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Report of the Benchmark and Data Compilation Workshop for Roundfish (WKROUND)

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Copenhagen, Denmark

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

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

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

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1 Executive Summary

The WKROUND 2009 benchmark workshop was held at ICES Headquarters in Copenhagen from 16–23 January 2009. The workshop was chaired by Pamela Mace (New Zealand) and ICES Coordinators Chris Darby (UK) and Eero Aro (Finland) and involved 38 participants representing 13 nations. The primary objectives of the Workshop were to compile and evaluate data sources and select appropriate assessment models to include in updated Stock Annexes for six stocks: North Sea whiting, North Sea cod, Celtic Sea cod, Kattegat cod, Western Baltic cod and Eastern Baltic cod. Benchmark workshops are designed to consider stocks under their jurisdiction on a rotational basis, with each stock being analysed in a 3–5 year cycle. The Stock Annexes are the most important product of this process, with each annex containing all relevant information that the benchmark workshop participants have identified as current best practice assessment inputs and models, providing sufficient detail to ensure that future assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments. The report also details the analyses undertaken during the benchmark workshop to inform the Stock Annexes.

This report consists of the benchmark workshop report and the Stock Annex for each stock in turn, followed by general recommendations arising from the plenary sessions of the workshop, and five annexes containing supplementary information. The species-specific benchmark reports are split into 15 sections dealing with data sources, data quality, environmental and ecosystem issues, stock assessment methods, forecasts, biological reference points, recommended modifications to the stock annex, recommendations on the procedure for assessment updates and recommendations for future work. Sections on industry-supplied data are also included where appropriate. The species-specific Stock Annexes follow the standard ICES format.

The benchmark was completed and corresponding Stock Annexes were updated for four of the six stocks: North Sea cod, Kattegat cod, Western Baltic cod and Eastern Baltic cod. In each of the cases, a preferred assessment model was identified. For North Sea whiting and Celtic Sea cod, the workshop concluded that more work was required before these could be benchmarked. The issue for North Sea whiting was a mismatch between survey and catch-at-age results in the early years of the assessment that was not able to be fully resolved during the benchmark workshop, although promising avenues for further analyses that could be undertaken to accomplish this were identified. The issue for Celtic Sea cod was a recent breakdown in the quality of the input data which is sufficiently serious that it is no longer possible to provide advice on this stock. Issues requiring further work were identified for all stocks. For example, although the benchmark was completed for Eastern Baltic cod, the workshop had reservations about the use of age-structured models due to aging difficulties and recommended exploration of length-based models for the next benchmark.

The workshop also evaluated a relatively new assessment modelling approach based on a state space approach (State Space Assessment Model, or SAM). The WK adopted this approach for Kattegat and Western Baltic cod but concluded that the approach requires further development and evaluation for other stocks.

General recommendations were formulated for an intersession benchmark change protocol, the use of commercial fleets in tuning assessments, the use of commercial cpue and VMS data, improvements to the use of survey data, the need to collect

additional data on multispecies interactions, protocols for evaluation of assessment models, the need to document assessment models, the use of biological reference points, data provision from the industry, involvement of industry members in stock assessments, archiving of working documents, and issues to be considered in future benchmark workshops.

2 Introduction

The requirements for benchmark workshops were detailed by ACOM in 2008 (ACOM December 2008 22/12/2008 FINAL document). This Roundfish Workshop (WKROUND 2009) is the first such benchmark workshop. Draft Terms of Reference were set out in the document ACOM32 (Annex 1). The key aspects of the Terms of Reference are:

to compile and evaluate data sources for stock assessments,

to solicit relevant data from industry and other stakeholders, and

to update the relevant Stock Annexes to include what benchmark participants identify as current best practice assessment inputs and methods, providing sufficient detail to ensure that assessment scientists can readily replicate assessments without the need to have been previously involved in such assessments.

Accordingly, the first two days of this benchmark workshop were devoted to data compilation, including invited input from stakeholders; and to identifying assessment issues. The next six days then focussed on resolving the assessment issues to the extent possible, with a view to revising the Stock Annexes for adoption for the following 3–5 years.

The workshop was chaired by Pamela Mace (New Zealand) and ICES Coordinators Chris Darby (UK) and Eero Aro (Finland). Anthony Thompson (NAFO) and Noel Cadigan (Canada) were invited experts. Other participants included members of the WGNSSK, WGBFAS and WGSSDS ICES assessment groups, industry representatives, and members of the ICES Secretariat. A full list of participants is provided in Annex 2. A numbered list of Working Documents considered by the WK, and subsequently archived by ICES, is given in Annex 3.

An evaluation of present and future industry participation in current and future assessment-related activities is provided in Annex 4. Annex 5 contains a brief description and preliminary evaluation of a new State- space Assessment Model (SAM).

3 Whiting (*Merlangius merlangus*) in the North Sea (Subarea IV) and the Eastern Channel (Division VIId)

3.1 Current stock status and assessment issues

The status of the whiting stock in the North Sea and eastern Channel is uncertain. The present assessment is indicative of recent trends, but absolute levels of fishing mortality and biomass cannot be confidently estimated. The problem lies in a mismatch between the available catch and survey data during the period 1980 to 1995. This is demonstrated in Figure 3.1.1 where a catch based estimate of spawning stock biomass (SSB) is compared to several survey based estimates of SSB. The figure shows that from around 1995 the trends in the catch and surveys are similar. The difference is that the surveys perceive an increasing SSB from 1985 to 1995 whereas the catch data shows a stable or declining SSB. This difference has caused long standing problems in the stock assessment of North Sea and eastern Channel whiting.

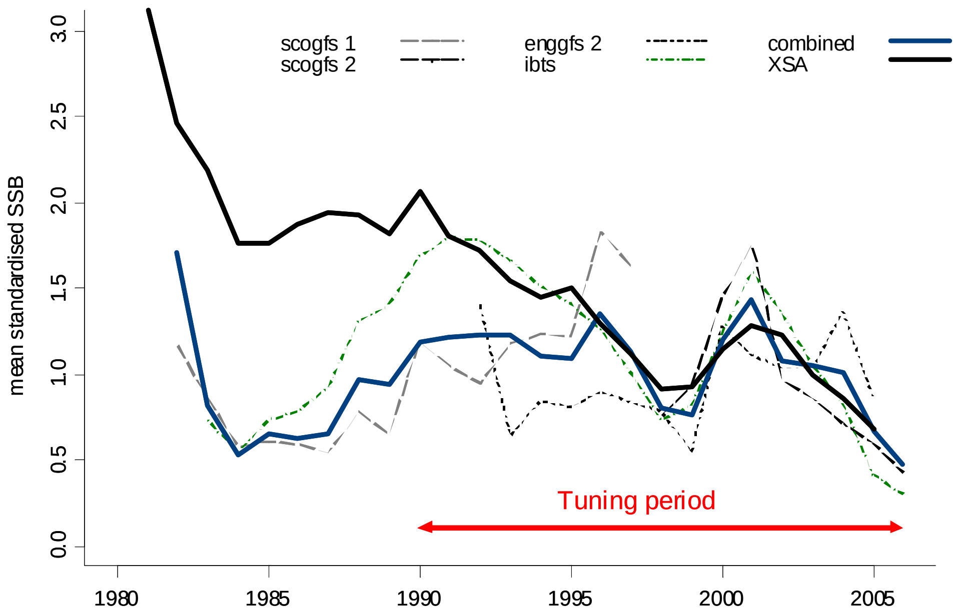


Figure 3.1.1. Catch based estimates of spawning stock biomass (black line) shown alongside survey based estimates of spawning stock biomass (blue, and dashed lines), the blue line showing an estimate based on all the surveys. These are scaled so that the mean of each line over the years 1996–2006 is one.

The reason for the mismatch is not clear. The quality of the majority of the catch data is thought to be good. Survey data also appear to be of good quality; nonetheless there have been various vessel changes that raise the question of potential changes in catchability over time. There is evidence that a regime shift occurred in the North Sea in the late 1980s which may have resulted in changes in natural mortality. Additionally, different biomass trends in different regions of the North Sea and eastern Channel (Figure 3.1.2) indicate population substructure.

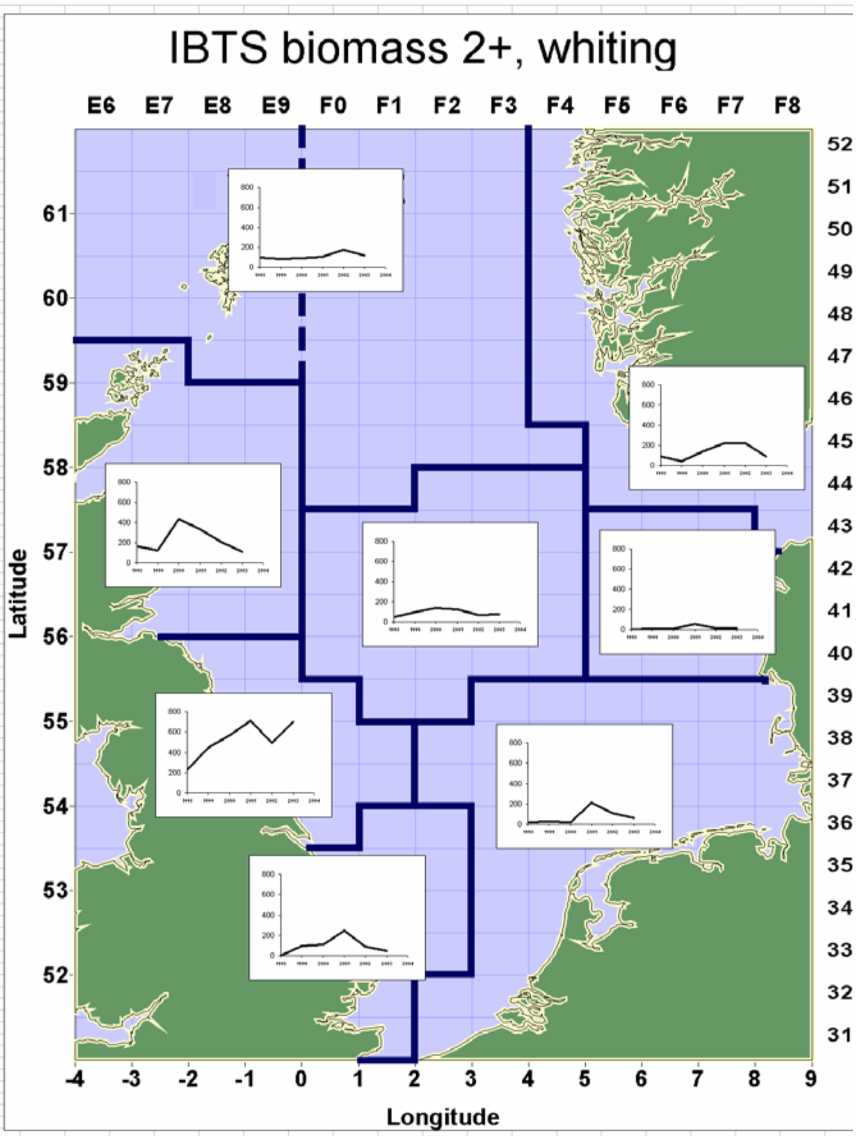


Figure 3.1.2. Biomass of 2+ whiting in the ICES North Sea roundfish areas taken from the IBTS quarter 1 survey.

3.2 Compilation of available data

3.2.1 Catch and landings data

Age disaggregated landings data are provided by Scotland, France, England, Denmark, The Netherlands, Germany and Norway. This accounts for more than 95% percent of landings taken from the North Sea and eastern Channel. Discard estimates are provided by Scotland, England, Denmark, The Netherlands, Germany, and Norway. France does not supply estimates of discards-at-age. Only Scottish discard ratios were used to estimate discards in the catch prior to around 1998. Age disaggregated catch from industrial bycatch fisheries are supplied by Denmark and Norway.

Newly available for the WKROUND meeting are spatially disaggregated landings data. These data consist of live catch weights of whiting for each statistical rectangle, disaggregated by gear type and supplied with fishing effort where appropriate. This is summarised in Table 3.2.1 and Figure 3.2.1. Figure 3.2.1 plots available landings by year and statistical rectangle, Table 3.2.2 shows for which years national data is available; note that the industrial fishery for whiting is predominantly a Danish fishery and Danish data does not appear in the plots until 1988; and that the English channel whiting fishery is predominantly a French fishery and French data does not appear in the plots until 1999.

Table 3.2.1. Landings data provided to the WKROUND.

Nation	Catch	Effort	Disaggregation	ICES area coverage	Proportion of total HC
France	HC	yes	Stat rectangle + gear	IV, VIId	30%
UK, Scotland	HC	yes	Stat rectangle + gear	IV, VIId	35%
UK, England	HC	yes	Stat rectangle + gear	IV, VIId	30%
Netherlands	HC	yes	Stat rectangle + gear	IV, VIId	4%
Belgium	HC	Not appropriate	Stat rectangle + gear	IV, VIId	1%
Denmark	HC, Ind	No	Stat rectangle + gear	IV	>1%
Germany	-	-	-	-	>1%
Norway	HC	Yes	sampling area + gear	IV	>1%

3.2.1.1 Evaluation of the quality of the catch data

Sampling of landings data is considered sufficient. The historical application of Scottish discard estimates across all fisheries prosecuting the fishery is a pragmatic solution, but is not considered an issue as a large portion of the landings were in the northern North Sea. However, in recent years, the northern fishery has declined and an increasing proportion of the catch is from the eastern Channel and English coast, prosecuted by English and French trawlers. Discard estimates are available for English vessels, but no French data has been made available. It is important that discard information for the French fleet is made available.

In recent years there has been reduced sampling of this fishery which has resulted in poor estimates of the age composition of the catch. In 2007 for example, the age composition was estimated to be 0- and 1- group whiting, both with low estimated mean weights. This can have a large impact on the estimates of age 1 whiting numbers in the total catch.

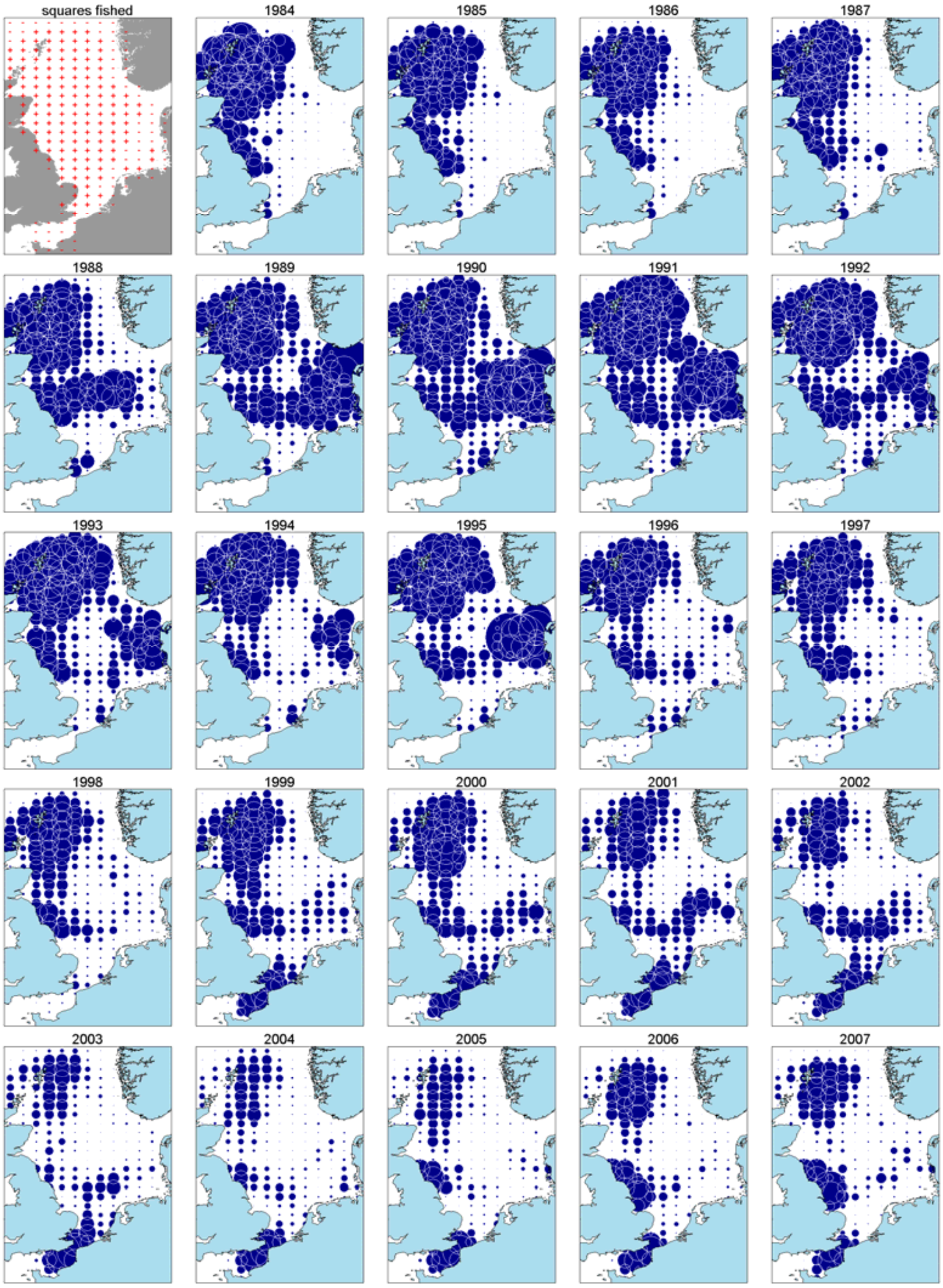


Figure 3.2.1. Commercial landings (human consumption and industrial fisheries in tonnes) by ICES statistical rectangle over the years 1980 to 2007. The most notable features are the decline of the industrial fishery near the Danish coast from 1996; the increase in landings off the English coast in 2006-2007; and the decline of the Northern fishery south east of Shetland over the full time period. The same scaling is used in each map. In the top left plot a '+' indicates where landings are reported / available in every year (1984–2007), '-' indicates that for some years no landings were reported / available for that square.

Table 3.2.2. Data available for Figure 3.2.1. Numbers of reported squares fished by nation for each year from 1980 to 2007.

	Scotland	England and Wales	Denmark	Netherlands	Belgium	France
1980	222	.	.	.	.	.
1981	204	.	.	.	.	.
1982	192	286	.	.	.	.
1983	201	305	.	.	.	.
1984	203	309	.	.	.	.
1985	264	406	.	.	.	.
1986	242	380	.	.	.	.
1987	265	428	270	.	.	.
1988	265	401	251	.	.	.
1989	288	425	768	.	.	.
1990	294	469	644	122	.	.
1991	290	473	560	53	.	.
1992	307	491	549	42	.	.
1993	306	432	662	35	.	.
1994	305	422	491	35	.	.
1995	351	433	747	28	.	.
1996	337	384	549	35	107	.
1997	350	378	503	43	103	.
1998	359	351	521	50	110	.
1999	341	350	532	44	127	131
2000	328	358	507	49	139	145
2001	340	346	498	44	121	159
2002	333	303	555	54	117	182
2003	347	268	487	42	112	208
2004	314	230	507	43	98	231
2005	293	264	423	46	77	177
2006	273	264	381	48	84	183
2007	283	285	300	53	79	194

3.2.2 Biological data

3.2.2.1 Weights-at-age

Weight-at-age in the population shows a decline since 1990 with an indication of much reduced growth at older ages (Figure 3.2.2). Similar declines can be seen in other stocks, but it is not clear if this pattern is also seen in the population or only in the catch data. Length, weight and age data are available on the DATRAS website from the IBTS surveys, and such data could be used to assess if current mean weight at age assumptions are appropriate. This was not considered a first priority and was not carried out.

Historically mean weight-at-age has been estimated by the application of a length weight relationship based on data from 1972 and 1989 (Coull *et al*., 1989).

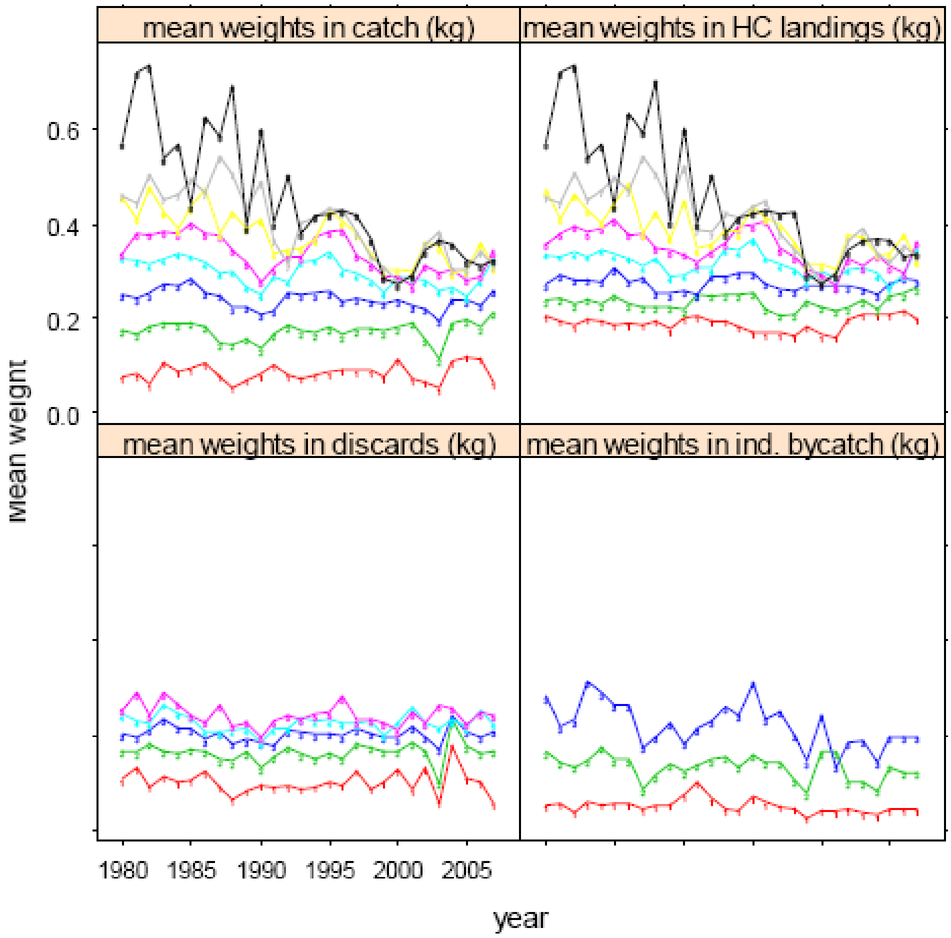


Figure 3.2.2. Mean weights at age for each catch component as estimated from national market sampling data bases.

3.2.2.2 Maturity-at-age

A fixed maturity-at-age has been assumed for the stock. Maturity data is available to estimate time varying maturities-at-age to test this assumption. Binomial logistic linear regression models were fit by cohort; however, the results were erratic because of years with no data, particularly 1997–2000. A useful strategy in this situation is to treat the cohort-specific logistic regression intercepts and slopes as random effects. A generalized linear mixed effects model (GLMM) with a common intercept and slope for all cohorts, and random zero-mean interaction terms (intercepts and slopes) for each cohort, was investigated to deal with the problem of missing data. The R function glmmPQL was used to estimate this model. In this approach, the maturity ogive for cohorts with no or little data is essentially the average for all cohorts. The results indicated there was basically no cohort variation in maturity. The variances for the cohort interaction terms were estimated to be very close to zero. The main-effects maturity estimates are given in Table 3.2.3. The fits to data for each cohort are shown in Figure 3.2.3. The model fit is reasonably good for all cohorts, although outliers are apparent and their impact on the estimates should be investigated in future assessments.

Table 3.2.3. Proportion mature (p) for all years.

AGE	1	2	3	4	5	6+
p	0.337	0.669	0.889	0.970	0.992	0.999

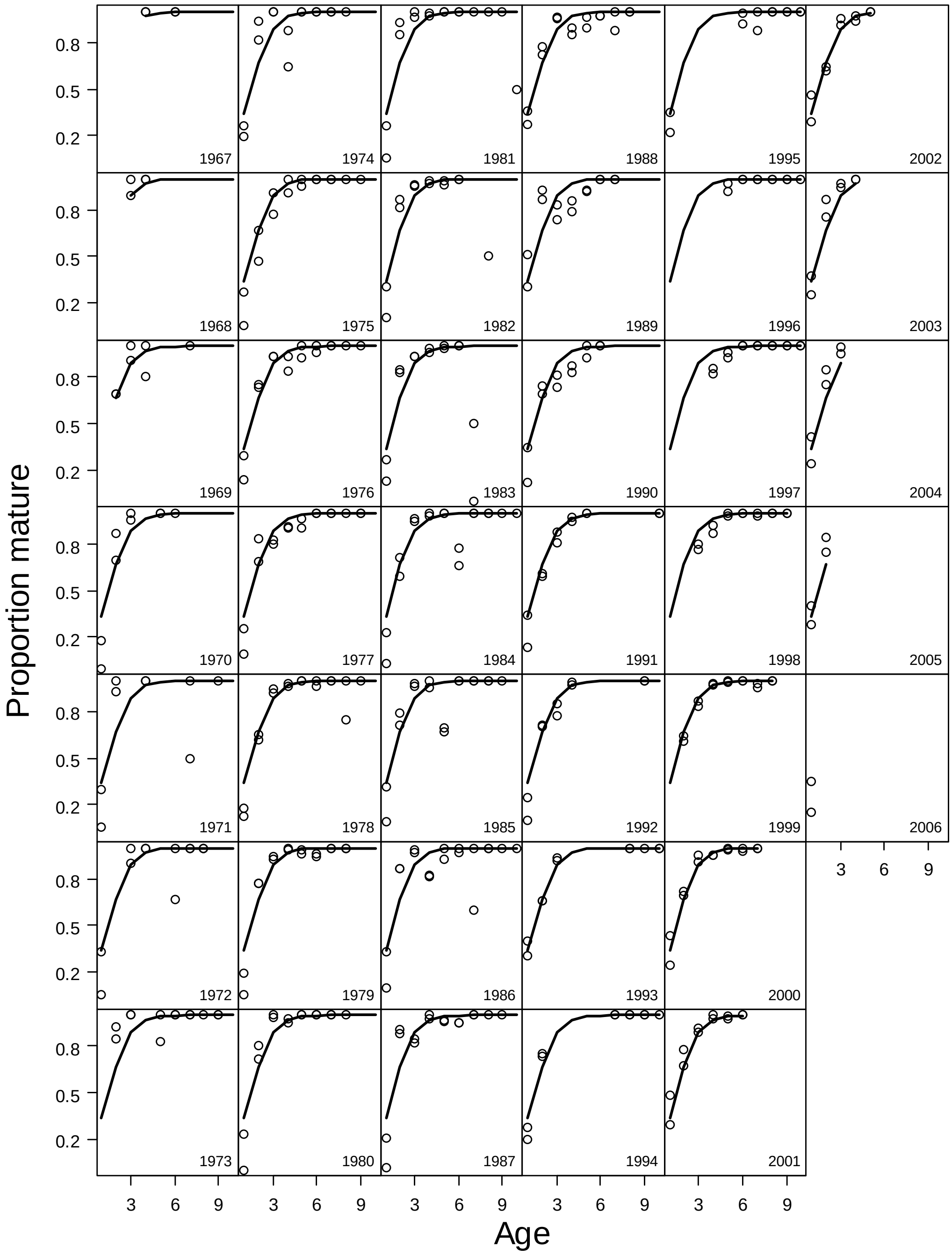


Figure 3.2.3. Maturity data for North Sea whiting fitted with a GLMM binomial logistic linear regression model with random cohort effects.

3.2.2.3 Natural mortality-at-age

In the current assessment natural mortality for whiting is assumed to be constant in time. However, calculations with the SMS (Stochastic Multi Species Model; Lewy and Vinther, 2004) keyrun carried out during the last meeting of the Working Group on Multi Species Assessment Methods (ICES 2008) indicate that predation mortalities (M2) declined in the last 20 years for older age groups of whiting due to the disappearance of large predators from the ecosystem. In contrast, predation mortalities for 0-group whiting increased over the 1990s due to an increasing grey gurnard stock. Therefore, natural mortalities for whiting were extracted from the SMS keyrun to provide input for evaluation runs with XSA. However, SMS uses maximum likelihood to fit the model from observations of catch-at-age, cpue and stomach observation, such that the final parameters give the best fit to all data sources. Therefore, the predation mortalities do also contribute to the fit of the separable fishing mortality model used within SMS. To remove the circularity, when the M2´s are used by XSA, the time series for M2s were smoothed over time using a spline smoother with five degrees of freedom (Figure 3.2.4).

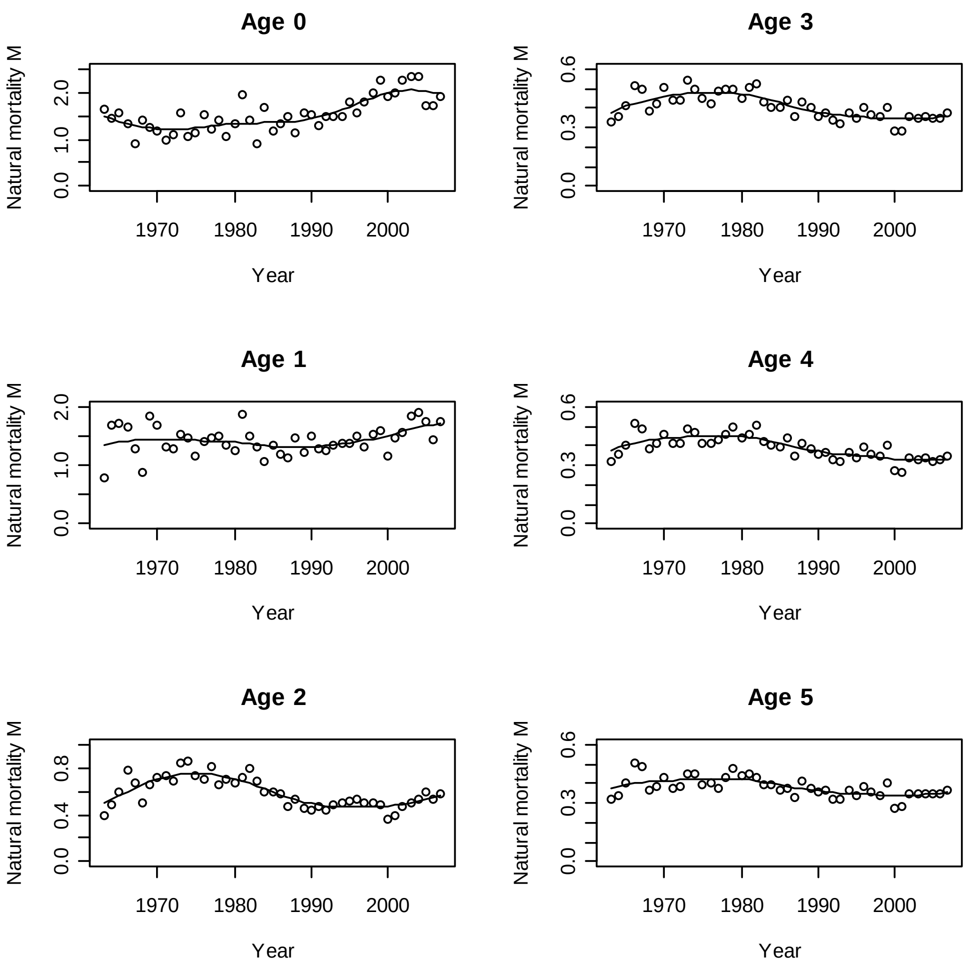


Figure 3.2.4. Smoothed input values for natural mortality M taken from the SMS keyrun 2008.

The effect of using the multispecies natural mortalities (M's) on spawning stock biomass (SSB), total stock biomass (TSB), recruitment and mean fishing mortality (F) is shown in Figure 3.2.4. The multispecies M's are generally higher than those currently used and so results in greater overall mortality each year, implying that more fish must have been there initially. This observation is borne out in Figure 3.2.5 where using the multispecies M's results in increased TSB, SSB and recruitment. Increasing natural mortality also has the effect of reducing fishing mortality though the effect is reduced in the most recent years.

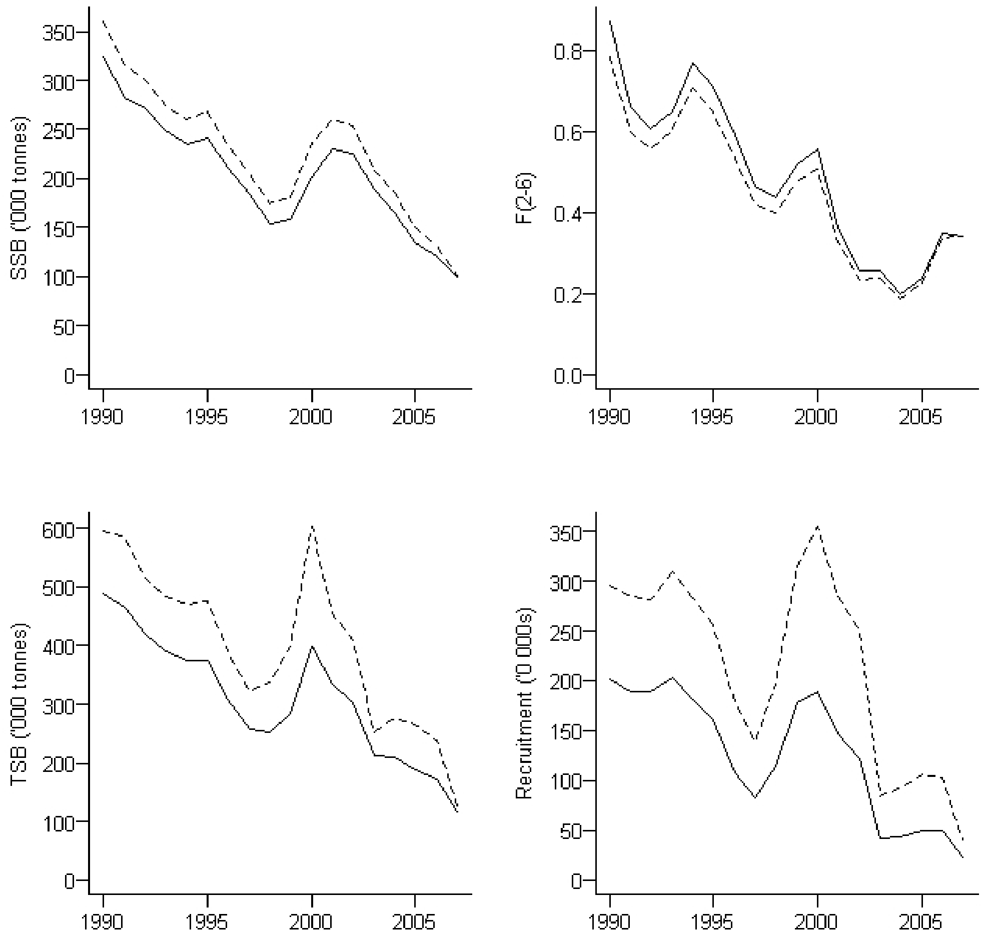


Figure 3.2.5. Spawning stock biomass (SSB), total stock biomass (TSB), mean fishing mortality F(2–6) and recruitment from two runs of XSA using the settings from the current assessment. Solid lines show results using fixed natural mortality (current assessment) and dashed lines show results using estimates of natural mortality from the key SMS run of the Working Group on Multi Species Assessment Methods (WGMSAM ICES 2008).

3.2.3 Survey data

Figures 3.2.6 and 3.2.7 show survey estimates of total stock biomass (TSB) by statistical rectangle from the IBTS quarter 1 and IBTS quarter 3 surveys. Survey TSB was estimated by

$$\mathrm{TSB}_{s,y} = \sum_{a=1}^{6+} w_{a,y} I_{a,s,y}$$

Where $w_{a,y}$ denotes mean weight in the stock at age a in year y; and $I_{a,s,y}$ denotes survey catch per unit effort at age a in statistical rectangle s in year y. These figures show three regions of high density, particularly in the 1990s: a northern offshore region, a UK coastal region and a southern coastal region. Also evident is an apparent increase in the stock around 1988. The quarter 1 survey shows high abundance in the nineties declining to moderate levels in the period 1998–2004 with low stock levels in 2005 and 2006. The quarter 3 survey shows similar trends in abundance but also shows a concentration of the stock around the 50 m contour from the northern Scottish coast, tracking south and then east across the North Sea to Denmark. Also evident from both surveys is the aggregation of whiting off the English coast in the most recent years.

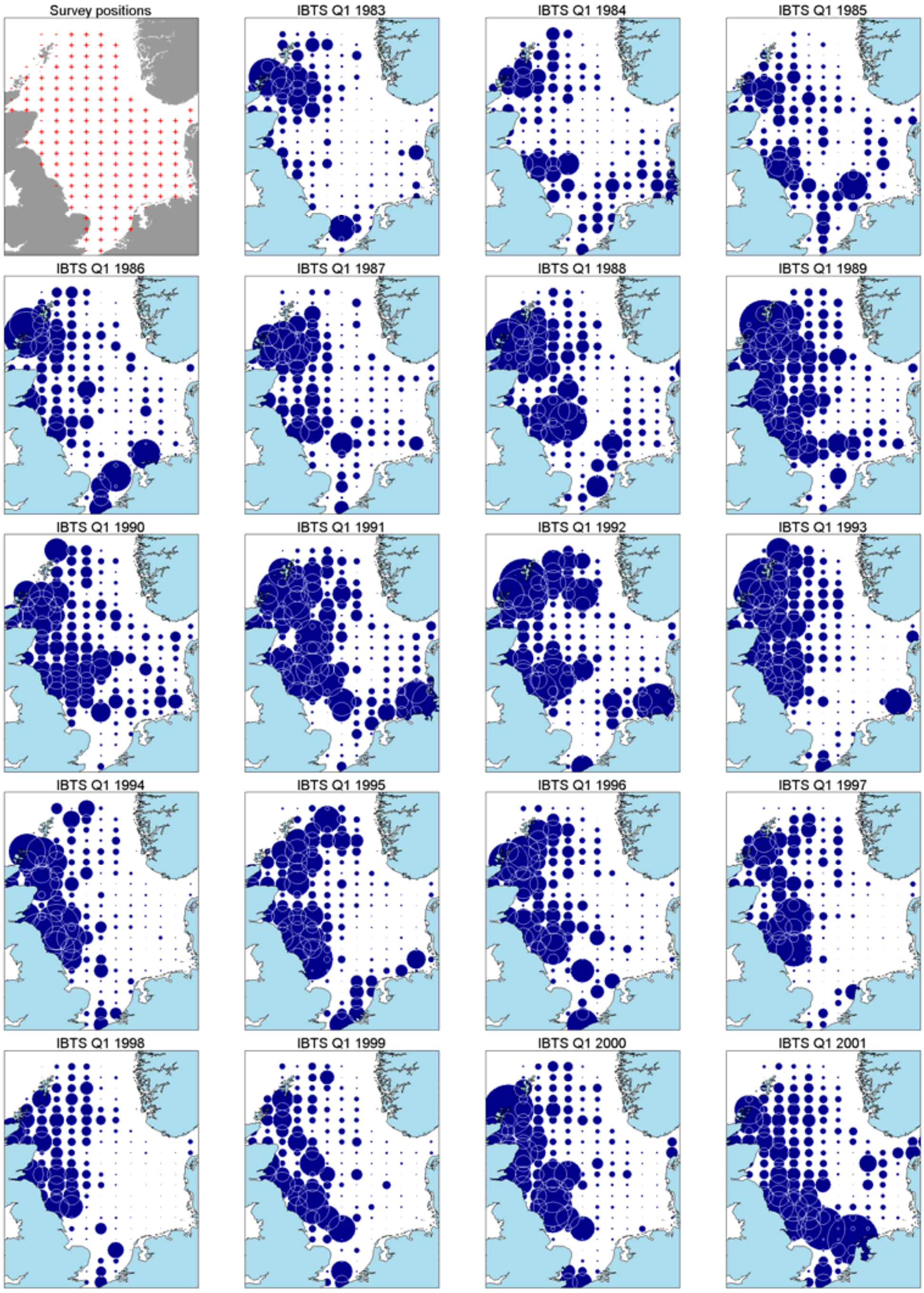


Figure 3.2.6. IBTS quarter 1 survey estimates of TSB by statistical rectangle (see text for calculation). Top left hand plot shows survey coverage: '+' indicates that sampling of that square took place every year from 1980–2007, '-' indicates that in some years this square was not sampled.

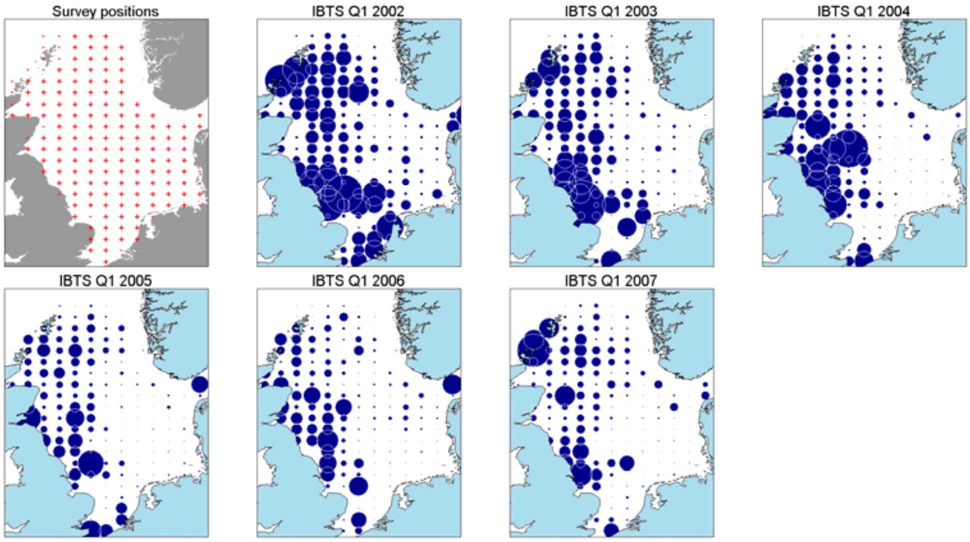


Figure 3.2.6 cont. IBTS quarter 1 survey estimates of TSB by statistical rectangle (see text for calculation). Top left hand plot shows survey coverage: '+' indicates that sampling of that square took place every year from 1980–2007, '-' indicates that in some years this square was not sampled.

3.2.3.1 Evaluation of the quality of the survey data

The evaluation of the quality of the survey data for whiting is a major issue for this stock. To explain the mismatch between survey and catch data obvious possibilities are that the survey catchability was lower prior to 1990; the catch was over reported prior to 1990 or the catch is under reported since 1990; or natural mortality has increased since around 1990. The ICES DATRAS database allows the extraction of detailed information on the IBTS surveys. Preliminary analysis shows that to explain the mismatch between survey and catch data solely in terms of survey catchability would require around a 2-fold increase in catchability during the period 1985 to 1995. In a working document to the study group on stock identity and management units of whiting (SGSIMUW) in 2003, Floeter *et al.*, 2003 present an analysis that makes upward revisions of the IBTS Q1 survey indices prior to 1991. This is based on an impression of reduced sampling prior to 1991, however this study was based on a subset of the IBTS Q1 data and it was shown to WKROUND that these issues are no longer relevant. Changes in catchability are likely to come from changes in gear, changes in vessel, changes in spatial coverage or a combination of these. The following subsections present the analysis conducted by WKROUND of the IBTS quarter 1 survey.

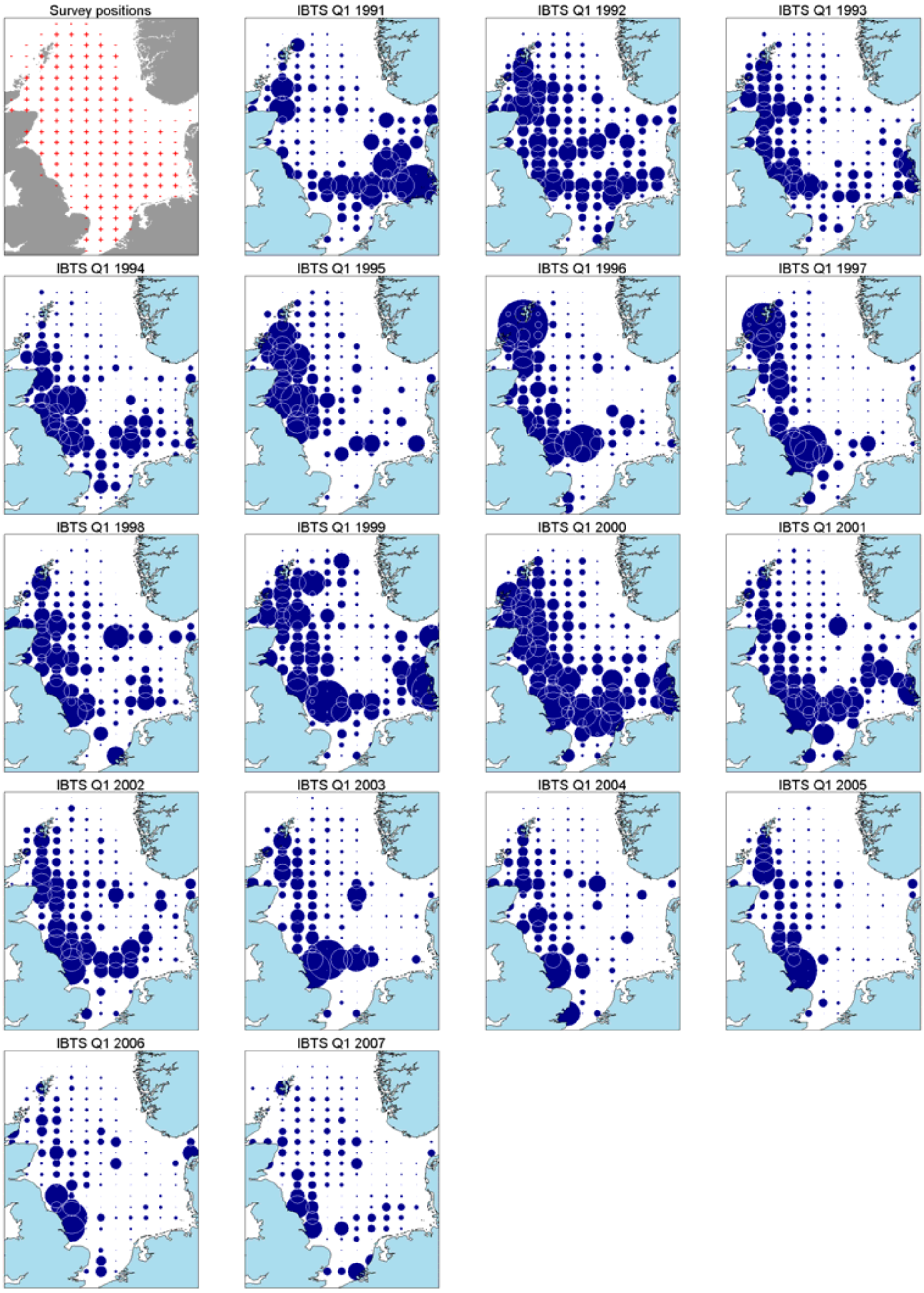


Figure 3.2.7. IBTS quarter 3 survey estimates of TSB by statistical rectangle (see text for calculation). Top left hand plot shows survey coverage: '+' indicates that sampling of that square took place every year from 1991–2007, '-' indicates that in some years this square was not sampled.

3.2.3.1.1 Gear changes in the IBTS quarter 1

In the current assessment, the IBTS Q1 is used from 1983. Prior to this year various gear types were used and are not considered consistent by the IBTS working group. Figure 3.2.8 shows the distribution of hauls by gear type in the years 1983 to 1985. The H18 trawl gear is used over a wide area in 1983. In order to remove the possibility of changes in catchability with time the IBTS Q1 survey will only be considered from 1984 for the remainder of the analysis. Furthermore, since after 1985 only the GOV trawl is used, the H18 and HOB gears are removed from 1984 and 1985 as this will have a minimal effect on spatial coverage and will result in a survey that utilises a single gear.

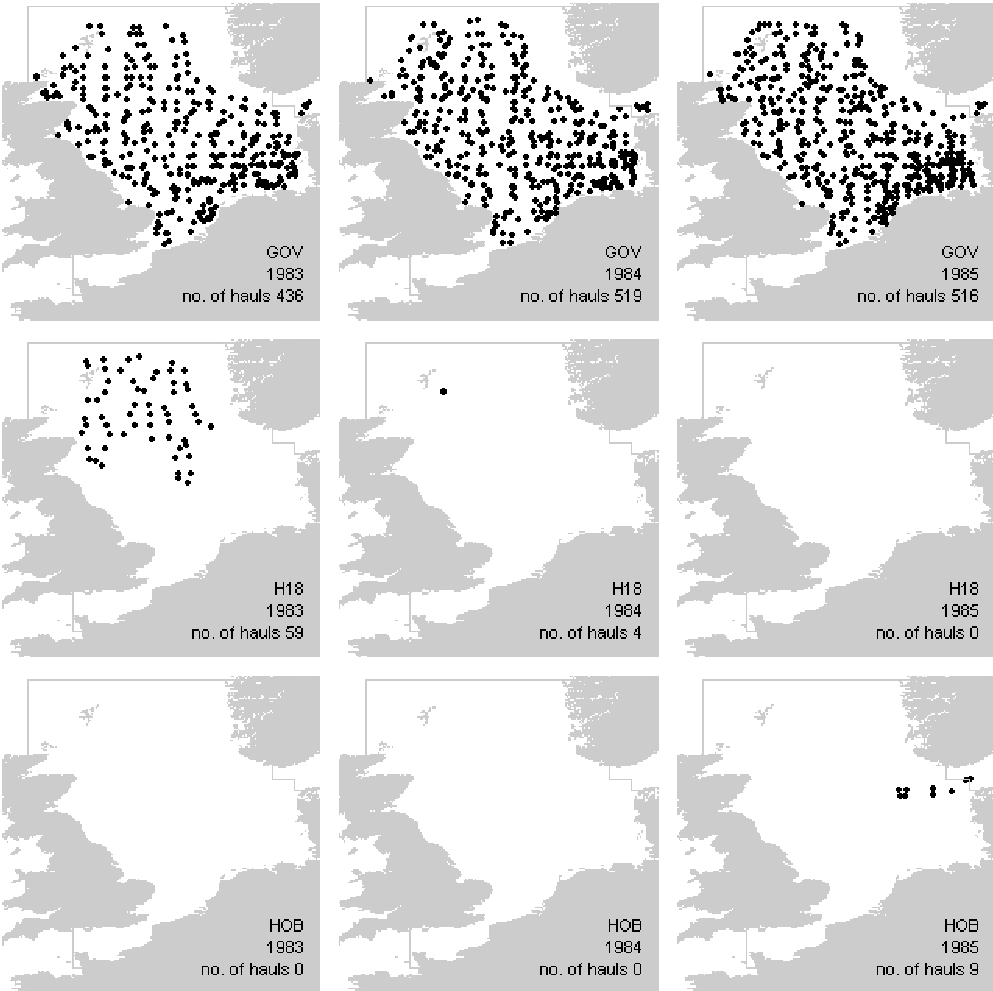


Figure 3.2.8. IBTS quarter 1 haul location by gear and year (1983 to 1985). After 1985 only the GOV trawl was used.

3.2.3.1.2 Vessel changes in the IBTS quarter 1

Changes in vessel within a survey are a potential source of changes in catchability. This may be due to differences in vessel characteristics, for example engine power or winch power or even how audible the vessels engines are to the fish below. Figure 3.2.9 shows the changes in vessel participation in the IBTS Q1 survey. The figure is drawn so that each nation’s vessels are of the same colour in order to see when new vessels replace old. If new vessels have a greater catchability than older vessels there are potential increases in catchability from around 1986 through to around 1998, though this will depend on the distribution of the stock. Figures similar to Figure 3.2.8 were produced showing the individual haul locations of each vessel. No obvious spatial change in vessel effort occurred over the period 1985 to 1995; these figures are not presented here.

In order to investigate the effect of each vessel on the survey index, the index was recalculated excluding a single vessel at a time and compared to that containing all vessels. The resulting figure (Figure 3.2.10) shows that no one vessel can account for a reduced index from 1985 to 1995.

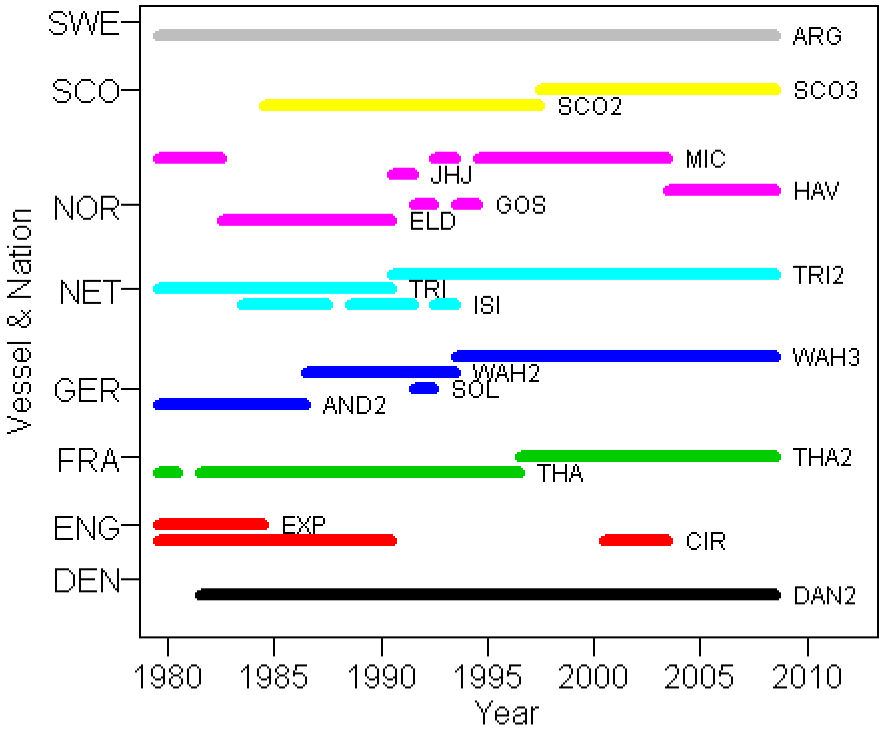


Figure 3.2.9. Research vessels used to provide data for the IBTS Q1 survey indices. Labels on vertical axis show nation owning the vessels. Text at the right hand side of time lines show a three letter code for vessel name. AND2 = Anton Dohrn, ARG = Argos, CIR = Cirolana, DAN2 = Dana, ELD = Eldjarn, EXP = Explorer, GOS = G. O. Sars, HAV = Haakon Mosby, ISI = Isis, JHJ = johan Hjort, MIC = Michael Sars, SCO2 = Scotia2, SCO3 = Scotia3, SOL = Solea, THA = Thalassa, THA2 = Thalassa2, WAH2 = Walter Herwig II, WAH3 = Walter Herwig III.

3.2.3.1.3 Conclusions and other work

The analyses carried out at the WKROUND on the IBTS Q1 indices are rather inconclusive. It is clear that more directed analysis is required similar to that of Simmonds and Rivoirard, 2000. This paper estimates relative catchabilities-at-age for North Sea herring for each vessel participating in the IBTS surveys. For herring, it was found that some vessels have a relative catchability significantly less that 1 and showed that 2-fold changes in catchability are possible, at least for herring. Although the catchabilities will differ between herring and whiting, it is considered (see for example Eigard and Holst, 2004) that whiting behaves similarly to herring in the mouth of a trawlnet and so may be subject to similar changes in catchability as shown in Simmonds and Rivoirard, 2000. Further to this type of work, it is also necessary to take into account the spatial abundance of whiting to estimate any North Sea wide summary of changes in catchability in the IBTS Q1. This stands as a recommendation for future work.

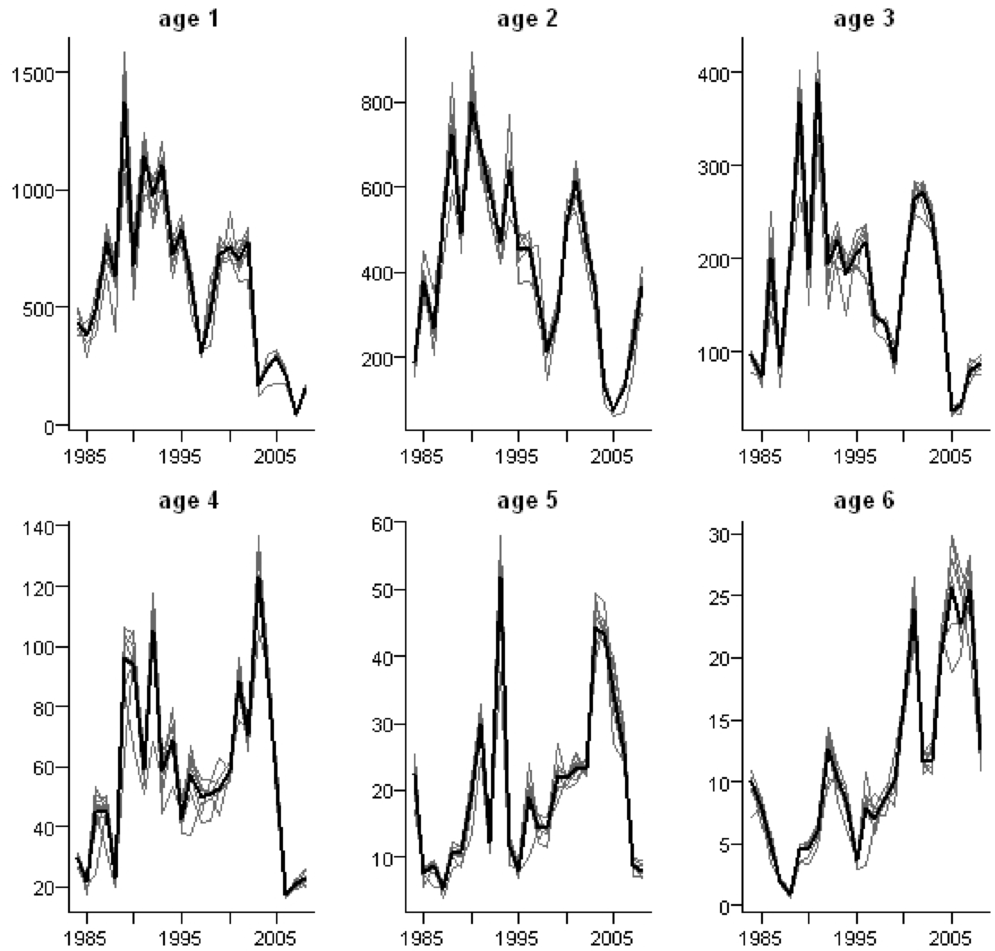


Figure 3.2.10. IBTS indices by age. The black line shows the index as calculated using all vessels. The grey lines show the indices as calculated by leavening one vessel out at a time.

3.3 Stock identity and migration issues

There have been several research projects examining the possibility of stock structure in whiting. A recent project (Wright *et al.*, 2007) summarised that segregation of northern North Sea whiting was supported by both genetic and non-genetic methods. The clear separation in spawning aggregations of whiting (Figure 3.3.1) together with the potential oceanographic barriers to larvae exchange may explain the genetic differences. No whiting tagged in the northern North Sea were recaptured in the southern North Sea (Newton, 1986 and Tobin and Wright, pers comm.). Otolith shape also differed between these regions (Gibb and Wright, *in review*). Knowledge of the sub-stock trends is important since differences may allow for continued fishing opportunities at a time when one component of the stock is in decline.

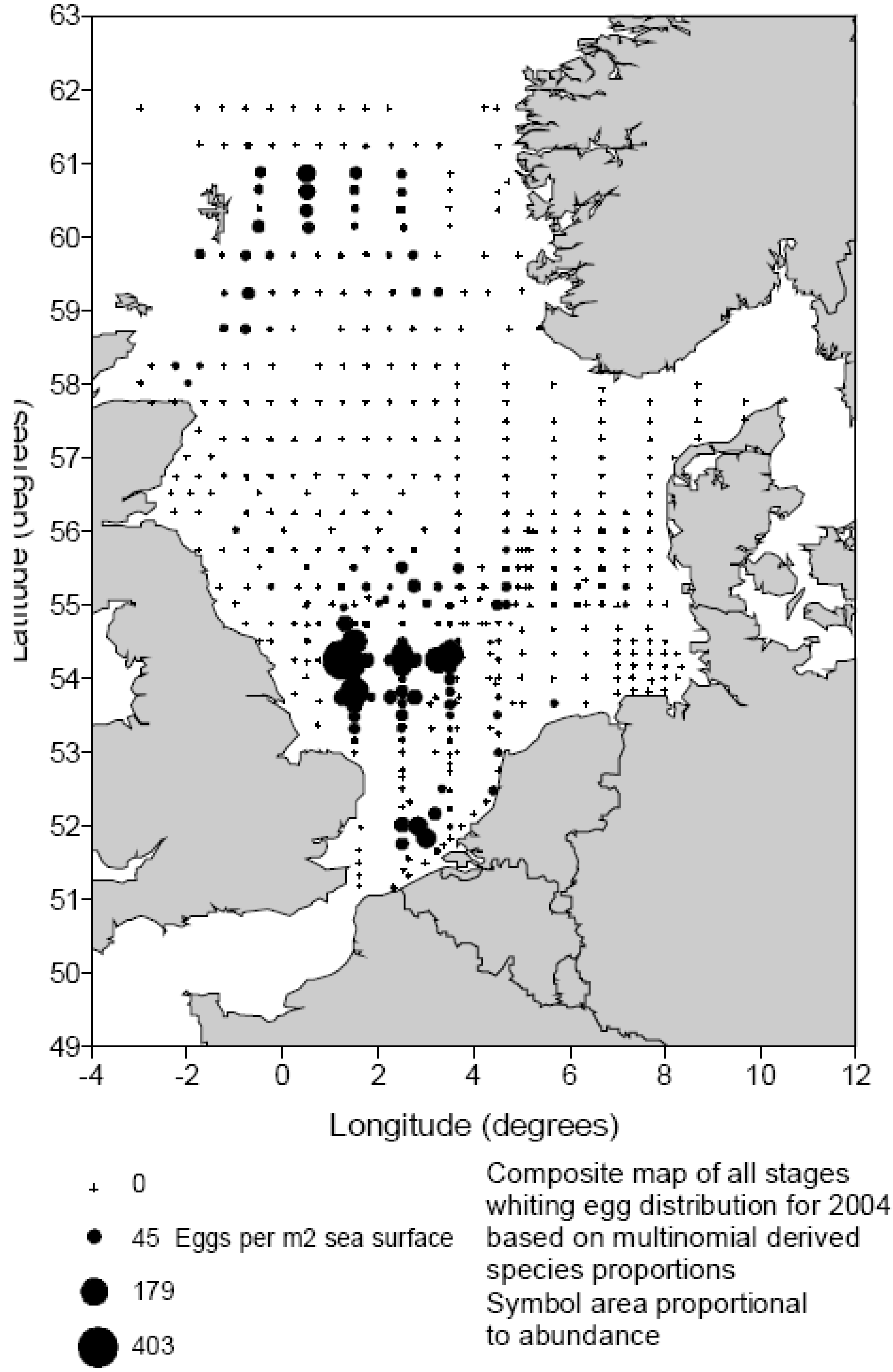


Figure 3.3.1. Density of whiting eggs from the 2004 ICES icthyoplankton survey.

3.4 Spatial changes in the fishery and stock distribution

The distribution of commercial landings has changed considerably during the period 1980 to 2007 (Figure 3.2.1). Prior to 1999 French landings are not included in this figure, FAO records of catch show that the landings from the whiting fishery in the eastern Channel has been stable since the late 1970s declining only in 2006 and 2007.

The industrial fishery off the Danish coast is much reduced since 1995. Landings from this fishery were mostly 0 and 1 group whiting. The level of implied (spatial) fishing mortality of this fishery over the years 1990 to 1995 can be seen by comparing the level of catches to relative survey biomass in the same area (Figure 3.2.3). In recent years, the quota for whiting has been very restrictive in certain sectors due to local aggregations (notably the English Coast). Several fisheries report high rates of discards which are not represented on this Figure 3.4.1.

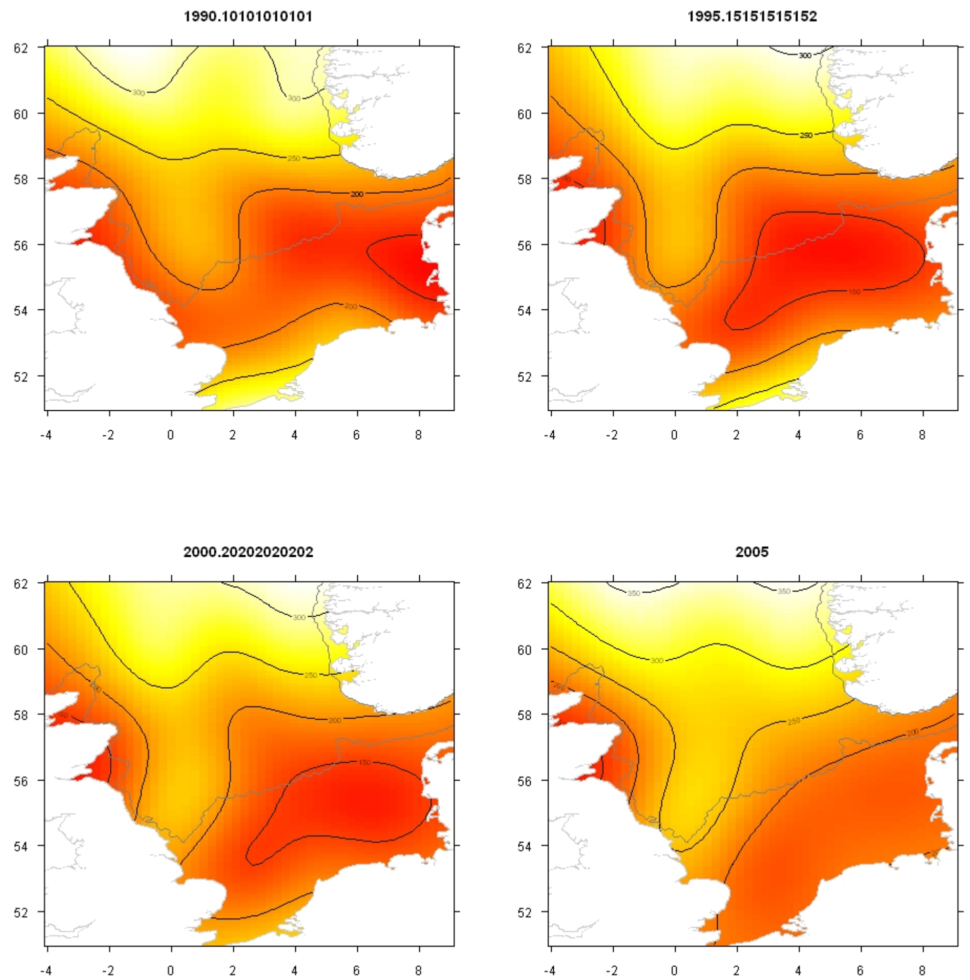


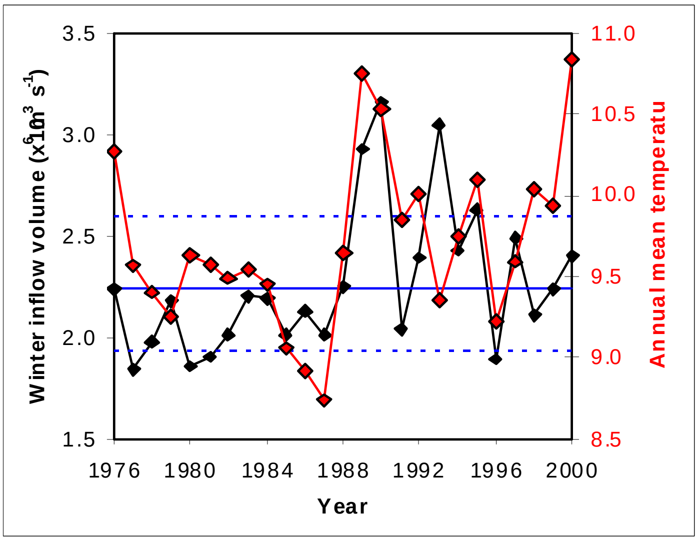
Figure 3.4.1. Generalized additive model estimates of mean length of whiting in a haul, from all IBTS survey hauls. Yellow indicates longer fish with the contours giving length in millimetres. The model used was a tensor product of three thin plate regression splines and was selected by minimum AIC. The plot titles give the decimal year.

