleets is high (0.811) but the r square between observed and fitted cpue values are negative, -0.436 for PT-TRC9a and 0.549 for PT-TRF9a. B_{2011}/B_{MSY} and F_{2010}/F_{MSY} have respectively -1.34% and 9.04% of bias and both have around 25% relative inter-quartile ranges. Biomass in 2011 is estimated to be 91% of B_{MSY} with 95% bias-corrected confidence interval between 59% and 124%. Fishing mortality in 2010 is estimated to be 0.39 times F_{MSY} with 95% bias-corrected confidence interval between 0.27 and 0.61 times F_{MSY}. MSY is estimated to be 2515 t with 95% CI from 2507 t to 2521 t. This parameter shows no bias and a negligible inter-quartile range.

Trends in relative biomass indicate a decrease since the late eighties with a slight recovery in the late nineties and in recent years. Fishing mortality remained at high levels between late eighties and late nineties, dropping after that. In 2010, biomass is estimated to be below B_{MSY} and fishing mortality is estimated to be below F_{MSY}.

Comparison between the 2010 and 2011 assessments show that both assessments are very consistent for the common period.

Comments on the assessment

For *L. budegassa* the correlation coefficient between input fleets is high but the *r* square between observed and fitted cpue values are negative, which is a matter of concern.

The assessment is based on information from the commercial fisheries. There is no fisheries-independent information. The only commercial tuning fleets used are Portuguese, whereas most landings are from Spanish fleets. This may result in a relatively poor fit of the model to the input abundance data, contributing to uncertainty in the assessment results. The assessment also displays a pattern of underestimation of fishing mortality and overestimation of biomass.

Data problems

Anglerfish is not a main target species of the surveys, by other words, surveys are not designed for anglerfish and is need to check whether the survey signal is clear enough to be incorporated into the assessment as tuning-series.

Spanish discards data are only available for one of the main fishing fleets: Spanish Trawl (1994–2009). The discards time-series has some missing years (1995, 1996, 1998, 2001 and 2002). The length compositions of discards have a large uncertainty.

Portuguese data shows very few discards occurrences and when existed very few individuals are rejected.

The ageing criteria proposed in 2007 was rejected at the assessment working group (WGHMM) due to its inconsistencies (ICES, 2007). A growth model is not available.

An updated and reliable maturity model is needed.

8.2 Compilation of available data

8.2.1 Catch and landings data

Total landings of *L. budegassa* by country and gear for the period 1978–2010, as estimated by the Working Group, are given in Table 8.2.1.1 No revision of catches was done for this meeting.

Spanish trawl discards estimates of *L. budegassa* in weight and associated coefficient of variation (CV) were available at the WGHMM 2011 (ICES, 2011). An increase in estimated discards rate was observed from 2004 to 2006, Spanish discards decreased to negligible values in 2007 and 2008 but since 2009 increased again, being 61 t in 2010. The maximum value of the time-series occurred in 2006 with 92 t. The coefficient of variation for weight data varied from 24% to 99%.

Santos and Pérez (2012) (WKFLAT 2012 WD06, see Annex 4)) concluded: On-board sorting process for anglerfish species in Spanish North Atlantic (ICES Divisions VIIIc and IXa) coastal fisheries is reviewed. The length effect analysis across the years sampled revelled an increasing trend in length of first retention (L50) since 2000, the year when Minimum Landing Weight (MLW 500 g) were implemented. Specific differences in the length-based sorting process were found, being the less valuable white angler discarded at larger lengths than the black species; further, the analysis found that discard decision is taken at narrower length range for black angler. These results indicate that fishers recognize angler species even at low length sizes, conditioning the degree of adoption of MLW with regards to species relative market value.

Fernandes and Prista (2012) (WKFLAT 2012 WD07, see Annex 4) compile the information available on the discards of anglerfish *Lophius piscatorius* and blackbellied angler *Lophius budegassa* produced by Portuguese vessels operating with bottom otter trawl feet (OTB) in the Portuguese reaches of ICES Division IXa. The data were collected under the Portuguese on-board sampling programme (EU DCR/DCF-NP) between 2004 and 2010. A brief description of the on-board sampling programme executed in 2004–2010 along with details on the estimation algorithms and data quality assurance procedures is in WKFLAT 2012 WD07. Results on species' annual frequency of occurrence, total discard estimates and length composition are provided for two bottom otter trawl fisheries: the crustacean fishery (OTB_CRU) and the demersal fish fishery (OTB_DEF). Discards of anglerfish and blackbellied angler by the OTB fleet are reduced but the low frequency of occurrence in number and weight in discard samples rules out estimates at fleet level. Preliminary information on discards of other Portuguese fleets operating in this geographical area is also provided.

Both WDs (i.e. WKFLAT 2012 WD06 and WKFLAT 2012 WD07) confirm the conclusion from the last WGHMM meeting (ICES, 2011) that estimation of discards at a fleet level is not possible for the moment. *L. budegassa* discards seems to be negligible.

Table 8.2.1.1. ANGLERFISH (*L. budegassa*) - Divisions VIIIc and IXa.
Tonnes landed by the main fishing fleets for 1978-2010 as determined by the Working Group.

	Div. VIIIc			Div. IXa				Div. VIIIc+IXa
	SPAIN			SPAIN	PORTUGAL			
Year	Trawl	Gillnet	TOTAL	Trawl	Trawl	Artisanal	TOTAL	TOTAL
1978	n/a	n/a	n/a	248	n/a	107	355	355
1979	n/a	n/a	n/a	306	n/a	210	516	516
1980	1203	207	1409	385	n/a	315	700	2110
1981	1159	309	1468	505	n/a	327	832	2300
1982	827	413	1240	841	n/a	288	1129	2369
1983	1064	188	1252	699	n/a	428	1127	2379
1984	514	176	690	558	223	458	1239	1929
1985	366	123	489	437	254	653	1344	1833
1986	553	585	1138	379	200	847	1425	2563
1987	1094	888	1982	813	232	804	1849	3832
1988	1058	1010	2068	684	188	760	1632	3700
1989	648	351	999	764	272	542	1579	2578
1990	491	142	633	689	387	625	1701	2334
1991	503	76	579	559	309	716	1584	2163
1992	451	57	508	485	287	832	1603	2111
1993	516	292	809	627	196	596	1418	2227
1994	542	201	743	475	79	283	837	1580
1995	913	104	1017	615	68	131	814	1831
1996	840	105	945	342	133	210	684	1629
1997	800	198	998	524	81	210	815	1813
1998	748	148	896	681	181	332	1194	2089
1999	571	127	698	671	110	406	1187	1885
2000	441	73	514	377	142	336	855	1369
2001	383	69	452	190	101	269	560	1013
2002	173	74	248	234	75	213	522	770
2003	279	49	329	305	68	224	597	926
2004	251	120	371	285	50	267	603	973
2005	273	97	370	283	31	214	527	897
2006	323	124	447	541	39	121	701	1148
2007	372	68	440	684	66	111	861	1301
2008	386	70	456	336	40	119	495	951
2009	301	148	449	172	34	114	320	769
2010	319	81	399	197	70	84	351	751

n/a: not available

8.2.2 Biological data

Landa *et al*. (2012) (WKFLAT 2012 WD09) studied the reproduction of black anglerfish (*Lophius budegassa*) from samples collected during five years, from January 2006 to December 2010, in Celtic Sea, West and South of Ireland (ICES Division VIIb–k) and Northern Spanish Atlantic waters (ICES Division VIIIc–IXa). A total of 1167 specimens (4–99 cm) were sampled. The sex ratio, the spawning period and the maturity ogives by length were studied. The sex ratio in both areas studied was close to 1:1 (male:female), 1:1.22 (54.90% of females) in ICES Division VIIb–k, and 1:1.01 (50.30% of females) in ICES Division VIIIc–IXa. The L50 values were: in ICES Division VIIb–k: 52.42 cm for combined sexes, 36.77 cm for males and 62.45 cm for females; in ICES Division VIIIc–IXa: 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.

8.2.3 Survey tuning data

Along time, several surveys were conducted in the ICES Division VIIIc–IXa, Table 8.2.3.1 summarizes the survey-series and respective data available for this benchmark:

Table 8.2.3.1. ANGLERFISH (*L. budegassa*) - Divisions VIIIc and Ixa: Surveys series summary.

Survey name	Season	Acronym	Data	Years missing	Data Available
Portuguese winter groundfish survey	1st Quater	PGFS-WIBTS-Q1	2005-2008		Stock indices and length frequencies
Portuguese crustacean survey	2nd Quarter	UWTV (FU 28-29), PT CTS, PtcruS	1997-2010		Stock indices and length frequencies
Portuguese summer groundfish survey	3rd Quarter		1990-2001	1994, 1996	Stock indices and length frequencies
Portuguese autunm groundfish survey	4th Quarter	PtGFS-WIBTS-Q4	1989-2010		Stock indices and length frequencies
Portuguese deepwater fish survey			1997-2002		Raw data
Spanish groundfish survey	4th Quarter	SpGFS-WIBTS-Q4	1983-2010		Stock indices and length frequencies

Both, SpGFS-WIBTS-Q4 and PtGFS-WIBTS-Q4, have been regularly provided to be used in the assessment. In this meeting the used of others surveys was attempted. Surveys were not designed to anglerfish therefore generally a very small amount of anglerfish is caught in the surveys, therefore the use of surveys indices is difficult and at the end were not considered to be representative of stock abundance.

8.2.4 Commercial tuning data

Six commercial lpue series were available to be used as abundance indices. New information about the tuning fleet SPCORTR8C was provided to the Benchmark. Morlán *et al*. (2012) (WKFLAT 2012 WD05) compiled and updated from the IEO fishery database the historical data of the A Coruña Trawl Fleet, operating in ICES Division VIIIc. The data refer to quarterly landings, effort and length composition of both anglerfish species. From 1982 to 1985 new data were presented and for the time period 1986–1993 the time-scale of the information was reduced from annual to quarter. Based on the available information the lpue is computed and can be used as abundance index in the assessment of these both stocks. Previous anglerfish stock assessments have used only the annual lpue of A Coruña Trawl Fleet for *L. piscatorius* assessment. This improved abundance index could be included in the configuration of upcoming stock assessment.

No new series or others updates were provided to the Benchmark, the data available are presented in Table 8.2.4.1.

Table 8.2.4.1. ANGLERFISH (*L. budegassa*) - Divisions VIIIc and Ixa: Commercial series summary.

Series name	Acronym	Other Acronym	Data	Years missing	Data Available
Portuguese trawlers targeting crustacean	PT-TRC9a	PT.crust.tr	1989-2010		LPUE and length frequencies
Portuguese trawlers targeting fish	PT-TRF9a	PT.fish.tr	1989-2010		LPUE and length frequencies
Coruña trawlers	SP-CORUTR8c	SPCORTR8c	1982-2010		LPUE and length frequencies
Avilés trawlers	SP-AVTR8c	SPAVITR8c	1986-2003		LPUE and length frequencies
Santander trawlers	SP-SANTR8c	SPSANTR8c	1986-2007		LPUE and length frequencies
Cedeira gillnet	SP-CEDGNS8c	SPCEDGN8c	1999-2010		LPUE and length frequencies

Both, PT-TRC9a and PT-TRF9a, were the only series used in the last assessment accepted. At this meeting, the use of other commercial series was attempted. The selection of abundance indices to be used in the assessment was carried out using two main criteria: their representativeness (in terms of proportion of total landings) and the quality of the data.

8.2.5 Industry/stakeholder data inputs

Part of the information regarding to tuning fleets was provided by Ports Authorities and Fishermen's Associations.

8.2.6 Environmental data

No environmental data were presented to WKFLAT, and therefore not used in the assessment.

8.3 Stock identity, distribution and migration issues

Some concerns about the structure of this stock structure were examined during the Benchmark (See Section 2 of this report).

8.4 Influence of the fishery on the stock dynamic

Not addressed at this meeting.

8.5 Influence of environmental drivers on the stock dynamic

Not addressed at this meeting.

8.6 Role of multispecies interactions

Not addressed at this meeting.

8.6.1 Trophic interactions

Not addressed at this meeting.

8.6.2 Fishery interactions

Not addressed at this meeting.

8.7 Impacts of the fishery on the ecosystem

Not addressed at this meeting.

8.8 Stock assessment methods

Three models were attempted during this meeting: a Bayesian state–space surplus production model, the Stock Synthesis (SS) model and the ASPIC. The results of the two first models shows some potential (specially the SS model) but more work is need to improve the fit of these models. The inclusion of new series in the current assessment with ASPIC was tested. A final run of the ASPIC which includes the "A Coruña" series was accepted.

8.8.1 Preliminary assessment of *L. budegassa* in ICES Areas VIIIc and IXa using a Bayesian state–space surplus production model

The purpose of this write-up is to detail analyses conducted for comparative purposes only.

Data

Details of the data provided are given in Table 8.8.1.1 and the data are plotted in Figure 8.8.1.1.

Table 8.8.1.1. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Data sources and description. Note that the series included here may be different from those used in the stock synthesis and ASPIC model runs.**

Dataset	Acronymn	Data source	Years	Years missing	Units
Landings	Landings	Commercial	1980—2010	—	Tonnes
Portuguese crustacean trawl fleet	PT.crust.tr	Commercial LPUE	1989—2010	—	$kg.hr^{-1}$
Portuguese fish trawl fleet	PT.fish.tr	Commercial LPUE	1989—2010	—	$kg.hr^{-1}$
Spanish Coruña trawl fleet	SPCORT8c	Commercial LPUE	1982—2010	—	$kg.hr^{-1}$
Portuguese crustacean survey	PtcruS	Survey CPUE	1997—2010	2004	$kg.hr^{-1}$

Model description

The model formulation largely follows the state–space model of Meyer and Millar (1999).

Process model

The biomass dynamics are given by a difference form of a Schaefer biomass dynamic model:

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

where B_t is the biomass at time t, r is the intrinsic rate of population growth, K is the carrying capacity, and C_t is the catch, assumed known exactly. To assist the estimation the biomass is scaled by the carrying capacity, denoted $P_t = \frac{B_t}{K}$. Lognormal error structure is assumed giving the scaled biomass dynamics model:

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)e^{u_t}$$

where the logarithm of process deviations are assumed normal $u_t \sim N(0, \sigma_u^2)$; σ_u^2 is the process error variance.

The starting year biomass is given by $B_{1980} = aK$, where a is the proportion of the carrying capacity in 1980.

Measurement model

The biomass dynamics process is related to the observations on the indices through the measurement error equation:

$$I_{j,t} = q_j P_t K e^{\varepsilon_{j,t}}$$

where $I_{j,t}$ is the value of abundance index j in year t, q_j is index-specific catchability, $B_t = P_t K$, and the measurement errors are assumed lognormally distributed with $\varepsilon_{j,t} \sim N(0, \sigma_{\varepsilon,j}^2)$; $\sigma_{\varepsilon,j}^2$ is the index-specific measurement error variance.

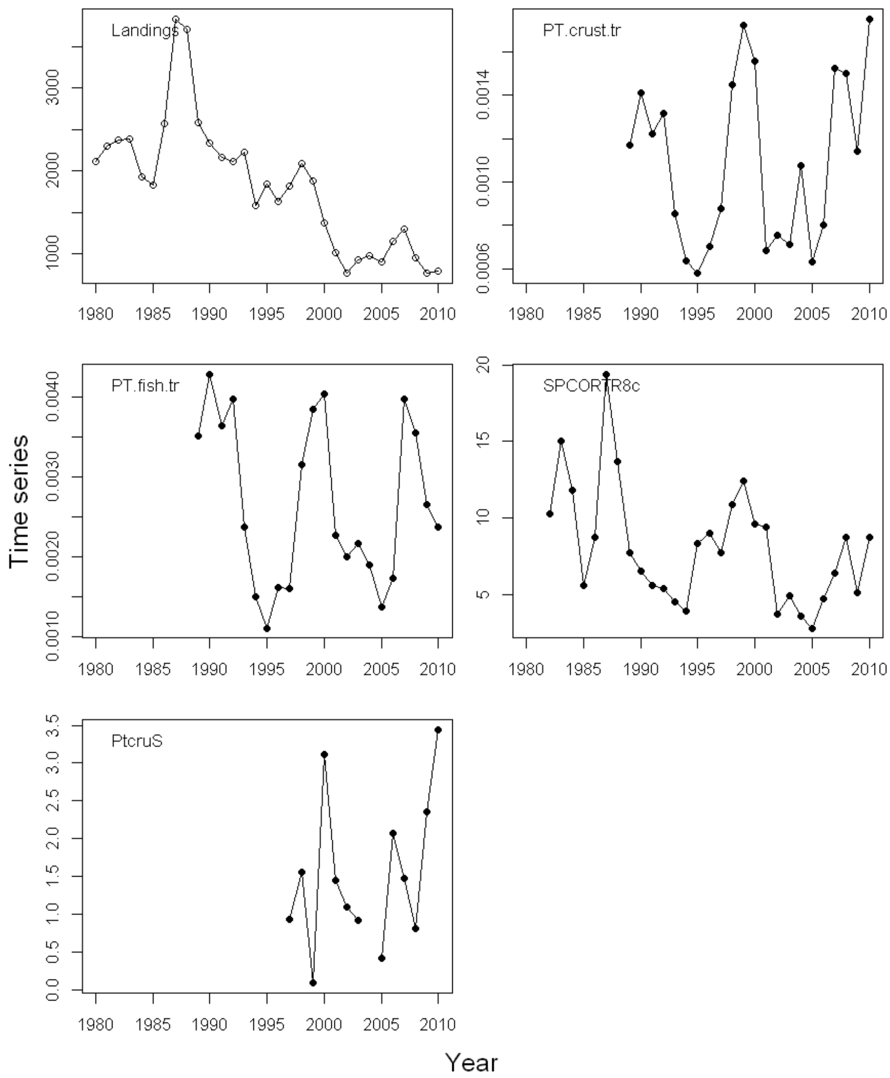


Figure 8.8.1.1. *Lophius budegassa* in ICES Divisions VIIIc and IXa. Data used in assessment. Dataset names and units are given in full in Table 8.8.1.1.

Estimation

Estimation was in a Bayesian framework with Markov Chain Monte Carlo (MCMC) sampling using WinBUGS (Spiegelhalter *et al.*, 1999). Prior distributions are given in Table 8.8.1.2. Note that prior distribution assumptions are important. In these preliminary runs we have assumed largely uninformative priors to see what information is present in the data to update these priors. Sensitivity to assumed priors would be required in further investigations.

Table 8.8.1.2. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Prior distributions on parameters.**

Parameter	Symbol	Prior distribution	Notes
Intrinsic rate of population growth	r	$\mathrm{Uniform}(0.001, 3.0)$	
Carrying capacity	K	$\mathrm{Uniform}(\max(C), 10 \times \sum_{t=1980}^{2010} C_t)$	From the maximum catch to ten times the cumulative catch across all years
Catchabilities	$\log(q_j)$	$\mathrm{Uniform}(-15.0, 0.0)$	Uniformly distributed on log-scale
Process error variance	$1/\sigma_u^2$	$\mathrm{Gamma}(\mathrm{shape} = 0.001, \mathrm{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Measurement error variances	$1/\sigma_{\varepsilon,j}^2$	$\mathrm{Gamma}(\mathrm{shape} = 0.001, \mathrm{rate} = 0.001)$	Gamma distributed on inverse variance (precision) scale
Proportion of K in 1980	a	$\mathrm{Uniform}(0.01, 2.0)$	

Following a first run with the prior distributions given in Table 8.8.1.2 (run 1), an additional run was conducted by assuming a fixed process error variance $\sigma_u^2 = 0.1^2$ (run 2).

Results

Run 1

Fits to the time-series and parameter estimates are given in Figures (8.8.1.2–8.8.1.3). The model converged well but points to note are:

- Potential overfitting to the Portuguese crustacean fishery lpue series;
- Large variability of the estimated biomass series (changes considerably from year to year);
- Unrealistically high harvest ratio around 1995.

These observations on the quality of the fit are reflected in the parameter estimates (Figure 8.8.1.3). These show:

- Large estimated process error variability (standard error scale - σ_u in Figure 8.8.1.3);
- High *r* value;
- Low measurement error variances on the Portuguese crustacean and trawl lpue series (sigmaI1 and sigmaI2 in Figure 8.8.1.3, respectively).

In a discussion on the quality of run 1, it was suggested that the process error variances may be too high, perhaps over-fitting the first two series, and resulting in an unrealistically flexible biomass series and high *r*. The effect of the magnitude of the process error variance was investigated using a fixed value of $\sigma_u^2 = 0.1^2$ in run 2.

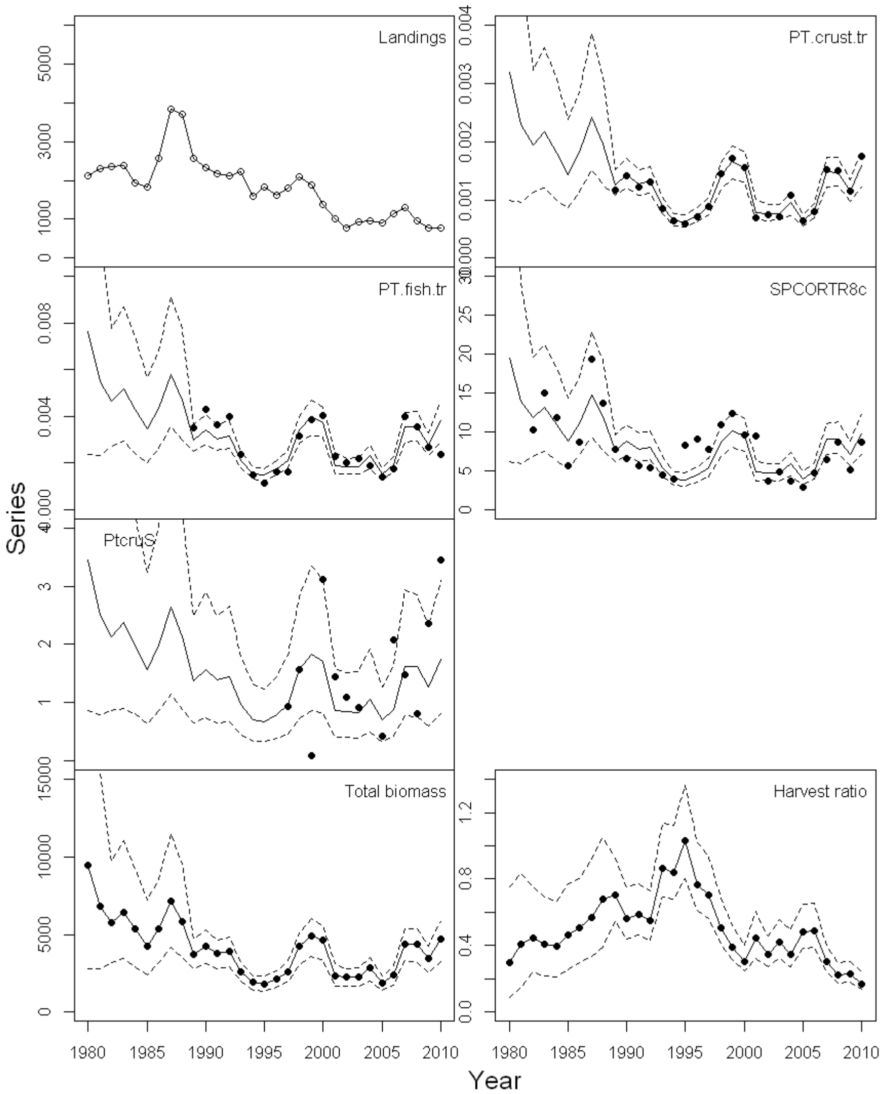


Figure 8.8.1.2. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Fits to each series in run 1. Corresponding posterior parameter distributions are plotted in Figure 8.8.1.3.**

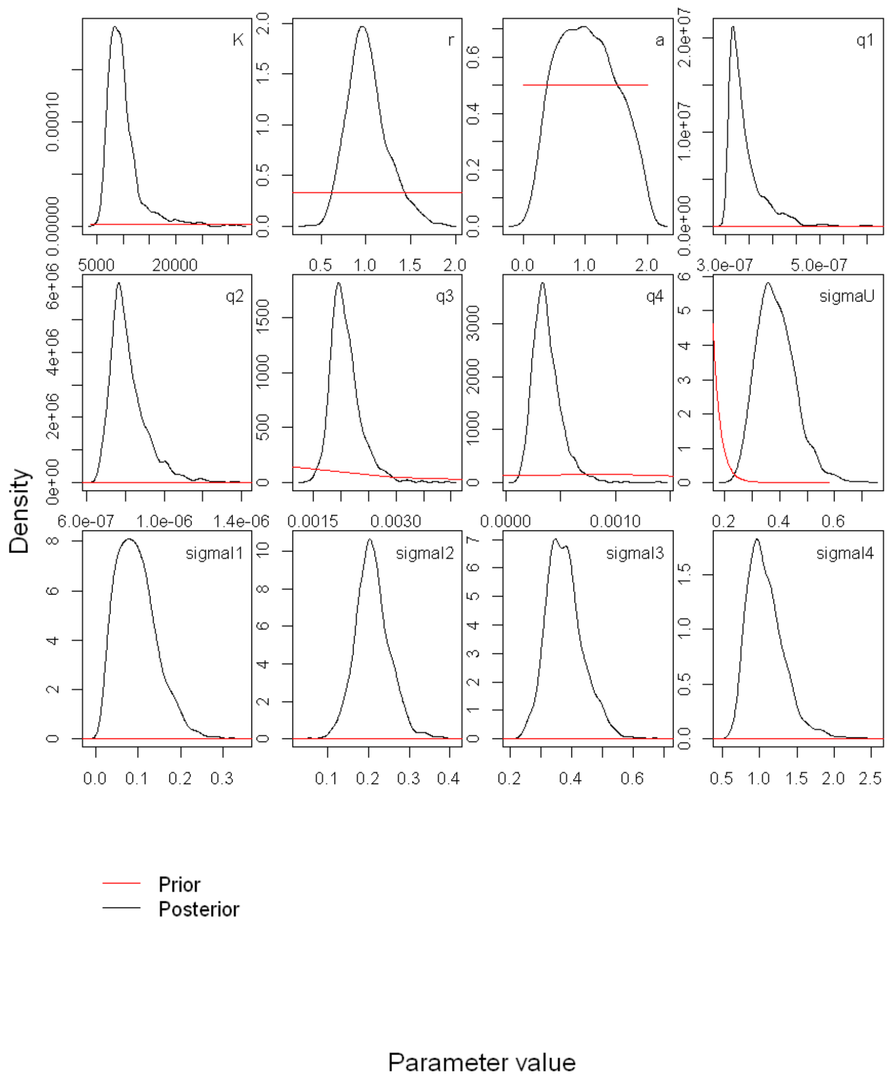


Figure 8.8.1.3. *Lophius budegassa* in ICES Divisions VIIIc and IXa. Parameter distributions from run 1. Posterior and prior distributions are plotted using black and red lines, respectively.

Run 2

Run 2 took a considerably longer time for the MCMC chains to converge, particularly for the carrying capacity parameter. The resultant fits are shown in Figures 8.8.1.4–8.8.1.5. Fixing the process error variance results in:

- Increased measurement error variances on all series, particularly the fits to the Portuguese crustacean and trawl lpue series. This removed previous evidence of overfitting;
- More stable estimated total biomass series (Figure 8.8.1.4);
- A lower estimate of the intrinsic population growth rate (mean of 0.56);
- The carrying capacity parameter having a well defined mode but occasionally sampling very large values (Figure 8.8.1.5). These weigh heavily on the mean. The model could potentially be run for longer to address this or median summary values taken as more robust estimates;
- More reasonable harvest ratios (Figure 8.8.1.4).

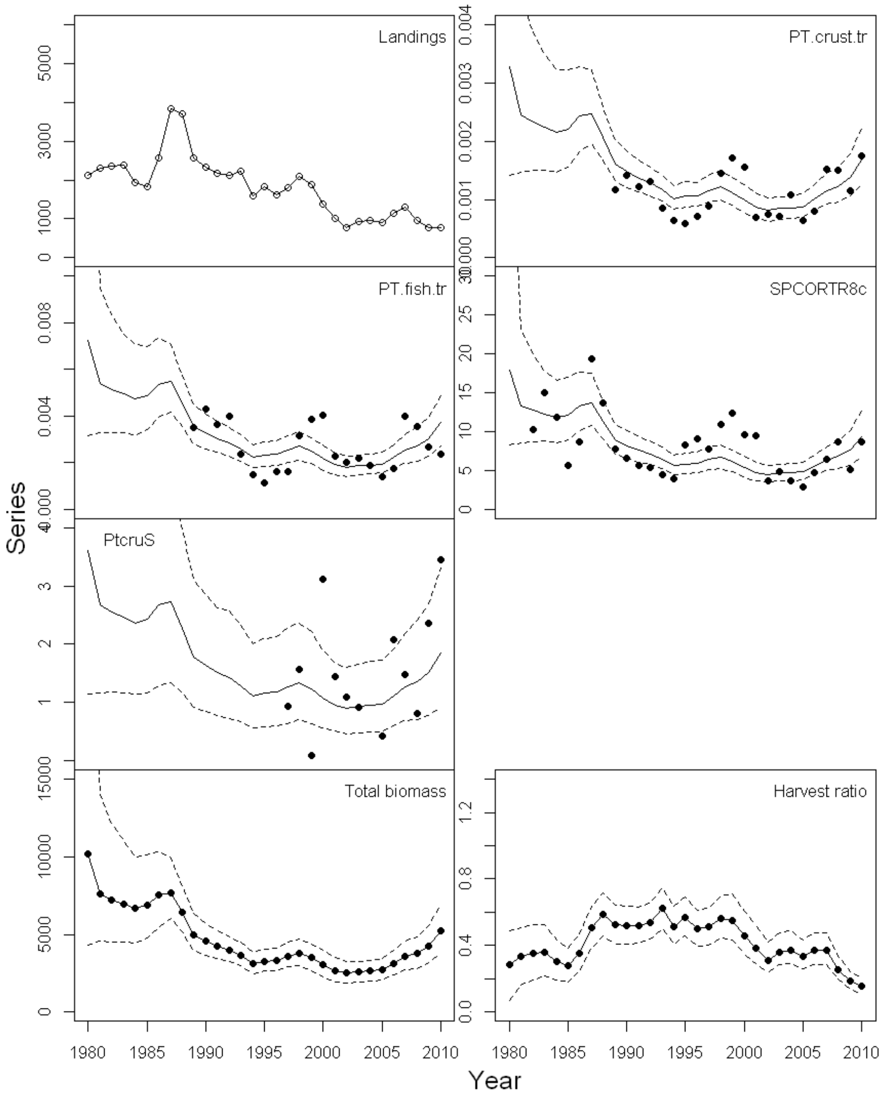


Figure 8.8.1.4. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Fits to each series in run 2. Corresponding posterior parameter distributions are plotted in Figure 8.8.1.5.**

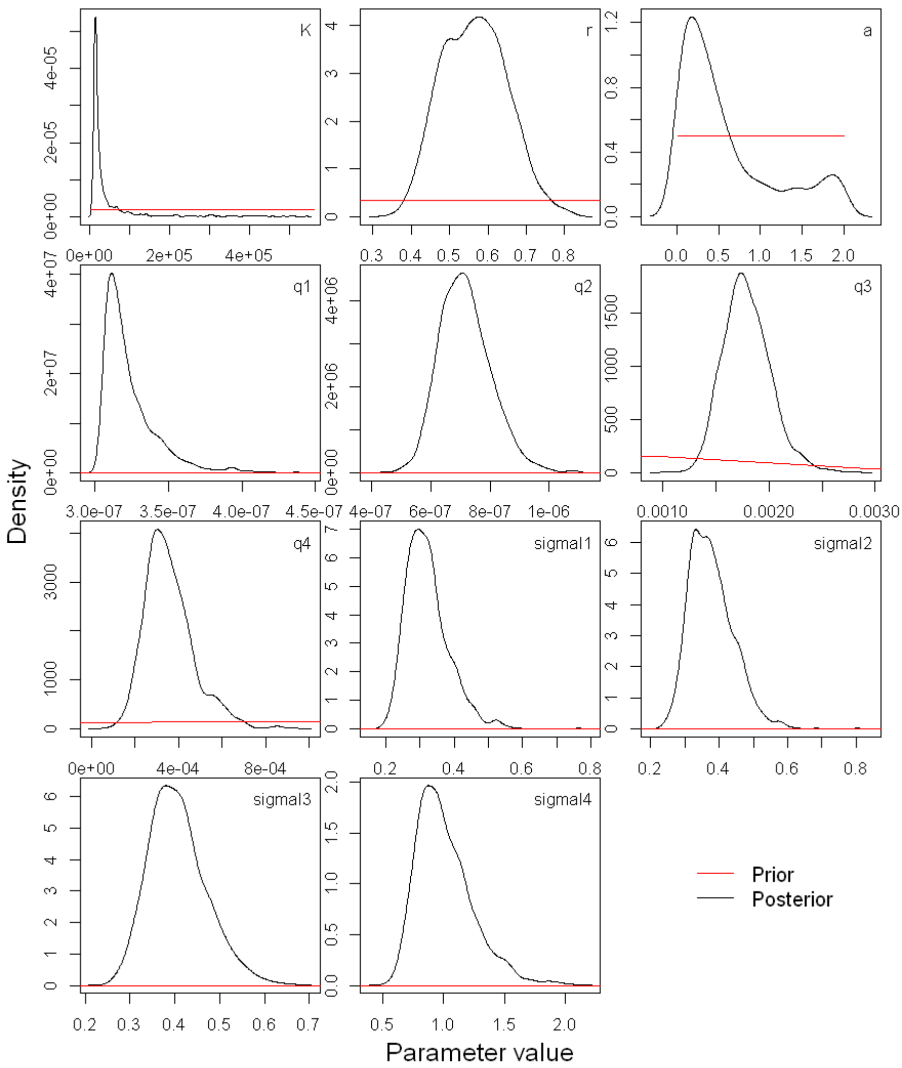


Figure 8.8.1.5. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Parameter distributions from run 2. Posterior and prior distributions are plotted using black and red lines, respectively.**

8.8.2 Configuration of stock synthesis for *L. budegassa* in ICES Areas VIIIc and IXa

The stock synthesis (SS) assessment approach can be configured to assess stocks with data such as are available for *L. budegassa* in ICES Divisions VIIIc and IXa. Here we describe three progressively more complex SS configurations to be considered for this stock. The first configuration is an age-structured production model that is quite similar to the non-age-structured ASPIC model. The second configuration adds process error by allowing for annual changes in recruitment of young fish into the stock. The third configuration adds length composition data in order to allow the SS model to estimate selection curves that differ from the asserted knife-edge selection that is specified in the first two SS configurations and is inherent to the biomass-dynamics ASPIC.

SS can be configured to operate as an age-structured production model that bears much similarity to the ASPIC model used in the current assessment. The difference is that the SS age-structured production model has an internal age structure so that natural mortality rate and growth rates that produce body weights-at-age are needed.

In the three SS configurations considered here, the natural mortality rate was set at 0.2, and the growth parameters were set such that *L. budegassa* would first appear at age 0.5 years old at a size of 9 cm, and would then grow according to a *K* of 0.08 yr^{-1} towards a mean $L_{infinity}$ of 132 cm. At each age, there was a specified variation of size-at-age with CV = 20%.

When an age-structured model like SS does not have size and/or age composition data, the selection pattern for each fishery and tuning index must be asserted. Based on patterns observed in more data rich assessments of other *Lophius* stocks, the selection is set as knife-edge at age 3 in the SS model runs for the first and second configuration. We note however, that other *Lophius* stocks and the size composition data for *L. budegassa* in ICES Divisions VIIIc and IXa are indicative of strongly dome-shaped selection and not the asserted knife-edged, asymptotic selection used in the first and second configuration.

The first and second SS configurations used only the commercial tuning indices that have been used in ASPIC model runs. These are from the Pt crustacean trawl fishery, the Pt groundfish trawl fishery, and the Spanish Corona trawl fishery. The third SS configuration, which allows foe estimation of selection patterns, also includes two fishery-independent surveys, the Spanish groundfish trawl survey at the northern portion of this stock and the Pt crustacean trawl survey at the southern extreme of this stock.

Each potential tuning index has an associated observation error. While the initial calculation of these indices may include some estimate of the observation error, these estimates do not include any process error associated with the calibration of the indices. Therefore, the SS configurations set a baseline observation error level of 0.1 (as the se of the observations on a logarithmic scale) and the model was allowed to estimate the degree of additional observation error necessary to approximate the root mean squared error of the difference between model estimates and each index.

The catch time-series starts in 1980 and shows no dramatic trend during the early 1980s. This leaves some ambiguity regarding the level of catch that probably was occurring prior to 1980, hence the degree to which the stock abundance in 1980 had been decreased due to catch that occurred prior to 1980. In the SS model runs, this was accommodated by allowing the model to estimate a level of historical average F to apply prior to 1980. This initial_F parameter was constrained to be between 0 and 0.5, to have an initial value of 0.1, and had a prior of 0.2 with a normal error of 0.5.

Configuration #1 – like ASPIC

The result of this model run is very similar to the ASPIC run that used only the three commercial tuning indices.

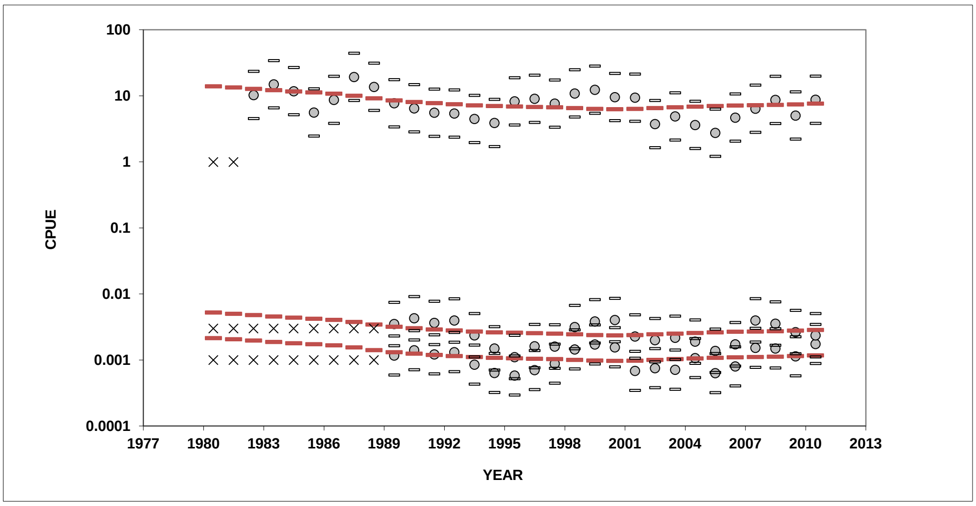


Figure 8.8.2.1. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Configuration #1: Fit to the three tuning indices in log scale. The Sp_Coruna is on top and the two Pt fishery fleets is shown at the bottom. The "X" are values not included in the model fitting and exist only to enable calculation of the expected value for the index.**

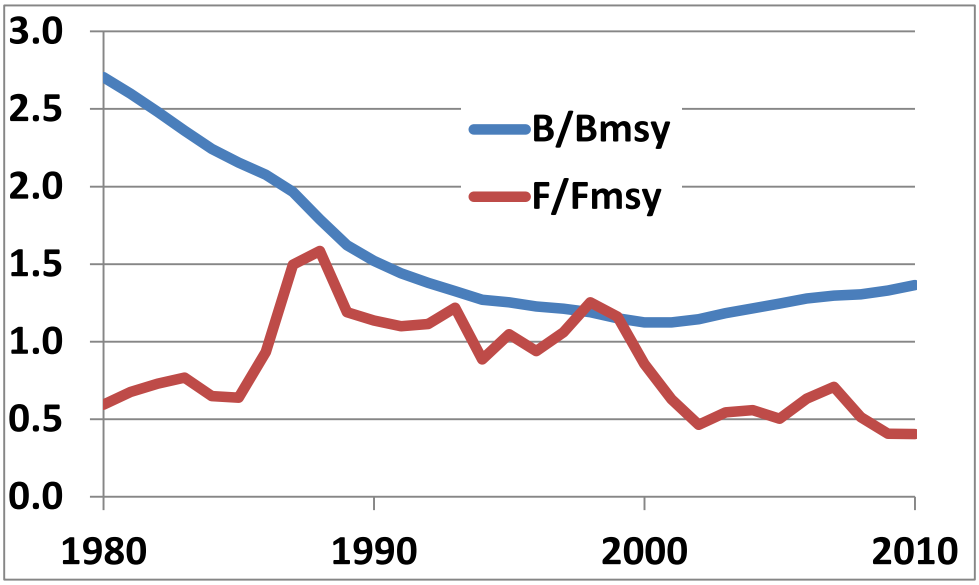


Figure 8.8.2.2. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Time-series of B/Bmsy and F/Fmsy from configuration #1. These results are similar to those obtained from ASPIC.**

Table 8.8.2.1. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Results for key model parameters and derived quantities from configuration #1 (SigmaR=0.0) and two runs for configuration #2. Standard errors are not presented for the sigma%=0.50 run because several parameters hit bounds.**

Quantity	Estimate with SigmaR=0.0	Se(estimate)	Estimate with sigmaR=0.40	Se(estimate)	Estimate with sigmaR=0.50
Pt crustacean (se)	0.34	0.051	0.33	0.050	0.17
Pt_trawl (se)	0.38	0.055	0.37	0.055	0.10 (bound)
Sp_Coruna	0.41	0.053	0.41	0.052	0.40
Initial_F	0.0046	0.018	0.0081	0.038	0.5 (bound)
steepness	0.61	0.19	0.73	0.29	0.999 (bound)
sigmaR	Fixed at 0.0	NA	Fixed at 0.40	NA	Fixed at 0.50
Unfished SSB (Bzero)	45476	8757	44808	10333	61139
SSB_at_MSY	15922	5309	14077	6517	13584
F_MSY	0.076	0.031	0.097	0.052	0.163
MSY	1437	249.	1667 mt	379.	2925 mt
Bmsy/Bzero	0.35	NA	0.31	NA	0.22
B/Bmsy_1980	2.71	0.77	2.90	1.75	0.15
B/Bmsy_1990	1.52	0.31	1.56	0.78	0.02
B/Bmsy_2000	1.12	0.31	1.15	0.62	0.02
B/Bmsy_2010	1.36	0.38	1.42	0.74	0.04
F/Fmsy_1980	0.59	0.22	0.49	0.35	2.99
F/Fmsy_1990	1.14	0.37	0.97	0.63	7.48
F/Fmsy_2000	0.86	0.33	0.74	0.51	5.54
F/Fmsy_2010	0.40	0.17	0.34	0.23	3.77
TAC_at_Fmsy_2011	1940 mt	793.	2334 mt	1541	297 mt

Configuration #2 – add recruitment variability

The only change added with this configuration is to allow for annual variability of recruitment. This is more realistic, but the only information about change in recruitment is in the change in the tuning index over time. The general finding here is that if the penalty on the recruitment variability, typically termed sigmaR, is set to a moderately low value such as 0.4, then the result closely matches the configuration #1 in which no recruitment variability is allowed. However, if sigmaR is set at 0.5, then a different result is obtained. In this alternative, the model shifts to a low biomass, high F result. This causes the age-structure of the stock to shift to young ages. Thus the model can then adjust recruitment variability to more closely track the changes in the tuning index. A biomass dynamics model can attain the same result: high process error, high productivity, extremely good fit to indices. The biomass dynamics model applies the process error to the entire stock, so it does not need to shift to a high F state in order to achieve this result. In the age-structured SS model, the age-structure provides inertia to change unless a high F causes age truncation.

The fit to the tuning indices is very similar to the low sigmaR run. The greatest change with the recruitment variability set to 0.4 is that the variance of all the results increases to a more realistic level given the low level of information being provided. For example, the standard error on the spawning biomass in 2010 increases from 0.38 in the configuration #1 with no recruitment variability, to 0.74 in configuration #2 with recruitment variability set to 0.4.

With recruitment variability set to 0.5, SS is able to shift to an alternative state in which a high initial_F parameter pushes the stock down to a low biomass level that then sustains high F and age truncation throughout the time-series. The greatly improved fit to the tuning indices with the high sigmaR is shown below. This excellent fit to the tuning indices is as unrealistic as the high F needed to achieve that fit. The problem is that SS is not being provided with sufficient information to know that such a result is unreasonable. This information could be attained by supplying stronger constraints on the initial_F or by using a lower sigmaR. The better approach is to provide SS with more actual data, such as non-fishery surveys and size compositions which should indicate that high Fs are not actually occurring. Addition of surveys and size composition will be deferred until a configuration #3 is explored in future.

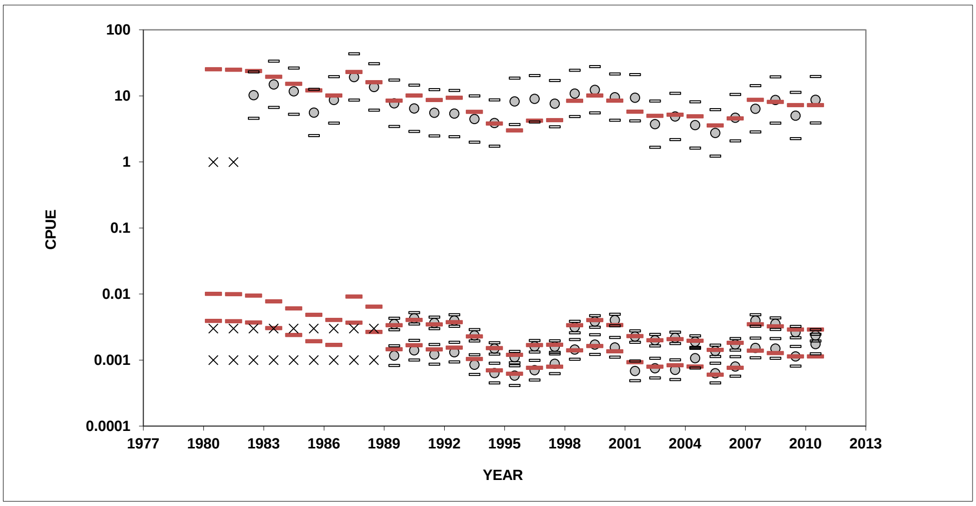


Figure 8.8.2.3. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Configuration #2: Fit to the three tuning indices in log scale. The Sp_Coruna is on top and the two Pt fishery fleets is shown at the bottom. The "X" are values not included in the model fitting and exist only to enable calculation of the expected value for the index.**

Configuration #3: add surveys and length composition

Preliminary work with this configuration was conducted at the WKFLAT 2012 benchmark. This involved adding the Spanish groundfish trawl survey and the Pt Crustacean survey as additional indices, adding length composition data from all commercial fleets and surveys, and allowing SS to estimate length-selectivity patterns from these data. The preliminary result using all these data was not substantially different from the simpler analyses, but is too premature to report here.

One observation is that the length composition data contains few fish beyond 90 cm. This indicates that the asymptotic selectivity pattern used in configuration #1 and #2, and implicit in the ASPIC biomass dynamics model, is not accurate and a dome-shaped selection pattern may be more accurate. However, the fact that the length composition data contained substantial proportions of fish out to 80 cm was sufficient to prevent the high F scenario that occurred in some configuration #2 results.

The preliminary configuration #3 used the length composition data from the Pt_Crustacean fleet to estimate the selection pattern of that fleet and for the entire catch. In future, it may be more accurate to separate the Pt_Crustacean tuning fleet and to provide length composition data that represent the entire catch fleet. Alternatively, the total catch could be separated into fleet-specific catch. Ideally, each of these catch fleets would have sufficient length composition data to estimate its selection pattern.

The preliminary configuration #3 substantially de-emphasized the fit to the length composition data because it was intended to provide a constraint on F and not to provide information on recruitment. In future, additional examination of the length composition data may provide sufficient confidence to use it to inform recruitment estimation. Alternatively, the length composition data for each fleet could be aggregated over years and used as a multiyear observation according to the "super-period" procedure included in SS.

8.8.3 ASPIC model

Data

Nine series, six commercial and three surveys (PT.crust.tr, PT.fish.tr, SPCORTR8c, SPAVITR8c, SPSANTR8c, SPCEDTR8c, SpGFS-WIBTS-Q4, PtGFS-WIBTS-Q4, PtcruS) were included in the first run of the ASPIC in order to have an idea what series to use.

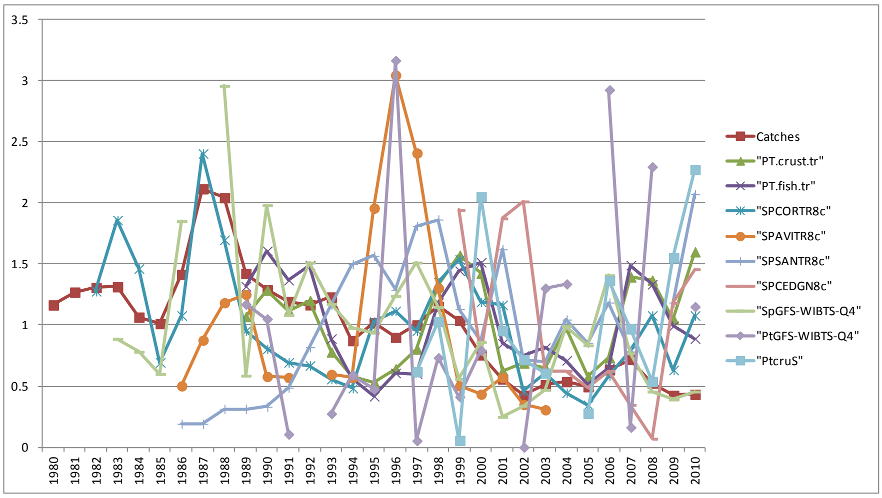


Figure 8.8.3.1. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Input series of the ASPIC first run (each series divided by its mean for comparison).**

Table 8.8.3.1. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Diagnostics of the ASPIC first run, correlation between series.**

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4	5	6	7	8	9
1	PT.crust.tr	1.000 22								
2	PT.fish.tr	0.812 22	1.000 22							
3	SPCORTR8c	0.512 22	0.362 22	1.000 29						
4	SPAVITR8c	-0.288 14	-0.476 14	0.161 17	1.000 17					
5	SPSANTR8c	-0.066 21	-0.498 21	-0.140 24	0.417 17	1.000 24				
6	SPCEDGN8c	-0.024 12	-0.082 12	0.340 12	0.500 5	0.405 11	1.000 12			
7	SpGFS-WIBTS-Q4	-0.027 22	0.087 22	0.207 27	0.225 16	-0.365 23	-0.517 12	1.000 27		
8	PtGFS-WIBTS-Q4	-0.116 18	-0.181 18	0.065 18	0.503 13	0.040 17	-0.555 9	0.114 18	1.000 18	
9	PtcruS	0.335 13	0.120 13	0.072 13	-0.118 7	0.323 12	0.008 11	0.002 13	0.193 10	1.000 13

Some series are very noisy (Figure 8.8.3.1) and the diagnostics of this run revels poor correlation between them (Table 8.8.3.1). A new run was done taking out some 5 series (SPAVITR8c, SPSANTR8c, SPCEDTR8c, SpGFS-WIBTS-Q4, PtGFS-WIBTS-Q4), this run improved the correlation between series but for the Portuguese crustacean survey (PtcruS) the *r* square between observed and fitted cpue values are negative (Table 8.8.3.2). The Portuguese crustacean survey was also removed from the assessment.

Table 8.8.3.2. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Diagnostics of the ASPIC run with four series.**

GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)

Loss component number and title		Weighted SSE	N	Weighted MSE	Current weight	Inv. var. weight	R-squared in CPUE
Loss(-1)	SSE in yield	0.000E+00					
Loss(0)	Penalty for B1 > K	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1)	PT.crust.tr	5.354E+00	22	2.677E-01	2.071E+00	1.432E+00	0.045
Loss(2)	PT.fish.tr	8.859E-01	22	4.429E-02	2.651E-01	1.108E+00	0.029
Loss(3)	SPCORTR8c	5.556E+00	29	2.058E-01	1.061E+00	9.539E-01	0.162
Loss(4)	PtcruS	3.182E+00	13	2.892E-01	2.961E-01	1.895E-01	-0.099
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:		1.49780977E+01		1.896E-01	4.354E-01		
Estimated contrast index (ideal = 1.0):		0.3281		C* = (Bmax-Bmin)/K			
Estimated nearness index (ideal = 1.0):		1.0000		N* = 1 - |min(B-Bmsy)|/K			

The three series used in the final runs were the commercial series - PT.crust.tr, PT.fish.tr and SPCORTR8c. There is no fishery-independent input data but these three series are representative of the fishery.

In order to reach the best fit, several runs were preformed allowing the model to estimate the series statistical weight, and also to give the starting guess for *q*, MSY, *K* and its boundaries. Playing with those settings the inputs of the best fit achieved are in Table 8.8.3.3, and the results are in Table 8.8.3.4.

Table 8.8.3.3. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Input file of the ASPIC best fit.**

FIT ## Run type (FIT, BOT, or IRF)
Southern Anglerfish - ank
LOGISTIC YLD SSE
2 ## Verbosity
1000 95 ## Number of bootstrap trials, <= 1000
1 10000 ## 0=no MC search, 1=search, 2=repeated srch; N trials
1.0000E-08 ## Convergence crit. for simplex
3.0000E-08 8 ## Convergence crit. for restarts, N restarts
1.0000E-04 ## Conv. crit. for F; N steps/yr for gen. model
8.0000 ## Maximum F when cond. on yield
1.0 ## Stat weight for B1>K as residual (usually 0 or 1)
3 ## Number of fisheries (data series)
8.5900E-01 1.2000E+00 9.8100E-01 ## Statistical weights for data series
0.6 ## B1/K (starting guess, usually 0 to 1)
1.81126E+03 ## MSY (starting guess)
1.81126E+04 ## K (carrying capacity) (starting guess)
8.2523E-04 1.1196E-07 2.7279E-07 ## q (starting guesses -- 1 per data series)
1 1 1 1 1 1 ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
1.81126E+02 3.62252E+03 ## Min and max constraints -- MSY
1.81126E+03 3.62252E+05 ## Min and max constraints -- K
1025957 ## Random number seed
31 ## Number of years of data in each series

SPCORTR8c			PT.crust.tr		PT.fish.tr	
CC			I1		I1	
1980	-1.00E+00	2.11E+03	1980	-1.00E+00	1980	-1.00E+00
1981	-1.00E+00	2.30E+03	1981	-1.00E+00	1981	-1.00E+00
1982	1.03E+01	2.37E+03	1982	-1.00E+00	1982	-1.00E+00
1983	1.50E+01	2.38E+03	1983	-1.00E+00	1983	-1.00E+00
1984	1.18E+01	1.93E+03	1984	-1.00E+00	1984	-1.00E+00
1985	5.60E+00	1.83E+03	1985	-1.00E+00	1985	-1.00E+00
1986	8.70E+00	2.56E+03	1986	-1.00E+00	1986	-1.00E+00
1987	1.94E+01	3.83E+03	1987	-1.00E+00	1987	-1.00E+00
1988	1.37E+01	3.70E+03	1988	-1.00E+00	1988	-1.00E+00
1989	7.70E+00	2.58E+03	1989	1.17E-03	1989	3.51E-03
1990	6.50E+00	2.33E+03	1990	1.41E-03	1990	4.29E-03
1991	5.60E+00	2.16E+03	1991	1.22E-03	1991	3.65E-03
1992	5.40E+00	2.11E+03	1992	1.32E-03	1992	3.97E-03
1993	4.50E+00	2.23E+03	1993	8.53E-04	1993	2.37E-03
1994	3.90E+00	1.58E+03	1994	6.37E-04	1994	1.50E-03
1995	8.30E+00	1.84E+03	1995	5.82E-04	1995	1.11E-03
1996	9.00E+00	1.63E+03	1996	7.03E-04	1996	1.62E-03
1997	7.70E+00	1.81E+03	1997	8.79E-04	1997	1.60E-03
1998	1.09E+01	2.09E+03	1998	1.45E-03	1998	3.16E-03
1999	1.24E+01	1.88E+03	1999	1.72E-03	1999	3.85E-03
2000	9.60E+00	1.37E+03	2000	1.56E-03	2000	4.04E-03
2001	9.40E+00	1.01E+03	2001	6.86E-04	2001	2.27E-03
2002	3.70E+00	7.70E+02	2002	7.54E-04	2002	2.00E-03
2003	4.90E+00	9.26E+02	2003	7.14E-04	2003	2.17E-03
2004	3.60E+00	9.72E+02	2004	1.07E-03	2004	1.90E-03
2005	2.80E+00	8.97E+02	2005	6.34E-04	2005	1.38E-03
2006	4.70E+00	1.15E+03	2006	8.01E-04	2006	1.73E-03
2007	6.40E+00	1.30E+03	2007	1.53E-03	2007	3.98E-03
2008	8.70E+00	9.51E+02	2008	1.50E-03	2008	3.56E-03
2009	5.10E+00	7.69E+02	2009	1.14E-03	2009	2.65E-03
2010	8.70E+00	7.84E+02	2010	1.75E-03	2010	2.37E-03

Table 8.8.3.4. ***Lophius budegassa*** **in ICES Divisions VIIIc and IXa. Results of the ASPIC best fit.**

```
Southern Anglerfish - ank                                                                                   Page 1
                                                                                 Wednesday, 07 Mar 2012 at 23:53:58
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.34)
                                                                                                  FIT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research          LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                          YLD conditioning
            Mike.Prager@noaa.gov                                                                  SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium              ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.                          gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)          Input file: c:\... gen seed c mc bk+50 posrew rest bk0 bound msy bk9.inp
-------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analysed:                    31            Number of bootstrap trials:                            0
Number of dataseries:                         3           Bounds on MSY (min, max):       1.811E+02    3.623E+03
Objective function:                Least squares           Bounds on K (min, max):        1.811E+03    3.623E+05
Relative conv. criterion (simplex):      1.000E-08          Monte Carlo search mode, trials:        1       10000
Relative conv. criterion (restart):      3.000E-08          Random number seed:                            1025957
Relative conv. criterion (effort):       1.000E-04          Identical convergences required in fitting:          8
Maximum F allowed in fitting:                8.000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                               error code   0
-------------------------------------------------------------------------------------------------------------------
Normal convergence
Number of restarts required for convergence:    111

CORRELATION AMONG INPUT SERIES EXPRESSED AS cpue (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-------------------------------------------------------------------------------------------------------------------
                                       |
 1  SPCORTR8c                          |   1.000
                                       |      29
                                       |
 2  PT.crust.tr                        |   0.512   1.000
                                       |      22      22
                                       |
 3  PT.fish.tr                         |   0.362   0.812   1.000
                                       |      22      22      22
                                       --------------------------------------------------
                                              1       2       3

GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-------------------------------------------------------------------------------------------------------------------
                                                     Weighted           Weighted      Current     Inv. var.    R-squared
Loss component number and title                           SSE      N          MSE       weight        weight      in cpue

Loss(-1)  SSE in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        0.000E+00    1          N/A    1.000E+00          N/A
Loss(1)   SPCORTR8c                                 4.354E+00   29    1.612E-01    8.603E-01    8.551E-01        0.181
Loss(2)   PT.crust.tr                               3.183E+00   22    1.592E-01    1.202E+00    1.210E+00        0.010
Loss(3)   PT.fish.tr                                3.211E+00   22    1.605E-01    9.824E-01    9.809E-01        0.052
...................................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:            1.07472226E+01          1.604E-01    4.005E-01
Estimated contrast index (ideal = 1.0):                 0.5015          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                 1.0000          N* = 1 - |min(B-Bmsy)|/K


Southern Anglerfish - ank                                                                                  Page 2

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1980)       9.299E-01          6.000E-01    4.000E-01            1            1
MSY       Maximum sustainable yield                 1.375E+03          1.811E+03    1.540E+03            1            1
K         Maximum population size                   4.391E+04          1.811E+04    9.237E+03            1            1
phi       Shape of production curve (Bmsy/K)        0.5000             0.5000            ----            0            1

--------- Catchability Coefficients by Dataseries --------------
q(1)      SPCORTR8c                                 3.092E-04          8.252E-04    7.840E-02            1            1
q(2)      PT.crust.tr                               4.850E-08          1.120E-07    1.064E-05            1            1
q(3)      PT.fish.tr                                1.165E-07          2.728E-07    2.592E-05            1            1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate                 Logistic formula          General formula

MSY       Maximum sustainable yield                 1.375E+03                            ----                     ----
Bmsy      Stock biomass giving MSY                  2.195E+04                             K/2          K*n**(1/(1-n))
Fmsy      Fishing mortality rate at MSY             6.263E-02                        MSY/Bmsy                 MSY/Bmsy

n         Exponent in production function           2.0000                               ----                     ----
g         Fletcher's gamma                          4.000E+00                            ----     [n**(n/(n-1))]/[n-1]

B./Bmsy   Ratio: B(2011)/Bmsy                       1.046E+00                            ----                     ----
F./Fmsy   Ratio: F(2010)/Fmsy                       5.522E-01                            ----                     ----
Fmsy/F.   Ratio: Fmsy/F(2010)                       1.811E+00                            ----                     ----

Y.(Fmsy)  Approx. yield available at Fmsy in 2011   1.436E+03                     MSY*B./Bmsy              MSY*B./Bmsy
          ...as proportion of MSY                   1.044E+00                            ----                     ----
Ye.       Equilibrium yield available in 2011       1.372E+03             4*MSY*(B/K-(B/K)**2)    g*MSY*(B/K-(B/K)**n)
          ...as proportion of MSY                   9.979E-01                            ----                     ----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------
fmsy(1)   SPCORTR8c                                 2.026E+02                      Fmsy/q( 1)               Fmsy/q( 1)
```

Southern Anglerfish - ank Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1980	0.053	4.083E+04	3.998E+04	2.110E+03	2.110E+03	4.477E+02	8.427E-01	1.860E+00
2	1981	0.060	3.917E+04	3.830E+04	2.300E+03	2.300E+03	6.120E+02	9.588E-01	1.784E+00
3	1982	0.065	3.748E+04	3.665E+04	2.370E+03	2.370E+03	7.580E+02	1.032E+00	1.707E+00
4	1983	0.068	3.587E+04	3.510E+04	2.380E+03	2.380E+03	8.815E+02	1.083E+00	1.634E+00
5	1984	0.057	3.437E+04	3.388E+04	1.930E+03	1.930E+03	9.692E+02	9.096E-01	1.565E+00
6	1985	0.055	3.341E+04	3.300E+04	1.830E+03	1.830E+03	1.027E+03	8.855E-01	1.522E+00
7	1986	0.080	3.260E+04	3.185E+04	2.560E+03	2.560E+03	1.095E+03	1.283E+00	1.485E+00
8	1987	0.129	3.114E+04	2.978E+04	3.830E+03	3.830E+03	1.198E+03	2.053E+00	1.418E+00
9	1988	0.136	2.851E+04	2.727E+04	3.700E+03	3.700E+03	1.293E+03	2.166E+00	1.299E+00
10	1989	0.101	2.610E+04	2.547E+04	2.580E+03	2.580E+03	1.339E+03	1.617E+00	1.189E+00
11	1990	0.096	2.486E+04	2.436E+04	2.330E+03	2.330E+03	1.358E+03	1.527E+00	1.132E+00
12	1991	0.092	2.389E+04	2.349E+04	2.160E+03	2.160E+03	1.368E+03	1.468E+00	1.088E+00
13	1992	0.093	2.310E+04	2.272E+04	2.110E+03	2.110E+03	1.373E+03	1.483E+00	1.052E+00
14	1993	0.102	2.236E+04	2.192E+04	2.230E+03	2.230E+03	1.375E+03	1.624E+00	1.018E+00
15	1994	0.076	2.150E+04	2.087E+04	1.580E+03	1.580E+03	1.335E+03	1.209E+00	9.795E-01
16	1995	0.088	2.126E+04	2.102E+04	1.840E+03	1.840E+03	1.373E+03	1.397E+00	9.684E-01
17	1996	0.079	2.079E+04	2.066E+04	1.630E+03	1.630E+03	1.370E+03	1.260E+00	9.471E-01
18	1997	0.089	2.053E+04	2.031E+04	1.810E+03	1.810E+03	1.367E+03	1.423E+00	9.353E-01
19	1998	0.106	2.009E+04	1.972E+04	2.090E+03	2.090E+03	1.361E+03	1.692E+00	9.151E-01
20	1999	0.098	1.936E+04	1.909E+04	1.880E+03	1.880E+03	1.352E+03	1.572E+00	8.819E-01
21	2000	0.073	1.883E+04	1.882E+04	1.370E+03	1.370E+03	1.347E+03	1.162E+00	8.578E-01
22	2001	0.053	1.881E+04	1.898E+04	1.010E+03	1.010E+03	1.350E+03	8.496E-01	8.567E-01
23	2002	0.040	1.915E+04	1.944E+04	7.700E+02	7.700E+02	1.357E+03	6.323E-01	8.722E-01
24	2003	0.046	1.974E+04	1.996E+04	9.260E+02	9.260E+02	1.364E+03	7.409E-01	8.990E-01
25	2004	0.048	2.017E+04	2.037E+04	9.720E+02	9.720E+02	1.368E+03	7.618E-01	9.189E-01
26	2005	0.043	2.057E+04	2.081E+04	8.970E+02	8.970E+02	1.371E+03	6.883E-01	9.369E-01
27	2006	0.054	2.104E+04	2.116E+04	1.150E+03	1.150E+03	1.373E+03	8.679E-01	9.585E-01
28	2007	0.061	2.127E+04	2.130E+04	1.300E+03	1.300E+03	1.374E+03	9.743E-01	9.687E-01
29	2008	0.044	2.134E+04	2.155E+04	9.510E+02	9.510E+02	1.375E+03	7.045E-01	9.721E-01
30	2009	0.035	2.176E+04	2.207E+04	7.690E+02	7.690E+02	1.375E+03	5.563E-01	9.914E-01
31	2010	0.035	2.237E+04	2.267E+04	7.840E+02	7.840E+02	1.374E+03	5.522E-01	1.019E+00
32	2011		2.296E+04						1.046E+00

