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Report of the Benchmark Workshop on Western Waters Roundfish (WKROUND)

22–29 February 2012

Aberdeen, UK

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive summary

Benchmark Workshop on Western Waters Roundfish (WKROUND) met in Aberdeen (UK) February 22–29 2012 to perform a benchmark assessment on the stocks of Cod in Divisions VIa, VIIa and VII e–k, Whiting in Division VIa and Haddock in Division VIIb–k. All the terms of reference were addressed, but most attention was on data and assessment methods.

For all the stocks, a procedure for obtaining data and performing an analytic assessment was recommended and approved by the group and the reviewers. Stock identity was considered and it was concluded that the current stock units are adequate for assessment purposes. A caveat was noted, however, that each stock may consist of several substocks, which may require specific attention by management.

For all stocks, assumed natural mortalities were revised according to the Lorenzen formula which links natural mortality to body weight. These natural mortalities were assumed to be constant over time, but are higher at young age than the previously used value of 0.2.

Discard estimates were revised for most stocks, and included in the assessment as relevant. Survey data were scrutinized, and the most reliable tuning data selected, sometimes by combining several surveys. The main survey in Division VIa changed in 2011. Consequently, the assessments in that area will have to be made without that information from 2012 onwards until the new series is long enough to provide reliable catchability estimates.

For Cod in Division VIa, TSA was revised prior to the meeting, and further modified to estimate underreporting of catches in the period 1990–2005, while still using the age structure of the sampled catches in that period. It was confirmed that the method could be applied without survey information in the most recent years; however it is not known whether this result is general as the most recent survey data were not highly informative. Predation by seals was considered, but it was recommended not to include this source of mortality in the assessment. However, it was recommended to provide an additional assessment incorporating the best available estimate of seal consumption for comparison.

For Whiting in Division VIa, TSA was recommended as the assessment model. Here, the Irish groundfish survey could be used as supporting information.

For Cod in Division VIIa major progress was made in establishing an assessment method. SAM was approved as the assessment tool. SSB estimates from egg surveys as well as data from the Fisheries Science Partnership roundfish surveys were included. The assessment still requires refinement and a list of recommended actions is included. The new method does not alter the current advice to keep the fishery closed.

For Cod in Divisions VII e–k, a major revision of the input data to the assessment was done, leaving only a merged French/Irish bottom-trawl survey and a French cpue series as tuning data. Both ASAP and XSA could be recommended for assessing this stock. XSA was preferred because the involved analysts have more experience with this method.

For Haddock in Divisions VII b–k, the data in the early period are very noisy and the available tuning-series are short. It was concluded that the estimates of the state of the stock in the most recent years is more reliable than estimates of long-term trends,

and sufficient to derive TAC recommendations. ASAP was proposed as the main method for assessment, with support by XSA.

1 Introduction

The WKROUND 2012 met in Aberdeen, UK to address the following terms of reference:

2011/2/ACOM50 A **Benchmark Workshop on Western Waters Roundfish (**WKROUND), chaired by External Chair Dankert Skagen, Norway, ICES coordinator Colm Lordan, Ireland, and two invited external experts Michael Palmer (USA) and Liz Brooks (USA) will be established and will meet in Aberdeen, UK, 22–29 February 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 about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology.

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 MSY 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;

The Benchmark Workshop will report by 15 March 2012 for the attention of ACOM.

All the terms of reference were addressed, but as outlined below, most attention was on data revisions and assessment methods. A data compilation workshop as mentioned in ToR e(i) was not held, but the task was covered before and during the meeting.

Stock identity was considered based on two Working Documents, as described in Section 2. It was concluded that the present stock units are adequate for assessment and management purposes, with the caveat that each stock may consist of several substocks, which may require specific attention by management.

Sections 3–7 describe, by stock, the work that was done at the workshop. For each stock, the report includes a description of the current status of assessment and advice, overview of data sources, including revisions and proposals for future use and improvements, current and proposed assessment and short-term prediction methods, and notes on implications for reference points. Time did not allow for the in-depth considerations of reference points outlined by WKFRAME.

Section 8 presents comments to the process by the external reviewers.

The WKROUND initially scrutinized the available data, including updates to several datasets, and considered their usefulness as information about the state and the history of the stocks. Some dataseries were excluded from assessments on various grounds. The dataseries that were excluded were primarily tuning data that ended several years ago and overlapped with longer series as well as cpue data from local fisheries and surveys that could not be assumed to cover the stock in a stable way. The Scottish groundfish surveys, which have been the backbone of the assessments for roundfish stocks in Division VIa, were altered in 2011 with a new gear and a new survey design. It was concluded that the old and new survey were too incompatible to be combined. Therefore, for these stocks, the main tuning information is lost for a number of years ahead. As soon as catchability estimates for this new survey can be reliably estimated, this survey should be included as a separate time-series.

Discarding is prominent in all these fisheries, and although data on discards are available from observer programs, these data only cover the most recent period and the number of observed trips is generally very low. For several stocks, there are also clear indications of underreporting or misreporting of landings in some periods, often triggered by the introduction of regulations aimed at reducing fishing pressure. To some extent, there was information available to provide estimates that could be used to correct the landings data externally. Alternatively, the levels of misreporting were estimated internally within the assessment model by including multipliers to the catches that could be estimated with the support of survey data. The way to approach these problems is described in detail for each stock.

Predation by seals is regarded as an important source of mortality of cod in Division VIa. The available data were considered and it was decided to leave out predation by seals in the routine assessments, but to present an assessment with this information as a sensitivity analysis. This rationale was based on several factors including the uncertainty with respect to the actual level of the additional mortality and the relative stability of the grey seal populations. Since the seal predation most likely is quite stable over time, the inclusion of seal predation would mostly imply a rescaling of the stock abundance estimates rather than leading to new perceptions about the stock dynamics, and thus would have only a minor influence on the catch advice.

For all stocks, new values for natural mortality were calculated,, based on the Lorenzen equation (Lorenzen, 1996), where natural mortality varies with the weight of the fish. These values were used for all stocks except for VIIa cod, where the method still needs refinement. This brings assumed levels of natural mortality for the stocks in the western waters in line with what is assumed for the North Sea and several other areas. No attempts were made to include time dynamics in the natural mortality, so the only effect of the revision is a rescaling of the abundance estimates at younger ages.

For all of the stocks, the assessment might be considered as problematic. Some assessments have been accepted in the past, but none of them have been firmly established. The data problems outlined above imply that routine methods may not be readily applicable. Rather, most of the stocks represented methodological challenges. Therefore, the methodological aspect was more prominent at this benchmark than in many others. Developing solutions for such problems must be an incremental process. The methods proposed here cannot be regarded as the final answer, but the WKROUND concluded that they were sufficiently mature to be used as a basis for management advice in the coming years. Nevertheless, improvements can be expected, and should be considered as they emerge.

Apart from seal predation, environmental influence on the stocks was not considered in depth. Hence, issues such as the contribution of environmental factors to the poor recruitment seen in several of the stocks, or predictors of strong year classes, as have appeared in the Celtic Sea recently, remain unanswered.

Major progress was made for all the stocks with regard to consolidating the input data and with regards to assessment methods at this benchmark. The work was concentrated on these aspects, which left less time available for considering other terms of reference. The need to revise reference points and implications for short-term prediction procedures were considered, but only briefly. In particular, time did not allow for the in depth considerations of reference points outlined by WKFRAME.

2 Stock identity

As part of the benchmark process, the WKROUND addressed question of whether the current stock units are adequate for assessment and management purposes. Two working papers were presented to the WG on this subject.

One by Peter Wright (WD#4) was an overview of the evidence for stock structure primarily in Scottish waters, including distribution of fishing grounds, genetics, particle tracking and otolith microchemistry. The fishery in recent years is concentrated in two distinct areas, one near the shelf break extending into the northern North Sea and one more inshore in the Minch/Firth of Clyde region (M/C for short). Genetically, there appears to be differences between these areas. Particle tracing indicates that eggs and larvae from the M/C area tend to be retained there, while particles from the shelf break outside the Outer Hebrides is transported northeastwards with the major currents along the shelf break. This pattern is also supported by otholith microchemistry studies. Hence, there is evidence that the cod in Division VIa is composed of two major components, one associated with the shelf break extending into Division IVa, and one more inshore from the Minch to the Firth of Clyde.

WD#9 by Bendall *et al*. summarizes results of tagging studies in the waters covered by WKROUND. The material is partly conventional tags that have been released on several occasions since the 1960s, and partly recent releases of data storage tags (DST). Conventional tags have been released and recaptured in all parts of the area and in all seasons. DSTs were released mostly since 2007. Altogether 291 DSTs have been released, and for 81 of them the movement could be reconstructed. In summary, this study indicates that although there is evidence for seasonal migrations into neighbouring regions, most fish will stay within its management area. The seasonal migrations may have implications for survey coverage.

The WKROUND2 concluded from these studies that:

- The present evidence does not call for radical changes in the current assessment units. Most fish can be expected to remain within its respective area.
- Seasonal migrations, sometimes leading outside the area, may affect catchability in surveys. In particular, surveys in quarter 4 in Division VIIa may not pick up all ages properly.
- Within each area, the population of cod is likely to consist of several partly isolated substocks. The opportunity for exchange may be variable, but in general, one cannot expect a depleted substock to be repopulated from neighbouring areas.
- For management, this implies that in addition to maintaining the current stocks units at a productive level, care needs to be taken to avoid depletion of local stock components.

3 Cod in Division VIa

3.1 Overview of data sources

3.1.1 Landings

Official landings of cod come mainly from Scotland, France, Ireland, Norway and Spain. Landings by Scottish and Irish vessels constitute roughly 65–75% of official landings over the last decade. The following table gives the source of landings data for West of Scotland cod:

	Kind of data				
Country	Caton (catch-in-weight)	Canum (catch-at-age in numbers)	Weca (weight-at-age in the catch)	Matprop (proportion mature-by-age)	Length composition in catch
UK(NI)	X				
UK(E&W)	X				
UK(Scotland)	X	X	X	X	X
Ireland	X	X	X		X
France	X				
Norway	X				

Figures 3.1 to 3.3 show the result of linking logbook and vessel monitoring system (VMS) data from the Scottish and Irish fleets to infer the distribution of cod landings. The figure of absolute tonnages (Figure 3.1) shows the majority of recent landings to have come from the shelf edge and concentrated in the north and south of the region. The figures of lpue and proportion of cod in landings (Figures 3.2 and 3.3) show that cod are not as absent in inshore waters as the absolute landings values suggest and Figure 3.3 shows an area adjacent to the north coast of Ireland where fishing trips retain a significant proportion of cod in the landings.

3.1.2 Area misreporting and underreporting

The existing assessment only includes landings and discard numbers-at-age data up to 1994 because of concerns over deteriorating quality of landings data from the mid 1990s onwards. From 2006 the Registration of Buyers and Sellers legislation in the UK and Sales Notes management system in Ireland are believed to have reduced under reporting to low levels.

Marine Scotland Compliance regularly compares VMS data from vessels with the areas from which landings are reported to have originated, and uses this as the basis for Figure 3.4 of suspected and detected area misreporting and under-reporting. Underdeclaration (that is, underreporting by weight) was substantial in 2001, then declined to a very low level following introduction of the Buyers and Sellers regulation. Figure 3.4 also shows an increase in area misreporting out from VIa.

WKROUND concluded that because estimates of area misreporting are aided by VMS data they could be considered reliable enough for the basis of correcting reported landings. It was debated whether area misreported landings would be associated with the same level of discards as estimated for landings reported into VIa. It is known that discard ratios are significantly different between vessels targeting gadoids and anglerfish and those targeting *Nephrops* and further work will be conducted to determine the composition of area misreported landings in terms of gear type. The discard ratio of misreported catch will always be uncertain to a greater or lesser extent and WKROUND concluded application of a correction factor to landings and discards was acceptable, that is

$$\hat{n}_{a,y} = n_{a,y} * \frac{(W_{ICES,y} + W_{mis,y})}{W_{ICES,y}},$$

where $n_{a,y}$ is number of fish at age a in year y in the landings or discards reported to ICES, $W_{ICES,y}$ is the total weight of landings supplied to ICES in year y and $W_{mis,y}$ the total net weight of misreported landings. Scottish landings represent the majority of those reported into VIa (see WD 5) and WKROUND also considered application of the correction to the international data was acceptable as giving a first approximation to an unbiased input of landings and discards.

3.1.3 Discards

To date estimates of discards are available only from Scotland and Ireland. Observer data are collected using standard at-sea sampling schemes. A table of data made available by year is given below.

Country	1978–2003	2004–2005	2006–2009	2010	2011*
UK(Scotland)	X	X	X	X	X
Ireland		X		X	X

*** Irish discard ratio only applied to Irish landings (small sample size).**

Discard data is available from 1978 but the observer programme was very limited until 1981. Discards are almost exclusively at ages one and two until 2005. From 2006 discards are consistently recorded at ages three and four and sometimes at older ages. This is considered to be a reflection of how the Buyers and Sellers and Sales notes legislation has prevented undeclared landings. As stated above it is not known whether discards are affected by area misreporting in the same way as landings and an analysis of the gear type(s) suspected as misreporting might help in this respect.

Cod in VIa is caught by both finfish and *Nephrops* targeted fleets and this means the proportion of cod in a catch discarded can vary greatly dependent on the quota held by a vessel and its targeted species. Discards up to 2008 were raised using cod landings from the same vessel as the auxiliary variable. Millar and Fryer (2005) found this could lead to considerable bias in some years and developed a new method of raising the same raw discard data from the Scottish fleet, first presented at $WGNSDS_{2004}$, which demonstrated a reduction in estimation bias. Discard data from the Scottish fleet was raised against a group of gadoid species (cod, haddock, whiting, saithe) in 2009 and since 2010 the gadoid species and *Nephrops*.

3.1.4 Surveys

ScoGFS – WIBTS – Q1: 1985–2010. Ages 1 to 6 where oldest age is a true age. Fixed station design. This survey-series has been used in assessments of VIa cod to date. Log mean standardised survey indices and log catch curves for this survey are shown in Figure 3.5. The series finished in 2010 to be replaced by the New Scottish first-quarter west coast groundfish survey – Q1 (no formal code assigned yet) – Q1.

ScoGFS – WIBTS – Q4: 1996–2009. Ages 1 to 6 where oldest age is a true age. Fixed station design. Consideration of log mean standardised survey indices and log catch curves for this survey (Figure 3.6) suggest modest to poor self consistency (a weak ability to track cohorts). The series also finished in 2009 to be replaced by the New Scottish first-quarter west coast groundfish survey – Q4. Exploratory assessment runs were conducted using this survey in addition to the ScoGFS – WIBTS – Q1 but the addition of the second survey had little influence on outcome metrics. WKROUND concluded little or no benefit was gained from including this series in the assessment.

IGFS – WIBTS – Q4: 2003– . Ages 0 to 4 where oldest age is a true age. Sufficient non-zero entries are only present for ages 1 and 2 (Figure 3.7). The termination of the ScoGFS – WIBTS – Q1 and Q4 indices meant this series provides the only survey-series for VIa cod until the new Scottish surveys have sufficient years of data. The survey, however, only extends to 56°30′N. Doubt on whether the index could be considered a true reflection of the abundance of cod throughout VIa is cast by consideration of stock structure in the region (WD 4). The consistency of signals for recruitment at age 1 and SSB between indices compiled over subareas of VIa south and north of 56°30′N (Figure 3.8) were tested (see WD 5 for details). Results from the comparisons are shown in Figures 3.9and 3.10. The small number of common years between surveys means even smoothed trends that look quite different in their trend still fall within the reference bands, i.e. the results suggest the test has too few years to deliver conclusive results. These inconclusive results on whether the survey is representative of the full assessment area lead WKROUND to conclude the series should not be included in the assessment.

New Scottish first-quarter west coast groundfish survey – Q1 (no formal acronym assigned yet): 2011– . Ages 1 to 6 where oldest age is a true age. Random stratified design. Introduction of new ground gear and a change from a fixed station to a random stratified design lead WGCSE 2011 to conclude the Scottish west coast survey series was not a continuation of the ScoGFS – WIBTS – Q1 but a new survey-series. WKROUND confirmed this conclusion. ICES will consider inclusion as a tuning index through an inter-benchmark procedure when 4+ years of data have been gathered.

New Scottish first-quarter west coast groundfish survey (no formal acronym assigned yet):– Q4: 2011– . Ages 1 to 6 where oldest age is a true age. Random stratified design. New ground gear and a change from a fixed station to a random stratified design have been introduced as for the Scottish Q1 survey and the same conclusion that this constitutes a new survey-series applies. ICES will consider inclusion as a tuning index through an inter-benchmark procedure when 4+ years of data have been gathered.

Combination of Scottish and Irish surveys

The changes to the Scottish Q1 and Q4 surveys have make them comparable in design and groundgear to the IGFS – WIBTS – Q4. Work can begin on investigating the practicality of combining the New Scottish first-quarter west coast groundfish survey – Q4 and IGFS – WIBTS – Q4 to form a more comprehensive IBTS survey-series.

3.1.5 Catch and stock weights

Landings and discard weights are supplied separately. Stock weights are formed using a sum of products combination of landings and discards weights-at-age. The time-series for landings and discards weights are given in Figure 3.11. Visual inspection indicates a possible downward trend in mean weight-at-age for the oldest ages.

Calculation of mean weight dependent natural mortalities suggest trends in mean weight at the youngest ages may be more significant when estimating historic stock trends (see below).

3.1.6 Maturity

Changes to maturity data were not considered at this benchmark. Therefore the proportion mature-at-age remained as assumed constant over the full time-series with the values as shown below.

Age	1	2	3	4+
Proportion mature-at-age	0.0	0.52	0.86	1.0

3.1.7 Natural mortality

The existing assessment assumed a natural mortality (M) of 0.2 at all ages in all years. A lack of data makes it impossible to perform multispecies VPA (MSVPA) analyses as conducted for the North Sea but the workshop considered use of age (mean weight) dependent M values after Lorenzen (1996) (see also WD 1). Figure 3.12 shows the resulting values for M at age after using the mean stock weights-at-age. The M values calculated for the 7+ age group are very close to the old constant of 0.2 but considerably higher at ages 1 and 2. The values appear to have little trend over time (with a possible exception at age 1). WKROUND concluded introducing age dependent M values was an improvement to the model in that it allowed a more realistic representation of natural mortalities at age (including predation mortalities). Although an exhaustive comparison of different models for age, weight or length dependent M values had not been conducted the group was of the opinion that differences between such models would not be significant compared to the difference between an age based M model and the old assumption of M=0.2 at all ages. WKROUND also concluded that the assessment should not use M values calculated for each year as this was likely to introduce noise (originating from sampling error on stock weights) into the assessment. Therefore M values were made time invariant for the time being; calculated by finding the time-series means for stock weights-at-age before applying the Lorenzen parameters, i.e.

$$M_a = 3\overline{W}_a \exp(-0.29)$$

Where M_a is natural mortality-at-age a, $\overline{W_a}$ is the time averaged stock weight-at-age a (in grammes) and the numbers are the Lorenzen parameters for fish in natural ecosystems.

3.1.8 Other data: consumption of cod by seals

Using scat samples gathered in 1985 and 2002 Hammond and Harris (2006) estimated grey seal feeding in the West of Scotland and the North Sea. In the west of Scotland area (ICES Division VIa), the estimates suggested that the consumption of commercially exploited fish species was increasing and that for cod, annual consumption had become comparable in weight to the estimates of cod population biomass from the ICES assessment working group.

The UK Special Committee on Seals (SCOS) produces an annual estimate of grey seal numbers around the British Isles. These show grey seal numbers in the west of Scotland area increased through the 1980s and have been stable since (Thomas, 2011).

3.2 Assessment

3.2.1 Problems with current assessment

Because of a lack of data, the gadoid assessments west of Scotland have assumed natural mortalities of 0.2 for all ages and years. While these might in principle include seal predation, the estimates provided by Hammond and Harris (2006) suggested they do not. Meanwhile concerns over bias in the reported landings data from the mid 1990s lead to the VIa cod assessment only using commercial data up to 1994. The estimated total removals were persistently higher than reported catch (landings plus discards) even though the introduction of new compliance legislation (see Section 3.1.2) is understood to have made the commercial data much more unbiased in recent years.

The assessment was judged to still be a good indication of biomass trends but the estimate of mean F was very uncertain. There was also doubt as to whether the mean F estimate was an estimate of mortality imposed solely by fishing. Until 2011 there existed greatly differing estimates of seal population trends west of Scotland with no statistical test capable of determining which was the most likely. Population projections showing the greatest growth in seal numbers implied predation mortality rates highly unlikely to be encompassed by an M value of 0.2 and highly likely to be changing with time. Mean F estimates became termed 'Z-0.2' estimates and ICES considered option tables forecasting outcomes at different mean F levels were not possible.

In 2011 the Scottish research survey changed ground gear and design (see Section 3.1.4) and was classified as a new survey-series. A lack of a benchmark to assess the use of commercial data in recent years or the quarter four surveys meant no accepted input data was available for the assessment.

3.2.2 Assessment methods and trial runs

3.2.2.1 Exploratory Assessments of cod in VIa using a Bayesian approach

Two working papers were presented on the assessment of West of Scotland cod using an age structured model fitted within a Bayesian framework. WD2 is a development of an approach to the analysis of age structured survey data described in Cook (1997) while WD1 extends this model to include commercial landings and discard age compositions. Full descriptions of the models and results are given in the working documents.

The main differences between the assessments described in these papers and previous ICES assessments (ICES, 2011) is the inclusion of all four available surveys and modelling natural mortality as a function of mean weight (Lorenzen, 1996). The full assessment (WD2) also differs from ICES 2011 in the inclusion of all years of catch-at-age data.

The analysis of survey data alone suggests that fishing mortality has gradually increased since 1985 but began to decline around 2006 (FigURE 12 in WD#2). The estimated trends in SSB are very similar to those from the last ICES assessment (ICES, 2011) shown in Figure 13 in WD#2.

The model runs reported in WD2 produce trends in fishing mortality which indicated a very strong decline in mean F after 2005 which differed markedly from the survey data only run and previous ICES assessments. Investigating the raw data did not show any evidence of declining Z either from the log survey index ratios or the log of the commercial catch ratios. It appears that the decline is the result of the change in the sampling error in the catches after 2005. When the model was rerun allowing a different measurement error on most recent age composition data, and a change in exploitation pattern, the trend in F is much closer to previous ICES assessments and the survey data only run. However, the 95% CI is extremely large indicating that the recent trend in F is almost completely unknown.

The model described in WD1 allows for the estimation of misreporting if it is assumed that the surveys are free of catchability trends. Conditioned on this assumption the model estimates typical levels of missing landings at about 2–4 thousand tonnes but the 95% CI is very large and for many years misreporting cannot be distinguished from noise.

The assessment in WD1 and WD2 introduce weight dependent natural mortality, M, for this stock for the first time. One of the main reasons for making this change is to overcome the inconsistency between the earlier values used for this stock (M=0.2 for all ages) compared to the adjacent North Sea stock for which estimates of M from MSVPA are used. Figure 11 in WD#2 shows the estimated values from the Bayesian assessment compared to the very similar MSVPA values in the North Sea. The values are much more consistent, and given the connection between the two stocks, are probably preferable to the constant values used earlier.

Figure 5 on WD#2 shows the estimated measurement error for each of the four surveys. Clearly the Scottish quarter 1 survey (sco1) performs best overall, but all the other surveys perform better at age 1, probably because they sample fish later in the year and are likely to be useful for estimating recruiting year classes.

3.2.2.2 Revised Kalman filter

To date TSA has used what is known as the extended Kalman filter. This makes linear approximations to non-linear state and measurement equations during the log likelihood maximisation. The linearization can lead to fast and effective maximisation but there is a risk that if applied to a strongly non-linear system the end results - state vector values (i.e. numbers-at-age and F at age) and model parameter estimates - will be biased. Simulation studies have demonstrated that the risk of biased results can be greatly reduced if an 'unscented' Kalman filter is used (Wan and van der Merwe, 2001, Simpson *et al*., 2011). With this type of Kalman filter there is no need for linearization. The TSA model developed in advance of WKROUND and proposed for stock assessments from now on is based on the unscented Kalman filter.

To test differences between new results and the old assessment results to changes in data inputs or model parameterisation, a version of the new model was initially configured as for the 2010 and 2011 stock assessments and results checked for consistency with those runs (see WD 5).

3.2.2.3 Conditioning of the TSA model

Technical differences between the new and previous TSA model are outlined in Table 1 of WD5. Decisions on significant aspects of the modelling approach are outlined below.

3.2.2.4 Use of landings and discards data

WKROUND considered that landings subject to underreporting could still be expected to yield unbiased age structures when sampled. Therefore, rather than exclude landings and discards data completely from 1995 it was agreed to make use of the information on age structure from the landings and discards data. The survey tuning data is then used to estimate a correction factor on overall catch amounts in these years. To allow the model an overlap with a period considered to contain relatively unbiased commercial data the 'age structure only' period was started in 1991. Figure 3.13 shows the estimated removals as a percentage of reported catch (LHS) and the difference between reported catch and estimated removals in tonnes. It can be seen that the differences between estimated and reported values remains low from 1991 to the late 1990s indicating 1991 to be a reasonable year to switch to using age structure only from the commercial data.

For 2006 onwards WKROUND considered application of a correction to the international landings and discards data using estimates of Scottish fleet misreporting was acceptable as giving a first approximation to an unbiased input of landings and discards (see Section 3.1.2). Input data was therefore corrected for misreporting and then assumed unbiased from 2006. Figure 3.13 was from an exploratory run where the estimates of bias in the commercial data were carried through to the end of the time-series. Added to the right hand frame are the estimates of additional catch resulting from the misreporting adjustment. It can be seen these are compatible with the estimates of additional removals from the 'age structure' model.

Because the discard observer programme was very limited until 1981 the start of the historical modelling period is moved to 1981. Landings and discards are modelled separately to reflect the different precisions of these data sources.

3.2.2.5 Modelling of discards

To accommodate the observed pattern in discarding (see Section 3.1.3) TSA was altered to allow a step change in discarding at age. This allows for both a step change in discarding proportion at ages one and two and discarded proportions at older ages to change from zero to a finite value. Ages 1 to 4 are modelled but the workshop agreed it was important to retain the flexibility to include more ages should observer data indicate consistent discarding at older ages.

3.2.2.6 Consumption of cod by seals

On the basis there were only two years of data available giving consumption at length by seals and the uncertainties associated with those estimates WKROUND considered the risk of introducing bias in the assessment from inclusion of the seal feeding element of the TSA model too great and it was agreed the VIa cod assessments going forwards should not include a seal predation element.

Instead the seal predation question should be considered by performing a supplementary model run with seal predation included. This would be to test the sensitivity of the VIa cod assessment to the inclusion of explicit seal predation modelling and to provide estimates of M2 and quantities of cod consumed at age. Because seal population estimates are only available from 1984 this supplementary model would start in 1984. Details of the seal predation model are given in WD5.

3.2.2.7 Variance structures

The main diagnostics of the quality of the model fit come from consideration of the objective value (-2*log likelihood), prediction error results and a consideration of how well the model has replicated discard ratios in the input data. As new years of data become available these diagnostics will indicate the need to down weight individual data points or that the data – be it landings, discards or survey - for a given age is more or less variable than previously thought. It is therefore important that changes to the variance structures used in the TSA models will be allowed if they improve model diagnostics.

3.2.3 TSA model performance

Prediction errors from the assessment run are given in Figures 3.14 to 3.16. Errors in the region of ± 2 are preferable and between ± 3 acceptable. Prediction errors in early years for landings-at-age one are mostly negative. Prediction errors represent supplied data value minus forward predicted value from the Kalman Filter, i.e. the Kalman Filter was consistently over-predicting the landings-at-age one in the next year. It must be remembered however that after predicting forwards the Kalman Filter updates the modelled value based on the supplied data point. A regular overprediction of landings-at-age is consistent with a rising proportion of catch at that age coming from discards which is as shown in Figure 3.17.

Figure 3.17 shows input versus modelled discard ratio at ages one to four. The jump in discard ratio in 2006 at age one and the steep increase in discard ratio from 2005 to 2007 at age 2 are well modelled. The model also does well at reproducing discard rates post 2006 at ages 3 and 4 given the greater variability of the data at these ages.

Prediction errors from the supplementary run that includes seal predation are given in Figures 3.18 to 3.21. The pattern and size of prediction errors for landings, discards and survey indices are very similar to the assessment run. Figure 3.21 shows the model generally under predicts seal consumption of cod at age.

3.2.4 Output metrics

Figure 3.22 contrasts a proxy for mean F constructed by taking the log catch ratio on ages 2 to 4, a five year running average of the log catch ratio values and the mean F (ages 2–5) resulting from the assessment model. It can be seen the log catch ratios show a more significant fall in mean F proxy in recent years compared to the assessment result. The majority of catch in recent years is comprised of discards. Discard numbers at ages 3 and 4 are highly variable and it is believed the Kalman filter has interpreted much of the information from the discard data to be noise rather than signal.

Figures 3.23 and 3.24 contrast the mean F and SSB trends resulting from the assessment and supplementary model runs. The time-series of mean F from the supplementary run can be seen to stay within the confidence interval of the assessment run throughout but for SSB the mean value for the supplementary run is mostly just above the upper confidence limit of the assessment run. The difference in mean F and SSB estimates in the terminal year are 7 and 57% respectively.

The model assumes a Ricker stock–recruitment relationship. The stock–recruit scatter plot and associated model fit are shown in Figure 3.25. The fit passes through the data points without any obvious upward or downward bias. A summary of the stock trends from the assessment model is given in Figure 3.26.

3.2.5 Coping with missing surveys

Because the New Scottish first-quarter west coast groundfish surveys – Q1 and Q4 will not be ready to tune the assessment for at least another 3 to 4 years, a version of the proposed assessment model was run removing any survey indices values for the final 5 years of data. Figure 3.27 shows the mean F and SSB results from the full assessment and model with missing survey data. Figure 3.28 shows the difference in CVs of the estimated mean Fs and SSBs.

The CVs on the estimates of SSB are very similar between models and for mean F are a little higher for the model with less survey data. The figures of mean trends are virtually identical suggesting the danger of biased estimates resulting from a lack of tuning data are not great if the span of years without tuning data is not great. On the other hand, it could be that the years removed were not informative, either because the data were noisy or did not provide much contrast; if so, then the generality of the statement should be questioned.

3.3 Short-term predictions

WKROUND had little time to consider short-term predictions. Nothing in the changes to the assessment approach suggest the short-term predictions should be changed with the exception of the fact the model is now considered to provide estimates of mean mortality due to fishing. Predicted mortality and removals need to be partitioned into those from landings, discards and unaccounted mortality (estimated landings and discards resulting from area misreported landings). In turn assumptions for the intermediate year now need to be made for the overall level of mean F and also whether the partition between the different sources of removals is stationary.

3.3.1 Method

Age structured deterministic projection using the MFDP package with management option table and yield-per-recruit routines. MLA suite (WGFRANSW) used for sensitivity analysis and probability profiles.

3.3.2 Recruitments

Recruitment in the intermediate year is taken from the TSA assessment. For the TAC year and following year the short term (ten years to year before terminal year) geometric mean recruitment-at-age 1 is used.

3.3.3 Weights and maturities

Average stock weights for last three years, (assumed equal to the catch weight-at-age). Adopted because mean weights-at-age have been relatively stable over the recent past. CVs are calculated from the standard errors on weights-at-age. Maturities-at-age as for the historical assessment.

3.3.4 Assumptions for intermediate year

Not considered due to time constraints. This should be further considered by the WGCSE.

3.3.5 Procedures used for splitting projected catches

Not considered due to time constraints. This should be further considered by the WGCSE.

3.4 Implications for reference points

The current reference points for VIa cod are:

	Type	Value	Technical basis
MSY	$MSY_{Btrigger}$	22 000 t	B_{pa}
Approach	F_{MSY}	0.19	Provisional proxy by analogy with North Sea cod F_{max}. Fishing mortalities in the range 0.17–0.33 are consistent with F_{msy}
	B_{lim}	14 000 t	B_{lim} = B_{loss}, the lowest observed spawning stock estimated in previous assessments.
Precautionary Approach	B_{pa}	22 000 t	Considered to be the minimum SSB required to ensure a high probability of maintaining SSB above B_{lim}, taking into account the uncertainty of assessments. This also corresponds with the lowest range of SSB during the earlier, more productive historical period.
	F_{lim}	0.8	Fishing mortalities above this have historically led to stock decline.
	F_{pa}	0.6	This F is considered to have a high probability of avoiding F_{lim}.

3.4.1 Precautionary reference points

The current value of B_{lim} was established in 1998 as the B_{loss} value from the assessment of that year. The adoption of weight dependent natural mortalities (M) at age has increased M values for younger ages and increased perceptions of SSB and recruitment. WKROUND, however, judged the differences too small to merit a revision of biomass reference points (the lowest SSB estimate up to 1998 was very close to B_{lim}).

Using the stock–recruit relationship given by the assessment values of F_{crash} and F giving equilibrium at the current B_{lim} were calculated as:

- F_{crash}–0.89.
- F giving equilibrium at B_{lim}–0.78.

These values bracket the current value of F_{lim} suggesting the current value of F_{lim} is appropriate.

3.4.2 MSY reference points

Stock–recruit relationship

The TSA model assumes a Ricker stock–recruit relationship. The stock–recruit curve resulting from the assessment run is shown by Figure 3.25.

Yield-per-recruit and SSB per recruit

The yield-per-recruit and SSB per recruit for this stock are shown in Figure 3.29. F_{max} and $F_{0.1}$ values are given by:

- F_{max}–0.33.

- $F_{0.1}$–0.19.

These values are consistent with the range of F values at the time of derivation of the existing F_{MSY} suggesting the current value of F_{MSY} is appropriate.

3.5 Future work

Work identified that should be prepared for a possible inter-benchmark procedure or in advance of the next benchmark for this stock was:

- Clarify what to assume for the intermediate year and for splitting projected catches in short-term predictions.
- Analysis of area misreported landings by gear type and consideration of whether correction of all discards for misreporting equally is appropriate.
- From 2014 onwards: consideration of whether it is appropriate to include the New Scottish first-quarter west coast groundfish survey – Q1 and Q4 indices as tuning indices.
- Comparing the current VIa stock assessment with assessments conducted on data split at 57°30′N. The purpose of the work would be to test whether the current stock assessment is robust to concerns about substock structure west of Scotland.

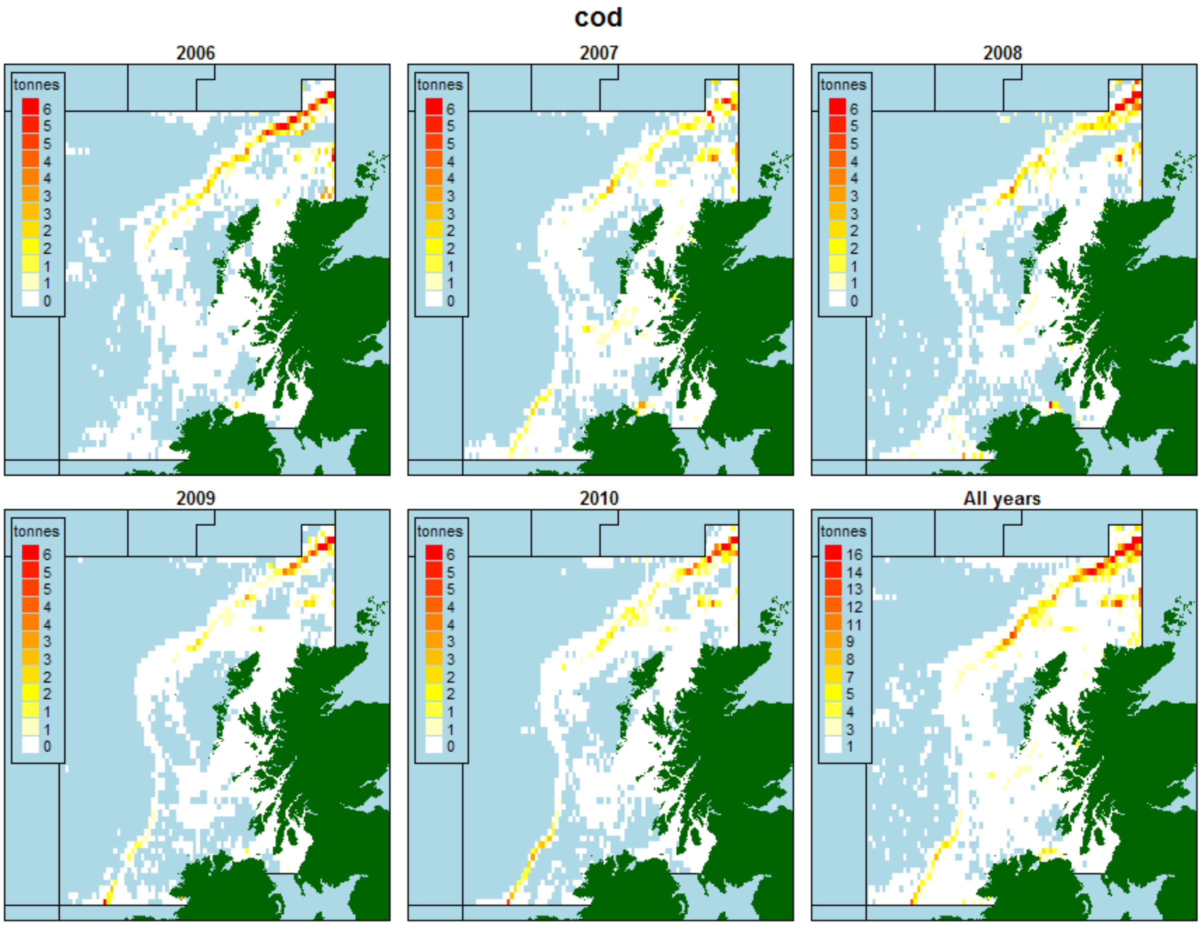


Figure 3.1. VIa cod; map of landings from Scottish and Irish fleets using logbook entries matched to VMS data filtered to fishing pings. Absolute levels of landings.

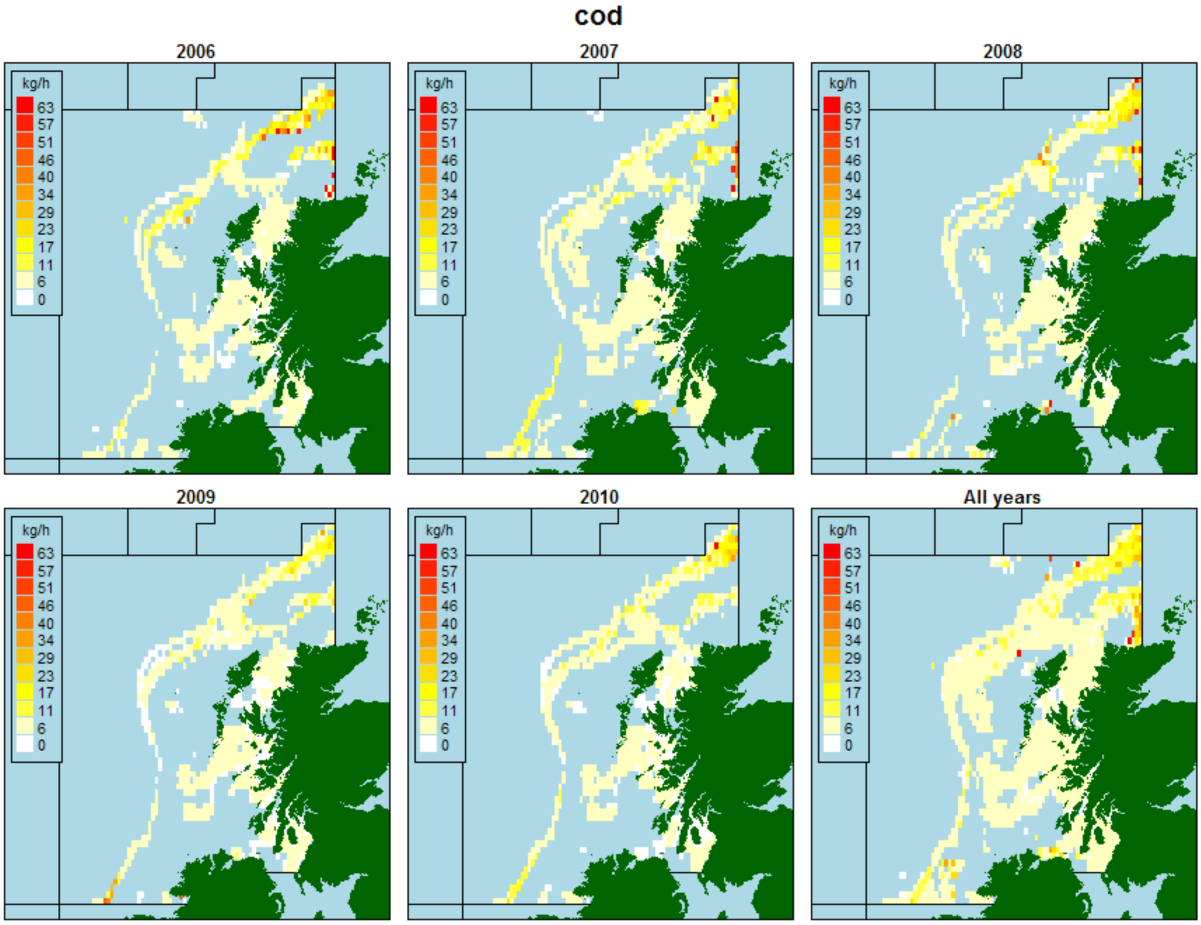


Figure 3.2. VIa cod; map of landings from Scottish and Irish fleets using logbook entries matched to VMS data filtered to fishing pings. Lpue in kg per hour.

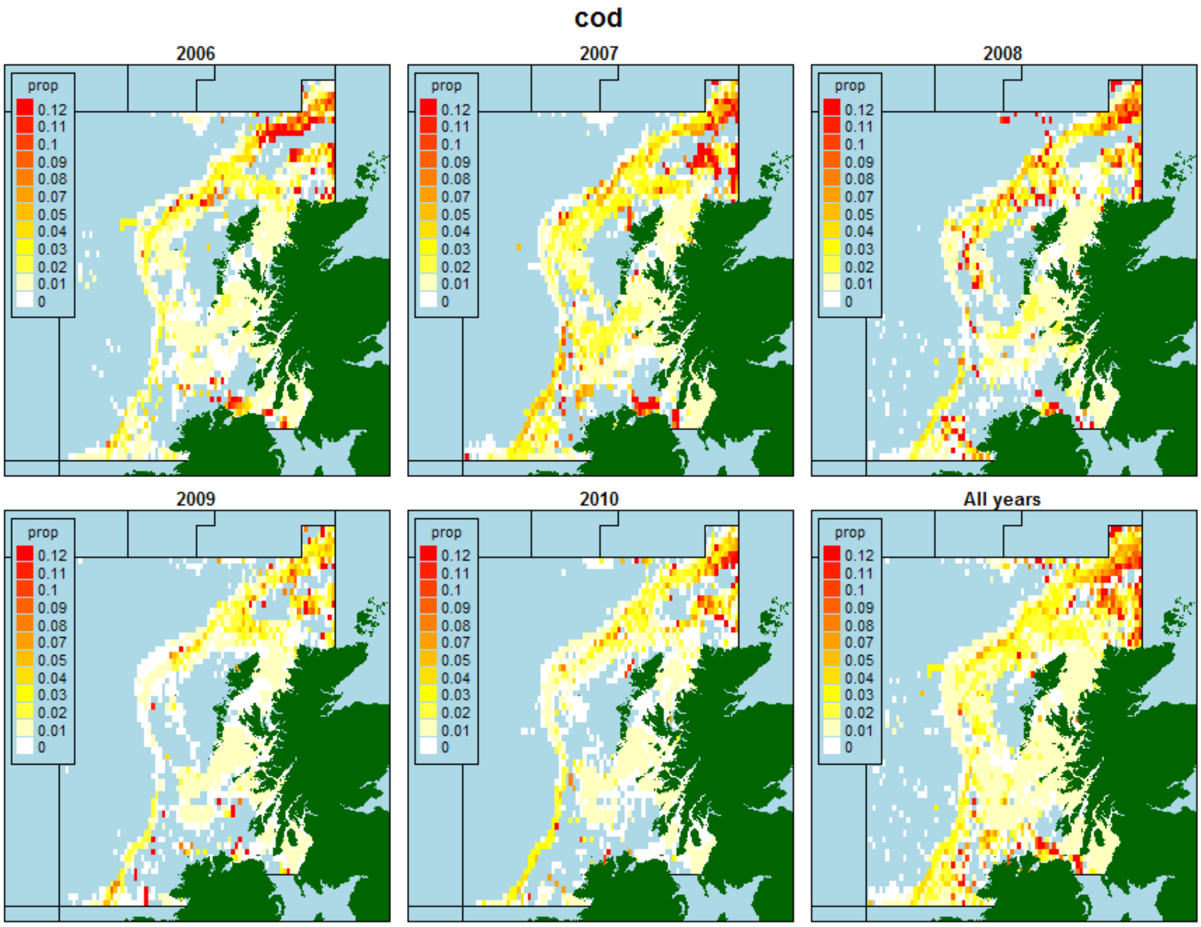


Figure 3.3. VIa cod; map of landings from Scottish and Irish fleets using logbook entries matched to VMS data filtered to fishing pings. Proportion of cod within the landings.

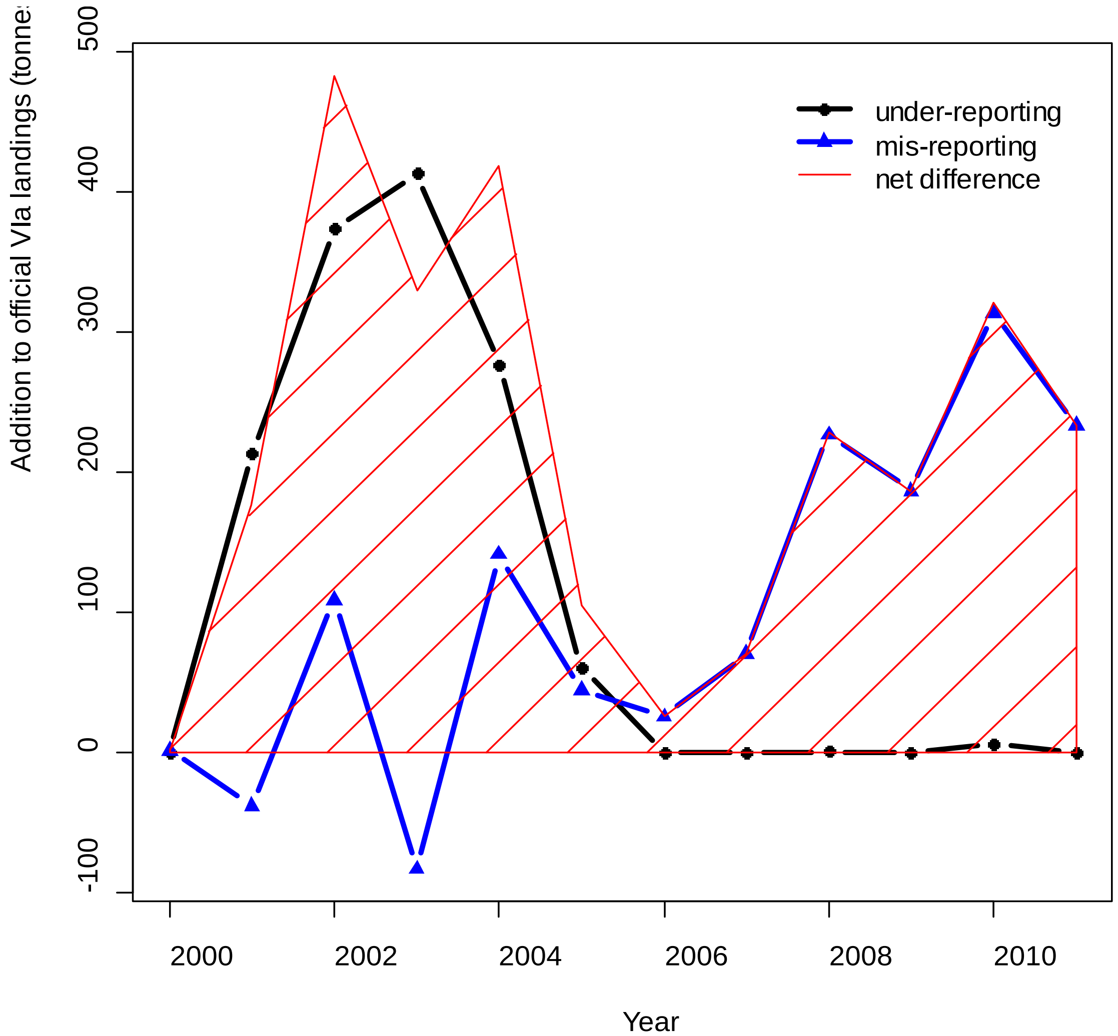


Figure 3.4. VIa cod; estimates of net misreporting of VIa cod landings from the Scottish fleet, i.e. landings that are in addition to reported landings for the VIa Division.

a) b)

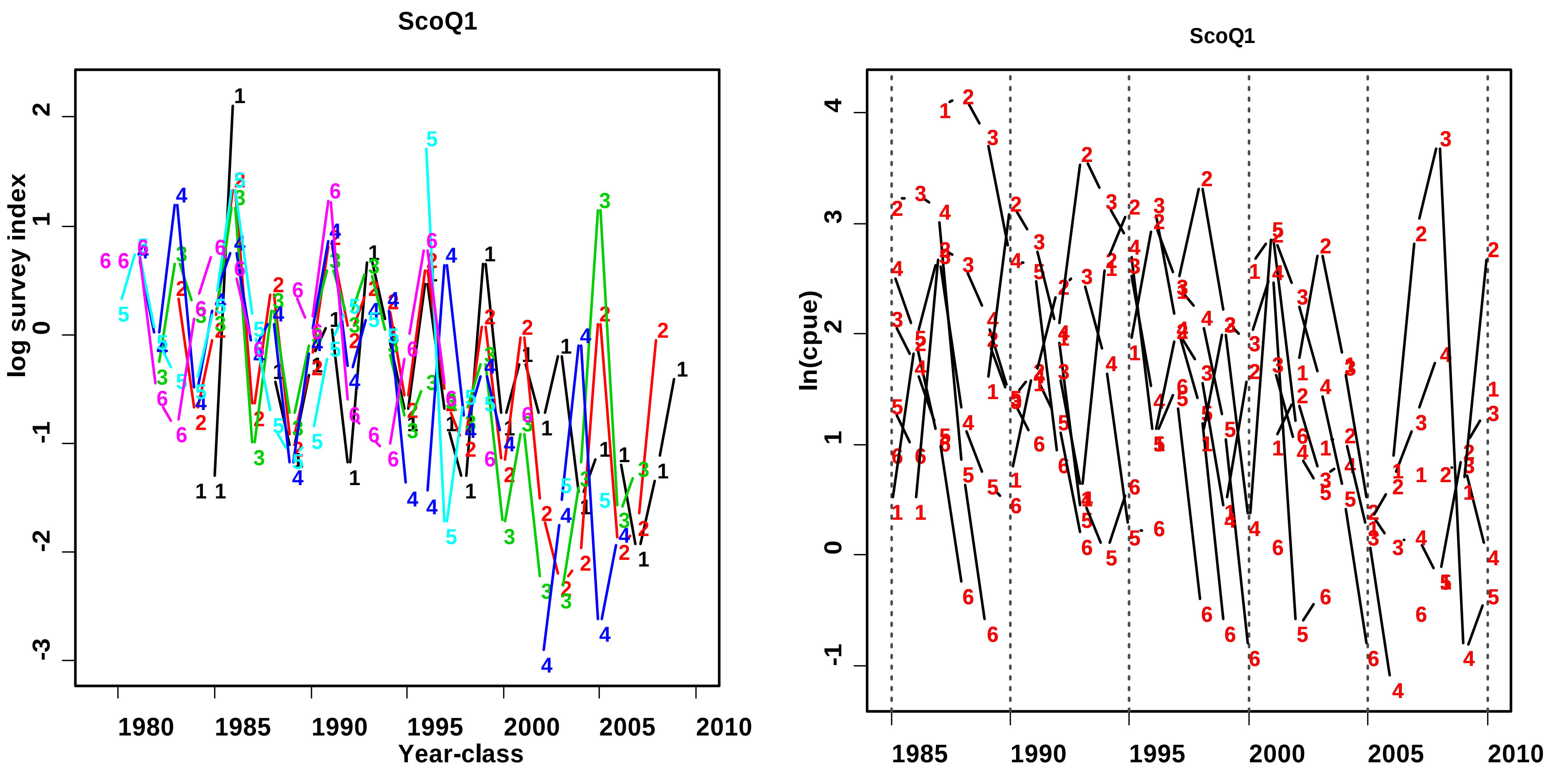


Figure 3.5. VIa cod; ScoGFS – WIBTS – Q1. a) mean standardised log indices by cohort; b) log catch curves.

a) b)

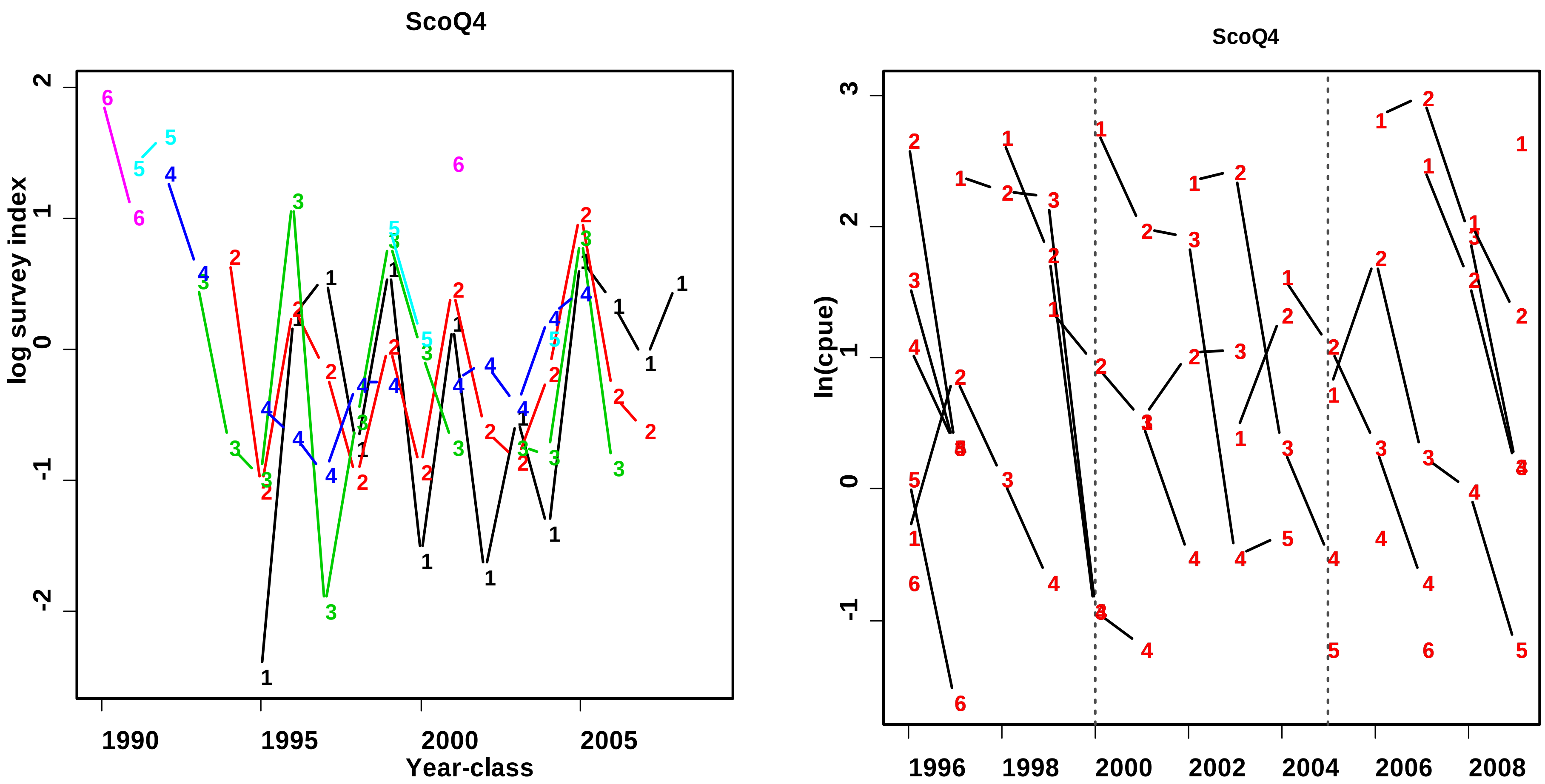
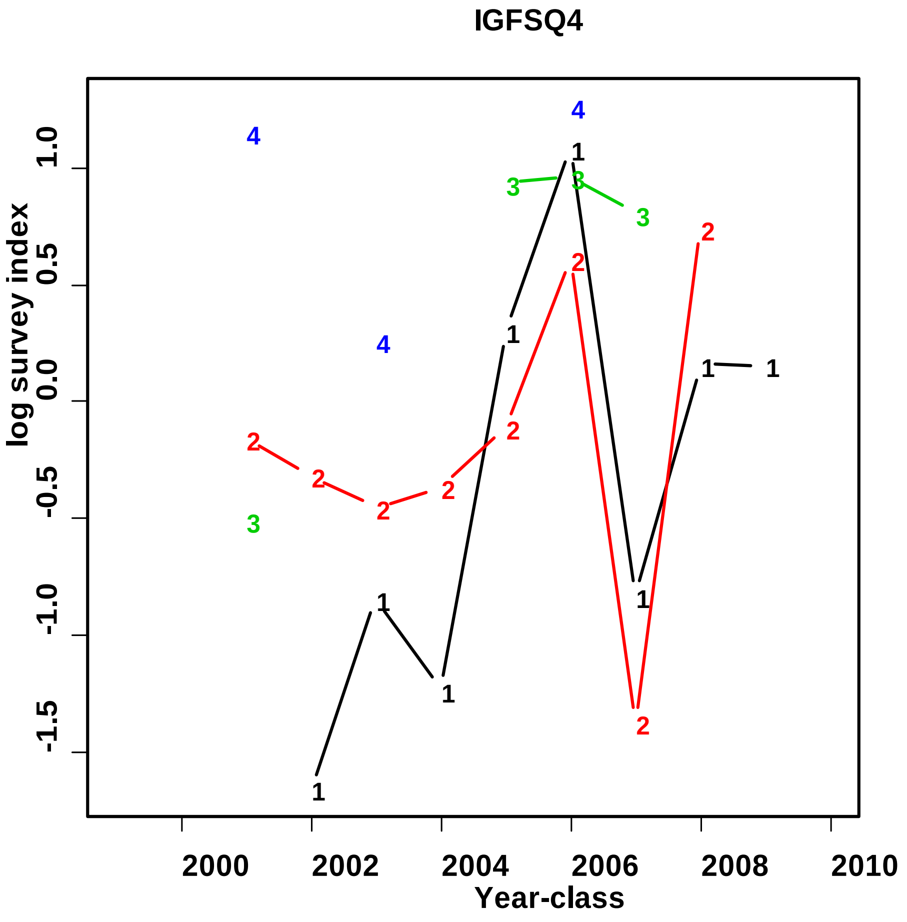


Figure 3.6. VIa cod; ScoGFS – WIBTS – Q4. a) mean standardised log indices by cohort; b) log catch curves.

a)



b)

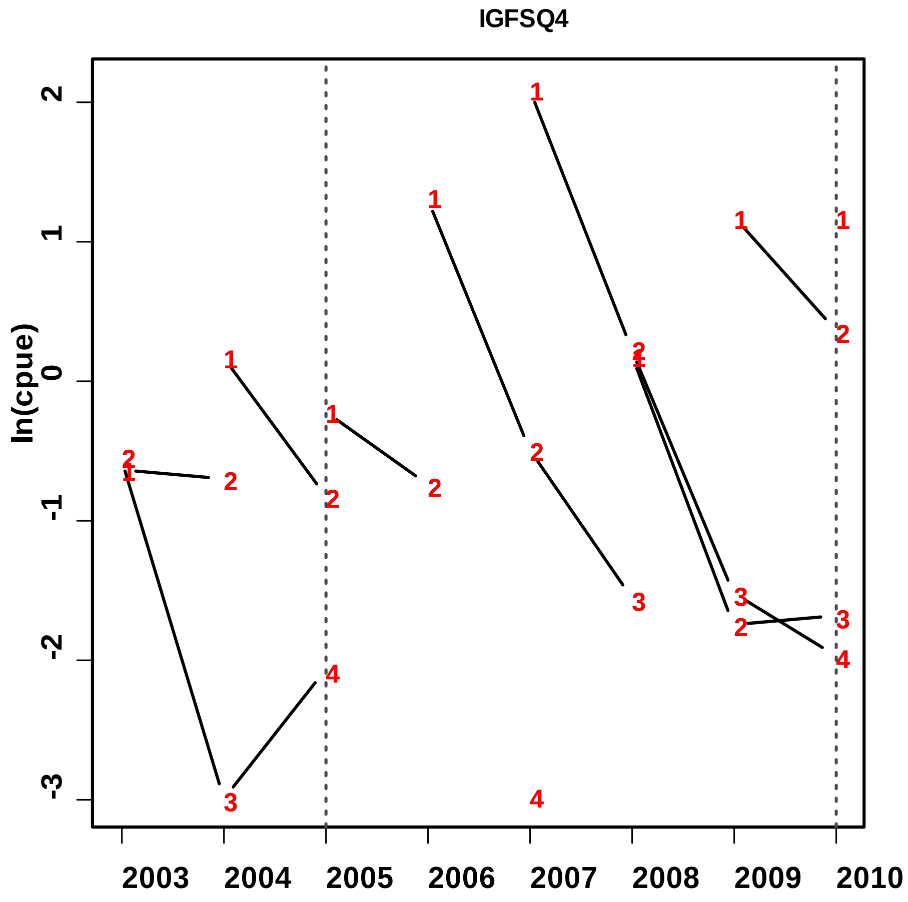


Figure 3.7. VIa cod; IGFS – WIBTS – Q4. a) mean standardised log indices by cohort; b) log catch curves.

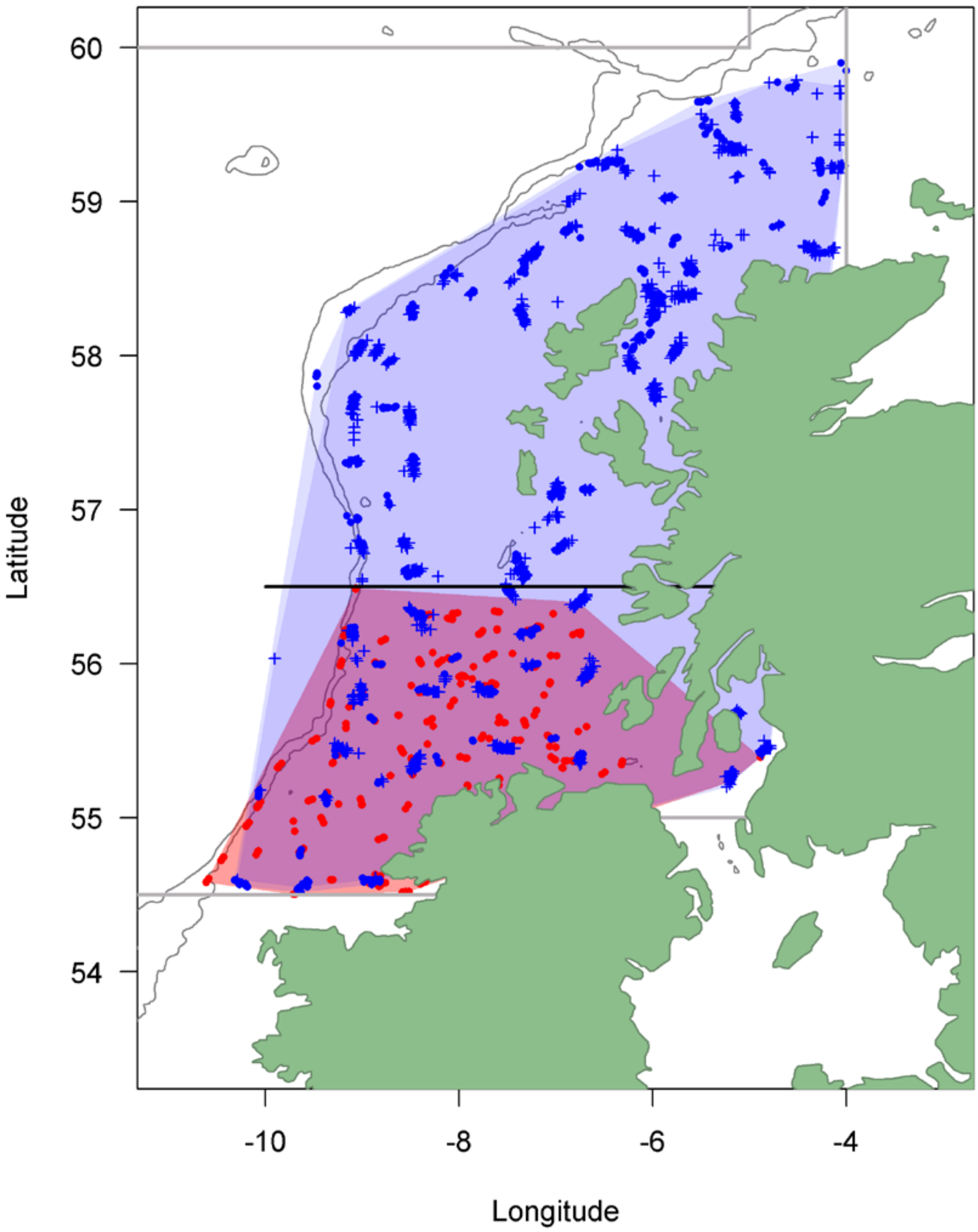


Figure 3.8. VIa cod; haul locations of Scottish Q1 (blue cross) and Q4 surveys (blue circle) and Irish Q4 (red circle) surveys. Blue and red shading join vertices that contain all hauls from the respective nation. Line at 56°30′ shows latitude used to split the Scottish survey-series into north and south component series.

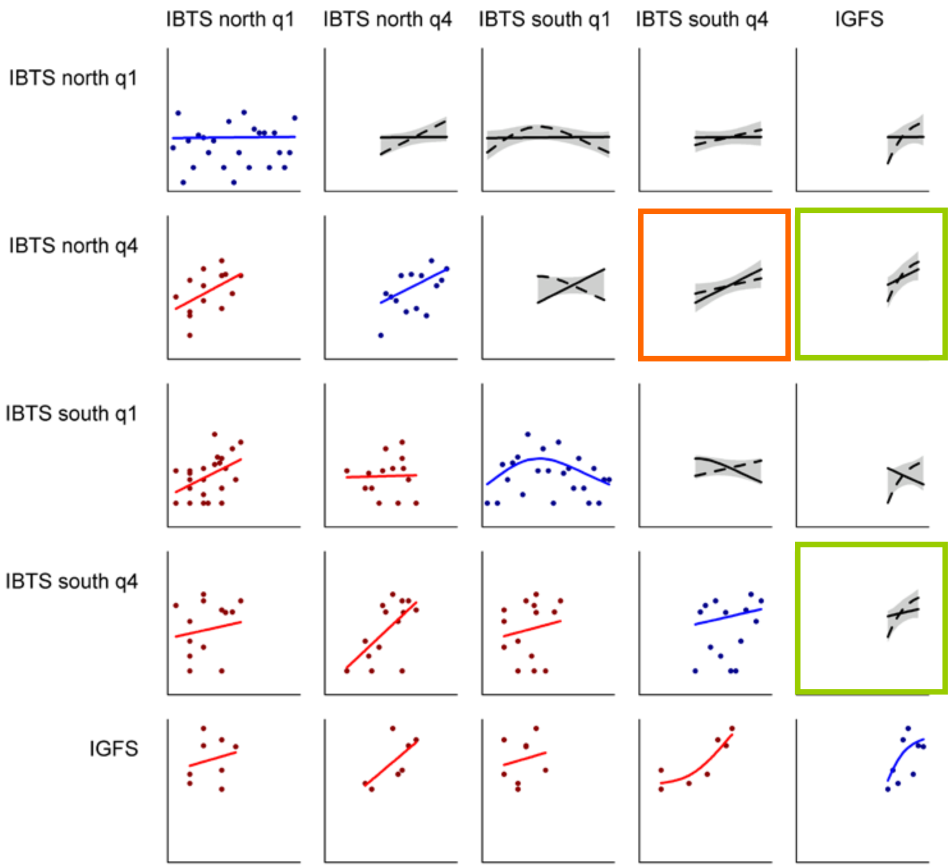


Figure 3.9. VIa cod; Paired comparisons between Scottish and Irish survey series (numbers-at-age one). IBTS north q1 and IBTS south q1 = ScoGFS – WIBTS – Q1 hauls from north of and south of 56°30′ respectively. IBTS north q4 and IBTS south q4 = ScoGFS – WIBTS – Q4 hauls from north of and south of 56°30′ respectively. IGFS = IGFS – WIBTS – Q4. Diagonal holds indices values with smooth. Lower left hand panels show scatter plot comparisons with smooth to indicate relationship. Upper right hand panels show indices smoothes plotted over reference bands used to test for significant deviations from parallel trends.

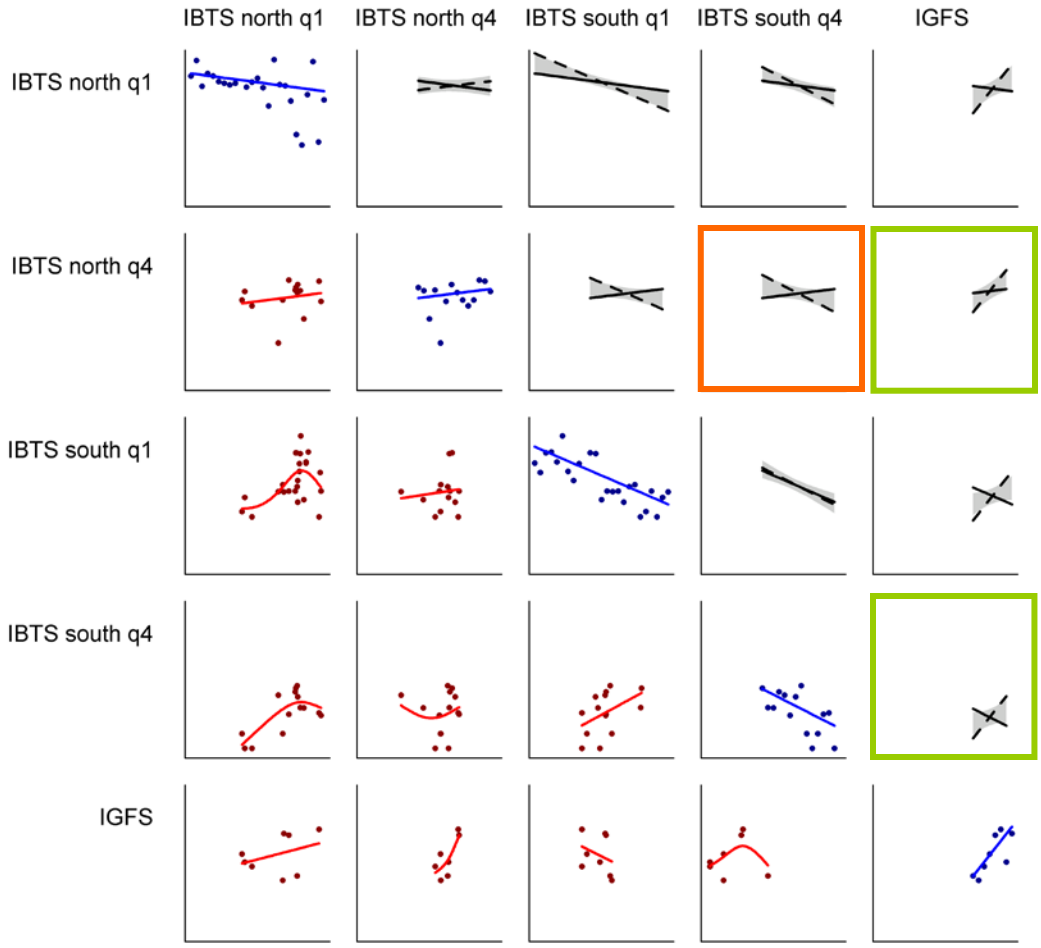


Figure 3.10. VIa cod; Paired comparisons between Scottish and Irish survey-series (SSB). IBTS north q1 and IBTS south q1 = ScoGFS – WIBTS – Q1 hauls from north of and south of 56°30′ respectively. IBTS north q4 and IBTS south q4 = ScoGFS – WIBTS – Q4 hauls from north of and south of 56°30′ respectively. IGFS = IGFS – WIBTS – Q4. Diagonal holds indices values with smooth. Lower left hand panels show scatter plot comparisons with smooth to indicate relationship. Upper right hand panels show indices smoothes plotted over reference bands used to test for significant deviations from parallel trends.

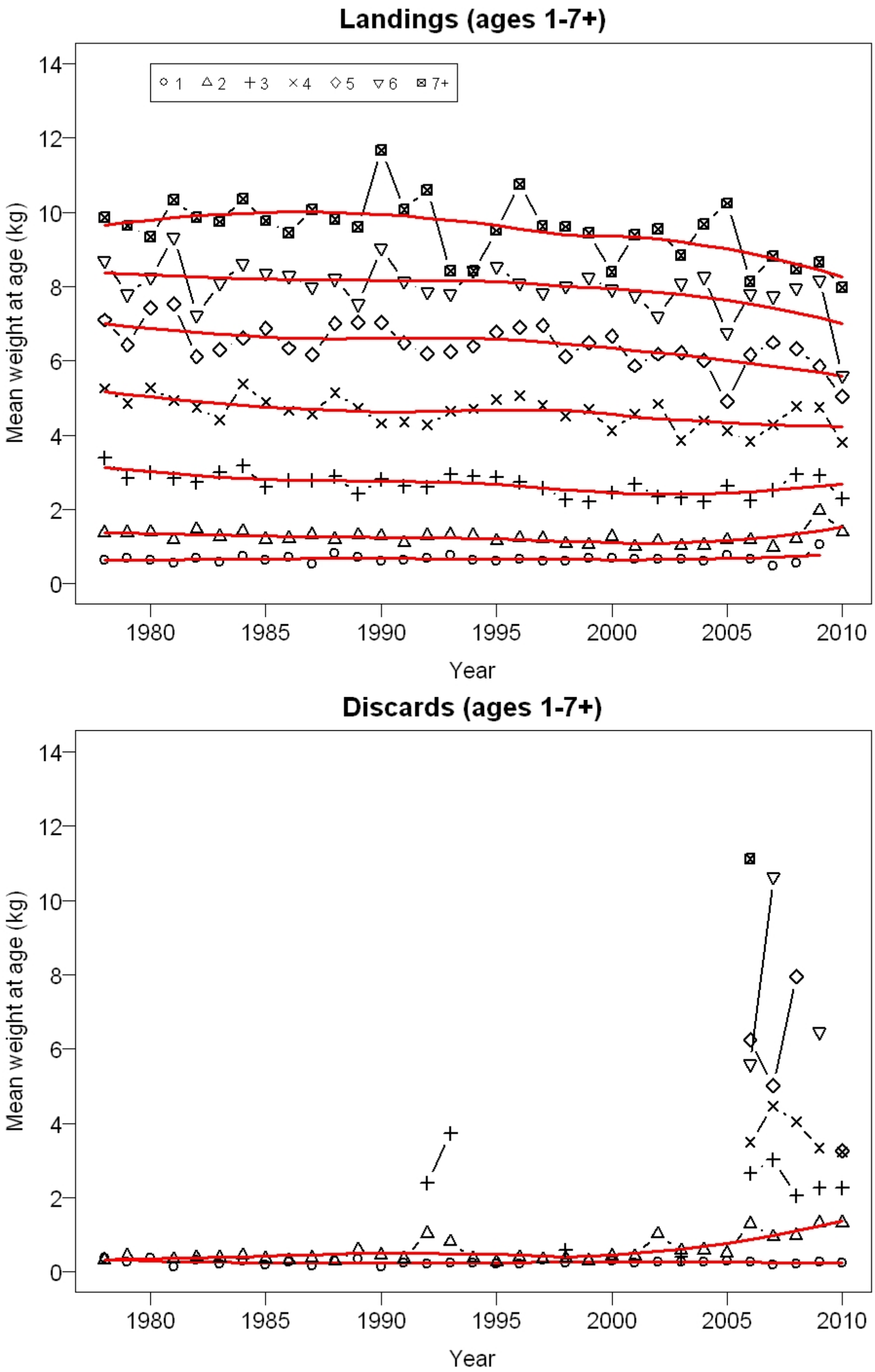


Figure 3.11. VIa cod; mean landings and discards weights-at-age.

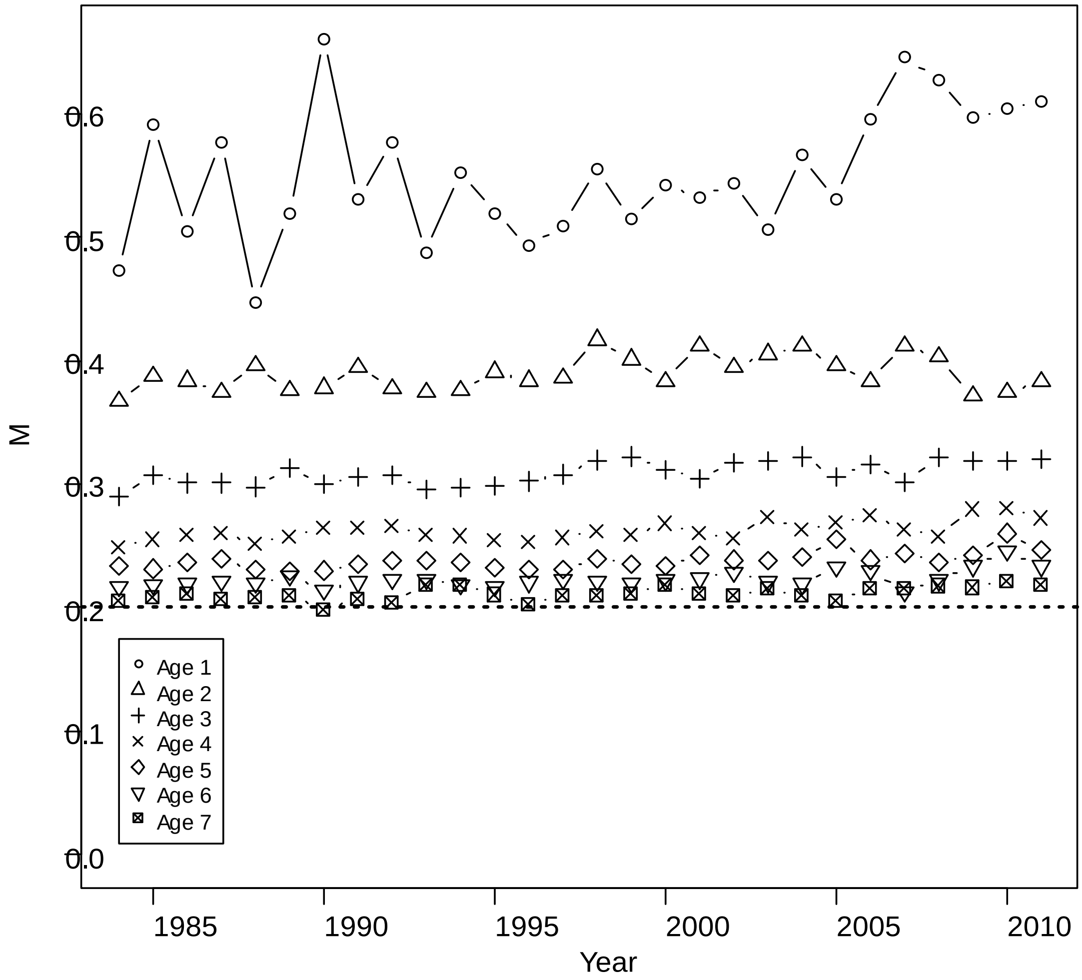


Figure 3.12. VIa cod; natural mortality (M)-at-age using mean weight related M-at-age after Lorenzen (1995).

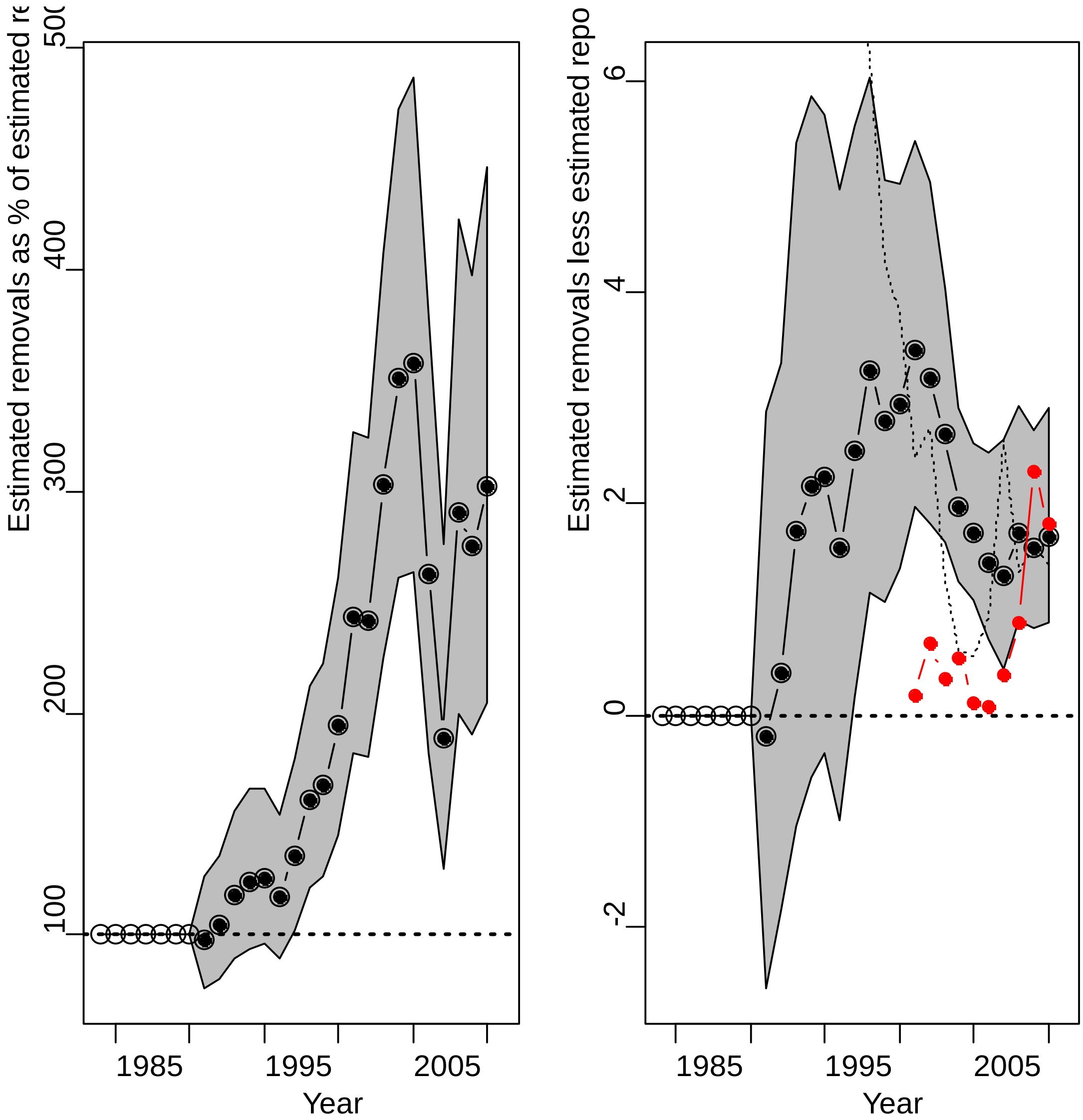


Figure 3.13. VIa cod; left: estimated removals as a percentage of reported catch; right: difference between estimated removals and reported catch in thousand tonnes. Red circles show additional catch arising from adjustment of catch data by misreporting estimates of Marine Scotland Compliance. Dotted line gives level of reported catch. Grey bands denote confidence intervals given by ± 2 s.e.

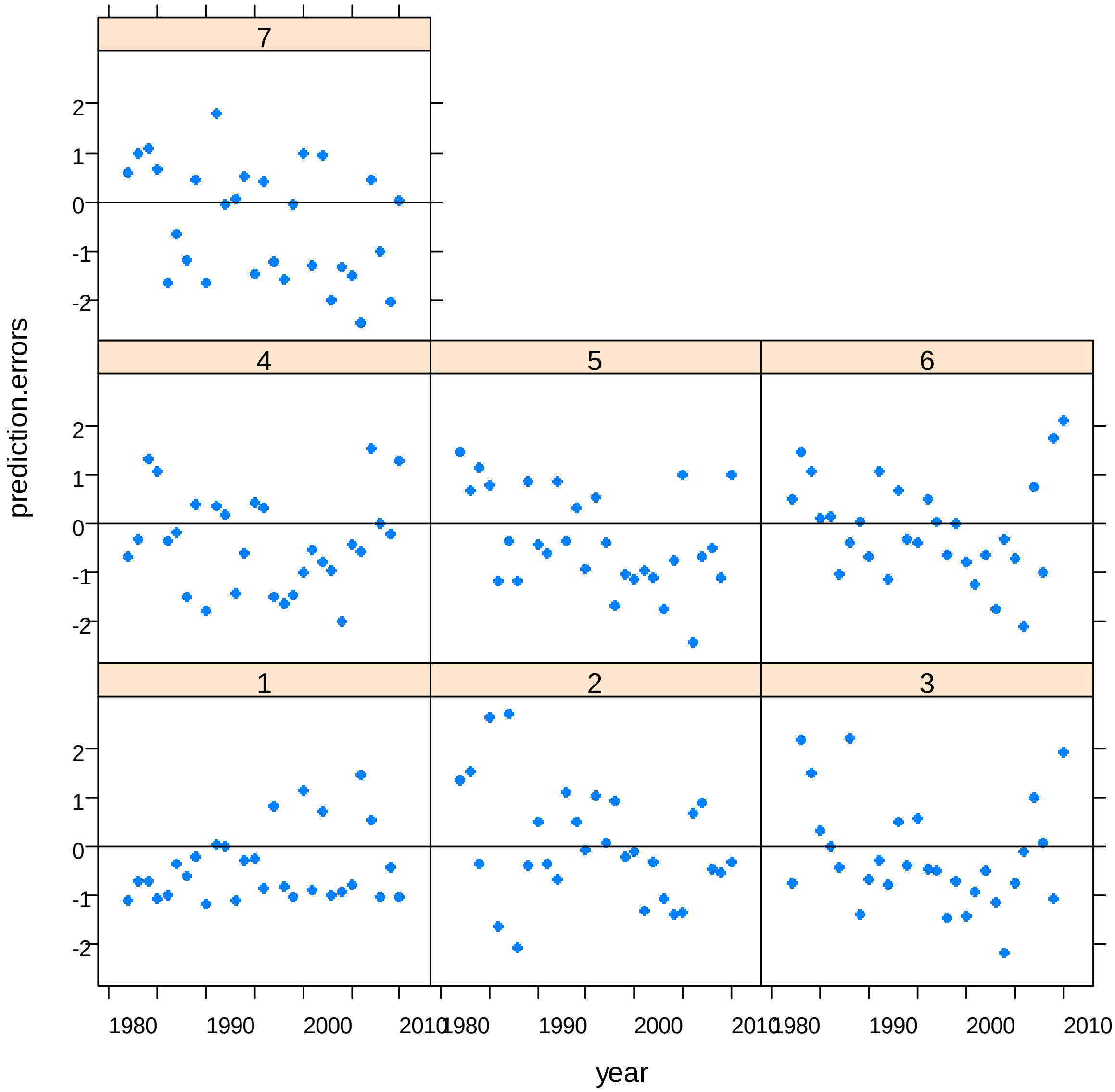


Figure 3.14. VIa cod; landings prediction errors. Assessment model (without seal predation).

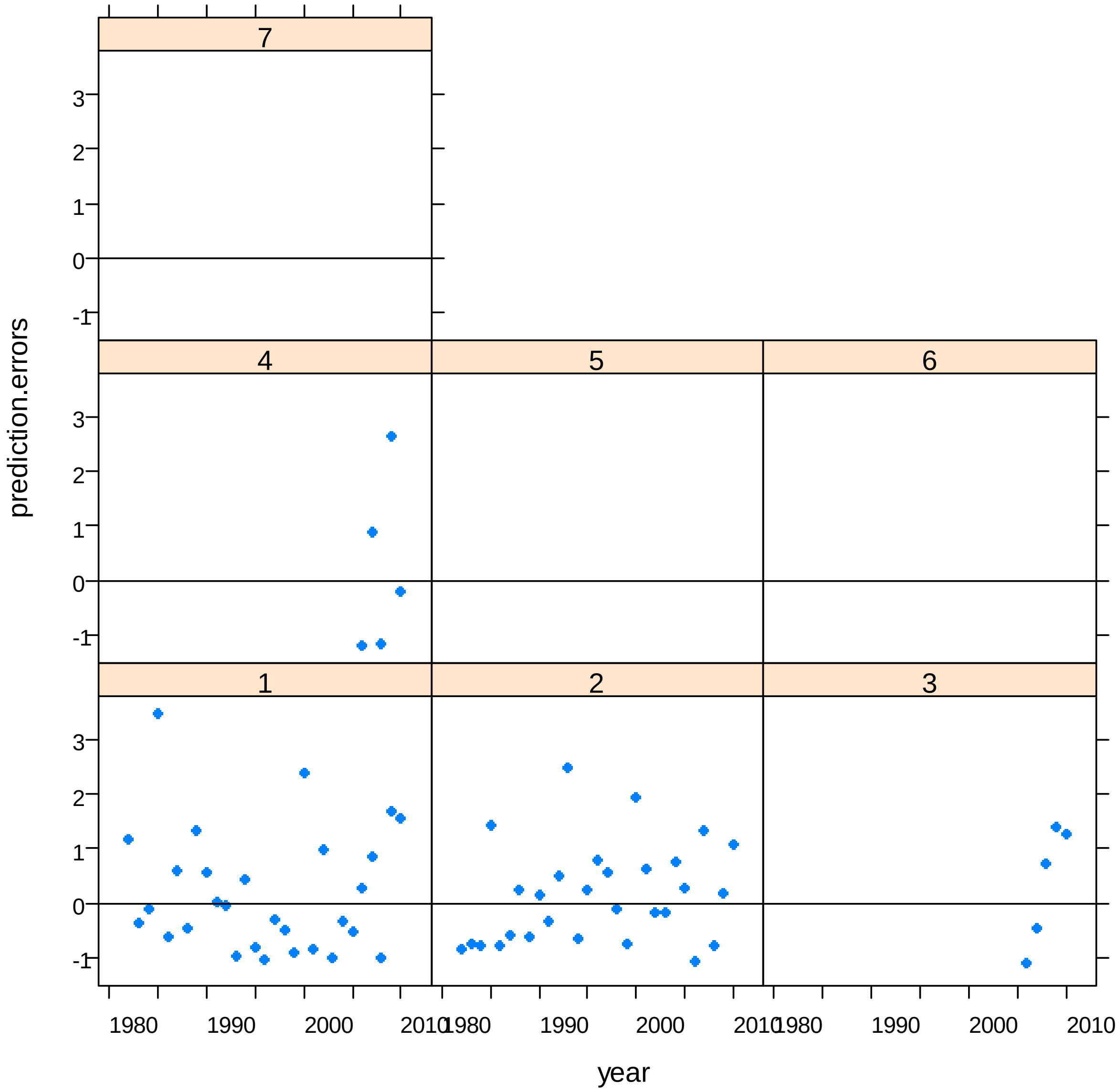


Figure 3.15. VIa cod; discards prediction errors. Assessment model (without seal predation).