Changes in the spatial size distribution of the stock have taken place, where the overall mean length of whiting has been seen to increase in the southern North Sea (Figure 3.4.1). This is particularly notable off the east coast of England whiting greater than 25 cm are found; previously whiting of this size were only found in the north eastern North Sea and eastern Channel. This localised increase in size corresponds to an increase in landings off the east coast of England.

3.5 Environmental drivers of stock dynamics

Currently there is no direct information linking environmental changes over the period 1985 to 1995 with changes in the dynamics of the North Sea whiting stock. Many of features of the North Sea underwent a step change in the late 1980s. Temperature and the inflow volume of water from the Atlantic were two physical features (Figure 3.5.1). The change in inflow volume has been correlated with horse mackerel catches (Iversen *et al.*, 2002), and gurnards are seen to have increased at the same time (Floeter *et al.*, 2005). There have been many papers showing changes in the plankton composition and abundance based on Continuous Plankton Recorder data (see for example Beaugrand, 2004) and others showing changes in environmental conditions as well as changes in plankton abundance (Weijerman *et al.*, 2005). For an overview of issues relating to regime shift see Steele, 2004.

Variations in the transport of ocean water into the northern North Sea, and North Sea temperature



Inflow data from Iversen *et al.*, 2002
0-30m temperature data from analysis of ICES hydrographic data set

Figure 3.5.1. Variations in the transport of ocean water into the northern North Sea, and North Sea temperature, from Iverson *et al.*, 2002.

3.6 Role of multispecies interactions

In the current assessment the natural mortality for North Sea whiting is assumed to be constant in time. However, the newest keyrun using the Stochastic Multi Species Assessment model SMS (Lewy and Vinther, 2004) carried out by the Working Group on Multi Species Assessment Methods in 2008 (ICES 2008) showed substantial changes in predation mortalities over time. According to this keyrun the predation mortality on large whiting (age 2 and older) systematically decreased over time (Figure 3.6.1). This is caused by the collapse of the cod stock and a general disappearance of large predators from the North Sea ecosystem. In contrast, the estimated predation mortalities for 0-group whiting increased systematically over the 90s caused by an increase in the grey gurnard stock. However, for grey gurnard only one stomach data year (from 1991) exists what makes the calculation of predation mortalities uncertain. The general difficulty for multi species modeling in the North Sea area is that the last "Year of the Stomach" was in 1991. Since then the North Sea ecosystem has changed considerably and it is a hard task to predict stomach contents from nearly 30 year old data. For example, the predator assemblage has changed since 1991. Therefore, new stomach data would be needed to determine the current status of the North Sea food web to allow for more certain estimates of current predation mortalities.

Nevertheless an impact on whiting recruitment strength could be also observed in an analysis outside of multi species assessment models (Floeter *et al.*, 2005). In an analysis based on Generalized Additive Models 41% of the variance in age 1 whiting recruitment for the years 1964–2001 could be explained by the abundance of large grey gurnard (> 30 cm) during the 0-group phase. The SSB explained only 21% and was no longer significant if both explaining variables were included in the GLM model.

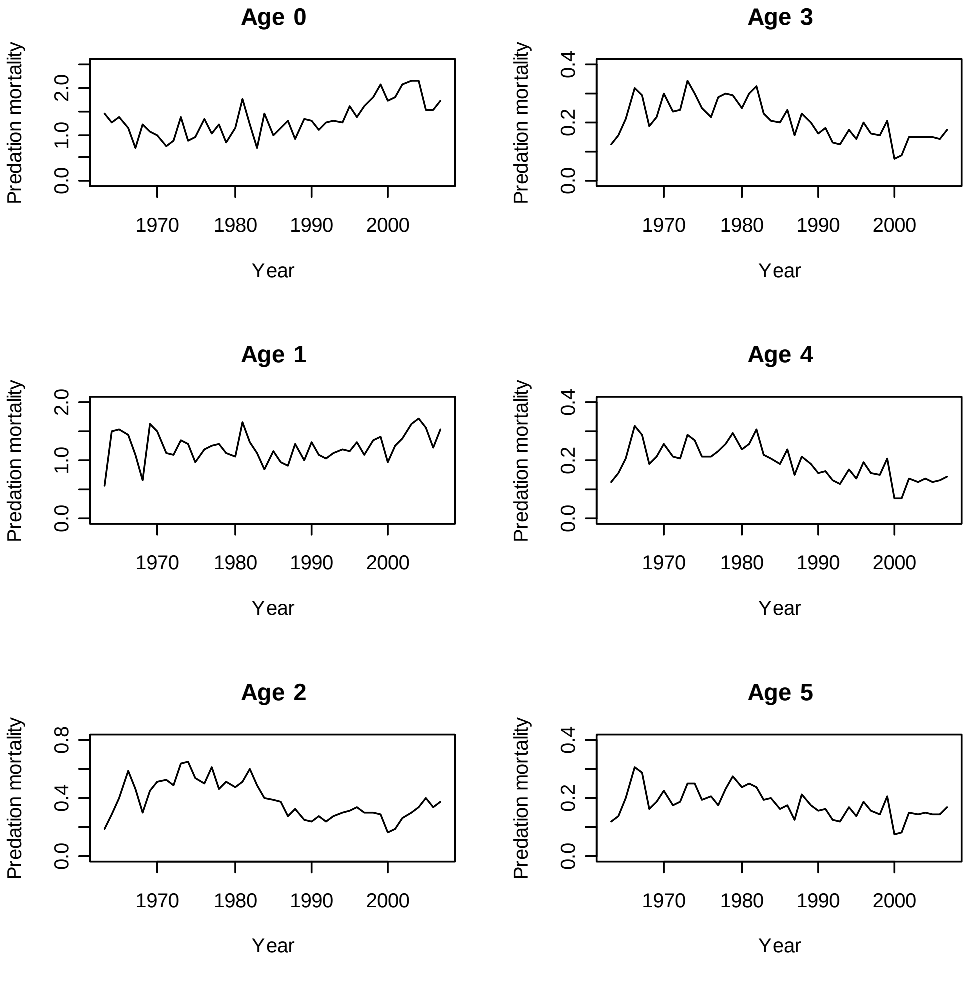


Figure 3.6.1. Predation mortalities for the different age groups of whiting in the SMS Keyrun of 2008.

3.7 Impacts on the ecosystem

No new information is available on the impact of the fishery on the ecosystem. See WGRED for information on the North Sea ecosystem.

3.8 Stock assessment methods

Different stock assessment methods were not investigated at WKROUND as the main issue with the stock is considered to be a problem with the input data and not a model problem. The most recent assessment, using data from 1990 only, has been accepted as indicative of stock trends. Further, WKROUND considers it valid to continue using the same approach until the data issues can be resolved.

3.9 Stock assessment

WKROUND considers that recent trends in the North Sea and eastern Channel whiting stock are appropriately estimated by the current assessment and are suitable for provision of management advice. The current assessment uses survey data and catch data from 1990 ignoring any issues prior to 1990. Estimates of SSB, TSB, F and recruitment are shown in Figure 3.9.1 and the residuals from this fit are shown in Figure 3.9.2.

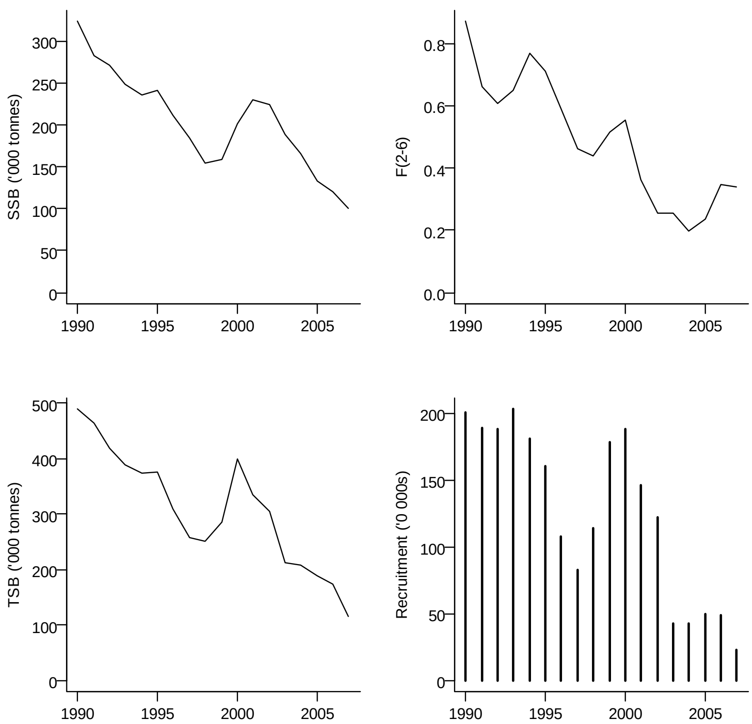


Figure 3.9.1. Trends in spawning stock biomass (SSB), total stock biomass (TSB), mean fishing mortality (F(2–6)) and recruitment, as estimated by the current XSA assessment.

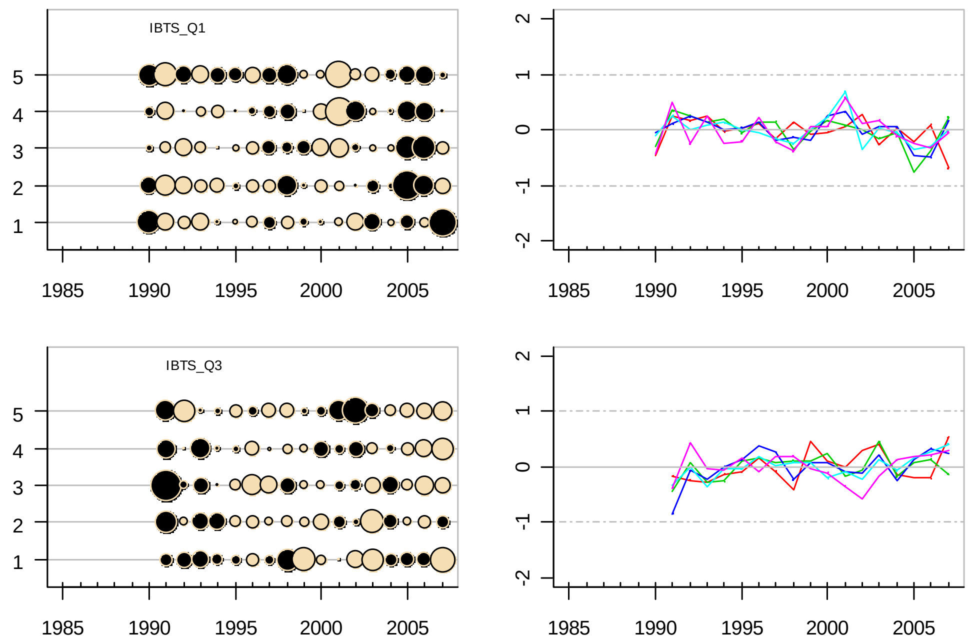


Figure 3.9.2. Log catchability residuals from the currently recommended XSA assessment of North Sea and eastern Channel Whiting. The top panel shows the residuals for the IBTS Q1 and the lower panels the residuals for the IBTS Q3. Residuals are displayed as bubble plots (left) and line plots (right).

3.10 Recruitment estimation

Recruitment estimation was not investigated.

3.11 Short term and medium term forecasts

Short term and medium term forecasts were not investigated.

3.12 Biological reference points

Biological reference points were not investigated.

3.13 Recommended modifications to the stock annex

Until data issues have been resolved (and given that the current assessment was accepted by ACOM in 2008), the methodology in the stock annex should be retained.

3.14 Recommendations on the procedure for assessment updates

It is recommended that due to the low level of the stock, the current assessment model, accepted by ACOM in 2008, should be run as an update assessment and used for stock forecasts until further analysis of historic data resolves the difficulties.

3.15 Industry supplied data

No new quantitative industry data were provided to WKROUND in 2009. The results of collaborative studies presented to the WGNSSK are used to interpret assessment results and regularly form input to the annual assessment and advisory process. In addition the responses to the annual industry questionnaire (Laurenson, 2008) are reviewed at each assessment and compared to survey results in order to provide spatial information on the stock dynamics.

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Stock Annex North Sea Whiting

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Whiting in Subarea IV and Division VIId
Date:	24th February 2009
Revised by	Colin Millar

A. General

A.1. Stock definition

Whiting is known to occur exclusively in some localised areas, but for the most part it is caught as part of a mixed fishery operating throughout the entire year. Adult whiting are widespread in the North Sea, while high numbers of immature fish occur off the Scottish coast, in the German Bight and along the coast of the Netherlands.

Tagging experiments, and the use of a number of fish parasites as markers, have shown that the whiting found to the north and south of the Dogger Bank form two virtually separate populations (Hislop and MacKenzie, 1976). It is also possible that the whiting in the northern North Sea may contain 'inshore' and 'offshore' populations. The report of the SGSIMUW (ICES WGNSSK 2005) documents the work performed on whiting stock identity issues.

A.2. Fishery

For whiting, there are three distinct areas of major catch: a northern zone, an area off the eastern English coast; and a southern area extending into the English Channel.

Northern area

In the northern area, roundfish are caught in otter trawl and seine fisheries, currently with a 120 mm minimum mesh size. Some vessels operating to the east of this area are using 130 mm mesh. These are mixed demersal fisheries with more specific targeting of individual species in some areas and/or seasons. Cod, haddock and whiting form the predominant roundfish catch in the mixed fisheries, although there can be important bycatches of other species, notably saithe and anglerfish in the northern and eastern North Sea and of *Nephrops* in the more offshore *Nephrops* grounds. Minimum mesh size in *Nephrops* trawls is 80 mm but a range of larger mesh sizes are also used when targeting *Nephrops*. Whiting is becoming a more important species for the Scottish fleet, with many vessels actively targeting whiting during a fishing trip and Scottish single seiners have been working closer to shore to target smaller haddock and whiting. Technological developments have included a shift towards pair trawling and the development of double bag trawls which reduce costs compared to twin trawling. The derogation in the EU effort management scheme allowing for extra days fishing by vessels using 90 mm mesh gears with a 120 mm square mesh panel close to the codend (a configuration which releases cod) has so far, been taken up by few vessels.

Recent fuel price increases and a lack of quota for deep-water species has resulted in some vessels formerly fishing in deep-water and along the shelf edge to move into the northern North Sea with the shift in fishing grounds likely to result in a change in the species composition of their catches from monkfish to roundfish species including whiting. Following the major decommissioning schemes a few years ago by the UK, there have not been further reductions, although a number of boats have taken advantage of oil support work and effort has probably been reduced.

Eastern English coast

Whiting are an important component in the mixed fishery occurring along the English east coast. Industry reports suggest better catch rates here than are implied by the overall North Sea assessment. Darby, 2006, 2007 WD7 analysed the catch per unit of effort (cpue) of the English fishery. In recent years vessels have been reporting unusually high catch rates of large whiting. Catch rates appear to have peaked and have recently begun to decline but are still well above historic levels. There is evidence from the cpue data of the English fishery that relative catch rates of age 5 and age 6 fish have increased recently (since 2004) to a considerably greater extent than relative abundance seen in the International Bottom Trawl Survey (IBTS) or ICES assessment for these ages (WGNSSK 08 Figures 12.1.1 and 12.1.2).

General

There has been a displacement of some French vessels steaming from Boulogne-sur-Mer from their traditional grounds in the southern North Sea and English Channel where they have reported very low catch rates during the past two years.

Whiting are a bycatch in some *Nephrops* fisheries that use a smaller mesh size, although landings are restricted through bycatch regulations. They are also caught in flatfish fisheries that use a smaller mesh size. Industrial fishing with small-meshed gear is permitted, subject to by-catch limits of protected species including whiting. Regulations also apply to the area of the Norway pout box, preventing industrial fishing with small meshes in an area where the bycatch limits are likely to be exceeded.

Historically, bycatch of whiting by industrial fisheries for reduction purposes was an important part of the catch, but due to the recent reduced fishery for sandeel and Norway pout the impact of this fishery on the whiting stock is considered much reduced.

Recent changes in fleet dynamics

WGFTFB 2008 reported use of bigger meshes in the top panel of beam trawler gear by Belgium vessels with an expected reduction in bycatch of roundfish species, especially haddock and whiting. Fluctuations in fuel costs can cause changes in fishing practices. WGFTFB 2008 reported a shift for Scottish vessels from using 100 mm–110 mm for whitefish on the west coast ground (Area VI) to 80 mm prawn codends in the North Sea (area IV), with increased fuel costs considered the major driver.

Conservation schemes and technical conservation measures

The present technical regulations for EU waters came into force on 1 January 2000 (EC 850/98 and its amendments). The regulations prescribe the minimum target species' composition for different mesh size ranges. Additional measures were introduced in Community waters from 1 January 2002 (EC 2056/2001).

Effort regulations in days at sea per vessel and gear category were in place from 2003 to 2008 and the limits for individual categories can be seen in the following references;

Year of application	Regulation
2003	(EC) No 2341/2002 – Annex XVII
2004	(EC) No 2287/2003 – Annex V
2005	(EC) No 27/2005 – Annex IVa
2006	(EC) No 51/2006 – Annex IIa
2007	(EC) No 41/2007 – Annex IIa
2008	(EC) No 40/2008 – Annex IIa

In 2008 additional provisions were introduced (points 8.5–7, Annex IIa, EC 40/2008) to provide Member States greater flexibility in managing their fleets, in order to encourage a more efficient use of fishing opportunities and stimulate fishing practices that lead to reduced discards and lower fishing mortality of both juvenile and adult fish. This measure allowed a Member State that fulfilled the requirements laid out in EC 40/2008 to manage a fleet (i.e. group of vessels with a specific combination of geographical area, grouping of fishing gear and special condition) to an overall kilowatt-days limit for that fleet, instead of managing each individual vessel in the fleet to its own days-at-sea limit. The overall kilowatt-days limit for a fleet is initially calculated as the sum of all individual fishing efforts for vessels in that fleet, where an individual fishing effort is the product of the number of days-at-sea and engine power for the vessel concerned. From 2009 (EC 43/2009) the kilowatt-days limit by fleet became the default effort control measure and revised gear groupings were introduced.

In 2008 Scotland adopted the provisions under points 8.5–7, Annex IIa, EC 40/2008 and the scheme was dubbed the 'Conservation Credits Scheme'. Vessels signing to this scheme were granted an additional 21 days at sea. The scheme included various measures including technical measures.

- A one net rule (derogation for Scottish seiners until the end January 2009). This is likely to improve the accuracy of reporting of landings to the correct mesh size range.
- Requirement to use a 110 mm SMP with an 80 mm codend. Implications: Possibly a 30% increase in L50 of haddock, whiting, saithe due to use of 110 mm SMP. Smaller increase in L50 of perhaps 10% for cod.
- From February 2008 there has been a concerted effort not to target cod by use of real time closures of areas recording high cod catch rates. Implication: that there will be greater effort exerted on haddock, whiting, monk, flats and *Nephrops*.

There was almost universal participation in the Conservation Credits Scheme from all Scottish fleet sectors. An alternative option to install a 120 mm SMP at 4–9 m used with a 95 mm x 5 mm double codend was not taken up by the Scottish prawn fleet despite offering 39 extra days at sea (concerns over loss of prawns due to twisting and too great a loss of marketable haddock and whiting).

A.3. Ecosystem aspects

Results from key runs of the North Sea MSVPA in 2002 and 2003 indicate three major sources of mortality. For ages two and above, the primary source of mortality is the fishery, followed by predation by seals, which increases with fish age. For ages 0–1, though more notable on 0-group, there is evidence for cannibalism. This is corroborated by Bromley *et al.*, 1997, who postulate that multiple spawning over a protracted period may provide continued resources for earlier spawned 0-group whiting.

Results from key runs of the North Sea Multispeces assessment in 2008 indicate that, as a predator, whiting tend to feed on (in order of importance): whiting, sprat, Norway pout, sandeel and haddock. A notable predator on 0-group whiting is grey gurnards.

Distribution maps of survey (IBTS) indices show a change in distribution of the stock. They show low recruitment in recent years (2003 to 2008), but also an apparent shift in where the recruiting year-class is found. Therefore catch rates from localised fleets may not represent trends in the overall North Sea and English Channel population. The spatial distribution of IBTS whiting catch rates during recent years (Figures 1 and 2) also indicate that ages 3+ whiting are located primarily around the north east coast of England and the east coast of Scotland with very low catch rates in the southern North Sea. The results support the idea of a spatial contraction of the stock as its total abundance declines following recent poor recruitment. Further supporting evidence is the displacement of some French vessels steaming from Boulogne-sur-Mer from their traditional grounds in the southern North Sea and English Channel where they have reported very low catch rates during the past two years.

B. Data

B.1. Commercial catch

For North Sea catches, human consumption landings data and age compositions are provided by Scotland, England, France, the Netherlands, Belgium, Norway and Germany. Discard data are provided by Scotland, England, the Netherlands and Germany and used to estimate total international discards. Other discard estimates do exist (Section 1.11.4, 2002 WG), but have not been made available to Working Group data collators. Since 1991 the age composition of the Danish industrial by-catch has been directly sampled, whereas it was calculated from research vessel survey data during the period 1985–1990. Norway provides age composition data for its industrial by-catch. Whiting industrial bycatch has been low since 1996 due to the limited fishery for Norway pout and a reduced sandeel fishery in 2005, 2006 and 2007.

In 2006 the samples used to raise Danish industrial bycatches (accounting for 98% of the industrial bycatch that year) were taken from Norwegian vessels whose catches have a different age structure. The data for 2006 have been replaced with an estimate $\hat{n}_{a,y}$ given by

$$\hat{n}_{a,y} = \hat{N}_y \hat{p}_a,$$

where $\hat{p}_a$ is the mean proportion-at-age over the years 1980 to 2005, and $\hat{N}_y$ is estimated to give a sums of products correction (SOP) factor of 1 by

$$\hat{N}_y = \frac{W_y}{\sum_a \hat{p}_a \hat{w}_a},$$

where W_y is the reported weight of industrial bycatch. Here $\hat{w}_a$ have been estimated by taking the mean weights-at-age in the industrial bycatch over the period 1995 to 2005 (zero weights are taken as missing values).

For eastern Channel catches, age composition data are supplied by England and France. England supplies discard estimates however France does not. Since France now lands approximately 30% of the total North Sea and eastern Channel landings, this lack of data is considered an important issue. There is a small industrial fishery in this area.

In 2002, the working group decided to truncate the catch data to start from 1980. This was due to the very large change in estimated recruitment levels around 1980 that was present in the assessment. The working group could not determine whether this was due to a shift in the recruitment regime or because discard data for years prior to 1978 were not measured but estimated according to a discard ogive. This may not have been representative of discarding during the earlier period. Biological reference points for this stock had originally been established on the basis of the truncated series, so this represented no change with respect to them.

B.2. Biological

Weight-at-age

Weight-at-age in the stock is assumed to be the same as weight-at-age in the catch. Unrepresentative sampling of industrial bycatch in 2006 and 2007 resulted in poor estimates of the mean weights-at-age and these have been replaced by the mean weight-at-age for the period 1995 to 2005 (zero weights are taken as missing values).

Natural mortality

Natural mortality values used in assessments up to 2008 are rounded averages of estimates produced by previous key runs of the North Sea MSVPA (see Section 1.3.1.3 of the 1999 WG report: ICES CM 2000/ACFM:7) and considered constant with time. However the Working Group on Multi Species Assessment Methods in 2008 (ICES 2008) showed substantial changes in predation mortalities on whiting over time. Revised time series of natural mortality values are available every two years and WKROUND (ICES 2009) concluded the time series values should be used and updated when new values are available. The current values used in both the assessment and the forecast are presented in Table 1.

Maturity

The maturity ogive is based on North Sea IBTS quarter 1 data, averaged over the period 1981–1985. The maturity ogive used in both the assessment and forecast is:

Age	1	2	3	4	5	6	7	8+
Maturity Ogive	0.11	0.92	1.00	1.00	1.00	1.00	1.00	1.00

Both the proportion of natural mortality before spawning (Mprop) and the proportion of fishing mortality before spawning (Fprop) are set to zero.

B.3. Surveys

The first quarter International Bottom Trawl Survey (IBTS Q1) is undertaken in February and March of each year, and covers depths of roughly 35 m to 200 m in the whole of the North Sea basin. The IBTS indices combine haul data from multiple vessels belonging to national institutes. As such it uses a higher density of survey stations than the constituent national surveys, with several hauls per statistical rectangle.

In previous assessments the Scottish third quarter Groundfish Survey (SCOGFSQ3) and English third quarter Groundfish Survey (ENGGFSQ3) were used as independent surveys. The SCOGFSQ3 is carried out in August each year, and covers depths of roughly 35 m to 200 m in the North Sea to the north of the Dogger Bank. It samples at most one survey station per statistical rectangle. In 1998 the coverage of this survey was extended into the central North Sea, but the index available to the Working Group has been modified so as to cover a consistent area throughout the time-series. The English third quarter Groundfish Survey (ENGGFSQ3) is carried out in August each year, and samples at most one station per rectangle. It covers depths of roughly 35 m to 200 m in the whole of the North Sea basin. In 1991 the ENGGFSQ3 changed fishing gear from the Granton trawl to the GOV trawl. For this reason the English groundfish survey is treated as two independent series.

The time-series of the survey indices of whiting supplied by the French Channel Groundfish Survey (FRAGFS) was revised in 2002. In 2001, the Eastern Channel was split into five zones. Abundance indices were first calculated for each zone, and then averaged to obtain the final FRAGFS index. This procedure was not thought to be entirely satisfactory, as the level of sampling was inconsistent across geographical strata. In 2002, it was thought more appropriate first to raise abundance indices to the level of ICES rectangles, and then to average those to calculate the final abundance index. Previous to the 2002 WG, only the hauls in which whiting were caught were used to derive abundance indices. This procedure biased estimates, and therefore, the indices supplied from 2002 are calculated on the basis of all hauls. However lack of internal consistency of this series means it has not been used in the assessment to date.

There is an unresolved problem in that the surveys available provide a different indication of stock trends before 1990 compared to an assessment based on catch data (Figure 3). The IBTS indices combine haul data from multiple vessels belonging to national institutes and periodically these vessels are replaced. In 1998 FRS (Aberdeen) introduced a new survey vessel; it was considered at the time that no evidence existed to say the new vessel had different catchabilities to the old vessel (Zuur *et al.*, 1999). This is now generally considered not to be the case. WKROUND 2009 investigated the possibility that changes in survey catchability over the period from the mid 1980s to the mid 1990s accounts for this mismatch. The required change in catchability was estimated to be approximately a factor of two. Details of the investigations can be found in the benchmark report. Evidence for a change in catchability was not found (although the meeting recommended further work) but the following was concluded with respect to survey data.

- Only IBTS Q1 and IBTS Q3 indices should be used. The SCOGFS and ENGGFS are incorporated into the IBTS Q3 survey which is involves several other fleets and is likely to better represent the North Sea as a whole.
- The IBTS Q1 survey should only be used from 1984 because the gear employed was not standardised before this date.

The IBTS Q1 and IBTS Q3 data can be downloaded from the DATRAS website at

http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx

B.4. Commercial cpue

Effort data are available for two Scottish commercial fleets: seiners (SCOSEI) and light trawlers (SCOLTR), both for the years 1978–2006. Non-mandatory reporting of fishing effort for these fleets means that they cannot be viewed as reliable for use for catch-at-age tuning.

Effort data are available for two French commercial fleets: otter trawl (FRATRO) 1986–2006 and beam trawl (FRATRB) 1978–2001. The same comment on non-mandatory reporting of fishing effort applies to these fleets.

Available commercial cpue data is presented in Table 2.

B.5. Other relevant data

The North Sea Fishers' Survey presents fishers' perceptions of the state of several species including whiting. The survey covers the years 2003–2008, (Laurenson, 2008).

C. Historical stock development

The following outlines the method currently used for North Sea whiting. Due to unresolved issues with data, this method cannot be considered as benchmarked. WKROUND 2009 considered that recent trends in the North Sea and eastern Channel whiting stock are appropriately estimated by the current assessment and are suitable for providing management advice. The assessment uses survey data and catch data from 1990 ignoring any issues prior to 1990. The outstanding issues and proposed directed research are detailed in ICES 2009.

Model used: Extended Survivor Analysis (XSA)

Software used: FLXSA run under

FLCORE 2.0
FLR 2.0
R 2.8.0

Model Options chosen:

Tolerance (tol):	1e-09
Maximum allowed iterations (maxit):	1000
Minimum standard error for surveys (min.nse):	0.3
Time series weighting in years (tsrange):	100
Time series weighting power (tspower):	0
Years of catch data to use (window):	100
Max age of power relationship in selection (rage):	0
First age of full selection (qage):	5
F shrinkage tolerance (Fse):	2.0
No. at age shrinkage; last # years (shk.yrs):	3
No. at age shrinkage; oldest # ages (shk.ages):	4

Mean F is taken over ages 2–6.

Mean weights-at-age in the catch is assumed equal to mean weights-at-age in the stock.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1980–	NA	Yes
Canum	Catch-at-age in numbers	1980–	1–8+	Yes
Weca	Weight-at-age in the commercial catch	1980–	1–8+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1980–	1–8+	Yes
Mprop	Proportion of natural mortality before spawning	1980–	1–8+	No
Fprop	Proportion of fishing mortality before spawning	1980–	1–8+	No
Matprop	Proportion mature-at-age	1980–	1–8+	No
Natmor	Natural mortality	1980–	1–8+	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	IBTS Q1	1991–	1–6+
Tuning fleet 2	IBTS Q3	1991–	1–6+
Tuning fleet 3	NA		
….			

D. Short-term projection

The following outlines the method currently used for North Sea whiting. Due to unresolved issues with data, this method cannot be considered as benchmarked. The outstanding issues and proposed directed research are detailed in ICES 2009.

Model used: MFYDP

Software used: MFYDP

Initial stock size: RCT3 estimate of recruitment at age 1. XSA survivors at start of intermediate year for ages 2 and above.

Maturity: As used for historic stock development.

F and M before spawning: Zero

Weight-at-age in the stock: Mean over the last three years. Mean weights-at-age have generally been consistent over the recent period but there are trends at some ages.

Weight-at-age in the catch: Set equal to mean weights-at-age in the stock.

Exploitation pattern: Mean F-at-age pattern over the final 5 years scaled to F(2–6) in the terminal year. Scaling justified by recent stability of F(2–6) values.

Intermediate year assumptions: F status quo.

Stock recruitment model used: Geometric mean over the most recent 4 years.

Procedures used for splitting projected catches: Application of partial Fs. Partial Fs derived by considering proportions of the catch at age in the terminal year.

E. Medium-term projections

Not done for this stock.

F. Long-term projections

Not done for this stock.

G. Biological reference points

The previously defined precautionary reference points (based on data from 1980 onwards) are no longer considered appropriate because of discrepancies between survey data and the catch data in the period before 1990. The assessment is now based on the period where catch and survey data are consistent (from 1990 onwards).

Yield and spawning biomass per Recruit F-reference points (2007)

	Fish. Mort.	Yield/R	SSB/R
	Ages 2–6		
Average last 3 years	0.39	0.0527	0.26
Fmax	0.19	0.0137	0.12
F0.1	0.10	0.0128	0.17

Candidates reference points consistent with high long-term yields and a low risk of depleting the productive potential of the stock are in the range of $F_{0.1}$–F_{max}.

H. Other issues

None identified.

I. References

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Table 1. Whiting in IV and VIId. Smoothed values for natural mortality extracted from the SMS keyrun 2008.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
1963	1.49	1.34	0.50	0.38	0.38	0.37	0.37	0.35	0.31
1964	1.44	1.37	0.53	0.39	0.39	0.38	0.38	0.35	0.31
1965	1.39	1.40	0.57	0.41	0.40	0.39	0.39	0.36	0.31
1966	1.34	1.42	0.60	0.42	0.41	0.40	0.39	0.37	0.32
1967	1.30	1.43	0.63	0.44	0.42	0.41	0.40	0.37	0.32
1968	1.26	1.44	0.66	0.45	0.43	0.41	0.40	0.37	0.32
1969	1.24	1.45	0.68	0.45	0.43	0.41	0.40	0.37	0.32
1970	1.22	1.45	0.70	0.46	0.44	0.42	0.40	0.37	0.32
1971	1.21	1.45	0.72	0.47	0.44	0.42	0.40	0.37	0.32
1972	1.21	1.44	0.74	0.47	0.44	0.42	0.40	0.36	0.32
1973	1.22	1.44	0.75	0.48	0.45	0.42	0.40	0.36	0.32
1974	1.24	1.43	0.76	0.48	0.45	0.42	0.40	0.36	0.32
1975	1.25	1.43	0.76	0.48	0.45	0.42	0.40	0.36	0.32
1976	1.27	1.42	0.76	0.48	0.45	0.42	0.40	0.37	0.32
1977	1.29	1.42	0.75	0.48	0.45	0.43	0.40	0.37	0.31
1978	1.31	1.42	0.74	0.48	0.45	0.43	0.40	0.37	0.31
1979	1.32	1.41	0.73	0.48	0.45	0.42	0.40	0.37	0.31
1980	1.34	1.40	0.71	0.47	0.45	0.42	0.40	0.37	0.31
1981	1.35	1.39	0.69	0.47	0.44	0.42	0.40	0.37	0.31
1982	1.35	1.37	0.67	0.46	0.44	0.41	0.39	0.37	0.31
1983	1.35	1.35	0.65	0.45	0.43	0.41	0.39	0.37	0.31
1984	1.35	1.33	0.62	0.44	0.42	0.40	0.38	0.36	0.31
1985	1.36	1.32	0.60	0.43	0.42	0.39	0.37	0.36	0.31
1986	1.36	1.31	0.57	0.42	0.41	0.38	0.37	0.35	0.31
1987	1.37	1.30	0.55	0.41	0.40	0.38	0.36	0.34	0.30
1988	1.39	1.30	0.53	0.40	0.39	0.37	0.35	0.34	0.30
1989	1.41	1.31	0.51	0.39	0.38	0.37	0.35	0.34	0.31
1990	1.44	1.31	0.50	0.38	0.37	0.36	0.34	0.33	0.31
1991	1.47	1.32	0.49	0.37	0.37	0.36	0.34	0.33	0.31
1992	1.52	1.33	0.48	0.37	0.36	0.35	0.34	0.33	0.31
1993	1.57	1.35	0.47	0.36	0.36	0.35	0.34	0.33	0.31
1994	1.63	1.36	0.47	0.36	0.35	0.35	0.33	0.33	0.31
1995	1.70	1.38	0.47	0.36	0.35	0.35	0.33	0.33	0.32
1996	1.77	1.41	0.47	0.35	0.35	0.35	0.33	0.33	0.32
1997	1.83	1.43	0.47	0.35	0.34	0.35	0.33	0.33	0.32
1998	1.90	1.45	0.47	0.35	0.34	0.34	0.33	0.33	0.32
1999	1.95	1.48	0.47	0.35	0.34	0.34	0.33	0.33	0.32
2000	2.00	1.51	0.47	0.34	0.33	0.34	0.33	0.33	0.32
2001	2.03	1.55	0.48	0.34	0.33	0.34	0.33	0.33	0.32
2002	2.05	1.58	0.49	0.34	0.33	0.34	0.34	0.34	0.32
2003	2.06	1.62	0.50	0.35	0.33	0.34	0.34	0.34	0.32
2004	2.05	1.65	0.52	0.35	0.33	0.34	0.34	0.34	0.33
2005	2.03	1.68	0.53	0.35	0.33	0.35	0.35	0.35	0.33
2006	2.01	1.71	0.55	0.35	0.33	0.35	0.35	0.36	0.34
2007	1.99	1.73	0.56	0.36	0.33	0.35	0.36	0.36	0.34

Table 2. Whiting in IV and VIId. Complete available tuning series.

SCOSEI_IV units = individuals

year	effort	1	2	3	4	5	6	7	8	9
1978	325246	14994	29308	43711	15390	1058	1409	201	36	0
1979	316419	90750	41092	28124	14745	6084	677	156	3	0
1980	297227	27032	73704	37658	11915	9368	2556	260	229	27
1981	289672	8727	22244	25048	10552	2402	2084	374	41	4
1982	297730	3721	7032	26194	13117	2713	539	277	81	5
1983	333168	11565	14957	21690	34199	9831	2155	407	158	16
1984	388035	4923	24016	20670	14986	21269	4715	960	87	50
1985	381647	20068	20263	19696	8956	4796	8013	1363	334	18
1986	425017	139498	48705	34509	11341	2624	1098	1771	216	7
1987	418536	13793	52715	38939	18440	3638	1097	298	348	16
1988	377132	2502	28446	44869	12631	4072	679	64	21	17
1989	355735	6879	15704	41407	23710	4769	1323	112	43	11
1990	252732	14230	124636	27694	29921	14768	721	207	23	0
1991	336675	11952	44964	63414	10436	8730	1743	195	94	0
1992	300217	16614	19452	21217	27962	2805	1958	565	32	3
1993	268413	9564	31623	26013	12458	14446	899	332	153	8
1994	264738	9236	21452	22571	11778	5531	5612	204	116	15
1995	204545	8288	22153	30007	9019	3875	1373	1270	86	15
1996	177092	5732	26021	21430	10506	3483	1031	296	289	28
1997	166817	6628	8974	16231	9922	4445	575	110	62	37
1998	150361	3711	4695	6806	6840	3670	1417	244	13	2
1999	93796	13384	13750	7009	6068	3462	1684	409	77	3
2000	69505	5176	11208	6458	2112	1972	836	298	90	7
2001	36135	607	6352	5592	1715	486	353	146	66	11
2002	21830	1017	3349	7716	2182	363	140	79	23	6
2003	15371	388	1089	2514	2980	1046	256	30	17	5
2004	15663	282	689	1912	2003	1711	456	108	16	4
2005	16149	1131	1889	994	1638	1852	1035	362	41	1
2006	13539	25	435	874	695	966	960	433	99	18

SCOLTR_IV units = individuals

year	effort	1	2	3	4	5	6	7	8	9
1978	236944	8785	19910	30722	14473	956	1612	635	72	6
1979	287494	171147	42910	23155	17996	4058	377	286	57	5
1980	333197	20806	58382	38436	9525	9430	1864	144	145	3
1981	251504	6576	19069	21550	9706	1777	1455	310	9	1
1982	250870	5214	8197	26681	12945	3334	647	339	74	16
1983	244349	37496	17926	12535	19234	6124	1217	183	141	26
1984	240775	38267	16048	10784	6307	9019	2371	479	13	30
1985	267393	28761	9368	7617	3086	1333	2901	443	173	14
1986	279727	8138	8572	9578	4109	767	425	609	52	2
1987	351131	18761	25933	16161	5954	1183	388	116	129	4
1988	391988	2398	15779	22526	5128	1641	207	31	15	6
1989	405883	20319	10052	21390	10837	2394	448	33	54	2
1990	371493	3677	35322	7665	8960	3423	160	40	5	0
1991	408056	8727	11908	22146	3192	2906	629	50	41	0
1992	473955	17581	14551	11823	15418	1500	1160	304	13	0
1993	447064	16439	20513	14386	6591	10105	574	204	97	24
1994	480400	4133	15771	13005	6454	2710	2997	172	84	14
1995	442010	9248	15887	19322	6262	2983	1092	1132	89	3
1996	445995	6662	12461	13523	9223	3012	861	282	243	9
1997	479449	2557	6768	15603	9464	4535	628	181	52	31
1998	427868	5096	5350	8058	9507	4312	1729	276	58	12
1999	329750	26519	20672	9295	6706	4080	2051	487	41	7
2000	280938	8385	16220	9287	3788	2621	1470	602	79	7
2001	245489	1303	11409	10419	3287	745	431	247	66	27
2002	184099	980	4653	11067	3686	818	221	180	60	13
2003	98721	871	1639	3986	5136	2080	286	73	59	7
2004	63953	224	1088	2225	2463	2168	669	123	18	15
2005	54905	954	2414	1236	1448	1901	831	251	26	2
2006	51456	66	495	1487	990	1055	1067	604	105	6

Table 2 (cont'd). Whiting in IV and VIId. Complete available tuning series.

FRATRO_IV units = individuals

year	effort	0	1	2	3	4	5	6	7	8
1986	56099	19	1542	1892	7146	3783	600	158	39	2
1987	71765	12	2508	4985	1271	5713	413	258	92	70
1988	84052	0	2537	8982	3223	704	1321	123	55	1
1989	88397	27	2958	3740	5629	1654	209	280	47	11
1990	71750	38	3210	6170	3781	2456	365	29	44	2
1991	67836	323	4465	6084	2864	1412	777	85	6	3
1992	51340	355	3427	6498	1940	635	358	96	5	0
1993	62553	938	3950	4586	4307	877	290	68	40	6
1994	51241	87	7006	3298	1191	612	108	11	8	1
1995	57823	263	6331	6125	2674	544	99	19	0	2
1996	50163	577	5523	4743	3214	890	156	8	12	0
1997	48904	267	1961	4677	3929	1020	221	18	3	0
1998	38103	567	4893	1959	533	161	68	36	0	2
1999	-9	51	7652	2886	1453	960	500	133	46	31
2000	30082	129	7367	8191	2453	1056	737	455	345	95
2001	50846	3357	10767	15476	6923	3227	1701	638	345	128
2002	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
2003	52609	625	9277	16880	7857	5528	1701	188	19	23
2004	21074	0	938	367	919	946	743	256	36	4
2005	23683	0	1037	1665	386	178	149	103	52	14
2006	19100	4.918	4402.199	2229.464	373.059	37.178	183.608	226.409	0.27	-9

FRATRB_IV units = individuals

year	effort	1	2	3	4	5	6	7	8	9
1978	69739	1153	10312	14789	8544	807	1091	227	34	4
1979	89974	698	12272	14379	10884	3789	394	315	45	14
1980	63577	90	5388	11298	4605	4051	1004	78	71	10
1981	76517	144	6591	13139	8196	2090	1644	314	16	10
1982	78523	173	1643	16561	11241	3948	1035	539	119	14
1983	69720	500	4407	8188	16698	5541	1061	228	126	19
1984	76149	317	4281	7465	4576	5999	1596	308	32	26
1985	25915	315	3653	2942	1225	566	599	117	12	4
1986	28611	891	3830	3991	1202	369	94	160	22	1
1987	28692	431	4823	3667	2152	497	166	48	46	3
1988	25208	150	2718	4815	1125	530	100	31	3	4
1989	25184	448	2064	4351	1877	314	106	10	4	1
1990	21758	164	3794	2124	2010	620	55	13	1	0
1991	19840	292	2224	3829	819	657	138	15	3	0
1992	15656	365	1598	1686	2204	248	195	44	3	0
1993	19076	173	1225	2633	1141	1233	97	37	14	4
1994	17315	108	1806	1721	1466	413	430	29	8	1
1995	17794	114	1023	3304	1537	1163	240	212	14	7
1996	18883	21	655	1594	1438	482	199	38	30	10
1997	15574	40	357	1407	1139	606	86	16	10	2
1998	14949	32	126	317	326	192	63	8	2	1
1999	-9	96	490	489	684	452	239	59	14	1
2000	11747	47	1148	2968	1205	320	298	124	54	5
2001	6771	298	649	528	150	36	36	14	6	2

FRATRO_7D units = individuals

year	effort	1	2	3	4	5	6	7
1986	257794	2587	2250	7741	4463	804	198	19
1987	188236	1955	5050	907	4606	331	218	54
1988	215422	2233	7957	2552	537	1193	127	61
1989	320383	2578	3916	6006	1490	216	343	50
1990	257120	2492	5240	3363	2168	251	30	51
1991	294594	4009	8177	3985	2625	1474	155	11
1992	285718	5733	10924	3241	882	587	171	3
1993	283999	3158	6543	8607	1677	442	124	79
1994	286019	13932	7980	3269	1776	444	40	21
1995	268151	6301	8450	5261	1217	264	63	8
1996	274495	6140	6466	5465	1623	324	47	14
1997	282216	3320	8144	6608	1974	451	59	8
1998	291360	9921	6863	2385	781	265	105	15
1999	-9	-9	-9	-9	-9	-9	-9	-9
2000	215553	7096	7026	1734	1724	1375	877	675
2001	163848	89	6101	10124	3976	2563	2303	1040
2002	192589	985	1922	6247	6476	2270	461	463
2003	296717	155	6896	5489	5551	2397	312	65
2004	89127	1831	706	2312	2945	2611	902	109
2005	108369	5813	3730	793	813	720	510	262
2006	78600	2864	1912	457	133	800	1013	0

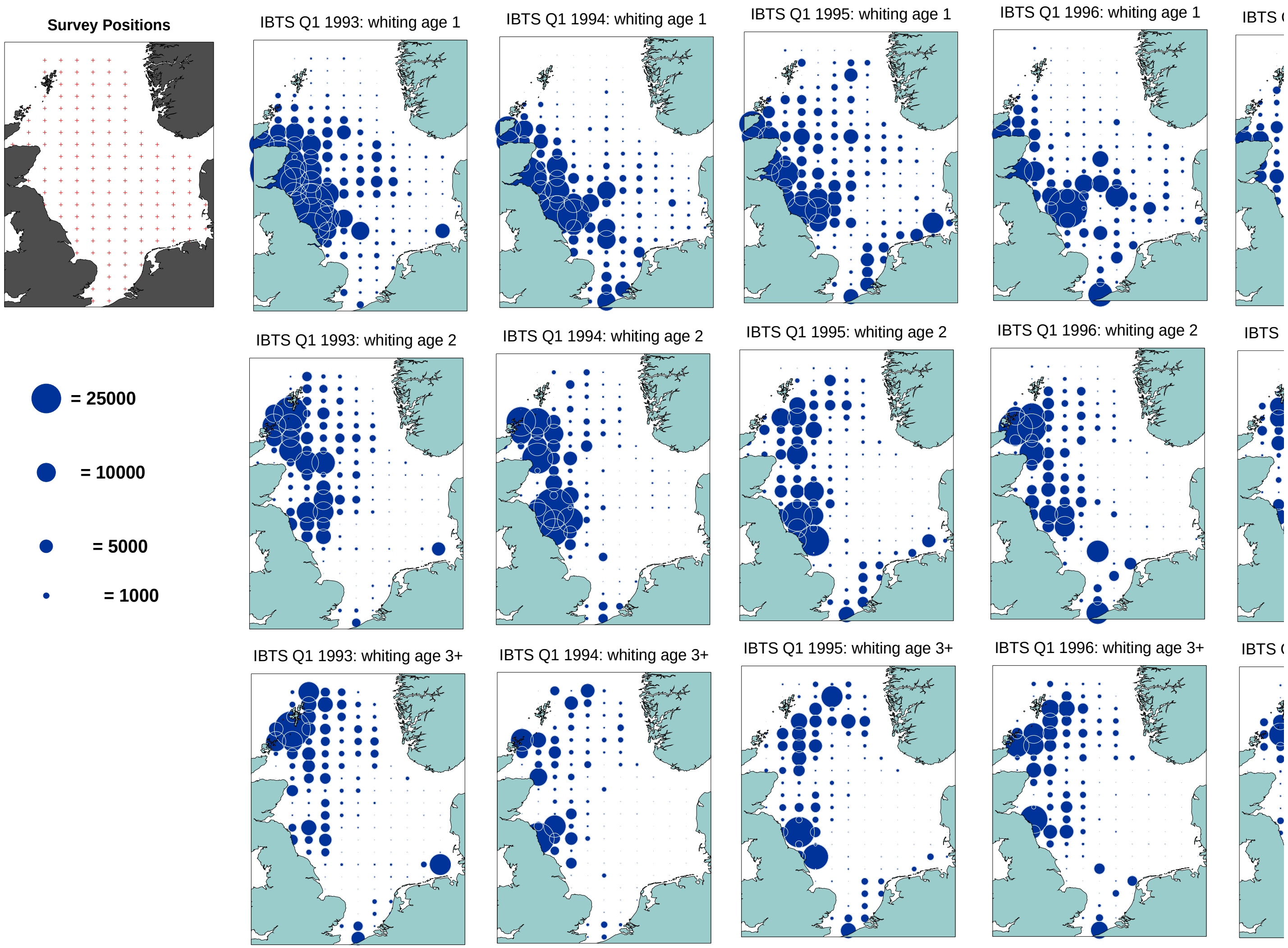


Figure 1. Whiting in IV and VIId. Distribution plot of the IBTS quarter 1 Survey.

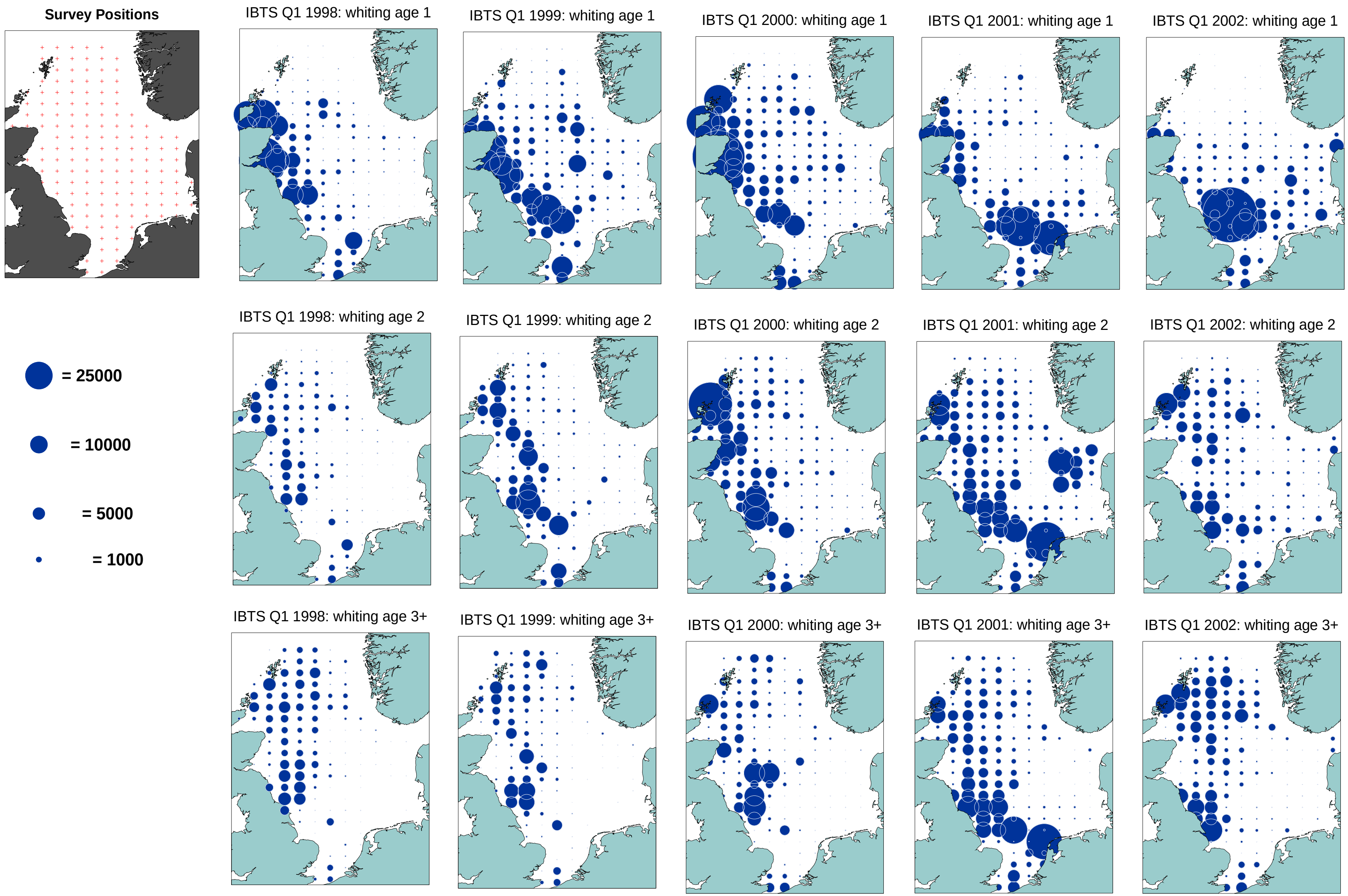


Figure 1 (cont.). Whiting in IV and VIId. Distribution plot of the IBTS quarter 1 Survey.

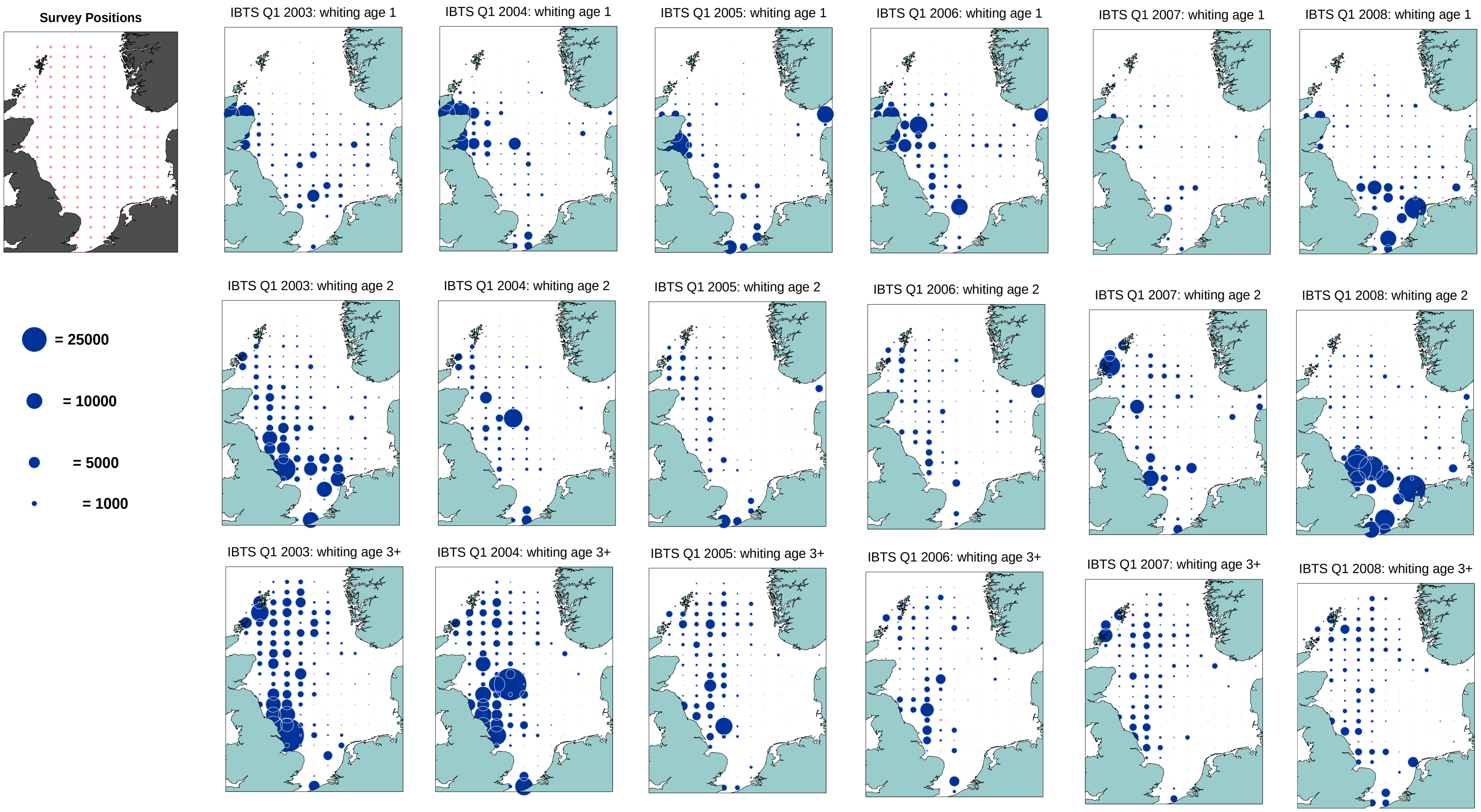


Figure 1 (cont.). Whiting in IV and VIId. Distribution plot of the IBTS quarter 1 Survey.

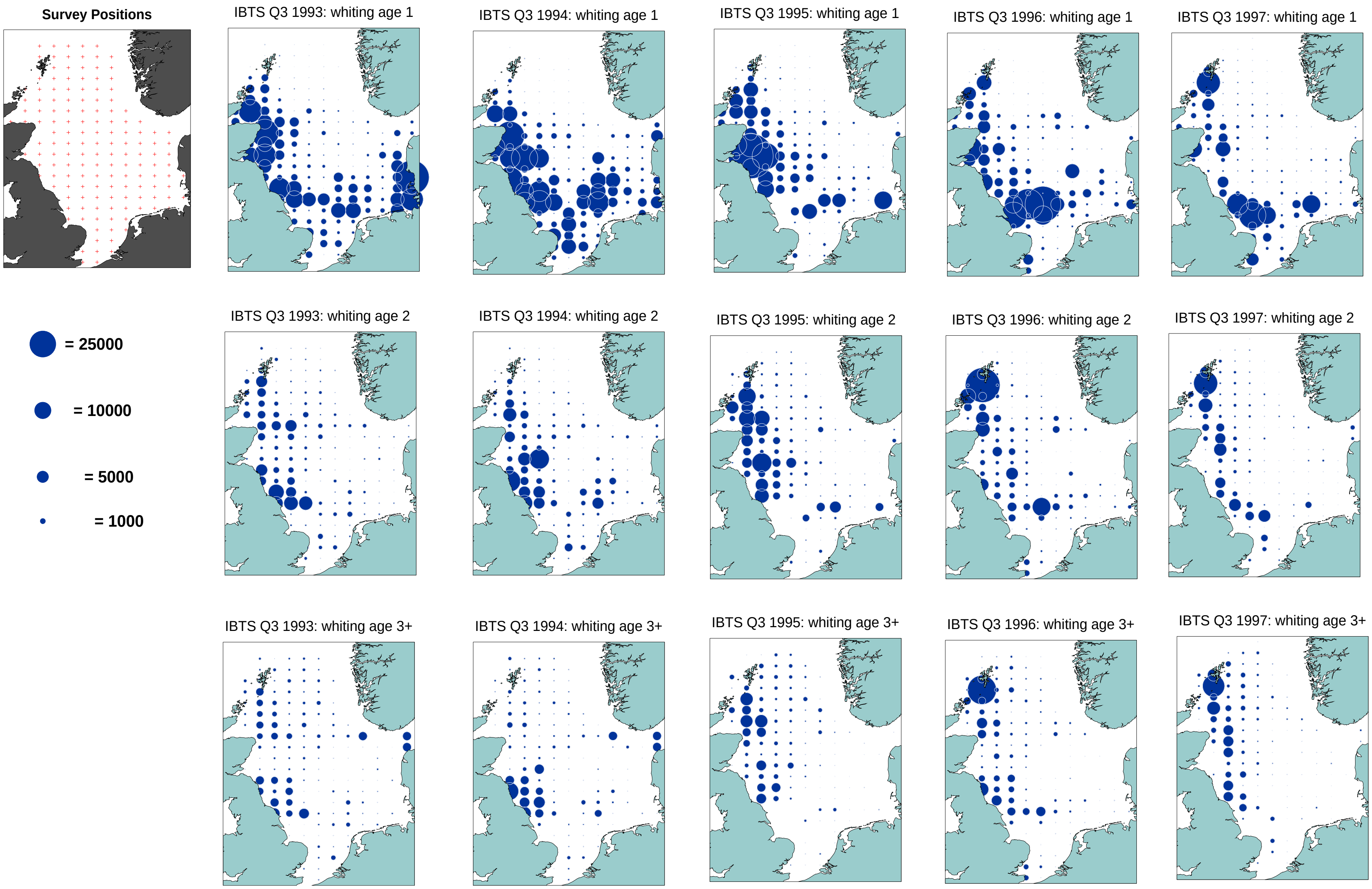


Figure 2. Whiting in IV and VIId. Distribution plot of the IBTS quarter 3 Survey.

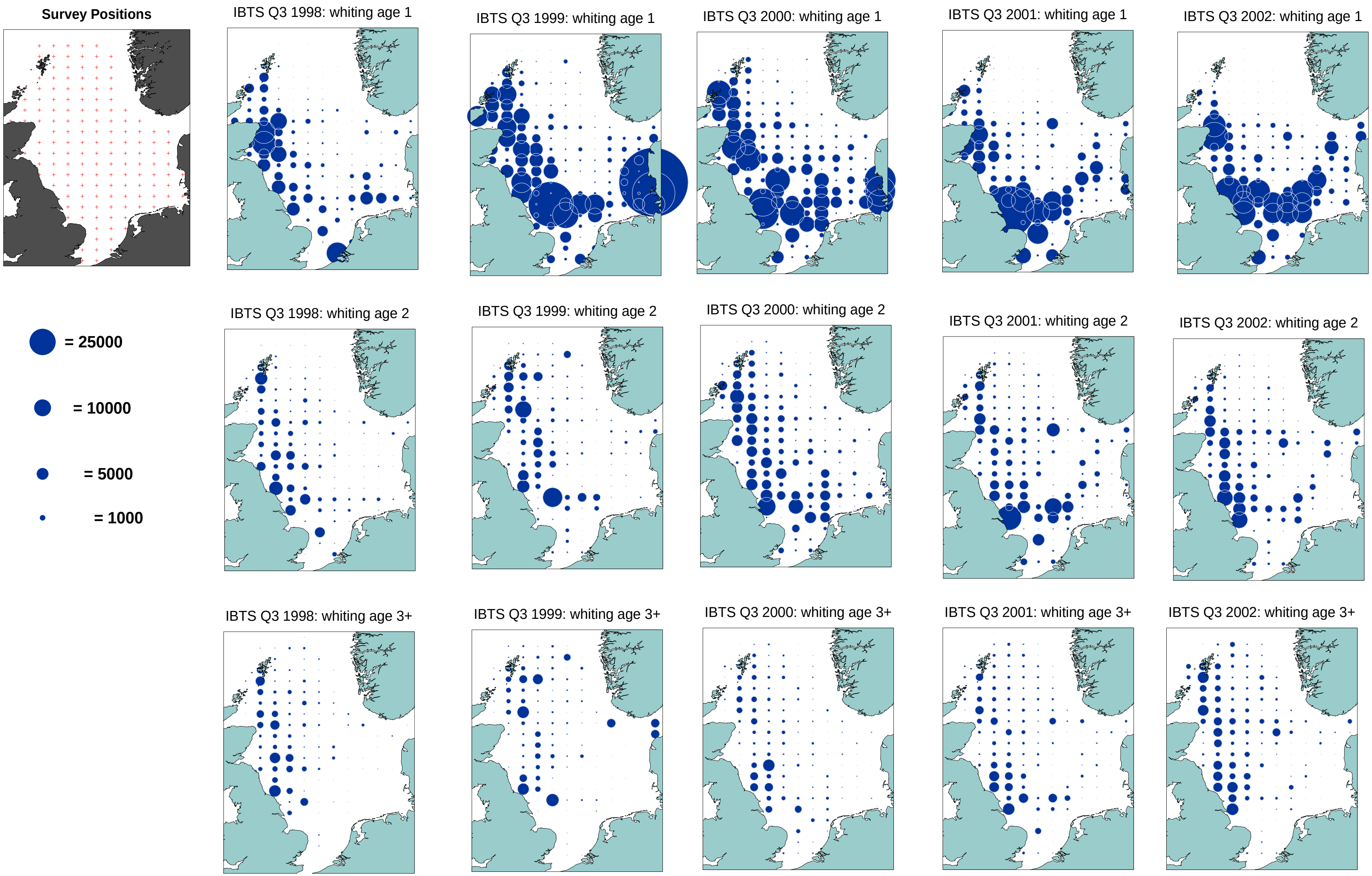


Figure 2 (cont.). Whiting in IV and VIId. Distribution plot of the IBTS quarter 3 Survey.

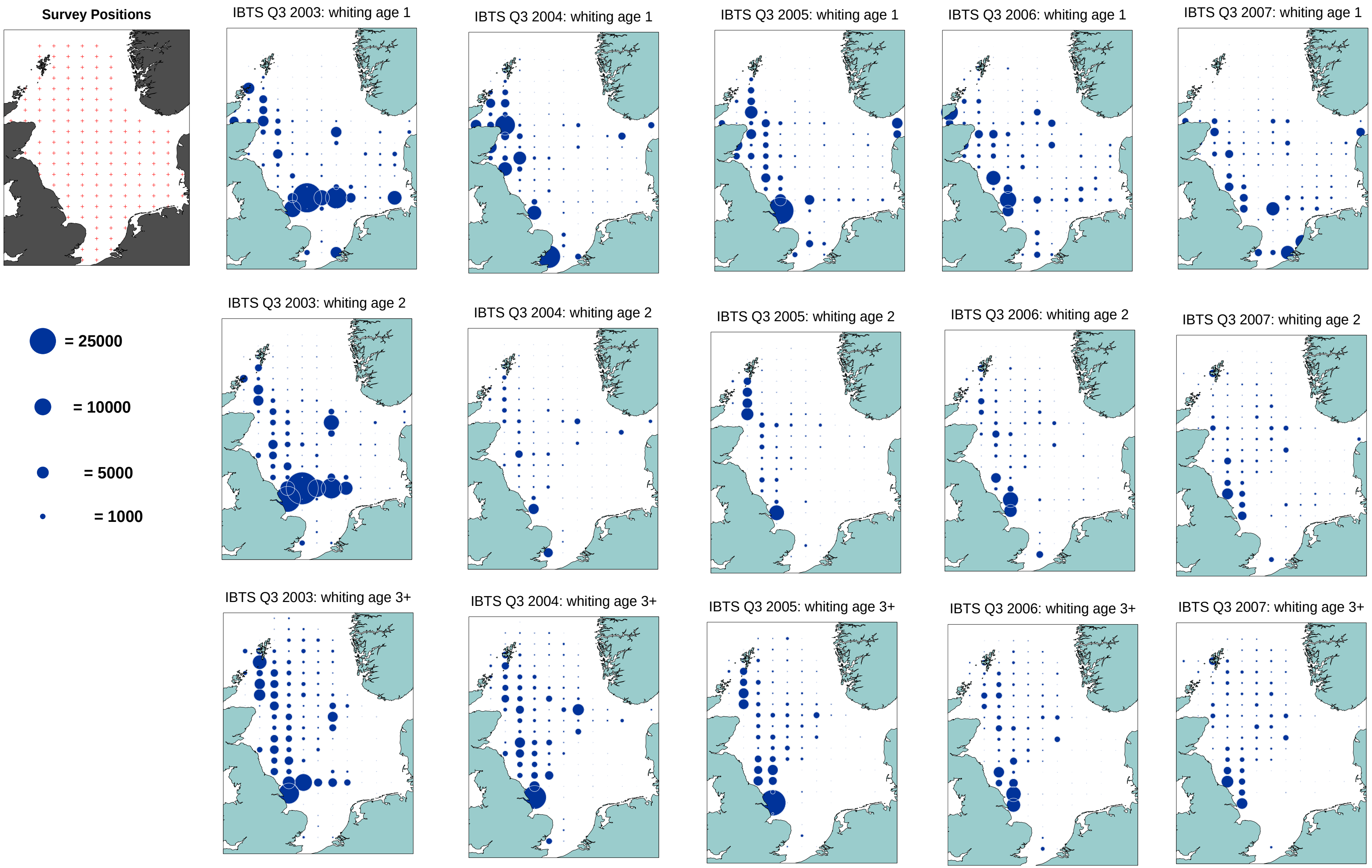


Figure 2 (cont.). Whiting in IV and VIId. Distribution plot of the IBTS quarter 3 Survey.