Southern Anglerfish - ank Page 4

RESULTS FOR DATASERIES # 1 (NON-BOOTSTRAPPED) SPCORTR8c

Data type CC: cpue-catch series Series weight: 0.860

Obs	Year	Observed cpue	Estimated cpue	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1980	*	1.236E+01	0.0528	2.110E+03	2.110E+03	0.00000	1.000E+00
2	1981	*	1.184E+01	0.0601	2.300E+03	2.300E+03	0.00000	1.000E+00
3	1982	1.030E+01	1.133E+01	0.0647	2.370E+03	2.370E+03	0.09557	1.000E+00
4	1983	1.500E+01	1.085E+01	0.0678	2.380E+03	2.380E+03	-0.32363	1.000E+00
5	1984	1.180E+01	1.047E+01	0.0570	1.930E+03	1.930E+03	-0.11911	1.000E+00
6	1985	5.600E+00	1.020E+01	0.0555	1.830E+03	1.830E+03	0.59990	1.000E+00
7	1986	8.700E+00	9.850E+00	0.0804	2.560E+03	2.560E+03	0.12410	1.000E+00
8	1987	1.940E+01	9.210E+00	0.1286	3.830E+03	3.830E+03	-0.74503	1.000E+00
9	1988	1.370E+01	8.432E+00	0.1357	3.700E+03	3.700E+03	-0.48535	1.000E+00
10	1989	7.700E+00	7.875E+00	0.1013	2.580E+03	2.580E+03	0.02241	1.000E+00
11	1990	6.500E+00	7.534E+00	0.0956	2.330E+03	2.330E+03	0.14758	1.000E+00
12	1991	5.600E+00	7.262E+00	0.0920	2.160E+03	2.160E+03	0.25985	1.000E+00
13	1992	5.400E+00	7.026E+00	0.0929	2.110E+03	2.110E+03	0.26316	1.000E+00
14	1993	4.500E+00	6.779E+00	0.1017	2.230E+03	2.230E+03	0.40976	1.000E+00
15	1994	3.900E+00	6.453E+00	0.0757	1.580E+03	1.580E+03	0.50359	1.000E+00
16	1995	8.300E+00	6.500E+00	0.0875	1.840E+03	1.840E+03	-0.24442	1.000E+00
17	1996	9.000E+00	6.388E+00	0.0789	1.630E+03	1.630E+03	-0.34276	1.000E+00
18	1997	7.700E+00	6.279E+00	0.0891	1.810E+03	1.810E+03	-0.20397	1.000E+00
19	1998	1.090E+01	6.097E+00	0.1060	2.090E+03	2.090E+03	-0.58093	1.000E+00
20	1999	1.240E+01	5.903E+00	0.0985	1.880E+03	1.880E+03	-0.74216	1.000E+00
21	2000	9.600E+00	5.819E+00	0.0728	1.370E+03	1.370E+03	-0.50059	1.000E+00
22	2001	9.400E+00	5.869E+00	0.0532	1.010E+03	1.010E+03	-0.47110	1.000E+00
23	2002	3.700E+00	6.012E+00	0.0396	7.700E+02	7.700E+02	0.48541	1.000E+00
24	2003	4.900E+00	6.170E+00	0.0464	9.260E+02	9.260E+02	0.23052	1.000E+00
25	2004	3.600E+00	6.299E+00	0.0477	9.720E+02	9.720E+02	0.55949	1.000E+00
26	2005	2.800E+00	6.434E+00	0.0431	8.970E+02	8.970E+02	0.83194	1.000E+00
27	2006	4.700E+00	6.541E+00	0.0544	1.150E+03	1.150E+03	0.33059	1.000E+00
28	2007	6.400E+00	6.587E+00	0.0610	1.300E+03	1.300E+03	0.02882	1.000E+00
29	2008	8.700E+00	6.664E+00	0.0441	9.510E+02	9.510E+02	-0.26654	1.000E+00
30	2009	5.100E+00	6.824E+00	0.0348	7.690E+02	7.690E+02	0.29115	1.000E+00
31	2010	8.700E+00	7.009E+00	0.0346	7.840E+02	7.840E+02	-0.21620	1.000E+00

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATASERIES # 1

```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0956                                             |====
1983    -0.3236                                =============|
1984    -0.1191                                        =====|
1985     0.5999                                             |========================
1986     0.1241                                             |=====
1987    -0.7450               ==============================|
1988    -0.4853                          ===================|
1989     0.0224                                             |=
1990     0.1476                                             |======
1991     0.2598                                             |==========
1992     0.2632                                             |===========
1993     0.4098                                             |================
1994     0.5036                                             |====================
1995    -0.2444                                   ==========|
1996    -0.3428                               ==============|
1997    -0.2040                                     ========|
1998    -0.5809                      =======================|
1999    -0.7422               ==============================|
2000    -0.5006                         ====================|
2001    -0.4711                          ===================|
2002     0.4854                                             |===================
2003     0.2305                                             |=========
2004     0.5595                                             |======================
2005     0.8319                                             |=================================
2006     0.3306                                             |=============
2007     0.0288                                             |=
2008    -0.2665                                  ===========|
2009     0.2912                                             |============
2010    -0.2162                                    =========|
                   ------------------------------------------------------------------------------------
```

Southern Anglerfish - ank   Page 5

RESULTS FOR DATASERIES # 2 (NON-BOOTSTRAPPED)   PT.crust.tr

Data type I1: Abundance index (annual average)   Series weight: 1.202

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1980	0.000E+00	0.000E+00	--	*	1.939E-03	0.00000	1.000E+00
2	1981	0.000E+00	0.000E+00	--	*	1.858E-03	0.00000	1.000E+00
3	1982	0.000E+00	0.000E+00	--	*	1.778E-03	0.00000	1.000E+00
4	1983	0.000E+00	0.000E+00	--	*	1.702E-03	0.00000	1.000E+00
5	1984	0.000E+00	0.000E+00	--	*	1.643E-03	0.00000	1.000E+00
6	1985	0.000E+00	0.000E+00	--	*	1.600E-03	0.00000	1.000E+00
7	1986	0.000E+00	0.000E+00	--	*	1.545E-03	0.00000	1.000E+00
8	1987	0.000E+00	0.000E+00	--	*	1.445E-03	0.00000	1.000E+00
9	1988	0.000E+00	0.000E+00	--	*	1.323E-03	0.00000	1.000E+00
10	1989	1.000E+00	1.000E+00	--	1.170E-03	1.235E-03	-0.05416	1.000E+00
11	1990	1.000E+00	1.000E+00	--	1.410E-03	1.182E-03	0.17668	1.000E+00
12	1991	1.000E+00	1.000E+00	--	1.220E-03	1.139E-03	0.06871	1.000E+00
13	1992	1.000E+00	1.000E+00	--	1.320E-03	1.102E-03	0.18055	1.000E+00
14	1993	1.000E+00	1.000E+00	--	8.530E-04	1.063E-03	-0.22036	1.000E+00
15	1994	1.000E+00	1.000E+00	--	6.370E-04	1.012E-03	-0.46308	1.000E+00
16	1995	1.000E+00	1.000E+00	--	5.820E-04	1.020E-03	-0.56065	1.000E+00
17	1996	1.000E+00	1.000E+00	--	7.030E-04	1.002E-03	-0.35440	1.000E+00
18	1997	1.000E+00	1.000E+00	--	8.790E-04	9.849E-04	-0.11375	1.000E+00
19	1998	1.000E+00	1.000E+00	--	1.450E-03	9.563E-04	0.41620	1.000E+00
20	1999	1.000E+00	1.000E+00	--	1.720E-03	9.259E-04	0.61926	1.000E+00
21	2000	1.000E+00	1.000E+00	--	1.560E-03	9.127E-04	0.53598	1.000E+00
22	2001	1.000E+00	1.000E+00	--	6.860E-04	9.205E-04	-0.29402	1.000E+00
23	2002	1.000E+00	1.000E+00	--	7.540E-04	9.430E-04	-0.22364	1.000E+00
24	2003	1.000E+00	1.000E+00	--	7.140E-04	9.678E-04	-0.30415	1.000E+00
25	2004	1.000E+00	1.000E+00	--	1.070E-03	9.880E-04	0.07971	1.000E+00
26	2005	1.000E+00	1.000E+00	--	6.340E-04	1.009E-03	-0.46479	1.000E+00
27	2006	1.000E+00	1.000E+00	--	8.010E-04	1.026E-03	-0.24758	1.000E+00
28	2007	1.000E+00	1.000E+00	--	1.530E-03	1.033E-03	0.39262	1.000E+00
29	2008	1.000E+00	1.000E+00	--	1.500E-03	1.045E-03	0.36115	1.000E+00
30	2009	1.000E+00	1.000E+00	--	1.140E-03	1.070E-03	0.06310	1.000E+00
31	2010	1.000E+00	1.000E+00	--	1.750E-03	1.099E-03	0.46496	1.000E+00

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATASERIES # 2

```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75      1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual   -------------------------------------------------------------------------------------
1980    0.0000                                              |
1981    0.0000                                              |
1982    0.0000                                              |
1983    0.0000                                              |
1984    0.0000                                              |
1985    0.0000                                              |
1986    0.0000                                              |
1987    0.0000                                              |
1988    0.0000                                              |
1989   -0.0542                                            ==|
1990    0.1767                                              |=======
1991    0.0687                                              |===
1992    0.1805                                              |=======
1993   -0.2204                                     =========|
1994   -0.4631                           ===================|
1995   -0.5607                        ======================|
1996   -0.3544                                ==============|
1997   -0.1138                                         =====|
1998    0.4162                                              |=================
1999    0.6193                                              |=========================
2000    0.5360                                              |=====================
2001   -0.2940                                  ============|
2002   -0.2236                                     =========|
2003   -0.3042                                  ============|
2004    0.0797                                              |===
2005   -0.4648                           ===================|
2006   -0.2476                                    ==========|
2007    0.3926                                              |================
2008    0.3612                                              |==============
2009    0.0631                                              |===
2010    0.4650                                              |===================
                  -------------------------------------------------------------------------------------
```

Southern Anglerfish - ank Page 6

RESULTS FOR DATASERIES # 3 (NON-BOOTSTRAPPED) PT.fish.tr

Data type I1: Abundance index (annual average) Series weight: 0.982

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1980	0.000E+00	0.000E+00	--	*	4.657E-03	0.00000	1.000E+00
2	1981	0.000E+00	0.000E+00	--	*	4.461E-03	0.00000	1.000E+00
3	1982	0.000E+00	0.000E+00	--	*	4.269E-03	0.00000	1.000E+00
4	1983	0.000E+00	0.000E+00	--	*	4.088E-03	0.00000	1.000E+00
5	1984	0.000E+00	0.000E+00	--	*	3.946E-03	0.00000	1.000E+00
6	1985	0.000E+00	0.000E+00	--	*	3.844E-03	0.00000	1.000E+00
7	1986	0.000E+00	0.000E+00	--	*	3.711E-03	0.00000	1.000E+00
8	1987	0.000E+00	0.000E+00	--	*	3.469E-03	0.00000	1.000E+00
9	1988	0.000E+00	0.000E+00	--	*	3.177E-03	0.00000	1.000E+00
10	1989	1.000E+00	1.000E+00	--	3.510E-03	2.967E-03	0.16823	1.000E+00
11	1990	1.000E+00	1.000E+00	--	4.290E-03	2.838E-03	0.41315	1.000E+00
12	1991	1.000E+00	1.000E+00	--	3.650E-03	2.736E-03	0.28836	1.000E+00
13	1992	1.000E+00	1.000E+00	--	3.970E-03	2.647E-03	0.40546	1.000E+00
14	1993	1.000E+00	1.000E+00	--	2.370E-03	2.554E-03	-0.07470	1.000E+00
15	1994	1.000E+00	1.000E+00	--	1.500E-03	2.431E-03	-0.48285	1.000E+00
16	1995	1.000E+00	1.000E+00	--	1.110E-03	2.449E-03	-0.79123	1.000E+00
17	1996	1.000E+00	1.000E+00	--	1.620E-03	2.407E-03	-0.39580	1.000E+00
18	1997	1.000E+00	1.000E+00	--	1.600E-03	2.366E-03	-0.39100	1.000E+00
19	1998	1.000E+00	1.000E+00	--	3.160E-03	2.297E-03	0.31898	1.000E+00
20	1999	1.000E+00	1.000E+00	--	3.850E-03	2.224E-03	0.54879	1.000E+00
21	2000	1.000E+00	1.000E+00	--	4.040E-03	2.192E-03	0.61132	1.000E+00
22	2001	1.000E+00	1.000E+00	--	2.270E-03	2.211E-03	0.02641	1.000E+00
23	2002	1.000E+00	1.000E+00	--	2.000E-03	2.265E-03	-0.12435	1.000E+00
24	2003	1.000E+00	1.000E+00	--	2.170E-03	2.325E-03	-0.06878	1.000E+00
25	2004	1.000E+00	1.000E+00	--	1.900E-03	2.373E-03	-0.22232	1.000E+00
26	2005	1.000E+00	1.000E+00	--	1.380E-03	2.424E-03	-0.56323	1.000E+00
27	2006	1.000E+00	1.000E+00	--	1.730E-03	2.464E-03	-0.35379	1.000E+00
28	2007	1.000E+00	1.000E+00	--	3.980E-03	2.482E-03	0.47241	1.000E+00
29	2008	1.000E+00	1.000E+00	--	3.560E-03	2.511E-03	0.34923	1.000E+00
30	2009	1.000E+00	1.000E+00	--	2.650E-03	2.571E-03	0.03041	1.000E+00
31	2010	1.000E+00	1.000E+00	--	2.370E-03	2.640E-03	-0.10799	1.000E+00

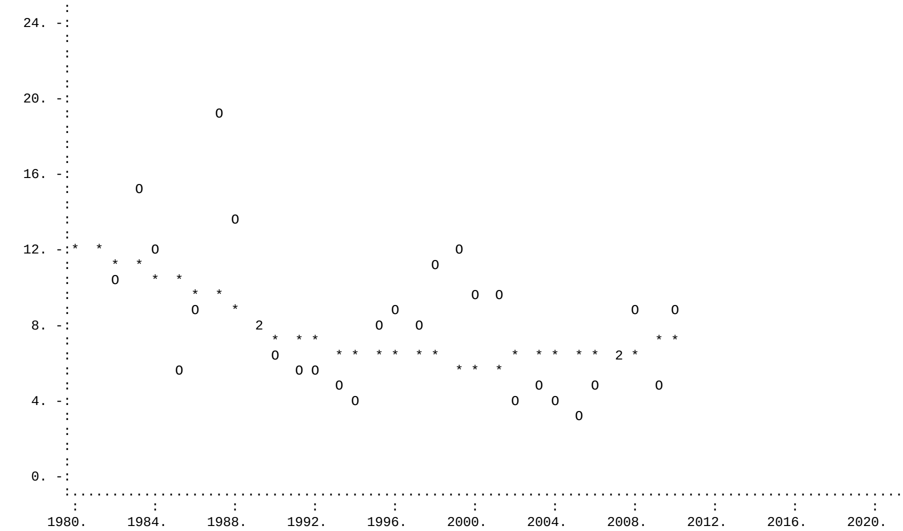
* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATASERIES # 3

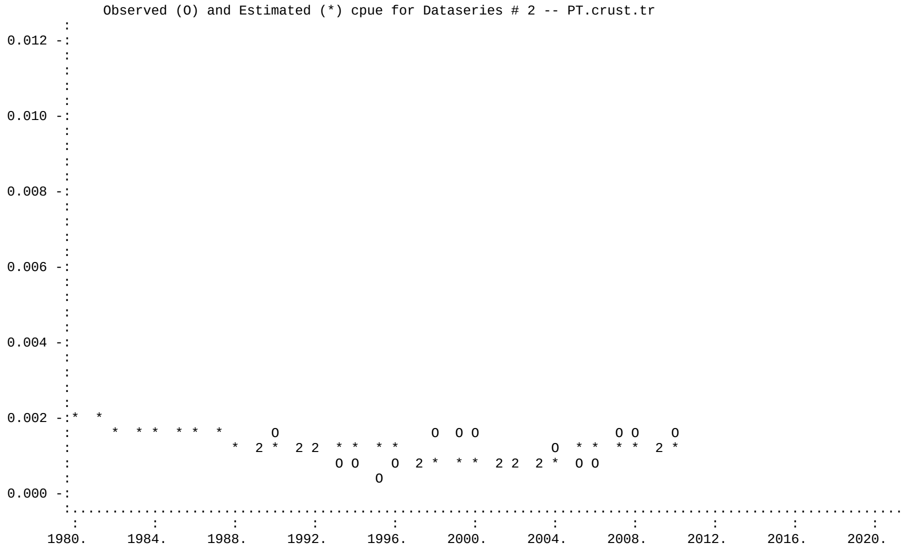
```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75      1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual  ------------------------------------------------------------------------------------
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.1682                                             |=======
1990     0.4132                                             |=================
1991     0.2884                                             |============
1992     0.4055                                             |================
1993    -0.0747                                          ===|
1994    -0.4829                          ===================|
1995    -0.7912             ================================|
1996    -0.3958                             ================|
1997    -0.3910                             ================|
1998     0.3190                                             |=============
1999     0.5488                                             |======================
2000     0.6113                                             |========================
2001     0.0264                                             |=
2002    -0.1243                                        =====|
2003    -0.0688                                          ===|
2004    -0.2223                                    =========|
2005    -0.5632                      =======================|
2006    -0.3538                               ==============|
2007     0.4724                                             |===================
2008     0.3492                                             |==============
2009     0.0304                                             |=
2010    -0.1080                                         ====|
                 ------------------------------------------------------------------------------------
```

Southern Anglerfish - ank Page 7

Observed (O) and Estimated (*) cpue for Dataseries # 1 -- SPCORTR8c



Observed (O) and Estimated (*) cpue for Dataseries # 2 -- PT.crust.tr



```
Southern Anglerfish - ank                                                                           Page  8
                Observed (O) and Estimated (*) cpue for Dataseries # 3 -- PT.fish.tr
           :
    0.012 -:
           :
           :
           :
           :
    0.010 -:
           :
           :
           :
           :
    0.008 -:
           :
           :
           :
           :
    0.006 -:
           :
           :
           :*
           :    * *                  O
    0.004 -:         * * *                O                 O O                 O
           :               *  *    O    O                                         O
           :                    *                        O
           :                       * *  * *                                          O *
           :                                 2 *  * *  * *  *    2 *  * *  * *  * *  * O
    0.002 -:                                                  *    O  O O
           :                                   O    O  O                     O
           :                                      O                        O
           :
           :
    0.000 -:
           :.........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1980.     1984.     1988.     1992.     1996.     2000.     2004.     2008.     2012.     2016.     2020.

                                   Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)
           :
      2.4 -:
           :
           :
           :                    F
           :                  F
      2.0 -:
           :
           :B
           :    B
           :      B                                      F
      1.6 -:         B B         F         F              F
           :             B B         F    F
           :                  B         F              F
           :                                      F
           :               F    B                   F
      1.2 -:                       B           F              F
           :         F               B  B
           :-  - 2  - -  - -  - -  - - 2  2 -  - -  - -  - -  - -  - -  - -  - -  - -  2  2 -  - -  - -  - -  - -
           :    F                              B  B B  B                   B B  2 B  B
           :F          F F                               B  B B  2 B  B B    F
      0.8 -:                                                            F
           :                                                          F    F      F
           :                                                       F
           :                                                                         F F
           :
      0.4 -:
           :
           :
           :
           :
      0.0 -:
           :.........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1980.     1984.     1988.     1992.     1996.     2000.     2004.     2008.     2012.     2016.     2020.
Elapsed time: 0 hours, 0 minutes, 6 seconds.
```

8.8.4 Sensitivity analysis of ASPIC

The sensitivity analysis was performed first with the assessment from last WGHMM 2011 (ICES, 2011) by changing, one at each time, the input parameters (B1/K, MSY, *K* and seed) by 10%, 25% and 50% (both plus and minus). Changing the starting guesses those key parameters change the final estimations of them, leading in some cases to unrealistic results (Table 8.8.4.1).

Table 8.8.4.1. *Lophius budegassa* in ICES Divisions VIIIc and IXa. Sensitivity analysis of the assessment from last WGHMM 2011 (yellow shadow – unrealistic results, red shadow – don´t run).

				WGHMM 2011			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
B1/K	0.25	0.375	0.45	0.5	0.55	0.625	0.75
Outputs							
B1/K	8.37E-01	2.81E-01	3.77E-01	4.01E-01	4.38E-01	5.19E-01	5.90E-01
MSY	4.40E+03	2.88E+03	2.55E+03	2.52E+03	2.49E+03	2.45E+03	2.44E+03
K	5.00E+03	1.68E+04	1.28E+04	1.17E+04	1.08E+04	1.03E+04	9.94E+03
q(1)	2.29E-07	3.91E-07	4.30E-07	4.65E-07	4.90E-07	4.14E-07	4.42E-07
q(2)	1.00E-06	1.00E-06	1.04E-06	1.12E-06	1.19E-06	1.17E-06	1.22E-06
TOF	1.48E+01	8.86E+00	9.25E+00	9.49E+00	9.72E+00	1.06E+01	1.04E+01
mse	3.80E-01	2.27E-01	2.37E-01	2.43E-01	2.49E-01	2.72E-01	2.68E-01
rmse	6.16E-01	4.77E-01	4.87E-01	4.93E-01	4.99E-01	5.22E-01	5.17E-01
CI	0.2503	0.3249	0.4363	0.4754	0.5181	0.5571	0.5796
CN	0.795	0.9103	1	1.00E+00	1.00E+00	1.00E+00	1
Rest	11	16	80	152	29	14	39
Error	20	20	0	0	0	0	0
r sq 1	-0.092	-0.321	-0.384	-0.436	-0.455	-0.427	-0.421
rsq 2	-3.557	-0.456	-0.501	-0.549	-0.614	-0.881	-0.846

				WGHMM 2011			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
MSY	1500	2250	2700	3000	3300	3750	4500
Low Boun	1000	1500	1800	2000	2200	2500	3000
Hy Bound	5000	7500	9000	10000	11000	12500	15000
Outputs							
B1/K	3.88E-01	4.62E-01	5.96E-01	4.01E-01	5.96E-01	2.26E-01	2.33E-01
MSY	4.95E+03	2.39E+03	2.32E+03	2.52E+03	4.94E+03	3.21E+03	3.51E+03
K	5.00E+03	1.45E+04	1.29E+04	1.17E+04	5.00E+03	5.00E+03	5.00E+03
q(1)	2.26E-07	3.63E-07	3.85E-07	4.65E-07	2.26E-07	2.47E-07	2.40E-07
q(2)	1.000E-06	1.000E-06	1.000E-06	1.12E-06	1.000E-06	1.000E-06	1.000E-06
TOF	1.51E+01	9.28E+00	9.22E+00	9.49E+00	1.51E+01	1.44E+01	1.43E+01
mse	3.87E-01	2.38E-01	2.37E-01	2.43E-01	3.87E-01	3.68E-01	3.67E-01
rmse	6.22E-01	4.88E-01	4.86E-01	4.93E-01	6.22E-01	6.07E-01	6.06E-01
CI	0.5727	0.4508	0.5207	0.4754	0.364	0.711	0.7095
CN	1.00E+00	1.00E+00	1.00E+00	1.00E+00	9.04E-01	1.00E+00	1
Rest	7	93	233	152	28	21	5
Error	20	20	20	0	20	20	20
r sq 1	-0.078	-0.376	-0.382	-0.436	-0.078	-0.22	-0.153
rsq 2	-3.755	-0.596	-0.524	-0.549	-3.753	-2.975	-3.127

error 20 - One or more estimates of q are at program-assigned maximum or minimum bounds

				WGHMM 2011			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
K	10000	15000	18000	20000	22000	25000	30000
Low Bounc	2500	3750	4500	5000	5500	6250	7500
Hy Bound	50000	75000	90000	100000	110000	125000	150000
Outputs							
B1/K	4.74E-01	4.75E-01	3.93E-01	4.01E-01	3.47E-01	4.85E-01	
MSY	3.41E+03	2.46E+03	2.54E+03	2.52E+03	2.61E+03	2.40E+03	
K	3.41E+03	1.08E+04	1.08E+04	1.17E+04	1.35E+04	1.26E+04	
q(1)	3.53E-07	4.85E-07	5.11E-07	4.65E-07	4.25E-07	4.07E-07	
q(2)	1.000E-06	1.17E-06	1.23E-06	1.12E-06	1.02E-06	1.000E-06 *	
TOF	8.34E+00	9.68E+00	9.74E+00	9.49E+00	9.15E+00	9.20E+00	
mse	2.14E-01	2.48E-01	2.50E-01	2.43E-01	2.35E-01	2.36E-01	
rmse	4.62E-01	4.98E-01	5.00E-01	4.93E-01	4.85E-01	4.86E-01	
CI	0.4679	0.5301	0.4947	0.4754	0.4082	0.4928	
CN	1.00E+00	1.00E+00	1	1.00E+00	1.00E+00	1.00E+00	
Rest	12	40	84	152	12	65	
Error	20	0	0	0	0	20	
r sq 1	-0.166	-0.469	-0.485	-0.436	-0.374	-0.379	
rsq 2	-0.366	-0.589	-0.608	-0.549	-0.482	-0.489	

				WGHMM 2011			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
seed	982093	1473139	1767767	1964185	2160604	2455231	2946278
	1000000	1473139	1767767	1964185	2160604	2455231	2946278
Outputs							
B1/K	7.53E-01	4.29E-01	6.47E-01	4.01E-01	4.94E-01	4.09E-01	3.84E-01
MSY	4.68E+03	2.46E+03	3.22E+03	2.52E+03	2.37E+03	2.49E+03	2.58E+03
K	5.00E+03	1.27E+04	5.00E+03	1.17E+04	1.35E+04	1.26E+04	9.01E+03
q(1)	2.27E-07	4.16E-07	2.46E-07	4.65E-07	3.80E-07	4.27E-07	3.56E-07
q(2)	1.000E-06	1.000E-06	1.000E-06	1.12E-06	1.000E-06	1.03E-06	1.30E-06
TOF	1.50E+01	9.21E+00	1.43E+01	9.49E+00	9.18E+00	9.27E+00	1.57E+01
mse	3.83E-01	2.36E-01	3.68E-01	2.43E-01	2.35E-01	2.38E-01	4.02E-01
rmse	6.19E-01	4.86E-01	6.06E-01	4.93E-01	4.85E-01	4.88E-01	6.34E-01
CI	0.2269	0.4674	0.4581	0.4754	0.4795	0.4607	0.6862
CN	7.69E-01	1.00E+00	1	1.00E+00	1.00E+00	1.00E+00	1
Rest	9	33	6	152	51	41	22
Error	20	20	20	0	20	0	0
r sq 1	-0.084	-0.379	-0.215	-0.436	-0.372	-0.39	-1.04
rsq 2	-3.662	-0.486	-2.981	-0.549	-0.527	-0.5	-2.2

A similar approach was tried with the new updated settings including A Coruna series. Changing in B1/K starting guess, produced much more stable results than the current model, changing MSY starting guess also gave more stable results besides there are some changes (Table 8.8.4.2). There was not time to run a sensitivity analysis changing K starting guess, change seed seems to be also stable.

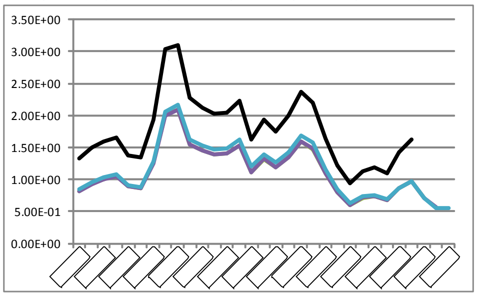
Table 8.8.4.2. *Lophius budegassa* in ICES Divisions VIIIc and IXa. Sensitivity analysis of the Benchmark ASPIC assessment (red shadow – don´t run).

				bench 2012			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
B1/K	0.3	0.45	0.54	0.6	0.66	0.75	0.9
Outputs							
B1/K	1.02E+00	1.02E+00	1.02E+00	9.30E-01	6.65E-01	1.02E+00	1.02E+00
MSY	1.36E+03	1.36E+03	1.36E+03	1.38E+03	1.49E+03	1.36E+03	1.36E+03
K	4.31E+04	4.31E+04	4.32E+04	4.39E+04	5.11E+04	4.31E+04	4.31E+04
q(1)	2.95E-04	2.95E-04	2.95E-04	3.09E-04	3.41E-04	2.95E-04	2.95E-04
q(2)	4.63E-08	4.63E-08	4.63E-08	4.85E-08	5.32E-08	4.63E-08	4.63E-08
q(3)	1.11E-07	1.11E-07	1.11E-07	1.17E-07	1.28E-07	1.11E-07	1.11E-07
TOF	1.08E+01	1.08E+01	1.08E+01	1.07E+01	1.08E+01	1.08E+01	1.08E+01
mse	1.61E-01	1.61E-01	1.61E-01	1.60E-01	1.62E-01	1.61E-01	1.61E-01
rmse	4.02E-01	4.02E-01	4.02E-01	4.01E-01	4.02E-01	4.02E-01	4.02E-01
CI	0.5598	0.5613	0.5564	0.5015	0.3329	0.561	0.5607
CN	1	1	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Rest	192	254	270	111	137	62	92
Error	0	0	0	0	0	0	0
r sq 1	0.181	0.181	0.181	0.181	0.177	0.181	0.181
rsq 2	0.003	0.003	0.003	0.01	0.01	0.003	0.003
rsq 3	0.048	0.048	0.048	0.052	0.046	0.048	0.048

				bench 2012			
Variation	-50%	-25%	-10%	0	+10%	+25%	+50%
MSY	906	1358	1630	1811	1992	2264	2717
Low Boun	91	136	163	181	199	226	272
Hy Bound	1811	2717	3260	3623	3985	4528	5434
Outputs							
B1/K		1.02E+00	1.02E+00	9.30E-01	5.37E-01	1.02E+00	1.02E+00
MSY		1.36E+03	1.36E+03	1.38E+03	1.62E+03	1.36E+03	1.36E+03
K		4.31E+04	4.31E+04	4.39E+04	5.88E+04	4.30E+04	4.31E+04
q(1)		2.95E-04	2.96E-04	3.09E-04	3.54E-04	2.95E-04	2.95E-04
q(2)		4.63E-08	4.64E-08	4.85E-08	5.51E-08	4.63E-08	4.63E-08
		1.11E-07	1.12E-07	1.17E-07	1.32E-07	1.11E-07	1.11E-07
TOF		1.08E+01	1.08E+01	1.07E+01	1.08E+01	1.08E+01	1.08E+01
mse		1.61E-01	1.61E-01	1.60E-01	1.62E-01	1.61E-01	1.61E-01
rmse		4.02E-01	4.02E-01	4.01E-01	4.02E-01	4.02E-01	4.02E-01
CI		5.61E-01	0.5598	0.5015	0.2582	0.5629	0.5596
CN		1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Rest		72	121	111	82	91	149
Error		0	0	0	0	0	0
r sq 1		0.181	0.181	0.181	0.175	0.181	0.181
rsq 2		0.003	0.003	0.01	0.012	0.003	0.003
rsq 3		0.048	0.048	0.052	0.045	0.048	0.048

8.8.5 Retrospective patterns

A 2010–2007 ASPICfit retrospective analysis was carried out on the assessment including the A Coruna series, this analysis show a severe retro pattern in F/F_{MSY} if three years are removed but no changes on removing only one or two years. Besides some retro pattern is observed in B/B_{MSY} but not severe as in F/F_{MSY} (Figure 8.8.5.1).



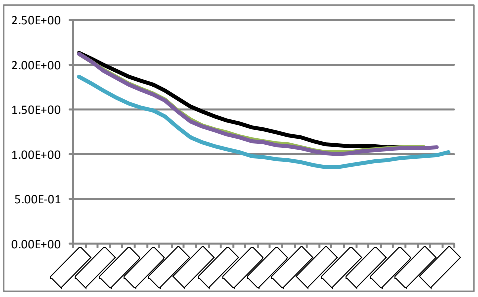


Figure 8.8.5.1. *Lophius budegassa* in ICES Divisions VIIIc and IXa. Retrospective analysis of the Benchmark ASPIC assessment.

8.8.6 Evaluation of the models

Both Bayesian surplus production model and SS3 have potential, but both are sensitive to what is assumed for process error, either of the two seems better than the ASPIC. Nevertheless, both need more exploration to come to a final model.

The ASPIC model continues to be accepted with some concerns, it was proposed to not discard the ASPIC but to accept this model with "A Coruna". The historic perspective of the stock is very different from the previous model, due to the inclusion of the series "A Coruna" that gives more information of the catches and also covers more time since it goes back in time further. The stability of the aspic model (particularly in the retro) is still a major issue.

8.8.7 Conclusion

A revised series from the Spanish fleet 'A Coruña' was available at this meeting, historical survey-series data, discard data and other commercial lpue series. The 'A Coruña' series is the longest of the potential tuning series and represents the bulk of the fishery and it was concluded that this series should be included in the modelling. Three potential models were applied to the data: a Bayesian surplus production model, SS3, and numerous formulations of ASPIC. The SS3 showed promise but it was determined that more exploration would be required before the model could be accepted as the basis for advice. A new formulation of ASPIC which included three tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to groundfish) was presented which tracks the central trend in the indices and is more stable than previous assessment. This was accepted as the basis for advice.

8.9 Short-term and medium-term forecasts

8.9.1 Input data

Although no forecasts were presented during the Benchmark, input data for short-term forecast were proposed.

Stock forecasts should use the average of the last three years fishing mortality with the possibility of projecting with fishing mortality estimated in the final year depending on trends.

8.9.2 Model and software

Continue to run the short-term and medium-term forecasts using the ASPIC projections model (Prager, 1994) and software ASPICP.

8.9.3 Conclusion

Forecast will be done in the same way of the past with the exception in the input F in the intermediate year, this F should be the average of the last three years fishing mortality with the possibility to be , depending on trends, the fishing mortality estimated in the final year.

8.10 Biological reference points

Reference points are F_{MSY} based from the ASPIC and 50% B_{MSY} is considered to be a proxy for $B_{trigger}$.

8.11 Recommendations on the procedure for assessment updates and further work

The preferred model is the ASPIC model with three tuning indices (Portuguese crustacean trawl fleet, Portuguese groundfish fleet, Spanish “A Coruña” trawl fleet). However, the current ASPIC with two tuning indices should also be run. If the addition of 2011 data changes substantially the diagnostics/population trend in the three tuning index model then the ASPIC as in the 2011 assessment should be considered.

General sense is to move to SS3 model. SS3 should continue to be developed if possible. The further development of this model is depending on the time availability of stock coordinator and WG members.

8.12 Implications for management (plans)

Lophius budegassa is managed together with *L. piscatorius* by a common TAC so the joint status of these species should be taken into account when formulating management advice.

It should be noted that anglerfish are essentially caught in mixed fisheries. Hence, management measures applied to this species may have implications for other stocks and vice versa. Besides it is necessary to take into account that a recovery plan for hake and *Nephrops* is taking place in the same area.

8.13 References

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8–17 May 2007, Vigo, Spain. ICES CM 2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

Meyer R. and Millar R.B. 1999. BUGS in Bayesian stock assessments. *Canadian Journal of Fisheries and Aquatic Sciences*, 56, 1078–1086.

Prager, M. H. 1994. A suite of extension to a non-equilibrium surplus-production model. Fish. Bull. 92: 374–389.

Praguer, M. H. 2004. User's manual for ASPIC: a stock production model incorporating covariates (ver. 5) and auxiliary programs. NMFS Beaufort Laboratory Document BL-2004-01, 25pp.

Spiegelhalter, D.J. and Thomas, A. and Best, N.G. 1999. WinBUGS Version 1.2 User Manual. MRC Biostatistics Unit.

9 Megrim (Divisions VIIb-k and VIIIabd)

9.1 Current assessment and issues with data and assessment

Current Assessment: No analytical assessment is available for this stock since 2007 consequently no forecast is either provided. Precise estimates of recent development of the stock population structure and SSB are not available.

Assessment model is based on cpue trends and Surveys. Up to date, biomass indices from three surveys (EVHOE-WIBTS-Q4, SpPGFS-WIBTS-Q4, and IGFS-WIBTS-Q4), and cpues trends from three Spanish fleets and lpues for four French commercial fleets have been also available till 2010.

Data issues: During 2010 a detailed list of data absent from the analysis and a work plan for obtaining them was detailed in Annex N of WGHMM 2011 Report (ICES, 2011). Basically data to be provided were:

Tuning series: Irish Otter trawl fleet lpue dataseries stopped in 2006 because of patterns in different areas and major changes in the fleet structure over time. Thus, trends in log-catchabilities residuals were still to be investigated. Ireland was in charge of revising tuning fleet catches and provides them to group. The industry could be involved at this stage helping in the interpretation of any possible change in the fleet in relation to strategy and/ or technological creeping.

The French Western gadoid fleet FU04 (lpues and Effort) series were every year updated. However, no data of numbers-at-age were available since 2001. No segmentation of the main commercial fleets used in the assessment has been ever carried out. There was a need of investigating whether this Fishing Unit (FU) data are the most appropriate level of aggregation for assessing this stock. An effort should be made to segment FU04 to the level 5 or 6 consistently with the Data Collection Framework (DCF). This new segmentation could be then revised and, if appropriated, will then be applied. The detailed segmentation was theoretically available for 2009 but reliability needed to be checked by France. As for the Irish tuning fleet, at this stage, French industry could be involved helping in the interpretation of any possible change in the fleet in relation to strategy and/ or technological creeping.

There was also a need of reviewing Vigo fleet tuning-series as conflicting trends in catchability were detected along the dataseries. Industry was required at this point to take decisions in relation to divide dataseries in two parts.

The lack of discards data was considered the main problem with megrim assessment. This fact resulted in an underestimation of the international catch matrix occurs as some main countries (mostly France) involved in the fishery have not provide discard data. The lack of consistency of the catch series, which could cause great bias in assessment, was also a result of only one country (Spain) providing discard data since 1999. To solve this problem, France was required to provide discard data since 1999. Also, other countries, such as, United Kingdom (England and Wales United) were asked to provide discard data raised to the total of the fleet, as just sampling data has been provided in the last years. The methodology to be used for raising should be that recommended by Workshop on Discards (Anon., 2003).

Landing for 2010 were just preliminary as France did not provide them to the WGHMM 2011 (ICES, 2011).

In relation to the biological parameters, France was not providing ALKs and consequently age composition of landings and weights routinely. A strong request for providing these data was made. In relation to the maturity ogive, there was pointed out the need of reviewing this as ogive used by group is dated in 1998. Countries under DCF should be able to provide these data for new calculations.

Finally, the Biological Reference Points have not been defined. These were expected to be recalculated if new assessment is approved during the Benchmark.

Proposed assessment methodology: As megrim experts were not confident about getting the complete discard data, an assessment method that could overcome data deficiencies were proposed. The preferable election was made for age-based models that allow for some missing discards data. Recent developments on analysis of fisheries data created the opportunity to use models that allow for missing discards data, as well as other uncertainties in the data. This situation requires previous practices to be developed in agreement, like forecasts, biological reference points, advice, etc.

9.2 Compilation of available data

9.2.1 Catch and landings data

Landings

France landing dataseries were reviewed from 1999 onwards and final landings were provided for 2010. Minor revisions were made for the Irish and Spanish landings and included in this revised dataseries.

Landings in 2010 are slightly lower than in 2009 (1%), reaching up to 13 185 t (Table 9.2.1.1).

Discards

Discard data deficiencies were partly overcome as United Kingdom (England and Wales) provided discard raised data from 2000 to 2010. Irish discard data were revised and updated and a new dataseries was provided since 1995. Spain provided some minor revised values of discards. France did not provided discard data since 1999, as data appear to be very uncertain in relation to sampling level affecting their representatively.

Discard data available by country and the procedure to derive them are summarised in Table 9.2.1.2. The discards decrease in 2000 (Table 9.2.1.1.) can be partly explained by the reduction in the minimum landing size from 25 cm to 20 cm. Since 2000, an increasing trend in the discards has been observed. This could be explained by the MLS plus due to the large number of small fish caught until 2004. In 2005, the decrease in the number of small fish resulted in a large decrease of discards (Figure 9.2.1.1). In 2006 discards increased again around 23%, especially in ages 4 and 5, while a decrease occurred till 2008. In 2010, discards increased in almost 40% close to levels of 2003.

In 2012, Spain, United Kingdom (England and Wales), and Ireland provide discard data since 2000. Still, France does not provide these data, which led to an artificial decrease in the amount of total discards. The group states strongly the importance of incorporating annual estimates of discards to obtain consistent data along the whole dataseries. Maybe also discards could explain some possible recruitment that could not be completely registered in the catch-at-age matrix and lpues.

Dataseries available for discards are detailed in the stock annex-Meg78 (Annex 6).

In the following table the discard ratio in weight of the most recent years is presented.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Disc.(%)	11%	13%	15%	20%	27%	17%	22%	17%	19%	16%	25%

9.2.2 Biological data

Age and Length distribution provided by countries are explained in Stock annex-Meg78 (Annex 6).

Age

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

Spain, Ireland and UK (England and Wales) provided number-at-age for discards and landings since 2000.

Age distribution for landings and discards from 1987 to 2010 are presented in Figure 9.2.2.1.

Lengths

Table 9.2.2.1 shows the available original length composition of landings by Fishing Unit in 2009.

The length compositions of the landings show an increase between 1990 and 1992 and, subsequently, a constant decrease until a rapid increase starting in 2000 (Figure 9.2.2.1) due to the change in MLS. Up to 2006, mean lengths stay relatively stable in the recent years with a decrease in length of discards. In 2010 the numbers discarded of small lengths markedly increased.

9.2.3 Survey tuning data

UK survey Deep Waters (UK-WCGFS-D, Depth >180 m) and UK Survey Shallow Waters (UK-WCGFS-S, Depth <180 m) indices for the period 1987–2004 and French EVHOE survey (EVHOE-WIBTS-Q4) results for the period 1997–2010 are summarised in Table 9.2.3.1.

EVHOE-WIBTS-Q4 indices for age 1 showed no evident general trend. Oscillations of high and low values are present from 2002 to 2007. In 2008 indices decreased sharply with a slight increase till 2010, to the second lowest value of the series.

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

An abundance index was provided for the Spanish Porcupine Ground Fish Survey (SpPGFS-WIBTS-Q4) from 2001 to 2010, and from Irish Groundfish Survey (IGFS-WIBTS-Q4) from 2003–2010. For the last three years of the dataseries, both surveys provide the lowest values of the age 1.

When comparing Spanish, French and Irish biomass indices some contradictory signals are detected (Figure 9.2.3.1). The EVHOE-WIBTS-Q4 index decreased from 2001 until 2005 and since then has sharply increased. The SpPGFS-WIBTS-Q4 biomass index appears to fluctuate without trend, with the lowest value of the period attained in 2008. However, some concerns about the good performance of the gear in 2008 were raised and thus the 2008 index may not be entirely reliable. In 2009, these performance problems were solved and the index increased for the last two years of the series.

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

For a more detailed inspection of the abundances indices of different age groups, these were inspected along the whole dataseries for surveys (Figure 9.2.3.2). Ages groups were identified as: i) age 1 + age 2; ii) age 3 + age 4 + age 5 and iii) age 6 + age 7 +age 8 + age 9 + age 10+. The most abundant age group was ii) at the beginning and the end of the dataseries for all the surveys. Age group i) appear most abundant during years 2005 to 2008. In 2010, surveys show contradictory signals for different age grouping. Thus, EVHOE-WIBTS-Q4 Survey identifies a positive increase for ages group i) and iii) while for the rest of the surveys last year estimation is negative for all age groups. At that same year, only Spanish Survey for ages in group i) coincides with EVHOE-WIBTS-Q4.

It must be noted that the areas covered by the three surveys almost do not overlap. There is some overlap between the northern component of EVHOE-WIBTS-Q4 and the southern coverage of IGFS-WIBTS-Q4, whereas the eastern boundary of SP-PGFS essentially coincides with the western one of IGFS-WIBTS-Q4 (Figure 9.2.3.3).

9.2.4 Commercial tuning data

For 2012 Benchmark, a new Irish trawler index was provided as the result of the revision carried out for the Irish Otter trawl fleet. Irish beam trawl (TBB) data are limited to TBB with mesh sizes of 80–89 mm, larger mesh sizes are disused since 2006. There was no obvious change in targeting behaviour in the fleet and changes in the spatial distribution of effort are fairly minor consequently this fleet was considered suitable for the assessment (WD 12, see Annex 4).

Commercial series of catch-at-age and effort data were available for three Spanish fleets in Subarea VII: A Coruña (SP-CORUTR7), Cantábrico (SP-CANTAB7) and Vigo (SP-VIGOTR7) from 1984–2010. Some minor revisions were carried out for SP-VIGOTR7 due to the incorporation of catches previously not recorded. The new dataseries was considered more adequate and used in the analysis (Figure 9.2.4.1a).

From 1985 to 2008, lpues from four French trawling fleets: FR-FU04, Benthic Bay of Biscay, Gadoids Western Approaches and *Nephrops* Western Approaches were available. (Table 9.2.4.1 and Figure 9.2.4.1a). FR-FU04, Benthic Bay of Biscay, Gadoids Western Approaches and *Nephrops* Western Approaches were revised and new series included. However no data for 2009 and 2010 were provided as effort deployed by these fleet was considered, at the time of the analysis, unreliable.

The general level of effort in SP-CORUTR7 and SP-VIGOTR7 has decreased since 1991, stabilising the last years of the series. SP-VIGOTR7 showed a very slight increase in 2007, decreasing slightly till 2010. SP-CANTAB7 remains quite stable since 1991 and decreased slightly since 2000. In 2009, no effort has been deployed by this fleet but in 2010, some trips were recorded (Figure 9.2.4.1a). The effort of the French benthic trawlers fleet in the Celtic Sea decreased from 1991 to 1994, then increased in 1995–1996 and decreasing again in 1999. Since then, effort has been fluctuating up and down for the last nine years (Figure 9.2.4.1a). Since French logbook data were only partially available since 1999, only the lpue data can be considered.

The cpue of SP-CORUTR7 has fluctuated until 1990, when it started decreasing, with a slight increase in 2007. In 2009, cpue for this fleet sharply increased (Figure 9.2.4.2b). Over the same period, SP-VIGOTR7 has remained relatively stable until 1999, when it started to increase, reaching in 2004 the historical maximum. In 2005 a sharp decrease occurred, increasing slightly again in 2006 and 2007. The cpue of SP-VIGOTR7, as for SP-CORUTR7, has had a sharp increase in 2009. In 2010, cpue of SP-CORUTR7 slightly decreased. SP-CANTAB7 has been fluctuating up to 1999 and then a general increasing trend is observed. No lpue value is available for this fleet in 2009, as no effort was deployed. In 2010, lpues increased as a result of some trips being deployed in Area VII.

The lpue of all French bottom trawlers fleets decreased from 1988 to 1991 and remained relatively stable until 1994 (Figure 9.2.4.2c). Since then, both benthic fleets have shown increasing lpue until 1997 and 1998. Benthic trawlers in VIIIa,b,d follow a decreasing trend while the FU04: Benthic Western Approaches remained at an increasing trend until 2002, then a sharp decreasing trend is observed till 2004. From then, lpue has increased and remain stable for the last three years of the series. From 1996, the demersal fleet lpue started decreasing. No update of lpue information for 2009 and 2010 was provided for French fleets.

An analysis of the abundance indices of different age's groups along the whole dataseries for commercial fleets was carried out (Figure 9.2.4.2). Ages groups were identified as: i) age 1; age 2; ii) age 3; age 4; age 5 and iii) age 6; age 7; age 8; age 9 and age 10+. For Spanish and Irish commercial fleets, the most abundant age group was ii) at the beginning and the end of the dataseries. Age group i) appear more abundant than older ages (ii) during years 2003 and 2004 and 2006 to 2010 in the Spanish fleet. French fleets appear to land mostly old individual at the beginning of the dataseries, while same quantities of medium age fish (group ii) and old fish (group iii) are presented till 2008. In general a marked decrease in abundance index of old fish was observed for French fleet. In 2010, Spanish and Irish fleets show contradictory signals for different age grouping. Whereas Spanish fleet identified a positive increase for all age groups in 2010, Irish fleet just identified that positive estimate for old fish.

9.2.5 Industry/stakeholder data inputs

In 2008, a first analysis of the cpue of this fleet for megrim was conducted using data from the observers on board IEO discards sampling programme. This analysis was presented in a working document to the ICES assessment working group WGHMM in 2008 (Fernández *et al.*, 2008). A bubble plot of log (Numbers cpue) by age, showed a sudden increase in 1999 for most ages. Industry was consulted in relation to the behaviour of the last years of the series of cpue of SP-VIGOTR7. The analysis from the observer data, examined on a trip by trip basis, did not show the same degree of increase in the cpue as obtained from the entire commercial fleet annual data. The best model residuals were obtained when the cpue series was split in two, one for the period 1984–1998 and another one from 1999 onwards. A detail analysis of this fleet is in Abad *et al.*, 2012 (WD 13). The conclusions were that there does not seem to be a clear change in species composition through the time-series analysed (1986–2010) but an increase in cpue for most species could be observed in approximately the last decade. Industry provided some qualitative information confirming that cpues have increased in the last decade and notes the fact that this fleet was substantially renovated during the 1990s, which may well have led to an increase in its efficiency. However, as this could not be quantified further, it was not possible to determine to which extent cpue increases are due to increases in fleet efficiency or stock abundances.

Based on the above, it was decided to split SP-VIGOTR7 in two separate periods, First one from 1984 to 1998 and the second one from 1999 onwards.

9.2.6 Environmental data

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

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

9.3 Stock identity, distribution and migration issues

There are two megrim species in the Northeastern Atlantic: megrim (*Lepidorhombus whiffiagonis*) and four spot megrim (*Lepidorhombus boscii*).

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

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

Although, there does not appear to be evidence of multiple populations in the Northeast Atlantic, since the end of the 1970s ICES has assumed three different stocks for assessment and management purposes: megrim in Subarea VI, megrim in Divisions VIIb,c,e–k and VIIIa,b,d and megrim in Divisions VIIIc and IXa. The stock under this section is called Northern Megrim and defined as megrim in VIIb,c,e–k and VIIIa,b,d.

Stock is defined as megrim VIIb,c,e–k and VIIIa,b,d. In this definition Division VIIa (Irish Sea) and VIId (Eastern English Channel) are not included.

A review of the division of landing data provided by countries and the data used in the assessment should be checked.

9.4 Influence of the fishery on the stock dynamic

There are no studies in which the impact of the fishery in the megrim stock dynamics is studied.

9.5 Influence of environmental drivers on the stock dynamic

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

9.6 Role of multispecies interactions

9.6.1 Trophic interactions

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

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

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

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

9.6.2 Fishery interactions

Megrim in the Celtic Sea, west of Ireland, and in the Bay of Biscay are caught in a mixed fishery predominantly by Spanish and French vessels. In 2010, both countries together have reported close to 70% of the total landings, the rest of the catches are reported by Irish and UK demersal trawlers.

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

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

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

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

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

9.7 Impacts of the fishery on the ecosystem

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

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

9.8 Data Exploratory analysis

The following catch, landings and discard numbers-at-age data were used to carry out the assessment:

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

ii) From 1990 to 2010, total international landings-at-age (separately from discards).

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

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

iv) For 1999, only Spanish and Irish discards-at-age are available. From 2000 onwards, discards-at-age are available for Ireland, Spain and UK. There was no information for France, Belgium and Northern Ireland. The main part of the missing discards is supposed to correspond to France, as the contribution of the other two nations to the stock landings is very small. France did not provide discards estimates due to the low sampling levels and major problems in the raising procedure.

In summary, the stock catch-at-age matrix shows inconsistencies in the data available for each identified different period: 1984–1989; 1990–1998 and 1999–2010.

Several exploratory analyses were carried out on these data with the software R. The results are described below.

The data analysed consist of landed, discarded and catch numbers-at-age and abundance indices-at-age. The available tuning fleets are summarised in the table below. Of these, five were considered appropriate to inclusion in the assessment model (Spanish Porcupine survey (SpPGFS_WIBTS-Q4), French Survey (EVHOE-WIBTS-Q4), Vigo commercial trawl cpue series separated in two periods: 1984–1998 (VIGO84) and 1999–2010 (VIGO99), and Irish Otter trawlers lpue (IRTBB), based on how representative of megrim stock abundance the indices were considered to and on the exploratory analyses examining their ability to track cohorts through time.

The table below summarizes the available information of the tuning fleets.

FLEET	ACRONYMS	PERIOD	AGE RANGE	Landings %
Spanish Survey	SpPGFS_WIBTS-Q4	2001–2010	1–8	-
French Survey	EVHOE-WIBTS-Q4	1997–2010	1–9	-
Irish Survey	IRGFS-WIBTS-Q4	2003–2010	1–9	-
French Benthic Western approaches	FR-FU04	1985–2008	2–9	5%
Spanish Vigo Trawl VII	VIGO84	1984–1998	2–9	37%
	VIGO99	1999–2010	2–9	47%
Irish Beam trawlers VII	IRTBB	1995–2010	2–9	3%

The analysis of the standardized log abundance indices revealed, for mostly all of them, negative values for older ages from 2008 onwards. This decrease in abundance of older ages was detected by SpPGFS-WIBTS-Q4 since 2007 and for ages older than 5. The analysis of the standardized log abundance indices revealed negative values and year trends for VIGO99. The same decrease in the index of old individuals was detected by this fleet in 2008 and 2009. In 1999 and 2000, VIGO99 showed negative high values for ages 1 and 2. IRTBB was the only fleet that showed high and positive values for older ages in years 2008 and 2009 (Figure 9.8.1).

FR-FU04 were not included in the analysis as there was no effort data available for 2009 and 2010, and no further revision on the adequacy of a further segmentation to métier level was deployed previous to the Benchmark. This French fleet has a relative low weight in the landings (around 5% in the last years). IGFS-WIBTS-Q$ was neither included as contradictory signals with the other surveys were found.

The time-series of catch by age (Figure 9.8.2) showed very low catches of ages 1–5 from 1984 to 1989. From 2004 to 2010, the catch of older ages (>6) was remarkably low, whereas catches of ages 1 and 2 increased markedly from 2003. This could be a result of an underestimation of catches of these ages (specially age 1) before this year due, most probably, to the sparseness of discard data in that period. For ages 6 and older, large discrepancies in the amount caught before and after 1990 are apparent, with large catches of these ages before 1990 and a decrease to almost no individuals caught at the end of the dataseries.

The analysis of the landings are presented since 1990 (Figure 9.8.3). Landings of ages 1 and 2 decreased from the beginning of the series to the last years. When analysing landings of ages older than 5, differences in the patterns were also quite apparent. In general, landings of these ages decreased from the beginning of the series until close to 1995, and then a sharp increase in the next two-three years was observed. Again a marked drop was detected in landings from then until the end of the time-series. In fact, older ages have almost disappeared from the landings in recent years, as already discussed in relation to the catch.

The signal coming from the discard data showed that at the beginning of the dataseries there were no discards of age 1 (Figure 9.8.4). Discards of this age increased along the dataseries, particularly from 2003. Also striking is the apparent medium to large discarded amounts for intermediate ages (age 2, 3 and 4) for almost the whole series of the data. Ages 4, 5, and 6 appeared to be highly discarded from 2000 to 2007, when very few fish were discarded

Based on these data and the decreasing landings in large ages, it seemed that fishing may have shifted towards targeting small fish in the last ten years. Changes in selection pattern apparently occurred around 2000, but it must also be kept in mind that the way the catch matrix is built changed in 1999, when it started to incorporate discards by country (as opposed to as stock totals) and that discards from France, Belgium and Northern Ireland are missing since 1999. The unexpected changes in the proportion of younger and older ages over time in the catch data and the coincidence of these strong changes with the years in which changes in the build-up of the catch matrix occurred (1990 and 1999), led us to have significant concerns about the underlying data.

9.9 Stock assessment methods

9.9.1 Models

Model

The model explored during the benchmark is an adaptation of one developed originally for the southern hake stock, published in Fernández *et al*. (2010). It is a statistical catch-at-age model that allows incorporating data at different levels of aggregation in different years and also allows for missing discards data by certain fleets and/or in some years. These are all relevant features in the megrim stock. The model is fitted in a Bayesian context, using the freely available software WinBUGS (Lunn *et al*., 2009).

Population dynamics

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

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

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

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

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

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

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

$$F(y,a) = F_L(y,a) + \sum_{j=1}^{J} F_{D,j}(y,a), \quad (3)$$

where $F_L(y,a)$ and $F_{D,j}(y,a), j=1,...,J$ relate to the total stock landings and discards from each of the J fleets fishing the stock, respectively. The fleets used for the megrim stock correspond to the countries fishing it and are: Spain, Ireland, United Kingdom and Others, where "Others" comprises France together with countries with minor stock catches. The reason for having France grouped together with countries with minor catches is the lack of French discards data, which makes treating France as a separate fleet unrealistic. However, given the volume of catch that France takes from this stock, it would make sense to have France as a separate fleet in the model if those data become available.

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

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

where $f(y)$ is an overall annual factor relating to total fishing effort on the stock and $r_L(y,a)$ and $r_{D,j}(y,a)$ for $j=1,...,J$ determine the exploitation pattern or, in other words, the distribution of *F* among ages and among landings and discards of different fleets. All factors in formulation (4) are positive and for identifiability, $r_L(y,a)$ is set to 1 for an age chosen arbitrarily (this was set as age 9 in the megrim model implementation, an age for which discards are assumed to be 0, i.e. $r_{D,j}(y,9)=0$ for all fleets; therefore, $f(y)$ is interpreted as the total fishing mortality-at-age 9). Each of the $r(y,a)$ factors, whether it corresponds to landings or discards, is assumed to have the same values for ages *A*–1 and *A*+ , so that the fishing mortality of the + group is the same as the fishing mortality of the last true age.

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

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

where the log-Normal (LN) distribution is parametrized using the median (first parameter) and coefficient of variation (second parameter). As megrim discarding is believed to have increased over the assessment period, the non-stationary random walk model in Equation (5) is considered appropriate. For each age, the value in the first year of the assessment period, $r_L(1,a)$, is an unknown parameter, whereas CV_{rcond} has been fixed at 20% (the value 10% was also explored in some model runs). The same modelling procedure is applied to $r_{D,j}(y,a)$, separately for each age and fleet $j=1,...,J$, where the values in the first assessment year, $r_{D,j}(1,a)$, are unknown parameters and CV_{rcond} is fixed at the same value as for $r_L(y,a)$.

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

$$f(y) \sim LN\left(med_f, CV_f\right), \tag{6}$$

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

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

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

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

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

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

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

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

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

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

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

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

$$r_{OTD}(y,a) = r_{OTD}(y-1,a)\left[OTLW(y)/LW(y)\right]/\left[OTLW(y-1)/LW(y-1)\right], \quad (11)$$

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

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

Observation equations for relative indices of stock abundance

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

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

The mean of the Normal distribution is the logarithm of the product of the average stock abundance during the period of the year to which the index relates and the catchability $q_k(a)$, which is unknown. The index precision, $\tau_k(a)$, is considered unknown for all indices explored in the assessment. As explained above, the relationship between the precision of a Normal distribution for the log of a variable and the

CV of the corresponding log-Normal distribution for the variable in original scale will be used when setting prior distributions for the precision parameters.

Data, priors, and computational method

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

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

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

Model fitting was done using MCMC to simulate the posterior distribution (Gilks *et al*., 1996, provide an accessible introduction to MCMC). This was programmed in the free software WinBUGS and run from R (R Development Core Team, 2009) using the R2WinBUGS package (Sturtz *et al*., 2005). MCMC simulates the posterior distribution with each draw depending on the one immediately preceding it. As a consequence of this dependence, many iterations are typically needed to obtain a representative sample from the posterior distribution, particularly when this is highly dimensional and strong correlations between some of its dimensions exist. The results for the main runs conducted during the benchmark are based mostly on chains of 48 000 iterations. The first 8000 were discarded to eliminate the effect of start-up values, and 5000 equally spaced iterations out of the other 40 000 iterations were kept. This was considered enough to provide a good representation of the posterior distribution. Running time was approximately 24 h on a standard desktop PC.

Model results

The model results were analysed looking at three different kinds of plots, convergence plots, to analyse the convergence behaviour of the MCMC chains, diagnostic plots, to analyse the goodness of the fit and finally plots of the models estimates to see the estimated stock status over time. The results commented here refer to the final run selected by the working group as the best one among the different configurations run during the meeting. The settings of this run are listed in Table 9.9.1.1.

In order to be sure that the model has produced a representative sample of the posterior distribution, the MCMC chain was examined for behaviour ("convergence" properties). This was done by examining trace plots and autocorrelation plots for most parameters in the model (See WD 15, see Annex 4). The trace and autocorrelation plots showed a good behaviour in most of the runs carried out with the model. Several runs were performed using different priors and model assumptions, most of them gave rather similar results, representing further support to the reliability of the output from the MCMC simulation conducted. In the final run no convergence problems were detected for any of the model parameters.

Model diagnostics plots were examined based on the results, prior–posterior plots, and time-series and bubble plots of the residuals. Posterior distributions for log-recruitment, log population abundance in first assessment year (1984), log-f(y) and log-catchabilities of abundance indices were much more concentrated than the priors and were often centred at different places. This indicated that the model was able to extract information from the data in order to substantially revise the prior distribution. In these cases, the model fits are mostly driven by the data, with the prior having only a small influence. The posterior distributions for log-rL, log-rSPD, log-rIRD, log-rUKD and log-rOTD in the first assessment year (1984) and the posterior distributions of the CVs of observation equations were similar to the prior distributions in most of the cases. This was especially true for log-rOTD, were data directly associated with it was not available to the model and for some of the CVs. This indicates that the available data does not contain very much information concerning these parameters (although the data contain some information, as there are differences between the prior and posterior distributions) and that the priors have to be chosen in a careful way, deemed to be realistic. This was done here.

Time-series and bubble plots of residuals were plotted for each of the tuning indices and ages and for catch, discard and landed numbers-at-age. The residuals are plotted in logarithmic scale (i.e. log(observed value)–log(value according to fitted model)) and there are two plots per indicator, one with raw residuals and a second one with standardized residuals, where in the first case the magnitude of the residuals gives an indication of the size of the error. As Bayesian fit incorporates uncertainty, the bubbles of the residuals plotted show the posterior median of the residuals. Residuals plots are expected to appear as random noise around the value 0. Any systematic departures from this random pattern would indicate a mismatch between model assumptions and observed data. No systematic patterns in the residuals were identified, suggesting that the model fit is adequate. The magnitude of the raw residuals was large for ages 1 and 2 in catch and landings-at-age (Figures 9.9.2.2.a and 9.9.2.2.b). The raw residuals of discards in the middle period, 1990–1998, were very small for all years and ages (Figure 9.9.2.2.c). On the contrary, the raw residuals by country in the final period, 1999–2010, were large for Spain and Ireland for age 1 and older ages (Figures 9.9.2.2d and 9.9.2.2e), whereas the magnitude of UK discard raw residuals was small, except for age 1 in some years (Figures 9.9.2.2.f).. The residuals of the abundance indices generally showed an acceptable behaviour (WD 15; Figures 72–81, 94–103), although some year effects were observed for example in the first two years of the VIGO99 cpue series (Figures 9.9.2.2g).

Time-series of estimated spawning–stock biomass (SSB), reference fishing mortality (F_{bar}), recruits and catch, landings and discards are shown in Figure 9.9.2.3. The SSB shows an overall decreasing trend from the start of the series in 1984 to 2005 with a marked increasing trend in the 1990s. In the last four years the SSB showed a weak increasing trend. The uncertainty in the SSB was low in the whole time-series. The median recruitment fluctuated between 200 000 and 300 000 thousand in the whole series without any trend. The uncertainty around median recruitment was small until the last five years, when it started to increase. As expected, uncertainty in recruitment estimates is largest at the end of the time-series, as those years correspond to cohorts that are still passing through the population and additional information about them will be gained in future years. The fishing mortality showed three marked periods which coincide with the data periods, 1984–1989, 1990–1998 and 1999–2010. The lowest F_{bar} was observed in the first period and the highest one in the last period. The uncertainty was small and increased slightly in the last years of the fit. Overall, the catches showed very weak decreasing trend. The landings decreased in a higher proportion than the catches and the discards showed an increasing trend. The uncertainty was small in all the years and increased slightly in the discards with the years.

Model results in relation to f(y) were also analysed (Figure 9.9.2.4). f(y) represents the fishing mortality of ages 9 and 10. The trend was similar to the trend in F_{bar}, taken as the average fishing mortality of ages 3–6, but the level was higher in f(y).

Fishing mortality-at-age for landings and discards are shown in Figure (9.9.2.5). For ages 1 and 2 a high increase in fishing mortality corresponding to discards was observed in the last data period produced by a high increase in the discards of these ages. The fishing mortality of landings was null for age 1 and almost negligible for age 2. The fishing mortality of landings and discards of age 3 showed roughly similar trends over time, except for the mid-1990s, when fishing mortality corresponding to discards increased and became larger than for landings, remaining that way thereafter. For ages 4 and older the trends were similar, they showed three marked periods corresponding to the periods already identified in the data (1984–1989, 1990–1998, 1999–2011) and the fishing mortality was higher for landings than for discards.

The selection pattern-at-age F(y,a)/Fbar(y) was also analysed for all ages and years (Figure 9.9.2.6). It showed an increasing roughly linear trend from ages 1 to 7, very similar for all years. For ages 8 to 10+ the increase in the selection pattern softened, being equal by assumption for ages 9 and 10+. In 2010 the selection of ages 9 and 10+ (relative to average selection of ages 3–6) was significantly lower than in 1984 and the selection for age 8 showed an unexpected dip.