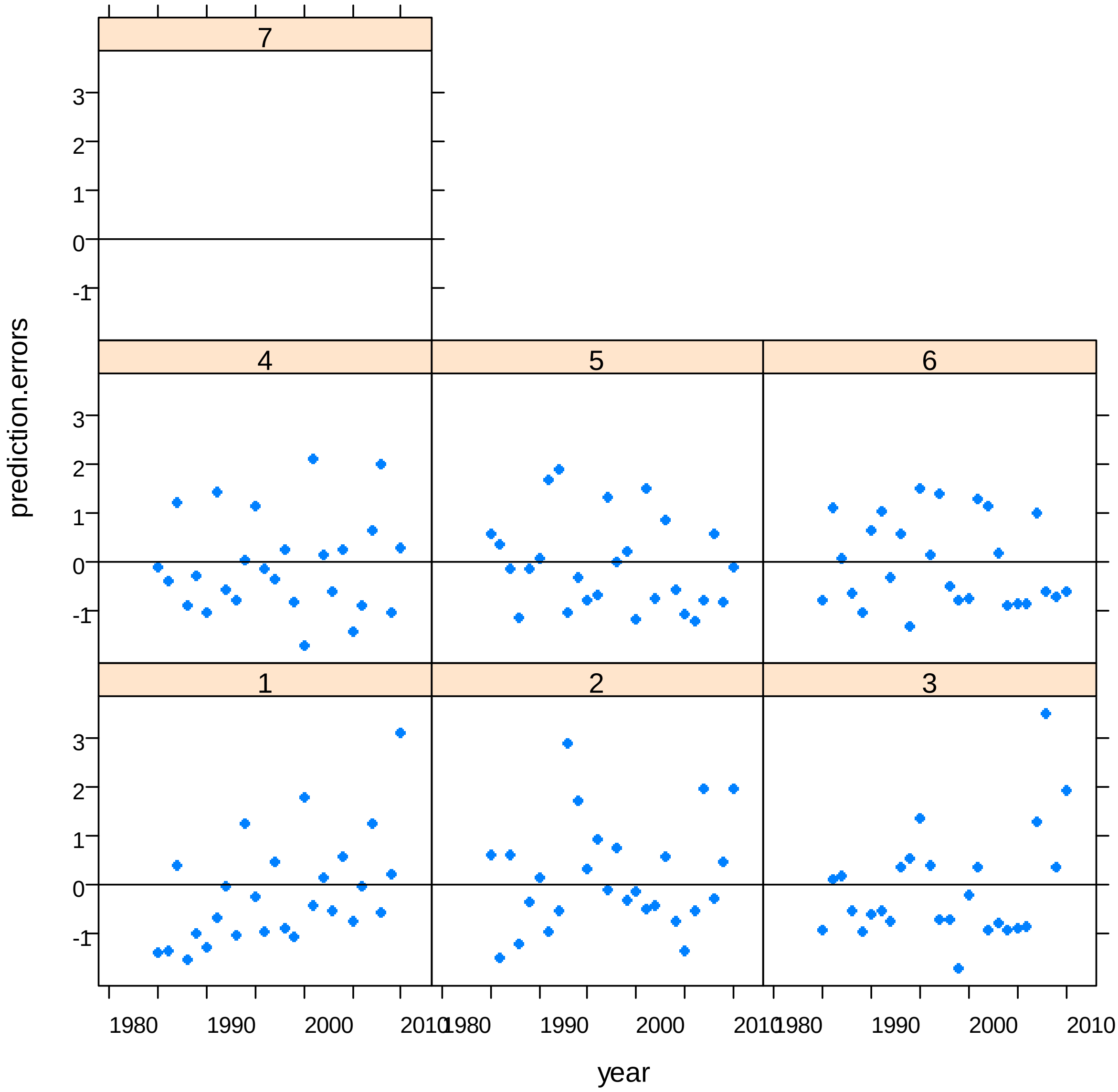


Figure 3.16. VIa cod; ScoGFS – WIBTS – Q1 prediction errors. Assessment model (without seal predation).

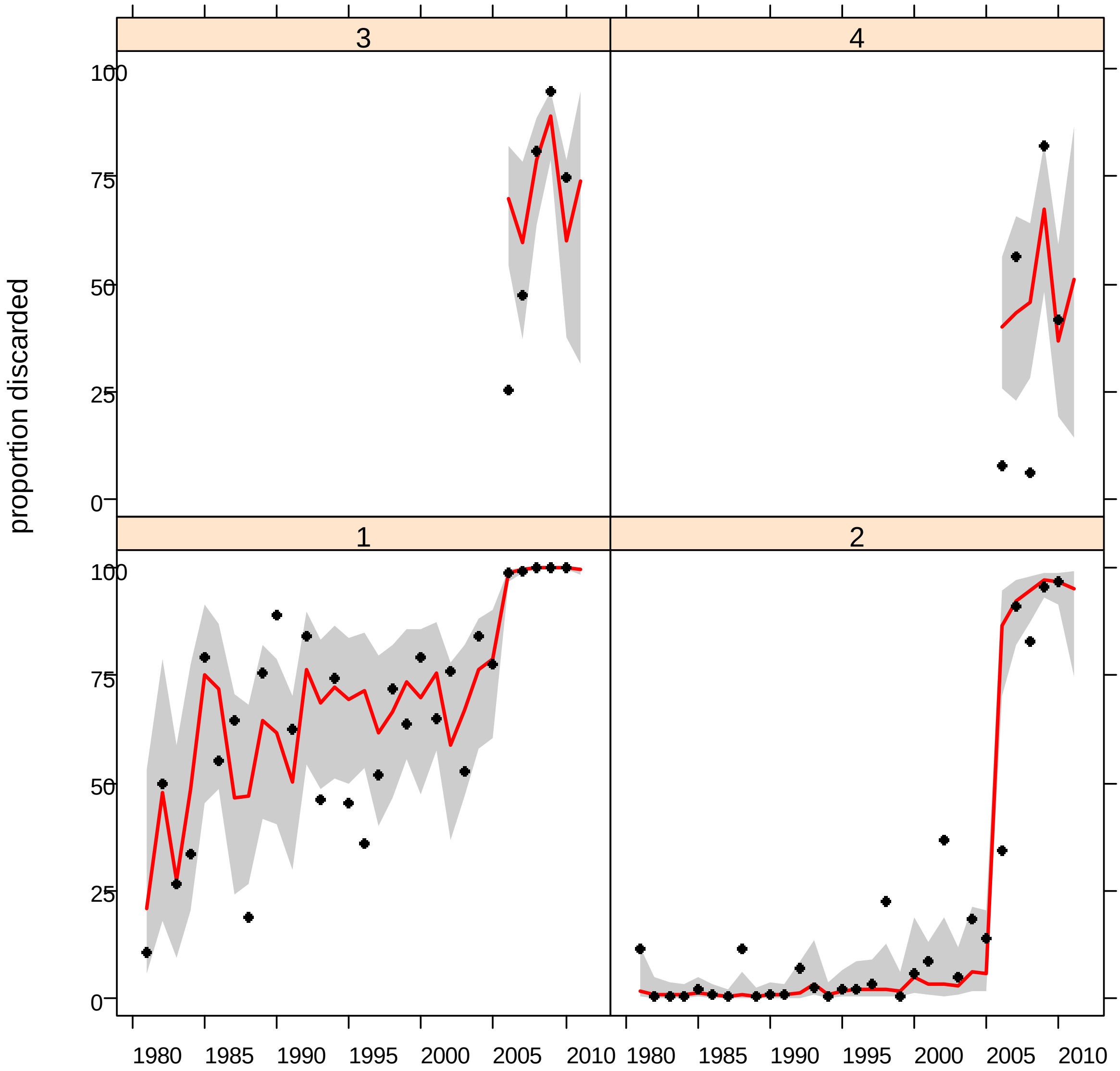


Figure 3.17. VIa cod; modelled discard ratio at age (solid line) against input values (circles). Solid circles indicate years where data is used fully, open circles indicate years where only information on age structure is used. Assessment model (without seal predation).

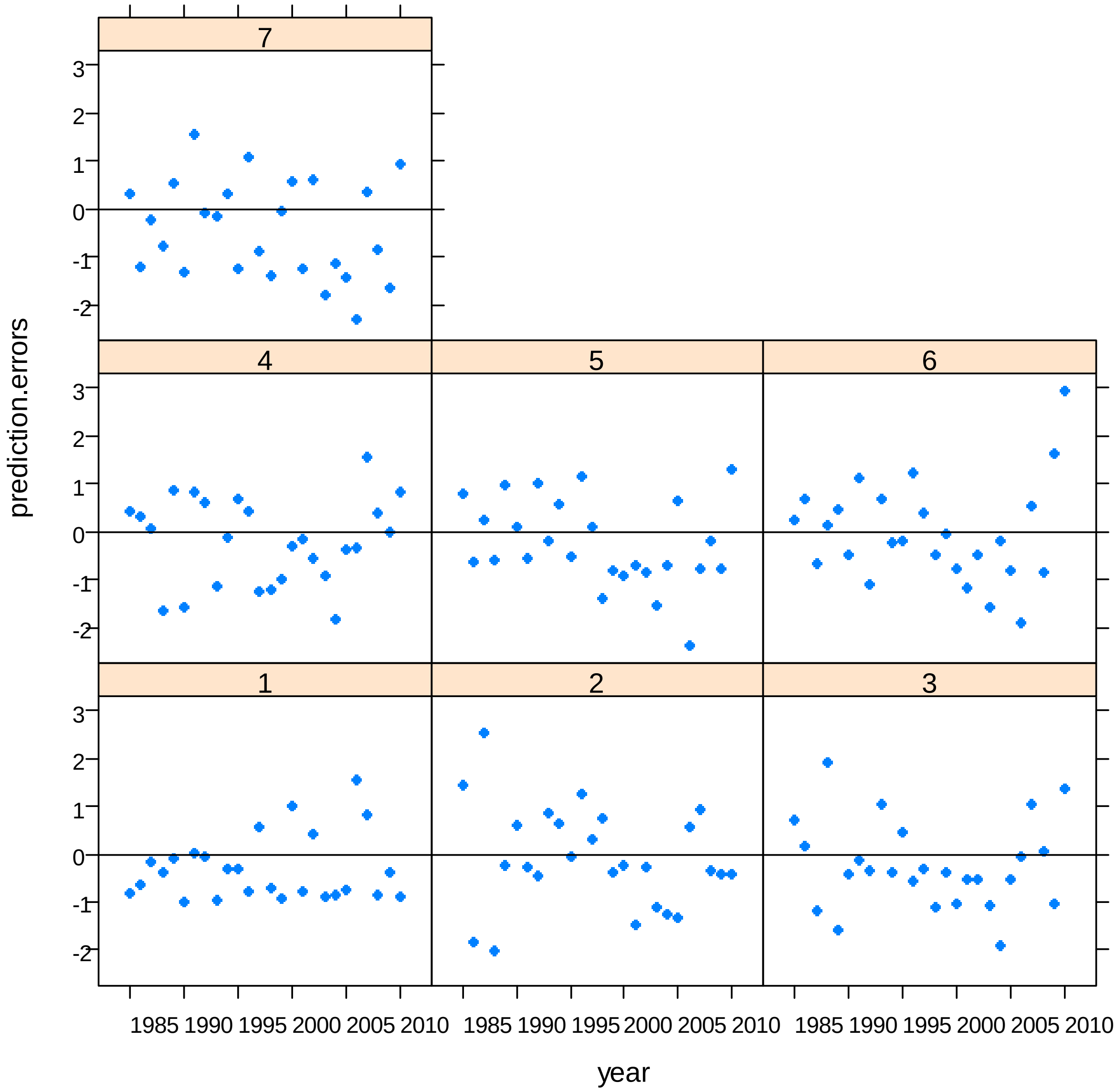


Figure 3.18. VIa cod; landings prediction errors. Supplementary model (including seal predation).

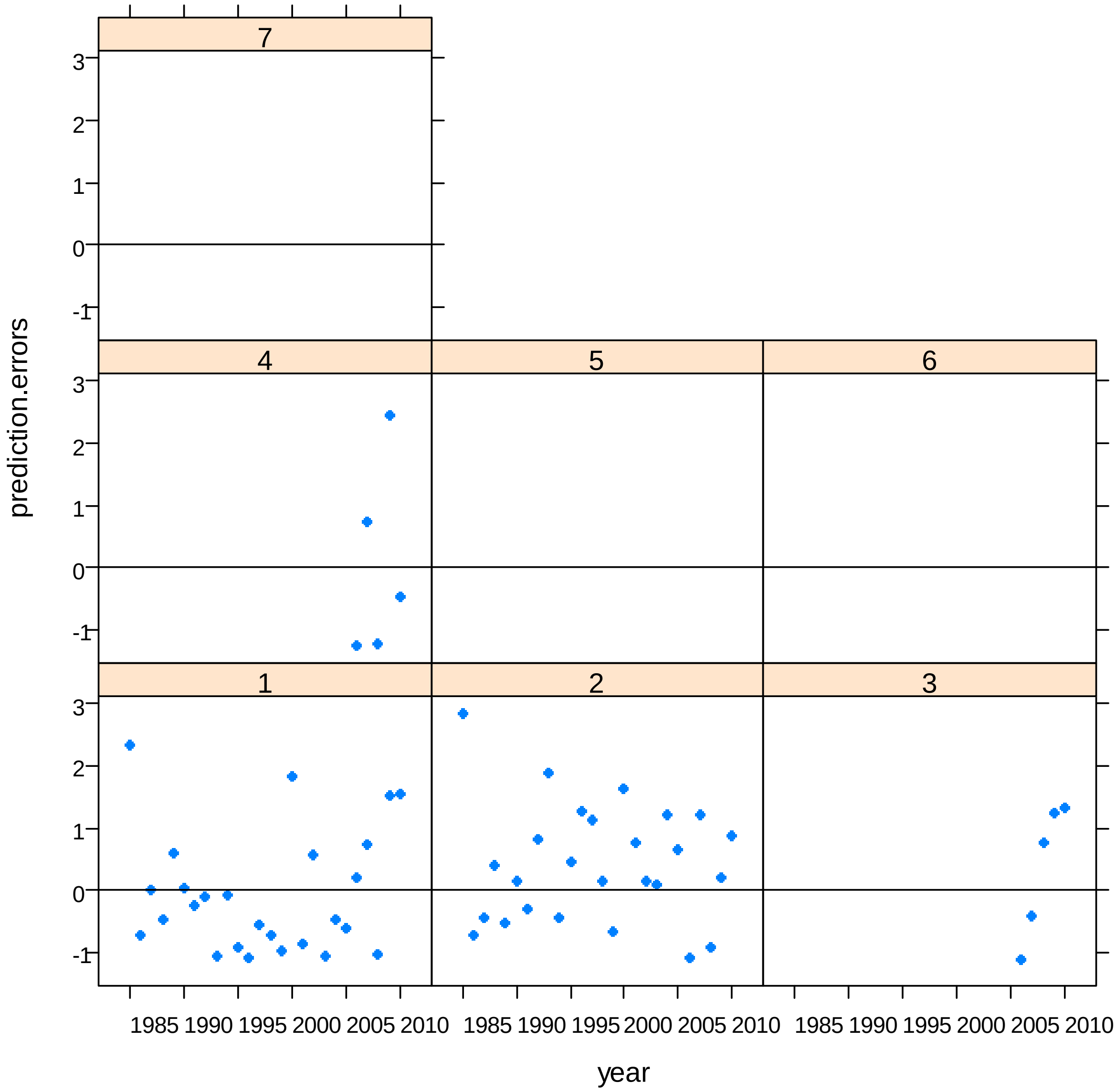


Figure 3.19. VIa cod; discards prediction errors. Supplementary model (including seal predation).

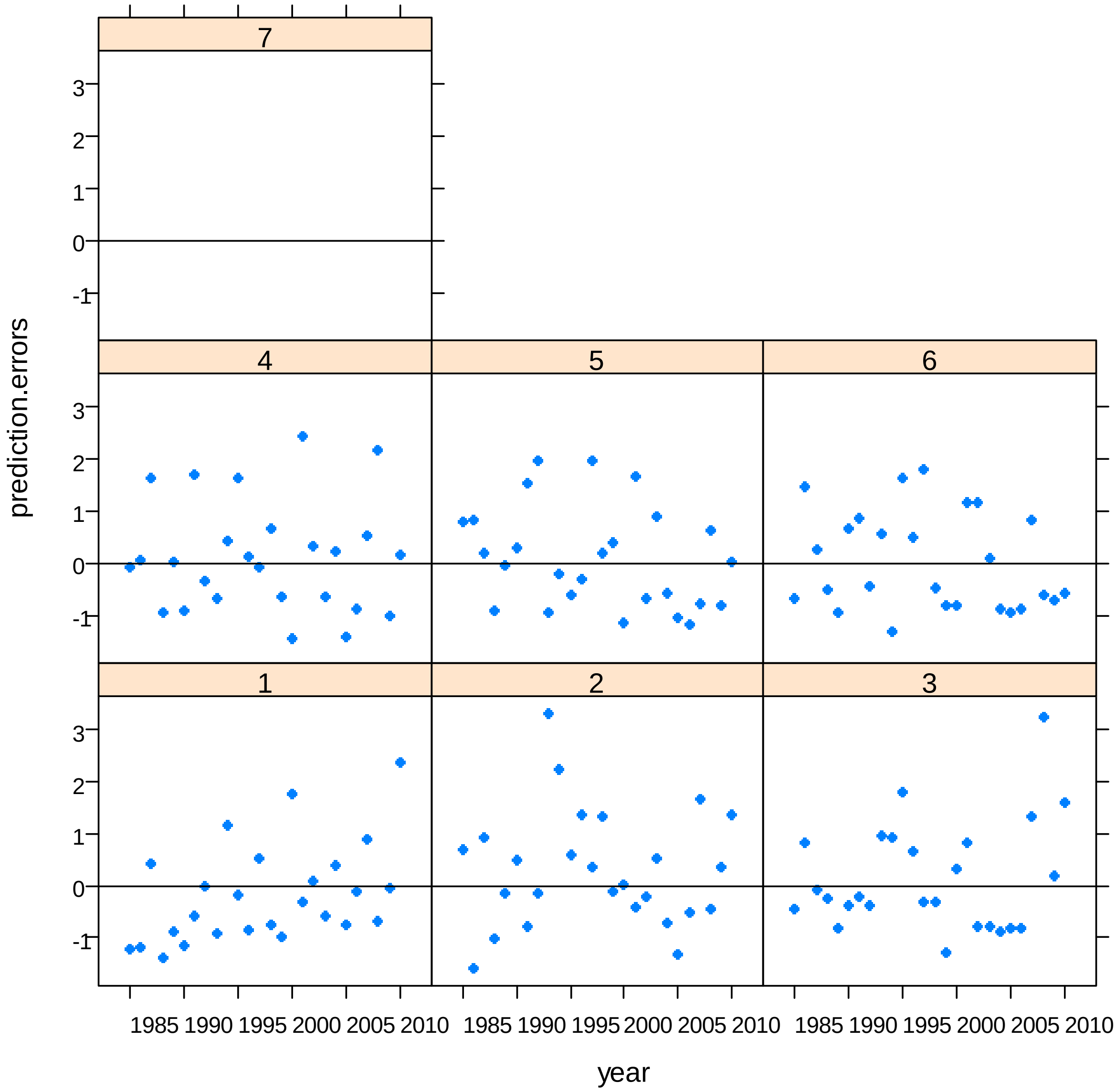


Figure 3.20. VIa cod; ScoGFS – WIBTS – Q1 prediction errors. Supplementary model (including seal predation).

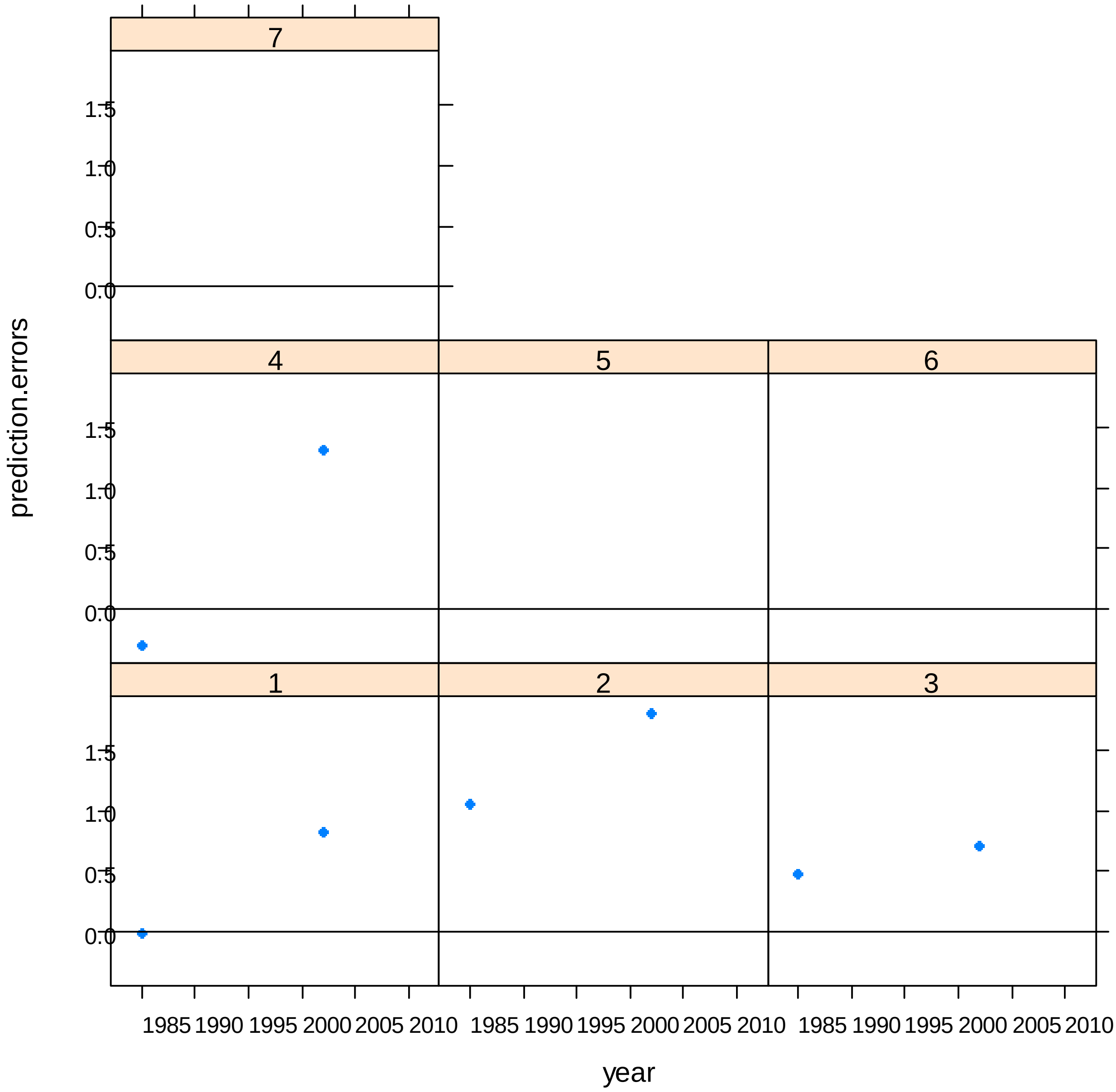


Figure 3.21. VIa cod; seal consumption of cod prediction errors. Supplementary model (including seal predation).

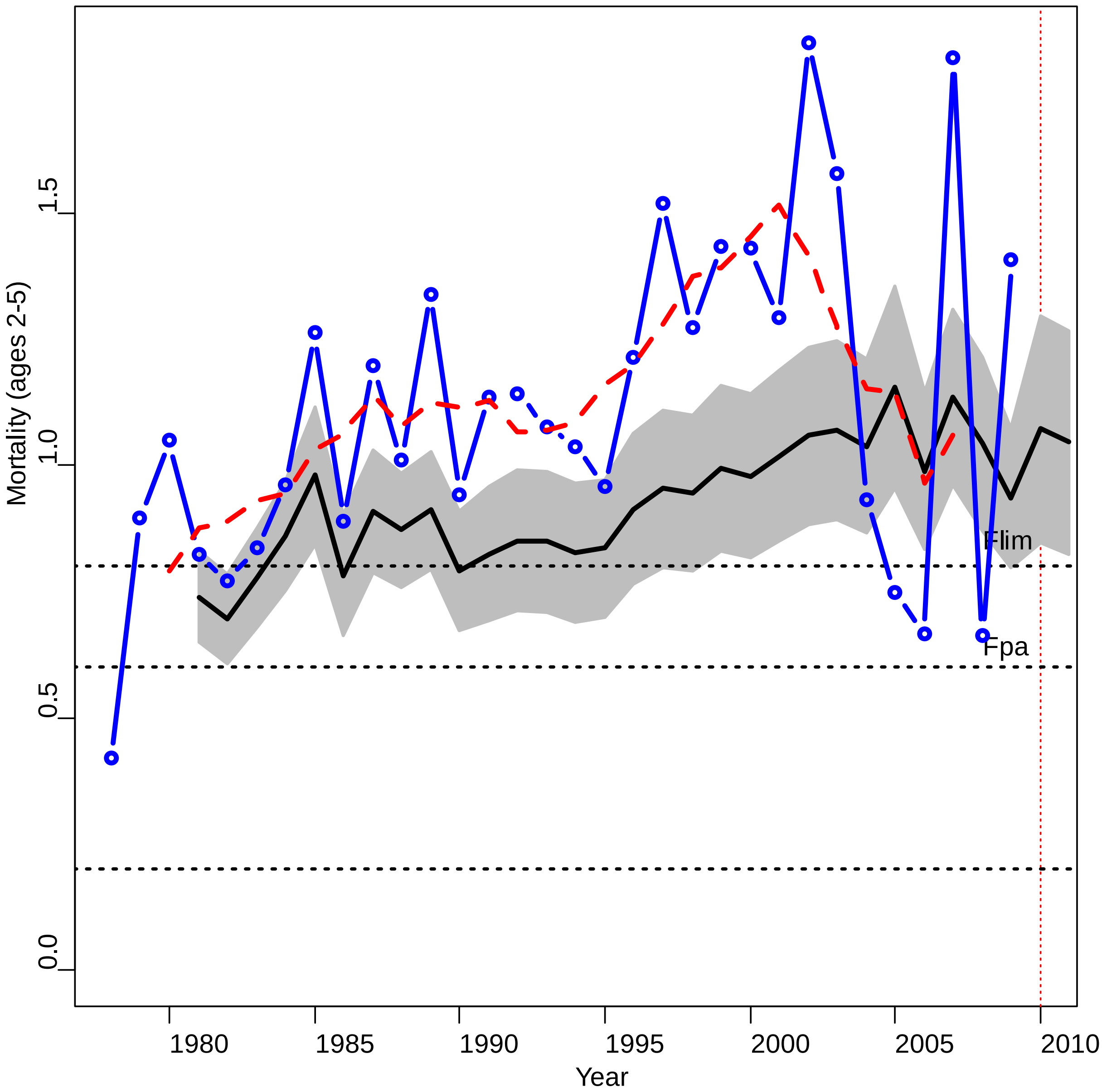


Figure 3.22. VIa cod; mean F (ages 2–5) resulting from the assessment model (solid line) with grey shading representing confidence interval (± 2 s.e.). Log catch ratio on ages 2 to 5 (blue circles with line). Five year running average of log catch ratio (red dashed line).

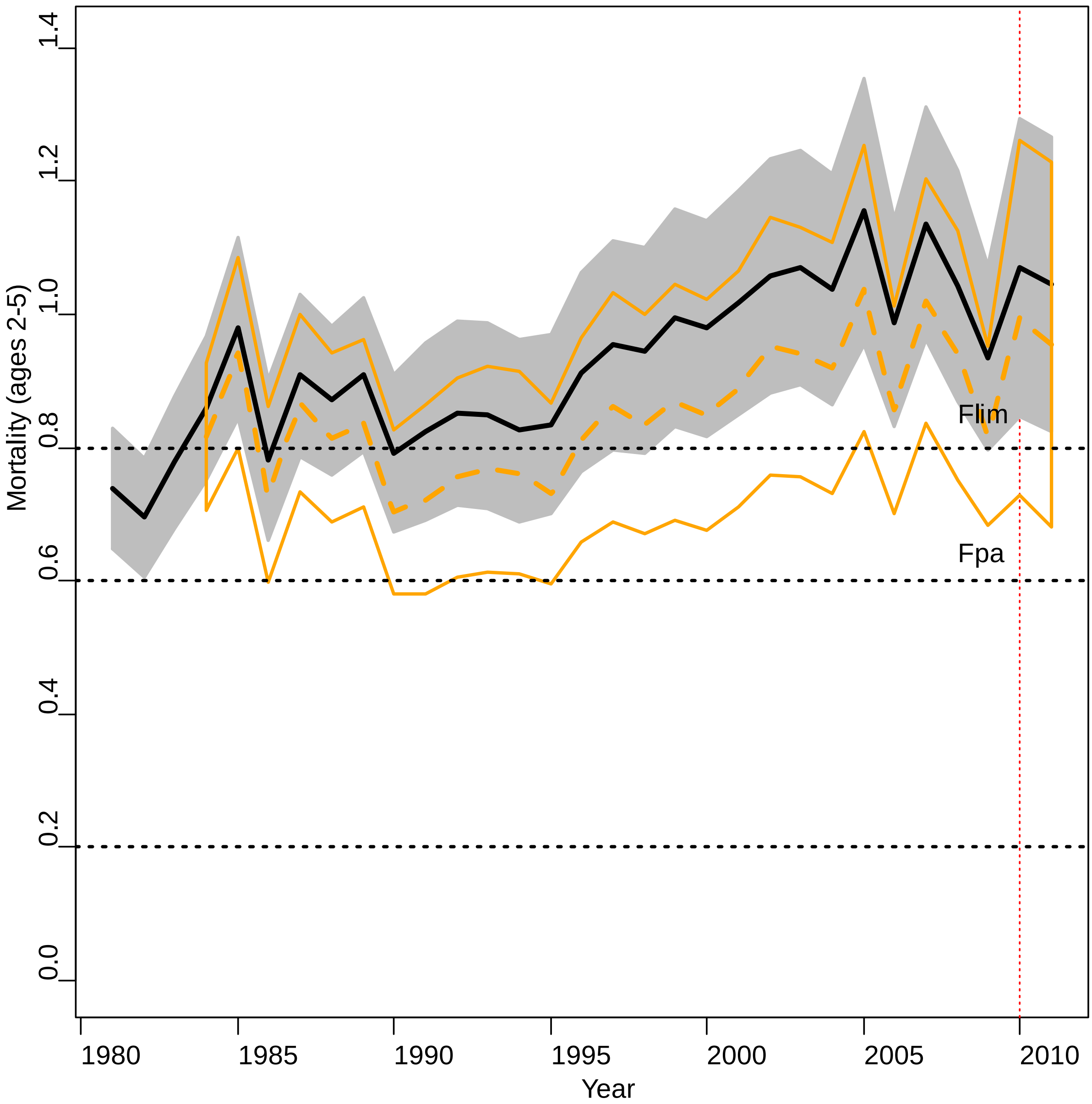


Figure 3.23. VIa cod; comparison of mean F trends. Black solid line: assessment model (without seal predation), grey shading representing confidence interval (± 2 s.e.); orange dashed line: supplementary model (including seal predation), orange outline representing confidence interval (± 2 s.e.).

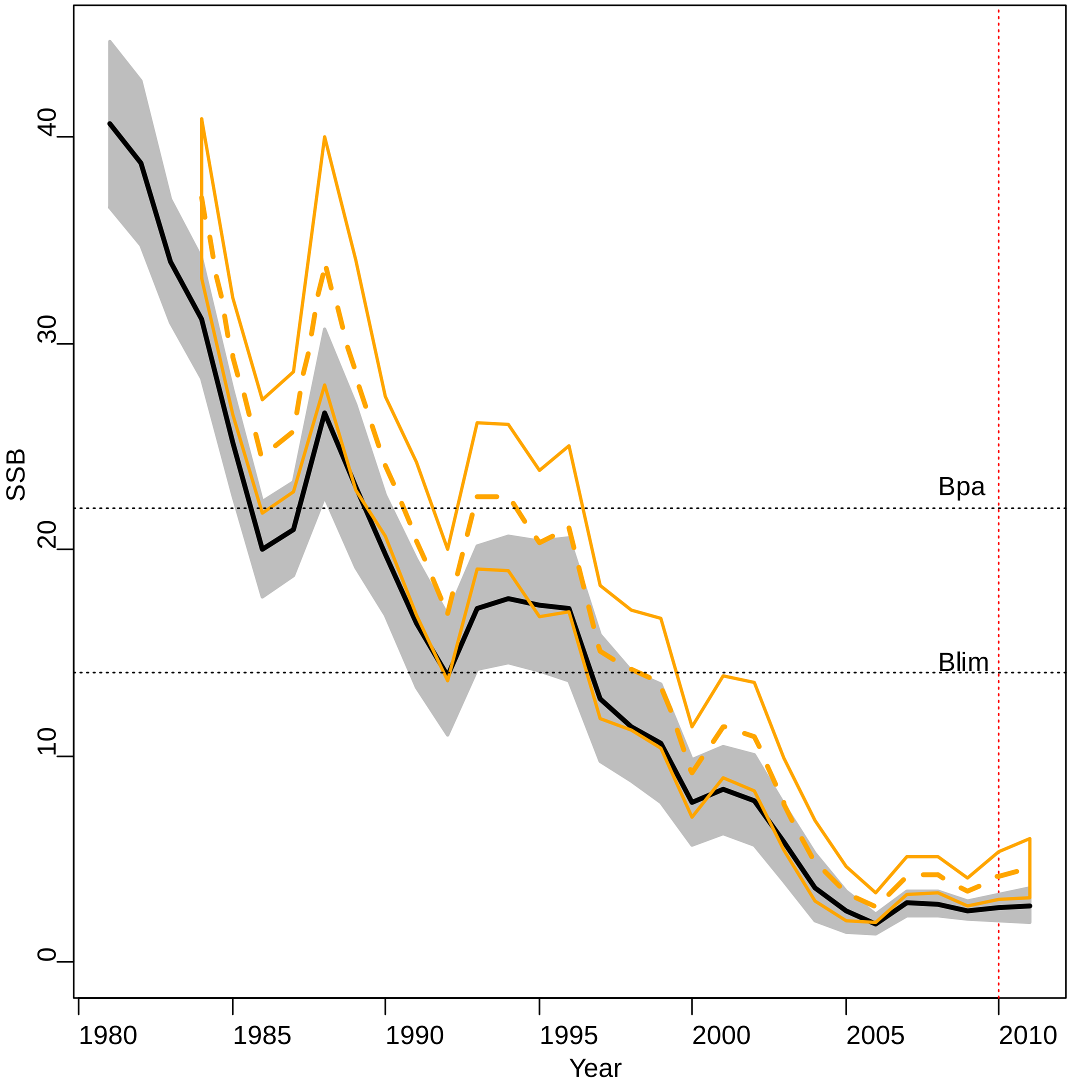


Figure 3.24. VIa cod; comparison of SSB trends. Black solid line: assessment model (without seal predation), grey shading representing confidence interval (± 2 s.e.); orange dashed line: supplementary model (including seal predation), orange outline representing confidence interval (± 2 s.e.).

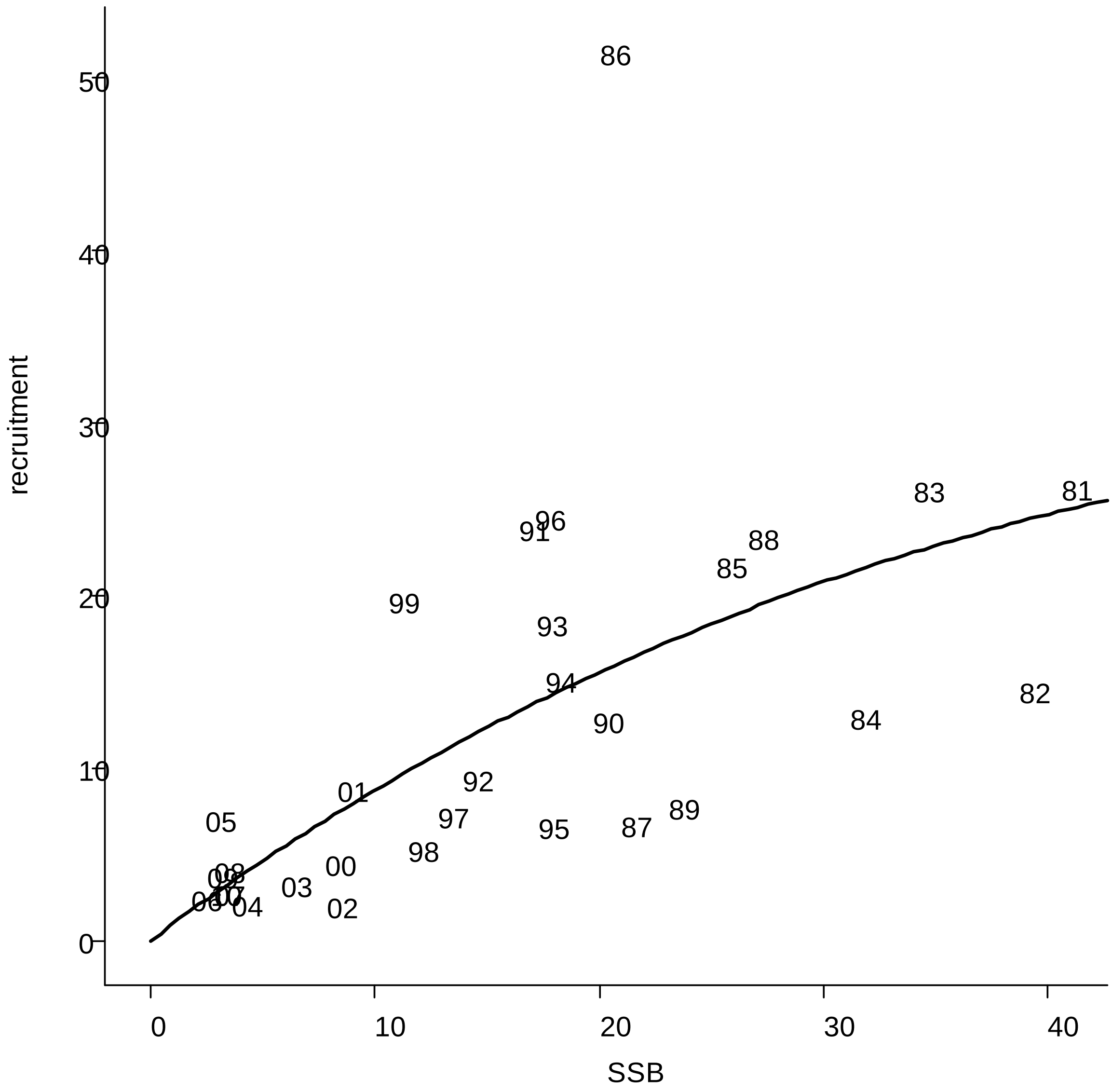


Figure 3.25. VIa cod; stock–recruit relationship and modelled fit for assessment model (without seal predation).

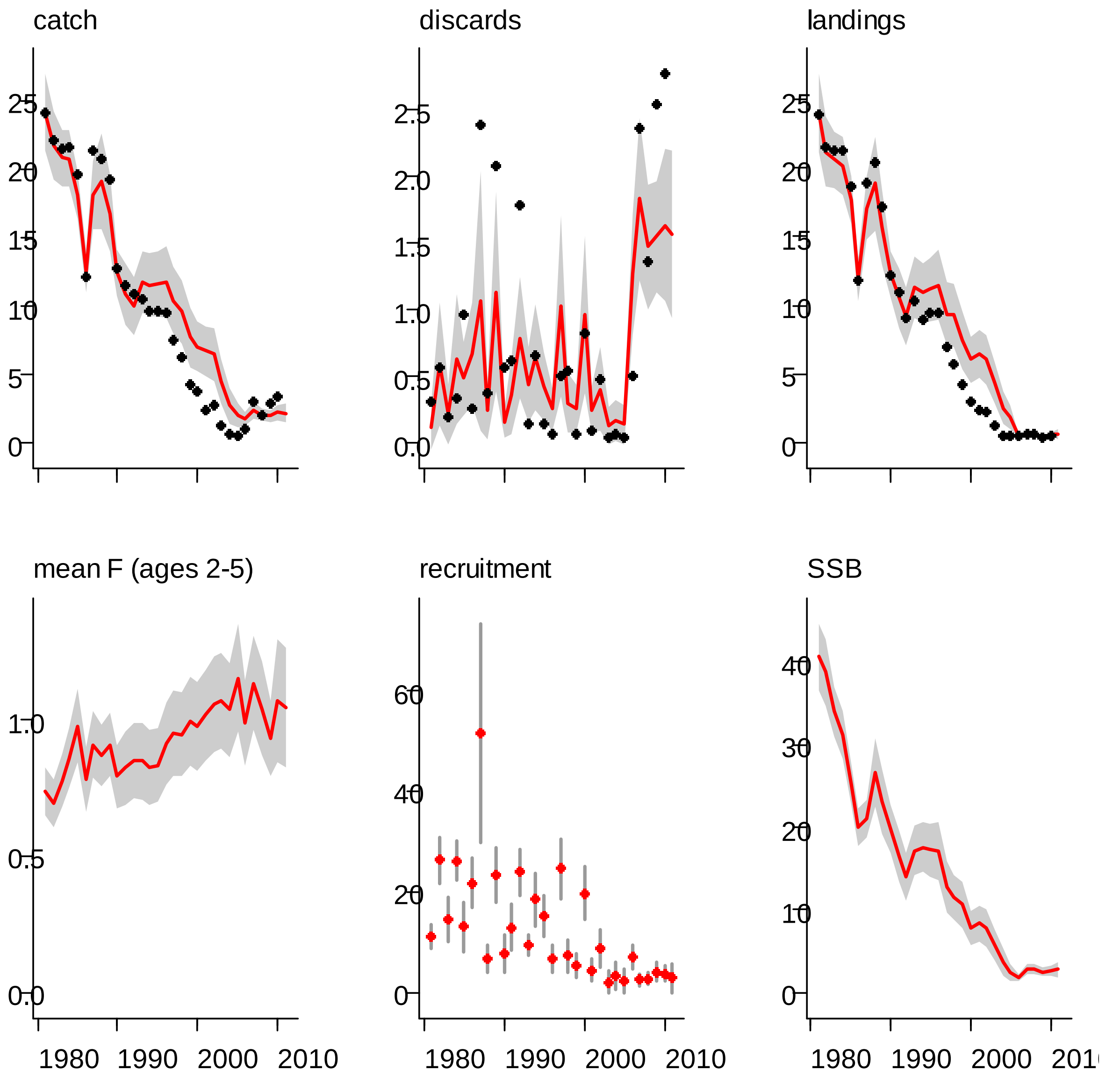
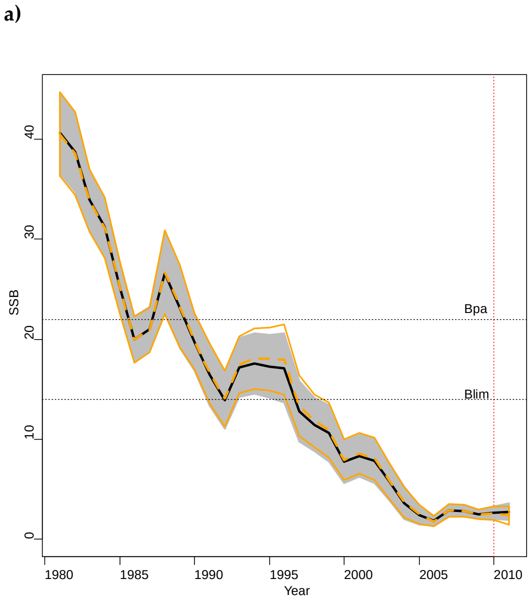


Figure 3.26. VIa cod; summary plots for assessment model (without seal predation).



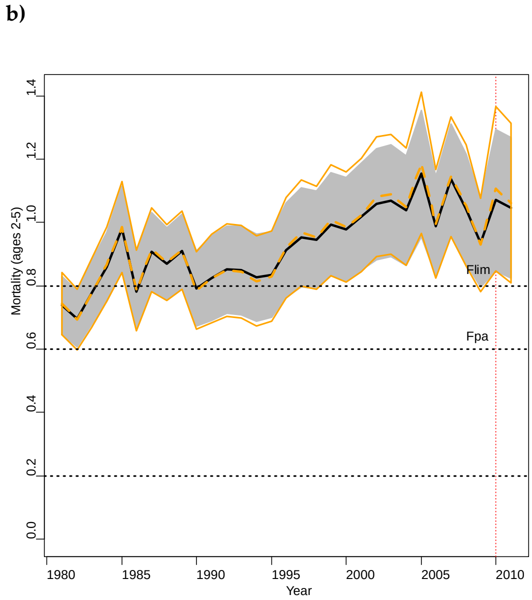


Figure 3.27. VIa cod; estimates from TSA a) SSB; b) MeanF. Solid black line and grey shading giving confidence interval (± 2 s.e.): full survey-series; dashed orange line and orange outline giving confidence interval (± 2 s.e.): survey data removed for 2006 to 2010.

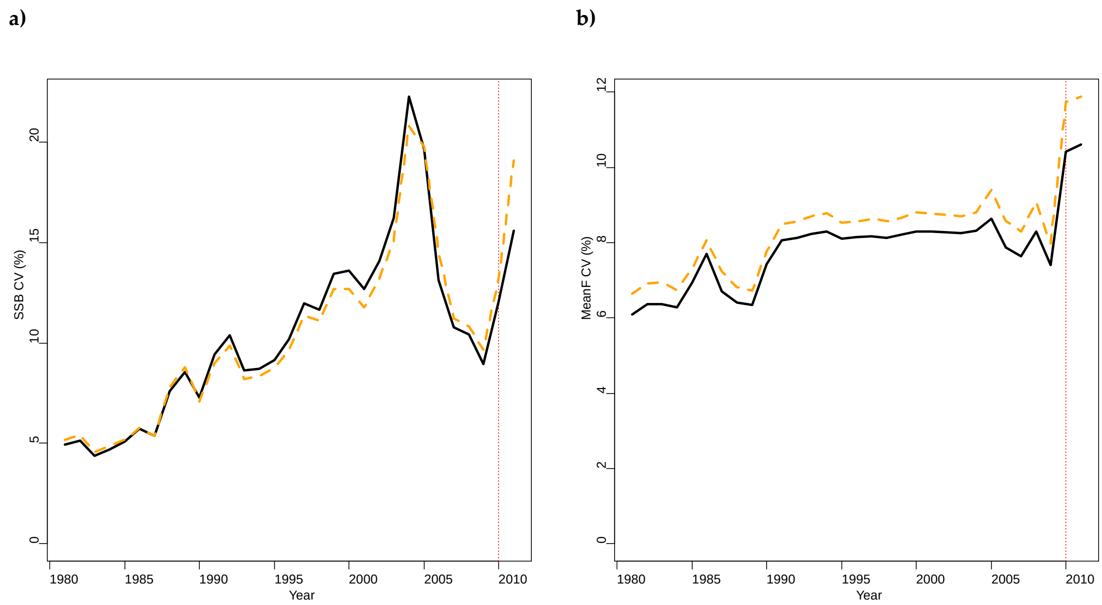


Figure 3.28. VIa cod; CV of estimates from TSA. a) SSB; b) MeanF. Solid black line: full survey-series; dashed orange line: survey data removed for 2006 to 2010.

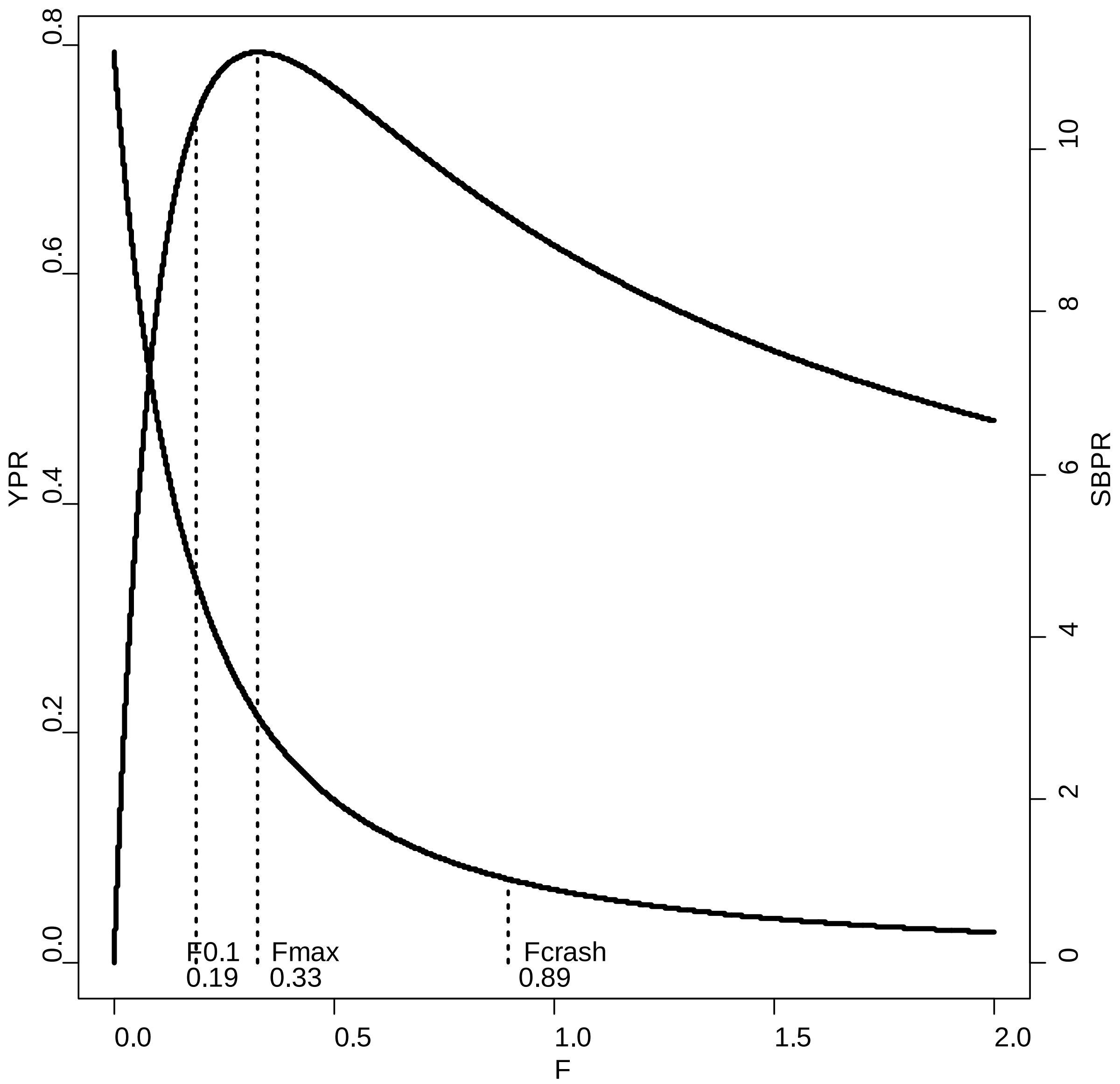


Figure 3.29. VIa cod; yield-per-recruit and SSB per recruit.

4 Whiting in Division VIa

4.1 Current status of assessment and advice

The assessment if whiting in Division VIa is currently based on survey data (ICES WGCSE, 2011). No formal analytical assessment has been conducted for this stock in recent years and, in consequence, no advice has been provided (under the old ICES paradigm). The current survey-based approach is complemented with an exploratory assessment with the Time-Series Analysis (TSA) (Fryer, 2001). The source data in the current assessment are reported catch data, one survey cpue indices (ScoGFS-WIBTS-Q1), fixed natural mortalities and maturities.

The benchmark assessment presented to WKROUND provided an opportunity to address the main issues for this stock: the lack of a formally accepted assessment in recent years, unreliability of discard data, misreporting and conflicting signals from groundfish surveys.

Alternative exploratory assessments conducted using SURBAR (Needle, 2003) and a Bayesian approach (Cook, WD#3) are also presented in this Section, and are compared with the TSA assessment.

4.1.1 Landings

Landings data are provided annually by UK, Ireland, France, Norway and Faroe Islands. Landings age compositions are provided by UK and Ireland. Total landings (as well as discards), as officially reported to ICES in 1965–2010, are shown in Figure 4.1. The detailed data are presented in ICES-WGCSE (2011).

No new catch or landings data were presented to WKROUND.

4.1.2 Misreporting (including area-misreporting and underreporting)

The proposed TSA assessment for VIa whiting (see Section 4.3) does not use full commercial landings and discards data from 1995–2005 (although age compositions are used). Anecdotal evidence from observers and industry reports indicates that commercial data from that period are unlikely to be very reliable, due to concerns over underreporting of landings. The UK Registration of Buyers and Sellers legislation, which came into effect in 2005 (Scottish Government, 2005), has implemented auditing procedures that make under-reporting extremely difficult for the industry to attempt. For this reason, it would appear very likely that under-reporting in the Scottish demersal fleet has effectively stopped, save for isolated incidents.

The concern remains that the industry may instead be avoiding quota restrictions by area misreporting. There is strong evidence for this with the VIa cod stock, for which detected area misreporting comprises around 200% of the officially reported landings (Section 3). Marine Scotland Compliance regularly compares VMS data from vessels with the areas from which landings are reported to have originated, and uses this as the basis for the table of suspected and detected misreporting and under-reporting, which is reproduced in Table 4.1. Under declaration (that is, underreporting by weight) was substantial in 2001, declined to a very low level when Buyers and Sellers came in force in 2005, and has risen very slightly in recent years (but is still comparatively negligible). The balance of landings misreported into and out of Division VIa fluctuates, and in 2011 was estimated to be around 59 tonnes: that is, 59 tonnes were caught in Division IVa and reported as being caught in Division VIa. The official landings in 2011 were 349 tonnes, so the estimated area misreporting represents around 17% of the reported total. This is much less than the equivalent for VIa cod.

Although relatively small, the existence of area misreporting is of some concern, and WKROUND considered the distribution of Scottish fishing effort more closely. Figure 4.2 shows a part of an inferred distribution of the areas in which whiting were caught by Scottish vessels in 2011 and subsequently landed. This map is produced by dividing the whiting landings for a trip equally among all the VMS pings for that trip that indicated fishing activity (that is, when the vessel was travelling at less than 4.5 knots; see Borchers and Reid, 2005). This exercise is repeated for all the trips of all Scottish vessels, and then the implied weight of whiting landed from all relevant VMS pings is summed over small areas (1/16th of an ICES statistical square).

Figure 4.2 summarises the distribution of summed implied whiting landings across these small areas for the immediate vicinity of the 4°W line. There is evidence of increased whiting-related fishing activity immediately to the east of the 4°W line, and it is tempting to conclude that this indicates area misreporting from Division VIa across the border into Division IVa. However, this is unlikely to be true. Firstly, Figure 4.2 indicates misreporting from Division VIa *into* Division IVa, and this contradicts the more direct evidence in Table 4.1. Secondly, the distribution in Figure 4.2 takes no account of where the skipper reported the landings as coming from, so it is difficult to see how they could be affected by misreporting.

There are at least three potential explanations for the concentration of implied whiting effort to the east of 4°W:

1) There could be a concentration of whiting in that area.

2) There could be a concentration of other fish species which were caught on trips that also caught some whiting: the methodology would show a whiting concentration even when there was none.

3) Vessels could be "pretending" to fish in that area during trips which also caught some whiting. Such activity has been observed in some vessels, and is done to attempt to subvert fishing-effort monitoring based on VMS pings.

Of these three possibilities, only the third would indicate an attempt deliberately to mislead the authorities. However, it seems very unlikely that such subversion could be coordinated across enough vessels to generate the pattern seen in Figure 4.2.

WKROUND concluded that:

a) The extent of area misreported suggested by Compliance authorities is relatively low for whiting, and is probably not consistent enough to affect the assessment.

b) VMS-based landings distribution plots are valuable in indicating large-scale effort patterns, but cannot be used to support fine-scale conclusions on area misreporting.

Given these conclusions, the assessment for VIa whiting was not modified to account for area misreporting or underreporting.

4.1.3 Discards

A landings and discards disaggregated assessment was proposed to WKROUND which reflected the different precisions of these data sources. A full model was used for discards. Previous discard estimates (ICES-WGCSE, 2011) for the years 1981–2003 were replaced by those estimated by Millar and Fryer (2005).

4.1.4 Surveys

Six research vessel survey-series for whiting in VIa were available to the WKROUND. In all surveys listed, the highest age represents a true age not a plus group.

- Scottish first-quarter west coast groundfish survey (ScoGFS-WIBTS-Q1): ages 1–7, years 1985–2010).
- Scottish fourth-quarter west coast groundfish survey (ScoGFS-WIBTS-Q4): ages 0–8, years 1996–2009).

The Q1 Scottish Groundfish survey was running in the period 1981–2010, and this was performed using a repeat station format with the GOV survey trawl together with the west coast groundgear rig, 'C'. Similarly the Q4 Scottish Groundfish survey was running in 1996–2010, once again using the GOV survey trawl with groundgear 'C' and the fixed station format.

In 2011, the Q1 and Q4 Scottish Groundfish surveys were redesigned. The previous repeat station survey format consisting of the same series of survey trawl positions being sampled at approximately the same temporal period every year is considered a rather imprecise method for surveying both these subareas and as such a move towards some sort of random stratified survey design was judged necessary. The largest obstacle preventing an earlier move to a more randomised survey design was the lack of confidence in the 'C' rig to tackle the potentially hard substrates that a new randomised survey was likely to encounter. The first step in the process of modifying the survey design was therefore to design a new groundgear that would be capable of tackling such challenging terrain. The introduction of the new design initiated two new time-series:

- Scottish first-quarter west coast groundfish survey (no formal code assigned yet): ages 1–7, years 2011–2012).
- Scottish fourth-quarter west coast groundfish survey (no formal code assigned yet): ages 0–8, years 2011–).

(see the distribution of whiting at age 1+ in the Q1 and Q4 surveys in 2011, Figure 4.3).

The Irish groundfish survey:

- Irish fourth-quarter west coast groundfish survey (IreGFS): ages 0–5, years 1993–2002.

was a comparatively short series. It was discontinued in 2003 and has been replaced by the IGFS:

- Irish fourth-quarter west coast groundfish survey (IGFS-WIBTS-Q4): ages 0–6, years 2003–2010.

This survey used the RV Celtic Explorer and is part of the IBTS coordinated western waters surveys. The vessel uses a GOV trawl, and the design is a depth stratified survey with randomised stations. Effort is recorded in terms of minutes towed. Further descriptions of these surveys can be found in ICES-IBTSWG (2011).

WKROUND decided to use three survey-series (ScoGFS-WIBTS-Q1, ScoGFS-WIBTS-Q4 and IGFS-WIBTS-Q4) in the tuning procedure in the final assessment. ICES will consider inclusion of the two new Scottish survey time-series to produce tuning indices through an inter-benchmark procedure when 4+ years of data have been gathered.

4.1.5 Catch weights

The detailed data on catch, landings and discards weights are given in ICES-WGCSE (2011). No new weight data were presented to WKROUND.

4.1.6 Biological data

An alternative to the assumption of constant natural mortality in the previous assessments was proposed to WKROUND linking *M* to fish weight. Thus, natural mortality (*M*) is assumed to vary and be dependent on fish weight (Lorenzen, 1996). *M* values are time-invariant and are calculated as:

$$M_a = 3.0\overline{W}_a^{-0.29}$$

where M_a is natural mortality-at-age a, $\overline{W}_a$ is the time averaged stock weight-at-age a (in grammes) and the numbers are the Lorenzen parameters for fish in natural ecosystems.

No changes to maturity data were considered by WKROUND. Maturity-at-age was assumed to be knife-edge, with the value 0 at age 1 and with 1 (full maturity) at age 2. That has been a source of criticism in previous assessments. However, recent research on gadoid maturity conducted by the UK gives no evidence for substantial change in whiting maturity since the 1950s, although there has been an increase in the incidence of precocious maturity-at-age 1, particularly in males, since 1998, in the Irish Sea.

4.2 Survey based analyses for whiting in Division VIa

4.2.1 Exploratory analyses

Figures 4.4 to 4.10 give a number of exploratory data analysis plots which WKROUND used to determine which survey series should be retained in the analysis. Figure 4.4 indicates that the Irish survey (IGFS) data has more noisy catch curves than either of the Scottish surveys (ScoGFS-WIBTS-Q1 and ScoGFS-WIBTS-Q4), while Figure 4.5 suggests that none of the available surveys are able to track year-class strength particularly consistently through time across all ages. However, the within-survey correlation plots in Figures 4.6 to 4.8 indicate that the Scottish surveys are reasonably consistent across one (or perhaps two) ages, while confirming that the Irish survey is poor at tracking year-class strength across any time period.

These diagnostics suggest that the Irish survey is perhaps a less reliable indicator of whiting population dynamics than the Scottish survey. On the other hand, Figure 4.9 shows that the whiting landings distribution is more widespread than that of cod, with significant concentrations in the southern part of Division VIa. This is supported by Figure 4.10 (from the Scottish Q1 and Q4 surveys), which indicate significant areas of whiting in the south of VIa. WKROUND concluded that the Irish survey, which is limited in extent to the southern area, is still likely to provide useful information on the wider VIa whiting stock.

4.2.2 SURBAR analyses

SURBA (Version 3.0: Needle, 2003; 2008; 2012) is a survey-based assessment model that is based on an assumption of separability in total mortality *Z*. It builds on the RCRV1A model of Cook (1997, 2004), and is widely used in ICES assessment working groups and elsewhere (see, for example, GFCM-SAC, 2008; STECF, 2010; Cadigan, 2010) for two purposes: in exploratory analyses, to indicate stock trends from research-vessel surveys; and to provide management advice for stocks with no catch data (or for which catch data are unreliable).

SURBAR is a relatively new implementation of SURBA, written using the R package (R Development Core Team, 2011) and dating from ICES-WGMG (2009). Parameters are estimated by nonlinear least-squares regression using the nls.lm function in the R minpack library (Elzhov *et al.*, 2010). To generate uncertainty estimates, the Hessian *H* of this model fit is used to define a multivariate Normal distribution of the model parameters, and the R function "mvrnorm" (Venables and Ripley, 2002; Ripley, 2011) is applied to draw 1000 samples from this distribution. This generates 1000 values of the required parameters in such a way that their variance-covariance structure from the Hessian is maintained. Each of these parameter resamples is then used in turn to produce estimated time-series of mortality and relative abundance, and a 90% confidence interval about these fitted time-series is derived from the 5% and 95% quantiles of these 1000 curves at each age. This is a far simpler and more powerful procedure than the delta method used in SURBA 3.0. SURBAR also avoids the use of loops and data-frames in the estimation function, so run-times are comparable with the Fortran-90 version (and hence NAG library routines can be dispensed with).

WKROUND produced a SURBAR analysis for VIa whiting, using the same survey-series as included in the final TSA run (see Section 4.1). The 2011 data points for the Scottish Q1 and Q4 series could not be used, however, as they represent new series and SURBAR cannot use one-year series in estimation. The following settings were used (see ICES-WGMG, 2009):

- Reference age for separable model = 3 (recall age range for mean *Z* is 2–4).
- Lambda smoother = 1.0.
- All SSQ weightings and catchabilities *q* set to 1.0.

SURBAR converged in six iterations for this analysis, and produced the output given in Figures 4.12 to 4.15. Stock summary plots (Figure 4.12) show relatively stable estimates of mean *Z* with fluctuations in the mid-2000s, SSB rising to a peak in the middle of the time-series before returning back down to the levels seen in the late 1980s, and a run of very low recruitments in recent years. Variance around parameter estimates (Figure 4.13) is reasonably consistent across all ages, years and cohorts. Residual plots (Figure 4.14) indicate that the stock signal from the Irish survey may be different from that in the Scottish surveys, with mostly positive residuals in the former and a downwards trend in the latter towards the end of the time-series. Finally, the retrospective plot (Figure 4.15) shows rather more noise than would be usual for a SURBAR analysis, which may be caused by differences between the Scottish and Irish surveys.

4.2.3 Exploratory Assessments of whiting in VIa using a Bayesian approach

A working paper (WD3) was presented on the assessment of West of Scotland whiting using an age structured model fitted within a Bayesian framework of the same type as described in WD2. A full description of the model and results is given in the working document. The main differences between the assessment described in the paper and previous ICES assessments (ICES-WGCSE, 2011) is the inclusion of all four available surveys and modelling natural mortality as a function of mean weight (Lorenzen, 1996).

The analysis of survey data alone suggests that fishing mortality has fluctuated since 1985 but began to decline around 2006 (Figure 4.16) and is now at a low level. The trends in F are very similar to the last ICES assessment but the mean level is lower. This is most likely due to the higher M values used in the current assessment. The estimated trends in SSB are similar to those from the last ICES assessment (ICES-WGCSE, 2011) shown in Figure 4.17 but there is clearly a change in scale around 1992. In the Figure, the ICES estimates are scaled to the period 1985–1992 so the early values coincide with the Bayesian model. A different reference period could rescale the later values to the survey-only assessment. Essentially there is a change in relative scale around 1992 as seen by the surveys and the commercial fishery data.

The assessment in WD3 introduces weight-dependent natural mortality, *M*, for this stock for the first time. One of the main reasons for making this change is to overcome the inconsistency between the earlier values used for this stock (*M*=0.2 for all ages) compared to the adjacent North Sea stock for which estimates of *M* from MSVPA are used. Figure 4.18 shows the estimated values from the Bayesian assessment compared to the comparable MSVPA values in the North Sea. The values are more consistent, and given the connection between the two stocks, are probably preferable to the constant values used earlier.

Figure 4.19 shows the estimated measurement error for each of the four surveys. The two Scottish surveys perform best overall, but all surveys show low measurement error for intermediate ages. Inclusion of surveys in addition to the Scottish quarter 1 survey then improves the precision of the estimates by about 20–30% for stock summary metrics (Figure 4.20). The figure shows the ratio of the 95% credible interval:

$$\frac{u_{all} - l_{all}}{u_{IBTSq1} - l_{IBTSq1}}$$

where u and l are the upper and lower bounds of the interval.

4.2.4 Conclusion

The Scottish Q1 and Q4 surveys cover the majority of the fishable areas in Division VIa. The Irish survey is limited to the southern area, but survey and landings distributions maps indicate that whiting are widespread throughout Division VIa and a survey of the southern area only is likely still to have validity as an indicator of stock dynamics. The SURBAR residuals and retrospective analyses suggest that the Irish and Scottish surveys do indicate somewhat different trends in recent years. However, all three surveys have been retained in this analysis, as the internal variability of the Irish survey means it is downweighted in the model fit in any case. It is important to try and retain it, as the Scottish surveys now comprise new time-series and the Irish survey is the only continuous series available for survey-based analysis in the near future.

4.3 Catch-at-age analyses using TSA

4.3.1 Method

The proposed final assessment of whiting in VIa was conducted using a TSA model. The method was first developed by Gudmundsson (1994), and it was modified by Rob Fryer for the purpose of assessing time-series containing several years with survey data but no reliable catch data (Fryer, 2002). Subsequent enhancements to the method are detailed in Needle and Fryer (2002).

4.3.2 Assessment

The availability of revised discard estimates made it possible to conduct a landings and discards disaggregated assessment. This approach was considered by WKROUND to be a reliable basis for determining the status of the stock. Natural mortality was assumed to vary with age being dependent on fish weight, which was a substantial change to previous assessments where it was assumed to be 0.2 for all ages. No modification was made to account for misreporting (see Section 4.1.2 above). A "hockey-stick" model was employed to describe the stock–recruitment relationship. Three survey-series (ScoGFS-WIBTS-Q1, ScoGFS-WIBTS-Q4 and IGFS-WIBTS-Q4) were included in the assessment. Some extra variability in landings and discards was allowed for some ages. Also some points in the time-series that were identified as outliers were downweighted to improve the fit. Methods of acquiring the input data are outlined in Section 4.1 and further details are given in the Stock Annex.

The main diagnostics of the quality of the model fit was the value of the objective function (–2*log likelihood), prediction errors and a consideration of how well the model has replicated discard ratios in the input data.

Standardised prediction errors for landings and discards are given in Figure 4.21, and those for the three surveys in Figure 4.22. None of these are large enough to invalidate the model fit and there are no obvious time-trends in recent years.

Discards continue to account for a large proportion of the total catch, with the proportion discarded tending to level off in the recent years (Figure 4.23). The TSA stock–recruit plot is presented in Figure 4.24 and shows a rather good relationship, partly because the stock was driven to very low levels of SSB in the last decade. TSA also estimated a large increase in catchability: this is plotted as the percentage change compared to the catchability at the start of each of the three surveys in Figure 4.25. The estimates are uncertain with relatively wide confidence intervals. The summary plots for the final assessment are shown in Figure 4.25.

4.3.3 Conclusion on assessment methods

WKROUND accepted TSA as the main assessment method for whiting in Division VIa. WKROUND considers the final assessment with this model as adequate given all the problems associated with this stock. With the new legislation on reporting landings, the quality of landings data is likely to continue to improve. The inclusion of the two new Scottish survey time-series in the coming years will enhance the assessment of this stock.

4.3.4 Recommendations for future developments

With regard to the assessment method, changes to the variance structures used in the model should be allowed if they improve model diagnostics (e.g. likelihood ratio tests, prediction error plots).

4.4 Short-term projection

Not done.

4.5 Implications for reference points

4.5.1 Precautionary reference points

No accepted precautionary reference points currently exist. ICES currently considers that B_{lim} is 16 000 t and B_{pa} be set at 22 000 t. ICES also proposes that F_{lim} is 1.0 and F_{pa} be set at 0.6.

4.5.1.1 Stock-recruit

The TSA model assumes a hockey-stick stock–recruit relationship (Figure 4.24). The following parameter values were estimated: α = 256.5 (million), β= 30.4 (thousand tonnes).

4.5.1.2 Y/R & SSB/R

No yield-per-recruit analysis was attempted with the output from the final TSA run. WKROUND considers that MSY reference points based on yield-per-recruit and stock–recruit relationships are not applicable at present due to the uncertainty in historical stock trends.

Table 4.1. Suspected and detected total weight of whiting misreported by area and underreported by the Scottish commercial demersal fleet during 2001–2011.

Sum of WEIGHT		Year											
TYPE	Direction	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
MISREPORTING	IVa to VIa	92.318	78.813	30.665	32.53				4.37	9.835	29.463	59.775	337.769
	IVa to VIb				0.217					0.144	2.45		2.811
	IVb to IVa									0.596	11		11.596
	Vb to VIa		2						0.44	1			3.44
	VIa to IVb	11.054		0.225									11.279
	VIa to Vb	0.05	2.806	6.2	2.032	0.63	8.114	4.4		0.74			24.972
	VIa to VIa									10.189	59.304	1.298	70.791
	VIa to VIb						0.637						0.637
	VIb to VIa										5		5
	VIIa to VIa		1.9	0.321									2.221
MISREPORTING Total		103.422	85.519	37.411	34.779	0.63	8.751	4.4	4.81	22.504	107.217	61.073	470.516
UNDER-DECLARATION		279.597	104.245	107.019	62.7	24.43				2.897	4.065	10.235	595.188
UNDER-DECLARATION Total		279.597	104.245	107.019	62.7	24.43				2.897	4.065	10.235	595.188
	Total to VIa	92.318	82.713	30.986	32.53	0	0	0	4.81	10.835	34.463	59.775	
	Total from VIa	11.104	2.806	6.425	2.032	0.63	8.751	4.4	0	10.929	59.304	1.298	
	Area misrep	81.214	79.907	24.561	30.498	-0.63	-8.751	-4.4	4.81	-0.094	-24.841	58.477	

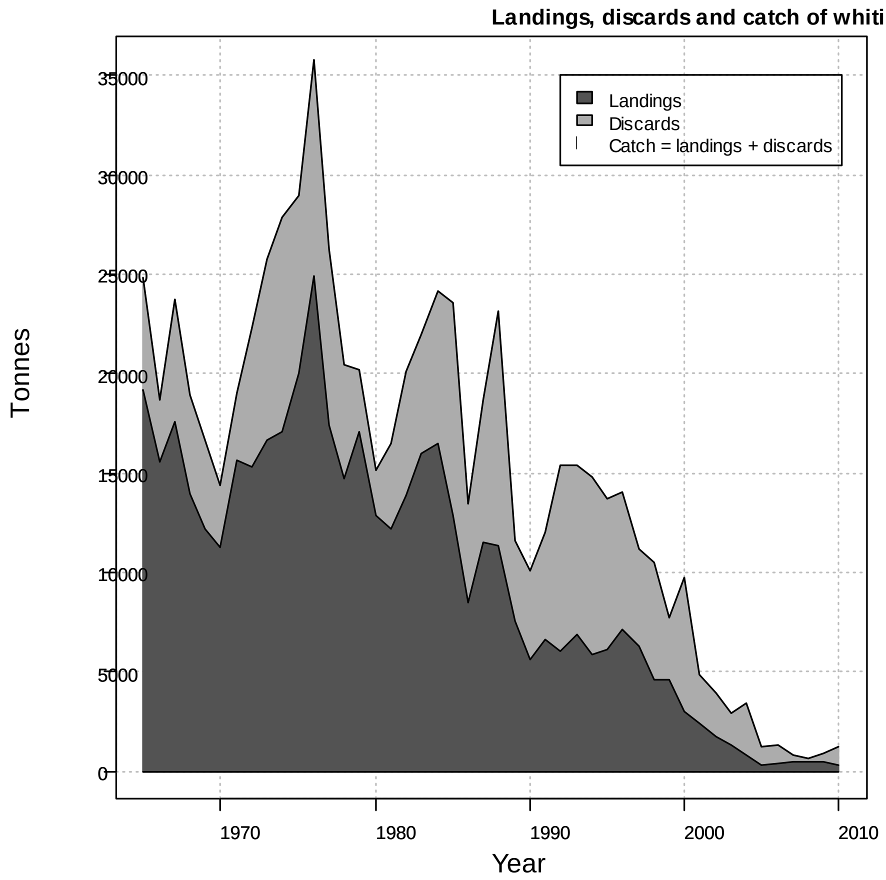


Figure 4.1. Landings, discards and catch (in tonnes) of whiting in Division VIa, as officially reported to ICES.

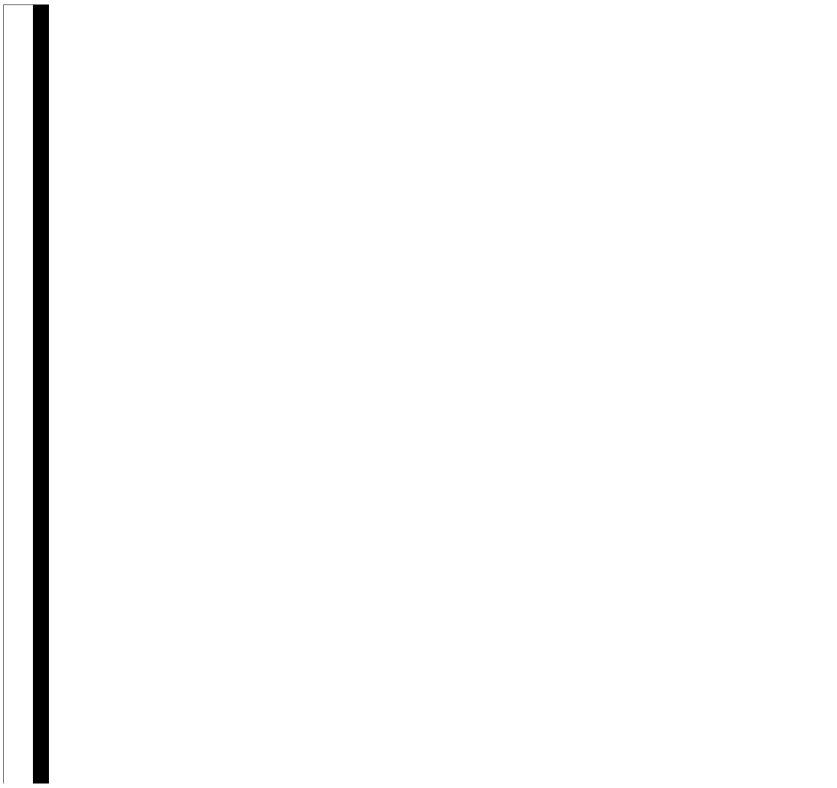


Figure 4.2. VMS-based distribution of whiting landings from the north of Scotland in 2011. See text for details.

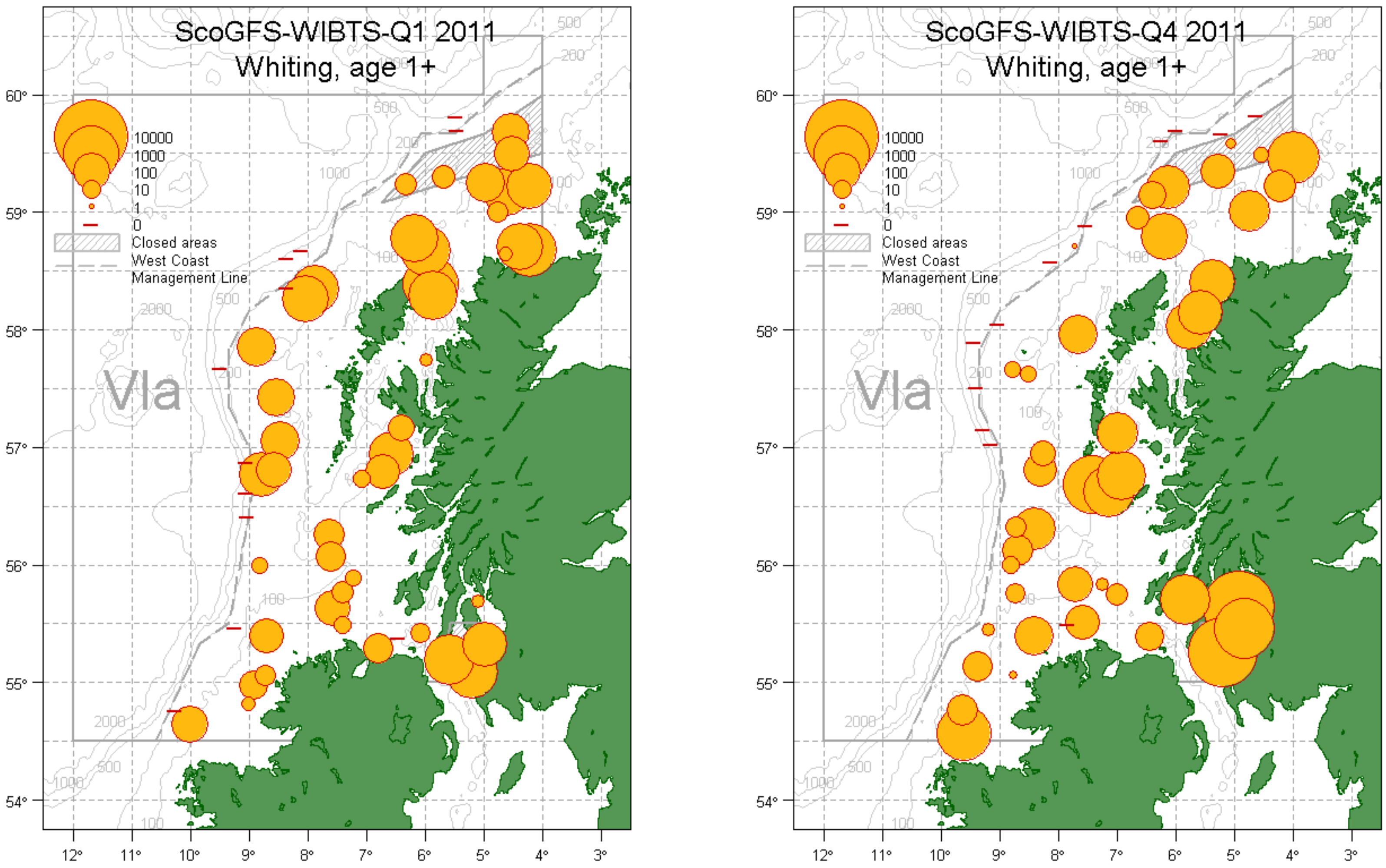


Figure 4.3. Map of the west coast of Scotland showing the catch per unit of effort of whiting during the 2011 Scottish first quarter west coast groundfish survey (ScoGFS-WIBTS-Q1) and the 2011 Scottish fourth quarter groundfish survey (ScoGFS-WIBTS-Q4). Each circle is centred on the sample location and the size of the circle is proportional to the log number density (n/30 min fished) of whiting at age 1+, according to the legend (top left).

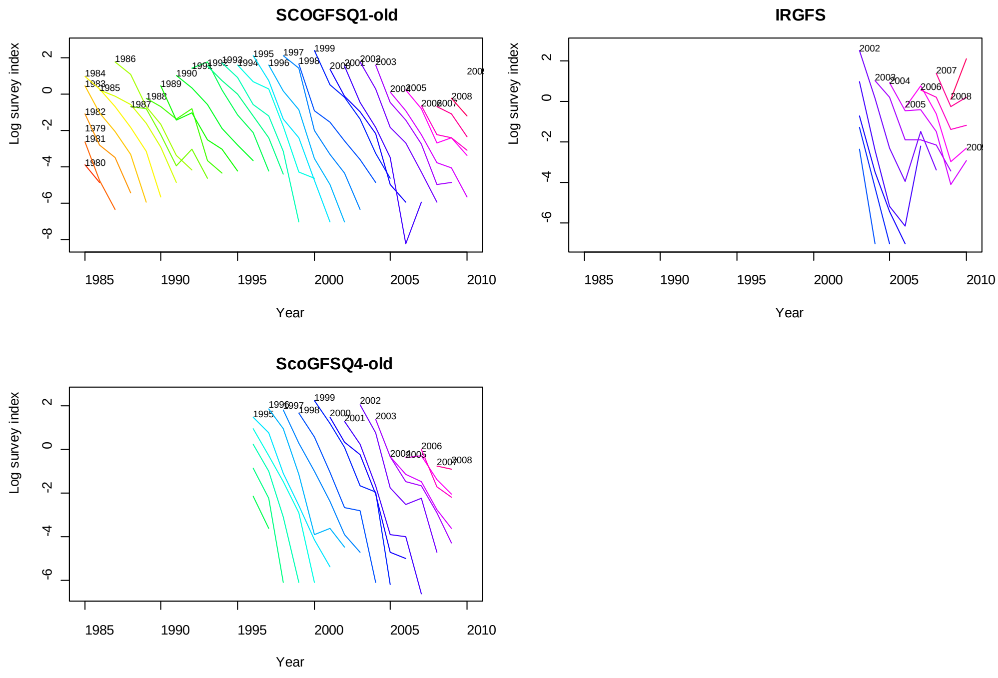


Figure 4.4. Whiting in Division VIa. SURBAR diagnostic plot: log abundance indices, by year with a line for each cohort, for each of the three survey indices. The spawning date of each cohort is indicated at the start of each line.

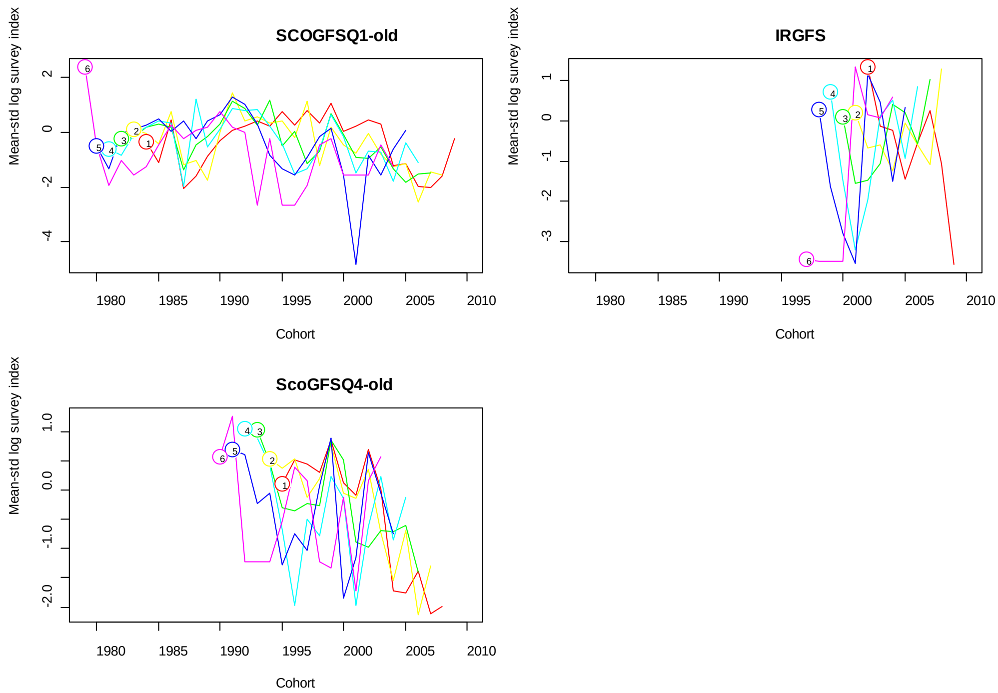


Figure 4.5. Whiting in Division VIa. SURBAR diagnostic plot: log abundance indices, by cohort with a line for each age, for each of the three survey indices. Colour coded ages are indicated by a label at the start of each line.

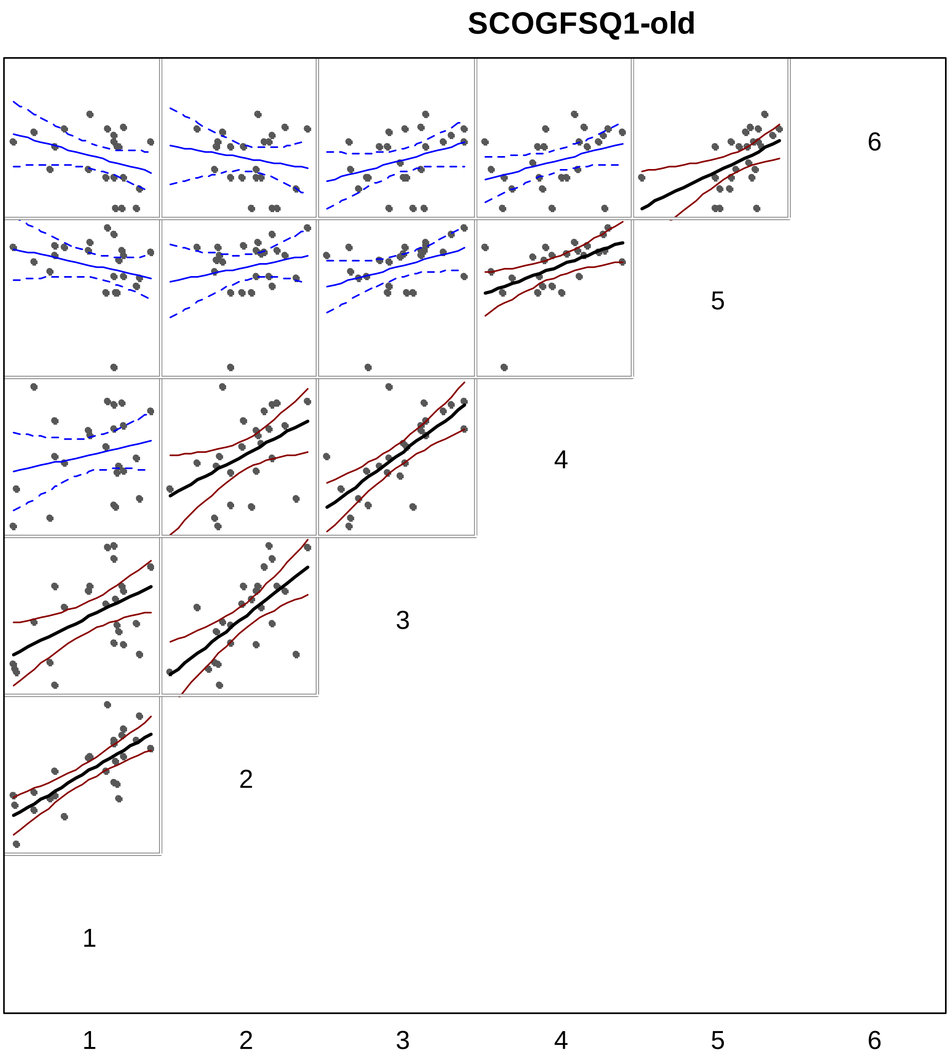


Figure 4.6. Whiting in Division VIa. SURBAR diagnostic plot: within survey correlations for the ScoGFSQ1-old survey-series, comparing index values at different ages for the same year classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant ($p < 0.05$) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

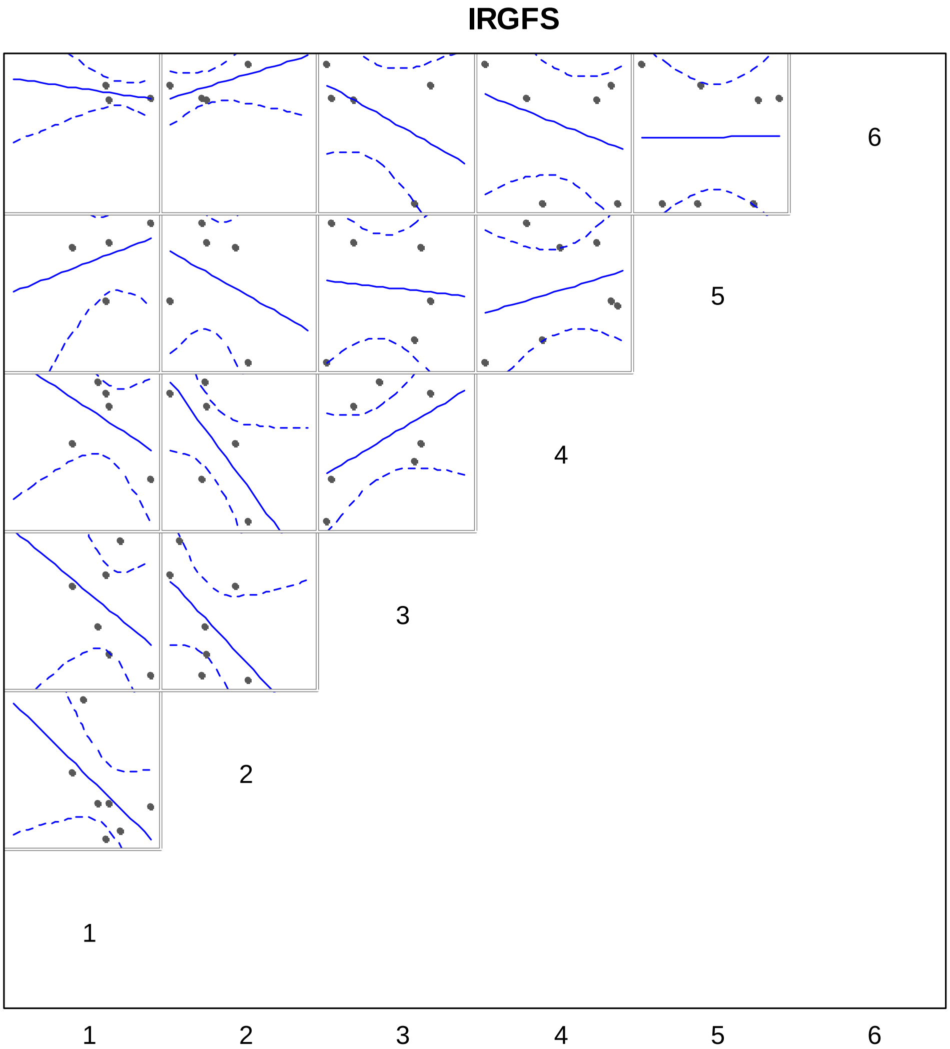


Figure 4.7. Whiting in Division VIa. SURBAR diagnostic plot: within survey correlations for the IGFS survey-series, comparing index values at different ages for the same year classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant (p <0.05) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

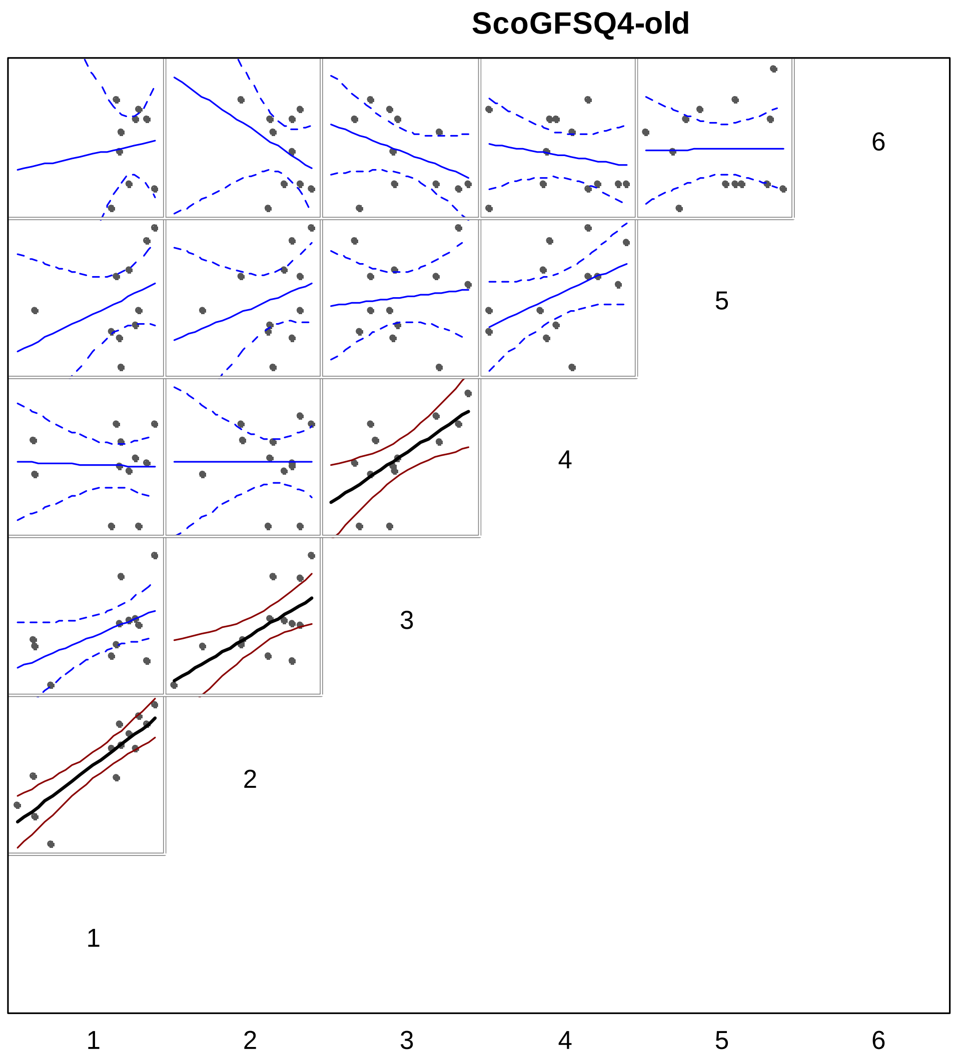


Figure 4.8. Whiting in Division VIa. SURBAR diagnostic plot: within survey correlations for the ScoGFSQ4-old survey-series, comparing index values at different ages for the same year classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant ($p < 0.05$) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

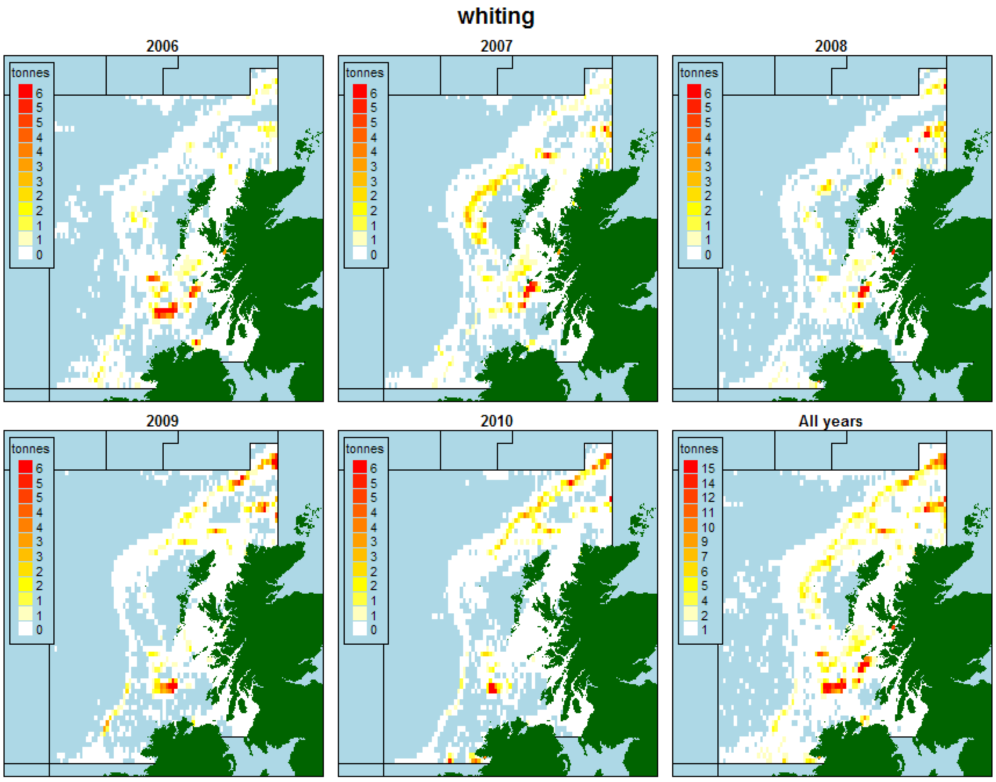


Figure 4.9. Whiting in Division VIa. Summary of inferred landings distributions, generated by assigning trip landings equally to VMS fishing pings (<4.5 knots) from that trip, for Scottish and Irish vessels.