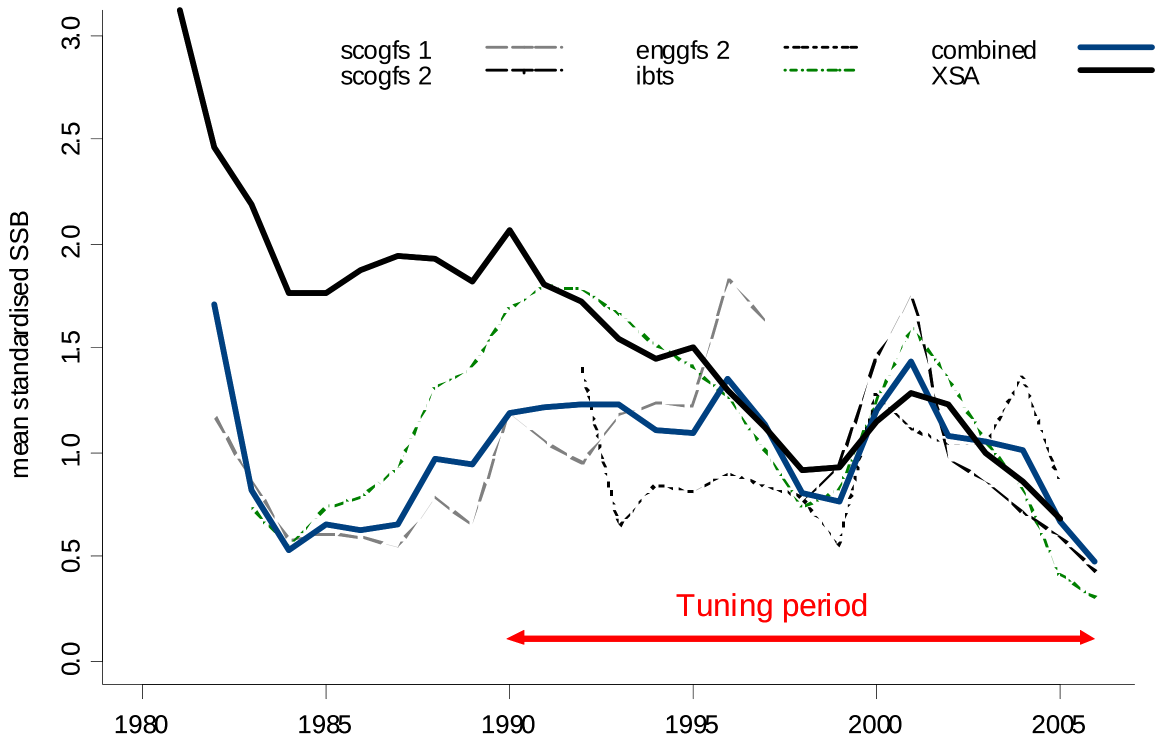


Figure 3. Catch based estimated of spawning stock biomass (black line) shown alongside survey based estimates of spawning stock biomass (blue, and dashed lines), the blue line showing an estimate based on all the surveys. These are scaled so that the mean of each line over the years 1996–2006 is one.

4 Benchmark for North Sea cod

4.1 Current stock status and assessment issues

Based on the most recent estimate of SSB (in 2008) and fishing mortality (in 2007), ICES classifies the stock as suffering reduced reproductive capacity and as being harvested sustainably. Cod SSB reached a historical low in 2006 and has shown an increase since then but remains below Blim. Fishing mortality has shown a decline since 2000, and is currently estimated to be just below Fpa. The 1997–2006 year classes are all estimated to have been well below average. The 2005 year class is estimated to be one of the most abundant amongst the recent below-average year classes.

Issues considered in this benchmark relate to:

a) whether annually varying estimates of natural mortality-at-age, based on multi-species considerations, should be included in the assessment;

b) whether annually varying estimates of maturity-at-age, based on IBTSQ1 survey data, should be included in the assessment;

c) whether the survey area used in the calculation of survey indices from the IBTSQ1 and IBTSQ3 surveys should be extended to include to include a wider area of stock distribution; and

d) whether there was an existing formulation of the SAM model that could serve as a feasible assessment model for North Sea cod.

4.2 Compilation of available data

4.2.1 Commercial catch data

No new commercial catch data was presented at the benchmark.

4.2.2 Biological data

New estimates were presented for natural mortality-at-age and proportion mature-at-age.

Natural mortality

In the historic assessment natural mortality for cod is assumed to be constant in time. However, calculations with the SMS keyrun (Stochastic Multi Species Model; Lewy and Vinther, 2004), carried out during the last meeting of the Working Group on Multi Species Assessment Methods (ICES-WGSAM 2008), indicate that predation mortalities (M2) declined substantially over the last 30 years for age 1 and age 2 cod. In addition, calculations with the latest 4M keyrun (Vinther *et al.*, 2002), carried out during the EU project BECAUSE (contract number SSP8-CT-2003-502482) in 2007, indicate a systematic increasing trend for older ages (3–6) of cod due to seal predation (Figure 4.2.2.1).

Since seals are not included in the SMS keyrun, predation mortalities for age groups 3–6 were taken from the 4M calculations, while predation mortalities for age groups 1 and 2 were extracted from the SMS keyrun to provide input for evaluation runs with B-Adapt. The 4M run showed that predation by seals on age 1 and 2 cod is very low. However, this partly contradicts new observations where grey seals predominantly feed on smaller cod (mode = 40–45cm; Hammond and Harris, 2006). Since only old stomach data from 1985 are available to the WGSAM, this needs further investigation when new stomach data become available.

SMS uses maximum likelihood to fit the model from observations of catch-at-age (international catch raised by the B-Adapt scaling factor), cpue (the same as used by B-Adapt) and stomach observation, such that the final parameters give the best fit to all data sources. Therefore, the predation mortalities also contribute to the fit of the separable fishing mortality model used within SMS. To remove the circularity, when the M2s are used by B-Adapt, the time series for M2 were smoothed over time using a spline smoother with 5 degrees of freedom (Figure 4.2.2.1).

Figure 4.2.2.2 shows population trajectories for B-Adapt runs based on constant M (as used in ICES-WGNSSK 2008) and variable M (the smoothed values shown in Figure 4.2.2.1). Results are similar, with the variable M results showing an upward shift of the SSB trajectory, and downward for the F(2–4) trajectory. Fits based on variable M show a slight deterioration in fit (in terms of SSQ). The variable time series of M, which include the major sources of predation on North Sea cod are considered appropriate for use in future assessments. As new stomach data (e.g. on seal predation) become available, a revision of more recent M2 values to reflect the current status of the food web, should be considered. Table 4.2.2.1 shows current estimates of M, based on multi-species considerations, which is suggested for use in future assessments.

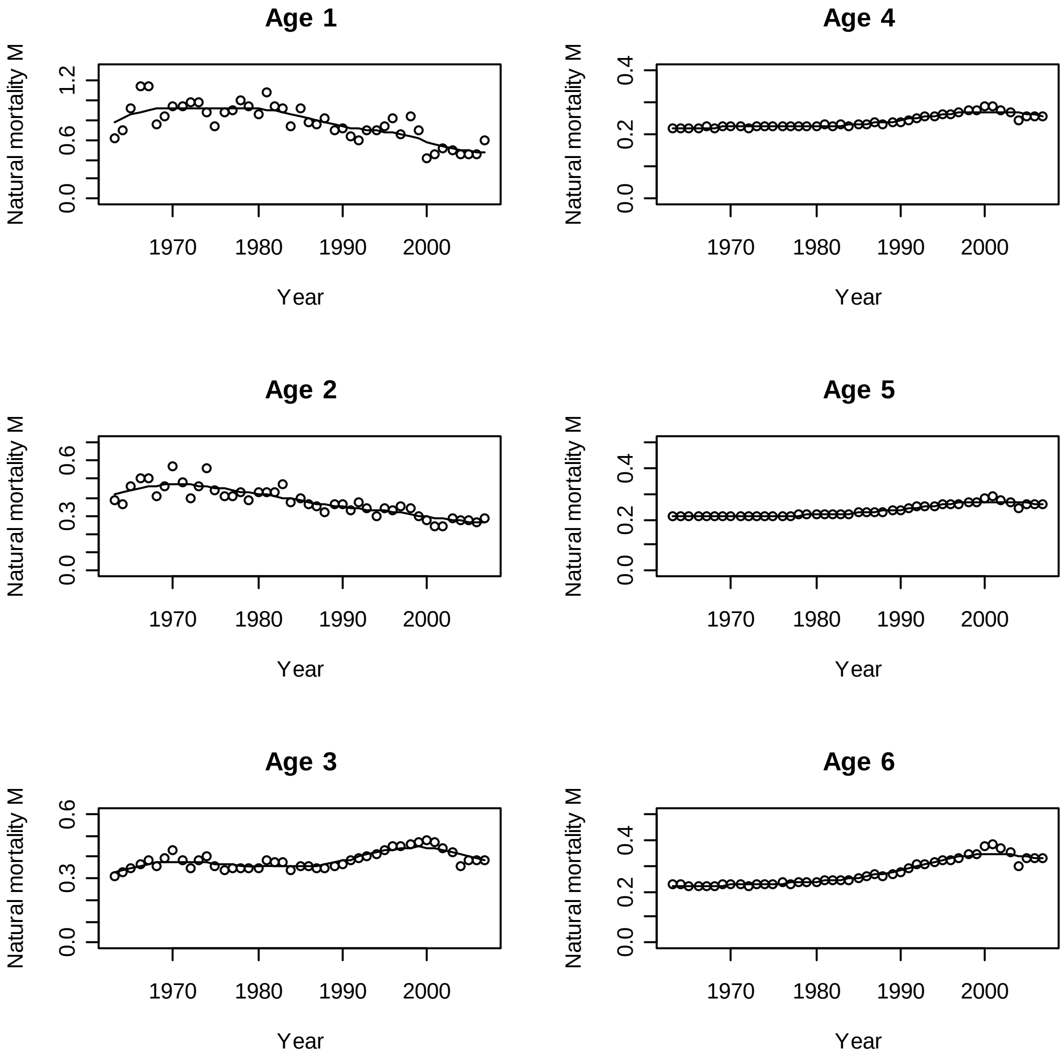


Figure 4.2.2.1 Time-series of estimated predation mortalities in multi-species assessment models. Values for age 1 and 2 were extracted from the SMS keyrun, predation mortalities for ages 3 to 6 were taken from 4M. Smoothed values are indicated with the solid lines and are based on a spline smoother with 5 degrees of freedom.

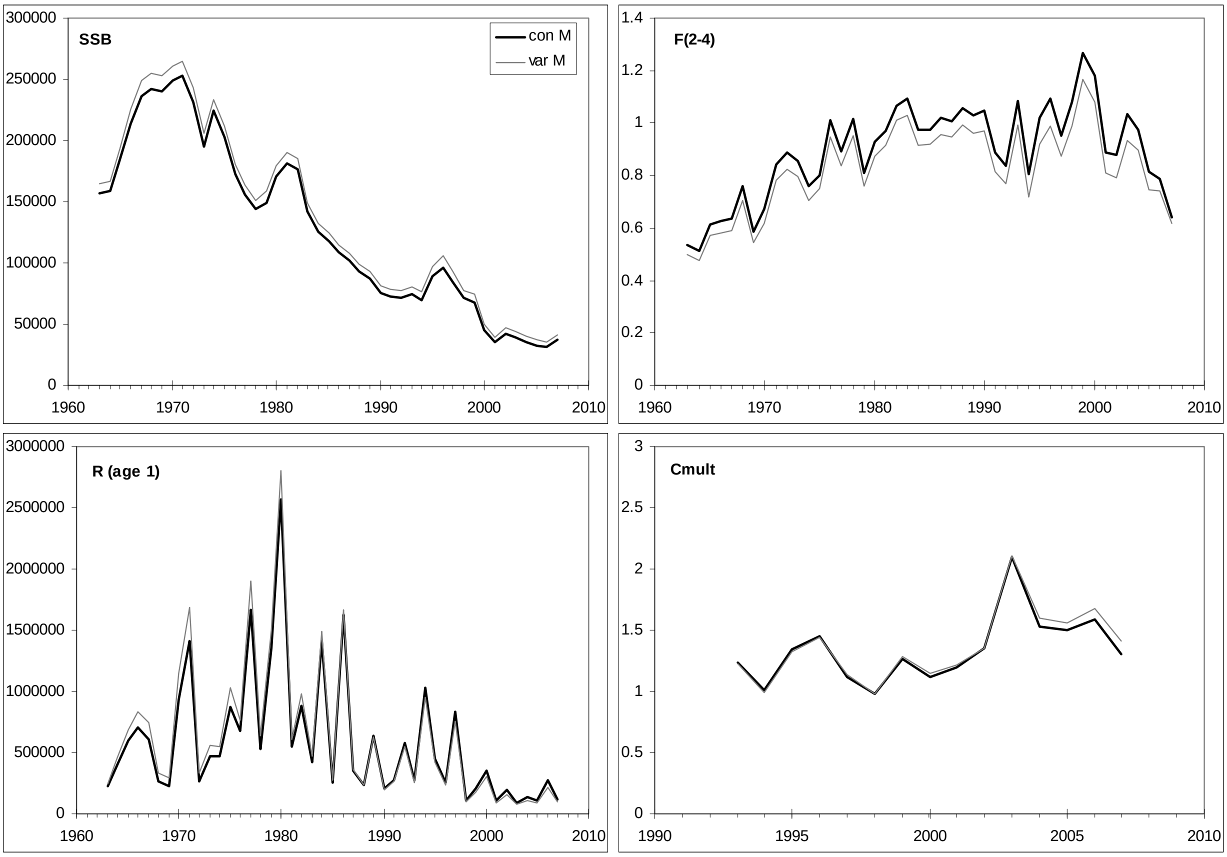


Figure 4.2.2.2 Comparison of time series of SSB, F(2–4), R and Cmult (the catch multiplier) estimates resulting from B-Adapt runs with the constant M (as for ICES-WGNSSK 2008) or variable M (as shown in Figure 4.2.2.1). SSQ values for the two fits are 25.0 and 26.7 respectively.

Table 4.2.2.1 Variable natural mortality (M) values for North Sea cod, based on multi-species considerations. The seal diet data were originally collated from information sampled over a period of years (ICES 1997). Data were then transformed to diet by age using age-length keys. Finally this set of data was allocated to one year (1985). Due to the stock structure of cod in this particular year, with a relatively low abundance of age 6, the M2 for this age becomes higher than for both younger and older cod. It is considered that, for assessment purposes, the M2 values for age 6 should be replaced by the M2 values for age 5, as reflected here.

	1	2	3	4	5	6	7+
1963	0.78	0.42	0.33	0.22	0.21	0.21	0.20
1964	0.82	0.43	0.34	0.22	0.21	0.21	0.20
1965	0.85	0.44	0.35	0.22	0.21	0.21	0.20
1966	0.87	0.45	0.36	0.22	0.21	0.21	0.20
1967	0.89	0.46	0.37	0.22	0.21	0.21	0.20
1968	0.91	0.46	0.37	0.22	0.21	0.21	0.20
1969	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1970	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1971	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1972	0.93	0.47	0.38	0.22	0.21	0.21	0.20
1973	0.92	0.46	0.38	0.22	0.21	0.21	0.20
1974	0.92	0.46	0.37	0.22	0.21	0.21	0.20
1975	0.92	0.45	0.37	0.22	0.21	0.21	0.20
1976	0.92	0.45	0.37	0.22	0.21	0.21	0.20

	1	2	3	4	5	6	7+
1977	0.92	0.44	0.36	0.22	0.22	0.22	0.20
1978	0.92	0.43	0.36	0.23	0.22	0.22	0.20
1979	0.92	0.43	0.36	0.23	0.22	0.22	0.20
1980	0.91	0.42	0.36	0.23	0.22	0.22	0.20
1981	0.90	0.41	0.36	0.23	0.22	0.22	0.20
1982	0.89	0.41	0.36	0.23	0.22	0.22	0.20
1983	0.87	0.40	0.36	0.23	0.22	0.22	0.20
1984	0.85	0.39	0.36	0.23	0.22	0.22	0.20
1985	0.83	0.38	0.36	0.23	0.23	0.23	0.20
1986	0.81	0.38	0.36	0.23	0.23	0.23	0.20
1987	0.79	0.37	0.36	0.24	0.23	0.23	0.20
1988	0.77	0.36	0.37	0.24	0.23	0.23	0.20
1989	0.75	0.35	0.37	0.24	0.24	0.24	0.20
1990	0.73	0.35	0.38	0.24	0.24	0.24	0.20
1991	0.72	0.34	0.39	0.25	0.24	0.24	0.20
1992	0.70	0.34	0.40	0.25	0.25	0.25	0.20
1993	0.70	0.34	0.41	0.26	0.25	0.25	0.20
1994	0.69	0.33	0.42	0.26	0.25	0.25	0.20
1995	0.68	0.33	0.43	0.26	0.26	0.26	0.20
1996	0.67	0.32	0.44	0.27	0.26	0.26	0.20
1997	0.65	0.31	0.44	0.27	0.26	0.26	0.20
1998	0.63	0.31	0.45	0.27	0.27	0.27	0.20
1999	0.61	0.30	0.45	0.27	0.27	0.27	0.20
2000	0.58	0.29	0.44	0.27	0.27	0.27	0.20
2001	0.56	0.29	0.44	0.27	0.27	0.27	0.20
2002	0.53	0.28	0.43	0.27	0.27	0.27	0.20
2003	0.51	0.28	0.42	0.27	0.27	0.27	0.20
2004	0.50	0.27	0.41	0.27	0.27	0.27	0.20
2005	0.49	0.27	0.40	0.26	0.26	0.26	0.20
2006	0.47	0.27	0.39	0.26	0.26	0.26	0.20
2007	0.46	0.26	0.38	0.26	0.26	0.26	0.20

Maturity

Variability or systematic changes in age at maturation has been seen in a number of cod stocks (Nash *et al*., WD15; Jørgensen, 1990; Hunt, 1996; Morgan and Brattey, 2005; Trippel, 1995). In recent years, North Sea cod has shown changes in maturity with fish maturing at a younger age and smaller size. Biological data on North Sea cod for the period 1973 to 2007 were obtained from the first quarter IBTS (International Bottom Trawl Survey) and trends in the proportion mature at age examined.

Figure 4.2.2.3 shows maturity data from IBTSQ1 together with a running mean, and the constant values used in recent assessments (ICES-WGNSSK 2008). The data indicate a strong trend of increasing maturity-at-age with time. Figure 4.2.2.4 shows the results of a binomial logistic linear regression model fitted separately for each cohort. The model was fitted to cohorts with data for at least 5 ages, and maturities for incomplete cohorts (i.e. less than 5 ages) were taken as geometric means for the same age from three adjacent cohorts. The resultant estimates of proportion mature-at-age are shown in Figure 4.2.2.5, and are used in subsequent analyses that consider variable maturity.

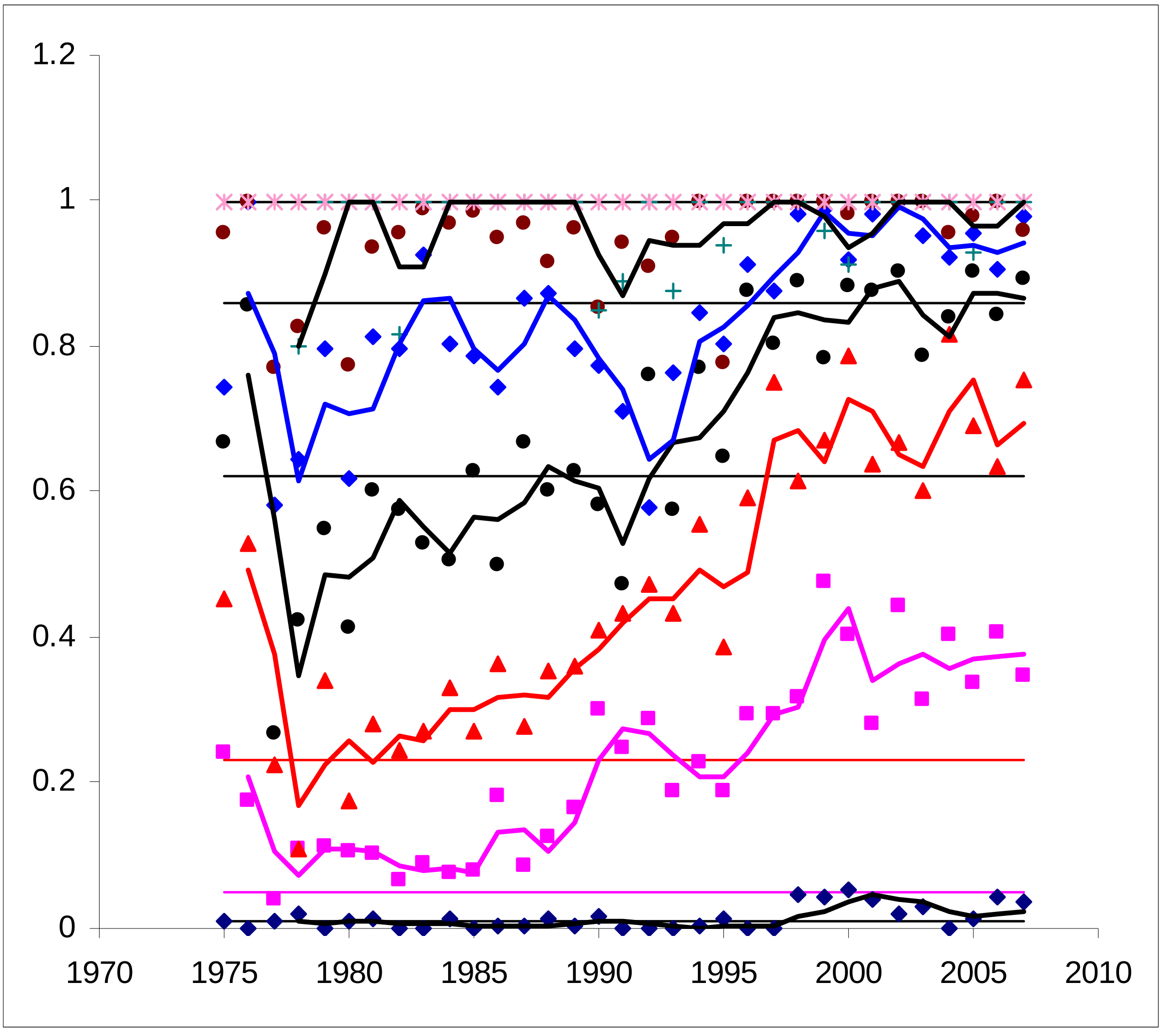


Figure 4.2.2.3 Maturity data for North Sea cod from IBTSQ1 for ages 1–7 (from bottom to top) fitted with a running mean, with the solid horizontal lines indicating the constant values used in ICES-WGNSSK (2008).

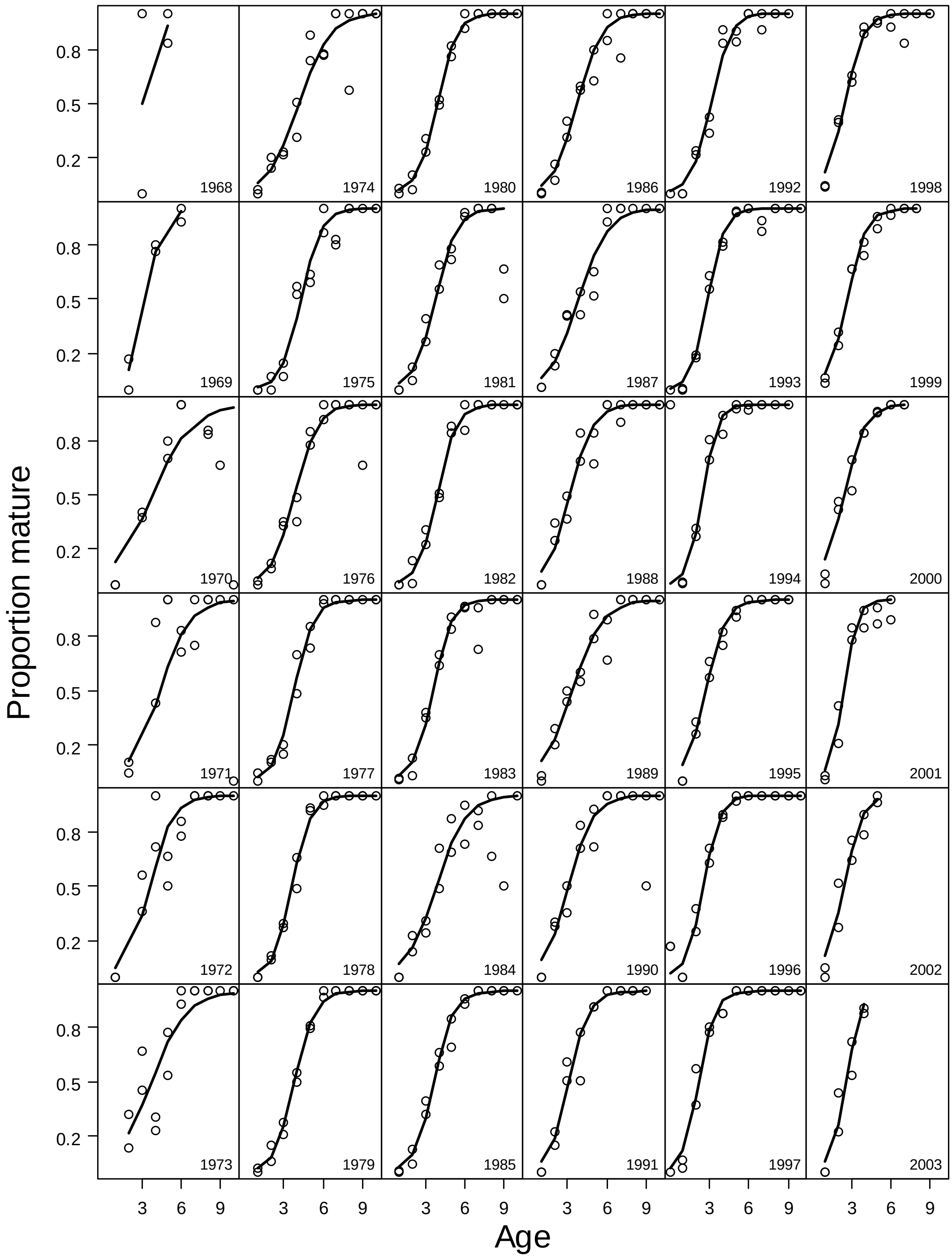


Figure 4.2.2.4 Maturity data for North Sea cod fitted with a binomial logistic regression model separately for each cohort.

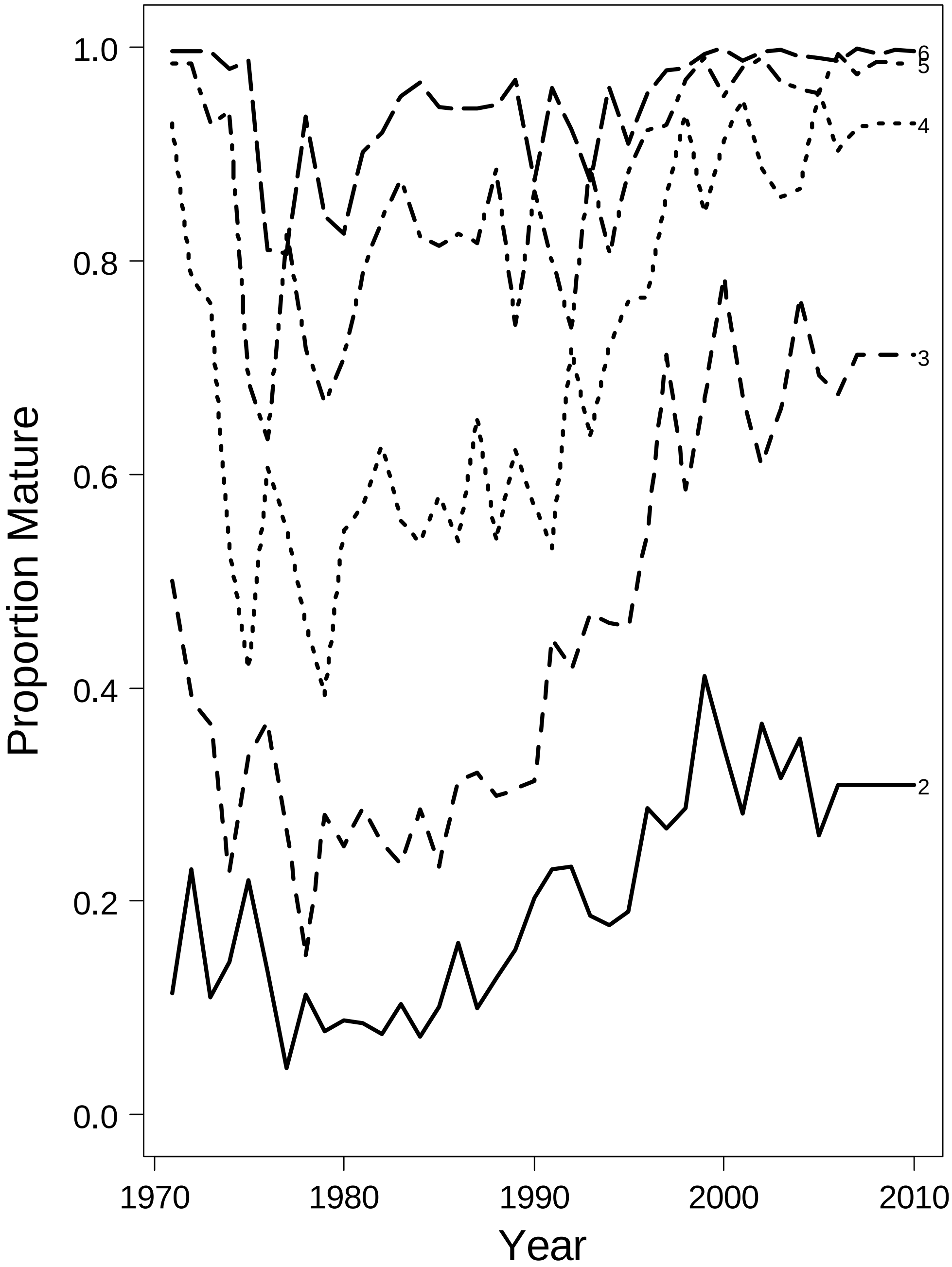


Figure 4.2.2.5 Estimates of proportions mature at age from the model shown in Figure 4.2.2.4.

In order to decide whether to use the variable maturity data in future assessments, the impact of the variable maturity data on estimates of the stock-recruit relationship (Ricker was used) for North Sea cod was investigated. This analysis was performed for both the constant and variable M runs illustrated in Figure 4.2.2.2. A comparison of maximum negative log-likelihood values are shown in the following table:

	Constant maturity	Variable maturity
Constant M	43.7	48.9
Variable M	44.5	51.8

Figures 4.2.2.6–9 illustrate fits of the Ricker stock-recruit curve to combinations of assumptions about how M- and maturity-at-age vary over time. The variable

maturity data leads to a substantial deterioration in fit (see above table), and therefore does not help explain the relationship between SSB and recruitment. Until further investigations are carried on issues linked to earlier maturity, for example relating the quality of reproductive output of young first-time spawners to recruitment success, the constant maturity ogive will continued to be used for future assessments.

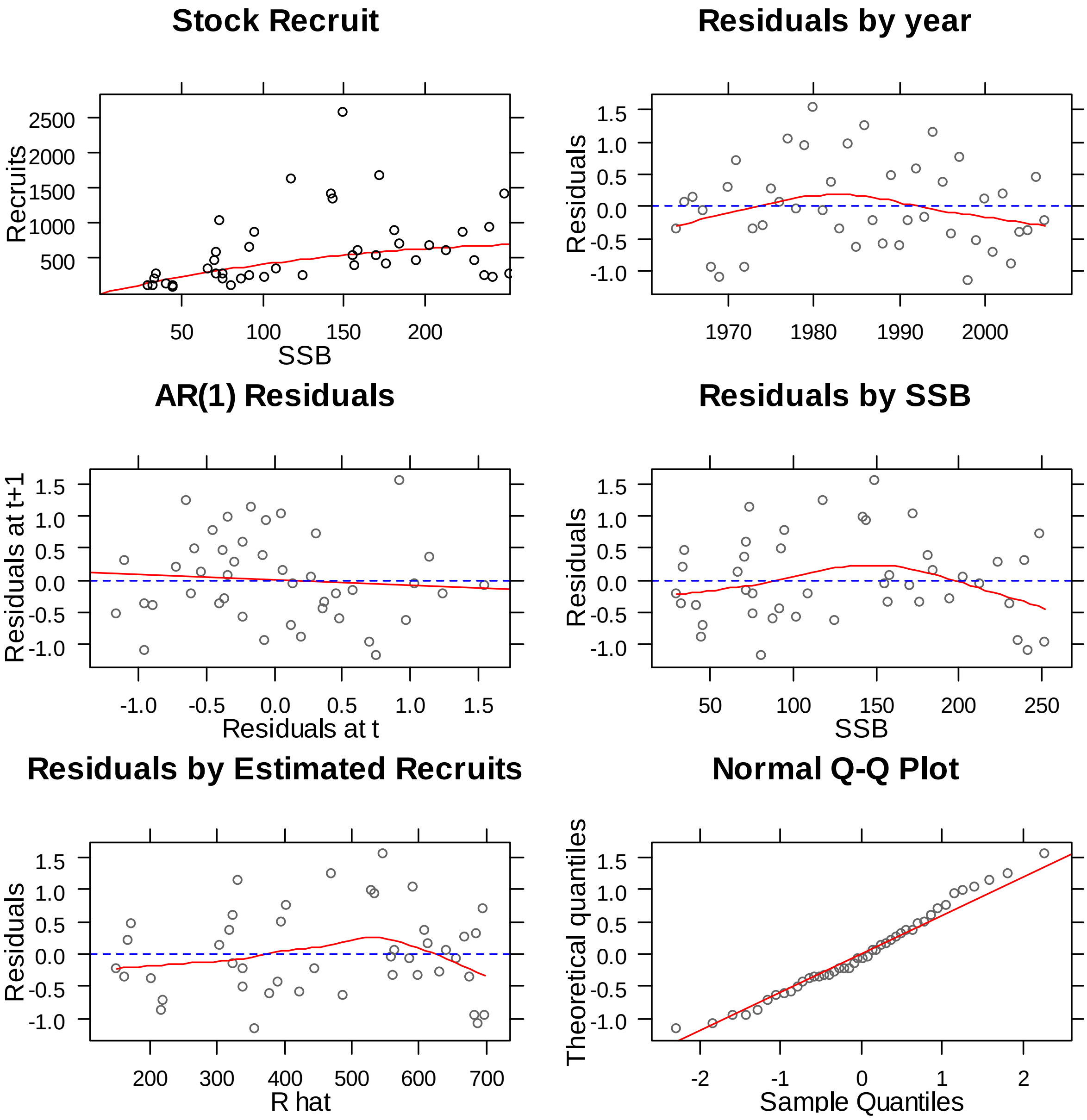


Figure 4.2.2.6 Diagnostics for a Ricker stock-recruit fit for constant M and constant maturity. The negative log-likelihood value was 43.7.

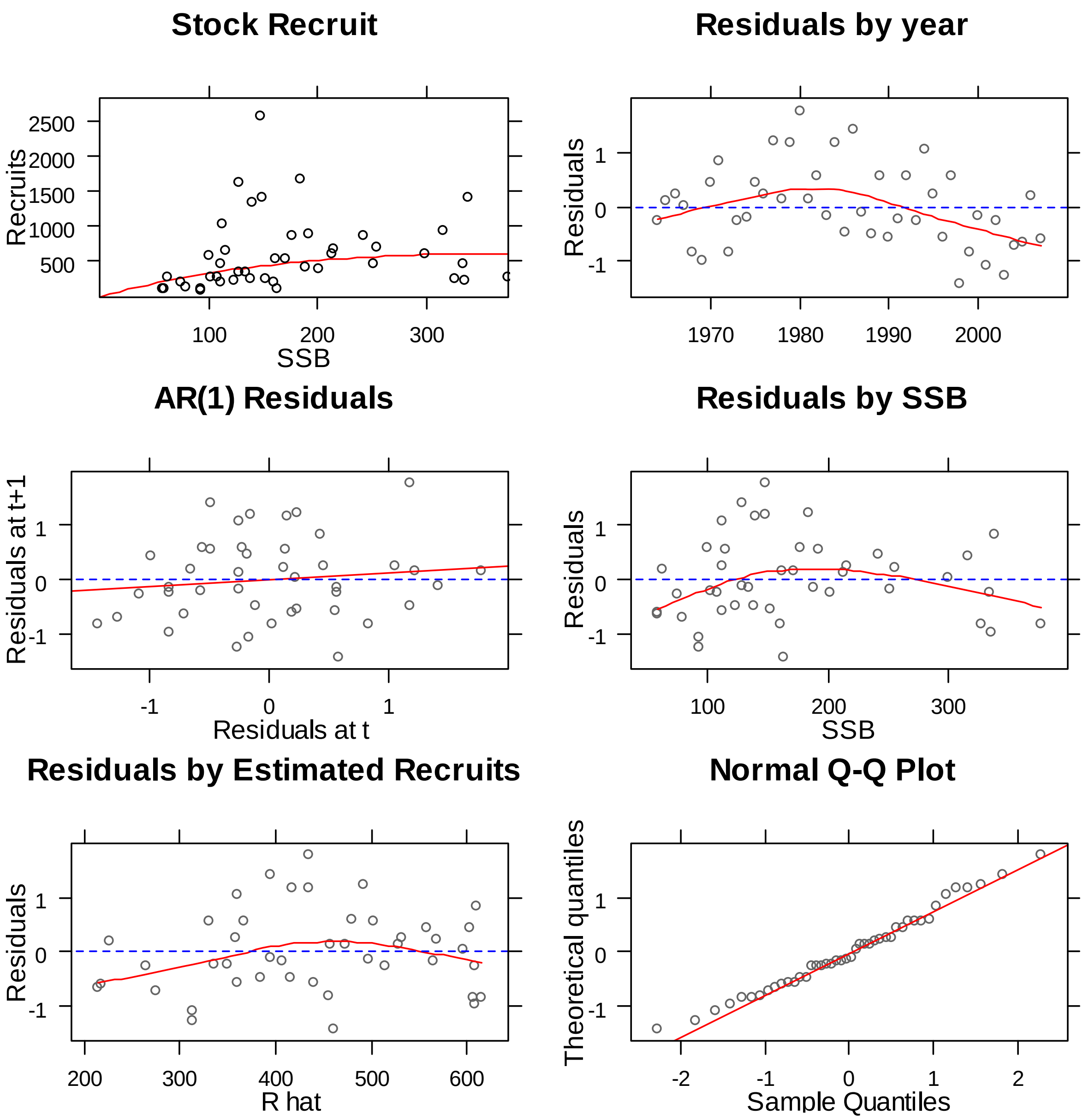


Figure 4.2.2.7 Diagnostics for a Ricker stock-recruit fit for constant M and variable maturity. The negative log-likelihood value was 48.9.

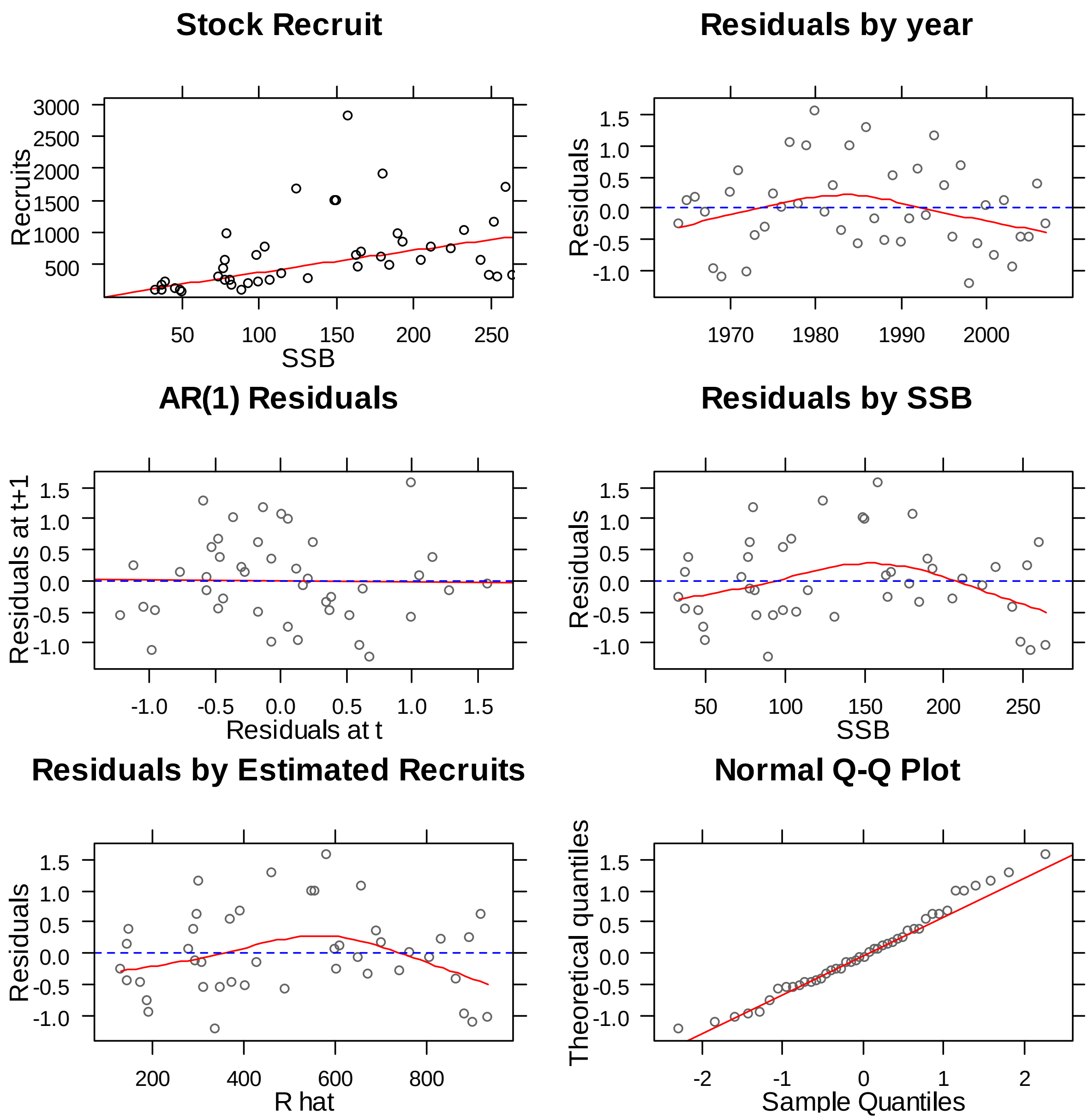


Figure 4.2.2.8 Diagnostics for a Ricker stock-recruit fit for variable M and constant maturity. The negative log-likelihood value was 44.5.

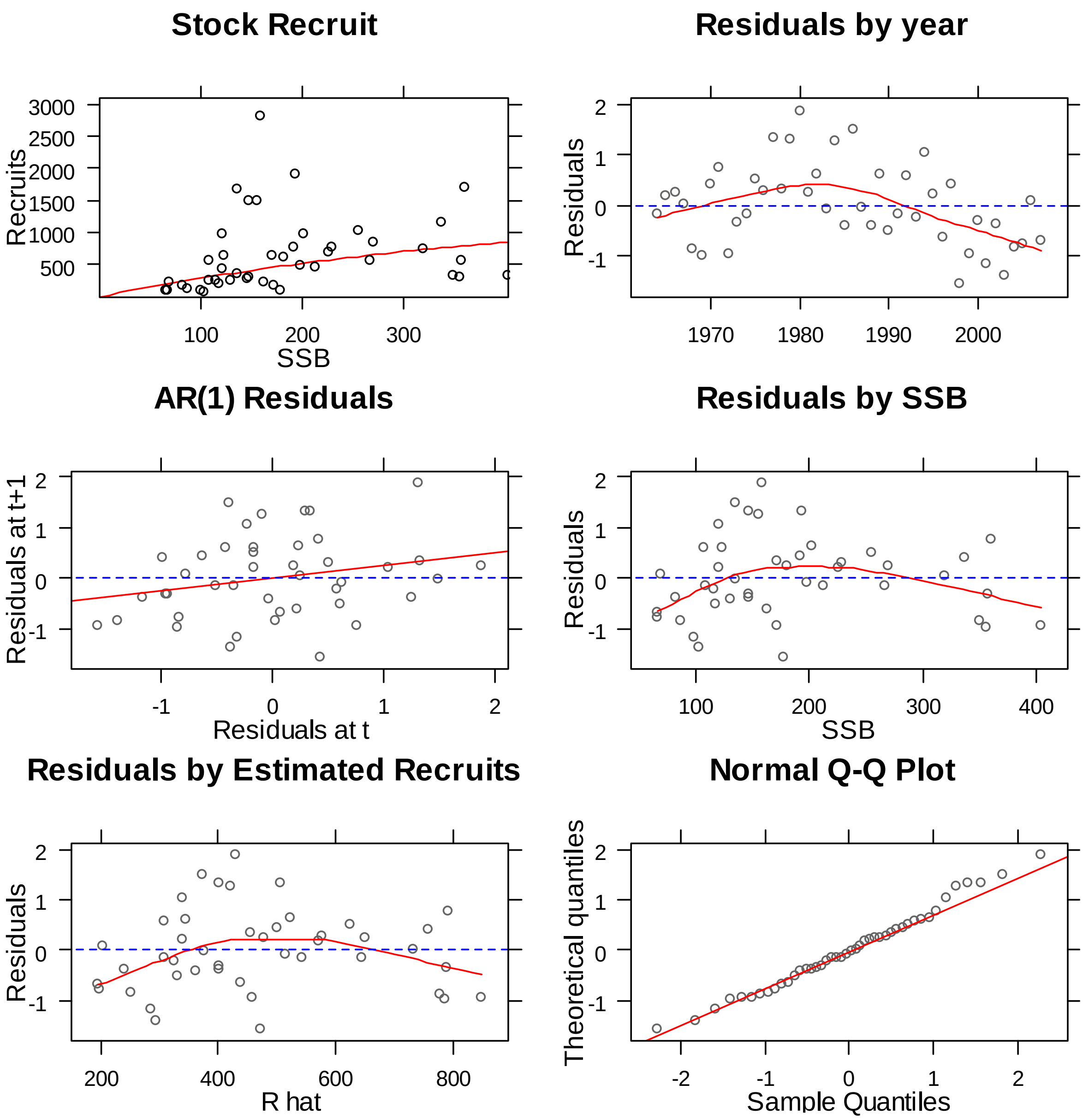


Figure 4.2.2.9 Diagnostics for a Ricker stock-recruit fit for variable M and variable maturity. The negative log-likelihood value was 51.8.

4.2.3 Survey data

Plots of the distribution of cod at age 1, 2 and 3+ from the IBTS showed that areas outside the cod standard area used in the routine calculation of the IBTS indices have become increasingly important in recent years (ICES WGNSSK 2008). Hence, the area on which the indices are based was extended mainly to include the eastern Skagerrak and the northern part of the English Channel (Figure 4.2.3.1). Some other rectangles were included as well so that the IBTS index area refers more closely to the stock distribution area. Rectangles in the southern English Channel, however, which were first introduced in the IBTS a few years ago (ICES IBTSWG 2008), were not considered in order to keep consistency throughout the time series.

A comparison between the standard and extended IBTS index (Figures 4.2.3.2–5) show minor changes for the ages used in the assessment (1–5 for IBTSQ1 and 1–4 for IBTSQ3) when the index is extended. The largest changes occur at the younger ages, particularly for age 0 in IBTSQ3, which is not used in the assessment. Residual plots for B-Adapt runs including the standard and extended indices are shown in Figure 4.2.3.6. These indicate a slight improvement in fit (SSQ improvement from 25.0 to 22.4) for the extended indices run compared to the standard indices run. A comparison of population trajectories for the two runs are shown in Figure 4.2.3.7.

Given the improved fit for the extended indices and other benefits of using these indices (such as better coverage of the stock distribution area), it would be beneficial for the North Sea cod assessment to use the extended indices in future analyses.

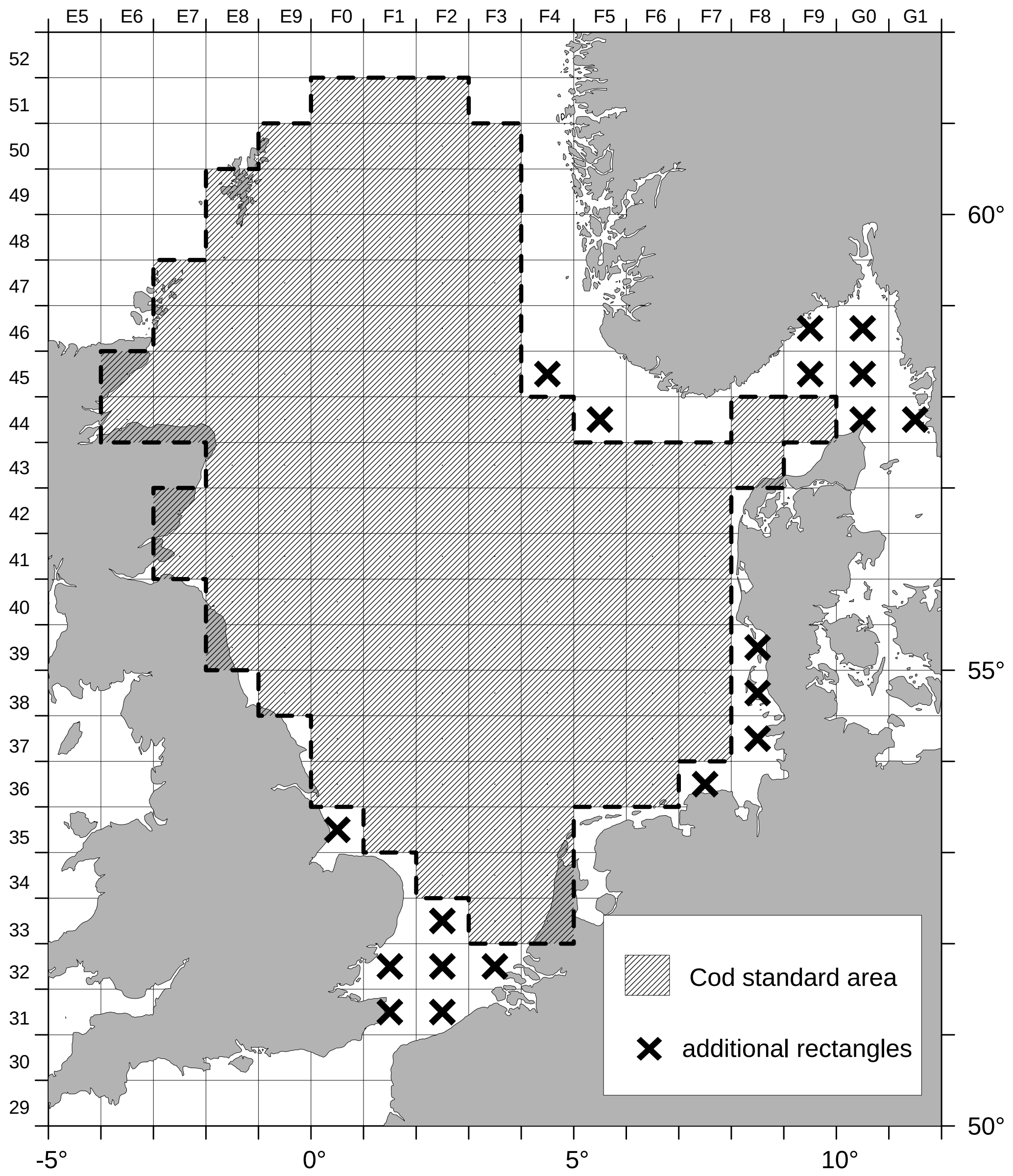


Figure 4.2.3.1: Extension of cod standard area used for the revision of IBTS indices.

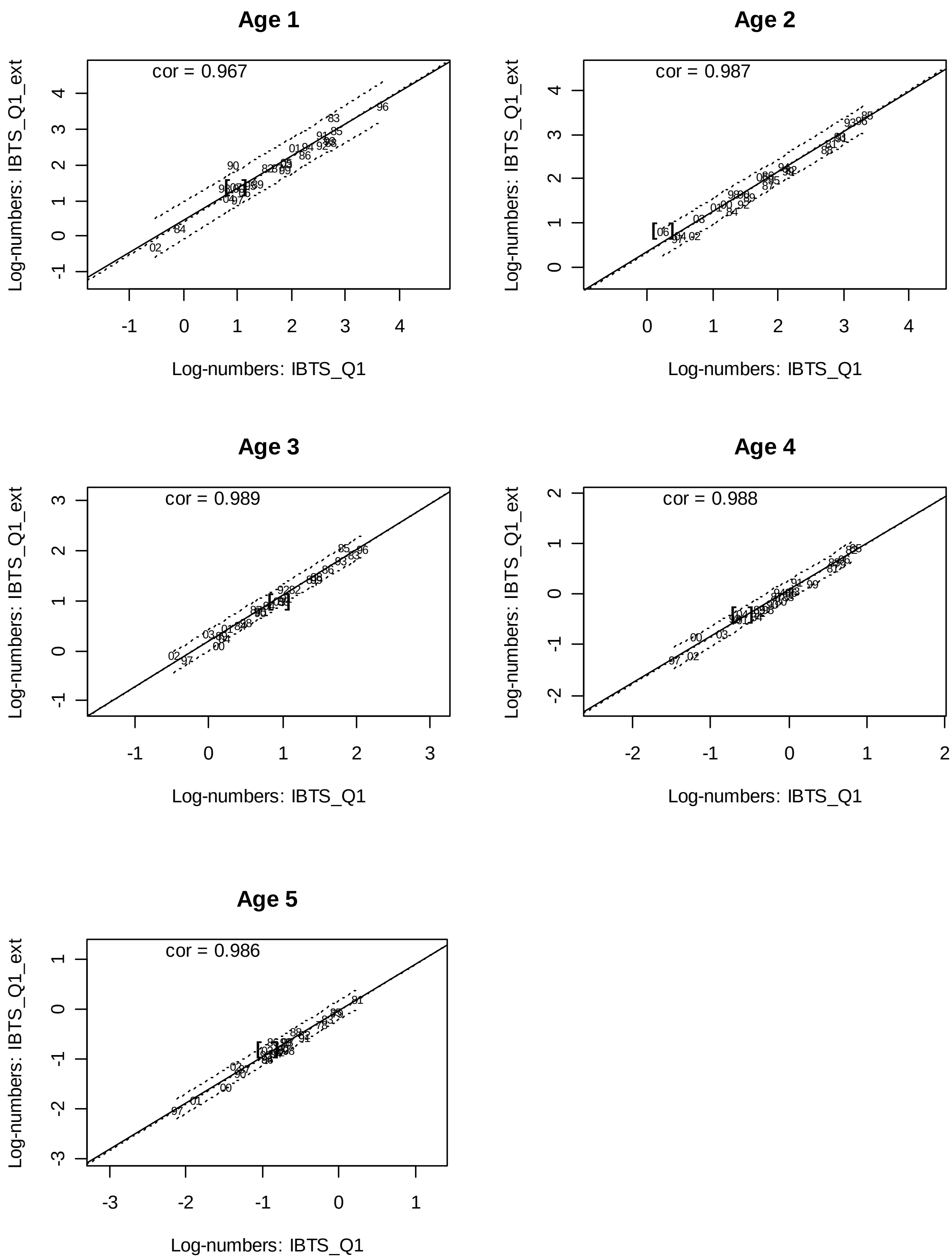


Figure 4.2.3.2 Correlations between the standard (IBTS_Q1) and extended (IBTS_Q1_ext) indices.

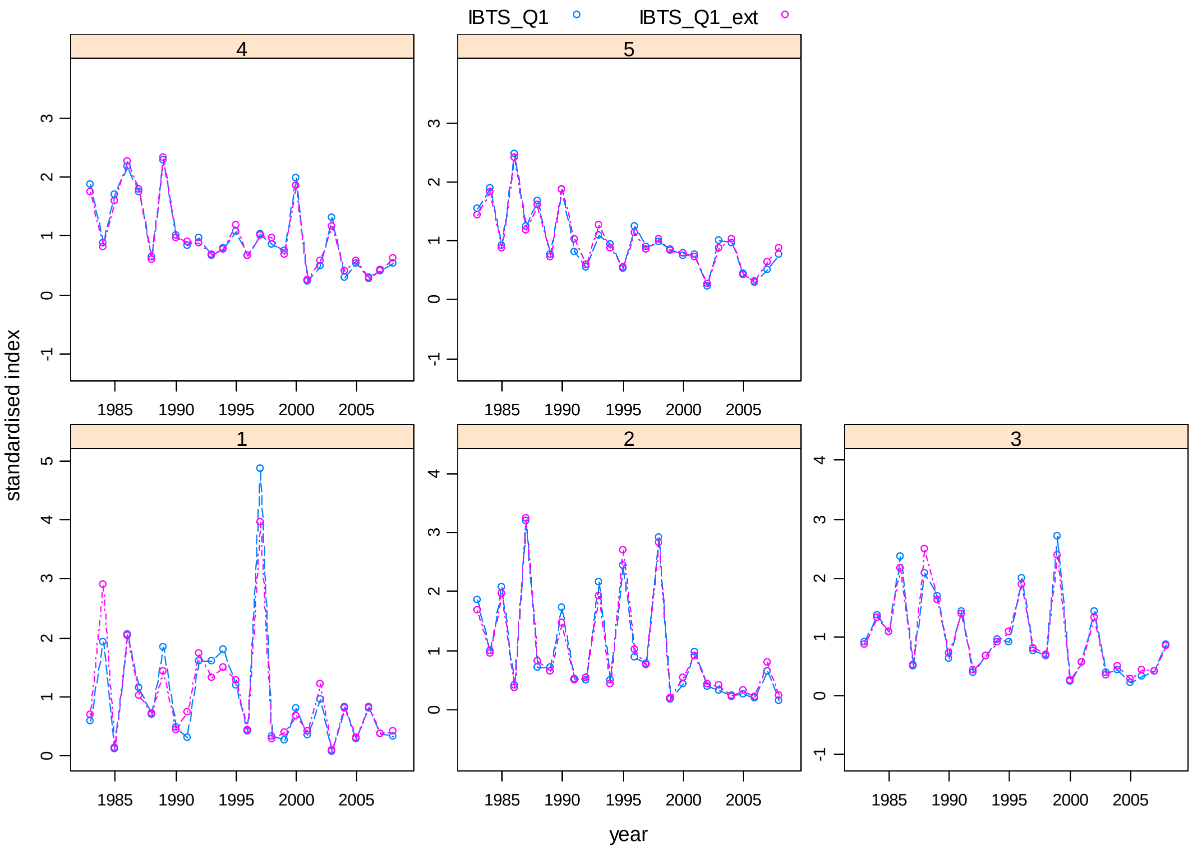


Figure 4.2.3.3 Direct comparison of the standard (IBTS_Q1) and extended (IBTS_Q1_ext) indices.

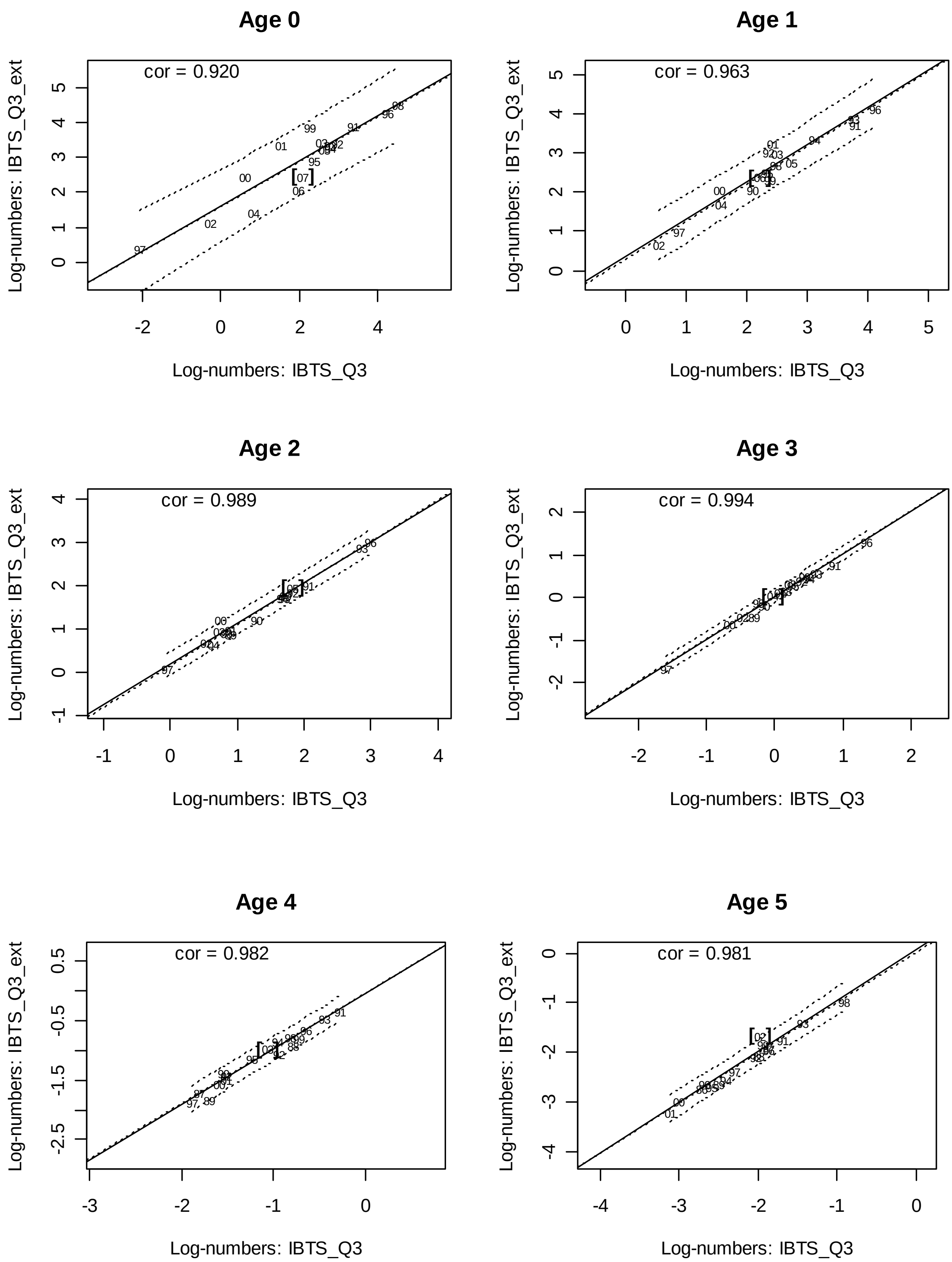


Figure 4.2.3.4 Correlations between the standard (IBTS_Q3) and extended (IBTS_Q3_ext) indices.

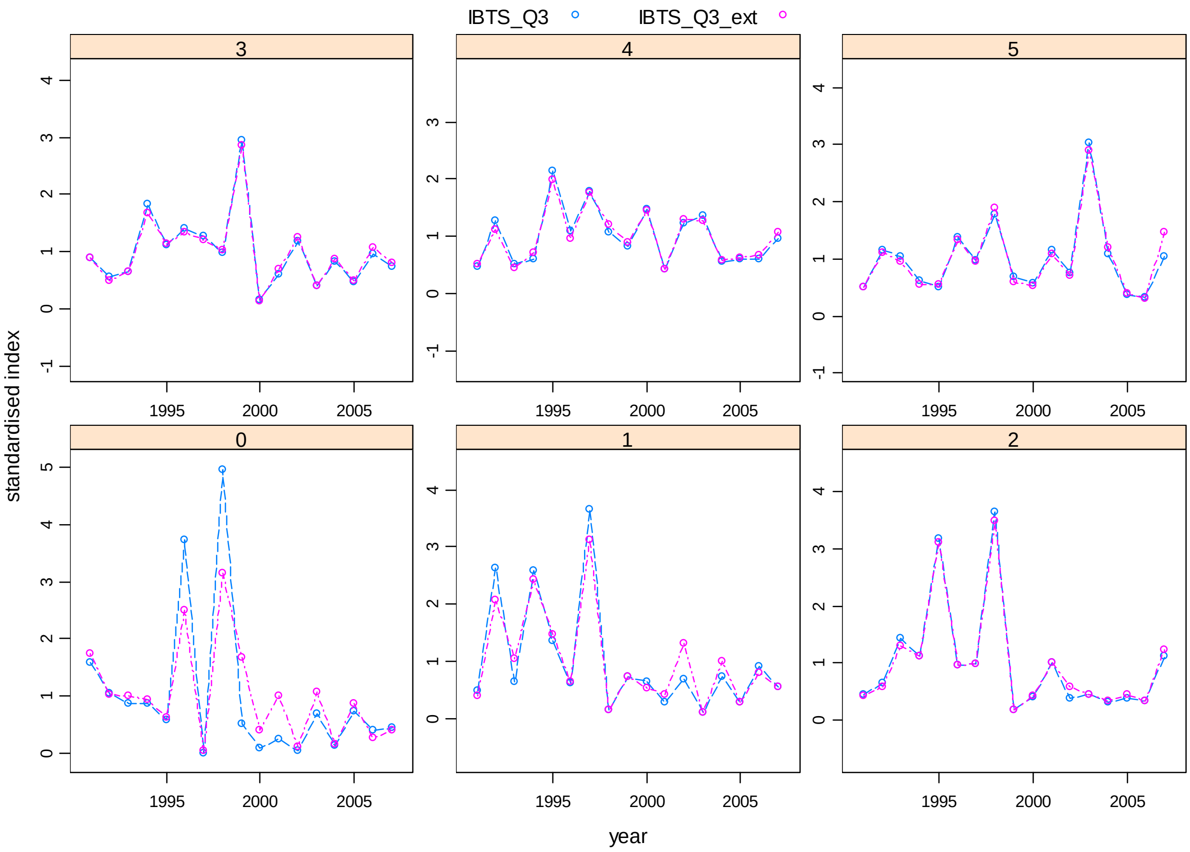
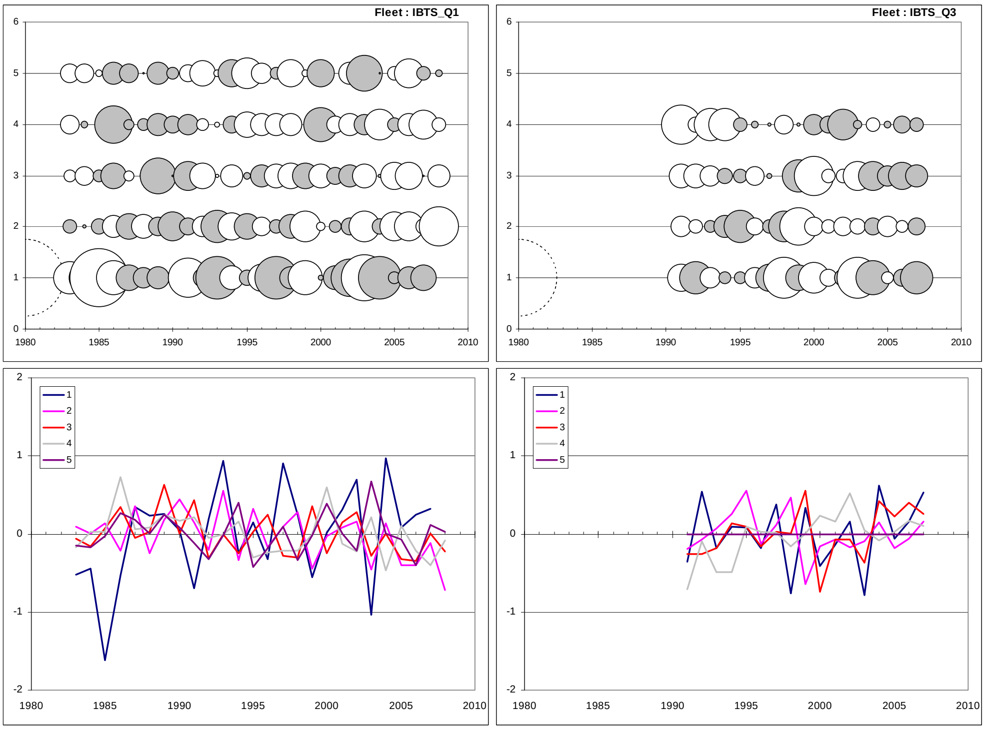


Figure 4.2.3.5 Direct comparison of the standard (IBTS_Q3) and extended (IBTS_Q3_ext) indices.

a. SSQ-value of 25.0:



b. SSQ-value of 22.4:

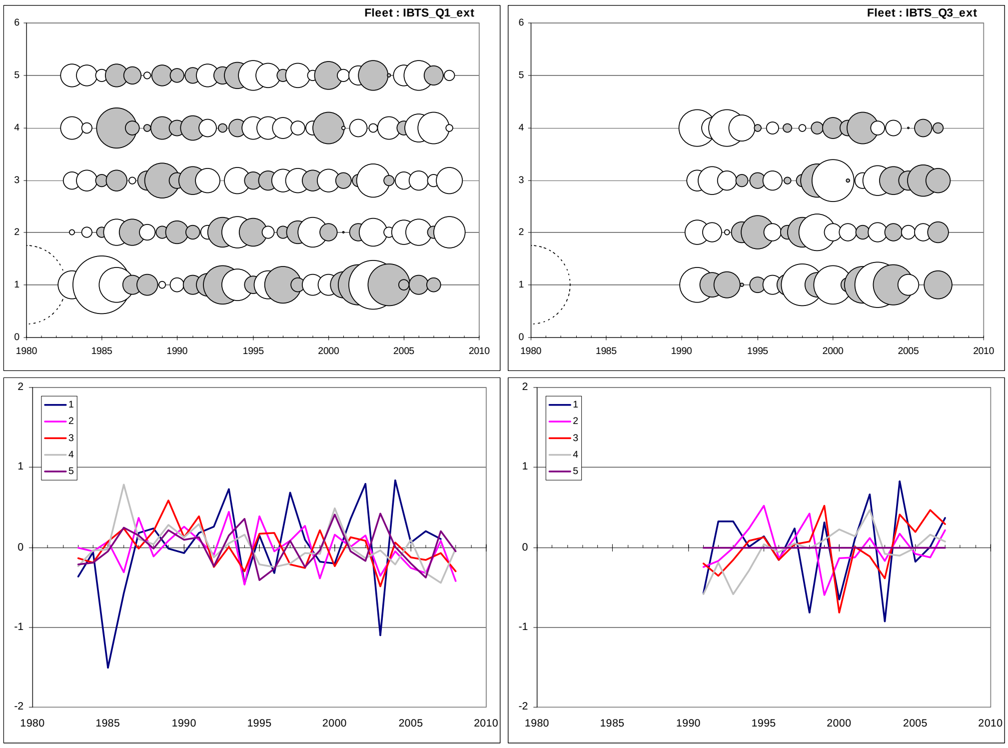


Figure 4.2.3.6 Residual plots for B-Adapt runs including the (a) standard and (b) extended IBTS indices. Grey bubbles indicate positive values, and white ones negative. The partially displayed dotted bubble indicates an absolute residual of size 3. The line plots show an alternative display of the residuals. SSQ values are shown above.