Population numbers-at-age are shown in Figure 9.9.2.7. From ages 1 to 4 there were no apparent overall trends and the values oscillated around a mean value. A marked decreased in the abundance starts appearing in 1990 for ages 5 and older. This drop in numbers of older ages is more striking from age 6 and older resulting almost in a lack of individuals of ages 8 and older in the last years of dataseries.

9.9.2 Sensitivity analysis

In order to find an adequate fit of the model to the data and to test the sensitivity of the results to different model settings more than 30 model configurations were tested before and during the benchmark workshop. First, several models were run until sensible results were obtained, at which point the fine tuning of the model and detailed analysis started.

In a first sensible run, bimodal posterior densities were obtained for some variables, which suggested non convergence of the model, and the rL parameters in ages 1 and experienced a sharp decrease in the first years of the assessment period (1984 to approximately 1987), which did not appear realistic. This suggested that the prior assumed for the values of these parameters in 1984 was centred at unrealistically high values and that the model was using the random walk feature (for the logarithm of these parameters) to move these parameters to a more appropriate range of values early in the time-series. Thus, in a following run, the length of the MCMC chains was increased (to deal with the convergence issues) and the values of medF (used to set the prior median of population abundances at age in 1984, see Table 9.9.1.1) and prior median for rL in 1984 for ages 1 and 2 were changed (decreased) to correct for the behaviour displayed by rL at the beginning of the time-series. It was also observed that the estimated OTD discards of age 5 increased enormously after 1999, which did not make any sense. It was checked that the problem with the estimated OTD discards of age 5 was not a problem of convergence, several alternative model settings were tried in an attempt to solve this extremely unrealistic result, and finally, it could only be solved by modelling $r_{OTD}(y,a)$ from 1999 as was indicated in equation (11). In the results it was also observed that the prior CV of the catch and landings for ages 1 and 2 was too low in relation to the posterior results, so the prior median was increased from 10% to 30% in order to have a prior distribution which was not completely at odds with what the data indicated. In later runs it was also assumed that the precision in landings from 1990 to 2010 was equal to the precision in catch from 1984 to 1989. The reason was that, in principle, in the first period there was no incentive to discard or misreport data, so there was, in principle, no reason to expect a lower quality of the 1984–1989 catch data than of the 1990–2010 landings data.

To deal with the high increase in OTD discards of age 5 two structural changes to the model were tried. In the first change it was assumed that OTD discarding pattern-at-age had not changed since 1998, and the changes in overall level (with the same change in level for all ages) between years were treated as unknown parameters and estimated by the model based on the available data. This still resulted in very unrealistic estimates of OTD discards in recent years, with very large increases, propagating the problem previously detected just for age 5 to all the ages. The second approach to deal with this problem was the same as the first one (i.e. it was assumed that OTD discarding pattern-at-age had not changed since 1998) but the changes in overall level (with the same change in level for all ages) between years were approximated by the changes in overall landings of the OTD fleet with respect to total stock landings in the same years (see equation (11)). This gave sensible results and the assumption was used in all following runs.

Using the later configuration of the model several runs were tested using different sets of abundance indices. In the light of the results and the exploratory data analysis it was decided to use as abundance indices: EVHOE-WIBTS-Q4 survey, SpPGFS-

WIBTS-Q4 Porcupine survey, IRTBB lpue and VIGO cpue divided into two dataseries (VIGO84 and VIGO99). The VIGO cpue time-series was split to account for the change in catchability around 1999, for which there is now fairly clear support. The ages used in EVHOE-WIBTS-Q4 and IGFS-WIBTS-Q4 indices were reduced to ages 1–5 and 2–7, respectively, which are the ages for which the exploratory plots showed some degree of cohort tracking. Besides, the prior median and CV of f(y) were also changed which did not have high influence on the results.

The CV of the random walk of rL, rIRD, rOTD, rSPD and rUKD, was treated as an unknown parameter in the first configurations, but later it was set at a fixed value. Two alternative values were tested for the CV of the random walk, 10% and 20%, the results were very similar, but the option of 20% was chosen because it gave slightly better results. Using the abundance indices listed in the previous paragraph different configurations were tested and the one described above was selected. This run was selected as possible proposal for the assessment and is the run whose detailed prior settings are described in Table 9.9.1.1. However several more runs were conducted to test for sensibility of the model selected.

The sensitivity of the model to the prior distribution of recruitment was tested and the results obtained did not vary between runs. Due to the high decrease in the abundance of age 6 and older age groups and the increased difficulty of tracking cohorts at those ages suggested by the data, the model was run using a plus group age at 6. Two configurations were tried: one using abundance indices up to age 5 and the second one using them up to age 6+. The MCMC algorithm for these runs was very slow, they took longer than two and four days, respectively, but the results were congruent with those obtained using the 10+ age. The slowness of the MCMC algorithm with a 6+ group was also a sign that the configuration with 10 age groups was better. In another two alternative runs, the assumption of constant f(y) across years was tested. This is not a sensible assumption, but it was tested in an attempt to shed light on the high fishing mortalities obtained for older age groups, particularly in later years. Within the constraints imposed by the assumption itself, the results were coherent with what was observed previously.

Finally, a set of runs were tested using data only from 1999 onwards, with the same settings as in the final run, except for the 'r' parameters, which now needed a prior distribution for year 1999 instead of for year 1984. The data time-series were considered too short to provide a meaningful assessment, but this short set of data was considered as probably the most reliable. The results obtained were similar to those obtained before, when the assessment was started in 1984. However, it was considered too short a time period and without sufficient contrast to be able to base the stock assessment and advice just on it.

During the last days of the benchmark workshop, the data were checked again and an error identified, leading to a significant revision of landings-at-age in 2000 and weight-at-age in 2007. Due to the long run times of the model, it was impossible to rerun all the sensitivity analyses, but it is not expected that the process followed to arrive at a final model configuration and settings and the results obtained would have changed significantly if done based on the new (corrected) dataset. The finally selected model was rerun with the selected configuration and the new data. The goodness-of-fit and convergence of the model did not experience appreciable changes with the new data. The estimates did suffer weak changes from 2000. The retrospective runs (discussed below) are also based on the new data.

9.9.3 Retrospective patterns

Retrospective analysis was conducted for four years, the retrospective time-series of most relevant indicators are shown in Figure 9.9.2.8. In terms of SSB, two groups were distinguished: one corresponding to the two shortest time-series (removing the three and four final years) and a second one with the three longest time-series (until 2010 and removing one and two years). The SSB estimates from the three longest time-series were very similar throughout the entire time-series. The recruitment estimates towards the end of the time-series showed significant revisions in the retrospective analysis, but this is something common, as recruitment in the most recent year(s) is usually not correctly estimated by assessment models. The fishing mortality in the most recent years was revised downwards year by year. The revision was especially marked in the most recent fit. The model-fitted catch showed the same behaviour as fishing mortality, but the differences were lower. The retrospective pattern in estimated catch was generally similar to the retrospective pattern in estimated discards. The retrospective pattern in landings was low, but it was significant for discards. Given the lack of discards data, it is natural to expect worse estimates in discards than in landings. The retrospective patterns in the rest of time-series could be due to the revision of discards year by year.

9.9.4 Evaluation of the models

The model gave promising results and seemed to be able to deal with the heterogeneity in the Northern Megrim data. The model fit to the data was adequate. However, a lack of confidence in the data used made it impossible to accept the absolute values of model results.

The lack of confidence in the data also makes it impossible to believe the results of any other model that could be applied to these data. Thus, in order to advance in the analytical assessment of this stock, the data used should be carefully examined and improved or, otherwise, additional information must be obtained to confirm the good quality of current data.

Using data only from 1999 gave similar results to using the whole dataseries. In principle, the available data in this period is expected to be more reliable, but no direct (or indirect) discard estimates are available for the "Others" fleet (mostly France) and the data period is too short and without sufficient contrast to base the stock assessment just on it.

The use of the Bayesian statistical catch-at-age model to assess the stock looks promising, but more effort is needed to improve the confidence in data. Work in this direction should take place to reach a reliable analytical assessment of the stock.

9.9.5 Conclusion

In the view of the current problems and deficiencies of available data, the Group concludes that no precise estimates of development of the stock population structure and SSB are available. The basis for the assessment should be then,

- The analysis of trends of Survey and Commercial Indices.
- For a more detailed analysis, which could be masked by the pooling ages in the above indices, qualitative results of the statistical catch-at-age Bayesian model will be scrutinised.
- A revision of the abundance of the ages of each of the fleets will be analysing by means of grouping ages (Group i: ages 1 + 2; Group ii: ages 3, 4, and

5 and Group iii: ages 6, 7 8, 9 and 10+). The objective is to discern for any possible change in abundance in young, intermediate and old ages along the dataseries.

9.10 Short-term and medium-term forecasts

No analytical assessment resulted available for this stock consequently no forecast is either provided.

9.11 Biological reference points

The calculation of possible reference points was not considered appropriate at this time due to the lack of analytical analysis.

9.12 Recommendations on the procedure for assessment updates and further work

1) Megrim VIIb,c, e–k and VIIIa,b,d. The group states strongly the importance of incorporating annual estimates of discards from France to explain some possible recruitment that could not be completely registered in the catch-at-age matrix and lpues. Also it is important to incorporate these estimates to obtain consistent data along the series.

2) Megrim VIIb,c, e–k and VIIIa,b,d. A complete revision and in depth analysis is needed for checking the changes detected in the data homogeneity of the three time periods identified: 1984–1989; 1990–1998 and 1999–2010.

3) Megrim VIIb,c, e–k and VIIIa,b,d. No progress can be expected if no international commitment to work com-promise for countries exploiting on data and methods to assess this stock is obtained. However it appears unlikely that time between possible future Benchmarks and Working Groups would be enough for: i) solving data availability, ii) reviewing their quality, iii) new model trials and even iv) exchange of experiences between researches working in same species but different stocks. That is why it would be recommended that resources could be made available for a real improvement in the assessment of this stock. A pilot project is suggested for in a depth treatment of data analysis and improvement and model selection.

4) Megrim VIIb,c, e–k and VIIIa,b,d. The distribution of megrim stock does not include ICES Division VIIa and VIId. Further work is needed to assess the stock identity of megrims in this area.

9.13 Implications for management (plans)

9.14 References

Anon. 2003. Workshop on Discard Sampling Methodology and Raising Procedures Danish Institute for Fisheries Research, Charlottenlund, Denmark.2–4 September, 2003. Final Report. The ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS).

BECAUSE. 2004. Critical Interactions BEtween Species and their Implications for a PreCAUtionary FiSheries Management in a variable Environment – a Modelling Approach. Proposal/contract no: 502482. March 2004–February 2007.

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

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

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

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

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

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

R Development Core Team. 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

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

Santurtún M., Lucio P. and Franco, J. 2000. Biology of Megrim (*Lepidorhombus whidffiagonis*) in waters of the Bay of Biscay during 1996–1997.Ozeanografika, 3:301–324, 2000.

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

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

Table 9.2.1.1. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Nominal landings and catches (t) provided by the Working Group.

	Total landings	Total discards	Total catches	Agreed TAC (1)
1984	16659	2169	18828	
1985	19597	1732	21329	
1986	18927	2321	21248	
1987	17114	1705	18819	16460
1988	17577	1725	19302	18100
1989	19233	2582	21815	18100
1990	14370	3284	17654	18100
1991	15094	3282	18376	18100
1992	15600	2988	18588	18100
1993	14929	3108	18037	21460
1994	13684	2700	16384	20330
1995	15862	3206	19068	22590
1996	15109	3026	18135	21200
1997	14230	3066	17296	25000
1998	14345	5371	19716	25000
1999	13305	3297	16602	20000
2000	15031	1870	16901	20000
2001	15778	2262	18040	16800
2002	15987	2813	18800	14900
2003	15687	4008	19695	16000
2004	14300	5240	19539	20200
2005	12703	2578	15281	21500
2006	12000	3368	15369	20425
2007	13048	2703	15750	20425
2008	10853	2531	13384	20425
2009	13348	2604	16442	20425
2010	13185	4406	19239	20106

(1) for both megrim species and VIIa included.

Table 9.2.1.2. Megrim (*L.whiffiagonis*) in VIIb–k and VIIIa,b,d. Discards information and derivation.

	FR	SP	IR	UK
1984	**FR84-85**	-	-	-
1985	**FR84-85**	-	-	-
1986	(FR84-85)	(SP87)	-	-
1987	(FR84-85)	**SP87**	-	-
1988	(FR84-85)	**SP88**	-	-
1989	(FR84-85)	(SP88)	-	-
1990	(FR84-85)	(SP88)	-	-
1991	**FR91**	(SP94)	-	-
1992	(FR91)	(SP94)	-	-
1993	(FR91)	(SP94)	-	-
1994	(FR91)	**SP94**	-	-
1995	(FR91)	(SP94)	**IR**	-
1996	(FR91)	(SP94)	**IR**	-
1997	(FR91)	(SP94)	**IR**	-
1998	(FR91)	(SP94)	**IR**	-
1999	-	**SP99**	**IR**	-
2000	-	**SP00**	**IR**	**UK**
2001	-	**SP01**	**IR**	**UK**
2002	-	(SP01)	**IR**	**UK**
2003	-	**SP03**	**IR**	**UK**
2004	-	**SP04**	**IR**	**UK**
2005	-	**SP05**	**IR**	**UK**
2006	-	**SP06**	**IR**	**UK**
2007	-	**SP07**	**IR**	**UK**
2008	-	**SP08**	**IR**	**UK**
2009	-	**SP09**	**IR**	**UK**
2009	-	**SP10**	**IR**	**UK**

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

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

Table 9.2.2.1. Megrim (*L.whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Original Length composition by fleet (thousands) has been deployed. None raised to the total landings. No length frequencies for Belgium are available.

Length class (cm)	FRANCE	SPAIN		IRELAND	UNITED KINGDOM			
	ALL FISHING U	FU04:Otter trawl-me	FU14:Otter trawl-med&	ALL FISHING	FU03:Fixed nets	FU 04: Otte	FU05:Otter t	FU06:Beam trav
10	0	0	0	0		0	0	0
11	0	0	0	0		0	0	0
12	0	0	0	0		0	0	0
13	0	0	0	0		0	0	0
14	0	0	0	0		0	0	0
15	0	0	0	0		0	0	0
16	0	0	0	0		0	0	0
17	0	0	0	0		0	0	0
18	0	0	0	0		0	0	0
19	0	0	0	0		0	0	0
20	0	5	4	0		0	0	0
21	0	2	20	1		0	0	0
22	0	10	76	3		0	0	0
23	0	178	140	7		0	0	0
24	5	949	226	26		0	0	2
25	16	2669	243	117		0	2	7
26	20	4066	193	257		0	2	21
27	45	4512	143	386	0.007	0	6	45
28	70	3477	150	484	0.000	0	6	69
29	99	2716	140	599	0.007	0	7	76
30	103	2998	176	750	0.038	0	11	92
31	116	2618	174	868	0.013	0	14	77
32	135	2082	157	797	0.045	0	16	93
33	160	1406	147	697	0.027	0	22	111
34	169	1021	98	574	0.050	0	28	133
35	167	921	73	466	0.044	0	23	98
36	164	688	60	422	0.043	0	25	106
37	156	556	38	311	0.068	0	21	111
38	156	398	29	269	0.080	0	19	110
39	140	370	15	198	0.062	0	18	92
40	135	193	10	140	0.091	0	15	70
41	119	194	6	107	0.026	0	12	53
42	114	189	4	90	0.043	0	10	44
43	71	161	3	74	0.013	0	6	31
44	59	90	2	46	0.018	0	5	30
45	44	73	2	40	0.012	0	5	19
46	37	103	1	37	0.018	0	3	16
47	32	101	1	29	0.012	0	2	11
48	23	64	1	26	0.012	0	1	10
49	24	33	1	13	0.007	0	1	10
50	16	20	0	14	0.006	0	1	6
51	16	14	0	5	0.006	0	0	7
52	19	10	0	7		0	0	7
53	11	8	0	5		0	0	4
54	8	20	0	3		0	0	3
55	3	0	0	2		0	0	2
56	3	0	0	0		0	0	1
57	2	0	0	2		0	0	1
58	1	0	0	0		0	0	1
59	0	0	0	0		0	0	0
60	0	0	0	0		0	0	0
61	0	0	0	0		0	0	0
62	0	0	0	0		0	0	0
63	0	0	0	0		0	0	0
64	0	0	0	0		0	0	0
65	0	0	0	0		0	0	0
66	0	0	0	0		0	0	0
67	0	0	0	0		0	0	0
68	0	0	0	0		0	0	0
69	0	0	0	0		0	0	0
70	0	0	0	0		0	0	0
TOTAL	2458	32917	2335	7874	1	0	280	1570

Table 9.2.3.1. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Abundance Indices for UK-WCGFS-D, UK-WCGFS-S, IGFS, SP-PGFS and EVHOE.

UK-WCGFS-D — Effort in hours

	Effort	Age 1	2	3	4	5	6	7	8	9
1987	100		863	5758	0	0	0	95	1753	151
1988	100	8	256	59	49	0	228	1008	1262	632
1989	100		70	188	471	2540	788	3067	680	1060
1990	100	8	526	1745	553	2584	1985	974	1154	974
1991	100		415	1375	1250	989	912	1677	593	731
1992	100	7	28	425	414	349	189	206	132	121
1993	100		122	382	1758	1505	728	739	666	718
1994	100		69	1593	1542	2663	1325	1278	825	595
1995	100	47	582	747	1755	1686	1303	548	281	421
1996	100	15	69	475	549	1580	1231	870	327	117
1997	100		329	751	1702	1518	541	149	47	17
1998	100		120	797	1432	1134	866	242	246	13
1999	100		237	270	734	760	302	94	33	17
2000	100		143	1004	619	681	395	67	35	13
2001	100	20	384	690	1426	581	460	376	226	45
2002	100		162	2680	1915	1349	761	690	315	104
2003	100		330	1705	3149	2662	1451	676	417	179
2004	100	168	1001	1382	1069	897	628	208	47	

UK-WCGFS-S — Effort in hours

	Effort	Age 1	2	3	4	5	6	7	8	9
1987	100		499	3082	641	891	180	794	264	587
1988	100		47	55	585	95	367	0	50	93
1989	100		616	574	547	1540	576	361	297	198
1990	100		375	1057	816	661	1220	195	454	176
1991	100	2	373	829	822	394	460	550	178	293
1992	100		149	278	323	193	109	164	93	36
1993	100		470	877	1140	601	327	321	143	233
1994	100		74	1000	1301	998	521	374	185	153
1995	100	28	435	878	1167	1054	805	488	359	130
1996	100	2	64	401	389	823	592	372	152	43
1997	100	3	284	1028	550	540	289	202	75	29
1998	100	4	30	438	665	381	209	97	48	21
1999	100		69	82	222	214	103	53	41	20
2000	100		72	377	249	313	169	81	52	20
2001	100	2	131	297	594	104	145	122	80	37
2002	100		134	808	506	757	339	326	181	82
2003	100	5	184	289	639	416	328	113	102	36
2004	100	50	343	467	270	394	303	124	49	21

EVHOE

	Effort	Age 1	2	3	4	5	6	7	8	9
1997	100	0.77	3.92	2.47	1.47	1.59	0.91	0.61	0.35	0.15
1998	100	1.61	0.66	4.48	3.07	1.52	0.98	0.84	0.43	0.14
1999	100	0.54	3.48	0.72	2.14	3.38	1.66	0.70	0.30	0.27
2000	100	1.38	2.79	2.64	1.35	1.22	0.73	0.40	0.28	0.14
2001	100	0.94	0.51	1.87	2.36	2.72	1.87	1.40	0.38	0.22
2002	100	3.12	2.28	4.24	3.18	1.67	0.68	0.49	0.23	0.10
2003	100	2.53	2.95	2.40	3.21	0.67	0.65	0.25	0.19	0.11
2004	100	0.97	4.64	1.70	0.96	0.77	0.66	0.33	0.25	0.12
2005	100	0.86	3.48	2.94	0.91	0.57	0.48	0.13	0.07	0.12
2006	100	2.77	5.06	3.25	0.25	0.86	0.36	0.38	0.21	0.07
2007	100	4.05	3.91	1.63	1.39	2.03	0.66	0.43	0.24	0.10
2008	100	0.54	5.52	3.72	2.05	0.69	0.38	0.22	0.06	0.01
2009	100	1.55	3.09	7.90	0.94	0.45	0.21	0.06	0.01	0.00
2010	100	2.71	2.67	2.75	4.59	1.20	0.54	0.25	0.21	0.13

Table 9.2.3.1. *Abundance Indices by kilograms and numbers by 30 minutes haul duration IGFS.

	Effort	Age 0	1	2	3	4	5	6	7	8	9
2003	100	0	152	316	368	238	96	36	14	5	2
2004	100	0	153	461	595	454	162	57	30	12	3
2005	100	29	414	643	431	370	215	68	44	18	17
2006	100	44	505	548	481	215	154	68	10	7	5
2007	100	1	100	293	125	91	70	25	7	7	3
2008	100	5	141	487	350	101	66	60	17	12	5
2009	100	3	1	234	371	455	346	159	53	44	23
2010	100	6	1	128	377	259	173	90	38	13	10

SP-PGFS

	Effort	Age 0	1	2	3	4	5	6	7	8
2001	100	43	1770	2208	2842	3434	1941	1357	487	132
2002	100	6	972	2064	3068	4265	2471	1209	340	118
2003	100	12	979	2292	3997	5653	3090	1393	417	144
2004	100	6	597	2841	4524	4616	2550	932	405	126
2005	100	65	541	532	1934	6987	4183	2193	407	100
2006	100	4	1426	1144	2592	3739	2619	713	161	88
2007	100	24	3937	5613	2836	2884	1444	681	191	66
2008	100	10	189	1595	3872	2861	1282	863	197	58
2009	100	4	360	445	3584	4840	1122	605	273	86
2010	100	30	236	1604	1913	5030	1732	366	165	114

FR-EVHOEFS Abundance Indices by kilograms and numbers by 30 minutes haul duration

	kg/30'	Nb/30'
1997	1.98	12.35
1998	2.20	13.96
1999	1.82	13.43
2000	1.42	11.14
2001	2.21	17.04
2002	2.03	16.55
2003	1.77	13.14
2004	1.50	10.67
2005	1.43	9.88
2006	1.7	15.63
2007	1.94	14.55
2008	2.01	13.34
2009	2.5	14.8
2010	2.57	15.53

SP-PGFS Abundance Indices by kilograms and numbers by 30 minutes haul duration

	kg/30'	Nb/30'
2001	6.80	143.34
2002	6.66	147.00
2003	8.15	180.79
2004	7.45	167.47
2005	8.28	170.17
2006	6.03	125.37
2007	7.31	177.38
2008	5.99	109.70
2009	8.11	113.68
2010	8.52	112.56

IGFS Abundance Indices by numbers by 10 square kilometers

2003	1227
2004	1926
2005	2254
2006	2039
2007	725
2008	1247
2009	1850
2010	1103

Table 9.2.4.1. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. French and Spanish cpues for different bottom-trawler fleets.

	French (single and twin bottom trawls combined) CPUE (kg/h)				Spanish CPUE (kg/(100day*100 hp))			Irish LPUE ('00
	Benthic Bay of Bisc	Benthic Western Approa	Gadoids Western Approa	Nephrops Western Approa	A Coruña -VI	Cantábrico- V	Vigo-VII	Otter trawlers
1984					16.3	130.1	99.1	-
1985	3.0	5.3	4.7	4.7	9.8	39.5	108.9	-
1986	3.2	4.8	2.8	4.4	21.1	52.8	105.1	-
1987	3.3	5.1	2.7	4.5	8.3	80.7	96.2	-
1988	3.8	5.8	3.0	4.1	9.8	78.3	106.1	-
1989	3.6	5.5	2.6	4.2	14.6	48.1	92.1	-
1990	3.1	4.2	1.8	3.4	15.1	18.4	73.8	-
1991	2.6	4.0	1.3	2.8	12.9	25.9	85.4	-
1992	2.5	4.5	1.5	3.4	6.9	32.8	105.6	-
1993	1.9	4.6	1.2	3.5	5.1	33.5	92.3	-
1994	1.9	4.2	1.2	3.4	7.4	52.7	78.7	-
1995	2.3	4.9	1.4	3.4	7.8	61.3	94.3	13.7
1996	2.6	5.0	1.4	3.5	3.9	58.4	79.3	13.6
1997	3.3	5.6	1.2	3.0	3.0	46.9	96.0	12.1
1998	2.9	6.5	1.5	3.6	2.4	35.7	82.4	10.0
1999	3.0	6.3	0.9	3.4	1.1	32.5	137.0	11.3
2000	2.9	6.8	0.6	4.0	5.5	45.0	128.9	13.4
2001	2.2	6.8	0.7	4.1	1.3	75.6	131.2	13.1
2002	2.1	6.8	0.5	3.2	1.3	76.4	185.3	12.2
2003	1.8	5.8	0.6	3.2	11.2	54.0	192.1	8.2
2004	1.8	4.6	0.5	3.4	3.3	60.0	211.0	9.3
2005	1.9	5.1	0.4	4.2	1.7	58.46	135.3	10.0
2006	2.5	4.8	0.3	3.6	1.4	76.42	146.1	7.5
2007	2.4	5.1	0.4	2.9	2.4	87.86	144.3	8.5
2008	2.2	4.6	0.5	3.1	3.0	37.58	114.0	8.4
2009	NA	NA	NA	NA	8.3	0.00	173.2	10.3
2010	NA	NA	NA	NA	7.9	38.78	198.3	11.8

Table 9.9.1.1. Prior distributions. $LN(\mu,\psi)$ **denotes the lognormal distribution with median** μ **and coefficient of variation** ψ**, and** $\Gamma(u,v)$ **denotes the Gamma distribution with mean** u/v **and variance** u/v^2**.**

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

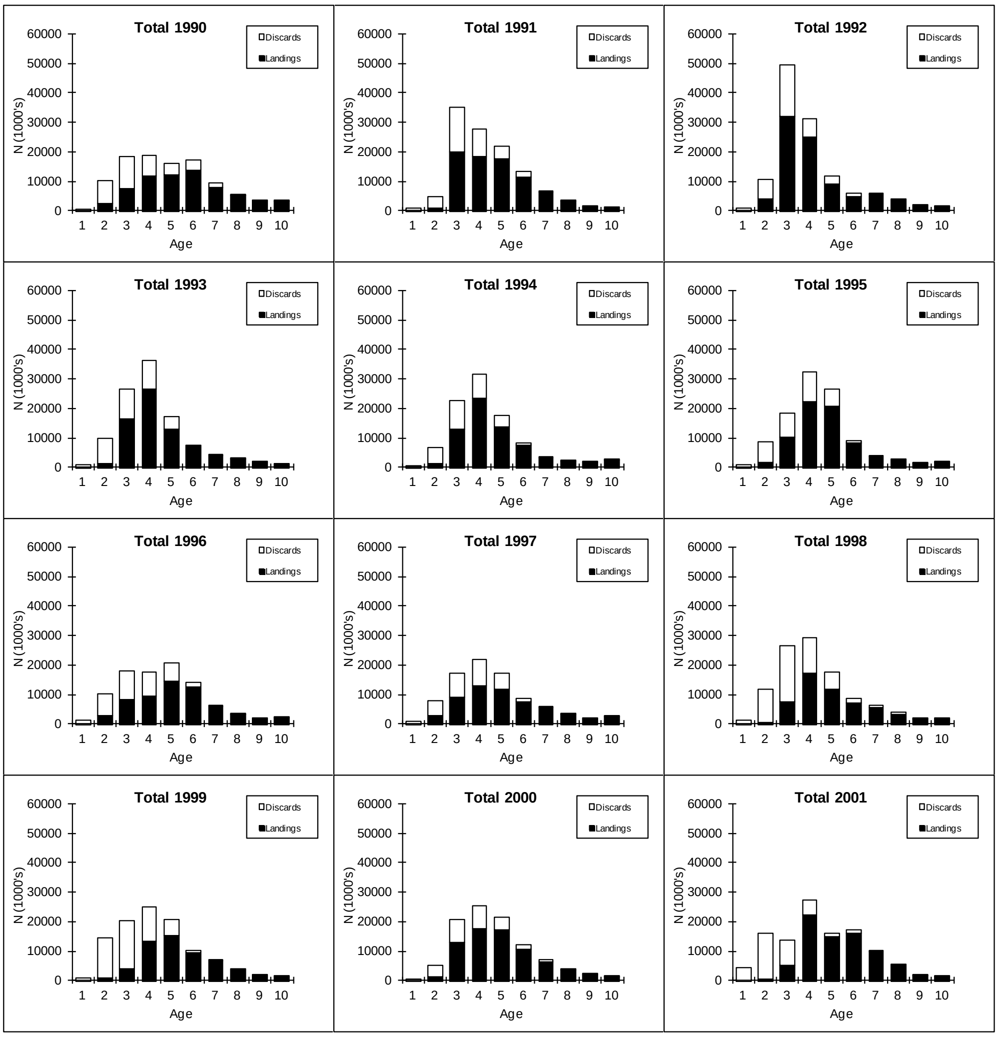


Figure 9.2.2.1. Megrim (*L.whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Age composition of catches for the years 1990 to 2010.

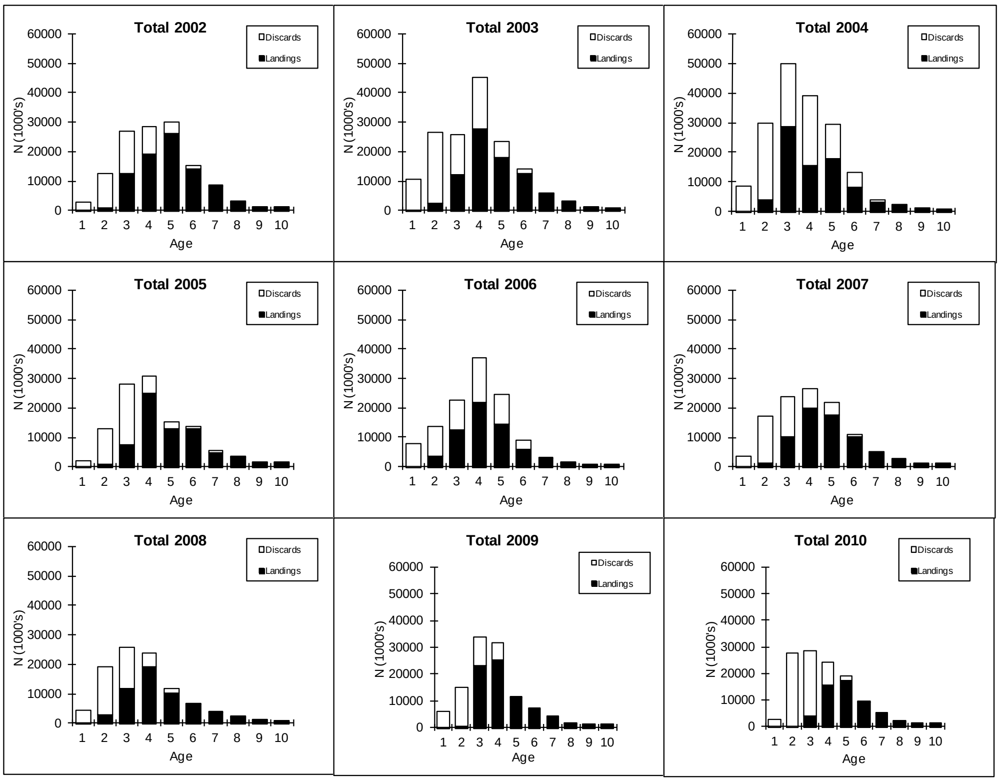


Figure 9.2.2.1. Continued.

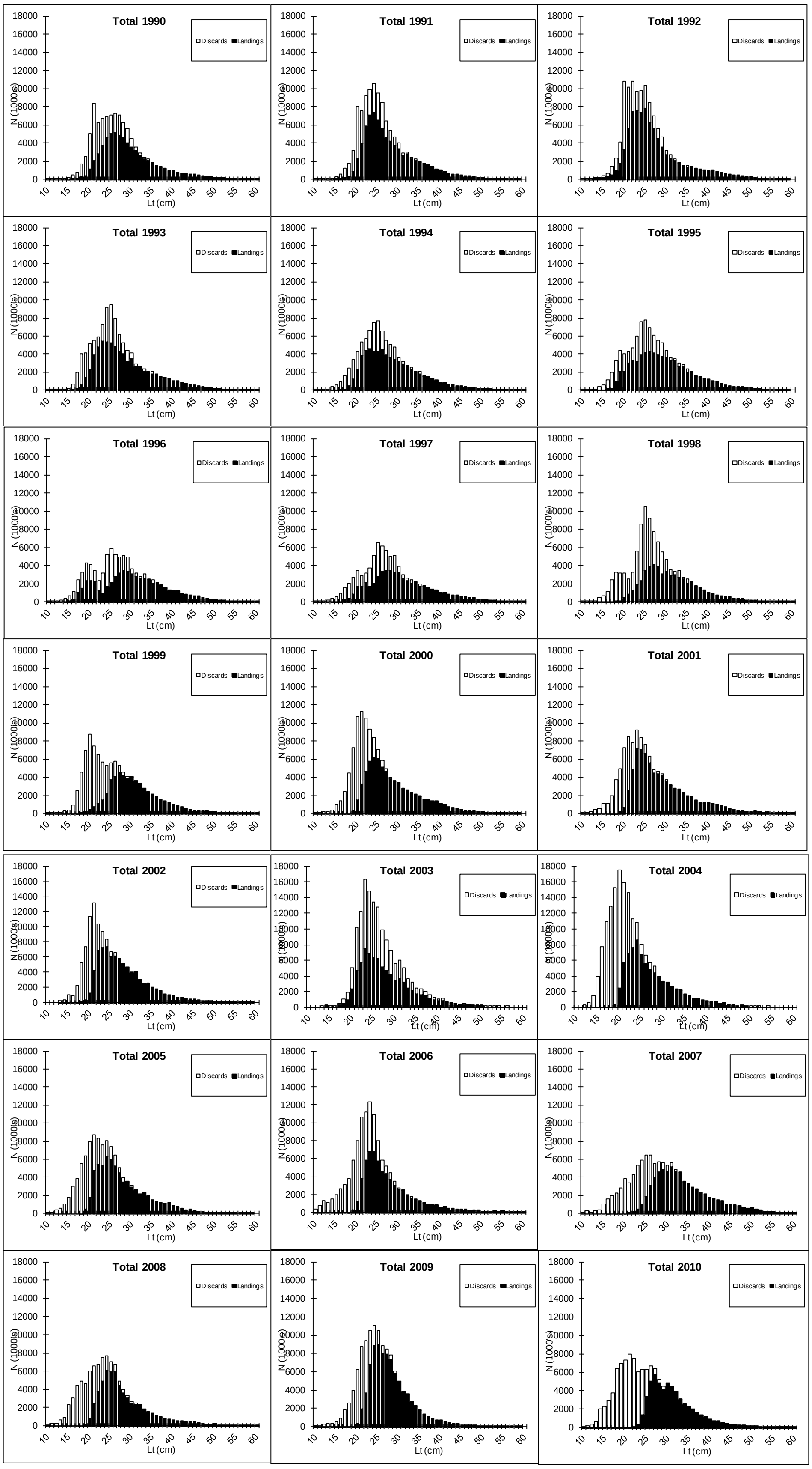


Figure 9.2.2.2. Megrim (*L.whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Length composition of catches for the years 1990 to 2010.

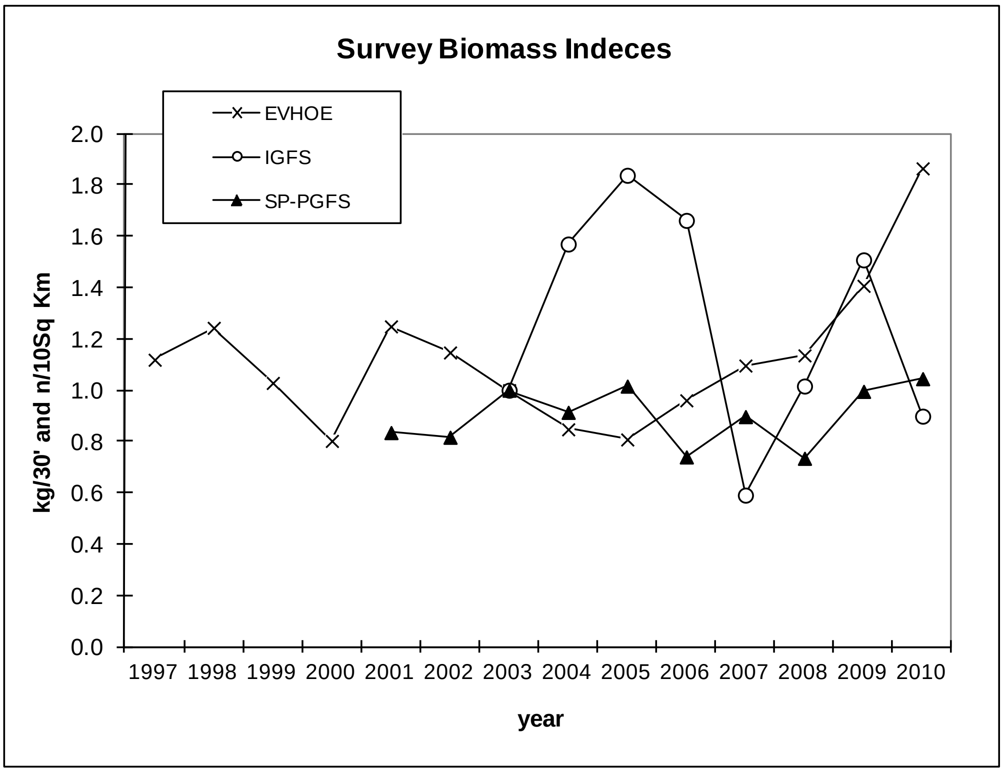
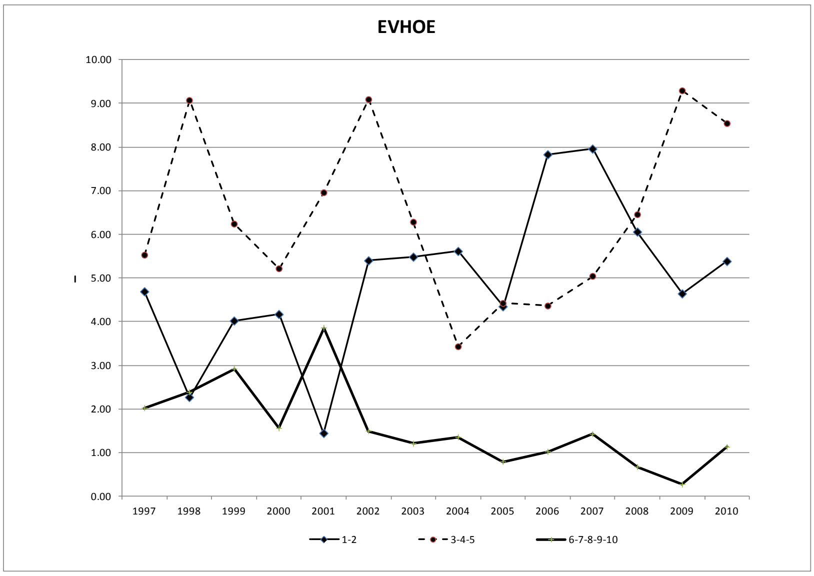
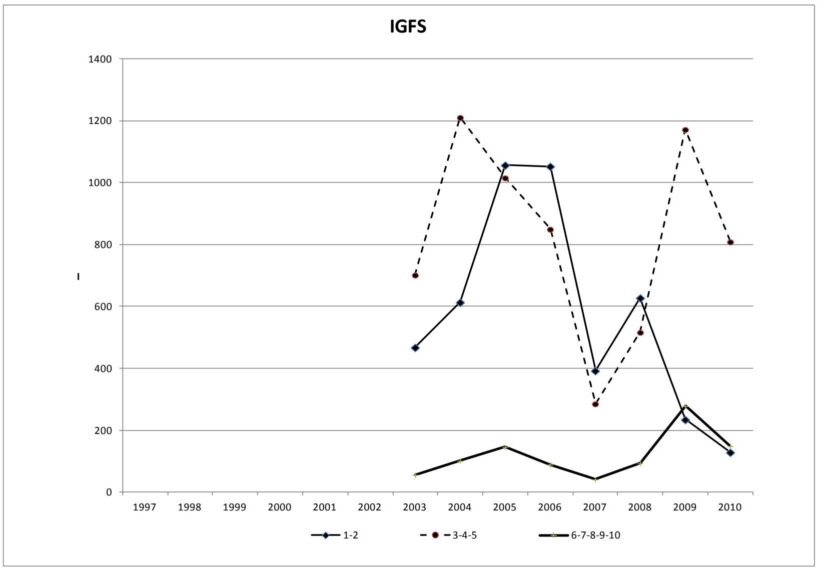


Figure 9.2.3.1. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Scaled Biomass Indices for EVHOE, SP-PGFS and IGFS.





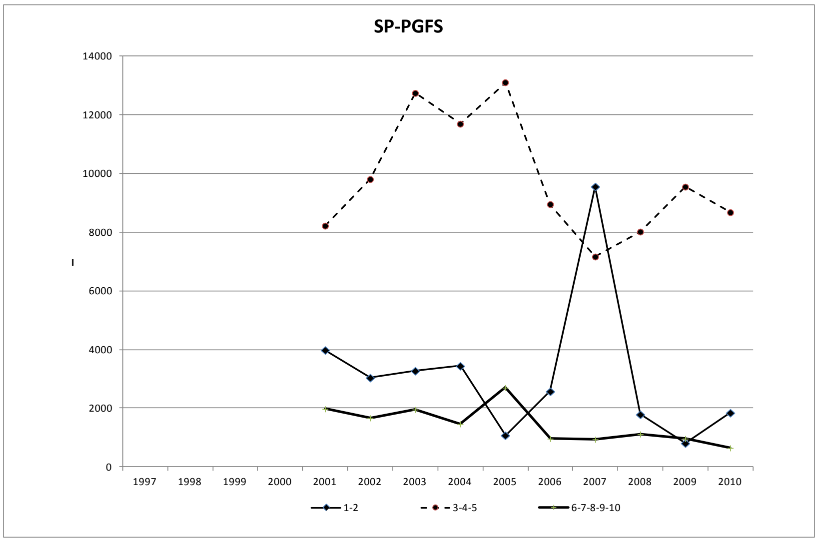


Figure 9.2.3.2. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Abundance Indices for EVHOE, IGFS and SP-PGFS by ages grouped: i) 1+2; ii) 3+4+5 and iii) 6+7+8+9+10+.

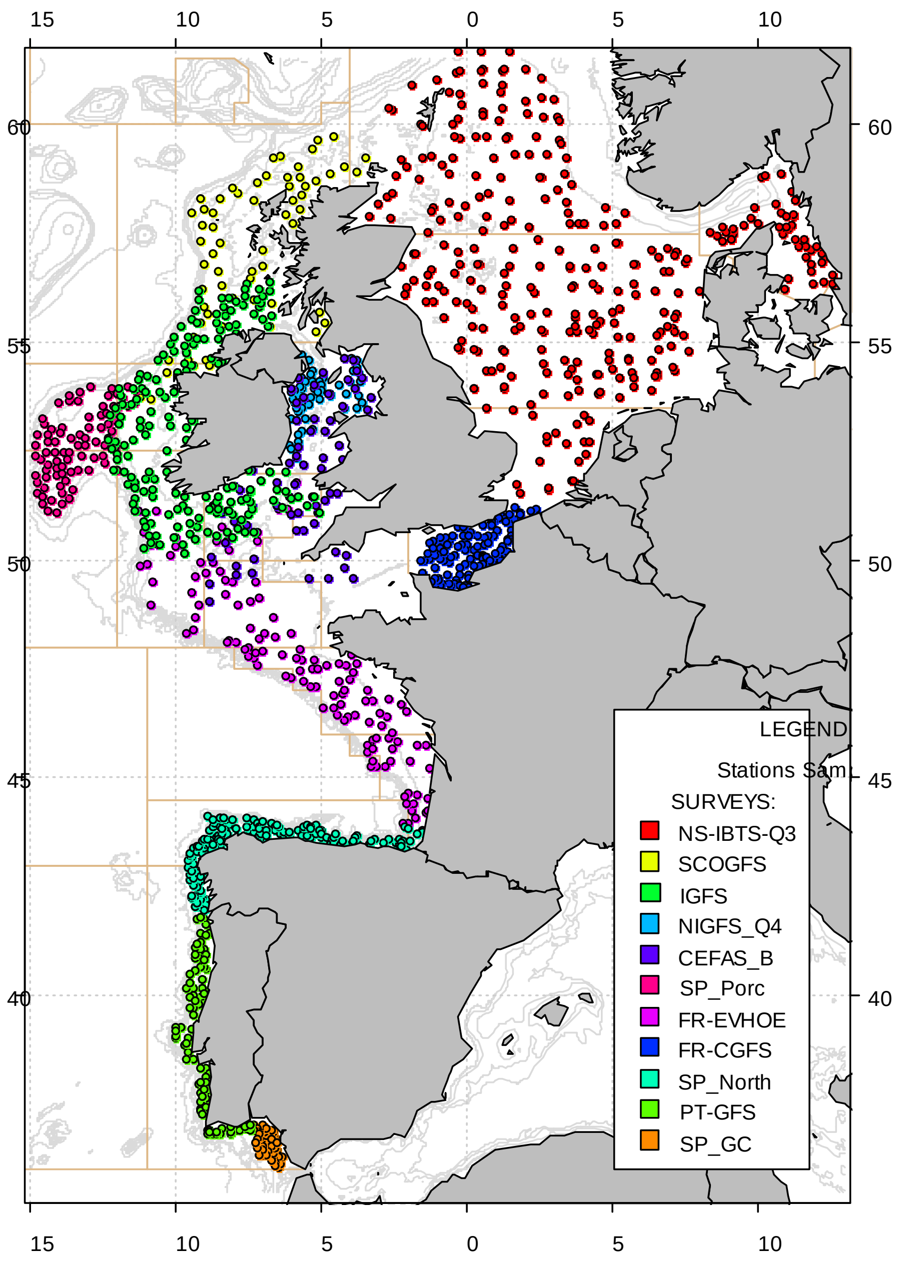


Figure 9.2.3.3. Station positions for the IBTS Surveys carried out in the Western and North Sea Area in autumn/winter of 2008. (From IBTSWG 2009 Report). Just to be used as general location of the Surveys.

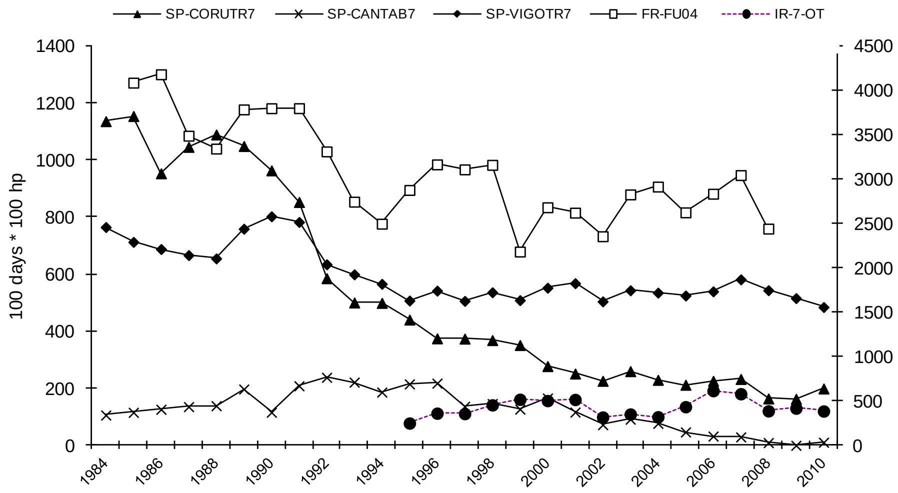


Figure 9.2.4.1a. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Evolution of effort for different bottom-trawler fleets.

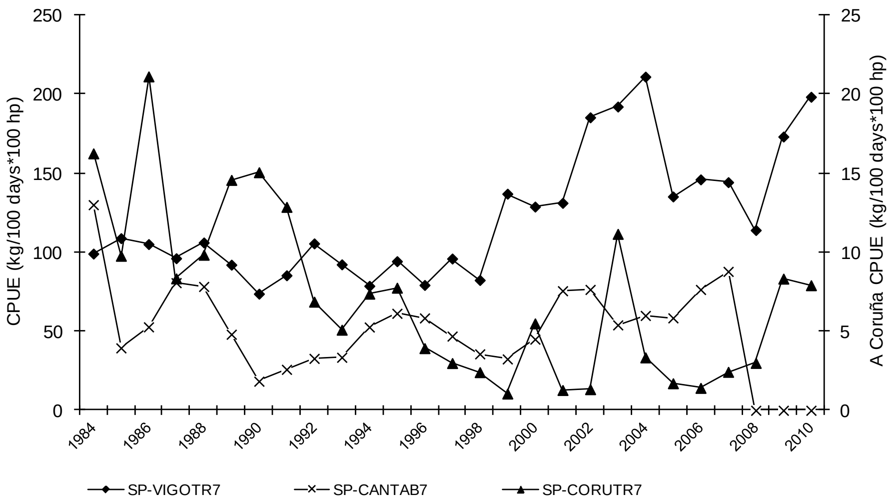


Figure 9.2.4.1b. Megrim (*L. whiffiagonis*) in Divisions VIIb,c,e-k and VIIIa,b,d. Spanish cpue for different bottom-trawler fleets.

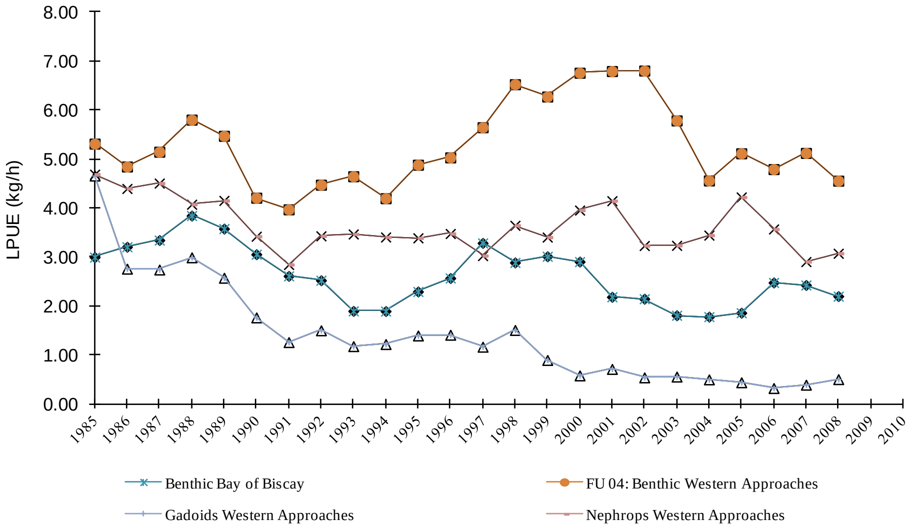


Figure 9.2.4.1c. Megrim (*L. whiffiagonis*) in Divisions VIIb,c,e–k and VIIIa,b,d. French lpue for different bottom-trawler fleet.

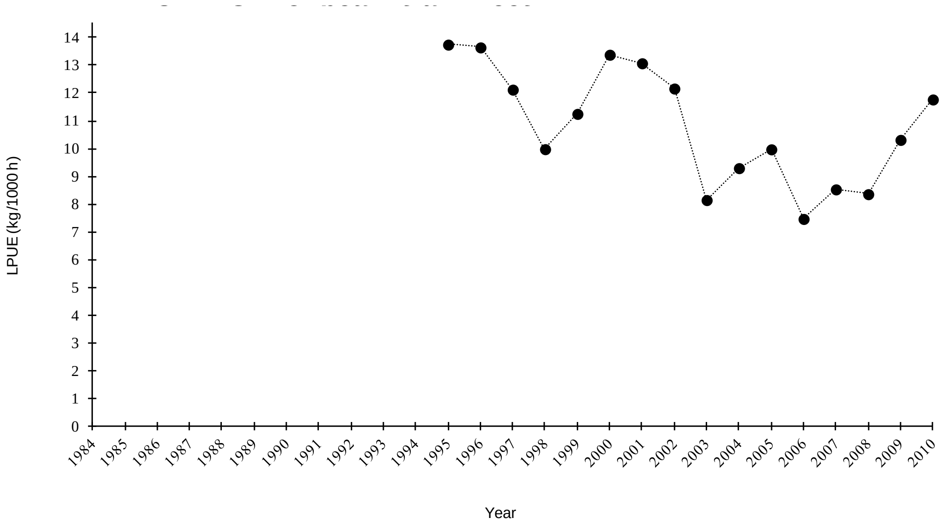


Figure 9.2.4.1d. Megrim (*L. whiffiagonis*) in Divisions VIIb,c,e-k and VIIIa,b,d. Irish lpue for beam trawl fleet.

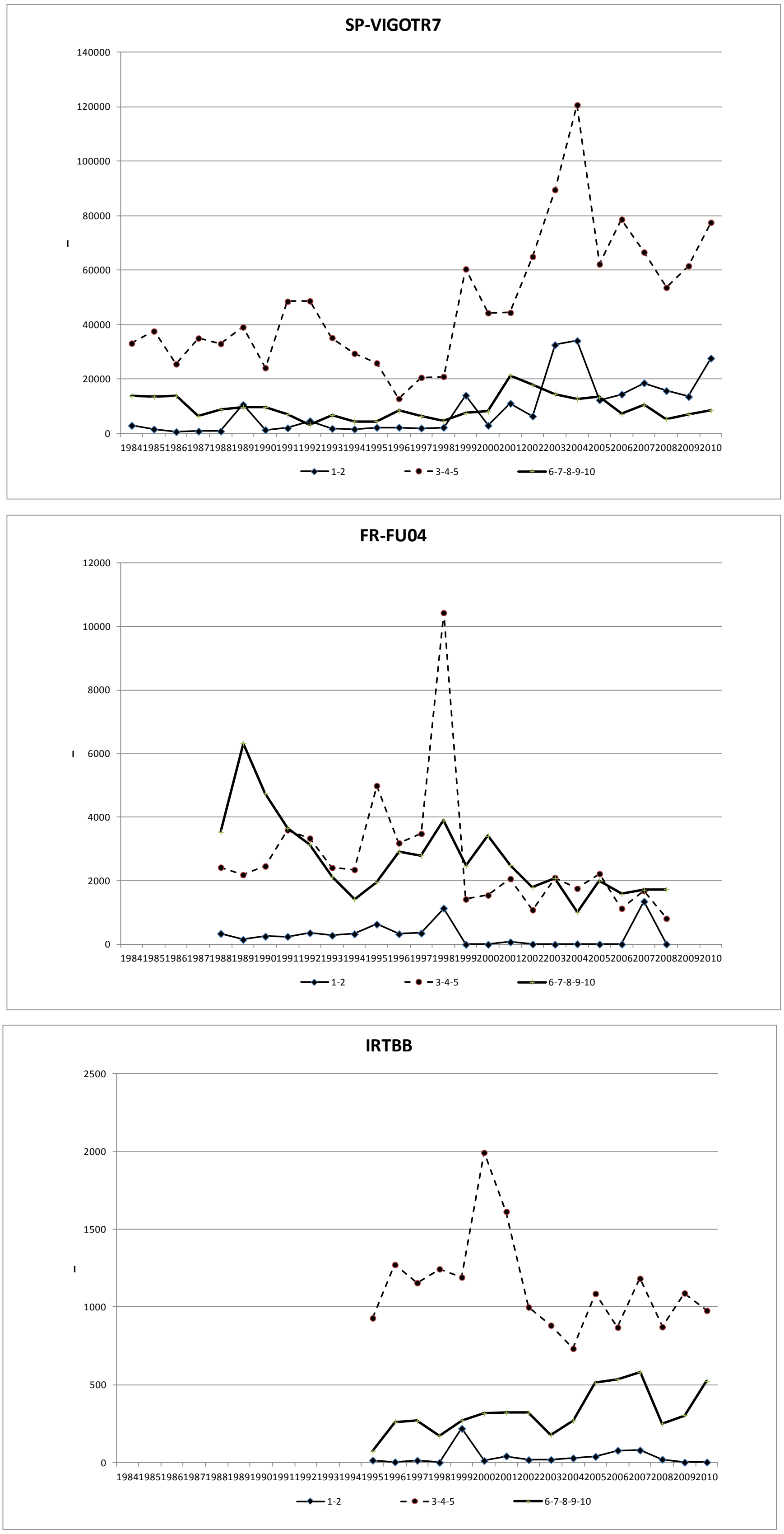


Figure 9.2.4.2. Megrim (*L. whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d. Abundance Indices for SP-VIGOTR7, FR-FU04 and IRTBB by ages grouped: i) 1+2; ii) 3+4+5 and iii) 6+7+8+9+10+.

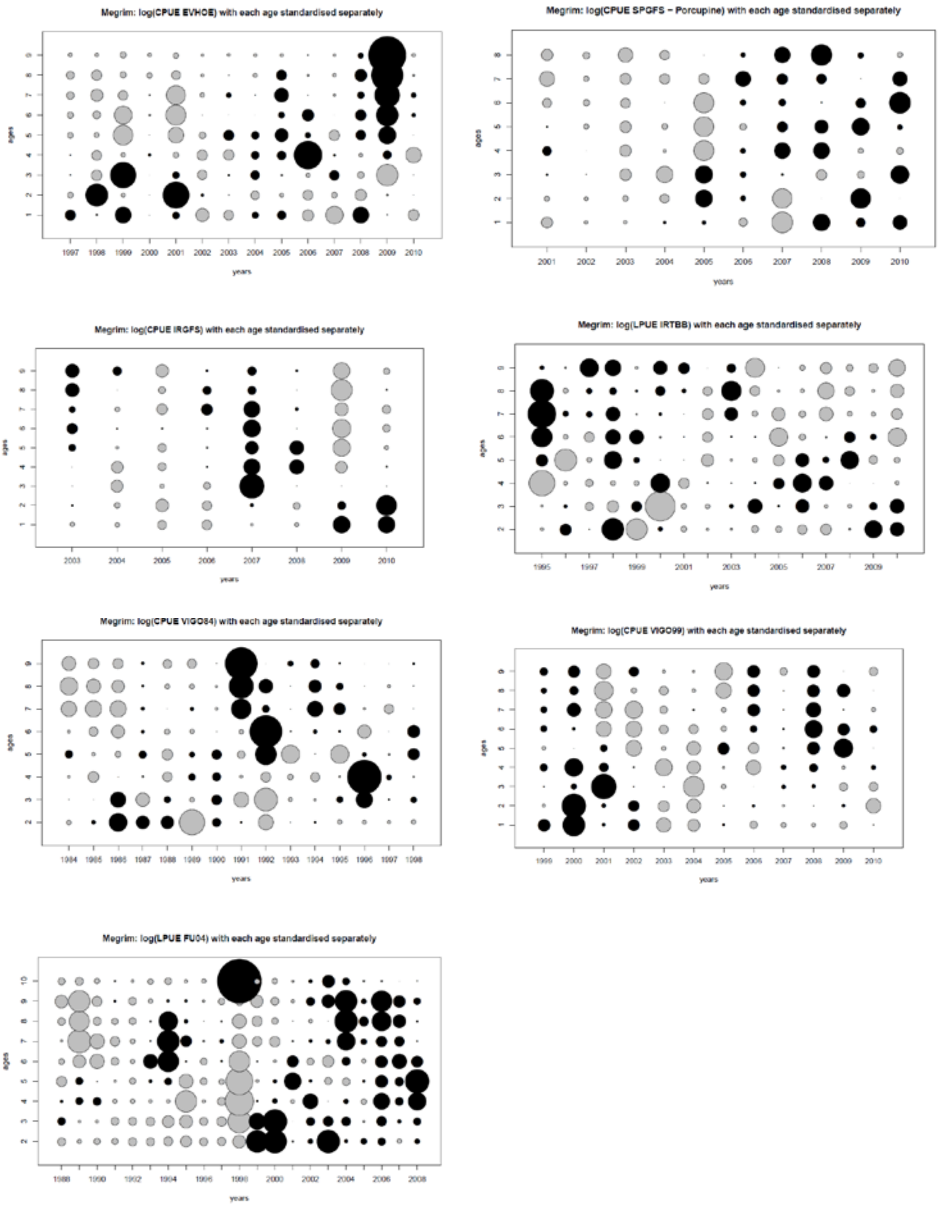


Figure 9.8.1 Bubble plots of the standardized log abundance indices of the surveys and commercial fleets for northern Megrim

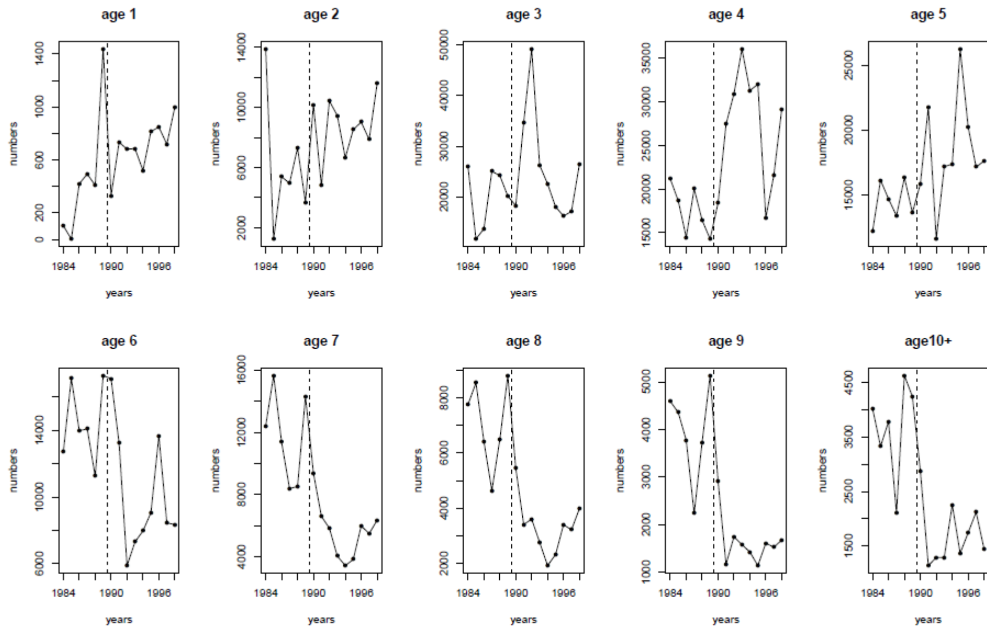


Figure 9.8.2. Time-series of catch numbers-at-age from 1984 to 1998.

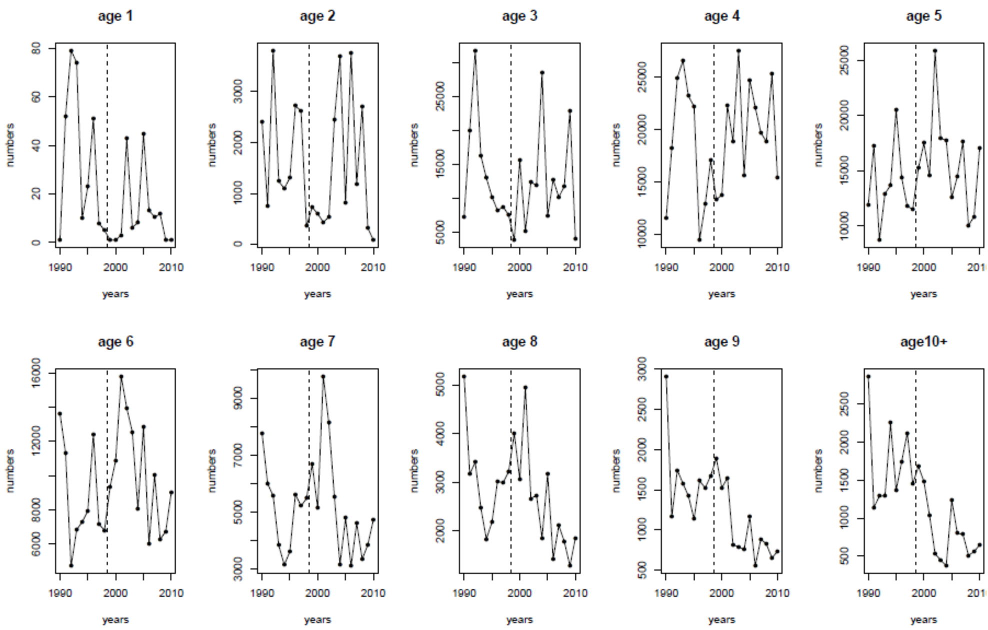


Figure 9.8.3. Exploratory data analysis. Landing numbers-at-age from 1990 to 2010.