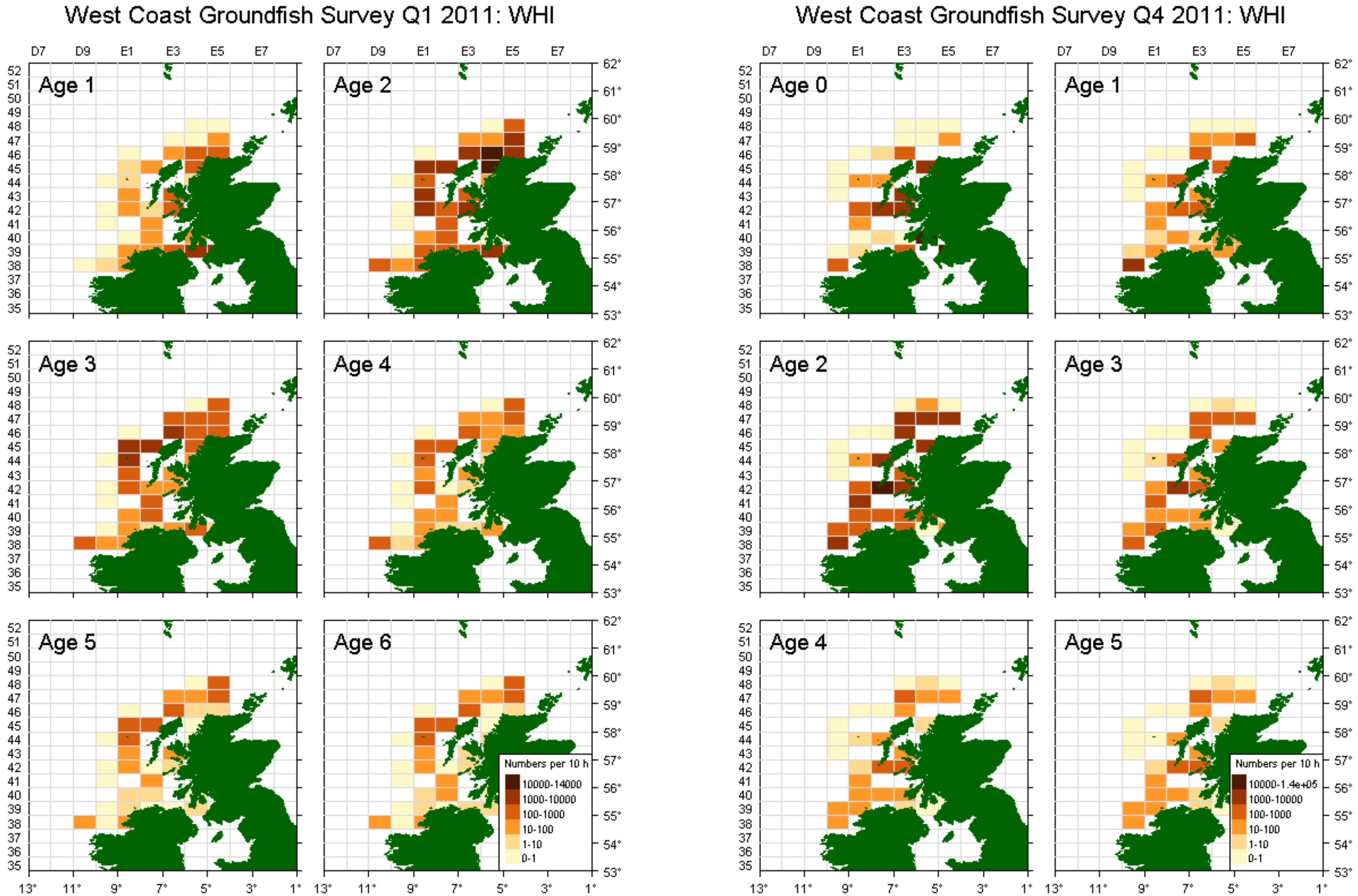


Figure 4.10. Whiting in Division VIa. Abundance distribution from the Scottish Q1 and Q4 surveys in 2011.

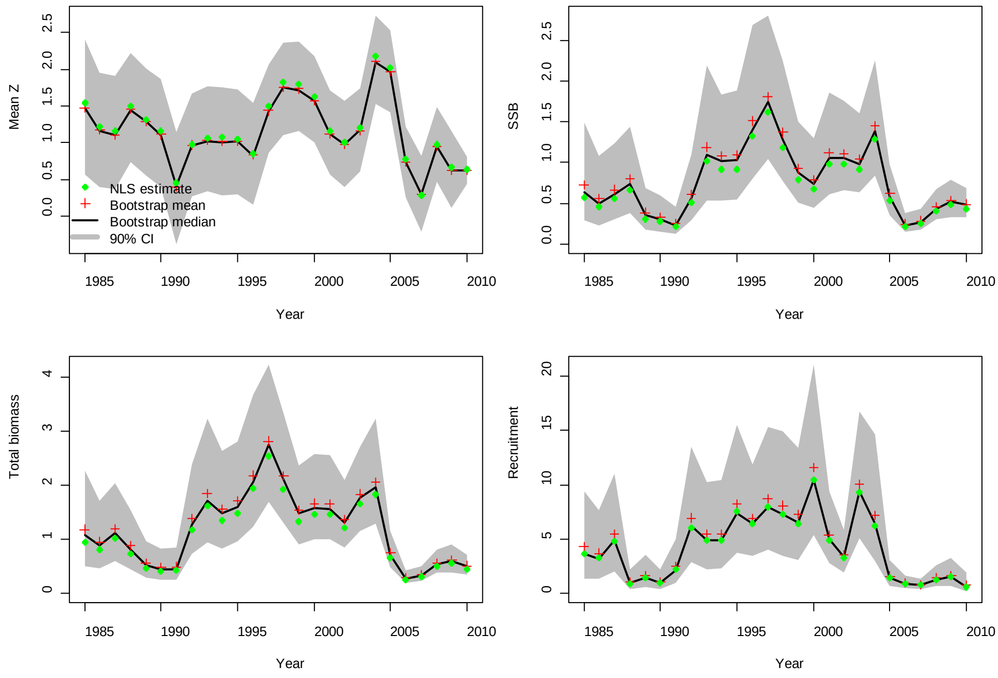


Figure 4.12. Whiting in Division VIa. Results of SURBAR analysis (see legend on mean *Z* plot for details). SSB, TSB and recruitment are relative estimates.

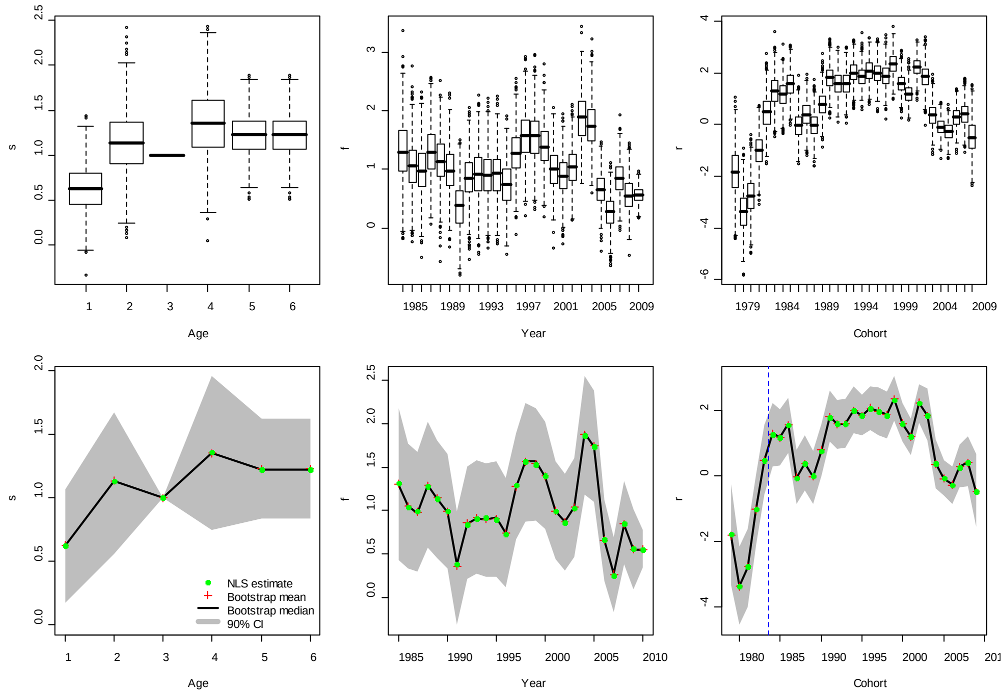


Figure 4.13. Whiting in Division VIa. Parameter estimates from SURBAR analysis. Top row: age, year and cohort effect estimates as box-and-whisker plots. Bottom row: estimates as line plots with 90% confidence intervals.

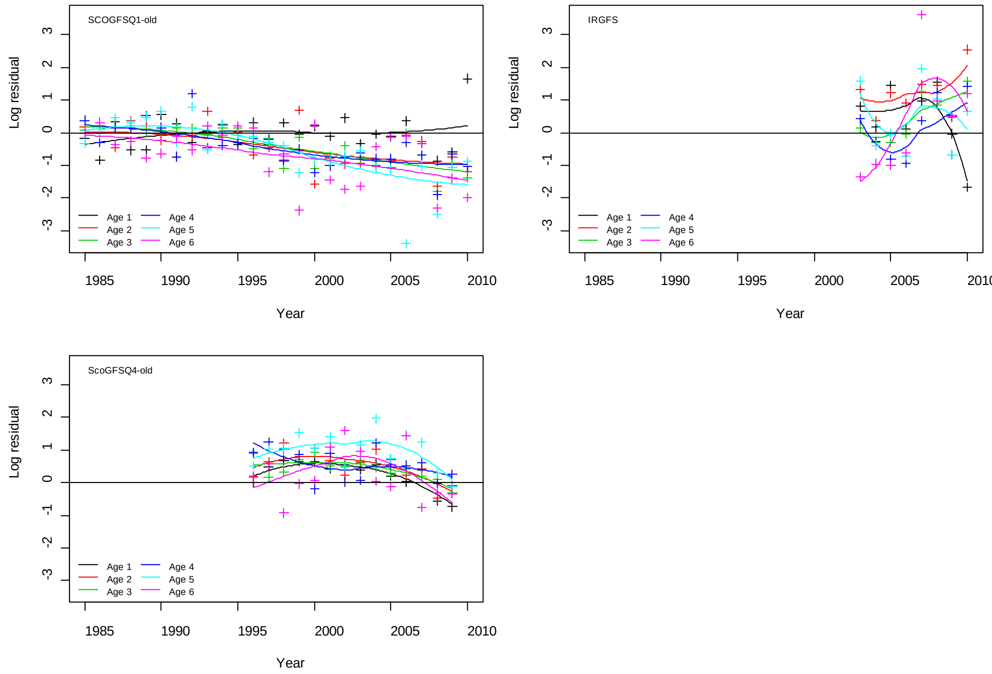


Figure 4.14. Whiting in Division VIa. Log survey residuals from SURBAR analysis. Ages are colour coded, and a loess smoother (span = 2) has been fitted through each age time-series.

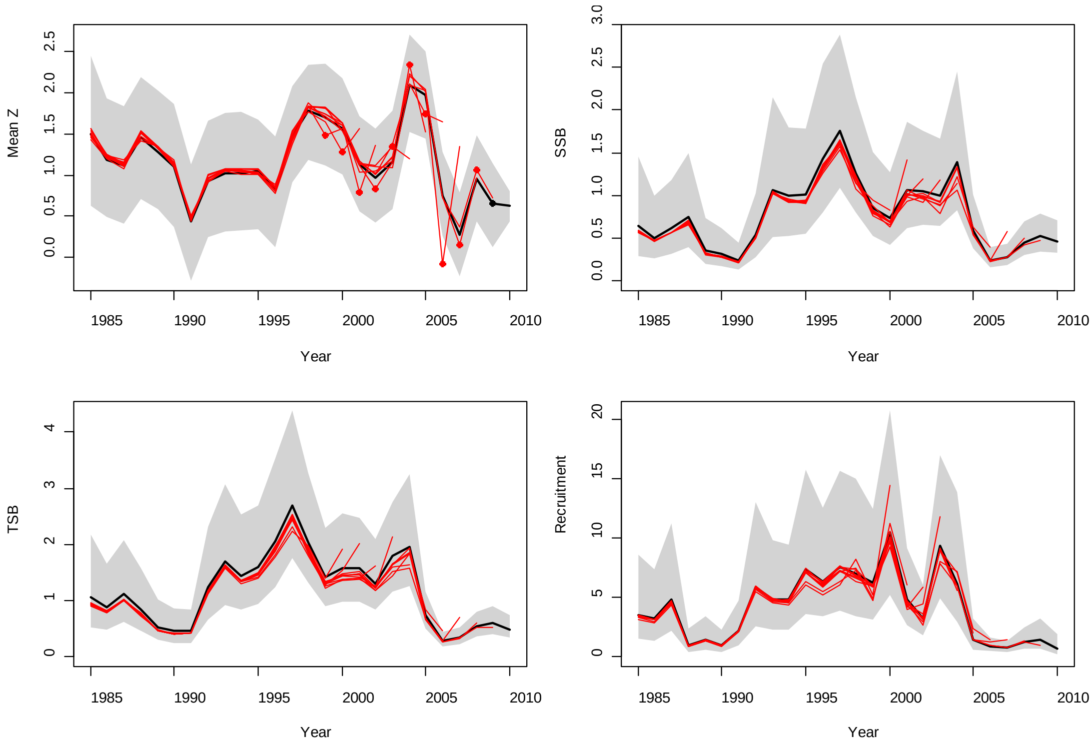


Figure 4.15. Whiting in Division VIa. Results of retrospective SURBAR analysis. For each plot, the black line gives the full time-series estimate (with 90% confidence intervals shown by a grey band), while the red lines show the retrospective estimates. The points on the mean *Z* plot show the last true data-derived estimate for each time-series (the final point is based on a three-year mean). SSB, TSB and recruitment are relative estimates.

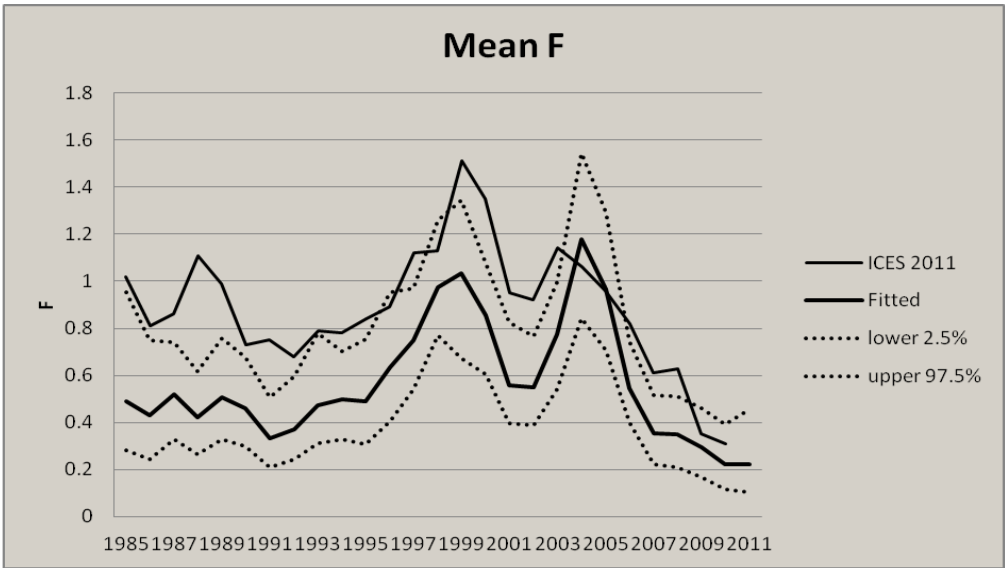


Figure 4.16. Whiting in Division VIa: trends in mean F estimated from Bayesian models using survey data only. The dotted lines show the 95% credible interval for the model. The estimated trend from the last ICES assessment is also shown.

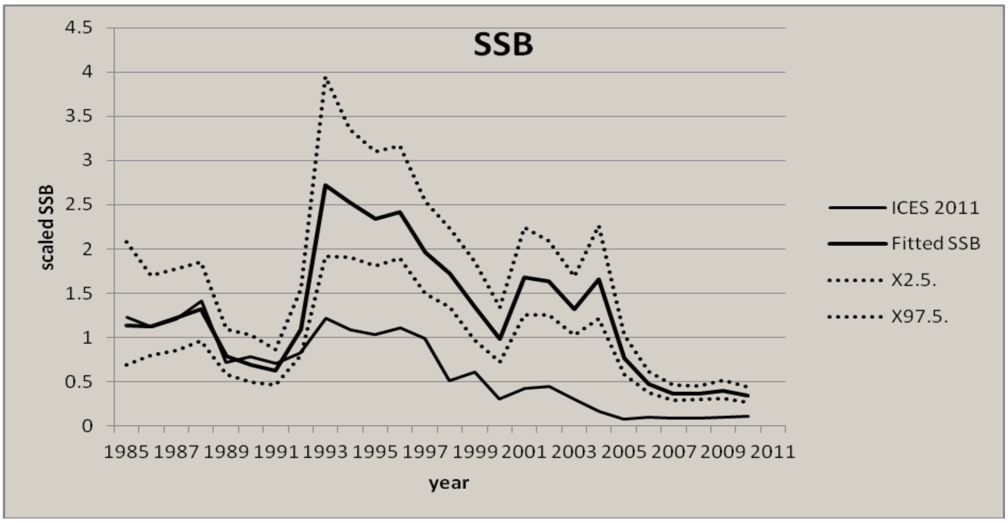


Figure 4.17. Whiting in Division VIa: estimated trends in SSB from the Bayesian model using survey data only. The trends are scaled to the mean for 1985–1992 when misreporting was believed to be low. The ICES values are from the 2011 assessment.

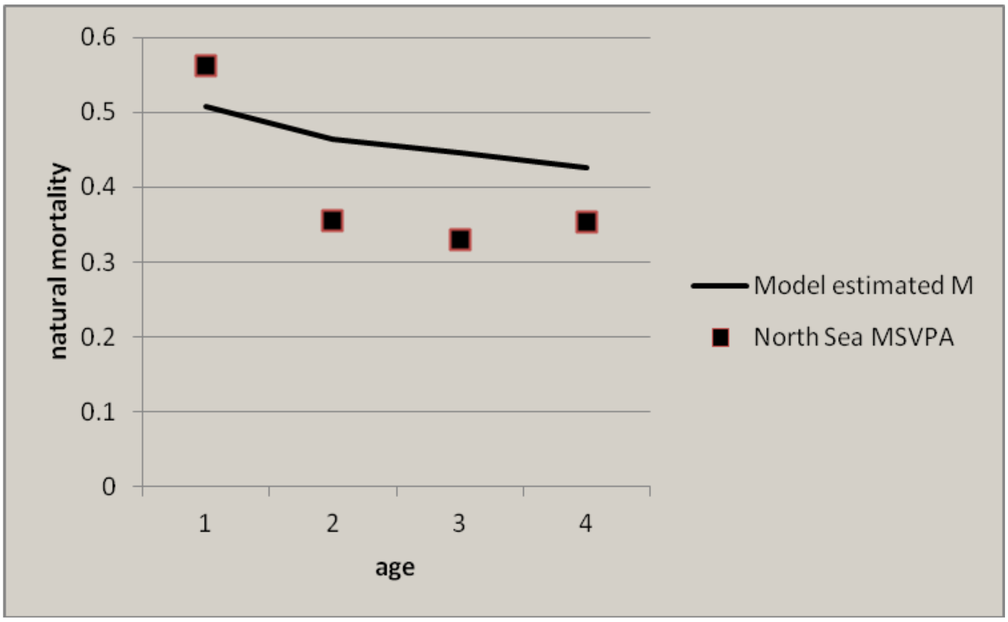


Figure 4.18. Whiting in Division VIa: values of natural mortality estimated from the Bayesian model averaged over all years. The points show the mean MSVPA values over all years taken from the North Sea whiting assessment.

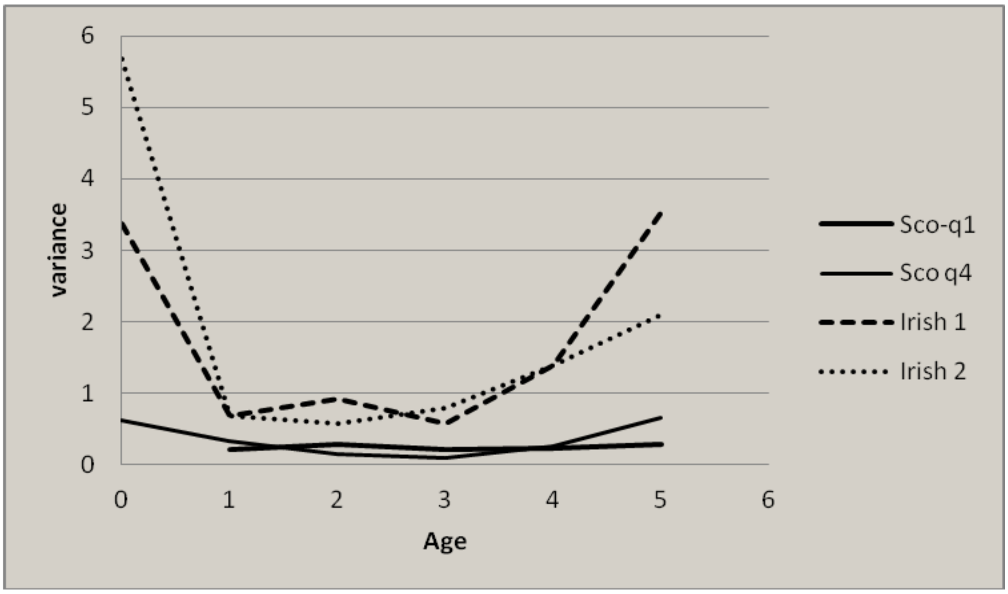


Figure 4.19. Whiting in Division VIa: estimated measurement error from the Bayesian model for the four surveys.

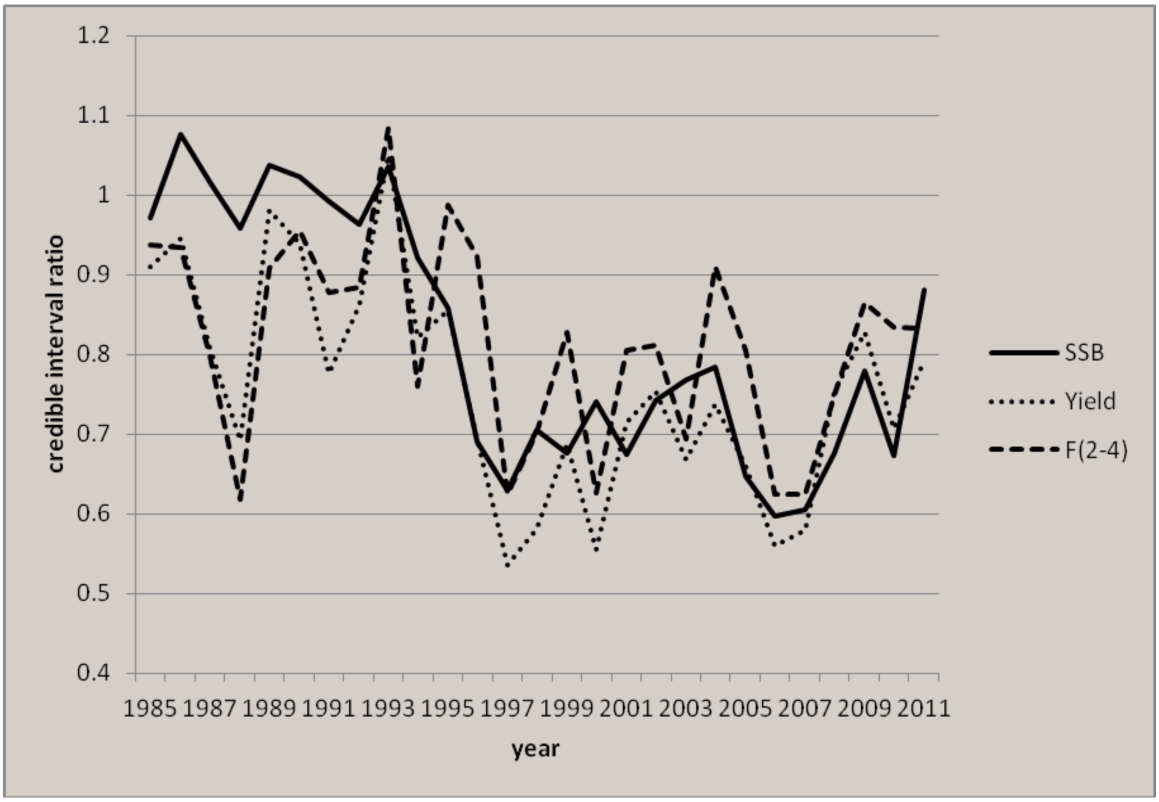
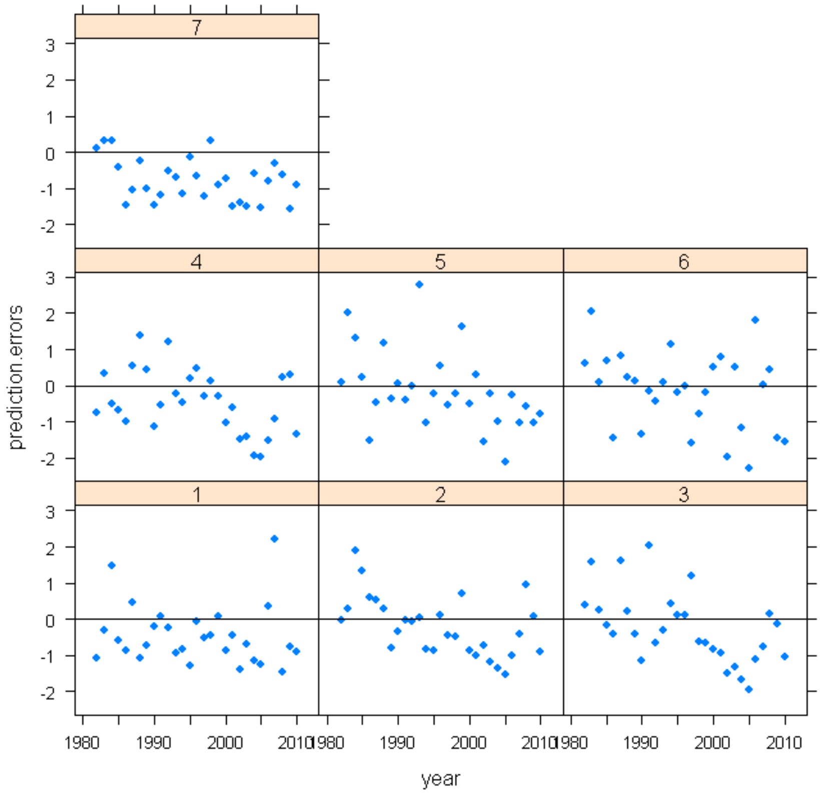


Figure 4.20. Whiting in Division VIa. Improvement in the estimated credible interval by including all surveys compared to only using the Scottish quarter one survey.



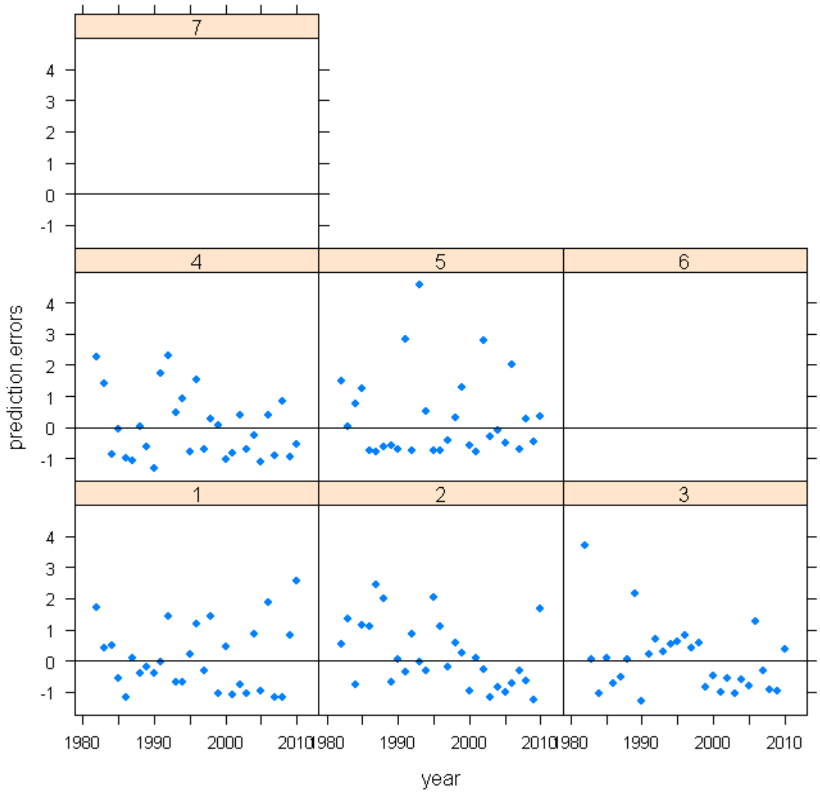


Figure 4.21. Whiting in Division VIa. Standardised landings (top figure) and discards (bottom figure) prediction errors from TSA.

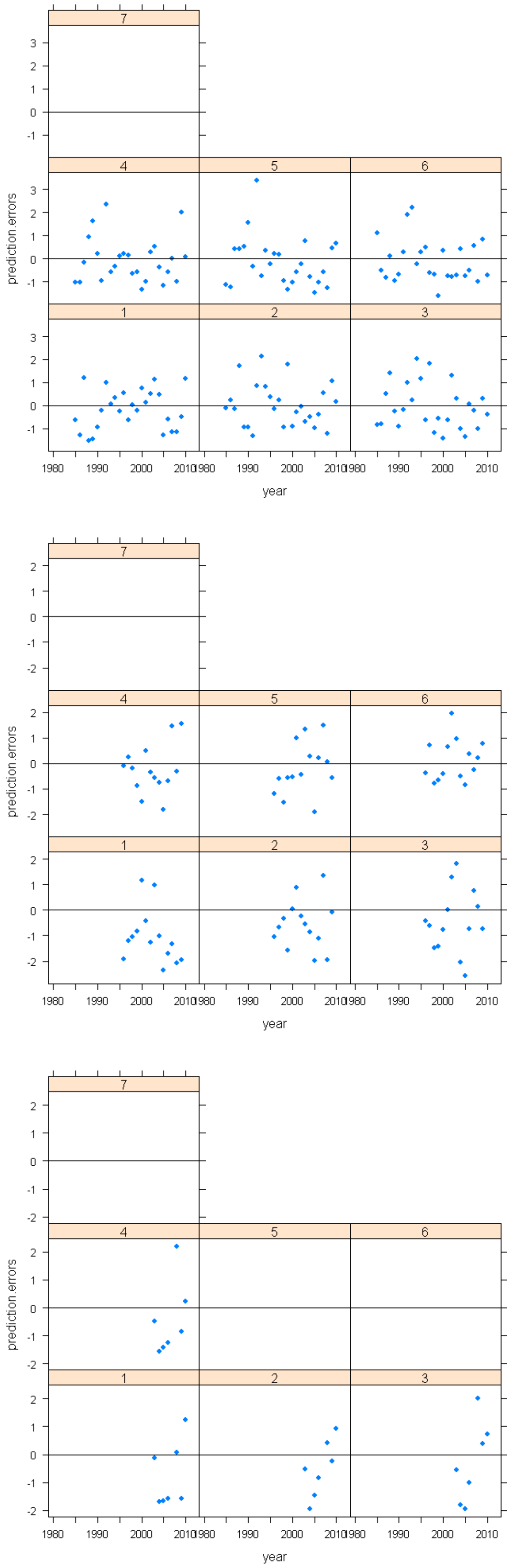


Figure 4.22. Whiting in Division VIa. Standardised survey errors from TSA in ScoGFS-WIBTS-Q1 (top panel), ScoGFS-WIBTS-Q4 (middle panel) and IGFS-WIBTS-Q4 (bottom panel).

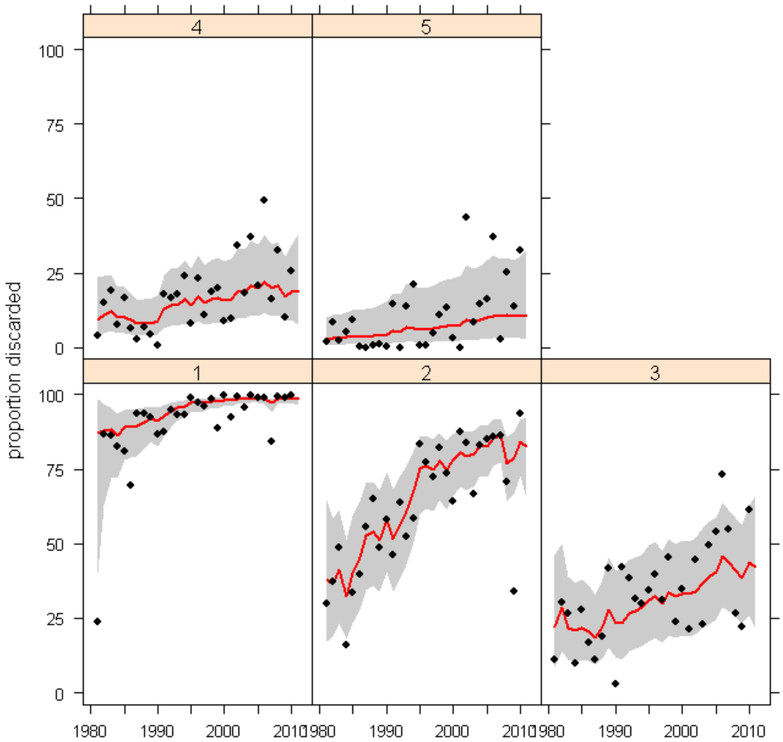


Figure 4.23. Whiting in Division VIa. Proportion discarded-at-age.

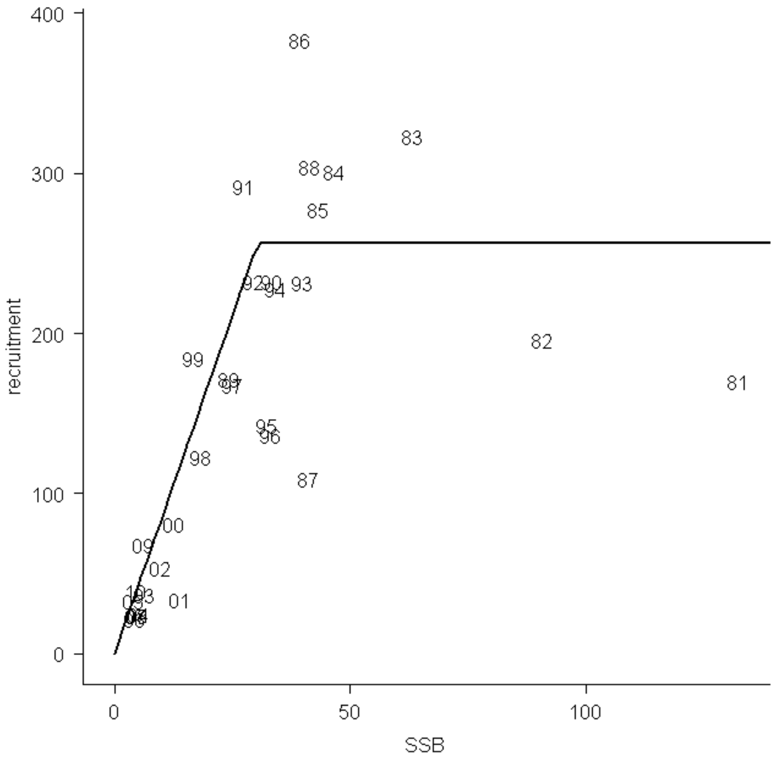


Figure 4.24. Whiting in Division VIa. Stock–recruitment relationship (recruitment in millions, SSB in thousand tonnes) from the final TSA run, with points labelled as year classes, and fitted with a "hockey-stick" model (solid line).

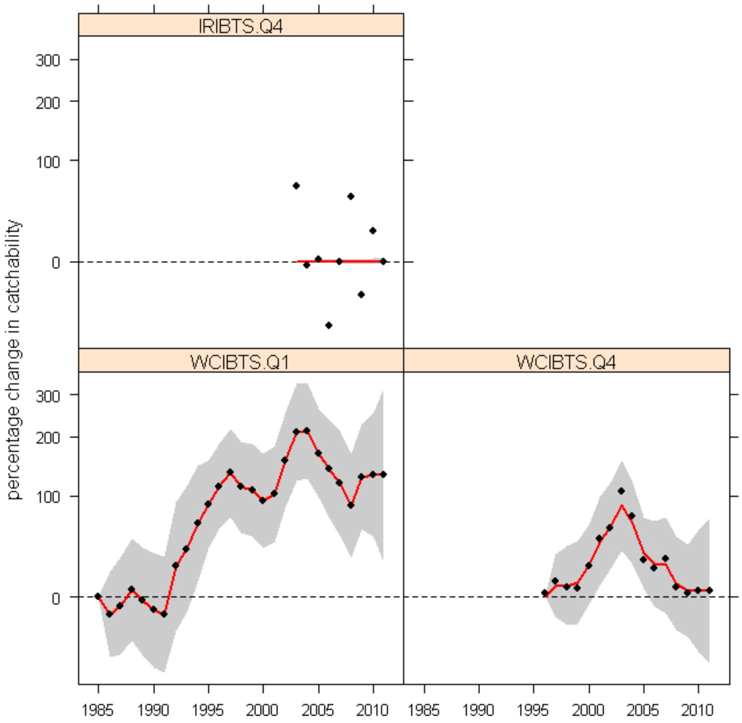


Figure 4.25. Whiting in Division VIa. Percentage change in catchability from the final TSA run. Transient changes (points) and the persistent change (solid line) with uncertainty bounds.

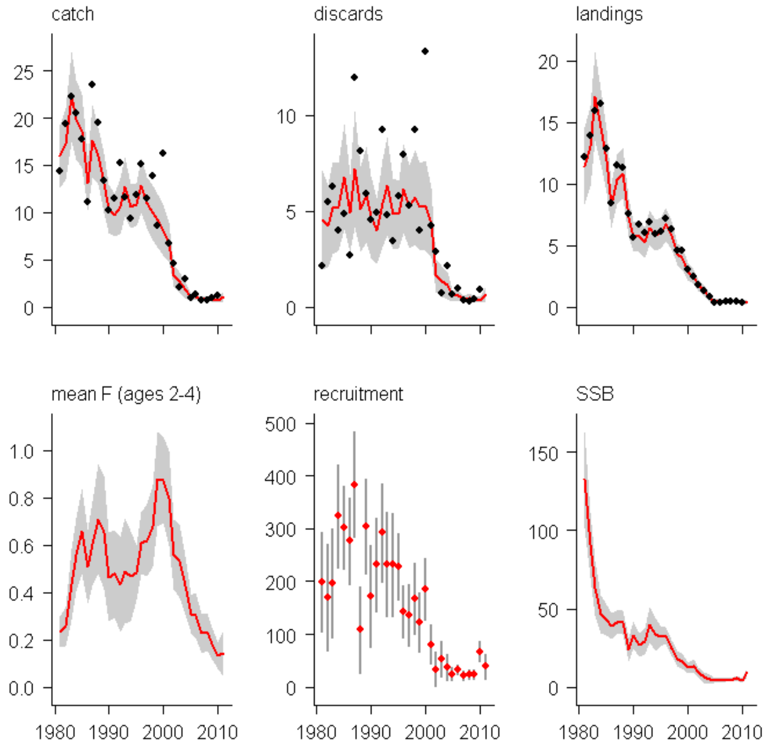


Figure 4.26. Whiting in Division VIa. TSA stock summaries from the final TSA run. Catch, landings, discards and SSB in tonnes, recruitment in thousands. Estimates are plotted with approximate pointwise 95% confidence bounds. Dots indicate observed values for catch, landings and discards.

5 Cod in Division VIIa (Irish Sea)

Current ICES advice for cod in Division VIIa is that

"...Given the low SSB and low recruitment it is not possible to identify any non zero catch which would be compatible with the MSY transition scheme. This implies no targeted fishing should take place on cod in Division VIIa. Bycatches including discards of cod in all fisheries in VIIa should be reduced to the lowest possible level."

Both the recruitment and reproductive capacity of this stock have become severely impaired in recent years. Recruitment has been below average for the past eighteen years and eight of the last nine years of recruitment are amongst the lowest on record. The stock has been harvested unsustainably since the late 1980s. The level of fishing mortality in recent years is considered uncertain, but total mortality rates remain very high.

5.1 Landings

5.1.1 Reported landings

Total landings as used by the working group are presented in Table 5.1.1. The recorded and WG adjusted annual landings numbers-at-age are presented in Table 5.1.2. The data represent four periods (Figure 5.1.1):

1) 1968–1990. Landings in this period, provided to ICES by stock coordinators from all countries, are assumed to be un-biased and are used directly as the input data to stock assessments.

2) 1991–1999. TAC reductions in this period caused substantial misreporting of cod landings into several major ports in one country, mainly species misreporting. Landings into these ports were estimated based on observations of cod landings by different fleet sectors during regular port visits. For other national landings, the WG figures provided to ICES stock coordinators were used.

3) 2000–2005. Cod recovery measures were considered to have caused significant problems with estimation of landings. The ICES WG landings data provided by stock coordinators for all countries are considered uncertain and estimated within an assessment model. Observations of misreported landings were available for 2000, 2001, 2002 and 2005. However, they have generally not been used to correct the reported landings but have been used to evaluate model estimates in those years.

4) 2006–2010. The introduction of the UK buyers and sellers legislation is considered to have reduced the bas in the landings data but the level to which this has occurred is unknown. Consequently comparisons were made between the fit of the model to recorded landings under an assumption of bias and unbiased information.

In periods 3 and 4 during which the total level of landings was assumed biased, the age structure of the landings is assumed unbiased. In addition to the above Irish landings of cod reported from ICES rectangles immediately north of the Irish Sea–Celtic Sea boundary (ICES rectangles 33E2 and 33E3) have been reallocated into the Celtic Sea as they represent a combination of inaccurate area reporting and catches of cod considered by ICES to be part of the Celtic Sea stock (ICES, 2009). The amount of Irish landings transferred from VIIa to VIIe–k by year is shown below:

Year	2004	2005	2006	2007	2008	2009	2010
Tonnes	108	54	103	527	558	193	143

The higher level in 2007 and 2008 was a consequence of limited quota in VIIe–k and available quota in VIIa. Since 2009 more restrictive monthly quotas have been set for VIIa during periods of high cod abundance close to the VIIa–VIIg boundary.

5.2 Discards

No discards data are included in the assessment. Available data indicates that discarding has historically been mainly a function of MLS (35 cm) and therefore mainly restricted to catches of <= 1-gp cod.

EU countries are now required under the EU Data Collection Framework to collect data on discards of cod and other species. Up to 2003, estimates of discards are available only from limited observer schemes and a self-sampling scheme. Observer data are collected using standard at-sea sampling schemes. Results are reported to ICES.

Discards data (numbers-at-age and/or length frequencies) are have been supplied for VIIa cod by Ireland, UK(Northern Ireland) and UK (E&W) and Belgium. The data were supplied raised to the appropriate fleet/métier level by the member states.

5.2.1 Raising to total national discards

Ireland: Length frequencies from Irish (Marine Institute) observer trips in specified fleet métiers are raised to the trip level, averaged across trips during each year (not by quarter) then multiplied by the annual number of trips per year in the Irish fleet in VIIa to give raised annual LFDs for discards. An age–length key from discards trips is then applied to give annual discards by age class and métier.

Northern Ireland self sampling scheme: The quantity of cod discarded from the UK (NI) *Nephrops* fishery from 1996 to 2002 was estimated on a quarterly basis from samples of discards and total catch provided by skippers. The discards samples contain the heads of *Nephrops* tailed at sea. Using a length–weight relationship, the live weight of *Nephrops* that would have been landed as tails only is calculated from the carapace lengths of the discarded heads. The number of cod in the discard samples is summed over all samples in a quarter and expressed as a ratio of the summed live weight of *Nephrops* in the discard samples (i.e. those represented as heads only in the samples). The reported live weight of *Nephrops* landed as tails only is then used to estimate the quantity of cod discarded using the cod:*Nephrops* ratio in the discard samples. The length frequency of cod in the discard samples is then raised to the fleet estimate. Age data have not been collected; however the discards are mainly of small cod that can be allocated to ages 0 and 1 based directly on their length. Roughly 40 discard samples were collected annually.

Northern Ireland observer trips: Length frequencies from NI (AFBI) observer trips in specified fleet métiers are raised to the trip level, summed across trips during each year or by quarter then raised to the annual number of trips per year in the NI fleet in VIIa to give raised annual LFDs for discards. An age–length key from discards trips is then applied to give annual discards by age class and métier.

UK(E&W) observer trips: Trips are arranged on vessels selected using a vessel randomisation scheme. Discard numbers are raised to sampled hauls then to the trip. The trip-raised length frequencies from Cefas observer trips in specified fleet métiers are then raised to the trip level, summed across trips during each quarter. Sampled quarters are then raised to total discards by quarter from the landings to discards ratios at age. As recorded in the data sent annually to ICES catches and discards of cod within the Irish Sea by UK(E&W) vessels have been extremely low for a number of years. For instance in 2010, 63 hours fishing were observed distributed across quarters 1–4 with three cod caught and one discarded in quarter 1 (six hours trawling), 21 caught and 20 discarded in quarter 2 (32 hours) and zero cod caught and discarded in quarters 3 (12 hours) and four (13 hours).

Belgium observer trips: Several Belgian métiers are operating in the Irish Sea. The beam trawl fleet targeting sole and plaice (TBB_DEF_70-99_0_0) is the most important fleet, but, it should be noted that the OTB_DEF_70-99_0_0 métier (otter trawls) is becoming more important each year. Part of the landings and effort that could not be allocated to the main métiers, are referred to as: 'no allocated métier'.

Since the observers only collect information from the commercial beam trawlers, the data can only be raised to the TBB_DEF_70-99_0_0 fleet and not to all Belgian métiers operating in the Irish Sea. In order to find the most suitable raising procedure for the Belgian discard (and landing) data, the tools developed by the COST project were used. Having considered the different raising procedures, raising by hauls was found to be the most appropriate method for the Belgian cod VIIa data. The results of the raising procedure were scaled relative to the official landings.

The time stratification for the Belgian data is by year, as sampling was insufficient to provide quarterly figures. It should be noted that due to the lack of Belgian individual length–weight information, the length–weight keys used in the analyses, are based on Irish sampling data.

Note also that the Belgian minimum landing size has changed a couple of times over the last years, which is reflected in the differences in length frequency distributions between years of the retained and discarded part of the catch.

- From the beginning of 2004 until the 30th of June 2008: 40 cm;
- From the 1st of July 2008 until 30th of September 2011: 50 cm;
- From the 1st of October 2011 up to today: 35 cm.

5.2.2 Raising to total international discards

National, raised to fleet discard numbers-at-age from Ireland, Belgium, UK(E&W) and NI were added to give the international numbers (with no additional weighting). The data represents the main fleets discarding cod, i.e., *Nephrops* and beam trawlers. Table 5.2.1 presents the raised discard numbers-at-age for the years 2007–2010, the years for which common raised discard datasets are available, the associated reported landings numbers-at-age and the proportion discarded-at-age.

5.2.3 Discard summary

Total raised discarding has been 100% at age 0 in all years with low numbers in 2007/2008 but a substantial increase in 2009 with a stronger year class entering the fishery and a relatively compared to 2007/2008 in 2010. At age 1 the discarding rate is high and has been relatively constant at around 80%. At older ages discarding has been very low until 2010 during which it has increased at all ages indicating highgrading.

The current discard information is considered representative of the information for the main fleets highlighting strong differences between national, quarterly and potentially regional discard rates as the national fleets tend to fish differing areas with differing gears. The time-series are still too short to include the data within an assessment and at the youngest ages discard raising still needs some development, however that also applies to landings numbers-at-age, which have deteriorated significantly in quality in recent years in terms of sampling levels due to low levels of landings.

5.3 Surveys

5.3.1 Time-series

Five research vessel survey-series for cod in VIIa have been used by WGCSE for the assessment of the stock until 2011. In 2012 three additional surveys have become available two fisheries science partnership surveys from the UK(E&W) and a UK(E&W) egg production biomass estimate. The year ranges for each survey are presented below.

Survey	Ages	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NIGFS-MAR	1 - 6		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
ScoGFS-Q1	1 - 5					■	■	■	■	■	■	■	■	■	■	■					
ScoGFS-Q4	0 - 4						■	■	■	■	■	■	■	■	■	■	■				
NIGFS-OCT	0 - 3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
E/W FSPW	1 - 6														■	■	■	■	■	■	■
E/W FSPE	1 - 5														■	■	■	■	■	■	■
E/W BTS Sept	0		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
NIMIK	0			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
AEPM SSB	Biomass				■					■						■		■		■	

The time-series of catch per unit of effort for each series are presented in Table 5.3.1.

It is very noticeable in the table that there are very few cod caught at the oldest ages in the survey-series and those series that did have shown a rapid decline over time. It is also apparent that the spring surveys consistently catch a broader range of ages than the autumn surveys and have less noise in their time-series at the oldest ages.

For each of the four survey-series for which several age classes of data are available, log catch per unit of effort curves and internal survey consistency scatter plots (log age x+1 vs log age x in the previous year) are plotted in Figures 5.3.1–5.3.6 and discussed following the survey description:

UK (Northern Ireland) October Groundfish Survey (NIGFS-Oct): ages 0–3, years 1992 onwards.

The survey-series commenced in its present form in 1992. It comprises 45 three mile tows at fixed station positions in the northern Irish Sea, with an additional 12 one mile tows at fixed station positions in the St George's channel from October 2001 (the latter are not included in the tuning data). The surveys are carried out using a rockhopper otter trawl deployed from the R.V. Lough Foyle. The survey designs are stratified by depth and seabed type. Virtually all cod are aged apart from 0-gp and 1-gp fish when particularly abundant. An ALK for the whole survey is used for filling in for any length groups with no ages at a station. Mean numbers-at-age per three mile tow are calculated separately by stratum, and weighted by surface area of the strata to give a weighted mean for the survey or group of strata. From 2002 onwards, all stations in the survey have been reduced to one nautical mile. A number of comparative one mile and three mile tows are done during each survey to build up calibration data. Since 2005, the RV Lough Foyle used for all surveys since 1992 has been replaced by the larger RV Corystes. The trawl gear and towing practices have remained the same.

Figures 5.3.1a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the Northern Ireland October groundfish survey. Even at the youngest ages the survey indicates a rapid decline in the age classes with time which may be mortality or catchability related. The survey picks out the year classes consistently from year to year especially at the youngest ages (0–2) age 3 is poorly correlated with age 2 and it would be appropriate not to include the series in the assessment model fit. The survey is consistent with other autumn surveys in not catching older fish consistently. More recently, at lower stock abundances, the noise in the time-series has increased but the survey still appears to be picking up a consistent signal from across ages 0–2.

UK (Northern Ireland) March Groundfish Survey (NIGFS-Mar): ages 1–7, years 1992 onwards.

General description as for NIGFS-October above, except that three mile stations have been retained in all strata other than in the St Georges Channel. Since 2005, the RV Lough Foyle used for all surveys since 1992 has been replaced by the larger RV Corystes. The trawl gear and towing practices have remained the same. The 1992 survey had only partial coverage of the western Irish Sea and is no longer used in the assessment.

Figures 5.3.2a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the Northern Ireland March groundfish survey. The survey picks up the year classes consistently from year to year across all ages. There is a rapid, relatively constant decline in the age classes with time; illustrated by the bottom right plot in Figures 5.3.2a, in which the negative slope of the catch curves indicates no decline in total mortality rate during the survey time-series. The longer time-series illustrating that recruitment from 2000–2007 was particularly poor but appears to have increased to historic levels in 2009 and 2010. Figure 5.3.2b indicates that there is good correlation between ages apart from a potential outlier at age 5 in 2000.

UK (Scotland) groundfish survey in Spring (ScoGFS-Q1): ages 1–8, years 1996–2006 and the

UK (Scotland) groundfish survey in Spring (ScoGFS-Q4): ages 1–5, years 1997–2007

These surveys represented an extension of the Scottish West Coast groundfish survey (Area VI), using the research vessel Scotia. The survey gear is a GOV trawl, and the design is two fixed-position stations per ICES rectangle from 1997 onwards (17 stations) and one station per rectangle in 1996 (nine stations). The survey extended from the Northern limit of the Irish Sea to around 53°30′.

Figures 5.3.3a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the Scottish quarter 1 groundfish survey for the years 1996–2006. The survey picks up the year classes consistently for ages 2–4 with reasonable consistency at age 1 and noisier signal at age 5 (Figure 5.3.3b). The negative slope of the catch curves indicates an increase in mortality rate during the mid 1990s to a constant level thereafter.

Figures 5.3.4a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the Scottish quarter 4 groundfish survey for the years 1997–2007. The survey only has a consistent time-series of data for age 2 and considerable noise ages 1 and 3. The survey is consistent with other autumn surveys in not catching older fish consistently. If only providing information at age 2, it may be that this survey should be omitted from the assessment.

UK (E/W) Fisheries Science Partnership Survey West (E/W FSPW): ages 1–6, years 2005 onwards

A commercial whitefish otter trawler carries out over 40 tows of around 4 hours average duration during February in the eastern Irish Sea using a Boris rock-hopper otter trawl with 118 ft headline and 160 ft ground gear comprising 100 ft of 14-inch hoppers and 2 × 30 ft ground chains. The net is fitted with an 80 mm codend. The survey is designed to have up to four tows in each of the 10 minutes (latititude) by 20 minutes (longitude) blocks covering the survey area. The survey is described in Armstrong (WD7, WKROUND 2012).

UK (E/W) Fisheries Science Partnership Survey East (E/W FSPE): ages 1–5, years 2005 onwards

A mid-water trawler carries out over 30 tows of around 6 hours duration during February in the western Irish Sea and North Channel using a 22 × 14 ft semi-pelagic trawl of the type used for whitefish fishing by vessels from Northern Ireland, fitted with a 100 mm mesh codend. The survey is designed to have up to three tows in each of the 15 minutes (latitude) by 20 minutes (longitude) blocks covering the survey area. The survey is described in Armstrong (WD7, WKROUND 2012).

Both FSP survey-series are relatively short at present but will have another year added before the assessment in May and therefore as they may provide assessment information of the next few years they need to be considered within WKROUND2 rather than being postponed until the next benchmark.

Figures 5.3.5a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the UK(E&W) western Irish Sea FSP survey. Figures 5.3.6a,b presents the log catch per unit of effort curves and internal survey consistency scatter plots for the UK(E&W) eastern Irish Sea FSP survey. The surveys follow the year classes consistently, which is less clear in the log cohort plots due to outliers at the scale shown but is clear in the catch curve plots which illustrate that there is consistent selectivity by the gear used in each survey and consistent tracking of the cohorts through the ages. A clear reason for including the surveys if possible is the information that they provide on the dynamics of the older ages which are scarce/noisy in the scientific surveys.

UK (England and Wales) Beam Trawl Survey (E/W-BTS): age 0, years 1993 onwards.

The survey covers the entire Irish Sea excluding the North Channel and is conducted in September. The survey uses a 4 m beam trawl targeted at flatfish. The survey is stratified by area and depth band, although the survey indices are calculated from the total survey catch in the eastern Irish Sea, and without accounting for stratification except for ALKs. Numbers of 0–gp cod at age per 100 km towed are provided for prime stations only (i.e. those fished in most surveys). The series was revised in 2008.

UK (Northern Ireland) Methot-Isaacs Kidd Survey (NIMIK): age 0, years 1993–2008.

The survey uses a Methot–Isaacs Kidd frame trawl to target pelagic juvenile gadoids in the western Irish Sea at 40–45 stations. The survey is stratified and takes place in June during the period prior to settlement of gadoid juveniles. Indices are calculated as the arithmetic mean of the numbers per unit sea area.

Spawning–stock biomass egg survey (AEPM SSB): spawning biomass, selected years

Annual Egg Production Method was applied to estimate spawning–stock biomass of cod in the Irish Sea in 1995, 2000, 2006, 2008 and 2010. This work is conducted jointly between Cefas and AFBI (Belfast). The Marine Institute (Galway) assisted with fecundity estimates in surveys up to 2008. The surveys are described in Armstrong (WD8. WKROUND 2012).

5.4 Other information

5.4.1 Fishing effort

Effort within the Irish Sea has been compiled by an EC STECF working group (Bailey and Mitrakis, 2011). Total nominal effort (kW*days-at-sea, Figure 5.4.1) within the Irish Sea has decreased by 33% since 2000; with most occurring since 2004 effort remained relatively stable between 2009 and 2010. STECF considers effort by gear type from 2003 (Figure 5.4.1) onwards due to the unavailability of Irish mesh size information prior to 2003 resulting in all Irish effort occurring within the 'none' category which encompasses unidentified effort and effort by gears and mesh sizes not regulated under the cod plan.

In 2010 four demersal trawling gear types dominated the effort expended: TR1 (≥100 mm mesh sizes, 6%), TR2 (70–99 mm mesh sizes, 49%), BT2 (Large mesh beam trawlers, 10%) and unknown (34%). The proportion of unknown gear type has gradually increased. TR2 effort has remained relatively stable throughout the time-series and now dominates the categories; TR1 has declined by 85% since 2003 and BT2 by 69%, the effort by unknown gear types has increased by 20%.

5.4.2 Stock identity, migration

Bendall *et al*. (WD9, WKROUND2 2012) presented the results of a series of tagging studies of the cod stocks in ICES Divisions VIa, VIIa and VIIe–k. The study analysed conventional returns and data storage tag point location estimates to determine the movement within and between cod stocks during the year and consequently the potential exchange of fish between them.

Although there is evidence for limited seasonal migrations into neighbouring regions, most fish will stay within their management area. There is no significant long-term emigration from VIIa into the adjacent northern (VIa) and southern (VIIe–k) management units that would indicate that the areas should be considered together.

The seasonal migrations can be used to explain the underlying stock dynamics that have led to the selection of only the youngest survey ages from the autumn groundfish surveys in the VIIa cod assessment model calibration by the ICES WGCSE Working Group. Figure 5.4.2, taken from Bendall *et al*. (WD9, WKROUND2 2012) illustrates that during the first two quarters of the year the adult cod are distributed throughout the western Irish Sea (in quarter 2 two cod moved south into the VIIg but returned later). Later in the year in quarters 3 and 4 the cod have a very restricted distribution, confined to deeper waters in the northern and southern channels. If the survey station distributions do not cover the deeper water this could explain the lack of consistency in the catch rates of the surveys in autumn.

Tagging of cod off Greencastle on the north coast of Ireland (O Cuaig and Officer, 2007), and more limited tagging on UK Fisheries Science Partnership surveys (Armstrong *et al*., WD2 to WGNSDS 2007), have demonstrated movements of cod between Division VIa and VIIa. Most recaptures in VIIa from cod tagged in VIa have come from the North Channel and in or near the deep basin in the western Irish Sea that is a southward extension of the North Channel. The research surveys used for tuning the VIIa cod assessment cover only the western and eastern Irish Sea, and do not extend into the deeper water of the North Channel, where large catches of cod were made by mid-water trawlers in the 1980s and 1990s.

Historical tagging studies have also shown more limited movements of cod between spawning components in the western and eastern Irish Sea, for which the migrations tend to be in a north-south direction. STECF Subgroup SGRST (2005, Appendix 4) concluded that management of the Irish Sea stock on the basis of substock assessment regions would be difficult in practice, particularly the separation of catches when the stock units are mixed. Further tagging and genetics studies are required to investigate stock structure, seasonal movements and mixing in VIIa and neighbouring areas.

The WKROUND2 concluded from these studies that:

1) The present evidence does not call for radical changes in the current assessment units. Most fish can be expected to remain within their respective area.
2) Seasonal migrations, sometimes leading outside the area, may affect catchability in surveys. In particular, surveys in quarters 3 and 4 in Division VIIa may not pick up all ages properly as established by WGCSE.
3) Within VIIa, the population of cod is likely to consist of several partly isolated substocks. The opportunity for exchange may be variable, but in general, one cannot expect a depleted substock to be repopulated from neighbouring areas.
4) For management, this implies that in addition to maintaining the current stocks at a productive level, care needs to be taken to avoid depletion of local stock components.

5.5 Catch and stock weights

The annual mean weights-at-age in the landings are given in Table 5.5.1 and plotted in Figure 5.5.1; landings weights-at-age are also currently used for the stock weights in each year. There are no long-term trends in weights-at-age. Weights-at-age prior to 1982 are fixed at constant values which are lower than estimated for subsequent years. There are substantial differences between the total landings and the sums-of-products during 1968–1981. In recent years weights at the oldest ages are becoming noisy and obviously suffering from low sample size.

A correction that could be applied is to the historic data is to derive the average of a period of years following 1982 to calculate a value to be applied to the weight-at-age from 1968 to 1981 to which annual corrections for the sums of products can be then be applied to ensure compatibility between the recorded landings with the sampled numbers and weight-at-age. This exercise results in the time-series shown in Figure 5.5.2 and produces an obvious trend within the weights-at-age in the early year of the time-series.

At the oldest ages in the most recent years modelling of the oldest age weights-at-age could be considered to smooth out the sample variation. However, at the current time numbers-at-age in the catches and population are very low and such refinements will result in very minor variations to the projected catch and SSB.

WKROUND2 discussed the weights-at-age anomalies but noted that the problems associated with the information will result in variation in the historic biomass.

WKROUND2 recommends that:

1) The current weights-at-age are utilised for the assessment.
2) A review of the ICES literature be conducted to determine the historic reason for the anomaly between the sums of products and if the WG decisions made at that time are considered the best solution then the information be presented in the stock annex for future reference.
3) WGCSE explore the potential for modelling of the oldest age stock weights-at-age and also conduct sensitivity analyses of the assessment estimates to the raw weights at the oldest age that are currently used in the assessment each year, to determine whether they influence advice if and when the stock begins to recover.

5.6 Maturity

Maturity-at-age has been considered constant in all years within the assessment at the values listed in the text table below.

Age	0	1	2	3+
Proportion Mature	0	0	0.38	1

However, Armstrong *et al*. (2004) and Nash *et al*. (2010) have shown that maturity-at-age 2 has increased during the late 1990s. Figure 5.6.1 presents the time-series of maturity as estimated from the Northern Ireland first quarter groundfish survey by Armstrong *et al*. (2004) using a weighted average plotted with the raw average from the full time-series of data. The survey data indicates that the proportion mature-at-age 2 increased between 1995 to around 2003 from levels close to that of the WG historic estimate of 38% to 65% and has subsequently remained stable at that proportion. Figure 5.6.1 illustrates a potential linear model for a transition in the proportion mature-at-age 2 linking together the historic estimates previously used for the assessment with the mean (2000–2010) of the recent survey based values. Figure 5.6.2 shows two illustrative assessments fitted to the same dataseries with the same model settings. Changing the maturity-at-age 2 in the most recent years increases the estimated spawning biomass but does not change the conclusions that would be drawn from the assessment fit in that spawning biomass is well below historic values and the PA reference thresholds.

WKROUND2 recommends that:

1) The time-series of the proportion mature-at-age 2 be changed to reflect the increased proportion mature at that age.
2) That the average value from 200 is used for the recent time period and that the transition from the historic value of 0.38, developed at WKROUND2, be adopted for the period between 1996 and 2000.
3) The biomass thresholds for the stock will be unaffected by the change to recent maturity proportions however care will need to be taken in the choice of natural mortality values to use when estimating F_{MSY} as historic values recorded at higher stock biomass are more likely to be applicable.

5.7 Natural mortality

Natural mortality was previously assumed to be 0.2 for all ages.

Revised natural mortality estimates were derived from weights-at-age using the approach proposed by Lorenzen (1996). In absence of empirical data, parameter values were obtained from Table 1 in the Lorenzen paper (ocean ecosystems: α = 3.69; β = -3.05). The Lorenzen M at age was calculated from two matrices of weights-at-age: catch weights and survey weights. The survey weights from quarter 1 reflect the beginning of year weights which is probably the more appropriate basis for calculating mortality for the year. A 33 gram weight used for age 0 is considered appropriate to calculate mortality (should be soon after spawning).

For comparison, the corresponding mortality from catch weights was calculated, the only real difference occurring at ages 0 and 1 Figure 5.7.1. M at ages 0 to 7+ from the survey weights is tabulated below:

Age	0	1	2	3	4	5	6	7
M	1.27	0.83	0.43	0.31	0.26	0.24	0.24	0.23

WKROUND2 recommends that:

1) In the future assessments the Lorenzen natural mortality should be used, constant in time.

2) However the change should be introduced when the assessment model has been stabilised and issues such as the potential revision of the historic weights-at-age have been addressed as all of the changes will act together to alter the estimated PA and MSY management reference levels. The introduction of a new time-series of constant weights at age will only rescale biomass and recruitment levels rather than altering trends (Figure 5.7.2).

5.8 Assessment

5.8.1 Outline of known problems

Landings data

The quality of the commercial landings and catch-at-age data for this stock deteriorated in the 1990s following reductions in the TAC without associated control of fishing effort. The Working Group has, since the 1990s, attempted to overcome this problem by incorporating sample-based estimates of landings from three major ports in the WG landings figures. The data for this method have become more limited since 2003, and the WG used the B-Adapt modelling approach to estimate subsequent removals from 2000 onwards.

During 2006-2010 the introduction of the UK buyers and sellers legislation is considered to have reduced the bas in the landings data but the level to which this has occurred is unknown. Consequently comparisons are required between the fit of the model to recorded landings under an assumption of bias and unbiased information. The estimated removals could potentially include components due to increased natural mortality and discarding as well as misreported landings or catches from the stock taken outside VIIa, albeit distributed according to the age composition in the landings.

Discarding

Discarding has historically been mainly at age 1, and the absence of raised estimates of discarding for all fleets will result in underestimation of historical F at age 1. In the

2010 Irish and Northern Irish data do show shifts towards the discarding of older fish (Section 5.2). It is as yet unclear whether this is a long-term or temporary change.

The discard information collated in Section 5.2 does not have sufficient years to include the data within an assessment and at the youngest ages discard raising still needs some development. Discards will be introduced to the assessment as soon as is practicable.

Surveys

The Irish Sea has relatively good survey coverage. The surveys in general give consistent signals of fish abundance-at-age in the first quarter but are noisy at the older ages during the summer and autumn. Potential reasons for this related to the spatial distribution of the cod are discussed in Section 5.4.2.

Surveys which cover a long time span indicate a severe depletion of the SSB during a run of very poor recruitment from 2002, with one reasonable recruitment estimated in 2009. There has been no indication of improved recruitment since 2009.

A UK Fisheries–Science Partnership survey of the Irish Sea cod spawning grounds in spring 2005–2011, carried out using commercial trawlers, indicates a widespread distribution of cod mostly at low density but with some localized aggregations. The time-series is now long enough to evaluate and potentially include within the assessment.

Estimates of cod SSB from applications of the annual egg production method, although slightly higher than the assessment estimates, are still below B_{lim} and show a similar trend in SSB to the assessment. The time-series now has sufficient years to include within the assessment, even if not continued in the future it will help to calibrate the model during a period when there is considerable uncertainty in the level of bias within the catch data.

Model formulation

The B-Adapt and SAM estimates of removals bias are relatively high with values in the range 2.0–3.0 despite an awareness of more accurate landings reporting since 2005/2006 and lack of evidence for significant discarding of cod above MLS.

In order for bias to be estimated by the methods, an assumption of constancy in model parameters and constraints (e.g. M) has been violated. If for example unaccounted losses from other sources are occurring, such as fishery catches taken outside VIIa, or increased migration from the stock or increases in natural mortality, then they must have increased substantially since around 2000. There have been no changes in the condition of cod (e.g. loss of weight) in recent years that would indicate the potential causes for an increase in M.

An alternative explanation for the estimated bias is a trend or shifts in the survey to higher catchability (improved efficiency), across all ages and surveys, which would then be interpreted as missing catch within the model formulation.

5.8.2 Analysis of the age composition data independently of the assessment

Catch data

Figure 5.8.1a presents the log catch (landings) curve plot for the landings-at-age data for ages 2+ this can be considered to represent the catch-at-age data and the plot therefore represents a catch curve time-series. Figure 5.8.1b plots the negative of the slope of a regression fitted to the log catch data for ages 2–6.

Total mortality rates for the stock have been high throughout the time period for which information is available. Even when the stock was considered abundant and recruitment levels supported high levels of catch the gradient of the catch curve was in the range 0.8–1.0. Year classes rapidly disappeared from the commercial landings data. The increase in the negative slope indicates that total "mortality" rates have increased over time and now are double that recorded in the historic data during the period when the stock was abundant. The slope of the curve for cohorts after 2000 appears to have a step change decrease but this is during the period when the catch data is considered under-reported. There is currently no evidence from the age compositions from surveys or commercial fishery operations of any improvement in age structure that would result from a reduction in total mortality.

Assessment models fitted to the catch data assume that the decline in the cohort abundance results from fishing or natural mortality. Potentially there could be unaccounted losses from other sources, for example due to fishery catches taken outside VIIa during seasonal migrations or permanent emigration. The tagging studies carried out in Section 5.4.2 would indicate that at least the latter is unlikely.

Survey data

Figures 5.3.1a–5.3.6a present catch curve analyses for each of the surveys for which a range of ages is available. In all cases the catch curves indicate a very low comparative catch rate for old cod and steep slopes of the catch curves. None of the surveys indicate that old cod occur in the stock in abundances that would indicate that the assumption of high mortality rates is inappropriate.

5.8.3 The state-space model SAM

In 2010 ICES began to use the state–space model SAM developed by Neilson (e.g. ICES WKCOD 2011) State space model were introduced for stock assessment by Gudmundsson (1987, 1994) and Fryer (2001). Before SAM we were all in the dark as the state–space framework was rather computational demanding, with previous approaches have either used linear approximations (the extended Kalman filter), or simulation bases approaches (MCMC). Neilson's model SAM shines the light and a state–space assessment model is presented, based on the Laplace approximation and implemented in AD Model Builder (http://www.admb-project.org), which makes these the assessment model more easily available and understandable.

The model was extended for North Sea cod to allow estimation of possible bias (positive or negative) in the reported total catches in the specified years. It was applied by WGCSE in 2011 and shown to provide a very similar stock and fishing mortality trend to that of the B-ADAPT model used previously for the assessment. Both models assume that reported catches should be scaled by a year specific factor across all ages in the current formulation, although SAM is more flexible in allowing age effects.

The SAM model allows for the inclusion of a spawning biomass index which the B-ADAPT would need recoding for. Consequently and in view of the current trend within ICES to move assessments towards statistical models, and the consistency with B-ADAPT in the previous WGCSE evaluation of the stock, the SAM model was chosen for the assessment of the Irish Sea cod.

5.8.4 SAM model formulation

The SAM model was fitted to:

- The catch-at-age data for the years 1968–2010 with catch multipliers on differing years as sensitivity analyses and for the recommended assessment configuration. A plus group at age 6 was used to allow the full range of ages within the surveys to be explored. However, it quickly became apparent that SAM would not converge with catch-at-age 0 set to 0.0 in all years (as used with B-ADAPT to use surveys at age 0) therefore the assessment was specified for ages 1–6+ with the 0 group survey brought forward by one year as a 1 group index.
- Survey data for all of the age based surveys described previously in Section 5.3 (Table 5.3.1) with the age and year ranges as below:

Survey	Ages	Years				
NIGFS-MAR	1 – 6	1993	2011			
ScoGFS-Q1	1 – 5	1996	2006			
ScoGFS-Q4	1 – 4	1997	2007			
NIGFS-OCT	1 – 3	1992	2011			
E/W FSPw	1 – 6	2005	2011			
E/W FSPe	1 – 5	2005	2011			
E/W BTS Sept age 0 brought forward to age 1	1 (0)	1994 (1993)	2011 (2010)			
NIMIK age 0 brought forward to age 1	1 (0)	1995 (1994)	2011 (2010)			
AEPM SSB	Biomass	1995	2000	2006	2008	2010

5.8.5 The base run formulation

The configuration file for the assessment comparative base run is presented in Table 5.8.1:

- Catch-at-age data was assumed unbiased.
- Fishing mortality was estimated for ages 1–5 with 6+ equal to age 5.
- Separate catchability parameters for each survey age and a single value for the SSB index.
- A common random walk variance parameter for fishing mortality-at-age.
- A common random walk variance parameter for population numbers-at-age.
- Variance parameters estimated for the youngest age of the catch observations and then a common parameter for all other ages.
- Variance parameters estimated for the youngest age and then a single parameter for pairs of older ages (e.g. 1, 2 & 3, 4 &5) for each fleet's catchability.

Figures 5.8.2–5.8.8 present the diagnostic output from the SAM model fit for the catch-at-age data and the main surveys which determine the estimated bias in the catch data. The other surveys are not plotted for the base run to maintain brevity but will be plotted for the "recommended" assessment.

Figure 5.8.2 presents the estimated catchability parameters at age for each time-series. Clearly the noise in the estimates increases with age and the oldest ages of the NI March groundfish survey, the E/W FSP west and eats can be estimated as a single parameter for each survey as there is no difference between them. Both the NI GFS March survey and the E/W FSP east are dome shaped, catching fewer older fish whereas the historic Scottish surveys and the E/W western FSP survey have increasing catchability with age.

Figure 5.8.3 presents the estimated catch and catchability variances. As is usual with the SAM model the fit to the catch-at-age data is best and in general there is increasing variance at the youngest and oldest ages. The E/W FSP in the west may only need a single variance parameter and the Scottish groundfish quarter 1 survey two parameters. However these setting will be determined during the latter stages of the fitting as they are likely to be only a refinement of the fit.

Figure 5.8.6 illustrates the residuals for the fit of the model to the catch-at-age data for each age.

Figure 5.8.6a presents the fit to age 1. The fitted values track the trends in the observations well with no strong pattern in the residuals. There is some autocorrelation, especially in the early years, when there are known SOP problems previously discussed in Section 5.1. In general there is no problem with the fit at this age.

Figure 5.8.6b–f presents the fit to the catch-at-age data for ages 2–6+. In each of the plots the residual time-series starts to develop patterns after 1990 which are amplified after 2000 with positive residuals in the 1990s and negative residuals in the 2000s. There is a strong correlation in the patterns across the ages in the two time periods.

The diagnostics for the Northern Ireland groundfish March survey (Figure 5.8.7) also have time-series problems (as was detected by the WGCSE). The survey appears to be increasing in efficiency in time at all ages. There is a transition from negative to positive residuals around 2000 the time after which the catch data have not been adjusted by the WG. A similar transition from negative to positive residuals is seen in the edited plots presented for the Scottish quarter 1 groundfish survey which also spans this period (Figure 5.8.8).

Figure 5.8.9 presents the SAM base run estimated spawning–stock biomass average F (ages 2–6) and recruitment. SSB is estimated to be very low, well below historic and reference levels following a protracted period of low recruitments and fishing mortality is estimated to be very high.

Based on the diagnostics of the model fit the SAM model is detecting the period of underreporting bias reported by WGCSE and estimated by that group using the B-ADAPT model for the years 1999/2000 onwards.

5.8.6 A SAM formulation estimating landings bias

The SAM model was respecified to estimate single catch bias parameters for each of the years in the following ranges:

1) Run 1: 2000 to 2010 the period over which strong reductions in TAC and cod recovery measures are considered to have caused significant problems with estimation of landings.

2) Run 2: 2000 to 2005 the period introduction when bias was known to occur and before the introduction of the UK buyers and sellers legislation which was assumed to reduce the bas in the landings data in the period 2006–2010.

3) Run 3: catch bias estimated for 2003 and 2004 and also 2006 to 2010 utilising the full range of years for which the ICES WG observations of misreported landings were available. The years 2000 to 2003 and 2005 were previously used to evaluate model estimation process but should ideally be treated as observations.

The diagnostics for each model run are too substantial to include in the report and are therefore placed in the ICES SharePoint files and selected details highlighted for each run.

It should be noted that although the bias parameters are fitted to the catch data, the additional mortality in each year could also result from increased natural mortality. The mortality effects cannot be separated within the model due to confounding.

The parameter estimates from Run 1 established that when catch bias parameters are estimated within the model the variance estimates of the catch-at-age data for individual ages become extremely small; the model fits to them almost exactly. This is likely caused by over parameterisation of the model and consequently in order to reduce the number of parameters, all ages in the catch-at-age data were assigned a common variance parameter in a further Run 1 and all subsequent fits of the model. Given that the catch bias is estimated across all ages, a single variance parameter for all ages seems sensible.

Run 1 Catch bias estimated for the years 2000–2010

Figures 5.8.10 and 5.8.11 present the time-series of residuals for ages 1–4 of the catch-at-age data and the Northern Irish March groundfish survey when the bias is estimated for the years 2000–2010 as previously fitted by the WGCSE. There is clearly a more consistent model fit to the catch-at-age data and the Northern Irish survey as indicated by a marked improvement in the residual patterns; the time-series trends noted previously when the bias was not estimated (Figures 5.8.10–5.8.11, left) are largely removed when catch bias is estimated (Figures 5.8.10–5.8.11, right).

Figure 5.8.12 presents the landings data as officially reported, as estimated by the ICES WG and used to correct the reported totals and used to test the assessment model estimates (2000–2002 and 2005) and the SAM assessment model Run 1 estimates when estimating landings for the years 2000–2010. The model estimated landings have followed the trajectory of the reported landings but are significantly higher. The model estimates are consistent with the trend in the test values but the estimates are higher. The findings are consistent with those of WGCSE and the ADAPT model used to assess the stock previously.

Run 2 Catch bias estimated for the years 2000–2005

The introduction of the UK buyers and sellers legislation which was assumed to reduce the bas in the landings data in the period 2006–2010 consequently Run 2 assumes the data for that period are unbiased.

Figures 5.8.13 and 5.8.14 present the time-series of residuals for ages 1–4 of the catch-at-age data and the Northern Irish March groundfish survey. There clearly a problem with the model fit to the catch-at-age data and the Northern Irish survey as indicated the residual patterns. The patterns resulting from the fit with no bias estimation are only marginally improved when no bias is assumed in 2006–2010.

The model results indicate that there is still a problem with underestimation of mortality rates if the landings data since 2066 are assumed unbiased.

Figure 5.8.15 presents the landings data as officially reported, as estimated by the ICES WG and used to correct the reported totals and used to test the assessment model estimates (2000–2002 and 2005) and the SAM assessment model Run 2 estimates. The model estimated landings have followed the trajectory of the reported landings but are significantly higher. The model estimates are consistent with the trend in the test values and their magnitude.

Run 3 Catch bias estimated for the years 2003, 2004, 2006–2010

Run 3 utilises the corrected the catch-at-age data for the full range of years for which the ICES WG observations of misreported landings were available. The years 2000 to 2003 and 2005 were previously used to evaluate model estimation process but should ideally be treated as observations. In each of those years the WG catch-at-age data was rescaled using the ratio of the WG estimate of total international landings to the reported landings, as was carried out for the years 1991 to 1999. This run assumes (as with the years 1991 to 1999) that the WG bias corrections are appropriate. Catch-at-age is then estimated within the time-series model with the data treated as observations.

Figures 5.8.16 and 5.8.17 present the time-series of residuals for ages 1–4 of the catch-at-age data and the Northern Irish March groundfish survey compared to Run1 in which bias parameters were estimated for all years from 2000–2010. The addition of the WG corrected data for the additional years reduces residual variation in the added years, marginally. Residual patterns from q-q plots are improved and therefore the decision was made to make use of the additional data within the model fit to help reduce parameter numbers in the model fit.

Figures 5.8.18 presents the landings data as officially reported, as estimated by the ICES WG and used to correct the reported totals and the SAM assessment model Run 3 estimates. In general, the model estimated landings have followed the trajectory of the WG corrected landings in the years for which bias corrections are available. In recent years the model estimates that the estimated unallocated mortality has remained relatively constant with respect to the reported landings.

5.8.7 Sensitivity of the model estimates to the range of years for which bias is estimated

Figures 5.8.17–5.8.19 present the time-series of estimates of fishing mortality and spawning–stock biomass for each of Runs 1 to 3 compared to the base run. The estimated metrics fall into two clear patterns; the base run and Run 2 have similar trajectories as do Run1 and Run3.

Figure 5.8.17 compares the base run (WG rescaling from 1991–1999 followed by no bias) with Run1 (WG rescaling 1991–1999 with estimated bias 2000–2010). Figure 5.8.19 compares the base run with Run3 (WG rescaling 1991–2002 and 2005 with estimated bias in 2003, 2004, 2006–2010).

The base run estimates of average fishing mortality exhibit an increase until 1999 followed by a relatively constant decline until the end of the time-series. When bias is estimated in Run1 and Run 3, fishing mortality shows a more gradual increase throughout the time-series to its highest level in recent years at which it remains stable. Spawning–stock biomass declines over the period 1990–2010 apart from two temporary recoveries and is currently estimated to be well below the reference levels for the stock. When bias is estimated in Run1 and Run3 similar trends in SSB are estimated but the level reached in recent years in not as low due to the added catch increasing population estimates. The fishing mortality and SSB-series when bias is estimated are consistent with the results and advice from WGCE in recent years based on the B-ADAPT assessment model.

Figure 5.18.18 compares the base run with Run2 (WG rescaling 1991–1999, estimated bias 2000–2005 and an assumption of no bias from 2006–2010).

The both of the runs have almost identical trends in average fishing mortality with an increase until 1999 followed by a relatively constant decline until the end of the time-series. Spawning–stock biomass also follows similar trends with the decline over the period 1990–2010 with two temporary recoveries. Run2 has a slightly higher biomass during 2000–2005 when extra catch is added into the time-series.

5.9 Discussion

5.9.1 The model fitting and data evaluation

Within the SAM and B-ADAPT models the bias parameters are fitted to the catch data under an assumption of underestimation bias. In the years 1991–2002, 2005 information on underreporting of the landings data was provided to the WGCSE.

Run 1 demonstrated that, as with the B-ADAPT model, the SAM model is able to recover the trends in bias in the most recent years for which the information is available to the working group (2000–2002 and 2005). This has also been demonstrated for the cod stock in the North Sea (ICES, WKCOD 2011).

Following 2005 there is no information available to WKROUND to evaluate the extent of any bias in the landings from port records, consequently the fit of the model to the survey and catch dataseries are critical to the testing of the quality of the more recent data.

Run 2 therefore examined the assumption that the previous bias in the catch-at-age data had been removed by the changes in legislation. The correlated residual patterns from the fit of the SAM to the catch-at-age data and the Northern Ireland groundfish survey (Figure 5.8.13 and 5.8.14) indicate that an assumption of no bias in the catch data during the years 2006–2010 is not consistent with the available data and current model structure. The additional mortality bias is estimated to have been reduced from the levels previously recorded but is still estimated to be significant.

Run 3 fits a SAM model to all of the WG corrected catch-at-age data and estimates bias in the years for which the WG has no data. Bias is estimated 2003, 2004 and during the years 2006–2010. Figure 5.8.17 compares the diagnostics for the catch-at-age data and the Northern Ireland survey with that from Run 1 in which bias estimates are derived for 2000–2010. The models have very similar residual patterns with minor improvements apparent when the additional years of information are added in Run 3. Consequently given fewer parameters are estimated for the same model fit, and the marked improvement in the residual patterns from Run 3 when compared to Run 2 (no bias estimation in 2006–2020).

5.9.2 A recommended model for provision of advice and further development

The SAM model specification for Run3 was considered to be the best available to date to provide a basis from which the advice current for the stock can be taken and further analysis conducted in order to determine the cause of the unallocated mortality. The configuration file for the model is presented in Table 5.9.1, the model was fitted to all of the datasets including the age and year ranges described in Section 5.8.4. The full diagnostic output from the fit of Run 3 is presented in Figures 5.9.1–5.9.14. Figure 5.9.15 presents the estimated time-series of spawning–stock biomass average fishing mortality and recruitment, Table 5.9.2 presents the time-series of model estimates.

5.9.3 Additional unallocated mortality

The SAM and B-ADAPT models are specified to estimate the removals from the stock that would be added or removed from the catch-at-age data in order to account for persistent changes in survey catchability. The unallocated removals estimates could potentially include components due to increased discarding, survey catchability and natural mortality as well as misreported landings. In order to account for the residual patterns noted within the base run model fit, the factors or a combination of them would have had to increase during the last 5–10 years.

Discarding

Discarding of cod has been discussed in Section 5.2. The ages observed to be discarded by the fleets are predominantly ages 0 and 1 (Table 5.2.1), apart from 2010 when older ages have been observed to be discarded. The residual pattern noted in the base run fit of the model without estimation of bias are present across all ages (Figures 5.8.6, 5.8.7), indicating that discarding is an unlikely source of the addition mortality.

Survey catchability

The Northern Ireland survey vessel was changed in 2005; the survey design and gear was unaltered. It is possible that the new survey vessel has a higher catchability than that of the old; therefore an exploratory run was conducted with the Northern Ireland March survey split into two fleets, 1993–2004 and 2005–2011. Catch data was corrected for bias using the WGCSE estimates for the years 1991–2002, bias estimated for the years 2003 and 2004 with no bias was estimated for the years 2005–2010. Figure 5.9.16 presents the estimated catchability at age for the Northern Ireland March survey for period 1 and 2. The relative structure of the catchability selection curves is similar for the two time periods; the individual catchability values at age in the second time period are double those in the first period. Average survey catchability would have needed to double across the two time periods to result in the SAM model misspecifying a change to the survey catchability as bias in the catch at the scale estimated.

Comparison of the Northern Ireland catch curves across time and with the other survey's data at each age (Section 5.3.1) did not indicate that there was any marked change in the Northern Ireland survey catch rates.

In addition to the residuals patterns noted in the SAM fit to the survey data (Figure 5.8.7) there is a trend of opposite slope in the fit to the catch-at-age data which is still present when the survey time-series is divided. This would indicate that a change in survey catchability is most likely not responsible for a false estimation of missing catches.

Emigration

The VIIa commercial fishery for cod extends into the North Channel, particularly for vessels using midwater trawls. It is not clear if the catches from this cod region belong to the Irish Sea stock, the nearby Clyde stock which exhibits dense aggregations of adult fish during spring in the area covered by the Clyde closure, or to other VIa cod populations. Incorrect allocation of catches to stocks could lead to biases in the assessments.

Bendall *et al*. (WD9, WKROUND2 2012) demonstrated that there is relatively low level, short-term cod migration, out of the area defined for the Irish Sea assessment into adjacent areas. In order for migration to be interpreted as missing catch in the assessment of the stock the migration would need to be permanent emigration on a large scale and would have had to have increased in recent years (since ~2005) in order to have replaced the underreporting at the same level.

If short-term seasonal migration placed the Irish Sea cod stock in a location in which catches were high and unrecorded within the landings statistics for VIIa this could account for missing catch within the data to which the assessment model is fitted. However, VIa is under the same restrictions as VIIa with substantially reduced quotas and it is considered unlikely that this external mortality is occurring due to the interaction of the limited migration and reduced quota levels.

Natural mortality

The catch curve analyses conducted in Section 5.8.2 (Figure 5.8.1b) indicate that total mortality rates on the Irish Sea cod have always been high even during the 1970s and 1980s when the stock was productive and SSB fluctuated around 15 kt. Given the high total mortality rates it is highly unlikely that natural mortality is 0.2 as used in the assessment, however given that PA reference values are conditioned on the same value then changes to the value will only rescale fishing mortality and PA levels resulting in the same trends and relative positions.

If natural mortality were resulting in the unallocated catch losses then as other factors it would have to have increased since 2005 to replace the WG estimated underreporting. There has been no change in fish condition during that time period, for instance weight-at-age has shown no strong decline, that would indicate environmental stresses leading to increase natural mortality.

Underreporting

WGCSE provides estimates of the underreporting of catches during the period 1991–2002, and 2005. In 2005, the year in which UK buyers and sellers legislation was introduced the underreporting was estimated from port information to be 80% of the reported landings; the SAM model estimates added another 40%. Since 2005 the SAM estimated unallocated catch has been a relatively constant multiplier of the recorded catch.

5.10 Conclusions VIIa cod from the assessment review

The unallocated removals estimates could potentially include components due to increased levels of emigration, discarding, survey catchability and natural mortality as well as misreported landings. In order to account for the residual patterns noted within the base run model fit, the factors or a combination of them would have had to increase during the last 5–10 years.

For the reasons discussed in the previous section changes to emigration, historic discarding and survey catchability at the scale required to account for the unallocated mortality are considered highly unlikely and would have been detected by the tagging studies, observer observations and applied analysis of the fishery and survey data.

Changes in natural mortality, given that the condition of cod landed has not changed in time are also considered unlikely but cannot be excluded. Also at this stage in the analysis of the stock data, continued underreporting and externally applied fishing mortality cannot be ruled out.

However

- In all fits of the SAM model evaluated, current levels of fishing mortality including the unallocated mortality were estimated to be higher than sustainable.

- Spawning biomass is severely depleted to well below the PA reference levels.
- Estimating the bias in the catch data in all periods only defines the trend in fishing mortality it does not change the overall conclusion that mortality rates on the stock are excessive and spawning biomass depleted.

The current ICES advice for the stock is therefore not called into question by the application of a new assessment approach, the introduction of new dataseries and the analysis conducted by WKROUND.