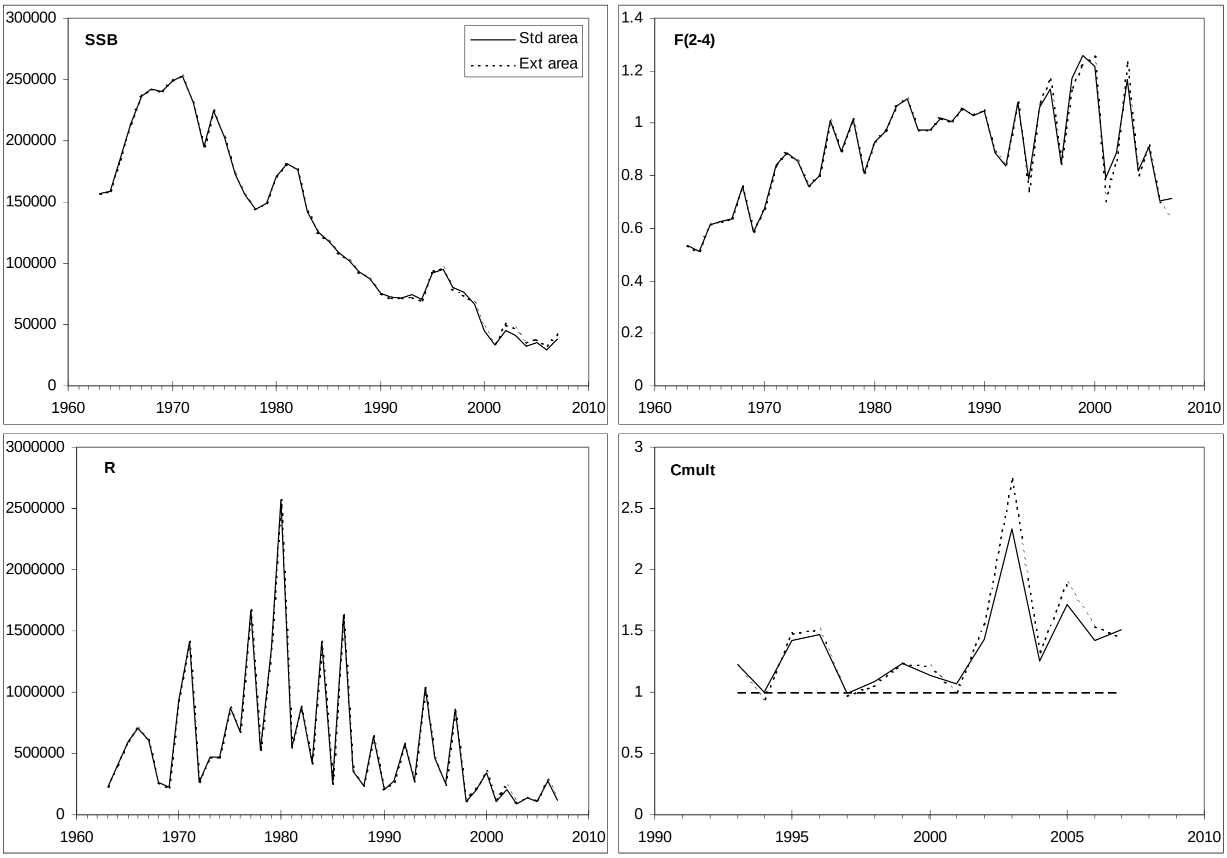


Figure 4.2.3.7 Comparison of time series of SSB, F(2–4), R and Cmult (the catch multiplier) estimates resulting from B-Adapt runs with the standard and extended IBTS indices.

4.2.4 Industry/stakeholder data inputs

Examples of Annual Fisheries Reports, as compiled by the NFFO (the National Federation of Fishermen's Organisations, a representative body for fishermen in England, Wales and Northern Ireland) are presented in WD10–13. During discussions on the potential contributions from the industry it was agreed that such reports would provide fisheries information that could be used to aid interpretation of the quantitative stock assessments and also in the provision of advice on the potential effect of proposed management actions.

Fisheries science partnerships

The NE Coast cod survey (Armstrong *et al.*, WD3 in ICES-WGNSSK 2008) is a designated time-series survey conducted since 2003 as part of the UK Fisheries Science Partnership (FSP). The objective of the survey series is to provide year-on-year comparative information on distribution, relative abundance and size/age composition of cod and whiting off the NE coast of England. The surveys also provide data on catches of other species important to the NE coast fishery, including haddock. Results indicate that the population of cod in the survey area has primarily comprised 1- and 2-year-olds, with some 3- and 4-year-olds. Older fish are scarce. The relative strength of recent year classes of cod, as indicated by the time-series of FSP catch rates of 1-year-olds, has been very similar to the trends given in the 2007 ICES assessment (ICES-WGNSSK 2007). Furthermore, the bulk of the FSP cod catches in 2005, 2006 and 2007 were fish of 21–45 cm, predominantly 1-year-olds that were most abundant on the inshore hard ground. Catch rates of cod in this length range were generally higher in 2006 than in 2005, owing to the relative strength of the 2005 year class. Both this FSP survey and the IBTS surveys indicate that the 2006 year-class of cod is less than half as abundant as the relatively strong 2005 year class.

A new UK FSP project in 2007 (the "North Sea Codwatch" project; Large *et al*., WD5 in ICES-WGNSSK 2008) has been mapping the distribution of young cod of the 2005 and 2006 year classes in the North Sea using a fisher self-sampling scheme (www.cefas.co.uk/fsp). The project involves 12 Eastern England Fish Producer Organisation (EEFPO) vessels, representing a wide range of fishing gears and target species, and operating throughout the North Sea. These vessels observe and record the incidence, and fine-scale distribution and abundance of the 2005 and 2006 year classes of cod, and of cod in general in the North Sea from commercial catches made between April 2007 and March 2008. The project has now been extended to March 2009, and will also consider the 2007 and 2008 year classes.

Based on fishers' perception of current year class strength relative to previous year classes (participants have an average of 30 years fishing experience), provisional North Sea Codwatch results suggest that the 2005 year class was widely distributed throughout the North Sea (appearing in most sampled areas), with the highest levels of abundance occurring in the western-central North Sea in Q3, and in the western central and southern North Sea in Q4. Of all rectangles sampled (153 in total), only 19% recorded perceptions of "high" or "very high" abundance of the 2005 year class relative to historical abundance (the remainder recording perceptions of "zero", "low" or "moderate" abundance), but the proportion of rectangles recording "high" or "very high" increased with time (from 10% in Q2 to 26% in Q4). In contrast, the 2006 year class was present in relatively few of the sampled rectangles, with 80% of sampled rectangles recording perceptions of "zero" or "low", but skippers noted that this may be a consequence of the gear used. Nevertheless, these perceptions are consistent with WG estimates of these two year classes, both relative to each other and in the historical context.

A collaborative biologist-fishermen project on North Sea cod (REX; Wieland *et al*., WD6 in ICES-WKROUND 2009) was initiated by DTU-Aqua (Institute for Aquatic Resources at the Technical University of Denmark) and the Danish Fishermen Association in summer 2006. Three commercial vessels representing different fishing methods participated in the study. These were a trawler, a flyshooter and a gillnetter. The original survey area consisted of 7 ICES statistical rectangles in the north-eastern central North Sea.

During the first two surveys in June and August 2006 the fishermen were free to select the fishing positions that tended to be mainly located on rough bottom, which is usually not covered by scientific bottom trawl surveys. In order to allow the investigation of a potential effect of bottom type, the fishermen were subsequently requested to select paired stations within a distance of 10 nmi with one station on sand bottom and the other on different bottom types (gravel and stone bottom, as well as ship wrecks in the case of the gillnetter) during the next two surveys in January/February and June 2007. In order to obtain a better impression of the spatial distribution, a higher degree of randomisation in the survey design was used in surveys conducted in August 2007, February 2008 and August 2008 (survey area divided into 5x5 nmi; randomly selected fishing position with the square chosen by the fishermen; at least 25 % of the stations on sand bottom; number of squares covered in an ICES rectangles differed between the vessels to account for differences in fishing method).

The first three surveys resulted in sampling of a few clusters of stations in favourite spots of fishermen, yielding considerable catch rates of cod. In the later surveys a much wider extension of areas with high densities of cod were recorded (e.g. catch rates of more than 1 ton of cod per nmi2 were found in 25% of the stations in the August 2007 survey). In general, catch rates were lower in spring than in summer, and catches were considerably higher on rough bottom than on sand in the summer surveys. The length frequencies ranged from 20 to 120 cm with a peak at 30 to 40 cm for the trawler and flyshooter, and at larger sizes for the gillnetter. Cod between 60 and 80 cm was well represented in the length frequencies for all vessels, and larger cod was caught regularly, in particular by the trawler and gillnetter. A comparison with the IBTS catches from the same area suggests a marked decline of the efficiency of the IBTS for cod larger than 40 cm compared to the catches rates of the commercial vessels. This, however, needs further investigation, and an analysis based on age disaggregated data is required before conclusive results can be obtained. No significant change in average cod density was detected between the 1st quarter 2007 and the 1st quarter 2008 while an increase in cod density from the 3rd quarter 2006 to the 3rd quarter 2007 and further to the 3rd quarter 2008. Scaling to the entire North Sea based on IBTS index ratios and adjustment of the average cpue from the 3rd quarter for catchability resulted in biomass estimates for age 2+ cod of 27 000 t in 2006, 101 000 t in 2007 and 137 000 t in 2008. These values indicate a faster rate of stock recovery than detected in the most recent assessment of changes in SSB in that period.

Additional information provided by the fishing industry

In May 2008, French fishers targeting cuttlefish in the eastern Channel reported discards of several tons per haul of undersized cod in ICES rectangle 28F0, forcing them to leave their usual cuttlefish fishing area. They reported that this also occurred in 2007. At the time of the WGNSSK (2008) meeting, the local fishermen were gathering additional information to verify these observations. Based upon the preliminary observations of fishermen in 2008, and observations during the summer of 2007, it seems undersized cod move westwards into VIIe in the spring. Inshore trawlers based in Granville have reported experiencing, for the first time, recurring bycatches of cod in some areas west of 28F0 during summer 2007. Bycatches of cod were reported in 2008 in 28E91.

4.3 Stock identity and migration issues

A review of studies and reviews carried out by the ICES WGNSSK and STECF and EU funded projects and within national laboratories was presented and discussed at the meeting. Migration studies have not indicated any significant linkages (emigration or immigration) to adjacent areas that would raise concerns about the current definition of the stock. The current areas used for defining the stock boundaries are considered appropriate.

4.4 Spatial changes in fishery or stock distribution

Spatial changes in annual fishing activities in response to management are reviewed each year by the WGNSSK. There are no long-term changes that are considered sufficient to impact the assessment and management advice provided for the stock.

4.5 Environmental drivers of stock dynamics

No new information was available.

4.6 Role of multi species interactions

The reason for the decline in predation mortalities (M2) over the last 30 years for age 1 and age 2 cod (Figure 4.2.2.1) is mainly decreasing cannibalism caused by the reduction of the cod stock. There has also been a systematic increasing trend for older ages (3–6) of cod due to seal predation (Figure 4.2.2.1). However, predation mortalities caused by seals are small compared to fishing mortalities, especially for age groups 4 and older. In addition, the amount of cod eaten in keyrun 2007 is smaller than in previous 4M keyruns (e.g., ICES-SGMSNS 2005) due to updated data on consumption rates. Predation mortalities caused by seals may have to be revised again when seals are also included in SMS.

The effect of using variable predation mortalities instead of constant ones becomes especially obvious when making long-term forecasts. A comparison between the SMS keyrun 2008 carried out in single species mode and the SMS keyrun 2008 carried out in multi species mode led to different recovery rates of cod when fished with a constant fishing mortality of F_{MSY} = 0.4 (Figure 4.6.1). The increasing cannibalism due to the recovering cod stock cannot be taken into account in standard single species assessment methods. Further investigations on the role of predation for North Sea cod can be found in WD5.

The difficulty for multi species modeling in the North Sea area is that only two complete stomach data sets exist and the last "Year of the "Stomach" was in 1991. Since then the North Sea ecosystem has changed considerably and it is a hard task to predict stomach contents from nearly 30 year old data. For example, the predator assemblage has changed since 1991. Therefore, new stomach data would be needed to determine the current status of the North Sea food web to allow for more certain estimates of current predation mortalities.

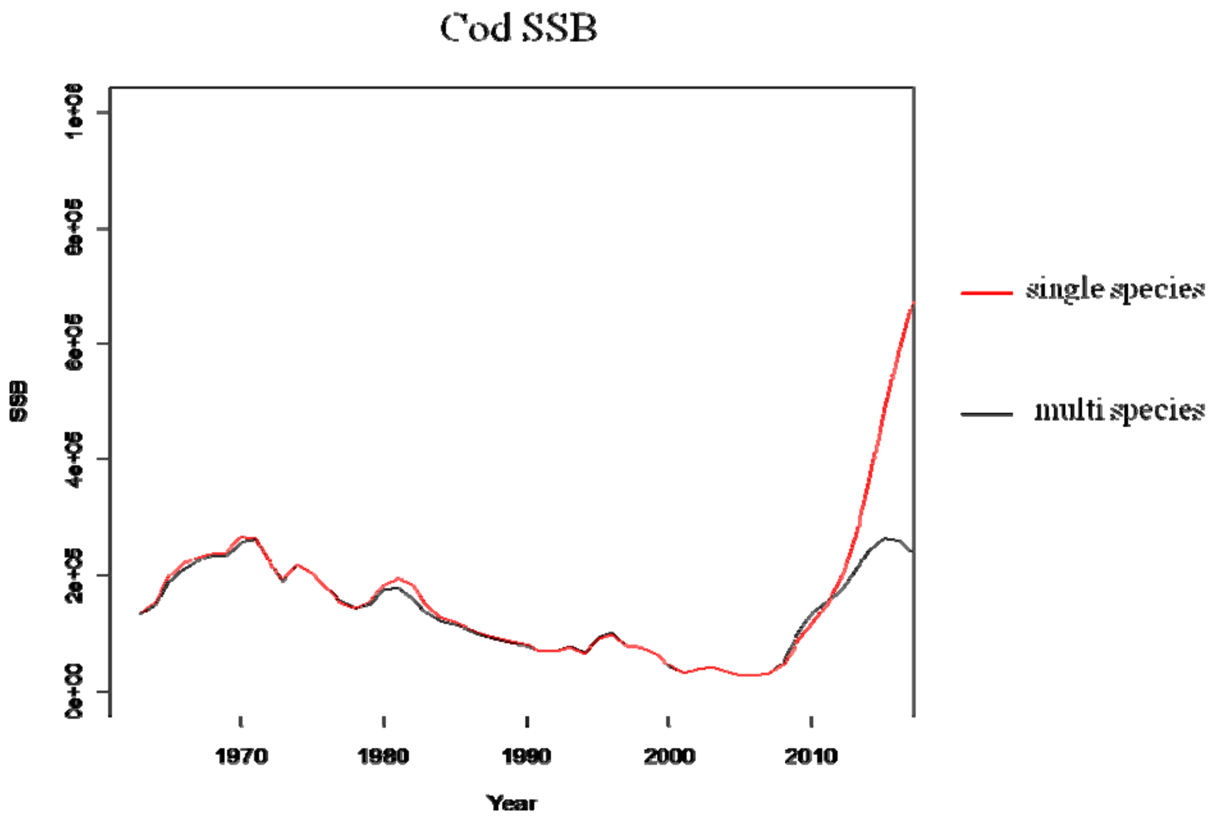


Figure 4.6.1 Hindcasted and forecasted SSB values in tonnes for North Sea cod comparing single species with multi species stock assessment.

4.7 Impacts of fishing on the ecosystem

No new information was available.

4.8 Stock assessment models

The two models available for the assessment of North Sea cod, namely B-Adapt (Darby, WD15 in ICES-WGNSSK 2004) and SAM (Nielsen, WD14) have previously been compared (ICES-WGNSSK 2008). However, comparisons of F-at-age trends were made between the most recent B-Adapt assessment (ICES-WGNSSK 2008) and a new SAM model formulation, and are shown in Figure 4.8.1.

The proposed SAM model formulation showed a retrospective pattern in average fishing mortality (Figure 4.8.2). Also, recent trends in fishing mortality at ages 6 and 7+ were different to the F trends at ages 3 to 5, which did not seem realistic (Figure 4.8.1). These issues require resolution before the model can be recommended as the primary mechanism for providing management advice for North Sea cod.

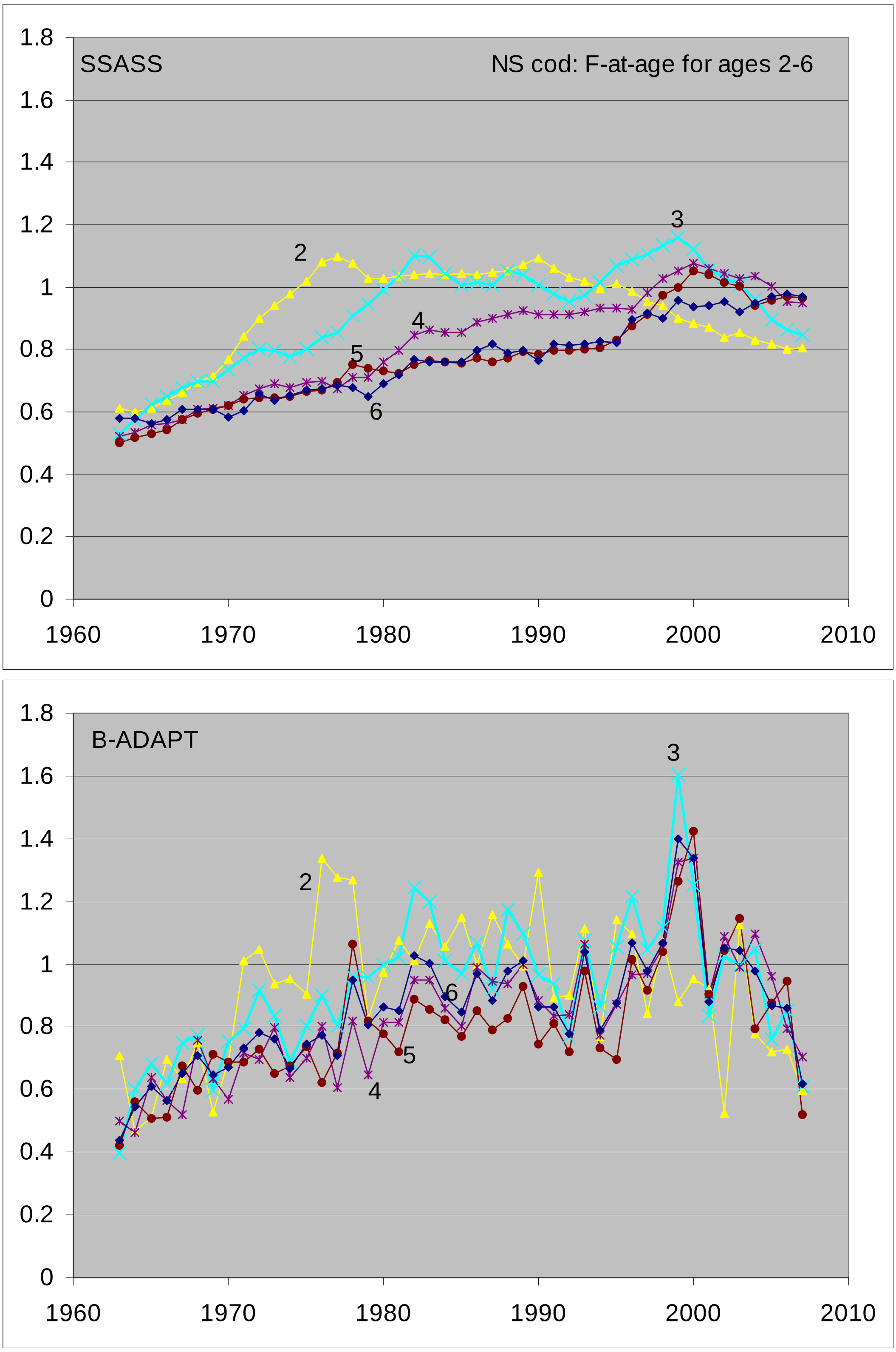


Figure 4.8.1 F-at-age trends for SAM (top panel) and B-Adapt (bottom).

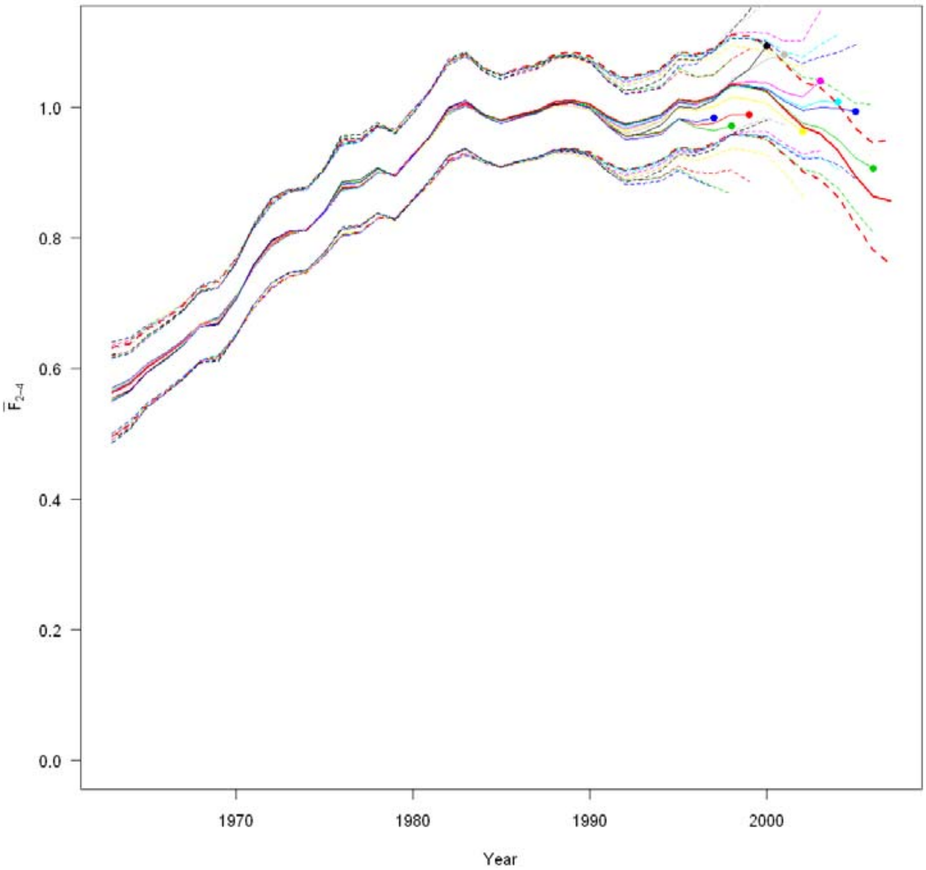
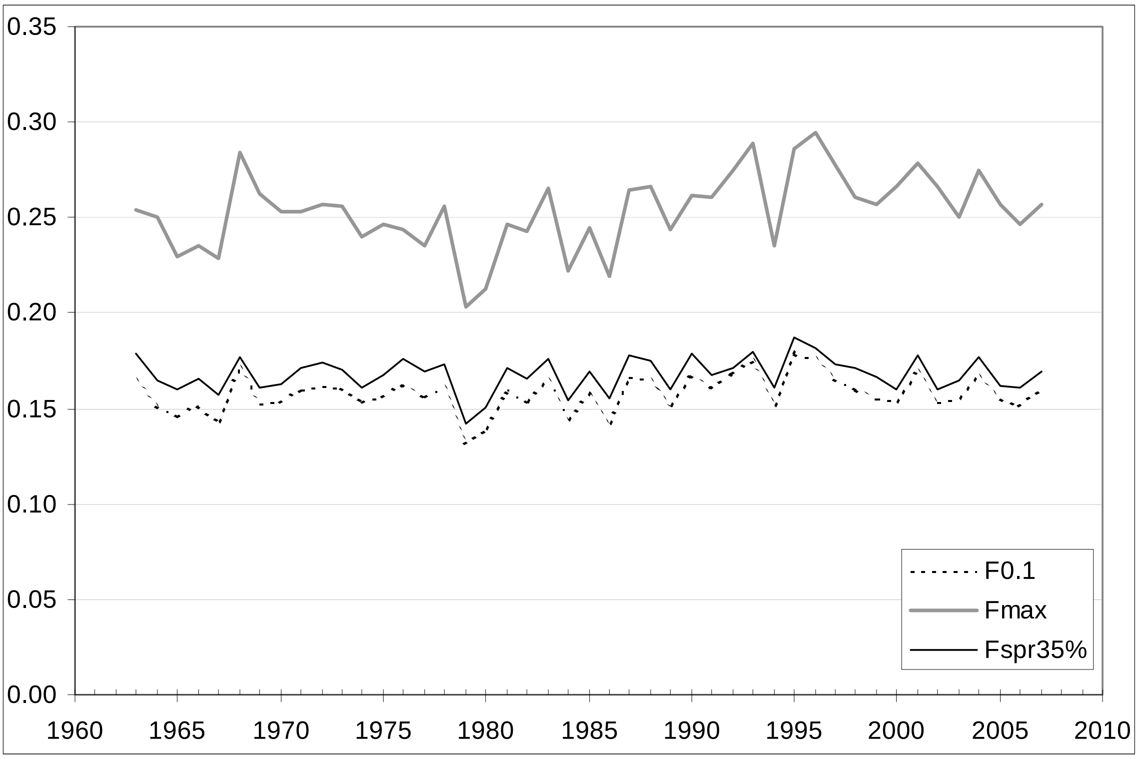


Figure 4.8.2 A 10-year retrospective analysis for F(2–4) for the SAM model.

4.9 Biological reference points

If alternative M and maturity estimates are being considered, then biological reference points need to be re-evaluated. Figure 14.9.1 illustrates yield-per-recruit based biological reference points estimated on an annual basis for the case where a variable M is assumed, together with alternatively a constant and variable maturity ogive, as discussed in Section 4.2.2. Estimates of F_{max} lie within the range 0.2–0.3, while estimates of $F_{0.1}$ and $F_{spr35\%}$ are 0.15-0.2. Table 4.9.1 summarizes results from the PA-soft program for various assumptions about M and maturity (details are provided in the caption to Table 4.9.1).

a.



b.

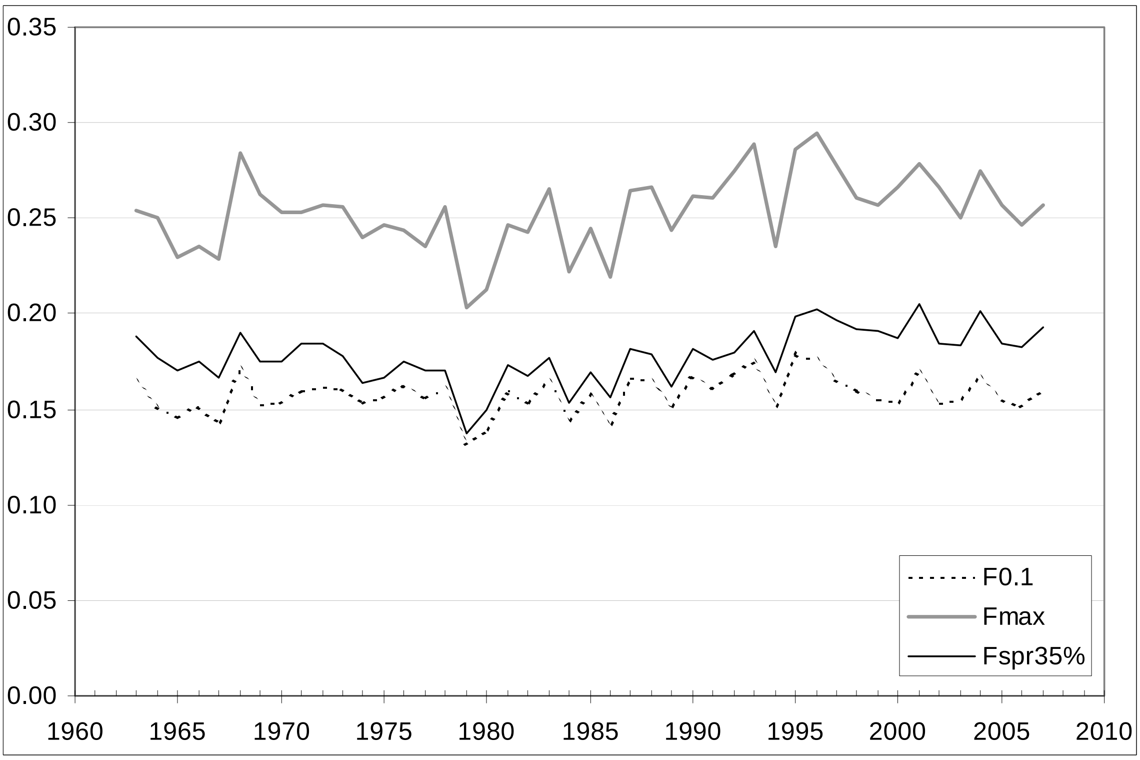


Figure 4.9.1 YPR-based F reference points based on variable M for (a) constant maturity and (b) variable maturity.

Table 4.9.1 Biological reference point estimates (deterministic values) from the PA-soft program for various assumptions about M and maturity. For the assumptions "con"=constant (assuming values used in ICES-WGNSSK 2008 for North Sea cod), "var"= assessment used annually varying estimates. However, the PA-soft program requires year-invariant values for M and maturity, so for "var", early (1977–1984) and late (2000–2007) periods were selected for calculating average M-, maturity-, and mean weights-at-age. These periods were selected to cover periods for which (to the extent possible) M-, maturity- and mean weights-at-age were constant. The option used in the Stock Annex is in bold.

M ASSUMPTION	MATURITY ASSUMPTION	BLOSS	SPRLOSS	S*	FMAX	F0.1	FLOW	FMED	FHIGH	F35%SPR	FLOSS	FS*
con	con	30985	0.19	144003	0.22	0.14	0.64	0.82	1.23	0.16	0.97	0.90
var early	con	34942	0.26	178789	0.24	0.15	0.49	0.71	1.12	0.16	0.75	0.76
var late	con	34942	0.26	178789	0.25	0.16	0.57	0.81	1.26	0.16	0.85	0.87
var early	var early	65304	0.38	228921	0.24	0.15	0.33	0.59	1.11	0.16	0.62	0.65
var late	var late	65304	0.38	228921	0.25	0.16	0.54	1.01	2.29	0.19	1.06	1.12

4.10 Recommended modifications to the stock annex

It is recommended that:

a) annually varying estimates of natural mortality-at-age (Table 4.2.2.1), based on multi-species considerations and updated every two years by WGSAM, be included in future assessments;

b) annually varying estimates of maturity-at-age not be included in future assessments until further work is carried out on the implications of changes in maturity for reproductive success;

c) the survey area used in the calculation of survey indices from the IBTSQ1 and IBTSQ3 surveys be extended to include to include a wider area of stock distribution, as indicated in Figure 4.2.3.1; and

d) B-Adapt continue to be used as the main assessment model for North Sea cod until an appropriate formulation of the SAM model can be found that deals with the issues of retrospective bias and trends in F that appear to diverge across ages in recent years.

4.11 Recommendations on the procedure for assessment updates

Model settings for the agreed B-Adapt assessment and short term forecast procedure are specified within the North Sea cod stock annex agreed by WKROUND (2009). The SAM model formulation should be developed in order to investigate the retrospective pattern and determine its potential for the assessment of this and other ICES stocks.

4.12 Industry-supplied data

No new quantitative industry data were provided to WKROUND in 2009. The results of collaborative studies presented to the WGNSSK are used to interpret assessment results and regularly form input to the annual assessment and advisory process. In addition to those mentioned in Section 4.2.4 the responses to the annual industry questionnaire (Laurenson, 2008) are reviewed at each assessment and compared to survey results in order to provide spatial information on the stock dynamics. This is especially important in the case of North Sea cod which is considered to comprise several sub-components.

4.13 References

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Stock Annex North Sea Cod

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Cod in Sub-area IV, Divison VIId & Division IIIa West (Skagerrak)

Working Group Working Group North Sea, Skagerrak and Kattegat

Date: January 2009

By: José De Oliveira

A. General

A.1. Stock definition

Cod are widely distributed throughout the North Sea. Scientific survey data indicate that historically, young fish (ages 1 and 2) have been found in large numbers in the southern part of the North Sea. Adult fish have in the past been located in concentrations of distribution in the Southern Bight, the north east coast of England, in the German Bight, the east coast of Scotland and in the north-eastern North Sea. As stock abundance fluctuates, these groupings appear to be relatively discrete but the area occupied has contracted. During recent years, the highest densities of 3+ cod have been observed in the deeper waters of the central to northern North Sea.

North Sea cod is really a meta-population of sub-populations with differential rates of mixing among them (Horwood *et al.*, 2006, Metcalfe 2006; Heath *et al.*, 2008). A genetic survey of cod in European continental shelf waters using micro-satellite DNA detected significant fine scale differentiation suggesting the existence of at least 4 genetically divergent cod populations, resident in the northern North Sea off Bergen Bank, within the Moray Firth, off Flamborough Head and within the Southern Bight (Hutchinson *et al.*, 2001). The differentiation was weak (typical of marine fishes with large population sizes and high dispersal potentials), but significant, with the degree of genetic isolation weakly correlated with geographical separation distance. This recent genetic evidence is largely consistent with the limited movements suggested by earlier tagging studies (ICES-NSRWG 1971, Metcalfe, 2006; Righton *et al.*, 2007). Furthermore, Holmes *et al.*, 2008 found significant differences in SSB trends between spawning areas in the North Sea, consistent with asynchronous population dynamics across spawning areas and providing support for the concept of meta-population structure.

Available information indicates that the majority of spawning takes place from the beginning of January through to April offshore in waters of salinity 34–35% (Brander, 1994; Riley and Parnell, 1984). Around the British Isles there is a tendency towards later timing with increasing latitude (ICES 2005). Cod spawn throughout much of the North Sea but spawning adult and egg survey data and fishermen’s observations indicate a number of spawning aggregations. Results from the first ichthyoplankton survey to cover the whole of the North Sea, conducted in 2004 to map spawning grounds of North Sea cod, are reported in Fox *et al.*, 2008. This study compared the results from the plankton survey with estimates of egg production inferred from the distribution of mature cod in contemporaneous trawl surveys. The comparison found general agreement of hot spots of egg production around the southern and eastern edge of the Dogger Bank, in the German Bights, the Moray Firth and to the east of the Shetlands, which mapped broadly into known spawning areas from the period 1940–1970, but was unable to detect any significant spawning activity off Flamborough (a historic spawning ground off the northeast coast of England). The study showed that most of the major cod spawning grounds in the North Sea are still active, but that the depletion of some localised populations may have made the detection of spawning activity in the corresponding areas difficult (Fox *et al*., 2008).

At the North Sea scale, there has been a northerly shift in the mean latitudinal distribution of the stock (Hedger *et al*., 2004; Perry *et al*., 2005). However the evidence for this being a migratory response is slight or non-existent. More likely, cod in the North Sea are composed of a complex of more or less isolated sub-stocks (as indicated above) and the southern units have been subjected to disproportionately high rates of fishing mortality (STECF-SGRST-07-01). Blanchard *et al*., 2005 demonstrated that the contraction in range of juvenile North Sea cod stock could be linked to reduced abundance as well as increased temperature, and further noted that the combined negative effects of increased temperature on recruitment rates and the reduced availability of optimal habitat may have increased the vulnerability of the cod population to fishing mortality. Rindorf and Lewy, 2006 linked the northward shift in distribution to the effect of a series of warm, windy winters on larvae and the resultant distribution of recently settled cod, followed by a northwards shift in the distribution of older age groups (because of the tendency for northerly distributed juveniles to remain northerly throughout their life). They noted further that this effect is intensified by the low abundance of older age cod due to heavy fishing pressure. In contrast, Neat and Righton, 2007 analysed the temperature experienced by 129 individual adult cod throughout the North Sea, and found that the majority experienced a warmer fraction of the sea than was potentially available to them (even though they had the capacity to find cooler water), with individuals in the south in summer experiencing temperatures considered superoptimal for growth. This suggests that the thermal regime of the North Sea is not yet causing adult cod to move to cooler waters.

Several tagging studies have been conducted on cod in the North Sea since the mid 1950s in order to investigate the migratory movements and geographical range of cod populations (Bedford, 1966; ICES-NSRWG 1971; Daan, 1978; Righton *et al*., 2007). These studies support the existence of regional populations of cod that separate during the spawning season and, in some cases, intermix during the feeding season (Metcalfe, 2006). Righton *et al*., 2007 re-analysed some of the historical datasets of conventional tags and used recent data from electronic tags to investigate movement and distribution of cod in the southern North Sea and English Channel. Their re-analysis of conventional tags showed that, although most cod remained within their release areas, a larger proportion of cod were recaptured outside their release area in the feeding season than the spawning season, and a larger proportion of adults were recaptured outside their release area than juveniles, with the displacement (release to recapture) occurring mostly to the southern North Sea for fish released in the English Channel, and to areas further north for fish released in the southern North Sea (see Table 5 in Righton *et al*., 2007). This suggests a limited net influx of cod from the English Channel to the southern North Sea, but no significant movement in the other direction (Metcalfe, 2006).

The lack of obvious physical barriers to mixing between different sub-populations in the North Sea suggests that behavioural and/or environmental factors are responsible for maintaining the relative discreteness of these populations (Metcalfe, 2006). For example, Righton *et al*., 2007 conclude that behavioural differences between cod in the southern North Sea and English Channels (such as tidal stream transport being used by fish tagged and released in the southern North Sea to migrate, but rarely being used by those tagged and released in the English Channel) may limit mixing of cod from these two areas during feeding and spawning season. Robichaud and Rose, 2004 describe four behavioural categories for cod populations: "sedentary residents" exhibiting year-round site fidelity, "accurate homers" that return to spawn in specific locations, "inaccurate homers" that return to spawn in a broader area around the original site, and "dispersers" that move and spawn in a haphazard fashion within a large geographical area. These categories are not necessarily mutually exclusive and behaviours in different regions may be best described by differing degrees of each category (Heath *et al*., 2008).

Evidence from electronic tags suggest that cod populations have a strong tendency for site attachment (even in migratory individuals), rapid and long-distance migrations, the use of deeper channels as migratory "highways" and, in some cases, clearly defined feeding and spawning "hot spots" (Righton *et al*., 2008). Andrews *et al*., 2006 used a spatially and physiologically explicit model describing the demography and distribution of cod on the European shelf in order to explore a variety of hypotheses about the movements of settled cod. They fitted the model to spatial data derived from International Bottom Trawl Surveys, and found that structural variants of the model that did not recognise an active seasonal migration by adults to a set of spatially stable spawning sites, followed by a dispersal phase, could not explain both the abundance and distribution of the spawning stock. Heath *et al*., 2008 investigated different hypotheses about natal fidelity, and their consequence for regional dynamics and population structuring, by developing a model representing multiple demes, with the spawning locations of fish in each deme governed by a variety of rules concerning oceanographic dispersal, migration behaviour and straying. They used an age-based discrete time methodology, with a spatial representation of physical oceanographic patterns, fish behaviour patterns, recruitment, growth and mortality (both natural and fishing). They found that active homing is not necessary to explain some of the population structures of cod (with separation possible through distance and oceanographic processes affecting the dispersal of eggs and larvae, such is in the Southern Bight), but that homing behaviour may be necessary to explain the structure of other sub-populations.

A.2. Fishery

Cod are caught by virtually all the demersal gears in Sub-area IV and Divisions IIIa (Skagerrak) and VIId, including beam trawls, otter trawls, seine nets, gillnets and lines. Most of these gears take a mixture of species. In some of them cod are considered to be a bycatch (for example in beam trawls targeting flatfish), and in others the fisheries are directed mainly towards cod (for example, some of the fixed gear fisheries).

An analysis of landings and estimated discards of cod by gear category (excluding Norwegian data) highlighted the following fleets as the most important in terms of cod for 2003–2005 (accounting for close to 88% of the EU landings), listed with the main use of each gear (STECF SGRST-07-01):

- Otter trawl, ≥ 120 mm, a directed roundfish fishery by UK, Danish and German vessels.
- Otter trawl, 70–89 mm, comprising a 70–79 mm French whiting trawl fishery centered in the Eastern Channel, but extending into the North Sea, and an 80–89 mm UK *Nephrops* fishery (with smaller landings of roundfish and anglerfish) occurring entirely in the North Sea.
- Otter trawl, 90–99 mm, a Danish and Swedish mixed demersal fishery centered in the Skagerrak, but extending into the Eastern North Sea.

- Beam trawl, 80–89 mm, a directed Dutch and Belgian flatfish fishery.

Gillnets, 110–219 mm, a targeted cod and plaice fishery.

For Norway in 2007, trawls (mainly bycatch in the saithe fishery) and gillnets account for around 60% (by weight) of cod catches, with the remainder taken by other gears mainly in the fjords and on the coast, whereas in the Skagerrak, trawls and gillnets account for up to 90% of cod catches.

With regard to trends in effort for these major cod fisheries since 2000, the largest changes to have happened in North Sea fisheries have involved an overall reduction in trawl effort and changes in the mesh sizes in use, due to a combination of decommissioning and days-at-sea regulations. In particular 100–119 mm meshes have now virtually disappeared, and instead vessels are using either 120 mm+ (in the directed whitefish fishery) or 80–99 mm (primarily in the *Nephrops* fisheries and in a variety of mixed fisheries). The use of other mesh sizes largely occurs in the adjacent areas, with the 70–79 mm gear being used in the Eastern Channel/Southern North Sea Whiting fishery, and the majority of the landings by 90–99 mm trawlers coming from the Skagerrak. Higher discards are associated with these smaller mesh trawl fisheries, but even when these are taken into account, the directed roundfish fishery (trawls with ≥ 120 mm mesh) still has the largest impact of any single fleet on the cod stock, followed by the mixed demersal fishery (90–99 mm trawls) in the Skagerrak.

Technical Conservation Measures

The present technical regulations for EU waters came into force on 1 January 2000 (EC 850/98 and its amendments). The regulations prescribe the minimum target species' composition for different mesh size ranges. Additional measures were introduced in Community waters from 1 January 2002 (EC 2056/2001).

In 2001, the European Commission implemented an emergency closure of a large area of the North Sea from 14 February to 30 April (EC 259/2001). An EU-Norway expert group in 2003 concluded that the emergency closure had an insignificant effect upon the spawning potential for cod in 2001. There were several reasons for the lack of impact. The redistribution of the fishery, especially along the edges of the box, coupled to the increases in proportional landings from January and February appear to have been able to negate the potential benefits of the box. The conclusion from this study was that the box would have to be extended in both space and time to be more effective. This emergency measure has not been adopted after 2001. A cod protection area was implemented in 2004 (EC 2287/2003 and its amendments), which defined conditions under which certain stocks, including haddock, could be caught in Community waters, but this was only in force in 2004.

Apart from the technical measures set by the Commission, additional unilateral measures are in force in the UK, Denmark and Belgium. The EU minimum landing size (mls) is 35 cm, but Belgium operates a 40 cm mls, while Denmark operates a 35 cm mls in the North Sea and 30 cm in the Skagerrak. Additional measures in the UK relate to the use of square mesh panels and multiple rigs, restrictions on twine size in both whitefish and *Nephrops* gears, limits on extension length for whitefish gear, and a ban on lifting bags. In 2001, vessels fishing in the Norwegian sector of the North Sea had to comply with Norwegian regulations setting the minimum mesh size at 120 mm. Since 2003, the basic minimum mesh size for towed gears targeting cod is 120 mm.

Effort regulations in days at sea per vessel and gear category are summarised in the following table, which only shows changes in 2008 compared to 2007 (2006 is included for comparison). The changes (2007–2008) were intended to generate a cut in effort of 10% for the main gears catching cod.

Maximum number of days a vessel can be present in the North Sea, Skagerrak and Eastern Channel, by gear category and special condition (see EC 40/2008 for more details). The table only shows changes in 2008 compared to 2007, but 2006 is also included for comparison.

Description of gear and special condition (if applicable)	Area			Max days at sea		
	IV,II	Skag	VIId	2006	2007	2008**
Trawls or Danish seines with mesh size ≥ 120 mm	x	x	x	103	96	86
Trawls or Danish seines with mesh size ≥ 100 mm and < 120 mm	x	x	x	103	95	86
Trawls or Danish seines with mesh size ≥ 90 mm and < 100 mm	x		x	227	209	188
Trawls or Danish seines with mesh size ≥ 90 mm and < 100 mm		x		103	95	86
Trawls or Danish seines with mesh size ≥ 70 mm and < 90 mm	x			227	204	184
Trawls or Danish seines with mesh size ≥ 70 mm and < 90 mm			x	227	221	199
Beam trawls with mesh size ≥ 120 mm	x	x		143	143	129
Beam trawls with mesh size ≥ 100 mm and < 120 mm	x	x		143	143	129
Beam trawls with mesh size ≥ 80 mm and < 90 mm	x	x		143	132	119
Gillnets and entangling nets with mesh sizes ≥ 150 mm and < 220 mm	x	x	x	140	130	117
Gillnets and entangling nets with mesh sizes ≥ 110 mm and < 150 mm	x	x	x	140	140	126
Trammel nets with mesh size < 110 mm. The vessel shall be absent from port no more than 24 h.	x		x	205	205	185*

*** For member states whose quotas less than 5% of the Community share of the TACs of both plaice and sole, the number of days at sea shall be 205.**

**** If member states opt for an overall kilowatt-days regime, then the maximum number of days at sea per vessel could be different to that set out for 2008 (see text below and EC 40/2008 for details).**

Additional provisions were introduced for 2008 (points 8.5–7, Annex IIa, EC 40/2008) to provide Member States greater flexibility in managing their fleets, in order to encourage a more efficient use of fishing opportunities and stimulate fishing practices that lead to reduced discards and lower fishing mortality of both juvenile and adult fish. This measure allowed a Member State that fulfilled the requirements laid out in EC 40/2008 to manage a fleet (i.e. group of vessels with a specific combination of geographical area, grouping of fishing gear and special condition) to an overall kilowatt-days limit for that fleet, instead of managing each individual vessel in the fleet to its own days-at-sea limit. The overall kilowatt-days limit for a fleet is initially calculated as the sum of all individual fishing efforts for vessels in that fleet, where an individual fishing effort is the product of the number of days-at-sea and engine power for the vessel concerned. This provision allowed Member States to draw up fishing plans in collaboration with the Fishing Industry, which could, for example, specify a target to reduce cod discards to below 10% of the cod catch, allow real-time closures for juveniles and spawners, implement cod avoidance measures, trial new selective devices, etc.

Incentives of up to 12 additional days at sea per vessel were in place for 2008 to encourage vessels to sign up to a Discard Reduction Plan (points 12.9–10, Annex IIa, EC 40/2008). The plan focused on discarding of cod or other species with discard problems for which a management/recovery plan is adopted, and was to include measures to avoid juvenile and spawning fish, to trial and implement technical measures for improving selectivity, to increase observer coverage, and to provide data for monitoring outcomes. For vessels participating in a Cod Avoidance Reference Fleet Programme in 2008 (points 12.11–14, Annex IIa, EC 40/2008), a further 10–12 additional days at sea was possible (over and above that for the Discard Reduction Plan). Vessels participating in this program were to meet a specific target to reduce cod discards to below 10% of cod catches, and be subject to observer coverage of at least 10%.

Under the provisions laid down in point 8.5 of Annex IIa (EC 40/2008), Scotland implemented a national kilowatt-days scheme known as the 'Conservation Credits Scheme'. The principle of this two-part scheme involved credits (in terms of additional time at sea) in return for the adoption of and adherence to measures that reduce mortality on cod and lead to a reduction in discard numbers. The initial, basic scheme was implemented from the beginning of February 2008 and essentially granted vessels their 2007 allocation of days (operated as hours at sea) in return for: observance of Real Time Closures (RTC), observance of a one net rule, adoption of more selective gears (110 mm square meshed panels in 80 mm gears or 90 mm square meshed panels in 95 mm gear), agreeing to participate in additional gear trials, and participation in an enhanced observer scheme.

For the first part of 2008, the RTC system was designed to protect aggregations of larger, spawning cod (>50 cm length). Commercial catch rates of cod observed on board vessels was used to inform trigger levels leading to closures. Ten closures occurred to the beginning of May and protection agency monitoring suggested good observance. The scheme was extended for the remainder of the year to protect aggregations of all sizes of cod. A joint industry/ science partnership (SISP) had a number of gear trials programmed for 2008 examining methods to improve selectivity and reduce discards, and an enhanced observer scheme was announced by the Scottish Government.

Observance of the above conditions also gave eligibility for vessels to participate in the second, enhanced, part of the Conservation Credits scheme.

Changes in fleet dynamics

The introduction of the one-net rule as part of the Scottish Conservation Credit Scheme and new Scottish legislation implemented in January 2008 were both likely to improve the accuracy of reporting of Scottish landings to the correct mesh size range, although some sectors of the Scottish industry have been granted derogations to continue carrying two nets (seiners until the end of January 2009, and others until the end of April 2008). The concerted effort to reduce cod mortality, through implementation of the Conservation Credit Scheme from February 2008, could have lead to greater effort being exerted on haddock, whiting, monk, flatfish and *Nephrops*.

Shifts in the UK fleet in 2007/8 included: (a) a move of Scottish vessels using 100–110mm for whitefish on west coast ground (Sub-area VI) to the North Sea using 80 mm prawn codends (motivated by fuel costs, and could increase effort on North Sea stocks; the simultaneous requirement to use 110 square mesh panels may mitigate unwanted selectivity implications-see below); (b) a move away from the Farne Deeps *Nephrops* fishery into other fisheries for whitefish because of poor *Nephrops* catch rates (implying increased effort in whitefish fisheries); and (c) a move of Scottish vessels from twin trawls to single rig, and increased use of pair trawls, seines and double bag trawls (motivated by fuel costs). For 2008 in the Scottish fleet, all twin-rig gear in the 80–99mm category have to use a 110 mm square mesh panel, but this also applied to single-rig gears from July 2008 onwards, which was likely to have improved whitefish selection. A large number of 110 mm square mesh panels have been bought by Scottish fishers at the beginning of 2008 in order to qualify for the Conservation Credit Scheme, which dramatically improved the uptake of selective gear. The ban on the use of multi-rigs in Scotland, implemented in January 2008, may have limited the potential for an uncontrolled increase in effective effort.

The Dutch fleet was reduced, through decommissioning, by 23 vessels from the beginning of 2008, while 5 Belgian beam trawlers (approximately 5% of the Belgian fleet) left the fishery in 2007, both changes implying reductions in effort in the beam trawl sector. The introduction of an ITQ regulation system in Denmark in 2007 might have influenced the effort distribution over the year, but this should not have affected the total Danish effort deployed or the size distribution of catches.

Dutch beam trawlers have gradually shifted to other techniques such as twin trawling, outrigging and fly-shooting, as well as opting for smaller, multi-purpose vessels, implying a shift in effort away from flatfish to other sectors. These changes were likely caused by TAC limitations on plaice and sole, and on rising fuel costs. Belgian and UK vessels have also experimented with outrigger trawls as an alternative to beam trawling, motivated by more fuel efficient and environmentally friendly fishing methods.

The increased effort costs in the Kattegat (2.5 days at sea per effort day deployed) in 2008 has led to a shift in effort by Swedish vessels to the Skagerrak and Baltic Sea. There has also been an increase in the number of Swedish *Nephrops* vessels in recent years, attributed to the input of new capital transferred from pelagic fleets following the introduction of an ITQ-system for pelagic species, and leading to further increases in effort. The Swedish trawler fleet operating in IIIa has had a steady increase in the uptake of the *Nephrops* grid since the introduction of legislation in 2004 (use of the grid is mandatory in coastal waters), and given the strong incentives to use the grid (unlimited days at sea). Uptake of the *Nephrops* grid should have resulted in improved selection.

A squid fishery in the Moray Firth has continued to develop using very unselective 40 mm mesh when squid species are available on the grounds. Although the uptake was poor in 2007 due to the lack of squid, the potential for high bycatches of young gadoids in future, including those of cod and haddock, remains. This fishery may provide an alternative outlet for the Scottish *Nephrops* fleet seasonally, and hence reduce effort in the *Nephrops* sector.

A.3. Ecosystem aspects

Cod are predated upon by a variety of species through their life history. The Working Group on Multi-species Assessment Methods (ICES-WGSAM 2008) estimated predation mortalities using SMS (Stochastic Multi Species Model) with diet information largely derived from the Years of the Stomach databases (stomachs sampled in the years 1981–1991). Long-term trends have been observed in several partial predation mortalities with significant increases for grey gurnard preying on 0-group cod. In contrast, predation mortalities on age 1 and age 2 cod decreased over the last 30 years due to lower cannibalism. Predation on older cod (age 3–6) increased due to increasing numbers of grey seals in the North Sea.

SMS identified grey gurnard as a significant predator of 0-group cod. The abundance of grey gurnard (as monitored by IBTS) is estimated to have increased in recent years resulting in a rise in estimated predation mortality from 1.08 to 1.76 between 1991 and 2003. A degree of caution is required with these estimates as they assume that the spatial overlap and stomach contents of the species have remained unchanged since 1991. Given the change in abundance of both species this assumption is unlikely to hold and new diet information is required before 0-group predation mortalities can be relied upon.

Several other predators contribute to predation mortality upon 0-group cod, whiting and seabirds being the next largest components.

The consumption of cod in the North Sea in 2002 by grey seals (*Halichoerus grypus*) has recently been estimated (Hammond and Grellier, 2006). For the North Sea it was estimated that in 1985 grey seals consumed 4150 tonnes of cod (95% confidence intervals: 2484–5760 tonnes), and in 2002 the population tripled in size (21–68 000) and consumed 8344 tonnes (95% confidence intervals: 5028–14941 tonnes). These consumption estimates were compared to the Total Stock Biomass (TSB) for cod of 475 000 tonnes and 225 000 tonnes for 1985 and 2002 respectively. The mean length of cod in the seal diet was estimated as 37.1 cm and 35.4 cm in 1985 and 2002 respectively. It should be noted, however, that seal diet analysis must be treated with a degree of caution because of the uncertainties related to modelling complex processes (e.g. using scat analysis to estimate diet composition involves complex parameters, and can overestimate species with more robust hard parts), and the uncertainties related to estimating seal population size from pup production estimates (involving assumptions about the form of density-dependent dynamics). The analysis may also be subject to bias because scat data from haul-out sites may reflect the composition of prey close to the sites rather than further offshore.

The effect of seal predation on cod mortality rates has been estimated for the North Sea within a multi-species assessment model (MSVPA), which was last run in 2007 during the EU project BECAUSE (contract number SSP8-CT-2003-502482) using revised estimates of seal consumption rates. The grey seal population size was obtained from WGMME (ICES-WGMME 2005) and was assumed to be 68 000 in 2002 and 2003 respectively. Estimates of cod consumption were 9657 tonnes in 2002 and 5124 tonnes in 2003, which is similar to the values estimated by Hammond and Grellier, 2006. Sensitivity analysis of the North Sea cod stock assessment estimates to the inclusion of the revised multi-species mortality rates were carried out at the 2009 meeting of the WKROUND. Inclusion of the multi-species mortality rates for older ages of cod had a relatively minor effect on the high levels of estimated fishing mortality rates and low levels of spawning stock biomass abundance. This suggests that the estimates of seal predation will not alter the current perception of North Sea cod stock dynamics (also stated by STECF-SGRST-07-01).

A recent meeting (2007) of the STECF reviewed the broad scale environmental changes in the north-eastern Atlantic that has influenced all areas under the cod recovery plan (STECF-SGRST-07-01), and concluded that:

- Warming has occurred in all areas of the NW European shelf seas, and is predicted to continue.
- A regime shift in the North Sea ecosystem occurred in the mid-1980s.
- These ecological changes have, in addition to the decline in spawning stock size, negatively affected cod recruitment in all areas.

- Biological parameters and reference points are dependent on the time-period over which they are estimated. For example, for North Sea cod FMSY, MSY and BMSY are lower when calculated for the recent warm period (after 1988) compared to values derived for the earlier cooler period.
- The decline in FMSY, MSY and BMSY can be expected to continue due to the predicted warming, and possible future change should be accounted for in stock assessment and management regimes.
- Modelling shows that under a changing climate, reference points based on fishing mortality are more robust to uncertainty than those based on biomass.
- Despite poor recruitment, modelling suggests that cod recovery is possible, but ecological change may affect the rate of recovery, and the magnitude of achievable stock sizes.
- Recovery of cod populations may have implications to their prey species, including *Nephrops*.

With the exception of the general effects noted above, the overall conclusion from the STECF meeting (STECF-SGRST-07-01) for the North Sea was that there is no specific significant environmental or ecosystem change in the Skagerrak, North Sea and eastern Channel (e.g. the effects of gravel extraction, etc.) affecting potential cod recovery. The conclusions from the STECF meeting merit further discussion within ICES, which is ongoing (e.g. ICES-WKREF 2007).

B. Data

B.1. Commercial catch

The WG estimate for landings from the three areas (IV, IIIa-Skagerrak and VIId) in 2006 and 2007 were based on annual data, as opposed to quarterly data prior to 2006, because of ongoing difficulties with international data aggregation procedures, particularly with regard to discard raising.

France, Belgium and Sweden, who respectively landed 9%, 5% and 2% of all cod for combined area IV and VIId, do not provide discard estimates for this combined area. Similarly, Belgium and Germany, who each land 2% of all cod in area IIIa, do not provide discard estimates for this area. Norwegian discarding is illegal, so although this nation landed 14% and 6% of all cod in combined area IV and VIId, and area IIIa respectively, it does not provide discard estimates. Although the Netherlands (7% of all cod landed in IV and VIId, 1% in IIIa) does provide discard data for area IV, these are based on very low sample sizes for cod, and are therefore not reliable enough to be raised to fleet level. All percentages quoted in this paragraph refer to landings in 2007.

Discard numbers-at-age were estimated for areas IV and VIId by applying the Scottish discard ogives to the international landings-at-age for years prior to 2006. For 2006, Denmark was excluded from this calculation as they provided their own discard estimates. For 2007, Scottish, Danish, German and England & Wales discard estimates were combined (sum of discards divided by sum of landings) and used to raise landings-at-age from the remaining nations in Sub-area IV to account for missing discards. Discard numbers-at-age for IIIa-Skagerrak were based on observer sampling estimates. For 2006 and 2007, Danish and Swedish discard estimates were combined (sum of discards divided by sum of landings) and used to raise landings-at-age from the remaining nations in Division IIIa-Skagerrak to account for missing discards. Although in some cases other nations' discard proportions were available for a range of years, these have not been transmitted to the relevant WG data coordinator in an appropriate form for inclusion in the international dataset.

For cod in IV, IIIa-Skagerrak and VIId, ICES first raised concerns about the mis-reporting and non-reporting of landings in the early 1990s, particularly when TACs became intentionally restrictive for management purposes. Some WG members have since provided estimates of under-reporting of landings to the WG, but by their very nature these are difficult to quantify. In terms of events since the mid-1990s, the WG believes that under-reporting of landings may have been significant in 1998 because of the abundance in the population of the relatively strong 1996 year-class as 2-year-olds. The landed weight and input numbers-at-age data for 1998 were adjusted to include an estimated 3000t of under-reported catch. The 1998 catch estimates remain unchanged in the present assessment.

For 1999 and 2000, the WG has no *a priori* reason to believe that there was significant under-reporting of landings. However, the substantial reduction in fishing effort implied by the 2001, 2002 and 2003 TACs is likely to have resulted in an increase in unreported catch in those years. Anecdotal information from the fisheries in some countries indicated that this may indeed have been the case, but the extent of the alleged under-reporting of catch varies considerably. Since the WG has no basis to judge the overall extent of under-reported catch, it has no alternative than to use its best estimates of landings, which in general are in line with the officially reported landings. An attempt is made to incorporate a statistical correction to the sum of reported landings and discards data in the assessment of this stock. Buyers and Sellers legislation introduced in the UK towards the end of 2005 is expected to have improved the accuracy of reported cod landings for the UK. This has brought the UK in line with existing EU legislation.

Age compositions

Age compositions are currently provided by Denmark, England, Germany, the Netherlands, Scotland and Sweden.

Landings in numbers-at-age for age groups 1–11+ and 1963-present form the basis for the catch–at–age analysis but do not include industrial fishery bycatches landed for reduction purposes. Bycatch estimates are available for the total Danish and Norwegian small-meshed fishery in Sub-area IV and separately for the Skagerrak.

During the five years 2003–2007, an average of 82% (84% in 2007) of the international landings in number were accounted for by juvenile cod aged 1–3. In 2007, age 1 cod comprised 32% of the total catch by number, and age 2 (the 2005 year class), 55%.

Estimated total numbers discarded have varied between 35 and 55% of the total catch numbers since 1995, but have shown an increase to above 70% in 2006 and 2007, due to the stronger 2005 year class entering the fishery (estimated to be almost the size of the 1999 year class), and a mismatch between the TAC and effort. Historically, the proportion of numbers discarded at age 1 have fluctuated around 80% with no decline apparent after the introduction of the 120 mm mesh in 2002. For 2004–2007, it is estimated to be at around 90%. At ages 2 and 3 discard proportions have been increasing steadily and are currently estimated to be 75% and 38% respectively in 2007. Note that these observations refer to numbers discarded, not weight.

Data exploration

Data exploration for commercial catch data for North Sea cod currently involves:

a) expressing the total catch-at-age matrix as proportions-at-age, normalised over time, so that year classes making above-average contributions to the catches are shown as large positive residuals (and vice-versa for below-average contributions);

b) applying a separable VPA model in order to examine the structure of the catch numbers-at-age before they are used in catch-at-age analyses, in particular whether there are large and irregular residuals patterns that would lead to concerns about the way the recorded catch has been processed;

c) performing log-catch-curve analyses to examine data consistency, fishery selectivity and mortality trends over time-the negative slope of a regression fitted to ages down a cohort (e.g. ages 2–4) can be used as a proxy for total mortality.

B.2. Biological Information

Weight at age

Mean catch weight-at-age is a catch-number weighted average of individual catch weight-at-age, available by country, area and type (i.e. landings and discards). For ages 1–9 there have been short-term trends in mean weight at age throughout the time series with a decline over the recent decade at ages 3–5 that recently seems to have been reversed. The data also indicate a slight downward trend in mean weight for ages 3–6 during the 1980s and 1990s. Ages 1 and 2 show little absolute variation over the long-term.

Using weight-at-age from annual ICES assessments and International Bottom Trawl Surveys, Cook *et al*., 1999 developed a model that explained weight-at-age in terms of a von Bertalanffy growth curve and a year-class effect. They found that the year-class effect was correlated with total and spawning stock biomass, indicating density-dependent growth, possibly through competition. Further evidence for density-dependent growth had previously been found by others (Houghton and Flatman, 1981; Macer, 1983; Alphen and Heessen, 1984), although they pointed to different mechanisms (Rijnsdorp *et al*., 1991; ICES 2005). Results from Macer, 1983 imply that juvenile cod compete strongly with adults, while the data from Alphen and Heessen, 1984 suggest strong within-year-class competition during the first three years of life.

Growth rate can be linked to temperature and prey availability (Hughes and Grand, 2000; Blanchard *et al*., 2005). Growth parameters of North Sea cod given in ICES 1994 demonstrate that cod in the southern North Sea grow faster than those in the north, but reach a smaller maximum length (Oosthuizen and Daan, 1974; ICES 2005). Furthermore, older and larger cod have lower optimal temperatures for growth (Björnsson and Steinarsson, 2002), and distributions of cod are known to depend on the local depth and temperature (Ottersen *et al*., 1998; Swain, 1999; Blanchard *et al*., 2005).