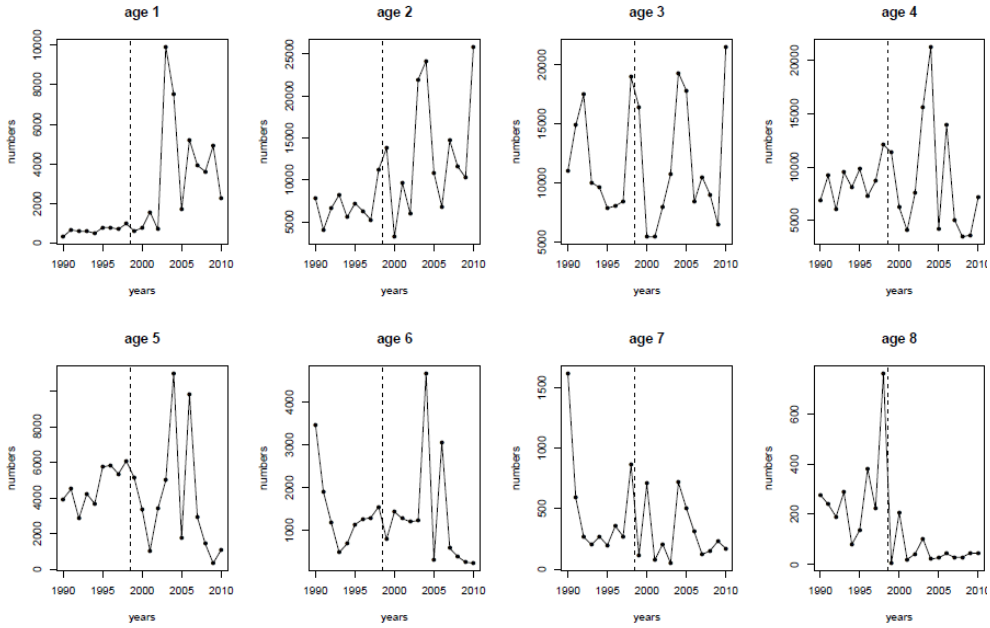


Figure9.8.4. Time-series of discards numbers-at-age from 1990 to 2010.

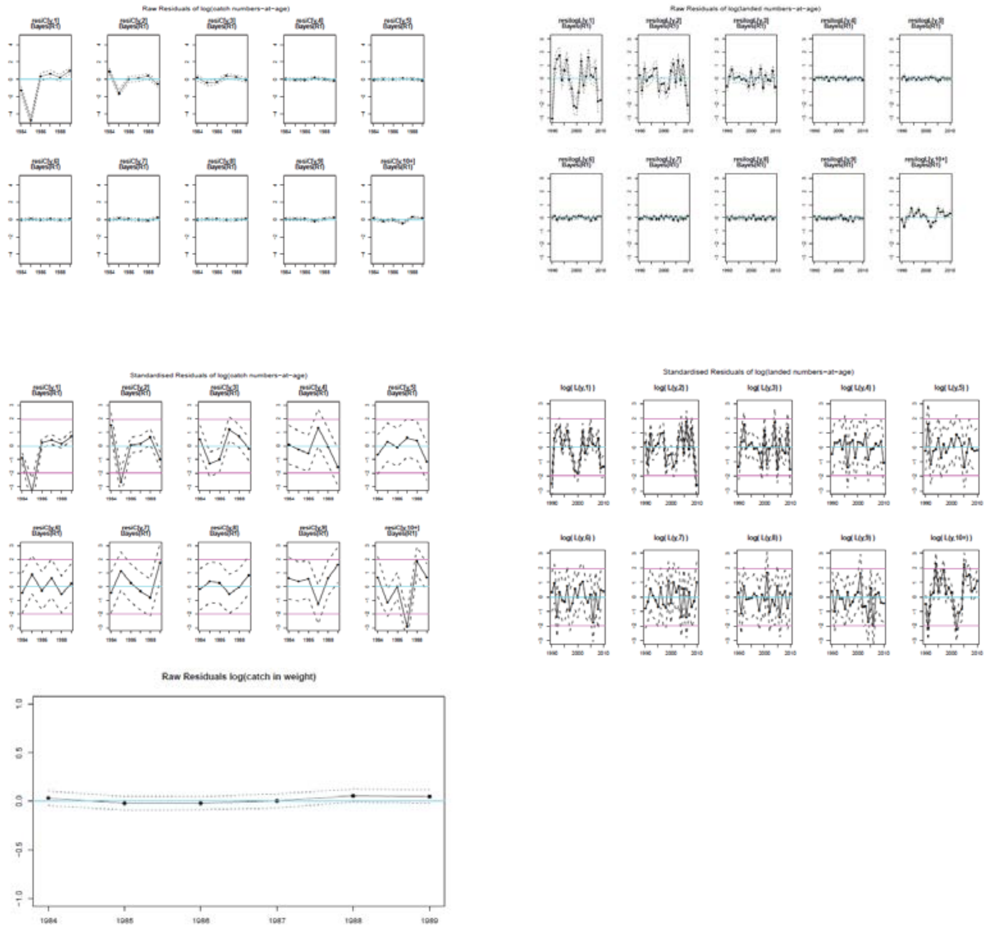


Figure 9.9.2.2.a Time series of raw and standardized log residuals from 1984 to 1988 for catches and landings. Solid lines correspond with the median of the distributions and dashed lines with 5% and 95% quantiles.

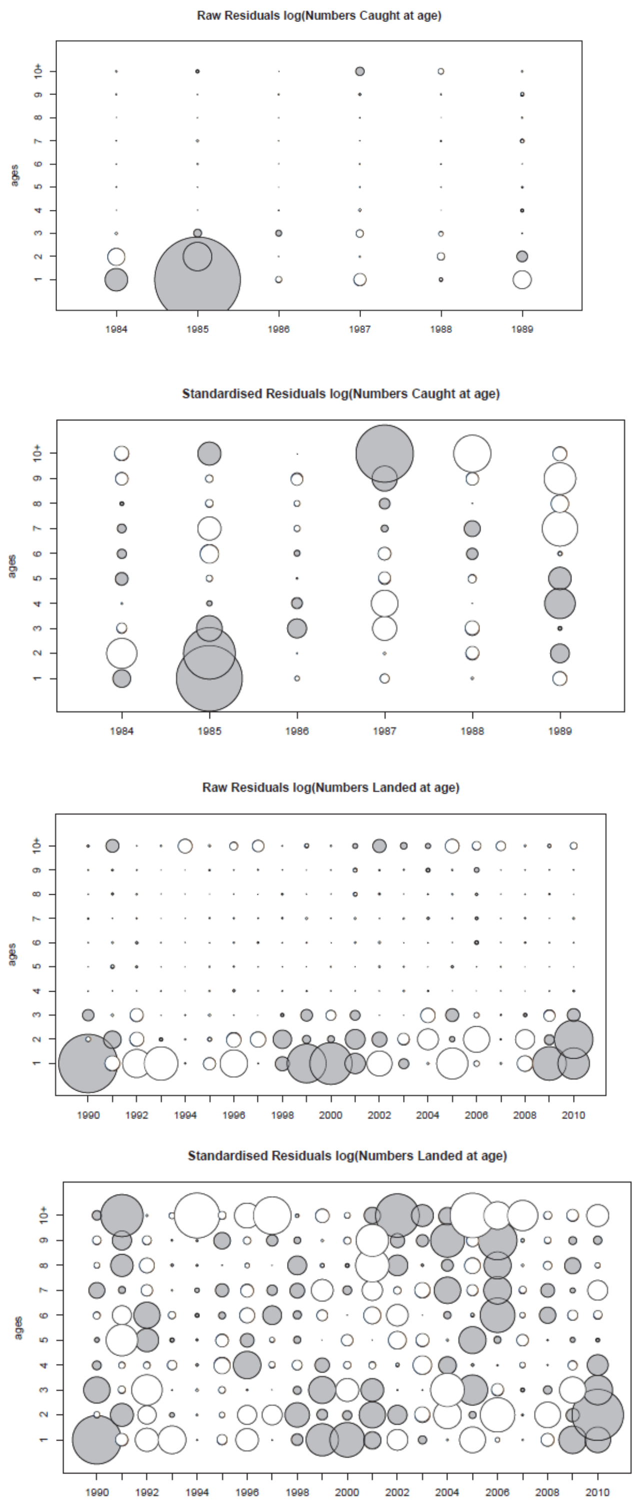


Figure 2.2.2.b Bubble plots on median raw and standardised lo
and landings from 1990 to 2010.

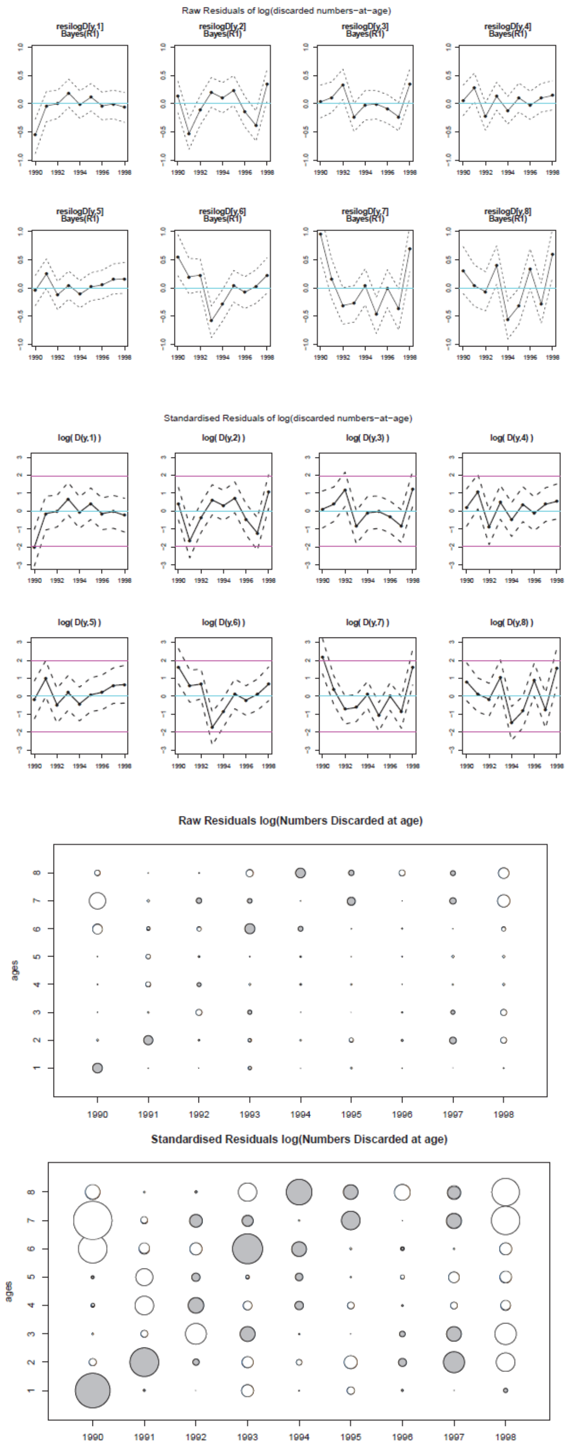


Figure 9.9.2.2.c. Time series of raw and standardized log-discards residuals at age from 1990 to 1998. Solid lines correspond with the median of the distributions and dashed lines with 5% and 95% quantiles. Bubble plots of raw and standardized log-residuals of discards from 1990 to 1998.

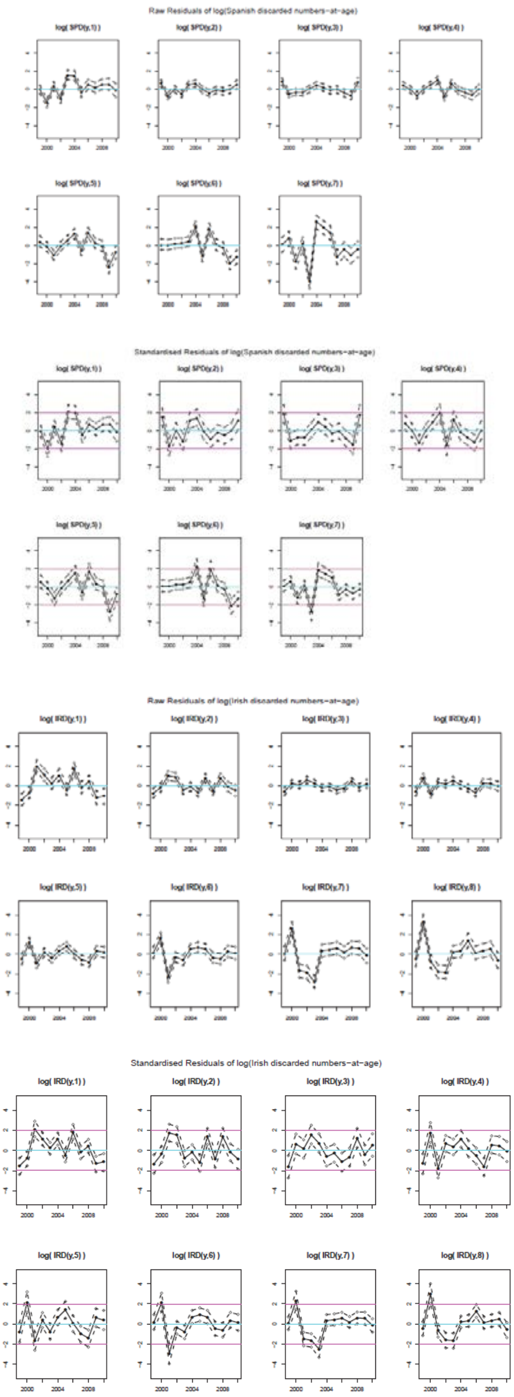


Figure 9.9.2.2.d. Time series of raw and standardized log -residuals at age of Spanish and Irish discards from 1999 to 2010. Solid lines correspond with the median of the distributions and dashed lines with 5% and 95%.

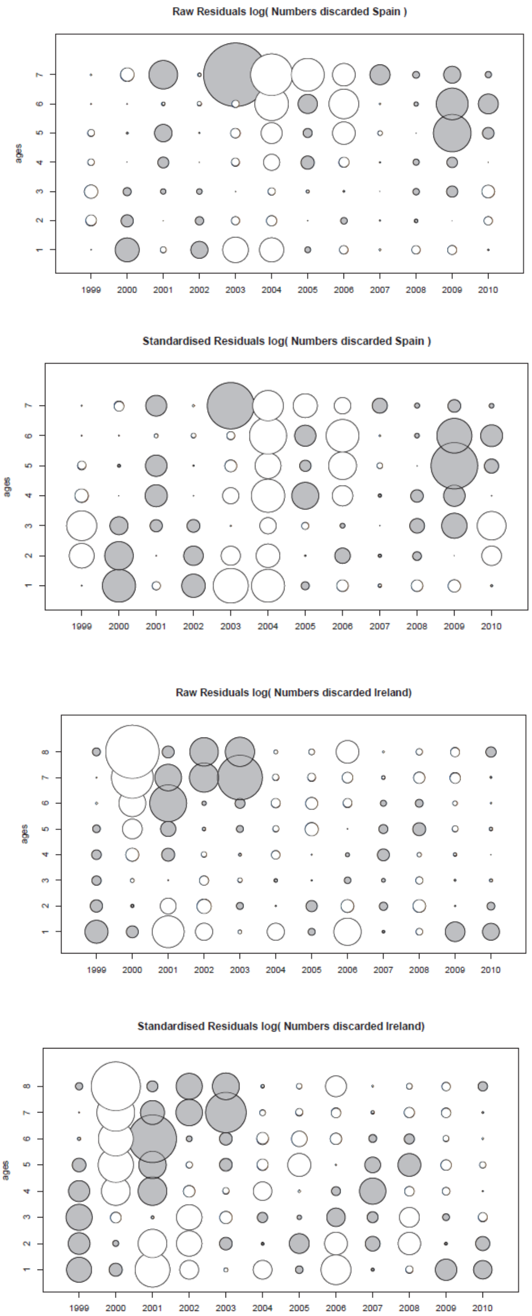


Figure 9.9.2.2.e. Bubble plots of median raw and standardized log residuals at age of Spanish and Irish discards 1999 to 2010.

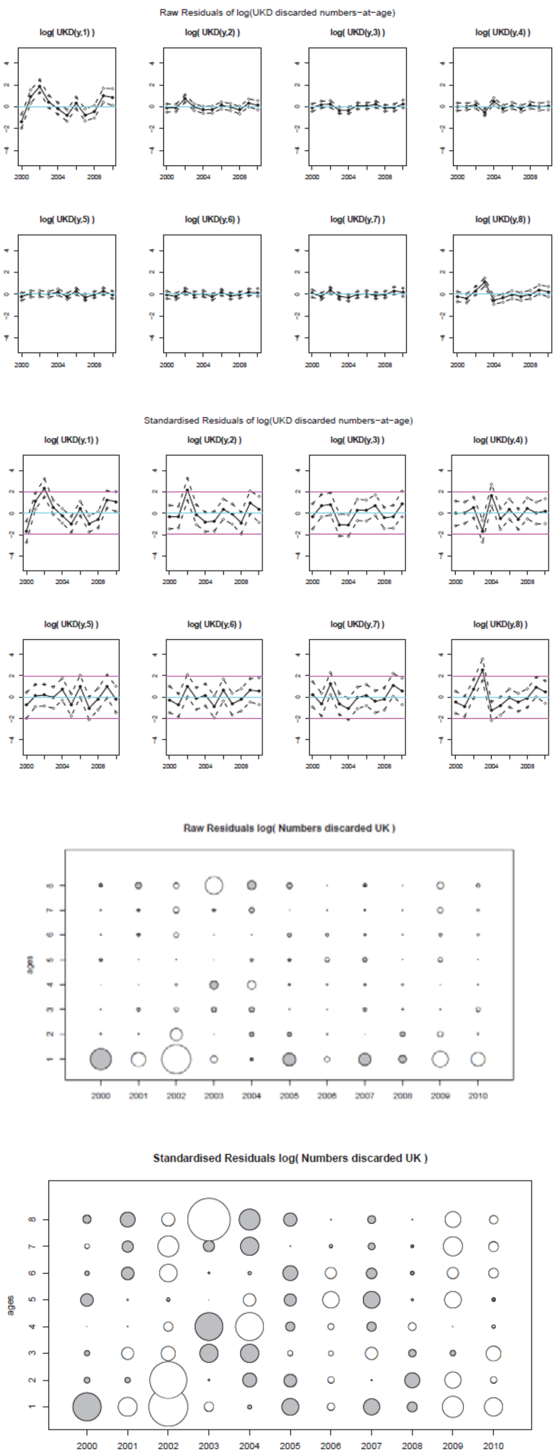


Figure 9.9.2.2.f. Time series of raw and standardized log- residuals at age of UK (England and Wales) from 2000 to 2010. Solid lines correspond with the median of the distributions and dashed lines with 5% and 95% Bubble plots of raw and standardized log- residuals at age of UK (England and Wales) discards from 2000 to 2010.

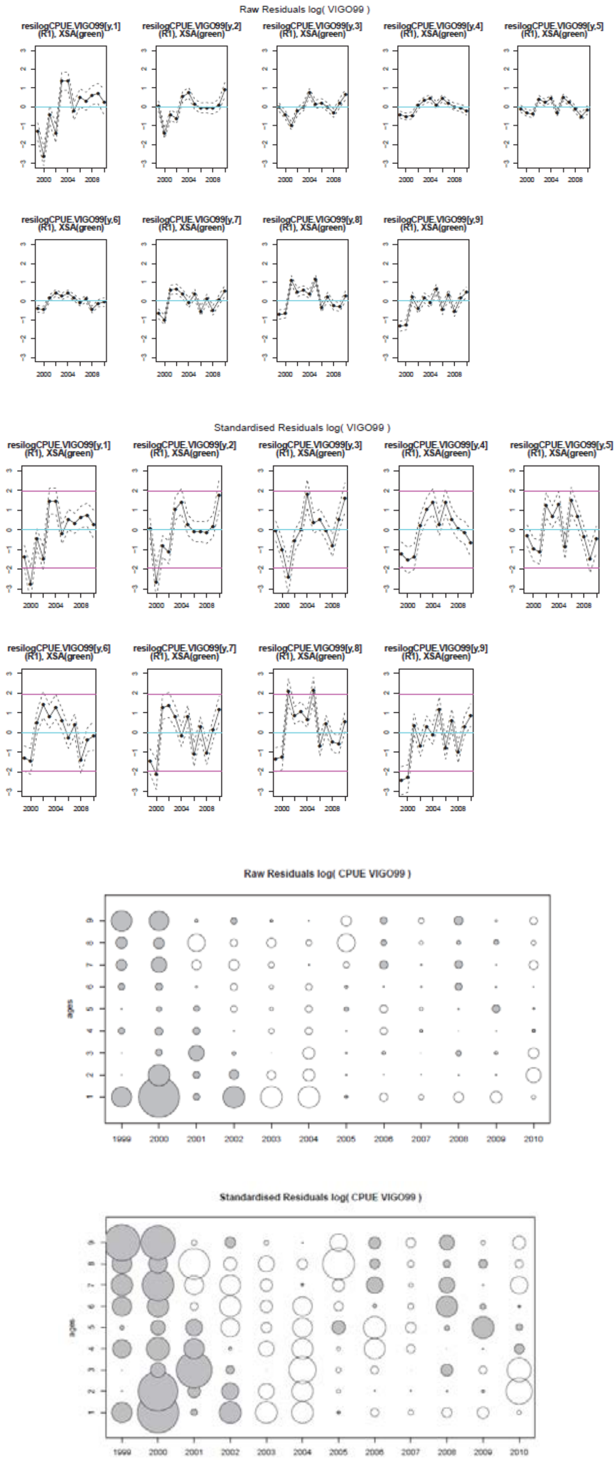


Figure 9.9.2.2.g. Time series and Bubble Plot series of raw and standardized log- residuals at age of Vigo99 fleet from 1999 to 2010. Solid lines correspond with the median of the distributions and dashed lines with 5% and 95%.

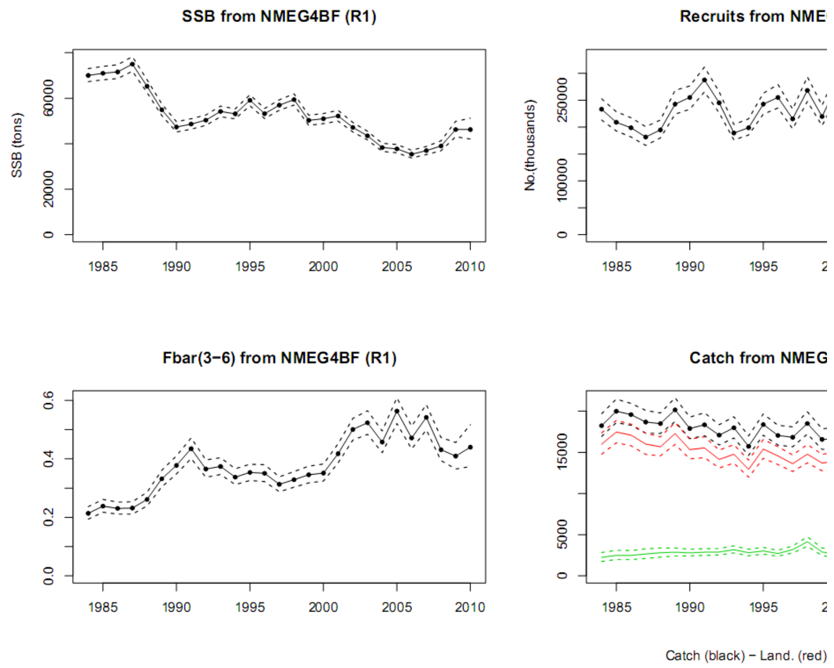


Figure 9.9.2.3. From top to down and left to rigth, time-series of SSB, recruits, mean fishing mortality of ages 3 to 6 (F_{bar}), catch (black), landings (red) and discards (green). The solid line indicates the median and the dashed lines the 5% and 95% quantiles.

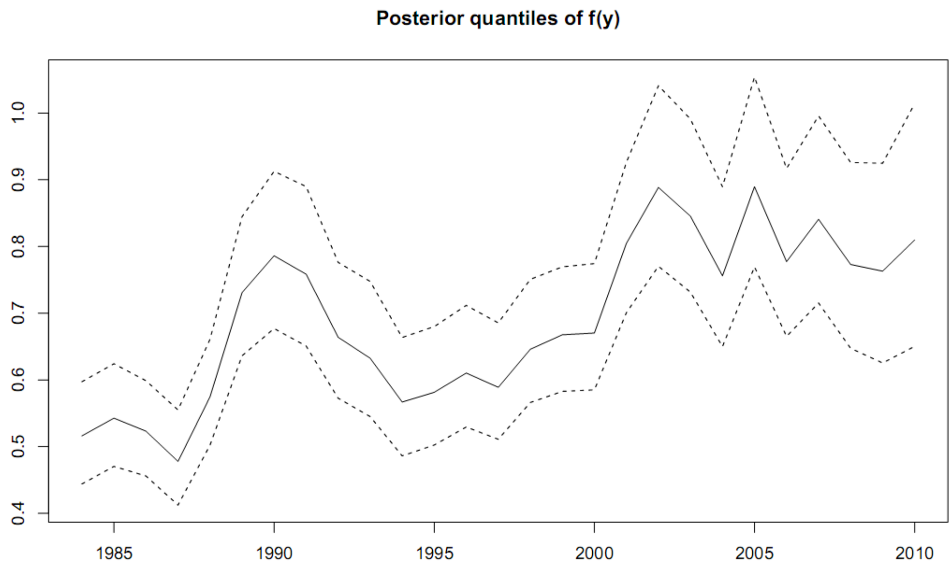


Figure 9.9.2.4. Time-series of fishing mortality in ages 9 and 10. The solid line indicates the median and the dashed lines the 5% and 95% quantiles.

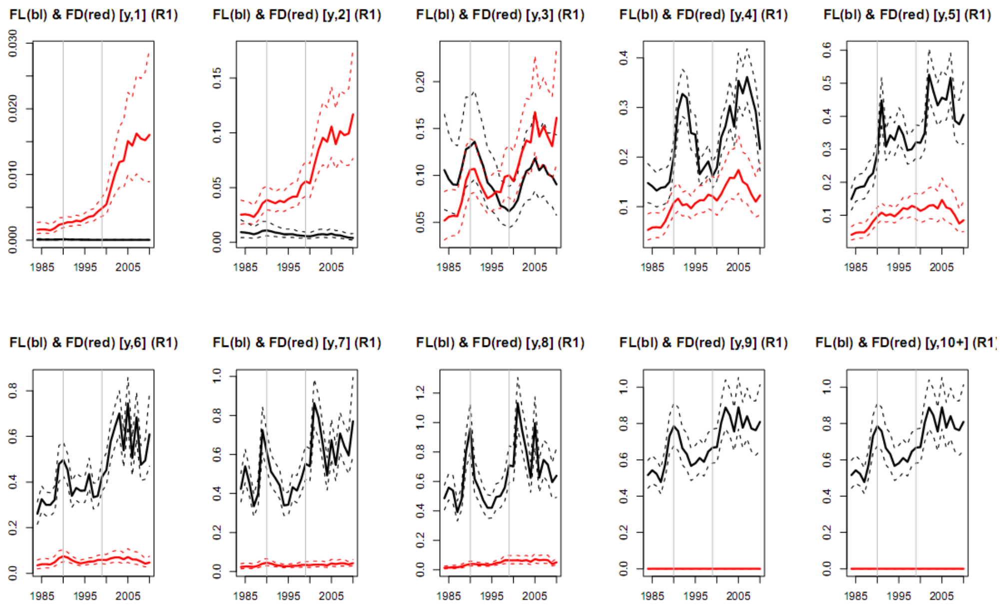


Figure 9.9.2.5. Time-series of landings (black) and discard (red) fishing mortality by age from 1985 to 2010. The solid line indicates the median and the dashed lines the 5% and 95% quantiles.

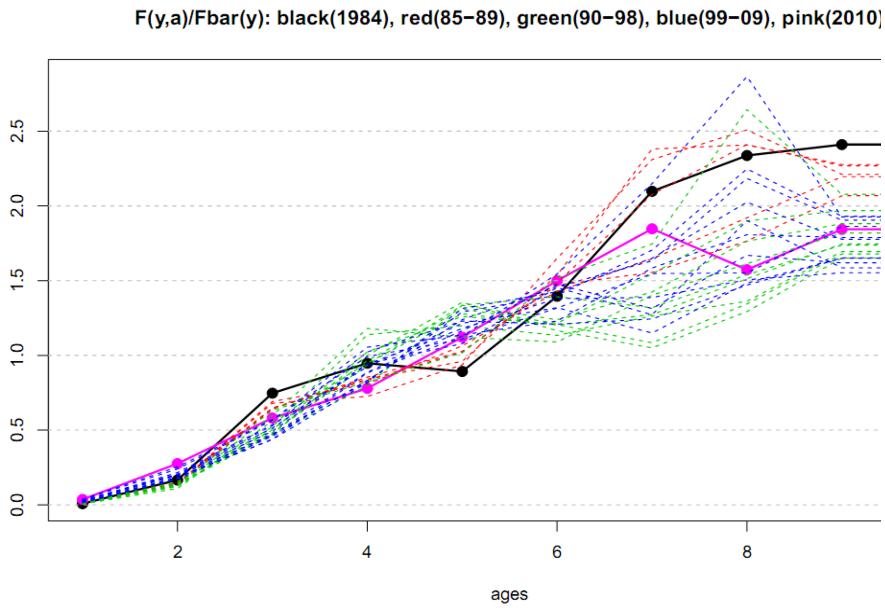


Figure 9.9.2.6. Exploitation pattern by year. Black solid line correspond to exploitation pattern in 1984, the red dasehed lines with years 1985 to 1989, the green dashed lines with years 1990 to 1998, the red dashed lines with years 1999 to 2009 and the pink solid line with year 2010.

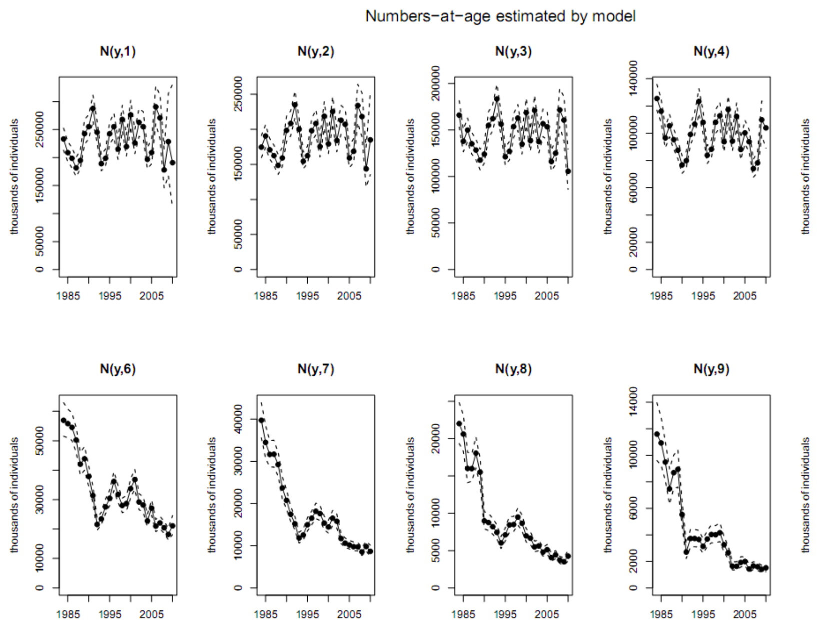


Figure 9.9.2.7. Time-series number-at-age from 1985 to 2010. The solid line indicates the median and the dashed lines the 5% and 95% quantiles.

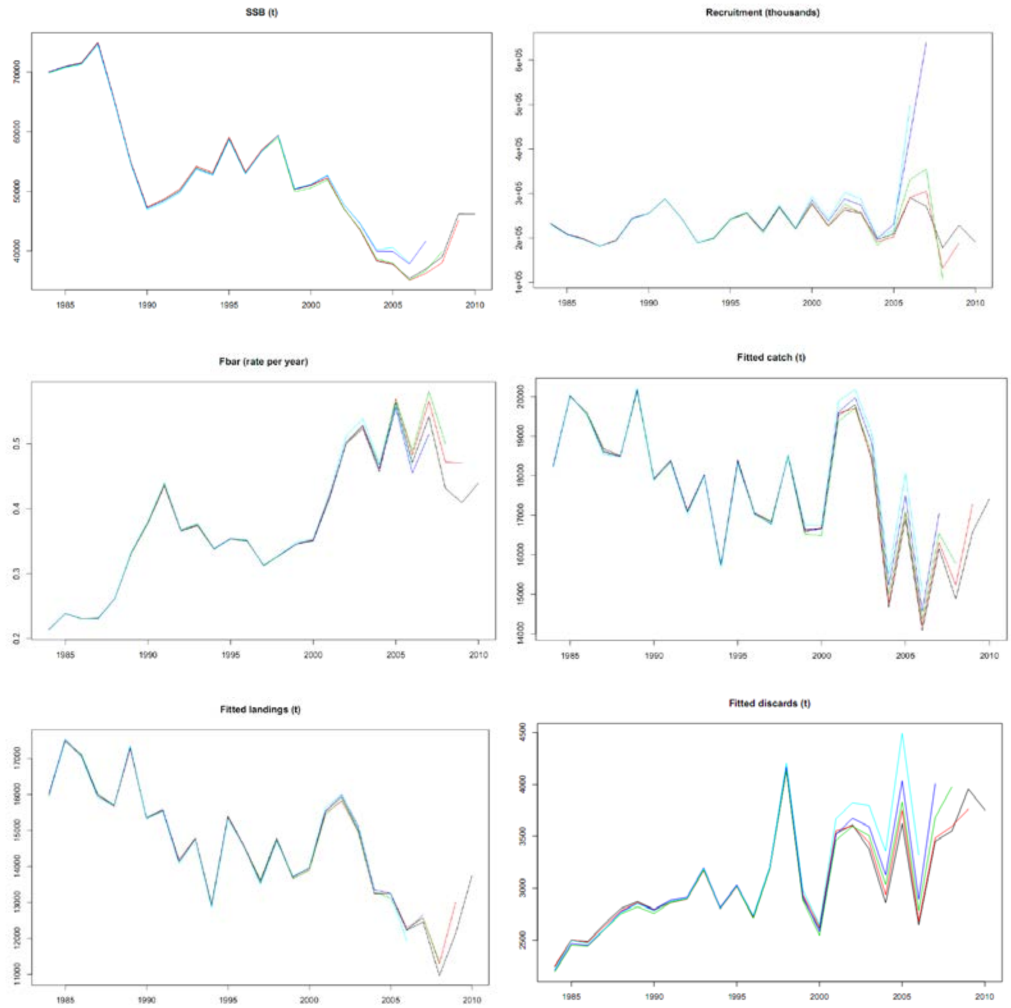


Figure 9.9.2.8. Time-series of retrospective analysis, from left to right and top to bottom, SSB, recruitment, F_{bar} and fitted catch, landings and discards.

10 Sole in Division VIIe

10.1 Current assessment and issues with data and assessment

There is currently no accepted assessment for this stock. The historic assessment for sole in the western channel was rejected by WKFLAT 2009 (ICES 2009) on the basis of a highly persistent bias in the XSA assessment apparent in the retrospective analysis of the assessment results repeatedly revising recent F estimates downwards for several years and a corresponding increase in SSB in each assessment. Other modelling approaches were also unsuccessful in representing the stock dynamics, requiring an significant shift in the selectivity at age (higher F's for older ages) in order to conform with the catch-at-age data and the composition of the commercial tuning fleet. In the absence of evidence of a change in the fleet behaviour adding parameters to allow for changes in the fleet selectivity seemed unreasonable and potentially masking the effects of reduced recruitment if these were to occur rendering the stock susceptible to unsustainable management. Because of the state of the stock in relation to management reference points the stock was always assessed to be below B_{pa} (defined at that time) in the final year suggesting strong management action. However subsequent assessment would revise those estimates suggesting the strong management actions were unnecessary, despite the fact that management was ineffective in reducing the substantial annual overshoot of the TAC.

The stock is currently under an EU management plan requiring estimates of current F to determine future catches. The lack of adequate ICES advice to furnish the requirements of the management plan lead to the investigations of other approaches that would be 'less scientific' but still suitable for sustainable management. The 2010 WGCSE (ICES Expert Group where this stock is annually assessed) following recommendations of the ICES Working Group on Methods of Fish Stock Assessments (WGMG) developed an XSA model using heavy shrinkage, which in the past had been shown to overcome or at least strongly reduce the effects. The method used substantial shrinkage over the last ten years and five ages, but continued to show a retrospective pattern. Last year's assessment indicated that the revisions in F and SSB for 2009 were much reduced, but that the heavy shrinkage was now likely to mask changes in the mean F in the fleet associated with the introduction of a single area licensing scheme (SLA) that prevented area misreporting for the UK fleet and finally implemented more effective management of the stock.

Both assessments, i.e. the rejected old assessment methodology and the interim one, indicated high levels of precision despite significant trends in the residuals. This suggests that the cause of the retrospective bias was model process error and the most significant effects of this were apparent from the commercial tuning-series required in the assessment because of the curtailed age range in the fisheries-independent survey-series.

In addition the survey index used in the assessment has shown substantial increases in the abundance of juveniles (series high for the UK-WEC-BTS which starts in 1988) which were not apparent from the catch-at-age information and thus were not feeding into the SSB appropriately. The survey was considered problematic, because it is indicative of only a small part of the management area and provides most information at the juvenile ages as it was designed specifically as a recruitment index, but has been used in the assessment up to age 9.

10.2 Compilation of available data

10.2.1 Catch and landings data

Retained portion

The catch-at-age data continues to be derived as in previous years for the UK data and French catch-at-age has been provided since 2003 and is provided aggregated annually by Ifremer. Age sampling for the French landings is difficult as landings, particularly in the third and fourth quarter, are only available for sampling very sporadically. The proportion of landings taken by netters (quarter 1 and 2) and those taken by trawler (mainly quarter 3 and 4) varies annually making accurate raising of length distribution difficult. Despite the latter concerns the overall age structure of catches are of high quality especially compared with other stocks assessed by WGCSE.

For the benchmark a working document was presented that investigated sampling levels and raising procedures for the UK landings in order to consider whether the trends historic trends which gave rise to the reasoning for the current raising procedure remained apparent in the data (WKFLAT 2012 WD16).

There were a number of conclusions from this work that are summarised briefly here:

1) The length and age structure of the landings taken in the eastern part of the management unit (Plymouth-Brixham) continue to indicate higher selectivities for younger ages than the much smaller portion of the landings taken in the western region (Newlyn and Pensance). This difference was already observed very early on in the development of the fishery and although no longer available for analysis the data were presented in an ICES CM document in 1984 (Palmer, 1984).
2) The above differences in both the length and age composition disappeared almost entirely in 2010 which is also the year that the SLA was introduced. Sampling levels are such that a single UK-ALK is used to raise the age composition and the difference in the age composition from the fleets depends on differences in the length composition from samples, potentially reducing the resolution of the catch-at-age data if there were differences in the growth rates between the regions.
3) Sampling levels are disproportionate compared to landings information, with the western region being proportionately over-sampled with respect to area and otter trawlers with respect to the gear used. The effects of the disproportionate sampling appear minor with respect to the gears, since there appears to be sufficient resolution in the data with respect to the gears and area. However it was not possible to investigate the effect of this on the age sampling as a single gear/area ALK was not possible.
4) It was determined that a revision of the age compositions by western and eastern region was appropriate, but given that due to recent changes in the DCF sampling any such change may not be applicable in future and it would be better to re-examine the effect once the new data were available to provide the most effective raising procedure given the new data structure.

Discarded portion

Generally discards in this fishery have been considered to be insignificant ranging in value between 4–6% in number and around 1% in weight. They are therefore not considered in the assessment, as it is currently not possible to derive an appropriate raising procedure to determine total discards. Due to the high value of the species with the historic ability to area misreport discarding has been limited to the size range below the minimum landing size (24 cm) for the stock. The proportion of this size in the catch is small due to the high degree of selectivity of the gear and is likely to have decreased with the more recent changes to the gear and the spatial distribution of the fishery (Section 10.2.5). French discard information has also shown generally low discard rates, with occasional high rates of discarding in the 'inshore mollusc trawl fishery' (ICES, 2010). The spatial and temporal extent as well as the level of annual effort in this fleet indicates that overall effect of this is small, and that due to the scarcity of the data it is not possible to raise these data effectively for a time-series of discards.

Recent information from a scientific study has suggested that since the introduction of the single area licence and it effect on the ability to area misreport has meant that highgrading in the fishery has become a significant portion of the catch. This led to the re-evaluation of the available discard information in the UK fleets described in WKFLAT 2012 WD18. Conclusions from the document are:

1) High discarding or highgrading rates are not evident from the discard information collected as part of the DCF. These continue to suggest that discarding has remained in the region of 4–8% by numbers and 1% by weight, although the values were found to be inconsistent (higher) than the rates extracted from the official STECF database.

2) Figure 10.2.1.1 shows the beam trawl effort distribution for 2008 as number of VMS pings per area overlaid with the discard sampling by haul (X) for the period 2002–2010. This plot shows that the general area of the beam trawl fishery for sole concentrated around the area of Lyme Bay and South of Start Point are effectively monitored by the discard programme over the period. It is more difficult to destinguish if there are temporal biases in the spatial distribution of discard sampling within a year, but none were evident visually. The western concentration of beam trawl effort is mainly targteted at anglerfish and megrim.

3) Catch composition data indicates spatial conservation of the distribution of species communities, with changes in community greater between areas, than between years suggesting that generally there has been little change in the ecosystem as observed by the discard programme.

4) The spatial scale of community variation is smaller than the spatial scale of the rectangle, suggesting that raising discards in general could potentially show high variance and even bias if the spatial distribution of landings within a rectangle differs from that sampled by the discard programme.

5) Examination of the retained portion of the catch only suggests that the spatial effect in species community is retained in the landings composition so that it may be possible to more adequately ascribe landings to an appropriate discard rate. However, the analysis also shows that the communities sampled at the trip level may to some degree mask the signal. Further effort should be expended into deriving more appropriate discard estimates

for this fishery in general, but for this assessment discarding is unlikely to have significant impact on the estimation of stock dynamics.

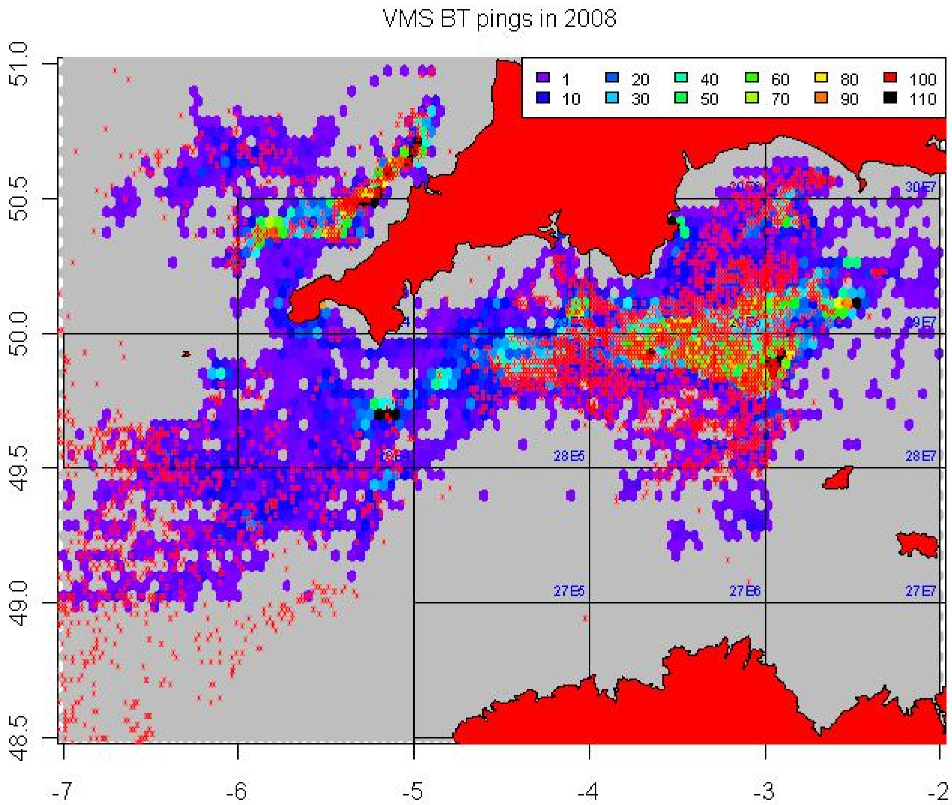


Figure 10.2.1.1 Discard samples from 2002-2010 (red crosses) ovleryed over the effort distribution plot based on VMS pings from the beam trawl fleet in 2008. The plot indicates that the eastern portion of the beam trawl effort where the majority of VIIe sole landings are attributed is generally well covered by the discard sampling programme.

10.2.2 Biological data

No new biological data were considered by the benchmark WK and the biological information used is reproduced here from the Stock Annex for completeness only.

Weights-at-age

Total international catch and stock weights-at-age for each year's catch data are calculated as the weighted mean of the annual weight-at-age data (weighted by catch numbers), and smoothed in-year using a quadratic fit so that:

$$Wt = a + b*Age + c* Age^2$$

where catch weights-at-age are mid-year values, and stock weights-at-age are 1 January values. Following the estimation of the weights-at-age catch-numbers are adjusted to so that the sum of products of the weights and catches sum to the estimated Landings (SOP correction). Catch numbers-at-age 1 are replaced by zeros, but the catch weights-at-age 1 were retained because they are part of the smoothing procedure and do not affect the assessment. They are also essential if a medium-term forecast is performed.

A smoother is applied to sampled catch weights-at-age to adjust for variation in the weight-at-age that may result from low levels of sampling rather than differences in growth rate between cohorts. It also allows estimation of the stock weights-at-age by extrapolation of the curve rather than by using quarter 1 samples, which may be sparse. However this smoother is applied through the plus group and the age range in the plus group is such that this will tend to overestimate the weights at the younger ages. This needs to be corrected as soon as possible.

Natural mortality and maturity-at-age

Natural mortality is assumed constant over ages and years at 0.1. This is consistent with the natural mortality estimates used for sole by other ICES working groups (WGNSSK: IV, VIId, WGCSE: VIIa; VIIfg; and VIIIa,b) and consistent with estimates of M reported in Horwood (1993) for sole in Divisions VIIfg as well as other stocks and papers cited therein.

Assessments prior to 1997 had use knife edge maturity-at-age 3. This was changed in 1997 to a maturity ogive from Divisions VIIf,g according to Pawson and Harley (WD presented to WGSSDS in 1997), which is applied in all years, 1969 to present, since the 1997 assessment.

Age	1	2	3	4	5	6,7, ...12+
Prop. Mature	0.00	0.14	0.45	0.88	0.98	1.00

Proportions of F and M before spawning are both set to zero to reflect the SSB calculation date of 1 January.

10.2.3 Survey tuning data

UK-BTS

The longest survey time-series available for this stock is the Western Channel Beam trawl Survey conducted by the UK in late September, early October (UK-BTS). The survey covers a relatively small area of VIIe from Start Point through to the middle of Lyme Bay and out to the edges of the Hurd Deep covering the immediate area of fishing for the Brixham and Plymouth fleets. Sampling started originally in 1984 on the chartered commercial fishing vessel 'Bogey One', replaced in 1988 by the 'Carhelmar' and moved to the research vessel 'Corystes' in 2002 to 2004. Concerns were raised regarding differences in catchability between the Carhelmar and Corystes, and in 2003 the survey was carried out on both vessels. The results of the comparison convinced Cefas to return the survey to the long-serving Carhelmar and to replace the 2003 data with the data from the comparison trials in order to improve consistency. Consequently, the time-series has been largely recovered, with only 2002 and 2004 data coming from the RV Corystes.

The survey cpue demonstrates a decline from 1986 to 1995 in line with the commercial data, after which SSB seems to have largely stabilized at lower levels. The abundance indices at-ages 1 and 2 demonstrate little overall trend, but ages 3 to 6 indicate a decline over the middle part of the series, despite intermittent peaks and troughs. More recently survey cpue has increased to the highest level over the consistent time-series (starting in 1988 as used in the assessment) with the majority of the increase coming from the younger ages and only a marginal increase at the older ages. The age information is internally consistent to the survey, with 1989 year class is indicated to be strong at all ages and this year class can also be traced through the catch-at-age matrix. More recently the 1998 year class can be tracked reasonably consistently.

UK-FSP

A shorter, but more spatially extensive survey-series has been developed and managed by Cefas since 2003 in the UK in conjunction with the industry. Age sampling issues preclude the use of the data in the first year and the time-series is used here since 2004. The survey vessels (two separate trips are carried out annually see working document) are subject to a three yearly tendering procedure and vessels characteristics and gears used have changed over the time period, which is why the index has been standardised as described in the WKFLAT 2012 WD20. The survey covers the extent of the UK fishery for the species including the less frequently exploited western part of the stock, which is why it is principally to be preferred over the more limited UK-BTS survey but is expected to be more variable due to the inconsistency of vessels used. Age information from this survey has shows evidence of some internal consistency in the medium age range (Figure 10.2.3.1), but the series is too short to evaluate this at the older or younger ages at present. However the survey appears to show consistency with other survey indices and is therefore included in the present assessment for the entire age range available (ages 2–11). Data from this survey has been used in the plaice assessment since 2008.

Q1SWBeam

This is the first consideration in an assessment of the new survey-series starting in 2006. A more detailed description of the information from this survey is available in the WKFLAT 2012 WD17, but important considerations for WKFLAT were that it is based on a stratified random survey approach and covers the entire region of the management area and some adjacent waters which may not fully conform to the delineation. The survey shows strong gradients in species composition within the western channel (justifying the stratification approach), although there is some indication that more appropriate post stratification could potentially provide an increase in precision of single species abundance estimates.

Given sampling effort, fundamentally this survey is more variable than fixed stations survey designs of equal effort, but also inherently is less biased when there are potential changes in the distribution of the species within the area. Although estimates of survey variance of the limited dataseries are available, these are unlikely to reflect the full range of the variance that would be encountered in a longer time-series as variance estimates are unlikely to have reached their asymptote, particularly since the range of SSBs observed by the survey is very restricted.

The survey-series was started in 2006 and surveys have been conducted consistently since then. To include as much information as is available at the time of the assessment working group the survey that is conducted in the first quarter has been shifted to back by one year and one age. This practical, because it adds further available information on the abundance of recruitment into the assessment, particularly important since there is uncertainty regarding the estimation of recruits from the UK-BTS which otherwise is the sole source of information of this parameter. The benefits of shifting the series were thought to out-weight the potential error that may be introduced by this procedure if the seasonal pattern of true F were to change in future.

Age information provides estimates of abundance for all ages in the assessment, despite the fact that the survey only catches between 250 and 300 sole in a given year. Theoretically this removes the necessity of retaining the commercial lpue (at age) series required as the UK-BTS survey does not cover the full age range in the assessment. Internal consistency estimation is very difficult given the short time-series, and relatively small contrast in cohort strength observed (based on other series). Despite this some cohort tracking is apparent and the signal matches the cohort signal from other survey-series, particularly the FSP survey.

Given these uncertainties regarding true survey variance and concerns regarding future funding for the survey it seemed unreasonable to put the entire weight on this survey, so at this stage it is not sensible to remove the commercial fleets from the assessment as they provide a high degree of precision at the cost of introducing some bias into the assessment.

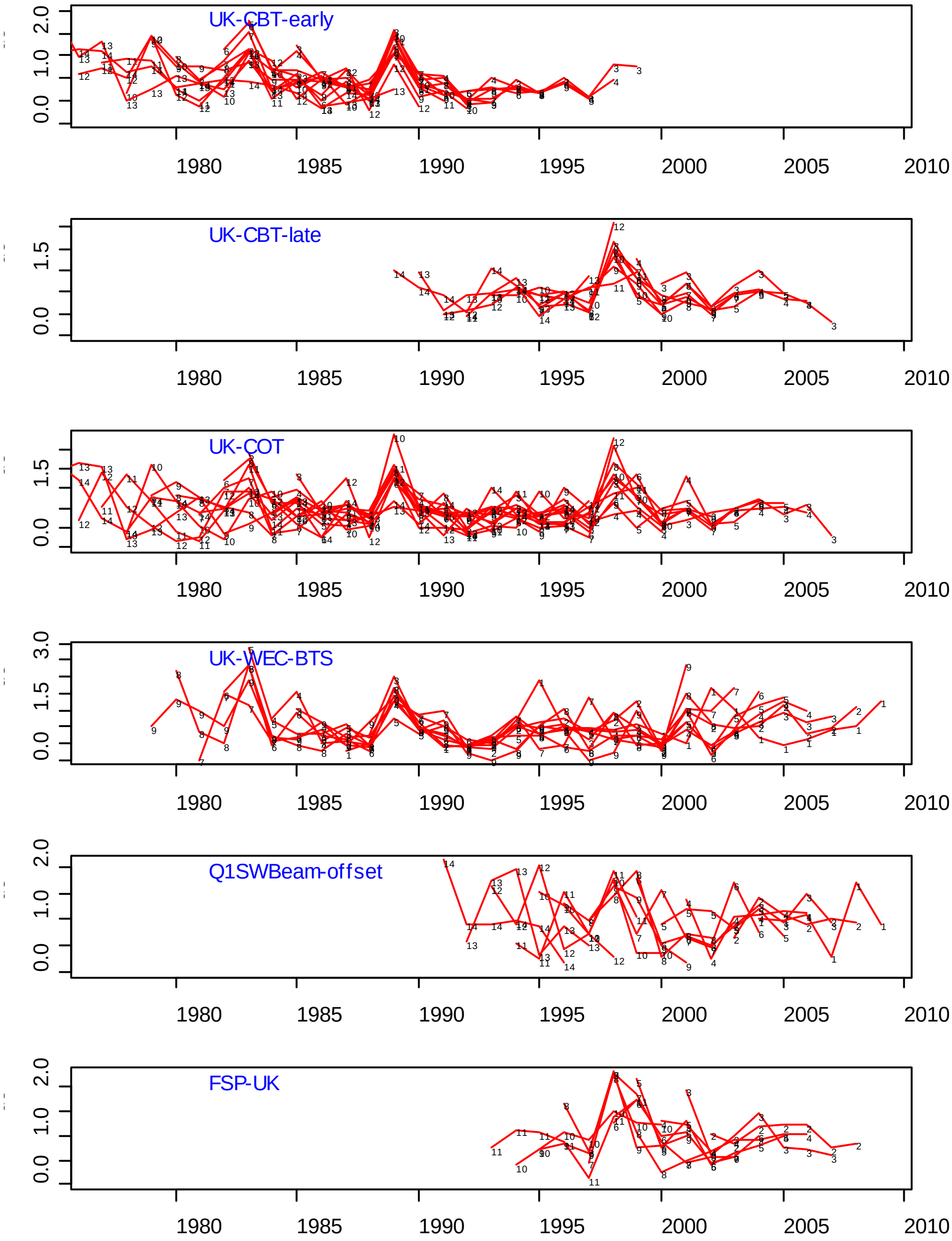


Figure 10.2.3.1. Means standardised abundance-at-age plotted by cohort to examine internal consistency of the individual tuning-series.

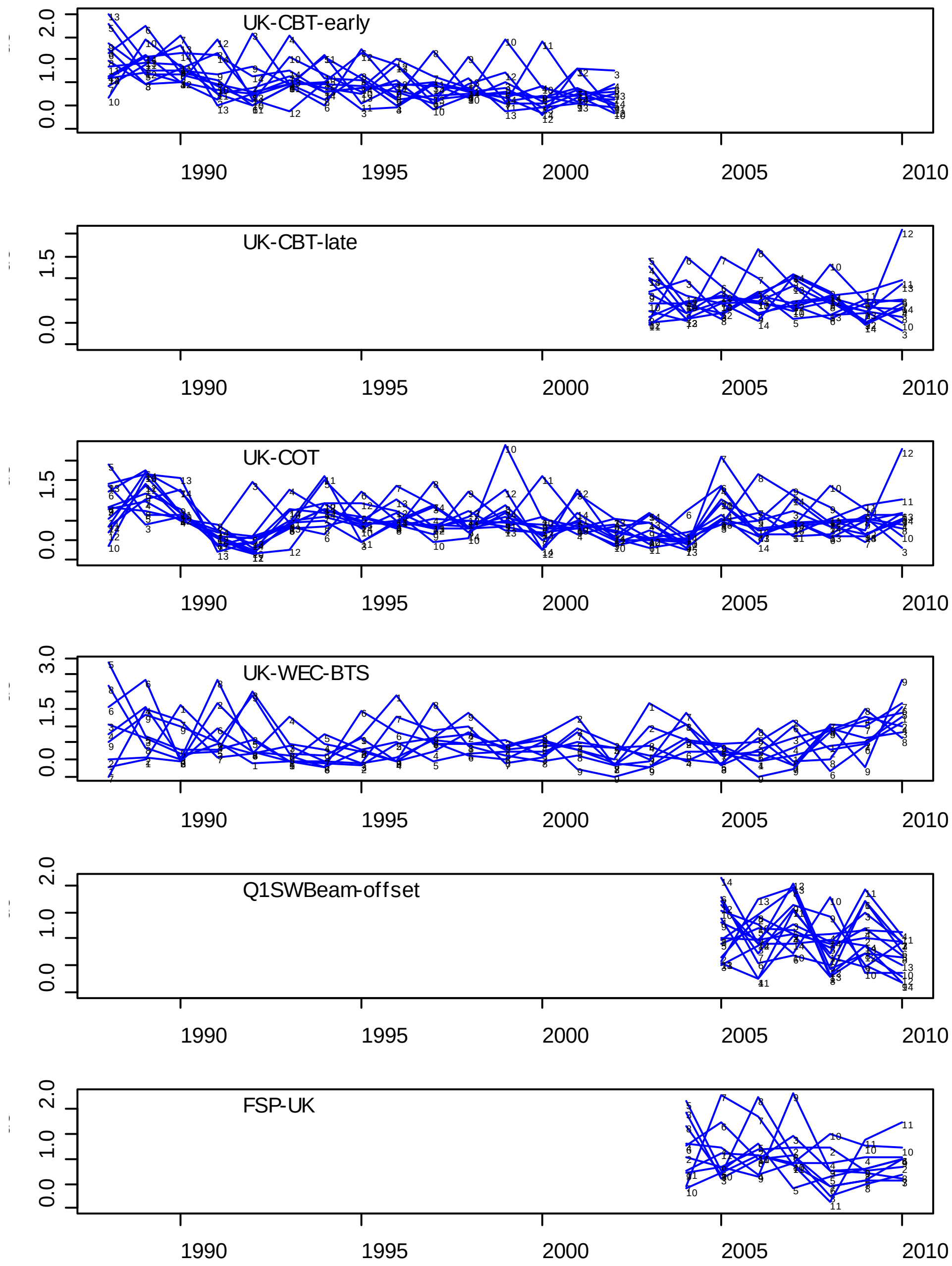


Figure 10.2.4.1. Means standardised abundance-at-age plotted by survey year to identify possible year effects in the individual tuning-series.

10.2.4 Commercial tuning data

The commercial tuning-series available for the assessment are the same as in previous assessments. Two historic surveys had been included in previous versions of the assessment because historically reference points in the stock had been based on historic development of the fishery and variance in the early time-series indicated considerable uncertainty with respect to these historic estimates as a response to the choice of plus group in the assessment. The new assessment is less susceptible to these variable estimates of catch-at-age, and the group decided to not base reference points on the historic development of the stock so that the historic indices are no longer required in the assessment and are not discussed further here.

UK–COT

The UK otter trawl index is the same as presented in previous assessments. As previously observed the index suffers from two distinct negative year effects in 1991–1992 and 2004 (Figure 10.2.4.1). These inconsistencies were observed in previous assessments and WKFLAT concluded that given the length of the period the effects of these in the historic period were minor on the current estimates of F and SSB as they are modelled mainly as residuals in the XSA model. For the new assessment there were no indications to presume that these effects were detrimental to the accuracy of the assessment so that the information is included as in previous years.

Currently this fleet contributes only a small proportion of the overall landings, but it is sampled much more heavily than its representation in the landings so continues to provide a good independent time-series from the main commercial catches. It is uncertain whether the new DFC sampling will continue to provide such accurate data as the intent is to sample catches more proportional to landings.

Despite the year effects the series is characterised by high internal consistency and is also consistent with other series in identifying strong cohorts.

UK–CBT

The time-series of commercial beam trawl information has always formed the backbone of this assessment, but investigations at WKFLAT 2009 indicated that this series showed declining lpue, particularly at the younger ages, in contrast to other information in the surveys and to a lesser degree to the catch-at-age despite the fact that the fleet accounts for around 60% of the landings in the stock. It was assumed that it was largely this fleet that was responsible for the persistent bias in the assessment. Historic area misreporting by the fleet prior to 2010 had been an issue, but after discussions with the industry in 2002 landings information and lpue data have been corrected for this, and the incidence of this practice had been decreasing. Increased scrutiny by enforcement, and lpue limits imposed by the producer organization contributed to the reduction.

The operation of the fleet was examined at this WK using VMS data from 2006–2011. The conclusions from this analysis were that since 2006 the fleet has been increasingly shifting its effort southwards more into the central regions of the channel. Effort in Lyme Bay, the region where catch data and survey information indicate the majority of younger fish are found are now much lower than previously and have ceased almost entirely in 2010 and 2011. This shift in the selectivity towards older ages is very apparent also from the catch-at-age information for the fleet from market sampling records examined in WKFLAT 2012 WD16 suggesting that it would be appropriate to split the fleet on the basis of inconsistent operation.

It was not possible from independent information to discern when the majority of the contrast in this information occurred, and hence to decide on appropriate time to split the series, because VMS data are not available prior to 2006. Discussion with the industry also confirmed (see Section 10.2.5) that there had been changes in the operation of the fleet, but again suggested that these changes had been gradual, rather than abrupt making the choice of the year for a split of this fleet difficult. The WK determined that 2002, the time at which the area misreporting was officially acknowledged, would be an appropriate point for splitting and would also be suitable for the assessment, as this would retain a sufficiently long time-series over which to estimate the new catchabilities for the fleet. This new methodology was adapted and the UK-

CBT fleet is used in the assessment as two fleets UK-CBT-early (1989–2002) and UK-BTS-late (2003–2010).

10.2.5 Industry/stakeholder data inputs

As in previous years the UK industry has provided information on the abundance of sole in the western channel through its contribution to the UK-FSP survey. The index developed on the basis of that survey is now included in the new assessment (using 2004–2010) data and the index is described in more detail in WKFLAT 2012 WD20 and summarised in the survey tuning information.

Stakeholder input to the WK was useful particularly with respect to the operation of the UK-CBT fleet. There have been a number of changes to the fleet with fishermen experimenting with more environmentally friendly gears and larger mesh-sizes to reduce the discards of species other than sole. Many of the vessels are now operating voluntarily at codend mesh sizes larger than the legal requirement of 80-mm often using nets of up to 100 mm. This change is coincidental to the move further offshore, because the run of fish in these areas is larger, so that smaller mesh sizes are of little benefit in terms of catching sole and create additional drag and hence fuel costs as well as lowering the price of the catch due to excessive amount of benthic organisms in the catch. This suggests that the larger mesh sizes in the catches are not distinguishable from the difference in the spatial distribution of the fleet.

The fleet has in recent years been increasingly reliant on catches of other species supplement the fishery on sole. Although sole still persistently produces an important financial contribution to the catch other species, in particular cuttlefish, scallops and monk fish have provided significant income and in many years the majority of income to the fishery. However the low variability of sole abundance and price has provided a high degree of stability to the fleet and as such it is likely that aside from the spatial changes in the fishery the fleet still appears appropriate as a tuning-series in the assessment.

In 2011 the UK started to operate a catch-quota scheme in the fishery with an additional 5% of the UK quota made available to the UK to test the technical feasibility of operating such a scheme. Only a small number of boats took up the offer to participate in the scheme in 2011 so its effect is unlikely to be discernible in the assessment in 2011, however 5–6 boats have signed for 2012 so that this may in future lead to an as yet poorly understood effect, because discard rates area generally negligible in this fishery.

Since the development of the beam trawl fleet in the western channel in the early 1980s there has been a consolidation to larger more powerful vessels, particularly in the late 1990s and early 2000s. However, the severe quota restrictions at that time have lead to a reversal of this trend and a lesser emphasis on sole as the major income for the fleet. Undoubtedly sole still form the back bone of this fishery due to the steady availability over the ground. However in recent years the fishery has adapted with smaller more flexible vessels and an overall reduction in kWH as well as a further small decrease in the number of boats due to a decommissioning scheme, to make the most of other resources such as scallops, cuttlefish, gurnards, etc. foregoing possible higher catch rates of sole. This is reflected in the offshore movement of the fishery around Start Point particularly apparent in the last few years in WKFLAT 2012 WD19.

At the lower catch rates described above the fleet is at an appropriate capacity to take the available quota and appears to have sufficient financial stability and certainty to allow for continued investment in the fishery. Were the industry to return to previous patterns of exploitation targeting the younger and more abundant sole in Lyme Bay it would almost certainly be able to increase the fishing mortality to levels greater than that assumed to be sustainable. The current enforcement regulations with a change in the attitude of the industry have meant that the TAC is an appropriate management tool in at least the UK fishery. Limiting days at sea further will have a perverse tendency to reverse this trend and focus effort grounds in Lyme Bay because of their proximity and the higher catch rates.

10.2.6 Environmental data

There is little or no evidence of a stock–recruitment relationship apparent from the assessment of this stock. It is therefore assumed that environmental conditions or species interactions are largely responsible for the variation in recruitment. There is also anecdotal evidence which suggests that cold winters result in large recruitments the following year however, it has been difficult to ascertain the timing and the temperature lows necessary to provide the right conditions for high recruitment. Further work should be undertaken, particularly as climate change may affect the frequency of such events.

10.3 Stock identity, distribution and migration issues

With respect to the stock as observed by the fishery there seem to relatively few issues regarding stock identity and once recruited the stock appears to represent a closed population. Spawning migrations by sole tend to be in a seasonal onshore offshore pattern with a small random movement alongshore described for the species in other areas. Given the layout of the stock and the apparent breaks in the distribution of sole at the edges of the management unit there appears to be little concern for significant leakage across stocks. However the biological stock unit for Division VIIe is much less certain at the larval and prerecruit stage. The proportion of the area that represents nursery grounds is much smaller than those for other sole stocks of equal size, with only two small regions (the inner part of Lyme Bay and the Bay de Mount St Michelle) known to regularly produce 1-groups sole.