5.11 Recommendations

- The status of the assessment of Irish Sea cod is considered to be "work in progress".
  - The current assessment structure which includes the estimation of unallocated mortality in the most recent period is considered suited to the provision of advice on the status of the biomass and the total mortality rate for the Irish sea cod.
  - The fishing mortality rate in recent years is uncertain, but total mortality remains very high; a conclusion that is independent of the model assumptions.
  - Spawning–stock biomass has declined ten-fold since the late 1980s and has been considered to be well below B_{lim} at reduced reproductive capacity since the mid-1990s. With the exception of the 2009 year class, recruitment has been low for the last nine years.
  - The model estimates of total removals continue to vary around 2 to 3 times the reported landings, despite more accurate catch reporting and lack of evidence for significant highgrading of cod until 2010.
- To minimize the impact on cod recovery measures on fisheries not targeting cod, gear designs and cod avoidance measures that have been proven to be effective in reducing by-catches of cod in other areas should be introduced.
- Discard estimates are not currently integrated into the assessment but sampling by observers indicates that until 2010 discarding only occurred at ages 0 and 1 consequently this could not result in the high mortality rates estimated across older ages.
  - It is recommended that the work to collate and provide discard estimates for each year should be continued and the data be used to partition the estimated mortality rates into landings discards and unallocated within a forecast in order to provide management advice on the order of their magnitude and the impact on the stock.
- Tagging studies have indicated that migration from the stock is not occurring at a rate that would lead to it being misinterpreted as unallocated mortality. The tagging studies have revealed that the aggregating behaviour of cod is resulting in high cod density even at low abundance which can result in high catches in localised areas and low levels of fishing effort causing high mortality on the stock.
  - Short-term migrations of cod out of and back into the Irish Sea in the north Channel is indicated by the studies and consequently the impact

of catches taken in these areas, assuming all are from the Irish sea stock, should be investigated in a sensitivity analysis.

- There are model assumption and data issues that require investigation and which should be included within the final assessment when the unallocated mortality issue has been resolved and reference point values reestimated.
  - Natural mortality-at-age; In the future assessments the Lorenzen natural mortality should be used, constant in time.
  - The proportion mature at age 2 should be reestimated from survey data and used within the assessment and estimation of reference levels.

Table 5.1.1. Cod in Division VIIa: Landings (tonnes) as reported to ICES and WG estimates based on sampled port returns. Values in bold are fitted within the assessment model landings after 1999 are assumed to be biased.

	Reported landings	WG estimates		Reported landings	WG estimates
1968	8541		1990	7379	
1969	7991		1991	6714	7095
1970	6426		1992	7173	7735
1971	9246		1993	5727	7555
1972	9234		1994	4187	5402
1973	11819		1995	3721	4587
1974	10251		1996	3622	4964
1975	9863		1997	4360	5859
1976	10247		1998	4418	5310
1977	8054		1999	2975	4784
1978	6271		2000	1274	2179
1979	8371		2001	2252	3598
1980	10776		2002	2695	4431
1981	14907		2003	1285	
1982	13381		2004	1072	
1983	10015		2005	910	1646
1984	8383		2006	840	
1985	10483		2007	702	
1986	9852		2008	662	
1987	12894		2009	466	
1988	14168		2010	464	
1989	12751				

Table 5.1.2. Cod in Division VIIa: Landings numbers-at-age (thousands).

Year/Age	0	1	2	3	4	5	6	7
1968	0	364	1563	1003	456	177	28	2
1969	0	882	1481	1050	269	186	76	37
1970	0	1317	1385	352	204	163	52	19
1971	0	2739	2022	904	144	67	39	12
1972	0	789	3267	824	250	58	39	20
1973	0	2263	1091	1783	430	173	60	21
1974	0	530	3559	557	494	131	46	28
1975	0	1699	642	1407	294	249	95	22
1976	0	1135	3007	363	500	61	79	25
1977	0	816	511	1233	163	218	31	40
1978	0	687	1092	310	311	39	47	18
1979	0	1762	1288	608	127	164	38	33
1980	0	2533	2797	729	243	49	51	4
1981	0	1299	3635	1448	244	99	23	24
1982	0	345	2284	1455	557	102	57	22
1983	0	814	932	751	499	154	27	19
1984	0	1577	1195	439	240	161	56	19
1985	0	1218	2105	703	158	84	51	26
1986	0	974	2248	699	203	64	33	32
1987	0	4323	1793	841	252	75	19	24
1988	0	2792	4734	702	263	71	27	11
1989	0	582	2163	1886	231	86	21	16
1990	0	710	1075	545	372	70	23	7
1991	0	1973	1408	442	127	98	15	7
1992	0	1375	1243	664	132	42	46	3
1993	0	223	2907	403	119	16	6	7
1994	0	749	569	848	68	20	9	1
1995	0	498	1283	180	163	7	3	3
1996	0	317.6	1112.8	700.3	38.3	38.8	4.4	1.7
1997	0	523.2	1148.8	500.6	212.5	16.5	11.5	4.5
1998	0	204.4	1926.1	335.1	79.9	28	6.5	1.2
1999	0	69.6	842.8	871.1	65.7	21.2	6.2	0.3
2000	0	289	176	107	50	4	1	0.2
2001	0	338	841	53	13	9	0.3	2
2002	0	196	564	405	7	2	2	1
2003	0	45	439	93	35	1	0.1	0.03
2004	0	68	101	158	21	6	1.9	0.6
2005	0	42	224	62	33	5	0.7	0.2
2006	0	14	142	112	16	8.2	3.2	0.2
2007	0	49	205	56	11	0.5	0.4	0
2008	0	13.7	165.7	87.1	9.4	2.7	0.1	0.02
2009	0	19.7	53.2	65.5	16.9	2.9	0.4	0
2010	0	40.2	127.6	15	7.4	1.5	0.3	0.2

Table 5.2.1. Cod in Division VIIa. Discard and landings numbers-at-age (thousands) and the discarded proportion during 2007–2010 as estimated by WKROUND2.

Discards	0	1	2	3	4	5
2007	16	167	4.6	0	0	0
2008	5.5	63.4	3.4	0	0	0
2009	329.3	39.8	4.4	0.1	0	0
2010	48.7	180	60.3	1.4	0.5	0.1
Landings	**0**	**1**	**2**	**3**	**4**	**5**
2007	0	49	205	56	11	0.5
2008	0	13.7	165.7	87.1	9.4	2.7
2009	0	19.7	53.2	65.5	16.9	2.9
2010	0	40.2	127.6	15	7.4	1.5
Proportion	**0**	**1**	**2**	**3**	**4**	**5**
2007	1	0.773	0.022	0.000	0.000	0.000
2008	1	0.822	0.020	0.000	0.000	0.000
2009	1	0.669	0.076	0.002	0.000	0.000
2010	1	0.817	0.321	0.085	0.063	0.063

Table 5.3.1. Cod in Division VIIa: Survey catch numbers-at-age and annual effort multiplier.

Northern Ireland groundfish survey March							
Year	Effort/Age	1	2	3	4	5	6
1993	1	138.121	648.763	44.599	10.421	1.417	2.769
1994	1	1380.438	109.71	120.271	8.45	1.367	0
1995	1	700.728	386.153	20.039	10.779	0	0.994
1996	1	1106.129	329.282	111.668	1.394	8.808	0
1997	1	537.298	415.843	66.723	21.392	1.394	0
1998	1	169.385	769.234	56.874	11.984	0	0
1999	1	49.499	253.08	241.874	15.286	2.787	0
2000	1	629.595	101.053	34.576	33.014	0	2.258
2001	1	406.682	561.441	18.438	5.775	4.042	0
2002	1	662.163	253.311	333.543	0	0	1.129
2003	1	73.865	1079.204	104.05	32.702	3.652	3.049
2004	1	216.956	171.956	88.622	5.375	4.381	0
2005	1	63.533	225.07	29.407	27.963	18.27	0
2006	1	169.989	130.752	58.304	2.523	0	0
2007	1	164.351	124.393	30.601	5.148	0	0
2008	1	40.658	217.151	13.018	5.172	4.178	0.994
2009	1	144	59	33	9	0	0
2010	1	1022.117	208.961	14.656	2.258	0	0
2011	1	353.981	414.689	46.006	2.258	2.01	0

Scottish groundfish survey quarter 1						
Year	Effort/Age	1	2	3	4	5
1996	1	3	31	44	7	9
1997	1	22	29	15	13	2
1998	1	5	81	27	5	1
1999	1	7	33	93	15	5
2000	1	51	6	11	16	0
2001	1	28	56	1	1	4
2002	1	13	18	37	1	1
2003	1	8	69	18	9	0
2004	1	8	11	49	0	3
2005	1	1	25	8	9	1
2006	1	2	5	11	0	2

Table 5.3.1. (cont.) Cod in Division VIIa: Survey catch numbers-at-age and annual effort multiplier.

Scottish groundfish survey quarter 4						
Year	Effort/Age	0	1	2	3	4
1997	1	3	28	19	1	2
1998	1	0	8	42	5	0
1999	1	164	2	24	6	2
2000	1	24	136	4	0	0
2001	1	0	0	7	0	0
2002	1	0	18	15	9	0
2003	1	2	0	27	0	0
2004	1	2	12	5	5	0
2005	1	3	8	25	2	0
Northern Ireland groundfish survey October						
Year	Effort/Age	0	1	2	3	4
1992	1	57.9	1109.37	50.06	47.6	8.64
1993	1	780.82	553.23	146.44	0.76	0
1994	1	1996.19	1672.49	25.44	10.44	0
1995	1	788.56	1206.8	33.32	0	0
1996	1	1481.33	486.65	50.15	6.54	0
1997	1	420.45	1322.2	97.19	0	0
1998	1	36.98	376.51	163.9	5.72	0
1999	1	2022.49	58.47	32.48	9.49	0
2000	1	724.17	301.64	2.03	0	0
2001	1	841.1	506.79	109.91	0	0
2002	1	89.68	487.89	37.68	12.53	0
2003	1	275.94	161.45	29.4	0	0
2004	1	443.71	578.97	23.71	0	0
2005	1	824.45	706.13	107.72	17.28	2.89
2006	1	117.02	130.2	1.47	6.58	0
2007	1	6.78	86.99	0	2.98	0
2008	1	19	17	17	0	0
2009	1	535.61	213.62	6.1	0	0
2010	1	277.95	171.8	2.98	0	0

Table 5.3.1. (cont.) Cod in Division VIIa: Survey catch numbers-at-age and annual effort multiplier.

UK(E&W) Fisheries science partnership survey (west)

Year	Effort/Age	1	2	3	4	5	6
2005	1	0	0.427	1.409	0.99	0.084	0.025
2006	1	0.003	0.536	2.815	0.427	0.104	0.01
2007	1	0.008	0.611	1.322	0.585	0.055	0.058
2008	1	0.003	0.221	0.824	0.147	0.084	0.02
2009	1	0.009	0.171	1.152	0.377	0.099	0.018
2010	1	0	0.735	0.452	0.467	0.13	0.023
2011	1	0	0.407	1.681	0.144	0.095	0.039

UK(E&W) Fisheries science partnership survey (east)

Year	Effort/Age	1	2	3	4	5	6	7
2005	1	0.06	4.02	0.25	0.38	0.004	0.01	0
2006	1	0.83	0.77	0.67	0.007	0.042	0	0.001
2007	1	0.59	1.43	0.09	0.08	0	0	0
2008	1	0.01	1.8	0.32	0.02	0.03	0.003	0.01
2009	1	0.5	0.36	0.21	0.09	0.01	0.004	0
2010	1	0.97	0.65	0.03	0.04	0.01	0	0
2011	1	0.46	1.57	0.06	0	0	0	0

UK(E&W) September beam trawl survey / N. Ireland Methot–Isaacs Kidd Survey

Year	Effort/Age	0	Year	Effort/Age	0
1993	1	22			
1994	1	30	1994	1	57.4
1995	1	40	1995	1	6.9
1996	1	29	1996	1	66.3
1997	1	32	1997	1	5.7
1998	1	2	1998	1	0.1
1999	1	49	1999	1	26.2
2000	1	37	2000	1	6.1
2001	1	24	2001	1	9.6
2002	1	7	2002	1	3.4
2003	1	9	2003	1	3.2
2004	1	22	2004	1	25.8
2005	1	42	2005	1	11.4
2006	1	6	2006	1	9
2007	1	4	2007	1	0
2008	1	7	2008	1	0.8
2009	1	6	2009	1	23.6
2010	1	4	2010	1	5.7

Table 5.5.1. Cod in Division VIIa: Landings and stock weights-at-age (kg).

	Age							
Year	0	1	2	3	4	5	6	7
1968	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1969	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1970	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1971	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1972	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1973	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1974	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1975	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1976	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1977	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1978	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1979	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1980	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1981	0	0.61	1.66	3.33	5.09	6.19	6.76	8.3
1982	0	1.01	1.524	3.488	5.573	7.592	8.697	10.18
1983	0	0.995	1.842	3.988	5.964	7.966	9.306	10.925
1984	0	0.679	1.813	3.808	5.865	7.475	9.818	10.748
1985	0	0.783	2.023	4.244	5.825	7.5	8.81	9.504
1986	0	0.805	1.825	3.862	5.855	7.391	8.116	9.471
1987	0	0.713	2.161	3.91	6.41	7.821	9.888	10.658
1988	0	0.607	1.563	3.756	5.668	8.017	9.749	10.208
1989	0	0.936	1.846	3.223	5.408	6.571	8.256	11.052
1990	0	0.842	1.938	3.572	5.277	7.531	8.398	12.699
1991	0	0.856	1.637	3.542	5.419	6.39	8.507	10.397
1992	0	0.813	1.964	3.993	5.975	6.923	8.509	11.1
1993	0	0.847	1.706	3.666	5.675	7.365	9.486	10.761
1994	0	0.798	1.923	3.608	6.08	7.68	8.272	11.258
1995	0	0.9	1.84	4	5.791	8.452	8.712	9.56
1996	0	0.98	1.625	3.256	5.298	7.721	8.836	12.256
1997	0	0.846	1.937	3.624	5.291	6.115	8.672	11.263
1998	0	0.925	1.647	3.729	5.371	7.033	8.833	12.155
1999	0	0.853	1.624	3.179	5.505	7.517	10.137	12.618
2000	0	0.851	1.985	3.573	5.138	7.148	8.528	7.692
2001	0	0.99	1.823	4.149	5.606	7.332	8.471	9.667
2002	0	0.942	1.836	3.439	5.727	7.708	9.639	10.761
2003	0	1.205	1.662	3.287	5.425	10.198	10.308	13.696
2004	0	1.112	2.202	3.634	6.505	7.638	8.937	7.572
2005	0	0.913	1.938	3.514	5.318	7.739	7.94	12.237
2006	0	0.826	1.843	3.666	4.709	6.393	7.562	12.236
2007	0	0.832	1.852	3.781	5.347	7.991	10.038	0
2008	0	0.894	1.586	3.543	6.001	7.573	9.723	8.123
2009	0	1.097	2.006	3.458	5.314	7.1	6.815	0
2010	0	1.259	2.288	3.931	6.335	7.33	8.69	11.056

Table 5.8.1. The configuration file for the SAM model comparative base run.

```
# Min, max age represented internally in model
 1 6
# Max age considered a plus group? (0 = No, 1= Yes)
```

```
 1

# Coupling of fishing mortality STATES (ctrl@states)
 # 1 2 3 4 5 6 #
 1 2 3 4 5 5 # catch
 0 0 0 0 0 0 # NIGfsMar
 0 0 0 0 0 0 # ScoGfsQ1
 0 0 0 0 0 0 # ScoGfsQ4
 0 0 0 0 0 0 # NIGfsOct
 0 0 0 0 0 0 # UKFspW
 0 0 0 0 0 0 # UKFspE
 0 0 0 0 0 0 # EngBtsSep
 0 0 0 0 0 0 # NIMikNet
 0 0 0 0 0 0 # EggSurvey

# Coupling of catchability PARAMETERS (ctrl@catchabilities)
 # 1  2  3  4  5  6 #
   0  0  0  0  0  0 # catch
   1  2  3  4  5  0 # NIGfsMar
   6  7  8  9 10  0 # ScoGfsQ1
  11 12  0  0  0  0 # ScoGfsQ4
  13 14 15  0  0  0 # NIGfsOct
  16 17 18 19 20  0 # UKFspW
  21 22 23 24 25  0 # UKFspE
  26  0  0  0  0  0 # EngBtsSep
  27  0  0  0  0  0 # NIMikNet
   0  0  0  0  0  0 # EggSurvey

# Coupling of power law model EXPONENTS (ctrl@power.law.exps)
 # 1 2 3 4 5 6 #
   0 0 0 0 0 0 # catch
   0 0 0 0 0 0 # NIGfsMar
   0 0 0 0 0 0 # ScoGfsQ1
   0 0 0 0 0 0 # ScoGfsQ4
   0 0 0 0 0 0 # NIGfsOct
   0 0 0 0 0 0 # UKFspW
   0 0 0 0 0 0 # UKFspE
   0 0 0 0 0 0 # EngBtsSep
   0 0 0 0 0 0 # NIMikNet
   0 0 0 0 0 0 # EggSurvey
```

```
# Coupling of fishing mortality RW VARIANCES (ctrl@f.vars)
 # 1 2 3 4 5 6 #
   1 1 1 1 1 1 # catch
   0 0 0 0 0 0 # NIGfsMar
   0 0 0 0 0 0 # ScoGfsQ1
   0 0 0 0 0 0 # ScoGfsQ4
   0 0 0 0 0 0 # NIGfsOct
   0 0 0 0 0 0 # UKFspW
   0 0 0 0 0 0 # UKFspE
   0 0 0 0 0 0 # EngBtsSep
   0 0 0 0 0 0 # NIMikNet
   0 0 0 0 0 0 # EggSurvey
```

Table 5.8.1(cont.) The configuration file for the SAM model comparative base run.

```
# Coupling of log N RW VARIANCES (ctrl@logN.vars)
   1 1 1 1 1 1

# Coupling of OBSERVATION VARIANCES (ctrl@obs.vars)
 # 1  2  3  4  5  6 #
   1  2  2  2  2  2 # catch
   3  4  4  5  5  0 # NIGfsMar
   6  7  7  8  8  0 # ScoGfsQ1
   9 10  0  0  0  0 # ScoGfsQ4
  11 12 12  0  0  0 # NIGfsOct
  13 14 14 15 15  0 # UKFspW
  16 17 17 18 18  0 # UKFspE
  19  0  0  0  0  0 # EngBtsSep
  20  0  0  0  0  0 # NIMikNet
   0  0  0  0  0  0 # EggSurvey
# Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more
in time
 0
# Years in which catch data are to be scaled by an estimated
parameter (mainly cod related)
 0
# Fbar range
 2 4

# Checksums to ensure correct reading of input data
 123456 123456
```

Table 5.9.1. The configuration file for the recommended SAM model to be used for the provision of advice by ICES WGCSE and also form the basis for further studies to determine the probable cause of unallocated mortality.

```
# Auto generated file
# Datetime : 2012-02-28 07:44:57

# Min, max age represented internally in model
 1 6
# Max age considered a plus group? (0 = No, 1= Yes)
 1

# Coupling of fishing mortality STATES (ctrl@states)
 # 1 2 3 4 5 6 #
   1 2 3 4 5 5 # catch
   0 0 0 0 0 0 # NIGfsMar
   0 0 0 0 0 0 # ScoGfsQ1
   0 0 0 0 0 0 # ScoGfsQ4
   0 0 0 0 0 0 # NIGfsOct
   0 0 0 0 0 0 # UKFspW
   0 0 0 0 0 0 # UKFspE
   0 0 0 0 0 0 # EngBtsSep
   0 0 0 0 0 0 # NIMikNet
   0 0 0 0 0 0 # EggSurvey

# Coupling of catchability PARAMETERS (ctrl@catchabilities)
 # 1  2  3  4  5  6 #
   0  0  0  0  0  0 # catch
   1  2  3  4  4  0 # NIGfsMar
   5  6  7  8  9  0 # ScoGfsQ1
  10 11  0  0  0  0 # ScoGfsQ4
  12 13 13  0  0  0 # NIGfsOct
  14 15 16 17 17  0 # UKFspW
  18 19 20 20 20  0 # UKFspE
  21  0  0  0  0  0 # EngBtsSep
  22  0  0  0  0  0 # NIMikNet
   0  0  0  0  0  0 # EggSurvey

# Coupling of power law model EXPONENTS (ctrl@power.law.exps)
 # 1 2 3 4 5 6 #
   0 0 0 0 0 0 # catch
```

```
   0 0 0 0 0 0 # NIGfsMar
   0 0 0 0 0 0 # ScoGfsQ1
   0 0 0 0 0 0 # ScoGfsQ4
   0 0 0 0 0 0 # NIGfsOct
   0 0 0 0 0 0 # UKFspW
   0 0 0 0 0 0 # UKFspE
   0 0 0 0 0 0 # EngBtsSep
   0 0 0 0 0 0 # NIMikNet
   0 0 0 0 0 0 # EggSurvey
```

Table 5.9.1 (cont.) The configuration file for the recommended SAM model.

```
# Coupling of fishing mortality RW VARIANCES (ctrl@f.vars)
 # 1 2 3 4 5 6 #
   1 1 1 1 1 1 # catch
   0 0 0 0 0 0 # NIGfsMar
   0 0 0 0 0 0 # ScoGfsQ1
   0 0 0 0 0 0 # ScoGfsQ4
   0 0 0 0 0 0 # NIGfsOct
   0 0 0 0 0 0 # UKFspW
   0 0 0 0 0 0 # UKFspE
   0 0 0 0 0 0 # EngBtsSep
   0 0 0 0 0 0 # NIMikNet
   0 0 0 0 0 0 # EggSurvey

# Coupling of log N RW VARIANCES (ctrl@logN.vars)
   1 1 1 1 1 1
# Coupling of OBSERVATION VARIANCES (ctrl@obs.vars)
 # 1  2  3  4  5 6 #
   1  1  1  1  1 1 # catch
   2  3  3  4  4 0 # NIGfsMar
   5  6  6  7  7 0 # ScoGfsQ1
   8  9  0  0  0 0 # ScoGfsQ4
  10 11 11  0  0 0 # NIGfsOct
  12 13 13 14 14 0 # UKFspW
  15 16 16 17 17 0 # UKFspE
  18  0  0  0  0 0 # EngBtsSep
  19  0  0  0  0 0 # NIMikNet
   0  0  0  0  0 0 # EggSurvey


# Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more
in time
```

```
 0
# Years in which catch data are to be scaled by an estimated parameter (mainly cod related)
 7
# Years
 2003 2004 2006 2007 2008 2009 2010
#Ages
  1  1  1  1  1  1
  2  2  2  2  2  2
  3  3  3  3  3  3
  4  4  4  4  4  4
  5  5  5  5  5  5
  6  6  6  6  6  6
  7  7  7  7  7  7

# Fbar range
 2 4

# Checksums to ensure correct reading of input data
 123456 123456
```

Table 5.9.2. Estimates of stock and fishery summary trends from the recommended SAM model fit.

SSB (tonnes)			Total biomass (tonnes)			Fishing mortality			Estimated catch (tonnes)		
Lower	Estimate	Upper	Lower	Estimate	Upper	Lower	Estimate	Upper	Lower	Estimate	Upper
10854	14704	18554	15222	19983	24744	0.67	0.83	0.99	7849	9995	12727
9327	12358	15389	13833	17643	21453	0.68	0.83	0.98	6917	8522	10500
6683	8599	10516	12345	15898	19451	0.69	0.83	0.97	5694	6962	8511
7766	10470	13174	15808	20808	25808	0.69	0.83	0.96	7041	8812	11030
10341	13783	17225	18046	24204	30362	0.69	0.83	0.96	8751	11196	14324
12707	17640	22573	19379	25192	31005	0.70	0.83	0.96	9369	11838	14958
11493	14927	18361	18289	24158	30027	0.71	0.84	0.96	9227	11652	14713
11096	15280	19464	16198	20950	25702	0.72	0.84	0.97	8022	10104	12727
9188	12026	14864	15585	20590	25595	0.72	0.85	0.98	7689	9743	12345
8461	11814	15167	12124	15850	19576	0.73	0.86	0.98	6147	7834	9983
5902	7780	9658	10085	12983	15881	0.74	0.86	0.99	4855	6023	7471
6494	8514	10534	12665	16220	19775	0.75	0.87	1.00	5793	7110	8728
8363	11014	13665	17386	22909	28432	0.76	0.89	1.01	7978	10088	12756
11998	16299	20600	20469	27153	33837	0.78	0.91	1.03	10404	13320	17053
13503	18182	22861	19419	24975	30531	0.80	0.92	1.05	10359	12982	16269
10748	14162	17576	16260	20444	24628	0.81	0.94	1.07	8362	10270	12614
7651	9715	11780	13505	16926	20347	0.83	0.96	1.09	6723	8140	9855
8315	10911	13507	15962	20690	25418	0.85	0.98	1.12	7945	9965	12497
8166	10796	13426	15859	20573	25287	0.88	1.01	1.14	7918	9938	12473
9108	12064	15020	20113	26295	32477	0.91	1.04	1.18	9519	11792	14609
9947	13080	16213	20174	27147	34120	0.94	1.07	1.21	10522	13613	17612
10606	14781	18956	17654	23129	28604	0.97	1.11	1.25	9867	12651	16221

6906	9067	11228	11922	15136	18350	1.00	1.15	1.29	6436	7966	9862
4901	6325	7750	11100	14538	17976	1.04	1.19	1.34	5432	6700	8263
5370	7180	8990	11139	14451	17763	1.08	1.24	1.40	5753	7218	9058
4228	5484	6740	8601	11414	14227	1.11	1.28	1.45	4872	6323	8207
3845	5338	6831	7276	9326	11376	1.13	1.30	1.47	3776	4810	6126
3040	3879	4718	7324	9357	11390	1.14	1.30	1.46	3607	4501	5616
3797	4942	6087	7496	9363	11231	1.15	1.31	1.47	3960	4880	6013
3864	4878	5892	8016	9962	11907	1.17	1.33	1.50	4161	5071	6179
3943	4989	6035	7812	10058	12304	1.18	1.34	1.51	4459	5626	7097
4245	5811	7378	5975	7734	9493	1.18	1.36	1.53	3898	4998	6409
1686	2157	2628	4050	5224	6398	1.19	1.36	1.53	1825	2186	2619
1819	2435	3050	6173	8228	10283	1.18	1.35	1.51	2694	3515	4587
3630	5102	6574	7213	9246	11279	1.17	1.33	1.49	3796	4850	6197
3807	4876	5945	7505	9674	11842	1.17	1.34	1.50	4177	5255	6613
2835	3811	4787	4857	6120	7383	1.16	1.32	1.49	2640	3324	4184
1764	2202	2641	3308	4177	5045	1.15	1.32	1.49	1825	2250	2773
1609	2091	2572	2508	3156	3803	1.16	1.34	1.52	1495	1851	2291
1285	1639	1992	2543	3234	3926	1.16	1.34	1.52	1363	1689	2093
1173	1531	1888	2035	2609	3182	1.15	1.34	1.53	1194	1502	1890
1071	1393	1715	2010	2561	3112	1.14	1.34	1.54	1029	1262	1549
993	1312	1631	2954	4086	5218	1.11	1.33	1.55	1279	1646	2118
1335	2124	2913	3203	5249	7294	1.09	1.33	1.57	1695	2474	3611

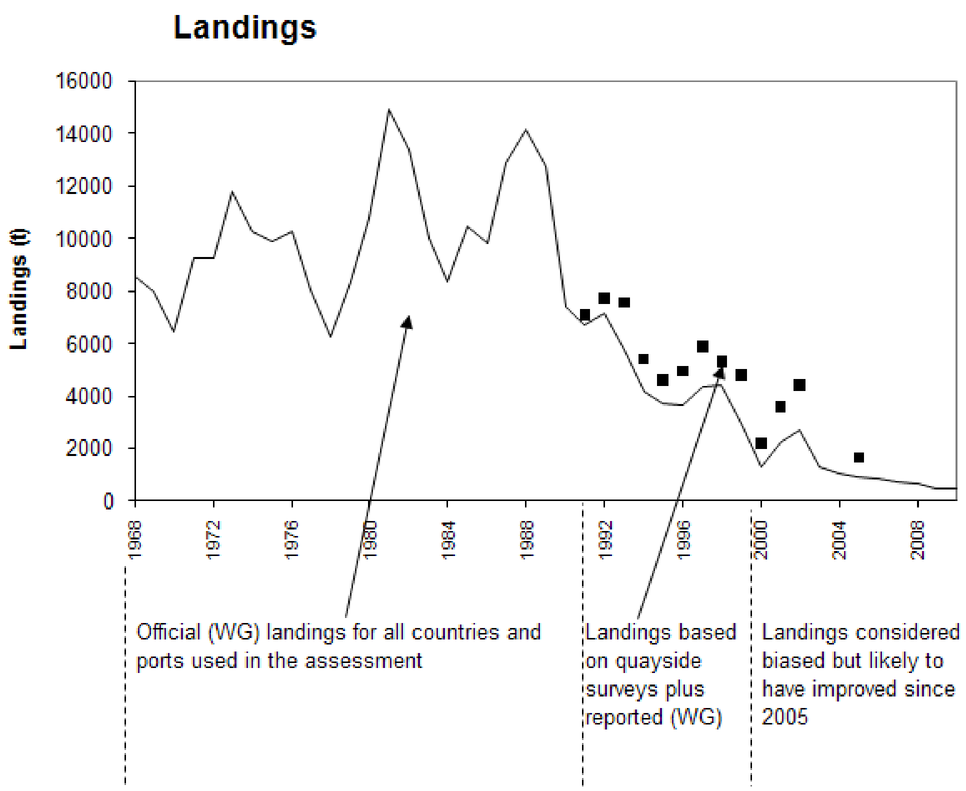


Figure 5.1.1. Cod in ICES Division VIIa: Landings as reported to ICES (solid line) and as estimated by the WG after 1998 (black squares).

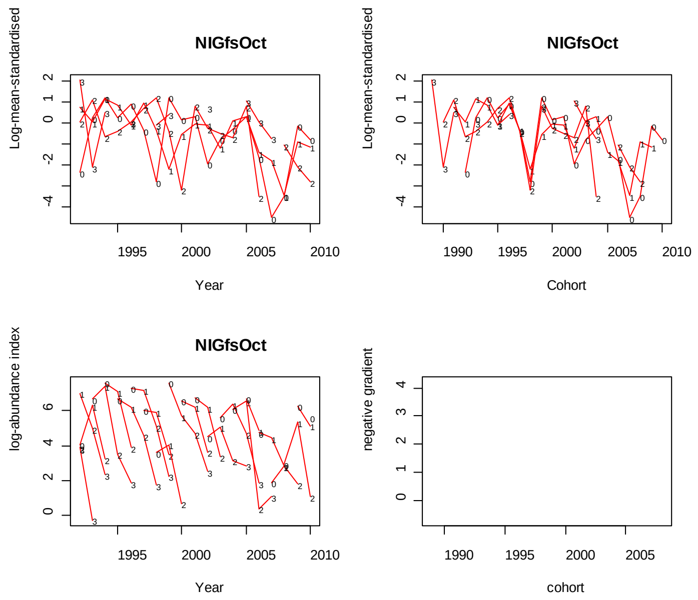


Figure 5.3.1a. Cod in Divisions VIIa: Log cpue cohort curves for the Northern Ireland October groundfish survey.

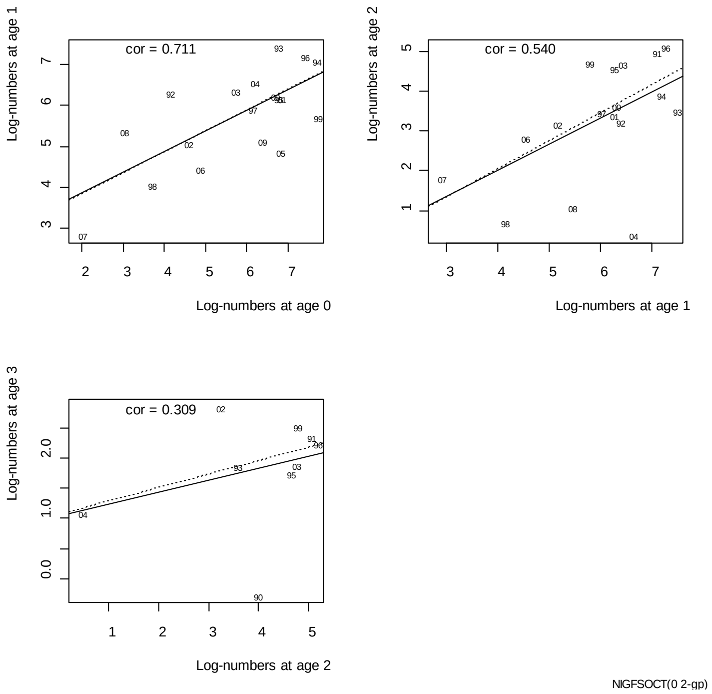


Figure 5.3.1b. Cod in Divisions VIIa: Northern Ireland October groundfish survey age log index comparative scatter plots.

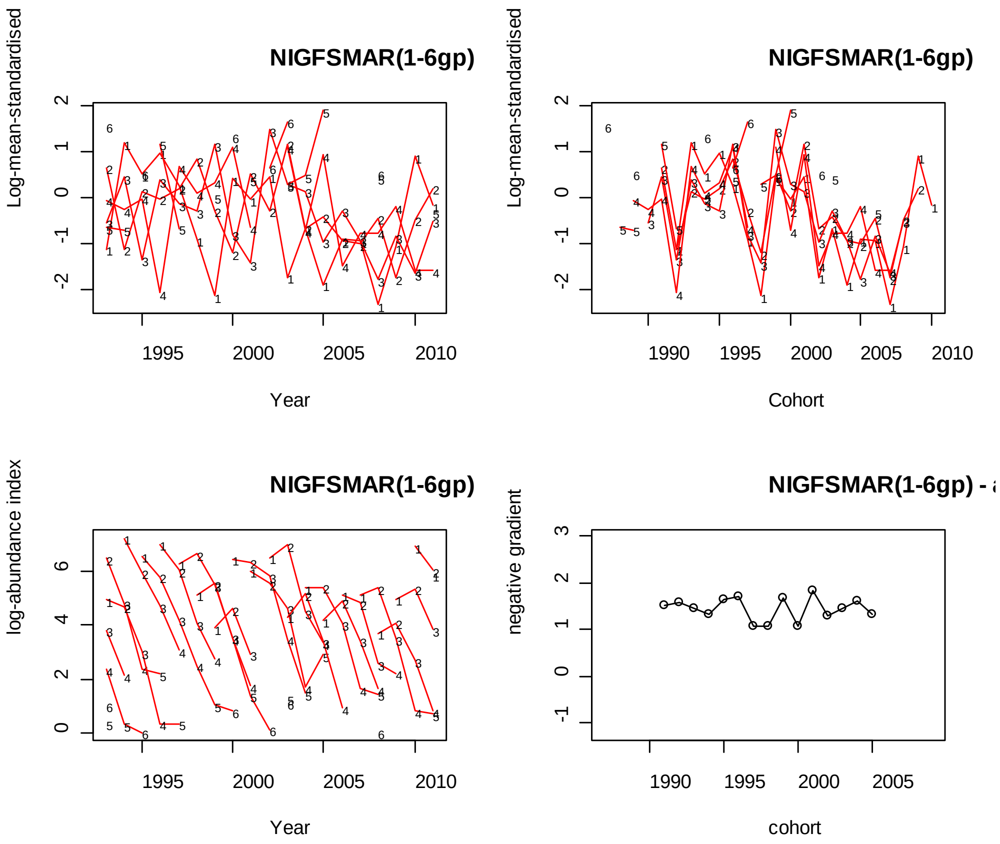


Figure 5.3.2a. Cod in Divisions VIIa: Log cpue cohort curves for the Northern Ireland March groundfish survey.

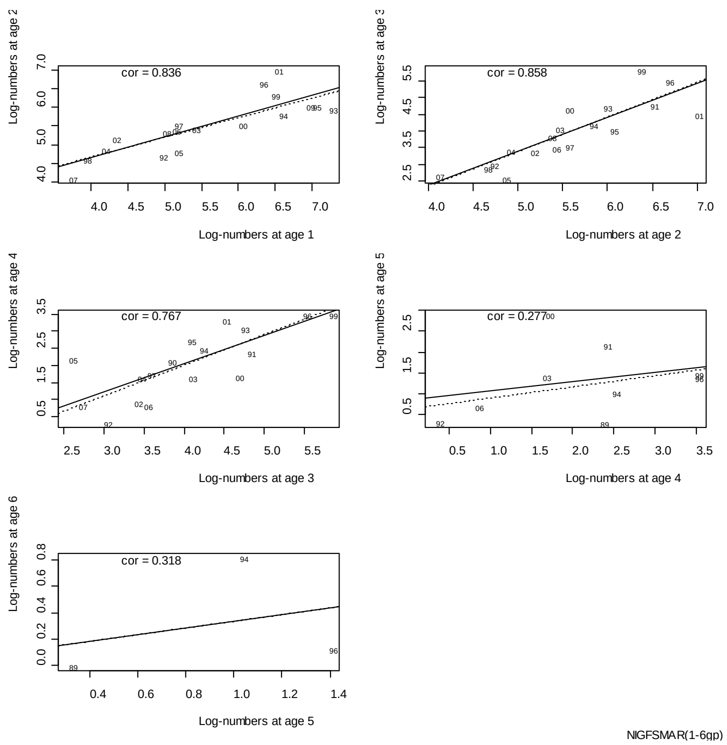


Figure 5.3.2b. Cod in Divisions VIIa: Northern Ireland March groundfish survey age log index comparative scatter plots.

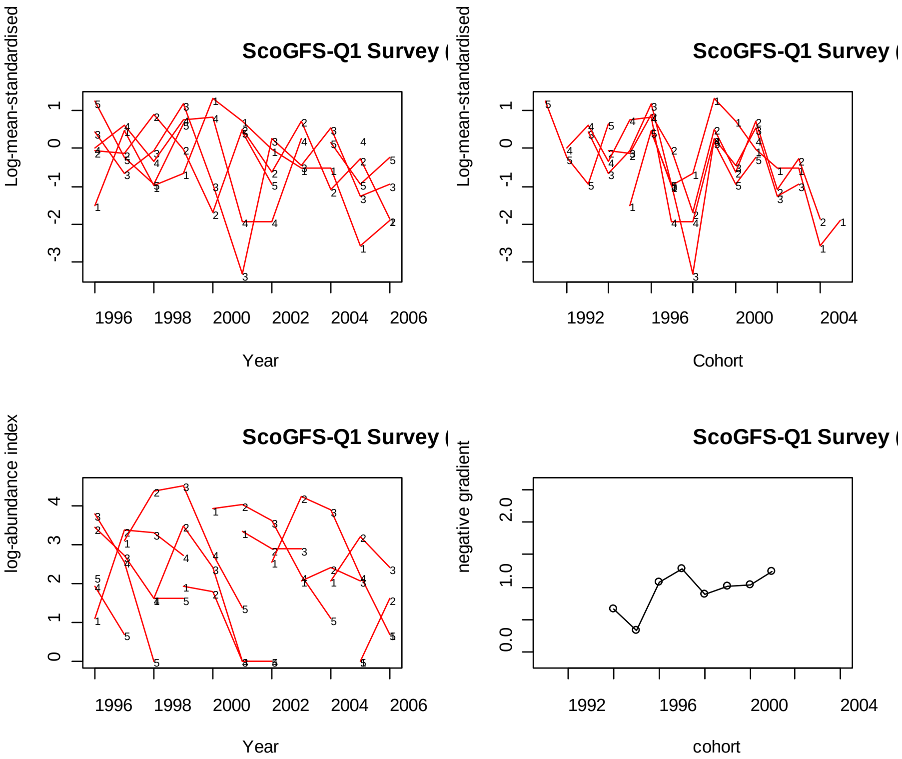


Figure 5.3.3a. Cod in Divisions VIIa: Log cpue cohort curves for the Scottish quarter 1 groundfish survey.

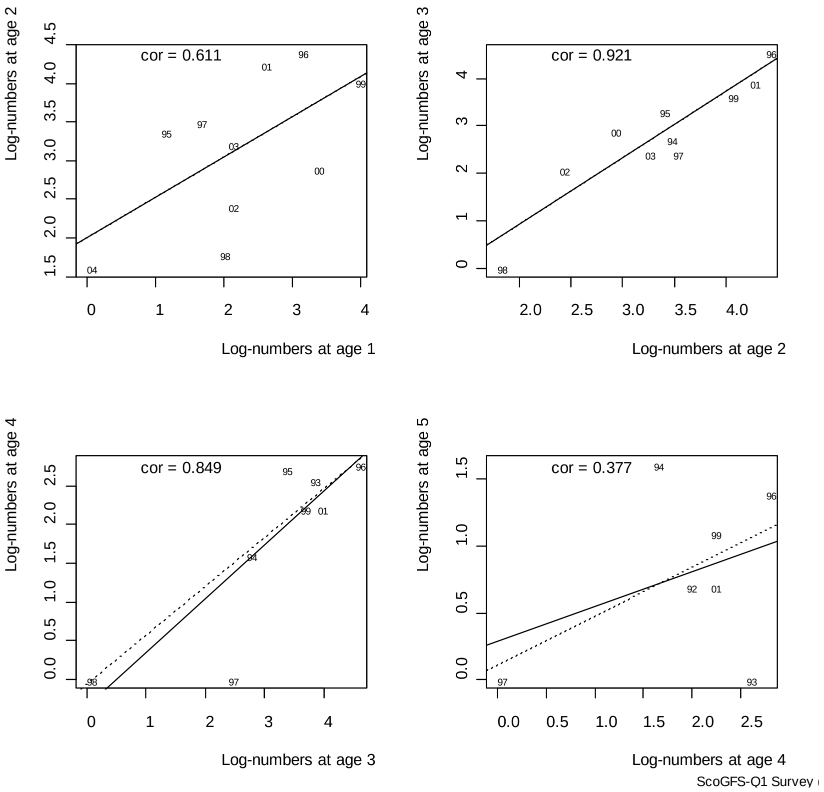


Figure 5.3.3b. Cod in Divisions VIIa: Scottish quarter 1 groundfish survey age log index comparative scatter plots.

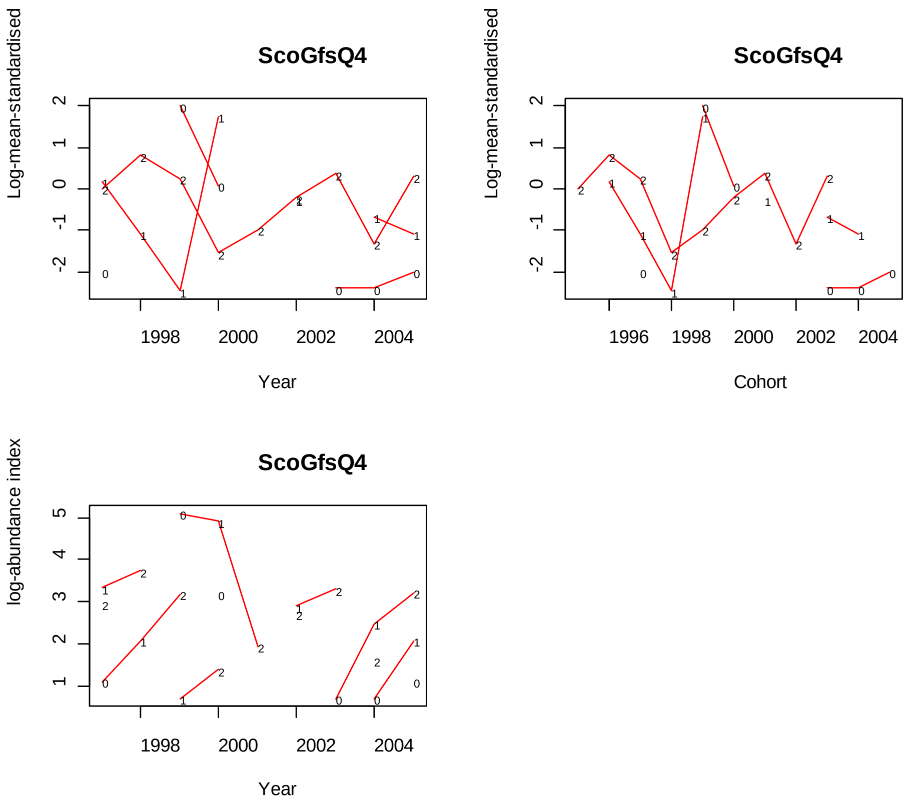


Figure 5.3.4a. Cod in Divisions VIIa: Log cpue cohort curves for the Scottish quarter 4 groundfish survey.

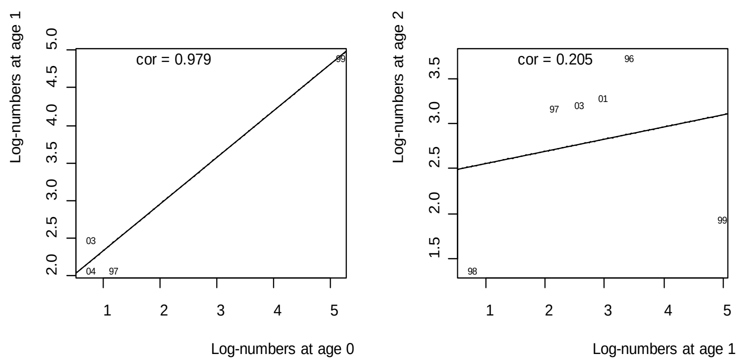


Figure 5.3.4b. Cod in Divisions VIIa: Scottish quarter 4 groundfish survey age log index comparative scatter plots.

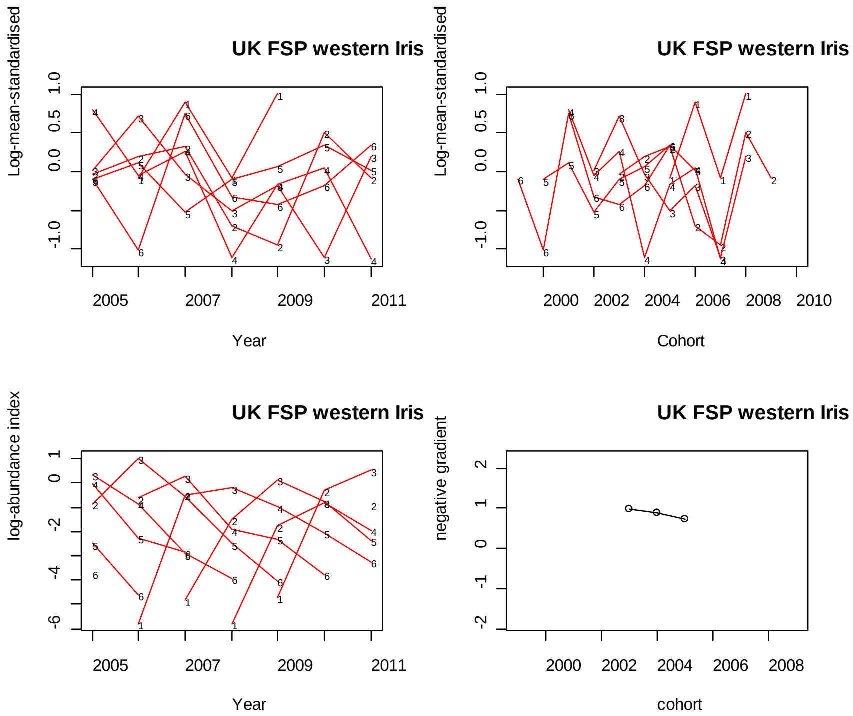


Figure 5.3.5a. Cod in Divisions VIIa: Log cpue cohort curves for the UK(E&W) western FSP UK(E&W) western FSP groundfish survey.

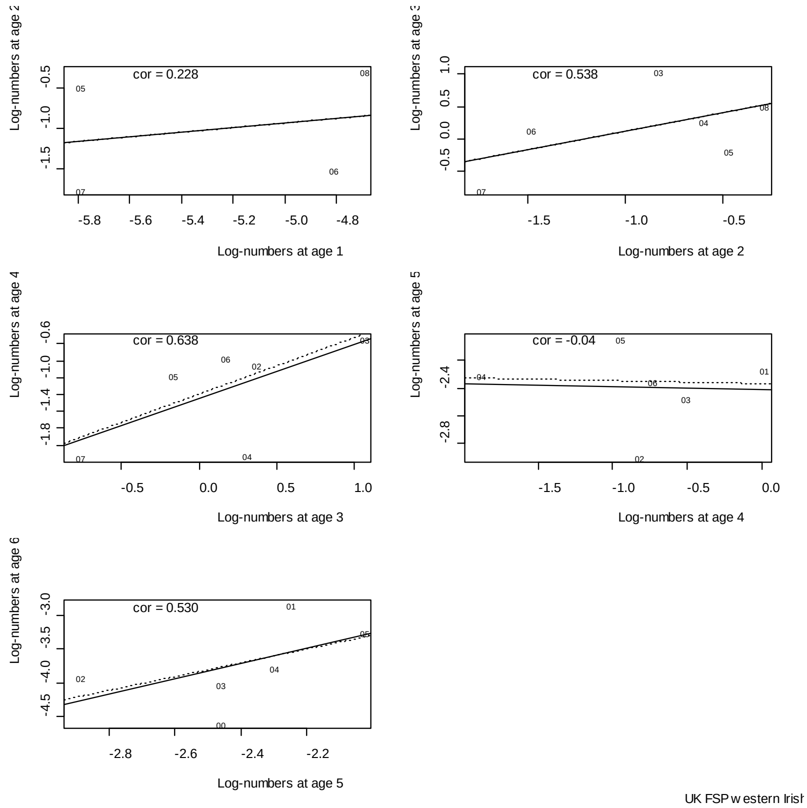


Figure 5.3.5b. Cod in Divisions VIIa: UK(E&W) western FSP groundfish survey age log index comparative scatter plots.

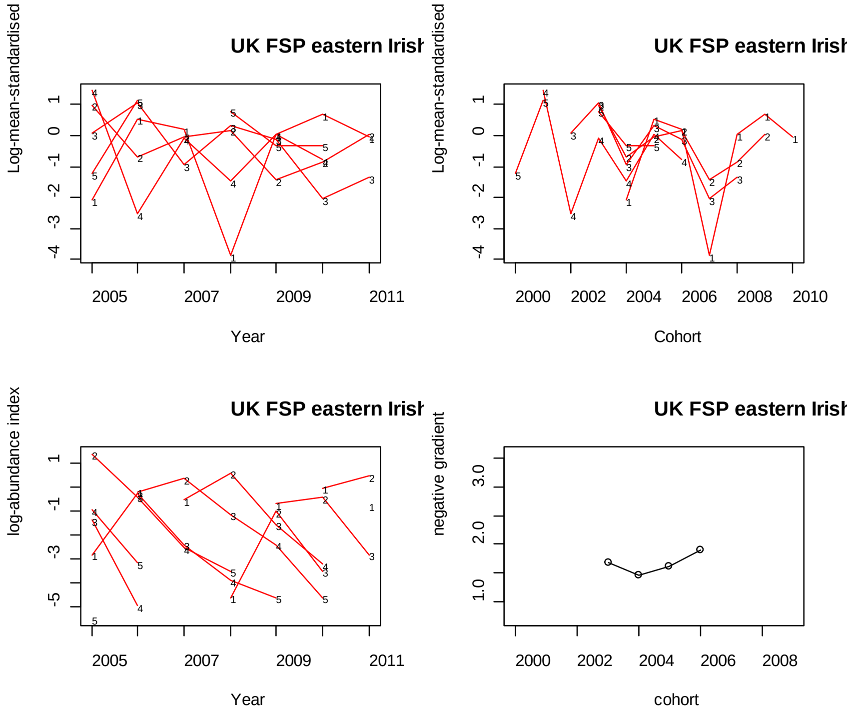


Figure 5.3.6a. Cod in Divisions VIIa: Log cpue cohort curves for the UK(E&W) eastern FSP UK(E&W) western FSP groundfish survey.

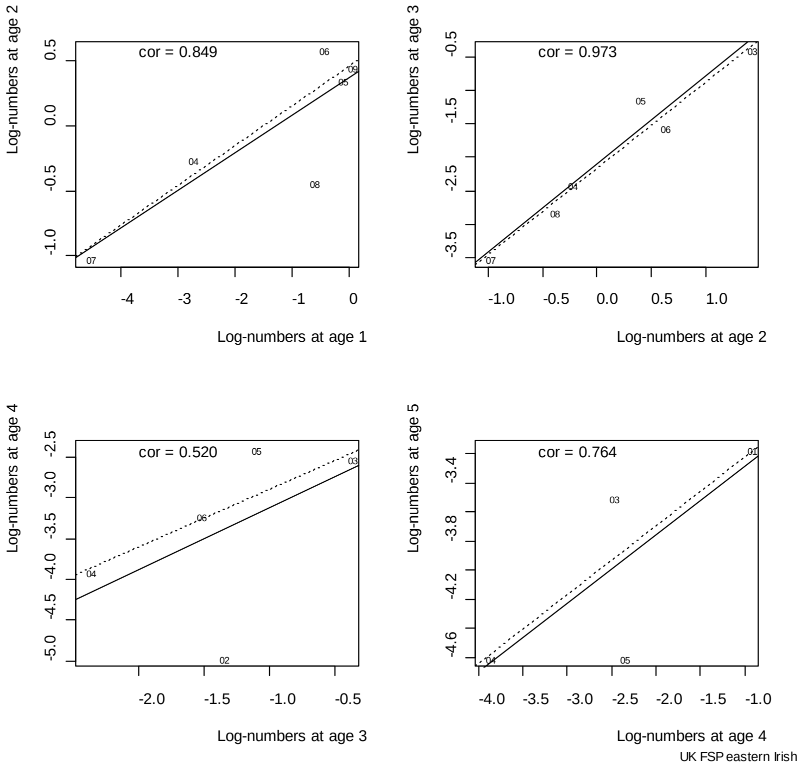


Figure 5.3.6b. Cod in Divisions VIIa: UK(E&W) esstern FSP groundfish survey age log index comparative scatter plots.

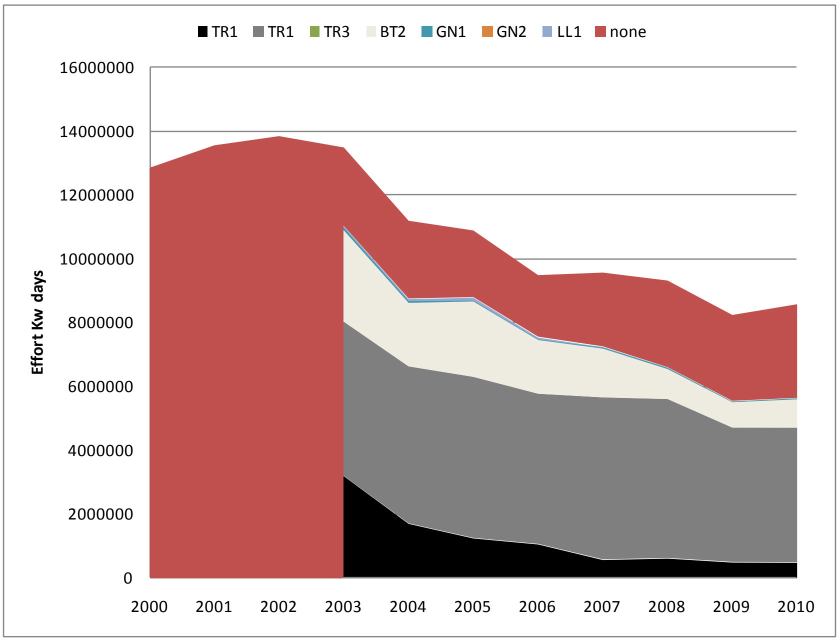


Figure 5.4.1. Cod in ICES Division VIIa: Effort (kw x Days) for each of the fishing gear categories catching cod (Source STECF, 2011).

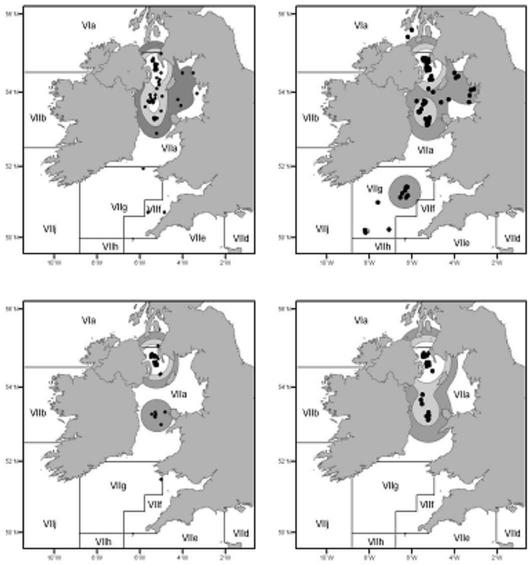


Figure 5.4.2. From Bendall *et al*. (WD 9, WKROUND2 2012). Quarterly data storage tag 'virtual' cod recapture positions of cod released in ICES Area VIIa (Irish Sea). Solid symbols 'virtual' recapture locations, while shading shows the probability density surfaces for 50% (centre white), 75% (mid grey) and 95% (dark grey) of the recaptures. Adults "recaptured" during seasonal quarters (top left) Quarter 1; (top right) Quarter 2; (bottom left) Quarter 3.

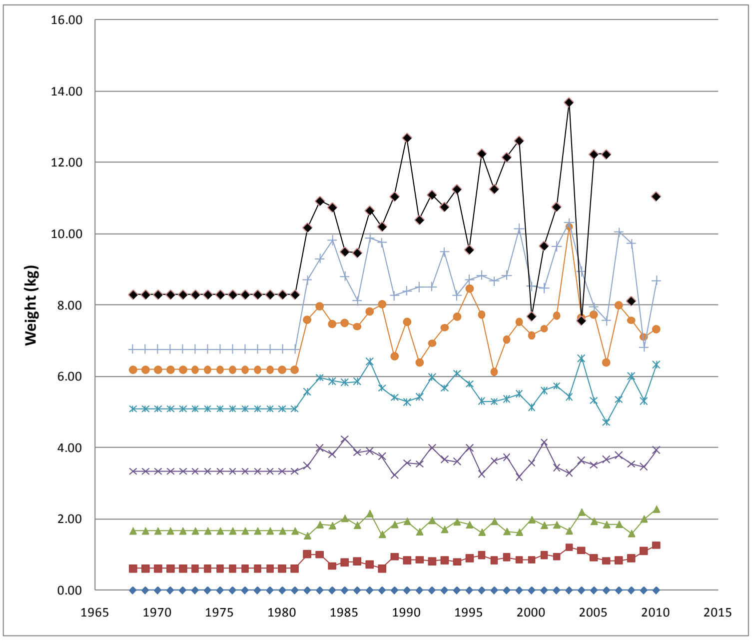


Figure 5.5.1. Cod in ICES Division VIIa: Landings and stock weight-at-age as currently used.

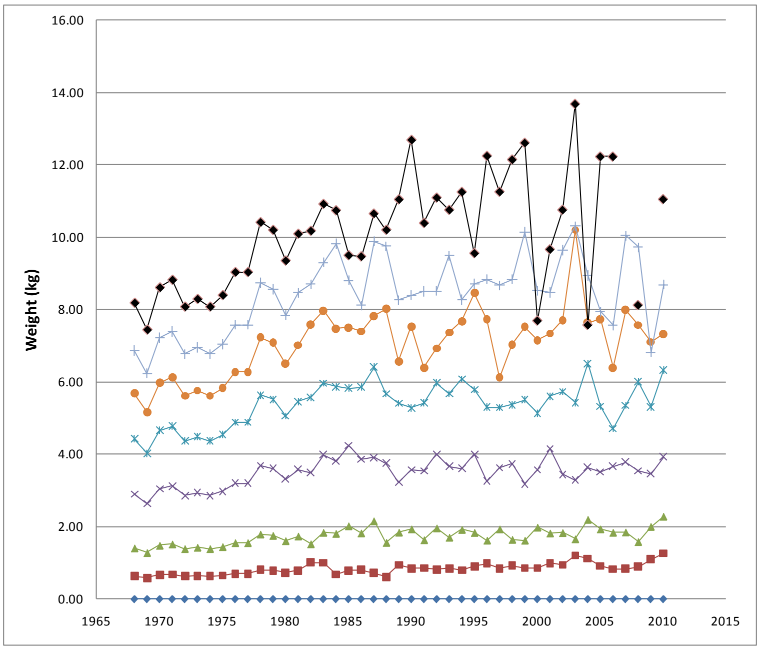


Figure 5.5.2. Cod in ICES Division VIIa: Landings and stock weight-at-age corrected for the SOP discrepancies which induces a trend in time prior to 1982.

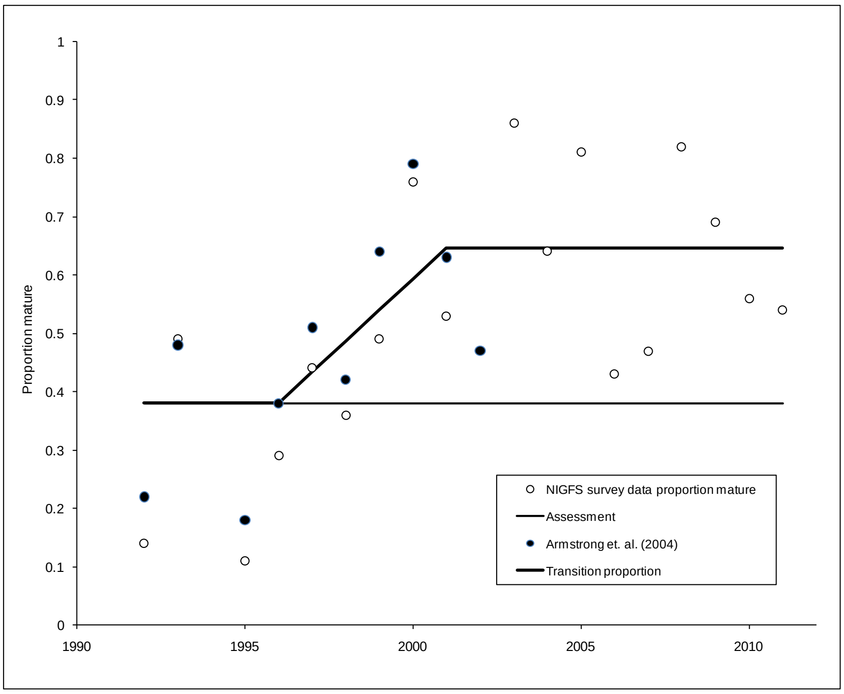


Figure 5.6.1. Cod in ICES Division VIIa: Proportion mature at age 2 as estimated by Armstrong *et al.* (2004) with and unweighted survey mean value, the current assessment constant value and a transition scheme from the historic estimate to the current survey average.

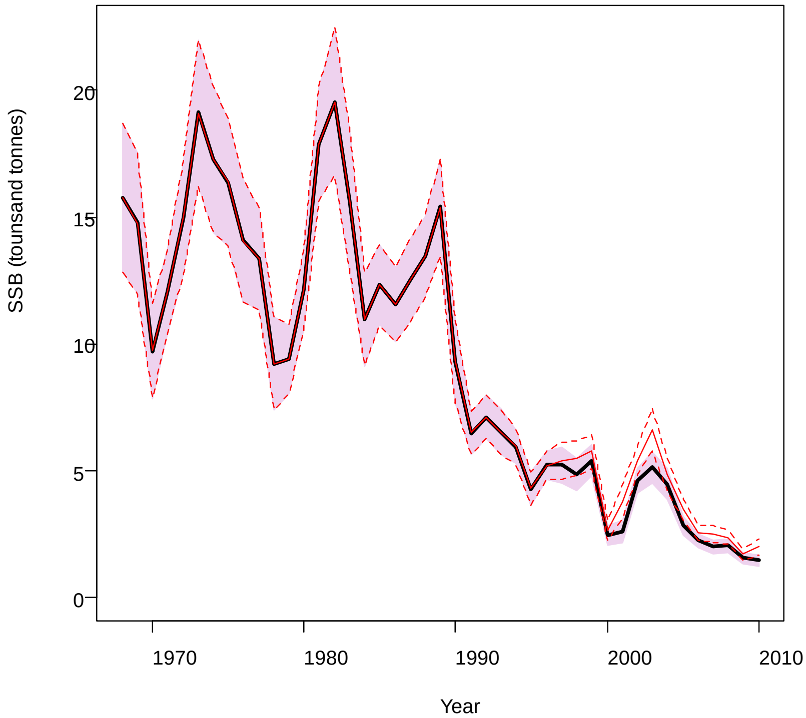


Figure 5.6.2. Cod in ICES Division VIIa: Spawning–stock biomass as estimated based on the current WGCSE constant proportion mature at age 2 (black line and shading) and a transition scheme from the historic estimate to the current survey average value (red line and hashing).

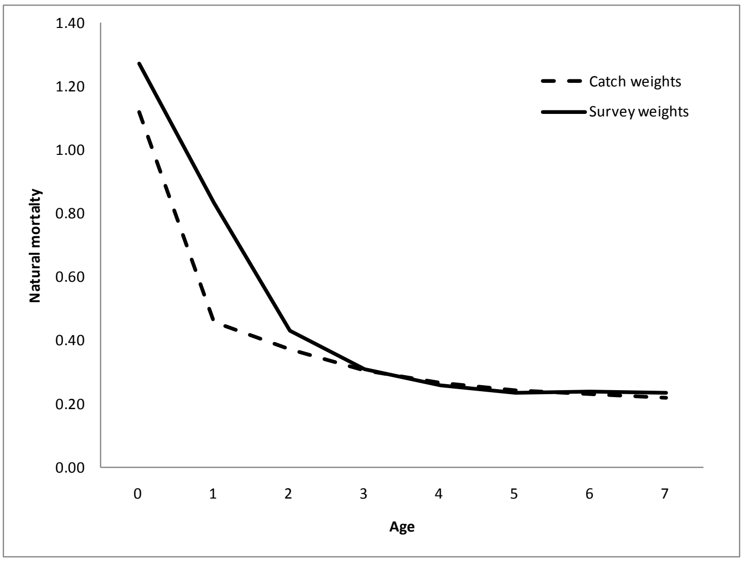


Figure 5.7.1. Cod in ICES Division VIIa: Natural mortality-at-age estimated using the approach proposed by Lorenzen (1996) and based on average catch and survey weights.

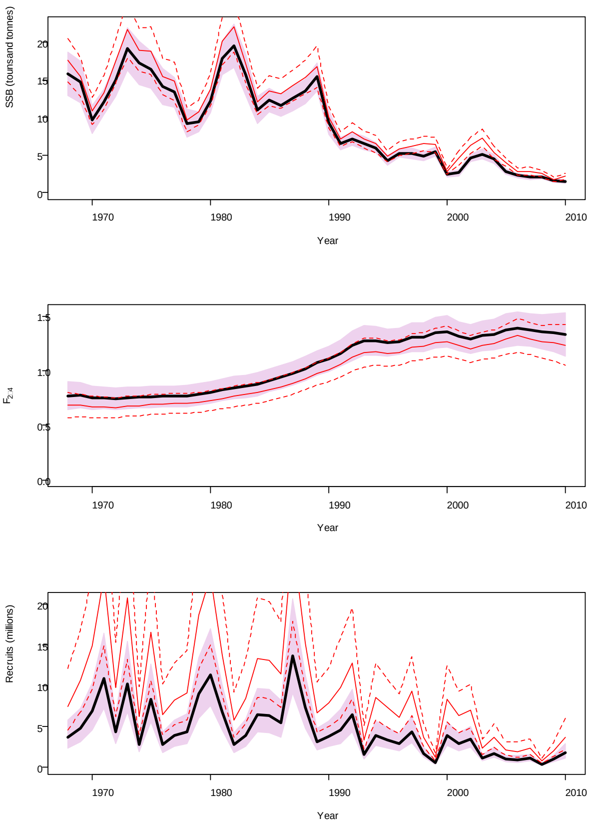
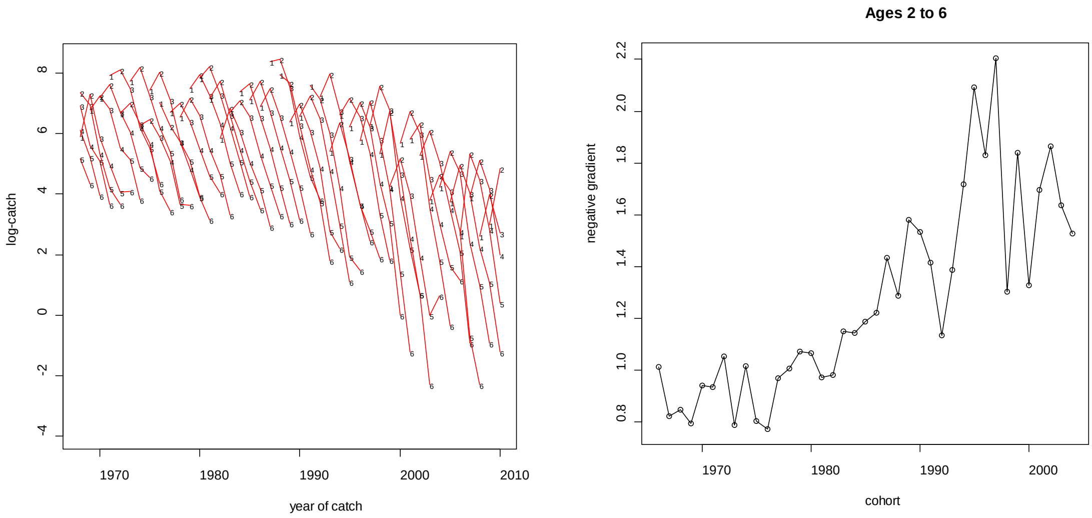
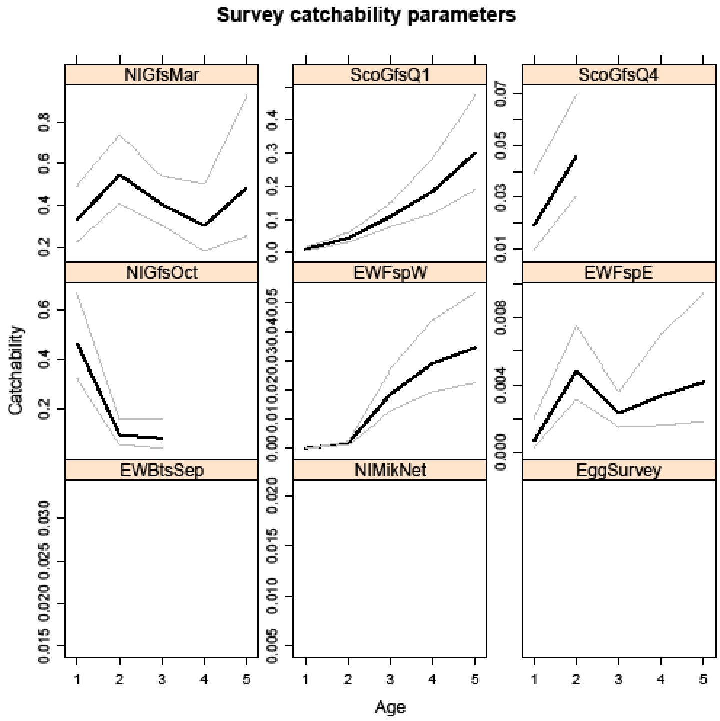


Figure 5.7.2. Cod in ICES Division VIIa: Spawning–stock biomass, average fishing mortality and age 1 recruitment estimated using natural mortality-at-age estimated using the approach proposed by Lorenzen (1996) (redlines) and the previous constant values at age (black line and shading). The trends remain unchanged, the series are rescaled.

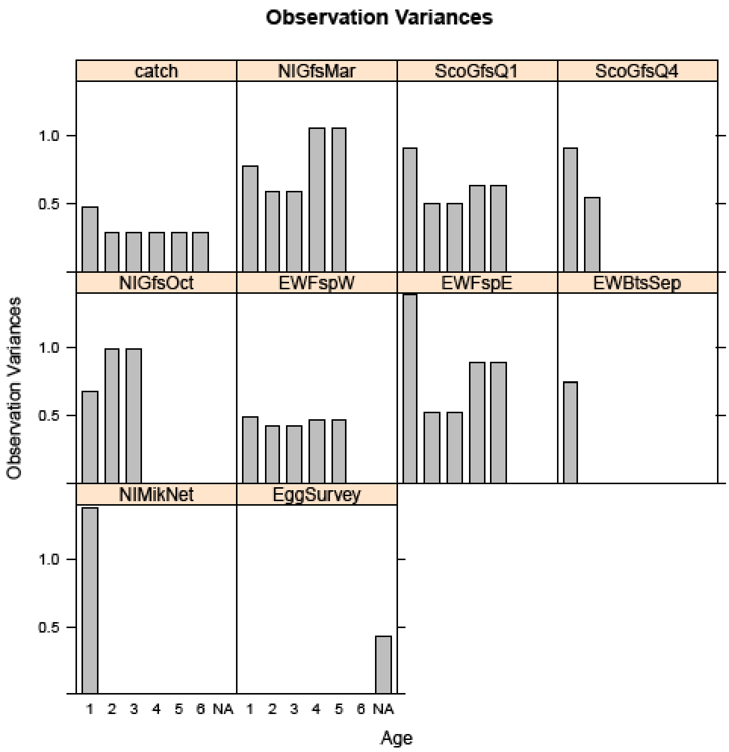


(a) (b)

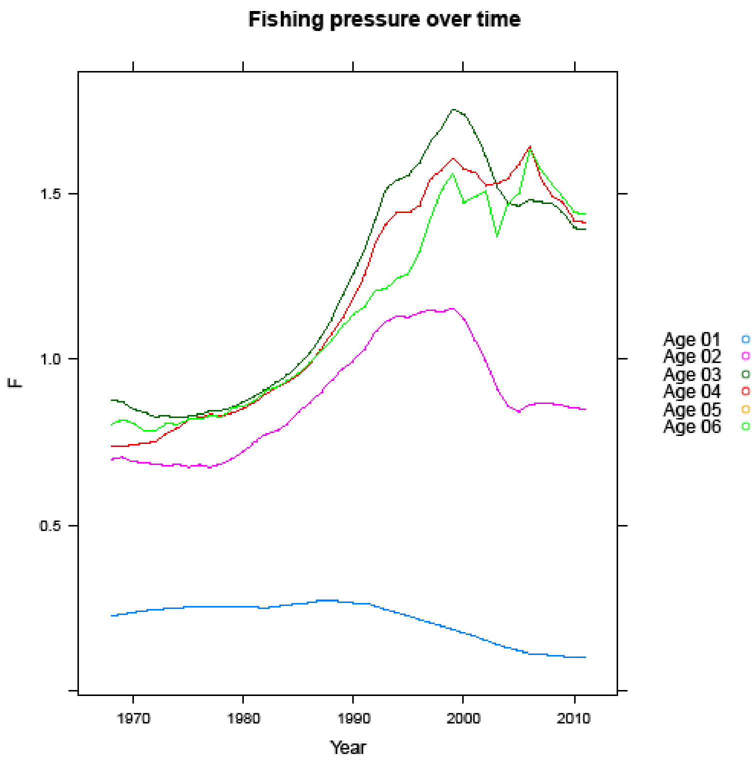
Figure 5.8.1. Cod in ICES Division VIIa: (a) Log landings by year class and (b) the negative slope of the year class catch curves (~Z) for ages 2–6.



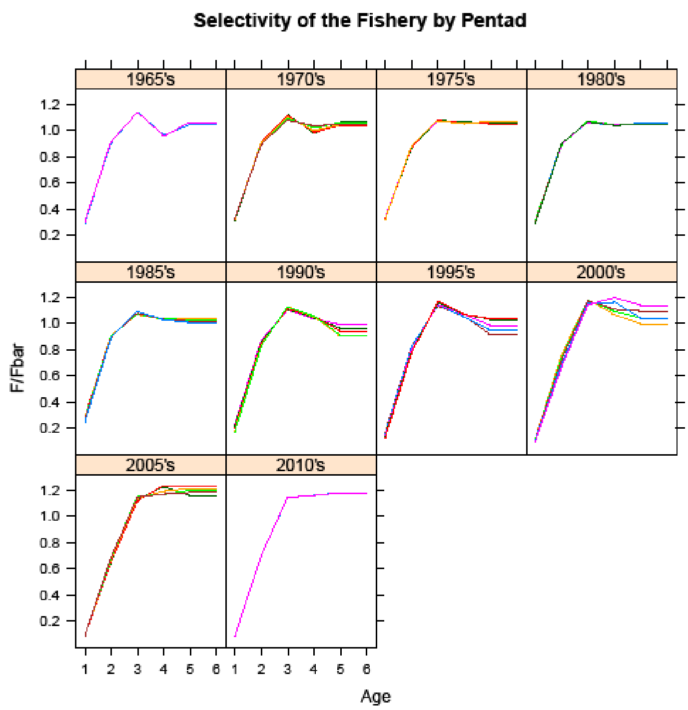
Figures 5.8.2. Cod in ICES Division VIIa: SAM estimated survey catchability at age for the base run.



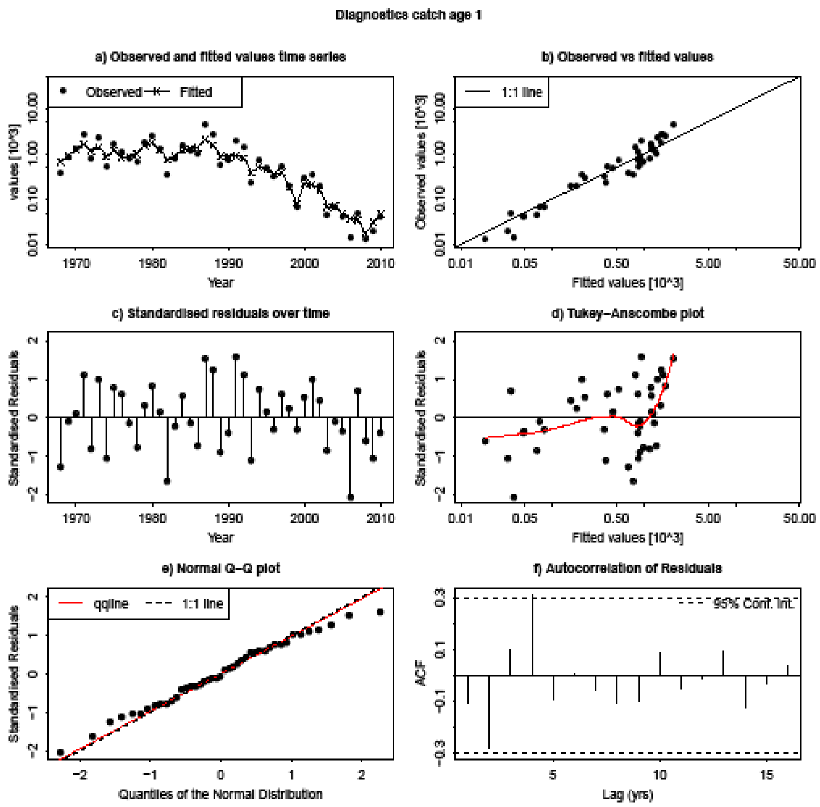
Figures 5.8.3. Cod in ICES Division VIIa: SAM base run estimated paired parameter variance at age.



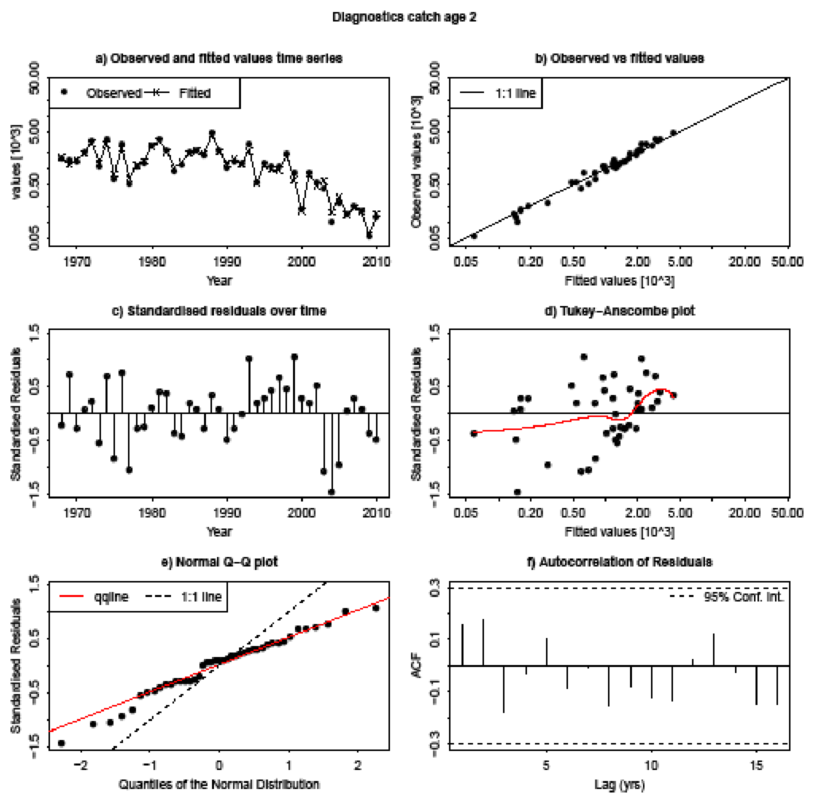
Figures 5.8.4. Cod in ICES Division VIIa: SAM base run estimated fishing mortality-at-age, age 5=age 6.



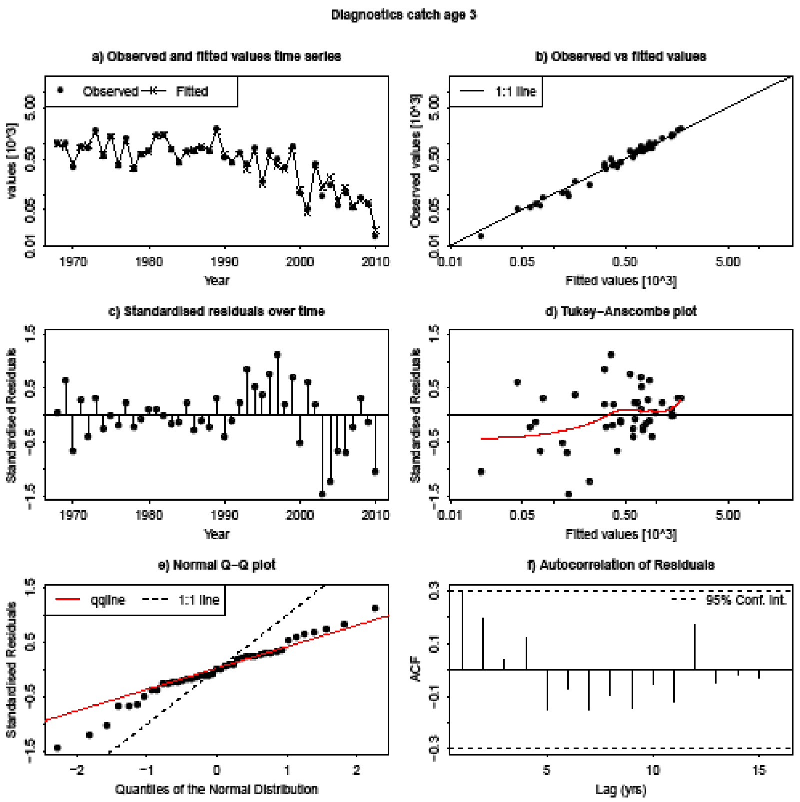
Figures 5.8.5. Cod in ICES Division VIIa: SAM base run estimated fishery selectivity-at-age.



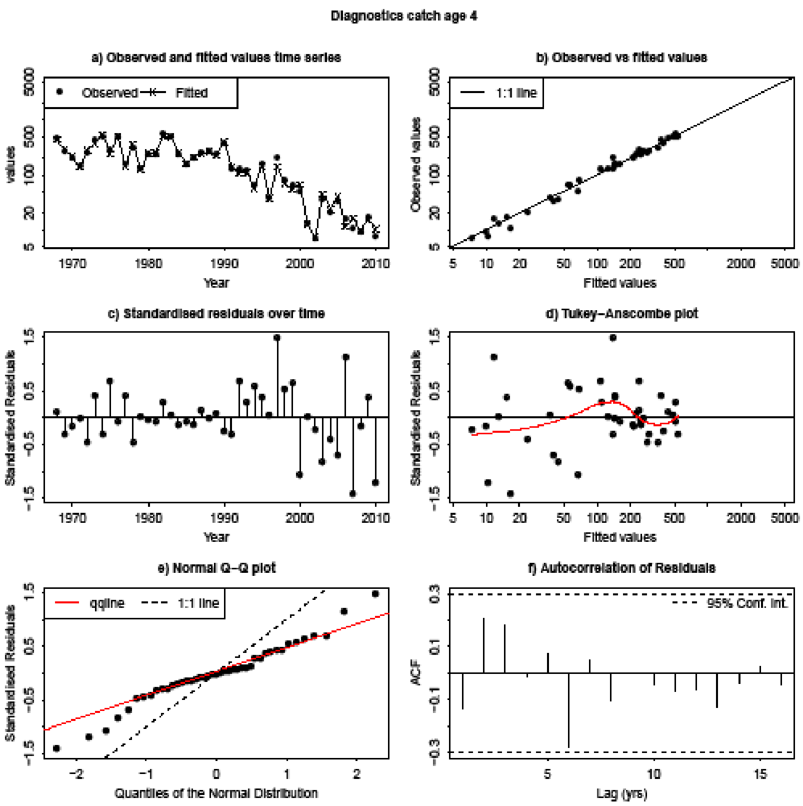
Figures 5.8.6a. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 1.



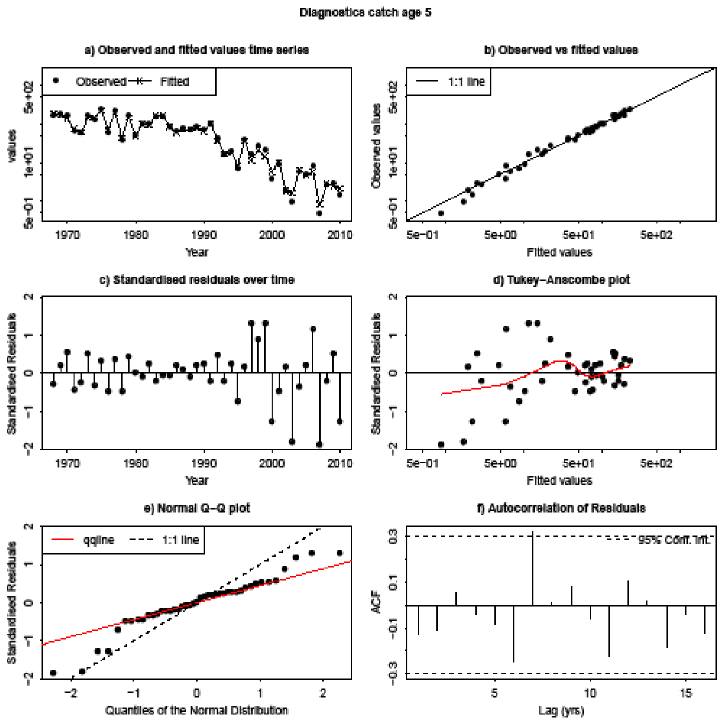
Figures 5.8.6b. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 2.



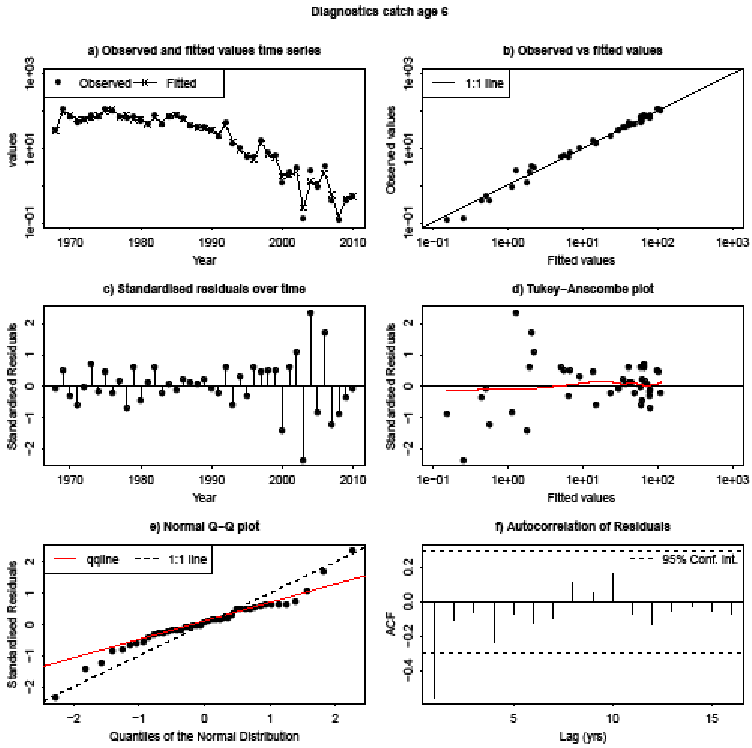
Figures 5.8.6c. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 3.



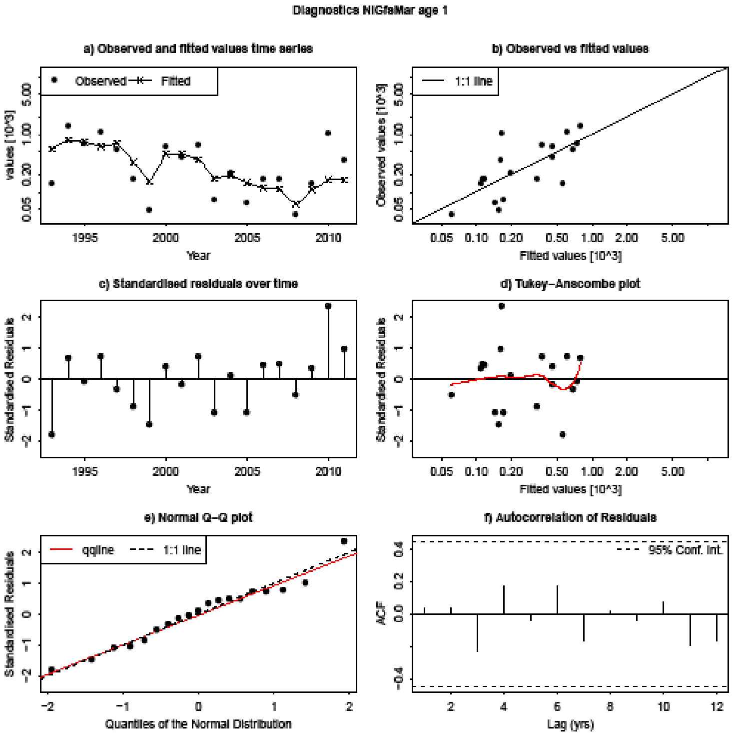
Figures 5.8.6d. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 4.



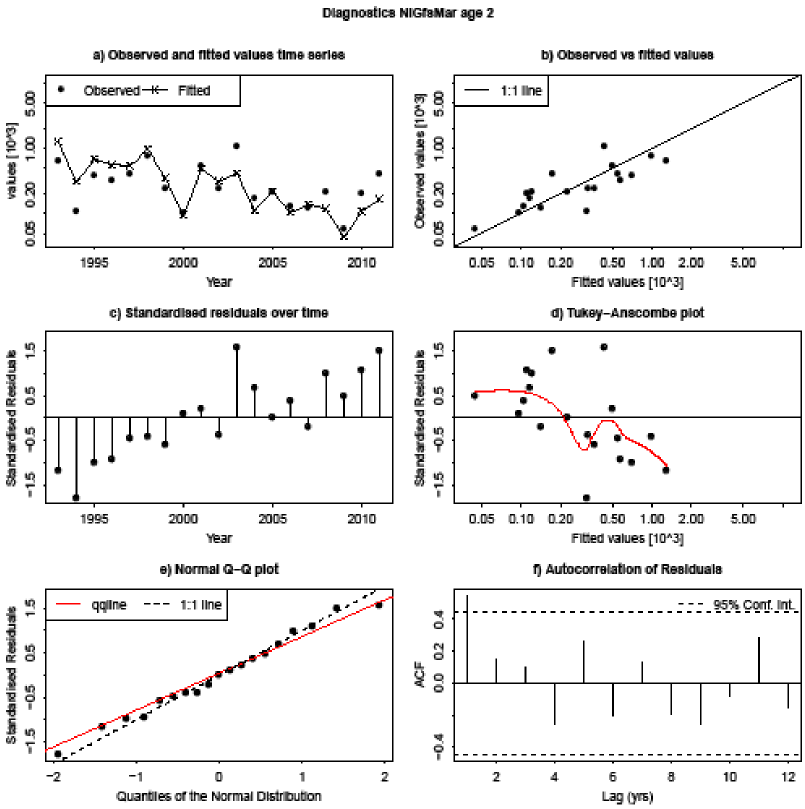
Figures 5.8.6e. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 5.