Differences in mean length by age and sex can also be found for mature vs. immature cod (ICES 2005). For example, Hislop, 1984 found that within an age group, mature cod of each sex are, on average, larger than immature cod.

Maturity and natural mortality

Values for natural mortality are assumed to be variable in time. The natural mortality values are model estimates from multi-species models (SMS and 4M) fitted by the Working Group on Multi Species Assessment Methods (ICES-WGSAM 2008, see Table 1).

The maturity values are applied to all years and are left unchanged from year to year. They were estimated using the International Bottom trawl Survey series for 1981–1985. These values were derived for the North Sea.

AGE GROUP	PROPORTION MATURE
1	0.01
2	0.05
3	0.23
4	0.62
5	0.86
6	1.0
7+	1.0

Relative fecundity appears to have changed over time, with values in the late 1980s being approximately 20% higher than those in the early 1970s, an increase that coincided with a 4-fold decline in spawning stock biomass (Rijnsdorp *et al.*, 1991; ICES 2005).

In an analysis of International Bottom Trawl Survey maturity data, Cook *et al.*, 1999 found that proportion of fish mature-at-age is a function of both weight and age. They used a descriptive model based on both age and weight to reconstruct the historical series of maturity ogives where no observations existed, and calculated new spawning stock sizes that could be compared to those estimated by the conventional assessment. They found that, although accounting for changes in growth and maturity for North Sea cod altered the scale of SSB values, it did not make substantial changes to trajectories over time, and did not substantially alter the estimates of sustainable exploitation rates for the stock.

Recruitment

Recruitment has been linked not only to SSB, but also to temperature (Dickson and Brander, 1993; Myers *et al.*, 1995; Planque and Fredou, 1999; O'Brien *et al.*, 2000) plankton production timing and mean prey size (Beaugrand *et al.*, 2003), and the NAO (Brander and Mohn, 2004; ICES 2005).

B.3. Surveys

Four survey series are available for this assessment:

- English third-quarter groundfish survey (EngGFS), ages 0–7, which covers the whole of the North Sea in August-September each year to about 200 m depth using a fixed station design of 75 standard tows. The survey was conducted using the Granton trawl from 1977–1991 and with the GOV trawl from 1992–present. Only ages 1–6 should be used for calibration, as catch rates for older ages are very low.
- Scottish third-quarter groundfish survey (ScoGFS): ages 1–8. This survey covers the period 1982–present. This survey is undertaken during August each year using a fixed station design and the GOV trawl. Coverage was restricted to the northern part of the North Sea until 1998, corresponding to only the northernmost distribution of cod in the North Sea. Since 1999, it has been extended into the central North Sea and made use of a new vessel and gear. Only ages 1–6 should be used for calibration, as catch rates for older ages are very low.

- Quarter 1 international bottom-trawl survey (IBTSQ1): ages 1–6+, covering the period 1976–present (usually data are available up to the year of the assessment for this survey, whereas it is only available up to the year prior to the assessment year for the other surveys). This multi-vessel survey covers the whole of the North Sea using fixed stations of at least two tows per rectangle with the GOV trawl.
- Quarter 3 international bottom-trawl survey (IBTSQ3): ages 0–6+, covering the period 1991–present. This multi-vessel survey covers the whole of the North Sea using fixed stations of at least two tows per rectangle with the GOV trawl. The Scottish and English third quarter surveys described above contribute to this index.

The recent dominant effect of the size and distribution of the 1996 and, to a lesser extent, the 1999 and 2005 year-classes are clearly apparent from maps of the IBTS distribution of cod (ages 1–3+). However, fish of older ages have continued to decline due to the very weak 2000, 2002 and 2004 year-classes. The abundance of 3+ fish is at a low level in recent years.

An analysis of the third quarter Scottish and English survey data by Parker-Humphries and Darby (WD 24 in ICES-WGNSSK 2006) showed that the extremely high catch rates estimated for ages 2–4 in a single station in the third quarter Scottish survey in 2004 resulted in the estimation of a strong reduction in mortality in 2004 followed by high mortality in 2005. When the station with high catch rates was removed, total mortality was then consistent with values obtained in previous years. The WG agreed that it would be *ad hoc* and statistically inappropriate to remove the station from the calculation of the Scottish index. After reviewing the information available on survey catch rates and spatial distribution, the WG decided to discontinue the use of the English and Scottish surveys on their own in the cod assessment because of the current low catch rates recorded by these surveys and the potential for noise at the oldest ages due to low sampling levels. Instead, the WG decided to use the IBTSQ3 survey, which incorporates both the Scottish and English surveys, together with the IBTSQ1 survey.

An analysis of IBTSQ1 data by Rindorf and Vinther (WD 4 in ICES-WGNSSK 2007) illustrated the increased importance of recruitment from the Skagerrak. Up until 2008 (ICES-WGNSSK 2008) the survey indices from IBTSQ1 and Q3 used in the stock assessment only include catch rates from the three most easterly rectangles of Skagerrak. More of the Skagerrak area should be considered for inclusion in the IBTS standard areas for abundance indices, in order to produce an unbiased abundance index for the management unit (IV, IIIa-Skagerrak and VIId) of cod. Furthermore, the Skagerrak is almost entirely covered by a single vessel in both the IBTSQ1 and Q3 surveys. This is not advantageous as it does not allow for a comparison of cod catchability between vessels, which is essential for comparison of catch rates between roundfish areas. In the North Sea, each rectangle is covered by at least 2 nations to reduce bias in indices.

WKROUND (2009) compared the standard and extended IBTS index for ages 1–5 for IBTSQ1 and 1–4 for IBTSQ3 with an extended are index. The largest changes in abundance were observed at the younger ages, particularly for age 0 in IBTSQ3 (not used in the assessment). Residual plots indicated a slight improvement in fit for the extended indices run compared to the standard indices run. Given the improved fit for the extended indices and other benefits of using these indices (such as better coverage of the stock distribution area) the group recommended that it would be beneficial for North Sea cod to use the extended indices in future assessments.

Data exploration

Data exploration for survey data for North Sea cod currently involves:

a) expressing the survey abundance indices (IBTSQ1 and IBTSQ3) in log-mean standardised form, both by year and cohort, to investigate whether there are any year effects, and the extent to which the surveys are able to track cohort signals;

b) performing log-catch-curve analyses on the abundance indices to examine data consistency and mortality trends over time-the negative slope of a regression fitted to ages down a cohort (e.g. ages 2–4) can be used as a proxy for total mortality;

c) performing within-survey consistency plots (correlation plots of a cohort at a given age against the same cohort one or more years later) to investigate self-consistency of a survey;

d) performing between-survey consistency plots (correlation plots of a given age for IBTSQ1 against the same age for IBTSQ3) to investigate the consistency between surveys;

e) applying a SURBA analysis to the survey data for comparison with models that include fishery-dependent data.

B.4. Commercial cpue

Reliable, individual, disaggregated trip data were not available for the analysis of cpue. Since the mid-to-late 1990s, changes to the method of recording data means that individual trip data are now more accessible than before; however, the recording of fishing effort as hours fished has become less reliable because it is not a mandatory field in the logbook data. Consequently, the effort data, as hours fished, are not considered to be representative of the fishing effort actually deployed.

The WG has previously argued that, although they are in general agreement with the survey information, commercial cpue tuning series should not be used for the calibration of assessment models due to potential problems with effort recording and hyper-stability (ICES-WGNSSK 2001), and also changes in gear design and usage, as discussed by ICES-WGFTFB (2006, 2007). Therefore, although the commercial fleet series are available, only survey and commercial landings and discard information are analysed within the assessment presented.

B.5. Other relevant data

The annual North Sea Fishers' Survey presents fishers' perceptions of the state of several species including cod; the survey covers the years 2003–2008, (Laurenson, 2008). In addition, a number of collaborative research projects are reported to the WGNSSK each year. To date the studies providing time series of quantitative information have been relatively local, whereas those with wider coverage have been qualitative. The studies have therefore been used to corroborate assessment results and highlight differences in perception. The studies have proven useful in examining the dynamics of sub-stocks within the North Sea, for instance local recruitment, and thereby in the provision of advice to managers.

C. Historical stock development

Available stock assessment models

There are currently two models that could be used to provide an assessment of North Sea cod, namely B-Adapt and SAM. Both models estimate an annual catch multiplier, which appears to be necessary for any assessment of this stock (ICES-WGNSSK 2008). B-Adapt is currently used as a basis for ICES advice for North Sea cod (ICES-WGNSSK 2008). Further details about B-ADAPT can be found in Darby (WD15 in ICES-WGNSSK 2004), and about SAM in ICES-WKROUND (2009) Annex 5, which discusses general aspects and in Nielsen (WD14 in ICES-WKROUND 2009). A comparison of these two methods appears in ICES-WGNSSK (2008).

Model used as a basis for advice

The North Sea cod assessment is based on B-ADAPT (Darby, WD15 in ICES-WGNSSK 2004), a variation of ADAPT-VPA (Gavaris, 1988), developed specifically to handle the problem of mis-reported catch (ICES-WGNSSK 2008). B-ADAPT corrects for retrospective bias by estimating the quantity of additional "unallocated removals" that would be required to be added or removed from the catch-at-age data in order to remove any persistent trends in survey catchability. The model therefore uses survey information to estimate additional mortality not represented by recorded landings, estimated discards and the assumed levels of natural mortality.

Model used: B-ADAPT
Software used: ADAPT_16_04_07.exe

Model Options chosen

Settings used at the 2008 WGNSSK meeting (ICES-WGNSSK 2008):

[Note "→" on a new numbered line with no text indicates pressing the return button with NO input (i.e. accepting the default). Thus in the second line below, "→ → →" implies accepting the default three consecutive times. Furthermore an asterisk "*" next to an input indicates that that input will change from year to year, accounting for an additional year of data, or an appropriate assumption about the intermediate-year F-multiplier.]

1. Please input [path]name of stock index file → cod347.idx

2. → → →

3. Please give last age: <default=15> → 7

4. →

5. Your choice? <default=1> → 2

6. → →

7. Please give lower age limit for the mean: <default=3> → 2

8. →

[Central Menu appears]

9. Please select one of the options → 3

10. →

11. Enter report name (LPT1 for line printer) → codrep.csv

12. →

13. Do you wish to use the survey data for the year after the final catch at age year? Y/<N> → Y

14. F multiplier <1.0> → 0.9*

15. Exact VPA (V) or Cohort analysis <C> → V

16. Fleet 1

First age of constant catchability (Fleet range: 1-4) <Default: 3> → 1

Age for the catchability plateau (Fleet range: 1-4) <Default: 4> → 5

17. Fleet 2

First age of constant catchability (Fleet range: 0-3) <Default: 3> → 1

Age for the catchability plateau (Fleet range: 0-3) <Default: 4> → 3

18. →

19. Estimate missing year catch multipliers? <N>/Y → Y

20. Enter the number of years for catch multiplier Maximum: 45 <Default 1> → 15*

21. → → → →

22. Use inverse variance weighting? <Y>/N → N

23. →

24. Constrain Catch? Y/<N> → Y

25. → →

[Program will run and Central Menu will re-appear. If bootstraps required, continue to 26, else go to next comment after 66.]

26. Please select one of the options: → 5

27. Please give [path]name of fleet effort and catch data file → cod347_2008.tun*

28. →

29-41. {Repeat 13-25}

42. Do you run predictions? Y/<N> → Y

43. First year with SSB: <default = 1964> → 1998

44. Last year <default = 2004> → 2007*

45. Model type:

Shepherd	S
Beverton Holt	B
Ricker	R
Geometric mean	G
Bootstrap	P → P

46. →

47. Prediction type:

TAC constraint	T
F multiplier	M
Target F	F
TAC option range	C
F option range	R → M

48. F multiplier → 0.9*

49-66. {Repeat 47–48 nine times}

[If requested, program runs bootstraps. Central Menu re-appears. Save output files.]

67. Please select one of the options: →9

68. Please select required tables → 16

69. Enter report filename

(LPT1 for line printer)→ codout.csv

[End program]

70. Please select one of the options: → 0

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1963–present	-	Y
Canum	Catch at age in numbers	1963–present	1–7+	Y
Weca	Weight at age in the commercial catch	1963–present	1–7+	Y
West	Weight at age of the spawning stock at spawning time.	Weca used for West	Weca used for West	Weca used for West
Mprop	Proportion of natural mortality before spawning	1963–present	1–7+	N
Fprop	Proportion of fishing mortality before spawning	1963–present	1–7+-	N
Matprop	Proportion mature at age	1963–present	1–7+	N
Natmor	Natural mortality	1963–2007*	1–7+	Y

***Updated values for natural mortality will only be provided every 2 years**

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	IBTS-Q1	1983–final year of catch data + 1	1–5
Tuning fleet 2	IBTS-Q3	1991–final year of catch data	1–4

Recruitment estimation

Estimation of recruitment relies on the age-structure in the catch and survey data, but stock-recruit parameters are not estimated internally in the B-Adapt assessment model. Furthermore, when performing short-term projections in order to evaluate future stock dynamics, estimates of recruitment are not based on a stock-recruit function, but instead are sampled from the year-classes 1997–most recently estimated year-class, reflecting recent low levels of recruitment, but including the stronger 1999 and 2005 year classes.

D. Short-term projection

Due to the uncertainty in the final year estimates of fishing mortality, the WG agrees that a standard (deterministic) short-term forecast is not appropriate for this stock. Therefore, stochastic projections are performed, from which short-term projections are extracted. The stochastic projections are carried out using each of 1000 non-parametric bootstrap iterations. These projections are an extension of the program that provides the final B-Adapt assessment, and therefore the assessment and stochastic projections are self-consistent.

Model used: B-ADAPT
Software used: ADAPT_16_04_07.exe

Initial stock size

Starting populations taken from each bootstrap iteration.

Maturity

Average of final three years of assessment data (constant for North Sea cod).

Natural mortality

Average of final three years of assessment data.

F and M before spawning

Both taken as zero.

Weight-at-age in the catch

Average of final three years of assessment data.

Weight-at-age in the stock

Same as weight-at-age in the catch.

Exploitation pattern

Fishing mortalities taken as a three year average scaled to the final year.

Intermediate year assumptions

Multiplier reflecting intended changes in effort (and therefore F) relative to the final year of the assessment.

Stock recruitment model used

Recruitment is re-sampled from the year-classes 1997-most recently estimated year-class; for ICES-WGNSSK (2008), these comprised eight years with low recruitment and two with the slightly higher levels (1999 and 2005 year classes). This is a conservative estimate to account for the possibility that the low levels estimated in the last few years may continue.

Procedures used for splitting projected catches

For the purposes of the forecast, the WG assumes that future removals due to fishing comprise only landings and discards. Landings and discards in the forecasts were estimated by applying the landings- and discard-at-age ratios for 2007 to total fishing mortality-at-age for the projection period.

E. Medium-term projections

Medium-term projections are not carried out for this stock.

F. Long-term projections

Long-term projections are not carried out for this stock.

G. Biological reference points

The Precautionary Approach reference points for cod in IV, IIIa (Skagerrak) and VIId have been unchanged since 1998. They are:

	Type	Value	Technical basis
Precautionary approach	Blim	70 000 t	Bloss (~1995)
	Bpa	150 000 t	Bpa = Previous MBAL and signs of impaired recruitment below 150 000 t.
	Flim	0.86	Flim = Floss (~1995)
	Fpa	0.65	Fpa = Approx. 5th percentile of Floss, implying an equilibrium biomass > Bpa.
Targets	Fy	0.4	EU/Norway agreement

Unchanged since 1998

Yield and spawning biomass per Recruit F-reference points

	Fish Mort	Yield/R	SSB/R
	Ages 2–4		
Fmax	0.25	0.69	2.1
F0.1	0.16	0.69	3.2
Fmed	0.81	0.51	0.3

Estimated by ICES in 2009, assuming constant maturity and variable M, with M and stock weights averaged over the period 2000–2007. Selectivity is averaged over 2005–2007, and scaled to 2007.

H. Other issues

No other issues.

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Table 1 Variable natural mortality (M) values for North Sea cod, based on multi-species considerations. The seal diet data were originally collated from information sampled over a period of years (ICES 1997). Data were then transformed to diet by age using age-length keys. Finally this set of data was allocated to one year (1985). Due to the stock structure of cod in this particular year, with a relatively low abundance of age 6, the M2 for this age becomes higher than for both younger and older cod. It is considered that, for assessment purposes, the M2 values for age 6 should be replaced by the M2 values for age 5, as reflected here.

	1	2	3	4	5	6	7+
1963	0.78	0.42	0.33	0.22	0.21	0.21	0.20
1964	0.82	0.43	0.34	0.22	0.21	0.21	0.20
1965	0.85	0.44	0.35	0.22	0.21	0.21	0.20
1966	0.87	0.45	0.36	0.22	0.21	0.21	0.20
1967	0.89	0.46	0.37	0.22	0.21	0.21	0.20
1968	0.91	0.46	0.37	0.22	0.21	0.21	0.20
1969	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1970	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1971	0.92	0.47	0.38	0.22	0.21	0.21	0.20
1972	0.93	0.47	0.38	0.22	0.21	0.21	0.20
1973	0.92	0.46	0.38	0.22	0.21	0.21	0.20
1974	0.92	0.46	0.37	0.22	0.21	0.21	0.20
1975	0.92	0.45	0.37	0.22	0.21	0.21	0.20
1976	0.92	0.45	0.37	0.22	0.21	0.21	0.20
1977	0.92	0.44	0.36	0.22	0.22	0.22	0.20
1978	0.92	0.43	0.36	0.23	0.22	0.22	0.20
1979	0.92	0.43	0.36	0.23	0.22	0.22	0.20
1980	0.91	0.42	0.36	0.23	0.22	0.22	0.20
1981	0.90	0.41	0.36	0.23	0.22	0.22	0.20
1982	0.89	0.41	0.36	0.23	0.22	0.22	0.20
1983	0.87	0.40	0.36	0.23	0.22	0.22	0.20
1984	0.85	0.39	0.36	0.23	0.22	0.22	0.20
1985	0.83	0.38	0.36	0.23	0.23	0.23	0.20
1986	0.81	0.38	0.36	0.23	0.23	0.23	0.20
1987	0.79	0.37	0.36	0.24	0.23	0.23	0.20
1988	0.77	0.36	0.37	0.24	0.23	0.23	0.20
1989	0.75	0.35	0.37	0.24	0.24	0.24	0.20
1990	0.73	0.35	0.38	0.24	0.24	0.24	0.20
1991	0.72	0.34	0.39	0.25	0.24	0.24	0.20
1992	0.70	0.34	0.40	0.25	0.25	0.25	0.20
1993	0.70	0.34	0.41	0.26	0.25	0.25	0.20
1994	0.69	0.33	0.42	0.26	0.25	0.25	0.20
1995	0.68	0.33	0.43	0.26	0.26	0.26	0.20
1996	0.67	0.32	0.44	0.27	0.26	0.26	0.20
1997	0.65	0.31	0.44	0.27	0.26	0.26	0.20
1998	0.63	0.31	0.45	0.27	0.27	0.27	0.20
1999	0.61	0.30	0.45	0.27	0.27	0.27	0.20
2000	0.58	0.29	0.44	0.27	0.27	0.27	0.20
2001	0.56	0.29	0.44	0.27	0.27	0.27	0.20
2002	0.53	0.28	0.43	0.27	0.27	0.27	0.20
2003	0.51	0.28	0.42	0.27	0.27	0.27	0.20
2004	0.50	0.27	0.41	0.27	0.27	0.27	0.20
2005	0.49	0.27	0.40	0.26	0.26	0.26	0.20
2006	0.47	0.27	0.39	0.26	0.26	0.26	0.20
2007	0.46	0.26	0.38	0.26	0.26	0.26	0.20

5 Cod in Divisions VIIe–k (Celtic Sea cod)

5.1 Current stock status and assessment issues

Cod in Divisions VIIe–k are taken by mixed trawl fisheries with landings mainly (about 70% of international landings) made by French gadoid and *nephrops* trawlers, Ireland (14%), UK (9%) and Belgium (4%). Landings are made throughout the year but mainly from November to April. Landings were around 4000 t in the 1970s and increased to a historical peak of 20 000 t in 1989. They fluctuated at around 10 000 t up to 2002. Landings dropped to 6000 t in 2003, 3000–3500 t in 2004–2005 as a combined result of limitation, lower stock biomass and high-grading. From 2005, a closed area has been imposed during the first quarter in the area where lpue on spawning fish were the highest, at least for the French fleets.

Spawning stock biomass is estimated to have been below B_{lim} since 2004 with the most recent estimate slightly above B_{lim}. Fishing mortality has been very high since the mid-1980s, but has declined since 2002. Recruitment since 2002 has been well below average. This picture contrasts with the perception of the fishermen. Representatives from France, UK and Ireland, all reported that cod was abundant and widespread during the springs of 2007 and 2008 and highlighted the issue of restrictive quotas resulting in high-grading practices.

The main uncertainties for the assessment of this stock are partial information available on recent quota-induced changes in discarding, underreporting, and area misreporting of landings. The uncertainties in the forecasts are associated with the strength of the incoming and assumed recent recruitment estimates and any future high-grading practice.

The following table summarises the working documents that have been presented during the benchmark workshop:

WD	Title
#17	Estimates of French high-grading in the recent years for the Celtic Sea Cod Robert Bellail, Lionel Pawlowski
#3	Sensitivity of the Cod VIIe–k assessment to under-estimation of catches Hans Gerritsen, Colm Lordan
#2	The Celtic Sea: possible climate, oceanographic and planktonic influences on cod recruitment success Chris Lynam, Martin Edwards, Colm Lordan
#4	Effect of a change of maturity ogive on the assessment of the Celtic Sea Cod Lionel Pawlowski, Robert Bellail, Hans Gerritsen
#1	Overview of Cod (Gadus morhua) survey data in the Celtic Sea from the Irish Groundfish Survey (IGFS) David Stokes

5.2 Compilation of available data

The assessment is based on landings, three surveys and four commercial cpue series. Discard data are not included in the assessment. Corrections to take account high-grading have been applied to the data from the French fisheries from 2003.

5.2.1 Catch and landings data

5.2.1.1 Overview

Landings

International landings data have been available since 1971.

Misreporting

Landings data in some years have been corrected for area misreporting with 108 t in 2004, 54 t in 2005,103 t in 2006 and 514 t in 2007 assumed to be misallocated into the southern rectangles of VIIa (See WGSSDS 2008, WD #8). The higher level in 2007 is a consequence of limited quota in VIIe–k and available quota in VIIa.

Under-reporting of cod landings is also known to occur in some fleets in the recent past (2003–2006) when quota has been limited. Observations of under reporting suggest under-reporting rates are highly variable between trips. These observations are not frequent enough to precisely estimate under-reporting rates for use in assessment. The recent implementation of "buyers and sellers" legislation in the UK (2006) and Sales notes in Ireland (2007) is thought to have reduced under reporting of cod.

Discards

The availability of discard data for this stock is variable and discards are not included in the assessment. In the past discarding was not considered a problem for this cod stock due to largely unrestrictive quotas and low catchability of juvenile fish. Since 2003 discarding studies in the area assessed have been carried out on UK (E&W) fisheries under the EU Data Collection Regulation. Since 2005, Ireland and France have also provided discarding data from otter trawlers. Discarding was more important in 2005 than in 2006 and increased in 2007 for the Irish fleets as the quota was restrictive. Few French data have been reported in 2007 and mainly by the benthic fleets (13 trips) in area where cod are scarce.

In 1997, discards for the French fleets operating in the Celtic Sea were estimated to be around 8% (SGDBI, 2001). In recent years discarding practices have changed. For the French fleet, significant discarding occurred in the last quarter of 2002, when the French fishery was closed for cod. To prevent a new closure, fishermen started the following year to discard individuals above the MLS. This practice is called high-grading (see section below).

For Ireland, discarding due to quota restrictions was thought to be substantial in 2007. The Irish quota in VIIe–k was exhausted by August 2007 and reported landings after this period were minimal. All Irish catches were discarded from August through to December 2007. It is not possible to accurately estimate the "landings equivalents" that may have been discarded during this period but it is likely to be in the region of 200–300 t (based on the percentage of landings by month in recent years; 2003–2006). The landings-at-age data has not been corrected for this since it was not possible to fully evaluate how the closure affected fleet behaviour. Irish discarding is mainly of fish under the MLS. There is a mismatch in terms of scaling between the port sampling data of the trip raised sampling by observers at sea. The cause of this is not clear. The UK data indicates that discarding has occurred throughout the year but is more important in quarters two and four for both under MLS fish and high graded fish in VIIe and VIIf, and also some bigger damaged fish were also discarded all the year. Due to the lack of data in 2007, discarding practice of the important French

Gadoid fleet (FU05) is not quantified and is thought to have occurred in 2007, but still important as the high-grading practice remained.

High-grading

French landings and landings-numbers-at-age have been corrected for high grading from 2003 to 2005 using both UK and French length distributions.

In 2003, fishermen started high grading in order to prevent a new closure. This practice continued in the following years though fishermen were encouraged to avoid catching small cod, especially during the 2nd semester when small fish are recruited to the fishery. High grading was reduced in 2006 as most of the trips sampled at fish markets have landed the smaller commercial category. High-grading was again a major problem in the French fishery during 2007.

Because UK and French length frequencies showed the same shape in 2006, it was also assumed there was no high grading in 2006 to add to French landings. In 2007, high-grading occurred both in UK and French landings and the method used in previous years based on length frequencies from UK was considered unusable.

A new procedure based on the 2008 data from the French self-sampling program has been presented (Bellail and Pawlowski, WD#17) to reconstruct high-grading from 2003 to 2007. As the management rules set by the fishing organisations have changed through years, it is not reasonable to use the estimates from this method for the period 2003–2005 and for this reason; high-grading estimates for those years were those from the previous method combining UK and French length distribution.

5.2.1.2 Evaluation of the quality of the catch data

Misreporting

There is no quantitative information on the absolute level of misreporting for this stock but it might have increased from 2002 when quotas became restrictive.

Discards

As the quality and availability of discard data for this stock is variable, discards (on small individuals, in contrast to high-grading) are not included in the assessment.

Correction for High-grading

This reconstruction was described by WGSSDS, 2007. The accuracy of this procedure is unknown. Samplings on the *Nephrops* fleet (FU08) also shows that high grading practice has occurred although the absolute numbers of fish caught by this fleet during observed trips was very low. The extent of high-grading by this fleet from observation is uncertain but it is assumed in the assessment the intensity of this practice is the same than for the French gadoid trawlers.

5.2.2 Biological data

5.2.2.1 Overview of the biological data

Natural mortality

Natural mortality is assumed to be constant. No new information has been provided during the benchmark.

Maturity

A fixed combined sex maturity ogive has been used for all years prior to 1999 by WGSSDS. This was based on data collected during the UK Westerly Groundfish Surveys in spring from 1996 up to 1999. Recent investigations from the "Irish biological survey" data sets during the years 2004 to 2007 from VIa and VIIb, g and j have suggested an alternative maturity ogive for cod around Ireland (Gerritsen, WD WGSSDS 2008). The values for combined sex are given in the text table below:

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
Gerritson2009	0.01	0.67	1.00	1.00	1.00

Irish survey data for cod in VIIgj data are quite sparse, therefore data from surrounding areas (VIa and VIIbjg) have been added to the analysis. The data were collected in the spring of 2004–7. The survey is based on 119 males and 136 females. Considering those numbers result from aggregated data from some areas other than VIIe–k, it is uncertain how the proposed ogive truly reflects the current situation in VIIe–k and therefore the new series was not adopted until further information is available.

5.2.3 Survey data

5.2.3.1 Overview of the survey data

Estimates of abundance

FR-EVHOE (1997–present) and the IrGFS VIIg,j (2003–present) are currently the two surveys in the area contributing to estimates of abundance-at-age. The numbers of cod caught is generally low as those surveys, contrary to fishing fleets, do not specifically target cod but all demersal species.

The discontinued UK-WCGFS (1992–2004) was also used in the assessment. The indices have been truncated at 1992 as survey residuals were dome shaped. The influence of the data from this survey is reduced to the older ages and due to the absence of recent data the series has been omitted from assessment analysis.

In an attempt to overcome this, a combined French and Irish survey index was calculated to produce cod information on the overlapping area (VIIg) for the period 1997–2008; the IrGFS survey series 2003–2008 and the FR-EVHOE survey series 1997–2008. Two exploratory assessments were examined using the combined survey indices. The overlapping area of the IrGFS and FR-EVHOE surveys is mainly the Division VIIg.

As the Irish and French surveys in Celtic Sea do not use the same stratification scheme for sampling, it was necessary to disaggregate the indices from the French survey in the common sampling area before combining the datasets. The stratification of EVHOE surveys relies on bathymetric strata within geographic strata as shown in the Figure 5.1. The overlapping area of both the Irish and the French surveys includes the strata Cn and Cc up to a deep of 120 m and defines the new geographic strata where abundance indices of cod have to be estimated in the EVHOE series (Figure 5.2).

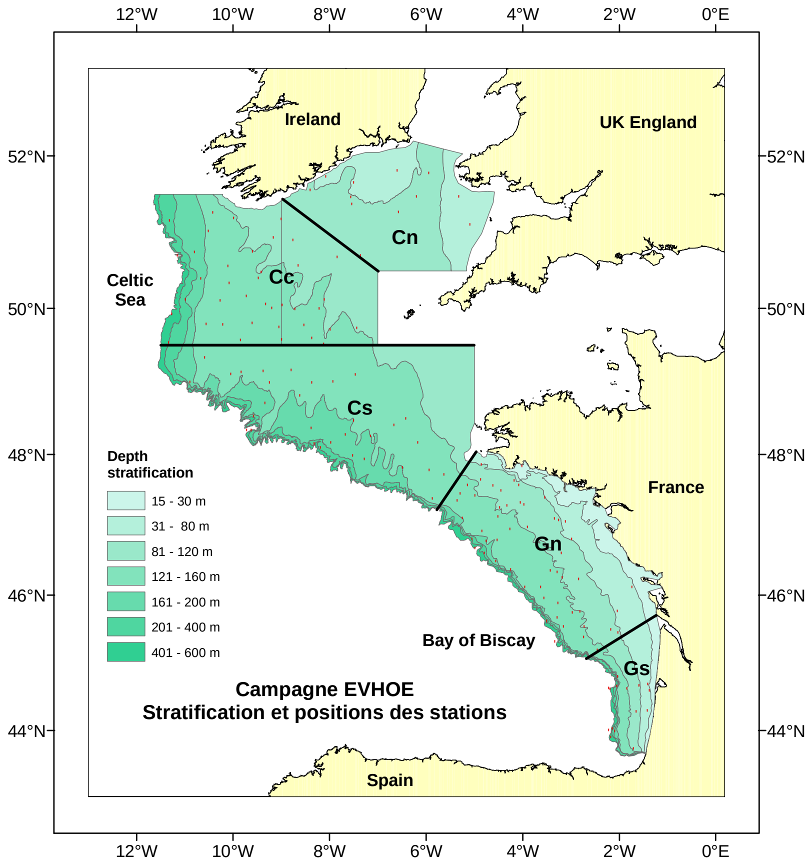

Figure 5.1: Geographic and bathymetric stratification used in EVHOE surveys.

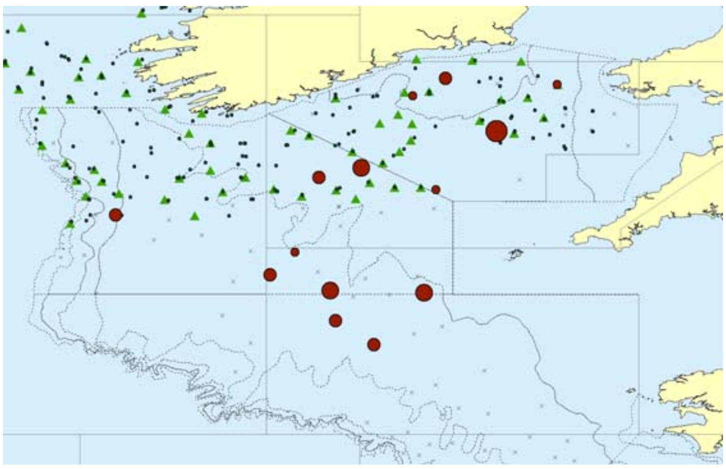

Figure 5.2: Combined map of 2008 FR-EVHOE (circles) and IrGFS (triangles) hauls since 2003.

For a given year, the average number of cod per age and haul was weighted by the area of each bathymetric strata to give the average number-at-age per haul in the overlapping area. This value raised by the total number of hauls carried out in the overlapping area gives the absolute number of cod caught by age-group. The total number of hauls converted in minutes (the duration of a haul is 30 mn) gives the fishing effort. The data obtained have the same format than the Irish datasets in VIIg and VIIj (numbers of cod and effort in mn). The effort data for the combined datasets are in the table below:

Year	Effort (minutes)	Number of fish						
		Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1997	450	9.47	1.81	6.17	5.11	0.6	0	0
1998	630	12.26	19.13	9.03	2.44	1.17	0	0
1999	600	9.26	7.94	4.21	0	0	0	0
2000	480	44.36	1.29	5.64	2.5	0.64	0	0
2001	570	39.9	7.52	1.24	1.05	1.05	0	0
2002	540	1.78	7.41	5.03	0	0.81	0	0
2003	1432	9.1	12.4	17.51	7.2	0	0	0
2004	1550	19.18	11.93	5.63	7.12	2.59	0	0
2005	1475	40.18	10.02	2.68	0	0	0	0
2006	1556	42.04	19.52	4.43	0	0	1	0
2007	1828	65.01	25.96	11.44	6.1	0	0	0
2008	1679	20.98	29.08	8.87	5.6	0	0	0

5.2.3.2 Evaluation of the quality of the survey data

Estimates of abundance

The recent low numbers of cod caught during the surveys is considered to be related to the low abundance in the population rather than to the quality of the survey design (which does not focus on cod). The impact of the small numbers caught on the surveys will mean that these estimates will be variable from year to year. In addition, the surveys do not provide an abundance estimate of 0-group cod which would be helpful for this stock given the sensitivity of the short term forecast to the estimates of recruitment to the fishery.

5.2.4 Data input from the industry and stakeholders

French self sampling program

Due to the management rules adopted year by year by the French POs since 2003 and in response to the restricting quotas set, high-grading has occurred in the French fishery, mainly in VIIfgh.

A self sampling program for cod in the Celtic Sea initiated by the French P.O. "PMA – Pêcheurs de Manche et Atlantique" and conducted both by PMA and IFREMER has started in January 2008. The data from this program have the quality required to estimate discarding and high-grading and the datasets obtained have been used to estimate the discarding and the high-grading which has occurred in previous years.

The success of this partnership between science and the industry is related to the fast feedback to the vessels involved in the self sampling program. Practically, the catch length composition and graphs of cod from hauls a trip sampled during a trip are sent to the P.O. the day after the reception of the data. This process also allows permanent exchange in order to correct or exclude data when mistakes are suspected in the datasets.

In 2009, the self sampling program for Celtic Sea cod is continuing. Five trawlers are involved in: 2 demersal trawlers directed to gadoids fish, 2 *Nephrops* trawlers and a benthic trawler targeting mainly monkfish, megrim, rays.

The sensitivity of the assessment model to high-grading has been investigated during the benchmark (see the sensitivity analysis section of the report).

UK Cod watch

From UK, the NFFO has examined the impact of the Trevose box closure on the activity of the otter trawlers over 15 m. The Trevose box closure has resulted in a displacement of the fishing effort and lower volumes of whitefish at the market. The Trevose box is far larger than the industry intended it to be and although all fishermen in the sector agree with the principle of the box, huge displacement of fishing effort has been caused because of the sheer size of the area. Therefore, the box needs to be tailored to meet its original objectives i.e. to protect cod spawning areas-originally proposed by fishermen approx. 25% of the size of the existing box.

Irish input

There are regular meetings between scientists and the fishing industry representatives in Ireland. The industry has disagreed with the perception of stock status given in the analytical assessment. In term of co-operative research programs there has been a recent project evaluated the possibility of developing a recruitment survey for Celtic Sea cod. The industry have also been involved in a tagging project in the Celtic Sea that has successfully tagged >4000 fish including some data storage tags. There is ongoing co-operation with at-sea observer and in port sampling programs. It is hoped that self sampling programs along the lines developed in the Irish Sea and in France be developed for Celtic Sea cod.

Belgian input

There is an interest of the industry about a self sampling program using a protocol looking like the French protocol currently used.

Overview

Overall countries, representatives of the industry participating to the benchmark WK are in favour of data collected at sea improving the quality of assessments.

At a national level, a co-ordination would be useful to choose the actions. Programs improving the quality of data from commercial tuning fleets are important and the industry could take part of this by the input of historical changes in efficiency of the fleets which might overcome the problem of change of catchability over the time series.

5.3 Stock identity and migration issues

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. Since 1997, this assessment has related to the cod in Division VIIe–k. Landings in the very southern part of VIIa, when significant, are also included in the assessment. The assessed area for this stock has been gradually widened from VIIfg up to 1992, VIIfgh in 1994, VIIefgh in 1996 to VIIe–k in 1997. In the past few biological criteria have been used to justify the widening the stock area. 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.

Migrations are known to occur in this cod stock. Cod can be caught throughout the English Channel (ICES areas VIId and VIIe) in autumn (quarter 4) and winter (quarter 1), being more aggregated during the spawning season in January/February.

Electronic tagging experiments in the English Channel (VIId and VIIe) have shown that cod tagged on or close to English Channel spawning grounds in quarters 4 and 1 either remain close to the point of release (residency), or move to feeding grounds to the south and/or west. Smaller fish (<50 cm) are more likely to be resident. Migrants tend to move offshore to deeper areas, whereas the habitat selection of residents is less clear cut.

In the light of the migratory phenotypes identified by electronic tagging, historic mark-recapture experiments can be re-evaluated. Although sample size is limited, results from data on the movements of adult cod (>50 cm) show that, after tagging in VIIe (the western Channel) in quarters 1 and 4, 47% of cod (27 of 58) are recaptured in ICES areas VIIf through VIIj, while 48% are recaptured in VIIe (i.e. are probably resident). In contrast, none of the adult cod tagged in VIId are recaptured in ICES areas VIIf through VIIj, 5% move into VIIe and 51% remain in VIId. Juvenile cod are more likley to be recaptured in the same area that they were tagged in. These figures vary slightly when recaptures are separated into autumn/winter and spring/summer seasons, but are broadly comparable. The data therefore provide evidence that cod in the eastern English Channel and western English Channel might be classed as separate sub-stocks, and that movement of cod between eastern English Channel and the Celtic Sea is limited, whereas movement between the western Channel and the Celtic Sea is frequent.

5.4 Spatial changes in fishery or stock distribution

The spatial distribution of landings by rectangle for the most important countries engaged in Celtic Sea demersal fisheries are shown in Figure 5.4.1. The majority of the landings from this stock in recent years have been in VIIg in or around the Celtic Sea deep (31E3). There are two noticeable changes since 2000. Three rectangles shown in yellow have been closed for part of Q1 since 2005 and the relative contribution of these rectangles to the overall catch of cod has declined since the introduction of this measure. The second major change is the decline in effort and landings of the "French gadoid fleet". This has contributed to a decline in the relative proportion of cod caught by 'Otter trawlers' since 2003.

Fishing different gears and areas are known to result in slightly different age compositions of Celtic Sea cod (e.g. gillnets mainly catch larger individuals compared with otter or *Nephrops* trawlers). The changing relative contributions of gears, times or areas to landings have the potential to bias recent catch numbers-at-age. However, the uncertainties surrounding high-grading and under-reporting probably far out weigh any bias due to spatial changes in the stock or fishery.

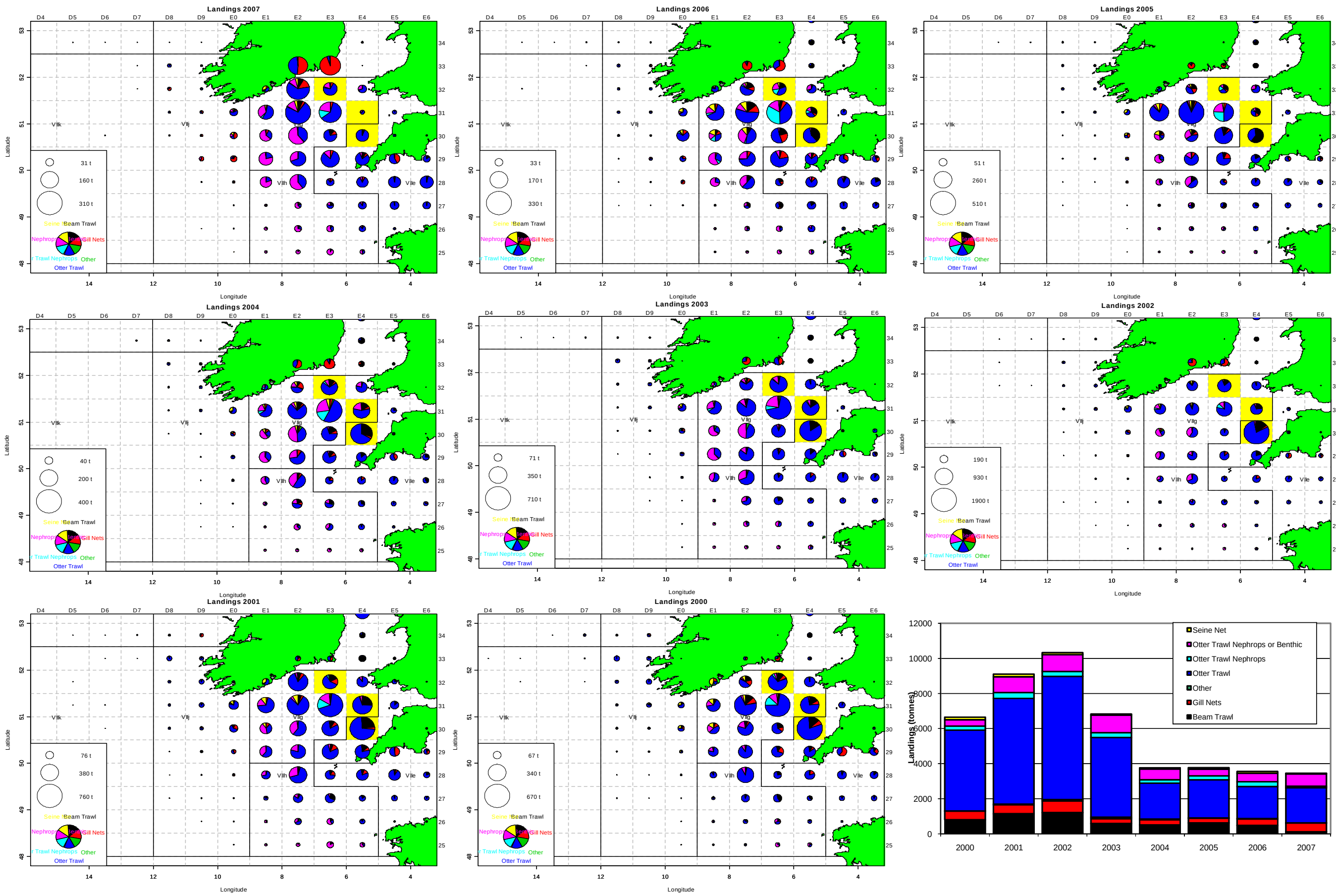

Figure 5.4.1: The spatial and temporal distribution of Cod Landings from the Celtic Sea from 2000–2007 by gear type. The closed rectangles are highlighted in yellow. Each year is scaled to the maximum. Note: Belgium landings for 2007 are not included. These are mainly beam trawl landings.

5.5 Environmental drivers of stock dynamics

A working document has been presented during the meeting (Lynam *et al.*, WD2) investigating possible climate, oceanographic and planktonic influences on cod recruitment success through a modelling approach.

Results suggest that cold anomalies during the spring (i.e. following spawning) are associated weakly with greater recruitment success. The long term increasing trend in recruitment success has been concomitant with a warming trend, which does not agree with the hypothesis that cooler temperatures are beneficial for cod. A possible explanation for this is that the reduction of predators on the larval stage (i.e. though overexploitation of adult cod) may have resulted an increased probability of survival of larval cod. Further results suggest that the 'reduced predation' hypothesis is not supported by a change in predation by adult cod but could still be influenced by other species like whiting *Merlangius merlangus* or haddock *Melanogrammus aeglefinus*.

The contradiction in response of cod recruitment success to the temperature anomalies and trend is therefore most likely due to the complex ecosystem responses (e.g. change in the plankton community) expected following a warming of the sea.

The abundance of zooplankton prey species is undoubtedly important for cod larvae survival and the analysis suggests that early population growth of *C. helgolandicus* may be beneficial to larval survival as *Calanus finmarchicus*, generally considered the key prey species for many cod stocks, is the least abundant of the possible prey in the Celtic Sea. In contrast, *C. helgolandicus*, a species with a more southern distribution, which has been suggested to be a poorer food source for cod due to its smaller body size, is highly abundant and second only to the smaller *Para/psuedocalanus* spp. Cod larvae select prey based on size and therefore *C. helgolandicus* could be a useful food source if it is encountered at the correct stage in the growth of cod larvae.

Major changes in the zooplankton composition have been reported in 2005 (ICES WGRED, 2008). The rank order of the top ten species changed and new groups, Echinoderm larvae, *Noclula scintillans*, Siphonophores and *C. helgolandicus* appeared in the dominant species for the first time, contributing 4.6% to 3% of the total zooplankton abundance.

Cod also preys upon other species and if climate change is indeed altering species phenology in the Celtic Sea such changes may prove increasingly important in years to come. Many projections of global warming suggest continued warming in the coming decades. However, there is possibility that the rapid rate of increase in sea temperatures in recent decades in the northeast Atlantic may reduce or even reverse temporarily in the coming decades since the Atlantic Multidecadal Oscillation has been predicted to switch to a cool phase (Keenleyside *et al.*, 2008).

5.6 Roles of multispecies interactions

No new information has been presented during the benchmark workshop.

5.7 Impacts of fishing on the ecosystem

No new information has been presented during the benchmark workshop.

5.8 Stock assessment methods

5.8.1 Models

Three assessment models have been compared during this benchmark workshop: XSA, B-Adapt and SAM a state-space stock assessment model.

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.

The following parameters were used as reference runs:

	FLEETS SERIES	AVAIL.	2008 XSA		2009 XSA	
Catch data range			71–07		71–07	
Age range of the assessment		1–10	1–7+		1–7+	
Commercial tuning series:						
	FR-GADOIDQ2+3+4	83–06	1–6	83–07	1–6	83–07
	FR-NEPHROPS	87–06	1–6	87–07	1–6	87–07
	UK-WECOT	88–06	1–6	89–07	1–6	89–07
	IR-7J-OT	95–06	1–6	95–06	1–6	95–06
Survey tuning series:						
	UK-WCGFS	86–04	1–5	92–04	1–5	92–04
	FR-EVHOE	97–06	1–5	97–07	1–5	97–07
	IRGFS VIIg,j	03–06	1–5	03–07	1–5	03–07
	IrGFS&EVHOE combined in VIIg	97–08				
Taper			No		No	
Ages catch dep. Stock size			None		none	
q plateau			5		5	
F shrinkage se			1.0		1.0	
year range			5		5	
age range			3		3	
age range of mean F			2–5		2–5	

The F range used in the assessment was 2–5.

B-Adapt

B-Adapt has been tested during the benchmark meeting as a potential alternate model to XSA. In order to estimate the uncertainties of the dynamic parameters of this stock and allow comparison with the XSA results, some exploratory assessments with B-Adapt have been carried out.

The settings are summarized in the table below.

	Fleets series	Avail.	2009 XSA		2009 B-Adapt	
Catch data range			71–07		71–07	
Age range of the assessment		1–10	1–7+		1–7+	
Commercial tuning series:						
	FR-GADOIDQ2+3+4	83–06	1–6	83–07		
	FR-NEPHROPS	87–06	1–6	87–07		
	UK-WECOT	88–06	1–6	89–07		
	IR-7J-OT	95–06	1–6	95–06		
Survey tuning series:						
	UK-WCGFS	86–04	1–5	92–04	1–5	92–04
Excluded when combined fleet used	FR-EVHOE	97–06	1–5	97–07	1–5	97–07
Excluded when combined fleet used	IRGFS VIIg,j	03–06	1–5	03–07	1–5	03–07
IrGFS&EVHOE combined in VIIg	IBTS VIIg	97–08			1–5	97–08
Taper			No		No	
Ages catch dep. Stock size			none		none	
q plateau			5		5	
F shrinkage se			1.0			
Constraint catch					Y	
Stiffness weight					0.5	
year range			5		5	
age range			3		3	
age range of mean F			2–5		2–5	

SAM

The state-space fish stock assessment model was introduced (WD#14) as an alternative to the commonly used (semi-) deterministic approaches and fully parameterised statistical models. The current implementation has been applied to different cod stocks related to this benchmark. The state-space assessment model is proposed because of a number of appealing properties: this is a full statistical model and as such quantification of uncertainties is an integrated part of the model. It allows selectivity to evolve gradually in the data period. It is able to handle missing data (e.g. missing catches in a year). Finally it has fewer model parameters than other statistical assessment models, as quantities such as fishing mortalities (F) and stock sizes (N) are included in this model as so-called random effects. This model was tested against B-Adapt and XSA as well as catch-at-age data from observations during the benchmark.

The treatment of log F with a random walk approach was of interest in that F could be related to real changes in effort or management quotas over time and might provide any indication since 2003.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1971–2007		No
Canum	Catch at age in numbers	1971–2007	1–10	Yes
Weca	Weight at age in the commercial catch	1971–2007	1–10	Yes
West	Weight at age of the spawning stock at spawning time.	1971–2007	1–10	Yes
Mprop	Proportion of natural mortality before spawning	1971–2007	1–10	No
Fprop	Proportion of fishing mortality before spawning	1971–2007	1–10	No
Matprop	Proportion mature at age	1971–2007	1–10	No
Natmor	Natural mortality	1971–2007	1–10	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	FR-GADOID	1983–2007	1–10
Tuning fleet 2	FR-NEPHROPS	1987–2007	1–10
Tuning fleet 3	UK-WECOT	1988–2007	–-6
Tuning fleet 4	IR-7J-OT	1995–2007	1–7
Tuning fleet 5	UK-WCGFS	1986–2004	1–5
Tuning fleet 6	FR-EVHOE	1997–2008	0–7
Tuning fleet 7	IrGFS-VIIg	2003–2007	0–7
Tuning fleet 8	IrGFS-VIIj	2003–2007	0–7
Tuning fleet 9	IrGFS-VIIgj combined	2003–2007	0–7
Tuning fleet 10	IrGFS-VIIg & FR-EVHOE VIIg combined	1997–2008	0–7

The whole series of exploratory assessments carried out during this benchmark workshop is summarized in the table below:

Run #	Used models			Tuning fleets		Major changes
	XSA	B-Adapt	SAM	Commercial	Surveys	
X1	✓			✓	✓	Reference run
X12	✓				✓	Commercial tuning fleets removed
B1		✓		✓	✓	Reference run
	Sensitivity analyses					
X11	✓			✓	✓	A new maturity ogive is tested
X3	✓			✓	✓	Underreporting of landings taken account (re-estimates of landings)
X4	✓			✓	✓	Underreporting of landings taken account (another re-estimates of landings)
X5	✓			✓	✓	Inclusion of a new recruitment model
X6	✓			✓	✓	High-grading estimates removed from data
X7	✓			✓	✓	High-grading estimates based on UK data (old estimates)
X8	✓			✓	✓	High-grading estimates based on 2008 data (new estimates)
X9	✓			✓	✓	High-grading estimates based on both UK and 2008 estimates
X10	✓				✓	High-grading estimates based on both UK and 2008 estimates, single tuning fleet (EVHOE)
B2		✓			✓	Commercial tuning fleets removed
B4		✓		✓	✓	UK-WCGFS + recombined IrGFS & EVHOE surveys
B5		✓			✓	UK-WCGFS + recombined IrGFS & EVHOE surveys
	Intercomparison between models					
S1			✓		✓	Commercial tuning fleets removed

5.8.2 Sensitivity analyses

The following sensitivity analyses were carried out during the benchmark meeting:

- Consequence of using a new maturity ogive.
- Taking account unallocated landings.
- Impact on high-grading for the stock assessment.
- Using combined surveys indices

5.8.2.1 Change of maturity ogive

A series of exploratory assessments using XSA (runs X1 and X11) have been carried out with the maturity ogive presented in Gerritsen, 2008. Four runs were performed: one reference using the current WG ogive, a second using the new ogive after 2003, a third run with a transitory period from the current ogive to the new one between 1999 and 2004 (linear interpolations of ogives) and a final run using the proposed ogive for the whole time series.

All runs (Figure 5.8.1 and Table 5.8.1) show the changes in maturity ogives only affect the SSB. The implementation of a new ogive whenever it occurs leads to a 20% increase of SSB. Retrospective analyses were also performed. The model traditionally underestimates SSB. While the level of SSB is changed whenever a different ogive is used, this trend remains observed.

The variation of SSB can also be mathematically estimated between old and new matury ogives *mo* using the following formula:

$$\Delta SSB = \sum_{a=1}^{10} \left(\left(mo_{a,y}^{new} - mo_{a,y}^{old} \right) \cdot w_{a,y} \cdot n_{a,y} \right)$$

Where

a : age class

y : year

$mo_{a,y}$: proportion of mature individuals at age (new and old ogives)

$w_{a,y}$: individual weight-at-age

$n_{a,y}$: stock number-at-age

	WG (1971-2007)	WG(1971-2003) NEW(2004-2007)	Transitory	New ogive (1971-2007)
SSBs (tons)				
prior 1996	11000 ± 3844	11000 ± 3844	11001 ± 3844	13089 ± 4760
1996-1999	12013 ± 1756	12013 ± 1756	12013 ± 1755	14385 ± 2156
2000-2003	7824 ± 1127	7824 ± 1127	8673 ± 1536	9481 ± 1506
2004-2007	4719 ± 742	5647 ± 910	5674 ± 916	5674 ± 916
Relative differences of SSB against reference (WG) %				
prior 1996		0.0 ± 0.0	0.0 ± 0.0	18.5 ± 7.2
1996-1999		0.0 ± 0.0	0.0 ± 0.0	19.7 ± 1.2
2000-2003		0.0 ± 0.0	10.3 ± 4.4	21.0 ± 6.2
2004-2007		19.7 ± 4.3	20.3 ± 4.6	20.3 ± 4.6
Yield/SSB				
prior 1996	0.745 ± 0.220	0.745 ± 0.220	0.745 ± 0.220	0.622 ± 0.155
1996-1999	0.933 ± 0.055	0.933 ± 0.055	0.933 ± 0.055	0.779 ± 0.041
2000-2003	0.986 ± 0.139	0.986 ± 0.139	0.896 ± 0.133	0.812 ± 0.087
2004-2007	0.770 ± 0.028	0.644 ± 0.034	0.641 ± 0.035	0.641 ± 0.035
Relative differences of Yield/SSB against reference (WG) %				
prior 1996		0.0 ± 0.0	0.0 ± 0.0	-15.3 ± 4.9
1996-1999		0.0 ± 0.0	0.0 ± 0.0	-16.4 ± 0.9
2000-2003		0.0 ± 0.0	-9.2 ± 3.7	-17.2 ± 4.2
2004-2007		-16.4 ± 3.1	-16.7 ± 3.3	-16.7 ± 3.3

Table 5.8.1: Comparison between SSBs and Yield/SSB for the different types of combination of maturity ogives.

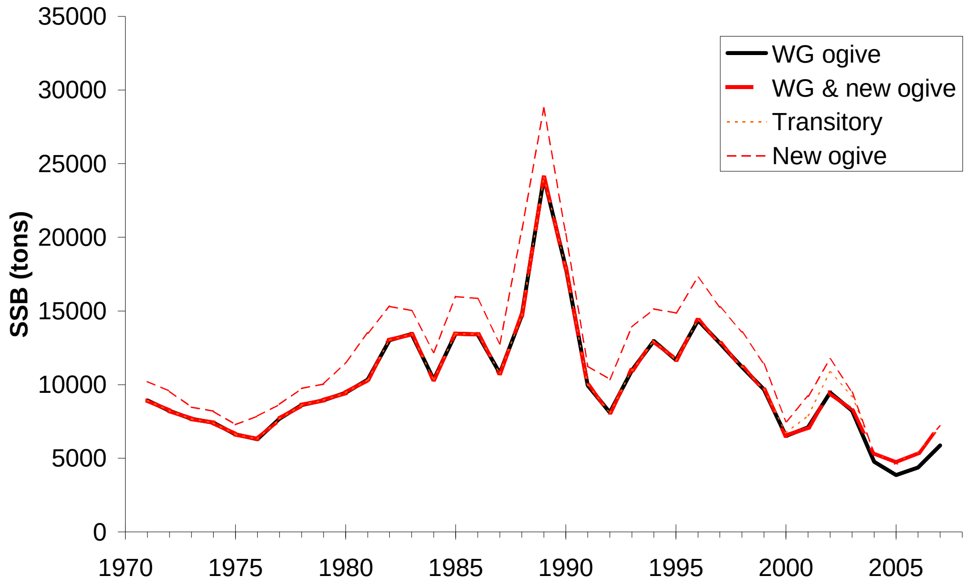

Figure 5.8.1: Comparison of SSBs between assessments using the alternative and/or current WG ogive. «WG ogive» is a regular run using the working group ogive. «WG and New ogive» uses the current ogive up to 2004 and then the alternative ogive. «Transitory» use the current ogive up to 1999, the new ogive after 2003 and a transition period between 1999 and 2004. «New ogive» has the alternative ogive used for the whole time-series (1971–2007).

5.8.2.2 Unallocated landings

Discarding, high-grading and under-reporting of landings are all thought to be biases in the Celtic Sea cod assessment. A sensitivity analysis was carried out to explore the sensitivity of the assessment to under-estimation of catches at the scale of 1.5–2.0

times the reported landings (XSA run X3) and ~1.4 times the reported landings (XSA run X4). The results of these sensitivity analyses are presented and discussed in WD #3.

The catch number adjustments presented in WD #3 in Run X3 and X4 are rather crude and are unlikely to be an accurate reflection of the true catches. It is more likely that there are inter-annual fluctuations in the national catch multipliers. The main impact of inflating the catch numbers is to increase fishing mortality in recent years compared with the base assessment. Both run X3 and run X4 still show SSB to be close to the lowest ever observed levels. In recent years SSB remains below Bpa. Similarly, recruitment in recent years is amongst the lowest observed.

The retrospective bias in F is the main diagnostic difference between the SPALY assessment and XSA 3. The SPALY assessment shows little retrospective revisions particularly in SSB and recruitment. The retrospective pattern exhibits underestimation of fishing mortality. Inflating the catch numbers (as for XSA run X3) results in a reversed fishing mortality retrospective pattern, under-reported catches are likely overestimated. Run X4 is an intermediate scenario and this shows almost no retrospective change in F estimates.

5.8.2.3 Sensitivity to high-grading

In advance of the meeting, attempts were made to correct the French data for high grading (WD #17). Correcting the catch numbers for high grading using 2008 self-sampling data resulted in an increased landings estimate of ~1.14 in 2007 and 2006 (see text table below). This correction does not take into account under reporting in the French or other fleets catching Celtic Sea cod.

Year	Reported Landings	XSA Run X7	XSA Run X8	HG Correction
2002	9236	9356	9356	9236
2003	6221	9624	8243	6432
2004	3523	6549	4941	3672
2005	2988	6387	4338	3062
2006	3326	7046	4759	3758
2007	4224	8853	6049	4817
		Catch Multipliers By Year		
2002	1.00	1.01	1.01	1.00
2003	1.00	1.55	1.33	1.03
2004	1.00	1.86	1.40	1.04
2005	1.00	2.14	1.45	1.02
2006	1.00	2.12	1.43	1.13
2007	1.00	2.10	1.43	1.14

5.8.2.4 Sensitivity to combined survey abundances indices

The effect of combining IrGFS to FR-EVHOE data as an attempt to reduce the noise from the surveys data has been investigated through runs B4 (only surveys in the tuning fleets) and B5 (commercial fleets added). “Single” IrGFS and FR-EVHOE tuning fleets were removed and replaced by the single combined fleet. The reference B-Adapt run was B2.

Compared to the reference run, the use of these new set of surveys tuning fleets has resulted in a decrease of fishing mortality in 2003 and then a strong increase up to a value of 1.9 in 2007, a level above those observed in the past. Estimated landings declined in 2002 and then rise to 6000 t in 2005, remaining constant subsequently. Recruitment values are scaled at higher values and raised around twice the long term GM in 2007. There is also a scaling of SSB since 2003 but a convergence rather to the same values in the terminal year. It is necessary, however, to keep in mind that numbers remain small in the new survey series.

Another run (B5), which included the commercial fleets, has been carried out. Results in terms of F, predicted landings, SSB and recruitment are intermediate but closer to those of the reference run. The decrease of F since 2005 is smoothed. Recruitment has the same pattern of continuous increase since its lowest value in 2003, reaching values above the long term GM in 2007. Predicted landings fluctuates around 4000 t for the period 2004–2006 and raised to below 6000 t in 2007, a higher value than the actual landings recorded.

5.8.2.5 Other runs

Run X5: the inclusion of new recruitment model results in higher residuals. The recruitment model does not match with the higher year classes.

Run X6: the removal of high-grading estimates leads to higher residuals at age 1 and a stronger pattern of underestimation of recruits.

Run X10: the use of a single fleet allowed the tracking of the 1999 and 2000 year classes.

5.8.3 Retrospective patterns

The Celtic Sea cod assessment can be briefly characterised in the following way. The steep age profile in the catches results is a highly converged VPA. This gives the perception of a "very good assessment" with little retrospective revisions particularly in SSB and Recruitment. XSA treats the catch numbers-at-age as exact. Here we know there is considerable uncertainty around the recent catch numbers.

Figures 5.8.3.1 to 5.8.3.3 show the impact of ad hoc scaling of catch numbers on the retrospective pattern in this XSA assessment. The results support the notion that catch numbers-at-age maybe under estimated but cannot be used to conclusively estimate what catches might be.

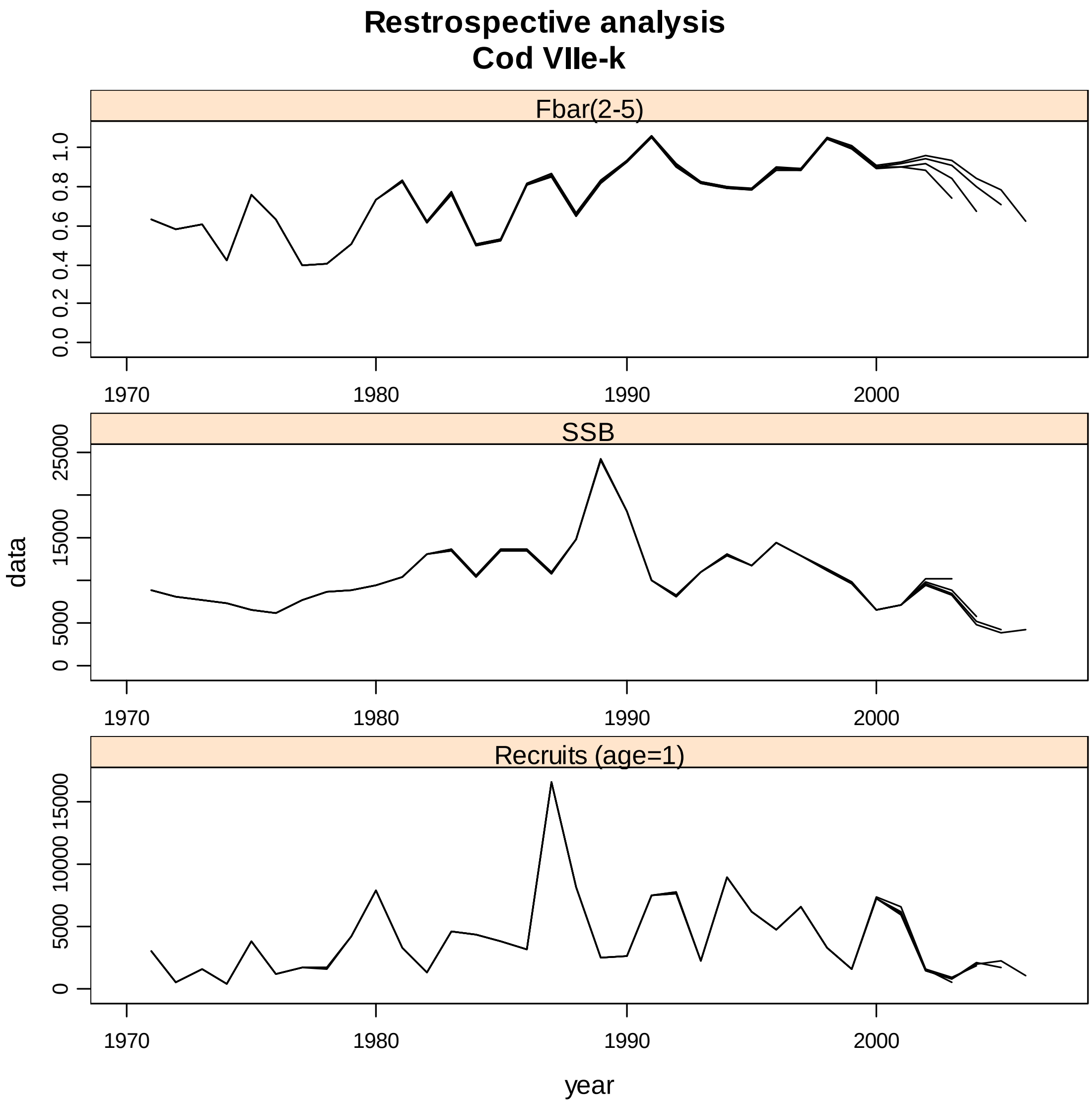

Figure 5.8.3.1: The Retrospective pattern in the XSA Run2 (the SPALY assessment). There is little retrospective change in SSB or Recruitment. There is some upward revision of fishing mortality.