Tagging information of juvenile sole, mostly 1–3 year olds show that there is significant ingress of recruits from the adjacent stock in ICES Division VIId from both the French and the UK coast that appear in the region of out Lyme Bay. Unfortunately, very little tagging data are available to examine if there is an equal or greater reciprocal movement in the opposite direction, but given the limited nursery habitat and the abundance of sole recruits in Division VIIe it seems reasonable to assume that there is a net inwards migration of prerecruits that remain in the area following maturation.

Spawning is known to occur in the Division VIIe from survey evidence in a relatively small concentration on the 'Bank de Langustine' and intermittently in very low concentrations in the western part of the UK coastal region and around the edges of the hurd deep. Little is known about the fate of the spawning products, but given the relatively long egg and larval stage as well as the significant net eastward movement of waters in the channel it is plausible that the stock utilises nursery habitat in the eastern half of the channel. The degree of stock isolation in terms of these recruits has not been investigated, as it is possible that the recruits contribute to a common pool of recruits with the eastern stock.

Isolation from the Celtic Sea (both the Bristol Channel and the Bay of Biscay) appears to be more rigorous according to tagging information, with few individual traversing the strong environmental and habitat gradients found in the rocky areas around lands end. However, the 1998 year class is indicated to be above average from all tuning information (Figure 10.2.3.1) with the exception of the UK-BTS survey. The fact that this cohort is not well represented in what is thought to be the best indicator of recruitment, yet is readily observed in information from the more westerly and offshore parts of the stock area may indicate that there are other, as yet poorly understood recruit sources within the region.

From a stock assessment point of view and in the absence of a modelled stock–recruitment relationship there appears then relatively little concern over a lack of a closed population given the low movement rates post maturation. The low movement and its seasonality in conjunction with the high concentration of fishing effort around Start Point may produce effects of local depletion that may imply higher rates of fishing mortality for the UK-CBT fleet when compared to mortality rates from other indices covering a wider area. Such conjecture is potentially supported by the fact that when the new Q1SWBeam survey is viewed as an absolute index of abundance it produces higher estimates of stock size than the assessment. While stock size remains relatively stable and the behaviour of the fishery remains stable this is likely to have little impact on the assessment as the difference is absorbed in the estimates of catchability. If the fishery expands spatially with a commensurate reduction in the per-unit-area effort, or as migration rates change in response to stock size such affects may become apparent in the assessment so that it is important to consider / examine such changes in future.

10.4 Influence of the fishery on the stock dynamic

Given the substantial catches of sole from a relatively confined area of thee western channel it almost certain the fishery has had a direct impact (Fishing mortality) on the abundance of sole in the division. However secondary effects on the stock are much more difficult to discern given the limited contrast in terms of F and SSB (Section 10.8) observed in the fishery and the potential effects of less than full mixing in the stock on the estimates (see Section 10.3). From the assessment information no significant changes in the stock dynamics in terms of growth (weight-at-age), natural mortality, or recruitment dynamics are apparent and no other independent studies on these dynamics were available to the WK at the time of the meeting.

10.5 Influence of environmental drivers on the stock dynamic

Sole form an integral part of the ecosystem of the western channel. Their temporally highly consistent distribution with respect to habitats and species communities (WKFLAT 2012 WD17; WKFLAT 2012 WD18), suggest that their dynamics are intertwined with the environmental and ecosystem dynamics of the area. However little information on specific key elements of the ecosystem or suitable indicators of ecosystem components in response to which stock dynamics change are currently available for this stock. Further investigation on habitat quality and availability are ongoing as part of the Q1SWbeam survey and it is hoped that such investigations can contribute to a better understanding of sole stock dynamics as well as a more general understanding of the ecosystem under the auspices of 'the ecosystem approach to fisheries management' and the 'marine strategy framework directive'.

10.6 Role of multispecies interactions

Nothing is currently known about specific multispecies interactions for this stock, especially at the larval and post-larval stage, when such interactions are most likely to influence recruitment. For more general comments see Section 10.5.

10.6.1 Trophic interactions

There are no specifics known, although there is at least some indication from the scientific literature that there is an effect of the invasive slipper limpet on the distribution of juvenile sole in nursery areas. The slipper limpet is a highly invasive species throughout the channel and their shells litter large areas of the central channel and UK coastal area. This could be a result of trophic interactions, but is more likely to be a result of the shell rendering the substrate less suitable for juveniles which have a preference specifically for soft, often muddy sediments. Although small-scale distributional changes have been observed, there is currently no clear evidence that this has lead to a limitation in recruitment from the current assessment that could be linked to the expansion of the slipper limpet population.

10.6.2 Fishery interactions

The fishery for sole has often been termed a targeted fishery, and in many ways the fishery is targeted at this species since it provides a stable predictable income for the beam trawl fleet. However the species catches a wide variety of species and as such should be considered a multispecies fishery taking cuttlefish, scallops, monkfish, plaice, lemon sole, gurnards, brill and turbots as significant parts of the catch in value so that landings of these species need to be seen in context. Although the fishery is to some degree able to control the catches of different species due to the strong spatial habitat gradients observed in the Division VIIe (WKFLAT 2012 WD18), the flexibility is to some degree limited by the cost of fuel, gear efficiencies and limits on the available TAC for other species.

Other fisheries, such as the otter trawl fishery, which these days made up of small inshore vessels, take sole while targeting lemon sole, gadoids and a general mixed fishery. The small-scale inshore pelagic fishery has been shown to have sporadic bycatch of sole in ringnets, both on the UK and French coast. This is the results of bottom interactions of the gear, rather than a pelagic behaviour of the species and because of the rarity of the interaction and the small scale of the fisheries is considered to be incidental.

Historically there has been a significant amount of interaction between scallopers and the sole stock. French dredges employed by the UK fleet from the early to mid-1980s indicated high catchabilities of the gear for sole, however this gear has been banned and the currently employed spring-loaded dredges are much less effective at taking sole, though landings from the fleet are still of a noticeable size. Due to health and safety considerations this gear is no longer sampled in on-board operations, and market landings are too sparse to examine whether this gear has a different selectivity/ age structure for the catches from the beam trawl fleet. Many of the boats involved in scalloping are the same boats that catch sole (using different gears) when quota is available.

10.7 Impacts of the fishery on the ecosystem

Beam trawls are known to have heavy impacts on the seabed, particularly those using chainmats as employed by the fleet in the western channel. The direct impacts are heaviest on the permanently sessile fauna, but have been thought to be insignificant on the sandy sediments. Recent evidence does suggest that there is a decrease in the level of sediment sorting with some consequences on infaunal species distributions. However, no direct evidence exists for the stock area and ocean currents and wave action are likely to restore the sediment sorting in the high energy environments exploited by the beam trawl fishery over a relatively short period of time following disturbance. The recovery rates of the infaunal communities in these habitats are much less understood.

10.8 Stock assessment methods

10.8.1 Models

Initial considerations in the development of a new assessment model were to develop a model in the SS3 framework in order to be able to test a wide range of possible processes against the available information at a highly disaggregated level. Investigations of the data in preparation for this meeting continually threw up spatial issues, both with the respect to the distribution of the stock (WKFLAT 2012 WD17) and the fishery (WKFLAT 2012 WD19; WKFLAT 2012 WD18), suggesting that greater spatial resolution of the available information was essential if the greater model flexibility in SS3 was not to be confused with changes in these trends. However historic data were not aggregated at the appropriate spatial resolution and raw data are not available in electronic format to facilitate new raising procedures.

The group felt that the new stratified random survey covering the entire management unit may well be the preferred advisory toll, but that at this stage the time-series was too short to rely solely on this information until the survey variance components are better understood. In the interim if was decided to retain an XSA model and to find a better model parameterisation by the inclusion of the new survey information.

A large number of settings and index permutations were considered and an appropriate model was honed in on iteratively. The total number of runs is in excess of what can be described here, but the results are presented in the form of a sensitivity analysis highlighting the choices made and the reasons for choosing the final settings for each of the parameters.

Single fleet runs

The first step was to investigate the differences in the information provided by each of the indices, using a very general set up of the model. The resultant summary output (Figure 10.8.1.1) indicated that as apparent from the raw indices (Figure 10.2.3.1) that there was general agreement with respect to the identification of strong and weak year classes in the data. What differed between the indices is the relative strength of these over time. The UK-BTS survey has observed stronger recruitments in the most recent years than is seen from the other fleets, which in the single fleet consideration has resulted in higher recent SSB estimates, but similar F values compared to all but the UK-CBT commercial fleet (Figure 10.8.1.1). In the single fleet run the historic SSB around 1990 was also affected through the effect of q over the long time-series. Residual patterns observed were as expected given the consistency of the raw indices.

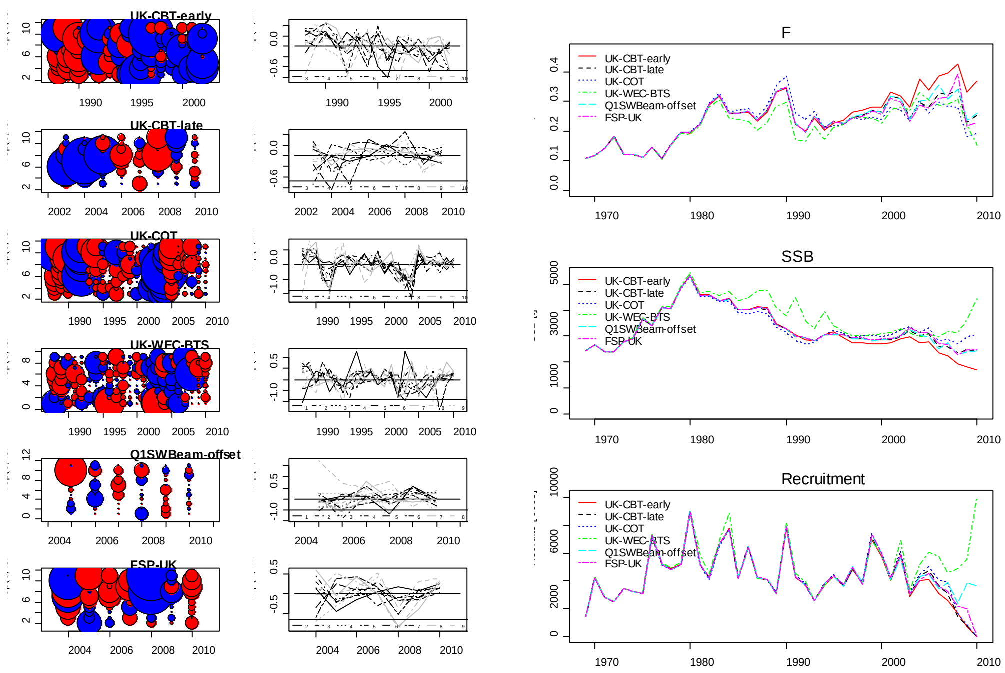


Figure 10.8.1.1. Summary plot for single-fleet XSA runs showing the difference in trends for the individual indices (left) and the respective residual patterns indicating differences between each index and the catch-at-age data.

Given the consistency of the raw indices and the similarity in the single-fleet model outputs despite a general set up the hope was that all index information could be sensibly retained in the model.

Choice of +group age

Theoretically there should be little effect of +groups age in a VPA based assessment, but because XSA does not track the plus group there can be some effects. In previous examinations of the effect of the stock when WGSSDS was asked to raise the +group age to twelve significant changes in the historic stock development were noted. Previously some historic tuning information that greatly lessened the effect was included in the assessment. The new model setting are much less sensitive to the changes in +group age except at age 8, but this model run also requires a different set of q-plateau settings compared to the other models (because there are fewer ages in the assessment) so the comparison is not entirely representative of the effects of the +group age only (Figure 10.8.1.2).

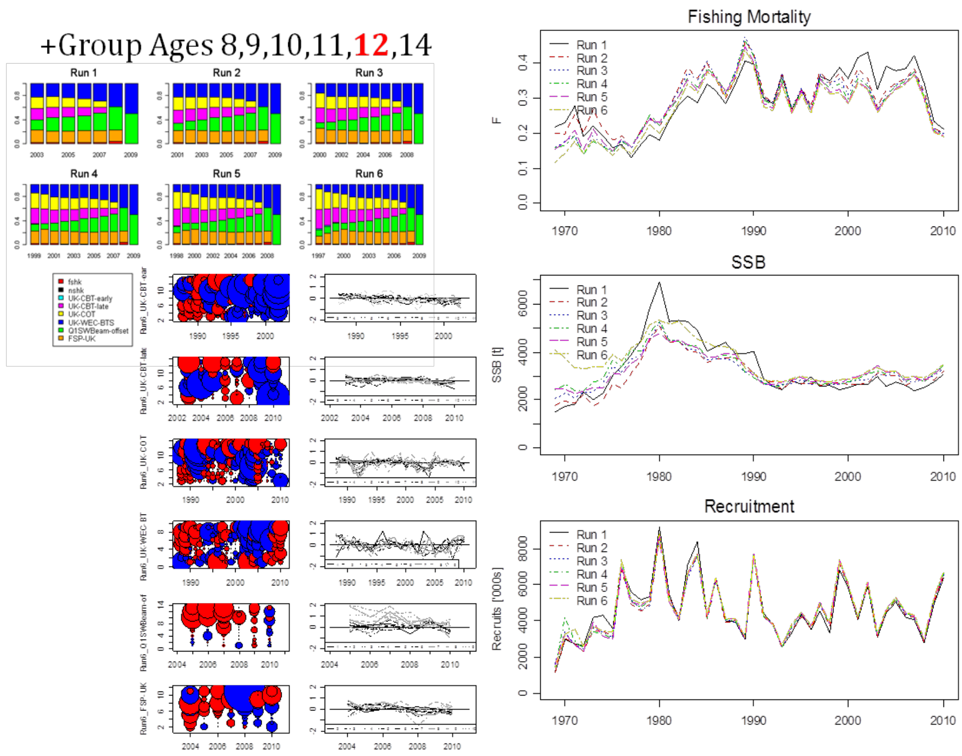


Figure 10.8.1.2. Sensitivity of the model to the choice of +group age showing strong changes in estimation over the time-series for 8+ and minor changes early in the time-series for other ages.

The WK determined that the effects were sufficiently small not warrant the additional model complexity required to include the historic information. Nor was there good reason to change the current plus group age for this stock from age 12.

q-plateau age settings

XSA estimates selectivity-at-age independently, so that there is no assumed asymptotic or dome-shaped selection pattern implicit to the model. This means that the selection patters estimated by the model can be used to qualitatively asses the model fit. The model does however can be used to restrict the flexibility of the selection pattern at the older ages (i.e. constant selectivity); however this age is the same for all indices so that the choice of q-plateau is always a compromise between the information when selectivity patterns differ between fleets.

Inherently leaving the model to estimate all selectivities freely is desirable, but particularly when tuning information is short, the tendency is for selectivities to vary unrealistically from age to age absorbing sampling variance in the estimate of q. For this reason the selectivity curves for the different fleets were examined at different setting of q-plateau, the results of this analysis are shown with the associated summary plots in Figure 10.8.1.3.

At first glance there appears to be little effect of the parameter on the estimation of stock status, but closer examination indicates that a q-plateau of 11 estimates SSB to be considerably higher. The reason is that in these setting selectivity of the survey at the oldest ages is assumed to be very low so that stock numbers at the older ages are assumed to be higher. Such age related jumps in selectivity, particularly at the older ages seem appropriate to the survey design and lower levels should be chosen. Q plateaus at the younger ages appear to be inappropriate as there is consistent evidence that the selectivity of the commercial fleets does decline somewhat at the older ages as a result of the spatial distribution of the fleet in relation to the spatial distribution of the older ages in the stock. Constant selectivity at the ages 6 or 9 seem reasonable compromises. The final choice of age 6 made was based largely on theoretical model parsimony considerations particularly in light of the fact that the UK-CBT needed to be split and as such almost all the indices were now relatively short.

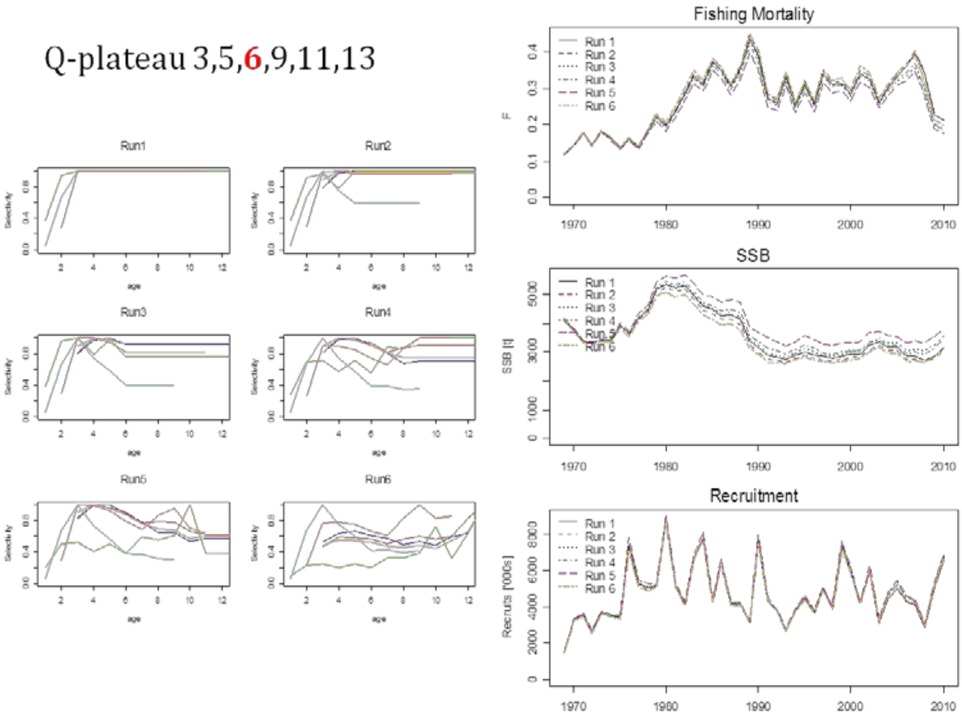


Figure 10.8.1.3. Sensitivity to q-plateau choice showing the assumed selectivity pattern for each index, demonstrating the increased variability (age to age) particularly for the Q1SWBeam and UK-FSP indices (left) and the effects on estimates of stock status (right).

min standard error to shrink to

This setting relates to the inverse variance weighting applied to the tuning information in XSA. The model iteratively re-weights the indices based on their conflict with the rest of the information. If there is conflict in the data the model tends to focus on an individual fleet. This is appropriate when all information in known to have equal information content, however in this case the different series provide quite different information in terms of recruitment, etc. More over the UK-CBT fleet is highly consistent with the catch-at-age information, since it provides about 60% of the data. Consequently there is a need to limit the effects of the inverse variance weighting in order to attain a balanced assessment.

Here various values were tested ranging from 0.1–1.0 the full range of these values is relatively small compared to setting used for other stocks. Despite this there was little change in the relative weightings in the fleets observed at setting greater than 0.6 (Figure 10.8.1.4, bottom left). At very low values, e.g. 0.1 the weighting given to the UK-CBT increases significantly probably because it shows very high internal consistency, but also because it is most consistent with the catch information.

In order to maintain a balanced assessment, and to retain information on ages not covered by the UK-CBT fleet, it was considered most appropriate to use value of 0.6 for the minimum standard error to shrink to. This value considered small in most assessments, but this merely underlines the precision/quality of the information used in the assessment.

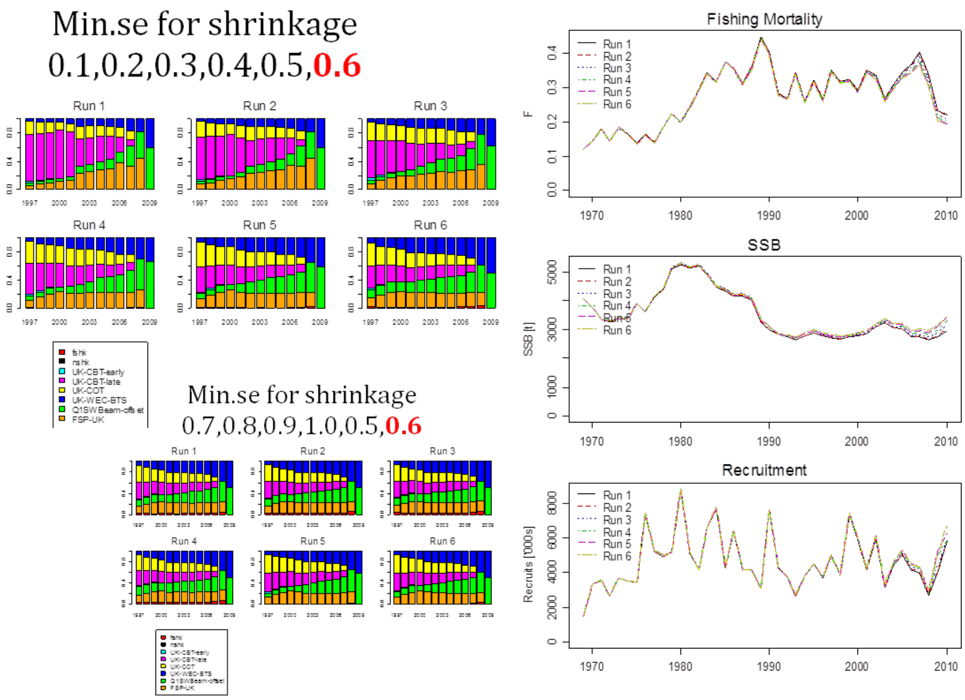


Figure 10.8.1.4. Sensitivity of XSA weights to the choice of min.se illustrating the focus on the UK-BT fleet when choosing low values and a much more balanced assessment model considering all fleets more evenly at setting of 0.6 (left top), little additional change in the weightings is observed at 0.7–1.0 setting indicating the relatively high level of precision and internal consistency of all the index information (left bottom). The impact on the stock status output (right) is small mainly because the UK-CBT index on which the model focuses is effective in the in the most recent years only since the series was split.

shrinkage

Shrinkage in XSA is a means of stabilising the selection pattern in the catch data to reduce the effects of sampling variability in the assessment. As such it is a constraint designed to deal with variance issues. Historically low shrinkage has been used in this assessment, because the data were considered to be of high internal consistency and sufficient sampling levels. In 2010 an assessment with high shrinkage (0.5) was used because it was thought to reduce the effects of biases that had developed in the assessment and were apparent in the form of a highly persistent retrospective pattern which led to the rejection of the previous model at WKFLAT 2009. Shrinkage was applied over ten years and five ages, with the result that the interim model was much less responsive to actual changes in F.

Given the understanding regarding the changes in the fishery such extensive shrinkage, especially with respect to the number of years used in the estimate were considered unreasonable so only the final three years and five ages were used in this sensitivity analysis examining levels of shrinkage from 0.1–2.5.

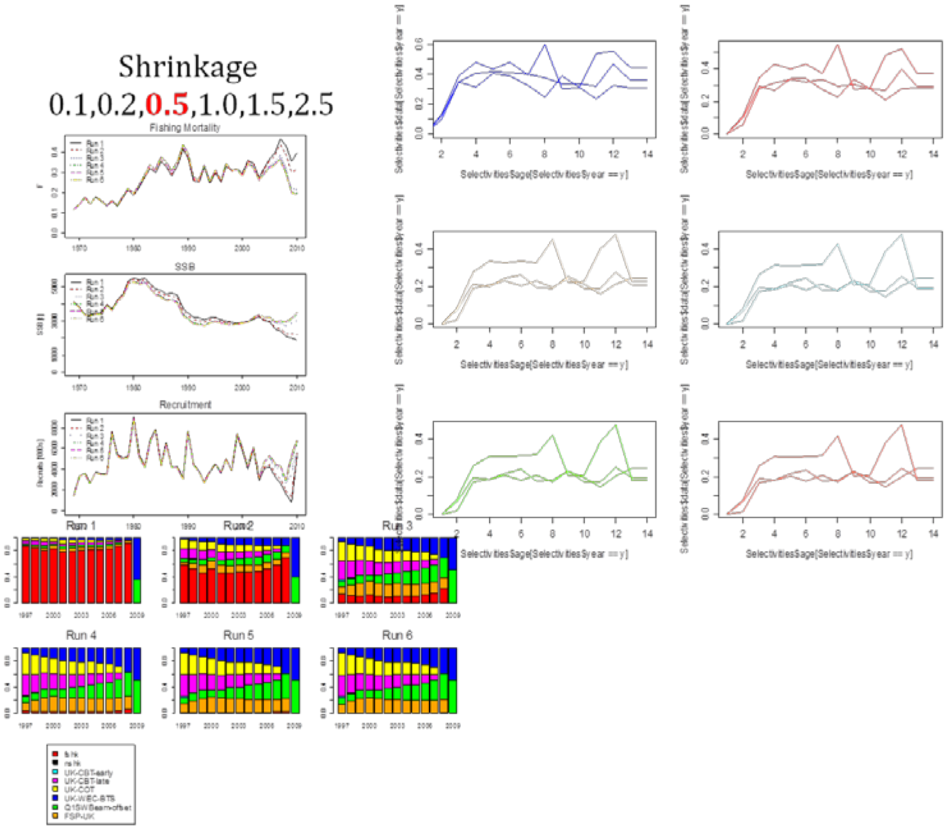


Figure 10.8.1.5. Sensitivity to F-shrinkage values on the weights used in the estimation of survivors (bottom left), F-at-age (left) and the stock status estimates (top left).

The XSA weightings for shrinkage values of 0.1 and 0.2 are dominated by the catch matrix and index information caries relatively little weight in the estimation of F and SSB in the final year. Such values are of little consequence when the F-at-age is constant, but when either the selectivity pattern or the overall F change from one year to the next such heavy shrinkage becomes problematic in estimation of stock status in the final year and more significantly in the forecast.

Weak shrinkage is desirable from a scientific perspective as it does allow the stock dynamics to alter in response to changes in the fishery. From this perspective a value of 1.0 or 1.5 appears to be appropriate based on the survivor weights information in Figure 10.8.1.5. There is however the risk of including variance information from indices in this assessment as trends. Given the large number of indices used in this assessment there seems relatively little chance of this occurring why a lower shrinkage (higher value) should be sought. However, it is clear from the single-fleet runs that there are small relative differences in the estimates of stock dynamics from the different sources of information potentially leading to retrospective patterns in the assessment.

F-at-age for the final three years of each of the runs are shown in Figure 10.8.1.5 (right). At the highest level (0.1), F for the final three years are scaled very similarly and the final year appears strongly smoothed, but only the later effect is the desirable one, where as the former should be considered inappropriate. At 0.2 the smoothing effect has largely disappeared, while the scaling effect is still present. At levels of 0.5 and greater there appears to be little effect on the estimation of F-at-age in the final year. These differences in the assumptions lead to quite dramatic changes in the estimation of stock status for levels of shrinkage less than 0.5. Smoothing by a selectivity pattern would be more desirable than averaging by F-at-age as it would allow for a better separation of the two effects, but this is not implemented in the model.

As a result the WK determined that in the short term, while the new survey-series bed in, shrinkage of 0.5 should be applied to estimate stock status but to allow the option of using shrinkage of 1.5 in future This should be re-examined in 2013 by WGCSE, when an additional two years of survey data are available. The longer survey indices will make the retrospective comparison more appropriate. At that point a five year retrospective should be run and the model with the best retrospective pattern chosen.

10.8.2 Sensitivity analysis

Timing of the split in the UK-CBT information

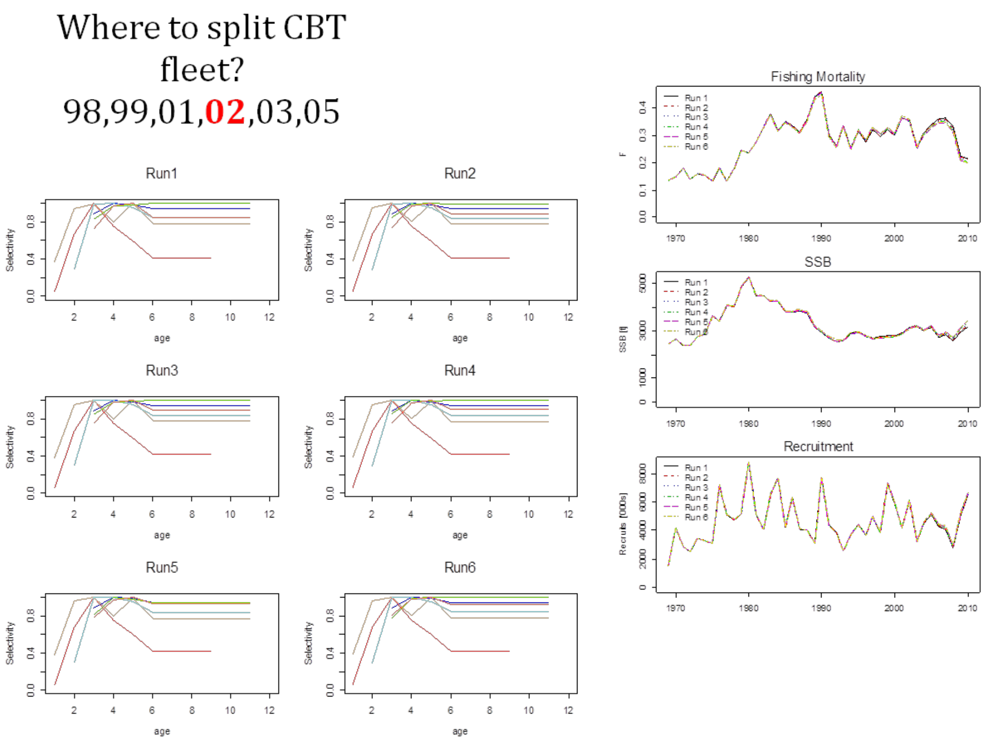


Figure 10.8.2.1. Sensitivity of fleet selectivity and stock status determinants to the choice of the last year in the UK-CBT early fleet with a commensurate change in the starting year for the UK-CBT late fleet.

Given the observed changes in the distribution of the fleet and the assumed change in selectivity and catchabilility given the less than homogenous distribution of sole in the division it was clear that catchability of the UK-CBT fleet could not be considered constant over the entire period of the original time-series (1989–2010). However it was much less clear where to split the fleet and the benchmark workshop decided on a value of 2002 for the end of the new survey-series based on information from the industry and an understanding of the economic and enforcement drivers in the behaviour of the fleet. The change in the fleet had not been abrupt but had occurred over a period of time prior to the implementation of the SLA so it was important to check the appropriateness of the choice using a sensitivity analysis. All other setting and indices were maintained as previously.

The results of the analysis indicate that there is relatively little effect of the exact year of splitting and that the main effect is the inconsistency of the data in the early part of the time-series with that of the later part (Figure 10.8.2.1). In order to maintain stability in the tuning information (i.e. not to have too short a time-series so that the estimation of q changes significantly annually) and to avoid breaks in other time-series which can confound the parameter estimation the initial value of ending the old time-series in 2002 synchronous with the correction of official landing statistics accounting for area misreporting carried out by the WG since 2004.

Sensitivity to individual indices

Generally it is not desirable to rely too heavily on a single index for providing estimates of stock status. There are two main reasons for this. Firstly, different indices usually provide information on different parts of the population. Secondly, when the future of indices is uncertain or there is potential to have significant variability associated with a year (year effects), then stock status estimation and forecasts become sensitive to these.

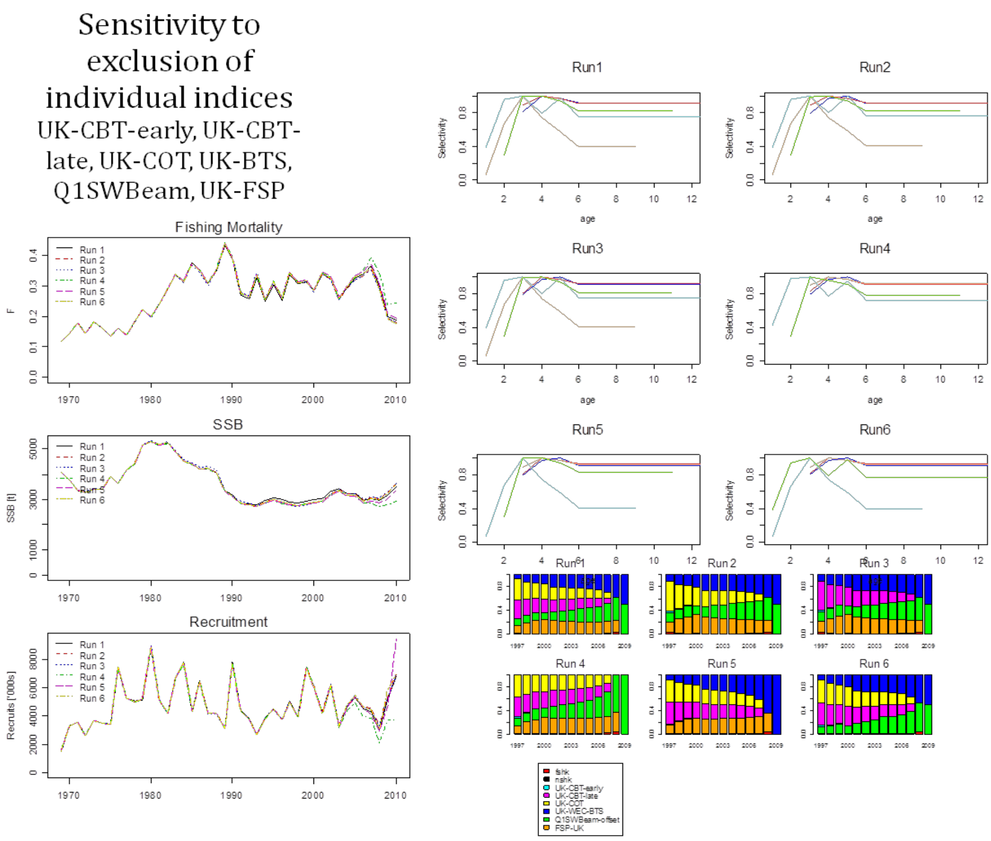


Figure 2. Sensitivity to the exclusion of individual tuning indices on stock status estimates (left), fleet selectivity estimates (top right) and survivor estimate weighting (bottom right).

In contrast this assessment now relies on five current indices (two commercial and three surveys) and one old index (commercial beam trawl early) all of which provide slightly different perspectives of the stock dynamics, leading to the potential that stock status estimates in the final year may be highly susceptible to the availability/future appropriateness of individual indices. To test the stability of the model a jack-knife strategy was adopted to rerun the assessment six times, each time excluding one of the indices used in the assessment (Figure 10.8.2.2).

Recent recruitment estimates and affects survivor estimates the final year with a consequence for an assumption of higher F and lower SSB. However given that the new survey now provides information on age-1 estimates and at worst we will not be able to extend the series of the UK-BTS the assessment should remain stable in future.

Also see previous section.

10.8.3 Retrospective patterns

Particular attention was paid to this form of diagnostic in the assessment, due to the problems in previous assessments and the difficulty associated with providing advice from the previous assessment. Realistically it is difficult to provide useful retrospective diagnostics from the new assessment, because of the length of the majority of the indices used in the new assessment. The Q1SWBeam survey represents only six years so that in a retrospective so that the weight of the information in a retrospective analysis of this and other short time-series diminishes rapidly. Nevertheless reasonably stable estimates of F and SSB are essential to management because of both the estimation in relation to fixed management reference points and forecasting on the basis of the equally fixed management target of F=0.27 in the management plan.

Figure 10.8.3.1 shows the sensitivity of the retrospective pattern to different levels of shrinkage (0.5 and 1.5) respectively. The retrospective is less severe in the case of the higher level of shrinkage so this setting was accepted for the 2012 assessment. However because scientifically and from the desirability of management of a quick response of the assessment to changes F, (both absolute levels and selectivity) the WK recommends that the effect be re-examined at the 2013 WGCSE when a more appropriate comparison is possible with longer time-series.

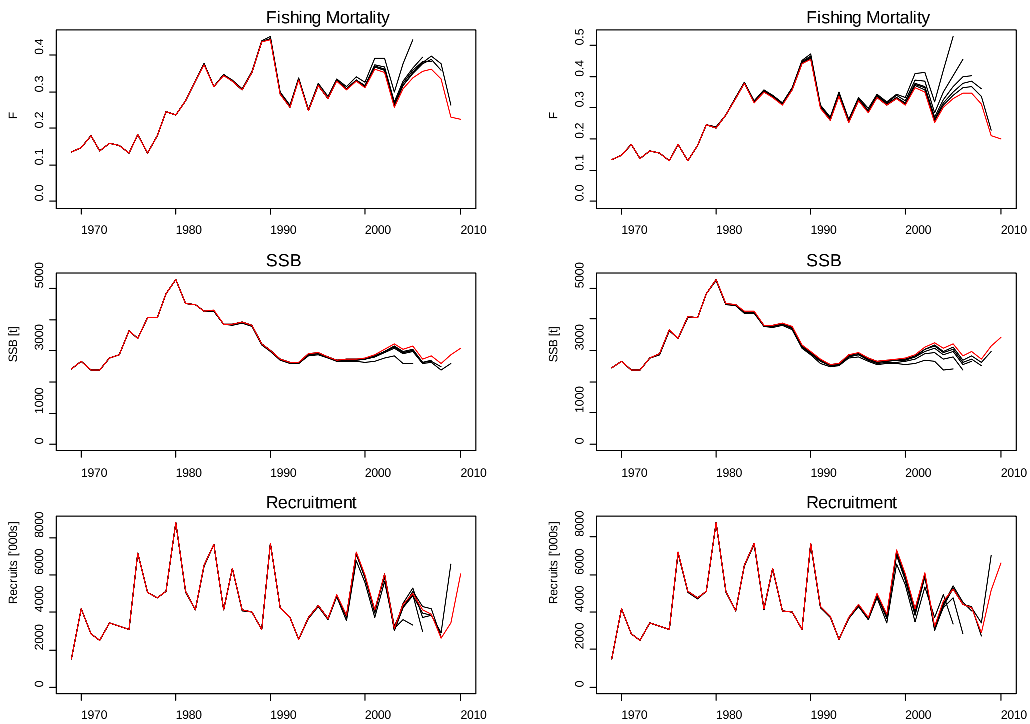


Figure 3. 5-year retrospective analysis for shrinkage = 0.5 model (left) and shrinkage = 1.5 (right) showing a more persistent perception for the stock status in recent years for higher shrinkage, but a lesser revision in F in the final year for the lower shrinkage, as would be expected for the different settings if the assumed trends in stock dynamics and the spatial changes in the indices are real.

10.8.4 Evaluation of the models

Evaluation and contrasting between different models and previous assessment models is described in Section 10.8.1 and 10.8.2.

10.8.5 Conclusion

The main reasons for rejection of the previous assessment methodology were the bias in the assessment from the retrospective analysis precluding efficient management of in conjunction with suitable reference points. While the new assessment methodology retains some, though arguably smaller retrospective trends, the security of the management plan in conjunction with more realistic reference points and a better understanding as to the causes of the retrospective bias, it should allow for much more appropriate advice of the stock in the near future. In the long term the hope is to move to a more fisheries-independent approach for assessing the stock once the new survey-series is better understood and can be relied on to provide better advice.

The report goes into significant detail as to some of the shortcoming of this assessment which may indicate high sensitivity of the assessment to certain assumptions but there are a number of indicators:

- A high degree of certainty in the landings and catch-at-age information especially in recent years;

- The large number of independent tuning-series and their high degree of internal and external consistency with respect to the strength of specific cohorts;
- understandings of the biology and fleet dynamics of the stock

that suggest this assessment is representative of the stock dynamics. The problems highlighted in this report should be seen more as a result of the detailed examination of each individual component of the data, rather than as a specific weakness of the assessment. When compared to other stocks examined by WKFLAT 2012 this is an extremely data rich and consistent assessment that highlight a small degree of process error precisely because the variance in the assessment is so small that it is discernible from the assessment output.

The main changes to the assessment methodology were the splitting of the commercial beam trawl information (UK-CBT) in 2002–2003 on the basis of documented changes in the fishery, the addition of two new, more spatially extensive surveys providing a larger range of ages from fisheries independent information, a reduction in the q-plateau from age 8 to age 6 and a reduction in the years of shrinkage from 10 to 3. The reason for each of the changes is highlighted in the previous section.

The WK felt that the models provided a stable platform as the basis of management advice with only a small sensitivity to individual pieces of tuning information. The long-term goal is to support the assessment entirely with fisheries-independent information and utilising information on a stock wide basis rather than the spatially limited survey information used historically. However, the group concluded that at this time, given the short time-series, the limited understanding of the variance components of the new survey-series and the greater precision in the estimates of year to year change sin F afforded by the commercial information it was too soon to rely entirely on the new survey information especially given that there is still some uncertainty surrounding future funding for the survey.

10.9 Short-term and medium-term forecasts

ICES has provided advice for this stock on the basis of a short-term forecast with the exception of 2009 when the advice was based on a trends only assessment. The assessment methodology developed at this benchmark meeting is determined to be appropriate to such projections and advice. This conclusion is largely based on the diagnostics of the assessment. The forecast methodology described below has not been specifically been evaluated at the benchmark, but given the biology of the species, the understanding of fleet dynamics and the similarity to previous assessment the previous procedure as described below is considered suitable.

10.9.1 Input data

Short-term forecasts require the input of a selection pattern, which is taken from the average of the last three years. In cases where a Fsq forecast is appropriate (i.e. where there is no documented trend in the level of F in the final three years) the selection pattern is scaled to the average F over the final three years. When there are significant changes in F over the last three years the selectivity pattern is rescaled to the final year to estimate catches in the ‘interim year’. When catches have been constrained at the level of the TAC a TAC constraint is implemented and the selectivity pattern is rescaled by the value of F that produces landings equal to the TAC for the ‘interim year’.

Survivor estimates for fish greater than age three in the interim year are used in the projections. Recruits, including the last cohort in the assessment (age one, given as survivors at age 2) are not thought to be particularly reliably estimated as they are poorly selected even in the inshore survey so their values is replaced by geometric mean recruitment determined as in the paragraph below depreciated for natural mortality.

Recruitment in subsequent years is determined as geometric mean recruitment over the appropriate time-series. For this stock in recent year this is currently the entire time-series excluding the last two years (i.e. 1969–2008 for the 2011 assessment). Historically there have been periods where recruitment was thought to be lower or higher, in which case GM is calculated over a shorter recruitment-series, minus one year).

10.9.2 Model and software

The assessment at the benchmark was developed using the FLR framework under the versions numbers and package descriptions listed below. This framework has been used to assess the stock since 2006, but until now the results have been quality checked with the original FORTRAN based program vpa95.exe developed and distributed by the Lowestoft Laboratory (now Cefas). These checks have not produced any quality concerns regarding the methodology in the past. However there was insufficient time to perform this quality check at the benchmark working group, but the check should be performed at the WG.

Package: FLCore

Title: Core package of FLR, fisheries modelling in R.

Version: 1.4-3

Date: 2005

Author: FLR Team and various contributors. Initial design by Laurence T. Kell and Philippe Grosjean.

Built: R 2.4.1; ; 2007-02-01 12:14:19; windows

Package: FLXSA

Title: eXtended Survivor Analysis for FLR

Author: Laurence Kell

Version: 1.4-2

Depends: methods, FLCore, FLAssess(>= 1.3.2)

Packaged: Wed Feb 14 18:08:21 2007; imosqueira

Built: R 2.4.1; i386-pc-mingw32; 2007-02-14 18:08:59; windows

Package: FLSTF

Title: A short-term forecast

Version: 1.4-1

Author: Robert Scott.

Depends: methods, R(>= 2.4.0), FLCore(>= 1.4-0)

Maintainer: FLR Core Team <flr-core@lists.sourceforge.net>

Licence: GPL 2 or above

Packaged: Thu Jan 25 14:58:34 2007; imosqueira

Built: R 2.4.1; ; 2007-01-25 14:58:59; windows

10.9.3 Conclusion

No additional validation of the forecasting procedure has been carried out here as the previous procedure based on the assumptions described in assumptions as described in 10.9.2 are considered to remain appropriate to the new assessment model.

10.10 Biological reference points

The WK examined the assessment output to determine whether there was a basis for providing biological reference points. The stock–recruit plot from the new assessment did not provide a significantly different perspective of the state of the various estimators of stock status in the past and only some minor changes to the estimates in recent year. Despite this the WKFRAME software (ADMB module developed by Cefas) for determining MSY reference points was used to calculate the parameters for three stock–recruit functions (Ricker, Beverton and Holt and Hockey Stick). The MCMC approach was able to determine "statistically appropriate fits" as interpreted by WKFRAME (ICES, 2010b). However the stock history shows very little contrast in SSB and long-term contrasts recruitment so that the models treat the cloud of datapoints more or less as a single observation leading to estimates of B_{MSY} that are more than twice the estimate of the highest ever observed SSB despite the fact that this stock is known to have been only lightly exploited prior to the assessment period (Figure 10.10.1).

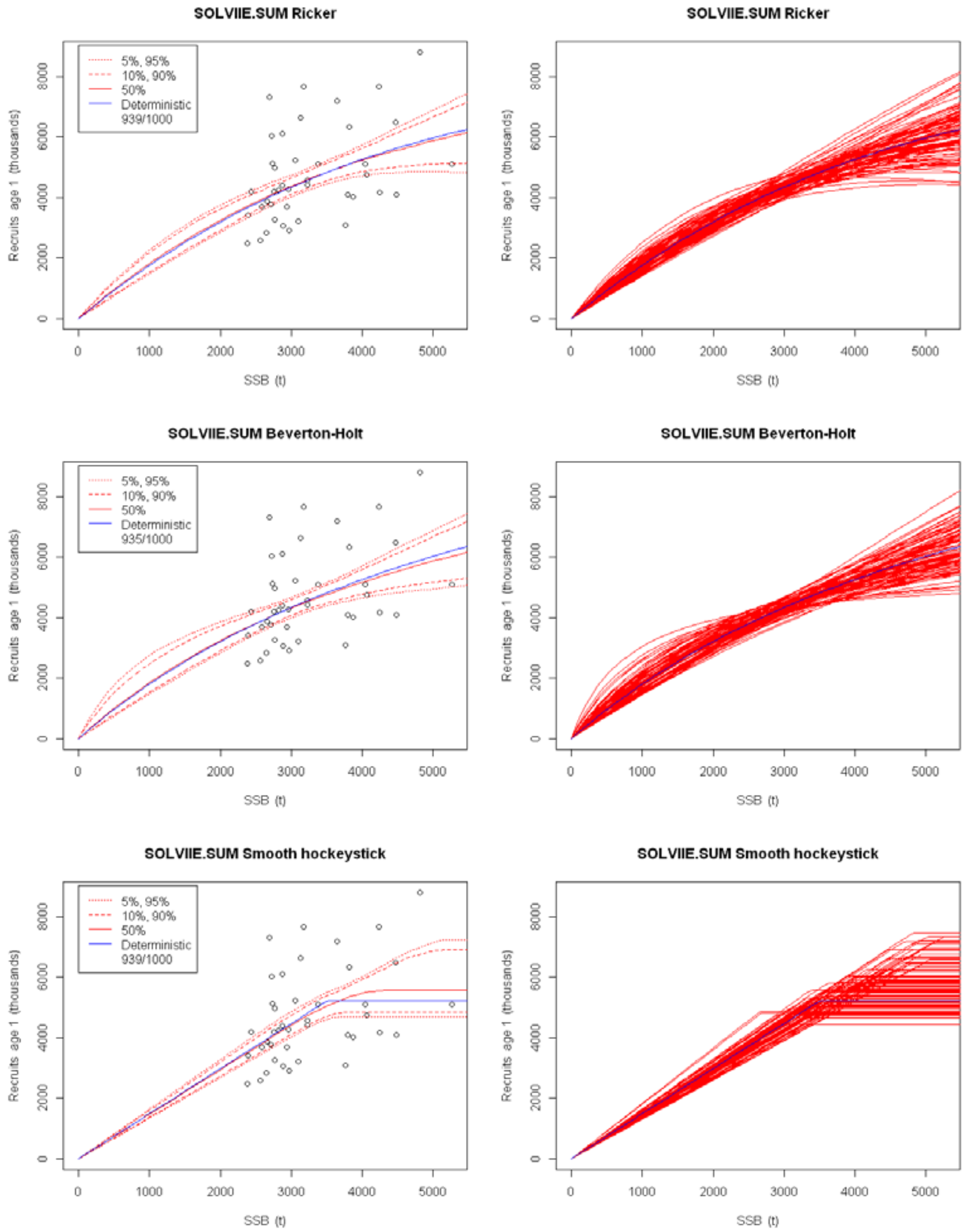


Figure 4. Statistical comparisons of possible stock–recruitment relationships derived on the basis of the new assessment output using MCMC fitting in ADMB as developed by WKFRAME.

Similarly the HS-fit appears to estimate the inflection at the centre of the cloud of estimates of SSB and recruitment and so are unlikely to be informative as to the effects of SSB on recruitment (Figure 10.10.1). Closer examination of the data does not provide any evidence that the stock has suffered from impaired recruitment, certainly not as a cause of changes in SSB, further complicating the estimation of biological reference points.

In the absence of appropriate PA reference points the WK felt that it could only rely on the meta-analysis produced for sole stocks by WKFRAME2 (ICES, 2011) which considered this stock as part of its work. It suggested that 1300 t and 1800 could be taken as appropriate levels for B_{lim} and B_{pa} respectively, and the WK adopted these values for this stock, despite the fact that the stock has never reached such low levels since current management is unlikely to drive the stock to such levels.

Although it would be possible to derive appropriate levels of F_{lim} and F_{pa} from the simulations, the current management target of F=0.27 is likely to take precedence over these estimates which are higher. Consequently it was deemed unnecessary to derive such values here.

F_{max} which appeared to be reasonably defined on the basis of the WKFRAME work (Figure 5) could therefore be considered as an appropriate F_{msy} target provided it would not reduce the stock to levels of SSB outside the known stock dynamics. To test whether this is appropriate and to determine level of MSY $B_{trigger}$ the WK made use of the R-code used to evaluate the management plan by STECF. These simulations also demonstrated that F_{max} was an appropriate proxy for F_{msy} since it by definition maximises the yield, while it did not reducing the stock to levels where recruitment is impaired. Further evidence from this comes from the assessment itself, where the level of F is estimated to have been around or above 0.27 since the early 1980s without apparent impairment to recruitment.

The biological reference points from the meta-analysis are outside the observed range of biomass values so the WK felt it was scientifically unsound to set $B_{MSY\ trigger}$ at the level of B_{pa} as is done for most stocks currently in ICES. Instead WK used the 95% confidence limits for SSB from the simulations, given the assumed long-term average F of 0.27, variance in recruitment, recruitment autocorrelation, assessment variance, retrospective assessment bias. As suggested by WKFRAME2 the median value of 2800 t the lower 95% confidence limit in SSB over the next 50 years (to 2061) was taken from a simulation run using the best guess at the appropriate setting for the simulations (Figure 6). In addition this value satisfied both the criteria that it was sufficiently far away from what potentially might be a biological response (B_{pa}) and it would keep the stock well within the biomass estimates that had previously been observed.

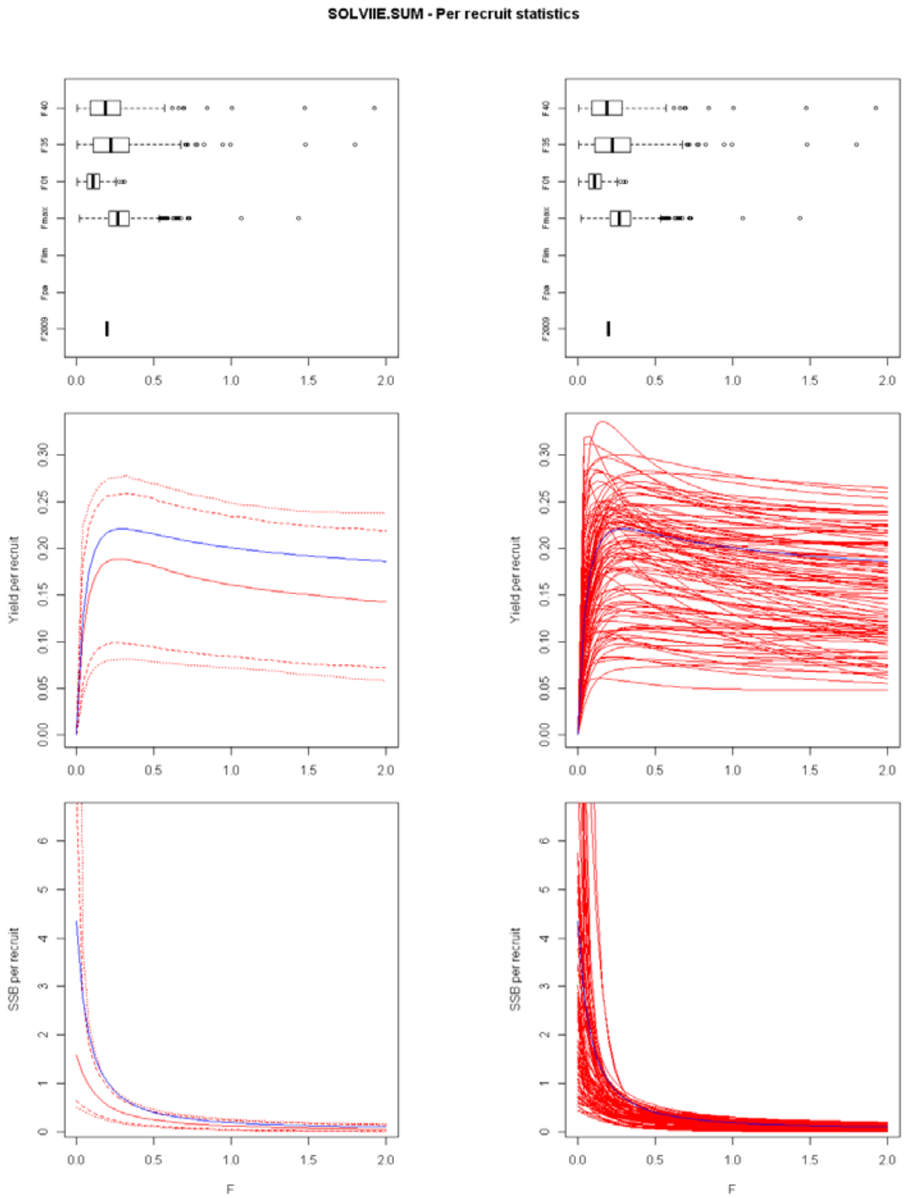


Figure 5. Deterministic values for the yield-per-recruit curve shown in blue and stochastic simulations based on estimated variance in the selection pattern and weights-at-age derived using the software recommended by WKFRAME.

The new reference points for this stock are thus:

B_{lim} = 1300 t

B_{pa} = 1800 t

F_{lim} and F_{pa} are not defined

F_{MSY} = 0.27

B_{MSY} not defined

$B_{MSYtrigger}$ = 2800 t

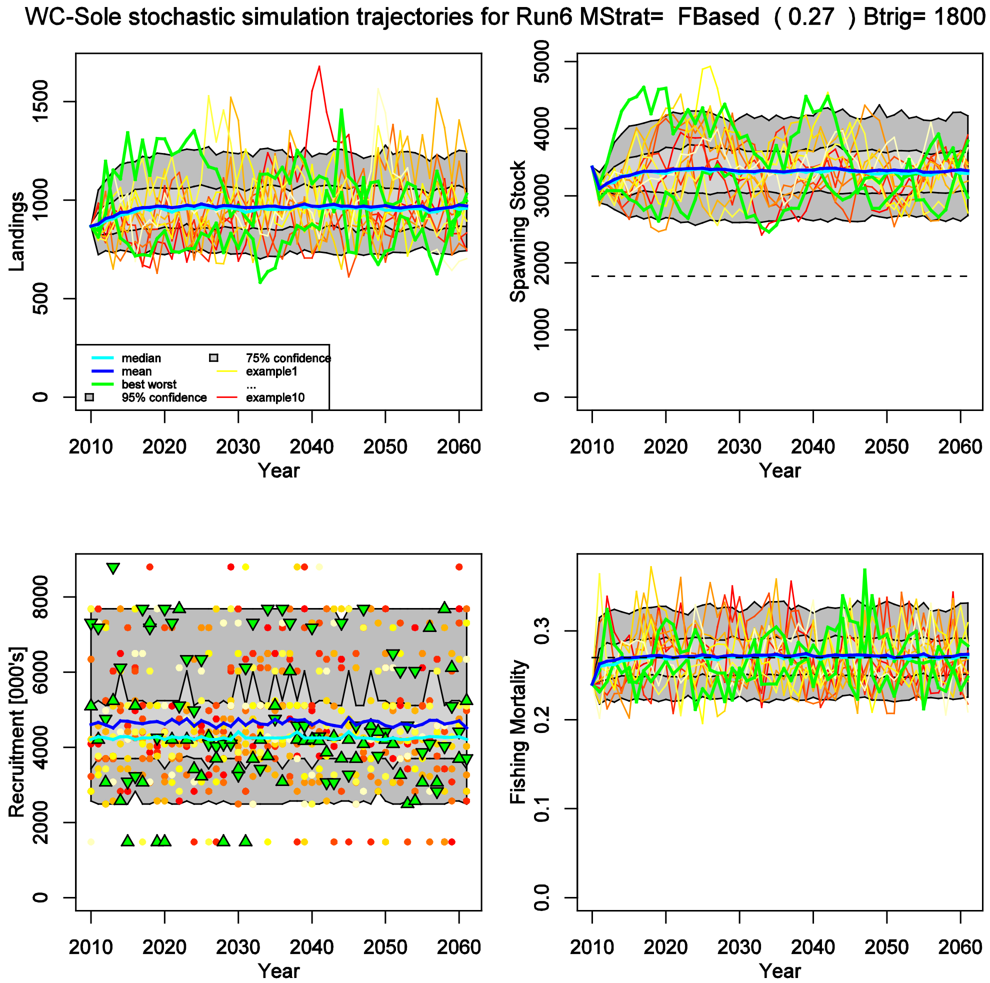


Figure 6. Output from 500 50-year management simulations assuming the best guess estimates of assessment bias and variance as well as the most likely management implementation error usign R-code developed for STECF (SG-MOS 1006a) based on estimates of selection and recruitment from the new assessment methodology.

10.11 Recommendations on the procedure for assessment updates and further work

The WK recommends the following settings for future assessments:

	2012	2013	after 2013, until next benchmark
Assmnt Age Range	1–12+	1–12+	1–12+
Fbar Age Range	F(3–9)	F(3–9)	F(3–9)
Assmnt Method	XSA	XSA	XSA
Tuning Fleets			
Q1SWBeam (offset by 1y 1a)	2006–12 2–12	2006–13 2–12	2006–(assessment year) 2–12
UK-FSP	2004–11 2–11	2004–12 2–11	2004–(assessment year -1) 2–11
UK combined beam Ages (early)	1988–02 3–11	1988–02 3–11	1988–02 3–11
UK combined beam Ages (late)	2003–11 3–11	2003–12 3–11	2003– (assessment year -1) 3–11
UK otter trawl Ages	1988–11 3–11	1988–12 3–11	1988–(assessment year -1) 3–11
UK BTS yrs Ages	1988–11 1–9	1988–12 1–9	1988–(assessment year -1) 3–11
Time taper	No	No	No
Power model ages	No	No	No
P shrinkage	No	No	No
Q plateau age	6	6	6
F shrinkage S.E	0.5	consider 0.5/1.5	0.5 or 1.5, as decided in 2013
Num yrs	3	3	3
Num ages	5	5	5
Fleet S.E.	0.6	0.6	0.6

Given that the new assessment methodology retains at least some of the retrospective characteristics observed in previous assessments the decision to retain a significant amount of F-shrinkages in the assessment was considered a useful stabilising factor for management purposes. This is scientifically less desirable than a lower level of shrinkage and will tend to mask responses in the stock dynamics to changes in exploitation. More over with the shorter time-series (Q1SWBeam, UK-FSP and CBT-late) an independent investigation of the retrospective characteristics is not possible as this tuning information receives progressively less weight as the analysis goes back in time.

To ensure responsive yet accurate management it was therefore decided to implement the management model using the heavier shrinkage value of 0.5 in 2012, and update the assessment procedure with respect to the level of shrinkage in 2013 when there will be two additional years of tuning information available to conduct more valid comparison of the effects of shrinkage on the assessment.

The WK accepted PA reference points for the stock based on a meta analysis with other sole stocks (WKFRAME2) as the best currently available information on the reproductive capacity of the stock. However, given the uncertainty around the source of recruitment and the difference in the proportion of habitats available there is no direct evidence that the stock would be able to sustain productivity at such low biomass levels since F in the stock has never been sufficiently high to drive SSB down to such levels. Current management targets for this stock are likely to increase SSB in this stock and maintain it in the range previously observed stock levels indefinitely (see Section 10.10). Nevertheless the potential effects of climate change and changes in abundance of stocks contributing to a potentially cross stock recruitment pool may alter the recruitment dynamics observed in this stock. The WK therefore recommends that recruitment dynamics continue to be investigated, particularly through new tagging initiatives of juveniles in this and surrounding stock areas and that potential climatic and ecosystem effects are researched to ensure the exploitation remains sustainable. Such information will be essential to managers to assess the reasons for changes in the stock dynamics should it be indicated by future assessments that SSB has fallen below MSY $B_{trigger}$ and the assumed stock assessment dynamics area no longer applicable.

10.12 Implications for management (plans)

The current EU management plan (Council Regulation (EC) No 509/2007) for this stock implies that this stock should be exploited at F=0.27 on the ground that this level of fishing mortality produces high yield whilst running little risk of impaired recruitment. The plan was assessed and evaluated in two separate meeting by STECF (2009, 2010). ICES still has not evaluated this management plan due to the absence of a sound assessment basis.

The new assessment does not differ significantly in scale from previous assessments with respect to SSB and F. F_{max} (F=0.27) is considered an appropriate proxy for F_{msy} given the mortality and growth schedule of the stock as well as the uncertainty about the sources of recruitment and is also in line with the previous assessment and management plan target, suggesting the management plan F target to be appropriate, though a full evaluation of ICES including issues such as TAC constraints in the near future is desirable to align the official ICES advice with the management decisions executed by the European Commission.

10.13 References

Burt, G.J. and Millner, R.S. 2008. Movements of sole in the southern North Sea and eastern English Channel from tagging studies (1955–2004). Sci. Ser.Tech. Rep., Cefas Lowestoft, 144:44pp.

Horwood, J. 1993. The Bristol channel sole (*Solea solea* (L.)): a fisheries case study. Advances in marine biology. 1993, vol. 29, pp. 215–367.

ICES. 2009. Report of the Benchmark and Data Compilation Workshop for Flatfish (WKFLAT 2009), 6–13 February 2009, Copenhagen, Denmark. ICES CM 2009/ACOM:31. 192 pp.

ICES. 2010. Report of the Working Group on the Celtic Seas Ecoregion (WGCES), 12–20 May 2010, Copenhagen, Denmark. ICES CM 2010/ACOM:12. 1435 pp.

ICES. 2010b. Report of the Workshop on Implementing the ICES F_{MSY} framework , 22–26 March 2010, Copenhagen, Denmark. ICES CM 2010/ACOM:54. 83 pp.

ICES. 2011. Report of the Workshop on Implementing the ICES F_{MSY} Framework (WKFRAME2), 10–14 January 2011, ICES, Denmark. ICES CM 2011/ACOM:33. 110 pp.

Pawson, M.G and Harley, B.F.M. 1997. (WD presented to WGSSDS in 1997).

Palmer, D.W. 1984. Western English Channel sole: a comparison of length and age data collected at English ports. ICES CM 1984/G:18.

STECF. 2010. Report of the Subgroup on Management Objectives and Strategies (SGMOS 10–06). Part c) Impact assessment of Western Channel sole multi-annual plan (eds. J. Simmonds, Kupschus, S., Goti, L. and Vanhee, W.). Publications Office of the European Union, Luxembourg, ISBN 978-92-79-18744-5, JRC 61948, 128 pp.

STECF. 2009. Report of the STECF Study Group on the Evaluation of Fishery Multi-annual Plans (SGMOS 09–02) (eds. J. Simmonds) Publications Office of the European Union, Luxembourg, ISBN 978-92-79-15793-6JRC 58542, 227 pp.

Annex 1: Terms of Reference

2011/2/ACOM47 A **Benchmark Workshop on Flatfish Species and Anglerfish** (WKFLAT), chaired by External Chair Joanne Morgan, Canada, ICES coordinator Rob Scott, UK, and invited external (Richard Methot (USA) and Paul Nitschke (USA)) experts will be established and will meet in Derio, Bilbao, Spain, 1–8 March 2012 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 fishery-dependent, fishery-independent, environmental, multispecies and life-history data.

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.

  i) If no new analytical assessment method can be agreed, then an alternative method (the former method, or a trends based assessment) should be put forward;

c) Evaluate the possible implications for biological reference points, when new standard analyses methods are proposed. Propose new reference points taking into account the WKFRAME results and the introduction to the ICES advice (Section 1.2).

d) Develop recommendations for future improving of the assessment methodology and data collection;

e) As part of the evaluation:

  i) Conduct a one day data compilation workshop. Stakeholders shall be 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) Consider further inclusion of environmental drivers, including multispecies interactions, and ecosystem impacts for stock dynamics in the assessments and outlook;

  iii) Evaluate the role of stock identity and migration.

Stock	Stock leader
Anglerfish (*L. piscatorius*) (Divisions VIIb–k and VIIIabd)	Inaki Quincoces
Anglerfish (*L. budegassa*) (Divisions VIIb–k and VIIIabd)	Jean Claude Mahé
Anglerfish (Divisions IIa and IIIa, Subarea IV and Subarea VI)	Paul Fernandes
Anglerfish (*L. piscatorius*) (Divisions VIIIc and IXa)	Paz Sampedro
Anglerfish (*L. budegassa*) (Divisions VIIIc and IXa)	Ricardo Alpoim
Sole in Division VIIe	Sven Kupschus
Megrim (Divisions VIIb–k and VIIIabd)	Marina Santurtun

The Benchmark Workshop will report by 15 March 2012 for the attention of ACOM.