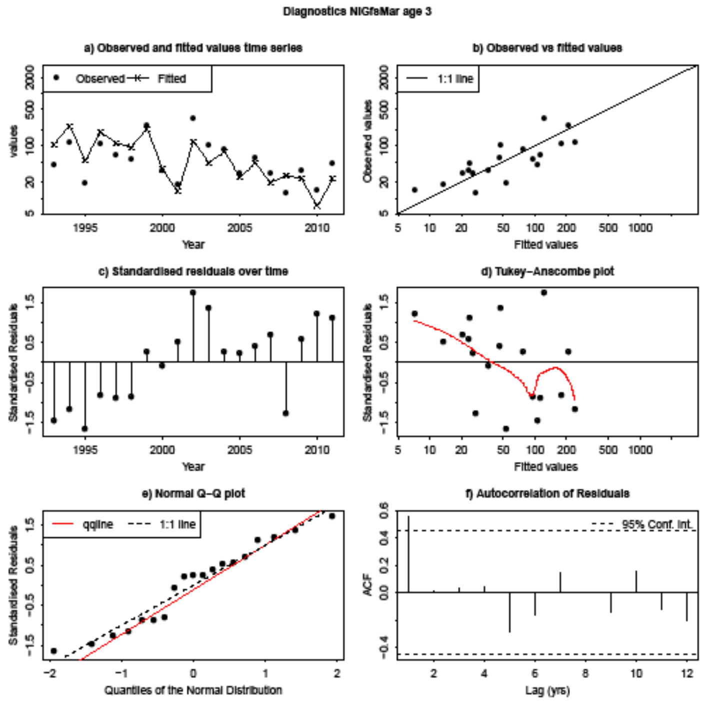
Figures 5.8.6f. Cod in ICES Division VIIa: SAM base run estimated catch residuals for age 6+.



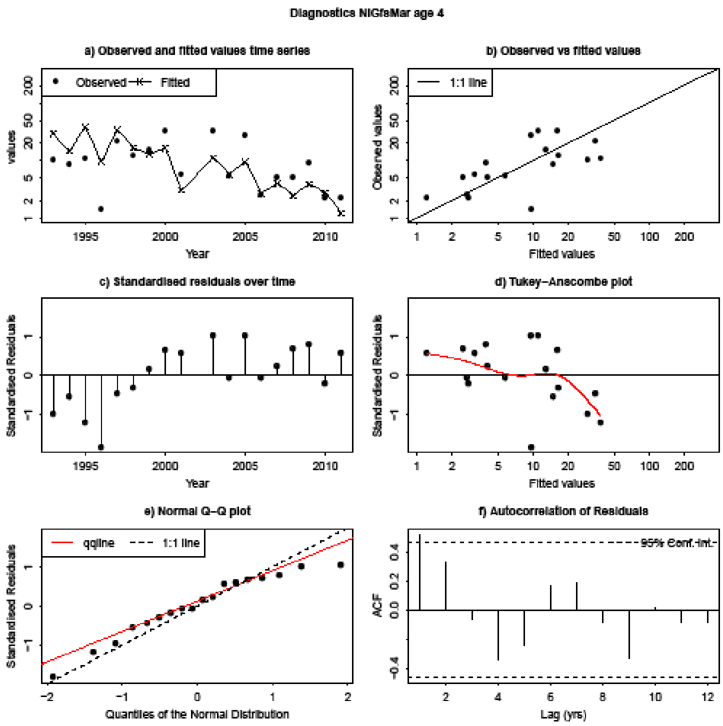
Figures 5.8.7a. Cod in ICES Division VIIa: SAM base run estimated Northern Ireland groundfish survey index residuals for age 1.



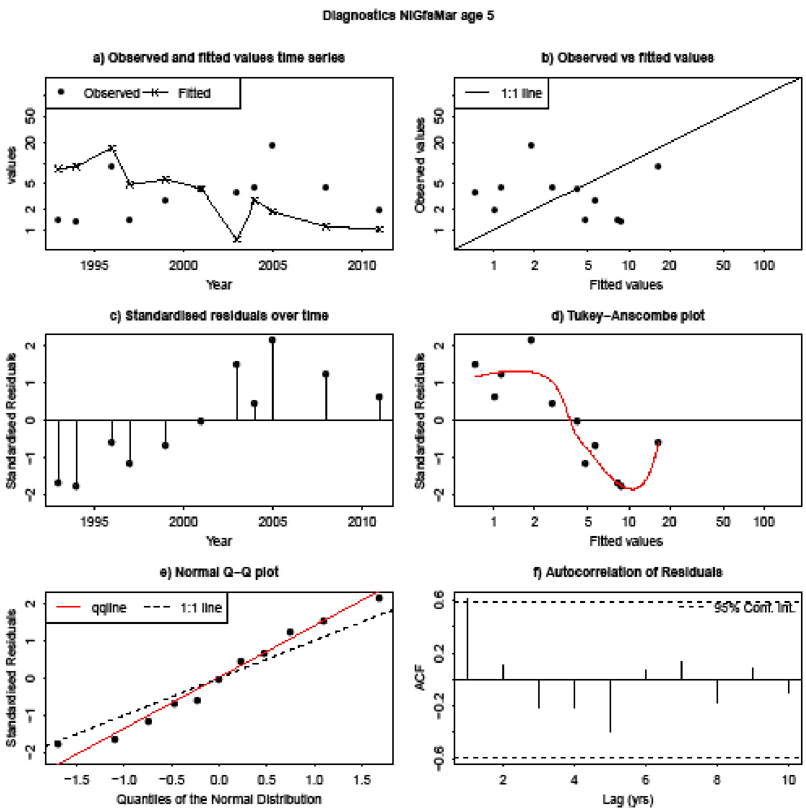
Figures 5.8.7b. Cod in ICES Division VIIa: SAM base run estimated Northern Ireland March groundfish survey index residuals for age 2.



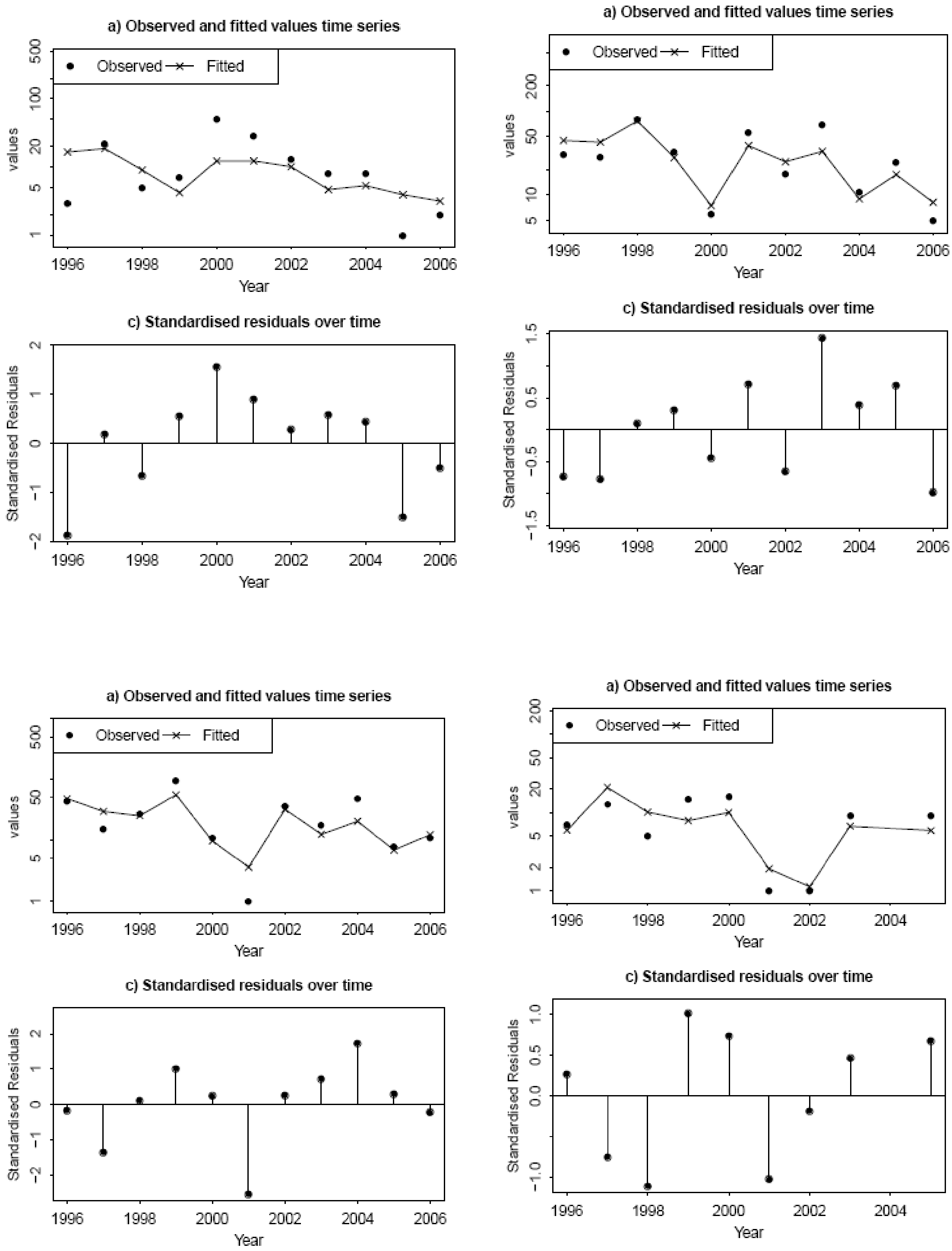
Figures 5.8.7c. Cod in ICES Division VIIa: SAM base run estimated Northern Ireland March groundfish survey index residuals for age 3.



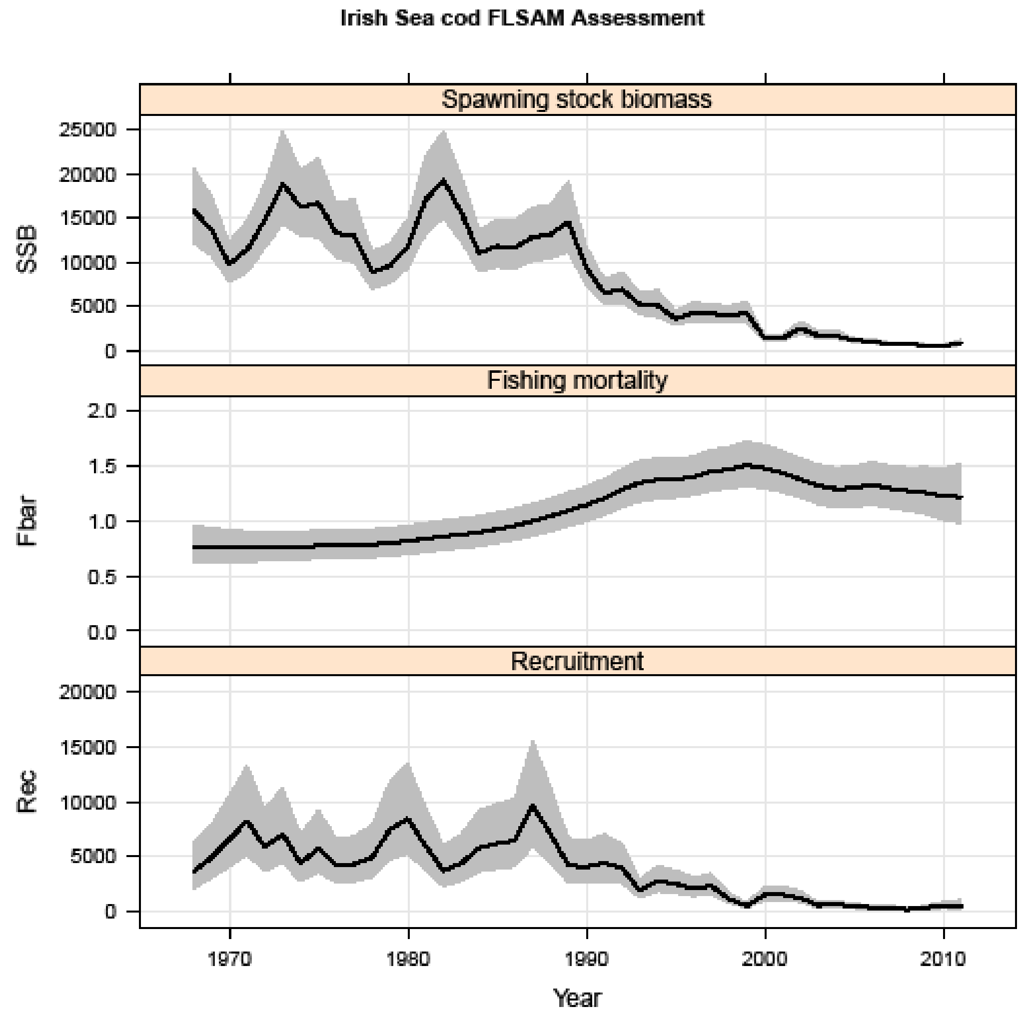
Figures 5.8.7d. Cod in ICES Division VIIa: SAM base run estimated Northern Ireland March groundfish survey index residuals for age 4.



Figures 5.8.7e. Cod in ICES Division VIIa: SAM base run estimated Northern Ireland March groundfish survey index residuals for age 5.

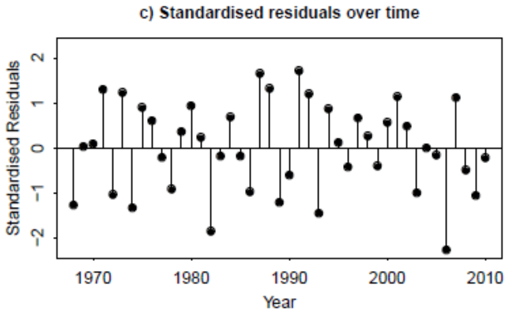


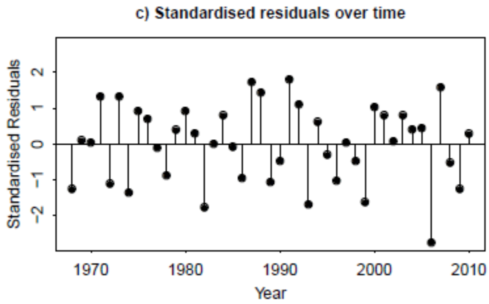
Figures 5.8.8. Cod in ICES Division VIIa: SAM base run estimated Scottish quarter 1 groundfish survey index residuals for ages 1 (tp left) to 4 (bottom right).



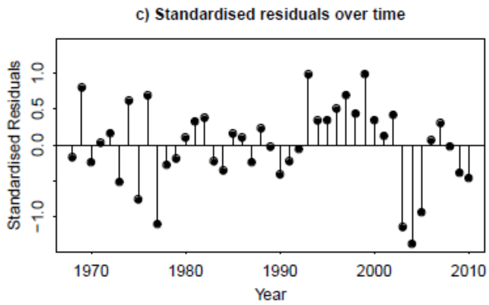
Figures 5.8.9. Cod in ICES Division VIIa: SAM base run estimated spawning–stock biomass average F (ages 2–6) and recruitment.

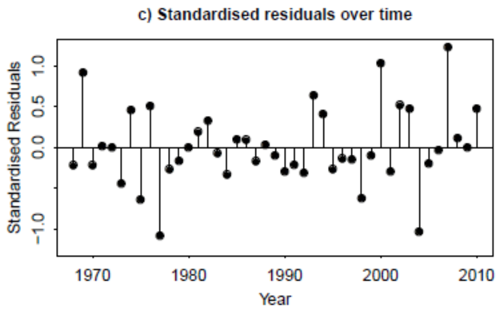
Age 1 no bias estimation left



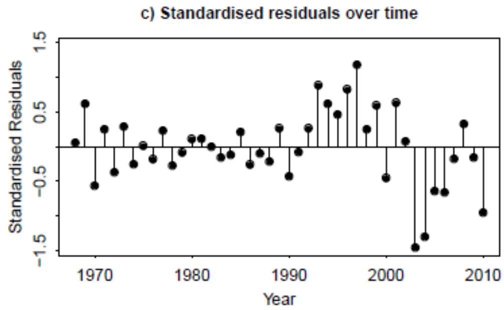


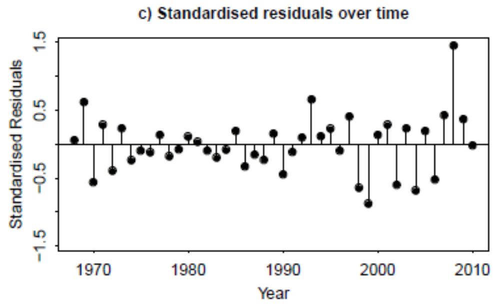
Age 2 no bias estimation left



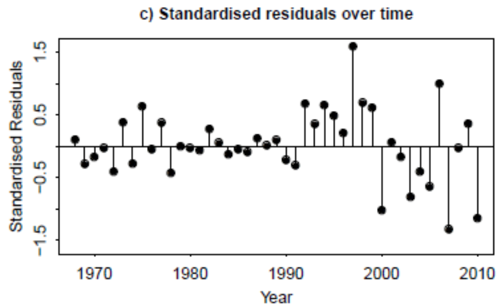


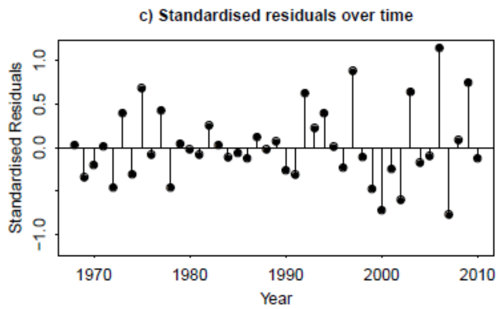
Age 3 no bias estimation left





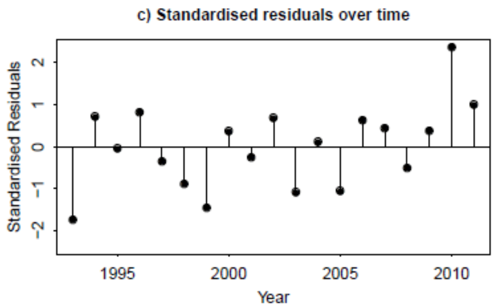
Age 4 no bias estimation left

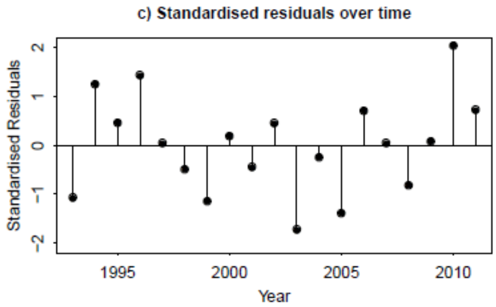




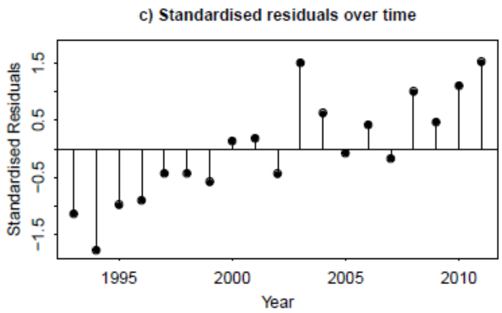
Figures 5.8.10. Cod in ICES Division VIIa: Run 1 SAM catch-at-age residuals for ages 1–4 without bias estimation left and with bias estimation for the years 2000–2010 right.

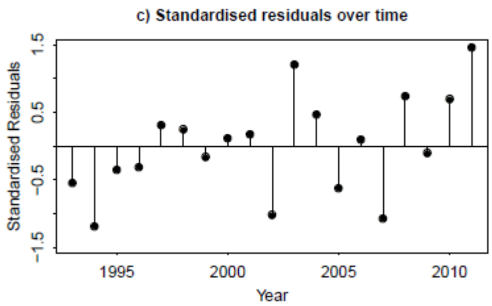
Age 1 no bias estimation left



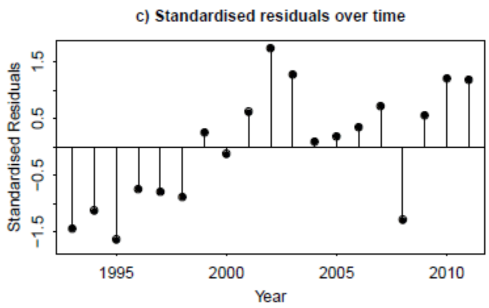


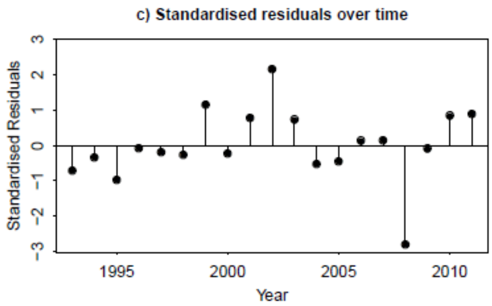
Age 2 no bias estimation left



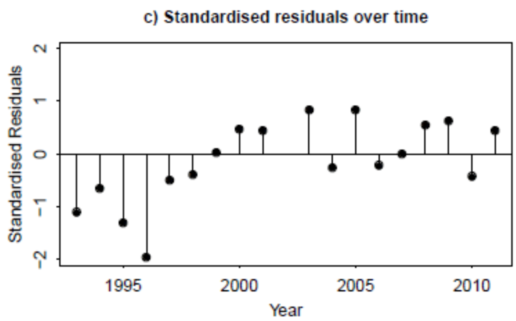


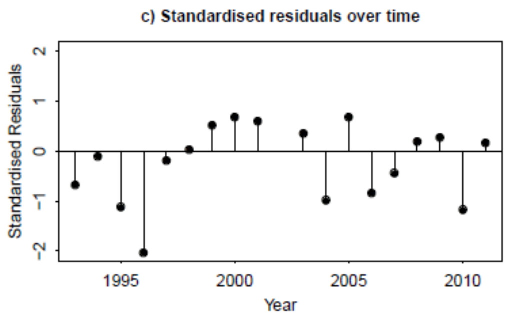
Age 3 no bias estimation left



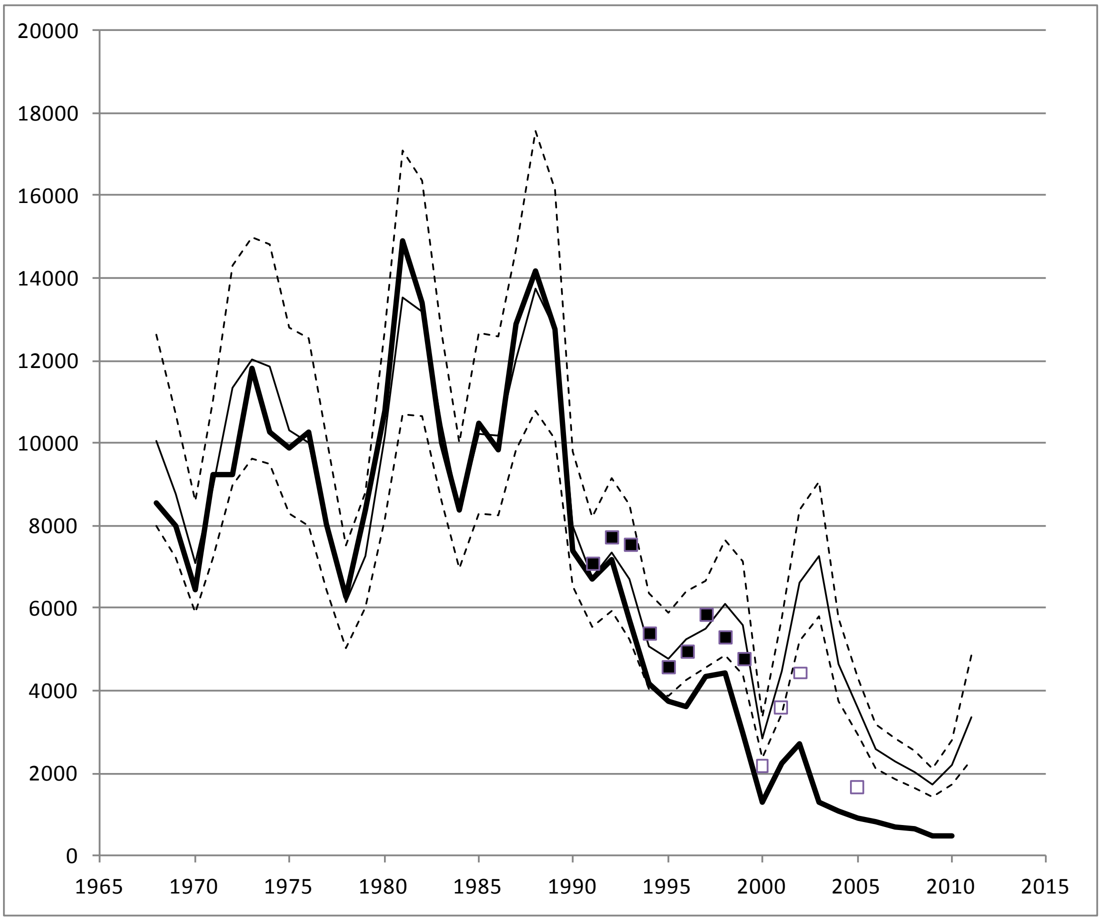


Age 4 no bias estimation left



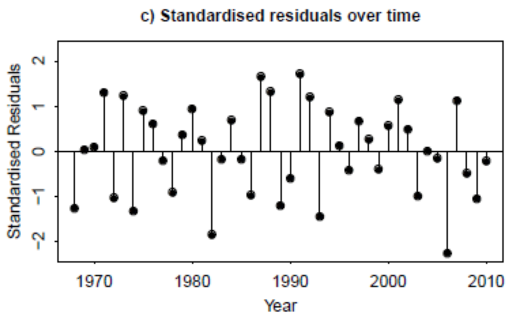


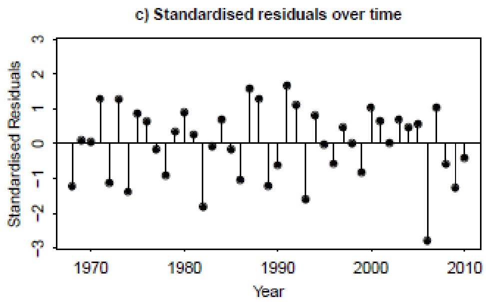
Figures 5.8.11. Cod in ICES Division VIIa: Run 1 SAM Northern Ireland March groundfish survey residuals for ages 1–4 without bias estimation left and with bias estimation for the years 2000–2010 right.



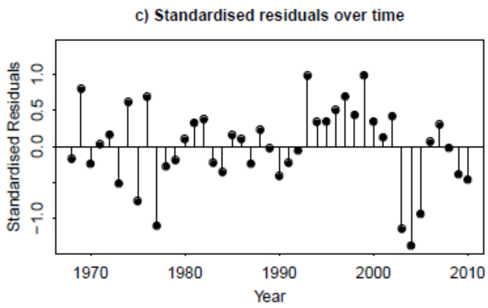
Figures 5.8.12. Cod in ICES Division VIIa: Landings data as officially reported (solid black line) as estimated by the ICES WG and used to correct the reported totals (black squares) and used to test the assessment model estimates (open squares) and the SAM assessment model Run 1 estimates (thin line with +/- 2 standard error confidence intervals) when estimating landings for the years 2000–2010.

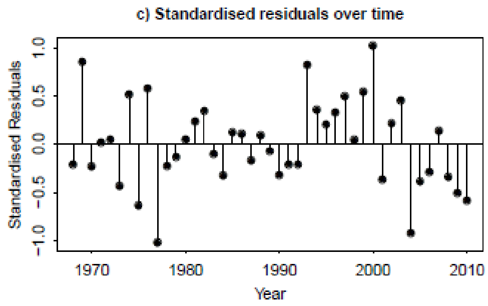
Age 1 no bias estimation left



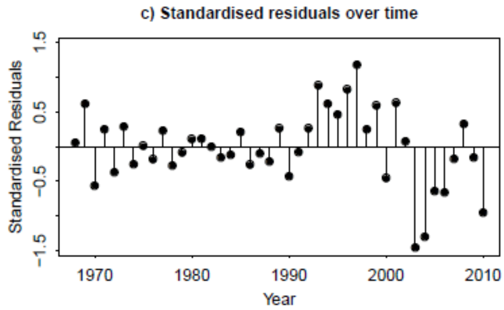


Age 2 no bias estimation left

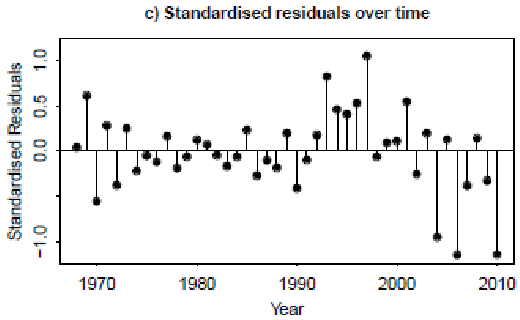




Age 3 no bias estimation left

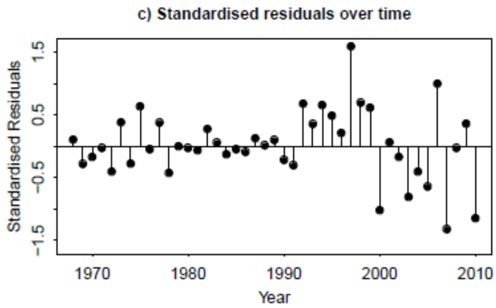


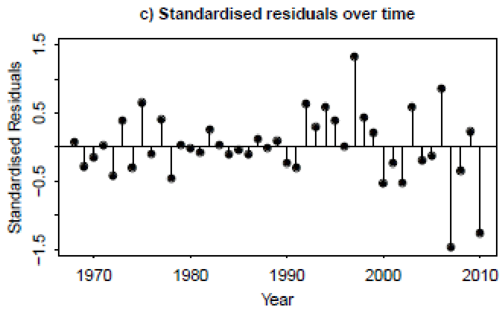
c) Standardised residuals over time
Standardised Residuals
1.5
0.5
−0.5
−1.5
1970
1980
1990
2000
2010
Year



c) Standardised residuals over time
Standardised Residuals
1.0
0.5
0.0
−1.0
1970
1980
1990
2000
2010
Year

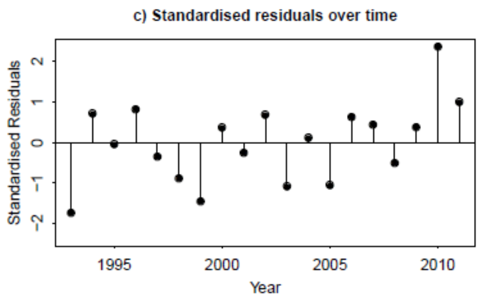
Age 4 no bias estimation left

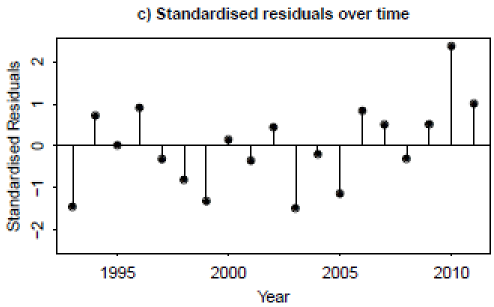




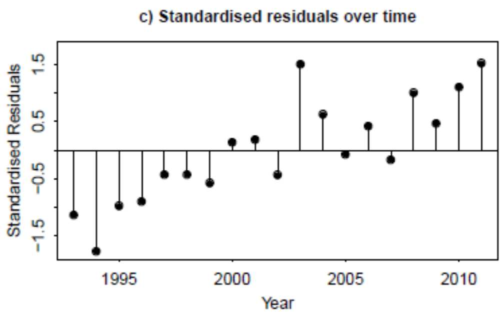
Figures 5.8.13. Cod in ICES Division VIIa: Run 2 SAM catch-at-age residuals for ages 1–4 without bias estimation left and with bias estimation for the years 2000–2005 right.

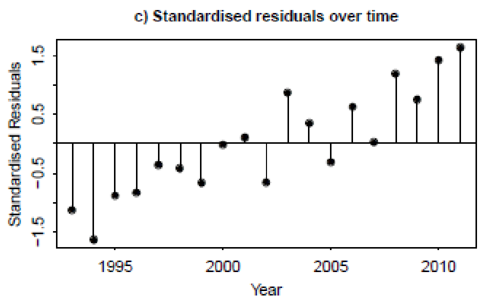
Age 1 no bias estimation left



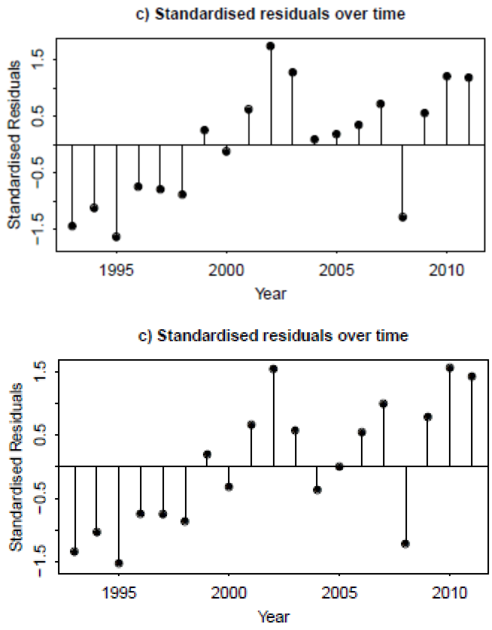


Age 2 no bias estimation left

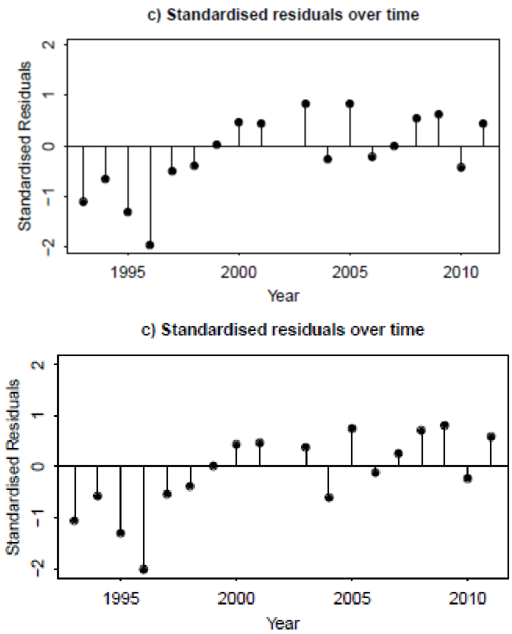




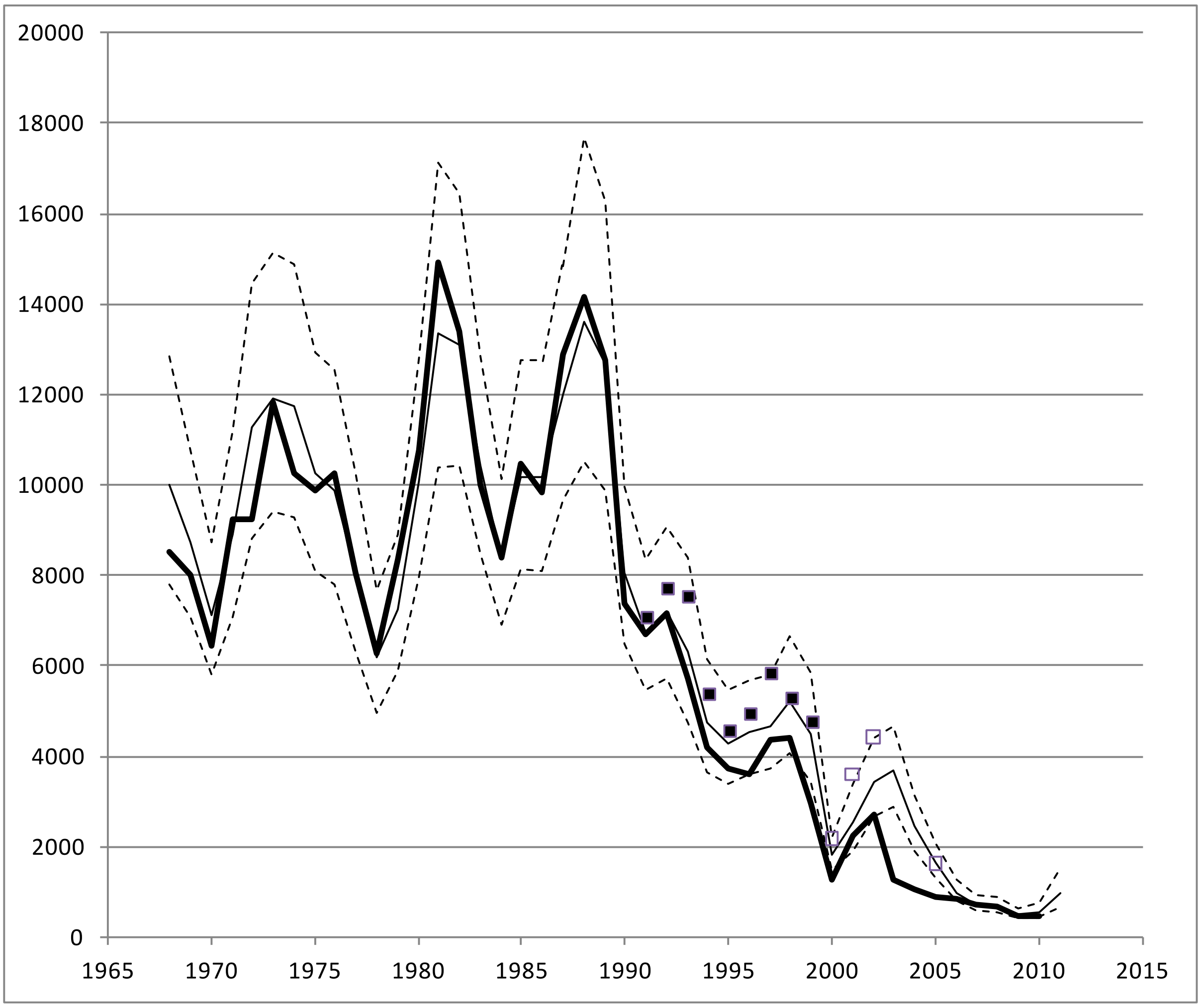
Age 3 no bias estimation left



Age 4 no bias estimation left

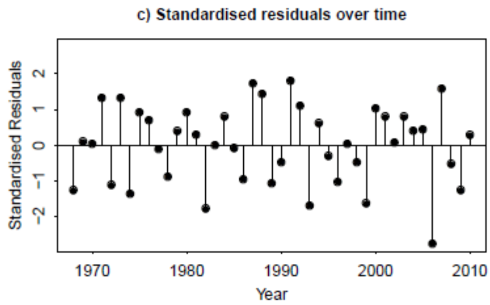


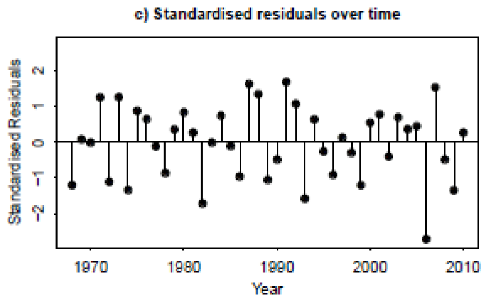
Figures 5.8.14. Cod in ICES Division VIIa: Run 2 SAM Northern Ireland March groundfish survey residuals for ages 1–4 without bias estimation left and with bias estimation for the years 2000–2005 right.



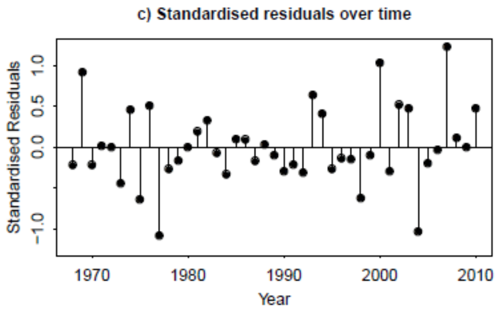
Figures 5.8.15. Cod in ICES Division VIIa: Landings data as officially reported (solid black line) as estimated by the ICES WG and used to correct the reported totals (black squares) and used to test the assessment model estimates (open squares) and the SAM assessment model Run 2 estimates (thin line with +/-2 standard error confidence intervals) when estimating landings for the years 2000–2005.

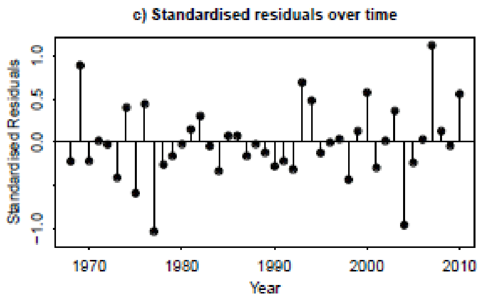
Age 1, years 2000–2010 estimated left



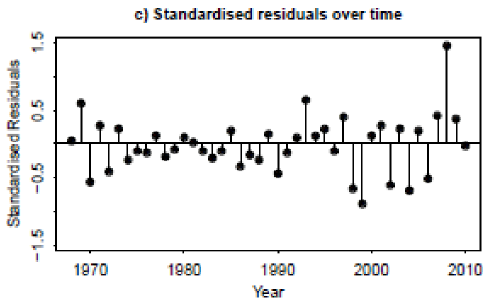


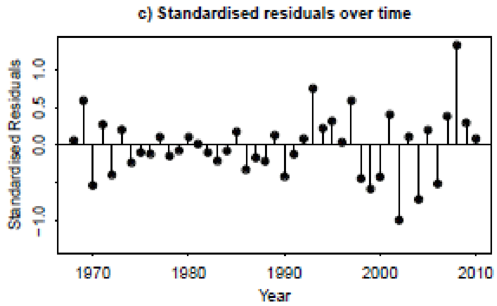
Age 2, years 2000–2010 estimated left



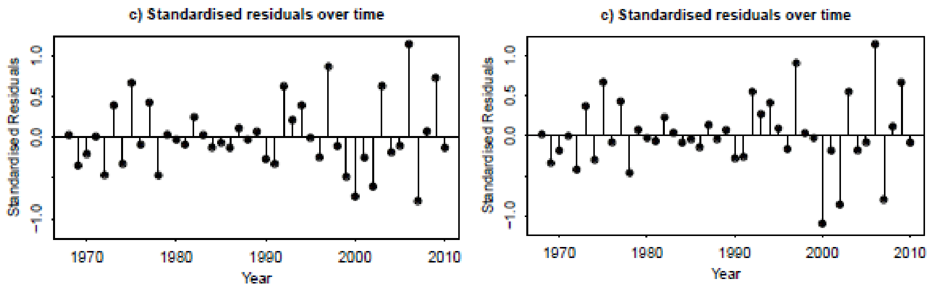


Age 3, years 2000–2010 estimated left



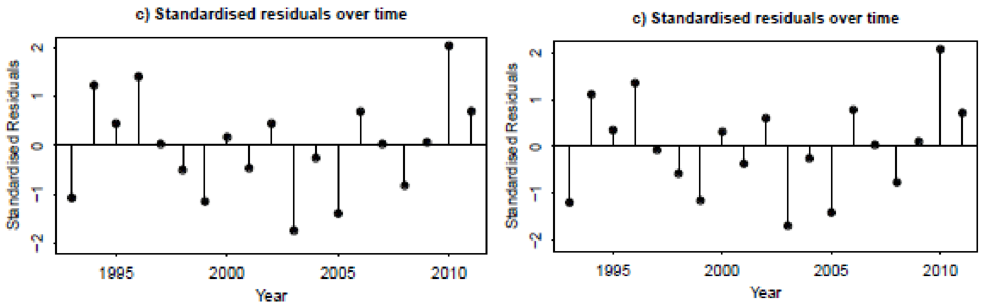


Age 4, years 2000–2010 estimated left

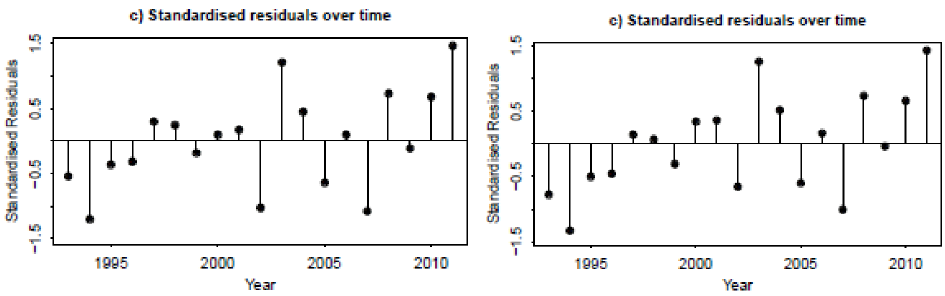


Figures 5.8.16. Cod in ICES Division VIIa: Run 1 and Run 3 catch-at-age residuals for ages 1–4 with bias estimation for the years 2000–2010 left and with bias estimation for the years 2003, 2004, 2006–2010 right.

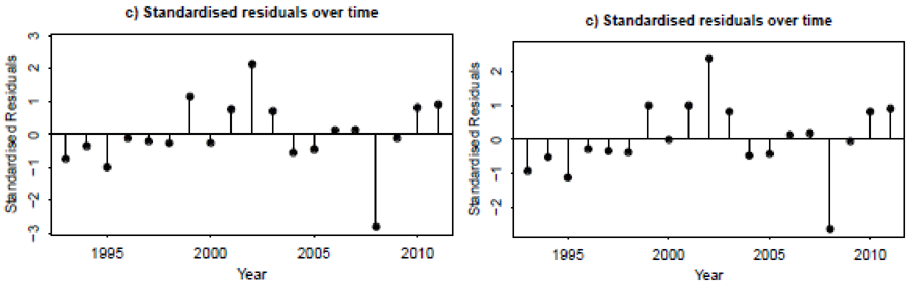
Age 1, years 2000–2010 estimated left



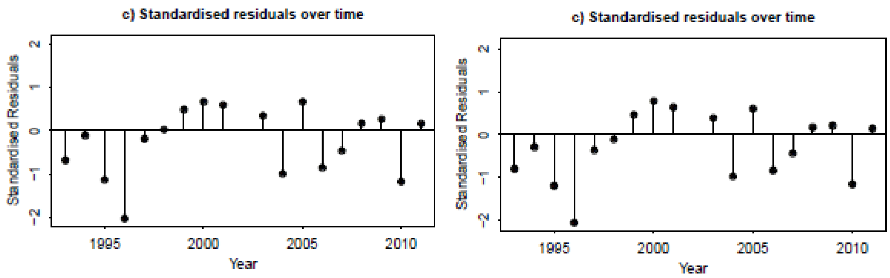
Age 2, years 2000–2010 estimated left



Age 3, years 2000–2010 estimated left



Age 4, years 2000–2010 estimated left



Figures 5.8.17. Cod in ICES Division VIIa: Run 1 and Run 3 Northern Ireland March groundfish survey residuals for ages 1–4 with bias estimation for the years 2000–2010 left and with bias estimation for the years 2003, 2004, 2006–2010 right.

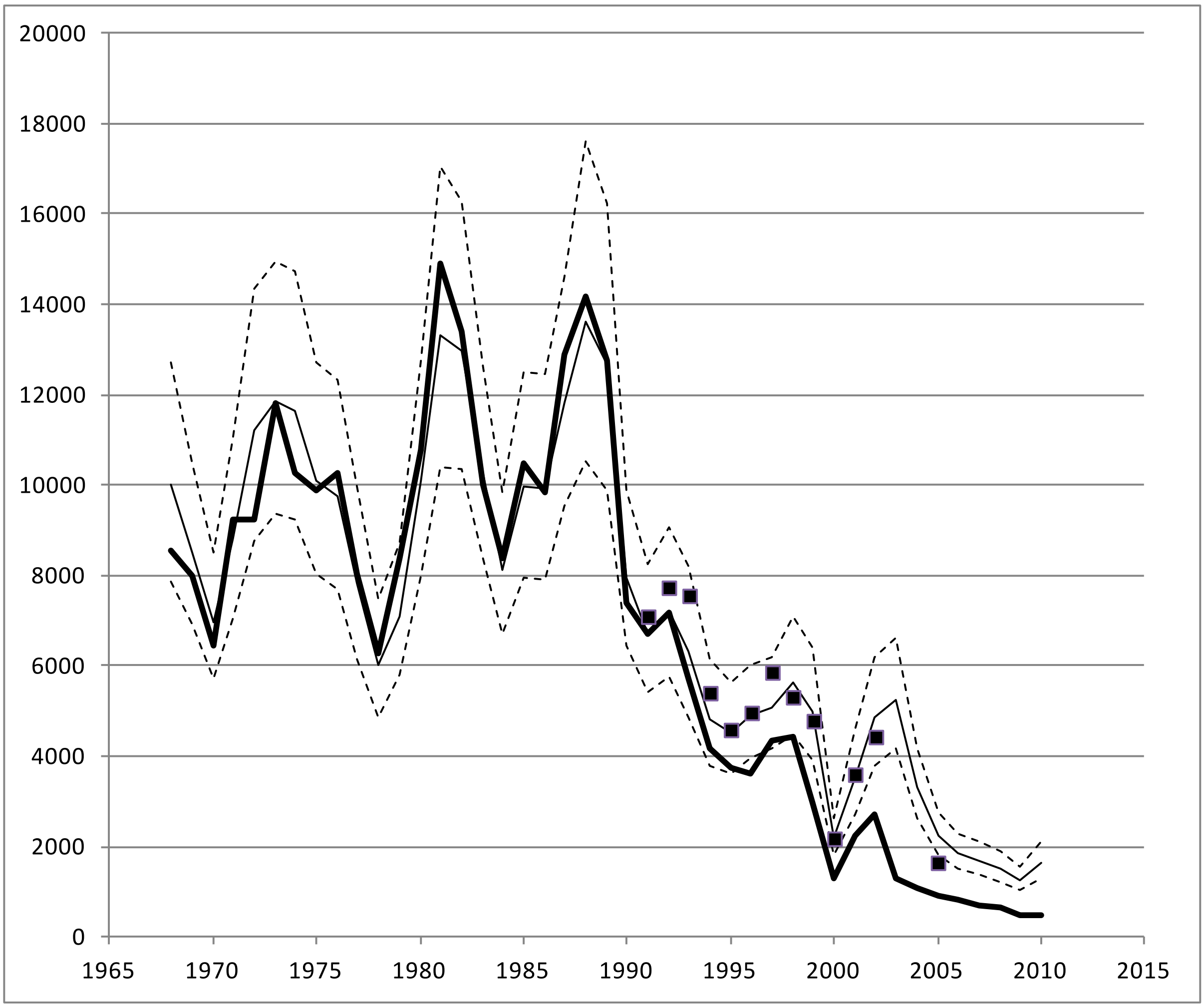
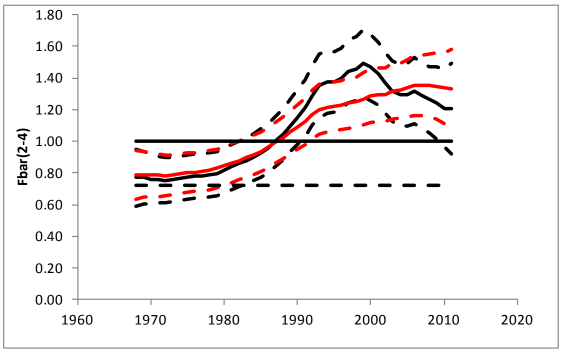


Figure 5.8.18. Cod in ICES Division VIIa: Landings data as officially reported (solid black line) as estimated by the ICES WG and used to correct the reported totals (black squares) and the SAM assessment model Run 3 estimates (thin line with +/-2 standard error confidence intervals) when estimating landings for the years 2003, 2004, 2006–2010.



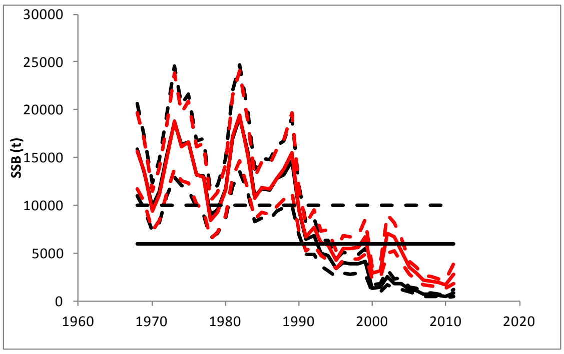


Figure 5.8.17a. Cod in ICES Division VIIa: Comparison between the estimates of average fishing mortality-at-ages 2–6 (left) and spawning biomass (right) between the base run (black) in which catch-at-age data are assumed unbiased and Run 1 (red) with bias estimation for the years 2000–2010.

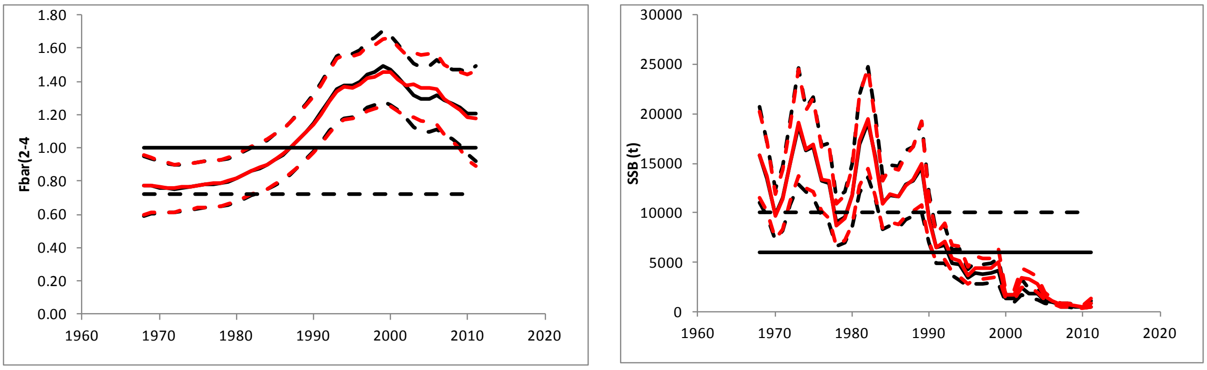


Figure 5.8.17b. Cod in ICES Division VIIa: Comparison between the estimates of average fishing mortality-at-ages 2–6 (left) and spawning biomass (right) between the base run (black) in which catch-at-age data are assumed unbiased and Run 2 (red) with bias estimation for the years 2000–2005 prior to the years in which the UK buyers and sellers legislation is considered to have influenced landings reliability.

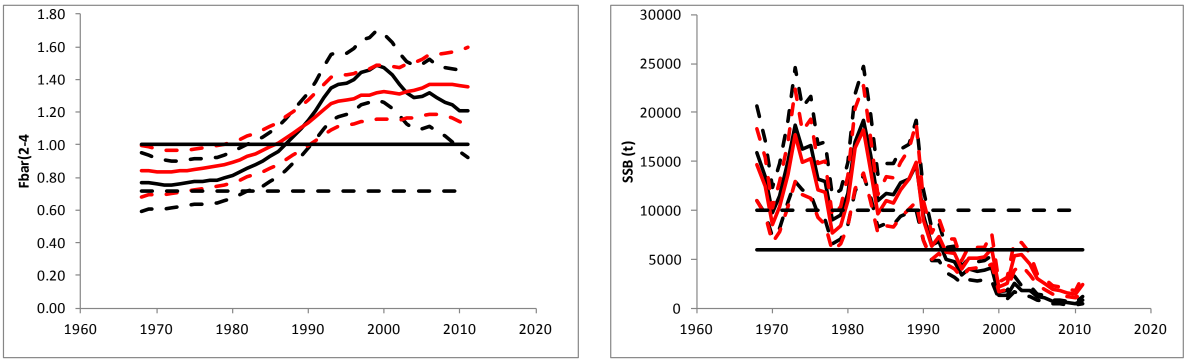
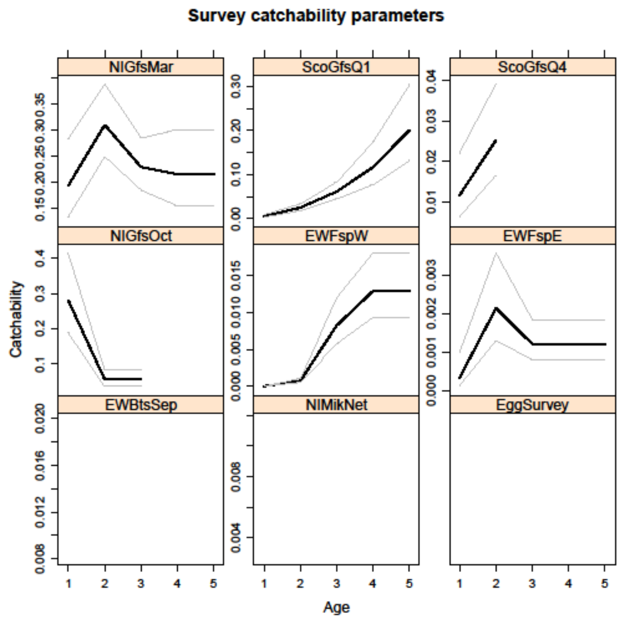
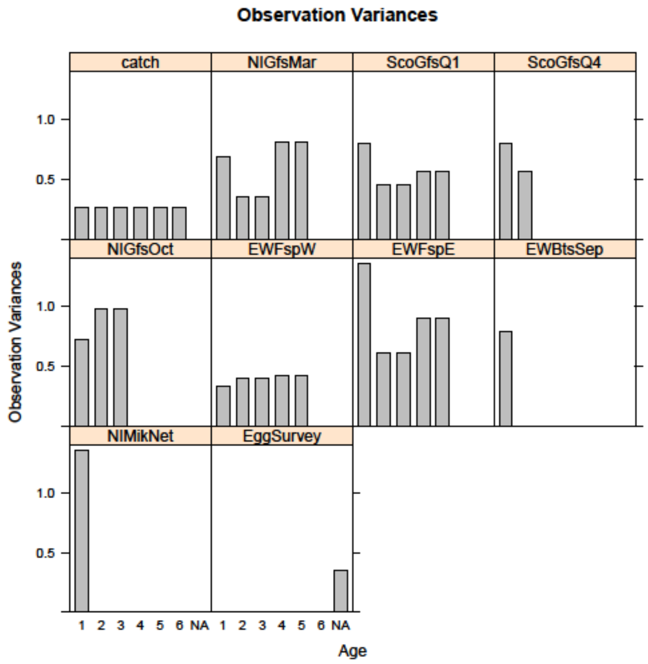


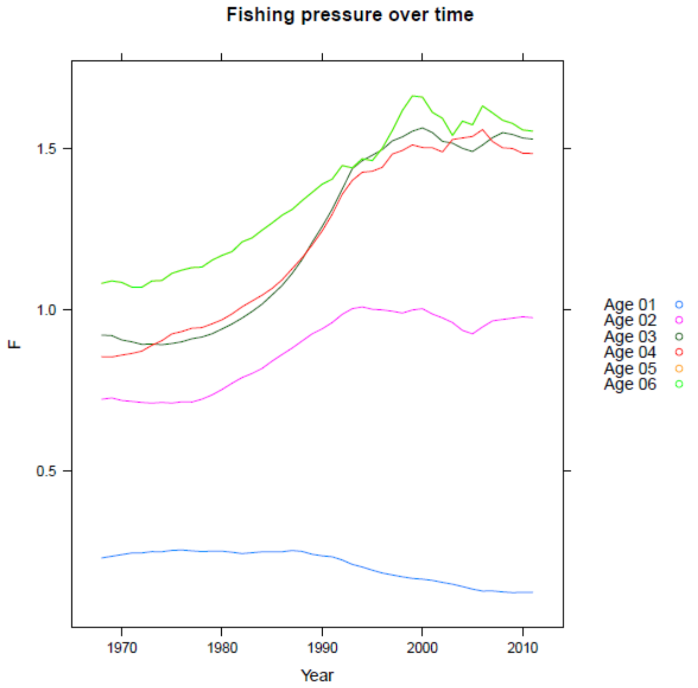
Figure 5.8.17c. Cod in ICES Division VIIa: Comparison between the estimates of average fishing mortality-at-ages 2–6 (left) and spawning biomass (right) between the base run (black) in which catch-at-age data are assumed unbiased and Run 3 (red) with bias estimation for the years 2003, 2004, 2006–2010.



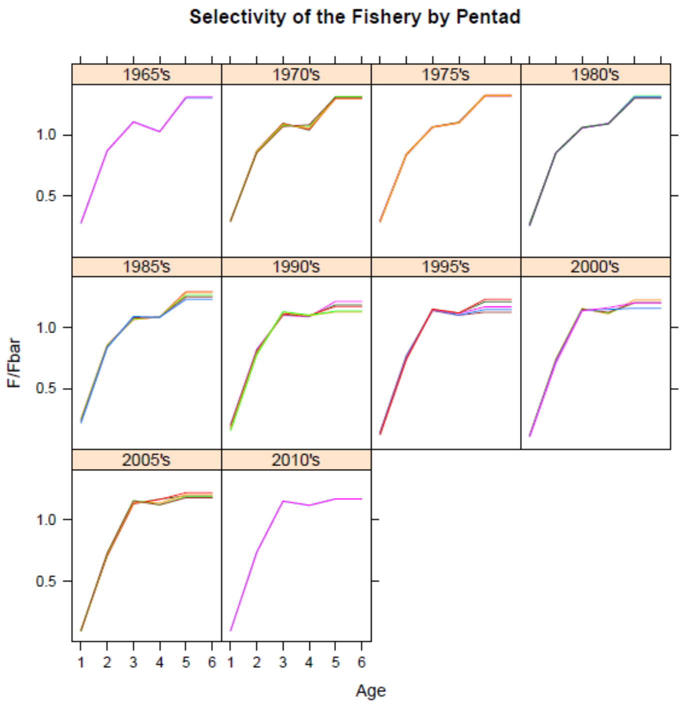
Figures 5.9.1. Cod in ICES Division VIIa: SAM estimated survey catchability at age for the Run 3.



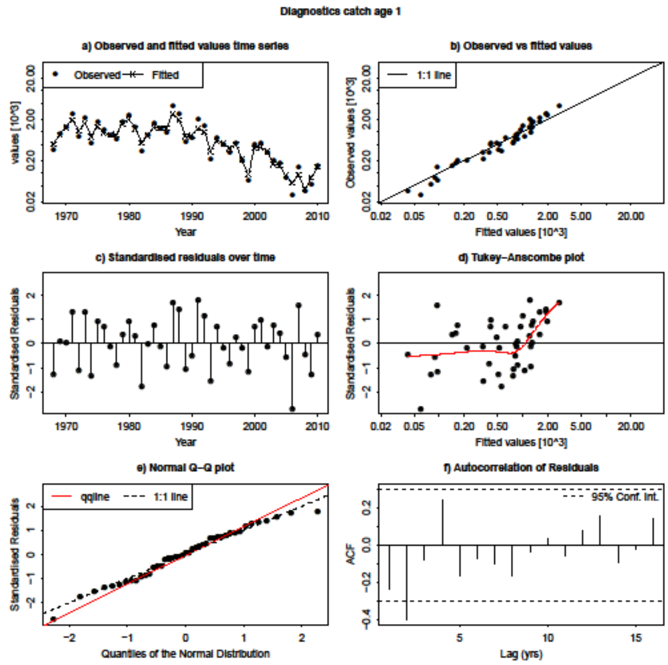
Figures 5.9.2. Cod in ICES Division VIIa: SAM Run 3 estimated paired parameter variance at age.



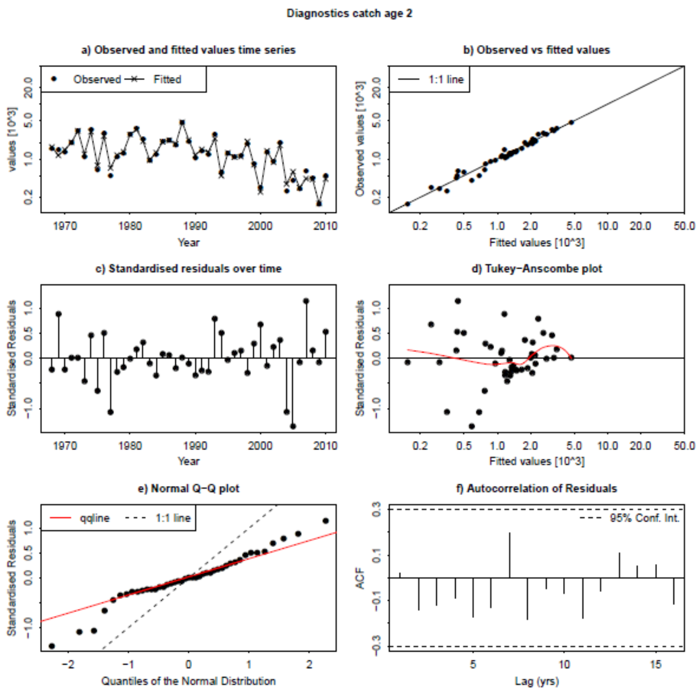
Figures 5.9.3. Cod in ICES Division VIIa: SAM Run 3 estimated fishing mortality-at-age, age 5=age 6.



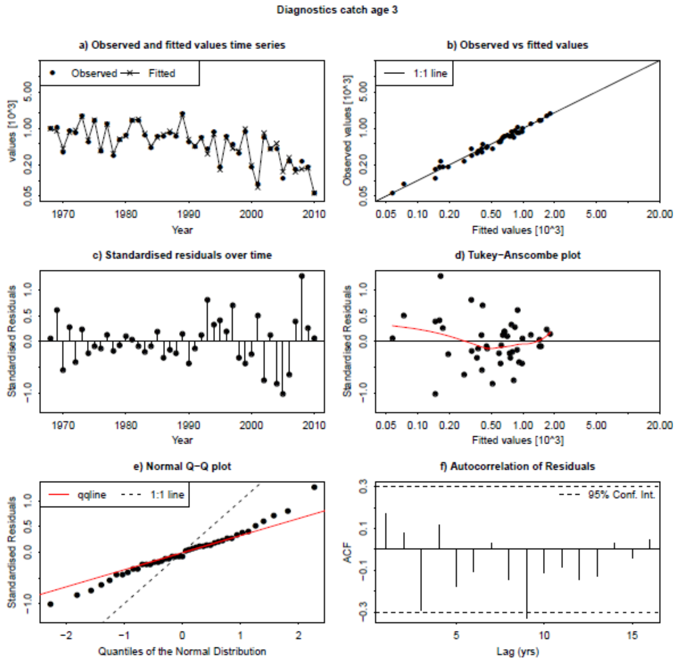
Figures 5.9.4. Cod in ICES Division VIIa: SAM base Run 3 estimated fishery selectivity at age.



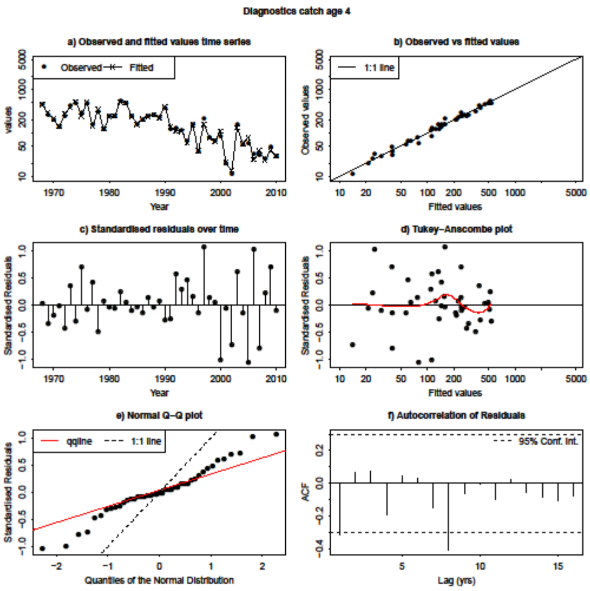
Figures 5.9.5a. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 1.



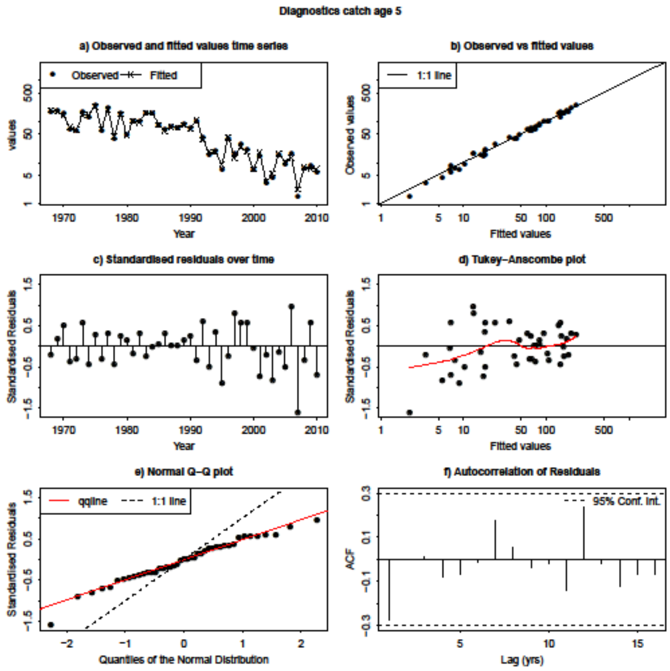
Figures 5.9.5b. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 2.



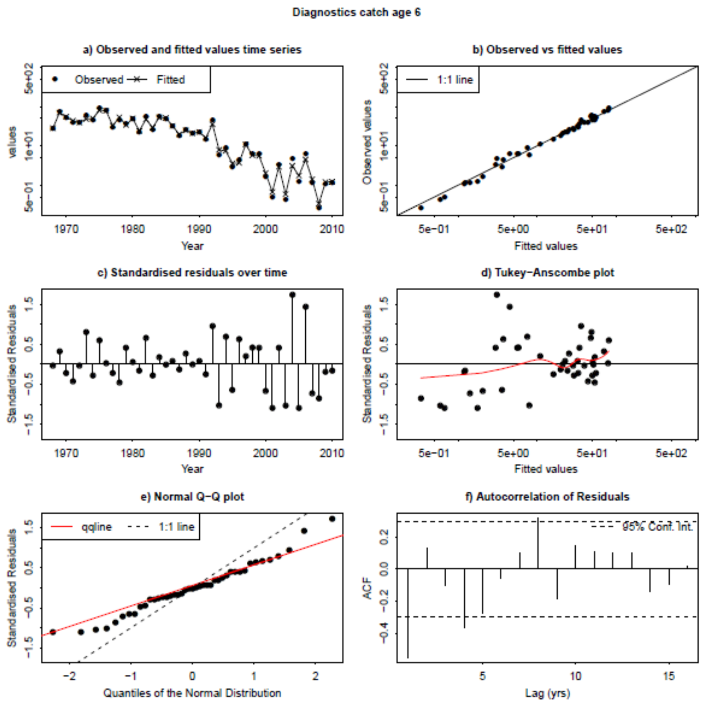
Figures 5.9.5c. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 3.



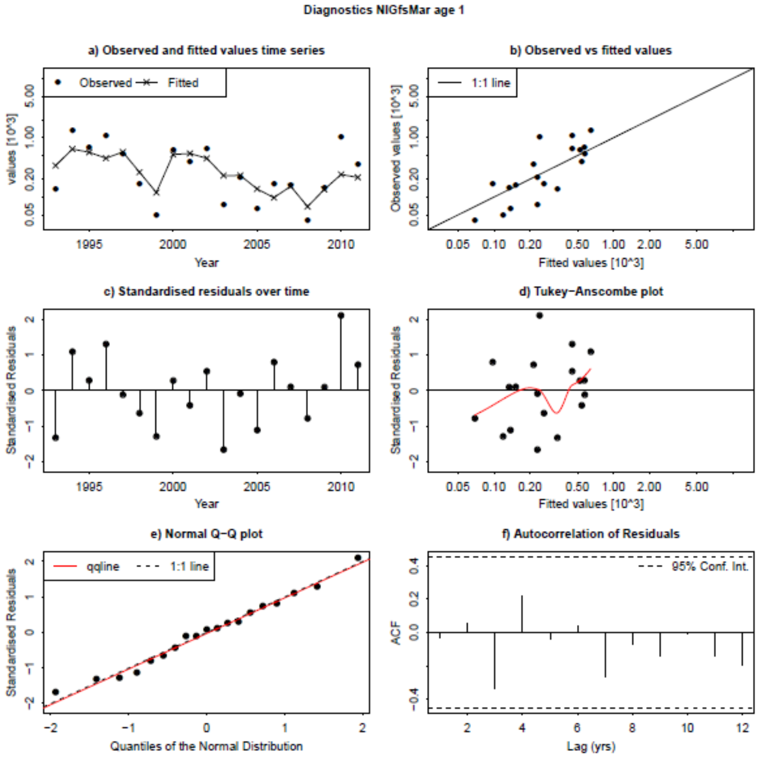
Figures 5.9.5d. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 4.



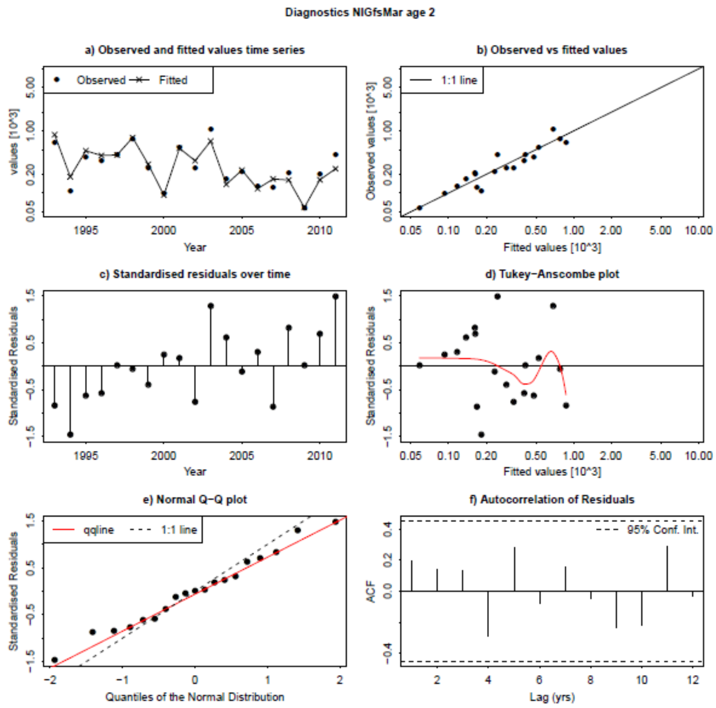
Figures 5.9.5e. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 5.



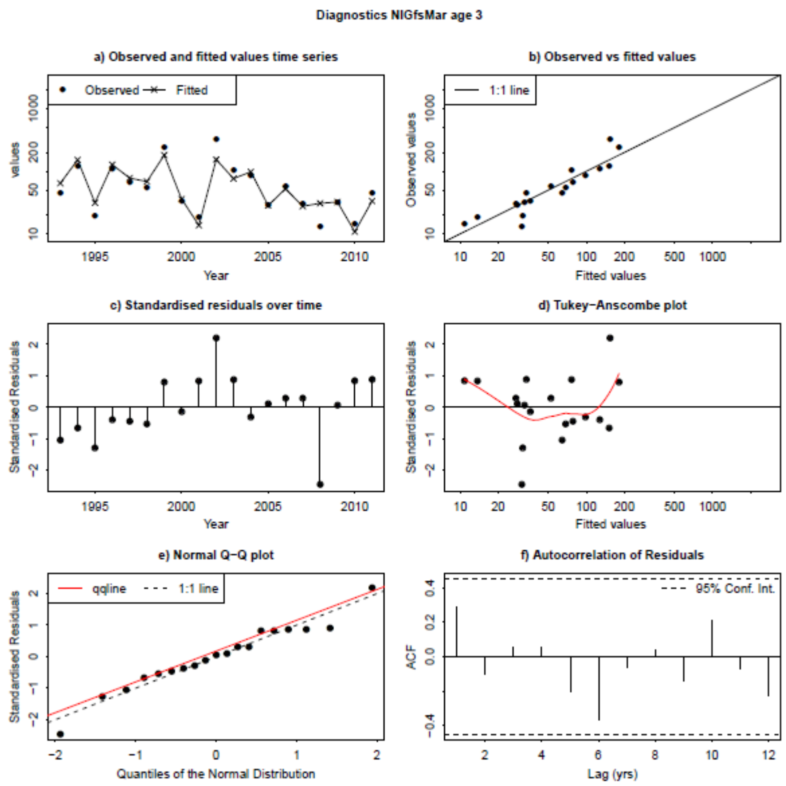
Figures 5.5.5f. Cod in ICES Division VIIa: SAM Run 3 estimated catch residuals for age 6+.



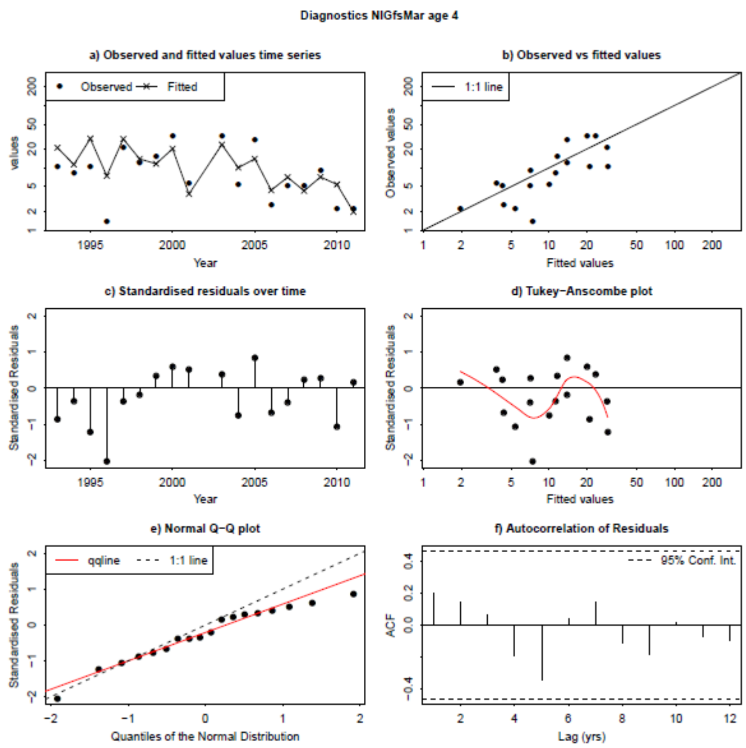
Figures 5.9.6a. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland groundfish survey index residuals for age 1.



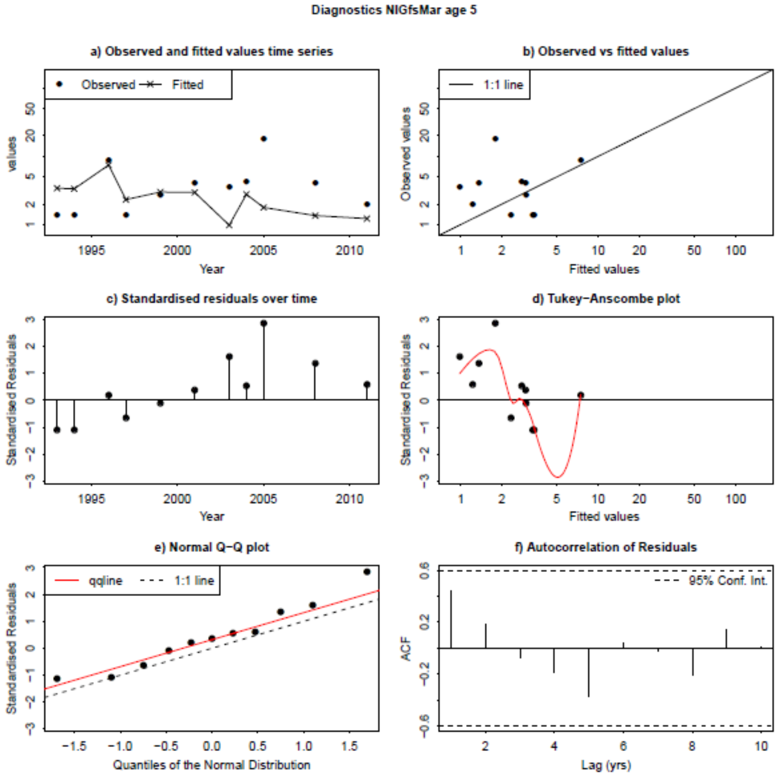
Figures 5.9.6b. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland March groundfish survey index residuals for age 2.



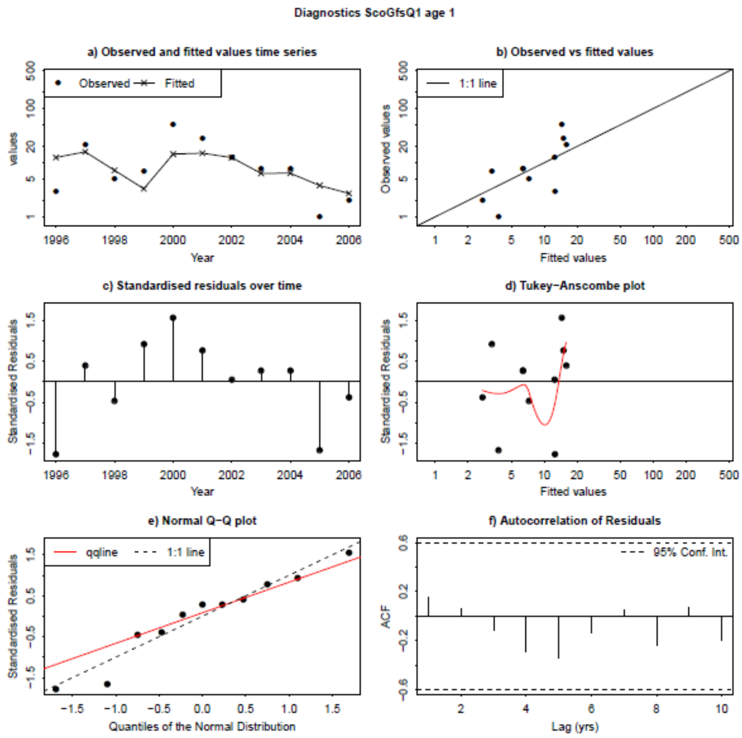
Figures 5.9.6c. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland March groundfish survey index residuals for age 3.



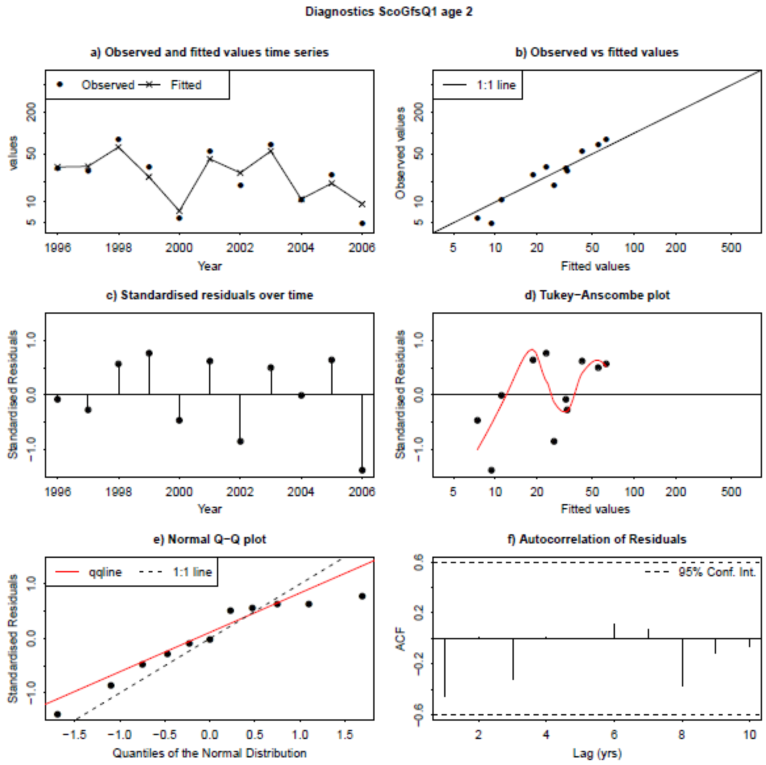
Figures 5.8.7d. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland March groundfish survey index residuals for age 4.



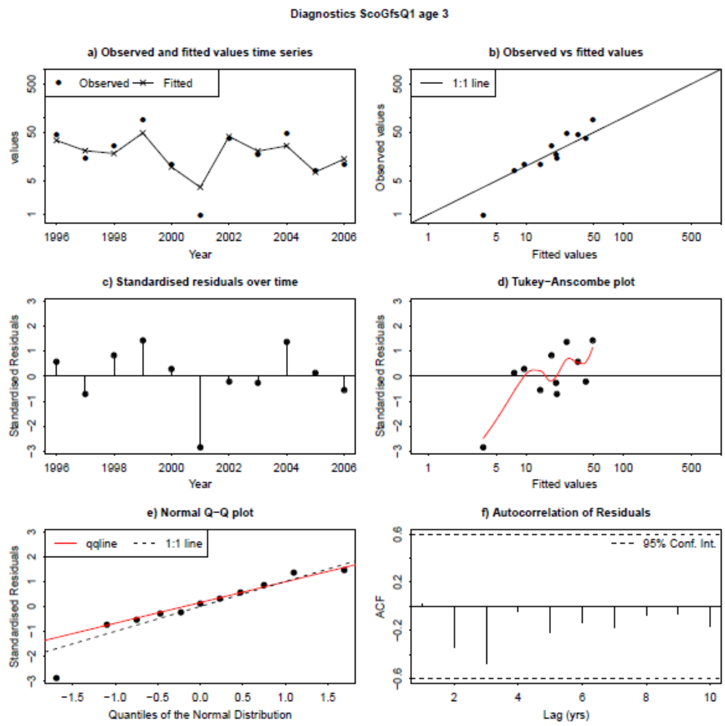
Figures 5.9.6e. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland March groundfish survey index residuals for age 5.



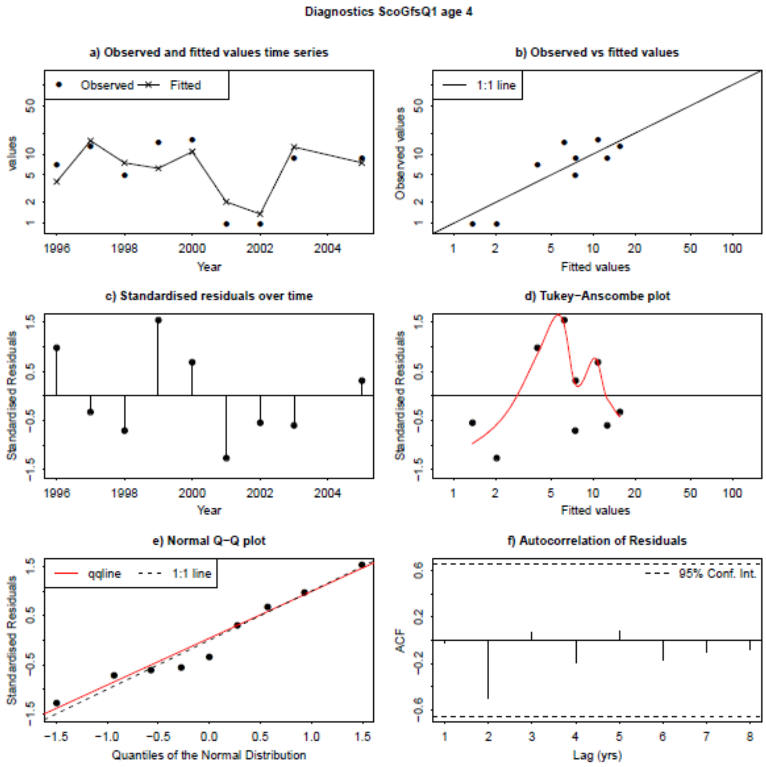
Figures 5.9.7a. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 1 groundfish survey index residuals for age 1.



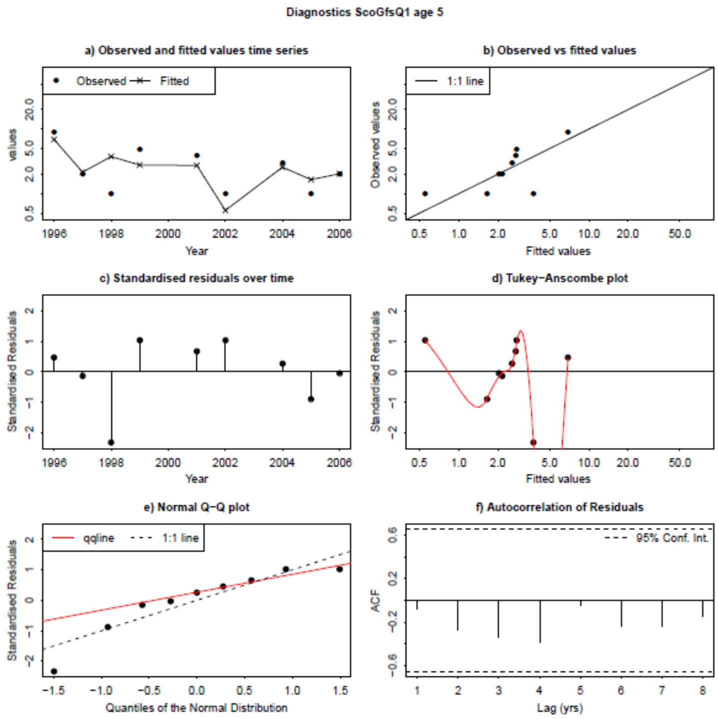
Figures 5.9.7b. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 1 groundfish survey index residuals for age 2.



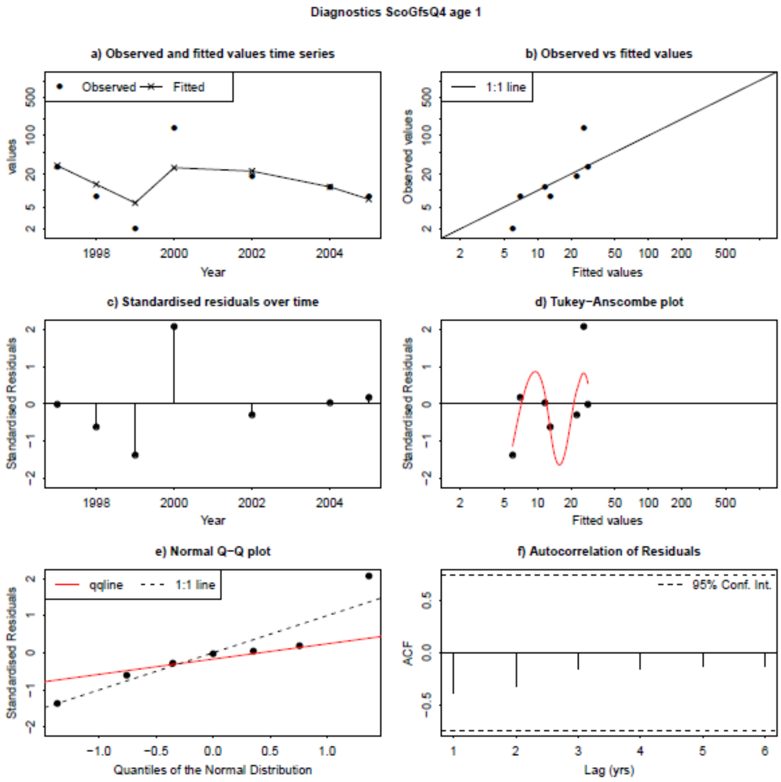
Figures 5.9.7c. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 1 groundfish survey index residuals for age 3.



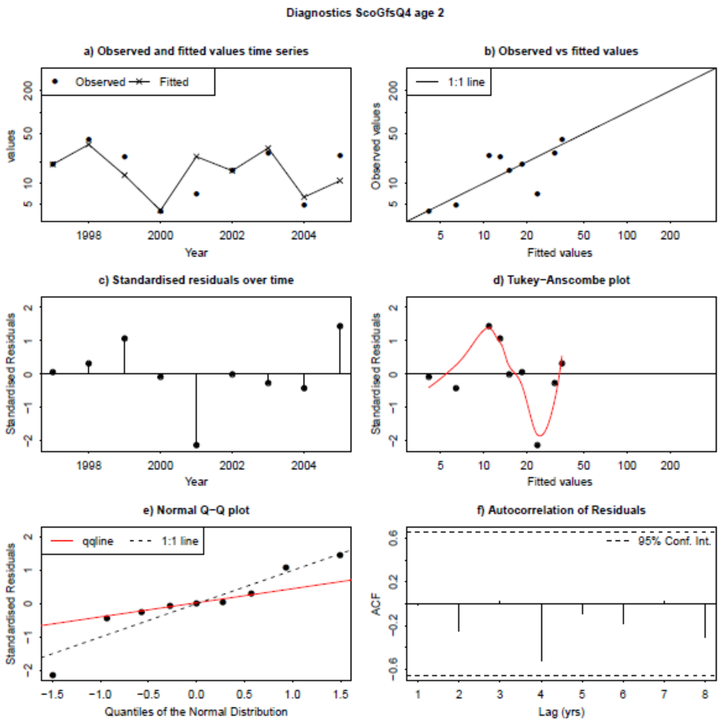
Figures 5.9.7d. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 1 groundfish survey index residuals for age 4.