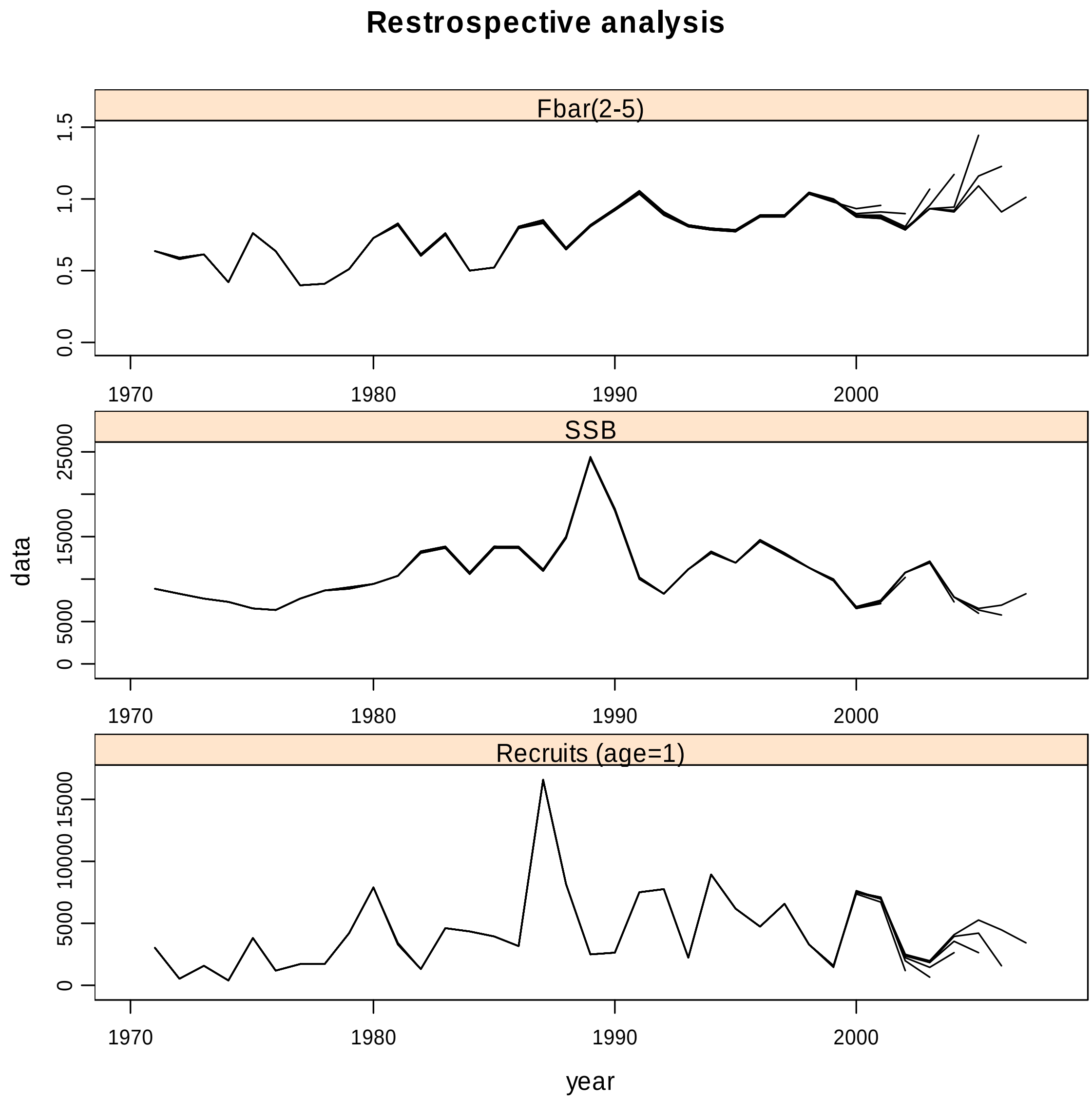

Figure 5.8.3.2: The Retrospective pattern in the XSA Run3. This used inflated catch numbers in the landings and commercial tuning fleets for 2003–2007 (Ire X 4, UK X 2, Fr 1.25, Be X 1). F tends to get adjusted downward as new data gets added to the assessment.

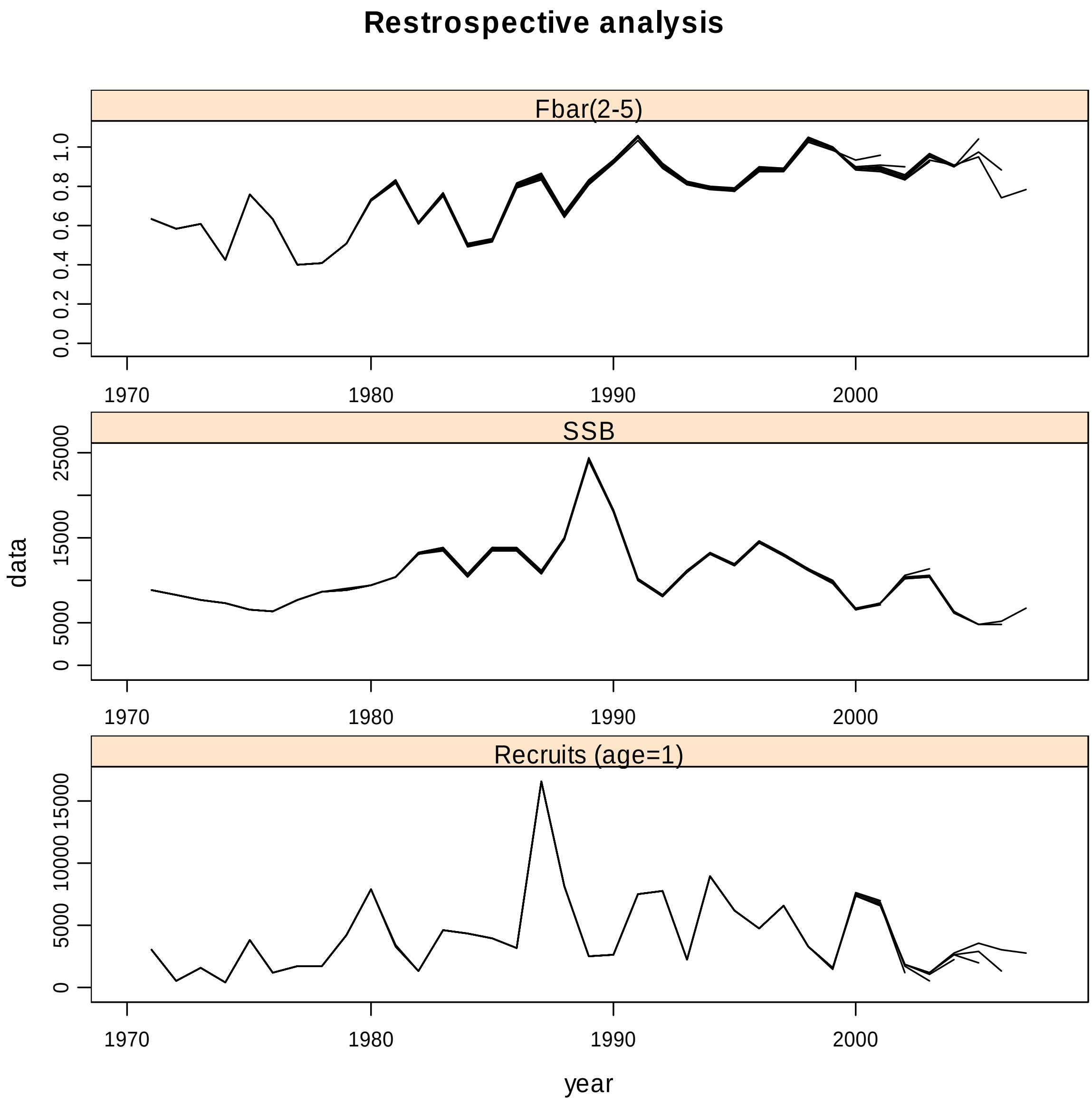

Figure 5.8.3.3: The Retrospective pattern in the XSA Run4. This used inflated catch numbers in the landings and commercial tuning fleets for 2003–2007 (Ire X 2, UK X 1.5, Fr 1.25, Be X 1). F tends to get adjusted downward as new data gets added to the assessment.

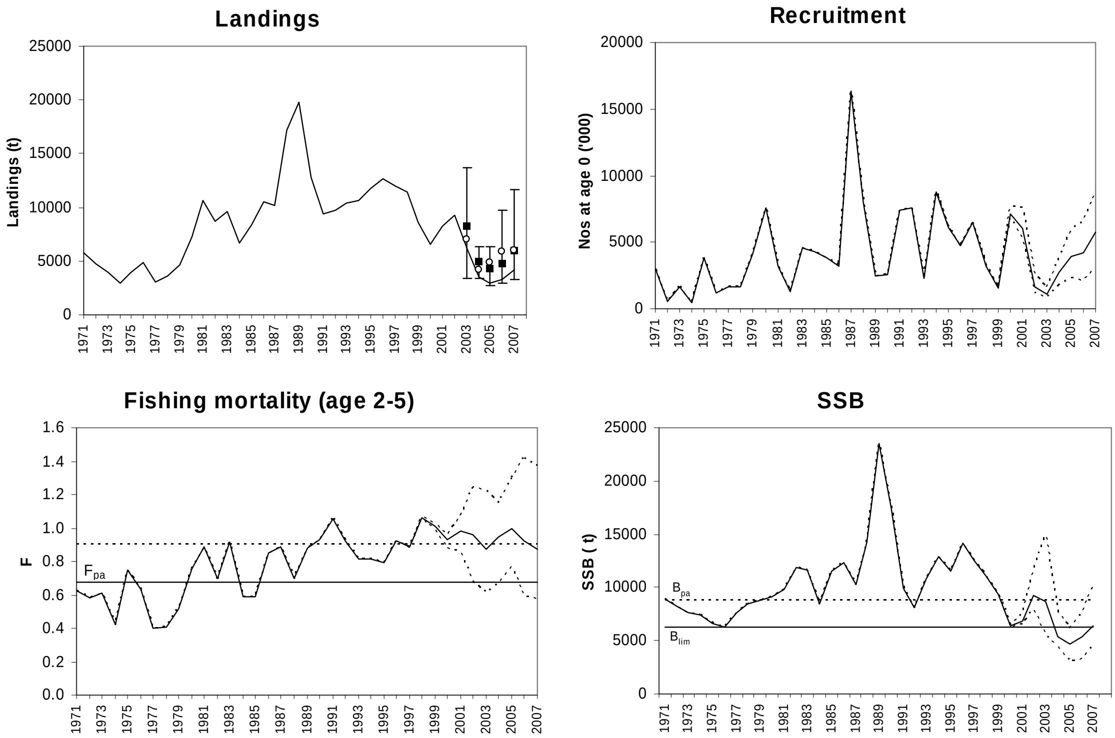

Figure 5.8.3.4: Badapt run 3: The stock summary plots for a bootstrapped assessment run with BADAPT tuning with survey data (UK, IRGFS and EVHOE) only and allowing landings scaling from 2003. The dotted lines indicate 5 and 95 percentiles the solid lines on SSB, R, and F are the 50th percentile. Continuous line on landings plot is the reported landings with no high grading estimates; filled squares are landings scaled up as in XSA Run4; open circles with 90% confidence intervals are total removals estimates (in excess of assumed natural mortality) from B-Adapt.

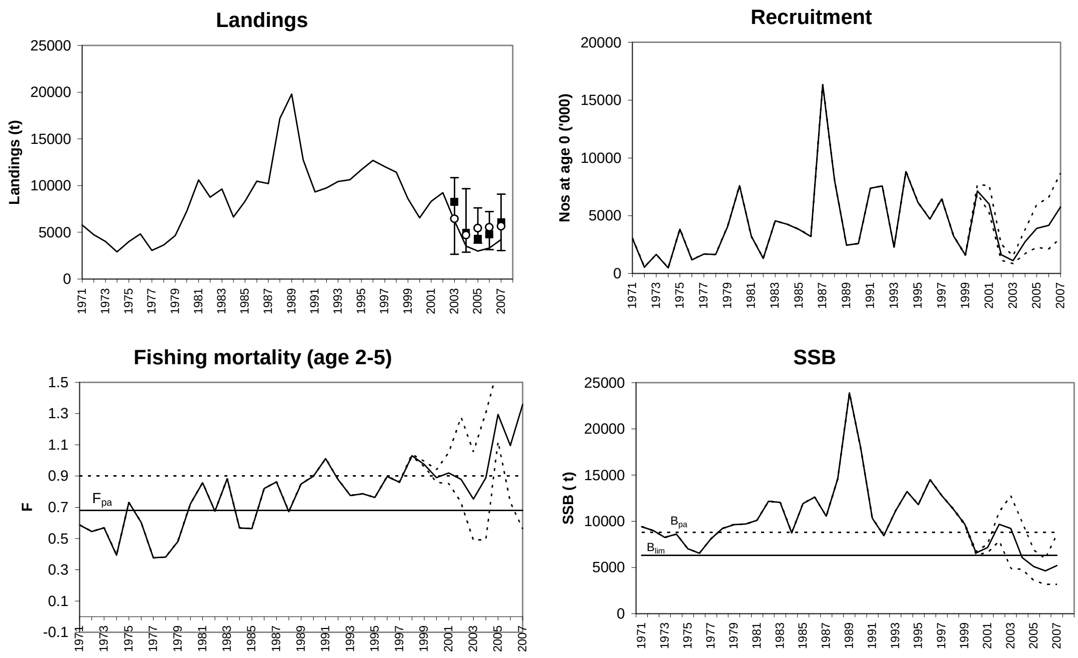

Figure 5.8.3.5: Badapt run 3: The stock summary plots for a bootstrapped assessment run with BADAPT tuning with survey data (UK and combined IBTS) only and allowing landings scaling from 2003. The dotted lines indicate 5 and 95 percentiles the solid lines on SSB, R, and F are the 50th percentile. Continuous line on landings plot is the reported landings with no high grading estimates; filled squares are landings scaled up as in XSA Run4; open circles with 90% confidence intervals are total removals estimates (in excess of assumed natural mortality) from B-Adapt.

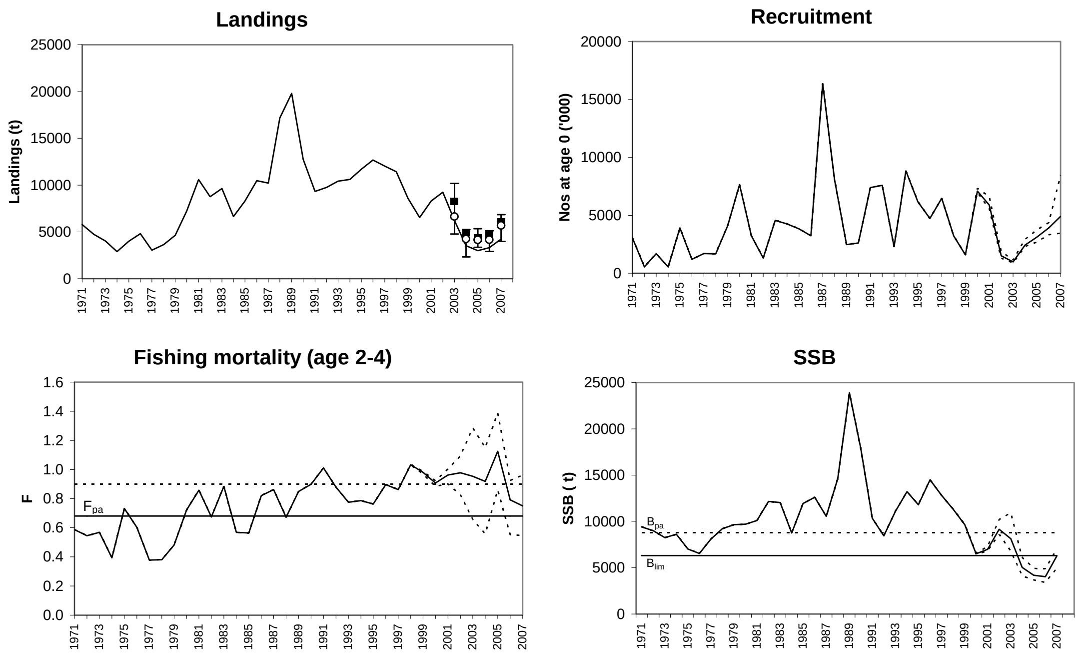

Figure 5.8.3.6: Badapt run 5: The stock summary plots for a bootstrapped assessment run with BADAPT tuning with survey data (combined IBTS index) and commercial tuning fleets and allowing landings scaling from 2003. The dotted lines indicate 5 and 95 percentiles the solid lines on SSB, R, and F are the 50th percentile. Continuous line on landings plot is the reported landings with no high grading estimates; filled squares are landings scaled up as in XSA Run4; open circles with 90% confidence intervals are total removals estimates (in excess of assumed natural mortality) from B-Adapt.

5.8.4 Evaluation of models

B-Adapt and SAM outputs (respectively runs B2 and S1) have been compared to reference XSA runs (X1 and X12). The IR-GFS, FR-EVHOE, UK-WCGFS surveys have been the only tuning fleets used in all assessments made for this inter-comparison.

XSA and B-Adapt runs follow the same pattern (Figures 5.8.4.1 to 5.8.4.3) for recruitments, SSB, fishing mortalities and catch in numbers except for the recent years (after 1998–2000). In the recent years, B-Adapt provides estimates of recruits about twice those of XSA. Fishing mortalities drop for XSA during the last years to a near Fpa level while B-Adapt is above Flim with a large confidence interval. SSB is slightly higher for B-Adapt in 2007 around Blim.

SAM outputs recruits evolve through time with lower amplitude than the two other models with a rather large confidence interval. In 2007, recruits are slightly higher than the estimate from B-Adapt. Fishing mortalities are smoothed and at the same average rates than those for XSA and B-Adapt. Confidence intervals are lower than those from B-Adapt in the recent years. SSB estimates are about the same than XSA and B-Adapt until 2002 and then while the trend is qualitatively the same than the other models, estimates of SSB are the highest and to a Bpa level in 2007.

Comparisons between predicted and observed catch in numbers-at-age between observations and SAM show (Figure 5.8.4.4) the state space model tends to underestimate catches-at-age 1 and follows quite closely observations for the others ages before 2002. From 2002, the estimates are generally twice the observations.

The result of the B-adapt, SAM and the XSA with inflated catches all suggest that fishing mortality and recruitment has been higher in recent years than the XSA with the high-graded corrected French Landings estimates. Given the uncertainties in the input catches, the group was unable to recommend a model at the time of the benchmark meeting. The prerequisite to any analytical assessment will be improved catch estimates particularly in the most recent years 2007 and 2008. This may be achieved by using diaries, discard estimate, self-sampling, etc. If reliable catch estimate can be provided in advance of the assessment WG, then it might be possible to develop an assessment that allows bias in some years but treats the catch as exact in the final year (e.g. Badapt). Further investigation of the various settings would also be needed.

Figure 5.8.4.1: Inter-comparison of recruit estimates from XSA, B-Adapt and SAM.

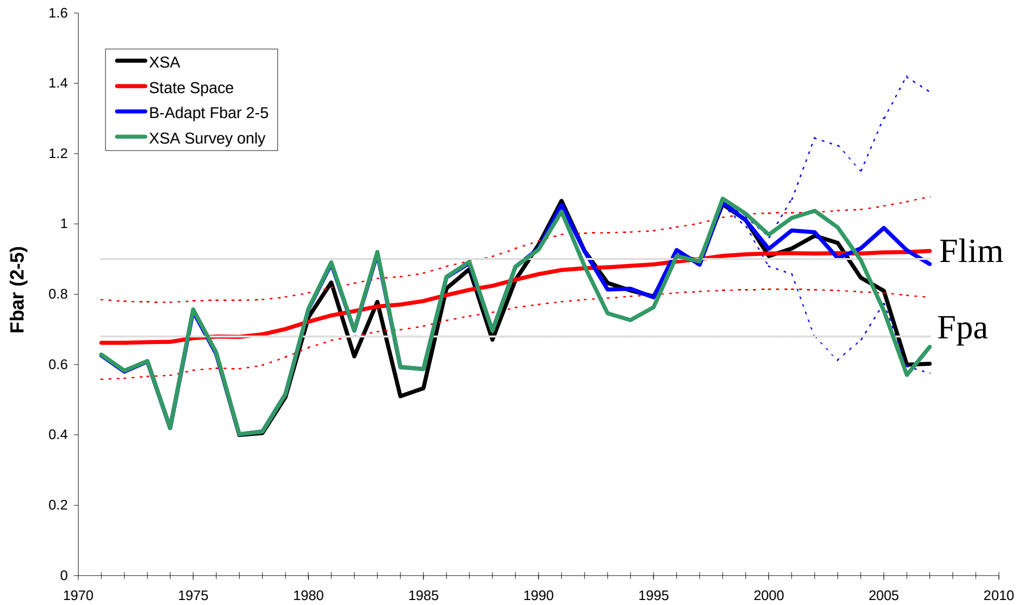

Figure 5.8.4.2: Inter-comparison of estimates of fishing mortality from XSA, B-Adapt and SAM.

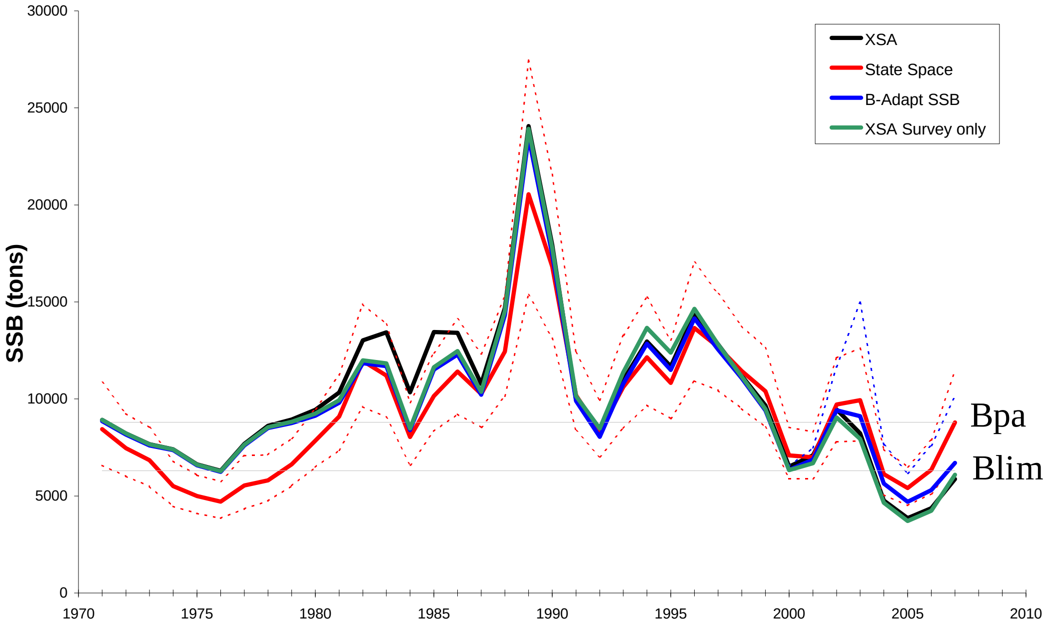

Figure 5.8.4.3: Inter-comparison of estimates of SSB from XSA, B-Adapt and SAM.

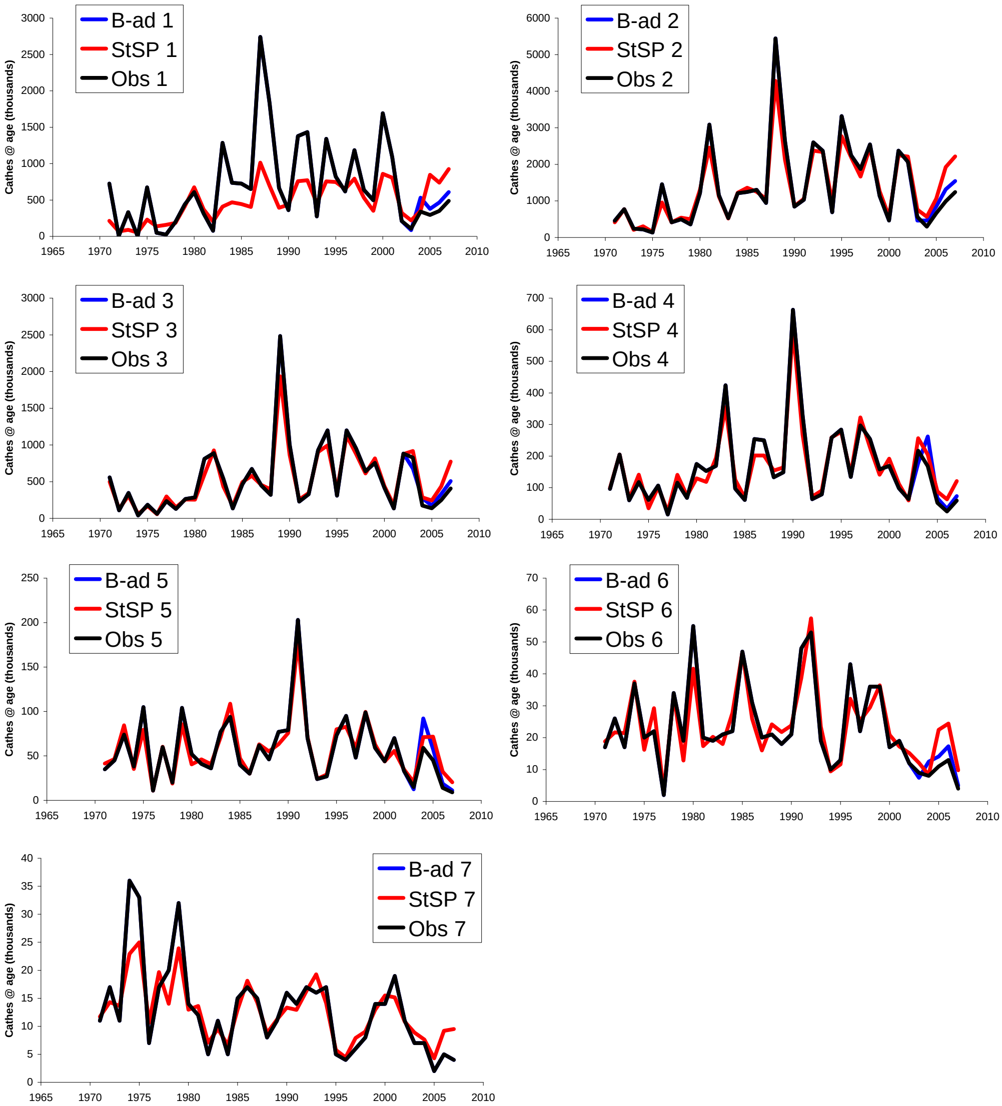

Figure 5.8.4.4: Inter-comparison of catch-at-ages estimates (B-Adapt, SAM) and observations.

5.9 Stock assessment

No change has been made to the set of procedures used for the stock assessment.

5.10 Recruitment estimation

There is no 0-group index for this stock and it is not possible to accurately estimate recruitment from the stock-recruitment relationship. Recruitment for Celtic Sea cod is poorly estimated by the available survey data and one-year-olds are landed in low numbers by the fishery. While the surveys do provide estimates of one year old fish at the end of Q4 these fish enter the fishery in Q1 the following year so there is a timing issue if this Q4 estimate of 1 year olds is to be used in catch forecast for the next year.

At WGSSDS 2008 the short term forecast (STF) was performed with an assumption that recruitment in 2008, 2009 and 2010 would be the GM of 2002-6 (ICES, 2008). Use of a longer term GM was discontinued several years ago because of its tendency to grossly over estimate catch in the forecast. The text table below summarises the typical scenario with regard to recruitment assumptions in Celtic Sea cod forecast.

	AGE0	AGE1	AGE2	AGE3	AGE4	AGE5	COMMENT
Y-3	XSA	XSA	XSA	XSA	XSA	XSA	
Y-2	XSA	XSA	XSA	XSA	XSA	XSA	
Y-1	Assumed	XSA	XSA	XSA	XSA	XSA	
Y	Assumed	Assumed	XSA	XSA	XSA	XSA	Last Year of Data
Y+1	Assumed	Assumed	Assumed	XSA	XSA	XSA	Assessment/Interim Year
Y+2	Assumed	Assumed	Assumed	Assumed	XSA	XSA	Forecast Year

In the most recent STF 31% of landings and 39% of SSB were composed of recruitment assumptions. These percentages vary between years but remain at high values. At the benchmark two options for recruitment were considered using RCT3 or using the .recruitment model described in WD 2 to predict recruitment.

5.11 Short-term and medium term forecasts

In the past when landings have increased for this stock, the STF has tended to underestimate the future landing and when landings decrease, the STF tends to overestimate the future landings (Lordan and Gerritsen, 2008). In order to evaluate the performance of the STF, retrospective forecasts were carried out by iteratively truncating the time-series of data by the most recent year, starting with 2007 and ending with 1990 and running an XSA with the same settings as the final assessment of WGSSDS 2008. Because of the short duration of the survey indices and the IR7jOT, these had to be removed from the tuning fleets. The remaining tuning fleets were FRGADOID, FRNEPHROPS and UKWECOT.

For each of the retrospective XSAs a two-year STF was performed using the same settings as WGSSDS, except for the recruitment assumption. Four different recruitment assumptions were applied to the STF.

- (i) 3 year GM, omitting the most recent year.
- (ii) 3 year GM, replacing the recruits from the retrospective XSA with the converged recruit numbers from the most recent assessment.
- (iii) Replacing the recruits from the retrospective XSA with the converged recruit numbers from the final assessment including the 'future recruits'. E.g. for the 2003 retrospective STF, the recruits for 2004, 2005, 2006 were used from the most recent assessment.
- (iv) Replacing all recruits with modelled recruit numbers (for the full time series, so also into the future). Lynam *et. al.* (Working Document).

The STF with the 3 year GM assumption tends to predict landings that lag behind the actual landings by 1 or 2 years (Figure 5.11.1). Using the converged recruits in combination with the 3 year GM does not increase the performance of the STF much. However, substituting the future recruitment with the converged recruits from the most recent assessment does appear to result in better forecasts, illustrating the sensitivity of the landings prediction from future year classes to the recruitment assumptions. In recent years landings were still over-estimated due to the fishing mortality assumption in the STF. The quota became restrictive around 2003 so it is likely that recent catch figures are not accurate (WD 3). Substituting all recruitment numbers with modelled values (WD 2) does not result in a clear improvement in STF performance.

Uncertainty around the recruitment figures plays an important role in the STF. However, substituting the recruitment figures from the retrospective XSA with the converged figures does not improve predictions much. Only if the future recruitment is known (option 3) does the STF perform well. The GM assumption for future recruitment is also important. The model used to predict recruitment from sea surface temperature and *Calanus helgolandics* abundance does not perform better than the current approach and it is unlikely that the parameters for the model can be predicted with any accuracy.

In conclusion, the current WG practice of using a recent average recruitment for the STF is currently the best option for this stock as it results in the least biased forecast of landings and SSB. There has been some variation in the numbers of years to select. If y is the last year of data the recruitment should be an average of age 1 from y-1 to y-3.

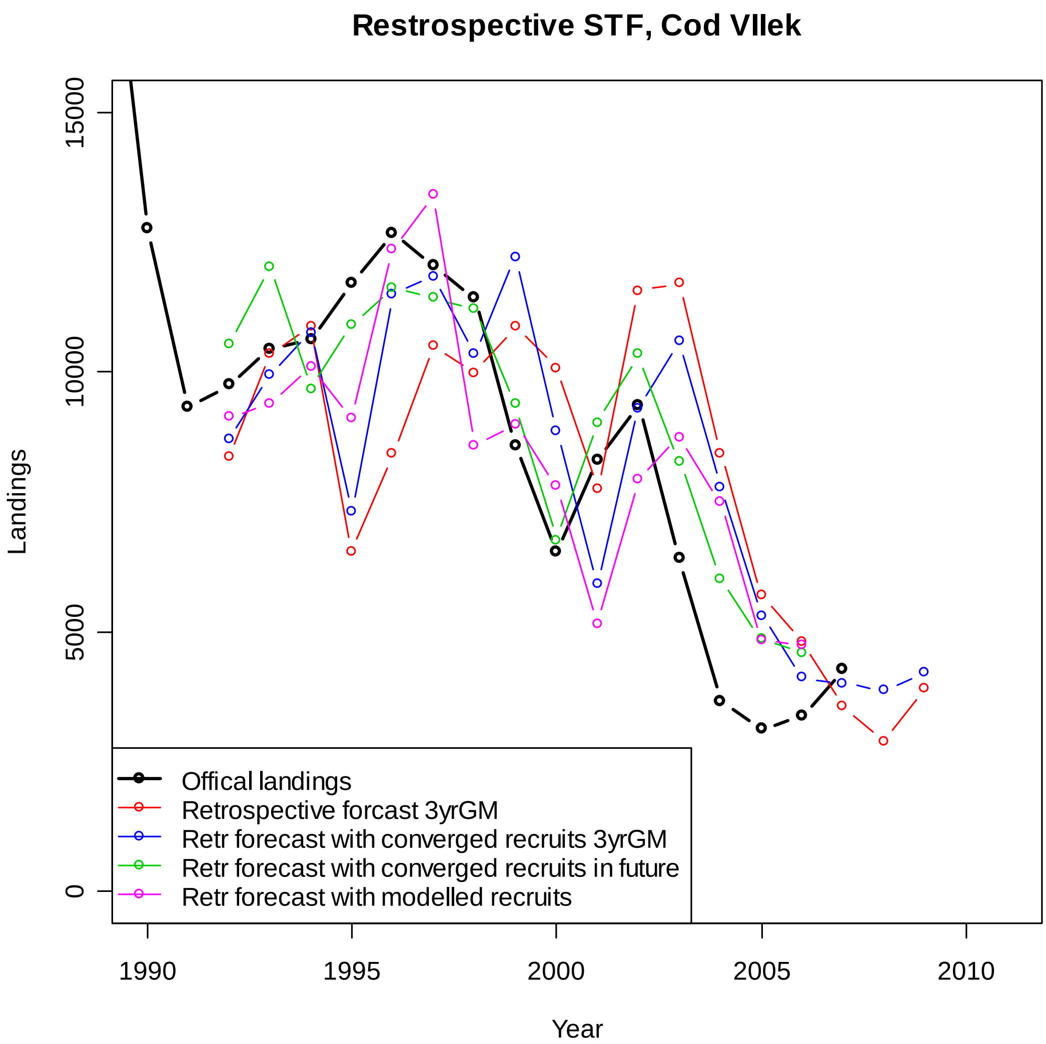

Figure 5.11.1: Landings of Cod in VIIe–k and the retrospective short-term forecasts (2 year forecast) with various recruitment assumptions.

No medium term projections were carried out at the meeting. Previously CS5 and the MLA software were used to carry out medium term analysis. Given the sensitivity of such simulations to the starting vectors it was not considered worthwhile to carry out such an analysis until the assessment inputs can be improved.

5.12 Biological reference points

The table below summarized the reference point proposals and technical basis to date and the values adopted by ICES.

REF. POINT	ACFM 1998	WG 1999*	ACFM 1999	WG 2004	ACFM 2004
Flim	0.90 (Floss WG98)	0.90 (history WG99)	0.90 (history WG99)		0.90 (history WG99)
Fpa	0.68 (5th perc Floss WG98)	0.65 (Flim*0.72)	0.68 (5th perc Floss WG98)		0.68 (5th perc Floss WG98)
Blim	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)
Bpa	8000 t (Blim*1.65)	9000 t (Blim*1.65)	10 000 t (history)	Reject – no SR relation	8800 t (Bpa = Blim * 1.4)

***The maturity ogive was changed in the WG of 1999.**

The current biological reference points seem consistent with the current status of the stock. However, recent estimates of proportions of mature individuals at age suggest maturity may occur at younger age but due to a low number of individuals used for the estimates and geographic aggregation of the available information, those estimates are uncertain. Therefore, there is no solid reason to suggest a change of biological reference points without further investigation about a possible change in maturity. If maturity is proven to have changed in the future, biological reference points may need to be revised.

5.13 Recommendations

There has been a recent deterioration in the quality of assessment input data for this stock. Various corrections have been proposed to correct data for high grading in the French fleet. In the interest of transparency and consistency these procedures need to be clearly documented in the stock annex. We can expect deviations from these over time but these will need to be documented in the EG reports.

A check list describing data provision and raising procedure needs to be developed to catalogue the approach to aggregation of historical assessment data. Data integration and integrated fishery descriptions at a regional level need to be developed for the Celtic Sea eco-region. This could be facilitated by the development of a regional database (e.g. FISHFRAME) in which disaggregated sampling and fishery data could be housed. This database is expected in the next 1–2 years and will greatly help quality assurance and transparency required in the annex.

5.14 Recommendations on the procedure for assessment updates

Considering the above and the results from the inter-comparison between XSA and alternative models, it is clear that the current assessment procedure which treats the catch numbers as unbiased is no longer appropriate. Unfortunately the stock annex can not be updated with definite assessment model and procedures to use in future. Models like Badapt and SAM highlight the considerable uncertainty in stock parameters (ie. F, SSB and R) when not constrained by reliable catch-numbers-at-age or a coherent tuning index. The way forward for the assessment in the short to medium term will require accurate catch statistics to be reintroduced into the assessment.

Recommendations for future work on assessment related issues:

- There needs to be an evaluation of sampling levels by fleet required to derive sufficiently precise discard estimates for stock assessment.
- Most countries supply discard data to the WG but sampling levels are low and variable for the main fleets catching cod. Discard rates are also highly variable and changing in response to recruitment and management. There may be scope to develop co-operative projects with industry on self sampling, reference fleets, etc.
- Reported landings data and "landings equivalents" since 2003 are considered to be underestimated. It may be possible to estimate unbiased landings levels from diaries or other sources. This is a major source of uncertainty in the assessment and requires a high priority due to the low stock level.
- There is evidence from sampling on the Irish "biological survey" that maturity has changed for this stock. The new estimates increase SSB by up to 20% which is significant and warrants future sampling to obtain improved estimates of maturity-at-age. There is no routine survey during Q1 to provide annual maturity estimates for this or other stocks in the Celtic Sea. Collecting maturity data from commercial fleets will introduce bias and not appropriate to the assessment. RCM should consider international co-ordination of maturity sampling and whether a directed survey might be needed. Q1 catch weights might also be improved with a directed survey.
- Tagging (particularly data storage), genetic, otolith microchemistry and other tools have been applied to give better understanding of the cod stock in the North Sea and Baltic. The stock structure and migration behaviour of cod in the Celtic Sea is not as well studied. This may have significant importance in developing management for the stock particularly in relation to current and potential closed areas. The RCM should consider whether a regionally co-ordinated tagging programme could be developed for this stock.
- The noise in the data from the surveys should be reduced which may require additional surveys.

5.15 Industry-supplied data

5.15.1 Types of data

The members of the working groups, composed of both scientists and representatives of some fishing organisations emphasize the need of an international collaborative effort on self-sampling. Further dialogue between scientists and fishing organisations is needed to define what type of information could be provided by the industry considering the necessary trade-off required between the usefulness of collection of data for the knowledge and assessment of the stock and the practical constraints (e.g. time required at sea for sampling) of providing such information.

The group recommends the pursuit of the French self-sampling program and its extension to a higher number of fishing vessels. Other countries are also encouraged to participate in such a program. Suggested data are length distributions from onboard sampling from both retained and discarded portions of the catches.

The industry is also encouraged to provide additional information about past discards as well as potential changes in the fishing practices (including changes in fishing gears, areas).

5.15.2 Impact of provision of such data

The expected impact of such data is a reduction of uncertainties regarding discard practices (small discard and high-grading) and misreporting which are the major sources of uncertainties in the assessment.

5.16 References

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Stock Annex Celtic Sea cod

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 January 2009

Revised by Robert Bellail, 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. The area assessed has gradually increased from VIIfg before 1994 to VIIfgh, to VIIefgh in 1996 and finally to VIIe–k.

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.

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, WD3). 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.

Migrations are known to occur in this cod stock. Cod can be caught throughout the English Channel (ICES areas VIId and VIIe) in autumn (quarter 4) and winter (quarter 1), being more aggregated during the spawning season in January/February. Electronic tagging experiments in the English Channel (VIId and VIIe) have shown that cod tagged on or close to English Channel spawning grounds in quarters 4 and 1 either remain close to the point of release (residency), or move to feeding grounds to the south and/ or west. Smaller fish (<50 cm) are more likely to be resident. Migrants tend to move offshore to deeper areas, whereas the habitat selection of residents is less clear-cut.

In the light of the migratory phenotypes identified by electronic tagging, historic mark-recapture experiments can be re-evaluated. Although sample size is limited, results from data on the movements of adult cod (>50 cm) show that, after tagging in VIIe (the western Channel) in quarters 1 and 4 , 47% of cod (27 of 58) are recaptured in ICES areas VIIf through VIIj, while 48% are recaptured in VIIe (i.e. are probably resident). In contrast, no adult cod tagged in VIId were recaptured in ICES areas VIIf through VIIj, 5% moved into VIIe and 51% remain in VIId. Juvenile cod are more likley to be recaptured in the same area that they were tagged in. These figures vary slightly when recaptures are separated into autumn/winter and spring/summer seasons, but are broadly comparable. The data therefore provide evidence that cod in the eastern English Channel and western English Channel might be classed as separate sub-stocks, and that movement of cod between eastern English Channel and the Celtic Sea is limited, whereas movement between the western Channel and the Celtic Sea is frequent.

A.2. Fishery

Cod in Divisions VIIe–k are mainly taken as components of catches in mixed demersal trawl fisheries with a minor part by gillnets. 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 led the landings to spread across the first-3 quarters of the year.

WGSSDS has been collating a database of landings and effort for the Celtic Sea. Available data on cod landings are analyzed and presented. Effort data is not yet fully available for similar investigations. Recent temporal and spatial patterns in landings distributions for the main fleets catching Celtic Sea Cod are shown in Figure A.2.1 and Figure A.2.2. Highest landings are in quarter 1 when the cod aggregate to spawn. There is an indication that Q1 landings have declined in 2006 and 2007 as a result of the closure of a known spawning area at Trevose Head, although this was not the case in 2005 the first year of introduction of the closure. In most years there is a distinct peak in landings in February or March. The scale of this peak may be related to the relative strength of age 2 fish entering the fishery. The majority of the landings come from VIIg, ~55%, and the relative contributions of different ICES Divisions to the landings has been fairly stable over recent years. In 2002 there were larger than normal landings from rectangle 30E4 in VIIf.

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 has been from gillnets and otter trawls targeting *Nephrops* and benthic species.

A.3. Ecosystem aspects

No environmental drivers are known for this stock.

B. Data

B.1. Commercial catch

Landings

On a quarterly basis, France and UK (E+W) have provided catch numbers-at-age and catch weights-at-age for their landings. Ireland has provided with the same data in Divisions VIIg and j separately and estimates of misreporting in VIIg. Landings only are available for Belgium.

Irish data are first aggregated to the landings in VIIe–k and then both datasets for France, UK and Ireland are added 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.

Discards

Discards data sampled under EU/DCR since 2003 have been generally presented in previous WGSSDS 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, high grading 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 high grading 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 high-grading rates. Assuming the same pattern of discarding in recent years, estimates of French discarding and high-grading back to 2003 were also computed. Estimates of high grading were also calculated for the French tuning fleets used in the analysis (ICES WKROUND, 2009, *WD 17)*.

Lpue

The table below summarizes the available data.

NAME	AREA	SERIES
FR gadoid fleet 1	VIIfgh	1983–2007
FR Nephrops fleet 1	VIIfgh	1983–2007
FR otter trawlers 2	VIIe	1983–2007
FR otter trawlers 2	VIIfgh	1983–2007
FR otter trawlers 2	VIIe–k	1983–2007
UK otter trawlers	VIIe	1972–2007
UK otter trawlers	VIIe–k	1972–2007
UK beam trawlers	VIIe–k	1978–2007
IR otter trawlers	VIIg	1995–2007
IR beam trawlers	VIIg	1995–2007
IR Scottish seiners	VIIg	1995–2007
IR otter trawlers	VIIj	1995–2007
IR beam trawlers	VIIj	1995–2007
IR Scottish seiners	VIIj	1995–2007

[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 data sets. Since 2002, VIIe–k catch weights-at-age have been calculated as the annual weighted means of French, Irish and UK datasets.

Stock weights-at-age are the catch weight-at-age data from the 1st quarter.

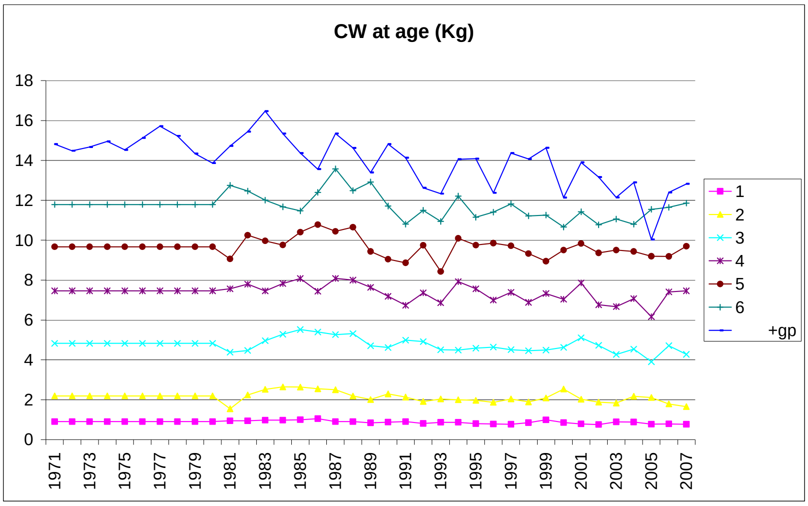

Figure B.1.1: Cod in VIIe–k. Series of mean weights-at-age in the catch (landings). The decreasing trend-at-age 7+ is due to both the lower catch numbers in this component and the variable proportion from year to year of the oldest true age groups in the + group. In 2005, only Irish datasets provided with this age group in a large amount during the 1st quarter with low mean weight. Values 71–80= average value 1981–2000.

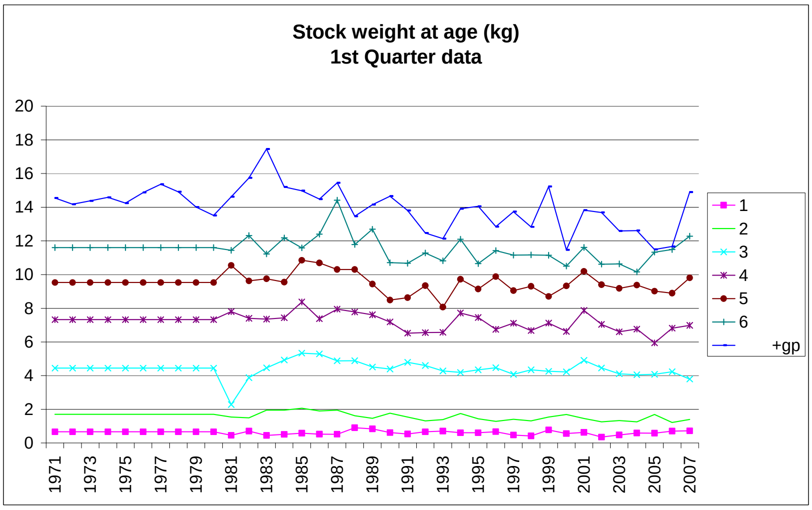

Figure B.1.2: Cod in VIIe–k. Mean weights-at-age in the stock (1st quarter value of landings-at-age).

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. 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 (M=0.2) for the whole range of years and ages.

B.3. Surveys

Three surveys series are available. The common range of ages used is 1–5:

The discontinued UK-WCGFS (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 for calibration.

The FR-EVHOE survey (1997–2008), during the 4th quarter, covers the Divisions VIfghj. The full series is used.

The IrGFS survey (2003–2008), during the 4th quarter, in VIIg and VIIj is also used in the assessment. It is the main contributor to the terminal year estimates, partly because this series is short.

The absolute numbers of cods caught in all of these surveys are extremely low.

B.4. Commercial cpue

Two French commercial fleets are used for tuning: the French trawlers targeting Gadoids in Divisions VIIf, g, h (FR-GADOIDS) and the French *Nephrops* trawlers in VIIf,g,h (FR-NEPHROPS), for which cod is generally a bycatch. Both fleets account on average for ~30% of the international landings from 1988; the series starts in 1983. Other commercial fleets used are the English West Coast otter trawlers (UK-WECOT) in VIIe from 1988 and the Irish 7J otter trawlers (IR-7J-OT) in VIIj from 1995. Both fleets fish throughout the majority of the assessed area.

B.5. Other relevant data

Input from industry.

No new data sets.

C. Historical stock development

Model used:

The Separable VPA was used at the former Irish Sea and Bristol Channel WG and the Laurec-Shepherd model in the period 1987–1992. The XSA was the model used subsequently. SURBA was also used for survey catch-at-age analysis in 2005–2007.

Corrections for some misreporting estimates have been input to the datasets used in the assessment but the change of discarding practices to manage the restricting national quotas may impact the assessment. This also affects the reliability of the commercial tuning fleets used.

In previous assessments (2006, 2007 and 2008), adding the new year's data has generally raised the stock numbers at younger ages (ages 1 and 2) resulting in increased estimates of recruitment strength. These upwards revisions are considered a result of the recent high grading practices. Given this uncertainty and the recent reports from the industry of under-reporting the XSA assessment, which assumes unbiased catch data cannot be applied. Improved datasets on landings, recorded and high grading, are required before XSA could be used.

WKROUND (2009) evaluated XSA with adjusted recent catch levels against B-Adapt and the SAM state-space model, which estimate additional unallocated mortality. All models exhibited different patterns in the recent years with a high degree of uncertainty. The group concluded that no model could be recommended as a basis for providing advice on recent stock trends until further investigations or additional data sets were available to resolve the situation.

D. Short-term projection

No decision has been taken on the forecast methodology.

E. Sensitivity analysis and medium-term projections

Medium-term forecasts are not provided for this stock.

F. Long-term projections

Long-term forecasts are not provided for this stock.

G. Biological reference points

Reference points

	Type	Value	Technical basis
Precautionary approach	B_{lim}	6 300 t	$B_{lim} = B_{loss}$.(B76), the lowest observed spawning-stock biomass.
	B_{pa}	8 800 t	$B_{pa} = B_{lim} * 1.4$. Biomass above this value affords a high probability of maintaining SSB above B_{lim}, taking into account the variability in the stock dynamics and the uncertainty in assessments.
	F_{lim}	0.90	The fishing mortality estimated to lead to potential collapse.
	F_{pa}	0.68	F_{pa} = 5th percentile of F_{loss}. This F is considered to have a high probability of avoiding F_{lim} and maintaining SSB above B_{pa} in the medium term (assuming normal recruitment), taking into account the uncertainty assessments.
Targets	F_y	Not defined.	

(unchanged since: 2004)

Due to the current uncertainties on the state of this stock, the Benchmark WK is unable to make new proposals for the Reference Points and the 2004 values remain.

H. Other issues

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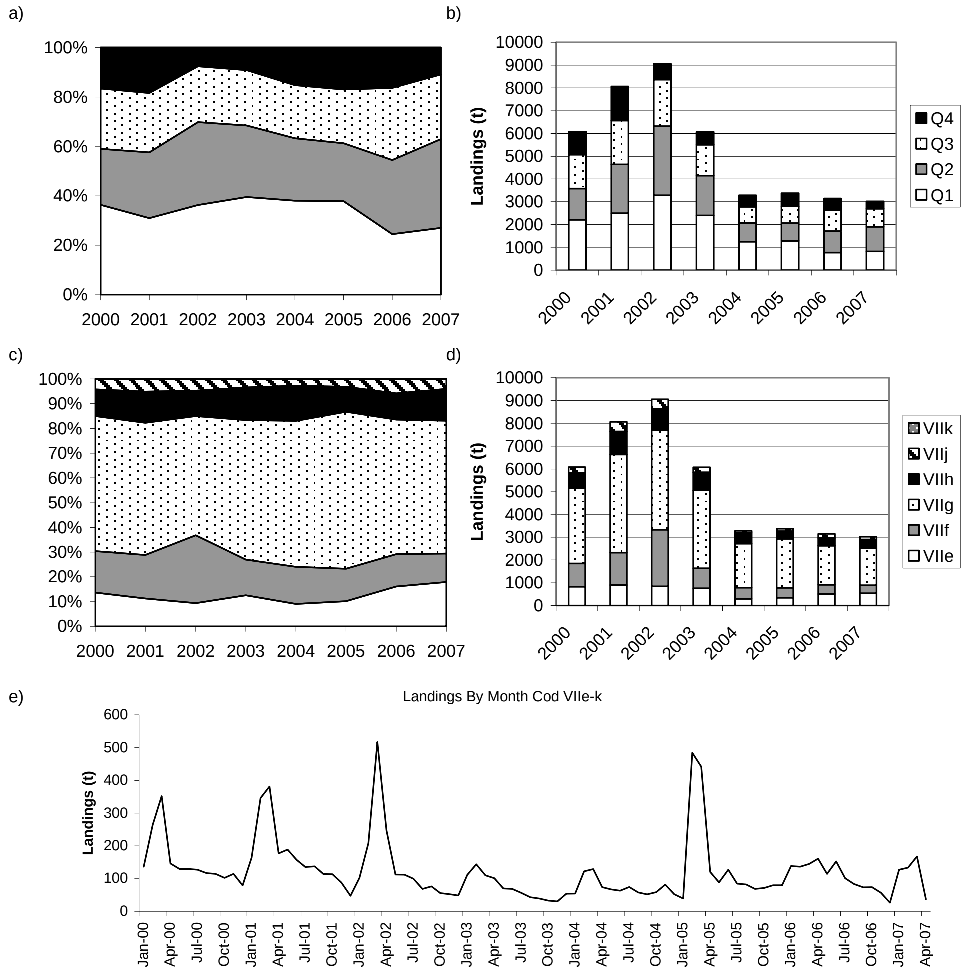


Figure A.2.1 Temporal and spatial patterns in landings patterns for Celtic Sea Cod (VIIe–k).

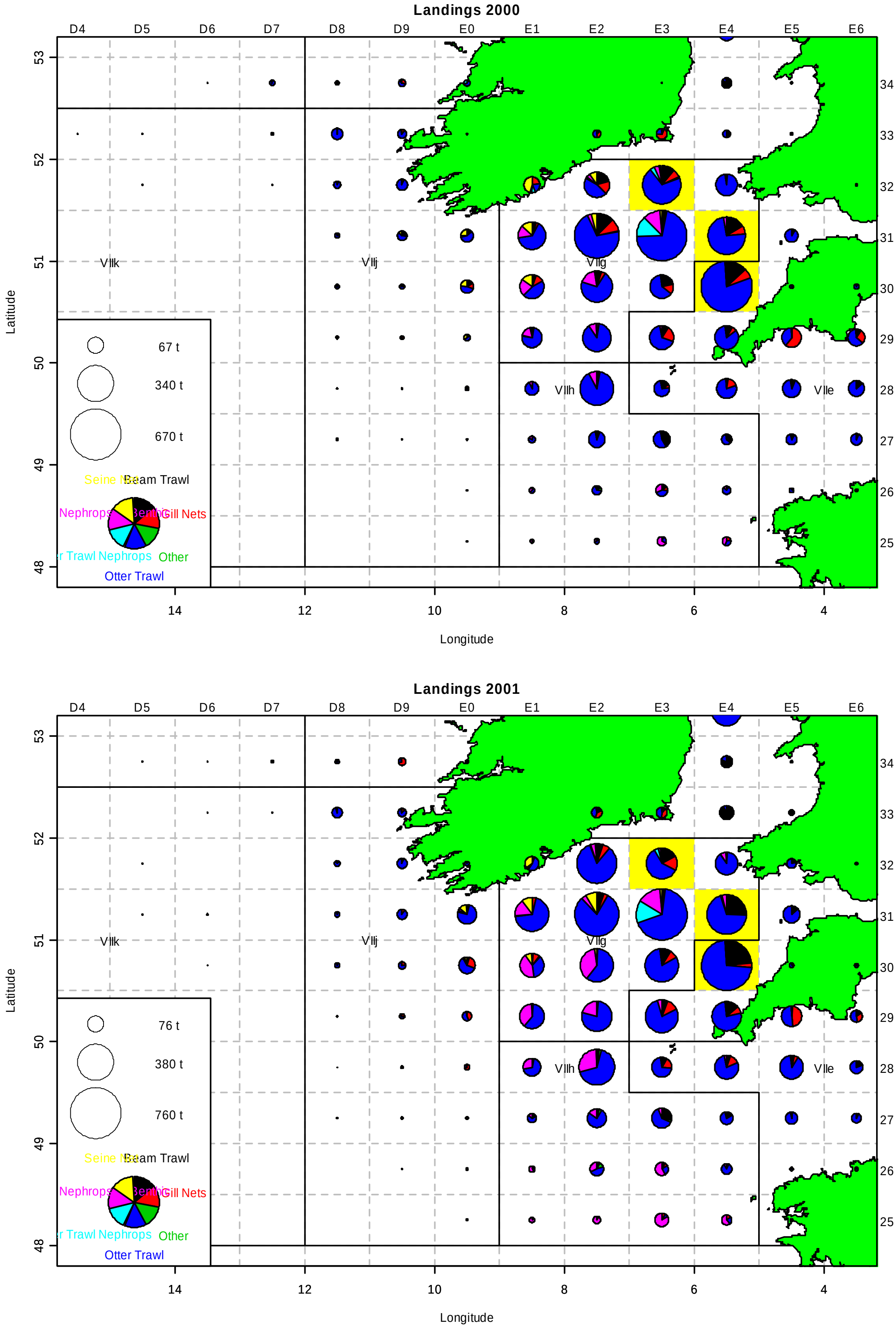
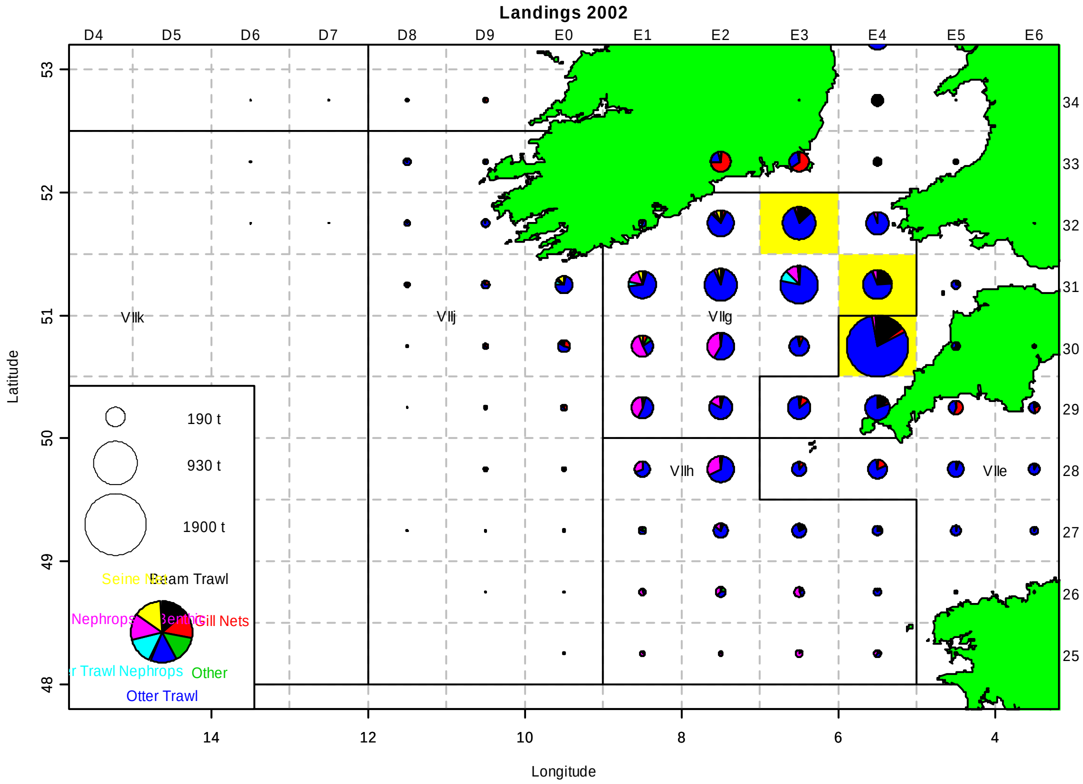
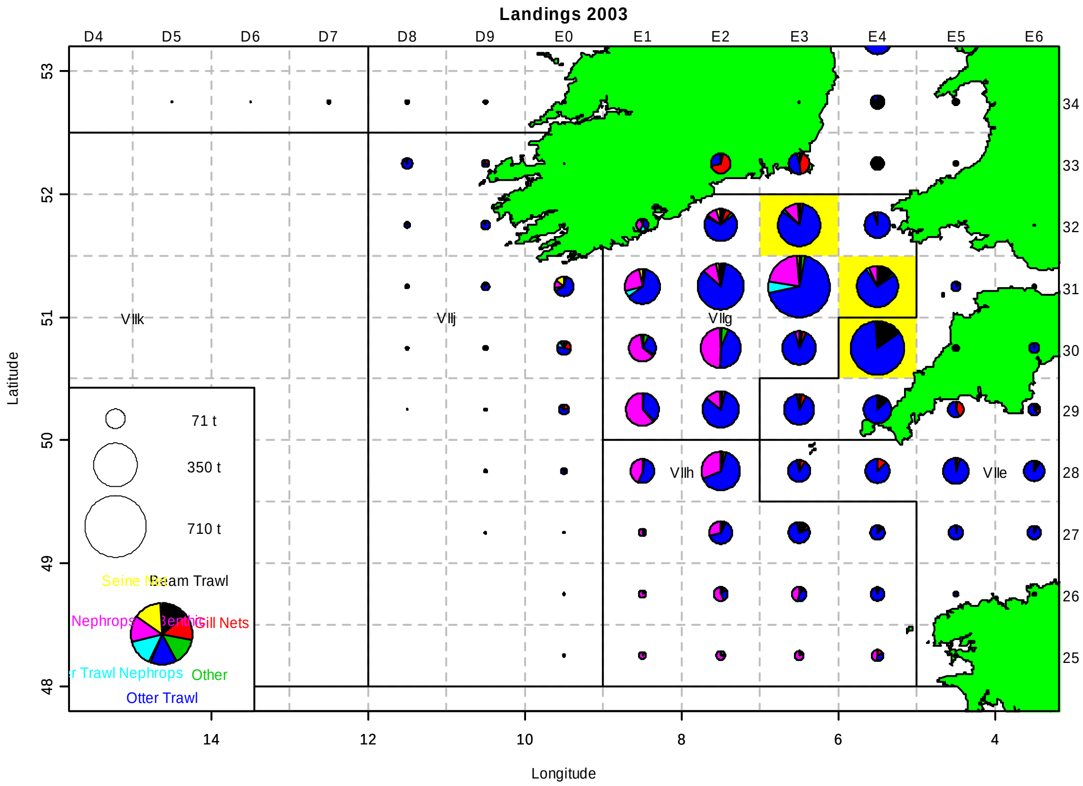


Figure A.2.2 The spatial and temporal disribution of Cod landings from the Celtic Sea, from 2000–2007 by gear type. The Closed rectangles are highlighted in yellow. Each year is scaled to, the maximum.





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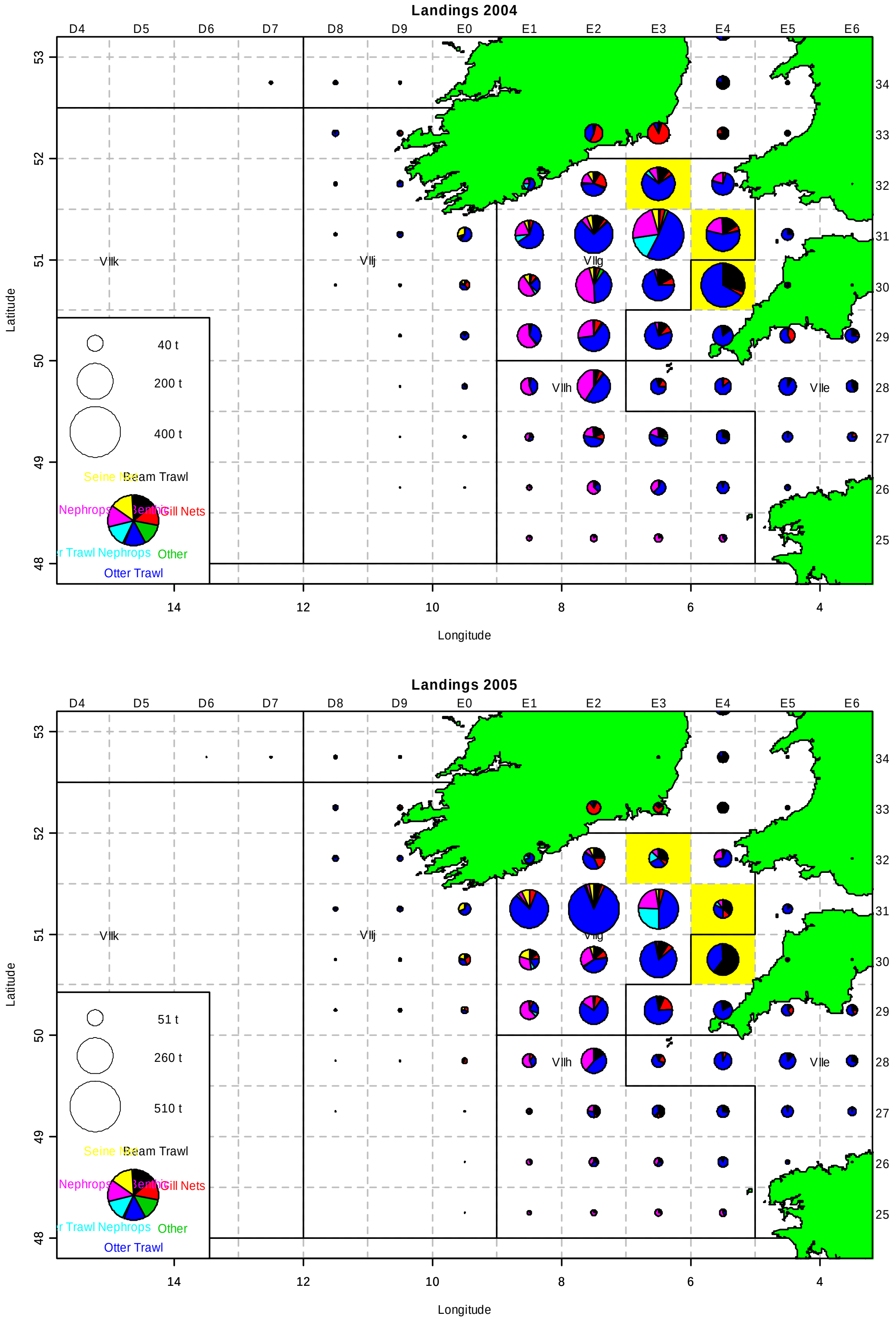

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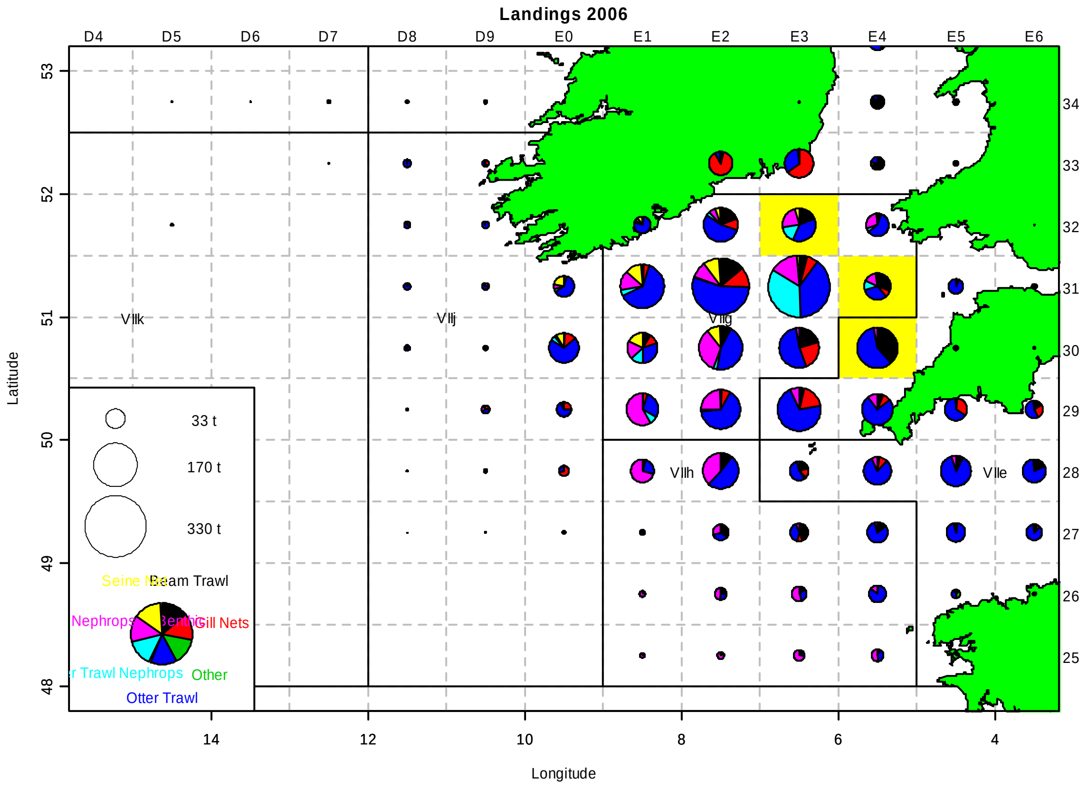

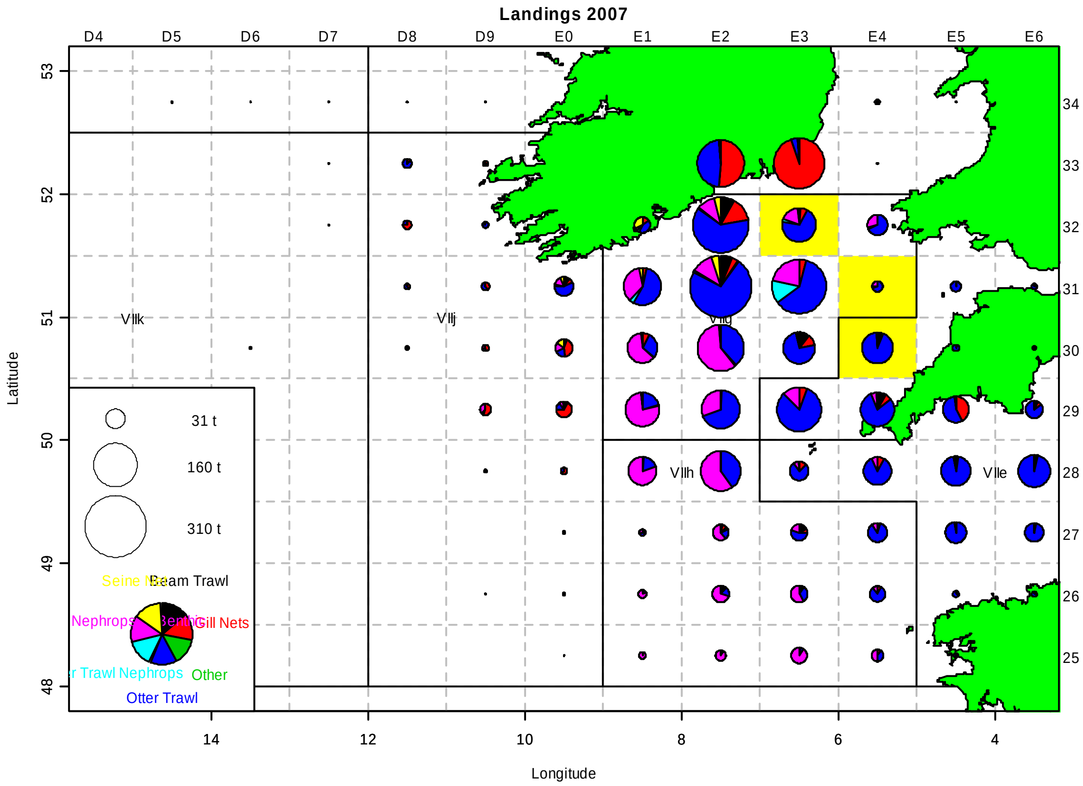

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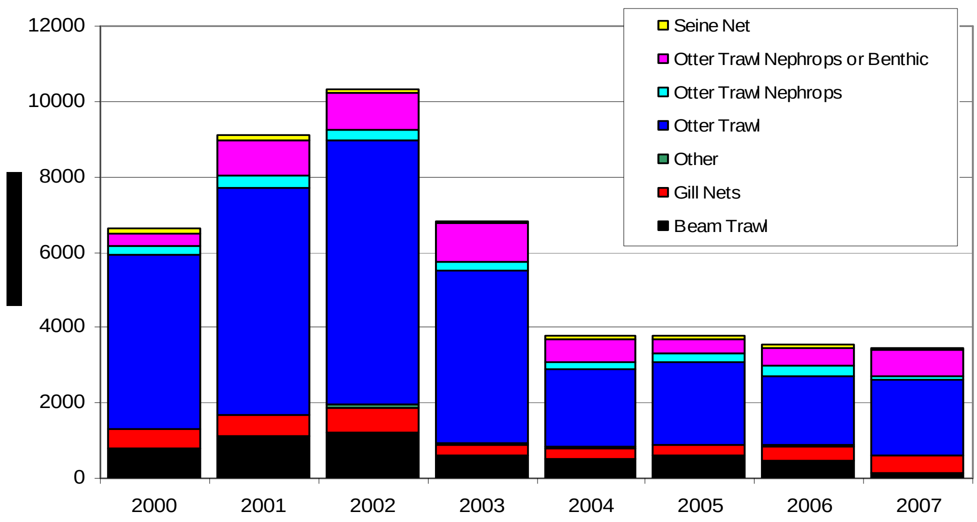


Figure A.2.2 continued.