Annex 2: List of participants

Name	Address	Phone/Fax	E-mail
Esther Abad	Instituto Español de Oceanografía Centro Oceanográfico de Vigo PO Box 1552 36200 Vigo (Pontevedra) Spain	Phone +34 986 492111 Fax +34 986 498626	esther.abad@vi.ieo.es
Ricardo Alpoim	INRB - IPIMAR Avenida de Brasilia 1449-006 Lisbon Portugal	Phone +351 21 302 70224 Fax +351 21 301 5948	ralpoim@ipimar.pt
Liz Clarke (by correspondence)	Marine Scotland Science Marine Laboratory PO Box 101 AB11 9DB Aberdeen United Kingdom	Phone +44 1224 876544 Fax +44 1224 295511	liz.clarke@scotland.gsi.gov.uk
Paul Fernandes	University of Aberdeen King s College AB24 3FX Aberdeen United Kingdom	Phone +44 1224 295 403 Fax +44 1224 295511	fernandespg@abdn.ac.uk
Carmen Fernandez	International Council for Exploration of the Sea H. C. Andersens Boulevard 44-46 DK-1553 Copenhagen V Denmark		carmen.fernandez@ices.dk
Dorleta Garcia	AZTI-Tecnalia Herrera Kaia Portualde z/g 20110 Pasaia (Gipuzkoa) Spain	Phone +34 946 574 000 Fax +34 946 870 006	dgarcia@azti.es
Norman Graham	Marine Institute Rinville Oranmore Co. Galway Ireland	Phone +353 91 387 307	norman.graham@marine.ie

Name	Address	Phone/Fax	E-mail
Sven Kupschus	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 1502 562244 Fax +44 1502 513865	Sven.Kupschus@cefas.co.uk
Jorge Landa	Instituto Español de Oceanografía Centro Oceanográfico de Santander PO Box 240 39004 Santander Cantabria Spain		jorge.landa@st.ieo.es
Jean-Claude Mahé	Ifremer Lorient Station 8, rue François Toullec 56100 Lorient France	Phone +33 (0)2 97 87 38 18 Fax +33 (0)2 97 87 38 36	jean.claude.mahe@ifremer.fr
Richard Methot Invited Expert	National Marine Fisheries Services Northwest Fisheries Science Center 2725 Montlake Boulevard East Seattle WA 98112-2097 United States	Phone +1 206 860-3365	richard.methot@noaa.gov
Cóilín Minto	Galway-Mayo Institute of Technology Dublin Road Galway Ireland		Coilin.Minto@gmit.ie
Cristina Morgado ICES Secretariat	International Council for the Exploration of the Sea H. C. Andersens Boulevard 44–46 1553 Copenhagen V Denmark	Phone +45 33 38 67 21 Fax +45 33 63 42 15	cristina@ices.dk

Name	Address	Phone/Fax	E-mail
Joanne Morgan Chair and Invited Expert	Fisheries and Oceans Canada DFO Science Branch PO Box 5667 St John's NL A1C 5X1 Canada	Phone +1 (709) 772-2261	Joanne.Morgan@dfo-mpo.gc.ca
Paul Nitschke Invited Expert	National Marine Fisheries Services Northeast Fisheries Science Center 1315 East West Highway Silver Spring MD 20910-6233 United States	Phone +1-508-495-2295	paul.nitschke@noaa.gov
Mike Park	Scottish White Fish Producers Association Limited North Lodge, 11, Bath St. AB39 2DH Stonehaven United Kingdom	Phone +44 7710504773	mikeswfpa@aol.com
Jim Portus	South Western Fish Producers Organisation Ltd. 49–50 Fore Street PL21 9AE Ivybridge Devon United Kingdom		swfpo@btopenworld.com
Iñaki Quincoces	AZTI-Tecnalia AZTI Sukarrieta Txatxarramendi ugartea z/g E-48395 Sukarrieta (Bizkaia) Spain	Phone +34 94 602 94 00 Fax +34 94 687 00 06	iquincoces@suk.azti.es
Lisa Readdy	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom		lisa.readdy@cefas.co.uk

Name	Address	Phone/Fax	E-mail
Ruben Roa	AZTI-Tecnalia AZTI Sukarrieta Txatxarramendi ugartea z/g E-48395 Sukarrieta (Bizkaia) Spain	Phone +34 94 6574000 (ext. 426) Fax +3494 6572555	rroa@azti.es
Paz Sampedro	Instituto Español de Oceanografía Centro Oceanográfico de A Coruña PO Box 130 15001 A Coruña Spain	Phone +34 981 205 362	paz.sampedro@co.ieo.es
Jane Sandell	Scottish Fishermens Federation 24 Rubislaw Terrace AB10 1XE Aberdeen United Kingdom		jane.sandell@scottishfishermen.co.uk
Marina Santurtún	AZTI-Tecnalia AZTI Sukarrieta Txatxarramendi ugartea z/g E-48395 Sukarrieta (Bizkaia) Spain	Phone +34 946 029 400 Fax +34 946 870 006	msanturtun@suk.azti.es
Rob Scott ICES Convener	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44(0)1502524265	Robert.scott@cefas.co.uk
Willy Vanhee	Institute for Agricultural and Fisheries Research (ILVO) Ankerstraat 1 8400 Oostende Belgium	Phone +32 5 956 9829 Fax +32 5 933 0629	willy.vanhee@ilvo.vlaanderen.be

Annex 3: Recommendations

Recommendation	Adressed to
1. Guidance on stocks identity methods for anglerfish. WKFLAT 2012 recommends a new ToR for the next SIMWG meeting: "Evaluated the previous stocks identity studies on anglerfish in the ICES and adjacent areas and proposed new methodologies for future studies." The background material on previous studies will be compiled and provided to SIMWG by WKFLAT 2012 members.	SIMWG
2. WKFLAT 2012 recommends WGISDAA to investigate the possibility to combine the three surveys that are being currently used in the megrim in (Divisions VIIb–k and VIIIabd) assessment (i.e. EVHOE groundfish Survey; Spanish Porcupine groundfish survey; Irish groundfish survey-Q4). The effect of using the combine survey instead of the three abundance index in the assessment.	WGISDAA
3. WKFLAT 2012 recognizes the improvements on assessing the anglerfish in Subarea IV and VI achieved at this meeting. However further work needs to be done before using this methodology as basis for advice. Proposals for future work are available in Section 4.11. WKFLAT 2012 recommends that this work is presented at the next WGCSE 2012 meeting. Depending on the progress made, this assessment could be benchmarked in a near future.	WGCSE; ACOM (benchmark preparation)
4. WKFLAT 2012 recognizes the improvements on assessing the anglerfish stocks in Divisions VIIb–k and VIIIabd using SS3 model. However further work needs to be done on data compilation and assessment settings. WKFLAT 2012 proposes that this work is done intersessionally and presented at the WGHMM meetings.	WGHMM
5. The SS3 assessment explored at WKFLAT 2012 for black anglerfish (*L. budegassa*) in Division VIIIc and IXa (see Section 8.8.2) seems to be promising and further work on this assessment is highly recommended in the incoming year.	WGHMM
6. Megrim VIIb,c, e–k and VIIIa,b,d. The group states strongly the importance of incorporating annual estimates of discards from France to explain some possible recruitment that could not be completely registered in the catch-at-age matrix and lpues. Also it is important to incorporate these estimates to obtain consistent data along the series.	France delegate
7. Megrim VIIb,c, e–k and VIIIa,b,d. A complete revision and in depth analysis is needed for checking the changes detected in the data homogeneity of the three time periods identified: 1984–1989; 1990–1998 and 1999–2010.	France, Spain, UK, Ireland delegate and WGHMM members
8. Megrim VIIb,c, e–k and VIIIa,b,d. No progress can be expected if no international commitment to work on data and methods to assess this stockis obtained. However it appears unlikely that time between possible future Benchmarks and Working Groups would be enough for: i) solving data availability, ii) reviewing their quality, iii) new model trials and even iv) exchange of experiences between researches working in same species but different stocks. That is why it would be recommended that resources could be made available for a real improvement in the assessment of this stock. A pilot project is suggested for indepth treatment of data analysis and improvement and model selection.	ACOM and RCM - Atlantic

Recommendation	Adressed to
9. Discussions with industry representatives at WKFLAT 2012 concluded with a number of recommendations for data which could be supplied by the fishing industry. There is some uncertainty concerning the status of large old anglerfish. The numbers of (large) mature females sampled either by the national sample programmes or by the survey(s) are small. It would, therefore, be useful for the fishing industry to make biological measurements of any large anglerfish that are caught prior to any market processing. Such measurements include length, weight, sex, maturity stage and the collection of the otolith and illicium for any individual greater than 100 cm. Some form of guidance will be required, perhaps in the form of an information leaflet, video or training course. Information leaflets could also highlight the need to be vigilant in identifying (and returning) anglerfish that have been tagged. As with any stock, the accurate recording of catch and logbook entry is always advantageous: apart from the obvious direct use in stock assessment, these data also help to understand the nature of the fishery and can assist in examining the distribution of the fished component of the stock.	MIRAC and ACOM
12. The distribution of anglerfish stocks does not include ICES Division VIIa, and the megrim does not include VIIa and VIId. Further work is needed to assess the stock identity of anglerfish and megrims in this area.	ACOM

Annex 4: Working documents

The following Working Documents (WDs) were presented to WKFLAT.

WD Code	Authors	Title
WKFLAT 2012 WD01	J. Landa	Report of the Anglerfish (*Lophius piscatorius*) illicia and otoliths exchange 2011
WKFLAT 2012 WD02	R. H. Roa-Ureta and I. Quincoces	Assessment of white anglerfish (*Lophius piscatorius*) from the Bay of Bizcay and the Celtic Sea: A Pella-Tomlinson production model fitted by marginal likelihood to survey and commercial indices of abundance
WKFLAT 2012 WD03	H. Gerritsen	Maturity Estimates for Megrim and Monkfish in Division VII
WKFLAT 2012 WD 04	J. Landa, J. Barrado and F. Velasco	Age and growth of anglerfish (*Lophius piscatorius*) on the Porcupine Bank (west of Ireland) based on illicia age estimation.
WKFLAT 2012 WD 05	R. Morlán, P. Sampedro and A. C. Fariña	Review and update information of A Coruña trawl fleet to be used as abundance index of white and black anglerfish southern stocks
WKFLAT 2012 WD 06	J. Santos, N. Pérez	Modelling anglerfish discard behaviour in Spanish North Atlantic coast fisheries
WKFLAT 2012 WD 07	A. C. Fernandes and N. Prista	Portuguese discard data on anglerfish *Lophius piscatorius* and blackbellied angler *Lophius budegassa* (2004–2010)
WKFLAT 2012 WD08	J.Landa, A. Antolínez, B. Castro, M. Ámez, U. Autón, L. Cañás, P. Sampedro and A.C. Fariña	Reproduction of white anglerfish (*Lophius piscatorius*) caught by the Spanish fleet in Northeastern Atlantic waters
WKFLAT 2012 WD 09	J. Landa, A. Antolínez, B. Castro, M. Ámez, J. Barrado, and C. Hernández	Sexual maturity of black anglerfish (*Lophius budegassa*) caught by the Spanish fleet in Northeastern Atlantic waters
WKFLAT 2012 WD10	J. Landa, J. Fontenla and A. Gómez	Sexual maturity of megrim (*Lepidorhombus whiffiagonis*) caught by the Spanish fleet in ICES Subarea VII
WKFLAT 2012 WD 11	H. Gerritsen and C. Lordan	Irish megim (*Lepidorhombus whiffiagonis*, Walbaum) discards in VIIb–k. Evaluation of raising methods and derivation of a revised series.
WKFLAT 2012 WD12	H. Gerritsen	Irish megrim tuning fleets
WKFLAT 2012 WD13	E. Abad, C. Fernández, P. Sampedro, N. Pérez, and B. Patiño	Analysis of the Vigo-Marin bottom-trawl fleet operating in ICES Division VII for possible standardization
WKFLAT 2012 WD14	N. Graham and A. Campbell	Methodology employed by Ireland to split commercial landings between *Lophius piscatorius* and *Lophius budegassa* for generation of annual and species-specific landings-at-age

WKFLAT 2012 WD15	D. Garcia, C. Fernandez, M. Santurtun, and E. Abad	Application of a Bayesian statistical catch-at-age model to the megrim stock in Division VIIb–k and VIIIab
WKFLAT 12 WD16	I. Holmes	Detailing trends in UK(E+W) sampling, landings and effort of sole in Division VIIe
WKFLAT 2012 WD17	S. Kupschus	The Quarter 1 South West Beam Trawl Survey (Q1SWBeam), a first look at a new stratified random survey designed developed by Cefas to monitor flatfish populations in the western channel while providing data in support of the ecosystem approach to fisheries management.
WKFLAT 2012 WD18	S. Kupschus	Discards estimates of UK Beam trawlers fleet in Division VIIe
WKFLAT 2012 WD19	S. Kupschus	A description of the UK vessel monitoring system (VMS) data for towed gear in the Celtic sea and western approaches and a look at the obvious spatial and temporal trends
WKFLAT 2012 WD20	R.Bush, J. Ashworth and M. Evans	FSP Western Channel sole and plaice 2010

WKFLAT 2012 WD01. Report of the Anglerfish (*Lophius piscatorius)* illicia and otoliths exchange 2011. J. Landa

The age estimation for stock assessment of white anglerfish (*Lophius piscatorius*) in the ICES area has been traditionally based on two different calcified structures, the *illicium* (used in most of the European countries) and the *sagitta* otolith (used in only two countries). The otoliths from *Lophius* have confusing secondary structures (Woodroffe *et al*., 2003), and an increase in the opacity of the otoliths with age, makes them more difficult for age estimating. The growth pattern is easier to distinguish in the *illicia*, which exhibit fewer secondary structures (Dupouy *et al*., 1986).

Growth studies alternative to the age estimates on calcified structures (CS) of white anglerfish, such as tagging-recapture (Laurenson *et al*., 2005; Landa *et al*., 2008a), daily growth (Wright *et al*., 2002) and length–frequency distributions of catches (Dupouy *et al*., 1986; Thangstad *et al*., 2002; Landa, 2004; Jónsson, 2007), showed that the growth pattern estimated using the traditional standardized age estimation criterion based on *illicia* (Duarte *et al*., 2002) was underestimated and that criterion was not accurate, although it was standardized and used in several age estimation anglerfish workshops. The last anglerfish *illicia* exchange and workshop using that criterion took place in 2004 (Duarte *et al*., 2005). The ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) (ICES, 2011) recommended an exchange of *illicia* and otoliths for 2011, when a new age estimation criterion on *illicia* was expected. Modifications in the methodology of *illicia* preparation and in the traditional standardized age estimation criterion have allowed a new age estimation criterion on *illicia* to be obtained. Using this new criterion, the catches-at-age have been tracked more successfully (Landa *et al*., pers. com.). Therefore this criterion seems to be more accurate and it was presented in the protocol of the present exchange.

A white anglerfish exchange of 200 images (100 *illicia* and 100 otoliths) from the same specimen took place during the third quarter of 2011. Each reader was asked to mark the annual rings on the images, using an image analysis software program (GIMP). The exchange was carried out through the European Age Readers Forum (EARF). Fourteen readers (including two Mediterranean readers) from ten institutes from eight European countries participated.

Three age estimation analyses were performed within each CS: (i) *illicia* age readings, (ii) otoliths age readings, and (iii) a comparison between *illicia* and otoliths age readings. The analyses within each CS (i and ii) were performed for all readers and also for the readers contributing to the stock assessment. For both analyses, the between reader agreement was higher in *illicia* compared to otoliths. The *illicia* readings were less relatively biased than otolith readings, although had slightly lower precision. However the overall values of the mean CV were strongly influenced by the high CV values at first ages, especially at age 0. More specimens were aged 0 years using *illicia* than otoliths, and therefore the slightly lower precision in *illicia* was influenced by that.

i) *Illicia*. Analysing all *illicia* readers, the overall percentage agreement was 45.0%, the CV was 26.7%, and the relative bias was 0.39. The first annulus was located by most of readers between 300 and 350 μm. When analysing the *illicia* readers that contribute to the stock assessment, the agreement, precision and especially the relative accuracy increased: the overall percentage agreement was 49.3%, the CV was 22.4%, and the relative bias was 0.11.

ii) Otoliths. Similar to the last anglerfish *illicia*/otoliths ageing workshop in 2004, two different analyses had to be performed when the readings were analysed, using R8 and R9 as reference readers, due to the low agreement between both experienced otolith readers. Analysing all otoliths readers, the overall percentage agreements were 19.5% and 19.5% when R8 and R9 were, respectively, the reference readers; the CV were 23.7% and 24.0%; and the relative biases were -0.96 and 0.47, respectively. There were discrepancies among the readers in the location of the first annulus. Analysing only the otolith readers contributing to the stock assessment, the overall percentage agreements were 18.3% and 25.4% when R8 and R9 were, respectively, the reference readers; the CV were 13.3% and 16.6%; and the relative biases were -1.23 and 0.52, respectively.

iii) *Illicia* and otoliths age readings comparison. Results indicate strong discrepancies between *illicia* and otoliths readings, there are similar to the conclusions in the last anglerfish exchange and workshop in 2004 (Duarte *et al*., 2005). Comparing the expert otoliths readers vs. the expert *illicia* readers, the overall percentage agreement were 4.7% and 16.5%, when R8 and R9 were compared, respectively, to the modal *illicia* readings; and the relative bias were 2.67 and 0.92, respectively. The 86% and 71% specimens were aged older using otoliths than using *illicia* when the readings of the experienced *illicia* readers and experienced otoliths readers R8 and R9 were compared;

Considering the above there are implications regarding the stock assessment of this species, given that the stock is undergoing a benchmark assessment at ICES WKFLAT in 2012, the following should be considered:

i) *Illicia* vs. otoliths. Considering the low levels of agreement between both CS (5–16%) it is not possible to use the age estimations of both *illicia* and otoliths together for stock assessment purposes.

ii) *Illicia*. Although the relative bias values (0.11) among the assessment readers can be considered good, the agreement values (49%) and precision (CV: 22%, APE: 16) suggest that they are not still sufficiently acceptable for building since now a valid ALK for stock assessment, using the readings of several readers. If the new age estimation criterion is validated in other geographical areas by cohorts tracking, and the agreement among readers is increased, then the age estimation using *illicia* could be used for stock assessment in future.

iii) Otoliths. The age estimation of white anglerfish, based on otoliths, is difficult, mainly due to the occurrence of confusing false annuli and to the increasing of opacity with age. The location of the first annulus is also a problem, even among expert readers, both in the last and present exchanges. There have been advances in daily growth studies that can help locate the first annulus more precisely. It is not possible to use otoliths of white anglerfish for stock assessment without a validated growth pattern and further research in that issue is needed.

WKFLAT 2012 WD02. Assessment of white anglerfish (*Lophius piscatorius*) from the Bay of Biscay and the Celtic Sea: A Pella-Tomlinson production model fitted by marginal likelihood to survey and commercial indices of abundance. R. H. Roa-Ureta and I. Quincoces.

An index of abundance based on the commercial catch by Basque trawlers was built using a generalized mixed linear model with the vessel as random effect and the Tweedie distribution for the catch data in number of fish boxes per fishing trip, over the period 2001 to 2010 and ICES Divisions VI-VII-VIII. The resulting index plus four survey indices (EVHOE, FPS, PGFS, WCGFS) spanning from 1984 to 2010 were used to fit a Pella-Tomlinson non-equilibrium surplus production model to the landings series. Two model fit scenarios produced similar results, showing a stock that is exploited under the MSY. Results are to be considered preliminary as some parameters, specifically the intrinsic rate of growth of the stock, tuned out to be too high (close to 1) when contrasted to current biological wisdom.

WKFLAT 2012 WD03. Maturity Estimates for Megrim and Monkfish in Division VII. Hans Gerritsen.

Ireland has collected maturity data since 2004. During the years 2004–2009 sampling was carried out on a spring groundfish survey. The spatial coverage of this survey varied between years (Figure 1). Since 2010, maturity sampling is mostly carried out on observer trips during the first quarter of the year. Maturity stages were assessed using a 7-stage maturity scale (Marine Institute, 2009) whereby stages 1–2 are considered immature while stages 3–7 are considered mature. Stages 3–7 are characterised by the appearance of vitellogenesis or hydrated cells or clear signs of recent spawning. Maturity-at-age estimates are similar to the maturity ogive used by WGHMM for the young ages but the Irish data suggest that full maturity is not reached until the age of 9. Mature female monkfish are rarely encountered on surveys. Even the oldest ages encountered have low proportions mature. Maturation appears to be mainly a function of length and that within length classes. Therefore, the use of a length-based maturity ogive might be more robust than an age-based ogive. L50 estimates are only provided for males as there were insufficient mature females in the samples.

WKFLAT 2012 WD04. Review and update information of A Coruña trawl fleet to be used as abundance index of white and black anglerfish southern stocks. J. Landa, J. Barrado and F. Velasco.

The age of white anglerfish (*Lophius piscatorius*) on the Porcupine Bank was estimated based on the age estimation of 991 *illicia* (first dorsal fin ray) obtained from a series of nine annual groundfish surveys (2001–2009). Modifications in the methodology of *illicia* preparation and in the traditional biased age estimation criterion are presented. This is the first time that a growth pattern of white anglerfish based on *illicia* age estimations can be indirectly validated by tracking cohorts, using the abundance indices per age class from surveys. Previous studies of cohort tracking using the traditional *illicia* age estimation criterion showed a mismatch, suggesting a faster growth. With the new proposed criteria, abundant cohorts from 2001 to 2004, and scarce ones, from 2005 to 2007, can be tracked over the time throughout several age groups. A new growth pattern and von Bertalanffy growth parameters are presented (L_{∞}: 161.00; k: 0.084; t_0: -1.035). The results are compared with previous studies in other areas.

WKFLAT 2012 WD05. Review and update information of A Coruña trawl fleet to be used as abundance index of white and black anglerfish southern stocks. R. Morlán, P. Sampedro and A. C. Fariña.

Historical data of the A Coruña Trawl Fleet, operating in ICES Division VIIIc, were compiled and updated from the IEO fishery database. The data refer to quarterly landings, effort and length composition of both anglerfish species. From 1982 to 1985 new data are presented and for the time period 1986–1993 the time-scale of the information was reduced from annual to quarter. Based on the available information the lpue is computed and can be used as abundance index in the assessment of these both stocks. Previous anglerfish stock assessments have used only the annual lpue of A Coruña Trawl Fleet for *L. piscatorius* assessment. This improved abundance index could be included in the configuration of upcoming stock assessments of both anglerfish stocks.

WKFLAT 2012 WD06. Modelling anglerfish discard behaviour in Spanish North Atlantic coast fisheries. J. Santos, N. Pérez.

On-board sorting process for anglerfish species in Spanish North Atlantic (ICES VIIIc, IXa) coastal fisheries is reviewed. The length effect analysis across the years sampled revealed an increasing trend in length of first retention (L50) since 2000, the year when Minimum Landing Weight (MLW 500g) were implemented. Specific differences in the length-based sorting process were found, being the less valuable white angler discarded at larger lengths than the black species; further, the analysis found that discard decision is taken at narrower length range for black angler. This results indicate that fishers recognize angler species even at low length sizes, conditioning the degree of adoption of MLW with regards to species relative market value.

WKFLAT 2012 WD07. Portuguese discard data on anglerfish *Lophius piscatorius* and blackbellied angler *Lophius budegassa* (2004–2010). A. C. Fernandes and N. Prista.

We compile the information available on the discards of anglerfish *Lophius piscatorius* and blackbellied angler *Lophius budegassa* produced by Portuguese vessels operating with bottom otter trawl fleet (OTB) in the Portuguese reaches of ICES Division IXa.

The data were collected under the Portuguese on-board sampling programme (EU DCR/NP) between 2004 and 2010. A brief description of the on-board sampling programme executed in 2004–2010 along with details on the estimation algorithms and data quality assurance procedures is presented. Then, results on species' annual frequency of occurrence, total discard estimates and length composition are provided for two bottom otter trawl fisheries: the crustacean fishery (OTB_CRU) and the demersal fish fishery (OTB_DEF). Discards of anglerfish and blackbellied angler by the OTB fleet are reduced but the low frequency of occurrence in number and weight in discard samples rules out estimates at fleet level. Preliminary information on discards of other Portuguese fleets operating in this geographical area is also provided.

WKFLAT 2012 WD08. Reproduction of white anglerfish (*Lophius piscatorius*) caught by the Spanish fleet in Northeastern Atlantic waters. J. Landa, A. Antolínez, B. Castro, M. Ámez, U. Autón, L. Cañás, P. Sampedro and A.C. Fariña.

The reproduction of white anglerfish (*Lophius piscatorius*) was studied from samples collected during five years, from January 2006 to December 2010, in Celtic Sea, West and South of Ireland (ICES Division VIIb–k) and Northern Spanish Atlantic waters (ICES Division VIIIc–IXa). A total of 3732 specimens (5–162 cm) were sampled. The sex ratio, the spawning period and the maturity ogives by length were studied. The sex ratio in both areas studied was close to 1:1 (male:female), 1:0.83 (45.30% of females) in ICES Division VIIb–k, and 1:0.89 (47.10% of females) in ICES Division VIIIc–IXa. The L50 values were: in ICES Division VIIb–k: 54.26 cm for combined sexes, 50.21 cm for males and 88.72 cm for females; in ICES Division VIIIc–IXa: 66.08 cm for combined sexes, 54.75 cm for males and 88.08 cm for females. These values of sex ratio and L50 are within the range given for this species in previous studies.

WKFLAT 2012 WD09. Sexual maturity of black anglerfish (*Lophius budegassa*) caught by the Spanish fleet in Northeastern Atlantic waters.. J. Landa, A. Antolínez, B. Castro, M. Ámez, J. Barrado, and C. Hernández.

The reproduction of black anglerfish (*Lophius budegassa*) was studied from samples collected during five years, from January 2006 to December 2010, in Celtic Sea, West and South of Ireland (ICES Division VIIb–k) and Northern Spanish Atlantic waters (ICES Division VIIIc–IXa). A total of 1167 specimens (4–99 cm) were sampled. The sex ratio, the spawning period and the maturity ogives by length were studied. The sex ratio in both areas studied was close to 1:1 (male:female), 1:1.22 (54.90% of females) in ICES Division VIIb–k, and 1:1.01 (50.30% of females) in ICES Division VIIIc–IXa. The L50 values were: in ICES Division VIIb–k: 52.42 cm for combined sexes, 36.77 cm for males and 62.45 cm for females; in ICES Division VIIIc–IXa: 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.

WKFLAT 2012 WD10. Sexual maturity of megrim (*Lepidorhombus whiffiagonis*) caught by the Spanish fleet in ICES Subarea VII. Jorge Landa, Jorge Fontenla, Antonio Gómez.

The reproduction of megrim (*Lepidorhombus whiffiagonis*) was studied from samples collected during eleven years (2000–2010), in Celtic Sea, West and South of Ireland (ICES Subarea VII). A total of 19 824 specimens (6–64 cm) were sampled. The sex ratio and the maturity ogive by length and age were studied. The sex ratio was 1:3.07 (75.40% of females). The L50 values are 22.93 cm for combined sexes (n: 2459), 26.73

cm for males (n: 382) and 20.86 cm for females (n: 2074). These values of sex ratio and L50 are within the range given for this species in previous studies.

WKFLAT 2012 WD11. Irish megrim (*Lepidorhombus whiffiagonis*, Walbaum) discards in VIIb–k. Evaluation of raising methods and derivation of a revised series. Hans Gerritsen and Colm Lordan.

The Irish demersal otter trawl fleet is the dominant Irish fleet catching megrim (81% of landings during 2003–2010). The Irish otter trawl fleet operates in a complex multispecies multi-gear fishery, spanning a wide geographic area, and involving around 275 trawlers (Davie and Lordan, 2011). Historically Irish Megrim discard estimates provided to WGHMM have been raised using total landings of all species on each trip as the auxiliary variable (after equation 7 Borges *et al*., 2005). This study was initiated to simultaneously explore several options and find the most appropriate auxiliary variable and stratification for megrim discards in this fleet. The objective was to explore precision and accuracy considerations given the fairly variable underlying observational data. Discarding was dominated by smaller fish; 95% of the fish discarded by number were in the length range 13–28 cm. The minimum landings size for megrim is 20 cm and ~69% of the fish discarded were above this MLS most of those were in the 20–28 cm length categories. The CV estimates are in the rage of 15–30% mainly with an average around 25%. There is no obvious difference between the various raising procedures. As there is no substitute for improved levels of discard sampling, integrating the spatial variability in discarding patter could be investigated in future to explain some of the year effects observed.

WKFLAT 2012 WD12. Irish Landings Tuning Fleets. Hans Gerritsen.

Irish Megrim landings are mainly taken in VIIg, followed by VIIj. There are a number of *métiers* that land megrim: OTB targeting demersal fish using a variety of mesh sizes, TBB with mesh size 80–89 mm and to a lesser extent OTB targeting crustaceans (*Nephrops*) and TBB with mesh size 90–99 mm (but not in recent years). The beam trawl grounds cover a relatively small part of the stock which is distributed throughout Divisions VII and VIII from around 100 m to 700 m depth. The main mesh size used in the TBB fleet during the time-series is 80–89 mm. From 2002 to 2006 larger meshes were also used but these have are no longer commonly in use. Therefore the following analysis is limited to TBB with mesh sizes of 80–89 mm only. Effort of the TBB 80–90 mm fleet is highest in the centre of Division VIIg, spilling over into the surrounding divisions. Lpue is generally highest towards the southwest and lowest in the northeast. GLMs were fitted with lpue (per vessel per day) as the response variable and year, vessel, month, ICES rectangle and beam length as explanatory variables (beam length was fitted as a continuous variable; all others were fitted as categorical variables). After investigation, it was acceptable to use the index without standardisation. The lpue appears to be robust against changes in the fleet and although it only covers a marginal area of the stock, it is likely to reflect stock abundance in Division VIIg.

WKFLAT 2012 WD13. Analysis of the Vigo-Marin bottom-trawl fleet operating in ICES Division VII for possible standardization. Esther Abad, Carmen Fernández, Paz Sampedro, Nélida Pérez, Baltasar Patiño.

In order to consider the possible standardization of the cpue of the Vigo-Marín trawl fleet operating in ICES Division VII for its potential use as an abundance index for the assessments of the stocks of megrim (*Lepidorhombus whiffiagonis*) and anglerfish (*Lophius piscatorius* and *L. budegassa*) in ICES Divisions VIIb–k and VIIIabd, a series of preliminary analyses were conducted on data collected on both landings and discards historic time-series. This document complements the work conducted in Fernández *et al*. (2008). Updated information through to 2010 is now available, which is taken into consideration. At the same time, the present document considers the main species caught by this fleet (*L. whiffiagonis, L. boscii, L. budegassa, L. piscatorius, Merluccius merluccius* and *Nephrops norvegicus*) in order to try to ascertain whether possible changes in the directionality of the fleet may have occurred over time. There does not seem to be a clear change in species composition through the time-series analysed (1986–2010) but an increase in cpue for most species could be observed in approximately the last decade. Qualitative information from the fishing industry confirms that cpues have increased in the last decade and notes the fact that this fleet was substantially renovated during the 1990s, which may well have led to an increase in its efficiency. For megrim (*L. whiffiagonis*), the information examined by Fernández *et al*. (2008) and further extensions considered in this work suggests that the strong increase in cpue from 1999 onwards is more likely due to the technological improvement mentioned above rather than to a strong increase in stock abundance. Thus, the recommendation made by Fernández *et al*. (2008) that if this cpue series were to be used for tuning the megrim assessment, it should better be split in two periods, one covering from 1984 to 1998 and another one from 1999 onwards, still seems appropriate.

WKFLAT 2012 WD14. Methodology employed by Ireland to split commercial landings between *Lophius piscatorius* and *Lophius budegassa* for generation of annual and species-specific landings-at-age. N. Graham and A. Campbell.

The two anglerfish species (*Lophius piscatorius* and *Lophius budegassa)* are assessed by ICES as two separate stocks. However, the two species are managed by a common TAC and as such commercial landings are not differentiated by species. In order generate species disaggregated catch numbers-at-age, it is necessary to use data from the national sampling programme where both species are separated. For the period 2002 to 2010, 75 149 number of *L. piscatorius* and 19 860 number of *L. budegassa* were sampled for length, while a subset of these, representing 9328 and 3180 individual *L. piscatorius* and *L. budegassa* respectively were also sampled for weight and age. A weight–length relationship derived from the aged samples and applied to the measured (length) only samples to derive the species-specific weights from the individual sample. An annual single split estimate is then obtained by estimating the mean across all samples for a given year. To provide annual precision estimates, the sample data are bootstrapped with replacement. The results show that ~80% of Irish landings are associated with *L. piscatorius.* There is evidence that the proportion has decreased slightly from 2006. Bootstrapped estimates indicate that the confidence bounds on the annual estimates are relatively narrow.

WKFLAT 2012 WD15. Application of a Bayesian statistical catch-at-age model to the Northern stock of Megrim. Dorleta García, Carmen Fernández, Marina Santurtún and Esther Abad.

A Bayesian statistical catch-at-age model was applied to the Northern Megrim stock (Divisions VIIb,c,e–k and VIIIa,b,d) data from 1984 to 2010. The model allowed using data at different aggregation levels in different years and also missing data. The Megrim data had three differentiated periods depending on their availability and aggregation level. In the model the data, all expressed as numbers-at-age, were used in the following form: from 1984 to 1989 total international catch, from 1990 to 1998 total international landings and discards, from 1999 to 2010 total international landings, Spanish and Irish discards and, lastly, from 2000 to 2010 UK discards. In this last period, discards from France, Belgium and Northern Ireland were not available. Since the landings from the last two nations were small, the missing discards are expected to correspond mainly to France. Before 1999 indirect information about discards of these nations was available through total international catch and total international discards, but from 1999 onward there was not any information. In order for the model to be able to deal with this lack of data, it was necessary to make an assumption about the dynamics of the missing discards. Several model configurations, in terms of model structure and priors, were tried. Finally a configuration which fitted properly to the data and was robust to several assumptions was found. However, aside from the missing discard data in the last period, patterns in the data were detected during the model fitting process that cast doubt on the quality of the data. This led the benchmark workshop group to reject the absolute values of the assessment model results, accepting them only as indicative of stock trends.

WKFLAT 2012 WD16. Detailing trends in UK(E+W) sampling, landings and effort of sole in Division VIIe. I. Holmes.

The working document examines that spatial and temporal differences in the length and age composition of the UK fleets catching sole in Division VIIe and investigates the methodology used to raise landings to the catch-at-age. The study considers four fleets consisting of two gears (beam trawl and all other gears) from two port groups (the west (Newlyn-Penzance) and the east (Plymouth-Brixham and Looe).

Around 75% of the landings come from the eastern ports and around 80% of landings being accounted for by the beam trawl fleet. Sampled length measurements reflect the proportion of ports reasonably, but the beam trawl fleet is under sampled in relation to the proportion of its landing and only about 50% of samples come from this gear.

Quarterly raised length distributions for these fleets indicate that about 75% of the catch-at-length comes from the eastern beam trawl fleet, the western beam trawl fleet and the eastern all bar beam trawl fleets take about 10% each and the western all bar beam trawl fleet catch only about 5% in number.

Prior to 2010 there was a small but significant difference in the length distributions taken by these fleets, with the eastern fleets taking a larger proportion of smaller sole compared to the western fleet. In 2010 this distinction has diminished and the length composition of the fleets is much more comparable.

Age composition by fleet using a single ALK combined over ports and gears (as currently processed for the WG) suggests that in 2008 and 2009 age compositions still differed between east and west, but that this difference has disappeared in 2010. A comparison with the catch-at-age raised by port-based ALK shows that although the length information has become much more similar the differences in the age distribution persist with the western fleet continuing to take a larger proportion of younger sole. Even with this more appropriate methodology the increase in mean age in the eastern fleet in 2010 compared to 2008-9 remains apparent.

Future work should focus on determining if sampling levels are appropriate to derived port based ALKs without greatly increasing the variance. However with the upcoming changes in the EU data collection (2011 data) regulations it seemed unwise to make these changes to the raising procedure at this juncture.

WKFLAT 2012 WD17. The Quarter 1 South West Beam Trawl Survey (Q1SWBeam), a first look at a new stratified random survey designed developed by Cefas to monitor flatfish populations in the western channel while providing data in support of the ecosystem approach to fisheries management. S. Kupschus.

The key element of the survey design, the appropriate designation of strata is examined through multivariate analysis indicating that the choice of strata based on fisheries information is overall appropriate. Current boundaries of strata are based in part on sediment information interpolated from large-scale sampling and the data suggests that there may be more appropriate ways to develop the stratum boundaries. However the species composition represents gradients with various rates of change, rather than discrete groupings, so that strata will always be less than homogenous. It would be useful to investigate whether there is now sufficient information to develop new stratum boundaries and determine if post-stratification is possible given the allocation of effort on the basis of the original strata.

For sole in Division VIIe this new survey provides an important new source of fisheries-independent information. In contrast to the other surveys conducted this survey covers the entirety of the management area and some surrounding area considered important in assessing stocks where mixing is likely to be less than complete. Over the period 2006–2012 68% of stations yielded sole, varying from 61% in 2011 to 77% in 2008, while stratum 10 and 12 on the French coast consistently yielded the lowest occurrences.

The total catch standardized to a 2 mile tow / sample has been 1530 sole (average 220 per year), and over 13% of these fish are 10 or older, with around 3.5% greater than age 15. The consistency and evenness with which these older ages are caught becomes apparent in the index information and cohort tracking for ages 4–13 is particularly coherent. This is the fisheries independent information that has been lacking in the assessment with the other surveys providing mainly information up to age 6. In future assessments there is thus likely to be much less reliance on the lpue information from the fishery for which it seems constant selectivity over longer periods of time is an in appropriate assumption.

A GLM analysis for the catch in numbers suggests that the stratum variable explains around one quarter of the total variability, with the significant year effect only contributing a further 1 percent, with year and stratum effects are largely orthogonal as expected. It is concluded therefore that the distribution of the species has remained similar and that abundance of the stock has remained relatively stable.

WKFLAT 2012 WD18. Discards estimates of UK Beam trawlers fleet in Division VIIe. S. Kupschus.

The working document examined the available discard information for UK beam trawlers from the western approaches and channel (Division VIIe–VIIk) which has been collated under the DCR and DCF since 2002. Historically discarding of this valuable stock has been low 4–8% by number, and very low by weight (about 1%) as highgrading was virtually absent from the fleet. However, in November 2009 the UK introduced a single area licence to ensure area misreporting which was known to occur could be controlled and effective management introduced to the fishery. Discard data collected in 2009 and 2010 as part of the UK funded 50% project suggested the discard rate was substantially higher, in that period close to 35%, prompting a review of the discard data.

The spatial comparison of the location of the discard data with that from the VMS data suggested the whole area of the fishery was well covered in the division VIIe over the entire period, though this does not discount the possibility that in some years discard sampling may not have been disproportionate to effort in some areas. The species composition identifies two spatially distinct beam trawl fleets. One mostly pursuing sole and place and the associated mixed fishery in the east, the other exploiting monk and megrim and linked species in the western approaches.

Catch composition data indicates spatial conservatism of the distribution of species communities, with changes in community greater between areas, than between years suggesting that generally there has been little change in the ecosystem/fishery as observed by the discard programme. The spatial scale of community variation is smaller than the spatial scale of the rectangle, suggesting that raising discards in general could potentially show high variance and even bias if the spatial distribution of landings within a rectangle differs from that sampled by the discard programme. The retained portion of the catch in the discard data exhibits the same spatial trends so that retained catch at the level of the haul can be used to describe the total catch.

Unfortunately landings data are aggregated at the trip level and there is evidence of significant loss of spatial precision by use of aggregated data so that landings are more difficult to ascribe to an appropriate catch/discard composition. Further effort should be expended into deriving more appropriate discard estimates for this fishery in general, but for this assessment discarding is unlikely to have significant impact on the estimation of stock dynamics as an analysis of the discard data confirmed that discarding has remained in the region of 4–8% by numbers and 1% by weight despite claims to the contrary. The values seen as appropriate to this fishery on the basis of this study are inconsistent (higher) than the rates extracted from the official STECF database.

WKFLAT 2012 WD19. A description of the UK vessel monitoring system (VMS) data for towed gear in the Celtic sea and western approaches and a look at the obvious spatial and temporal trends. S. Kupschus.

The WD examined the UK VMS data for towed gears, separated into beam trawlers and otter trawlers. Otter trawl information was very sparse, due to the small number of boats using this gear that have so far been required to carry VMS data since most of the UK fleet is below the minimum size required to carry the equipment. Beam trawl data were much more abundant and spatially informative due to the large number of boats contributing to the data.

Three more or less distinct areas of beam trawling activity could be identified, one north of Land’s End (North), the other two south of Land’s End and split east–west at around a longitude of 5 deg W (East and West). These grouping also matched up well with the areas of the different fisheries identified from species compositional data from discard sampling.

There appears to be little change in the spatial extent of these fisheries over time, however the distribution of relative effort within the extent has changed quite dramatically in 2010 in the East, with the focal point in effort shifting south. The trend though not as dramatic as in 2010 is apparent since the beginning of the time-series.

In the north there is a distinct seasonal component to the fishery, it starts in the first quarter close to the shore, moving offshore subsequently. In recent years the management changes in the area closure for cod are apparent in the data, but aside from this there appears to be little change between years. There appears to be a random component in the distribution in effort between years in the West. Peak effort within a year moves around between years, but there appears to be no overall trend in the direction of this movement unlike in the East.

WKFLAT 2012 WD20. FSP Western Channel sole and plaice 2010. R. Bush, J. Ashworth and M. Evans.

During September and October 2010, the beam trawler *Carhelmar* carried out the seventh in a series of FSP surveys of Western Channel sole and plaice. Similar FSP surveys were carried out during the months August–October of 2003–2009. The surveys are aimed at showing trends in distribution, abundance and age composition of sole and plaice, and providing information on bycatch species.

The survey design followed that of the 2009 survey carried out by *Carhelmar.* This trawler that deploys 2 × 4 m beams surveyed both the western and eastern legs of the survey area. The survey differed from those of 2003–2007, because a larger beam trawler, fishing 2 x 12 m beams, was not made available for the eastern part of the survey thereafter. The western area has been surveyed with a 2 × 4 m beam trawler throughout 2003–2010. The survey covered exclusively 45 western and 45 eastern core stations, for which consistent data were available for all previous years.

The catch rates of Western Channel sole and as indexed by this survey saw a modest increase from last year. This may hint that the moderate, long-term decline over the period 2003–2007 in this stock may have ceased, and/or the stocks may be improving. However, catch rates of plaice would appear to be significantly higher than the previous year and would appear to in a similar area to that of the 2004 survey. However, a note of caution is needed before we can definitely say that the fishery has recovered to, say, the 2004 level. The catch rates of lemon sole, monkfish and megrim were all reasonably comparable with the 2009 survey, but there is one point of potential difference in that catches of megrim during the western leg were less than in 2009. Cod were encountered only scarcely, a total of 17 being caught, although the gear is not considered appropriate to catching cod and the survey not representative for monitoring that species.

As in previous surveys, the age distribution for sole was broad, with ages of fish >15 years recorded on both survey legs and one fish of 23 years recorded for the eastern leg. As usual, plaice age distribution was much narrower than that of sole, the oldest recorded being 12 years old from the western leg. The trends in sole spawning–stock biomass (SSB) from the FSP surveys show similarities with the recent, steadily declining or static trends shown by the ICES assessment (ICES, 2009, 2010). The story, however, is different for plaice stocks, which have shown a notable increase in SSB to a perceived level not seen since 2004. The sudden reduction of SSB in 2008 for both stocks was followed by higher estimates in 2009, but interpretation needs to be cautious owing to the poor weather conditions and survey delay during the 2008 FSP survey.

Annex 5: Data problems relevant to data collection programmes

Stock	Data Problem	How to be addressed in DCR	By who
Anglerfish (all stocks)	Uncertainty on stock definition. The current management units are not supported by the scientific evidence.	Information on the rate of movements between management areas is important. This could only be obtained through tagging programme. A study programme on anglerfish tagging should be established. To access stock movement rates within the ICES areas. This programme will also be relevant on age validation (see recommendation below).	The RCM-Atlantic and RCM-North Sea and Eastern Arctic to consider a tagging study proposal. Note: stock identity analysis should take into account the stock identity methods proposed by SIMWG
Anglerfish (all stocks)	Uncertainty in age estimation. The 2011 illicia and otoliths exchange showed low age reading precision on age readings based on illicia and otoliths.	Age validation studies are needed. A tagging programme using OTC chemical marker should be established to provide accurate growth information. Indirect age validation is also encouraging, such as daily increments, otoliths weight and / or shape analysis, length–frequency distribution, etc. The tagging study proposal would provide information on age estimation and stock identity.	The RCM-Atlantic and RCM-North Sea and Eastern Arctic to consider a tagging study proposal. A complementary indirect age validation project is also an option to consider.
Anglerfish (all stocks)	Sampling intensity. Currently the sampling intensity for anglerfish is not adequate due to the wide length range of anglerfishes.	The sampling intensity for all anglerfish stocks needs to increased in order to have a proper coverage of all length range of the species.	The RCM-Atlantic and RCM-North Sea and Eastern Arctic, to consider a recommendation to intensify the anglerfish sampling in the DCF National Programmes
Anglerfish (all stocks)	Uncertainty in spawning migratory behaviour	Different studies demonstrates that the sex ratio in the landings of both species shows a great change during the spawning period with an increased presence of males that would be due to a migratory behaviour of reproductive active females. This behaviour needs to be confirmed and measured in order to input it in the assessments models.	The RCM-Atlantic and RCM-North Sea and Eastern Arctic to consider a reproductive study proposal about the spawning season and the sex-ratio on the landings of both anglerfish species.

Stock	Data Problem	How to be addressed in DCR	By who
Anglerfish (all stocks)	Need for better discard estimates	The fractions of discarded anglerfishes (ones bellow 0.5 kg) are very valuable information for the incoming recruitment. If the data are not available for the assessment the only available information for recruitment comes from scientific surveys, impairing the assessment.	The RCM-Atlantic and RCM-North Sea and Eastern Arctic consider a request for better discard estimates under the DCF.
Megrim (Divisions VIIb,c, d-k and VIIIabd) discards sampling	France: No discard data (biomass, length distributions and age composition) is delivered to the WGHMM since 1998.	STRONG request to Member State to provide these data	France and ICES delegate & PGCCDBS, RCM-Atlantic
Megrim (Divisions VIIb,c, d-k and VIIIabd)	France: No update of cpues dataseries are provided to the group.	STRONG request to Member State to provide these data	France and ICES delegate & PGCCDBS
Sole in Division VIIIe	Recruitment migrations. A better knowledge of sole movements between Division VIIe and adjacent areas.	A tagging study should be established on the Division VIIe recruitment area for further evaluations of migration rates of recruits with adjacent areas.	The RCM-Atlantic and RCM-North Sea and Eastern Arctic to consider a tagging study proposal.

Annex 6: Stock Annexes

Anglerfish in Divisions VIIb–k and VIIIa,b,d

Stock	Anglerfish (*L. piscatorius and L. budegassa*) in Divisions VIIb–k and VIIIa,b,d
Working Group	WGHMM, Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim
Date	13 March 2012 (WKFLAT, 2012)
Revised by	Iñaki Quincoces, and Lisa Readdy

A. General

A.1. Stock definition

ICES assumes since the end of the 1970s three different stocks for assessment and management purposes: Anglerfish in Division IIa (Norwegian Sea), Division IIIa (Kattegat and Skagerrak), Subarea IV (North Sea), and Subarea VI (West of Scotland and Rockall) (*Lophius piscatorius* and *L. budegassa*); Anglerfish in Divisions VIIb–k and VIIIa,b,d (*L. piscatorius* and *L. budegassa*) and Anglerfish in Divisions VIIIc and IXa (*L. piscatorius* and *L. budegassa*). These stock definitions apply for both anglerfish species White anglerfish (*L. piscatorius*) and Black anglerfish (*L. budegassa*). In Divisions VIIb–k and VIIIa,b,d, the two species are assessed separately but advised as a single stock since the EU gives a unique TAC for both species.

A.2. Fishery

Anglerfish are an important component of mixed fisheries taking hake, megrim, sole, cod, plaice, and *Nephrops*. A trawl fishery by Spanish and French vessels developed in the Celtic Sea and Bay of Biscay in the 1970s, and overall annual landings may have attained 35 000–40 000 t by the early 1980s. Landings decreased between 1981 and 1993 and since 2000, landings show an increasing trend. France and Spain together still report more than 75% of the total landings of both species combined. The remainder is taken by the UK and Ireland (around 10% each) and Belgium (less than 5%). Otter trawls (the main gear used by French, Spanish, and Irish vessels) currently take about 80% of the total landings of *L. piscatorius*, while around 60% of UK landings are by beam trawlers and gillnetters. Over 95% of total international landings of *L. budegassa* are taken by otter trawlers. There has been an expansion of the French gillnet fishery since the early 1990s in the Celtic Sea and in the north of the Bay of Biscay, mainly by vessels landing in Spain and fishing in medium to deep waters. Otter trawling in medium and deep water in ICES Subarea VII appears to have declined, although the increasing use of twin trawls by French vessels may have increased significantly the overall efficiency of the French fleet.

A.3. Ecosystem aspects

Lophius piscatorius is a Northeastern Atlantic species, with a distribution area from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea). *Lophius budegassa* has a more southern distribution from the British islands and Ireland to Senegal (including the Mediterranean and the Black Sea). Though the Working Group assesses two different stocks for each species (VIIIc, IXa stock and VIIb–k, VIIIabd), the boundaries are not based on biological criteria. Recent studies were carried out in genetic and morphometric analysis (GESSAN, 2002; Duarte *et al*., 2004; Fariña *et al*., 2004).

The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m (Afonso-Dias and Hislop, 1996; Hislop *et al*., 2001; Quincoces *et al*., 2002). This particular spawning results in a highly clumped distribution of eggs and newly emerged larvae (Hislop *et al*., 2001) and favourable or unfavourable ecosystem conditions can therefore have important impacts on the recruitment.

B. Data

The particularity of the data gathering processes for anglerfish species is that, except in Spain, anglerfishes are sold without any species distinction. The overall catch per species is estimated from the species ratio observed in the biological sampling.

Biological sampling is carried out by the countries contributing most catches, but assumptions about species proportion have to be made for countries reporting raw tonnages for species combined. The amount of tonnage with no biological sampling for species composition has been much reduced since the early 2000s and in 2007 these represented less than 8% of the total *Lophius* landings. In some countries however, anglerfish are landed as tails only and conversion factors have to be used to estimate total length, which still may introduce errors.

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

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

B.1. Commercial catch

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

The derivation used to compute the landings by fishery units and by species is given in the following table.

Anglerfish in Divisions VIIb–k and VIIIa,b,d; Derivation of the historical length compositions, by fishery unit for *L. piscatorius* and *L. budegassa*, in Divisions VIIb–k and in VIIIa,b,d.

	Country/FU																			
Year	IR-FU04	IR-FU05	BE-FU06	EW-FU03	EW-FU04	EW-FU05	EW-FU06	EW-Other	FR-FU03 + FU13	FR-FU03	FR-FU04	FR-FU05	FR-FU08	FR-FU13	FR-FU09	FR-FU10	FR-FU14	FR-unallocated	SP-FU04	SP-FU14
1986	FR-FU04/Q, IR-FU04 annual tonnage/4	FR-FU05/Q, IR-FU04 annual tonnage/4	FR-FU04+SP-FU04/Q BE annual tonnage/4	?	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	FR-FU05/Q EW-FU05 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU06 annual tonnage/4	-	-		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1987	FR-FU04/Q, IR-FU04 annual tonnage/4	FR-FU05/Q, IR-FU04 annual tonnage/4	FR-FU04+SP-FU04/Q BE annual tonnage/4	?	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	FR-FU05/Q EW-FU05 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU06 annual tonnage/4	-	-		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1988	FR-FU04/Q, IR-FU04 annual tonnage/4	FR-FU05/Q, IR-FU04 annual tonnage/4	FR-FU04+SP-FU04/Q BE annual tonnage/4	?	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	FR-FU05/Q EW-FU05 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU06 annual tonnage/4	-	-		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1989	FR-FU04/Q, IR-FU04 annual tonnage/4	FR-FU05/Q, IR-FU04 annual tonnage/4	FR-FU04+SP-FU04/Q BE annual tonnage/4	?	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	FR-FU05/Q EW-FU05 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU06 quarterly tonnages	-	-		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1990	FR-FU04/Q, IR-FU04 annual tonnage/4	IR-FU05-annual LD	FR-FU04+SP-FU04/Q BE annual tonnage/4	?	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	FR-FU05/Q EW-FU05 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU06 quarterly tonnages	-	-		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q

Year	Country/FU																			
	IR-FU04	IR-FU05	BE-FU06	EW-FU03	EW-FU04	EW-FU05	EW-FU06	EW-Other	FR-FU03 + FU13	FR-FU03	FR-FU04	FR-FU05	FR-FU08	FR-FU13	FR-FU09	FR-FU10	FR-FU14	FR-unallocated	SP-FU04	SP-FU14
1991	IRL-FU04/Q	IRL-FU05/Q	FR-FU04+SP-FU04/Q BE annual tonnage/4	FR-FU03/Q, EW-FU03 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU04 annual tonnage/4	EW-FU05/Q	EW-FU06/Q	-	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1992	FR-FU04+SP-FU04/Q, IR-FU04 quarterly tonnages	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	FR-FU04+SP-FU04/Q BE annual tonnage/4	FR-FU03/Q, EW-FU03 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	-	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1993	FR-FU04+SP-FU04/Q, IR-FU04 quarterly tonnages	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	FR-FU04+SP-FU04/Q BE quarterly tonnages	FR-FU03/Q, EW-FU03 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	-	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1994	IRL-FU04/Q	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	FR-FU04+SP-FU04/Q BE quarterly tonnages	FR-FU03/Q, EW-FU03 annual tonnage/4	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	-	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
1995	FR-FU04+SP-FU04/Q, IR-FU04 quarterly tonnages	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	EW-FU06/Q/Q BE quarterly tonnages	EW-FU03	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	-	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	Total LDs raised to FR species split	SP-FU04/Q	SP-FU14/Q

	Country/FU																			
Year	IR-FU04	IR-FU05	BE-FU06	EW-FU03	EW-FU04	EW-FU05	EW-FU06	EW-Other	FR-FU03 + FU13	FR-FU03	FR-FU04	FR-FU05	FR-FU08	FR-FU13	FR-FU09	FR-FU10	FR-FU14	FR-unallocated	SP-FU04	SP-FU14
1996	IRL-FU04/Q	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	EW-FU06/Q/Q BE quarterly tonnages	FR-FU03 + EW-FU03 quarterly tonnages 95% allocated to piscatorius - all countries quarterly LDs raised to these tonnages	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03 + EW-FU03 quarterly tonnages 95% allocated to piscato-rius - all countries quarterly LDs raised to these tonnages		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	Total LDs raised to FR species split	SP-FU04/Q	SP-FU14/Q
1997	IRL-FU04/Q		EW-FU06/Q/Q BE quarterly tonnages	FR-FU03 + EW-FU03 quarterly tonnages 95% allocated to piscatorius - all countries quarterly LDs raised to these tonnages	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03 + EW-FU03 quarterly tonnages 95% allocated to piscato-rius - all countries quarterly LDs raised to these tonnages		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	Total LDs raised to FR species split	SP-FU04/Q	SP-FU14/Q
1998	IRL-FU04/Q	FR-FU05/Q+EW-FU05, IR-FU05 quarterly tonnages	EW-FU06/Q/Q BE quarterly tonnages	FR-FU03/Q, EW-FU03 quarterly tonnage	FR-FU04+SP-FU04/Q EW-FU04 quarterly tonnages	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	Total LDs raised to EW species split	SP-FU04/Q	SP-FU14/Q

	Country/FU																			
Year	**IR-FU04**	**IR-FU05**	**BE-FU06**	**EW-FU03**	**EW-FU04**	**EW-FU05**	**EW-FU06**	**EW-Other**	**FR-FU03 + FU13**	**FR-FU03**	**FR-FU04**	**FR-FU05**	**FR-FU08**	**FR-FU13**	**FR-FU09**	**FR-FU10**	**FR-FU14**	**FR-unallocated**	**SP-FU04**	**SP-FU14**
1999	Total LDs and species ratio used	Total LDs and species ratio used	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to FU04 tonnage, EW 2000 FU04 species ratio	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2000	Total LDs and species ratio used	Total LDs and species ratio used	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to FU04 tonnage, EW 2000 FU04 species ratio	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2001	Total LDs and species ratio used	Total LDs and species ratio used	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to FU04 tonnage, EW 2000 FU04 species ratio	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2002	Total LDs and species ratio used	Total LDs and species ratio used	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to EW-FU04 quarterly tonnages per species	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q

	Country/FU																			
Year	**IR-FU04**	**IR-FU05**	**BE-FU06**	**EW-FU03**	**EW-FU04**	**EW-FU05**	**EW-FU06**	**EW-Other**	**FR-FU03 + FU13**	**FR-FU03**	**FR-FU04**	**FR-FU05**	**FR-FU08**	**FR-FU13**	**FR-FU09**	**FR-FU10**	**FR-FU14**	**FR-unallocated**	**SP-FU04**	**SP-FU14**
2003	Total LDs and species ratio used	Total LDs and species ratio used	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to EW-FU04 Q2 species split used for tonnage	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2004	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage, EW 2000 FU03 species ratio	FU05+FU06 LDs raised to EW-FU04 quarterly tonnages per species	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2005	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used except for Q2 (species ratio provided)	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2006	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used except for Q2 (species ratio provided)	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q

	Country/FU																			
Year	IR-FU04	IR-FU05	BE-FU06	EW-FU03	EW-FU04	EW-FU05	EW-FU06	EW-Other	FR-FU03 + FU13	FR-FU03	FR-FU04	FR-FU05	FR-FU08	FR-FU13	FR-FU09	FR-FU10	FR-FU14	FR-unallocated	SP-FU04	SP-FU14
2007	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2008	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	FR-FU03/Q		FR-FU04/Q	FR-FU05/Q	FR-FU08/Q		FR-FU09/Q	FR-FU10/Q	FR-FU14/Q	-	SP-FU04/Q	SP-FU14/Q
2009	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	-	FR-GNS_DEF_7/Q	FR-OTB_DEF_7/Q	-	FR-OTB_CRU_7/Q	FR-GNS_DEF_8/Q	FR-OTB_CRU_8/Q	-	FR-GNS_DEF_8/Q	-	SP-FU04/Q	SP-FU14/Q
2010	IRL-FU04+FU05/Q	IRL-FU04+FU05/Q	Total LDs and species ratio used	FU05+FU06 LDs raised to FU03 tonnage100 % L. piscatorius assumed	FU05+FU06 LDs raised to EW-FU04 2004 species ratio used	EW-FU05/Q	EW-FU06/Q	Total LDs raised to EW species split	-	FR-GNS_DEF_7/Q	FR-OTB_DEF_7/Q	-	FR-OTB_CRU_7/Q	FR-GNS_DEF_8/Q	FR-OTB_CRU_8/Q	-	FR-GNS_DEF_8/Q	-	SP-FU04/Q	SP-FU14/Q

Discards: **preliminary information is available but not used due to uncertainties in adequacy of raising methodologies used.**

B.2. Biological

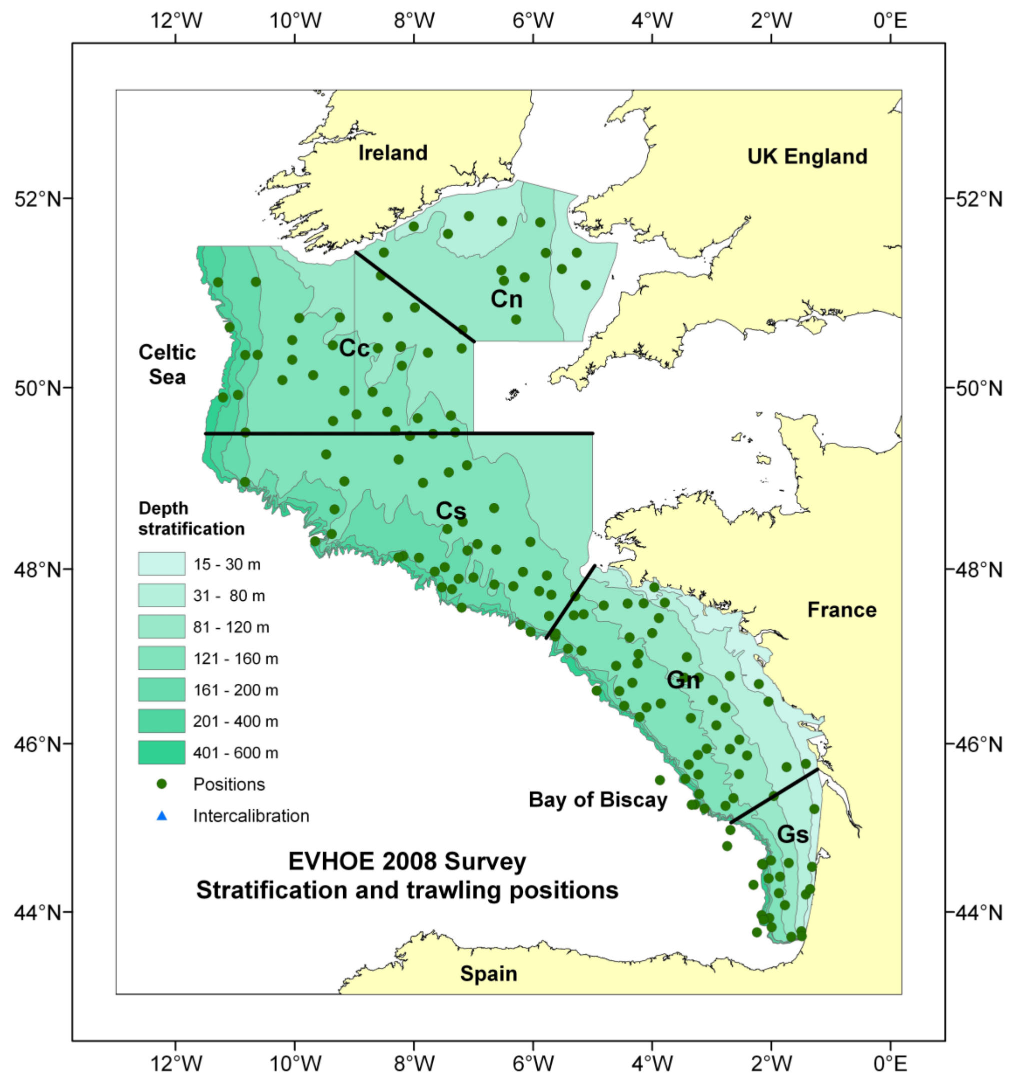
In 2007, WGHMM rejected the XSA age based assessments of both species because of data quality (increased discards not incorporated) and ageing problems clearly identified. Therefore there is no age based data used to assess the stocks. Only length distributions of landings and survey indices are used.

B.3. Surveys

For the first three surveys presented, a full description can be found on the ICES DATRAS website: http://datras.ices.dk/Home/Descriptions.aspx.

The French FR-EVHOE survey

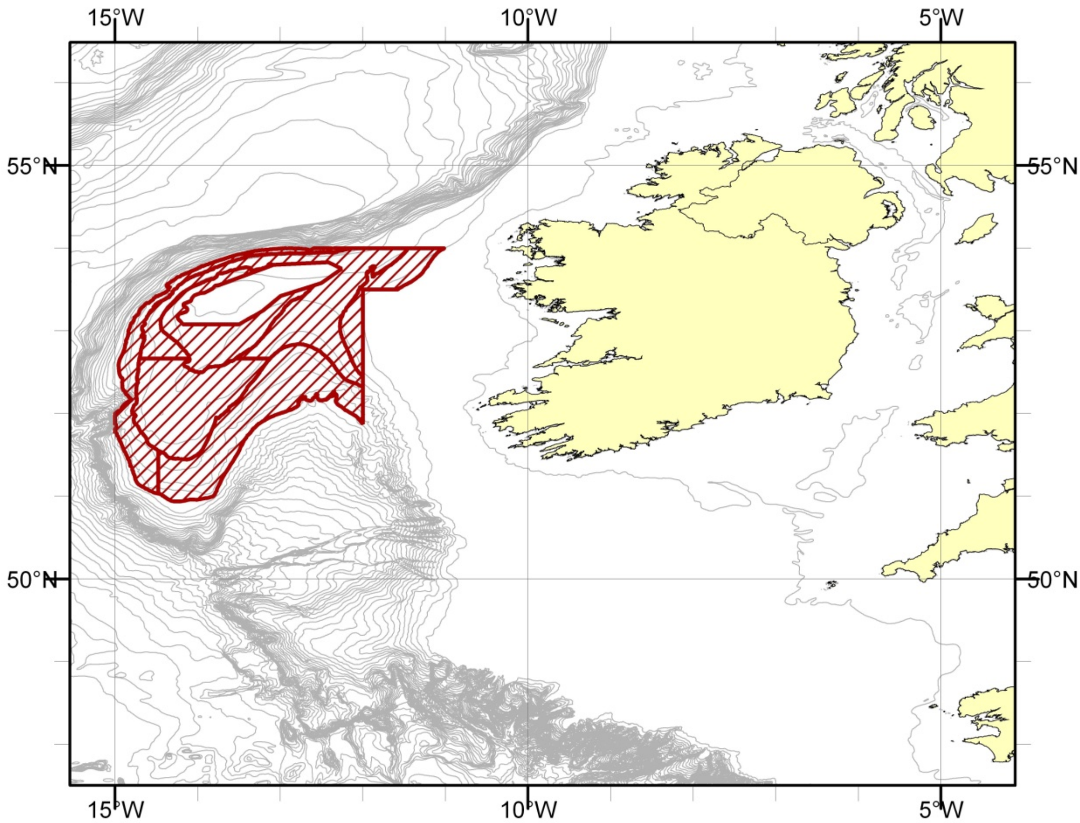
This survey covers the largest proportion of the area of stock distribution. It started in 1997.