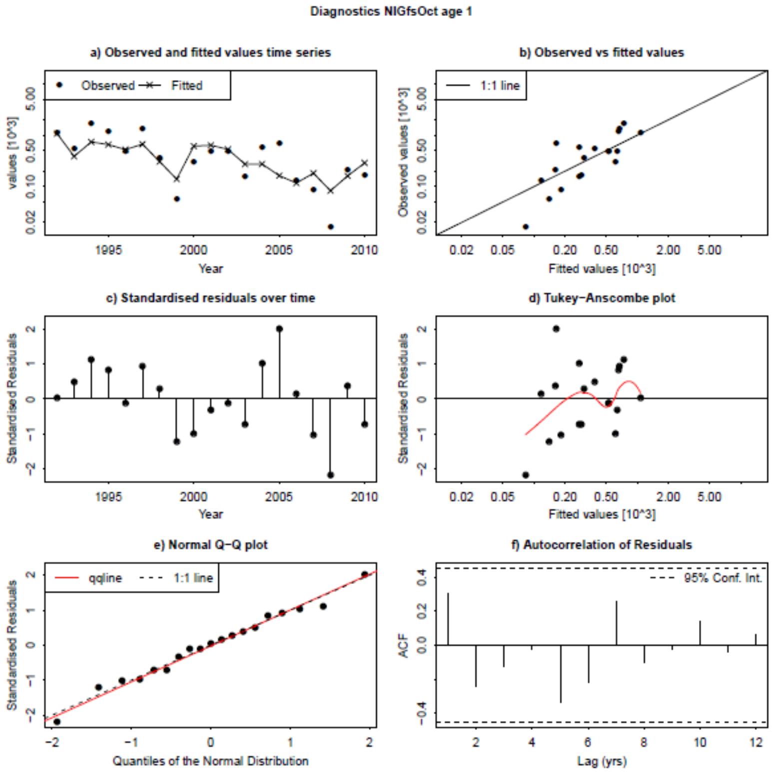
Figures 5.9.7e. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 1 groundfish survey index residuals for age 5.



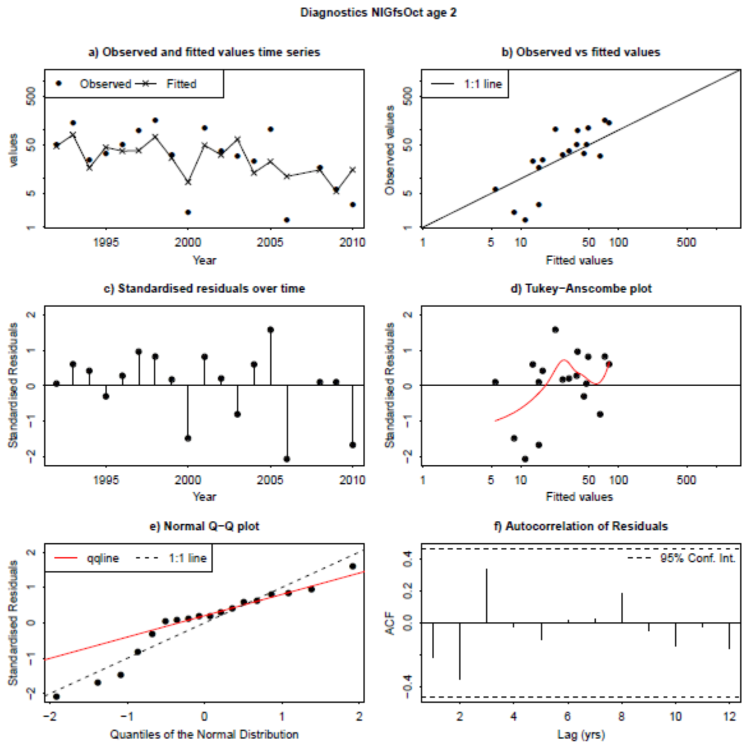
Figures 5.9.8a. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 4 groundfish survey index residuals for age 1.



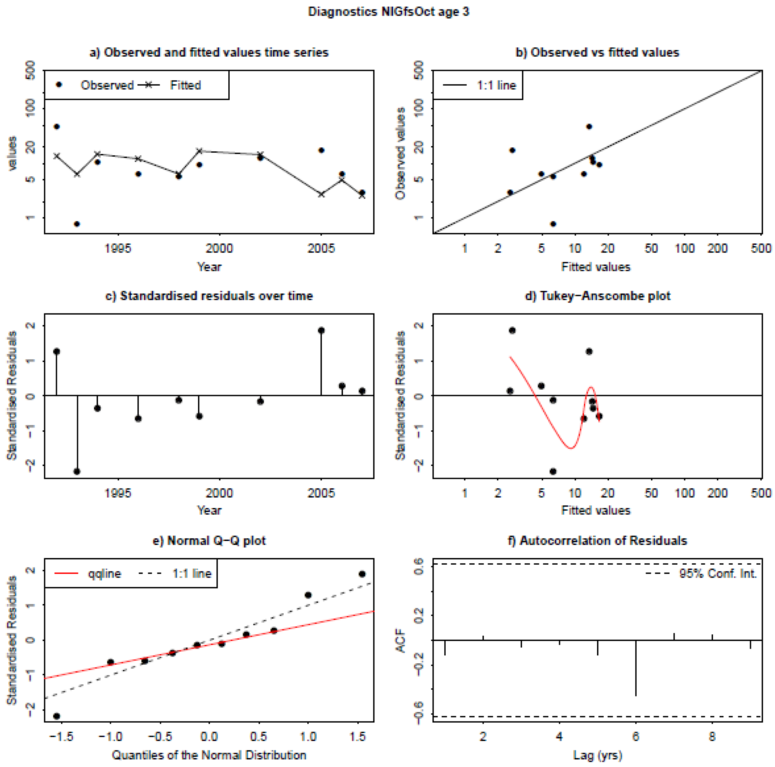
Figures 5.9.8b. Cod in ICES Division VIIa: SAM Run 3 estimated Scottish quarter 4 groundfish survey index residuals for age 2.



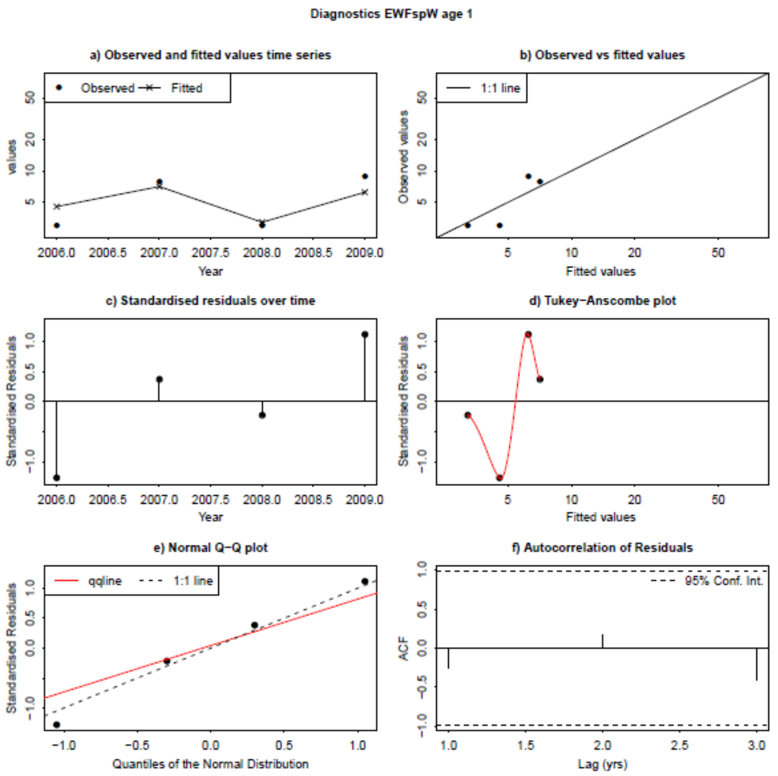
Figures 5.9.9a. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland October groundfish survey index residuals for age 1.



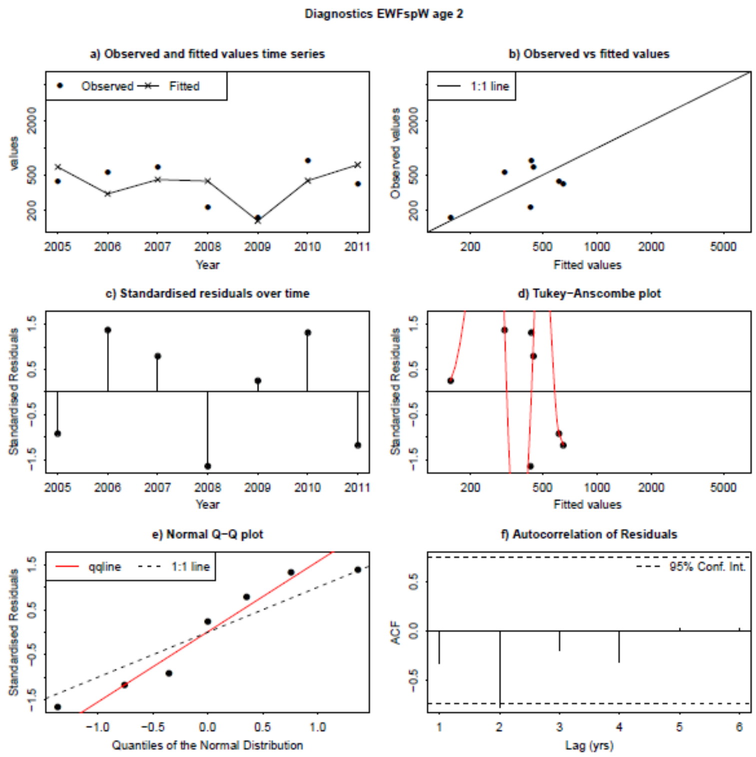
Figures 5.9.9b. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland October groundfish survey index residuals for age 2.



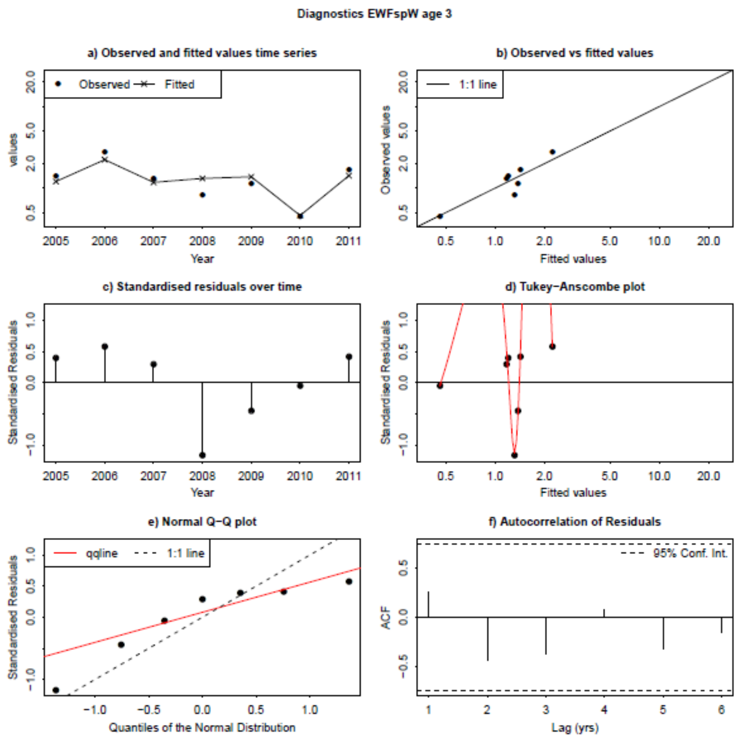
Figures 5.9.9c. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland October groundfish survey index residuals for age 3.



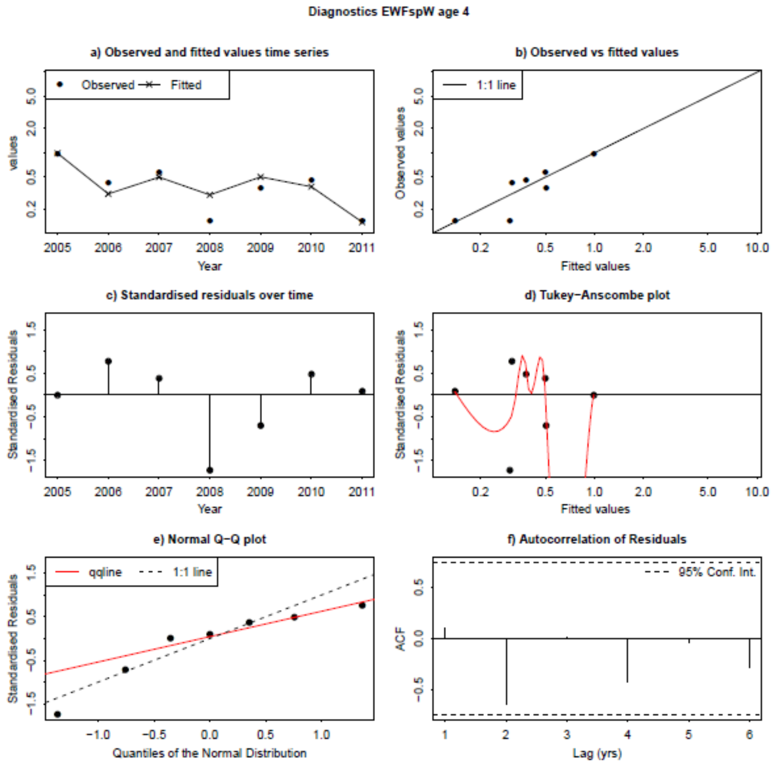
Figures 5.9.10a. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP west survey index residuals for age 1.



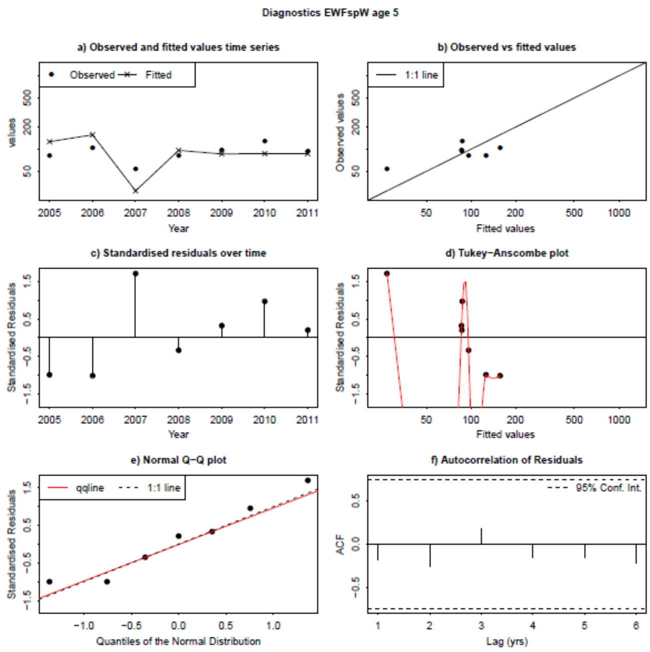
Figures 5.9.10b. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP west survey index residuals for age 2.



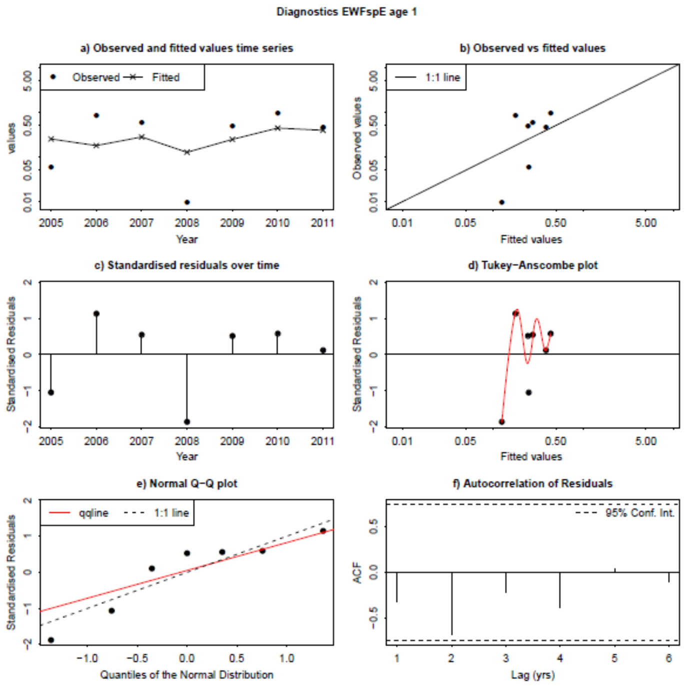
Figures 5.9.10c. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP west survey index residuals for age 3.



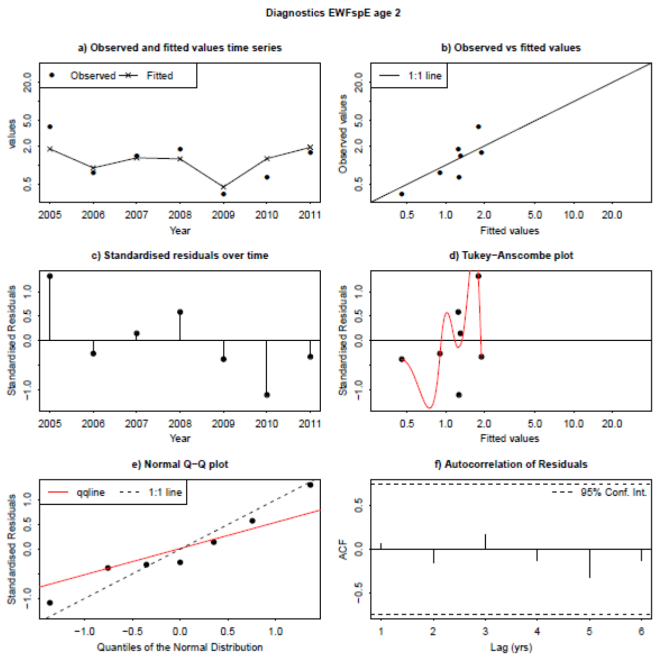
Figures 5.9.10d. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP west survey index residuals for age 4.



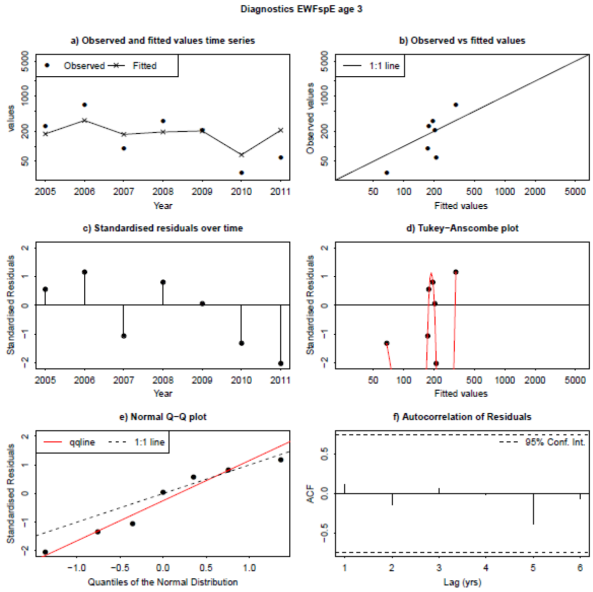
Figures 5.9.10e. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP west survey index residuals for age 5.



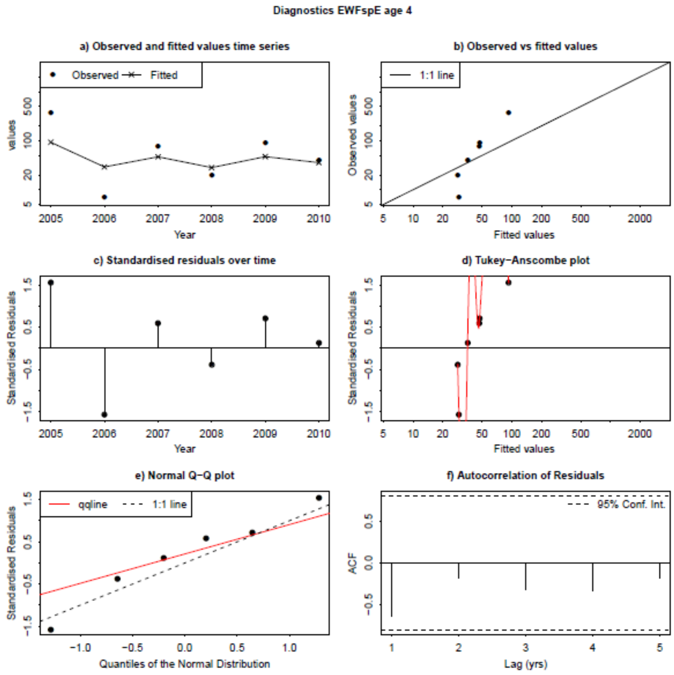
Figures 5.9.11a. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP east survey index residuals for age 1.



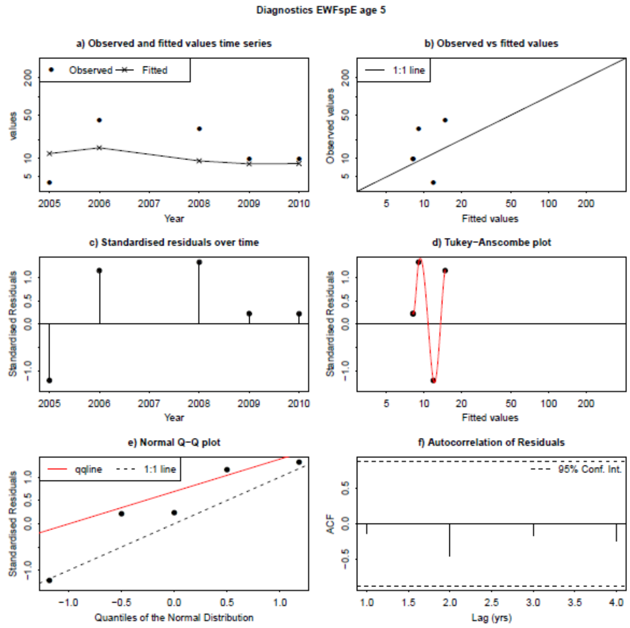
Figures 5.9.11b. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP east survey index residuals for age 2.



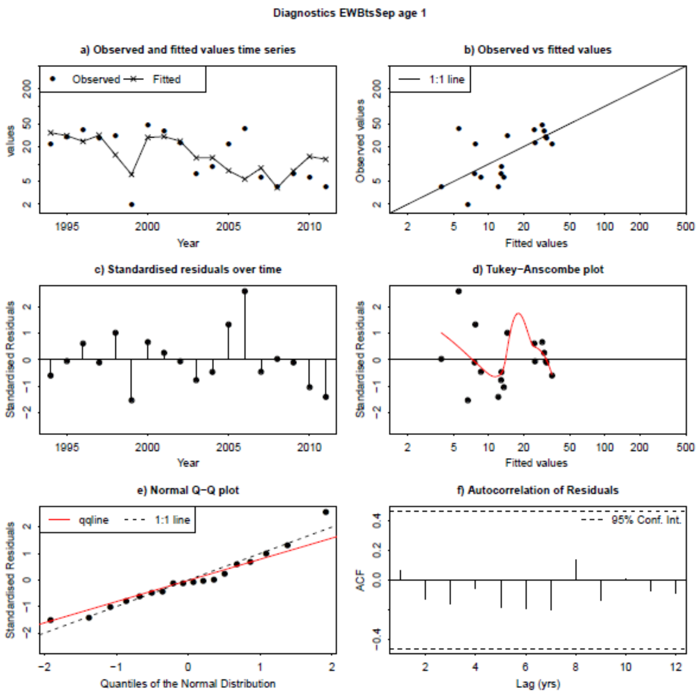
Figures 5.9.11c. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP east survey index residuals for age 3.



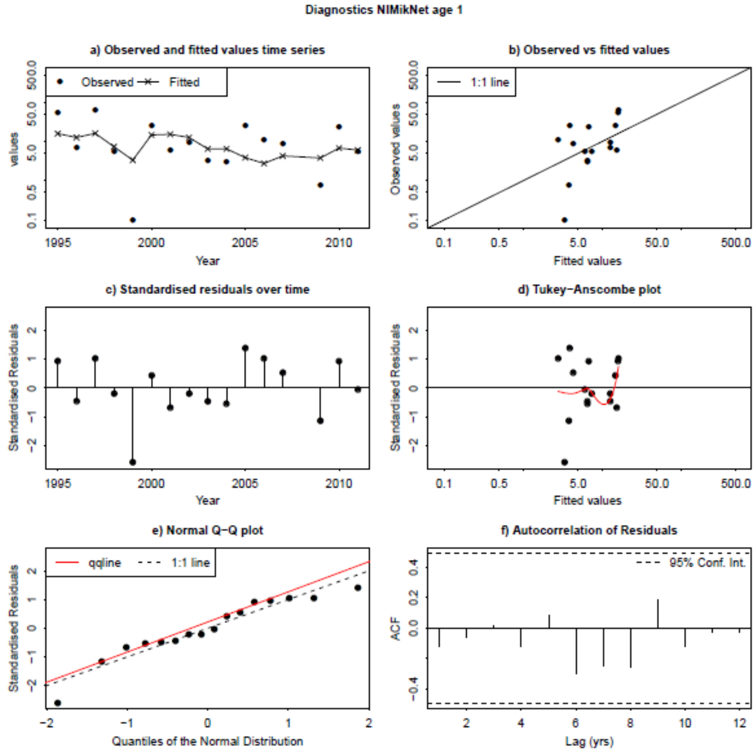
Figures 5.9.11d. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP east survey index residuals for age 4.



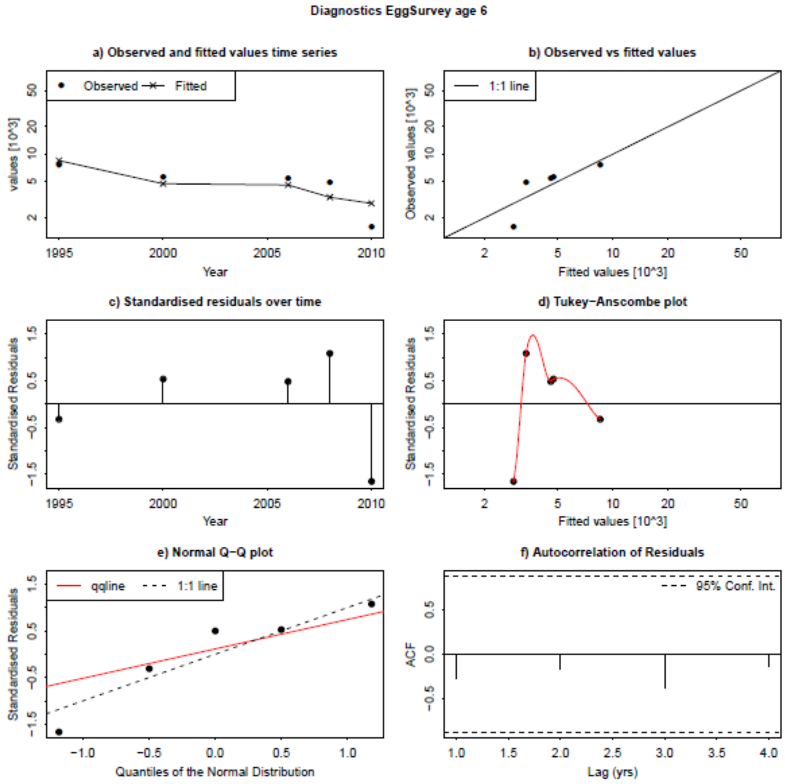
Figures 5.9.11e. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) FSP east survey index residuals for age 5.



Figures 5.9.12. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) beam trawl survey index residuals for age 1 (age 0 moved forward 1 year).



Figures 5.9.13. Cod in ICES Division VIIa: SAM Run 3 estimated Northern Ireland MIKNET survey index residuals for age 1 (age 0 moved forward 1 year).



Figures 5.9.14. Cod in ICES Division VIIa: SAM Run 3 estimated UK(E&W) egg biomas survey index residuals.

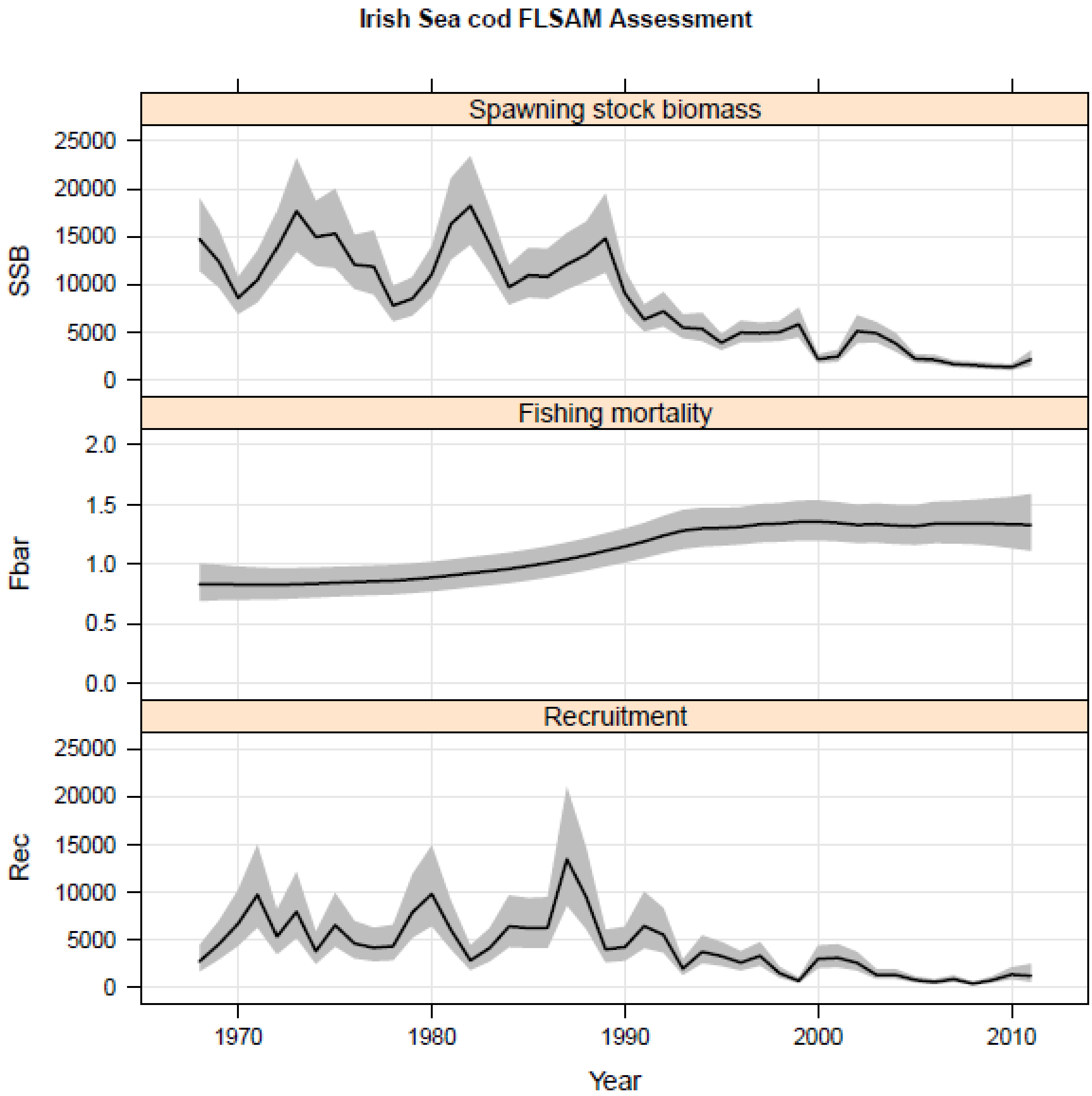
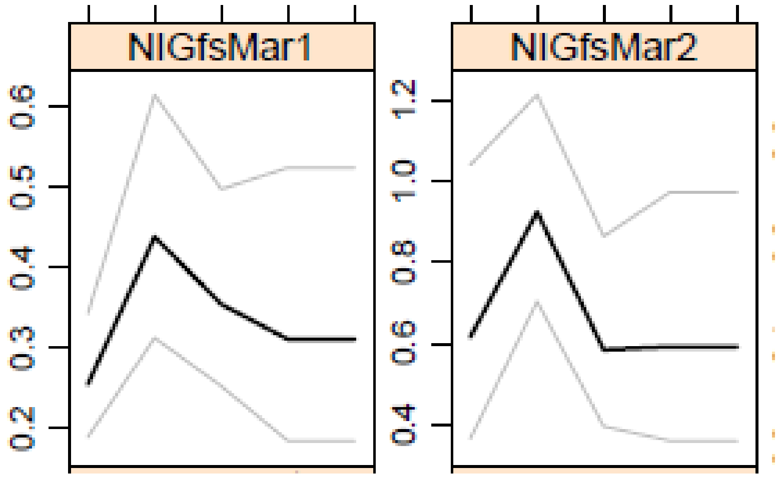


Figure 5.9.15. Cod in ICES Division VIIa: SAM Run 3 estimated time-series of spawning–stock biomass, average fishing mortality-at-ages 2–4 and recruitment-at-age 1.



Figures 5.9.2. Cod in ICES Division VIIa: SAM estimated survey catchability at age estimated for the Northern Ireland March survey during 1993–2004 and 2005–2010 when a new vessel was used. The second period catchability at age is estimated to be double the first.

6 Cod in Divisions VIIe-k (Celtic Sea cod)

6.1 Current status of assessment and advice

The Benchmark Workshop WKROUND in 2009 concluded that more work was required before this stock could be benchmarked. The Review Group of WGCSE 2009 added that shortcomings of the data and reconstruction of datasets should be completed in order to continue using an aged based assessment in future. The following recommendations were made by WKROUND 2009 regarding data and assessment:

- Improvement of the quality of assessment input data, of documentation on data correction in the Stock Annex and data integration and fishery description at regional level through a regional database.
- Estimates of "true landings" as reported landings data and landings equivalents since 2003 are thought to be underestimated.
- International coordination on maturity sampling as there is evidence that maturity has changed for this stock. A directed survey might be needed.
- Reduction of noise in the data from the surveys.

The years following the benchmark, the assessment working group followed the WKROUND advice not to perform an analytical assessment due to catch uncertainties. The Review Group noted that *"this unfortunately precludes any presentation of long term trends in SSB, F and recruitment other than the separable VPA recruitment series presented, and it is not possible to see if the addition of new data has affected the WKROUND conclusions. This leaves a critical cod stock with very little quantitative advice on stock status."*

In 2010, the French EVHOE and Irish Groundfish surveys both confirmed a strong 2009 year class. This circumstance pushed ACOM to reinstate an analytical assessment and forecasts into the advice for 2012, departing as such from the usual ICES practices. In normal circumstance, the stock would have been treated as "data poor" which would have led to an advice such as "no increase in catch" or "reduce catch" but considering this stock is part of a mixed fishery, a limited TAC would have resulted in large amounts of discards.

For 2012, the current ICES advice is "The strong 2009 year class is expected to bring the SSB above $MSY_{Btrigger}$. Based on the MSY framework, ICES advises that F in 2012 be set at F_{MSY}=0.40, resulting in landings of 10 000 t in 2012."

6.1.1 Landings

Landings data in France are obtained from sales notes on the auction halls since 2009. These data are cross referenced with the official landings made in EU logbooks for those trips. In Ireland, the UK and Belgium landings data are collected by census from the EU logbooks for vessels >10 m. Landings of vessels <10 m are minimal but are estimated or sampled by fisheries officers in local ports (normally on a monthly basis). "Buyers and sellers" and "Sales notes" regulations were introduced in the UK and Ireland respectively since 2007. This may have improved the accuracy of landings data since then.

6.1.2 Misreporting

There is no information on the absolute level of misreporting for this stock but there is anecdotal information from the industry that misreporting has increased from 2002 when quotas became restrictive with a maximum in 2008. A number of misreporting scenarios were run at WKROUND 2009 to look at the sensitivity of the assessment to possible misreporting. The general conclusion was that any misreporting could result in biased underestimates of recruitment and fishing mortality but the level of SSB not would not be overly sensitive to the under reporting scenarios tested. Some uncertainties in the level of catch between 2003–2007 remain but the survey time-series are not long enough to try assessment approaches that estimate unallocated catch.

Misreporting is thought to have decreased since 2008. The Irish landings data in some years have been corrected for area misreporting into the southern rectangles of VIIa. These area reallocations are summarized in the table below.

Year	2004	2005	2006	2007	2008	2009	2010
Mis alloc (t)	108	54	103	527	558	193	143

Many of the cod catches were made on, or close to, the VIIa–VIIg border. Vessels made use of the individual monthly quotas set for both areas particularly when the trips spanned both areas as is often the case. In attempting to reduce this practice, Irish authorities have set more restrictive VIIa quotas particularly in Q1. Effort has also been more restricted in Q1 since 2009 due to the cod long-term management plan (Davie and Lordan, 2011). Recent tagging information shows that fish tagged in that area are mainly associated with the VIIe–k stock and not VIIa (WDs 9 and 11).

WKROUND concluded that this practice of allocating Irish landings reported in the most southern rectangles of VIIa to the Celtic sea stock should continue in the future.

6.1.3 Discards

France–French landings have been corrected with highgrading estimates from 2003 to 2005. The method used to estimate the highgraded component is described in WD#1 of the WG SSDS 2006. For smaller length classes, a scaling of French numbers-at-length based on UK length frequencies or UK number-at-length has been used to estimate length compositions of the French component of highgrading. The accuracy of this method is unknown but it probably underestimates the highgrading levels for those years. Unfortunately, the sampling level of total catch at sea in that period was too poor to get an estimate of the level of bias. This method was not applied from 2006 onward because highgrading was also observed in the UK landings. Instead, self-sampling data obtained in 2008–2009 have been used to estimate the French highgrading level, assuming that the discarding practices in 2006–2007 were the same as those observed in 2008 for the main self-sampled fleet. Applying this method back to 2003 was considered inappropriate. The representatives of Fishermen Organisations at WKROUND 2009 indicated that the discarding level was probably not the same in earlier years as highgrading practices are linked to the level of the TAC. The whole method has been described in the WD#17 of WKROUND 2009. In 2009 and 2010, the low estimate of highgrading is likely to be related to the French vessels not being restricted by quota because of the decommissioning plan and the reports of effort directed towards more profitable species.

Ireland–Discard estimates are available from Ireland since 1995 (see Marine Institute and Bord Iascaigh Mhara, 2011). Discards are typically 1 year old fish and are <u>not</u> currently included in the catch-at-age matrix. Discarding of larger fish has occasionally been observed and has been anecdotally reported by industry particularly since 2007 due to restrictive quotas and tight quota enforcement. Sampling levels for discards are typically very low (Figure 6.1.1). Dpue is strongly skewed and quite variable (See Figure 6.1.2). The relative standard errors (RSE) on discard volumes are of the order of 40% when estimated since 2003 using the same method described for haddock (in WD 13). Discard volume estimates are very sensitive to choice of raising auxiliary variables. Historically trip has been used as the raising auxiliary but there is some evidence to say that effort may be less prone to bias and more precise as for haddock (WD13).

Nevertheless the sampling does provide some coherent information, Irish Cod Discards from the VIIe–k stock are mainly in VIIg (Figure 6.1.3) with the total highest volume discarded around "the Smalls" *Nephrops* ground. Dpue are very low in all areas, typically less than 2.3 kg per hr. There were almost no discards (and few landings) observed along the west coast close to the Shelf edge. The proportion of cod discarded by weight is very low in all areas. There are a few pixels with higher discard rates but these reflect variability in the data rather than areas with higher discarding.

Conclusion: Irish discards were not added to the time-series before the benchmark. For now the assumption is that the discards are mainly at age 1 and the estimates are very uncertain. There are indications that Irish discard rates have increased since 2005. Raised estimates in 2005, 2007 and 2010 are in the order of 200 t with a 40% RSE; raised estimates for other years were mainly <50 t. For the moment WKROUND recommends that WGCSE investigates the impact of including these discards in the assessment but given the high M now used on age 1 fish this is unlikely to have a major impact on the overall assessment and conclusions.

6.1.4 Surveys

Two IBTS surveys EVHOE and Irish provide information on this stock. Both surveys catch relatively few individual fish. There was a proposal to combine the surveys (WD#10). Two combinations were tested: mixing data for the whole area and just those in the overlapping area.

WKROUND concluded that the overlap area combined index was an improvement on using the two surveys independently or using the full area index. This conclusion was based on the good cohort tracking and fairly consistent catch curves in the combined index Ages 1–4.

6.1.5 Commercial tuning fleet

The former *Nephrops* and Gadoids trawler tuning fleets from France have been discontinued since 2008 because of strong administrative changes in the data collection of logbooks in France. This has led to substantial loss of information on effort after 2008. That information is unlikely to be retrieved in the future. Ifremer has developed an algorithm (SACROIS) for cross-validation of collected data between logbooks, vms and sales at fish market. This algorithm is currently being applied to current and previous years to consolidate the information on fishing times, landings, species, statistical rectangle just to name a few. For the WKROUND 2012 benchmark, only years between 2007 and 2010 were available using this algorithm. Previous years starting in 2000 were available with the former algorithm. 2007–2008 are overlapping years between the former database system and the data from the SACROIS algorithm. Information from those years was compared between database and a good agreement was found for gadoid species in the VIIb–k area. Therefore, data from 2000 to 2008 from the former database were combined to data from 2009–2010 to provide information on landings per statistical rectangle, fishing times.

A new time-series of tuning indices has been built upon those datasets considering landings and fishing efforts from otter trawlers (OTDEF métier) where catch per trip are at least 40% made of gadoids in Divisions VIIb–k during quarters 2 to 4. There is a good agreement between this new fleet and the former gadoids trawler fleet (Figures 6.1.4 to 6.1.6). No similar work has been performed to build a new *Nephrops* fleet. Prior work before the benchmark indicated that the former *Nephrops* fleet which used to consist of vessels having at least 10% of landings made of *Nephrops* and 40% of gadoids was actually not contributing additional information beyond that from the gadoid fleets. This is consistent with the idea that the gadoids fleet is actually partly made of vessels that used to belong to the *Nephrops* fleet.

The table below indicates the proportion of the total international catch numbers-at-age accounted for by the new French commercial tuning fleet. Catch numbers-at-age here includes highgrading estimates but not discards. Early in the time-series the fleet accounted for the majority of the older fish whereas later in the time-series it accounts for the majority of younger fish.

FR-OTDEF Q2+3+4 trawlers in VIIe–k (effort hours operation, n° individuals).

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
2000	12%	20%	14%	21%	26%	33%	33%
2001	11%	16%	33%	46%	50%	60%	44%
2002	90%	23%	16%	61%	49%	81%	72%
2003	22%	24%	17%	28%	53%	81%	74%
2004	4%	18%	24%	13%	23%	22%	5%
2005	5%	20%	8%	12%	20%	26%	18%
2006	7%	15%	11%	15%	14%	10%	21%
2007	54%	33%	19%	22%	23%	17%	27%
2008	63%	33%	14%	16%	17%	16%	8%
2009	66%	21%	14%	15%	14%	19%	45%
2010	39%	24%	13%	10%	11%	8%	5%

WKROUND concluded that the index should be used to tune the assessment from ages 1–6. Although it is relatively unusual to include commercial tuning information in the assessment it was considered preferable to have something to tune the older ages in this assessment.

6.1.6 Catch weights and stock weights

Catch weights before 1981 are the average values for 1981–2000. Depending on the annual datasets available by country for the period 1988–2001, catch weights-at-age data were calculated as the weighted means from French, Irish and UK datasets. Since 2002, VIIe–k catch weights-at-age have been calculated as the annual weighted means of French, Irish and UK datasets in VIIe–k.

WKROUND reviewed the data and concluded that there is a downward trend in mean weights-at-age during the 1980s but they have been relatively stable since then at about 10% lower mean weights than observed in the 1980s. There is some evidence of year effects (e.g. 2001 and 2005) and cohort effects (e.g. 1999).

6.1.7 Maturity

No change has been proposed mainly because the number of individuals is too low and results from aggregating of data from different areas where maturity might be different than in the Celtic sea.

6.1.8 Tagging data

Two WDs on new or a synthesis of historic tagging information were presented to WKROUND (WD 9 and WD 11). The first dealt with the stock structure question and mixing issues (WD 9). WKROUND concluded that there was limited movement of adult tagged fish between the Celtic Sea VIIe–k and other areas based on the conventional tagging and DST information presented in WD 9. Even within the Celtic Sea there is some indication of two components in VIIg and VIIefh with limited mixing between them.

The WD 11 also showed that the vast majority of juvenile and adult cod tagged in VIIg and in VIIaS were recaptured within the VIIe–k assessment area.

The second aspect of the WD 11 was estimation of cod mortality rates based on simple recapture model. The WD discussed a number of strong assumptions and potential uncertainties and biases in the mortality estimates (post tagging mortality, loss of tags, emigration of fish, under reporting of recaptures, etc). The results still suggest that natural, or other unaccounted mortality, was higher than fishing mortality for Celtic Sea cod with the old M assumption of 0.2. The WD recommended exploring the sensitivity of the assessment and management advice to higher M values.

WKROUND have adjusted the M for Celtic Sea cod based on the Lorenzen equation (Lorenzen, 1996). This change results in elevated M estimates for ages 1 and 2 in particular. The majority of tagged fish were less than 40 cm and so are likely to be either 1 or 2 year olds. The M estimates now used in the assessment make it easier to reconcile the results of this tagging study given the potential underlying assumptions and biases in the method. The tagging data are probably too sparse to disaggregate an M by age but it could be interesting to evaluate if return rates of larger fish were higher as suggested in the new M assumption.

AGE	New Lorenzen M	Average Fishing Mortality 2008–2010	Percentage of total mortality Z due M assumption
1	0.51	0.07	88%
2	0.37	0.53	41%
3	0.30	0.80	28%
4	0.27	0.74	27%
5	0.25	0.88	22%
6	0.23	0.80	23%

6.2 Assessment

6.2.1 Current status of the assessment, known problems

At the last benchmark (ICES WKROUND, 2009), the main uncertainties for the assessment of this stock were partial information available on quota-induced changes in discarding, underreporting, and area misreporting of landings that occurred in previous years. Use of survey data has also been considered limited by the number of individuals caught. Previous attempt in 2009 to combine survey data failed to improve substantially the quality of the assessment. Overall, the different methods that were tried at that time were unable to overcome the partiality of information and to provide a suitable assessment to be used by the Celtic Seas Eco-region Working Group.

Problems with this stock have been considered to be data-related rather than related to modelling. Since the first benchmark of this stock, the time-series have been revised with new information on discards and highgrading and correction for misreporting but the assessment has been rejected each year from 2009 to 2011 by the members of the Working Group.

In 2010, the French EVHOE and Irish Groundfish surveys both confirmed a strong 2009 year class. This circumstance pushed ACOM to accept this assessment and forecasts into the advice for 2012, derogating as such from the usual ICES practices. In normal circumstance, the stock would have been treated as "data poor" which would have led to an advice such as "no increase in catch" or "reduce catch" but considering this stock is part of a mixed fishery, a limited TAC would have resulted in large amounts of discards.

Forecasts have not been provided since the rejection of the assessment. The uncertainties in the forecasts for this stock are associated with the strength of the incoming and assumed recruitment estimates and any future TAC-induced highgrading practice.

6.2.2 Analyses of data (index ratios, consistencies, etc.)

The following input data have been explored and/or revised during the 2012 benchmark:

- Age-dependant natural mortality estimates.
- Internal consistency of tuning indices.
- Effects of using combined survey indices rather than individual surveys.

Those data have been compared with the previous assessment carried out with XSA which was used as reference run.

6.2.2.1 Age-dependant natural mortality estimates

The natural mortality is in many stocks set to M=0.2 regardless of the age structure of the stock. Based on the relationship between weight and length (Lorenzen, 1996), $M_w = M_u \cdot W^b$, natural mortality-at-age has been introduced into both models by combining the parameters from von Bertalanffy growth curve and allometric relationship.

Parameters were estimated from length, weight and age information collected by France during the FR-EVHOE cruises since 2006 and sampling at sea and fishmarkets. The following estimates were used to compute M-at-age.

Von Bertalanffy growth curve parameters estimates:

- K: 0.343
- L_∞: 120.38
- t0: -0.199

Allometric relationship parameters estimates:

- a: 0.0136
- b: 2.937

Mortality–Weight relationship constants (taken from Lorenzen, 1996):

- M_u: 3.69
- b: -0.305

The M-at-age values used in the assessment models were estimated to be:

Age	0	1	2	3	5	6	7	8	9	10
M-at-age	1.115	0.512	0.368	0.304	0.269	0.247	0.233	0.223	0.216	0.210

Those parameters were kept constant from one year to another as it was considered no substantial change in the individual body growth has occurred since the beginning of the time-series used for the assessment.

6.2.2.2 Internal consistencies of tuning indices

The former assessment had eleven tuning fleets, many of them being discontinued, localised on a specific region of the assessed area. Fleets and available datasets were reviewed one by one using log catch ratio.

- FR-Gadoid (French gadoid trawlers operating in VIIfgh in quarters 2 to 4, 1983–2008) has been disrupted since the change in the data collection processing in France in 2009. This fleet has been replaced by a new tuning fleet starting in 2000 (see FR-OTDEF). It was decided its use in the assessment was no longer needed.
- FR-*Nephrops* (French *Nephrops* trawlers operating in VIIfgh all year long, 1987–2008) has been disrupted since the change in the data collection processing in France in 2009. This fleet has been replaced by a new tuning fleet starting in 2000 (see FR-OTDEF). It was decided its use in the assessment was no longer needed in XSA. In ASAP, due to calculation forward in time, that fleet was kept as tuning indices.
- UK-WECOT (UK Otter trawlers in VIIe, 1989–2010) is still an ongoing time-series but it was removed from the assessment because of its narrow

area of fishing operation and as it only contributes to a small fraction of the cod catch in the assessed area.

- IR-7J-OT, IR-7G-OT, IR-7GT-OTB (Irish otter trawlers in VIIj, VIIg and combined, 1995–2008) have been removed for the same reasons than UK-WECOT. It was noted from the review of the log catch ratios that the combined indices have some potential for improvement.
- UK-WCGFS (West Coast March survey, 1992–2004) has been removed as this survey is discontinued and last data are now too far in the past.
- Indices from FR-EVHOE (French groundfish survey quarter 4, 1997–ongoing), IR-GFS (Irish IBTS Q4 groundfish survey in VIIg,j) show noisy log catch ratios especially at older ages. This is mainly due to the generally low number of fishes and the fact those surveys catch very few old fish possibly because the older individuals are out of reach of the survey coverage. Those surveys do not target specifically cod or haddock. Those indices have been removed from the assessment and replaced by some combined survey indices which are evaluated below.

Three new tuning fleets have been considered:

- A Belgian otter trawler fleet from 2004 to 2010 operating mainly in VIIf. Indices contain both landings and discards. The log catch ratios showed a relatively poor consistency for this fleet for two reasons: 1) a low number of sampled individuals, 2) two changes in the minimum Belgian landings size since 2004, 40 cm until 30/06/2008, 50 cm between that date and 30/09/2011 and 35 cm since then. For these reasons and the fact the fleet like others above only contributes to a small fraction of the catch.
- A French otter trawl fleet in VIIe–k quarter 2 to 4 starting in 2000 and ongoing, FR-OTDEF, was introduced as a substitute for the discontinued FR-Gadoid and FR-*Nephrops*. Those indices are in line with the previous French indices. Log catch ratios (Figure 6.2.2) show a relatively good consistency except for the year 2000. Those fleet indices were considered a suitable replacement for the former French fleets and were included into the assessment for both XSA and ASAP runs.
- The combined survey indices (WD#10) of French and Irish survey show (Figure 6.2.3) a relatively good consistency and was therefore accepted for use with both XSA and ASAP models.

A similar work as the one done on cod in Division VIa using the combined survey indices and a Bayesian model of age structured population dynamics was done for Celtic Sea cod. The overall fit of the index was fine but the estimates of SSB, catch and fishing mortality are all flat with wide credible intervals (Figure 6.2.4). The survey selectivity was fixed to 1 for all ages and the mortality values were constant through the time-series. As age 5 index has a lot of zeros, age 4 was considered to be a plus group. As a consequence, the model is effectively fit as maximum likelihood since any priors are flat. The variance estimate by age on the index is very low for ages 1–3 but is very high on age 4+ (Figure 6.2.3). From the last assessment at WGCSE 2011, F shows no trend in comparison to the clear downward and more realistic trend at the previous working group.

Conclusion: After reviewing one by one all previous and new indices, it was decided that XSA would use the new FR-OTDEF and the Combined survey indices. ASAP would use FR-OTDEF, the combined survey indices and FR-*NEPHROPS*.

6.2.2.3 Effects of using combined survey indices rather than individual surveys

Several XSA exploratory runs were carried out using different combinations of the survey indices and with or without the FR-OTDEF fleet resulting in various runs with different outputs. Diagnostic plots and table were found to be more useful to compare the effects of removing or adding datasets. Residuals from using combined or non-combined survey data were compared. In all cases the combined indices provide the least noisy residuals (Figure 6.2.5). An explanation might be that survey data are based on a low number of individuals. At older ages, the very low number of individuals adds substantial noise to the data. Both surveys have been known over the years to show some similar abundance trends therefore combining numbers is not expected to change the information embedded into datasets from both surveys but remove the noise due to the low number of individuals. **The use of the combined survey indices is therefore recommended**.

6.2.3 Trial assessments

6.2.3.1 Description of method or reference

Two assessment models were evaluated during the benchmark: eXtended Survivors Analysis (XSA) and the Age-Structured Assessment Program (ASAP, Legault and Restrepo, 1998).

XSA

XSA has been used by the SSDS working group for the assessment of the Celtic Sea cod since 1993. This model served as the reference model for all exploratory assessments and sensitivity analyses during the benchmark meeting.

ASAP

This model (Legault and Restrepo, 1998) is based on forward computations assuming separability of fishing mortality into year and age components. This assumption is relaxed by allowing for fleet-specific computations and by allowing the selectivity-at-age to change smoothly over time. The software can also allow the catchability associated with each abundance index to vary smoothly with time. The problem's dimensions (number of ages, years, fleets and abundance indices) are defined at input and limited by hardware only. This model was tested for the first time on Celtic Sea cod data during this benchmark.

6.2.3.2 Conditioning of the models

The major change from the previous XSA assessment was the plateau for full selectivity formerly set to age 5. After reviewing catch curves (Figure 6.2.6 to 6.2.8), it was assumed that full selectivity was at age 3. Initial model runs with the new datasets were done for both XSA and ASAP with full selectivity-at-age 5 and then at age 3.

The following parameters were used for the final run of XSA and only differ from previous years for the q plateau value set to age 3 instead of age 5. Catch curves (Figure 6.2.6) showed that full selectivity was reached at age 2 or 3.

		Year range	Age range
Catch data		1971–2010	1–7+
Commercial tuning-series			
	FR-OTDEF	2000–2010	1–7+
Scientific surveys			

	Combined FR-EVHOE IR-IBTS	2003–2010	0–4+
Parameters			
	Taper		No
	Age s catch dep. Stock size		none
	q plateau		3
	F shrinkage se		1
	Year range		5
	Age range		3
	Age range of mean F		2–5

For ASAP, the stock was modelled with a plus group at age 7. Prior to modelling, it was determined that the M-at-age had begun to asymptote by age 7, so no weighted averaging was needed to derive an M-at-age for the plus group, rather the value for age 7 was used.

Selectivity was estimated by age for the total catch (aggregated landings and discards) and also for the two indices. In order to inform the age of full selectivity, catch curves were examined. Cohort-specific catch curves indicated full selectivity-at-age 2 or 3 for the catch, with a constant slope thereafter (Figure 6.2.6). The French otter-trawl tuning index suggested the age of full selectivity was 2 or 3, and the combined Irish/French survey appeared to select ages 1–3 nearly equally (Figures 6.2.7 and 6.2.8).

One typically interprets catch curves with constant slope as indicative of logistic or flat-topped selectivity. However, as natural mortality is now presumed to follow the Lorenzen pattern of decreasing M with age, a simple simulation was performed to evaluate whether a constant slope was still indicative of flat selectivity when M is not constant. In fact, since catch curves are examined on the log scale, the power function of the Lorenzen curve is basically linearized, and the intuition about constant slope implying flat selectivity was confirmed (Figure 6.2.1).

Based on this empirical evaluation of the raw data, flat selectivities were assumed for both the catch and the indices. Selectivity was fixed to 1.0 for ages 3–7 in the catch and the French Otter Trawl tuning index, and it was fixed to 1.0 for age 3 in the combined Irish/French survey. Ages 1 and 2 were freely estimated for the catch and both indices. A single selectivity block was assumed for the catch time-series (1990–2010).

Total catch was fit assuming a CV of 0.10 in all years. Fits to indices assume lognormal error on the index total, and the age composition is fit assuming a multinomial error structure. A CV of 0.35 was assumed for the French Otter Trawl tuning index, and a CV of 0.25 was assumed for the combined Irish/French survey.

6.2.4 Performance (residuals, retros, variances, etc.)

ASAP

There is a pattern in the residuals, with predicted catch slightly lower than observed through 2002 and slightly higher than observed from 2003, but the magnitude of the residuals was inconsequential (Figure 6.2.9). The catch age composition is fit assuming a multinomial error structure. Patterning in the residuals showed no pathological problems, although there was a slight tendency to overestimate catch-at-age 1 from 2005–2010 (Figure 6.2.10).

Fits to indices assume lognormal error on the index total, and the age composition is fit assuming a multinomial error structure. Both tuning indices totals were fit very well, with very reasonable residual diagnostics (Figures 6.2.11 and 6.2.12). Some blocking of residuals was observed in the age composition fits for the French Otter Trawl index, but this was not evident in the age composition fits for the combined Irish/French survey. The estimated selectivity for the total catch and the French Otter Trawl index were very similar, as expected. Selectivity-at-age 1 was 0.15 for the catch and 0.2 for the index; selectivity-at-age 2 was 0.83 for the catch and 1.0 for the index. The slightly lower selectivity values in the catch compared to the French Otter Trawl index could reflect the influence of more young discards in the catch or to a younger age composition in the Irish catches compared to the French. Selectivity for the combined Irish/French survey was 0.8 for age 1, 0.88 for age 2, and as previously noted, fixed at 1.0 for age 3.

Recruitment-at-age 1 has averaged about 5 million over the last 30 years, but has been consistently below that for years 2002–2009 (Figure 6.2.13). The most recent year class is estimated to be above the average, at 16 million. There appears to be a tendency for higher recruitments in the past, which coincided with higher spawning biomass, however there is not sufficient contrast in the time-series to justify estimating a stock–recruit curve (Figure 6.2.14).

SSB was estimated to have declined steadily from a high in 1990 (19 000 t) to the lowest point in 2005 (4400 t) and has since increased consistently to about 9300 t in 2010. Over the same period, fishing mortality fluctuated between about 0.8 and 1.0 until year 2003, where F was estimated to decline continuously to the present value of 0.29 (Figure 6.2.15). This is consistent with the decline of the fishery but the magnitude of the decline is probably overestimated as the final value of 0.29 is probably lower than the actual fishing pressure.

XSA

Figure 6.2.16 represents the residuals from the final runs for both FR-OTDEF and the combined survey indices. The residuals have low value. For the commercial cpue, the value of residuals exhibit the same patterns as the proportion of the total international catch numbers-at-age accounted for by the new French commercial tuning fleet (Section 6.1.4.) i.e. the highest numbers-at-age contribute to the international catch, the higher the residuals are. Therefore, when early in the time-series the fleet accounted for the majority of the older fish, the residuals are the highest for the older fish. Later in the time-series, the catch is mainly made of younger fish which exhibit the highest residuals. Residuals are lower for survey indices.

A retrospective analysis (last five years) suggests (Figure 6.2.17) that F is underestimated. Recruitment and Spawning–stock biomass on the other hand are slightly overestimated. The final run has been compared with the previous XSA assessment (WGCSE, 2011). In all cases, the time-series do not quantitatively differ from the initial run. Recruitment estimates (Figure 6.2.18) are somehow rescaled. This is mainly the consequence of the change from a set natural mortality at 0.2 and the use of other age dependant values for natural mortality.

For fishing mortality (Figure 6.2.19), earlier years are rescaled by the change of selectivity-at-age and lowered by 0.05. The new run has a lower F in the earlier years. The situation becomes inverted after 2002 where new estimates of F are higher than those from the last assessment. The overall decrease in F is consistent with the evolution in the French fleets as there has been some decommissioning. Market opportunities have recently been less interesting for the fleet. Some vessels are now targeting other species than cod. The rate of decrease in F in recent years for the new run is loess than for the previous run. It was found that the slope of the decline in F is actually very dependent on the assumption made on q plateau.

SSB (Figure 6.2.20) estimates are rescaled in the earlier years and are lower than for the former assessment procedure. The situation becomes inverted in 2003 and SSB is then lower than the previous assessment. This is consistent with the high F values estimated after mid-2000s.

6.2.4.1 Lessons learned

Age-dependant natural mortality estimates

M-at-age being a set of constants, the effect of changing those constants only leads to a rescaling of the outputs from the models. The average F on ages 2 to 5 has been shifted up by 0.068. Resulting SSB was increased by a factor of 1.096 and recruitment estimates were on average 1.526 times higher except in the last year where the change from one run to the other was rather the consequence of changes on other input parameters. Overall, the use of this set of parameters appears more realistic than the usual M=0.2.

Effects of using new tuning indices and full selectivity-at-age 3

The exploratory work on the quality of the tuning indices has only retained the commercial FR-OTDEF fleet and the combined survey indices. Survey indices concentrate on younger individuals while commercial fleets catch older ones. Age 3 is the age where survey and commercial indices are of equal importance. Residuals follow the same pattern than the contribution of catch number-at-age to the international landings. The new tuning indices do not contradict our former perception of the status of the stock and diagnostics indicates that those indices actually fit better with the assessment.

Lowering q plateau to set full selectivity from age 5 to age 3 has some substantial effects on the assessment. SSB and F plots suggest in earlier years the output to be simply rescaled by the change in natural mortality. However, things become inverted starting in 2002–2003. This is when both tuning indices start to be used in the model. Some exploratory runs have shown q plateau affects the steepness of F in recent years. High value of q such as full selectivity only at age 5 leads to a somewhat high value for F but relatively constant over time. There are been evidence notably from the activity of the French fleets that F should decrease because of decommissioning and other fishing opportunity more profitable than cod. Using a lower value for full selectivity tend reflect more this trend. For ASAP, age 3 might be a little too strong as the decline appears too fast. Moving full selectivity from age 5 to 3 is also an indicator that cod for this stock should almost be treated as a short-lived species.

6.2.5 Conclusions on assessment methods

In 2009, WKROUND rejected the assessment methods mostly because of data problem such as misreporting and noisy information. It is worth noting that the revision that has been made on data and the reduction of the number of tuning fleets has globally improved the quality of the assessments made by both XSA and ASAP.

Both XSA and ASAP appeared suitable to carry analytical assessment of the Celtic Sea cod stock. XSA has been the traditional model used for this stock assessment and one of the most well known models among the ICES community and therefore appears as the natural choice until the next benchmark. ASAP might be used as a backup solution should XSA performances become questionable.

6.2.6 Recommendations for future developments

New development could include a specific population model for the Celtic Sea cod. Catch data have uncertainties related to recurrent problems of misreporting and highgrading. There is room for development in regards to treating those uncertainties. Other developments might include the linkage of recruitment with environmental drivers like temperature anomalies and plankton composition.

6.3 Short-term predictions

6.3.1 Method

No new method for short-term predictions has been presented. Short-term predictions have been removed from the assessment procedure since the last benchmark and were reintroduced by the Advice Drafting Group in the Celtic Sea cod advice in 2011.

6.3.2 Recruitments

Short-term forecasts of recruitment are estimated with a long-term geometric mean (GM) omitting the last two years. Celtic Sea cod stock had a few sporadic events of high recruitments therefore the geometric mean appears more appropriate to lower the numerical weight of these sporadic events in the forecasts. The time-series of recruitment does not show any long-term trends.

6.3.3 Weights and maturities

Maturities are assumed to be constant. Stock and catch weights are based on the average from the last three years.

6.3.4 Assumptions for intermediate year

Recruitment is considered to be the long-term geometric-mean (see above). The F vector used will be the average F-at-age in the last three years, unless there is strong indication of a significant trend in F. In the latter case the average selectivity pattern will be rescaled to the final F in the series.

6.4 Implications for reference points

6.4.1 Precautionary reference points

Although new values have been set for natural mortality, full selectivity, precautionary reference points have not been revised. The current available time-series suggest that the current values are still in line with our knowledge of this stock and its harvesting. **Precautionary reference points are therefore unchanged**.

Reference point	ACFM 1998	WG 1999*	ACFM 1999	WG 2004	ACFM 2004
F_{lim}	0.90 (Floss WG98)	0.90 (history WG99)	0.90 (history WG99)		0.90 (history WG99)

F_{pa}	0.68 (5th perc Floss WG98)	0.65 (Flim*0.72)	0.68 (5th perc Floss WG98)		0.68 (5th perc Floss WG98)
B_{lim}	4500 t (Bloss =B76 WG98)	5400 t(Bloss=B76 WG99)	5400 t (Bloss=B76 WG99)	6300 t (Bloss=B76 WG04)	6300 t (Bloss=B76 WG04)
B_{pa}	8000 t (Blim*1.65)	9000 t (Blim*1.65)	10 000 t (history)	Reject – no SR relation	8800 t (Bpa = Blim * 1.4)

6.4.2 MSY reference points

6.4.2.1 Stock–recruitment

It is proposed that MSY $B_{trigger}$ remains set at B_{pa} (8800 t). No new additional data regarding the stock–recruitment relationship suggested a revision of this reference point.

6.4.2.2 Yield and SSB per recruit

Yield-per-recruit and SSB-per-recruit were estimated with YPR version 2.7 (NOAA Fisheries Toolbox, http://nft.nefsc.noaa.gov/). A previous exercise using the same toolbox was performed at WGCSE 2010. Y/R and SSB/R curves were drawn from the outputs of both XSA and ASAP models (Figure 6.4.1). Estimates of F_{01} and F_{max} are in line from both models with previous estimates. Therefore, **no change of reference points related to F_{01} and F_{max} is proposed**.

Yield and spawning biomass per Recruits based on XSA and ASAP outputs

Based on XSA outputs	F	Y/R	SSB/R	Tot. Biom/R	Mean age	Mean gener. Time	Expected spawning
F0	0.00	0.00	17.43	19.12	4.30	8.01	1.10
F-01	0.21	1.24	7.11	8.70	2.63	5.60	0.61
F-Max	0.37	1.33	4.51	6.05	2.20	4.80	0.42
F at 40% MSP	0.22	1.25	6.97	8.56	2.61	5.56	0.61

Based on ASAP outputs	F	Y/R	SSB/R	Tot. Biom/R	Mean age	Mean gener. Time	Expected spawning
F0	0.00	0.00	17.71	19.76	4.31	6.40	1.10
F-01	0.22	1.33	6.86	8.79	2.55	4.18	0.61
F-Max	0.41	1.45	3.99	5.83	2.06	3.49	0.42
F at 40% MSP	0.21	1.32	7.09	9.02	2.58	4.23	0.61

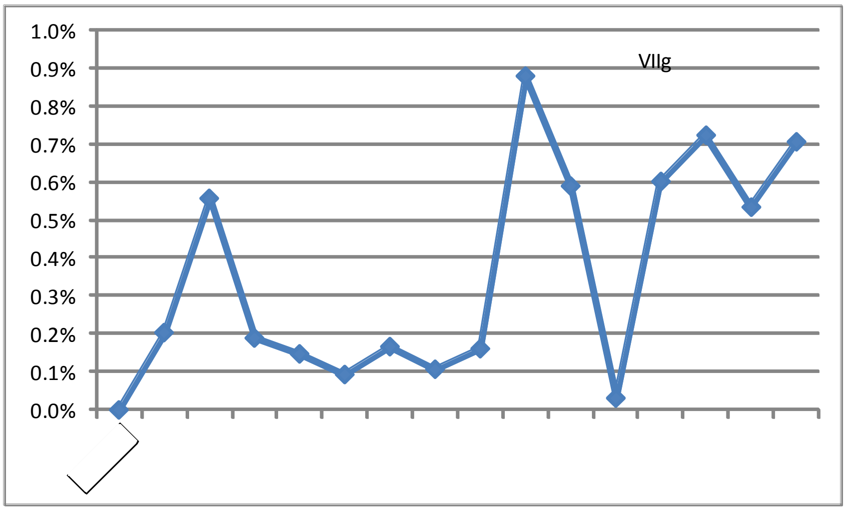


Figure 6.1.1. Percentage of Irish fishing effort observed for discards in VIIg.

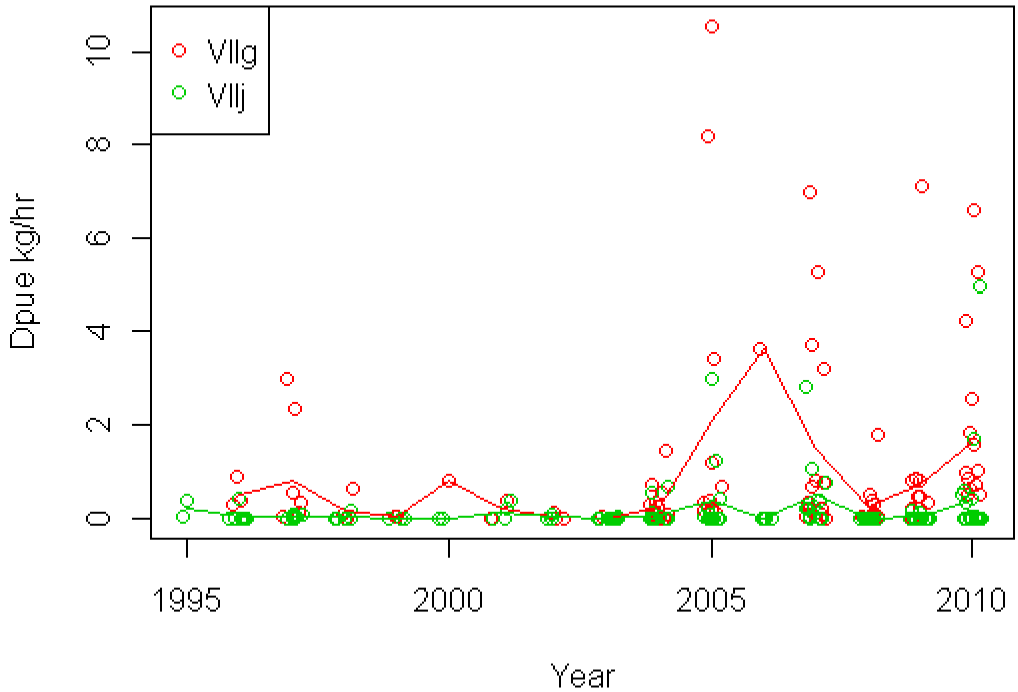


Figure 6.1.2. Discards per unit of effort from individual sampling trips.

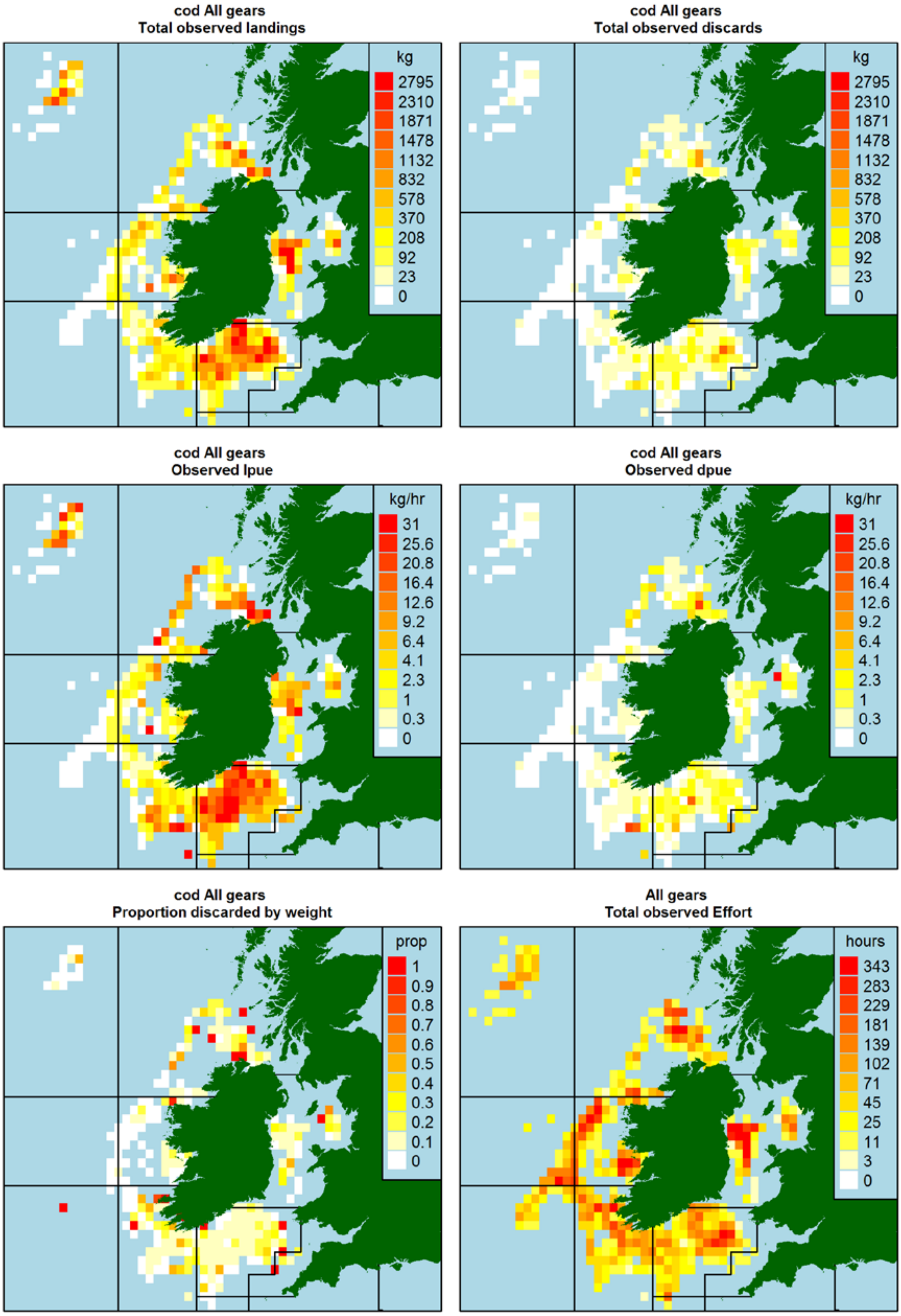


Figure 6.1.3. Observed Cod Landings, Discards and effort from Irish Discard Sampling Trips carried out between 1995–2009.

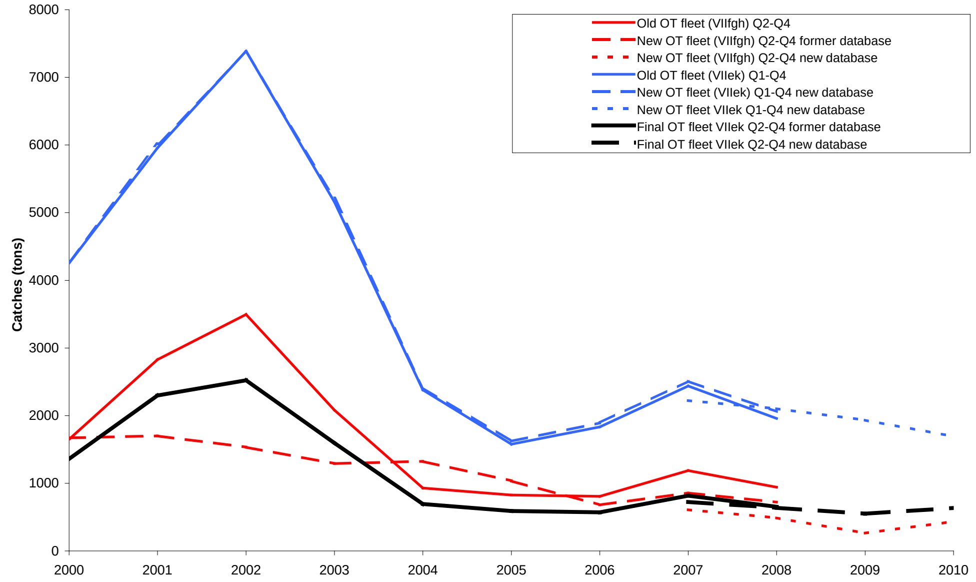


Figure 6.1.4. Comparison of French catch of cods between former and new otter trawlers gadoid tuning fleets in Divisions VIIe–k, VIIfgh, all year round or quarters 2 to 4 only. Final tuning indices (used for assessment) are in black.

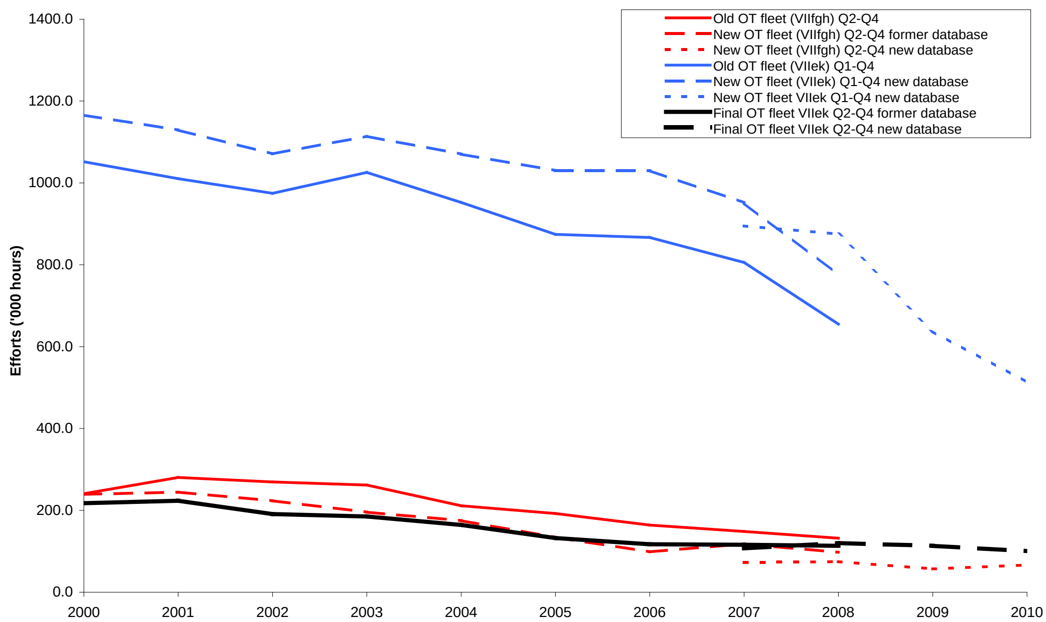


Figure 6.1.5. Comparison of French fishing effort ('000 hours of fishing operation) between former and new otter trawlers gadoid tuning fleets in Divisions VIIe–k, VIIfgh, all year round or quarters 2 to 4 only. Final tuning indices (used for assessment) are in black.

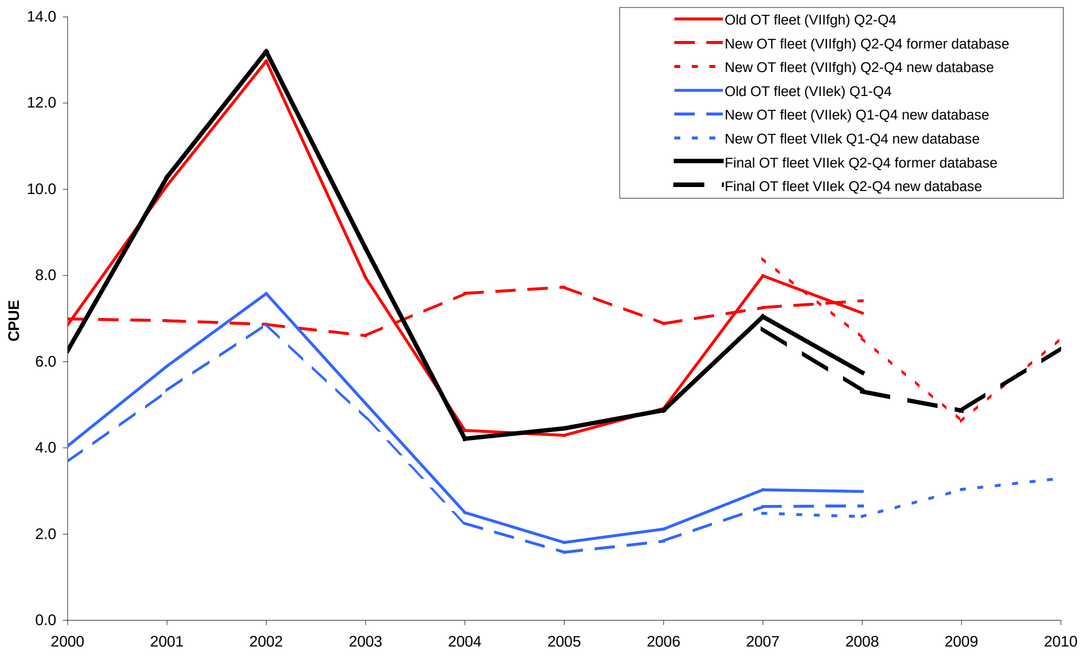


Figure 6.1.6. Comparison of French cpue between former and new otter trawlers gadoid tuning fleets in Divisions VIIe–k, VIIfgh, all year round or quarters 2 to 4 only. Final tuning indices (used for assessment) are in black.

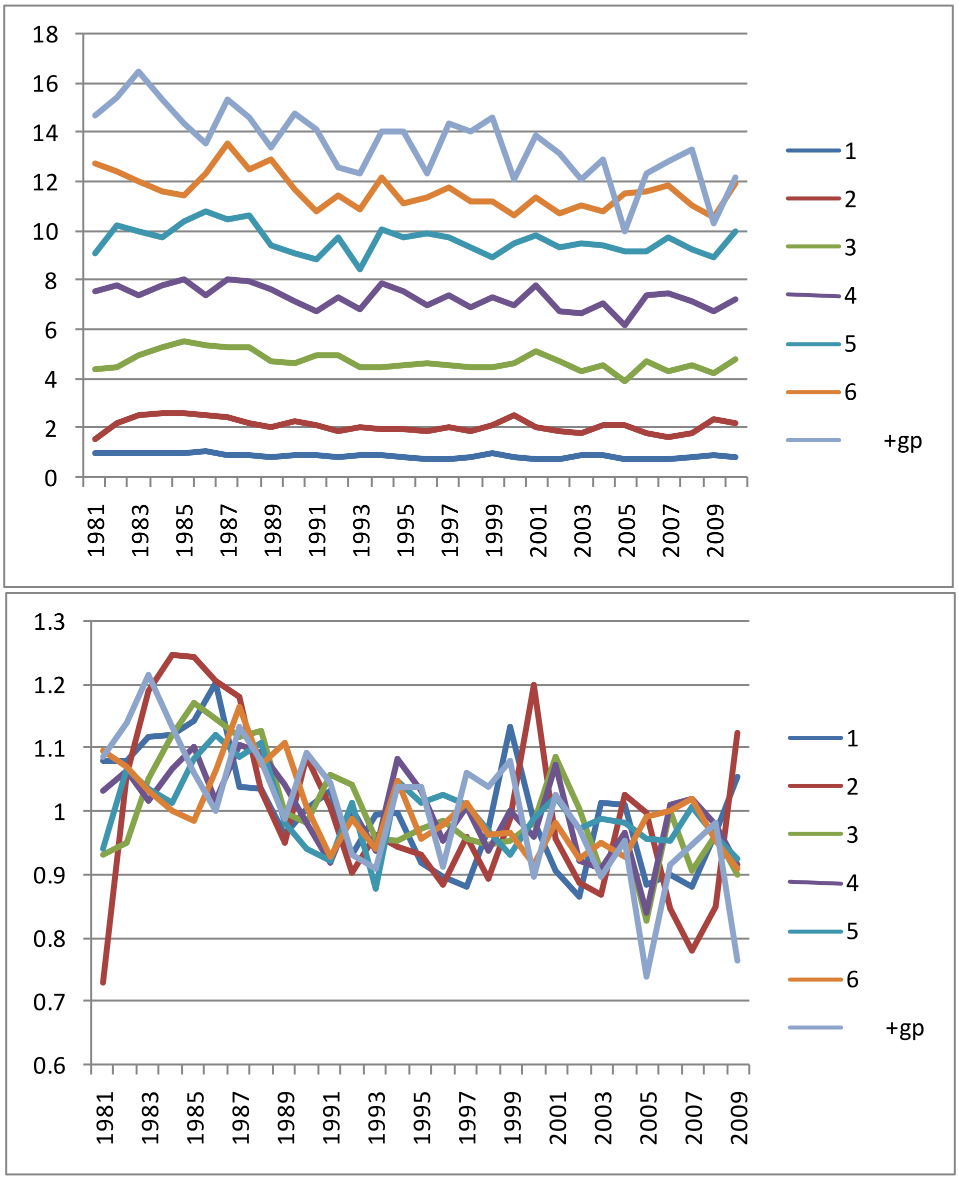


Figure 6.1.7. Top panel mean weights-at-age for Celtic Sea cod and bottom panel time-series standardised by the mean at each age.

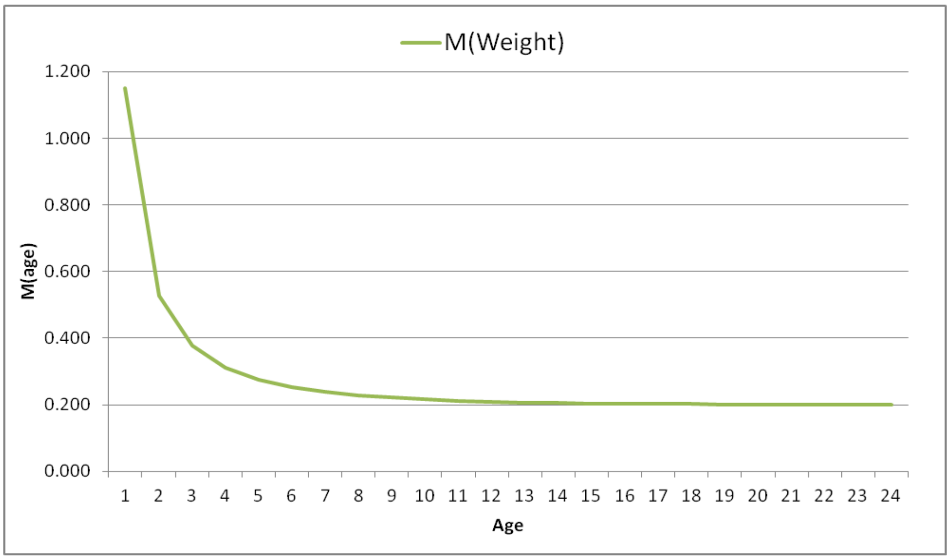


Figure 6.2.1. Estimated mortality-at-age as a function of weight for cod VIIe–k. Parameters to derive M were taken from Lorenzen (1996).

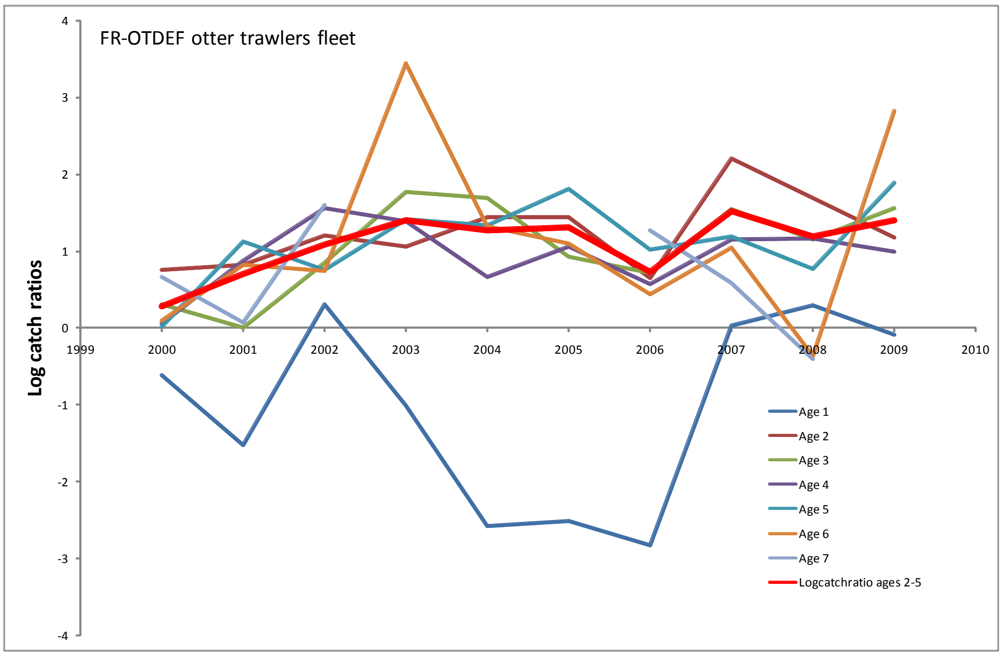


Figure 6.2.2. Log-catch ratios for the FR-OTDEF tuning fleet.

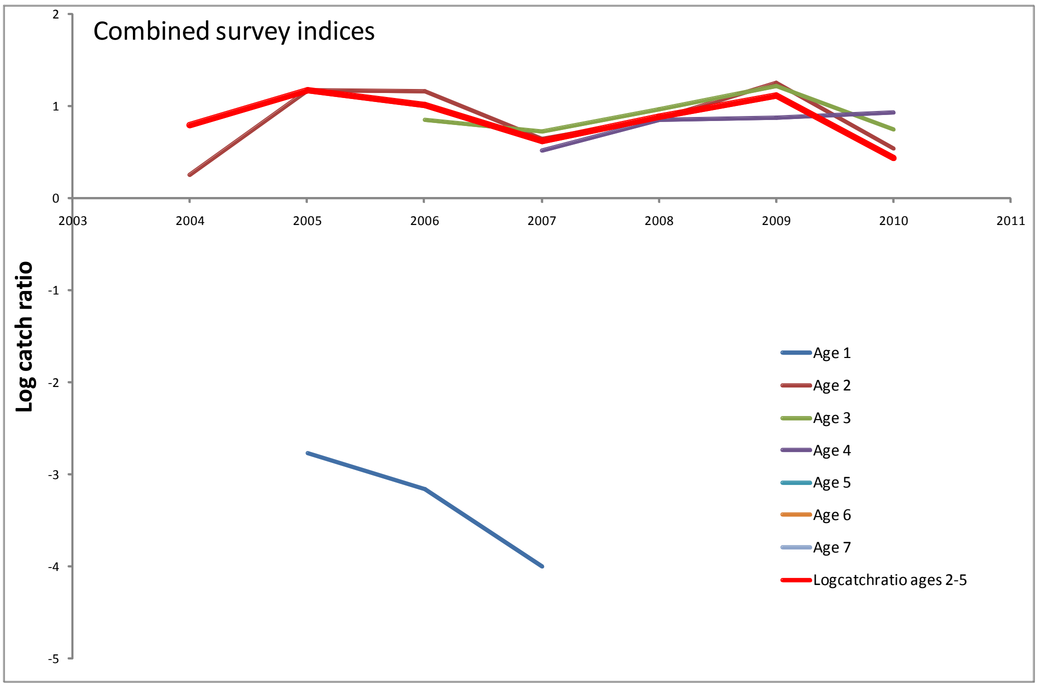


Figure 6.2.3. Log-catch ratios for the combined surveys tuning indices.

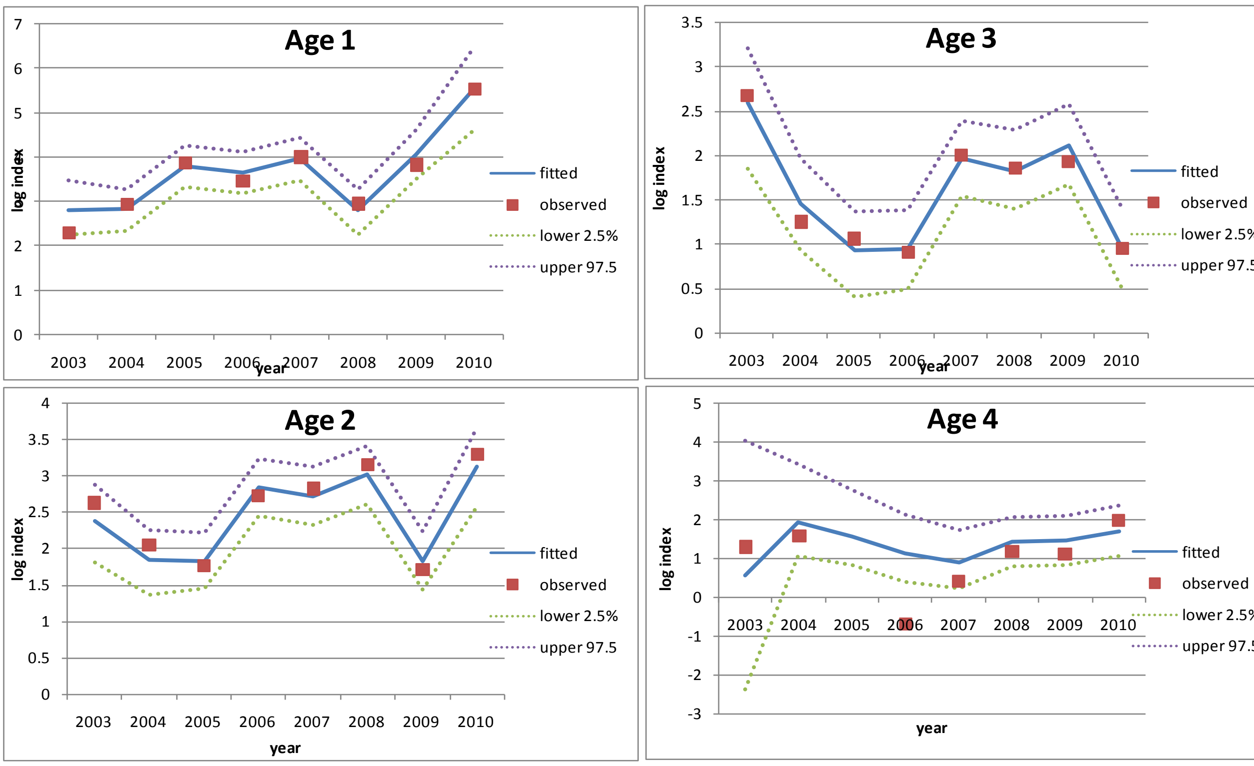


Figure 6.2.3. Log index by age for the combined survey indices for model outputs and survey data.