6 Cod in Division IIIa East (Kattegat)

6.1 Current stock status and assessment issues

The quality of assessment in recent years has deteriorated mainly due to uncertain catch data and the assessment has not been accepted by ICES since 2004. The assessment is considered indicative for trends. The SSB has been on a historically low level since the late 1990s. The estimates of mortality do not indicate major changes in the last five years; the removals from the stock in recent years are indicated considerably higher than the reported landings. Recruitment has been at a low level in recent years; the value for 2007 is indicated to be among the lowest in the time series.

Presented Working Documents relevant for Kattegat cod assessment:

Working document #9: Kattegat Cod survey

Working document #14: State-space fish stock assessment model as alternative to (semi-) deterministic approaches and stochastic models with a high number of parameters.

6.2 Compilation of available data

6.2.1 Catch/landings data

Data on reported landings is available since 1971. No discard information is included in the assessment

6.2.1.1 Evaluation of the quality of the catch data

Catch data are considered uncertain for recent years due to restrictive TACs. Discard data are not included in the assessment due to high uncertainty (further details are provided in Stock Annex). Information from discard sampling indicates that discarding is a major problem especially concerning age-group 1. Changes in size composition of Danish cod landings, i.e. sharp reduction of smallest size category and respective increase in landings of larger fish in recent years may be partly due to high-grading (Figure 6.1).

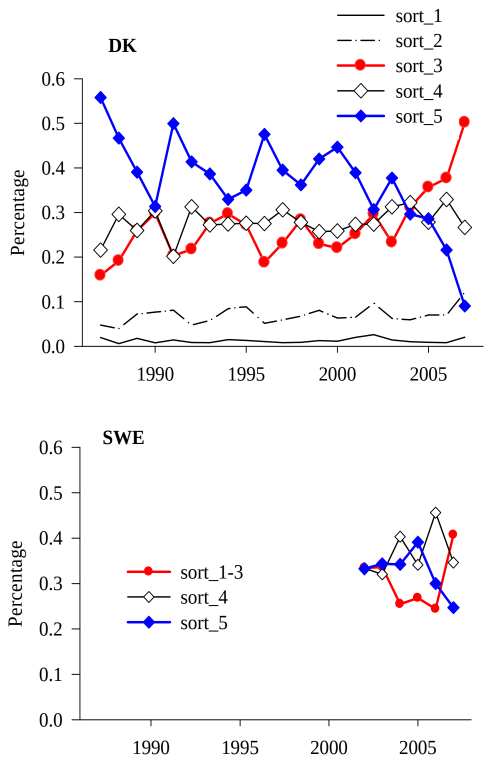


Figure 6.1. Cod landings of Danmark and Sweden by sorting categories.

6.2.2 Biological data

Annual estimates of weight-at-age in the stock and maturity ogives are available from IBTS 1st quarter survey.

6.2.2.1 Evaluation of data quality

Precision of biological sampling in DCR requirements by EU Commission:

(details available in: COMMISSION DECISION of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy (2008/949/EC).

According to above mentioned EU Decision 949/2008 the national sampling programmes shall include estimation of precision on the collected data, if the sampling cannot be defined by a quantitative target, such as sample size or sampling rate.

Where reference is made to precision the following levels shall apply:

Level 1) +/- 40% for a 95% confidence level or CV of 20%

Level 2) +/- 25% for a 95% confidence level or CV of 12.5%

Level 3) +/- 5% for a 95% confidence level or CV of 2.5%

The COST (Common Open Source Tool) is addressing how to estimate precision in an EU project running from 1 July 2007 until 31 December 2008 (. They will develop methods to investigate and estimate sampling indicators for discards, length and age structure of catches and landings and biological parameters such as growth, maturity and sex- ratio from all the regions covered by the DCR.

The outcome of COST will be implemented by national sampling programmes in future and the procedure for implementing will be evaluated in future benchmark assessments.

Histological analyses have shown that maturity ogives especially for younger ages are overestimated (Vitale *et al.*, 2005, 2006). Problematic issues concerning the maturity scale applied during IBTS surveys until 2007 have also been identified. These are described in further detail in Stock Annex.

6.2.3 Survey data

Relative abundance indices available and used in the assessment are the following:

IBTS q1 1983–2008 (excl. 1994) ages 1–6

IBTS q3 1991–2007 ages 1–4

Havfisken q1 1996–2007 ages 1–3

Havfisken q4 1994–2007 ages 1–3

This selection of tuning indices has been used in previous assessments and no change to this was made during benchmark workshop.

In December 2008 a joint Swedish-Danish cod directed survey was initiated in Kattegat, in cooperation between fishers and scientists. In total 80 trawl hauls were made. Two attempts were made to estimate absolute biomass of cod based on this survey, based on either a simple swept area method or using a GAM modelling approach. The biomass estimates were generally in line with the result from the assessment, indicating a very low stock level (WD 9).

6.2.3.1 Evaluation of data quality

Quality of survey data was evaluated based on consistency analyses within and between the surveys. For younger age-groups, similar patterns were observed for all four surveys both in internal consistency analysis as well as between surveys, i.e. all time series are relatively noisy but contain information that is to a certain extent consistent between years within individual surveys and agree on the same level with estimates from other surveys.

6.2.4 Industry/stakeholder data inputs

No new input data by industry/stakeholder was provided.

6.3 Stock identity and migration issues

Available information on stock identity and migration patterns has been reviewed and an extended overview is provided in Stock Annex. The issue of most concern for the assessment is related to inflow of recruits into the Kattegat from North Sea/Skagerrak and their return migration at maturation.

Since the beginning of 2000s, abundance of 0-group cod in the IBTS 3rd quarter survey has declined sharply south off 57º N. To the opposite, north off 57º N, the level of recruitment shows inter annual variation but no trend during the same period of time (Figure 6.2 a). The differences in recruitment patterns are probably due to an inflow of recruits from the Skagerrak/ North Sea into the northern Kattegat, whereas south off 57º N the decline in local recruitment has much higher impact on the abundance of juveniles. The proportion of recruits of North Sea/Skagerrak origin is thus indicated to have increased in recent years.

Tagging studies have shown that cod leave the Kattegat at the age of maturity for the Skagerrak or North Sea, i.e. indicating the existence of return migration at ages 2–3 (Svedäng *et al.*, 2007). Such a conclusion has been reinforced by genetic studies conducted on recaptured cod whose migratory patterns have been possible to elucidated (André *et al.*, manuscript).

In other words, an increased proportion of return migrations to the Skagerrak/North Sea due to the decline of the Kattegat cod might be taking place. Inspection of the ratio in mean cpue between the areas south and north of 57º for age groups 1and 3, is illustrative in this sense (Figure 6.2.b). The ratio for age group 1 (based on IBTS in first quarter of the year) declined drastically during the 1980s, and thereafter increased during the 1990s, i.e. showing the same evolution as SSB in the Kattegat. During 2000s, this ratio has declined even more profoundly than in the 1980s and is now on a very low level. On the other hand, the ratio for age group 3 (based on the IBTS in the third quarter in order to avoid effects of internal migration patterns within the Kattegat due to spawning) from 1991 and onwards shows no clear trend. This observation gives a circumstantial evidence that an increased proportion of cod of Skagerrak/North Sea origin actually may inflict on the estimate of fishing mortality.

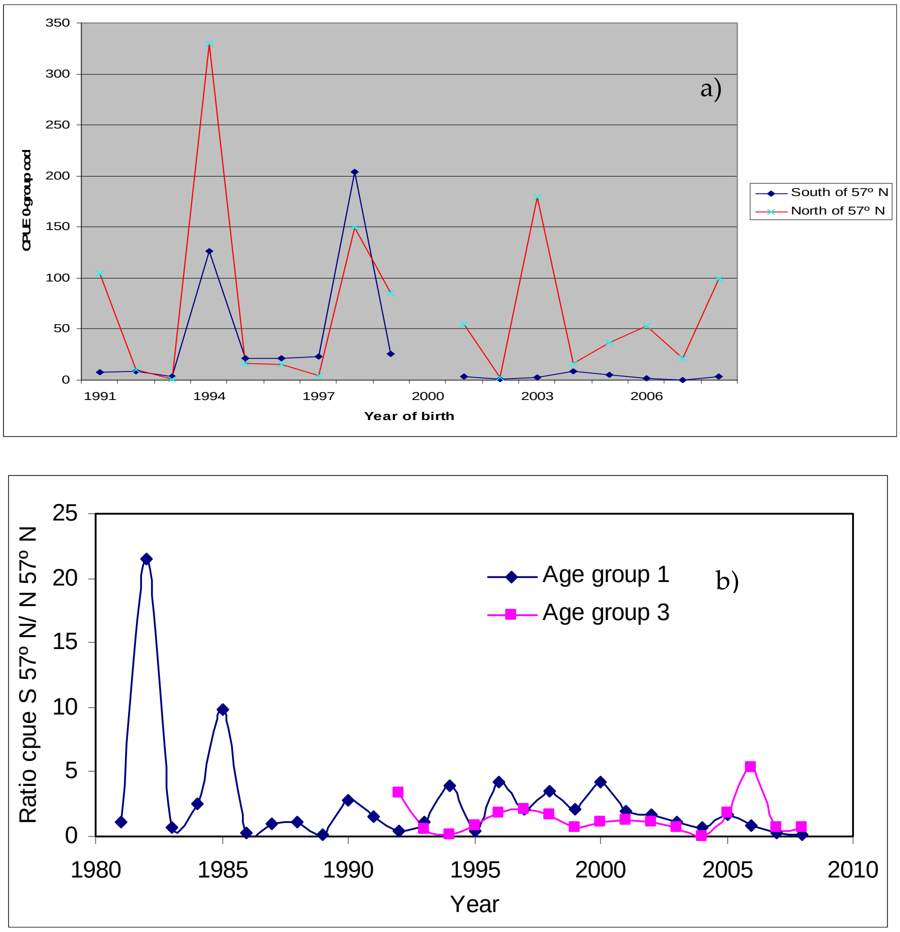


Figure 6.2. a) Mean cpue of 0-group cod in the IBTS third quarter survey in the Kattegat north and south of 57º N. b) The ratio in mean cpue between the area north and south of 57º for age groups 1 and 3, respectively. For age group 1, estimates refer to IBTS Q1, and for age group 3 to IBTS Q3.

6.4 Spatial changes in fishery or stock distribution

Spatial changes in fishery or stock distribution is currently not considered an issue for the assessment. Large spatial changes in fishery are expected to take place since 2009 in relation to the implementation on seasonal and permanently closed areas.

6.5 Environmental drivers of stock dynamics

Major environmental influence on the dynamics of cod in the Kattegat has not been identified. The present state of knowledge in the field is summarised in Stock Annex.

6.6 Role of multispecies interactions

The most important predator on cod in the Kattegat in the last decades has presumably been adult cod foraging on juvenile cod. As other predator species such as whiting, pollack and haddock have declined as much as cod or even more, there are no other likely piscivore candidates. Due to the decline of the cod stock, natural mortality is considered to have possibly decreased since 1980s. Increasing harbour seal populations during the last decades, partly coinciding in time with decline of the cod stock, could to some extent have led to increased natural mortality of juvenile cod. Adult cod feed on herring and tagging studies using data storage tags clearly indicate an active, almost semi-pelagic feeding behaviour at least for cod bigger than 40 cm (Svedäng, unpubl. data). There are no indications that cod in the Kattegat is experiencing food limitation as the growth patterns in both the Kattegat and in the adjacent Sound are very similar, although the cod density is much higher in the Sound than in the Kattegat.

Sensitivity of assessment results to different estimates of natural mortality was explored during the benchmark workshop.

6.7 Impacts of fishing on the ecosystem

Impacts of fishing on the ecosystem have not been considered by the benchmark group.

6.8 Stock assessment methods

6.8.1 Models

Up to 2007, XSA was used for assessing cod in the Kattegat, and survey-based SURBA method was applied in parallel to this. In the assessment in 2007, large discrepancies in the estimates of fishing mortality from XSA and from SURBA were observed. Consequently, B-Adapt model was applied that allows estimating potential bias in catch data in recent years. In 2008, additionally stochastic state-space assessment model (Nielsen, 2008) became available and was applied on cod in the Kattegat in parallel to B-Adapt.

The assessment methods that treat catches as representing exact removals from the stock are at present not considered applicable for assessment of cod in the Kattegat. From available methods that allow estimating unallocated removals for certain years, the stochastic state-space model (Nielsen, 2008, WD 14) is considered to have the most advantages, mainly related to its statistical basis and that uncertainty related to each of the model estimates can be provided.

6.8.2 Sensitivity analyses

Sensitivity analyses were conducted concerning the uncertainties related to:

(i) removals from the stock in recent years

(ii) lack of discard data (entire time series)

(iii) natural mortality

Sensitivity analyses were conducted using state-space model. Different exploratory runs were compared with the "standard" run, using the input data and model settings as in the latest assessment, i.e. tuning indices from the four surveys for all years that were available and used by WGBFAS in 2008 and estimating annual catch scaling factor (common for all ages within a year) for 2003–2007.

(i) An exploratory run was performed not estimating catch scaling for any of the years. The estimates of SSB showed some differences compared to the standard run; these were however considerably smaller compared to the difference in the estimates of fishing mortality. Without estimating catch scaling, fishing mortality showed a drastic reduction in recent years down to a very low level. In the run estimating scaling factor for the latest 5 years resulted in fishing mortality estimates at historically high levels, indicating no declining trend during the recent 5 years (Figure 6.3). P-value (<0.001) for the likelihood ratio test for the model reduction and enlarged confidence intervals in the exploratory run indicated an improvement of the model by estimating catch scaling.

It should however be mentioned as pointed out in the section dealing with stock identity issues, that there are indications that the proportion of cod of Skagerrak/North Sea origin in the Kattegat has increased in recent years. As return migration is indicated to take place at age 2 or 3, migration might contribute significantly to the estimated unallocated removals. The mortality caused by fishery is therefore likely in between the two levels estimated with and without catch scaling.

SSB **Fbar**

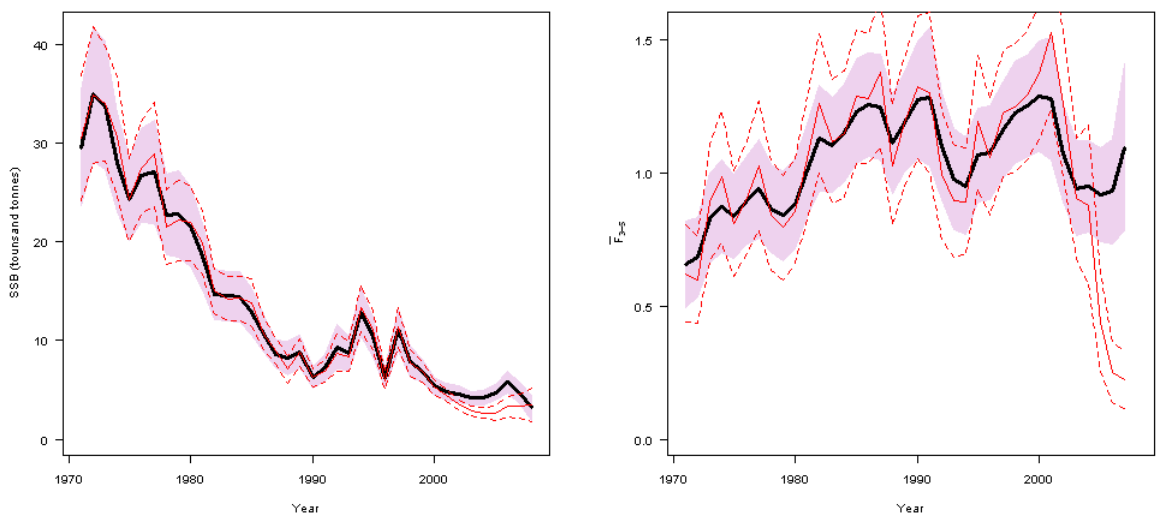


Figure 6.3. SSB and Fbar estimates with (black lines) and without (red lines) estimating catch scaling for the last 5 years.

An exploratory run was performed estimating catch scaling for the last 10 years. The results showed that only the scaling factors for 2003–2007 were significant (Table 6.1).

Table 6.1. Estimated catch scaling factors for 1998–2007 with confidence intervals.

Year	Catch multiplier	Low	High
1998	0.99	0.69	1.41
1999	0.90	0.62	1.31
2000	0.98	0.66	1.44
2001	0.94	0.63	1.40
2002	1.31	0.88	1.94
2003	1.70	1.15	2.51
2004	1.73	1.17	2.56
2005	3.53	2.39	5.22
2006	5.03	3.39	7.45
2007	4.97	3.33	7.43

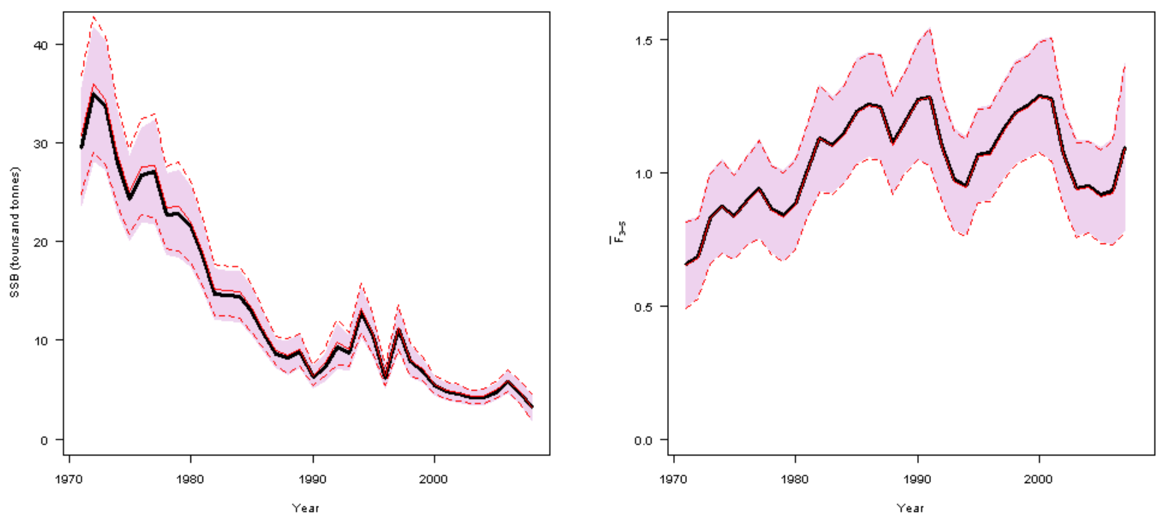
An exploratory run was performed estimating separate scaling factors for ages 1, 2, and 3+ within a year. Adding these additional parameters to the model did not improve model fit (P=0.176). Therefore, estimating separate catch scaling by age was not indicated to be necessary.

Natural mortality for all years and all ages is currently assumed at 0.2. Much higher values for younger ages have been used in the assessment for the neighbouring cod stock in the North Sea. In order to evaluate the sensitivity of the perception of Kattegat cod stock development to the assumption of natural mortality, an exploratory run applying M values used in the latest North Sea cod assessment was performed. The values applied were 0.8, 0.35, 0.25 for ages from 1 to 3, respectively. Natural mortality 0.2 was applied on older ages. These M values were applied for all the years. The SSB and Fbar estimates showed to be insensitive to these natural mortality values applied. The absolute level of recruitment in the entire time series was however estimated considerably higher compared to the standard run (Figure 6.4 a–c). Assuming cannibalism to be a major source of natural mortality of cod in the Kattegat, natural mortality on young cod can be expected to have been higher in the 1970s-early 1980s when the stock was much larger than at present. A sensitivity run was conducted applying the following 3 sets of natural mortalities on younger ages:

Years	a1	a2	a3	a4+
1971-1980	0.8	0.35	0.25	0.2
1981-1990	0.5	0.3	0.2	0.2
1991-2007	0.2	0.2	0.2	0.2

This assumption resulted in a higher level of recruitment at the early part of time series, indicating larger decline in the recruitment over time than obtained assuming constant natural mortality (Figure 6.4 d).

a) **SSB** b) **Fbar**



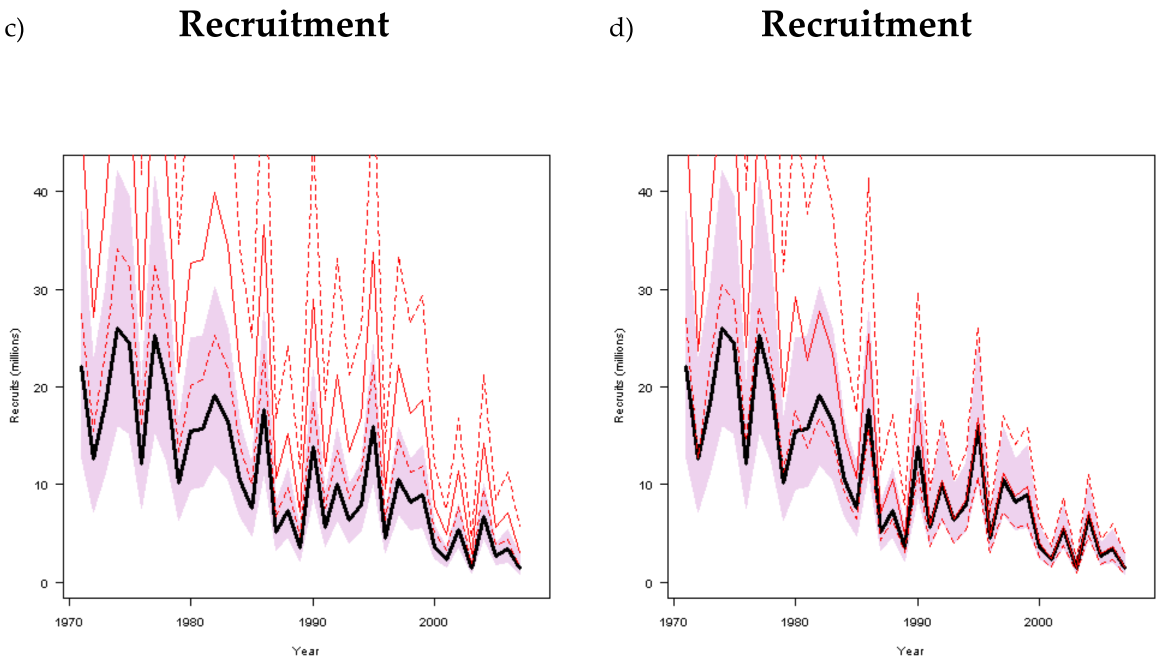
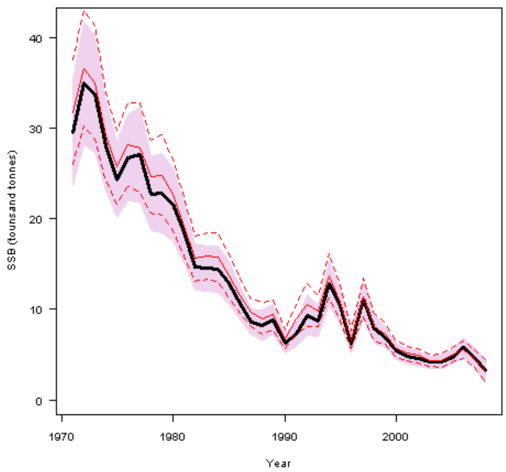


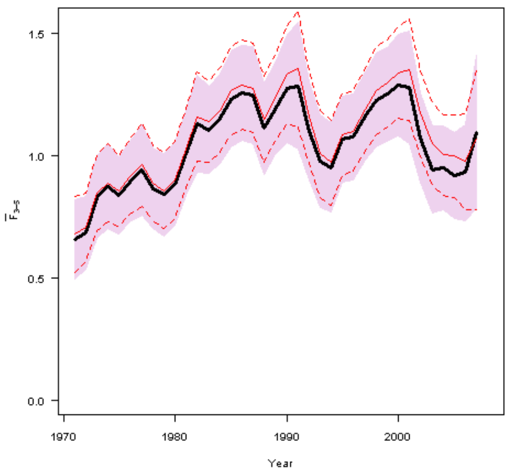
Figure 6.4. a–c) SSB , Fbar and recruitment from the run assuming natural mortality 0.2 all years all ages (black lines) compared to the estimates from the run applying M values 0.8, 0.35, 0. 25, 0.2 on ages 1, 2, 3, and 4+, respectively, in all years (red lines). d) Recruitment estimates from the run applying M at 0.2 on all years and ages (black line) compared to the run assuming for the years 1971-80 M at 0.8, 0.35, 0. 25, 0.2 on ages 1, 2, 3, and 4+, respectively; for years 1981-90 assuming M at 0.5, 0.3, 0.2, 0.2 on ages 1, 2, 3, and 4+, respectively; for years 1991-2007 assuming M at 0.2 for all ages (red line).

Discard estimates for cod in the Kattegat are available from 1997 onwards, however the data are considered highly uncertain and therefore not included in the assessment. An exploratory run was performed applying the available discard estimates. For the years 1971–1996, the same proportion of discards as estimated for 1997–1999 was applied (although this assumption is known to be incorrect due to large changes in fisheries over time). The estimates of SSB and Fbar were similar to the standard run including no discard estimates. However, large differences were obtained in the estimates of recruitment and in the fishing mortality on younger ages (Figure 6.5).

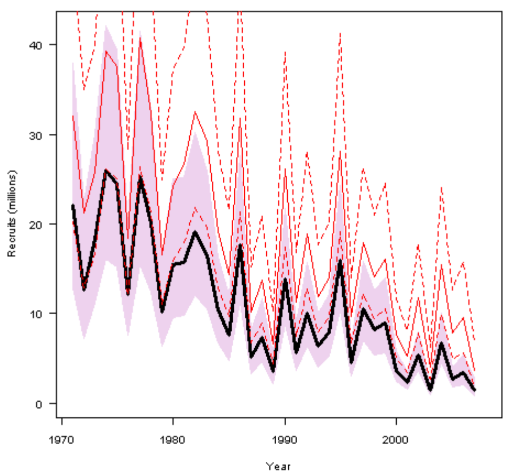
SSB



Fbar



Recruitment



F at age 1 and 2

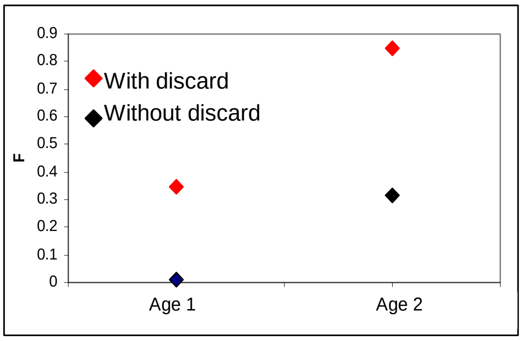


Figure 6.5. SSB, Fbar, Recruitment and F on ages 1 and 2 (average for years 1997–2007) from the run not including discard data (black lines) and the run including discard estimates (red lines).

A potential source of error in the relative development of spawning stock if used as a proxy for egg production (Marshall *et al.*, 2006 and references therein) can arise from using combined SSB for females and males. In a population where males and females have the same longevity (sex ratio=0.5), the same maturation pattern and the same growth (female weight=male weight) the female spawning biomass is half of the total SSB. Growth, maturation and mortality are known to be sexually dimorphic in cod, i.e. earlier maturity and shorter lifespan in males (Tomkiewicz *et al.*, 2003 and references therein). Furthermore, sex ratio is generally moving towards higher proportion of males in the stocks when size/age structure has changed towards smaller/younger individuals (Jakobsen and Ajiad, 1999; Storr-Paulsen *et al.*, in preparation). Therefore skewed sex-ratio affects the composition of the spawning stocks and compromises the reliability of SSB as a measure of stock reproductive potential.

The potential differences in the trends of female spawning biomass (FSSB) and combined spawning biomass (SSB) for the Kattegat cod was analysed for the period 1991–2007.

FSSB was calculated, using female maturity ogives and female weights, as following:

> FSSB= Σ (age 2-6) FMO * FW* SR * NAA
> where FMO is the female maturity ogives, FW is the female weight, SR is the sex ratio and NAA is the number-at-age.

When plotting separately the time series of FSSB and males spawning biomass (MSSB = SSB-FSSB) together with the combined SSB (Figure 6.6) it is evident that the difference between the FSSB and MSSB is higher at higher values of SSB with a prevalence of spawning females. Moving towards the period at lower values of SSB the MSSB may exceed the FSSB, reflecting that the population is skewed towards males. In this way the inclusion of spawning males in the calculation of SSB when used as a measure for egg production, leads to a violation of the basic assumption of proportionality between SSB and population's egg production. For Kattegat cod FSSB shows larger reduction since 1990s compared to SSB, indicating that stock reproductive potential might be reduced more than indicated by combined SSB.

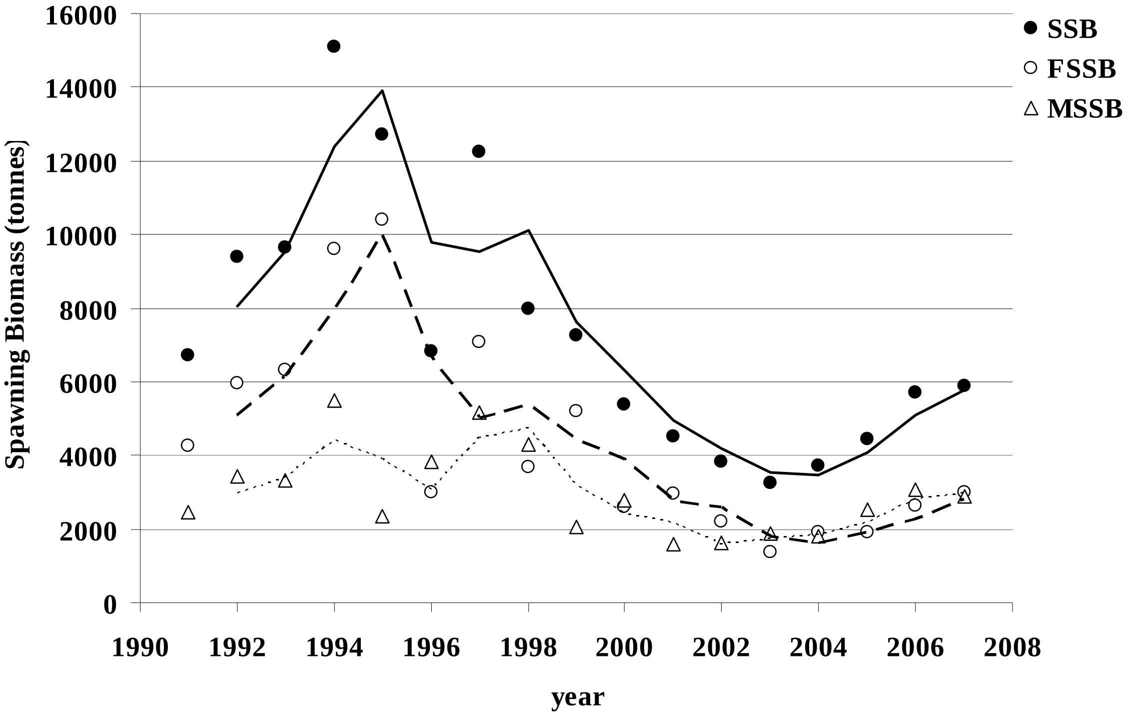


Figure 6.6. Time series of combined (SSB), female (FSSB) and male (MSSB) spawning biomass.

6.8.3 Retrospective patterns

Retrospective patterns were evaluated and not considered to have systematic bias.

6.8.4 Evaluation of models

The assessment methods that treat catches as representing exact removals from the stock are at present not considered applicable for assessment of cod in the Kattegat. From available methods that allow estimating unallocated removals for certain years, the stochastic state-space model (Nielsen 2008; WD 14) is considered to have the most advantages, mainly related to its statistical basis and that uncertainty related to each of the model estimates can be provided. Therefore, the state-space model is considered to be the most appropriate model for assessment of cod in the Kattegat.

6.9 Stock assessment

No changes were made to input data compared to the assessment in 2008. Concerning the model, state-space assessment model was chosen to be applied in the update assessments.

6.10 Recruitment estimation

Recruitment estimates from assessment were found to be sensitive to assumptions of natural mortality and lacking discard data. Therefore, the recruitment values from the assessment should be considered uncertain, though likely representing long-term changes in recruitment over time. Recent variability in year-class strength can probably best be evaluated based on survey data.

6.11 Short-term forecast

Not performed due to uncertainty in estimates for recent years.

6.12 Biological reference points

The precautionary approach reference points defined in 1999 and the technical basis for these values is given in the following table:

	TYPE	VALUE	TECHNICAL BASIS
Precautionary approach	Blim	6 000 t	lowest observed SSB before the late 1990s
	Bpa	10 500 t	Blim*exp(1.645*0.3)
	Flim	1.0	The spawning stock has declined steadily since the early 1970s at fishing mortality rates averaging F = 1.0. Flim is tentatively set equal to F = 1.0.
	Fpa	0.6	Flim*exp(-1.645*0.3)
Targets	Fy	not defined	

The S-R relationship has been previously analysed and the change point in recruitment estimated from segment regression has been found unrealistic, because it is close to the highest observed biomass. It has also been also pointed out that establishing meaningful stock-recruitment relationship for this stock is difficult due to inflow of recruits from adjacent areas (Cardinale and Svedäng, 2004). Therefore, current stock-recruitment data are considered uninformative of change level in recruitment.

The exploitation level has been considered high for most of the time series and around 1.0 or higher in the latest two decades. Such a high level of F has proved to be unsustainable. The F_{lim} at 1.0 is therefore considered invalid. As the estimation of F_{pa} is linked to F_{lim}, F_{pa} is invalidated as well.

F_{01} and F_{max} from yield per recruit analysis were estimated at 0.22 and 0.43, respectively. F 35% SPR was estimated at 0.26.

No new information giving basis for changing biomass reference points was available to the group.

Suggested reference points by the Benchmark Workshop in 2009:

	TYPE	VALUE	TECHNICAL BASIS
Precautionary approach	Blim	6 400 t	lowest observed SSB where recruitment was not impaired
	Bpa	10 500 t	Blim*exp(1.645*0.3)
	Flim	Not defined	
	Fpa	Not defined	
Potential targets	Fmax	0.43	Y/R analysis
	F0.1	0.22	Y/R analysis
	F35%SPR	0.26	Y/R analysis

6.13 Modifications to the stock annex

The stock is at present at a very low level and in such a situation biological factors (e.g. migration patterns, changes in stock productivity etc.) might become relatively more influential on the assessment results. Therefore, an extended review of relevant available biological knowledge on the stock was included in the Stock Annex.

Due to uncertainties in the catch data, an overview of fisheries and changes in regulations should also be considered as important background information, especially for interpreting the results. Therefore, the description of major issues related to the fisheries and regulations was expanded.

Some further explanations were added to Stock Annex concerning input data and their calculation in order to improve transparency and reproducibility of the results.

Stochastic state-space assessment model (Nielsen 2008; WD 14) was chosen to be applied for update assessments.

Fishing mortality precautionary reference points as defined in 1999 were considered as invalid. Potential F targets in the range of 0.2–0.4 were suggested based on yield-per-recruit analyses.

6.14 Recommendations on the procedure for assessment updates

Update assessments are recommended to use the input data and assessment model as specified in the Stock Annex. Both the results with and without catch scaling are recommended to be presented as a final assessment as the stock and F levels are considered to be between the estimates obtained from the two runs. This is because the proportion of the fisheries and biology driven factors in estimated unallocated removals can at present not be specified.

6.15 Industry-supplied data

The cod survey that was initiated in Kattegat in 2008 as cooperation between the industry and scientists from both Sweden and Denmark is recommended to be continued in the future. The survey coverage is considerably better than in any of the surveys currently available. Therefore, after a time series from this survey becomes available for assessment, quality of the assessment that is currently mainly relying on survey data, could be considerably improved.

6.16 References

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Stock Annex Cod in Division IIIa East (Kattegat)

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Cod in Division IIIa East (Kattegat)

Working Group: Baltic Fisheries Assessment Working Group

Date: January 2009

By: Margit Eero

General

A.1. Stock definition

Genetic surveys

The existence of separate subpopulations in the Kattegat in relation to putative subpopulations in the Skagerrak and the North Sea has been corroborated by genetic surveys (André *et al*., in prep.) based on nine reference samples gathered from the Kattegat, Skagerrak and North Sea. Analyses suggested that the nine reference samples could be pooled into two regional groups: "North Sea" and "Kattegat". The temporal stability of the genetic differentiation between the two regional groups was assessed by dividing all fish into year classes based on otolith ageing, and testing for genetic heterogeneity. This test did not indicate any temporal instability in either the North Sea or the Kattegat reference, and verified the genetic differentiation between the two regions. All samples within the two regions were thus pooled in subsequent statistical analyses; the overall F_{ST} between the pooled North Sea reference sample (n=201) and the pooled Kattegat sample (n=435) was 0.0041 ($P < 0.0001$).

Migration and natal homing, mixing of stocks between assessment units

There are indications of a significant transportation of cod larvae from the North Sea stocks into the Kattegat (Munk *et al*., 1999; Cardinale and Svedäng, 2004). Recent tagging studies also suggest that the Kattegat may function as a nursery area for North Sea cod, and that return migration to the North Sea are commonplace (Svedäng and Svenson, 2006; Svedäng *et al*., 2007). The principal age when most return migration from the Kattegat towards the North Sea seems to take place is observed to be at age 2 to 3 (Svedäng *et al*., 2007).

The migrations of cod (>37 cm) in the Skagerrak and Kattegat were investigated in an archival tagging programme conducted between 2003 and 2006 (Svedäng *et al*., 2007). Cod tagged at different localities showed non-random, directional movements in agreement with the hypothesis that the cod population in this region comprises a mixture of resident and migratory stocks. Cod tagged off the eastern Skagerrak coast migrated towards the North Sea, predominantly during the spawning period from January to April, and most of these fish returned to the eastern Skagerrak later in spring. In contrast, concurrently tagged cod in the Kattegat and the Gullmar Fjord (Skagerrak) showed a higher degree of resident behaviour. However, some fish also left these two areas for migration towards the North Sea, predominantly during the spawning period, in accordance with the theory that recruits from the North Sea will eventually leave the Kattegat and the eastern Skagerrak coast for their natal spawning sites. Taken together, these findings implied natal homing behaviour to be the intrinsic mechanism that underlies population separation in marine fishes such as Atlantic cod.

Genetic surveys along the Skagerrak coast have shown that the composition of young-of-the-year cod change from year to year consistently with year class strength variation in the entire Skagerrak (Knutsen *et al*., 2004). Thus, in years with a general low level of recruitment, juveniles were assigned to neighbouring coastal cod populations (i.e. reference material attained from adult, spawning fish), whereas in years with high levels of recruitment, the juveniles were, in contrast, assigned to reference populations sampled at spawning in the western part of the Skagerrak or in the eastern North Sea. This implies that immature cod also in the Kattegat are an assortment of North Sea and Kattegat cod stock components where the proportion of the two stocks in the area varies between years.

The spatial distribution of observed cod recruits (0-group in the IBTS third quarter) gives an illustration of the impact of various recruitment sources. Since the beginning of 2000s abundance of 0-group cod has declined sharply south off 57º N. To the opposite, north off 57º N, the level of recruitment shows interannual variation but no trend during the same period of time. The differences in recruitment patterns are probably due to an inflow of recruits from the Skagerrak/ North Sea into the northern Kattegat, whereas south off 57º N the decline in local recruitment has had a much higher impact on juvenile abundance. Thus, an increased proportion of return migrations to the Skagerrak/North Sea due to the decline of the Kattegat cod might be taking place. An increased proportion of cod of Skagerrak/North Sea origin may inflict on the estimate of fishing mortality.

At the present, the question whether subpopulation structures may occur on an even finer scale than those observed between the Kattegat and Skagerrak/ North Sea cannot be addressed. However, such a differentiation is very likely considering following observations: a) The occurrence of several separate spawning sites within the Kattegat (e.g. Vitale *et al*., 2008), b) the fact that some previously important spawning sites such as Laholmsbukten and Skälderviken were abandoned during 1990s but have not been recolonised in spite of the presence of juvenile cod, c) a demographically separate cod subpopulation in the adjacent sea area Öresund (ICES subdivision 23).

Spawning activities (first quarter of the year) in the Kattegat show that the southernmost spawning area stretches into the northern Sound from an area northwest of the Swedish peninsula Kullen (Vitale *et al*., 2008). Several mark-recapture experiments have shown that cod in the spawning period migrate towards the northern Sound/southernmost part of the Kattegat both from other parts of the Kattegat and from the Sound south of Helsingborg/ Helsingør (Svedäng in prep.). This behaviour is confined to the spawning period, indicating a homing behaviour to this particular area for some cod in the Sound and Kattegat.

Spawning areas

Before the stock declined in the 1990s, spawning cod could be found throughout the Kattegat, but the southern part was generally recognized as the main spawning area, especially the bay of Skälderviken and Laholmsbukten (Pihl and Ulmestrand, 1988; Hagström *et al*., 1990; Svedäng and Bardon, 2003). Historically, large spawning aggregations were also observed in the bay of Kungsbackafjorden and north of Läsö (Hagberg, 2005). The stock decline coincided with the disappearance of large spawning aggregations and the abundance of adult fish in the area has dropped to very low levels (Cardinale and Svedäng, 2004).

Spawning activity of cod in the Kattegat during the last decades has been investigated (Vitale *et al*., 2008) based on combined fishery data and survey information for the first quarter of the year that corresponds to the main spawning period of cod in the Kattegat (Vitale *et al*., 2005). Data from 1996-2004 indicated that cod catches during the Swedish bottom trawl fishery were made to a large extent in spatially rather restricted areas in the south eastern part of the Kattegat, i.e. either close to the entrance to the Sound, or off the coast at Falkenberg. In some years, large landings of cod were also reported from Fladen and from the northern part of the Kattegat, i.e. north off Läsö. The cpue of spawning cod in the IBTS data 1996–2004 was not evenly distributed throughout the area, but coincided to a large extent with the areas identified as hot spots for the commercial landings. Put together, these data sources indicate several possible spawning grounds for cod in the Kattegat.

For the time being, two areas in the southeastern part appear to be most important, one close to the entrance to the Sound and one off the coast at Falkenberg. This observation is in general agreement with previous information on location of spawning aggregations in the Kattegat for the periods 1981–1990 (Pihl and Ulmestrand, 1988; Hagström *et al*., 1990), and 1975–1999 (Svedäng and Bardon, 2003) and with the ongoing study on egg distribution (Svedäng *et al*., 2004). However, the present number of spawning localities in the Kattegat is indicated to be reduced in comparison to what can be elucidated about the past distribution of spawning activities, i.e. before 1990. Besides the two areas presently indicated as the main spawning grounds, only weak signals of spawning activities were obtained in the central and northern parts of Kattegat. These areas might no longer be recognized as spawning grounds, although large spawning aggregations were frequently encountered by research surveys in the early part of 20th century (Hagberg, 2005). Moreover, it was also noted that possibly separate spawning locations may have been abandoned in the bights of Skälderviken and Laholmsbukten. Svedäng and Bardon, 2003 depicted rather big spawning aggregations in these areas, which eventually disappeared in the 1990s.

Summary

The present knowledge about the biological Kattegat stock can be summarised as follows:

- There is a small but significant genetic differentiation between spawning aggregations of cod in the Kattegat versus the North Sea/Skagerrak area (André *et al*., in prep.), i.e. the resident Kattegat cod stock is unlikely to be replenished from elsewhere at least in a mid-term perspective.
- The historical spawning grounds in Kattegat are well documented (Pihl and Ulmestrand, 1988; Hagström *et al*., 1990; Svedäng and Bardon, 2003). Spawning still occurs in these particular grounds albeit some of them might have become abandon (Vitale *et al*., 2008)

There are indications of a significant transportation of cod larvae from the North Sea stocks into the Kattegat. Immature cod in the Kattegat are an assortment of North Sea and Kattegat stock components, where the proportion of the two stocks in the area varies between years. The principal age when most return migration from the Kattegat towards the North Sea seems to take place is observed to be at age 2 to 3.

A decline in recruitment level (estimated as the cpue-level of 0-group cod in the third quarter of the year) has been observed in 2000s in the Kattegat south off 57º N, whereas no such trend is discernible in the northern part, presumably due to an inflow of juveniles from the North Sea/Skagerrak. This implies that the proportion of the stock component of North Sea/Skagerrak origin may have increased in recent years.

One spawning ground is more or less shared between SD 21 and 23, as one spawning area stretches from the Kattegat into the northernmost part of the Sound. On the whole, the Kattegat cod is however well separated from the cod stock in the Sound (SD 23), as there is a limited migration going on between the two areas. The population dynamics in the two areas are also showing considerable deviating patterns.

A.2. Fishery

Regulations

Before 2007, the quotas in Denmark were split into 14-days rations which were continuously adjusted to the amount of quota left. In 2007, this system was changed to a right-based system (FKA-Vessel Quota Share). The year 2007 is considered as a transition year to the new system, which implies that Danish quotas of several stocks were not fully utilized in 2007, including the cod in Kattegat. In Sweden, the landings of the fisheries are regulated by weekly rations, administered by the Swedish fishermen federation. The rations are continuously adjusted to the amount of quota left. Since 2003 the Swedish fisheries have also been characterised by long periods (usually in the 2nd and 3rd quarter) of prohibition to land cod. These "cod stops" have an impact on discard rates and the size composition of the cod discards but also on the behaviour of the fishing fleets.

Concerning changes in technical measures, since 2004 the usage of trawls below 90 mm is only allowed when the trawl is equipped with a sorting grid. In 2007 fishermen were allocated additional fishing days when using trawls with an exit-window with square-meshes at a minimum 120 mm. Usage of exit-window may have had an influence on discarding of small cod, the effect can however not be evaluated with available data. Since 1 February 2008, the usage of the exit-window in trawls has been made mandatory in Denmark. The Danish minimum landing size was set down to 30 cm from February 25 in 2008, in order to match the international minimum landing size and potentially reduce cod discards.

Besides TAC regulation, fishing effort in the Kattegat is regulated by the number of fishing days. In 2008, a new effort restriction was implemented both in Denmark and Sweden: when fishing in the Kattegat, a day present in the area during the period between 1 February 2008 and 30 April should be counted as 2.5 days. Only the trawls using a sorting grid were not subject to this effort restriction. The regulation of the fishing days in the first quarter was abolished when seasonal and permanent closed areas were implemented in the Kattegat from 1 January 2009.

Fishery description

The fishery is almost exclusively Danish and Swedish, with these countries taking about 60–70% and 30–40% of the landings, respectively. Kattegat cod are mainly taken by trawls, Danish seines and gill-nets, the former being the most important. Within the trawling group, three fleets have historically been important, the *Nephrops* fleet (mesh size 70–89 mm), the flatfish fleet (mesh sizes 90–104 mm) and the cod directed fleet (mesh sizes >105 mm). The effort of 70–89 mm trawl fishery after *Nephrops* has ceased since 2003 due to technical measures that require sorting grids for mesh size below 90 mm. Major part of the cod landings in the Kattegat is currently taken by 90–104 mm trawls. The usage of trawls equipped with sorting grids have increased in Sweden as a consequence of the unlimited number of days at sea allowed for this gear in the effort regulation. Usage of grids in *Nephrops* fisheries reduce the discard and catch rate of cod conspicuously (total catch rate approximately 1%). The regulation implemented in 2008, where a day present in the area counted as 2.5 days between 1st of February and 30th of April constituted a strong incitement for the usage of sorting grid equipped trawls. During this period more than 70% of the Swedish *Nephrops* landings by trawl where caught using trawls equipped with grids.

Traditionally, in Swedish fisheries, cod have been caught as target species during the spawning season in the beginning of the year and as by-catch in fisheries primarily targeting *Nephrops*. The status of the stock and the corresponding large cuts in quota has however reduced the targeted cod fisheries. In 2007 the cod landings are more evenly distributed between the quarters, indicating that most cod is caught as by-catch. Concerning Danish fisheries in the Kattegat in recent years, cod is mainly caught as a bycatch species and landings are distributed throughout a year. It should however be noted that a considerable targeted cod fishery is taking place in the border area between Kattegat and Øresund (northern part of SD 23) that belongs to the management area of western Baltic cod (Figure 1).

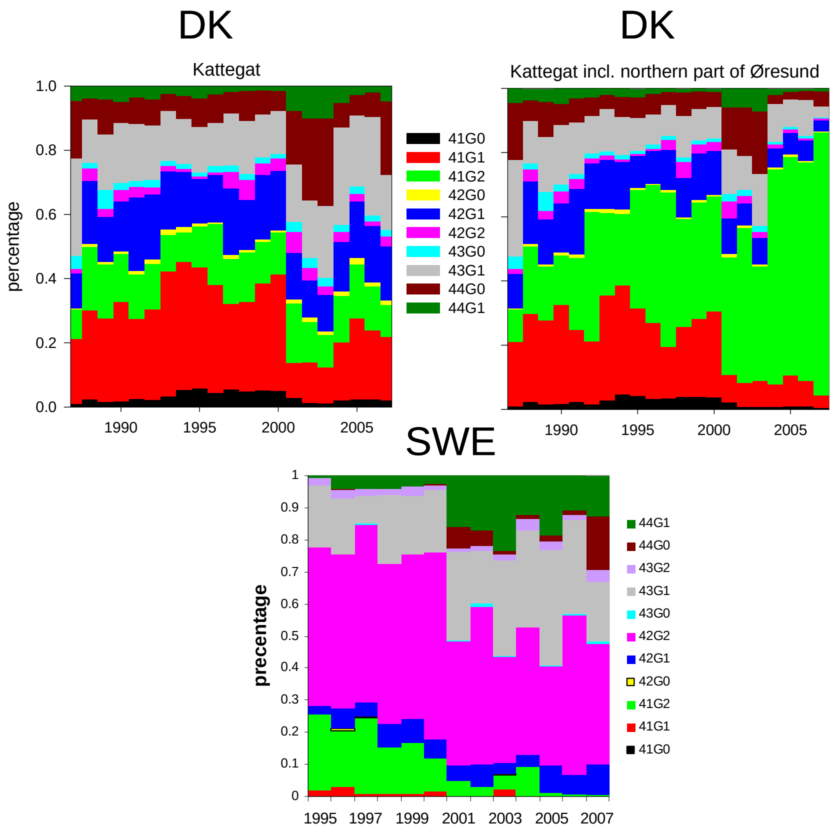

Figure 1. Spatial distribution of Swedish cod landings in Kattegat and Danish cod landings in the Kattegat and including the entire square 41G2 (the northern part of Øresund).

The total nominal effort (kWdays) in the Kattegat has decreased by 35% between the years 2002–2007 (STECF 2008).This is mainly due to a decrease in trawls of 70–89 mm mesh size (87%) and trawls with mesh >100 mm mesh size (69%). The ban of the 70–79 mm trawl caused an increase in effort by trawls in 90–99 mm mesh size category during 2004. Effort within this category, however has decreased by 10% during the period of 2005–2007. The overall effort in this fishery has increased by 9% since 2002. The decrease in the use of the 100 m mesh size trawl could probably be an effect of the lower number of days given to this mesh size category in comparison with 90–99 mm gear. A similar major decrease can be seen in the gillnetters, where effort has decreased by 49% since 2002.

A.3. Ecosystem aspects

Recruitment is possibly partially dependent on inflow of eggs and larvae from the Skagerrak-North Sea cod stock (Munk *et al*., 1999; Cardinale and Svedäng, 2004). No relationship has been found between recruitment success and sea surface temperature for Kattegat cod stock (Cardinale *et al*., 2008). Also, the decline of adult cod abundance and recruitment could not be attributed to any of the environmental factors tested and thus no evidence was obtained which could link the observed decline in cod abundance to environmental factors (Cardinale and Svedäng, 2004). It has been hypothesised that the abundance of young-of-year in both the Kattegat–eastern Skagerrak is dependent on an inflow of offspring from the same spawning stock, i.e. cod larvae transported from spawning areas in the eastern North Sea (Munk *et al*., 1999). However, appearance of large year classes of cod in the Kattegat are associated with those in the Skagerrak and therefore it is likely that similar processes in both areas probably regulate the recruitment. Especially in the northern part of the Kattegat, most of the young of year might be of North Sea origin but they do not contribute to the Kattegat stock as they migrate back to the North Sea prior to maturation (Svedäng *et al*., 2007).

The growth pattern in the Kattegat and Öresund was compared for age groups 1–4 between 1987 and 2003. Growth was clearly indicated to be cohort dependent whereas no sex or area differences could be evidenced. The growth performance in the first year of life, measured as mean length at age 1, propagated into higher age groups within the same cohort. Size at age 1, in its turn, was found to be correlated to the water temperature regime in the year of birth. Such correlations between growth performance and temperature are however commonplace; it has been shown for most major cod stocks in the North Atlantic that changes in size-at-age are temperature related (Brander, 2007).

The most important predator on cod in the Kattegat in the last decades has presumably been adult cod foraging on juvenile cod. As other predator species such as whiting, pollack and haddock have declined as much as cod or even more, there are no other likely piscivore candidates. Due to the decline of the cod stock, natural mortality is considered to have possibly decreased since 1980s. Increasing harbour seal populations during the last decades, partly coinciding in time with decline of the cod stock, could to some extent have led to increased natural mortality of juvenile cod. Adult cod feed on herring and tagging studies using data storage tags clearly indicate an active, almost semi-pelagic feeding behaviour at least for cod bigger than 40 cm (Svedäng, unpubl. data). There are no indications that cod in the Kattegat is experiencing food limitation as the growth patterns in both the Kattegat and in the adjacent Sound are very similar, although the cod density is much higher in the Sound than in the Kattegat.

B. Data

B.1. Commercial catch

Landings

The landings statistics are considered unreliable from the period 1991 and up to 1994. During this period, a considerable amount of the catches were possibly not reported or mis-reported by area or species. The control and enforcement measures have been tightened considerably since the late 1994. Since 2000–2001, the ration sizes in the Kattegat were reduced substantially and the rations in the Kattegat were lower compared to adjacent areas, giving incentives for misreporting of catches by area (Hovgård, 2006). Kattegat cod stock is currently subject to stringent management measures and one obvious consequence can be a serious decline in the quality of catch data due to mis-reporting and discarding. In 2006–2007, a substantial change was observed in size composition of Danish cod landings.

The proportion of small cod (sorting category 5) in landings has historically varied between 30 and 50 percent, but fell below 10 percent in 2007. As a consequence the proportion of larger cod in landings increased. This can possibly be an indication of high-grading. The increase in the proportion of larger cod in landings can also be observed in the Swedish fishery, although on a much smaller scale. Changes in size composition of the catches are partly expected to reflect changes in stock structure, especially due to the relatively stronger 2003 year-class going through the stock, being 4-year-old in 2007.

Discard

Discard data are not included in the assessment due to large uncertainties in the provided estimates. Discard estimates have only been used in exploratory runs during benchmark workshop in 2009 and these should not be used to evaluate the total level of discarding or interannual changes in discarding practise. This is mainly due to uncertainty in the estimation of Danish discards, which is related to a low sampling level, high variability in discard rates (Figure 2) and the calculation procedures that are averaging discard rates over four years. Therefore, any changes in discarding practice due to e.g. changes in technical measures are not reflected in the estimates. The level of discard estimates is also sensitive to raising procedures.

The discard sampling data indicated that discarding mostly affects cod at ages 1–2. If discarding of larger fish also occurs due to high-grading, it is unlikely to be revealed by incidentally having observers on board.

The discarding of cod in Kattegat is mainly taking place in *Nephrops* fishery. Therefore, extrapolating discard estimates back in time where no discard data are available, assuming the numbers of cod discarded to be proportional to the numbers of cod landed is not appropriate for Kattegat. Besides, the fishery has changed shape several times during the time period since 1971; in the beginning of the time period there was hardly any *Nephrops* fishery going on, and the fishery for cod and gadoid species dominated. Since then, the *Nephrops* fishery developed and cod is virtually the only gadoid species of any importance left. Therefore, extrapolation of discard estimates back from 1997 cannot be conducted reliably.

Number of available discard samples by year and country are shown in the table below:

Country /Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark				52	68	43	30	47	33	22	10
Sweden	45	50	55	63	40	63	38	26	48	66	72
Total	45	50	55	115	108	106	68	73	81	88	82

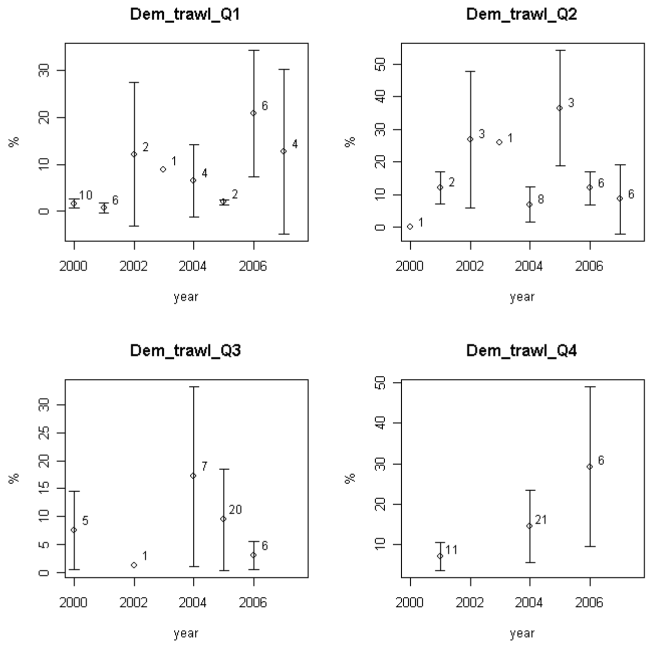

Figure 2. Discard rates (in percent) is Danish samples from demersal trawlers by quarters including standard deviation. The numbers on the panels refer to the number of samples.

Discard samplings by Denmark and Sweden have been conducted since 1995. Considering the fact that many different fisheries are taking place in the Kattegat, it has been difficult to allocate sufficient sampling effort in order to estimate reliable discard rates. In addition, bias in selection of fishing vessels may have occurred as large parts of the Swedish fishing fleet in the Kattegat from time to time have refused to admit sampling officers onboard. The sampling strategy during the first years of the sampling period was to get an overview of the discard rates in all fisheries and then in the later years the sampling effort was concentrated on the fisheries where the highest discard rates were demonstrated. The fishery, which in the later years has been sampled most intensively, is the *Nephrops* fishery, which generally has demonstrated high discards rates.

Discard estimates are available from Sweden for 1997–2007 and from Denmark for 2000–2007.

The sampling procedure differs somewhat between Denmark and Sweden which could not be handled in a common estimation process. The discard estimation was therefore conducted independently by the two countries.

Danish discard numbers were calculated separately for Danish seines and demersal trawls with mesh size >90 mm for 2004–2006. For 2000–2003 discards were calculated additionally for trawls with mesh size 70–89 mm, however fishery with this mesh size has basically disappeared after 2003. No discard estimation was conducted for gill-net fishery, however discarding in this part of the fishery is considered to be of relatively little importance. Due to low sampling level and high variability in discard rates, samples from four years for a given quarter were pooled in order to stabilize the estimates of discard rates. Average discard rates based on samples from 2000–

2003 were applied for these years. From 2004 onwards, running mean over four years was applied. The discards during the sampling trips were raised to the level of a fishery based on landings of all species in this particular fishery in a given year:

$$\frac{cod\_discarded(samples)}{all\_species\_landed(samples)} = \frac{cod\_discarded(fishery)}{all\_species\_landed(fishery)}$$

For demersal trawls the sampling data from 3rd quarters in 2000 and 2002 were applied also for the 4th quarter and for Danish seines the data from 2003 3rd quarter were applied for the 4th quarter. This is because sampling level in the 4th quarter has been particularly low and even combining the data from 4 years did not give sufficient samples.

Swedish discard numbers until 2007 were calculated separately for cod bottom trawl fishery and *Nephrops* fishery. No discards samples were available for passive gears. The hauls in log-books with more than 5% *Nephrops* were included as *Nephrops* fishery and the rest was included as fishery with cod bottom trawls. 5% limit was defined based on the landing structure observed during discard sampling tours, when fishermen defined it as a fishery after *Nephrops* or cod. The discards from samplings of *Nephrops* and cod bottom trawl fisheries were raised to the level of total fisheries with the landings of *Nephrops* and cod, respectively:

$$\frac{Nephrops\_landed(fishery)}{Nephrops\_landed(samples)} = \frac{cod\_discarded(fishery)}{cod\_discarded(samples)}$$

$$\frac{cod\_landed(fishery)}{cod\_landed(samples)} = \frac{cod\_discarded(fishery)}{cod\_discarded(samples)}$$

Samples from 1997–1999 and 2000–2002 were pooled while estimating discard rates in these time periods, respectively. In calculation of annual discards for the years 2003–2005, data for some quarters were borrowed from other years inside of this period. In the last years it has been prohibited to land cod at certain periods of a year. Since this has an effect on the discard pattern, the discard rising for these periods was conducted separately. In 2007, the separation between *Nephrops* and cod trawls was not possible due to changes in fishing pattern. These fleets were therefore combined.

In 2009 FishFrame version 5.0 has been released. This version includes the possibility to make data extrapolation and raising. It is now possible to do all data processing from dis-aggregated data to final stock estimates for both landings and discard within FishFrame if each country upload data to FishFrame. It is now also possible to do the extrapolation of discard data on a sufficient low aggregation level which allows a more precise extrapolation based on fisheries having similar discard patterns. In each extrapolation the data coordinator are able to judge the data based on information of the data to be extrapolated. This system will make it possible by time to update and potentially quality improve the whole discard data serial.

Landings in numbers and weight-at-age in the landings

Information about quarterly landings composition and mean weight-by-age was made available from Danish and Swedish sampling onboard commercial vessels and in ports. For each country, the annual mean weights-by-age were derived by weighing the quarterly mean weight by the respective landings in numbers.

Landings in tons and in numbers-at-age and weight-at-age in the landings are up to the national level compiled by the national institutes. Data are in this stage nationally aggregated to quarter, sub-division and gear type (active, passive) even though the sampling in each country often is stratified on several fisheries (metiers). Not all landings strata have matching biological information and biological information must therefore be extrapolated from other sub-divisions, quarters or fisheries. On the national level, data extrapolations of biological data are only done for strata for which additional biological information from other countries are not relevant. If additional biological information from other countries is relevant, only total landings in tons are given. The national data are submitted to the data coordinator in a fixed EXCEL sheet format. The national data sheets are aggregated to stock level by quarter and sub-division. The remaining extrapolations of age distributions and mean weight-at-age are made by applying the compiled data based on the countries which have performed sampling in the strata. All data extrapolations are logged for later documentation.

B.2. Biological data

Weight-at-age

Mean weight-at-age in the landings is provided by Sweden and Denmark and weight-at-age values are weighted by catch numbers for all years included in the assessment.

Mean weight-at-age in the stock are based on the Swedish IBTS 1st quarter survey for age-groups 1–3 and the weight of ages 4–6+ were set equal to the mean weights in the landings.

Maturity ogives

The time series of maturity ogives is based on the annual macroscopic analysis of the gonads since 1990 collected on board of the Swedish RV "Argos", during the 1st quarter of the IBTS in the Kattegat. The maturity index is currently calculated by the Swedish Institute of Marine Research.