Map of Survey Stations completed by the EVHOE Survey in 2008.

The Spanish Porcupine Groundfish Survey (SP-PGFS)

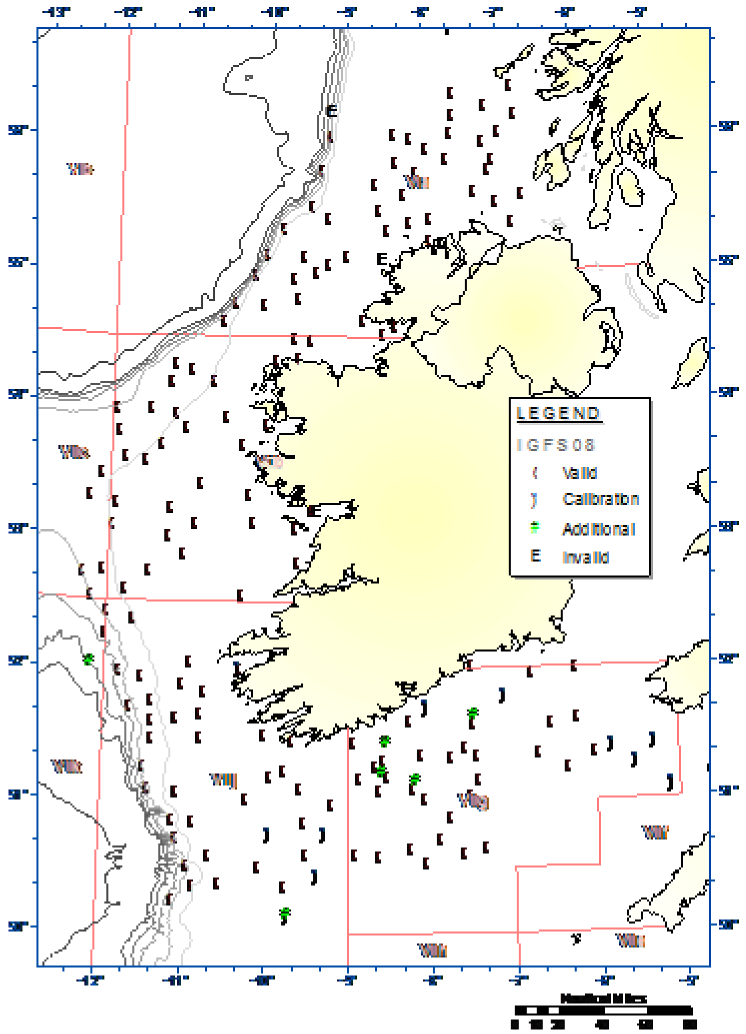
This survey was initiated in 2001 and covers the Porcupine Bank.



Map of area covered by the Porcupine Groundfish Survey.

The Irish Groundfish Survey (IR-IGFS)

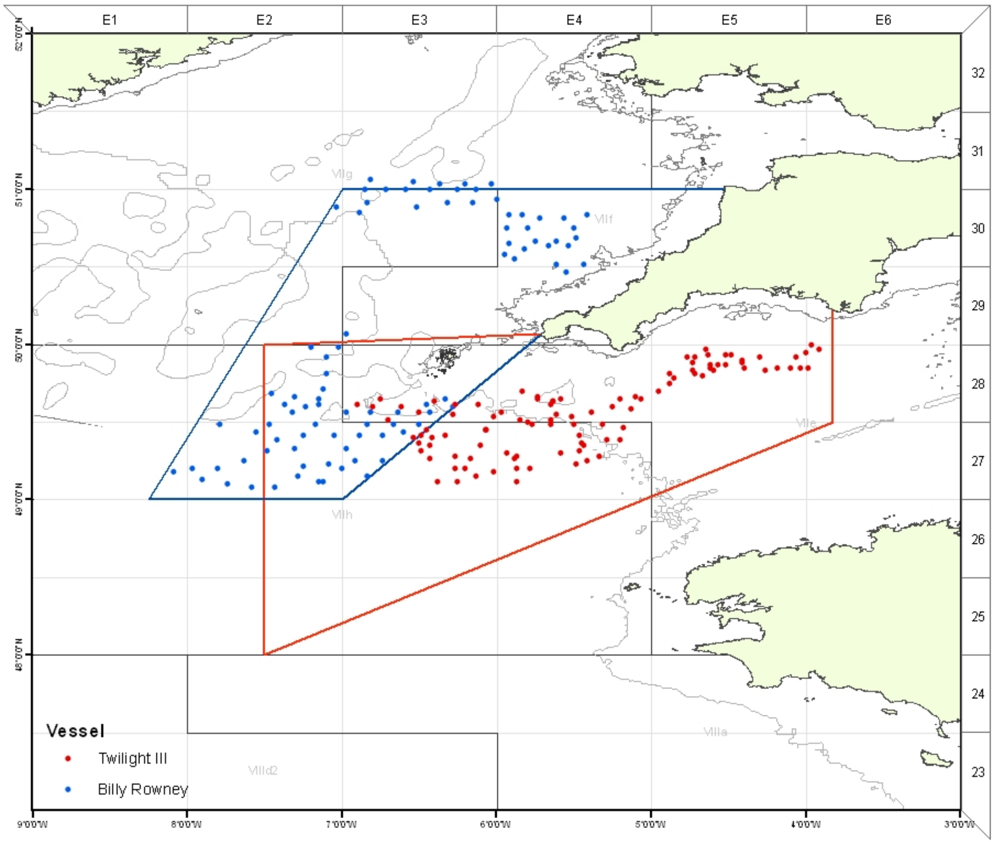
This survey was initiated in 2003 and covers areas around Ireland.



Map of Survey Stations completed by the Irish Groundfish Survey in 2008. Valid = red circles; Invalid = crosses; Intercalibration = blue squares; intercalibration and additional stations not valid for IBTS survey indices = green triangles.

The English Fisheries Science Partnership survey

This survey traverses Areas VIIe–h and started in 2003.



Map of Survey Stations completed by the EW-FSP Survey in 2011.

A full description of the survey can be found in Section 2.2.12 of the WGHMM 2011 report.

B.4. Commercial cpue

Effort and lpue data are available for four Spanish trawl fleets (SP-VIGO7, SP-CORUTR7, SP-BAKON7 and SP_BAKON8). The French data for the FR-FU04 and FR-FU14 are also provided. Finally UK provides effort and lpue data for EW-FU06.

B.5. Other relevant data

C. Assessment: data and method

The assessments of the two species (WG 2011) are based on the analysis of lpues (SP-VIGO7 , SP-CORUTR7, SP-BAKON7, SP-BAKON8, FR-FU04, FR-FU14 and EW-FU06), surveys indices (FR-EVHOE since 1997, SP-PGFS since 2001, IR-IGFS since 2003 and the EW-FSP since 2003 and length distributions from landings and surveys.

D. Short-term projection

E. Medium-term projections

F. Long-term projections

G. Biological reference points

There are precautionary reference points defined for these stocks. However, considering the underestimation of growth that is now obvious for both species, the reference points from earlier assessments are no longer valid. Reference points will have to be redefined based on an approved analytical assessment.

H. Other issues

H.1. Historic development

The analytical assessment was rejected in 2007 and advice was based on analysis of lpues, length frequencies of landings and survey data. In 2008, no new advice was delivered as the information available was considered too weak to provide any advice. The advice given for 2008 was also applicable until 2011. The stocks were reviewed in 2012 by the WKFLAT 2012 not founding an acceptable method for providing analytical assessment and recommended to continue using the analysis of trends for providing non analytical assessment.

I. References

Afonso-Dias, I.P. and J.R.G. Hislop. 1996. The reproduction of anglerfish *Lophius piscatorius* Linnaeus from the northwest coast of Scotland. Journal of Fish Biology 49: 18–39.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

Gessan. 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the North Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

Hislop, J. R. G., Gallego, A., Heath, M. R., Kennedy, F.M., Reeves, S.A. and Wright., P.J. 2001. A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus, 1758) in northern British waters. ICES Journal of Marine Science 58: 70–86.

Quincoces, I., Santurtún, M. and Lucio, P. 1998. Biological aspects of white anglerfish (*Lophius piscatorius*) in the Bay of Biscay (ICES Division VIIIa, b,d), in 1996–1997. ICES Doc. CM 1998/O:48: 29 pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.

Southern white anglerfish (*Lophius piscatorius*) (Divisions VIIIc, IXa)

Stock	Southern white anglerfish (Divisions VIIIc, IXa)
Date	18/04/2012
Revised by	Paz Sampedro (WKFLAT2012)

A. General

A.1 Stock definition

The two species of anglerfish (the white, *Lophius piscatorius,* and the black, *L. budegassa*) are Northeastern Atlantic species; however black anglerfish has a more southerly distribution. White anglerfish is distributed from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea) and black anglerfish from the British Isles to Senegal (including the Mediterranean and the Black Sea). Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce, therefore the stock structure remains unclear. This lack of information is due to their particular spawning behaviour. Anglerfish eggs and larvae are rarely caught in scientific surveys.

ICES gives advice for the management of several anglerfish spp. stocks in European waters: one stock on the Northern Shelf area, that includes anglerfish from the Northern Shelf, Division IIIa, Subarea IV and Subarea VI, and Norwegian Sea, Division IIa, and the stocks on the Southern Shelf area, one in Divisions VIIb–k and VIIIa,b and d and the Southern stocks in Divisions VIIIc and IXa. The stock under this Annex is called Southern White Anglerfish and is defined as white anglerfish in Divisions VIIIc and IXa. The boundaries of anglerfish in Divisions VIIb–k and VIIIa,b and d and Southern Anglerfish stocks were established for management purposes and they are not based on biological or genetic evidences (GESSAN, 2002; Duarte *et al.*, 2004; Fariña *et al.*, 2004).

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.

A.2 Fishery

Anglerfish in ICES Divisions VIIIc and IXa is exploited by Spanish and Portuguese vessels, since 2000 the Spanish landings being more than 83% for both anglerfish total reported landings. International catches for these two stocks have increased since the beginning of the 1980s, until a maximum was reached in 1988 (10 021 t). They have decreased to 1801 t–1802 t in 2001–2002. In the 2003–2010 period the catches were between 2300 t and 4500 t. Both species are caught on the same grounds by the same fleets and are marked together.

White and black anglerfish are caught together by Spanish and Portuguese bottom trawlers and gillnet fisheries. Spanish and Portuguese bottom trawlers are mixed fisheries. The Spanish bottom-trawl fleet predominantly targets hake, megrim, Norway lobster and anglerfish. Since 2003 the alternative use of a trawl gear with High Vertical Opening (HVO) has taken place in higher proportion relative to previous years. This gear targets horse mackerel and mackerel with very few anglerfish catches. Since 2002, the Spanish landings were on average 61% from the trawl fleet and 39% from the gillnet fishery. The Spanish gillnet fishery can use different artisanal gears, but most catches come from "Rasco" that is a specific gear targeting anglerfish.

Anglerfish are caught by Portuguese fleets in trawl and artisanal mixed fisheries. Portuguese landings were on average, from 2002, 17% from trawlers and 83% from artisanal fisheries. The trawl fleet has two components, the trawl fleet targeting demersal fish and trawl fleet targeting crustaceans. Since 2005, Portuguese combined species landings were TAC constrained and very low landings were registered during the 4th quarter since then.

Discarding in white anglerfish is considered low for the trawl fishery, based on estimated data for Spanish trawl fleet (ICES, 2011) and information from Portuguese trawl fleet (ICES, 2012).

Each year, the European Union sets a combined TAC and quota for white and black anglerfish. 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.

A.3 Ecosystem aspects

White anglerfish is a benthic species that occur on muddy to gravelly bottoms. It attains a maximum size of around 163 cm corresponding to a weight of approximately 51 kg. Historically white anglerfish has been considered a slow growing species, with a late maturation (Duarte *et al.*, 2001). Nevertheless, new evidences from mar-recapture experiments indicate that the anglerfish growth could be faster (Landa *et al.*, 2008).

The ovarian structure of anglerfish differs from most other teleosts. It consists of very long ribbons of a gelatinous matrix, within individual mature eggs floating in separate chambers (Afonso-Dias and Hislop, 1996). The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m and contain more than a million eggs (Afonso-Dias and Hislop, 1996; Hislop *et al.*, 2001; Quincoces, 2002). Eggs and larvae drift with ocean currents and juveniles settle on the seabed when they reach a length of 5–12 cm. This particular spawning leads to highly clumped distributions of eggs and newly emerged larvae (Hislop *et al.*, 2001) and favourable or unfavourable ecosystem conditions can therefore have major impacts on recruitment.

Due to their particular reproduction aspects (that shows a high parental investment in the offspring) the population dynamics of these species is expected to be highly sensitive to external biological/ecosystem factors.

Vertical displacements of immature and mature white anglerfish from the seabed to the near surface have been recorded in the Northeast Atlantic (Hislop *et al.*, 2001) and are suggested to be related to spawning or feeding.

Improvement of knowledge regarding growth, spawning behaviour, migratory behaviour and juvenile drift are essential to present and future assessment and management of both Southern Anglerfish stocks.

B. Data

B.1 Commercial catch

Landings data are provided by National Government and research institutions of Spain and Portugal. Quarterly landings by country, gear and ICES Division are available from 1978. There were unrecorded landings in Division VIIIc between 1978 and 1979, and it was not possible to obtain the total landings in those years. Portuguese landings were TAC constrained since 2005. Very low landings have been registered during the 4th quarters since then. The Portuguese landings were relatively stable during the first two years, but have decreased substantially from 2006 to 2010.

The two species are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the ports' statistics. Therefore, estimates of each species in Spanish landings from Divisions VIIIc and IXa and Portuguese landings of Division IXa are derived from their relative proportions in market samples.

For white anglerfish the maximum landing of the available series was recorded in 1986 at 6870 t. After that, a general decline to 788 t in 2001 was observed, reaching the minimum of the available series. From 2002 to 2005 landings increased reaching 3644 t. Since 2005 landings have slowly decreased to 1548 t in 2010.

Discards

Since 1994 a Spanish Discard Sampling Programme is being carried out for trawl fleets operating in the ICES Divisions VIIIc and IXa. However, the time-series is not complete and years with discard data are 1994, 1997, 1999, 2000 and from 2003 to 2009. The raising procedure used to estimate discards was based on effort. The Portuguese Discard Sampling Programme recorded anglerfish data from 2004. The frequency of occurrence of white anglerfish in discard samples is very low and its discard is considered negligible.

B.2 Biological

Landing numbers-at-length

Since 2009 the quarterly Spanish and Portuguese sampling for length compositions is by métier and ICES Division. Length data from sampled vessels are summed and the resulting length composition is applied to the quarterly landings of the corresponding métier and ICES Division. The sampled length compositions were raised for each country and SOP corrected to total landings on a quarterly or half yearly basis (when the sampling levels by quarter were low). The average lengths of trawl caught anglerfish are lower compared to the artisanal fleets.

Catch numbers-at-age

No catch numbers-at-age are provided to the Working Group. At the WGHMM 2007 meeting (ICES, 2007), age–length keys, based on *illicia* readings, were used to obtain catch number-at-age for each species. The exploratory analysis of estimates indicated that the biased age reading criterion does not allow following cohorts along years in either of the two species. The last research about white anglerfish ageing, *White Anglerfish Illicia and Otoliths Exchange 2011* (ICES, 2012), highlighted that neither *illicia* nor otolith age readings have been validated and, in the case of *illicia* studies, the agreement among readers and the precision were not acceptable. Therefore it was concluded that the available age reading criteria for white anglerfish southern stock is not valid to build an ALK.

Growth curve

The most recent study about white anglerfish growth in Atlantic integrates results for different growth researches (tag–recapture study, length–frequency of catches, and microstructure analysis of hard parts) (Landa *et al*., 2008). A von Bertalanffy growth curve fitted to all data provided the parameter values L*inf* = 140 cm and K = 0.11. This growth rate is faster than estimated recently using *illicia* for age estimation.

Maturity-at-length

Different estimates of maturity ogive based on macroscopic maturity staging are available for white anglerfish (Duarte *et al*., 2001; Landa *et al*., 2012). In these studies the difficulty of finding mature females in the field resulted in samplings with low coverage of mature individuals. Besides, the inadequacy in same instances of the macroscopic examination to determine maturity stage, let it to consider a maturity ogive of white anglerfish from other areas. The available study was carried out in ICES Divisions VIIIabd and determined microscopically the maturity stage (Quincoces, 2002). The parameters of maturity ogive are 50% maturity at 61.84 cm and a slope at 0.1001.

Natural mortality

No specific studies about natural mortality of white anglerfish were available. However, taking into consideration its growth rate and the high size that can attain, a constant annual instantaneous natural mortality rate (M) of 0.2 yr^{-1}, for all ages and years, is assumed.

Length-weight relationship

The weight at length relationship was calculated using data from an international project with a sampling that spatially covered a high proportion of the stock and which number of samples (BIOSDEF, 1998):

$$W = 2.70\times10^{-5}\cdot L^{2.839}$$

where W = weight in kilograms and L = length in centimetres.

B.3 Surveys

SpGFS-WIBTS-Q4

The Spanish Groundfish Survey aims to collect data on the distribution and relative abundance, and biological information of commercial fish in ICES Divisions VIIIc and Northern IXa. Since 1983 it is annually carried out in fourth quarter (September/October) of the years, except for 1987. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The full time-series of this survey is used in the assessment of white anglerfish since 2012.

PtGFS-WIBTS-Q4

Portuguese Autumn Groundfish Survey has been carried out in Portuguese continental waters since 1979 in the fourth quarter of the years. Abundance indices for both anglerfish species are available from 1989 to 2010. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

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

B.4 Commercial cpue

Six commercial series of landing-effort are available to the WG. Four of them are Spanish fleets in the ICES Division VIIIc and two Portuguese fleets in the ICES Division IXa. The Portuguese trawl fleet was split into fish trawlers and crustacean trawlers (WD12, Duarte *et al.*, 2007 in ICES, 2007) according to the fleet segmentation proposed by the IBERMIX project (WD06, Castro *et al.*, 2007 in ICES, 2007).

SP-CORTR8C

A Coruña trawl fleet fishing in Division VIIIc is available for years 1982–2010. Data provided for A Coruña trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 13% of international catches of white anglerfish along the time-series. A standardized series from 1994 to 2006 is also available for this fleet with annual effort data (in fishing days) and annual lpue.

Data from this commercial lpue series has been used in the white anglerfish assessment since 2007.

SP-CEDGNS8C

Cedeira gillnet fleet fishing in Division VIIIc is available for years 1999–2010. Data provided for Cedeira gillnets comprise quarterly standardized effort (in soaking days), landings and length composition of landings. This fleet represents an average of 10% of international catches of white anglerfish since 1999.

Data from this commercial lpue series has been used in the white anglerfish assessment since 2007.

Other available commercial series of lpues that have never been employed in the assessment are

PT-TRF9A

Portuguese trawlers targeting fish: years 1989–2010. 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% of international catches of white anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

PT-TRC9A

Portuguese trawlers targeting crustacean: years 1989–2010. 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% of international catches of white anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

SP-AVITR8C

Avilés trawl fleet fishing in Division VIIIc is available for years 1986–2003. Data provided for Avilés trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 6% of international catches of white anglerfish along the time-series. The effort-series was interrupted in 2003.

SP-SANTR8C

Santander trawl fleet fishing in Division VIIIc is available for years: years 1986–2010. Data provided for Santander trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 7% of international catches of white anglerfish along the time-series. Effort data for 2008 was not provided to the WG.

C. Assessment: data and method

Until 2011 white anglerfish stock was assessed with a non-equilibrium production model (ASPIC software). Results from growth studies provide a growth pattern for this stock allowing the application of a length-based assessment model. Stock Synthesis is was considered a suitable model to assess this stock by WKFLAT (ICES, 2012).

Model

Model used: Stock Synthesis 3 (SS3) (Methot, 2000)

Software used: Stock Synthesis v3.23b (Methot, 2011)

Stock Synthesis 3 (SS3) is an integrated assessment model. SS3 has been used for stock assessment all around the world. The area of highest used is on the US Pacific Coast. SS3 is coded in C++ using Auto-Differentiation Model Builder (http://www.admb-project.org) and available from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/SS3.html). SS3 has three main characteristics that differentiate it from classical assessment models:

- SS model structure allows for building of simple to complex models depending upon the data available. It is capable to build models with age and/or length structure and spatial structure.
- It is capable to use different sources of information.
- All parameters have a set of controls to allow prior constraints, time-varying flexibility, and linkages to environmental data.

The overall SS3 model is subdivided into three submodels. The first submodel simulates the population dynamics, where the basic abundance, mortality and growth functions create a synthetic representation of the true population. The second submodel is the observation submodel. This contains the processes and filters designed to derive expected values for the various types of data. The last submodel is the statistical that quantifies the magnitude of the difference between observed and expected data and employs an algorithm to find the set of parameters that maximizes the goodness-of-fit.

The SS3 model developed for white anglerfish during the WKFLAT 2012 has been designed for a particular set of data and specifications. White anglerfish is harvested by four fleets, and two commercial lpue series and one fishery-independent survey provide information about relative abundance. No discard information is considered. Length composition data are available from both the fisheries and surveys. No age information is available for this stock.

Input data

Years: 1980–2010.

Model structure:

- Temporal unit: quarterly based data (landings, lpue and length–frequency) were used in SS3 calculations.
- Spatial structure: One area.
- Sex: Both sexes combined.

Fleet definition:

Four *fleets* were defined attending to the gear type and country:

- Spanish trawlers in ICES Division VIIIc-IXa (SPTR8C9A)
- Spanish artisanal in ICES Division VIIIc (SPART8C)
- Portuguese trawlers in ICES Division IXa (PTTR9A)
- Portuguese artisanal in ICES Division IXa (PTART9A)

Landed catches:

Quarterly landings entered the model as biomass (in weight) for the four fleets. Landings data for January 1980 to December 2010 were used to conduct the stock assessment of white anglerfish.

From 1980 to 1988 quarterly landings were estimated using the average proportion for the further five years (1989–1993) by fleet. In the case of SPART8C quarterly landings were estimated from 1980 to 1993 using the average proportion for the further five years (1994–1998).

Abundance indices:

- A Coruña trawlers (SPCORTR8C): Quarterly lpue in weight from 1982 to 2010. It is entered as four separate indices, one index per quarter.
- Cedeira gillnetters (SPCEDGN8C): Quarterly lpue in weight from 1999 to 2010. It is entered as four separate indices, one index per quarter.
- Spanish Groundfish Survey (SPGFS): Abundance index in numbers from 1983 to 2010, except for 1987.

Length composition of data:

The length bin was set by 2 cm, from 4 to 100 cm, by 10 cm from 100 to 160 cm and by 40 cm from 160 to 200 cm. Length composition for the four fishing fleets and the three abundance indices were used. The available length data and their disaggregated level differ among fleets:

Length composition of Fleets:

- SPTR8C9A: 1986–2010, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach available in SS3.
- SPART8C: 1986–2010, quarterly basis. From 1986 to 1994 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach available in SS3.
- PTTR9A: 1986–2010, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach presented in SS3.
- PTART9A: 1986–2010, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach present in SS3.

Length composition of Abundance Indices:

- SPCORTR8C: 1982–2010, quarterly basis. Gaps are presented in years 1982, 1984, 1985 and 1986.
- SPCEDGN8C: 1999–2010, quarterly basis.
- SPGFS: length composition for fourth quarter, from 1983–2010. 1987 length composition is missing.

Model assumptions and parameters

- Natural mortality: M=0.2 for all ages and years.
- Growth: von Bertalanffy function: K=0.11 fixed, L_{max} and mean length-at-age 0.75 are estimated.
- Maturity ogive: length-based logistic, L_{50}=61.84 and slope=-0.1001, constant over time.
- Weight-at-length: a=2.70×10-5 b=2.839, not estimated.
- Recruitment allocation in Quarter 3.
- Stock–recruitment relationship: Beverton–Holt model: steepness h=0.999, sigmaR=0.4, R0 estimated.
- Selectivity: For all fleets selectivity was only length-based and was modelled as a double normal function. Selectivity varies among fleets, but is assumed to be time-invariant.

D. Short-term projection

Model used: Stock Synthesis 3.

Software used: *ad hoc* R code.

Initial stock size: SS3 outputs in the last assessment year.

Natural mortality: Set to 0.2 for all ages in all years.

Growth model: von Bertalanffy function, with parameters estimated in the assessment model.

Maturity-at-length: The same ogive as in the assessment is used for all years.

Weight-at-length in the stock and in the catch: The same length–weight relationship as in the assessment model

Exploitation pattern: Average of the final three assessment years (with the possibility of scaling to final year F).

Intermediate year assumptions: *status quo* F.

Recruitment: geometric mean of estimated recruitment from 1980 until the final assessment year. If trends in recruitment become evident a shorter range of years could be selected.

E. Medium-term projections

No medium-term projections are conducted for white anglerfish stock.

F. Yield and biomass per recruit/long-term projections

None.

G. Biological reference points

The new assessment methodology developed for white anglerfish in WKFLAT 2012 provides the technical basis to set Biological Reference Points for this stock. Although F_{max}, $F_{0.1}$, $F_{35\%}$ and $F_{30\%}$ were estimated based on this methodology, a thorough analysis of these parameters should be done before setting a proxy of F_{MSY}.

H. Other issues

H.1 Historical development of assessment

Southern Anglerfish stocks were assessed for the first time in the 1990 ICES WG meeting. Different assessment trials were performed during the subsequent eight years but analytical assessments indicated unrealistic results. The database (both biological and fisheries data) were improved along these years trying to apply an analytical assessment model. Since 1998 a non-equilibrium surplus production model ASPIC (Prager, 1994) was applied to each stock or to the combined stock data. These stock assessments were accepted by the ACFM and used to provide management advice. The assessment of white anglerfish as a separate stock has been carried out continuously from 2007. The history of white anglerfish assessment from 2007 to 2011 is presented in Table 1.

Table 1. History of southern white anglerfish assessment from 2007 to 2011.

WG	2007	2008	2009	2010	2011
Assessment Model	Non-equilibrium Surplus production model (Prager, 1994a)	No updated	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)
Software	ASPIC (v. 5.16)	No updated	ASPIC (v. 5.16)	ASPIC (v. 5.34)	ASPIC (v. 5.34.9)
Catch data range	1980–2006		1980–2008	1980–2009	1980–2010
Cpue Series 1 (years)	SP-CORUTR8c (1986–2006)		SP-CORUTR8c (1986–2008)	SP-CORUTR8c (1986–2009)	SP-CORUTR8c (1986–2010)
Index of Biomass (years)	SP-CEDGNS8c (1999–2006)		SP-CEDGNS8c (1999–2008)	SP-CEDGNS8c (1999–2009)	SP-CEDGNS8c (1999–2010)
Error Type	Condition on yield		Condition on yield	Condition on yield	Condition on yield
Number of bootstrap	500		500	1000	1000
Maximum F	8.0 (y-1)		8.0 (y-1)	8.0 (y-1)	8.0 (y-1)
Statistical weight B1/K	1		1	1	1
Statistical weight for fisheries	1,1		1,1	1,1	1,1
B1-ratio (starting guess)	0.5		0.5	0.5	0.5
MSY (starting guess)	5000 t		5000 t	5000 t	5000 t
K (starting guess)	50 000 t		50 000 t	50 000 t	50 000 t
q1 (starting guess)	1d-5		1d-5	1d-5	1d-5
q2 (starting guess)	1d-6		1d-6	1d-6	1d-6
Estimated parameter	All		All	All	All
Min and Max allowable MSY	2000 (t) –10 000 (t)		2000 (t)–10 000 (t)	2000 (t)–11 500 (t)	2000 (t)–11 500 (t)

WG	2007	2008	2009	2010	2011
Min and Max K	5000 (t)–500 000 (t)		5000 (t)–100 000 (t)	5000 (t)–112 000 (t)	5000 (t) – 112 000 (t)
Random Number Seed	1 964 185		1 964 185	1 964 185	1 964 185

I. References

Afonso-Dias, I.P. and J.R.G. Hislop. 1996. The population of anglerfish (*Lophius piscatorius*) from the northwest coast of Scotland. J. Fish. Biol. 49 (Suppl A): 18–39.

BIOSDEF. 1998. Biological studies of demersal fish. Ref.: EU, DG XIV, Study Contract 95/038.

Castro, J., Cardador, F., Santurtún, M., Punzón, A., Quincoces, I., Silva, C., Duarte, R., Murta, A., Silva, L., Abad, E. and Marín, M. 2007. Proposal of fleet segmentation for the Spanish and Portuguese fleets operating in the Atlantic national waters. ICES CM 2007/ACFM: 21

Duarte, R., Azevedo, M., Landa, J. and Pereda, P. 2001. Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. Fisheries Research 51: 349–361.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Duarte, R., Sampedro, P., Landa, J. and Azevedo, M. 2007. Revision of available data (landings, effort, length frequency distributions and age–length keys) from 1996–2005 for an age-structured assessment of Southern anglerfish stocks. ICES CM 2007/ACFM: 21.

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

GESSAN. 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the North Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

Hislop, J.R.G., Holst, J.C., Skagen, D. 2001. Near–surface captures of post-juvenile anglerfish in the Northeast Atlantic- an unsolved mystery. Journal of Fish Biology 57: 1083–1087.

Hislop, J.R.G., A. Gallego, M.R. Heath, F.M. Kennedy, S.A. Reeves and Wright, P.J. 2001. A synthesis of the early life history of anglerfish, *Lophius piscatorius* (Linnaeus, 1756) in northern British waters. ICES Journal of Marine Science, 58: 70–86.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8–17 May 2007, Vigo, Spain. ICES CM 2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

ICES. 2012. Report of the Benchmark Workshop on Flatfish and Anglerfish (WKFLAT), 1–8 March 2012, Bilbao, Spain. ICES CM 2012/ACOM:47.

Landa, J., Antolínez, A., Castro, B., Ámez, M., Autón, U., Cañás, L., Sampedro, P., Fariña, A.C. 2012. Reproduction of white anglerfish (*Lophius piscatorius*) caught by the Spanish fleet in Northeastern Atlantic waters. Working Document in WKFLAT 2012.

Landa, J., Duarte, R. and I. Quincoces. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. ICES Journal of Marine Science, 65: 72–80.

ICES. 2012. Report of the Anglerfish (*Lophius piscatorius*) illicia and otoliths exchange 2011. 61pp.

Methot, R.D. 2000. Technical Description of the Stock Synthesis Assessment Program. National Marine Fisheries Service, Seattle, WA. NOAA Tech Memo. NMFS-NWFSC-43: 46 pp.

Methot, R.D. 2011. User Manual for Stock Synthesis, Model Version 3.23b. NOAA Fisheries Service, Seattle. 167 pp.

Prager, M.H. 1994. A suite of extension to a non-equilibrium surplus-production model. Fish. Bull. 92: 374–389.

Praguer, M.H. 2004. User's manual for ASPIC: a stock production model incorporating covariates (ver. 5) and auxiliary programs. NMFS Beaufort Laboratory Document BL-2004-01, 25pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.

Southern black anglerfish (*Lophius budegassa*) (Divisions VIIIc, IXa)

Stock	Southern black anglerfish (Divisions VIIIc, IXa)
Date	22/04/2012
Revised by	Ricardo Alpoim (WKFLAT2012)

A General

A.1 Stock definition

The two species of anglerfish (the white, *Lophius piscatorius,* and the black, *L. budegassa*) are Northeastern Atlantic species; however black anglerfish has a more southerly distribution. White anglerfish is distributed from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea) and black anglerfish from the British Isles to Senegal (including the Mediterranean and the Black Sea). Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce, therefore the stock structure remains unclear. This lack of information is due to their particular spawning behaviour. Anglerfish eggs and larvae are rarely caught in scientific surveys.

ICES gives advice for the management of several anglerfish spp. stocks in European waters: one stock on the Northern Shelf area, that includes anglerfish from the Northern Shelf, Division IIIa, Subarea IV and Subarea VI, and Norwegian Sea, Division IIa, and the stocks on the Southern Shelf area, one in Divisions VIIb–k and VIIIa,b and d and the Southern stocks in Divisions VIIIc and IXa. The stock under this Annex is called Southern Black Anglerfish and is defined as black anglerfish in Divisions VIIIc and IXa. The boundaries of anglerfish in Divisions VIIb–k and VIIIa,b and d and Southern Anglerfish stocks were established for management purposes and they are not based on biological or genetic evidences (GESSAN, 2002; Duarte *et al.*, 2004; Fariña *et al.*, 2004).

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.

A.2 Fishery

Anglerfish in ICES Divisions VIIIc and IXa are exploited by Spanish and Portuguese vessels, since 2000 the Spanish landings being more than 83% for both anglerfish total reported landings. International catches for this stock have increased since the beginning of the 1980s, until a maximum was reached in 1988 (10 021 t). They have decreased to 1801 t–1802 t in 2001–2002. In the 2003–2010 period the catches were between 2300 t and 4500 t. Both species are caught on the same grounds by the same fleets and are marked together.

White and black anglerfish are caught together by Spanish and Portuguese bottom trawlers and gillnet fisheries. Spanish and Portuguese bottom trawlers are mixed fisheries. The Spanish bottom-trawl fleet predominantly targets hake, megrim, Norway lobster and anglerfish. Since 2003 the alternative use of a trawl gear with High Vertical Opening (HVO) has taken place in higher proportion relative to previous years. This gear targets horse mackerel and mackerel with very few anglerfish catches. Since 2002, the Spanish landings were on average 61% from the trawl fleet and 39% from the gillnet fishery. The Spanish gillnet fishery can use different artisanal gears, but most catches come from "Rasco" that is a specific gear targeting anglerfish.

Anglerfish are caught by Portuguese fleets in trawl and artisanal mixed fisheries. Portuguese landings were on average, from 2002, 17% from trawlers and 83% from artisanal fisheries. The trawl fleet has two components, the trawl fleet targeting demersal fish and trawl fleet targeting crustaceans. Since 2005, Portuguese combined species landings were TAC constrained and very low landings were registered during the 4th quarter since then.

Discarding in black anglerfish is considered low for the trawl fishery, based on estimated data for Spanish trawl fleet (ICES, 2011) and information from Portuguese trawl fleet (ICES, 2012).

Each year, the European Union sets a combined TAC and quota for white and black anglerfish. 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.

A.3 Ecosystem aspects

Black anglerfish is a benthic species that occur on muddy to gravelly bottoms. It attains a maximum size of around 93 cm corresponding to a weight of approximately 12 kg. Historically black anglerfish has been considered a slow growing species, with a late maturation (Duarte *et al.*, 2001). Nevertheless, new evidences from mar-recapture experiments indicate that the anglerfish growth could be faster (Landa *et al.*, 2008).

The ovarian structure of anglerfish differs from most other teleosts. It consists of very long ribbons of a gelatinous matrix, within individual mature eggs floating in separate chambers (Afonso-Dias and Hislop, 1996). The spawning of the *Lophius* species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m and contain more than a million eggs (Afonso-Dias and Hislop, 1996; Hislop *et al.*, 2001; Quincoces, 2002). Eggs and larvae drift with ocean currents and juveniles settle on the seabed when they reach a length of 5–12 cm. This particular spawning leads to highly clumped distributions of eggs and newly emerged larvae (Hislop *et al.*, 2001) and favourable or unfavourable ecosystem conditions can therefore have major impacts on recruitment.

Due to their particular reproduction aspects (that shows a high parental investment in the offspring) the population dynamics of these species is expected to be highly sensitive to external biological/ecosystem factors.

Vertical displacements of immature and mature white anglerfish from the seabed to the near surface have been recorded in the Northeast Atlantic (Hislop *et al.*, 2001) and are suggested to be related to spawning or feeding.

Improvement of knowledge regarding growth, spawning behaviour, migratory behaviour and juvenile drift are essential to present and future assessment and management of both Southern Anglerfish stocks.

B. Data

B.1 Commercial catch

Landings data are provided by National Government and research institutions of Spain and Portugal. Quarterly landings by country, gear and ICES Division are available from 1978. There were unrecorded landings in Division VIIIc between 1978 and 1979, and it was not possible to obtain the total landings in those years. Portuguese landings were TAC constrained since 2005. Very low landings have been registered during the 4th quarters since then. The Portuguese landings were relatively stable during the first two years, but have decreased substantially from 2006 to 2010.

The two species are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the ports' statistics. Therefore, estimates of each species in Spanish landings from Divisions VIIIc and IXa and Portuguese landings of Division IXa are derived from their relative proportions in market samples.

After 1980, black anglerfish landings increased and reached a peak of 3832 t in 1987. Since then, landings decreased and reached a minimum in 2002 of 770 t. From 2002 to 2007 landings increased to 1301 t, decreasing thereafter to a new minimum in 2010 of 751 t.

Discards

Since 1994 a Spanish Discard Sampling Programme is being carried out for trawl fleets operating in the ICES Divisions VIIIc and IXa. However, the time-series is not complete and years with discard data are 1994, 1997, 1999, 2000 and from 2003 to 2009. The raising procedure used to estimate discards was based on effort. The Portuguese Discard Sampling Programme recorded anglerfish data from 2004. The frequency of occurrence of black anglerfish in discard samples is very low and their discard is considered negligible.

B.2 Biological

Landing numbers-at-length

Since 2009 the quarterly Spanish and Portuguese sampling for length compositions is by métier and ICES division. Length data from sampled vessels are summed and the resulting length composition is applied to the quarterly landings of the corresponding métier and ICES division. The sampled length compositions were raised for each country and SOP corrected to total landings on a quarterly or half yearly basis (when the sampling levels by quarter were low). The average lengths of trawl caught anglerfish are lower compared to the artisanal fleets.

Catch numbers-at-age

No catch numbers-at-age are provided to the Working Group. At the WGHMM 2007 meeting (ICES, 2007), age–length keys, based on *illicia* readings, were used to obtain catch number-at-age for each species. The exploratory analysis of estimates indicated that the biased age reading criterion does not allow following cohorts along years in either of the two species. The last research about white anglerfish ageing, *White Anglerfish Illicia and Otoliths Exchange 2011* (ICES, 2012), highlighted that neither *illicia* nor otolith age readings have been validated and, in the case of *illicia* studies, the agreement among readers and the precision were not acceptable. Therefore it was concluded that the available age reading criteria for white anglerfish southern stock is not valid to build an ALK.

Growth curve

An agreed growth model is not available for black anglerfish *in* Divisions VIIIc, IXa.

Maturity-at-length

Different estimates of maturity ogive at length are available for *Lophius bugegassa* (Duarte *et al*., 2001; Quincoces, 2002; Landa *et al*., 2012). The last study (Landa *et al*., 2012) indicates, for ICES Division VIIIc–IXa, 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.

Natural mortality

Trial assessment, in the past, of the black anglerfish stock used a natural mortality rate of 0.15 yr-1. This value was adopted for all ages and years in the absence of any direct estimates.

Length-weight relationship

The weight at length relationship was calculated using data from an international project with a sampling that spatially covered a high proportion of the stock and which number of samples (BIOSDEF, 1998):

$$W= 2.11\text{x}10^{-5}\cdot L^{2.9198}$$

where W = weight in kilograms and L = length in centimetres.

B.3 Surveys

SpGFS-WIBTS-Q4

The Spanish Groundfish Survey aims to collect data on the distribution and relative abundance, and biological information of commercial fish in ICES Divisions VIIIc and Northern IXa. Since 1983 it is annually carried out in fourth quarter (September/October) of the years, except for 1987. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species.

This survey is not used in the actual assessment of black anglerfish.

PtGFS-WIBTS-Q4

Portuguese Autumn Groundfish Survey has been carried out in Portuguese continental waters since 1979 in the fourth quarter of the years. Abundance indices for both anglerfish species are available from 1989 to 2010. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

This survey is not used in the actual assessment of black anglerfish.

PtGFS-WIBTS-Q1

Portuguese Winter Groundfish Survey has been carried out in Portuguese continental waters from 2005 till 2008 in the first quarter. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The abundance values detected by this survey are very low for the whole time-series.

This survey is not used in the actual assessment of black anglerfish.

PT CTS

Portuguese Crustacean Survey has been carried out in south of the Portuguese coast since 1997 in the second quarter. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. This survey detects better anglerfish (especially *L. budegassa*) but the area cover is very small compared with the anglerfish stocks distribution.

This survey is not used in the actual assessment of black anglerfish.

PtGFS (summer)

Portuguese Summer Groundfish Survey has been carried out in Portuguese continental waters from 1990 till 2001 (except 1994, 1996) in the third quarter. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

This survey is not used in the actual assessment of black anglerfish.

Portuguese deep-water fish survey

Portuguese deep-water fish Survey has been carried out in Portuguese continental waters from 1997 till 2002. No indices are available only raw data.

This survey is not used in the actual assessment of black anglerfish**.**

B.4 Commercial cpue

Six commercial series of landing-effort are available to the WG. Four of them are Spanish fleets in the ICES Division VIIIc and two Portuguese fleets in the ICES Division IXa. The Portuguese trawl fleet was split into fish trawlers and crustacean trawlers (WD12, Duarte *et al*., 2007 in ICES, 2007) according to the fleet segmentation proposed by the IBERMIX project (WD06, Castro *et al*., 2007 in ICES, 2007).

SP-CORTR8C

A Coruña trawl fleet fishing in Division VIIIc is available for years 1982–2010. Data provided for A Coruña trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 13% of international catches of black anglerfish along the time-series. A standardized series from 1994 to 2006 is also available for this fleet with annual effort data (in fishing days) and annual lpue.

It was agreed (WKFLAT 2012) to use the data from this commercial lpue series in the black anglerfish assessment.

SP-CEDGNS8C

Cedeira gillnet fleet fishing in Division VIIIc is available for years 1999–2010. Data provided for Cedeira gillnets comprise quarterly standardized effort (in soaking days), landings and length composition of landings. This fleet represents an average of 5% of international catches of black anglerfish since 1999.

Information from this commercial series is not used in the actual assessment of black anglerfish.

PT-TRF9A

Portuguese trawlers targeting fish: years 1989–2010. 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 3% of international catches of black anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

Data from this commercial lpue has been used in the black anglerfish assessment since 2007.

PT-TRC9A

Portuguese trawlers targeting crustacean: years 1989–2010. 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 3% of international catches of black anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

Data from this commercial lpue has been used in the black anglerfish assessment since 2007.

Other available commercial series of lpues that have never been employed in the assessment are

SP-AVITR8C

Avilés trawl fleet fishing in Division VIIIc is available for years 1986–2003. Data provided for Avilés trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average 3% of international catches of black anglerfish along the time-series. The effort series was interrupted in 2003.

SP-SANTR8C

Santander trawl fleet fishing in Division VIIIc is available for years: years 1986–2010. Data provided for Santander trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 3% of international catches of black anglerfish along the time-series. Effort data for 2008 was not provided to the WG.

C. Assessment methods and settings

Until 2011 black anglerfish stock was assessed with a non-equilibrium production model (ASPIC software).

A revised series from the Spanish fleet 'A Coruña' was available at WKFLAT 2012, historical survey-series data, discard data and other commercial lpue series. The 'A Coruña' series is the longest of the potential tuning-series and represents the bulk of the fishery and it was concluded that this series should be included in the modelling. At WKFLAT 2012 three potential models were applied to the data: a Bayesian surplus production model, SS3, and numerous formulations of ASPIC. The SS3 showed promise but it was determined that more exploration would be required before the model could be accepted as the basis for advice. A new formulation of ASPIC which included three tuning indices (A Coruña, Portuguese Trawler fleet directing to crustaceans, Portuguese Trawler fleet directing to groundfish) was presented which tracks the central trend in the indices and is more stable than previous assessment. This was accepted as the basis for advice.

Model, input data and settings

Assessment Model: Non-equilibrium Surplus production model (Prager, 1994; 2004)

Software: ASPIC (v. 5.34.9)

Stock: black anglerfish (*L.budegassa*)

Catch data range: 1980–2010

Cpue Series 1 (years): PT-TRC9a (1989–2010)

Cpue Series 2 (years): PT-TRF9a (1989–2010)

Index of Biomass (years): SPCORTR8c (1982–2010)

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: 1 025 957

D. Short-term projection

Model: ASPIC projections (Prager, 1994).

Software: ASPICP

Stock forecasts should use the average of the last three years fishing mortality with the possibility of projecting with fishing mortality estimated in the final year depending on trends.

Projections are performed based on ASPIC estimates. Projections are performed for the following scenarios:

- Reduction of F in the first year from 10% to 50%.
- F sq (*status quo*).
- F_{MSY}
- Zero catches.

TAC, - 15% TAC and + 15% TAC

E. Medium-term projections

No medium-term projections are conducted for black anglerfish stock.

F. Yield and biomass per recruit/long-term projections

None.

G. Biological reference points

WKFLAT (ICES, 2012) endorsed the basis for MSY reference points previously assumed by ICES (i.e. F_{MSY} based on the ASPIC output and a proxy for $MSY_{Btrigger}$ as 50% of B_{MSY} of the ASPIC output).

H. Other issues

H.1. Historical development of assessment

Southern Anglerfish stocks were assessed for the first time in the 1990 ICES WG meeting. Different assessment trials were performed during the subsequent eight years but analytical assessments indicated unrealistic results. The database (both biological and fisheries data) was improved along these years trying to apply an analytical assessment model. Since 1998 a non-equilibrium surplus production model ASPIC (Prager, 1994) was applied to each stock or to the combined stock data. These stock assessments were accepted by the ACFM and used to provide management advice. The assessment of black anglerfish as a separate stock has been carried out continuously from 2007. The history of black anglerfish assessment from 2007 to 2011 is presented in Table 1.

Table 1. History of southern black anglerfish assessment from 2007 to 2011.

WG	2007	2008	2009	2010	2011
Assessment Model	Non-equilibrium Surplus production model (Prager, 1994a)	No updated	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)	Non-equilibrium Surplus production model (Prager, 1994a)
Software	ASPIC (v. 5.16)	No updated	ASPIC (v. 5.24)	ASPIC (v. 5.34)	ASPIC (v. 5.34.9)
Catch data range	1980–2006		1980–2008	1980–2009	1980–2010
Cpue Series 1 (years)	PT-TRF9a (1989–2006)		PT-TRF9a (1989–2008)	PT-TRF9a (1989–2009)	PT-TRF9a (1989–2010)
Cpue Series 2 (years)					
Index of Biomass (years)	PT-TRC9a (1989–2006)		PT-TRC9a (1989–2008)	PT-TRC9a (1989–2009)	PT-TRC9a (1989–2010)
Error Type	Condition on yield		Condition on yield	Condition on yield	Condition on yield
Number of bootstrap	500		500	1000	1000
Maximum F	8.0 (y-1)		8.0 (y-1)	8.0 (y-1)	8.0 (y-1)
Statistical weight B1/K	1		1	1	1
Statistical weight for fisheries	1,1		1,1	1,1	1,1
B1-ratio (starting guess)	0.5		0.5	0.5	0.5
MSY (starting guess)	3000 t		3000 t	3000 t	3000 t
K (starting guess)	20 000 t		20 000 t	20 000 t	20 000 t
q1 (starting guess)	1d-5		1d-5	1d-5	1d-5
q2 (starting guess)	1d-4		1d-4	1d-4	1d-4
Estimated parameter	All		All	All	All
Min and Max allowable MSY	2000 (t)–10 000 (t)		2000 (t)–11 500 (t)	2000 (t)–10 000 (t)	2000 (t)–10 000 (t)
Min and Max K	5000 (t)–500 000 (t)		5000 (t)–112 000 (t)	5000 (t)–100 000 (t)	5000 (t)–100 000 (t)
Random Number Seed	1 964 185		1 964 185	1 964 185	1 964 185

I. References

Afonso-Dias, I. P. and J.R.G. Hislop. 1996. The population of anglerfish *(Lophius piscatorius*) from the northwest coast of Scotland. J. Fish. Biol. 49 (Suppl A): 18–39.

BIOSDEF. 1998. Biological studies of demersal fish. Ref.: EU, DG XIV, Study Contract 95/038.

Castro, J., Cardador, F., Santurtún, M., Punzón, A., Quincoces, I., Silva, C., Duarte, R., Murta, A., Silva, L., Abad, E. and Marín, M. 2007. Proposal of fleet segmentation for the Spanish and Portuguese fleets operating in the Atlantic national waters. ICES CM 2007/ACFM: 21.

Duarte, R., Azevedo, M., Landa, J. and Pereda, P. 2001. Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. Fisheries Research 51: 349–361.

Duarte, R., Bruno, I., Quincoces, I., Fariña, A.C. and Landa, J. 2004. Morphometric and meristic study of white and black anglerfish (*Lophius piscatorius* and *L. budegassa*) from the south-west of Ireland to the south-western Mediterranean. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 22.

Duarte, R., Sampedro, P., Landa, J. and Azevedo, M. 2007. Revision of available data (landings, effort, length frequency distributions and age–length keys) from 1996-2005 for an age-structured assessment of Southern anglerfish stocks. ICES CM 2007/ACFM: 21.

Fariña, A.C., Duarte, R., Landa, J., Quincoces, I. and Sánchez, J.A. 2004. Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. ICES 2004 Annual Science Conference, Vigo (Spain). ICES CM 2004/EE: 25.

GESSAN. 2002. Genetic characterisation and stock structure of the two species of anglerfish (*Lophius piscatorius* and *L. budegassa*) of the North Atlantic. Ref.: EU DG XIV Study Contract: 99/013.

Hislop, J. R.G., Holst, J.C., Skagen, D. 2001. Near–surface captures of post-juvenile anglerfish in the Northeast Atlantic- an unsolved mystery. Journal of Fish Biology 57: 1083–1087.

Hislop, J. R. G., A. Gallego, M. R. Heath, F. M. Kennedy, S. A. Reeves and Wright, P. J. 2001. A synthesis of the early life history of anglerfish, *Lophius piscatorius (*Linnaeus, *175*6) in northern British waters. ICES Journal of Marine Science, 58, 70–86.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8–17 May 2007, Vigo, Spain. ICES CM 2007/ACFM:21. 700 pp.

ICES. 2011. Report of the Working Group on the Assessment of Southern Shelf stocks of Hake, Monk and Megrim (WGHMM), 5–11 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:11.625 pp.

ICES. 2012. Report of the Benchmark Workshop on Flatfish and Anglerfish (WKFLAT), 1–8 March 2012, Bilbao, Spain. ICES CM 2012/ACOM:47.

Landa, J., Antolínez, A., Castro, B., Ámez, M., Barrado, J. and Hernández, C. 2012. Sexual maturity of black anglerfish (*Lophius budegassa*) caught by the Spanish fleet in northeastern Atlantic waters.. Working Document n 9 in WKFLAT 2012.

Landa, J., Duarte, R. and I. Quincoces. 2008. Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. ICES Journal of Marine Science, 65: 72–80.

Prager, M. H. 1994. A suite of extension to a non-equilibrium surplus-production model. Fish. Bull. 92: 374–389.

Praguer, M. H. 2004. User's manual for ASPIC: a stock production model incorporating covariates (ver. 5) and auxiliary programs. NMFS Beaufort Laboratory Document BL-2004-01, 25pp.

Quincoces, I. 2002. Crecimiento y reproducción de las especies *Lophius budegassa* Spinola1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. PhD Thesis. Basque Country University. 276pp.

Megrim (*Lepidorhombus whiffiagonis*) Division VIIb-k and VIIIa,b,d

Stock	Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d
Working Group	WGHMM (Working Group on Hake Monk and Me grim from the Southern Waters)
Date	Updated March 2012: WKFLAT 2012
Revised by	Marina Santurtún

A. General

A.1. Stock definition

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

A.2. Fishery

Megrim in the Celtic Sea, west of Ireland, and in the Bay of Biscay are caught predominantly by Spanish and French vessels, which together have reported more than 65% of the total landings, and by Irish and UK demersal trawlers.

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

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

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

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

Countries	ICES area	% landings (based on 2011 landings data)	Fisheries
Spain	Divisions VIIb,c,e–k and VIIIa,b,d	54%	Otter trawls targeting mixed groups of species (hake, anglerfish, *Nephrops* and other). Netters targeting also mixed species (anglerfish, hake and megrim)
France	Subarea VII	13%	Benthic trawlers targeting benthic and demersal species
Ireland	Divisions VIIb,c,g	17%	Multipurpose vessels targeting gadoids, plaice, sole and anglerfish
UK (England and Wales)	ICES Divisions VIIe,f,g,h	14%	Beam trawlers
Belgium	Divisions VIIb,c,e–k and VIIIa,b,d	2%	Beam trawlers
UK (Northern Ireland)	Divisions VIIb,c,e–k	0.04%	Multipurpose trawlers

A.3. Ecosystem aspects

There are two megrim species in the Northeastern Atlantic: megrim (*Lepidorhombus whiffiagonis*) and four spot megrim (*Lepidorhombus boscii*).

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

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

Although, there does not appear to be evidence of multiple populations in the North-east Atlantic, since the end of the 1970s ICES has assumed three different stocks for assessment and management purposes: megrim in Subarea VI, megrim in Divisions VIIb,c,e–k and VIIIa,b,d and megrim in Divisions VIIIc and IXa.

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

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

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

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

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

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

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

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

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

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

B. Data

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

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

B.1. Commercial catch

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

B.2. Discard data

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

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

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

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

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

From 2000 to 2001 a reduction in the minimum legal size (MLS), from 25 to 20 cm took place.

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

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

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

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

	FR	SP	IR	UK
1984	**FR84-85**	-	-	-
1985	**FR84-85**	-	-	-
1986	(FR84-85)	(SP87)	-	-
1987	(FR84-85)	**SP87**	-	-
1988	(FR84-85)	**SP88**	-	-
1989	(FR84-85)	(SP88)	-	-
1990	(FR84-85)	(SP88)	-	-
1991	**FR91**	(SP94)	-	-
1992	(FR91)	(SP94)	-	-
1993	(FR91)	(SP94)	-	-
1994	(FR91)	**SP94**	-	-
1995	(FR91)	(SP94)	**IR**	-
1996	(FR91)	(SP94)	**IR**	-
1997	(FR91)	(SP94)	**IR**	-
1998	(FR91)	(SP94)	**IR**	-
1999	-	**SP99**	**IR**	-
2000	-	**SP00**	**IR**	**UK**
2001	-	**SP01**	**IR**	**UK**
2002	-	(SP01)	**IR**	**UK**
2003	-	**SP03**	**IR**	**UK**
2004	-	**SP04**	**IR**	**UK**
2005	-	**SP05**	**IR**	**UK**
2006	-	**SP06**	**IR**	**UK**
2007	-	**SP07**	**IR**	**UK**
2008	-	**SP08**	**IR**	**UK**
2009	-	**SP09**	**IR**	**UK**
2009	-	**SP10**	**IR**	**UK**

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

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

B.3. Biological

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

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

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

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

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

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

	France		Ireland		Spain		UK	
	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK	Length distribution	ALK
1984 – 1990	Quarter, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual, by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990	Annual by sex	(1984–1986) Synthetic ALKs using age reading from 1987–1990
1991	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1992	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1993	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, by sexes	Semestral, combined	Annual, combined	Quarter, combined

	France		Ireland		Spain		UK	
1994	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1995	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1996	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1997	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1998	Quarter, by sex	Quarter, combined	Annual, combined	Quarter, by sexes	Annual, combined	Semestral, combined	Annual, combined	Quarter, combined
1999	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2000	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2001	Quarter, by sex	Quarter, combined	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2002	NA	NA	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2003	NA	NA	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2004	NA	NA	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2005	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2006	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes

	France		Ireland		Spain		UK	
2007	Annual, by sex	NA	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2008	Annual, by sex	NA	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2009	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes
2010	Quarter, by sex	Quarter, by sex	Quarter, combined	Quarter, combined	Semestral, combined	Semestral, combined	Quarter, combined	Quarter, by sexes

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

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

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

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

B.4 Surveys

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

An abundance index was provided for the Spanish Porcupine Ground Fish Survey from 2001 to 2010. 2009 data have been incorporated in this update assessment.

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

Surveys available for the assessment:

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

It must be noted that area covered by the three current surveys does not overlap, just the northern component of EVHOE-WIBTS-Q4 and the southern coverage of IGFS-WIBTS-Q4. (Map B.3).

B.5 Commercial cpue

Commercial series of fleet-disaggregated catch-at-age and associated effort data were available for three Spanish fleets in Subarea VII (A Coruña (SP-CORUTR7) and Cantábrico (SP-CANTAB7) from 1986 to 2009, and Vigo (SP-VIGOTR7) 1984–2009. From 1985 to 2008, lpue s from four French trawling fleets: FR-FU04, Benthic Bay of Biscay, Gadoids Western Approaches and *Nephrops* Western Approaches are available.

In 2012, during the WKFLAT (ICES, 2012), a new Irish trawler index was provided as the result of the revision carried out for the Irish Otter trawl fleet. Irish beam trawl (TBB) data are limited to TBB with mesh sizes of 80–89 mm, larger mesh sizes are disused since 2006. No update for the French lpues series has been provided to the WKFLAT 2012 for 2009 and 2010 as effort deployed by these fleets was considered, at the time of the analysis, unreliable.

B.6 Other relevant data

The group reiterates the importance of incorporating estimates of discards from all main countries involved in the Northern Megrim fishery, specifically France, to obtain consistent data along the whole dataseries and also to detect possible recruitment processes that are not completely registered in the catch-at-age matrix and lpue.

C. Assessment: data and methods

In 2012, and during the WKFLAT (ICES, 2012), a Bayesian statistical catch-at-age model (described below in ‘Model used in Benchmark 2012’**) s**howed promising results and seemed to be able to deal with the heterogeneity in the Megrim in Divisions VIIb–k and VIIIa,b,d data.. The model fit to the data was adequate. However, a lack of confidence in the data used made it impossible to accept the absolute values of model results. The lack of confidence in the data also makes it impossible to believe the results of any other model that could be applied to these data. Thus, no precise estimates of development of the stock population structure and SSB are available. The basis for the assessment should be then,

- The analysis of trends of Survey and Commercial Indices.
- For a more detailed analysis, which could be masked by the pooling ages in the above indices, qualitative results of the statistical catch-at-age Bayesian model will be scrutinised.
- A revision of the abundance of the ages of each of the fleets will be analysing by means of grouping ages (Group i: ages 1 + 2; Group ii: ages 3, 4, and 5 and Group iii: ages 6, 7 8, 9 and 10+). The objective is to discern for any possible change in abundance in young, intermediate and old ages along the dataseries.

Summary of the data used for the Benchmark 2012

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

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

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

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

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

iv) For 1999, only Spanish and Irish discards-at-age are available. From 2000 onwards, discards-at-age are available for Ireland, Spain and UK. There was no information for France, Belgium and Northern Ireland. The main part of the missing discards is supposed to correspond to France, as the contribution of the other two nations to the stock landings is very small. France did not provide discards estimates due to the low sampling levels and major problems in the raising procedure.

In summary, the stock catch-at-age matrix shows inconsistencies in the data available for each identified different period: 1984–1989; 1990–1998 and 1999–2010.

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

FLEET	ACRONYMS	PERIOD	AGE RANGE	Landings %
Spanish Survey	SpPGFS-WIBTS-Q4	2001–assessment year-1	1–8	-
French Survey	EVHOE-WIBTS-Q4	1997–assessment year-1	1–9	-
French Benthic Western approaches	FR-FU04	1985–2008	2–9	5%
Spanish Vigo Trawl VII	VIGO84	1984–1998	2–9	37%
	VIGO99	1999–assessment year-1	2–9	47%
Irish Beam trawlers VII	IRTBB	1995–assessment year-1	2–9	3%

Model used in Benchmark 2012

The model explored during the benchmark is an adaptation of one developed originally for the southern hake stock, published in Fernández *et al.* (2010). It is a statistical catch-at-age model that allows incorporating data at different levels of aggregation in different years and also allows for missing discards data by certain fleets and/or in some years. These are all relevant features in the megrim stock. The model is fitted in a Bayesian context, using the freely available software WinBUGS (Lunn *et al.*, 2009).

Population dynamics

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

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

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

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

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

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

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

$$F(y,a) = F_L(y,a) + \sum_{j=1}^{J} F_{D,j}(y,a) \text{,} \quad (3)$$

where $F_L(y,a)$ and $F_{D,j}(y,a),\ j=1,\dots,J$ relate to the total stock landings and discards from each of the J fleets fishing the stock, respectively. The fleets used for the megrim stock correspond to the countries fishing it and are: Spain, Ireland, United Kingdom and Others, where "Others" comprises France together with countries with minor stock catches. The reason for having France grouped together with countries with minor catches is the lack of French discards data, which makes treating France as a separate fleet unrealistic. However, given the volume of catch that France takes from this stock, it would make sense to have France as a separate fleet in the model if those data become available.

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

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

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

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

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

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

where the log-Normal (LN) distribution is parametrized using the median (first parameter) and coefficient of variation (second parameter). As megrim discarding is believed to have increased over the assessment period, the non-stationary random walk model in Equation (5) is considered appropriate. For each age, the value in the first year of the assessment period, $r_L(1,a)$, is an unknown parameter, whereas CV_{rcond} has been fixed at 20% (the value 10% was also explored in some model runs). The same modelling procedure is applied to $r_{D,j}(y,a)$, separately for each age and fleet $j=1,\ldots,J$, where the values in the first assessment year, $r_{D,j}(1,a)$, are unknown parameters and CV_{rcond} is fixed at the same value as for $r_L(y,a)$.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$r_{OTD}(y,a) = r_{OTD}(y-1,a)\left[OTLW(y)/LW(y)\right]/\left[OTLW(y-1)/LW(y-1)\right] \tag{11}$$

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

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

Observation equations for relative indices of stock abundance

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

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

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

Data, priors, and computational method

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

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

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

Model fitting was done using MCMC to simulate the posterior distribution (Gilks *et al.*, 1996, provide an accessible introduction to MCMC). This was programmed in the free software WinBUGS and run from R (R Development Core Team, 2009) using the R2WinBUGS package (Sturtz *et al.*, 2005). MCMC simulates the posterior distribution with each draw depending on the one immediately preceding it. As a consequence of this dependence, many iterations are typically needed to obtain a representative sample from the posterior distribution, particularly when this is highly dimensional and strong correlations between some of its dimensions exist. The results for the main runs conducted during the benchmark are based mostly on chains of 48 000 iterations. The first 8000 were discarded to eliminate the effect of start-up values, and 5000 equally spaced iterations out of the other 40 000 iterations were kept. This was considered enough to provide a good representation of the posterior distribution. Running time was approximately 24 h on a standard desktop PC.

Sensitivity analysis

In order to find an adequate fit of the model to the data and to test the sensitivity of the results to different model settings more than 30 model configurations were tested before and during the benchmark workshop. First, several models were run until sensible results were obtained, at which point the fine tuning of the model and detailed analysis started.

In a first sensible run, bimodal posterior densities were obtained for some variables, which suggested non convergence of the model, and the rL parameters in ages 1 and experienced a sharp decrease in the first years of the assessment period (1984 to approximately 1987), which did not appear realistic. This suggested that the prior assumed for the values of these parameters in 1984 was centred at unrealistically high values and that the model was using the random walk feature (for the logarithm of these parameters) to move these parameters to a more appropriate range of values early in the time-series. Thus, in a following run, the length of the MCMC chains was increased (to deal with the convergence issues) and the values of medF (used to set the prior median of population abundances-at-age in 1984, see Table 9.9.1.1) and prior median for rL in 1984 for ages 1 and 2 were changed (decreased) to correct for the behaviour displayed by rL at the beginning of the time-series. It was also observed that the estimated OTD discards of age 5 increased enormously after 1999, which did not make any sense. It was checked that the problem with the estimated OTD discards of age 5 was not a problem of convergence, several alternative model settings were tried in an attempt to solve this extremely unrealistic result, and finally, it could only be solved by modelling $r_{OTD}(y,a)$ from 1999 as was indicated in equation (11). In the results it was also observed that the prior CV of the catch and landings for ages 1 and 2 was too low in relation to the posterior results, so the prior median was increased from 10% to 30% in order to have a prior distribution which was not completely at odds with what the data indicated. In later runs it was also assumed that the precision in landings from 1990 to 2010 was equal to the precision in catch from 1984 to 1989. The reason was that, in principle, in the first period there was no incentive to discard or misreport data, so there was, in principle, no reason to expect a lower quality of the 1984–1989 catch data than of the 1990–2010 landings data.

To deal with the high increase in OTD discards of age 5 two structural changes to the model were tried. In the first change it was assumed that OTD discarding pattern-at-age had not changed since 1998, and the changes in overall level (with the same change in level for all ages) between years were treated as unknown parameters and estimated by the model based on the available data. This still resulted in very unrealistic estimates of OTD discards in recent years, with very large increases, propagating the problem previously detected just for age 5 to all the ages. The second approach to deal with this problem was the same as the first one (i.e. it was assumed that OTD discarding pattern-at-age had not changed since 1998) but the changes in overall level (with the same change in level for all ages) between years were approximated by the changes in overall landings of the OTD fleet with respect to total stock landings in the same years (see equation (11)). This gave sensible results and the assumption was used in all following runs.

Using the later configuration of the model several runs were tested using different sets of abundance indices. In the light of the results and the exploratory data analysis it was decided to use as abundance indices: EVHOE survey, SPGFS Porcupine survey, IRTBB lpue and VIGO cpue divided into two dataseries (VIGO84 and VIGO99). The VIGO cpue time-series was split to account for the change in catchability around 1999, for which there is now fairly clear support. The ages used in EVHOE and IRGFS indices were reduced to ages 1–5 and 2–7, respectively, which are the ages for which the exploratory plots showed some degree of cohort tracking. Besides, the prior median and CV of f(y) were also changed which did not have high influence on the results.