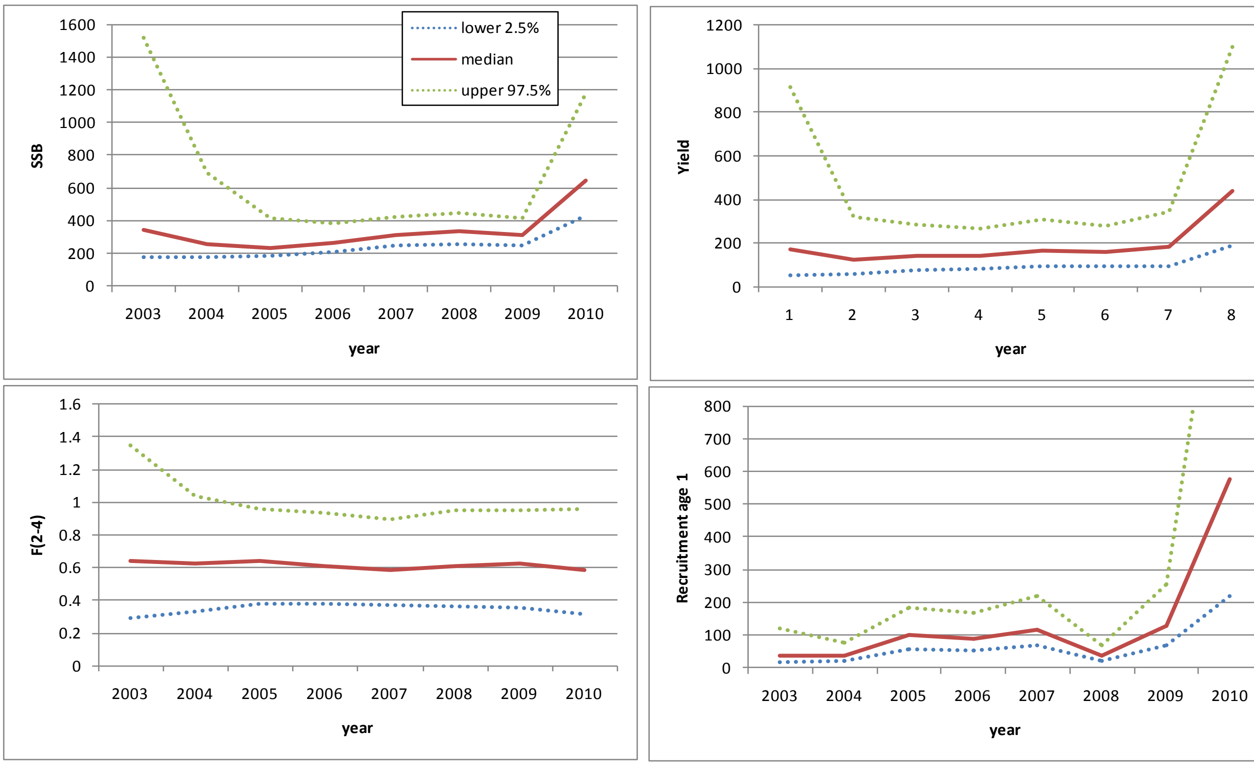
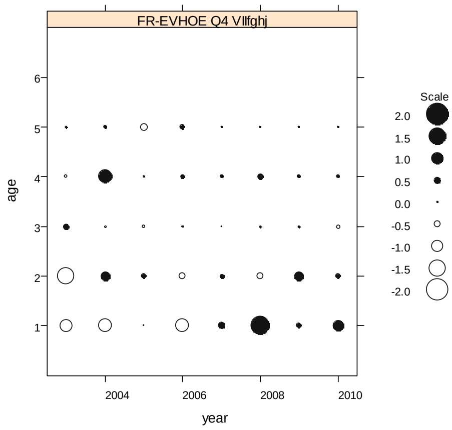
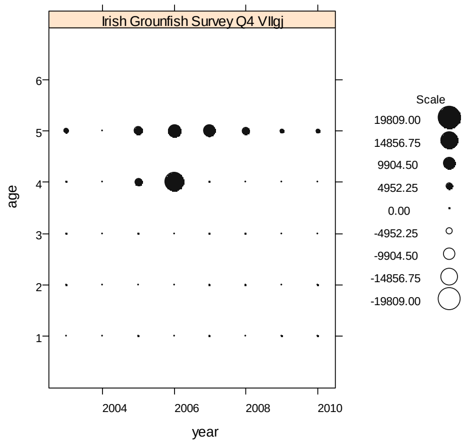


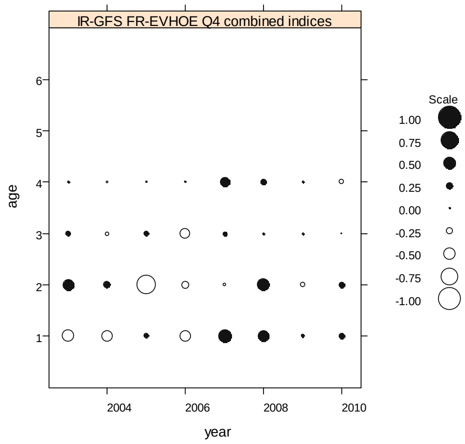
Figure 6.2.4. Model outputs (SSB estimates in tons, Recruitments in thousands of individuals, fishing mortality and yields) based on the combined survey indices.



a)



b)



c)

Figure 6.2.5. Residuals from the following exploratory XSA assessments: a) IRGFS indices only used as tuning fleet, b) EVHOE only, c) Combined IRGFS-EVHOE indices.

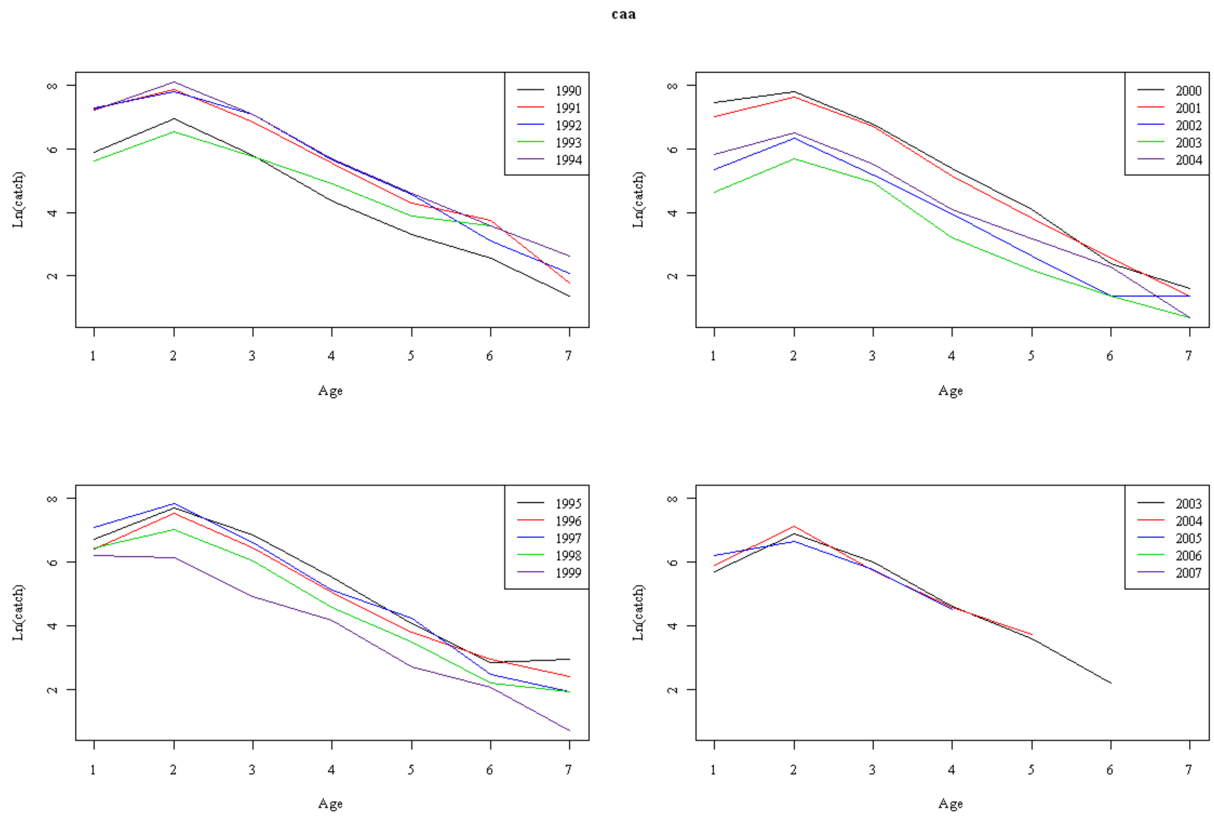


Figure 6.2.6. Estimated catch curve by cohort for the total catch of Cod VIIe–k.

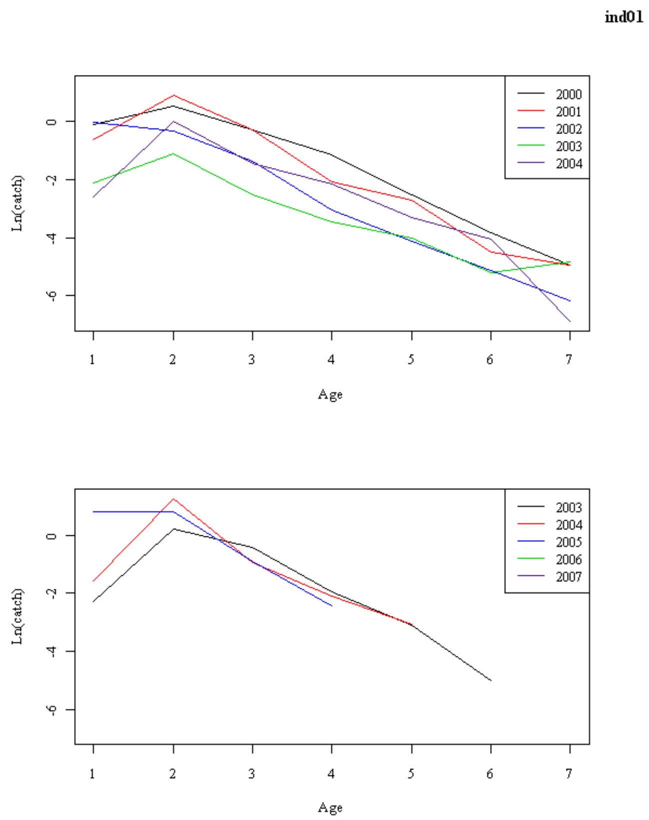


Figure 6.2.7. Estimated catch curve by cohort for the French Otter Trawl tuning index for Cod VIIe–k.

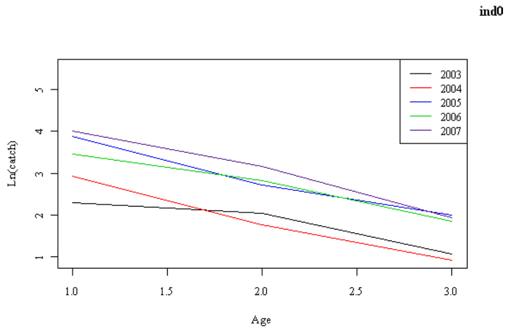


Figure 6.2.8. Estimated catch curve by cohort for the Irish/French combined survey for Cod VIIe–k.

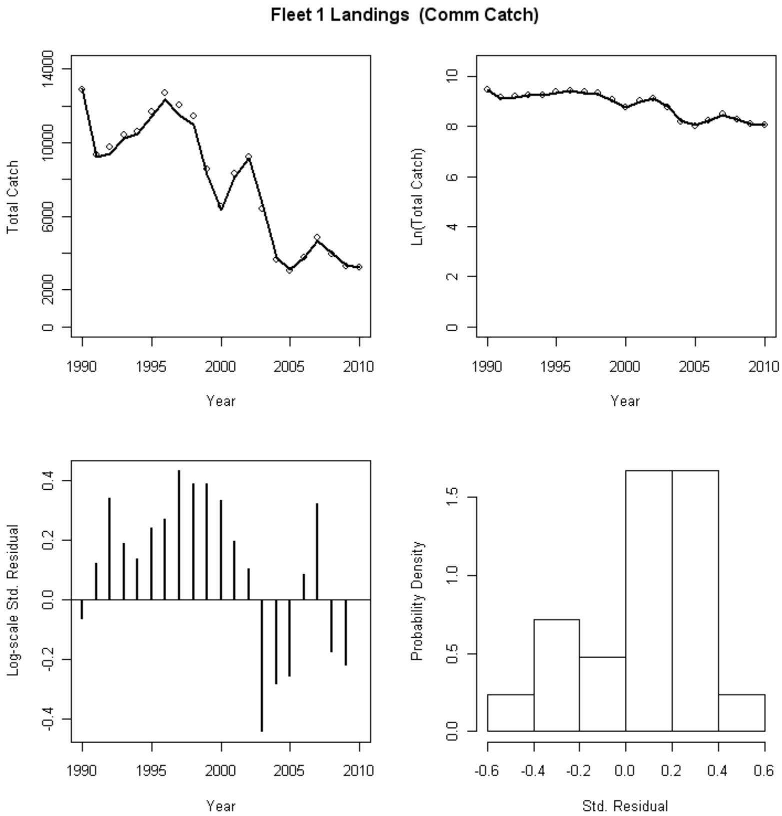


Figure 6.2.9. Fits to total catch of Cod VIIe–k.

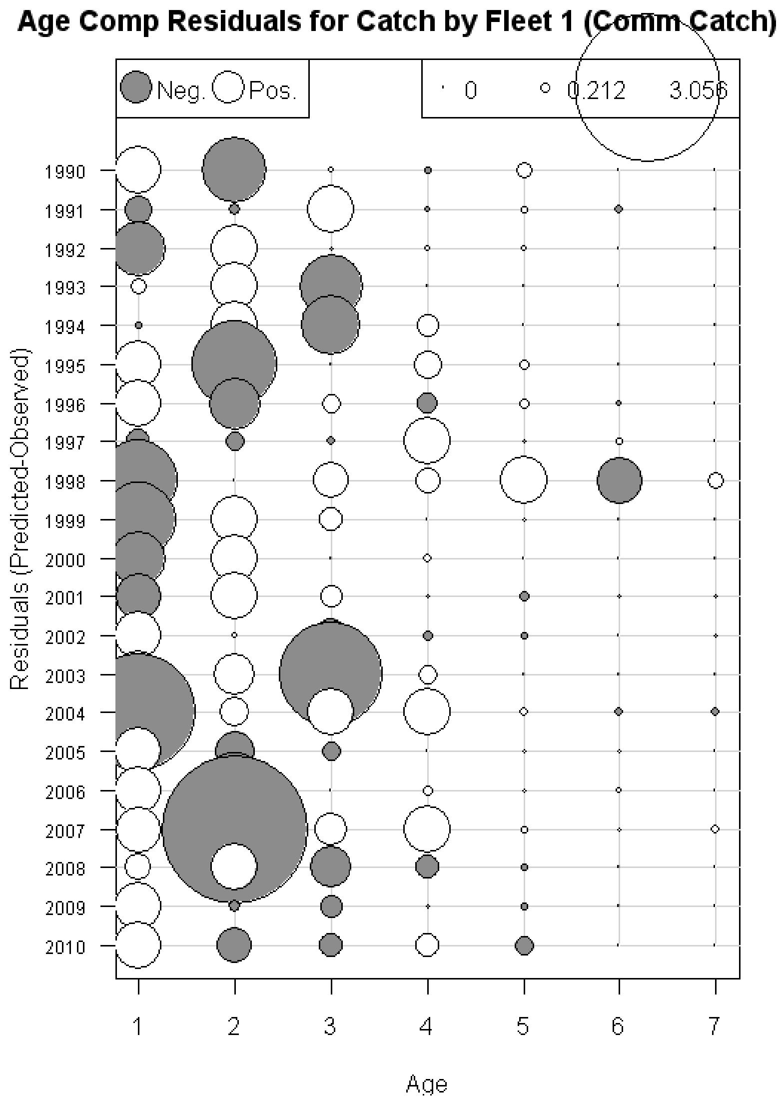


Figure 6.2.10. Residuals to the fit of catch age composition for Cod VIIe–k. A single selectivity block was assumed for all years.

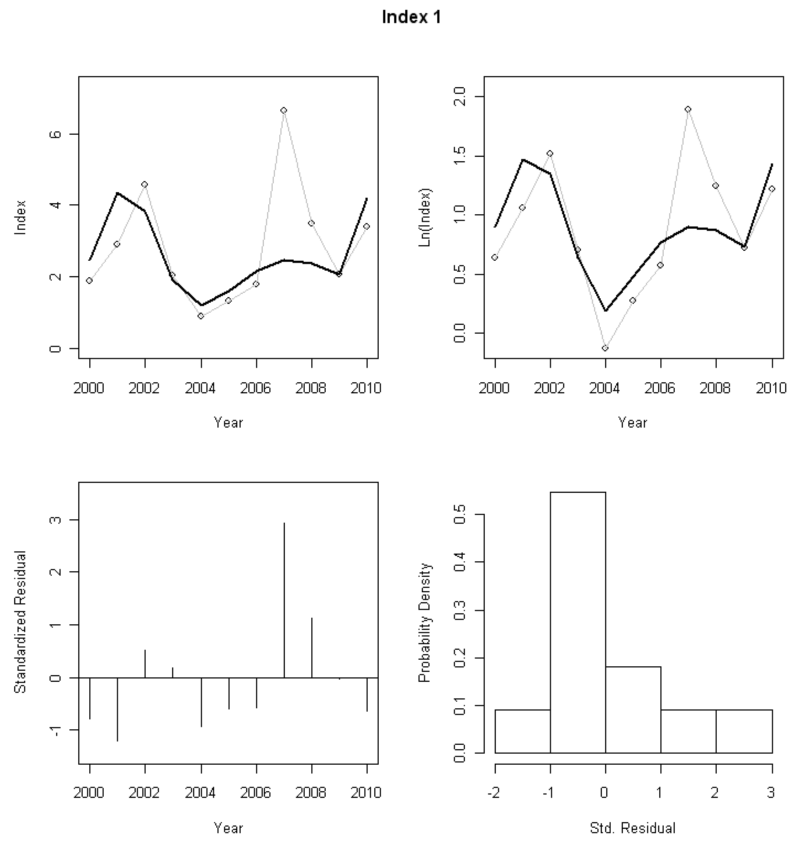


Figure 6.2.11. Fit to the French Otter Trawl tuning index for Cod VIIe–k.

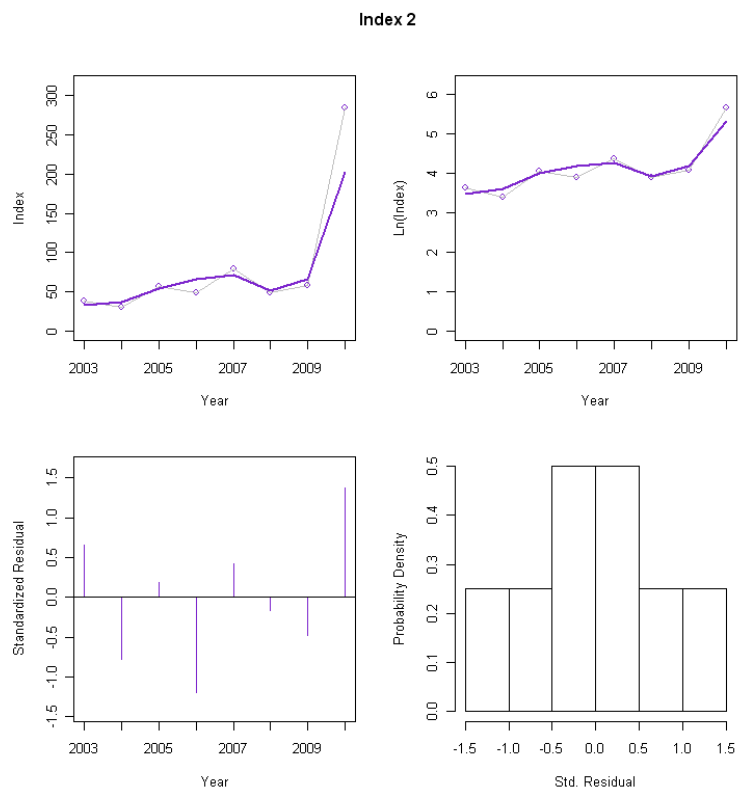


Figure 6.2.12. Fit to the combined Irish/French survey index for Cod VIIe–k.

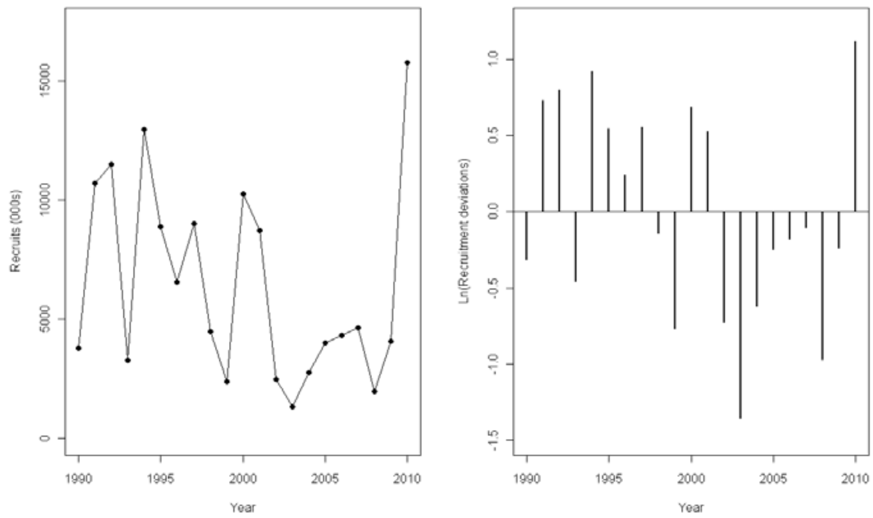
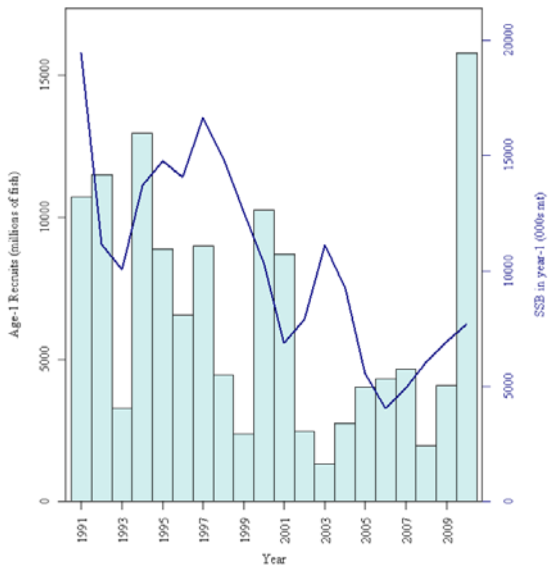


Figure 6.2.13. Predicted recruitment (left) and annual deviations from the mean (left) for Cod VIIe–k.



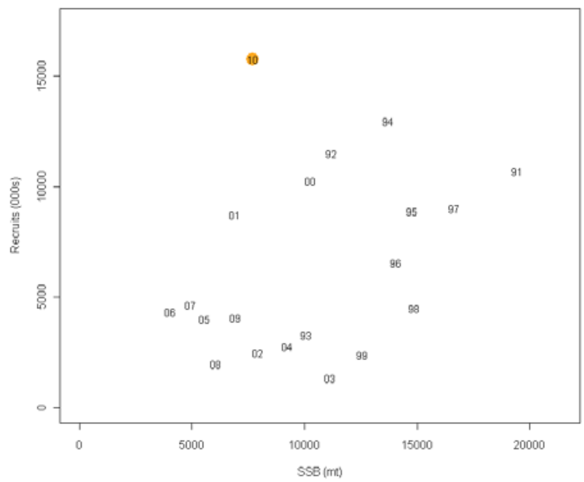


Figure 6.2.14. Estimated recruitment (blue bars, top) and SSB (blue line, top) and also the scatter-plot of recruitment versus SSB with two digit year symbol (bottom) for Cod VIIe–k.

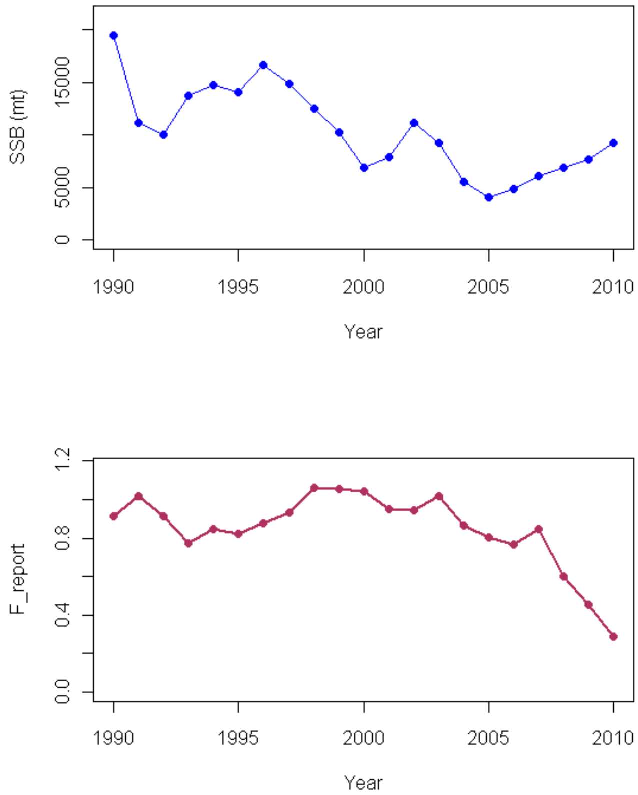


Figure 6.2.15. Estimated trajectories for SSB and F2–5 for cod VIIe–k.

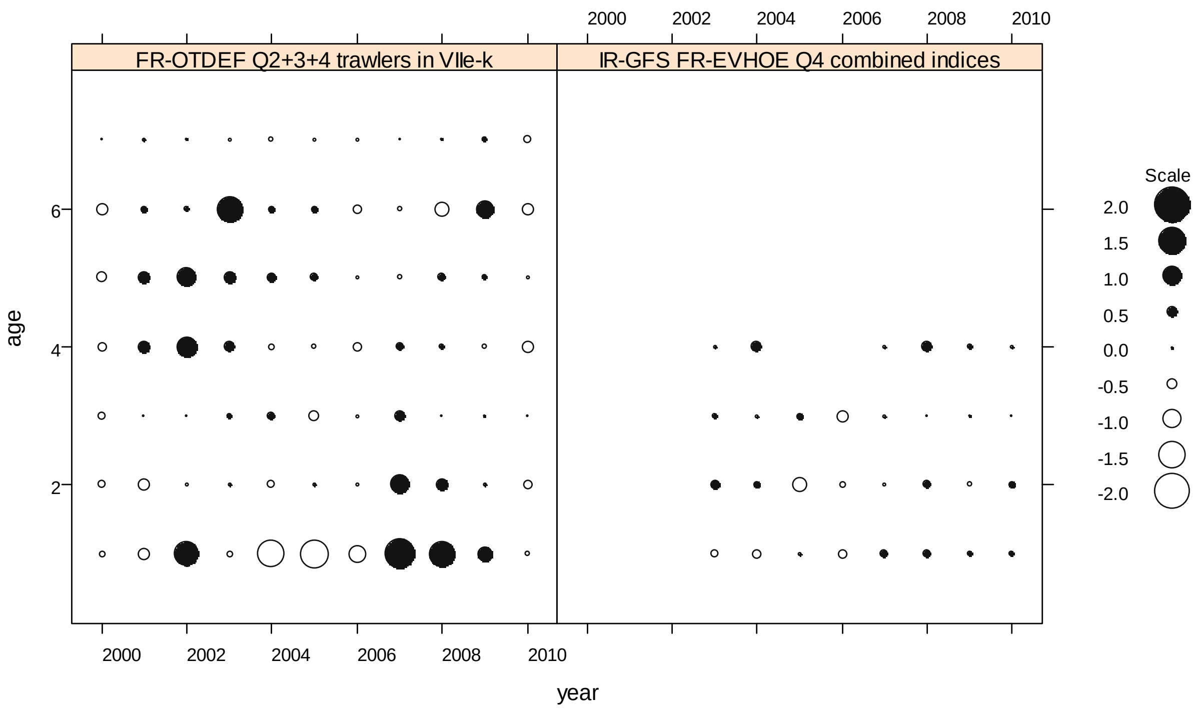


Figure 6.2.16. Residuals from both XSA assessment for both FR-OTDEF commercial fleet and combined EVHOE-WIBTS and IGFS-WIBTS survey.

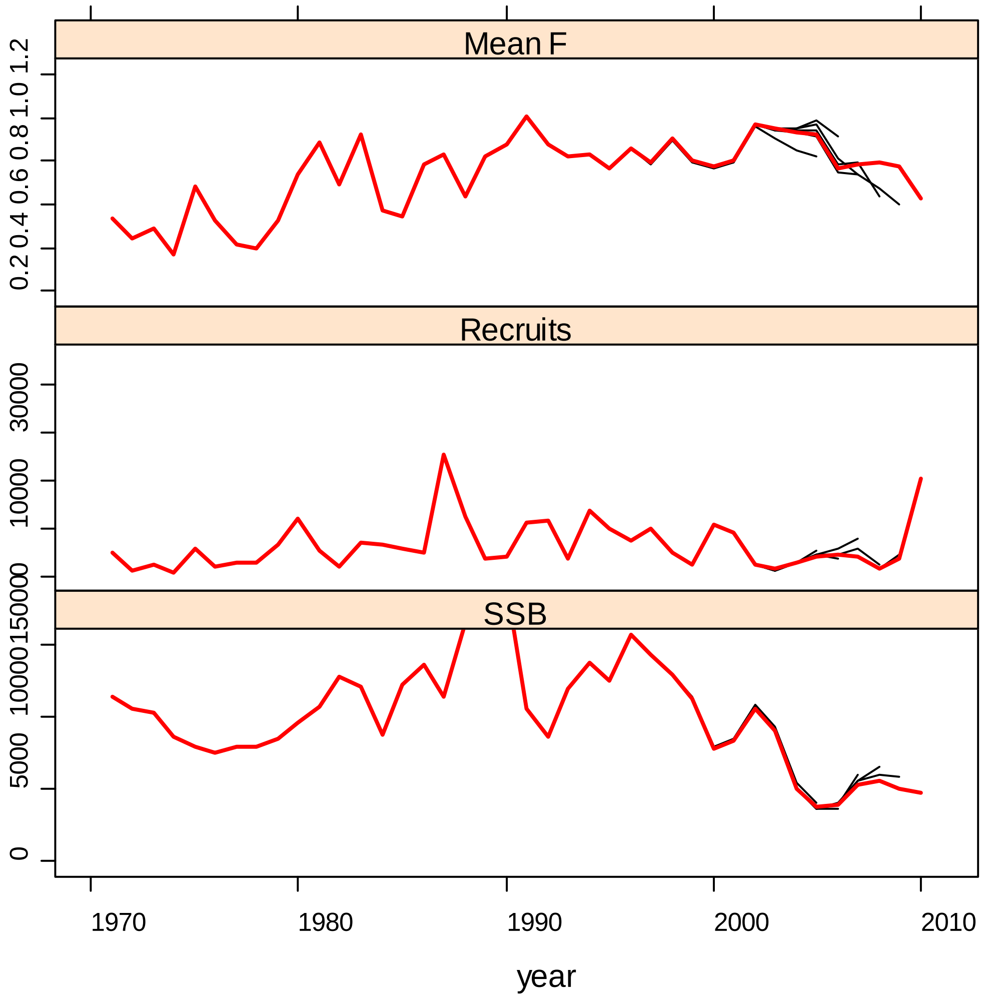


Figure 6.2.17. Retrospective runs.

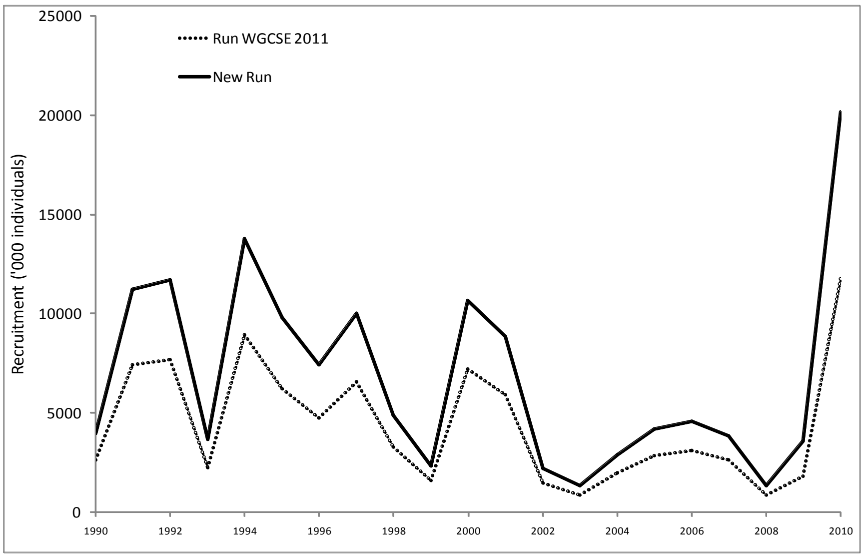


Figure 6.2.18. Estimates of Recruitment (continuous line: XSA with new parameters, dotted line: previous XSA assessment. WGCSE, 2011).

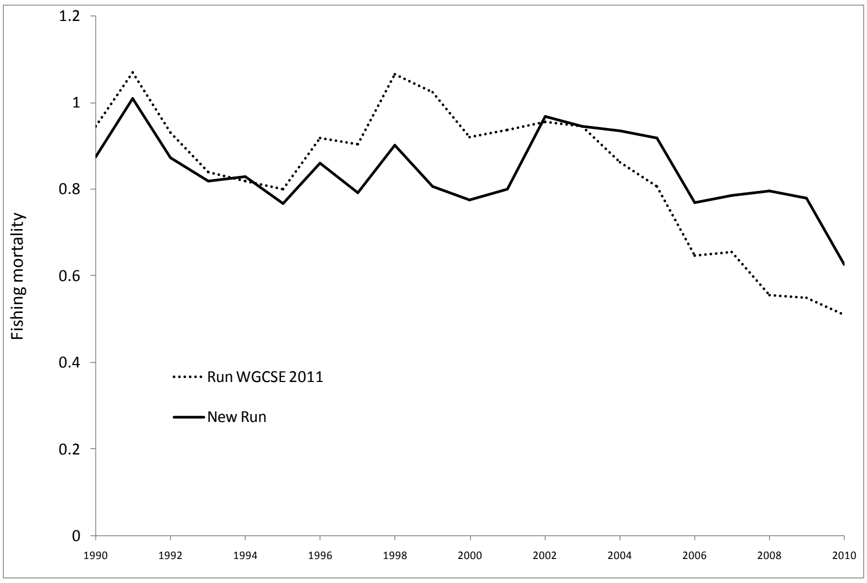


Figure 6.2.19. Estimates of fishing mortality (continuous line: XSA with new parameters, dotted line: previous XSA assessment. WGCSE, 2011).

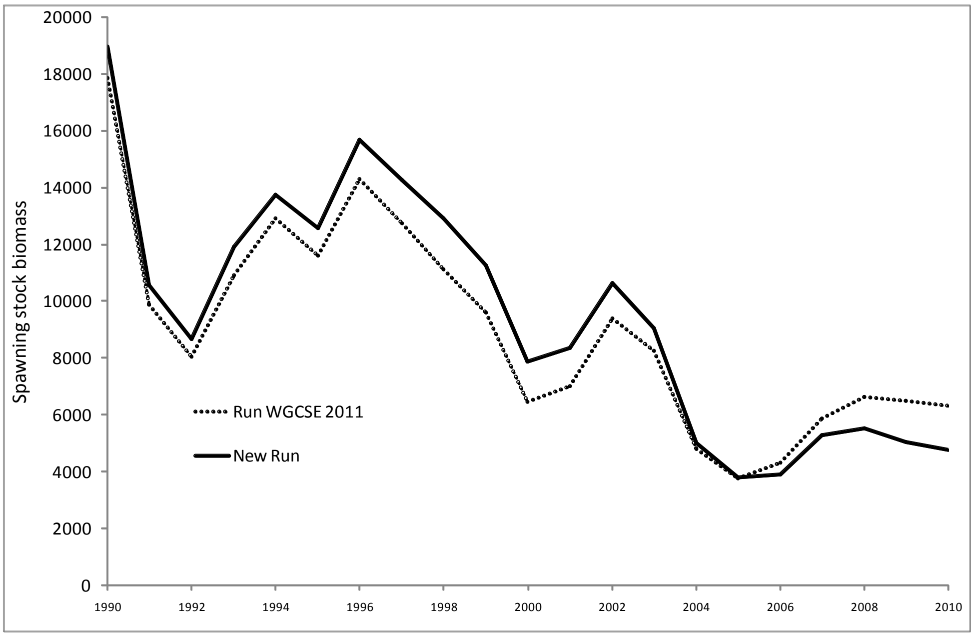


Figure 6.2.20. Estimates of SSB (continuous line: XSA with new parameters, dotted line: previous XSA assessment. WGCSE, 2011).

	0.0000	0.0100	0.0200	0.0300	0.0400	0.0500	0.0600	0.0700	0.0800	0.0900	0.1000	0.1100
YPR	0.0000	0.1415	0.2678	0.3807	0.4819	0.5726	0.6541	0.7274	0.7933	0.8527	0.9062	0.9544
SSB/R	17.4335	16.5101	15.6626	14.8827	14.1628	13.4967	12.8789	12.3046	11.7698	11.2706	10.8039	10.3668

YPR SSB/R

Figure 6.4.1. Yield and SSB per Recruit plots.

7 Haddock in Divisions VIIb–k (Celtic Sea)

7.1 Overview of data sources

7.1.1 Landings

Landings data are provided annually by France, Ireland, UK and Belgium. Landings age compositions are provided by France (VIIfgh), Ireland (VIIbc,VIIjk, VIIfgh) and UK (VIIe–k) since 2002.

Up to 2001 only the Irish age compositions were available; these data were raised to the international landings. Figure 7.1 shows the log catch ratios for the landings-at-age. There are some year-effects at the start of the time-series, which appear to be related to changes in effort in those years. Table 7.2 includes the landings data (including discards).

Revisions and amendments

The Irish age compositions that were used to estimate the international numbers-at-age for the period 1993–2001 were revised. Originally the age compositions for all ICES Divisions were raised to the international level. However the age composition in VIIb is known to be different and nearly all haddock catches in this area are taken by Irish vessels. Therefore the Irish age compositions in VIIgj were used to estimate the international numbers-at-age as these were expected to be more representative.

7.1.2 Misreporting

Some anecdotal evidence of species-misreporting was presented at WGSSDS 2005. Misreporting has never been quantified and is not considered to be a major problem.

7.1.3 Discards

Irish discards have been monitored since 1995. The number of trips sampled has varied considerably over time (between three and 59 trips per year). Sample numbers were particularly low in 1995, 1999–2002 and 2006. During the remaining years, the number of sampled trips was considered sufficient to give reliable estimates of discards.

French discard data exist from 2004 onwards but the data are not considered to be reliable before 2008.

Revisions and amendments

Historically, Irish discards were raised using the number of fishing trips as auxiliary variable, stratified by ICES division. WD13 outlines an analysis of a range of raising methods. This document concluded that the most appropriate raising method was to use fishing effort (hours fished) as auxiliary variable. This raising procedure resulted in the highest precision and was considered to be less likely to be biased than the use of trips as auxiliary variable. Stratification by ICES division was retained because sampling targets are set using this stratification.

French discards were also raised using effort (hours fished) as auxiliary variable. Length distributions of the French and Irish discard data are shown in Figure 7.2.

Age data were available for the Irish discards, however these data appeared to be unreliable, therefore a quarterly age–length split was applied to the smallest age classes (where the cohorts can be easily identified from the length distribution), while quarterly ALKs for the landings were used for length classes where the discards and landings overlap. Table 7.1 gives the age splits used. The age composition of haddock in VIIb is known to be different to that in VIIe–k. Therefore separate age–length-splits and ALKs were applied for Irish data from VIIb and VIIe–k. French data were also treated separately (French landings ALKs were used for the French discard data and the length-splits were slightly different). ALKs were also applied to length distributions of the retained catch to estimate proportions discarded-at-age.

The time-series of French discards was reconstructed by assuming that 90% of one-year olds, 50% of two-year olds and 10% of three year olds were discarded throughout the time-series. These proportions were estimated from the available discard and retained catch data provided by France (Figure 7.3). The discard rates were applied to the French landings numbers-at-age to estimate the discard numbers-at-age. For the period 1993–2001, no French age composition data were available, therefore Irish age composition data in VIIgj were raised to French landings and the discard numbers were estimated from these. The French and Irish discards were combined and a further raising factor was applied to account for discards from other countries. This raising factor was based on the total landings divided by the combined French and Irish landings and varied between 1.08 and 1.15.

Proposals for use in future assessments

It is proposed to include discards in the catch data in the ASAP assessment. However it needs to be noted that the precision and accuracy of the discard data is very low, particularly at the start of the time-series. Therefore the CV for landings needs be set at a relatively high value.

7.1.4 Surveys and commercial tuning fleets

The following tuning fleets were available:

FR_IR_IBTS	2003–2010	VIIbghj	Combined Irish and French Western IBTS Q4 (IGFS/EVHOE)
FR_IBTS	1997–2002	VIIghj	French Western IBTS Q4 (EVHOE)
IR_IBTS	1997–2002	VIIg	Irish Sea / Celtic Sea Groundfish Survey Q4 VIIg
FR_OT_DEF	2004–2010	VIIb-k	French demersal fish otter trawlers
IR_GAD	1995–2010	VIIgj	Irish otter trawlers in 32D9, 31D9, 31E0, 31E1, 31E2, 32E1 and 32E2

WKROUND decided to use a combined survey index (FR_IR_IGFS), rather than two separate survey indices that each cover part of the stock. WD12 outlines the detailed methods for combining the two surveys. In summary: the cpue and length distributions of the shared stations between the two surveys were very similar and it was concluded that the two indices could be combined directly, weighted only by the surface area of each survey (Irish survey: 37 000 nm^2; French survey 30 000 nm^2).

The combined survey index starts in 2003 and covers nearly the entire stock area (except VIIe). The French survey (FR_IBTS) started in 1997 so there is a remaining time-series from 1997–2002 for this survey. There is also a short time-series of an Irish survey in VIIg (IR_IBTS); this could not be incorporated in the combined survey because it used a smaller gear and only covered VIIg.

A French commercial OTB DEF tuning fleet (targeting demersal fish) has also been made available.

An Irish commercial OTB fleet is available from 1995 onwards. This fleet is based on the landings and effort from ICES Rectangles 32D9, 31D9, 31E0, 31E1, 31E2, 32E1 and 32E2. These rectangles were selected in order to avoid changes in lpue due to shifts in targeting behaviour. The Irish OTB fleet has shown changes over time in the targeting of *Nephrops* and monkfish. The selected rectangles do not include any major *Nephrops* or monkfish fishing grounds or areas with seasonal closures and is therefore not considered to be very sensitive to changes in spatial distribution of the fisheries.

Proposals for use in future assessments

Figures 7.4-7.6 give information on the internal consistency of the indices. The combined IR_FR_IBTS survey showed good internal consistency and provides valuable information on incoming cohorts. Therefore WKROUND considers that this index should be included. It was decided not to include the FR_IBTS and IR_IBTS because they were noisy and would not add much information to the model. The FR_OT_DEF index was based on the majority of the landings data and was therefore likely to be correlated to the landings numbers-at-age. Therefore it was decided not to include this index. The IR_GAD index was retained because it spanned nearly the full time-series. It is somewhat unusual to include commercial tuning fleets in assessments, but the survey time-series is relatively short and provides no information on the older ages; therefore it was considered unavoidable to include the commercial tuning fleet.

Table 7.2 includes the tuning fleet data.

Proposals for future improvements

Once the time-series of VMS data is sufficiently long it will become possible to spatially stratify commercial lpue data. This will allow the construction of a commercial tuning fleet that has no bias due to changes in spatial distribution of the effort.

7.1.5 Natural mortality

Natural mortality was previously assumed to be 0.2 for all ages. Revised natural mortality estimates were derived from mean catch weights-at-age using the approach proposed by Lorenzen (1996). Parameter values were obtained from Table 1 in the Lorenzen paper (ocean ecosystems: $\alpha = 3.69$; $\beta = -0.305$). These values were chosen in absence of empirical data. Although some temporal variation is apparent in the weights-at-age, it is not clear how much of this is due to noise. It was decided that in the absence of a clear trend in weights-at-age, a time-invariant natural mortality would be used:

Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
0.99	0.72	0.60	0.50	0.43	0.40	0.37	0.36	0.34

7.1.6 Catch weights

Discard weights were estimated from a fixed length–weight relationship (a = -11.809; b = 3.069). This was applied to the discard length distributions-at-age. For the landings weights, length–weight relationships were estimated for each year and quarter from the individual weights of the fish that were aged. Landings and discard weights are combined to estimate catch weights. The values are weighted by the numbers-at-age. Catch weights are given in Table 7.2.

Revisions and amendments

The revision to the landings age composition estimation method for the period 1993–2001 resulted in some changes in the catch weights during that period.

7.1.7 Stock weights

Quarter-1 catch weights were used as stock weights. If no data were available, quarter-2 weights were used. Some temporal variation exists in the stock weights; however the weights appear to vary annually, rather than by cohort. In order to preserve this variation, while smoothing out some of the noise, a 3-year running average was applied to the stock weights. Stock weights are given in Table 7.2 and Figure 7.7. There appears to be a cyclical trend in the weights of the older fish, which were lowest around 1998 and highest around 2005.

Revisions and amendments

The revision to the landings age composition estimation method for the period 1993–2001 resulted in some changes in the catch weights during that period.

7.1.8 Maturity

Irish maturity data were available from 2004 onwards. These data suggested that the current age-2 knife-edge maturity ogive is appropriate for females. Some males are mature as early as age-1 but female maturity is considered more relevant in this context; the maturity ogive is used to estimate SSB, which is a proxy for reproductive potential, this in turn is probably more limited by female maturity than male maturity. Because there is no evidence of a trend in maturity, time-invariant maturity ogives were used. No revisions were made for this benchmark

7.2 Assessment

7.2.1 Outline of known problems

The assessment has historically been accepted to be indicative of trends and a relative short-term forecast has been supplied. The main reason why the assessment was not accepted to provide absolute estimates was that the XSA assumes the catch data to be exact. With the large uncertainty around the discards, this assumption was clearly violated. The ASAP model is a forward-projecting statistical catch-at-age model that allows uncertainty in both the catches and age composition to be specified. Therefore, it addresses this concern.

Nevertheless it should be noted that the historic discard data are estimated with considerable uncertainty and additionally, the age composition data before 2002 is based on Irish samples only and may therefore be biased.

Additionally there is no survey tuning fleet available for the start of the time-series, therefore it is necessary to include a commercial tuning fleet.

7.2.2 Trial assessments

7.2.2.1 Trial assessments with ASAP

Initial trials were performed in ASAP with discards and landings specified separately. This allowed a higher CV to be specified for the discard data than for the landings. However, this resulted in the predicted landings being consistently lower than the observed landings and the predicted discards were consistently higher than the observed discards. When the discards were included in the catch, the residual patterns were improved.

Because the low precision of the discard estimates was still a major concern, trial runs were performed where the discard numbers-at-age were halved or doubled. Figure 7.8 shows that the model results are surprisingly robust to these discard estimates.

A number of other trial runs were performed and the model outputs appeared quite insensitive to changes in the settings for CVs, selectivity, inclusion of additional tuning fleets and natural mortality.

Lessons learned

Overall the assessment appears to be very robust. This is likely to be due to the strong contrast that exists in the catch-at-age matrix.

7.2.2.2 Comparison with XSA

The final ASAP assessment was also compared with an XSA run with the same input data (Figure 7.9). In general the two assessments show similar trends and absolute estimates. ASAP estimates of SSB are slightly lower in most years than the XSA estimates but the trends are quite similar. ASAP and XSA disagree on the F-bar estimate at the start of the time-series and in 2002. The data at the start of the time-series are particularly uncertain and 2002 was the first year for which French data were available, which might have resulted in spurious F patterns. The trends in recruitment are very similar although the absolute estimates from ASAP are somewhat lower than those from XSA.

Lessons learned

Despite the assumption of exact catch data, the XSA model shows similar trends and absolute estimates to the ASAP model. The data at the start of the time-series are noisy and the estimates from the early years should be treated with caution. However, in more recent years the data are more reliable and therefore the model estimates in recent years and forecasts are expected to be reliable.

7.2.3 Final assessment (ASAP)

Input data and settings

ASAP was adopted as the main assessment tool. The input data and settings are shown in Table 7.2 and in the stock annex.

Residuals

Figure 7.10 shows the residuals of the catch proportions-at-age. The residuals are large for the young ages, which is to be expected because these are most abundant in the catch and are estimated with low precision. There are no clear patterns in the residuals. Figure 7.11 shows the observed and predicted catches. In general, the model followed the observed catches quite closely. Figure 7.12 shows the residuals of the index proportions-at-age. There are no clear patterns in the residuals. Figure 7.13 shows the observed and predicted cpue for the indices. The model follows the FR_IR_IBTS survey index quite closely, the difference between observed and predicted cpue for the IR_GAD commercial fleet is somewhat larger but there are no obvious residual patterns.

Selectivity

Figure 7.14 shows the fleet (catch) selectivity. The model estimates selectivity-at-age 1 to be 0.38 and at age 2 to be 1.00 (it was fixed at one for all older ages). Figure 7.15 shows the selectivity of the tuning fleets. Selectivity was fixed at one for all ages in the FR_IR_IBTS survey index. For the IR_GAD commercial index, the model estimated selectivity-at-age 3 to be 0.84 (it was fixed at one for all older ages).

Retrospective analysis

Figure 7.16 shows the retrospective analysis. Note that the survey only started in 2003. The catch estimates show no retrospective pattern. There appears to be some retrospective pattern in the SSB and F. SSB is generally adjusted upwards and F downwards as new data is added. This pattern may improve in the future as the survey time-series gets longer. There is no retrospective pattern in the recruitment estimate.

Final assessment

The summary table of the final assessment is given in Table 7.4

7.2.4 Conclusions on assessment methods

ASAP is proposed as the main assessment model. However, due to the short time-series and uncertain catch data at the start of the time-series, it is uncertain whether the separable assumption is valid. Therefore it is proposed to also use XSA to monitor if the two models continue to provide similar trends and absolute estimates of SSB and F. If the models start to diverge, the reasons for this will need to be investigated and explained.

The data informing about the historical abundance and exploitation of the Celtic Sea haddock are noisy and not very reliable. The more recent data are probably more reliable than the early part of the time-series. Therefore, the results should be treated with caution, in particular the early part of the assessment period. The present state of the stock is probably rather well estimated and a short-term prediction based on this assessment is probably a better basis for advice than the trends in the estimated population abundance. WKROUND therefore approves the proposed assessment as basis for future TAC advice, with the caveat that the estimates of exploitation and abundance in the early period of the assessment are highly uncertain.

7.2.5 Recommendations for future developments

Once the time-series of reliable discard data is longer, it may be advisable to split the catch data into two selectivity blocks. Also it would be desirable to include the discards separately from the landings to allow the discards to be given a higher CV and lower effective sample size than the catches.

7.3 Short-term predictions

7.3.1 Method

Software used: MFDP1a (http://www.ices.dk/datacentre/software.asp)

7.3.2 Recruitment

Long-term geometric mean (GM) omitting last two years. Haddock stocks are known to have sporadic events of very high recruitment. A GM is therefore more appropriate than an arithmetic mean. The alternative would be to take a mean of all the 'normal' recruitment years, thus assuming that the next year class will not be outstanding. However, this would require a clearer distinction between normal and outstanding year classes than is seen in the historical recruitment estimates. Any retrospective patterns in the recruitment estimates should be monitored to determine if more than just the last two years should be omitted.

7.3.3 Weights, maturity

Average stock and catch weights over the last three years. Some long-term trends may exist in the weights-at-age. It was felt that a 3-year average would be more robust than just the weights in the last year, while allowing long-term trends to be taken into account.

Maturity is assumed to be time-invariant.

7.3.4 Assumptions for intermediate year

Recruitment in the intermediate year: long-term GM (see above).

Use F in the last year. Monitor retrospective pattern for evidence of bias. There is currently some retrospective pattern in F, however this may be an artefact of the introduction of the survey in 2003 and observed French discards in 2008 (before 2008 French discards were estimated from the landings).

7.3.5 Results

Input data for the short-term forecast are given in Table 7.4. Landings and discard numbers and weights were supplied separately. Table 7.5 gives the management options. Estimates of the relative contribution of recent year classes to the 2012 landings and 2013 SSB are shown in Table 7.6. The high recruitment in 2009 accounts for 75% of the projected landings in 2012 and for 33% of the SSB in 2013.

7.4 Implications for reference points

7.4.1 Precautionary reference points

No accepted precautionary reference points currently exist. Fmax of the landings is 0.28 and F0.1 of the landings is 0.19.

The only biomass reference point that can be suggested is an SSB of 7500 tonnes, which is the lowest (and fist) in the time-series. The current SSB is more than four times that size and is expected to have increased further in 2011.

7.4.2 MSY reference points

No stock–recruitment relationship can be defined for this stock due to the erratic nature of recruitment.

If one assumes recruitment to be independent of stock size (flat line) then $F_{msy} = F_{max} = 0.28$.

Table 7.1. Length-splits applied to the discard data. For lengths where landings ALKs were available, these were used.

Country	Area	Quarter	Age 0	Age 1	Age 2	Age 3
Ireland	VIIb	1	≤10	11–18	19–27	≥28
		2	≤11	12–21	22–29	≥30
		3	≤14	15–23	24–33	≥34
		4	≤17	18–25	26–34	≥35
Ireland	VIIgj	1	≤15	16–23	24–34	≥35
		2	≤17	18–26	≥27	
		3	≤20	21–29	≥30	
		4	≤21	22–30	≥31	
France	VIIbk	1	≤18	19–23	24–32	≥33
		2	≤17	18–26	27–34	≥35
		3	≤20	21–29	≥30	
		4	≤21	22–29	≥30	

Table 7.2. Input data for ASAP, note that age 1 in ASAP corresponds to age 0.

```
# ASAP VERSION 2.0
# Had7b-k
#
# ASAP GUI - 15 JAN 2008
#
# Number of Years
18
# First Year
1993
# Number of Ages
9
# Number of Fleets
1
# Number of Selectivity Blocks (sum over all fleets)
1
# Number of Available Indices
3
# Fleet Names
#$LAND
# Index Names
#$FR-IRL-IBTS
#$FR-OT-DEF
#$IRL-GAD
#
# Natural Mortality Rate Matrix
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
```

```
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
0.99  0.72  0.60  0.50  0.43  0.40  0.37  0.36  0.34
# Fecundity Option
0
# Fraction of year that elapses prior to SSB calculation (0=Jan-1)
0
# Maturity Matrix
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
0.0  0.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
# Weight at Age for Catch Matrix
0.000  0.090  0.257  0.524  0.848  1.402  1.693  2.130  2.573
0.000  0.100  0.358  0.614  0.987  1.456  1.745  2.014  2.536
0.000  0.089  0.388  0.875  1.321  1.188  1.746  0.000  0.000
0.000  0.130  0.275  0.576  0.799  1.181  1.369  1.828  1.827
0.000  0.097  0.305  0.743  1.205  1.362  1.268  1.412  1.176
0.000  0.103  0.295  0.610  0.938  0.958  1.089  1.293  1.455
0.000  0.128  0.297  0.847  1.072  1.186  1.223  0.908  1.708
```

```
0.000  0.091  0.451  1.189  1.463  1.719  1.627  1.163  1.459
0.000  0.119  0.378  0.963  1.857  1.783  1.705  2.297  1.612
0.000  0.095  0.294  0.790  1.026  1.732  1.671  1.504  1.571
0.000  0.133  0.353  0.807  1.236  1.429  1.800  1.705  1.708
0.000  0.136  0.284  0.653  1.141  1.380  1.855  1.806  2.062
0.000  0.136  0.211  0.497  0.976  1.256  1.946  2.667  1.948
0.000  0.162  0.347  0.500  0.929  1.486  2.118  2.619  4.022
0.000  0.167  0.338  0.564  0.850  1.199  1.630  1.487  2.821
0.000  0.129  0.285  0.456  0.729  1.139  1.267  1.654  1.842
0.000  0.118  0.289  0.614  0.842  1.310  1.544  1.646  2.431
0.000  0.114  0.268  0.653  1.076  1.773  1.862  1.739  1.676
# Weight at Age for Spawning Stock Biomass Matrix
0.041  0.093  0.277  0.641  0.824  1.804  2.089  2.407  2.647
0.042  0.093  0.290  0.756  1.138  2.360  2.163  2.407  2.647
0.045  0.102  0.295  0.715  1.232  2.174  1.972  2.169  2.386
0.046  0.100  0.313  0.719  1.246  2.046  1.773  1.950  2.145
0.043  0.098  0.287  0.579  0.904  1.145  1.263  1.631  1.795
0.037  0.096  0.274  0.655  0.870  1.005  1.017  1.252  1.377
0.028  0.102  0.264  0.790  0.962  1.149  1.205  1.349  1.484
0.027  0.108  0.303  0.926  1.326  1.548  1.605  1.765  1.942
0.022  0.101  0.310  0.922  1.329  1.633  1.672  1.839  2.023
0.021  0.109  0.312  0.842  1.402  1.677  1.895  2.084  2.292
0.023  0.119  0.278  0.731  1.202  1.611  1.944  2.138  2.352
0.032  0.133  0.251  0.629  1.224  1.676  2.315  2.547  2.802
0.037  0.139  0.253  0.526  1.073  1.606  2.172  2.421  2.663
0.043  0.149  0.269  0.501  0.955  1.451  2.110  2.564  2.821
0.041  0.147  0.287  0.495  0.835  1.363  1.820  2.203  2.423
0.048  0.137  0.271  0.523  0.802  1.203  1.666  1.891  2.080
0.048  0.120  0.253  0.534  0.834  1.306  1.546  1.824  2.006
0.051  0.116  0.253  0.592  0.909  1.346  1.610  1.858  2.043
# Weight at Age for Jan-1 Biomass Matrix
0.041  0.093  0.277  0.641  0.824  1.804  2.089  2.407  2.647
0.042  0.093  0.290  0.756  1.138  2.360  2.163  2.407  2.647
0.045  0.102  0.295  0.715  1.232  2.174  1.972  2.169  2.386
0.046  0.100  0.313  0.719  1.246  2.046  1.773  1.950  2.145
0.043  0.098  0.287  0.579  0.904  1.145  1.263  1.631  1.795
0.037  0.096  0.274  0.655  0.870  1.005  1.017  1.252  1.377
0.028  0.102  0.264  0.790  0.962  1.149  1.205  1.349  1.484
0.027  0.108  0.303  0.926  1.326  1.548  1.605  1.765  1.942
0.022  0.101  0.310  0.922  1.329  1.633  1.672  1.839  2.023
0.021  0.109  0.312  0.842  1.402  1.677  1.895  2.084  2.292
0.023  0.119  0.278  0.731  1.202  1.611  1.944  2.138  2.352
0.032  0.133  0.251  0.629  1.224  1.676  2.315  2.547  2.802
0.037  0.139  0.253  0.526  1.073  1.606  2.172  2.421  2.663
0.043  0.149  0.269  0.501  0.955  1.451  2.110  2.564  2.821
0.041  0.147  0.287  0.495  0.835  1.363  1.820  2.203  2.423
```

```
0.048  0.137  0.271  0.523  0.802  1.203  1.666  1.891  2.080
0.048  0.120  0.253  0.534  0.834  1.306  1.546  1.824  2.006
0.051  0.116  0.253  0.592  0.909  1.346  1.610  1.858  2.043
# Selectivity Blocks (fleet outer loop, year inner loop)
# Sel block for fleet 1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
# Selectivity Options for each block 1=by age, 2=logisitic, 3=double logistic
1
# Selectivity initial guess, phase, lambda, and CV
# (have to enter values for nages + 6 parameters for each block)
# Sel Block 1
0              -1             0              1
0.5            1              0              1
1              1              0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              1              0              1
1              1              0              1
1              1              0              1
1              1              0              1
1              1              0              1
1              1              0              1
# Selectivity Start Age by fleet
1
# Selectivity End Age by fleet
```

```
9
# Age range for average F
4  6
# Average F report option (1=unweighted, 2=Nweighted, 3=Bweighted)
1
# Use likelihood constants? (1=yes)
1
# Release Mortality by fleet
1
# Fleet 1 Catch at Age - Last Column is Total Weight (including discards)
0     8107      6107     1108     816      255     129     129     42      4557.0
0     16396     8292     844      307      94      24      35      14      6017.0
0     37105     3599     1419     273      245     46      0       0       6688.0
0     24428     24973    1005     321      93      32      10      4       11064.0
0     13965     19667    6046     722      354     139     144     59      13710.0
0     3742      5424     7599     1400     298     173     84      41      8603.0
0     4210      2205     1538     2392     302     18      19      3       5468.0
0     31186     5482     839      735      1235    203     34      21      9913.0
0     29232     14808    1272     283      295     298     51      29      12050.0
0     22496     24945    3603     766      39      88      73      19      13476.0
0     52970     18984    2336     1157     112     42      48      41      17497.0
0     11850     27467    5935     943      573     50      12      16      15331.0
0     16687     11600    8481     2033     436     114     4       13      11746.0
0     10208     7443     1812     2139     376     64      7       0       7867.0
0     7041      13264    3228     537      827     149     29      3       9249.0
0     50292     19512    9704     1244     216     358     65      11      18236.0
0     24341     33741    4177     2461     475     140     107     24      18357.0
0     98318     27601    7893     996      472     156     65      53      26202.0
# Fleet 1 Discards at Age - (for reference only, already included in catch at
age!)
0      7617    2816    160     6       0       0       0       0       1208
0      15120   3069    170     5       0       0       0       0       1886
0      32830   1977    91      4       0       0       0       0       2218
0      20734   8976    187     9       0       0       0       0       4309
0      12613   10022   493     5       0       0       0       0       2883
0      3580    2348    445     5       0       0       0       0       934
0      3742    1562    100     10      0       0       0       0       586
0      29015   2521    64      3       0       0       0       0       2503
0      25234   6772    219     2       0       0       0       0       3418
0      21624   20729   249     7       0       0       0       0       7073
0      52305   10692   338     8       0       0       0       0       9351
0      11733   21598   1395    61      0       0       0       0       6750
0      15904   10766   4315    149     0       0       0       0       5191
0      9377    4130    381     33      0       0       0       0       2484
0      6387    7066    662     34      0       0       0       0       2739
0      48764   15658   5492    330     0       0       0       0       11187
0      23564   27018   873     581     0       0       0       0       9081
```

```
0       97083   22988   2105    130     0       0       0       0       16338
# Fleet 1 Release Proportion at Age
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
# Index Units
2  2  2
# Index Month
11  7  7
# Index Selectivity Choice
-1  -1  -1
# Index Selectivity Option for each Index 1=by age, 2=logisitic, 3=double lo-
gistic
1  1  1
# Index Start Age
1  4  4
# Index End Age
6  8  8
# Use Index? 1=yes
1  0  1
# Index Selectivity initial guess, phase, lambda, and CV
# (have to enter values for nages + 6 parameters for each block)
# Index-1
1              1              1              0.0001
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
1              -1             0              1
0              -1             0              1
0              -1             0              1
0              -1             0              1
```

1	1	0	1
1	1	0	1
0	-1	0	1
0.001	-1	0	1
1	1	0	1
1	1	0	1
# Index-2			
0	-1	0	1
0	-1	0	1
0	-1	0	1
0.8	1	0	1
1	-1	0	1
1	-1	0	1
1	-1	0	1
1	-1	0	1
0	-1	0	1
1	1	0	1
1	1	0	1
3	-1	0	1
1	-1	0	1
8	-1	0	1
1	-1	0	1
# Index-3			
0	-1	0	1
0	-1	0	1
0	-1	0	1
0.8	1	0	1
1	-1	0	1
1	-1	0	1
1	-1	0	1
1	-1	0	1
0	-1	0	1
1	1	0	1
1	1	0	1
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Index Data - Year, Index Value, CV, proportions at age and input effective sample size (only used if estimating parameters)

Phase for F mult in 1st Year

1

Phase for F mult Deviations

2

Phase for Recruitment Deviations

3

Phase for N in 1st Year

```
1
# Phase for Catchability in 1st Year
3
# Phase for Catchability Deviations
-5
# Phase for Stock Recruitment Relationship
1
# Phase for Steepness
-5
# Recruitment CV by Year
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
#Lambda for Each Index
1  1  1
# Lambda for Total Catch in Weight by Fleet
1
# Lambda for Total Discards at Age by Fleet
1
# Catch Total CV by Year and Fleet
0.300
0.300
0.300
0.300
0.300
0.300
0.300
0.300
0.300
0.300
0.300
```

```
0.300
0.300
0.300
0.300
0.200
0.200
0.200
# Discard Total CV by Year and Fleet
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
# Input Effective Sample Size for Catch at Age by Year & Fleet
25
25
25
25
25
25
25
25
25
50
50
50
50
50
50
50
50
50
# Input Effective Sample Size for Discards at Age by Year & Fleet
```

```
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
# Lambda for F mult in first year by fleet
0
# CV for F mult in first year by fleet
0.5
# Lambda for F mult Deviations by Fleet
0
# CV for F mult deviations by Fleet
0.5
# Lambda for N in 1st Year Deviations
0
# CV for N in 1st Year Deviations
1
# Lambda for Recruitment Deviations
0
# Lambda for Catchability in first year by index
0  0  0
# CV for Catchability in first year by index
1  1  1
# Lambda for Catchability Deviations by Index
0  0  0
# CV for Catchability Deviations by Index
1  1  1
# Lambda for Deviation from Initial Steepness
0
# CV for Deviation from Initial Steepness
1
# Lambda for Deviation from Initial unexploited Stock Size
0
```

```
# CV for Deviation from Initial unexploited Stock Size
1
# NAA for Year 1
100  90  80  70  60  50  40  30  20
# F mult in 1st year by Fleet
0.7
# Catchability in 1st year by index
1  1  1
# Initial unexploited Stock Size
1000
# Initial Steepness
1
# Maximum F
2.5
# Ignore Guesses
0
# Projection Control Data
# Do Projections? (1=yes, 0=no), still need to enter values even if not doing projections
0
# Fleet Directed Flag
1
# Final Year of Projections
2013
# Year Projected Recruits, What Projected, Target, non- directed F mult
2011     -1     4     0     1
2012     0     0     0     0
2013     0     0     0     0
# MCMC info
# doMCMC (1=yes)
0
# MCMCnyear option (0=use final year values of NAA, 1=use final year + 1 values of NAA)
0
# MCMCnboot
1000
# MCMCnthin
200
# MCMCseed
1415963
# R in agepro.bsn file (enter 0 to use NAA, 1 to use stock-recruit relationship, 2 to used geometric mean of previous years)
0
# Starting year for calculation of R
1993
# Starting year for calculation of R
2005
```

```
# Test Value
-23456
#####
# ---- FINIS ----
```

Table 7.3. Summary table.

Year	Catch (predicted)	SSB	Fbar	Recruits (age 0)
1993	4823	7504	1.13	102848
1994	5317	7530	1.12	361239
1995	6390	6494	0.93	495247
1996	11709	17450	0.87	135214
1997	12470	25530	0.72	67531
1998	8823	19397	0.77	141548
1999	5477	11972	0.56	384517
2000	9771	14523	0.70	367016
2001	14633	25094	0.71	411751
2002	21625	31769	1.31	743221
2003	15558	21752	0.65	200934
2004	20418	39173	0.80	257861
2005	13302	26047	0.83	245373
2006	9869	21097	0.54	176266
2007	7924	22196	0.43	634426
2008	14693	21016	0.81	372782
2009	16029	30616	0.68	1777860
2010	24787	31647	0.64	98700.2

Table 7.4. Input values for the short-term forecast (.prd file).

MFDP version 1a						
Run: mfdp						
Time and date: 12:07 13/03/2012						
Fbar age range (Total) : 3-5						
Fbar age range Fleet 1 : 3-5						
2011						
Age	N	M	Mat	PF	PM	SWt
0	257609	0.99	0	0	0	0.049
1	36675	0.72	0	0	0	0.124333
2	252688	0.6	1	0	0	0.259
3	15109	0.5	1	0	0	0.549667
4	7514	0.43	1	0	0	0.848333
5	695	0.4	1	0	0	1.285
6	404	0.37	1	0	0	1.607333
7	153	0.36	1	0	0	1.857667
8	93	0.34	1	0	0	2.043

CATCH						
Age	Sel	CWt	DSel	DCWt		
0	0	4.77E-02	0	4.77E-02		
1	6.83E-03	0.120333	0.260835	0.114333		
2	0.134283	0.280667	0.576376	0.221		
3	0.453115	0.574333	0.257552	0.298667		
4	0.557464	0.882333	0.153202	0.334		
5	0.710667	1.407333	0	0		
6	0.710667	1.557667	0	0		
7	0.710667	1.679667	0	0		
8	0.710667	1.983	0	0		
2012						
Age	N	M	Mat	PF	PM	SWt
0	257609	0.99	0	0	0	0.049
1	.	0.72	0	0	0	0.124333
2	.	0.6	1	0	0	0.259
3	.	0.5	1	0	0	0.549667
4	.	0.43	1	0	0	0.848333
5	.	0.4	1	0	0	1.285
6	.	0.37	1	0	0	1.607333
7	.	0.36	1	0	0	1.857667
8	.	0.34	1	0	0	2.043
CATCH						
Age	Sel	CWt	DSel	DCWt		
0	0	4.77E-02	0	4.77E-02		
1	6.83E-03	0.120333	0.260835	0.114333		
2	0.134283	0.280667	0.576376	0.221		
3	0.453115	0.574333	0.257552	0.298667		
4	0.557464	0.882333	0.153202	0.334		
5	0.710667	1.407333	0	0		
6	0.710667	1.557667	0	0		
7	0.710667	1.679667	0	0		
8	0.710667	1.983	0	0		
2013						
Age	N	M	Mat	PF	PM	SWt
0	257609	0.99	0	0	0	0.049
1	.	0.72	0	0	0	0.124333
2	.	0.6	1	0	0	0.259
3	.	0.5	1	0	0	0.549667
4	.	0.43	1	0	0	0.848333

5	.	0.4	1	0	0	1.285
6	.	0.37	1	0	0	1.607333
7	.	0.36	1	0	0	1.857667
8	.	0.34	1	0	0	2.043

CATCH				
Age	Sel	CWt	DSel	DCWt
0	0	4.77E-02	0	4.77E-02
1	6.83E-03	0.120333	0.260835	0.114333
2	0.134283	0.280667	0.576376	0.221
3	0.453115	0.574333	0.257552	0.298667
4	0.557464	0.882333	0.153202	0.334
5	0.710667	1.407333	0	0
6	0.710667	1.557667	0	0
7	0.710667	1.679667	0	0
8	0.710667	1.983	0	0

Input units are thousands and kg - output in tonnes

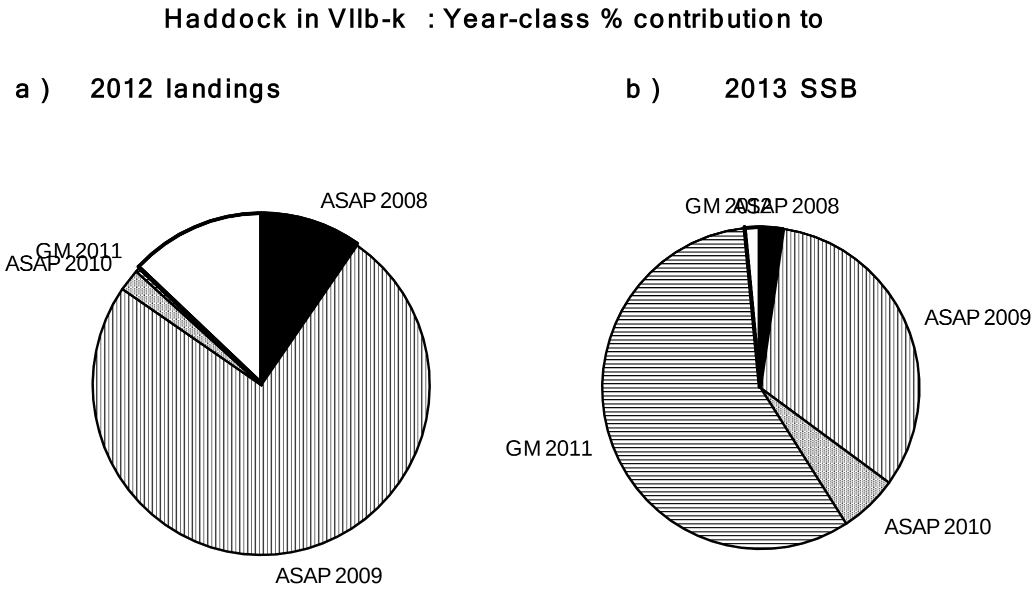
Table 7.5. Management options table (.prm file).

MFDP version 1a								
Run: mfdp								
Time and date: 12:07 13/03/2012								
Fbar age range (Total) : 3-5								
Fbar age range Fleet 1 : 3-5								
2011								
		"CATCH"	Landings		Discards			
Biomass	SSB	FMult	FBar	Yield	FBar	Yield		
99325	82142	1	0.5737	10697	0.1369	19534		
2012							2013	
		"CATCH"	Landings		Discards			
Biomass	SSB	FMult	FBar	Yield	FBar	Yield	Biomass	SSB
73215	48691	0	0	0	0	0	82734	58210
.	48691	0.1	0.0574	1803	0.0137	745	79250	54726
.	48691	0.2	0.1147	3493	0.0274	1452	75992	51468
.	48691	0.3	0.1721	5076	0.0411	2122	72944	48419
.	48691	0.4	0.2295	6561	0.0548	2758	70092	45568
.	48691	0.5	0.2869	7952	0.0685	3361	67423	42899
.	48691	0.6	0.3442	9258	0.0822	3935	64926	40402
.	48691	0.7	0.4016	10482	0.0958	4480	62588	38064
.	48691	0.8	0.459	11630	0.1095	4998	60399	35875
.	48691	0.9	0.5164	12708	0.1232	5491	58349	33825
.	48691	1	0.5737	13719	0.1369	5960	56429	31904
.	48691	1.1	0.6311	14669	0.1506	6407	54629	30105
.	48691	1.2	0.6885	15561	0.1643	6833	52943	28419
.	48691	1.3	0.7459	16399	0.178	7239	51363	26839
.	48691	1.4	0.8032	17186	0.1917	7626	49881	25357
.	48691	1.5	0.8606	17926	0.2054	7996	48492	23968
.	48691	1.6	0.918	18621	0.2191	8349	47189	22664
.	48691	1.7	0.9754	19275	0.2328	8686	45966	21441
.	48691	1.8	1.0327	19891	0.2465	9008	44818	20293
.	48691	1.9	1.0901	20470	0.2601	9317	43740	19216
.	48691	2	1.1475	21015	0.2738	9612	42728	18204
Input units are thousands and kg - output in tonnes								

Table 7.6. Stock numbers of recruits and their source for recent year classes used in predictions, and the relative (%) contributions to landings and SSB (by weight) of these year classes.

Year-class			2008	2009	2010	2011	2012
Stock No. (thousands) of 0 year-olds			266544	1252030	78342.1	257609	257609
Source			ASAP	ASAP	ASAP	GM	GM
Status Quo F:							
% in	2011	landings	21.3	49.6	0.2	0.0	-
% in	2012		9.6	74.9	2.1	0.4	0.0
% in	2011	SSB	10.1	79.7	0.0	0.0	-
% in	2012	SSB	5.0	76.4	15.3	0.0	0.0
% in	2013	SSB	2.3	32.7	5.9	57.5	0.0

GM : geometric mean recruitment



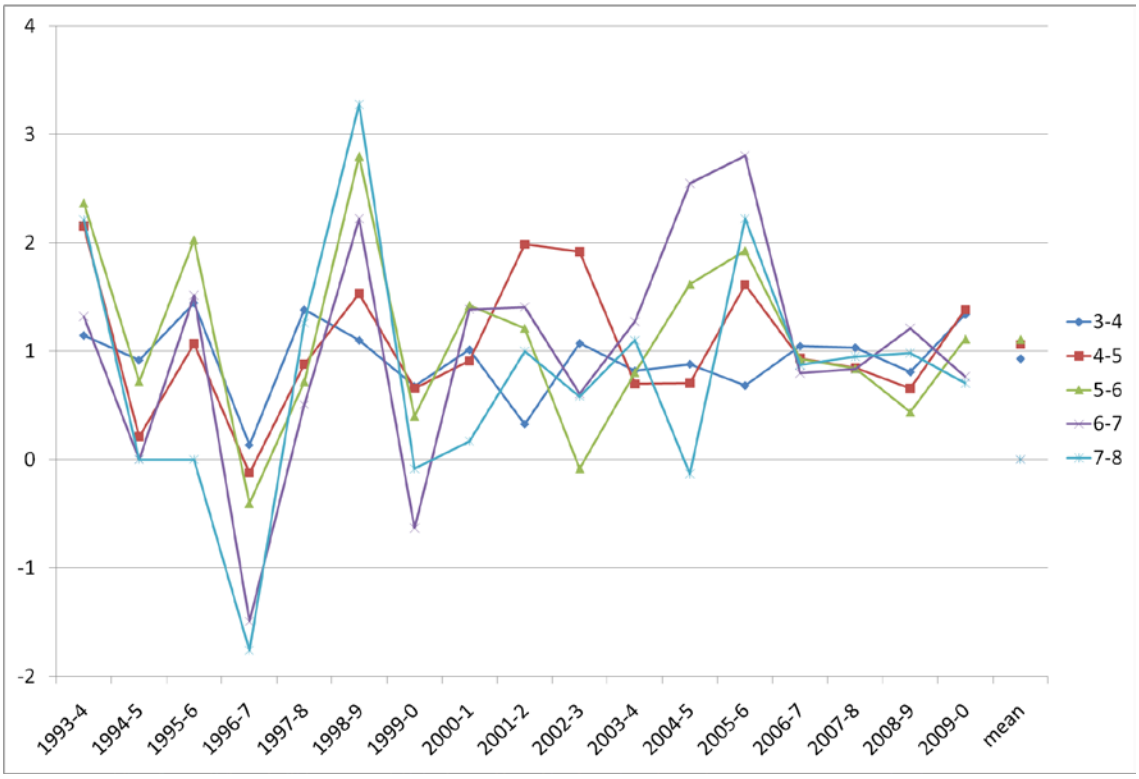


Figure 7.1. Log catch ratios of the landings data. There is a year-effect in 1994 but no overall trend over time. The mean log catch ratios for ages 3–7 are approximately the same, suggesting flat-topped selection.

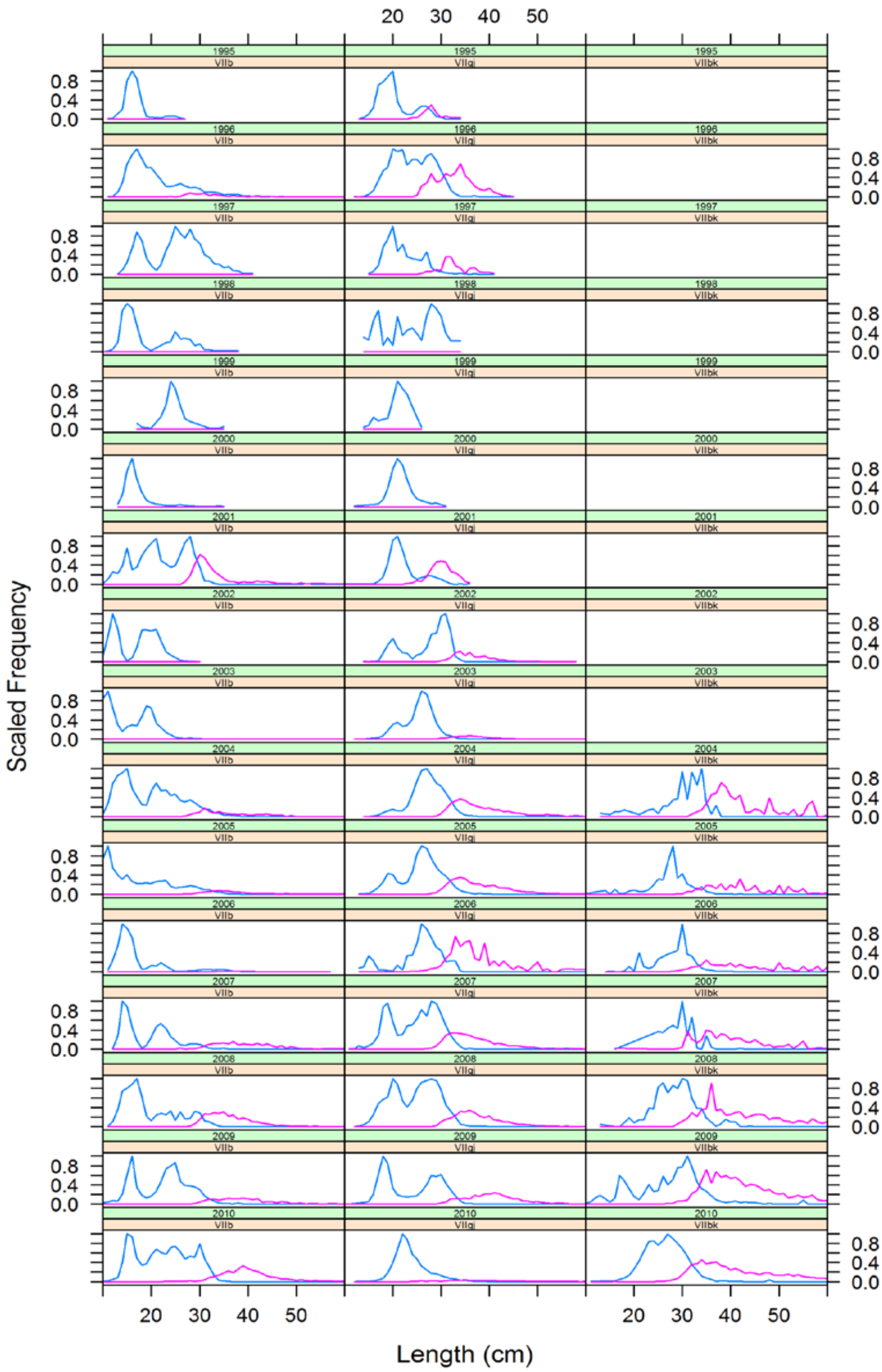


Figure 7.2. Discarded (blue) and retained (pink) catch length frequencies. Areas VIIb and VIIgj (left and middle columns) correspond to Irish data; Area VIIbk (right column) corresponds to French data. Retained catches were not always recorded at the start of the time-series.

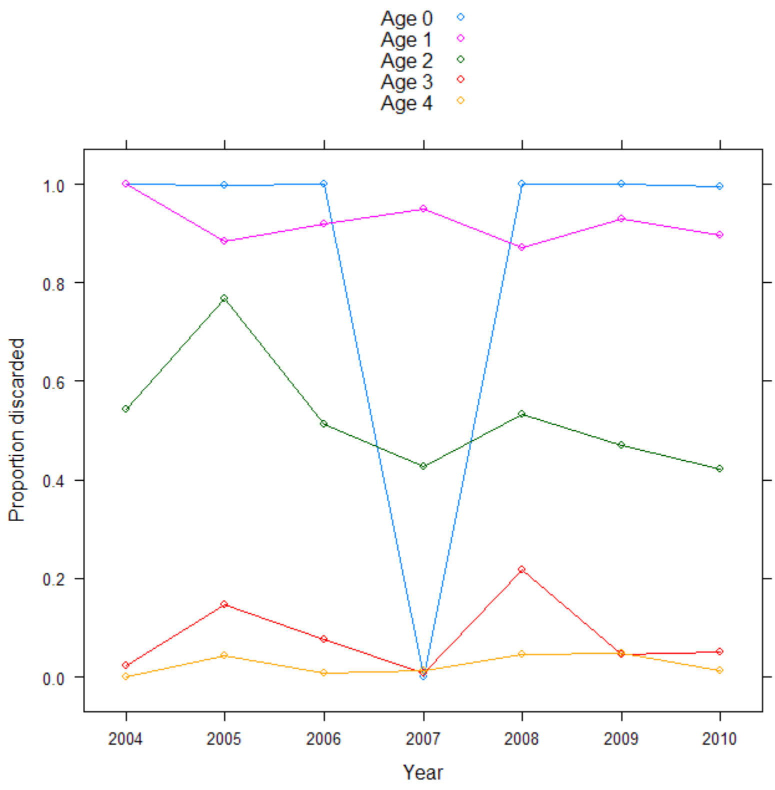


Figure 7.3. Proportion of the catch that was discarded by French otter trawlers. Note that data from before 2008 is considered unreliable.

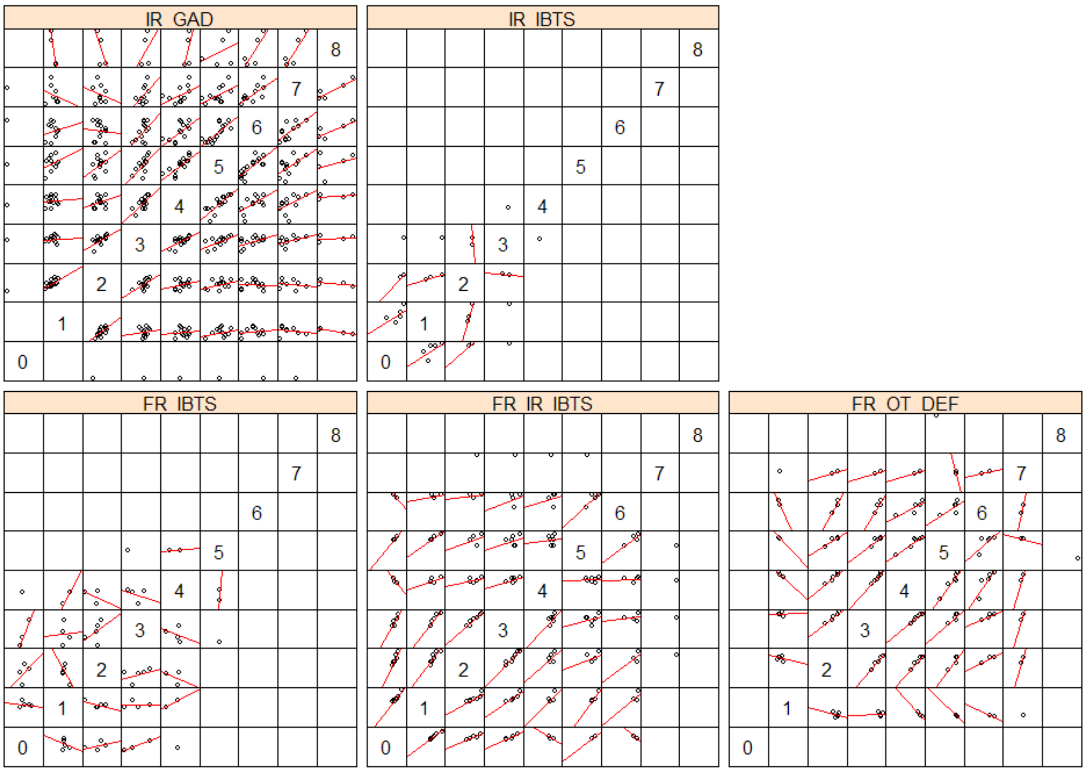


Figure 7.4. Log catchability regressions for all available tuning fleets. See main text for survey acronyms.

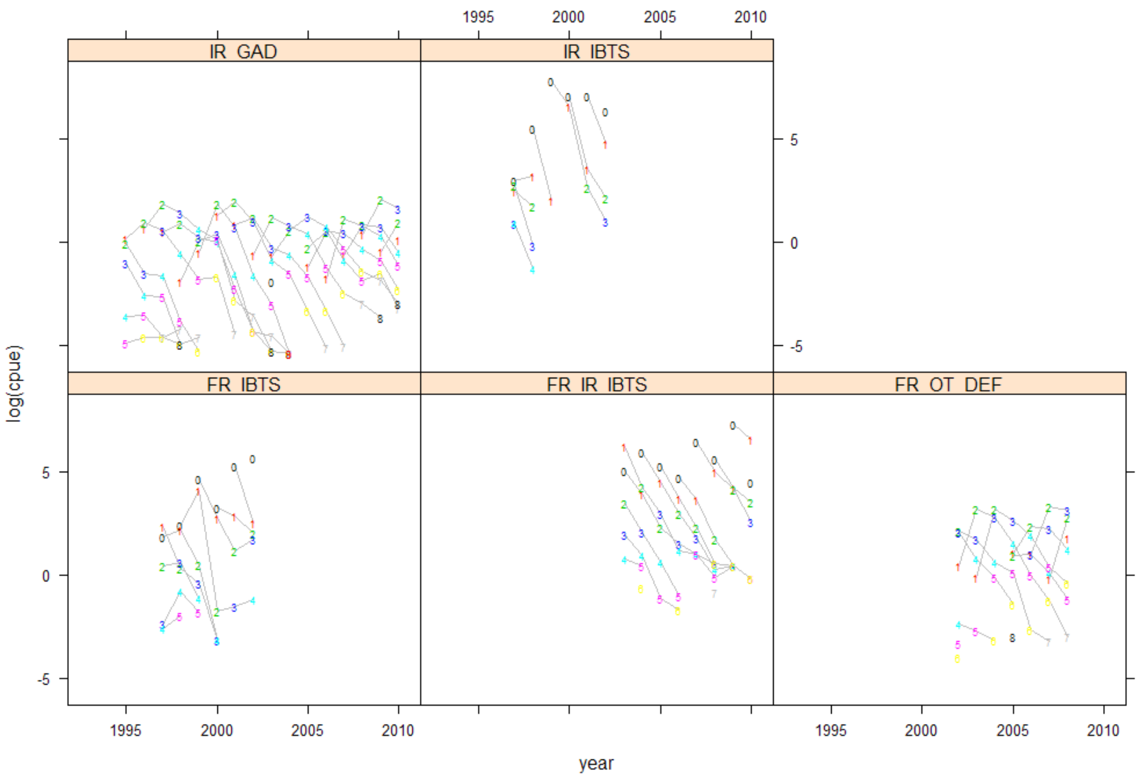


Figure 7.5. Catch curve for all available tuning fleets. See main text for acronyms.

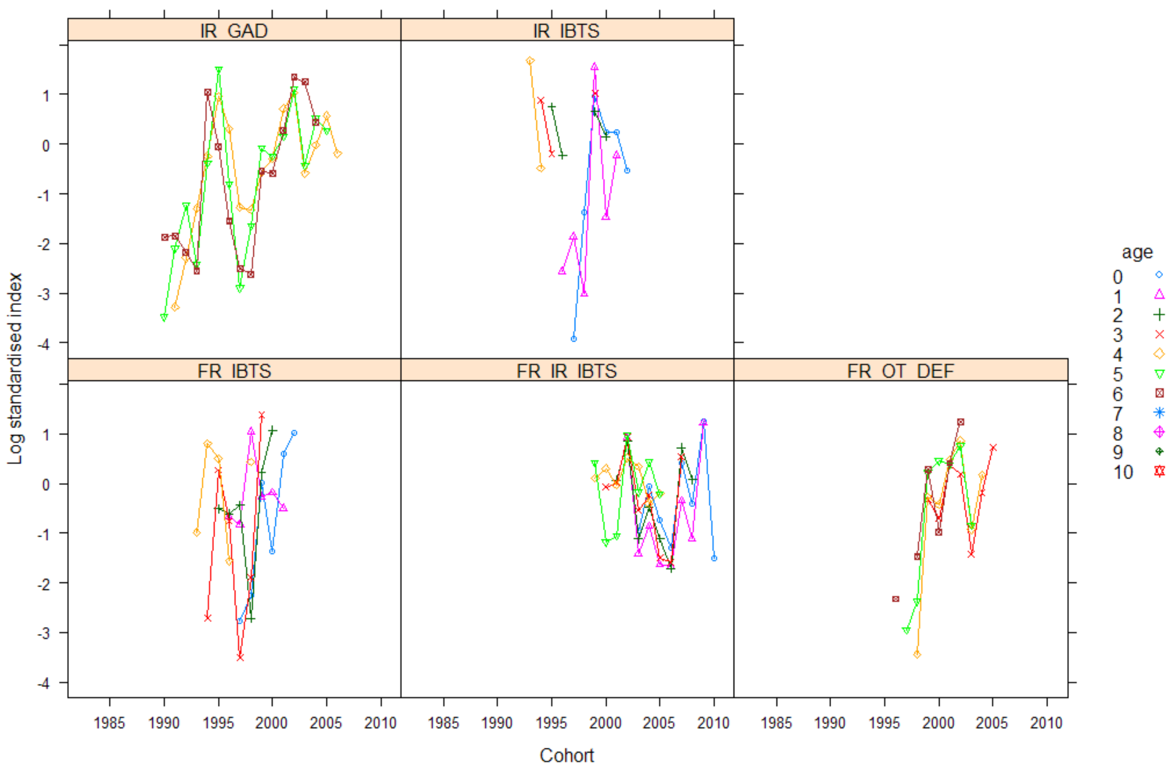


Figure 7.6. Log standardised indices by cohort for all available tuning fleets. See main text for acronyms.