The CV of the random walk of rL, rIRD, rOTD, rSPD and rUKD, was treated as an unknown parameter in the first configurations, but later it was set at a fixed value. Two alternative values were tested for the CV of the random walk, 10% and 20%, the results were very similar, but the option of 20% was chosen because it gave slightly better results. Using the abundance indices listed in the previous paragraph, different configurations were tested and the one described above was selected. This run was selected as possible proposal for the assessment and is the run whose detailed prior settings are described in Table 9.9.1.1. However several more runs were conducted to test for sensibility of the model selected.

The sensitivity of the model to the prior distribution of recruitment was tested and the results obtained did not vary between runs. Due to the high decrease in the abundance of age 6 and older age groups and the increased difficulty of tracking cohorts at those ages suggested by the data, the model was run using a plus group age at 6. Two configurations were tried: one using abundance indices up to age 5 and the second one using them up to age 6+. The MCMC algorithm for these runs was very slow, they took longer than two and four days, respectively, but the results were congruent with those obtained using the 10+ age. The slowness of the MCMC algorithm with a 6+ group was also a sign that the configuration with ten age groups was better. In another two alternative runs, the assumption of constant f(y) across years was tested. This is not a sensible assumption, but it was tested in an attempt to shed light on the high fishing mortalities obtained for older age groups, particularly in later years. Within the constraints imposed by the assumption itself, the results were coherent with what was observed previously.

D. Short-term projection

No short-term projection was proposed by WKFLAT, considering that the assessment model should only be used as indicative of trends.

E. Medium-term projections

No medium-term projections are proposed for this stock.

F. Long-term Projections (until 2006)

No medium-term projections are proposed for this stock.

G. Biological reference points

Benchmark 2012: The calculation of possible reference points was not considered appropriate at this time due to the lack of analytical analysis.

H. Other issues

H.1. Historical development

Starting from 2007, no analytical assessment has been carried out. Assessment is based on discard data (Spanish dataseries and "preliminary" discard data from UK, and IR), catch-at-age data, survey indices and commercial cpues and lpues dataseries of the commercial fleets described in Section B5.

Model used until 2006: XSA. Information on XSA options in the past is provided as background for stock coordinator and reviewers.

Software used: VPA95 Lowestoft suite

Model Options chosen (until 2006):

Age recruitment	1
Taper	Yes (tricubic) – 20
Plus group	10
Tuning range	All
Ages catch dep. Stock size	No
Q plateau	8
F shrinkage se	1.5
year range	5
age range	3

Input data types and characteristics (in 2006 XSA):

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1984–2005	1–10+	Yes
Canum	Catch-at-age in numbers	1984–2005	1–10+	Yes
Weca	Weight-at-age in the commercial catch	1984–2005	1–10+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1984–2005	1–10+	Yes
Mprop	Proportion of natural mortality before spawning	1984–2005	1–10+	NO
Fprop	Proportion of fishing mortality before spawning	1984–2005	1–10+	NO
Matprop	Proportion mature at age	1984–2005	1–10+	NO
Natmor	Natural mortality	1984–2005	1–10+	NO

Tuning data (in 2006 XSA):

Type	Name	Year range	Age range
Commercial Tuning fleet	SP – VIGOTR7	1984–2005	2–9
Commercial Tuning fleet	FR – FU04	1988–2001	4–9
Survey	UK-WCGFS-D	1993–2004	2–3
Survey	FR – EVHOES	1997–2005	1–9

Short-term forecast until 2006

- Model used: Age structured
- Software used: MFDP prediction with management option table and yield-per-recruit routines. MLA suite (WGFRANSW) used for sensitivity analysis and probability profiles.

- Initial stock size. Taken from the XSA for age 1 and older. The recruitment-at-age 1 in the last data year is estimated as a short-term GM (1987 onwards).
- Natural mortality: Set to 0.2 for all ages in all years.
- Maturity: The same ogive as in the assessment is used for all years.
- F and M before spawning: Set to 0 for all ages in all years.
- Weight-at-age in the stock: average stock weights for last three years.
- Weight-at-age in the catch: Average weight of the three last years.
- Exploitation pattern: Average of the three last years. Discard F's, are held constant while landings F's are varied in the management option table.
- Intermediate year assumptions: *status quo* F
- Stock–recruitment model used: None, non-parametric bootstrap for the whole period.
- Procedures used for splitting projected catches: vectors in each of the last three years of the assessment are multiplied by the proportion landed or discarded at age to give partial Fs for landings and discards. The vectors of partial Fs are then averaged over the last three years to give the forecast values.

Long-term projection until 2006

- Model used: yield and biomass per recruit over a range of F values that may reflect fixed or variable discard F's.
- Software used: MFY or MLA
- Maturity: Fixed maturity ogive as used in assessment.
- Stock and catch weights-at-age: mean of last three years
- Exploitation pattern: mean F array from last three years of assessment (to reflect recent selection patterns).

Procedures used for splitting projected catches: Catches are not split

Reference points prior to 2012

	ICES CONSIDERS THAT:	ICES PROPOSED THAT:
Limit reference points	B_{LIM} is not defined.	B_{pa} be set at 55 000 t.
	F_{LIM} is 0.44.	F_{pa} be set at 0.30.
Target reference points		F_y is not defined.

Technical basis

B_{LIM} = Not defined.	B_{pa} = B_{loss}. There is no evidence of reduced recruitment at the lowest biomass observed and B_{pa} was therefore set equal to the lowest observed SSB.
F_{LIM} = Floss.	F_{pa}= F_{med}; this implies a less than 45% probability that (SSBMT< B_{pa}).

2008 Review group issues

There is a serious shortage of basic information for this stock due to severe deficiencies in the data (lack of updates, gaps in time-series, few data on discards, limited survey information). There are conflicting signals on stock trends both from surveys and lpue data, and it will require considerable effort to provide a reliable assessment for this stock.

Data deficiencies in 2008

1) Limited discards data available: Only Spanish discard data are used. Some preliminary, not raised, discard data supplied from UK. Ireland raised discard data are provided. No French discard data are delivered.

2) Limited survey information, particularly on the strength of the incoming year classes: French EVHOE survey data should be provided.

3) Conflicting trends in commercial tuning data: a complete review of the commercial cpues from Ireland is needed. Update cpues of the French tuning-series.

4) Segmentation on the main commercial fleets used in the assessment should be revised and, if appropriated, applied.

Data improvement in 2009

1) Limited discards data available: French discard data are still not available. UK "preliminary" unraised data were delivered. Spain and Ireland provided raised estimations of discards.

2) Substantial improvement in survey information. The EVHOE index-series by age has been updated and revised.

3) Revision of Commercial cpue series. The Irish Otter trawl tuning fleet has not yet been revised. French Fleets have been all updated and revised.

4) No new fleet segmentation of tuning fleet dataseries has been proposed and consequently no new data have been handled in.

2009 Review group issues

- "severe deficiencies in the data" for this stock. There appears to be an ongoing effort to update and revise data for this stock. The lack of discard data from all countries involved in the fishery is of particular concern, as it is likely that the international catch of this stock is underestimated. Only one country has provided discard data since 1999 (Spain) and this is the only time-series incorporated in the assessment.
- Additionally, concern was expressed that survey indices conflict in their depiction of trends in biomass over time. Specifically, the Irish groundfish survey indicated much higher biomass levels in 2004–2006 than the French and Spanish groundfish surveys. Furthermore, commercial catch-effort data show different trends for the fishery in recent years. Lpue from the French fishing fleet appears to be stable since 2005, whereas the cpue of the Spanish fleet indicates an increasing trend since 2005, with a decrease in 2008.
- This stock is targeted as part of a mixed fishery (hake, megrim, sole, cod, plaice, and *Nephrops*), but this was not noted in the 2009 report. Ecosystem information was not considered in examination of stock trends.

Data deficiencies in 2009

In 2010, quality has even decreased.

- No estimation for catches for this stock are delivered this year as France has not provided landing data.
- Limited discards: Lack of discards data for all countries and years continues to be a major problem for this stock. No data other than Spanish and Irish dataseries have been provided for the assessment. Only sampling data from United Kingdom were available.
- Commercial tuning data for four French fleets have not been updated. The Irish Otter trawl lpues series has not been revised for the time of the meeting.
- No segmentation of the main commercial fleets used in the assessment has been carried out.

Improvement of 2010 data

The above data deficiencies should be corrected for the preparation and development of a successful benchmark planned in the 1st quarter of 2010.

Data improvement during the Benchmark 2012

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

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

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

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

v) Spain provided some minor revised values of discards.

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

Data deficiencies after Benchmark 2012

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

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

I. References

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

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

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

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

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

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

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

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

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

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

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

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

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

R Development Core Team. 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

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

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

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

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

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

Sole in Division VIIe

Stock	Sole in Division VIIe (Western Channel)
Date	13/03/2009
Revised by	Sven Kupschus (revised at WKFLAT 2012. ICES, 2012)

A. General

A.1. Stock definition

The management area for this stock is strictly that for Division VIIe. Biologically speaking however the picture is much less clear. Sole in general are relatively sedentary, once settled they perform a seasonal inshore offshore movements during their spawning migration with a random longshore component. Therefore the management unit of the stock is well defined for mature fish. There is good evidence to suggest that the stock is split into two biological stocks on either side of the Hurd Deep. If this prevents complete mixing of the stock it an assessment methodology capable of taking account of this should be applied. This could explain differences in the trends representative of stock dynamics in the different fisheries. The two main fisheries on the UK coast around Lyme Bay and the Start as well as the fishery on the coast in the eastern part of the management area are clearly separated by the deeper waters of the channel, so that the fishery covers only about half of the management area so that incomplete mixing may be a problem in this stock.

With respect to the stock as observed by the fishery there seem to relatively few issues regarding stock identity and once recruited the stock appears to represent a closed population. Spawning migrations by sole tend to be in a seasonal onshore offshore pattern with a small random movement alongshore described for the species in other areas. Given the layout of the stock and the apparent breaks in the distribution of sole at the edges of the management unit there appears to be little concern for significant leakage across stocks. However the biological stock unit for Division VIIe is much less certain at the larval and prerecruit stage. The proportion of the area that represents nursery grounds is much smaller than those for other sole stocks of equal size, with only two small regions (the inner part of Lyme Bay and the Bay de Mount St Michelle) known to regularly produce 1-groups sole.

Tagging information of juvenile sole, mostly 1–3 year olds show that there is significant ingress of recruits from the adjacent stock in ICES Division VIId from both the French and the UK coast that appear in the region of out Lyme Bay. Unfortunately, very little tagging data are available to examine if there is an equal or greater reciprocal movement in the opposite direction, but given the limited nursery habitat and the abundance of sole recruits in Division VIIe it seems reasonable to assume that there is a net inwards migration of prerecruits that remain in the area following maturation.

Spawning is known to occur in the division from survey evidence in a relatively small concentration on the ‘Bank de Langustine’ and intermittently in very low concentrations in the western part of the UK coastal region and around the edges of the Hurd Deep. Little is known about the fate of the spawning products, but given the relatively long egg and larval stage as well as the significant net eastward movement of waters in the channel it is plausible that the stock utilises nursery habitat in the eastern half of the channel. The degree of stock isolation in terms of these recruits has not been investigated, as it is possible that the recruits contribute to a common pool of recruits with the eastern stock.

Isolation from the Celtic Sea (both the Bristol Channel and the Bay of Biscay) appears to be more rigorous according to tagging information, with few individual traversing the strong environmental and habitat gradients found in the rocky areas around lands end. However, the 1998 year class is indicated to be above average from all tuning information with the exception of the UK-BTS survey. The fact that this cohort is not well represented in what is thought to be the best indicator of recruitment, yet is readily observed in information from the more westerly and offshore parts of the stock area may indicate that there are other, as yet poorly understood recruit sources within the region.

From a stock assessment point of view and in the absence of a modelled stock–recruitment relationship there appears then relatively little concern over a lack of a closed population given the low movement rates post maturation. The low movement and its seasonality in conjunction with the high concentration of fishing effort around Start Point may produce effects of local depletion that may imply higher rates of fishing mortality for the UK-CBT fleet when compared to mortality rates from other indices covering a wider area. Such conjecture is potentially supported by the fact that when the new Q1SWBeam survey is viewed as an absolute index of abundance it produces higher estimates of stock size than the assessment. While stock size remains relatively stable and the behaviour of the fishery remains stable this is likely to have little impact on the assessment as the difference is absorbed in the estimates of catchability. If the fishery expands spatially with a commensurate reduction in the per-unit-area effort, or as migration rates change in response to stock size such affects may become more apparent in the assessment so that it is important to consider/examine such changes in future.

The assessment method agreed by WKFLAT 2012 (ICES, 2012), and described in this "Stock Annex", does not specifically deal with the uncertainty regarding stock boundaries, nor the issue of incomplete mixing and spatial dynamics in the stock and fishers. However, for advisory purposes the assessment methodology agreed at WKFLAT 2012 is able to provide robust advice despite these slight omissions. Part of the problem is that such process error is apparent in this stock only because of the high degree of precision and certainty in the data. Spatial issues are known to occur in other stocks, but the results of this process error are not apparent from the assessments because overall variability is much greater.

A.2. Fishery

The principal gears used for sole in the Western Channel are beam and otter trawls, for the UK fleet and entangling nets and otter trawls for the French fleet. In recent years, UK vessels have accounted for around three quarters of the total international landings, with France taking approximately a quarter and Belgian vessels the remainder. UK landings were low and stable between 1950 and the mid-1970s, but increased rapidly after 1978 as a consequence of the replacement of otter trawlers by beam trawlers. Because the UK fleet is the major component of the international landings, they follow a similar trend. Sole is the target species of an offshore beam trawl fleet, which is concentrated off the south Devon and Cornish coasts, and also catches plaice and anglerfish. In recent years a winter fishery targeting cuttlefish has developed for the English beam trawl fleet in the Western Channel, lasting from November till the end of March. This has taken some of the reliance of the fleet away from sole, but sole still represents a substantial portion of the catch during this time so it is not clear to what degree the switch to cuttle-fishing has reduced fishing mortality on sole.

Discarding of sole in this fishery is thought to be minor, supported by the time-series (2002–2008) of discard information for the UK fleet shown in Figure A.2.1. Landings of sole reached a high level above 1400 t in the 1980s, boosted initially by high recruitment in the late 1970s, followed by an increase in exploitation. Landings declined between 1988 and 1991, following the recruitment of three below-average year classes (1986–1988); since 1991 they have fluctuated between 800 t and 1100 t. Substantial quantities of sole caught in VIIe have been reported to two rectangles in VIId in order to avoid quota restrictions. Corrections for this misreporting were first made during the 2002 WG, but misreporting to other areas has been more difficult to identify. In addition, black landings are likely to have occurred to various degrees since quotas became restrictive in the late 1980s. No estimates of the scale of the problem exist so that this uncertainty has not been incorporated into the assessment process.

Since the development of the beam trawl fleet in the Western Channel in the early 1980s there has been a consolidation to larger more powerful vessels, particularly in the late 1990s and early 2000s. However, the severe quota restrictions at that time have lead to a reversal of this trend and a lesser emphasis on sole as the major income for the fleet. Undoubtedly sole still form the back bone of this fishery due to the steady availability over the ground. However in recent years the fishery has adapted with smaller more flexible vessels and an overall reduction in kWH as well as a further small decrease in the number of boats due to a decommissioning scheme, to make the most of other resources such as scallops, cuttlefish, gurnards, etc. foregoing possible higher catch rates of sole. This is reflected in the offshore movement of the fishery around Start Point.

At the lower catch rates described above the fleet is at an appropriate capacity to take the available quota and appears to have sufficient financial stability and certainty to allow for continued investment in the fishery. Were the industry to return to previous patterns of exploitation targeting the younger and more abundant sole in Lyme Bay it would almost certainly be able to increase the fishing mortality to levels greater than that assumed to be sustainable. The current enforcement regulations with a change in the attitude of the industry have meant that the TAC is an appropriate management tool in at least the UK fishery. Limiting days at sea further will have a perverse tendency to reverse this trend and focus effort grounds in Lyme Bay because of their proximity and the higher catch rates.

A.3. Ecosystem aspects

Little is known with regards of the effect of the environment on the stock dynamics of VIIe sole. Certainly the division is on the convergence between the Celtic Sea proper and the Channel/North Sea ecosystem. If predicted increases in temperature were to materialize changes to the stock dynamics of this and other species in the Division would be expected. To date there is good evidence of a sizeable increase in the abundance of bass in the area, a species with a similar pan European distribution as sole. In addition there is some anecdotal evidence of changes in the range of some species such as langoustine, triggerfish, and black sea bream from warmer parts of the Atlantic. In the North Sea it has also been suggested that cold periods immediately prior to spawning have a tendency to increase year-class strength and there is some indication of this for this stock, but no statistical analysis has been carried out to date.

Beam trawling is known to have a significant impact on the seabed. It is understood though that those areas affected continue to be productive in terms of the target species. After the initial degradation of the habitat usually associated with the loss of sessile macro fauna, continued use of beam trawls seems to have few further impacts.

B. Data

B.1. Commercial catch

UK (>60%) and France (>30%) together provide almost all the catches for this stock. UK Landings data are based on EU logbook data for VIIe catches. In 2002 the UK industry indicated that there had been substantial misreporting of landings to two rectangles in Division VIId. It was possible to identify the misreported landings spatially and by reported lpue. Having identified misreported landings, data were corrected back to 1985 by the 2002 WG. This method of correction is ongoing. French official landings statistics have been poor since 1997, but since 1997 landings data have been calculated much more accurately using buyer and sellers notes. France has provided corrected landings information to the Working Group since 2002.

Numbers-at-age prior to 1994 are calculated by raising the UK age composition to UK and Channel Island Catches, adding the French age composition data, and finally raising the resulting age composition to the total international landings. From 1995 WG to 2005 WG the international landings for the stock were based entirely on English quarterly sampling effort then raised to quarterly international landings. Since 2006 WG French age data from 2003 onwards have been included.

Numbers-at-age 1 in the catch are low or zero in most years and most likely reflect variation in the sampling, rather than variation in the stock itself. Therefore, these were not considered to add useful information and are replaced by zeros.

Table A demonstrates the history of the derivation of catch numbers-at-age.

B.2. Biological

Weights-at-age

Total international catch and stock weights-at-age for each year's catch data are calculated as the weighted mean of the annual weight-at-age data (weighted by catch numbers), and smoothed in-year using a quadratic fit so that:

$$Wt = a + b*Age + c*Age^2$$

where catch weights-at-age are mid-year values, and stock weights-at-age are 1 January values. Following the estimation of the weights-at-age catch-numbers are adjusted to so that the sum of products of the weights and catches sum to the estimated Landings (SOP correction). Catch numbers-at-age 1 are replaced by zeros, but the catch weights-at-age 1 were retained because they are part of the smoothing procedure and do not affect the assessment. They are also essential if a medium-term forecast is performed.

A smoother is applied to sampled catch weights-at-age to adjust for variation in the weight-at-age that may result from low levels of sampling rather than differences in growth rate between cohorts. It also allows estimation of the stock weights-at-age by extrapolation of the curve rather than by using quarter 1 samples, which may be sparse. However this smoother is applied through the plus group and the age range in the plus group is such that this will tend to overestimate the weights at the younger ages. This needs to be corrected as soon as possible.

Natural mortality and maturity-at-age

Natural mortality is assumed constant over ages and years at 0.1. This is consistent with the natural mortality estimates used for sole by other ICES working groups (WGNSSK: IV, VIId, WGCSE: VIIa, VIIfg, VIIIa,b) and consistent with estimates of M reported in Horwood, 1993 for VIIfg sole as well as other stocks and papers cited therein.

Assessments prior to 1997 had use knife edge maturity-at-age 3. This was changed in 1997 to a maturity ogive from area VIIf and g according to Pawson and Harley (WD presented to WGSSDS in 1997), which is applied in all years, 1969 to present, since the 1997 WG.

Age	1	2	3	4	5	6,7, ...12+
Prop. Mature	0.00	0.14	0.45	0.88	0.98	1.00

Proportions of F and M before spawning are both set to zero to reflect the SSB calculation date of 1 January.

B.3. Surveys

UK-BTS

The longest survey time-series available for this stock is the Western Channel Beam Trawl Survey conducted by the UK in late September, early October (UK-BTS). The survey covers a relatively small area of VIIe from Start Point through to the middle of Lyme Bay and out to the edges of the Hurd Deep covering the immediate area of fishing for the Brixham and Plymouth fleets. Sampling started originally in 1984 on the chartered commercial fishing vessel 'Bogey One', replaced in 1988 by the 'Carhelmar' and moved to the research vessel 'Corystes' in 2002 to 2004. Concerns were raised regarding differences in catchability between the Carhelmar and Corystes, and in 2003 the survey was carried out on both vessels. The results of the comparison convinced Cefas to return the survey to the long-serving Carhelmar and to replace the 2003 data with the data from the comparison trials in order to improve consistency. Consequently, the time-series has been largely recovered, with only 2002 and 2004 data coming from the RV Corystes.

The survey cpue demonstrates a decline from 1986 to 1995 in line with the commercial data, after which SSB seems to have largely stabilized at lower levels. The abundance indices at-ages 1 and 2 demonstrate little overall trend, but ages 3 to 6 indicate a decline over the middle part of the series, despite intermittent peaks and troughs. More recently survey cpue has increased to the highest level over the consistent time-series (starting in 1988 as used in the assessment) with the majority of the increase coming from the younger ages and only a marginal increase at the older ages. The age information is internally consistent to the survey, with 1989 year class is indicated to be strong at all ages and this year class can also be traced through the catch-at-age matrix. More recently the 1998 year class can be tracked reasonably consistently.

UK-FSP

A shorter, but more spatially extensive survey-series has been developed and managed by Cefas since 2003 in the UK in conjunction with the industry. Age sampling issues preclude the use of the data in the first year and the time-series is used here since 2004. The survey vessels (two separate trips are carried out annually see Annex 1 of this Stock Annex) are subject to a three yearly tendering procedure and vessels characteristics and gears used have changed over the time period, which is why the index has been standardised by meter beam and hour fished. The survey covers the extent of the UK fishery for the species including the less frequently exploited western part of the stock, which is why it is principally to be preferred over the more limited UK-BTS survey but is expected to be more variable due to the inconsistency of vessels used. Age information from this survey has shows evidence of some internal consistency in the medium age range but the series is too short to evaluate this at the older or younger ages at present. However the survey appears to show consistency with other survey indices and is therefore included in the present assessment for the entire age range available (ages 2–11). Data from this survey has been used in the plaice assessment since 2008.

Q1SWBeam

This survey was included in the assessment for the first time in WKFLAT 2012. The survey-series starts in 2006. Important considerations for WKFLAT 2012 (ICES, 2012) were that the survey is based on a stratified random survey approach and covers the entire region of the management area and some adjacent waters which may not fully conform to the delineation. The survey shows strong gradients in species composition within the western channel (justifying the stratification approach), although there is some indication that more appropriate post stratification could potentially provide an increase in precision of single species abundance estimates.

Given sampling effort, fundamentally this survey is more variable than fixed stations survey designs of equal effort, but also inherently is less biased when there are potential changes in the distribution of the species within the area. Although estimates of survey variance of the limited dataseries are available, these are unlikely to reflect the full range of the variance that would be encountered in a longer time-series as variance estimates are unlikely to have reached their asymptote, particularly since the range of SSBs observed by the survey is very restricted.

The survey-series was started in 2006 and surveys have been conducted consistently since then. To include as much information as is available at the time of the assessment working group the survey that is conducted in the first quarter has been shifted to back by one year and one age. This practical, because it adds further available information on the abundance of recruitment into the assessment, particularly important since there is uncertainty regarding the estimation of recruits from the UK-BTS which otherwise is the sole source of information of this parameter. The benefits of shifting the series were thought to out-weight the potential error that may be introduced by this procedure if the seasonal pattern of true F were to change in future.

Age information provides estimates of abundance for all ages in the assessment, despite the fact that the survey only catches between 250 and 300 sole in a given year. Theoretically this removes the necessity of retaining the commercial lpue (at age) series required as the UK-BTS survey does not cover the full age range in the assessment. Internal consistency estimation is very difficult given the short time-series, and relatively small contrast in cohort strength observed (based on other series). Despite this some cohort tracking is apparent and the signal matches the cohort signal from other survey series, particularly the FSP survey.

Given these uncertainties regarding true survey variance and concerns regarding future funding for the survey it seemed unreasonable to put the entire weight on this survey, so at this stage it is not sensible to remove the commercial fleets from the assessment as they provide a high degree of precision at the cost of introducing some bias into the assessment.

B.4. Commercial cpue

The commercial tuning-series available for the assessment are the same as in previous assessments. Two historic surveys had been included in previous versions of the assessment because historically reference points in the stock had been based on historic development of the fishery and variance in the early time-series indicated considerable uncertainty with respect to these historic estimates as a response to the choice of plus group in the assessment. The new assessment is less susceptible to these variable estimates of catch-at-age, and the group decided to not base reference points on the historic development of the stock so that the historic indices are no longer required in the assessment and are not discussed further here.

UK-COT

The UK otter trawl index is the same as presented in previous assessments. As previously observed the index suffers from two distinct negative year effects in 1991–1992 and 2004. These inconsistencies were observed in previous assessments and the WG concluded that given the length of the period the effects of these in the historic period were minor on the current estimates of F and SSB as they are modelled mainly as residuals in the XSA model. For the new assessment there were no indications to presume that these effects were detrimental to the accuracy of the assessment so that the information is included as in previous years.

Currently this fleet contributes only a small proportion of the overall landings, but it is sampled much more heavily than its representation in the landings so continues to provide a good independent time-series from the main commercial catches. It is uncertain whether the new DFC sampling will continue to provide such accurate data as the intent is to sample catches more proportional to landings.

Despite the year effects the series is characterised by high internal consistency and is also consistent with other series in identifying strong cohorts.

UK-CBT

The time-series of commercial beam trawl information has always formed the backbone of this assessment, but investigations at WKFLAT 2009 (ICES, 2009) indicated that this series showed declining lpue, particularly at the younger ages, in contrast to other information in the surveys and to a lesser degree to the catch-at-age despite the fact that the fleet accounts for around 60% of the landings in the stock. It was assumed that it was largely this fleet that was responsible for the persistent bias in the assessment. Historic area misreporting by the fleet prior to 2010 had been an issue, but after discussions with the industry in 2002 landings information and lpue data have been corrected for this, and the incidence of this practice had been decreasing. Increased scrutiny by enforcement, and lpue limits imposed by the producer organisation contributed to the reduction.

The operation of the fleet was examined at this WK using VMS data from 2006–2011. The conclusions from this analysis were that since 2006 the fleet has been increasingly shifting its effort southwards more into the central regions of the channel. Effort in

Lyme Bay, the region where catch data and survey information indicate the majority of younger fish are found are now much lower than previously and have ceased almost entirely in 2010 and 2011. This shift in the selectivity towards older ages is very apparent also from the catch-at-age information for the fleet from market sampling records suggesting that it would be appropriate to split the fleet on the basis of inconsistent operation.

It was not possible from independent information to discern when the majority of the contrast in this information occurred, and hence to decide on appropriate time to split the series, because VMS data are not available prior to 2006. Information from the industry also confirmed that there had been changes in the operation of the fleet, but again suggested that these changes had been gradual, rather than abrupt making the choice of the year for a split of this fleet difficult. The WK determined that 2002, the period when the area misreporting was officially acknowledged, would be an appropriate point for splitting and would also be suitable for the assessment, as this would retain a sufficiently long time-series over which to estimate the new catchabilities for the fleet. This new methodology was adapted and the UK-CBT fleet is used in the assessment as two fleets UK-CBT-early (1989–2002) and UK-BTS-late (2003–2010).

B.5. Other relevant data

None.

C. Assessment: data and method

Model used: extended survivor analysis.

Software used: FLXSA (version 1.4-2)

Model Options chosen:

	2012	2013 and after
Assmnt Age Range	1–12+	1–12+
Fbar Age Range	F(3–9)	F(3–9)
Assmnt Method	XSA	XSA
Tuning Fleets		
Q1SWBeam (offset by 1y 1a)	2006–11 2–12	2006–11 2–12
UK-FSP	2004–11 2-–11	2004–11 2–11
UK combined beam Ages (early)	1988–02 3–11	1988–02 3–11
UK combined beam Ages (late)	2003–11 3–11	2003–11 3–11
UK otter trawl Ages	1988–11 3–11	1988–11 3–11
UK BTS yrs Ages	1988–11 1–9	1988–11 1–9
Time taper	No	No
Power model ages	No	No
P shrinkage	No	No
Q plateau age	6	6
F shrinkage S.E	0.5	1.5 or 0.5*
Num yrs	3	3
Num ages	5	5
Fleet S.E.	0.6	0.6

***Final decision on F shrinkage S.E will be made in 2013 at the WGCSE based on retrospective pattern.**

D. Short-term projection

ICES has provided advice for this stock on the basis of a short-term forecast with the exception of 2009 when the advice was based on a trends only assessment. The assessment methodology developed at this benchmark meeting is determined to be appropriate to such projections and advice. This conclusion is largely based on the diagnostics of the assessment. The forecast methodology described below has not been specifically been evaluated at the benchmark, but given the biology of the species, the understanding of fleet dynamics and the similarity to previous assessment the previous procedure as described below is considered suitable.

Input data

Short-term forecasts require the input of a selection pattern, which is taken from the average of the last three years. In cases where a Fsq forecast is appropriate (i.e. where there is no documented trend in the level of F in the final three years) the selection pattern is scaled to the average F over the final three years. When there are significant changes in F over the last three years the selectivity pattern is rescaled to the final year to estimate catches in the 'interim year'. When catches have been constrained at the level of the TAC a TAC constraint is implemented and the selectivity pattern is rescaled by the value of F that produces landings equal to the TAC for the 'interim year'.

Survivor estimates for fish greater than age three in the interim year are used in the projections. Recruits, including the last cohort in the assessment (age one, given as survivors at age 2) are not thought to be particularly reliably estimated as they are poorly selected even in the inshore survey so their values is replaced by geometric mean recruitment determined as in the paragraph below depreciated for natural mortality.

Recruitment in subsequent years is determined as geometric mean recruitment over the appropriate time-series. For this stock in recent year this is currently the entire time-series excluding the last two years (i.e. 1969–2008 for the 2011 assessment). Historically there have been periods where recruitment was thought to be lower or higher, in which case GM is calculated over a shorter recruitment-series, minus one year).

E. Medium-term projections

No longer applicable.

F. Long-term projections

Long-term projections are no longer carried out as part of the stock assessment procedure at working groups. However, STECF (SGMOS 9-02, SGMOS 10-06a) carried out long-term simulations as part of the management plan evaluations. The methodology examined the effects of different types of biases and uncertainty on the management of the stock running stochastic simulations under similar assumptions to the short-term forecast. This method was also employed to derive the level of MSY $B_{trigger}$ by WKFLAT 2012 (ICES, 2012).

G. Biological reference points

Biological reference points in this stock were originally set in 1998 as described in the Table below along with the reasoning and amended in 2001 to take account of a change to the assessment methodology.

	WG(1998)/ACFM(1998)	since WG(2001)/ACFM (2001)
		Age range extended from 1–10+ to 1–12+
F_{lim}	0.36 (F_{loss} WG98)	0.28 (F_{loss} WG01)
F_{pa}	0.26 (F_{lim}*0.72)	0.20 (F_{lim}*0.72)
B_{lim}	1800 t (B_{loss}= B73 WG98)	2000 t (B_{loss}= B_{00} WG01)
B_{pa}	2500 t (B_{lim}*1.4)	2800 t (Historical development)

The assessment methodology that formed the basis for these precautionary reference points was rejected by WKFLAT 2009 (ICES, 2009) and resulted in rejection of the reference points. ICES has adopted a provisional MSY $B_{trigger}$ based on the former B_{pa} as the technical basis. Having developed a new assessment methodology during WKFLAT 2012 (ICES, 2012) appropriate values for the assessment, given a sound technical basis, were determined as shown below.

	Type	Value	Technical basis
Precautionary approach	B_{lim}	1300 t	WKFRAME 2 meta-analysis (ICES, 2011)
	B_{pa}	1800 t	WKFRAME 2 meta-analysis (ICES, 2011)
	F_{lim}	Undefined	
	F_{pa}	Undefined	
MSY approach	F_{MSY}	0.27	Based on a suitably defined F_{max} and stochastic LT simulations
	MSY $_{Btrigger}$	2800 t	Based on the lower 95% confidence limits of exploitation at F_{max} from LT simulations.

(unchanged since 2012)

H. Other issues

H.1. Sole in Division VIIe management plan

A management plan was agreed for VIIe sole in 2007:

> Council Regulation (EC) No 509/2007 establishes a multi-annual plan for the sustainable exploitation of sole in Division VIIe. Years 2007–2009 were deemed a recovery plan, with subsequent years being deemed management plan. For 2007–2009 the TAC was required to be at a value whose application will result in a 20% reduction in F compared with F_{bar} (03–05). If this value exceeded a 15% change in TAC, a 15% change in TAC was to be implemented. Fishing mortality <0.27 was reached in 2009, although the average fishing mortality over three years as prescribed by the management plan was only reached in 2010. After reaching F_{MSY}=0.27 the stock is to be maintained at this level of fishing mortality.

H.2 Historical overview of previous assessment methods

Although this stock has been exploited historically for a long time at low levels, official landing statistics and catch-at-age data are available from 1969 onwards. At this time landings were 353 t mainly attributable to otter trawlers and netters. The development of a beam trawl fleet in UK waters lead to rapid increases in landings from the stock in the late 1970s which resulted in a commensurate decline in SSB after an initial increase in stock size to its maximum in 1980 as a consequence of particularly good recruitment in 1976. The decline as assessed by XSA occurred despite some subsequent good recruitment in 1980, 1984, 1986 until 1990 where the SSB appears to have level out near 3,000t. More recent estimates of recruitment are estimated to be high again and SSB has started to increase in response to this recruitment and reduced fishing mortality since the introduction of the single area licence since the end of 2009. Fishing mortality appears to have been stable in the fishery since the early 1980s at around 0.3 before declining to near F_{max} since 2010.

Key uncertainties with regards to the data quality/assessment quality of this stock are the uncertainty regarding the degree of mixing between this and adjacent stock, particularly with regards to recruitments, the fact that the survey covers only a small portion of the stock the lack of a discernible stock–recruit relationship which does not allow us to determine reference points with any certainty.

Table B demonstrates the history of Division VIIe sole assessments and details the assessment model used (XSA) and the parameters and settings used in each year's assessment until 2008.

I. References

ICES. 2009. Report of the Benchmark and Data Compilation Workshop for Flatfish (WKFLAT 2009), 6–13 February 2009, Copenhagen, Denmark. ICES CM 2009/ACOM:31. 192 pp.

ICES. 2011. Report of the Workshop on Implementing the ICES Fmsy Framework (WKFRAME-2), 10–14 January 2011, ICES, Denmark. ICES CM 2011/ACOM:33. 110 pp.

ICES. 2012. Report of the Benchmark Workshop on Flatfish Species and Anglerfish (WKFLAT 2012), 1–8 March 2012, Bilbao, Spain. ICES CM 2012/ACOM:47.

Horwood, J. 1993. The Bristol Channel sole (*Solea solea* (L.)): a fisheries case study. Advances in marine biology. 1993, vol. 29, pp. 215–367.

Pawson, M.G and Harley, B.F.M. 1997. (unpubl.: Cefas internal report).

Table A. VIIe Sole. Catch derivation table for assessment years 1981–2007.

		source			
Year of WG	Data	UK	France	derivation of international landings	% sampled
1981	length composition	quarterly	quarterly	UK ALKs applied to French LDs	95
	ALK	quarterly	-	UK+France raised to total international	
	Age composition	quarterly	-		
1982		As for 1981	As for 1981	As for 1981	99
1983		As for 1981	As for 1981	As for 1981	92
1984		As for 1981	As for 1981	As for 1981	96
1985		As for 1981	As for 1981	As for 1981	96
1986		As for 1981	As for 1981	As for 1981	96
1987	length composition	quarterly	quarterly	UK+France raised to total international	95
	ALK	quarterly	quarterly		
	Age composition	quarterly	quarterly		
1988		As for 1987	As for 1987	As for 1987	96
1989		As for 1987	As for 1987	As for 1987	95
1990		As for 1987	As for 1987	As for 1987	94
1991		As for 1987	As for 1987	As for 1987	96
1992		As for 1987	As for 1987	As for 1987	97
1993		As for 1987	As for 1987	As for 1987	94
1994	length composition	quarterly	quarterly	UK ALKs applied to French LDs	92

		source			
Year of WG	Data	UK	France	derivation of international landings	% sampled
	ALK	quarterly	-	UK+France raised to total international	
	Age composition	quarterly	-		
1995	length composition	quarterly	-	UK raised to total international	81
	ALK	quarterly	-		
	Age composition	quarterly	-		
1996		As for 1995	-	As for 1995	78
1997		As for 1995	-	As for 1995	73
1998		As for 1995	-	As for 1995	64
1999		As for 1995	-	As for 1995	57
2000		As for 1995	-	As for 1995	56
2001		As for 1995	-	As for 1995	59
2002		As for 1995	-	As for 1995	60
2003	length composition	As for 1995	quarterly	UK and French raised to total international	~95%
	ALK	As for 1995	biannually		~95%
2004		As for 1995	As for 2003	As for 2003	~95%
2005		As for 1995	As for 2003	As for 2003	~95%
2006		As for 1995	As for 2003	As for 2003	~95%
2007		As for 1995	As for 2003	As for 2003	~95%
2008		As for 1995	As for 2003	As for 2003	~95%
2009		As for 1995	As for 2003	As for 2003	~95%
2010		As for 1995	As for 2003	As for 2003	~95%

Table B. History of VIIe sole assessments.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Assmnt Age Range	1-9+	1-9+	1-9+	1-10+	1-10+	1-10+	1-10+	1-10+	1-10+	1-10+	1-12+	1-12+	1-12+	1-12+	1-12+	1-12+	1-12+	1-12+
Fbar Age Range	F(3-8)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)	F(3-7)
Assmnt Method	L.S.	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA	XSA
Tuning Fleets																		
UK Inshore beam Ages	1983-92 2-9	1973-92 2-9	1973-92 2-9	1973-93 2-9	1973-93 2-9	1986-95 2-9	1987-96 2-9	1983-97 2-9	1984-98 2-9	1986-99 2-9	1986-00 2-11			1973-87 2-11	1973-87 2-11	1973-87 2-11	1973-87 2-11	1973-87 2-11
UK Offshore beam Ages	1983-92 3-9	1973-92 3-9	1973-92 3-9	1973-93 3-9	1973-93 3-9	1986-95 3-9	1987-96 3-9	1983-97 3-9	1984-98 3-9	1986-99 3-9	1986-00 3-11			1973-87 3-11	1973-87 3-11	1973-87 3-11	1973-87 3-11	1973-87 3-11
UK < 24m beamtr Ages												1989-01 2-11						
UK > 24m beamtr Ages												1988-01 2-11						
UK combined beam Ages													1988-02 3-11	1988-03 3-11	1988-04 3-11	1988-05 3-11	1988-06 3-11	1988-07 3-11
UK otter trawl Ages												1988-01 3-11	1988-02 3-11	1988-03 3-11	1988-04 3-11	1988-05 3-11	1988-06 3-11	1988-07 3-11
UK BTS yrs Ages		1984-91 2-6	1984-92 2-6	1984-93 1-6	1984-94 1-6	1986-95 1-6	1987-96 1-6	1983-97 1-6	1984-98 1-6	1984-99 1-6	1984-00 1-6	1984-01 1-6	1988-02 1-6	1988-03 1-9	1988-04 1-9	1988-05 1-9	1984-06 1-9	1988-07 1-9
Time taper		20yr tri	20yr tri	20yr tri	20yr tri	No	No	No	No	No	No	No	No	No	No	No	No	No
Power model ages		1	1-2	1-4	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	No	No	No	No
P shrinkage		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Q plateau age		8	5	6	7	7	7	7	7	7	9	9	9	9	9	8	8	8
F shrinkage S.E		0.3	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0
Num yrs		5	5	5	5	5	5	5	5	5	5	5	5	5	3	4	5	5
Num ages		5	3	5	3	3	3	3	3	3	5	5	5	5	5	5	5	5
Fleet S.E.		0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5

	2009	2010	2011	2012
Assmnt Age Range		1-12+	1-12+	1-12+
Fbar Age Range		F(3-9)	F(3-9)	F(3-9)
Assmnt Method	Trends	XSA	XSA	XSA
Tuning Fleets				
UK Inshore beam Ages		1973- 87 2-11	1973- 87 2-11	
UK Offshore beam Ages		1973- 87 3-11	1973- 87 3-11	
Q1SWBeam (offset by 1y 1a)				2006- 11 2-12
UK-FSP				2004- 11 2-11
UK combined beam Ages (early)		1988- 09 3-11	1988- 10 3-11	1988- 02 3-11
UK combined beam Ages (late)				2003- 11 3-11
UK otter trawl Ages		1988- 09 3-11	1988- 10 3-11	1988- 11 3-11
UK BTS yrs Ages		1988- 09 1-9	1988- 10 1-9	1988- 11 1-9
Time taper		No	No	No
Power model ages		No	No	No
P shrinkage		No	No	No
Q plateau age		8	8	6
F shrinkage S.E		1.0	1.0	0.5
Num yrs		10	10	3
Num ages		5	5	5
Fleet S.E.		0.5	0.5	0.6

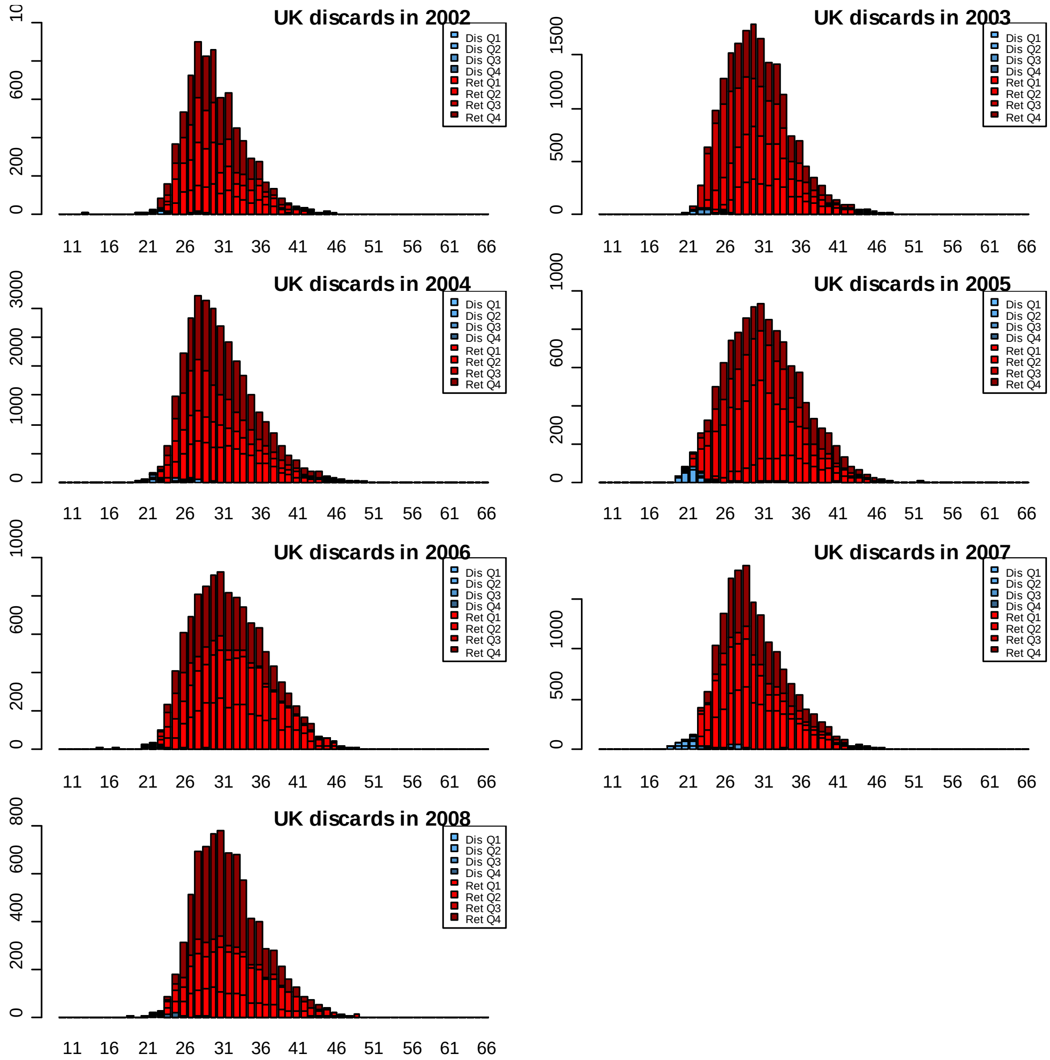


Figure A2.1. Time-series of UK discard data raised to trip information.

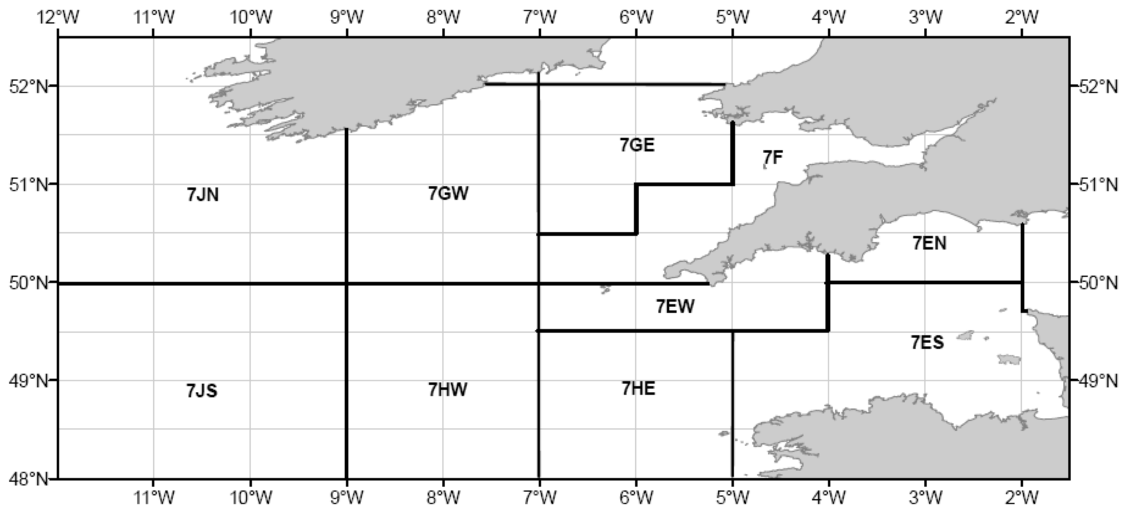


Figure B4.1. Areas used for the calculation of lpue time-series exploring temporal changes in the distribution of stock and effort.

Appendix 1: Beam trawl surveys of the western English Channel (ICES Division VIIe)

1. History of the survey

Complaints from the fishing industry in the southwest about the lack of scientific investigation and knowledge of the local sole stock provided the catalyst for the survey in VIIe. Following enquiries of the local fishery officers and normal tendering procedures, a skipper-owned 300 hp beam trawler, the Bogey 1, was selected. The first year (1984) the survey consisted of a collection of tows on the main sole grounds. In 1989 the Bogey 1 was replaced with the Carhelmar and the survey continued unchanged until 2002 when RV Corystes took over the survey as an extension to its 'near-west groundfish survey'.

As a consequence of the changes occurring through the time-series, the surveys completed on RV Corystes (2002 onwards) will be described separately to the 'previous' surveys (pre-2002).

2.a. Survey objectives (1984 to 2001)

To provide independent (of commercial) indices of abundance of all age groups of sole and plaice on the west channel grounds, and an index of recruitment of young (1–3 year old) sole prior to full recruitment to the fishery.

2.b. Survey objectives (2002 to present)

The primary objectives of the Irish Sea beam trawl survey are to (a) carry out a 4 m beam trawl survey of groundfish to i) obtain fisheries-independent data on the distribution and abundance of commercial flatfish species, and ii) derive age compositions of sole and plaice for use in the assessment of stock size; and (b) to collect biological data, including maturity and weight-at-age, for sole, plaice, lemon sole and other commercially important species. The epibenthic bycatch from these catches has been quantified, and these surveys are also used to collect biological samples in support of other Cefas projects and training courses.

3.a. Survey methods (1984 to 2001)

For the years 1984–1988 the vessel was unchanged and was equipped with two 6 m chain mat beam trawls with 75 mm codends. For the survey hauls one of the codends was fitted with a 60 mm liner. In 1989 the Bogey 1 was replaced by the latest design 24 m 300 hp (220 kw) beam trawler Carhelmar. In 1988 two commercial chain mat 4 m beam trawls (measured inside the shoe plates) were purchased by MAFF as dedicated survey gear. Both beams were fitted with the standard flip-up ropes and 75 mm codend. For years 1989 and 1990 only 1 codend was fished with a 40 mm liner but from 1991 with the introduction of 80 mm codends both were fitted with 40 mm liners. The vessel and gear has remained unchanged since 1991.

Between 1989 and 2001 the survey remained relatively unchanged apart from small adjustments to the position of individual hauls to provide an improved spacing. In 1995 two inshore tows in shallow water (8–15 m) were introduced. The survey now consists of 58 tows of 30 minutes duration, with a towing speed of 4 knots in an area within 35 miles radius of Start Point. The survey design is stratified by 'distance from the coast' bands, in contrast to the VIIa,f+g survey that is stratified by depth bands. The reason for this is that the coastal shelf with a depth of water less than 40 m is relatively narrow and in addition is often fished with fixed gear. The survey bands (in miles) are 0–3, 3–6, 6–12, 12+ inshore, and 12+ offshore.

3.b. Survey methods (2002 to present)

The standard gear used is a single 4 m beam trawl with chain mat, flip-up rope, and a 40 mm codend liner to retain small fish. The gear is towed at 4 knots (over the ground) for 30 minutes, averaging 2 nautical miles per tow. Fishing is only carried out in daylight, shooting after sunrise and hauling no later than sunset, as the distribution of some species is known to vary diurnally.

Once on board the catch is sorted to species level, with the exception of small gobies and sandeels, which are identified to genus. Plaice, sole, dab, and elasmobranchs are sorted by sex, all fish categories weighed, and total lengths are measured to the full centimetre below, or half centimetre if the species is pelagic. Area stratified samples of selected species are sampled for weight, length, sex, maturity, and otoliths or scales removed for ageing.

The standard grid of 58 stations was fished in 2002 and 2003 (see map), and although other stations have been fished in this period, they were for exploratory purposes and were not included in the assessment.

4. Abundance index calculation

Plaice and sole abundance indices are calculated by allocating the appropriate ages to the fish that are caught. This gives the age composition (AC) of the catch, and this is used in the appropriate working group analysis.

The AC's are calculated by proportioning a length distribution (LD) to an appropriate age–length key (ALK). To account for possible population differences within ICES Division VIIe, biological samples are taken from sectors stratified by distance from shore (see map). The survey bands (in miles) are 0–3, 3–12, 12+ inshore, and 12+ offshore. Where appropriate the ALK's are separated by sex, and this allows a particular 'sector, depth-band and sex' ALK to be raised to the corresponding LD to give an accurate AC for that particular habitat. The AC's can then be combined as required to give results in the form of 'numbers-at-age, per distance or time'.

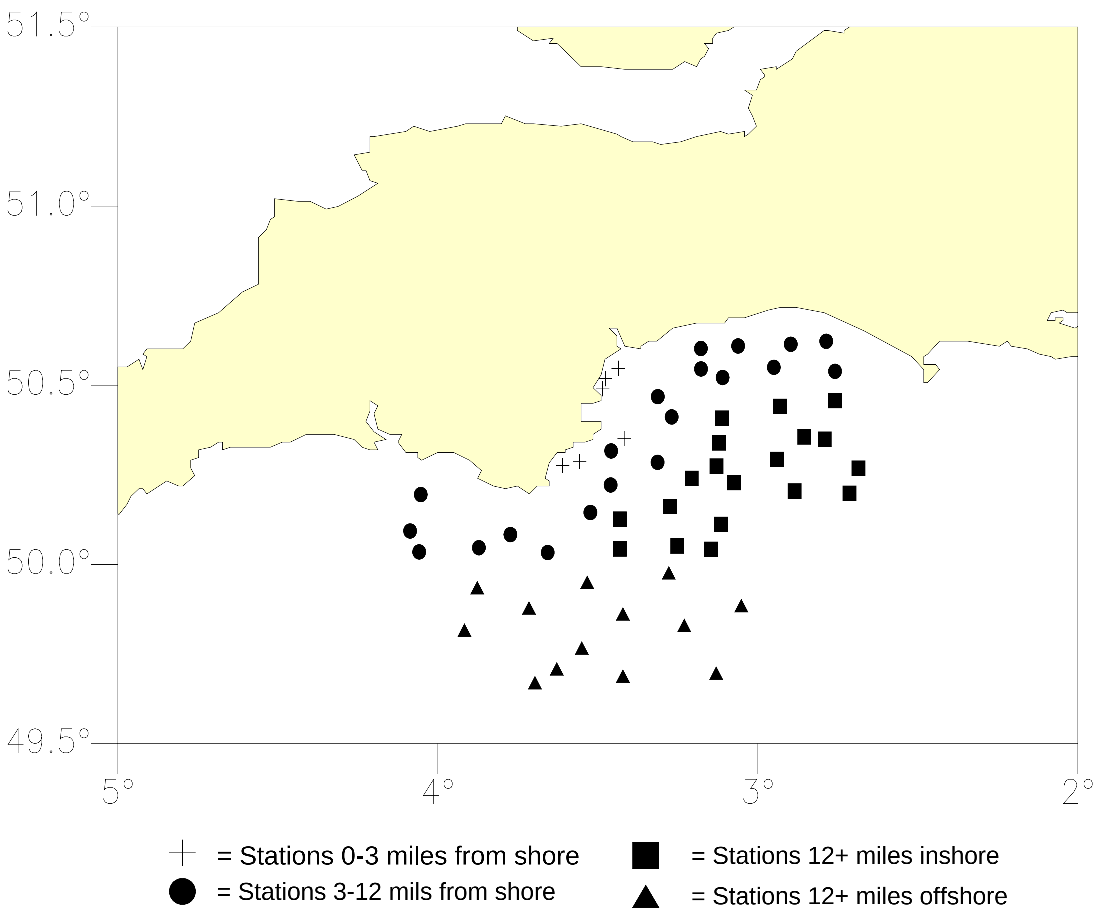
Between 1984 and 1990 a total survey age–length key was applied to the 'grid' length distribution, but from 1990 onwards stratum stratified age–length keys were used.

The Table below demonstrates the stratifications currently used to calculate the 'near-west groundfish survey' abundance indices.

		ALK stratified by			LD stratified by			
Species	**Sector**	**Sector**	**Depth band**	**Sex**	**Sector**	**Depth band**	**Sex**	**Used in assessment?**
Plaice	VIIe	✓	✓	✓	✓	✓	✓	✓
Sole	VIIe	✓	✓	X	✓	✓	X	✓

5. Map of survey grid

Additional stations have been fished throughout the time period, but as these stations are not consistently fished, they are excluded from this map.



6. Summary

Area covered	ICES Division VIIe
Target species	Flatfish, particularly prerecruit plaice and sole
Time period	September–October. 1988 to present.
Gear used	1984–1988 – 2 * 6m beam trawls
	1989–present , except 2002,2004 – 2 * 4m beam trawls
	2002, 2004 – 1* 4m beam trawl
Mean towing speed	4 knots over the ground
Tow duration	30 minutes
Vessel used	F.V. Bogey 1 1984–1988
	F.V. Carhelmar 1989–2001, 2003 and 2005–present
	R.V. Corystes 2002 and 2004

Annex 7: Score card results

Megrim 78.

How to fill?	No bias	Potential bias	Confirmed bias	Comment
A. SPECIES IDENTIFICATION				
1. Species subject to confusion and trained staff	X			
2. Species misreporting			X	
3. Taxonomic change	X			
4. Grouping statistics	X			
5. Identification Key	X			
Final indicator	X			
B. LANDINGS WEIGHT				
Recall of bias indicator on species identification				
1. Missing part	X			
2. Area misreporting	X			
3. Quantity misreporting	X			
4. Population of vessels	X			
5. Source of information	X			
6. Conversion factor	X			
7. Percentage of mixed in the landings	X			
8. Damaged fish landed	X			
Final indicator	X			
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme			X	Low sampling level . It is supposed not to cover properly all megrim metiers
2. Raising variable		X		No all raising procedures have been documented or even tried.
3. Size of the catch effect		X		Possible to occur
4. Damaged fish discarded	X			
5. Non response rate		X		
6. Temporal coverage		X		
7. Spatial coverage			X	
8. High grading			X	
9. Slipping behaviour	X			
10. Management measures leading to discarding behaviour			X	
11. Working conditions		X		
12. Species replacement	X			
Final indicator			X	
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition		X		Just for France in the last two years of the series (2009 and 2010)
2. Area misreporting	X			
3. Effort misreporting	X			
4. Source of information		X		
Final indicator		X		
E. LENGTH STRUCTURE				
Recall of bias indicator on discards/landing weight				
1. Sampling protocol	X			
2. Temporal coverage	X			
3. Spatial coverage	X			Forlandings
4. Random sampling of boxes/trips	X			
5. Availability of all the landings/discards	X			For discards
6. Non sampled strata	X			
7. Raising to the trip	X			
8. Change in selectivity		X		
9. Sampled weight		X		
Final indicator	X			

Megrim 78 continued.

How to fill?	No bias	Potential bias	Confirmed bias	Comment
F. AGE STRUCTURE				
Recall of bias indicator on length structure				
1. Quality insurance protocol	X			
2. Conventional/actual age validity		X		There is good agreement till age 6 (80%) for older ages agreement decreases to 20%
3. Calibration workshop	X			
4. International exchange	X			
5. International reference set		X		
6. Species/stock reading easiness and trained staff	X	X		Information included in the last Exchange report of Megrim
7. Age reading method	X			
8. Statistical processing	X			
9. Temporal coverage	X			
10. Spatial coverage	X			
11. Plus group	X	X		
12. Incomplete ALK	X			
Final indicator	X			
G. MEAN WEIGHT				
Recall of bias indicator on length/age structure				
1. Sampling protocol	X			
2. Temporal coverage	X			
3. Spatial coverage	X			
4. Statistical processing	X			
5. Calibration equipment	X			
6. Working conditions	X			
7. Conversion factor	X			
8. Final indicator	X			
H. SEX RATIO				
Recall of bias indicator on length/age structure				
1. Sampling protocol		X		
2. Temporal coverage		X		
3. Spatial coverage		X		
4. Staff trained		X		
5.Size/maturity effect		X		
6. Catchability effect		X		
Final indicator		X		
I. MATURITY STAGE				
Recall of bias indicator on length/age structure				
1. Sampling protocol	X			Some difficulties in all lengths been covered as fish smaller than 20–25 cm are discarded. Still in use BIOSDEF (1998) Ogive as considered the best sampled ogive.
2. Appropriate time period	X			
3. Spatial coverage		X		
4. Staff trained	X			
5. International reference set		X		
6. Size/maturity effect		X		
7. Histological reference	X			There is an histological reference (Santurtun *et al*., 2000)
8. Skipped spawning	X			
Final indicator	X			
Final indicator		X	X	**Red for an important part of the catch (DISCARD) which leads to an underestimation of the catch at age matrix difficulting the work of the Assessment WG.**

Sole VIIe.

	no Bias	Potential bias	Confirmed bias	Comment
SPECIES IDENTIFICATION				
Species subject to confusion and trained staff	x			Easy to ID correctly
Species misreporting	x			Could potentially be landed as sandsole - but only if skinned
Taxonomic change	x			No evidence
grouping statistics	x			No evidence
Identification Key	x			good quality keys available
Final indicator	5	0	0	
LANDINGS WEIGHT				
Recall of bias indicator on species identification	5	0	0	
Missing part		x		No current necessity to black land - but this was not the case prior to the management plan being implemented in 2004
Area misreporting		x		No current necessity to mis-report - but this was not the case prior to the management plan being implemented in 2004
Quantity misreporting		x		<10m fleet landings not going to auction?
Population of vessels		x		<10m fleet landings not going to auction?
Source of information		x		Logbook data for >10m vessels, monthly declarative forms <10 (France), buyers/sellers data for <10 but landings not always going to auctions?
Conversion factor	x			Fixed conversion factors - generally landed gutted.
Percentage of mixed in the landings	x			Not landed in mixed species boxes
Damaged fish landed	x			damaged fish unlikely to be discarded
Final indicator	8	5	0	
DISCARDS WEIGHT				
Recall of bias indicator on species identification	5	0	0	
Sampling allocation scheme		x		Gaps in sampling scheme, unable to sample aboard some metiers. Difficulty to follow the sampling scheme due administrative and logistic issues
Raising variable		x		Discard raising not currently included in assessment
Size of the catch effect	x			
Damaged fish discarded	x			damaged fish unlikely to be discarded
Non response rate			x	H+S grounds
Temporal coverage	x			levels.
Spatial coverage	x			Main area of fishery covered
High grading	x			Little high grading
Slipping behaviour	x			Does not occur in demersal fisheries
Management measures leading to discarding behaviour	x			Discarding is largely quota driven
Working conditions		x		Sampled weights are calculated (no scales taken)
Species replacement	x			
Final indicator	13	3	1	
EFFORT				
Recall of bias indicator on species identification	5	0	0	
Unit definition	x			
Area misreporting		x		in recent years
Effort misreporting	x			No necessity
Source of information		x		reported
Final indicator	7	2	0	

Sole VIIe continued.

	no Bias	Potential bias	Confirmed bias	Comment
LENGTH STRUCTURE				
Recall of bias indicator on discards/landing weight	8	5	0	
sampling protocol	x			all 'size' of ports now sampled. Concurrent sampling implemented from 2009 (France) increased the number of samples but decrease the total number of individual measured, this is good procedure provided that there is sufficient individuals measured
Temporal coverage	x			Sampling good across quarters
Spatial coverage	x			Main area of fishery covered
Random sampling of boxes/trips	x			Random sampling protocols in place
Availability of all the landings/discards		x		Not all catches on markets (pre-sold)
Non sampled strata	x			Major metiers/ports sampled
Raising to the trip		x		Good category weight information - but some recent evidence of non-category sampling
Change in selectivity	x			No evidence
Sampled weight		x		Can be affected by Icing the box
Final indicator	14	8	0	
AGE STRUCTURE				
Recall of bias indicator on length structure	14	8	0	
Quality insurance protocol	x			Annual QA procedures in place
Conventional/actual age validity		x		Difficult to evaluate, especially for old ages
Calibration workshop	x			Within last 5 years
International exchange	x			Within last 5 years
International reference set	x			From workshop
Species/stock reading easiness		x		Generally OK - mostly <8 years old but do get occasional sample >30 years old. Older males can be awkward.
Staff trained for age reading	x			Established training SOP's and training records in development
Age reading method	x			Established methods used (B+B and sectioned/stained otoliths)
Statistical processing				NA
Temporal coverage	x			Good coverage through quarterly sampling targets
Spatial coverage	x	x		Good
Plus group	x			no plus group used in ageing. 'True' age is determined for all fish.
Incomplete ALK		x		Possible need to use port base or spatial age keys to counter different structures in the catches.
Final indicator	23	12	0	
MEAN WEIGHT				
Recall of bias indicator on length/age structure	23	12	0	
Sampling protocol	x			Individual fish weights taken
Temporal coverage	x			Sampling good across quarters
spatial coverage	x			Good
Statistical processing	x			Recent Condition factors available.
Calibration equipment	x			User guides available for re-calibration
Working conditions	x			Not a factor on Markets. Good quality balances used at sea or at the lab.
Conversion factor	x			N/A
Final indicator	30	12	0	
SEX RATIO				
Recall of bias indicator on length/age structure	23	12	0	
Sampling protocol	x			Samples measured unsexed – samples taken when collecting the otoliths for ageing
Temporal coverage	x			Sampling good across quarters
spatial coverage	x			Good
Staff trained	x			Well trained staff in place
Size/maturity effect	x			Species easy to sex even at small sizes
Catchability effect	x			
Final indicator	29	12	0	

Sole VIIe continued.

	no Bias	Potential bias	Confirmed bias	Comment
MATURITY STAGE				
Recall of bias indicator on length/age structure	23	12	0	
Sampling protocol	x			
Temporal coverage	x			Sampling good across quarters 1 and 4 only
spatial coverage	x			Good
Staff trained		x		Workshops held in 2010 & 2012
International reference set		x		Workshops held in 2010 & 2012
Size/maturity effect	x			
Histological reference		x		Workshops held in 2010 & 2012
Skipped spawning	x			(to be checked)
Final indicator	28	15	0	

Final Statement about bias

Probable bias in landings/effort if <10m vessels trip data not available

Discards are generally low but the fleets are well sampled

Not all metiers sampled for discarding - H+S issues and refusals to sample. Sampling designed to cover the main metiers, not specifically for sole may generate bias and high uncertainties

Some auctions do not present the entire landings of a vessel to the buyers (pre-sales), this can affect length structure

Lack of randomness in sampling for length, majority of minor harbours are never sampled - but this is being addressed

Spatial coverage of all samples not considered a problem

Reference set for maturity about to be provided by the WKMSSPDF (2010/2012)

Icing of boxes on markets can affect sample weight if not accounted for in sampling

Make sure that all countries continue/increase on-board sampling

Welsh Assembly Govt. (WAG) now responsible for sampling UK (Wales) landings. Sampling program may not be in place!

Bias filled in from UK(England) perspective only. This will need revising in light of French information for this stock)