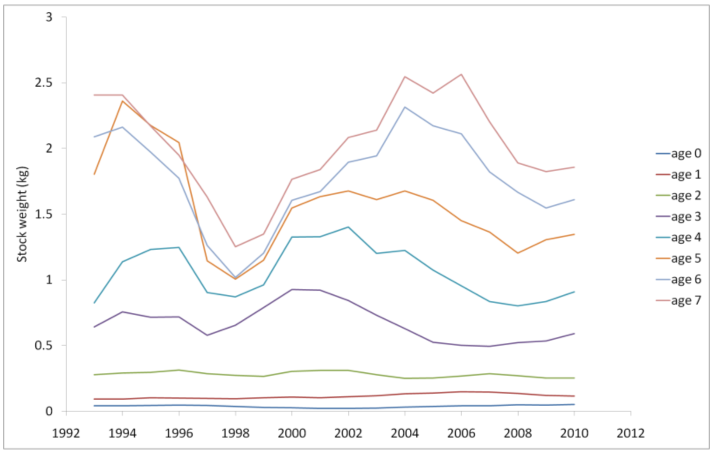


Figure 7.7. Stock weights-at-age (three year running average).

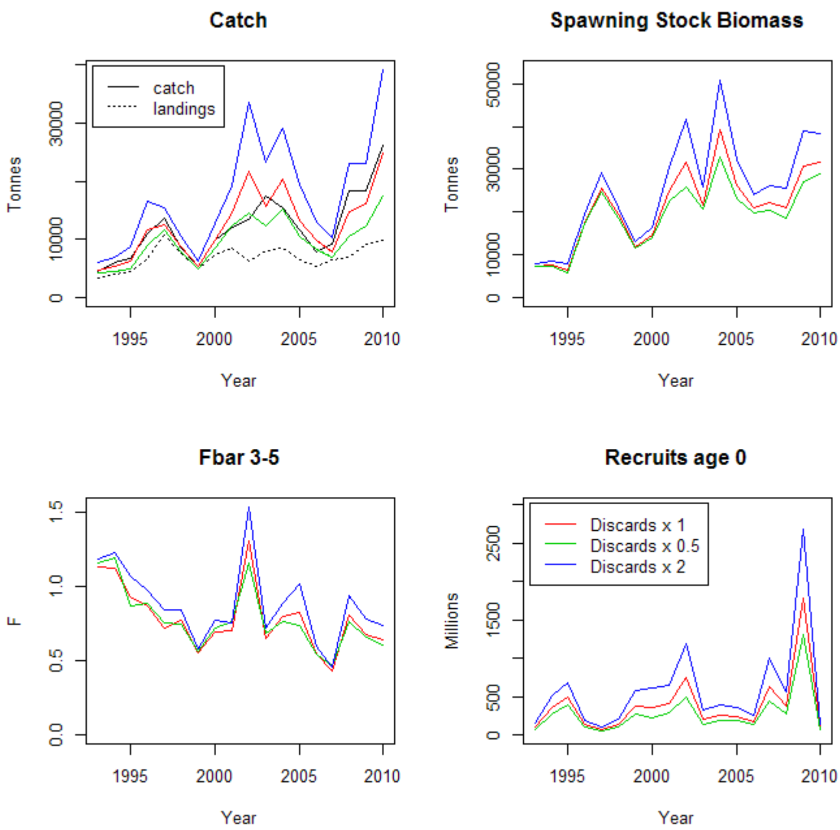


Figure 7.8. Comparative ASAP runs with the best estimate of discards (discards x 1) and runs where the discard numbers-at-age were halved (discards x 0.5) or doubled (discards x 2).

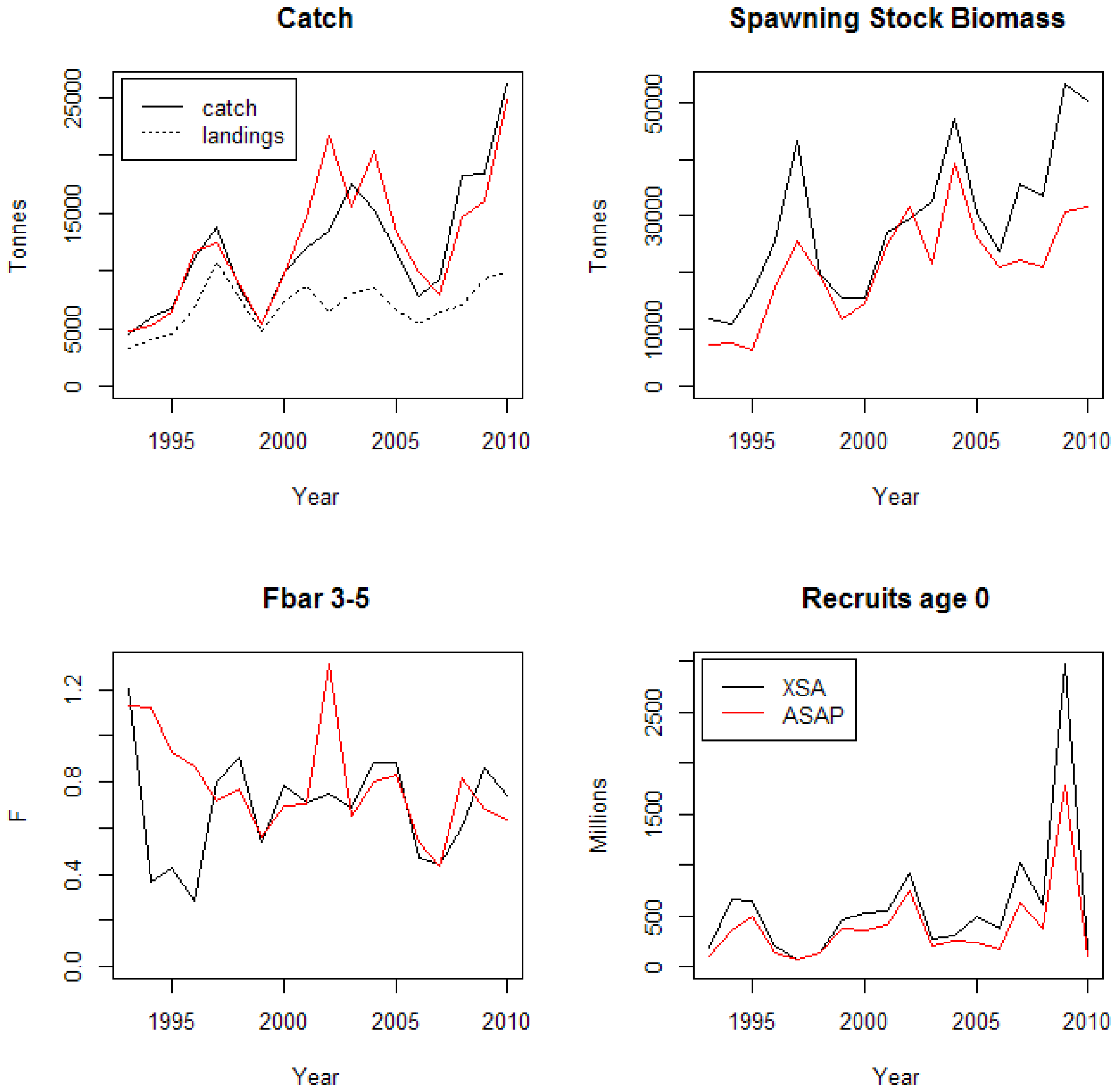


Figure 7.9. Comparison between ASAP and XSA runs with the same input data. The predicted catches are given for ASAP.

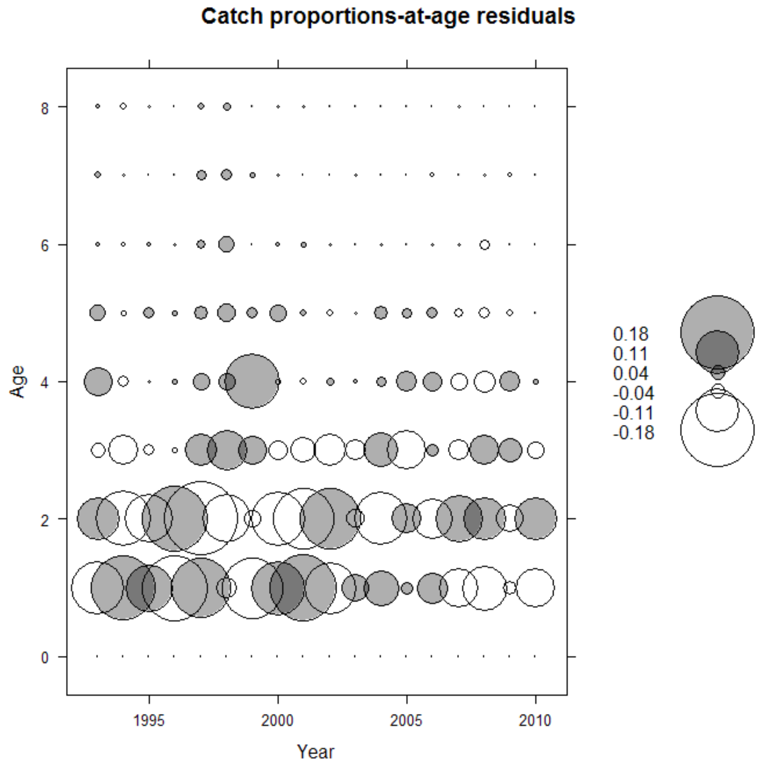


Figure 7.10. Catch proportions-at-age residuals (observed–predicted).

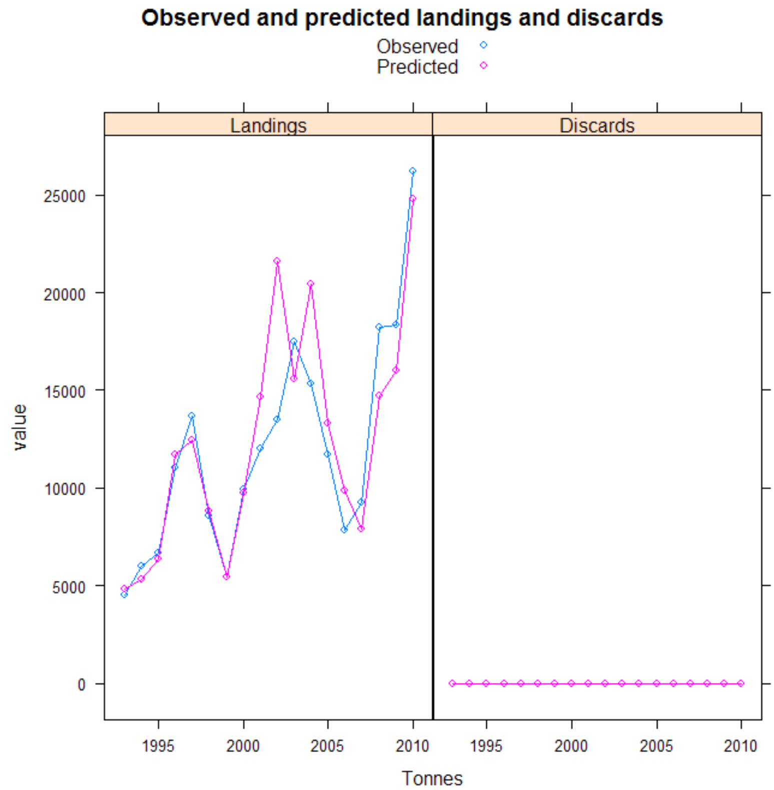


Figure 7.11. Observed and predicted catches (discards were included in the landings data).

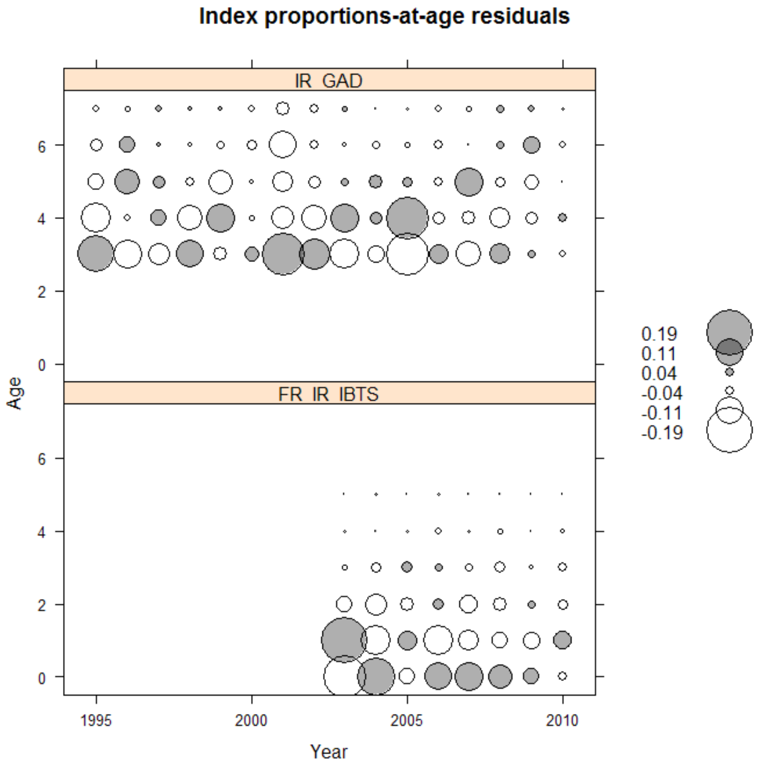


Figure 7.12. Index proportions-at-age residuals (observed–predicted).

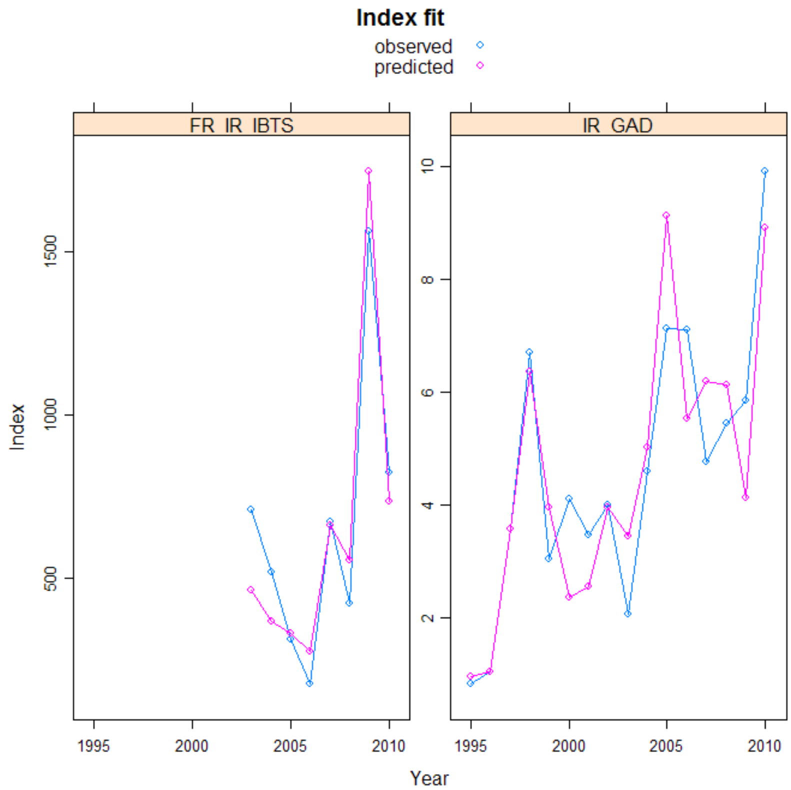


Figure 7.13. Observed and predicted index cpue.

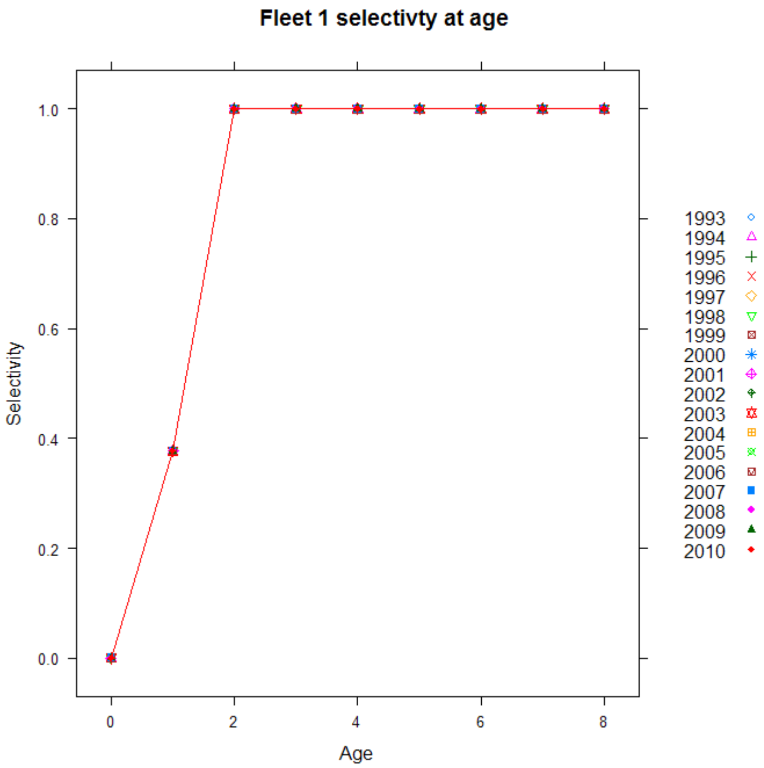


Figure 7.14. Selectivity of the catches, selectivity was fixed at zero for age 0 and at one for ages 3–8; it was freely estimated for ages 1–2. Selectivity was the same for all years.

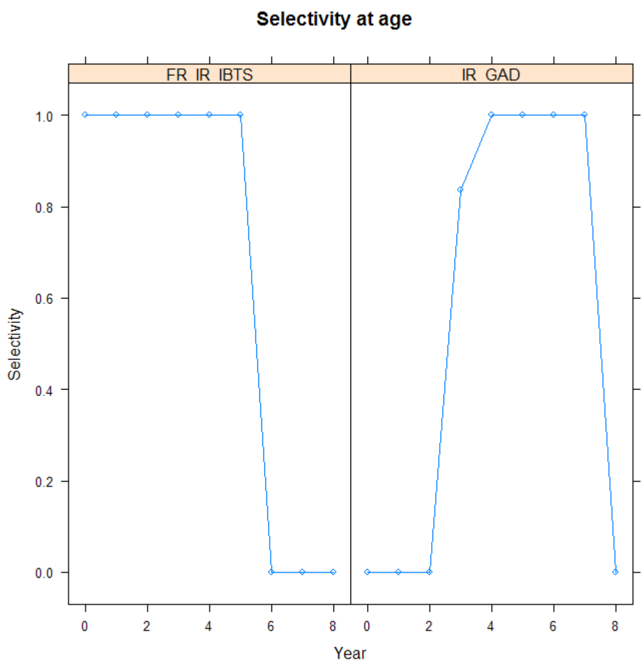


Figure 7.15. Selectivity of the tuning fleets. Selectivity was set to zero for ages that were not included in the model. For the FR_IR_IBTS survey the selectivity was fixed at 1 for all ages and for the IR_GAD commercial fleet selectivity was freely estimated for age 3 and fixed at 1 for the older ages.

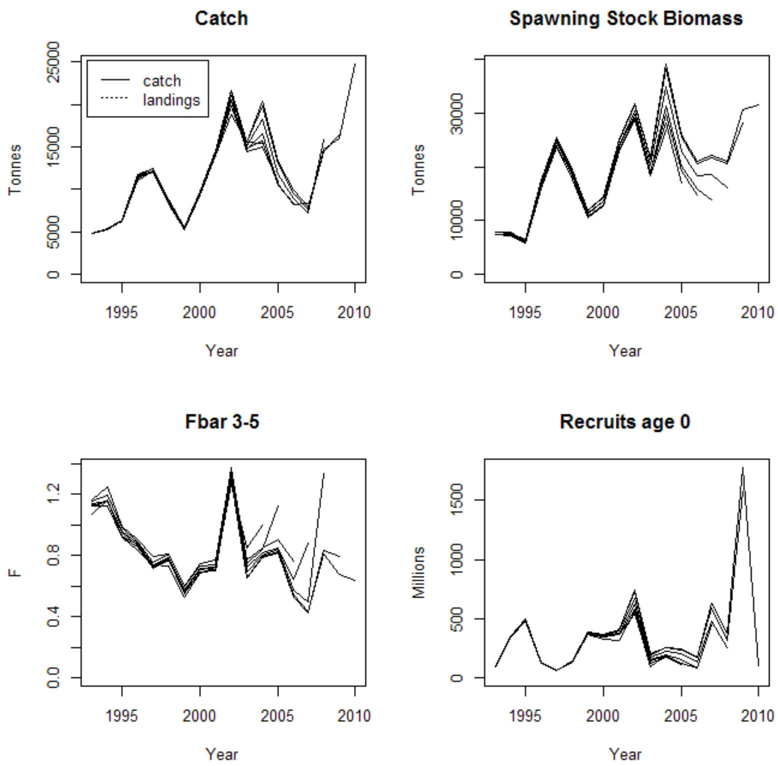


Figure 7.16. Retrospective analysis of the final ASAP run. Note that the survey index only started in 2003.

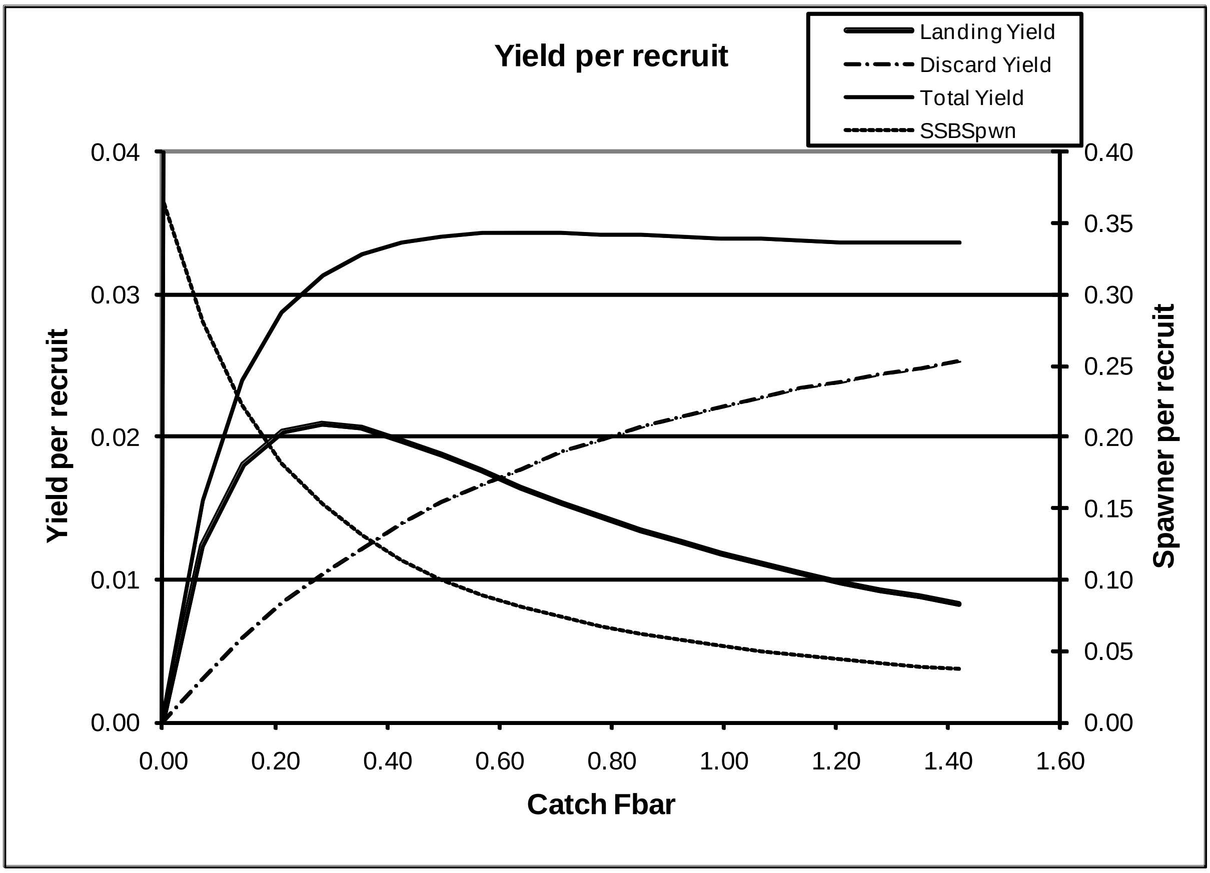


Figure 7.17. Yield-per-recruit analysis. F_{max} of the landings is 0.28 and $F_{0.1}$ of the landings is 0.19.

8 Recommendations by the External Experts

A few recommendations are provided with the aim of helping future invited experts come up to speed when participating in a working group benchmark for the first time. Additional suggestions are made to help improve the efficiency of the benchmark process in general.

Ideally, there should be an extensive working document for each stock outlining both characteristics of each stock and its management, data sources, problem areas and proposals for solutions. Such a document would be the outcome of a long incremental process, and be subject to review and approval or modification by the benchmark workshop. This would be in accordance with the instruction from ICES stating that: *'The Benchmark WK will largely work on benchmark analyses done before the workshop in consultation with external experts, and presented as working document. The review of working documents is a vital part of the workshop. '*

From a reviewers perspective a working paper should include the following:

- Some documentation of the key developments which have led to the stock being proposed for benchmark. It would be appropriate to summarize the results and models from previous assessments in this section.
- Descriptions of the available data and methods used to synthesize the model inputs. In the data descriptions information on the length of the time-series and a characterization of the relative strengths/weaknesses would be helpful.
- A draft summary of a desired work plan for the WK meeting (i.e., what are the assessment leads expectations for the meeting and what are the relative priorities).

We realized that the ICES benchmark system does not necessarily work that way. Rather than reviewing work that was presented, the external experts found themselves as part of a team that tried to improve matters that they were aware of.

To contribute within that kind of framework, reviewers need some insight. For an outsider, to get acquainted to the stocks and the main problem areas is difficult, as the relevant information is spread in many places and may be hard to find for one who is not familiar with the ICES way of working and documentation. Therefore, a sort of "welcome package" that would help new reviewers quickly orient to the stocks, methods, and key issues that were identified as the basis for a benchmark recommendation would be extremely helpful. The following could be included on the SharePoint in the background folder:

- Either upload the most recent annex for each stock, or simply post a note to the reviewers of where it could be found.
- Reference to working group reports, highlighting where important additional information can be found.
- Include a map of the ICES areas.
- Some documentation of the key developments which have led to the stock being proposed for benchmark. (We suppose there is no documentation other than the "issue list" or Benchmark Information document with the table structure).
- Full documentation of assessment methods that are proposed, including instructions for where to find and how to use the software.

- The WKFRAME 2010 document was quite helpful to understand the approach to reference points within the ICES community.

General comments on the benchmark process:

1) A large part of the benchmark meeting was spent scrutinizing, revising, and selecting appropriate dataseries for the stocks. While this is important, it takes away from the time that can be spent on modelling and report writing. It would be more efficient if the data preparation and screening were performed prior to the benchmark meeting.

2) The problem identified in (1) may be exacerbated by the limited number of analysts responsible for multiple stocks requiring annual updates and/or benchmarks. The apparent rigid structure of the assessment updates sounds inefficient and can become an obstacle to innovation and progress.

3) Web conferences in the preparatory phase did not work well, partly because important work still remained to be done, and partly for technical reasons. Far too often, participant's contributions were lost due to poor quality of sound.

4) The quality criteria for acceptance of new methodology are not clear. The instructions mention improved data (-sources), low bias, low uncertainty and improved diagnostics as criteria for accepting a new assessment method as an improvement. However, for a given set of data, typically of somewhat variable quality, it is almost always possible to come up with some kind of calculation of biomass and exploitation rates. This should not be sufficient to accept an assessment. On the other hand, it is hard to imagine that any analysis will be perfect, so obviously, some degree of imperfection will have to be accepted. Clearly, obvious mistakes in data, assumptions or calculations cannot be accepted. Beyond that, the view by the WKROUND in general and the reviewers in particular was that the best possible method would be one that derives the result from the most reliable signals in the data, and avoids assumption driven results. An additional perspective is what the consequence will be of stating that an acceptable assessment is out of reach. Being aware of how managers then can be expected to react, one may reach a situation where it may have to choose between two evils.

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Annex 2: Stock annexes

Stock Annex VIa Cod

Stock specific documentation of standard assessment procedures used by ICES.

Stock	West of Scotland Cod (Division VIa)
Working Group	Celtic Seas Ecoregion (WGCSE)
Date	February 2012
Revised by	WKROUND/Steven Holmes

A. General

A.1. Stock definition

Cod west of Scotland are believed to comprise of at least two subpopulations of cod that remain geographically separate throughout the year. The latitudinal boundary of these groups is between 57 and 58°30′ N. The southern component is characterised by coastal groups with a tendency towards year round residency, although there is some exchange with the Irish Sea. The northern component appears to inter-mix with cod in IVa at all stages of the life history (ICES 2012, WD 4).

A.2. Fishery

The minimum landing size of cod in this area is 35 cm.

The demersal fisheries in Division VIa are predominantly conducted by otter-trawlers fishing for cod, haddock, anglerfish and whiting, with bycatches of saithe, megrim, lemon sole, ling and skate *sp*.. Fishing in the area is conducted mainly by vessels from Scotland, France, Ireland, Norway and Spain with Scottish vessels taking the majority of cod catch. Since 1976, effort by larger Scottish trawlers and seiners has decreased. Records of effort trends since 2000 can be obtained from the (STECF) [https://stecf.jrc.ec.europa.eu/home]. Cod is believed to be no longer targeted in any of the fisheries now operating in ICES Division VIa. Cod are a bycatch in *Nephrops* and anglerfish fisheries in Division VIa. *Nephrops* fisheries use a smaller mesh size than the 120 mm mandatory for cod targeted fisheries, but landings of cod are restricted through bycatch regulations and from 2012 all fisheries are restricted to landings of cod through bycatch only (see below).

For 2009 Council regulation (EC) No 1342\2008 introduced a cod long-term management plan. The objective of the plan is to ensure the sustainable exploitation of the cod stock on the basis of maximum sustainable yield while maintaining a fishing mortality of 0.4.

For stocks above B_{pa}, but where mortality is above 0.4 the harvest control rule (HCR) requires:

1) setting a TAC that achieves a 10% decrease in the fishing mortality in the year of application of the TAC compared to the previous year, or a TAC that achieves a fishing mortality of 0.4, whichever is the higher.

2) limiting annual changes in TAC to ± 20%.

For stocks above B_{lim}, the HCR requires:

3) setting a TAC that achieves a 15% decrease in the fishing mortality in the year of application of the TAC compared to the previous year, or a TAC that achieves a fishing mortality of 0.4, whichever is the higher.

4) limiting annual changes in TAC to ± 20%.

For stocks below B_{lim} the Regulation requires:

5) setting a TAC that achieves a 25% decrease in the fishing mortality in the year of application of the TAC compared to the previous year.

6) limiting annual changes in TAC to ± 20%.

In addition the plan states:

- That if lack of sufficiently accurate and representative information does not allow a TAC affecting fishing mortality to be set with confidence then,
- If advice is for catches of cod to be reduced to the lowest possible level, the TAC shall be reduced by 25%,
- In all other cases the TAC shall be reduced by 15% (unless STACF advises this is not appropriate).
- TACs are to be set net of discards and fish corresponding to other sources of cod mortality caused by fishing.
- Initial baseline values for effort shall be set for effort groups defined by the Council and then annual effort and cod catch calculated for those effort groups. For effort groups where the percentage cumulative catch is ≥20% of that for all fleets, maximum allowable effort shall be adjusted by the same amount as the TAC.
- If STECF advises cod stocks are failing to recover properly the EU Council will set a TAC and maximum allowable effort lower than those derived from the HCR.

For 2012 council regulation (EU) No 43/2012 set a zero TAC for cod in VIa and EU and international waters of Vb east of 12°00′ W with the proviso that:

> Bycatch of cod in the area covered by this TAC may be landed provided that it does not comprise more than 1,5% of the live weight of the total catch retained on board per fishing trip.

A.3. Ecosystem aspects

Geographic location and timing of spawning

Spawning has occurred throughout much of the region in depths <200 m. However, a number of spawning concentrations can be identified from egg surveys in the 1950s, 1992 and from recent surveys of spawning adult distribution. The most commercially important of these, range from the Butt of Lewis to Papa Bank. There are also important spawning areas in the Clyde and off Mull. The relative contribution of these areas is not known. Based on recent evidence there are no longer any significant spawning areas in the Minch. Peak spawning appears to be in March, based on egg surveys (Raitt, 1967). Recent sampling suggests that this is still the case.

The main concentrations of juveniles are now found in coastal waters.

Fecundity

Fecundity data are available from West, 1970 and Yoneda and Wright, 2004. Potential fecundity for a given length is higher than in the northern North Sea but lower than off the Scottish east coast (see Yoneda and Wright, 2004). There was no significant difference in the potential fecundity–length relationship for cod between 1970 (West, 1970) and 2002–2003 (Yoneda and Wright, 2004).

B. Data

B.1. Commercial catch

Raised landings and discards data, ages 1 to 7+. Discard data are available from1978 but sampling was very limited before 1981. Discards in years 1981–2003 raised according to Millar and Fryer (2005).

The following table gives the source of landings data for West of Scotland cod:

	Kind of data				
Country	Caton (catch-in-weight)	Canum (catch-at-age in numbers)	Weca (weight-at-age in the catch)	Matprop (proportion mature-by-age)	Length composition in catch
UK(NI)	X				
UK(E&W)	X				
UK(Scotland)	X	X	X	X	X
Ireland	X	X	X		X
France	X				
Norway	X				

B.2. Biological

Natural mortality-at-age (M) is assumed weight-dependent after Lorenzen (1996) with mortality assumed to be time invariant, M is calculated by finding the time-series means for stock weights-at-age before applying the Lorenzen parameters, i.e.

$$M_a = 3\overline{W}_a \exp(-0.29)$$

Where M_a is natural mortality-at-age a, $\overline{W_a}$ is the time averaged stock weight-at-age a (in grammes) and the numbers are the Lorenzen parameters for fish in natural ecosystems.

Maturities-at-age are given by

Age	1	2	3	4+
Proportion mature-at-age	0.0	0.52	0.86	1.0

Weights-at-age are supplied separately for landings and discards. Catch weights are derived using the sum of products from the landings and discards weights-at-age. Stock weights-at-age are assumed equal to the catch weights-at-age.

B.3. Surveys

ScoGFS – WIBTS – Q1 : 1985–2010. Ages 1 to 6 where oldest age is a true age. Fixed station design.

ScoGFS – WIBTS – Q4 : 1996–2009. Ages 1 to 6 where oldest age is a true age. Fixed station design. Modest to poor self consistency (a weak ability to track cohorts) and very limited influence on exploratory assessment runs means not included in assessment.

IGFS – WIBTS – Q4 : 2003– . Ages 0 to 4 where oldest age is a true age. Sufficient non-zero entries only present for ages 1 and 2. Survey only extends to 56°30′N. Concerns survey not representative of full assessment area means not included in assessment.

New Scottish first-quarter west coast groundfish survey (no formal acronym assigned yet) – Q1 : 2011– . Ages 1 to 6 where oldest age is a true age. Random stratified design. Replaced ScoGFS – WIBTS – Q1. ICES will consider inclusion as a tuning index through an inter-benchmark procedure when 4+ years of data have been gathered.

New Scottish first-quarter west coast groundfish survey (no formal acronym assigned yet) – Q4 : 2011– . Ages 1 to 6 where oldest age is a true age. Random stratified design. Replaced ScoGFS – WIBTS – Q4. ICES will consider inclusion as a tuning index through an inter-benchmark procedure when 4+ years of data have been gathered.

B.4. Commercial cpue

Not used.

B.5. Other relevant data

Grey seal consumption of cod data from Hammond and Harris (2006). Supplementary model run only (used to test sensitivity of outcomes to assumptions about natural mortality).

C. Assessment: data and method

Model used: TSA

Software used: NAG library (FORTRAN DLL) and functions in R.

Model Options chosen:

Weight-dependent M after Lorenzen (1996); ‘natural system’ values.

- Mwght.b <- -0.29
- Mwght.Mu <- 3.0

Response: landings-at-age, discards-at-age and survey indices-at-age

Commercial data

- 1981–1990: treated as unbiased
- 1991–2005: age structure only used (with unaccounted mortality estimated)
- 2006–2010: adjusted to account for misreporting and then treated as unbiased

Points given greater variance at WKROUND 2012

- landings cvmult-at-age = c(1, 1, 1, 1, 1, 2, 2): extra variability for ages 6 and 7+
- landings cvmult = 3 for age 2 in 1987 and 7+ in 1989
- discards cvmult = 2 for age 1 in 1988, age 2 in 1988, age 1 in 1992
- discards cvmult = 3 for age 2 in 1992
- discards cvmult = 5 for age 2 in 1998, age 2 in 2002

Discard model

- step model: random walk for each age, with a step function allowed
- 1981–2005: ages 1and 2 modelled
- 2006–2010: ages 1 to 4 modelled, with a step function for ages 1 and 2

Stock–recruit model

- Ricker
    - Numbers-at-age 1 assumed to be independent and normally distributed with mean $\eta 1$ S exp($-\eta 2$ S), where S is the spawning–stock biomass at the start of the previous year. To allow recruitment variability to increase with mean recruitment, a constant coefficient of variation is assumed.
- Large year class: 1986
    - Mean in Ricker model replaced by 5$\eta 1$ S exp($-\eta 2$ S). The factor of 5 was chosen by comparing maximum recruitment to median recruitment from 1966–1996 for VIa cod, haddock, and whiting in turn using previous XSA runs. The coefficient of variation is again assumed to be constant.

Fishing selection model

- amat = 4: fishing selection flat (apart from noise) from age 4
- gudmundssonH1 = c(2, 1, 1, 1, 1, 1, 1): extra variability for age 1

Survey model (IBTS Q1)

- full model: separate catchability for each age
- ages 1 to 6 modelled
- transitory and persistent changes in catchability allowed

Points given greater variance at WKROUND 2012

- cvmult = 3 for age 4 in 2001, 2 in 2007, 4 in 2008, 2 in 2010
- cvmult = 5 for age 5 in 2001, 3 in 2008

The main diagnostics of the quality of the model fit come from consideration of the objective value (-2*log likelihood), prediction error results and a consideration of how well the model has replicated discard ratios in the input data. As new years of data become available these diagnostics will indicate the need to downweigh individual data points or that the data – be it landings, discards or survey - for a given age is more or less variable than previously thought. It is therefore important that changes to the variance structures used in the TSA models will be allowed if they improve model diagnostics.

Seal feeding model (supplementary model run only)

- M2(y,a) = qaSyByα where
  - M2(y,a) = Seal predation mortality (in year y on age of cod a)
  - qa = Catchability coefficient (varies with age but not year)
  - Sy = Seal numbers in year y
  - By = Total biomass of cod in year y
  - α = Cod biomass (density) dependency term

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1981 onwards (excluded 1991–2005)	1 to 7+	Yes
??	Landings at age in numbers	1981 onwards (excluded 1991–2005)	1 to 7+	Yes
??	Discards at age in numbers	1981 onwards (excluded 1991–2005)	1 to 7+	Yes
??	Weight at age in the commercial landings	1981 onwards	1 to 7+	Yes
??	Weight at age in the commercial discards	1981 onwards	1 to 7+	Yes
West	Weight at age of the spawning stock at spawning time.	Not used		
Mprop	Proportion of natural mortality before spawning	Not used		
Fprop	Proportion of fishing mortality before spawning	Not used		
Matprop	Proportion mature at age	1981 onwards	1 to 7+	No
Natmor	Natural mortality	1981 onwards	1 to 7+	No
For sensitivity analysis only	Numbers consumed by seals at age	1985 and 2002	1 to 7+	na

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	ScoGFS – WIBTS – Q1	1985–2010	1 to 6
Tuning fleet 2	ScoGFS – WIBTS – Q4	Not used	1 to 6
Tuning fleet 3	IGFS – WIBTS – Q4	Not used	1 to 2

D. Short-term projection

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.

The following configuration was agreed at WGNSDS 2008

Initial stock size: Taken from TSA for age 1 and older.

Weight-at-age in the catch: Average weight of the three last years.

Weight-at-age in the stock: Average stock weights for last three years. Assumed equal to the catch weight-at-age, (adopted because mean weights-at-age have been relatively stable over the recent past). CVs are calculated from the standard errors on weights-at-age.

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.

Exploitation pattern: Average of the three last years.

Not partitioned to give landings, misreporting and discard F. If further work can solve this problem, this partition should be applied.

Intermediate year assumptions: Still open.

Stock–recruitment model used: None, recruitment in the intermediate year (terminal year year class at age 1) is taken from the TSA assessment, (the value is based largely on the ScoGFSQ1 survey datum from the terminal year). For the TAC year and following year the short-term (10 years to year before terminal year) geometric mean recruitment-at-age 1 is used.

Procedures used for splitting projected catches: Still open.

E. Medium-term projections

Not considered at the WKROUND benchmark.

F. Long-term projections

Not considered at the WKROUND benchmark.

G. Biological reference points

	Type	Value	Technical basis
MSY	MSY Btrigger	22 000 t	Bpa
Approach	FMSY	0.19	Provisional proxy by analogy with North Sea cod Fmax. Fishing mortalities in the range 0.17–0.33 are consistent with Fmsy
	Blim	14 000 t	Blim = Bloss, the lowest observed spawning stock estimated in previous assessments.
Precautionary Approach	Bpa	22 000 t	Considered to be the minimum SSB required to ensure a high probability of maintaining SSB above Blim, taking into account the uncertainty of assessments. This also corresponds with the lowest range of SSB during the earlier, more productive historical period.
	Flim	0.8	Fishing mortalities above this have historically led to stock decline.
	Fpa	0.6	This F is considered to have a high probability of avoiding Flim.

(unchanged since: 2010)

Since these reference points were established the assessment has adopted weight dependent natural mortalities (M) at age. This has increased M values for younger ages and increased perceptions of SSB and recruitment in years where they were previously estimated using the old values for M. The differences were, however, judged too small to merit a revision of biomass reference points (ICES 2012).

The limit and MSY mortality reference points were also confirmed as still valid in 2012 (ICES 2012).

H. Other issues

H.1. Historical overview of previous assessment methods

2004 to 2011

Model used: TSA

Software used: Compaq visual FORTRAN using NAG library.

Model Options chosen:

Natural mortality (M) 0.2 at all ages.

Commercial data

- 1978–1994: treated as unbiased
- 1995-AY-1: omitted
- landings cvmult-at-age = c(1, 1, 1, 1, 1, 2, 2): extra variability for ages 6 and 7+

Discard model

- 1978–1994: ages 1and 2 modelled
- 1995-AY-1: omitted

Stock–recruit model

- ricker
- large year class: 1986

Fishing selection model

- amat = 4: fishing selection flat (apart from noise) from age 4
- gudmundssonH1 = c(4, 1, 1, 1, 1, 1, 1): extra variability for age 1

Survey model (IBTS Q1)

- amat = 4: catchability flat (apart from noise) from age 4
- survey catchabilities up to amat assumed to follow a log-linear model
- survey cvmult-at-age = c(2, 1, 1, 1, 2, 2): extra variability for ages 1, 5 and 6
- ages 1 to 6 modelled
- only transitory changes in catchability allowed; modelled using the additive scale.

Summary of data ranges used in recent assessments (no accepted assessment in 2011):

Data	2007 assessment	2008 assessment	2009 assessment	2010 assessment
Catch data	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+	Years: 1978–(AY-1) Ages: 1–7+
Survey: A_Q1	Years: 1985–AY Ages: 1–6	Years: 1985–AY Ages 1–6	Years: 1985–AY Ages 1–6	Years: 1985–AY Ages 1–6
Survey: B_Q4	Not used	Not used	Not used	Not used
Survey: C	Not used	Not used	Not used	Not used

AY – Assessment year

I. References

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Stock Annex Whiting in Subarea VI

Stock specific documentation of standard assessment procedures used by ICES.

Stock	West of Scotland Whiting (Subarea VI)
Working Group	Working Group for the Celtic Seas Ecoregion (WGCSE)
Date	February 2012
Author	Andrzej Jaworski
Revised by	WKROUND/Andrzej Jaworski

A. General

A.1. Stock definition

Whiting occur throughout Northeast Atlantic waters in a wide range of depths from shallow inshore waters down to 200 m. Adult whiting are widespread throughout Division VIa, while high numbers of juvenile fish occur in inshore areas. Whiting are less common in Division VIb, and it is likely these fish are migrants from VIa, rather than a separate stock.

Stock identity in Division VIa has recently been explored in greater detail. Tagging experiments on recruiting fish have shown that the whiting found to the south of 56°N and to the west of Ireland are distinct from those in the Minches, the Clyde and the Irish Sea. Five juvenile nursery areas have been discriminated off the west of Scotland and northern North Sea, three of them being found in VIa. The nursery areas on the Scottish west coast contribute individuals to the spawning aggregations in the Scottish coastal North Sea and Shetland, and there is no evidence of the converse (Tobin *et al.*, 2010). Within VIa, there is little indication of interaction between population components in the south and that off the northwest coast.

A.2. Fishery

The demersal fisheries in Division VIa are predominantly conducted by otter trawlers fishing for cod, haddock, anglerfish and *Nephrops*, with bycatch of whiting, saithe, megrim, lemon sole, ling and a number of skate species. Whiting are taken by trawlers using gear with mesh size between 80 mm and 120 mm. Since 1976, effort by Scottish heavy trawlers and seiners has decreased. Light trawler effort has declined rapidly since 1997 after a long-term increasing trend. More recently, days-at-sea limitations associated with the cod recovery plan and the seasonal closure of some areas has lead to some switching of effort away from VIa.

The demersal whitefish fishery in Subarea VI occurs largely in Division VIa with the UK, Ireland and France being the most important exploiters. Landings from Rockall (Division VIb) are generally less than 10 t. The whiting fishery in VIa is dominated by the UK (Scotland) and Irish fleets. French whiting landings have declined considerably since the late 1980s.

Landings of whiting in Division VIa are affected by emergency measures introduced in 2001 as part of the cod recovery programme. Council Regulation 423/2004 introduced a cod recovery plan affecting Division VIa. The measures only take effect, however east of a line defined in Council Regulation No 51/2006. Measures brought in 2002, such as a switch from 100 to 120 mm mesh codends at the start of 2002

(Commission Regulation EC2056/2001), are likely to have had some impact on whiting. The UK implemented a regulation requiring the fitting of a square mesh panel in certain towed gears.

Most catch of whiting comes in non-whiting directed fisheries, particularly the *Nephrops* trawl fishery. The *Nephrops* trawl fishery in VIa discards significant amounts of small whiting, making whiting landings figures a poor indicator of removals due to fishing. The proportion of whiting discarded has been very high and appears to have increased in recent years. Whiting also has a low market demand, which contributes to increased discarding and highgrading. In terms of the total weight of demersal fish landed by the Scottish fleet from the west coast, whiting is ranked fourth, with an annual value of £368 000 (in 2009).

The minimum landing size of whiting in the human consumption fishery in this area is 27 cm.

There have been some problems regarding area misreporting of Scottish landings during the early 1990s, which are linked to area misreporting of other species such as haddock and anglerfish into Division VIb. More recently there has been area misreporting of anglerfish from VIa to IVa, which may have affected the reliability of whiting landings distribution.

A.3. Ecosystem aspects

Unlike some species, whiting do not form distinct spawning shoals, and both ripe and immature fish are often found together. As the latitude increases, spawning of whiting occurs progressively later. This is closely associated with temperature changes, but spawning activity generally peaks in springtime, just as sea temperatures begin to rise. On the west coast of Scotland whiting spawn between January and June. Within this period, the spawning season of an individual female lasts around fourteen weeks, during which time she releases many batches of eggs. At two years old most whiting are mature and able to spawn. By the time it reaches four years old, a single female fish of reasonable size can produce more than 400 000 eggs. Like many other fish, whiting spend their first few months of life in the upper water layers before moving to the seabed. Male and female whiting grow very quickly reaching around 19 cm in their first year. After this the growth rate becomes much slower. There are large differences between the growth rates of individual fish and a 30 cm fish can be as young as one year or as old as six.

Whiting are active predators. Juvenile fish eat mainly crustaceans (shrimps and crabs) but as whiting grow, the amount of fish in their diet increases. The exact composition of the diet depends on the size of the fish, the area and the time of the year. Whiting is one of the main predators of other commercially important species of fish. Norway pout, sandeels, haddock, cod and even whiting themselves are frequently eaten. It has been estimated that each year the whiting population consumes several hundred thousand tonnes of these species.

B. Data

B.1. Commercial catch

Monthly length frequency distribution data were available from Scotland for Division VIa. A total international catch-at-age distribution for Division VIa was obtained by raising this distribution to the WG estimates of total international catch from this area. Landings officially reported to ICES were used for countries not supplying estimates directly to the WG. The Scottish market sampling length–weight relationships (given below) have been used to raise the sampled catch-at-length distribution data Working Group estimates of total landings for Division VIa.

Month	b	a
1	2.9456	0.01
2	2.9456	0.0094
3	2.9456	0.009
4	2.9456	0.0088
5	2.9456	0.0088
6	2.9456	0.0089
7	2.9456	0.009
8	2.9456	0.0092
9	2.9456	0.0095
10	2.9456	0.0096
11	2.9456	0.0097
12	2.9456	0.0097

Discard data are available from 1978 but sampling was very limited before 1981. To reduced bias and increase precision, discards in years 1981–2003 were raised according to the procedure described in Millar and Fryer (2005). Discard age-compositions are generally available from both Scotland and Ireland, but in some recent years (2006 and 2007) lack of access to fishing vessels by Irish observers has meant that no Irish data have been collected.

B.2. Biological

Natural mortality (*M*) is assumed to vary and be dependent on fish weight (Lorenzen, 1996). *M* values are time-invariant and are calculated as:

$$M_a = 3.0\overline{W}_a^{\,-0.29}$$

where M_a is natural mortality-at-age *a*, $\overline{W}_a$ is the time averaged stock weight-at-age *a* (in grammes) and the numbers are the Lorenzen parameters for fish in natural ecosystems.

A combined sex maturity is assumed, knife-edged at age 2. The use of a knife-edged maturity ogive has been a source of criticism in previous assessments. However, recent research on gadoid maturity conducted by the UK gives no evidence for substantial change in whiting maturity since the 1950s, although there has been an increase in the incidence of precocious maturity-at-age 1, particularly in males, since 1998, in the Irish Sea.

B.3. Surveys

Six research vessel survey-series for whiting in VIa were available to the WKROUND 2012. In all surveys listed, the highest age represents a true age not a plus group.

- Scottish first-quarter west coast groundfish survey (ScoGFS-WIBTS-Q1): ages 1–7, years 1985–2010).
- Scottish fourth quarter west coast groundfish survey (ScoGFS-WIBTS-Q4): ages 0–8, years 1996–2009).

The Q1 Scottish Groundfish survey was running in the period 1985–2010, and this was performed using a repeat station format with the GOV survey trawl together with the west coast groundgear rig, 'C'. Similarly the Q4 Scottish Groundfish survey was running in 1996–2010, once again using the GOV survey trawl with groundgear 'C' and the fixed station format.

In 2011, the Q1 and Q4 Scottish Groundfish surveys were re-designed. The previous repeat station survey format consisting of the same series of survey trawl positions being sampled at approximately the same temporal period every year is considered a rather imprecise method for surveying both these subareas and as such a move towards some sort of random stratified survey design was judged necessary. The largest obstacle preventing an earlier move to a more randomised survey design was the lack of confidence in the 'C' rig to tackle the potentially hard substrates that a new randomised survey was likely to encounter. The first step in the process of modifying the survey design was therefore to design a new groundgear that would be capable of tackling such challenging terrain. The introduction of the new design initiated two new time-series:

- Scottish first-quarter west coast groundfish survey (no acronym assigned yet): ages 1–7, years 2011–2012).
- Scottish fourth quarter west coast groundfish survey (no acronym assigned yet): ages 0–8, years 2011–).

ICES will consider inclusion of the above time-series to produce tuning indices through an inter-benchmark procedure when 4+ years of data have been gathered.

The Irish groundfish surveys:

- Irish fourth-quarter west coast groundfish survey (IreGFS): ages 0–5, years 1993–2002.

The Irish quarter four survey was a comparatively short series, was discontinued in 2003 and has been replaced by the IGFS.

- Irish fourth quarter west coast groundfish survey (IGFS-WIBTS-Q4): ages 0–6, years 2003–2010.

This survey used the RV Celtic Explorer and is part of the IBTS coordinated western waters surveys. The vessel uses a GOV trawl, and the design is a depth stratified survey with randomised stations. Effort is recorded in terms of minutes towed. Further descriptions of these surveys and distribution plots of whiting catch rates obtained on these surveys can be found in the IBTS WG Report of 2011.

B.4. Commercial cpue

Due to a number of concerns regarding the non-mandatory recording of effort in terms of hours fished, the present assessment of the stocks does not make use of commercial catch per unit of effort data. The data are included here for completeness and include:

- Scottish light trawlers (ScoLTR): ages 1–7 years 1965–2005
- Scottish seiners (ScoSEI): ages 1–6 years 1965–2005
- Scottish *Neprhops* trawlers (ScoNTR): ages 1–6 years 1965–2005
- Irish Otter Trawlers (IreOTB): ages 1–7 years 1995–2005

Data to update these time-series were not available for the recent years.

B.5. Other relevant data

Fecundity data for a number of areas are available from Hislop and Hall (1974), and was estimated at 4.933 $L^{3.25}$ for whiting in Subarea VI.

C. Assessment: data and method

Model used: TSA

Software used: NAG library (FORTRAN DLL) and functions in R.

Model Options chosen:

Weight-dependent M after Lorenzen (1996)

- Mwght.b <- –0.29
- Mwght.Mu <- 3.0

Response: landings-at-age, discards-at-age and survey indices-at-age

Commercial data

- 1981–1994: treated as unbiased
- 1995–2005: age structure only used (with unaccounted mortality estimated)
- 2006–2010: treated as unbiased
- landings cvmult-at-age = c(2, 1, 1, 1, 1, 1, 2): extra variability for ages 1 and 7+
- discards cvmult-at-age = c(1, 1, 1, 1, 2): extra variability for age 5
- discards cvmult = 3 for age 1 in 1981, age 1 in 1987, age 3 in 1991, age 1 in 2000

Discard model

- full model
- 1981–2010: ages 1–5 modelled

Stock–recruit model

- hockey stick

Fishing selection model

- amat = 4: fishing selection flat (apart from noise) from age 4
- gudmundssonH1 = c(2, 1, 1, 1, 1, 1, 1): extra variability for age 1

Survey model (ScoGFS-WIBTS-Q1)

- full model: separate catchability for each age
- ages 1 to 6 modelled
- transitory and persistent changes in catchability allowed
- cvmult = 3 for age 5 in 1992, age 2 in 1993, age 1 in 2000, age 2 in 2000
- cvmult = 5 for age 4 in 1992

Survey model (ScoGFS-WIBTS-Q4)

- full model: separate catchability for each age
- ages 1 to 6 modelled
- transitory and persistent changes in catchability allowed

- cvmult-at-age = c(1, 1, 1, 1, 1, 2): extra variability for age 6
- cvmult = 3 for age 4 in 2007, age 5 in 2007

Survey model (IGFS Q4 IGFS-WIBTS-Q4)

- full model: separate catchability for each age
- ages 1 to 4 modelled
- years 2003–2006 and 2008–2010 (year 2007 excluded due to a high prediction error)
- transitory and persistent changes in catchability allowed

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1981–2010	1 to 7+	Yes
Canum	Catch at age in numbers	1981–2010	1 to 7+	Not used
??	Landings at age in numbers	1981–2010	1 to 7+	Yes
??	Discards at age in numbers	1981–2010	1 to 7+	Yes
Weca	Weight at age in the commercial catch	1981–2010	1 to 7+	Not used
??	Weight at age in the commercial landings	1981–2010	1 to 7+	Yes
??	Weight at age in the commercial discards	1981–2010	1 to 7+	Yes
Weca	Weight at age in the commercial catch	1981–2010	1 to 7+	Not used
West	Weight at age of the spawning stock at spawning time.	1981–2010	1 to 7+	Not used
Mprop	Proportion of natural mortality before spawning	1981–2010	1 to 7+	No
Fprop	Proportion of fishing mortality before spawning	1981–2010	1 to 7+	No
Matprop	Proportion mature at age	1981–2010	1 to 7+	No
Natmor	Natural mortality	1981–2010	1 to 7+	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	ScoGFS-WIBTS-Q1	1985–2010	1–6
Tuning fleet 2	ScoGFS-WIBTS-Q4	1996–2009	1–6
Tuning fleet 3	IGFS-WIBTS-Q4	2003–2010	1–4

D. Short-term projection

Not done.

E. Medium-term projections

No medium-term projections are carried out for this stock.

F. Long-term projections

No long-term projections are carried out for this stock.

G. Biological reference points

	Type	Value	Technical basis
MSY	MSY Btrigger		No estimate
Approach	FMSY		No estimate
	Blim	16000 t	ICES proposition
Precautionary	Bpa	22000 t	ICES proposition
Approach	Flim	1.0	ICES proposition
	Fpa	0.6	ICES proposition

H. Other issues

H.1. Historical overview of previous assessment methods

Data	2008 assessment	2009 assessment	2010 assessment	2011 assessment
Catch data	No assessment	No assessment	Years: 1965–2009 Ages: 1–7+	Years: 1965–1994 and 2006–2010 Ages: 1–7+
Survey: ScoGFS Q1	No assessment	No assessment	Years: 1985–2010 Ages 1–6	Years: 1985–2011 Ages 1–6
Survey: ScoGFS Q4	No assessment	No assessment	Not used	Not used
Survey: IRGFS Q4	No assessment	No assessment	Not used	Not used

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Stock Annex Cod VIIe-k

Stock specific documentation of standard assessment procedures used by ICES.

Stock Cod in VIIe–k (Celtic Sea cod)

Expert Group Celtic Sea Working Group

Date March 2012

Revised by Colm Lordan, Lionel Pawlowski

A. General

A.1. Stock definition

Since 1997, this assessment has related to the cod in Divisions VIIe–k, covering the Western Channel and the Celtic Sea. Tagging information presented at WKROUND 2012 (WDs 9 and 11) confirms minimal movement of cod from VIIe–k to other areas. In fact even within VIIe–k there seems to be limited mixing between fish tagged in VIIg or VIIa South and those tagged in VIIf and VIIe.

Up to 2008, the management area was set in Divisions VIIb–k,VIII, IX, X, and CECAF 34.1.1 which does not correspond to the area assessed. The management area was revised in 2009 to exclude VIId. The new TAC covers ICES Areas VIIb–c, VIIe–k, VIII, IX, X, and CECAF 34.1.1(1). This is more representative of the stock area in recent years and landings from VIIbc, VIII, IX and X have been minimal.

The area assessed has gradually increased from VIIfg before 1994 to VIIfgh, to VIIefgh in 1996 and finally to VIIe–k. In 1994, at the request of ACFM, the ICES Working Group on Southern Shelf Demersal Stocks (WGSSDS) studied the possible extension of the area assessed from VIIfg to VIIfgh. Examination of data from surveys and logbooks indicated a continuity of the distribution of VIIg cod into VIIh. Depending on the year, catches in Division VIIh represented 9–15% of the catches in VIIfg, with a coincidence of years of peak or low catches in both areas. Therefore, catches from VIIh were included in the assessment. In 1996, at the request of ACFM, WGSSDS studied the possible extension of the area assessed from VIIfgh to VIIefgh. The population dynamics parameters for VIIfgh and VIIe cod were examined and compared for the period 1988–1994, when independent tuning fleets, international catch-at-age, mean weights-at-age in the landings and in the stocks were available for both areas. Patterns of F were consistent between VIIe and VII fgh in earlier years (1988–1990), and SSBs trends were similar in the period 1988–1992. The patterns of recruitments (age 1) were found to be fairly consistent through this period 1988–1994, though it cannot be assumed that this consistency was also valid in earlier years when catch-at-age were only available in Divisions VIIf, g, h. It was therefore decided to combine Western Channel Cod with the Celtic Sea Cod assessment for the years 1988–1995, but an independent assessment of Celtic sea Cod in VIIfgh was maintained for the longer period available 1971–1995. This was to allow scaling of the historic (1971–1987) SSBs and recruitments values from VIIfgh to VIIe–h.

At WGSSDS 1997, due to the lack of a long independent series of catch-at-age in Divisions VIIj,k, the estimate of landings from Divisions VIIjk was discussed and it was decided to combine the data of Divisions VIIe,f,g,h and Divisions VIIjk for the period 1993–1996 and to raise the data in Divisions VIIe–h to landings in Divisions VIIe–k for the period 1988–1992. The results of an XSA assessment of this series in Divisions

VIIe–k for 1988–1996 had been compared with the results of the assessment in Divisions VIIe–h in terms of trends of F, SSB and recruitment. Patterns of these parameters were found very similar and the merging of Divisions VIIjk with Divisions VIIe–h mainly resulted in a scaling upwards of SSB and recruitment. The new assessment areas comprised cod in Divisions VIIe–k.

At the 1999 WGSSDS meeting, an alternative procedure to the tedious re-scaling of SSB and recruitment of the earlier series 1971–1987 in VIIfgh to VIIe–k every year was proposed (Bellail, 1999). A long series of landings data from 1971–1987 was reconstructed. An average raising factor (1.24) from VIIfgh to VIIe–k in the period 1988–1997 was applied to VIIfgh landings of the series 1971–1987. Results of assessment in terms of SSB and R were very close to those obtained when these parameters were scaled. ACFM accepted this procedure.

In the past few biological criteria have been used to justify the widening the stock area. However, recent tagging work by Ireland and the UK supports the idea that there is a resident stock in the Celtic Sea and Western Channel (VIIe–k) and mixing with other areas appears to be minimal. The Irish Sea front, running from SE Ireland (Carnsore point) to the Welsh Coast, appears to act as boundary between the Irish Sea and Celtic Sea stock. Juveniles found close to the SE Irish Coast (south of VIIa) are considered part of the Celtic Sea stock.

Some migrations and mixing are known to occur in this cod stock. Both conventional and DST tagging information for VIIg (where the majority of landings are made) shows that distribution remained fairly constrained within VIIg. There was some preference to central areas within VIIg during January–March. Between April and June the cod appeared to be more widely dispersed within VIIg during Q1 & Q2. Fish tagged in VIIf tended to mix with those off shore in VIIg and h. Whereas some fish tagged in the western English Channel VIIe migrated into VIId for at least part of the year.

A.2. Fishery

The majority of the landings are made by demersal trawls targeting roundfish (i.e. cod, haddock and whiting), although, in recent years an increasing component have been from gillnets and otter trawls targeting *Nephrops* and benthic species.. Landings are made throughout the year but are generally more abundant during the first semester. Constraining TACs set since 2003 and the impact of the Trevose Head Closure applied since 2005 have reduced landings in Q1 somewhat and spread landing more throughout the year.

WGCSE should routinely monitor spatial and temporal changes in landings, effort and lpue for the main fleets catching cod in VIIe–k. This has previously been done using maps of landings and lpue by ICES rectangle.

A.3. Ecosystem aspects

Cod recruitment success has generally shown an increase over the period 1970–2006 during which time sea surface temperature in the Celtic Sea has increased (Lynam *et al*., 2009). Notably the highest recruitment success was for cod spawned in 1986, a year with an exceptionally cold spring. Lynam *et al*. (2009) also found that SST in spring (MAM) and *Calanus helgolandicus*, abundance in the Celtic Sea, did prove to be significant predictors of recruitment in Celtic Sea cod in a GAM model. The time lag between availability of this SST and zooplankton information means that their model cannot be readily used in forecasting recruitment in advance of what groundfish surveys might detect. Nevertheless this research should be pursued further, particularly in the context ecosystem determinants of the strong 2009 and 2010 year classes.

B. Data

B.1. Commercial catch

Landings

On a quarterly basis, France, Ireland and UK (E+W) have provided catch numbers-at-age and catch weights-at-age for their landings. The Irish landings in VIIg are augmented with some landings made or reported off the south east coast of Ireland in ICES rectangles 33E2 and 33E3. These rectangles are in the very south of VIIa. Landings only are available for Belgium.

France, UK and Ireland data are added quarterly and raised to international landings taking into account Belgian data. Then the quarterly datasets are summed up to the annual values.

As a consequence of an update to the French database of landings statistics, some minor revisions (downward) have been applied since 2002 and the updated datasets for international landings.

There is no information on the absolute level of misreporting for this stock but there is evidence that misreporting has increased from 2002 when quotas became restrictive with a maximum in 2008. Misreporting has decreased since then.

Discards

Discards data sampled under EU/DCR since 2003 have been generally presented in previous WGCSE but not used in the assessments as they do not cover all the main fleets and quarters yet.

Due to the annual management system adopted by the French POs since 2003 in response to the quota restrictions, highgrading has occurred in the French fishery, mainly in VIIfgh. A procedure using both the UK and French landings length data enabled estimation of the French highgrading for the years 2003–2005 (WD 1 WGSSDS 2006). The adjustments were reapplied to improved estimates of French landings from 2006 at the ICES WKROUND 2009.

In 2008 the French self sampling program on Celtic Sea cod has produced datasets enabling estimation of discarding and highgrading rates. Assuming the same pattern of discarding in recent years, estimates of French discarding and highgrading back to 2003 were also computed. Estimates of highgrading were also calculated for the French tuning fleets used in the analysis (ICES WKROUND, 2009, *WD 17)*. In 2009 and 2010, the low estimate of highgrading is likely to be related to the French vessels not being restricted by quota because of the decommissioning plan and the reports of effort directed towards more profitable species.

Discard estimates are available from Ireland since 1995 (see Marine Institute and Bord Iascaigh Mhara, 2011). For now the assumption is that the discards are mainly at age 1 and the estimates are very uncertain. There are indications that Irish discard rates have increased since 2005 this is something that WGCSE should monitor and discards should be included in the assessment if there are major changes or it is found to have a large impact on the assessment.

Lpue

Landings and effort data are available for all the main fleets operating in the area and catching cod. The table below summarizes the available data. WGCSE should monitor changes in these fleets over time.

Name	Area	Series
FR gadoid fleet [1]	VIIfgh	1983–onwards
FR Nephrops fleet [1]	VIIfgh	1983–onwards
FR otter trawlers [2]	VIIe	1983–onwards
FR otter trawlers [2]	VIIfgh	1983–onwards
FR otter trawlers [2]	VIIe–k	1983–onwards
UK otter trawlers	VIIe	1972–onwards
UK otter trawlers	VIIe–k	1972–onwards
UK beam trawlers	VIIe–k	1978–onwards
IR otter trawlers	VIIg	1995–onwards
IR beam trawlers	VIIg	1995–onwards
IR Scottish seiners	VIIg	1995–onwards
IR otter trawlers	VIIj	1995–onwards
IR beam trawlers	VIIj	1995–onwards
IR Scottish seiners	VIIj	1995–onwards

[1] For Q2+3+4 for consistency with the Trevose Head Closure since 2005 during the first quarter.

[2] Annual values, including the Fr gadoid and *Nephrops* fleets.

B.2. Biological

Weights-at-age

At the 1999 WGSSDS, data for the years 1971–1980 were set to the average 1981–1997. A revision was carried out at 2001 WGSSDS where the values for the period 1971–1980 were set to the average values 1981–2000. Depending on the annual datasets available by country for the period 1988–2001, catch weights-at-age data were calculated as the weighted means from French, Irish and UK datasets. Since 2002, VIIe–k catch weights-at-age have been calculated as the annual weighted means of French, Irish and UK datasets.

WKROUND 2012 reviewed the data and concluded that there is a downward trend in mean weights-at-age during the 1980s but they have been relatively stable since then at about 10% lower mean weights than observed in the 1980s. There is some evidence of year effects (e.g. 2001 and 2005) and cohort effects (e.g. 1999).

Stock weights-at-age are the catch weight-at-age data from the 1st quarter.

Maturity

The maturity ogive applied since 1999, was estimated from the datasets of the UK-WCGFS survey (1st quarter) has been used for the overall series. It replaced an assumed ogive used for the year prior to 1999, derived from Irish Sea cod data, when both stocks (VIIa and VIIfg) were assessed in the Irish Sea and Bristol Channel WG up to 1992. The table below summarizes the maturity ogives used.

Age	1	2	3	4	5+
Before 1999	0.00	0.05	1.00	1.00	1.00
Current	0.00	0.39	0.87	0.93	1.00

Natural mortality

In the assessments, natural mortality is assumed to be constant for the whole range of years and is age dependant The table below summarizes the values of M accordingly to age.

Age	0	1	2	3	4	5	6	7	8	9	10
M	1.12	0.51	0.37	0.30	0.269	0.247	0.233	0.223	0.216	0.210	0.207

B.3. Surveys

Three surveys-series are available.

The discontinued UK-WCGFS-Q1 (1986–2004), conducted during the first quarter, is generally truncated into a shorter series (1992–2004) as it showed a strong trend (dome-shaped) when using the full series. This pattern is related to the progressive extension of the studied area of this survey from VIIe to VIIefgh over the years. This time-series only contributes to the estimates at older ages (4 and older). Due to the lack of new data, the series is no longer used in the assessment.

The FR-EVHOE (EVHOE-WIBTS-Q4) survey (1997–), during the 4th quarter, covers the Divisions VIIfghj. The IrGFS (IGFS-WIBTS-Q4) survey (2003–), during the 4th quarter, in VIIg and VIIj is also used in the assessment.

The absolute numbers of cods caught in all of these surveys are extremely low. Attempts to combine survey data have been done at WKROUND 2009 and 2012 to overcome that problem. WKROUND 2012 tested two combinations: mixing data for the whole area and just those in the overlapping area.

WKROUND concluded that the overlap area combined index was an improvement on using the two surveys independently or using the full area index. This conclusion was based on the good cohort tracking and fairly consistent catch curves in the combined index Ages 1–4.

B.4. Commercial cpue

FR-OTDEF: a new time-series of tuning indices has been introduced at WKROUND 2012 upon French datasets considering landings and fishing efforts from otter trawlers (OTDEF métier) which catch per trip are at least 40% made of gadoids in Divisions VIIb–k during quarters 2 to 4. FR-OTDEF is a substitute for the discontinued FR-Gadoid and FR-*Nephrops* fleet.

B.5. Other relevant data

Input from industry

No new datasets. There are several industry–science partnerships regarding cod:

- French industry self-sampling programme.
- Ireland-UK tagging programme in the Irish and Celtic Seas.
- Irish industry–science partnership quarter 1 cod survey 2010.

At the moment only the data from the French self-sampling program are integrated into the observation-at-sea dataset used at the assessment working group. Information on tagging are however reviewed each year at the WG and by WKROUND. An Irish industry–science partnership survey was carried out in Q1 2010. This survey has not been repeated due to resource constraints. Any new information provided by the industry is also reviewed each year.

C. Historical stock development

Model to be used: XSA

Software: R 2.8.1 with FLR packages FLCore 2.2, FLAssess 2.0.1, FLXSA 2.0, FLEDA 2.0.

Model Options agreed at WKROUND 2012:

- Taper : no
- Age s catch dep. Stock size : none
- q plateau : 3
- F shrinkage se : 1
- F shrinkage year range : 5
- F shrinkage age range : 3
- F shrinkage age range of mean F : 2–5
- Fleet SE threshold : 0.3
- Prior weights : No

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1971–	1–7+	Yes
Canum	Landings at age in numbers	1971–	1–7+	Yes
Weca	Weight at age in the commercial catch	1971–	1–7+	Yes
West	Weight at age of the spawning stock at spawning time.	1971–	1–7+	Yes
Mprop	Proportion of natural mortality before spawning	1971–	1–7+	No
Fprop	Proportion of fishing mortality before spawning	1971–	1–7+	No
Matprop	Proportion mature at age	1971–	1–7+	No
Natmor	Natural mortality	1971–	1–7+	No

Tuning data:

Type	Name	Year range	Age range
French Otter Trawler in VIIek Q2-Q4	FR-OTDEF	2000–	1–7+
Combined EVHOE-WIBTS, IGFS-WIBTS	FR-IR-WIBTS	2003–	0–4+

D. Short-term projection

Model used: Age structured

Software used: MFDP

Initial stock size:

1) the survivors at age 2 and greater from the XSA assessment;

2) N at age 1 = long-term geometric mean omitting the last two years.

Maturity: same ogive as in the assessment

F and M before spawning: 0 (for all ages and years)

Weight-at-age in the stock: average stock and catch weights over the preceding three years.

Exploitation pattern: The F vector used is the average F-at-age in the last three years, scaled by F_{bar} (2–5) to the level of last year unless there is strong indication of a significant trend in F. In the latter case the average selectivity pattern will be rescaled to the final F in the series.

E. Medium-term projections

Medium-term forecasts are not provided for this stock.

F. Yield and Biomass per Recruit

Software used : YPR 3.0 (NOAA fisheries toolbox)

- Stock/catch-at-age/spawning–stock weights-at-age: Average last five years
- Selectivity on Fishing mortality: Rescaled F Average last five years
- Selectivity on Natural mortality: Rescaled M-at-age (Lorenzen), M-at-age 1=1
- Fraction mature: same as maturity ogive
- Proportion of fishing/natural mortality before spawning: 0.0

G. Biological reference points

	Type	Value	Technical basis
MSY	MSY Btrigger	8800 t	Provisionally set at Bpa.
Approach	FMSY	0.40	Provisional proxy based on Fmax (ICES, 2010).
	Blim	6300 t	Blim=Bloss (B76), the lowest observed spawning-stock biomass.
Precautionary	Bpa	8800 t	Bpa=Blim*1.4. Biomass above this value affords a high probability of maintaining SSB above Blim, taking into account the variability in the stock dynamics and the uncertainty in assessments.
Approach	Flim	0.90	The fishing mortality estimated to lead to potential collapse
	Fpa	0.68	Fpa=5th percentile of Floss. This F is considered to have a high probability of avoiding Flim and maintaining SSB above Bpa in the medium term (assuming normal recruitment), taking into accounts the uncertainty assessments.

H. Other issues

None.

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Stock Annex Haddock VIIb–k

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Haddock VIIb-k
Working Group	WGCSE
Date	last revision 29/02/12
Revised by	Hans Gerritsen

A. General

A.1. Stock definition

For assessment purposes, the stock is defined as VIIb–k excluding VIId. The TAC for haddock is set for VIIb–k, VIII, IX and X. However, official international landings from VIII, IX and X have been less than 2% of all landings in the TAC area in most years since 1973.

Adult haddock appear to be continuously distributed from the north of Biscay along the Irish coasts and the west of Scotland into the North Sea. It is not clear from their distribution if the VIIb–k stock is distinct from the surrounding areas. Irish Otter trawl lpue in the northernmost rectangles of VIIb is relatively high and similar lpue continues into VIa, suggesting that the haddock in the north of VIIb might belong to the same stock as those in VIa (Gerritsen, 2009). The pattern of lpue in the Irish Sea appears to be relatively distinct from VIIb–k with relatively high otter and beam trawl lpue in VIIg, low lpue in VIIa-South and high lpue in VIIa north (Gerritsen, 2009). Results from the French EVHOE-WIBTS-Q4 survey suggest that relatively low densities of haddock continue from VIIh into VIIIa. Irish Groundfish Survey (IGFS-WIBTS-Q4) data indicates two distinct nursery areas with high catches of 0-group haddock: one area off the southwest coast of Ireland (VIIb south and VIIj north) and one area off the southeast coast (VIIg north). Catches of older haddock in VIIb are generally low and it is not clear whether the young fish from VIIb move north to VIa or south to VIIj stock (Gerritsen and Stokes, 2006).

A.2. Fishery

Haddock in Divisions VIIb–k are taken as a component of catches in mixed trawl fisheries. France usually takes about 50–80% of the landings. French landings are made mainly by gadoid trawlers, which prior to 1980 were mainly fishing for hake in the Celtic Sea. Ireland has historically taken about 25–40% of the landings. Fleets from Belgium, Norway, the Netherlands, Spain, and the UK take the remainder of the landings. Landings reported between 1984 and 1995 varied between 2600 t and 4900 t, then increased sharply to 10 300 t in 1997. Since then the landings have varied between 5000 t and 10 000 t.

The vast majority of the landings are taken by otter trawls, most of the remainder of the landings are taken by seines and beam trawls.

A.3. Ecosystem aspects

Haddock are widely distributed throughout the stock area across a range of habitats. They have a varied diet but do not appear to be cannibalistic (Needle *et al*., 2003)

The mixed trawl fisheries impacts on benthic communities through bottom contact. Other ecosystem impacts result from discarding of non-target, undersize, over-quota or low-value fish.

Recruitment of haddock is highly variable. For North Sea haddock, no link could be found between temperature and recruitment (Cook and Heath, 2005). But parental condition has been linked to recruitment success in northwest Atlantic haddock (e.g. Friedland *et al*., 2003; Marshall and Frank, 1999).

B. Data

B.1. Commercial catch

Sampling and data raising

Data on landings-at-age and mean weight-at-age-are available for fleets landing into Ireland since 1993, and from France and the UK since 2002. Irish age compositions from VIIgj were used to estimate the age compositions of the international landings. Note that Irish landings contributed around 30% of the international landings so there is considerable uncertainty about the age composition of the landings before 2002.

The UK landings numbers-at-age are supplied for the combined VIIe–k area and the landings data from each Division are used to scale the catch numbers to each Division. French VIIfgh landings numbers are combined with Irish VIIg data to estimate VIIfgh landings numbers. Since 2009, the French landings numbers-at-age are supplied for the whole stock area (VIIb–k). The table below shows the data available and the procedures used to derive quarterly length compositions, age compositions and mean weights-at-age.

		Data source:				
Division	**Data**	**UK**	**France**	**Ireland**	**Belgium**	**Derivation of international landings**
VII b,c	Length composition			VII b		
	ALK			VII b		
	Age Composition			VII b		IRL raised
	Mean weight at age			VII b		IRL VIIb
	Landings		VIIb,c	VIIb,c		
VII e	Length composition	VIIe-k				Derived from UK VIIe-k
	ALK	VIIe-k				Raised to international Landings
	Age Composition	VIIe-k				
	Mean weight at age	VIIe-k				
	Landings	VIIe	VIIe		VIIe	
VII f,g,h	Length composition		VII f,g,h	VII g		
	ALK		VII f,g,h	VII g		
	Age Composition		VII f,g,h	VII g		IRL & FRA raised
	Mean weight at age		VII f,g,h	VII g		IRL & FRA raised
	Landings	VIIf,g	VIIf,g,h		VIIf,g,h,j,k	
VIIe-h	Length composition					VIIf,g,h & VIIe
	ALK					
	Age Composition					
	Mean weight at age					
	Landings					
VII j-k	Length composition			VII j		IRL raised
	ALK			VII j		
	Age Composition			VII j		IRL raised
	Mean weight at age			VII j		IRL VIIj
	Landings	VIIj,k	VIIj,k	VIIk		
VII b,c,e,f,g,h,j,k	Length composition					
	ALK					
	Age Composition					VIIb,c + VIIe + VIIfgh + VIIjk
	Mean weight at age					Weighted mean by numbers caught
	Landings					

Weights-at-age

Discard weights were estimated from a fixed length-weight relationship (a = 11.809; b = 3.069). This was applied to the discard length distributions-at-age. For the landings weights, length–weight relationships were estimated for each year and quarter from the individual weights of the fish that were aged. Landings and discard weights are combined to estimate catch weights. The values are weighted by the numbers-at-age.

Quarter-1 catch weights were used as stock weights. If no data were available, quarter-2 weights were used. Previous to the WGSSDS 2004, a three year running average was applied to the stock weights-at-age. In 2004, the working group estimation of stock weights was done using a quadratic function fitted through cohorts to the first-quarter catch weight data. In 2005 the stock weights were modelled using a von Bertalanfy growth equation. The raw stock weight data show significant year-effects and although these might be due to changes in sampling or ageing errors, it is also possible that weights-at-age are subject to inter-annual variation in condition. As the modelled stock weight did not fit the data very well and because it is not clear whether stock weights-at-age are more influenced by cohort- or year-effects, it was decided in 2007 to revert to using a three year running average to smooth the data, and constraining the weights in older ages to at least those of the preceding age in the cohort.

B.2. Biological

Natural mortality estimates were derived from mean catch weights-at-age using the approach proposed by Lorenzen (1996). Parameter values were obtained from Table 1 in the Lorenzen paper (ocean ecosystems: $\alpha = 3.69$; $\beta = -3.05$).

Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
0.99	0.72	0.60	0.50	0.43	0.40	0.37	0.36	0.34

Maturity was assumed to be knife-edged at age 2. Recent Irish Survey data is generally in agreement with this maturity ogive, although males occasionally mature at age one.

F and M before spawning were set to 0 for all ages in all years.

B.3. Surveys and commercial tuning fleets

Description

The surveys described below are co-ordinated by the IBTSWG (International Bottom Trawl Survey Working Group).

The French 7fghj EVHOE-WIBTS-Q4 annual groundfish has been carried out since 1997 on the RV Thalassa. Age data are available from 2001 onwards. ALK data from Irish surveys were applied to the EVHOE data for the years 1997–2000 to estimate numbers-at-age for these years. The sampling design is a stratified random allocation. The number of hauls per stratum is optimised by a Neyman allocation taking into account the most important commercial species in the area (hake, monkfish and megrim). The fishing gear used is a GOV with an average vertical opening of 4 m and a horizontal opening of 20 m.

The Irish Groundfish Survey (IGFS-WIBTS-Q4) has been carried out since 2003 and covers VIaS, VIIbgj. This survey is carried out on RV Celtic Explorer. The IGFS has a random stratified design and uses a GOV (with rockhopper in VIa) with a 20 mm codend liner.

The two surveys were combined to provide a single index that covers nearly the full stock area. Gerritsen (2012a) describes the justification and for combining the surveys. The two indices are directly combined, weighted by the surface area covered by each survey (37 000 nm^2 for the IGFS and 30 000 nm^2 for the EVHOE). The combined survey starts in 2003. The EVHOE data before 2003 are not used.

A French commercial OTB DEF tuning fleet is available but this fleet takes the majority of the landings and is therefore not included as tuning fleet.

An Irish commercial OTB fleet is available from 1995 onwards. This fleet is based on the landings and effort from ICES Rectangles 32D9, 31D9, 31E0, 31E1, 31E2, 32E1 and 32E2. These rectangles were selected in order to avoid changes in lpue due to shifts in targeting behaviour. The selected rectangles do not include any major *Nephrops* or hake, monkfish or megrim fishing grounds or areas with seasonal closures.

Consistency

The survey shows good internal consistency for ages 0 to 4. The Irish tuning shows good consistency from the age of 2 to 7. However discards are not included in this index and it is not known if discarding patterns have been consistent over time, therefore ages 2 and 3 were not included.

B.4. Commercial cpue

Effort and lpue data are available from the Irish otter trawl fleets operating in Divisions VIIb, VIIj and VIIg since 1995, French demeral trawlers in VIIfgh since 2004 and effort data are available for the UK beam trawl fleet in VIIe–k and all other trawl gears in VIIe–k since 1983. The effort in the French gadoid fleet has decreased in recent years and is now at a similar level to the Irish and UK fleets. Effort in the Irish OTB VIIg fleet has increased in recent years, while the Irish OTB effort in VIIb and

VIIj appears to have levelled off in recent years. The LPUE of the French gadoid fleet is still much higher than that of the other fleets. The Irish and UK fleets have seen a minor increasing trend in lpue in recent years.

B.5. Other relevant data

Discard data

Discard data are available from the Irish fleet since 1995. Data were raised using effort (hours fished) as auxiliary variable and stratified by ICES Division. The number of trips in some years is quite low, leading to concerns about the precision of the data.

French discard data are available since 2004. These data were also raised using effort (hours fished) as auxiliary variable. Data before 2008 are considered unreliable. Therefore French discards were estimated from the mean discard rate-at-age for the period 1993–2007. It was assumed that 90% of one-year-olds, 50% of two-year-olds and 10% of three-year-olds were discarded. These proportions were applied to the French catch numbers-at-age to estimate historic discards. For the period 1993–2001, no French age composition data were available, therefore Irish age composition data were raised to French landings and the discard numbers were estimated from these.

French and Irish discard data were combined and a further raising factor was applied to account for discards from other countries. This raising factor was estimated from the total landings of all countries as a proportion of the combined French and Irish landings. This raising factor did not exceed 1.15 in any year.

No French age data are available for the discards. Irish age data are available but there are some concerns about the reliability of these data. For this reason, a quarterly length split is applied to the smallest length classes (where the cohorts are quite distinct). For larger fish, quarterly ALKs from the French and Irish landings are used.

Length-splits applied to the discard data. For lengths where landings ALKs were available, these were used.

Country	Area	Quarter	Age 0	Age 1	Age 2	Age 3
Ireland	VIIb	1	≤10	11–18	19–27	≥28
		2	≤11	12–21	22–29	≥30
		3	≤14	15–23	24–33	≥34
		4	≤17	18–25	26–34	≥35
Ireland	VIIgj	1	≤15	16–23	24–34	≥35
		2	≤17	18–26	≥27	
		3	≤20	21–29	≥30	
		4	≤21	22–30	≥31	
France	VIIbk	1	≤18	19–23	24–32	≥33
		2	≤17	18–26	27–34	≥35
		3	≤20	21–29	≥30	
		4	≤21	22–29	≥30	

C. Historical stock development

Model used:

ASAP; (XSA is also used for quality control purposes; if the two models disagree the differences will need to be explained.)

Software used:

ASAP V2.0 NOAA Fisheries toolbox (http://nft.nefsc.noaa.gov)

VPA95 (http://www.ices.dk/datacentre/software.asp)

FLR with R version 2.8.1 with packages FLCore 2.2, FLAssess 2.0.1, FLXSA 2.0 and FLEDA 2.0 (http://cran.r-project.org; http://flr-project.org)

ASAP is proposed as the main assessment model. However, due to the short time-series and noisy catch data, it is uncertain whether the separable assumption holds. Therefore it is proposed to also use XSA to monitor if the two models continue to provide similar trends and absolute estimates of SSB and F.

C.1. Input data types and characteristics

A plusgroup of 8+ was used. Age group 0 was included in the assessment data to allow inclusion of 0-group indices. However, catch numbers and selectivity-at-age 0 were set to zero in all years because catches at this age were very low or zero.

Discard estimates are included in the catch numbers and weights, therefore catch is explicitly defined here as landings + discards.

Data	Year range	Age range	Variable from year to year
Catch (tonnes)	1993–current	0–8+	Yes
Catch-at-age in numbers (thousands)	1993–current	0–8+	Yes
Weight-at-age in the commercial catch (kg)	1993–current	0–8+	Yes
Weight-at-age of the stock at spawning time (kg).	1993–current	0–8+	Yes
Weight-at-age of the stock at Jan- 1 (same as stock weights)	1993–current	0–8+	Yes
Proportion of natural mortality before spawning (Lorenzen M)	1993–current	0–8+	No
Proportion of fishing mortality before spawning (XSA only)	1993–current	0–8+	No
Proportion mature-at-age	1993–current	0–8+	No
Natural mortality	1993–current	0–8+	No

C.2. Model Options

ASAP

Note that ASAP does not accommodate inclusion of data for age 0. Therefore the ages in ASAP are offset by 1 year. All age settings above refer to the real age, not the age group used by ASAP.

Option	Setting
Include discards separately	No
Use likelihood constant	Yes
Mean F (Fbar) age range	3–5
Number of selectivity blocks	1
Fleet selectivity	Fixed at 0 for age 0; freely estimated for age 1 and 2, fixed at 1 for ages 3–8+
Discards	Included in catch (not specified separately from landings)
Index units	2 (numbers)
Index month	FR_IR_IBTS: 11; IR_GAD: 7 (7 = July 1st, the middle of the year)
Index selectivity linked to fleet	-1 (not linked; the commercial index does not include discards)
Index age range	FR_IR_IBTS: 0-5; IR_GAD: 3–7
Index Selectivity – FR_IR_IBTS	Fixed at 1 for all ages
Index Selectivity - IR_GAD	Freely estimated at age 3, fixed at 1 for all other ages
Index CV & ESS – FR_IR_IBTS	CV 0.3 all years, estimated sample size 40 for all years
Index CV & ESS – IR_GAD	CV 0.2 all years, estimated sample size 40 for all years
Phase for F-Mult in 1st year	1
Phase for F-Mult deviations	2
Phase for recruitment deviations	3
Phase for N in 1st Year	1
Phase for catchability in 1st Year	3
Phase for catchability deviations	-5 (Assume constant catchability in indices)
Phase for unexploited stock size	1
Phase for steepness	-5 (Do not fit stock-recruitment curve)
Catch total CV	0.3 for 1993–2007; 0.2 for 2008-present (reliable discard data available)
Input effective sample size	25 for 1993–2001; 50 for 2002-present (only Irish age comp before 2002)
Lambda for recruit deviations	0 (freely estimated)
Lambda for total catch	1
Lambda for total discards	NA (discards included in catch)
Lambda for F-Mult in 1st year	0 (freely estimated)
Lambda for F-Mult deviations	0 (freely estimated)
Lambda for index	1 for both indices in the model
Lambda for index catchability	0 for all indices (freely estimated)
Lambda for catchability devs	NA (phase is negative)
Lambda N in 1st year deviations	0 (freely estimated)
Lambda devs initial steepness	NA (phase is negative)
Lambda devs unexpl stock size	0 (freely estimated)

Discards were not included separately because this resulted in undesirable residual patterns. Only one selectivity block was used due to the short time-series, as the time-series gets longer it may be appropriate to allow a separate block for the time period where observed discard data are available. Fleet selectivity was forced to be flat topped to reduce the number of parameters to be estimated. The F-pattern from XSA indicated flat-topped selectivity.

XSA

Option	Setting
Ages catch dep stock size	None
Q plateau	4
Taper	No
F shrinkage SE	1.5
F shrinkage year range	5
F shrinkage age range	3
Fleet SE threshold	0.3
Prior weights	No

There is no evidence to suggest that catchability is dependent on stock size; the linear regression fits the data well. The effect of releasing the q-plateau was investigated and catchability appeared to level off at age 4. There is no evidence to suggest that the tuning fleets have changed over time, therefore no tapered time weighting was applied. In recent years there has not been a clear retrospective pattern, therefore a relatively high F shrinkage SE was used with a short year and age range. The fleets are relatively well behaved so an SE threshold of 0.3 was applied.

Tuning data:

Type	Name	Year range	Age range
Survey	FR_IR_IBTS	2003–present	0–5
Commercial	IR_GAD	1995–present	3–7

D. Short-term projection

Model used: Multifleet Deterministic Projection. Landings and discards are modelled as separate fleets.

Software used: MFDP1a (http://www.ices.dk/datacentre/software.asp)

Option	Setting
Initial stock size	Long-term GM (omitting last two years) Stock numbers-at-age 1 and older from model
Natural mortality	Lorenzen M, as in model
Maturity	Knife-edged at age 2
F and M before spawning	0 for all ages in all years
Stock / catch weights-at-age	Average last 3 years
Exploitation pattern	Average last 3 years
Intermediate year assumptions	F in the last year – check retrospective pattern for evidence of bias
Stock–recruit model	None, long term GM recruitment (omitting last two years)
Fbar range	5–5*
Rescale to last year	No

*** The F_{bar} age range used in the assessment model outputs is 3–5 this F refers to the catch (including discards). Ages 3-–5 are fully selected in the catch (but not landings). MFYPR output supplies YPR based on landings F. In order to compare (landings) F reference points with the (catch) F_{bar} it was decided to calculate F_{bar} only for age 5 because at this age the catch and landings are both fully selected and because a flat-topped selection pattern was applied in ASAP the result will be correct. So, in this context F_{max} refers to the catch F where the landings per recruit are maximised.**

E. Medium-term projections

None.

F. Yield and biomass per recruit

No stock–recruit relationship exists for this stock; recruitment is characterised by sporadic extreme recruitment events.

Software used: NOAA fisheries toolbox YPR V3.0.

Option	Setting
Stock / catch weights-at-age	Average last 3 years
Selectivity	Average last 3 years
Natural mortality	Lorenzen M, as in model
Maturity	Knife-edged at age 2

G. Biological reference points

No reference points have been defined for this stock. The following results from the analyses by WKROUND could be informative:

F_{max} (landings) = 0.28

$F_{0.1}$ (landings) = 0.19

$F_{msy} = F_{max} = 0.28$

B_{loss} = 7500 tonnes

H. Other issues

None.

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