From 1991 until 2006, the IBTS maturity data for gadoids have been recorded using the ICES 4-stages scale. According to this scale, only individuals assigned to the first stage are considered immature (juveniles) and therefore have to be excluded from the calculation of the spawning biomass. The second stage should include all the maturing individuals that are going to finalize their maturation by the forthcoming spawning season. The third stage, i.e. spawning, includes only individuals which are expelling eggs when captured. The last stage, i.e. spent, comprises the individuals that have recently released all the eggs, but also specimens that have already entered a post-spawning condition (resting stage). All the stages from the second and upwards are therefore considered to contribute to the annual reproductive potential of the stock and consequently included as mature in the estimations of the maturity ogives. However, variation in the spawners' condition can impact fecundity and viability of eggs and larvae, or even cause spawning omission the given year (Rideout *et al.*, 2005 and references therein). A large interannual variability in food abundance has an obvious effect on the fish condition and will give a high annual variation in the skip of spawning (Marshall *et al.*, 2003). The 4–stages scale maturity key does not allow classifying and giving an appropriate code to those individuals.

From 2007, an 8-stages maturity scale has been introduced on a national (Swedish) level during the IBTS survey in Kattegat and successively converted into the international conventionally approved staging system before being reported to ICES. This maturity scale facilitates more detailed classification of maturity stages and allows distinguishing specimens that are sexually mature but are skipping spawning in a given year, and thus must be excluded from the SSB. This implies that maturity data refers to spawning probability rather than a maturity ogive taking into account that all mature fish are not part of the spawning stock. Using only the proportion of fish that will spawn as a basis for the assessment improves the accuracy of the SSB estimate as an index of the egg production for determinate spawners (ICES, 2007).

During the Workshop on Sexual Maturity Staging of Cod, Whiting, Haddock and Saithe in 2007 a new improved international maturity scale has been proposed. The newly introduced common scale includes 6 stages (1 Juvenile/Immature, 2 Maturing, 3 Spawning, 4 Spent, 5 Resting/Skip of spawning and 6 Abnormal) and will be implemented from 2009. The advantages deriving from the use of this new scale are to be found not only in the identification of individuals omitting spawning but also in the recognition and consequent exclusion from the SSB of individuals suffering from gonadal malformations.

This improvement in maturity scale for macroscopic analyses is expected to improve the accuracy of estimation of spawning proportion of the stock. However, a three year histological study of Kattegat cod gonads (Vitale *et al*., 2005, 2006) has shown that the macroscopic analysis overestimates the proportion of mature females for all age classes, but especially for first spawners. Histological analyses are generally considered to provide more accurate information on maturity ogives compared to visual inspection. Histological analyses are however laborious and costly and therefore difficult to conduct on a routine basis. Gonadosomatic and hepatosomatic indices may serve as robust proxies for distinguishing between mature and immature females and could greatly enhance the accuracy of macroscopic maturity evaluation of cod gonads when histological analyse are not available (Vitale *et al*., 2006). Furthermore the record of the hepatosomatic index on a routine base, also during the third quarter of the year, may be used as a bioindicator, allowing tracing the energetic condition of the stock. Therefore, recording gonad and liver weight of cod on a regular basis on research surveys is recommended.

Natural mortality

A constant natural mortality of 0.2 was assumed for all ages and years.

B.3. Surveys

Survey data were available from the IBTS 1st and 3rd quarter surveys (Swedish R/V Argos) and from the Danish Kattegat Bottom trawl 1st and 4th quarter surveys (Danish R/V Havfisken). Area coverage of the surveys is shown on Figure 3.

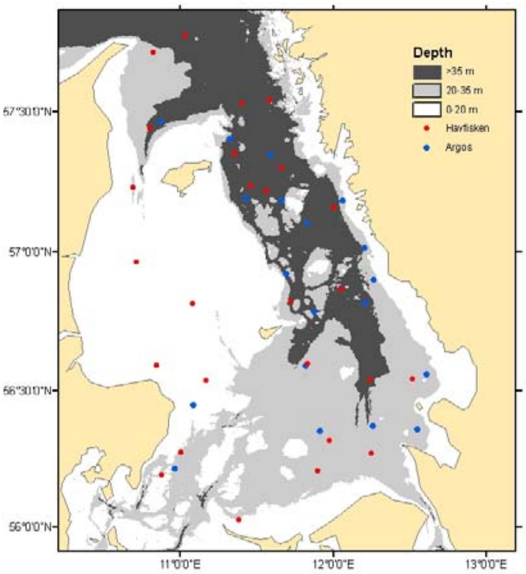

Figure 3. Spatial coverage of IBTS and Havfisken surveys (based on example of the 1st quarter 2007).

IBTS 1st and 3rd quarter surveys

The IBTS tuning indices are produced by ICES from DATRAS database. The indices are derived from arithmetic mean value over ICES rectangles, not weighed by the area of the rectangle. Age distribution of the IBTS 1st quarter survey indices for the years before 1996 are based on a combination of commercial age-length keys and modal separation for the fish below commercial sizes (Hovgård, 1995).

IBTS 1st quarter data for assessment year was available for the WG and the newest information from this survey was included in the assessment.

"Havfisken" 1st and 4th quarter surveys

The indices from "Havfisken" surveys are calculated by DTU-Aqua from national database. The indices are calculated as a mean over all stations. The procedure for filling in missing age information is the following:

At first, length distribution data are merged with annual available ALKs, separately for the 1st and 4th quarter surveys. When no age information in ALK is found for a given length-group, then:

if the length of the fish <15 cm then

in the 1st quarter the age is set to 1

in the 4th quarter the age is set to 0

if no match is found,

use the age information for 1cm smaller fish than itself

if no match is found,

use the age information for 1cm larger fish than itself f no match is found,

use the age information for 2 cm smaller fish than itself

if no match is found,

use the age information for 2 cm larger fish than itself

if no match is found,

use the age information for 3 cm smaller fish than itself

if no match is found,

use the age information for 3 cm larger fish than itself

if no match is found

use the age information for a given length using the average ALK for all year combined, separately by 1st and 4th quarter surveys

if no match is still found,

if the length of the fish >= 60 cm and < 70 cm the age is set to 4 and if the length > 70 cm the age is set to 5

As no age information is available for the 4th quarter survey in 1994 in the Kattegat, the average ALK for the years 1995–2000 is at first applied. For filling in the still missing age information, the general procedure is applied, as described above.

"Havfisken" survey in the 1st quarter takes place later in a year than IBTS 1st quarter survey, and indices for the assessment year were not available for the WG. Therefore, unlike IBTS 1st quarter survey where the data for assessment year was included, the latest year included for "Havfisken" surveys corresponds to the last data year.

The numbers of valid stations from all available surveys included in calculation of tuning indices are shown in the table below:

YEAR/ Survey	IBTS Q1	IBTS Q3	HAVFISKEN Q1	HAVFISKEN Q4
1983	13			
1984	14			
1985	11			
1986	15			
1987	16			
1988	17			
1989	19			
1990	21			
1991	15	23		
1992	22	23		
1993	22	22		
1994	22	22		25
1995	22	24		20
1996	22	22	24	20
1997	18	16	21	28
1998	18	19		17

Year/	IBTS	IBTS		
Survey	Q1	Q3	Havfisken Q1	Havfisken Q4
1999	19	19	25	26
2000	19		25	17
2001	19	19	25	17
2002	19	19	25	26
2003	19	19	26	26
2004	19	19	26	25
2005	19	19	26	26
2006	19	19	27	26
2007	19	19	26	28
2008	19			

The quality of survey indices was evaluated by internal consistency (numbers-at-age plotted against numbers at age+1 of the same cohort in the following year) and between surveys consistency analyses. Based on these analyses, older age-groups that have been caught in very few numbers (often 0-values) and show known consistency with younger age-groups were excluded from the assessment. The final selection of age-groups is presented in the subsequent section.

B.4. Commercial cpue

No new information available.

B.5. Other relevant data

No information.

C. Historical stock development

Model used:

Assessment model: Stochastic state-space model (Nielsen, 2008; 2009).

The model was run using web interface that can be viewed at www.kcod.stockassessment.org

Details concerning input data and model configuration can be found on this webpage. Some model configurations chosen are specified below:

Software used: R (an integrated suite of software facilities for data manipulation, calculation and graphical display)

Model Options chosen:

Fishing mortality-at-age is assumed constant for ages 4+

First age of catchability independent of stock size = 1

Variance parameter is estimated separately for age 1 (in landings and in all surveys) and for ages 2+

Catchability independent of age for ages >= 4

Catch scaling: two comparative runs presented as final assessment: without catch scaling and estimating catch scaling for the years from 2003 onwards. As unallocated removals related to fisheries and migration patterns cannot at present be separated, the stock parameters are considered to be between the two estimates, i.e. obtained from the runs with and without catch scaling.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to yearYes/No
Caton	Landings in tonnes	1971–last data year	1–6+	Yes
Canum	Landings-at-age in numbers	1971–last data year	1–6+	Yes
Weca	Weight-at-age in the commercial landings	1971–last data year	1–6+	Yes/No-constant from 1971–1977
West	Weight-at-age of the spawning stock at spawning time.	1971–last data year	1–6+	Yes/No-constant from 1971–1977
Mprop	Proportion of natural mortality before spawning	1971–last data year	1–6+	No-set 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1971–last data year	1–6+	No-set 0 for all ages in all years
Matprop	Proportion mature-at-age	1971–last data year	1–6+	Yes/No-constant from 1971–1990
Natmor	Natural mortality	1971–last data year	1–6+	No-set 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	IBTS Q3	1991–2007	1–4
Tuning fleet 2	IBTS Q1	1983–2008, (excl. 1994)	1–6
Tuning fleet 3	Havfisken Q1	1996–2007	1–3
Tuning fleet 4	Havfisken Q4	1994–2007	1–3

D. Short-term projection

Short-term prediction has not been conducted in most recent years due to uncertainty in assessments.

Benchmark workshop in 2009 concluded that stock parameters from two runs i.e. with and without catch scaling shall be presented as a final assessment, as these were considered to represent the possible range for stock parameters. This implies that the level of F and the numbers of survivors from assessments are uncertain and short-term predictions would be of no use.

If short term projection was to be conducted, the following general rules would then apply:

Model used: SAM age structured prediction module

Software in use: R (an integrated suite of software facilities for data manipulation, calculation and graphical display)

Initial stock size: Survivors from SAM run for ages 1+. Recruitment at age 1 for year-class 2007 is estimated by RCT3, for year class 2008 and onwards - geometric mean over 1990–2006 (period of low SSB and where recruitment is impaired).

Natural mortality: Set to 0.2 for all ages in all years

Maturity: Average of last 3 year if no time trend, otherwise-average of last 3 years scaled to the last year

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

Weight-at-age in the stock: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Weight-at-age in the catch: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Exploitation pattern: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Intermediate year assumptions: F status quo

Stock recruitment model used: For age one in all projection years geometric mean (1990–2005) is used.

Procedures used for splitting projected catches: Discards and landing split based on F by ages

E. Medium-term projections

Not performed

F. Long-term projections

Not performed

G. Biological reference points

The S-R relationship has been previously analysed and the change point in recruitment estimated from segment regression. In the present situation this has been found unrealistic, because it is close to the highest observed biomass. It has also been also pointed out that establishing meaningful stock-recruitment relationship for this stock is difficult due to inflow of recruits from adjacent areas (Cardinale and Svedäng, 2004). Therefore, current stock-recruitment data are considered uninformative of change level in recruitment.

The exploitation level has been considered high for most of the time series and around 1.0 or higher in the latest two decades. Such a high level of F has proved to be unsustainable. The F_{lim} at 1.0 (as defined in 1999) is therefore considered invalid. As the estimation of F_{pa} is linked to F_{lim}, F_{pa} is invalidated as well.

F_{01} and F_{max} from yield-per-recruit analysis (Figure 4) were estimated at 0.22 and 0.43, respectively. F 35% SPR was estimated at 0.26.

Suggested reference points by the Benchmark workshop in 2009:

	Type	Value	Technical basis
Precautionary approach	Blim	6 400 t	lowest observed SSB where recruitment was not impaired
	Bpa	10 500 t	Blim*exp(1.645*0.3)
	Flim	Not defined	

	Fpa	Not defined	
Potential targets	Fmax	0.43	Yield per Recruit analysis
	F0.1	0.22	Yield per Recruit analysis
	F35%SPR	0.26	Yield per Recruit analysis

Due to uncertainties in the current assessment, especially in the level of F, applicability of reference points is at present limited.

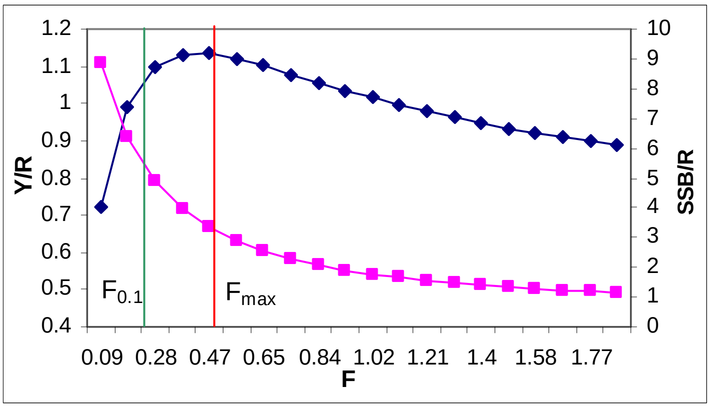

Figure 4. Yield-per-recruit analyses indicating F_{max} and $F_{0.1}$.

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7 Cod in Subdivisions 22–24 (Western Baltic cod)

7.1 Current stock status and assessment issues

The quality of assessment is estimated to be moderate due to a pattern in the retrospective analysis where F generally has been overestimated. The assessment has been accepted by ICES as an analytic assessment. The SSB has been below average since 2000, but with an increasing trend the last few years due to the moderate high 2003 year class. The mortality estimate of this stock has historically been very high and is fluctuating around 1. Recruitment has been at a low level in recent years except the 2003 year class; and the recruitment value for 2007 is indicated to be among the lowest in the time series. Migration pattern between Eastern Baltic and Western Baltic from both juveniles and adults cod does make stock identity difficult. Concerning the assessment model, the stochastic State-space Assessment Model (SAM) is considered as the most appropriate for assessing this stock; however the XSA has been used in comparison runs. The detailed description of the SAM model is provided in the Working Document (WD 14) that was presented at the Benchmark workshop.

7.2 Compilation of available data

7.2.1 Catch/landings data

Data on reported landings is available since 1970. Discard information is available and has been included in the assessment since 1996. More detailed information is available in the stock annex.

7.2.1.1 Evaluation of the quality of the catch data

Black landings and allocation of landings to other areas are not considered a major problem in this stock. Allocation of catches from adjacent areas into the Western Baltic has been look into in VMS data and tested as a catch multiplier in the SAM model. Although there was evidence for some underreporting it was not considered a large problem.

Discard data is included in the assessment and the estimate is considered reasonable (further details are provided in Stock Annex). Information from discard sampling indicates that discarding is a problem especially concerning age-group 1 and 2, however the introduction of BACOMA window in 2003 has decreased the number. There is no indication of high-grading due to changes in size composition of Danish cod landings, i.e. sharp reduction of smallest size category and respective increase in landings of larger fish.

According to EU Decision 949/2008 (Precision of biological sampling in DCR requirements by EU Commission) the national sampling programmes shall include estimation of precision on the collected data, if the sampling cannot be defined by a quantitative target, such as sample size or sampling rate. Details are available in in: COMMISSION DECISION of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy (2008/949/EC).

Where reference is made to precision the following levels shall apply:

Level 1) +/- 40% for a 95% confidence level or CV of 20%

Level 2) +/- 25% for a 95% confidence level or CV of 12.5%

Level 3) +/- 5% for a 95% confidence level or CV of 2.5%

The COST (Common Open Source Tool) is addressing how to estimate precision in an EU project running from 1 July 2007 until 31 December 2008 (They will develop methods to investigate and estimate sampling indicators for discards, length and age structure of catches and landings and biological parameters such as growth, maturity and sex- ratio from all the regions covered by the DCR.

The outcome of COST will be implemented by national sampling programmes in future and the procedure for implementing will be evaluated in future benchmark assessments.

7.2.2 Tuning fleet data

Relative abundance indices available and used in the assessment are the following:

One commercial tuning fleet and three surveys;

Danish Trawler	1997–2007	ages 3–6
- - - - - - - - - - - - - - - -	- - - - - - - - - - -	- - - - - - - - - -
Solea 4th quarter	1994–2007	ages 1–3
Havfisken 1st quarter	1995–2007	ages 1–3
Havfisken 4th quarter	1994–2007	ages 1–3

This selection of tuning indices has not been used on previous assessments. In last years assessment additional a commercial gillnet tuning fleet was used as well as a previous version of the commercial trawlers indices.

In 2008 it was recommended from BIFSWG to use a combined survey between the German vessel Solea and the Danish Havfisken for 1st and 4th quarter, respectively. As the two surveys covers different areas but with the same trawl and fishing speed it has been suggested to combined the two first quarter surveys and the two fourths quarter surveys (Figure 7.1). Two different approaches where applied to combine the surveys; the ICES standard indices calculated for the eastern BITS survey taking the depth strata and ICES square into account (http://datras.ices.dk/Documents /Manuals/Manuals.aspx) and a GAM model where depth, vessel effect and area were accounted for. However, the individual tuning series showed a very different catchability between the two ships within the same subdivisions. This could be coursed by an area effect as there is very little spatial overlap between ships but it could also be caused by a vessel effect. For this reason the combined surveys were not included in the final assessment.

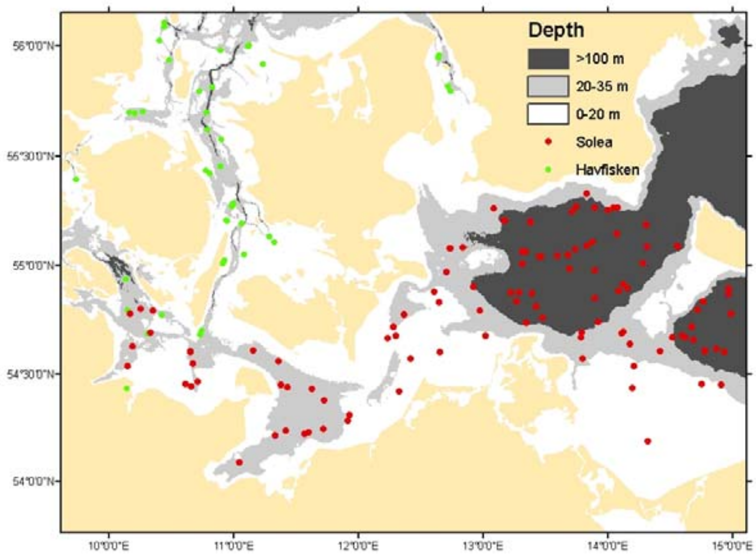


Figure 7.1. Survey area from the Danish survey "Havfisken" and the German survey "Solea" for 1st and 4th quarter.

7.2.2.1 Evaluation of data quality

Quality of survey data was evaluated based on consistency analyses within and between the surveys. For age 1–3, similar patterns were shown in all three surveys both in internal consistency analysis as well as between surveys, i.e. all time series are relatively good for younger age classes but noisier above age 3.

To use the combined surveys in future assessment a larger spatial overlap between vessels is needed to account for the vessel affect.

7.2.3 Industry/stakeholder data inputs

No new input data by industry/stakeholder was provided. However, a new project has been started in 2008 with the Danish and German pound net fishermen, for collecting and estimating 0-group cod. In both countries fishermen participating are writing a logbook during the whole pound net season and are sampling 0-group cod for analysing in the laboratories.

7.3 Stock identity and migration issues

Available information on stock identity and migration patterns has been reviewed and an extended overview is provided in Stock Annex. The issue of most concern for the assessment is related to outflow of recruits into the Eastern Baltic and the return migration at maturation to the Western Baltic Sea, which could cause the overestimation of F; however the amount cannot be quantified.

7.4 Spatial changes in fishery or stock distribution

Spatial changes in fishery or stock distribution are currently not considered an issue for assessment.

7.5 Environmental drivers of stock dynamics

Major environmental influence on the dynamics of cod in the Western Baltic has not been identified although the regime shift in the East Baltic might indicate that some change in the Western Baltic might have happened as well.

7.6 Role of multispecies interactions

No new information is available for the workshop.

7.7 Impacts of fishing on the ecosystem

The impact of fishing on the ecosystem has not been considered by the benchmark group. However, Germany has appointed six areas in the Western Baltic in connection to Natura 2000. Other countries are obliged to point out Natura 2000 areas as well.

7.8 Stock assessment methods

7.8.1 Models

In the benchmark assessment in 2009 a new stochastic state-space assessment model SAM (WD 14) became available and was applied on cod due to the advances in the new model compared with the one applied earlier. The new assessment model is considered to have many advantages, mainly related to its statistical background and that confidential interval related to each of the model estimates can be provided. Furthermore it is possible to test different assumptions in a statistical way.

Up to 2008, XSA was used for assessing cod in the Western Baltic.

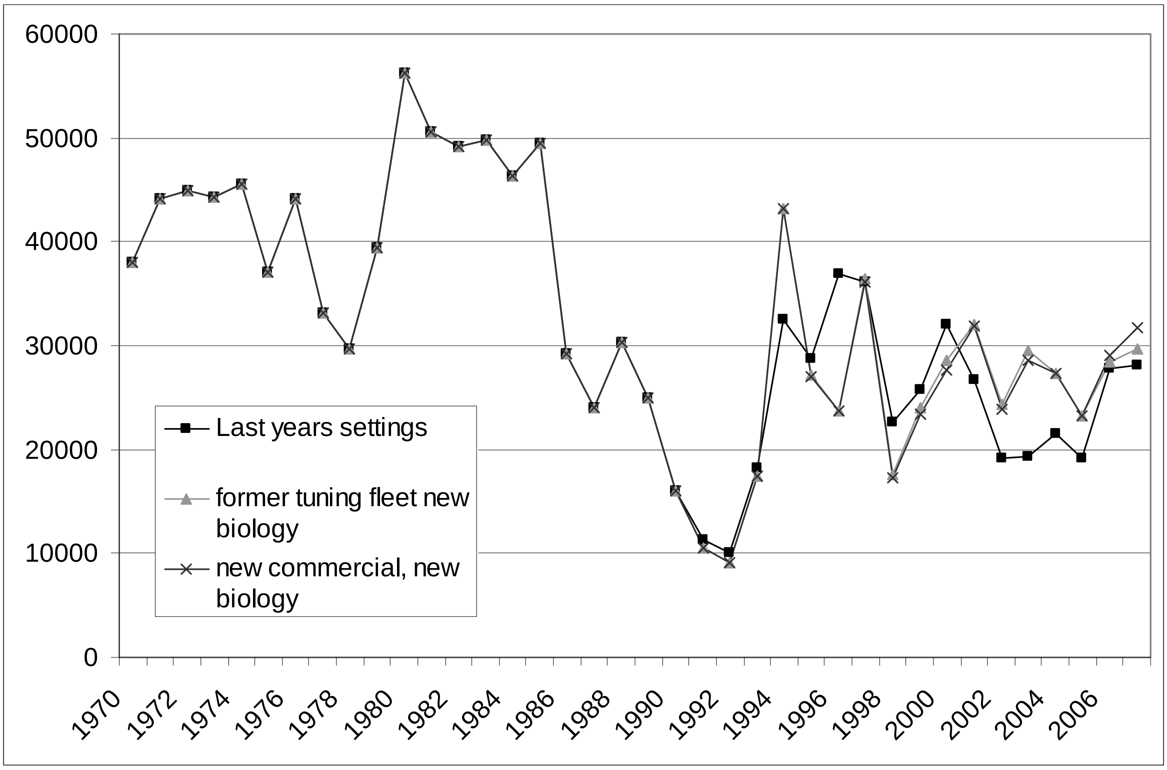


Figure 7.2. Plot of SSB for three different data series. Black squares are last years setting with old maturity ogive and old tuning fleet. Light grey triangles indicate new maturity ogive and new weight in stock and former tuning fleet. Dark grey cross indicate new maturity ogive and new weight in stock and new tuning fleet.

7.8.2 Influence of new data input

(i) Different tuning fleets: a) new commercial trawler b) removal of commercial gillnetters.

New stock weight for age 1–3 and new maturity ogive for combined sexes.

New data sets were tested in the assessment models (both XSA and SAM) to investigate the effect of single fleet and various tuning fleet combinations on SSB and F estimates. As the new maturity ogive and updated weight information were considered more appropriate than the former applied fixed values, the analysis were preformed in order to track the changed trend.

The new commercial trawler fleet did not change the SSB or F the final year very much and is not considered a major change in the assessment, although the removal of gillnetters as a tuning fleet increased the SSB a little the final year (Figures 7.2 and 7.3).

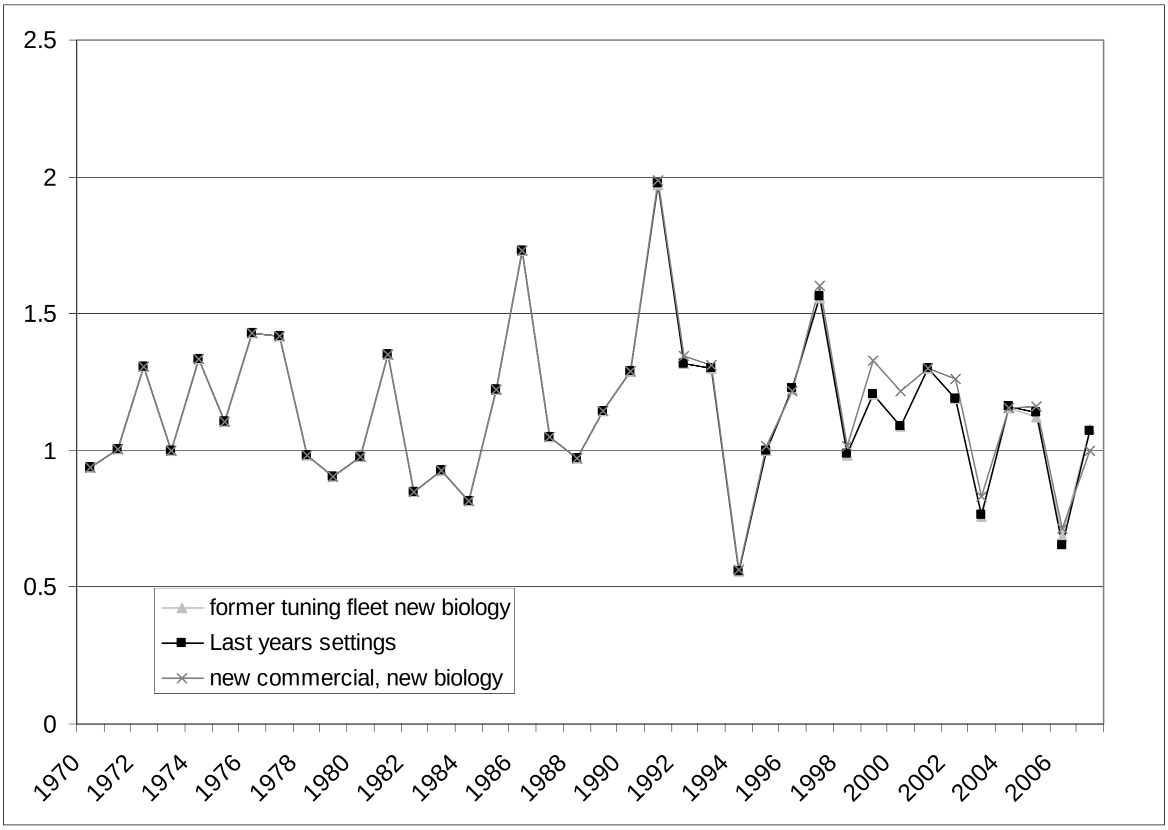


Figure 7.3. Plot of Fbar (3–6) for three different data series. Black squares are last years setting with old maturity ogive and old tuning fleet. Light grey triangles indicate new maturity ogive and new weight in stock and former tuning fleet. Dark grey cross indicate new maturity ogive and new weight in stock and new tuning fleet.

Single fleet approach showed that Havfisken 4th quarter, showed a lower SSB and a higher F compared to the two other surveys. The commercial trawler fleet showed an intermediate level (Figures 7.4 and 7.5). Indicating that commercial tuning and surveys did not show different pattern as such.

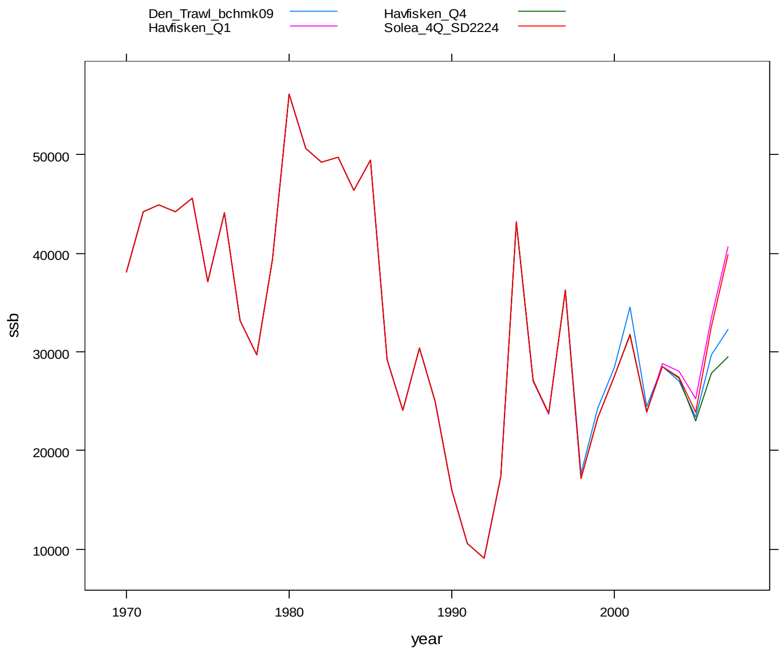


Figure 7.4. Single fleet runs for SSB in the four tuning fleets.

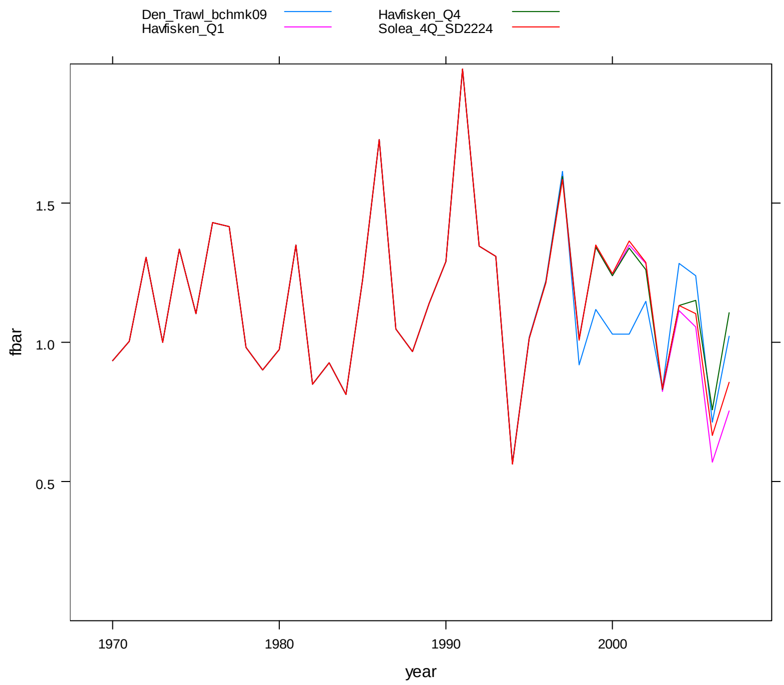


Figure 7.5. Fbar (age 3–6) in single fleet runs for the four tuning fleets.

7.8.3 Sensitivity analyses

Sensitivity analyses were conducted concerning the uncertainties related to:

(i) Reallocation of catches into Western Baltic in recent 5 years

Use of a stock size depended catchability for age 1

Sensitivity analyses were conducted using state-space (SAM) model. The different exploratory runs were compared against the "standard" run, using the input data and model settings as agreed to be the final setting in the benchmark workshop.

(i) an exploratory run was performed to analyse if there has been any substantial under reporting in the Western Baltic due to more restrictive TAC in the adjacent waters. Five years scaling on catches made no significant difference although most scaling values in the test runs were below 1, indicating that underreporting could be a problem.

Catchability dependent of stock size was tested for age =1, in all surveys and were significantly improving the model P=0.005. Residuals for age group 1 became smaller for both Havfisken surveys, however no change was seen for Solea.

A potential source of error in the relative development of spawning stock if used as a proxy for egg production (Marshall *et al.*, 2006 and references therein) can arise from using combined SSB for females and males. In a population where males and females have the same longevity (sex ratio=0.5), the same maturation pattern and the same growth (female weight=male weight) the female spawning biomass is half of the total SSB. Growth, maturation and mortality are known to be sexually dimorphic in cod, i.e. earlier maturity and shorter lifespan in males (Tomkiewicz *et al*., 2003b and references therein) Further more sex ratio is generally moving towards higher proportion of males in the stocks when size/age structure has changed towards smaller/younger individuals (Storr-Paulsen *et al*., in prep.). Therefore skewed sex-ratio affects the composition of the spawning stocks and compromises the reliability of SSB as a measure of stock reproductive potential.

The potential differences in the trends of female spawning biomass (FSSB) and combined spawning biomass (SSB) for the Western Baltic cod was analysed for the period 1991–2007.

FSSB was calculated, using female maturity ogives and female weights, as following:

FSSB= **Σ** (age 1-7) FMO * W* SR * NAA

where FMO is the female maturity ogives, W is the combined weight, SR is the sex ratio and NAA is the number-at-age.

When plotting separately the time series of FSSB and males spawning biomass (MSSB = SSB-FSSB) together with the combined SSB (Figure 6) it is evident that the difference between the FSSB and MSSB is higher at higher values of SSB with a prevalence of spawning females. Moving towards the period at lower values of SSB the MSSB may exceed the FSSB, reflecting that the population is skewed towards males. In this way the inclusion of spawning males in the calculation of SSB when used as a measure for egg production, leads to a violation of the basic assumption of proportionality between SSB and population's egg production. For Western Baltic cod FSSB showed to be above 0.5 at high stock number (1995), and below 0.5 when the stock is low, indicating that stock reproductive potential might be reduced more than indicated by combined SSB (Figure 7.6).

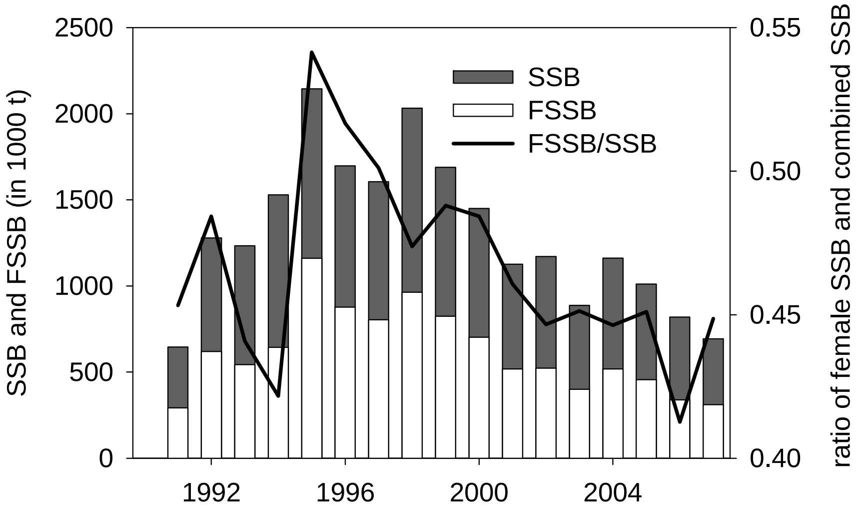


Figure 7.6. The ratio between female SSB and SSB.

7.8.4 Retrospective patterns

Retrospective patterns have been considered problematic for this stock due to a trend in overestimating F and underestimating SSB for most years. The new model shows the same pattern as the XSA and F is consistently overestimated and SSB underestimated (Figures 7.7 and 7.8).

7.8.5 Evaluation of models

The stochastic State-space Assessment Model (SAM, WD 14) is considered to have the many advantages, which are related to its statistical background and because standard deviation related to various parameter estimations can be provided. Therefore, the SAM model is considered to be a good candidate for assessing the western Baltic cod stock in the nearest future.

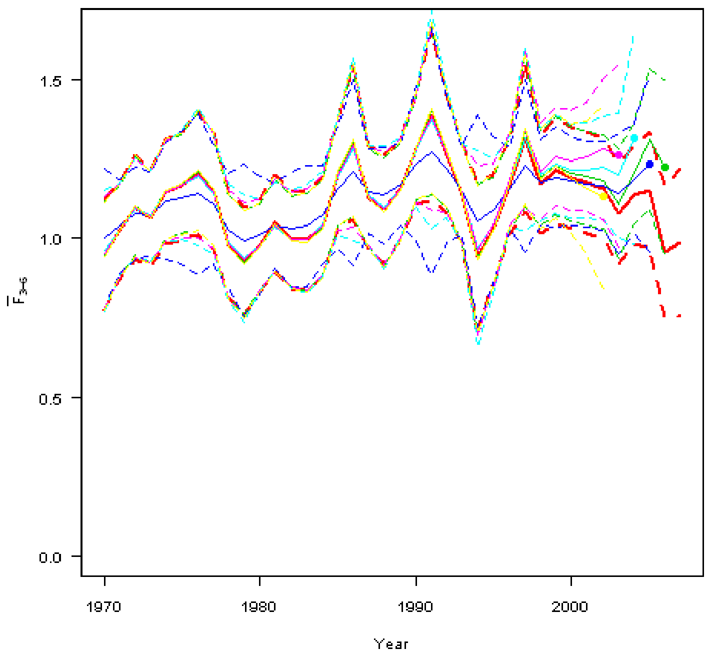


Figure 7.7. Retrospective pattern of Fbar (age 3–6) from the SAM.

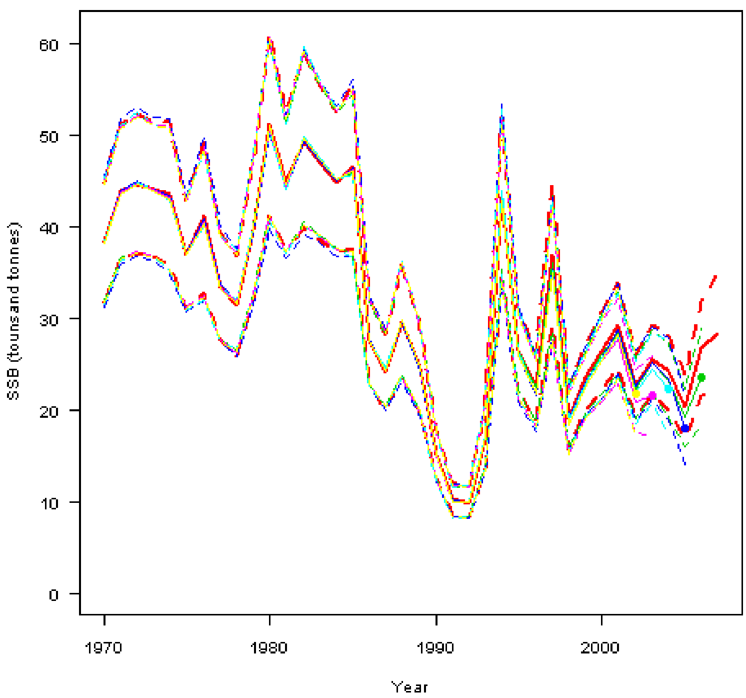


Figure 7.8. Retrospective pattern in SSB from the SAM.

7.9 Stock assessment

Changes were applied for the commercial tuning fleet were a new commercial tuning trawler fleet was replacing the former. The gillnetter tuning fleet was excluded.

A new stock weight was introduced for age 1–3 and a new combined maturity ogive from 1992–2007.

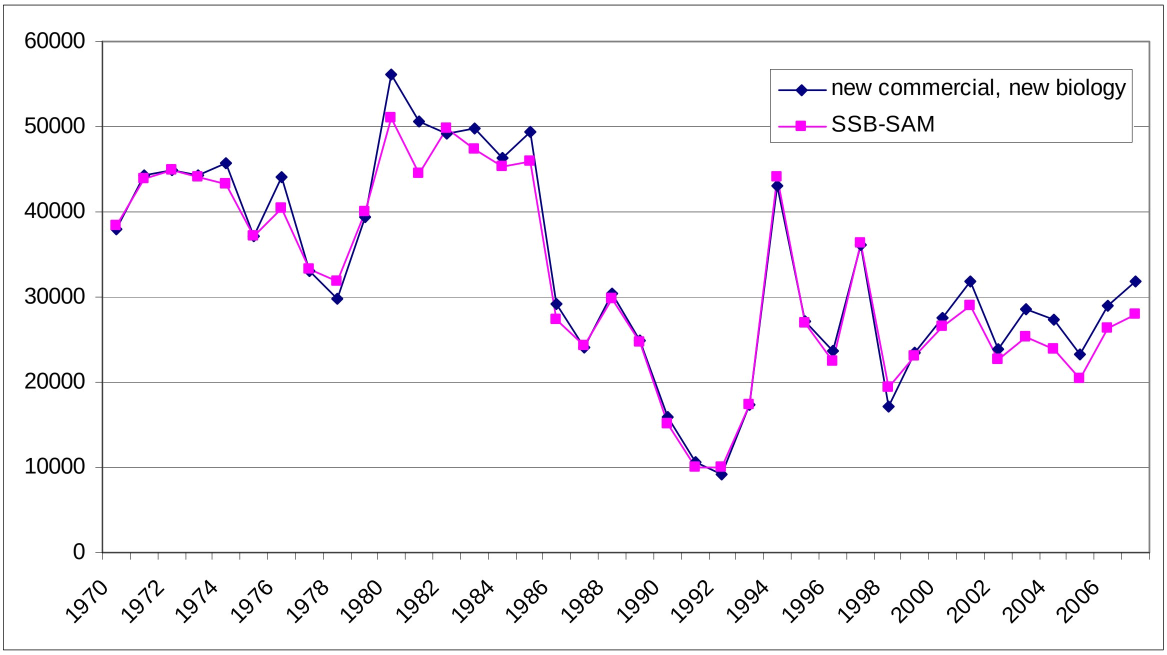
In 2009 the state-space assessment model (SAM) was chosen as the only model to be applied in the update assessments. The final results of XSA and SAM are shown in Figure 7.9. The SAM assessment results (SSB, F and R) and residuals in tuning fleets are shown in Figure 7.10.

7.10 Recruitment estimation

Recruitment estimates are provided by surveys. Last 4 years recruitment has been well below average. However, surveys in fall 2008 indicate that year class 2008 is larger than the previous year classes.

7.11 Short-term and medium-term forecasts

Short term forecast has previously been preformed with RCT3 and the standard model provided by ICES. Standard settings are given in the Stock Annex. In update assessments a new forecast module in SAM will be provided.



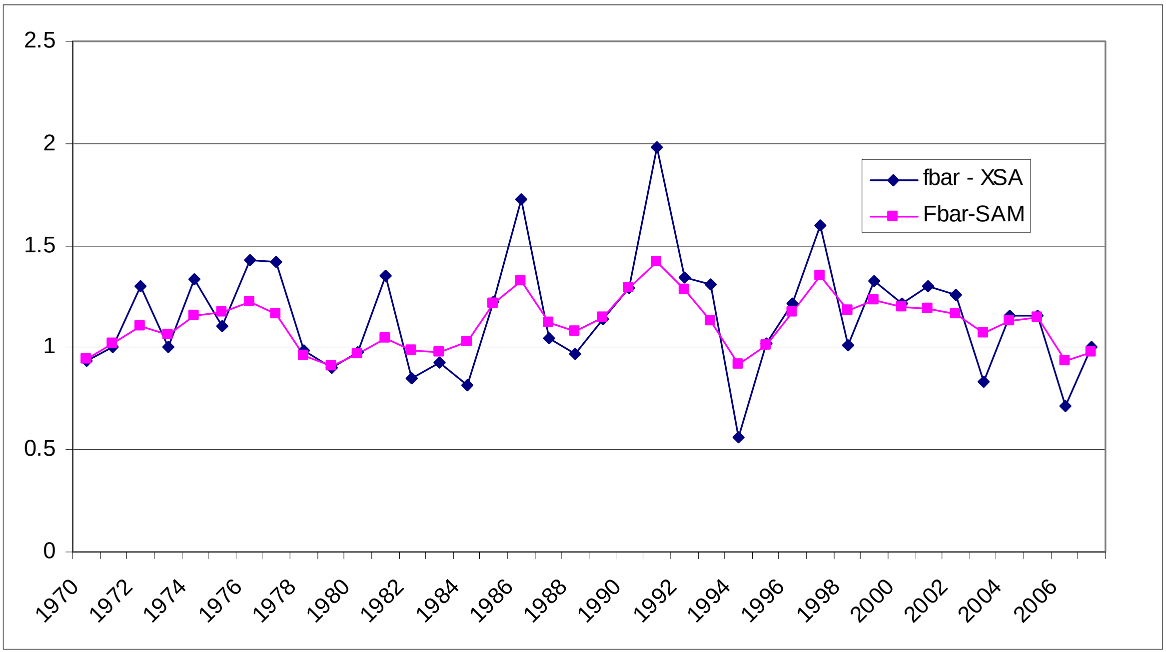
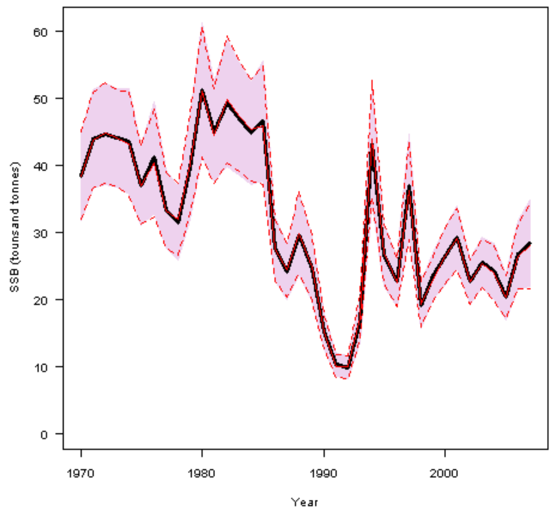
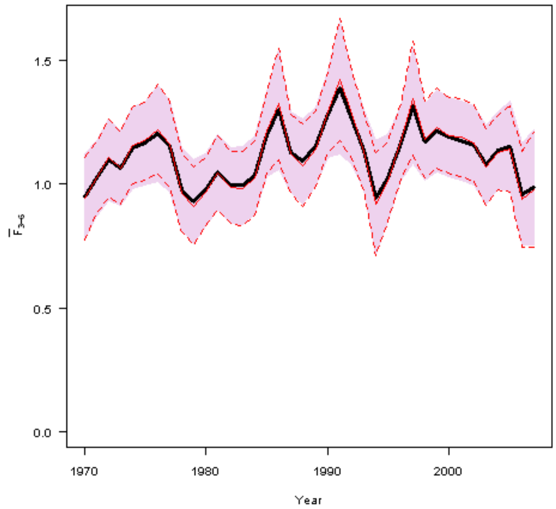


Figure 7.9. Comparisons between XSA and SAM in regard to SSB and Fbar (age 3–6).

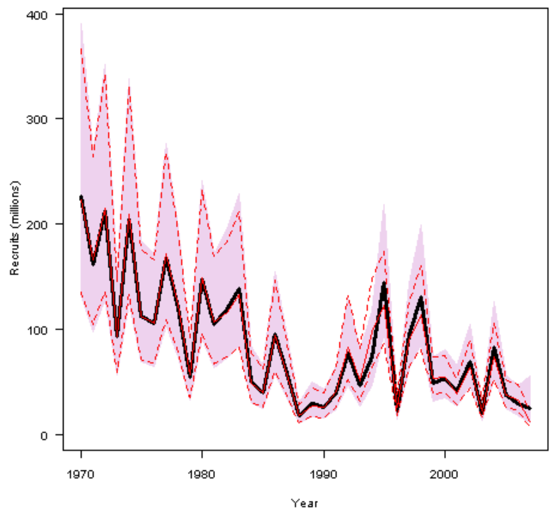
Medium-term forecast has not been preformed for this stock the last two years.



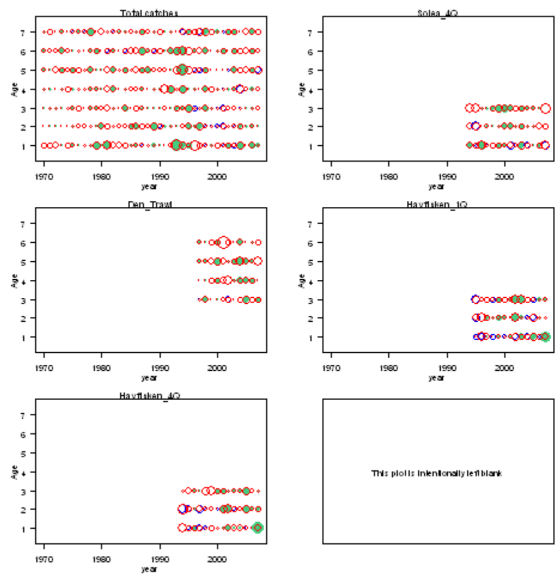
SSB



Fbar



recruitment



residuals

Figure 7.10. Final run with the SAM. (shaded regions / dashed lines indicate pointwise 95% confidence intervals).

7.12 Biological reference points

ICES has proposed $\mathbf{B}_{pa}$ at 23,000 t equal to the former established MBAL. MBAL was introduced in 1996 (ICES 1996, Report of the Baltic fisheries Assessment working Group, ICES CM / Assess:13) and is covering the time frame 1970-1994. Due to a linear relationship between SSB and recruitment the MBAL value estimated with data extended to 2007 will give unrealistic high B_{lim}. Today it appears that recruitment is impaired below 32 000 t. However, it is also possible that a similar regime shift has occurred in the western Baltic as in the Eastern Baltic.

ICES has since 1996 recommended a $\mathbf{B}_{pa}$ at 23 000 t. WKROUND found no basis for changes.

A yield per recruit estimate assumes a closed stock structure. Stock identity in the Western Baltic has not been solved, and there are strong indications on mixing of stocks (eastern Baltic cod/western Baltic cod and western Baltic cod/Kattegat cod) and homing migration of adult fish back to the original stock is documented. Furthermore the western Baltic cod stock has sustained an average F above 1 at least last two decades, which seems to be unrealistically high. Therefore a standard yield-per-recruit F reference point estimate is misleading. In present situation a yield-per-recruit analysis will not give any sensible results on F reference points.

This benchmark workshop recommend that Bpa is kept at 23 000 t as the stock has been around Bpa for the last 10–12 years and due to a precautionary measure the stock should not get lower. No new reference points for F have been estimated.

The present reference points are as follows:

	TYPE	VALUE	TECHNICAL BASIS
Precautionary approach	Blim	not defined	
	Bpa	23 000 t	MBAL
	Flim	not defined	
	Fpa	not defined	
Targets	Fy	0.6	EU management plan 2007

(unchanged since: 2008)

Yield and spawning biomass per Recruit F-reference points:

	FISH MORT	YIELD/R	SSB/R
	Ages 3–6		
Average last 3 years	0.959	0.684	0.661
Fmax	0.271	0.885	3.429
F0.1	0.163	0.829	5.398
Fmed	1.375	0.633	0.399

(WGBFAS 2008)

7.13 Modifications to the stock annex

The analytic assessment of the model indicates some retrospective pattern and thus discrepancy between catch matrix and the tuning fleets. This could partly be caused by migration pattern from larger individuals into the stock.

Therefore, an extended review of relevant available biological knowledge on the stock was included in the Stock Annex. Also more information on the fishery has been applied in the stock annex.

7.14 Recommended modifications to the stock annex

In 2008 it was recommended from BIFSWG to use a combined survey between the German vessel Solea and the Danish Havfisken for 1st and 4th quarter for tuning. However, the individual time series showed a very different catchability between the two ships within the same subdivisions. This is most probably caused by an area effect as there is very little spatial overlap between ships and also caused by a vessel effect. For these reasons the combined surveys were not included in the final assessment in WKROUND. To use the combined surveys in future assessment, a larger spatial overlap between vessels is necessary to take into account for the vessel affect. A combined survey indices should not be used for assessment before this exercise.

7.15 Recommendations on the procedure for assessment updates

It would be helpful for the assessment to combine the two surveys that is operating in different parts of the stock area. This would imply a larger overlapping fishing area for vessels for comparison purposes and for fishing power comparison in order to take into account ship effect in the final estimates.

7.16 Industry-supplied data

A new project has been started in 2008 with the Danish and German pound net fishermen, for collecting and estimating 0-group cod (Chapter 7.2.3) This new data set might prove to be very useful for estimating the incoming year class strength.

References

ICES 1996. Report of the Baltic Fisheries Assessment Working Group, ICES CM 1996 / Assess:13)

Working document # 14. State-space fish stock assessment as alternative to (semi-) deterministic approaches and stochastic models with a high number of parameters. ICES WKROUND 2009.

Stock Annex Cod in Subdivisions 22–24 (Western Baltic)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Cod in Subdivisions 22–24 (Western Baltic)
Working Group	WGBFAS
Date	January 2009
By	Marie Storr-Paulsen

A. General

A.1 Stock definition

The distribution area of the Western Baltic cod stock is defined as the ICES Subdivisions 22–24. Subdivision 23 is the Sound between Denmark and Sweden bordering up to Kattegat and subdivision 24 is bordering up to the Eastern Baltic. Stock identification: Cod in the Baltic Sea is managed as two stock units, Western Baltic Cod (ICES SD 22–24) and Eastern Baltic Cod (ICES SD 25–32). In 1997 subdivision 23 was included in the Western Baltic stock. The individual cod is currently only assigned to its stock of origin, Western or Eastern Baltic stock, according to the area where they were caught independently of its biological origin, however it is documented that mixture of both cod stocks occurs in the Arkona Sea (ICES SD 24) and the Bornholm Sea (ICES SD 25).

Studies of the last decade suggest that significant migrations and exchanges of juvenile and adult cod between both stocks occur. Qualitative evidence of occurrence of juvenile cod in the Bornholm Sea, but spawned in the western Baltic Sea, is given by a study based on the microstructure analyses of otoliths (Oeberst and Böttcher, 1998). This is further supported by Hinrichsen *et al.*, 2001, who have shown that wind-driven transport of the surface water layer may carry cod eggs from the Belt Sea to the Bornholm Basin within 25 days. Different studies suggest a homing migration take place when the development of sexual products starts (Müller, 2002; Bleil and Oeberst, 2005). Bleil *et al.*, in press have shown that some spawning activities were observed in the Arkona Sea (ICES SD 24) in summer. These individuals spawn at the same time like the summer spawning cod in the area east of Bornholm, therefore, it is rather difficult to distinguish between the two stocks. These results suggest that a more detailed separation of cod in the ICES SD 22 to 25 is necessary and an assignment of individuals to one of the stocks is required independently of the location of capture.

Biological background information

Maturation: Starts in the end of October/beginning of November. The period from the beginning of maturation until beginning of spawning takes about 4 month (Bleil and Oeberst, 1997).

Minimum length of maturation: The minimum length of maturation was observed with 22/28 cm in the Kiel Bight between 1992 and 1999 for male/female, respectively and varied slight in the Mecklenburg Bight (male: 23 cm, female: 24 cm) and in the Arkona Sea (male: 21 cm, female: 23 cm) (Bleil and Oeberst, 2002).

Spawning period: From end of February to beginning of June; main spawning season March to April-spring spawner (Poulsen, 1931; Strodmann, 1918;Kändler, 1944;

Berner, 1960; Bagge *et al.*, 1994; Aro, 2000). Male cod reach maturity stage spent earlier than females and stay longer in the spawning area. Larger cod start earlier and continue the spawning activities for a longer period of time than smaller cod (Bleil and Oeberst, 1997).

Spawning area: Deepest parts of the Danish Belt Sea, deepest parts of the Kiel Bight, of the Fehmarn Belt and of the Mecklenburg Bight (deeper than 20 m) and, but with lower importance, the deepest parts of the Arkona Sea (deeper than 40 m) (Bleil and Oeberst, 2002).

Salinity for successful reproduction: Salinity > 15 PSU is required for the fertilization and more than 20 PSU for the buoyancy of eggs (Westernhagen, 1970; Nissling and Westin, 1997).

Active spawner: The proportion of matured female cods varied in a wide range between 1993 and 1998, especially the proportions for small cod (first spawner) which present the main part of the reproductive population. This high variability of the proportion of matured female cod explained about 77% of the variability of the year-class between 1993 and 1998 (Oeberst and Bleil, 2003).

Drift and migration of juvenile stages: Studies based on wind driven transport have shown that pelagic stages are mainly transported into the eastern direction due to the dominance westerly wind (Hinrichsen *et al.*, 2001). It was shown that pelagic stages can be transported into the area east of Bornholm within 25 days during periods with strong and stable westerly winds like in January 1993. This qualitative evidence for the occurrence of cod in the Bornholm Sea, which were spawned in the Belt Sea in spring, was corroborated by analyses of the trawl surveys. Cohorts of the length frequencies were assigned to spawning periods and age groups (Oeberst, 2001). The growth of cod spawned in spring and summer was similar and relative stable over the studied period. Based on these studies the proportions of spring spawning cod in the Bornholm Sea were quantified for age group 0 to 2 in quarter 4 and age group 1 to 3 in quarter 1. Variable proportions of cod of the same age group captured in the Bornholm Sea during the Baltic International Trawl Surveys were spawned in the spring.

A.2 Fishery

Catches in the Western Baltic are taken mainly by trawlers, gillnetters and to a smaller degree Danish Seiners in Sub-divisions 22–24. The last couple of years fishing conducted with longlines and handlines have also been registered.

In 1932 a trawling ban was implemented in Sub-division 23 (The Sound), due to the heavy shipping activity. The ban is not implemented in a minor area “Kilen” adjacent to Kattegat (SD 21). Half of the commercial catch in this SD is landed by gillnetters, however in “Kilen” the landings are taken by trawlers. Catches are predominantly Danish, Swedish and German, with smaller amounts occasionally reported by other Baltic coastal countries (Figure 1).

Fishery regulation

Gear regulation

A BACOMA codend with a 120 mm mesh was introduced by IBSFC in 2001 in parallel to an increase in diamond mesh size to 130 mm in traditional codends. The expected effect of introducing the BACOMA 120 mm exit window was however not obtained. This was to some extent explained by the mismatch between the selectivity of the 120 mm BACOMA trawl and the minimum landing size. In October 2003 the regulation was changed to a 110 mm BACOMA exit window or a T90 codend (in which the mesh in the codend and extension piece is turned 90°). These were expected to enhance the compliance by the fishing industry and to be in better accordance with the minimum landing size, which was changed from 35 to 38 cm in the same year. The selectivity has been analysed and ICES concludes that both designs BACOMA and the T90 are indeed selective and give retention length (L50= 50% of the fish of this length will be retained in the net) equivalent to the current Minimum Landing Size (MLS) for cod of 38 cm.). There is no clear evidence of discrepancy in the selectivity between the two gears. Implementation of the BACOMA window in the new EU countries (Estonia, Lithuania and Poland) was made in May 2004.

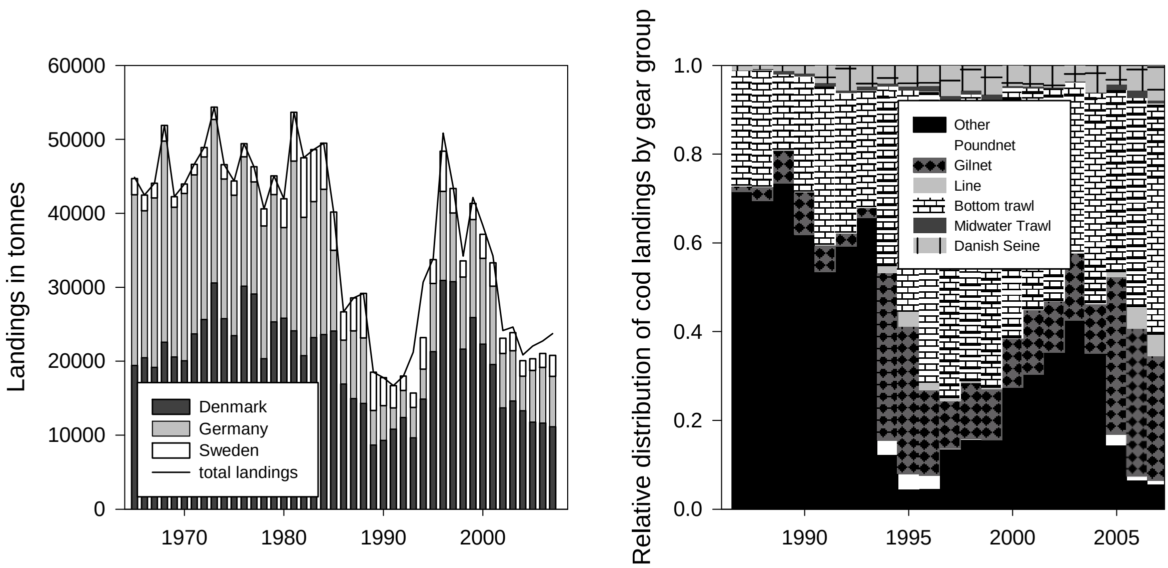


Figure 1a and b. Landings in tones by the most important nations and the main gear type used over time.

Changes in fleet dynamics

Historically around half (but in some years up to 80%) of the total cod landings has been caught in the first quarter of the year, 2nd and 3rd quarter are only accounting for 25% of the total landings Figures 2a and b. Furthermore, a very large part of the trips where cod is landed has more than 30% cod in the landings compared to the total catch weight. This indicates that cod in the Western Baltic is mainly fished in a directed cod fishery and to a lesser degree caught as by-catch in other fisheries. Small vessels are fishing the majority of cod in the Western Baltic and more than 60% of the Danish fleet operating in the Western Baltic are below 15 meters and VMS is not mandatory.

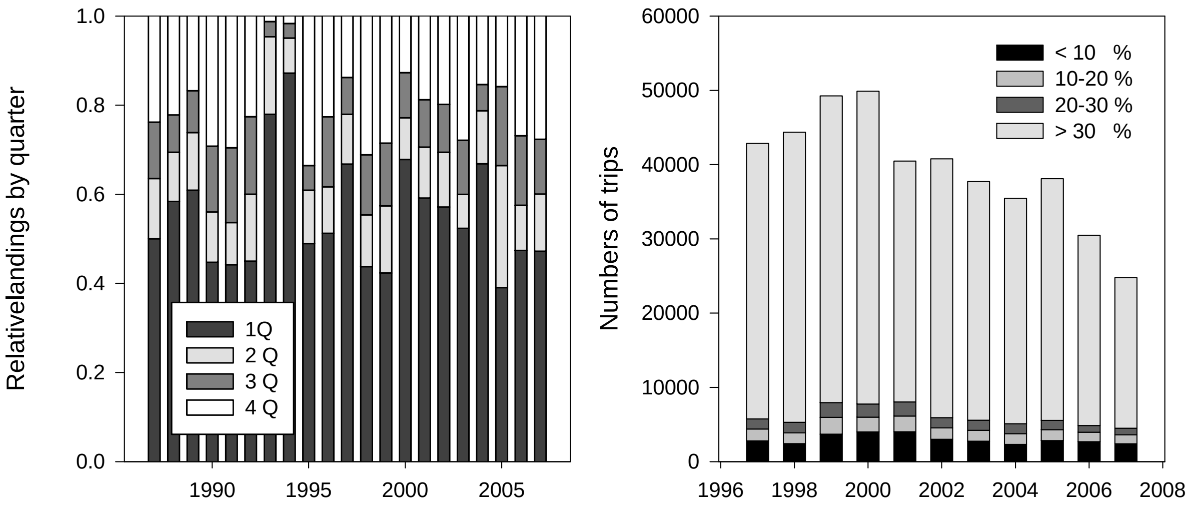


Figure 2a. Fishery in the Danish fleet by quarter. 2b The Danish directed cod fishery , the % refers to the amount of cod weight in relation to the total catch weight by trip.

Effort regulation

Effort is regulated by a seasonal closure with an annually 10% decrease in fishing days, this has been implemented since 2006:

- 2006-from March 15th to May 14th with an. additional 30 days of closure are to be allocated individually by the member states.
- 2007-from March 31st to May 1st, and on 31st of December with an additional 77 to be allocated individually by the member states.
- 2008-The fishery can be conducted in 223 days, however not in the timeframe from 1st to 30th of April.

National regulations

In 2008 a trawling band from ½–31/3 2009 has been implanted in the Northern part of SD 23 (The Sound) to protect the Kattegat cod, by reducing F. As a consequence the large cod catches in "Kilen" SD 23 is expected to be reduced in the 1st quarter of 2009.

In 2007 a new individual right based regulation system was introduced in Denmark. The regulation was introduced 1st of January 2007. Before this time quotas were split into 14-days rations which were continuously adjusted to the amount of quota left, particularly around the end of the year. In 2007 this system was changed to a rather complex rights-based system (FKA-Vessel Quota Share), where fishermen are allocated a yearly share of the quota, and can subsequently trade it, exchange it or pool it with other fishermen. They are of course still assigned to usual EU-regulations such as closed seasons and fishing days.

In May 2004, Germany as the first EU Member State nominated a comprehensive set of ten marine Natura 2000 sites to the European Commission, where 6 of the sites have been placed in the Baltic Sea. In February 2006, ICES in collaboration with the German Federal Agency for Nature Conservation (BfN) started the project "Environmentally Sound Fishery Management in Protected Areas [EMPAS]" aimed at developing fisheries management plans for the Natura 2000 sites within the German EEZ of the North Sea and Baltic Sea. The EMPAS project runs for three years and includes international workshops carried out in 2006, 2007, and 2008. (Reports and information at the EMPAS web-page: http://www.ices.dk/projects/empas.asp).

Recreational fishery

Reported estimated catches have not been included in the assessment due to the lack of time series, catches are however estimated to be substantial in the Western Baltic (Anon, 2007) Following STECF recommendations, an *Ad hoc* Workshop has been arranged by ICES (WKSMRF) in April 2009 to address the methodological issue for sampling of recreational fisheries.

A.3 Ecosystem aspects

The oceanographic conditions in the Baltic are very much driven by meteorological forcing, influencing the inflow of sea water from the North Sea into the Baltic Sea. Significant correlations have been demonstrated between the NAO and total fresh-water runoff, westerly winds, and salinity (Häninnen *et al*., 2000), ice conditions (Koslowski and Loewe, 1994) and local circulation and upwelling (Lehmann *et al*., 2002). Climate variability has been shown to affect the dynamics of many of the components of the Baltic ecosystem.

The species composition of the phytoplankton depends on local nutrients and salinity and changes gradually from the southwestern Baltic to the northeastern Baltic. Primary production exhibits large seasonal and inter annual variability (Helcom, 2002, p. 182). Normally, an intense spring bloom starts in March in the western Baltic. In the southern and western parts of the Baltic, the spring bloom is dominated by diatoms. Over the period from 1979 to 1999 downward trends were found for diatoms in spring and summer, whereas dinoflagellates generally increased in the Baltic proper, but decreased in the Kattegat.

Mass occurrences of blue-green algae are often made up of several species. Since 1992 the relative abundance of the most common species has shown a clear increasing trend in the Arkona Basin in the western Baltic.

The zooplankton community and species composition is influenced by the salinity gradient. Generally marine species (e.g. Pseudocalanus spp.) prevail in the western Baltic because higher salinity than in the eastern areas. Changes in the species composition of the zooplankton have been linked directly to changes in salinity and temperature.

The composition of the benthos depends both on the sediment type and salinity, with suspension-feeding mussels being important on hard substrate while deposit feeders and burrowing forms dominate on soft bottoms. The species richness of the zoobenthos is generally poor and declines from the southwest towards the north due to the drop in salinity.

The distribution of the roughly 100 fish species inhabiting the western Baltic is largely governed by salinity. Marine species dominate in the western Baltic, while fresh-water species occur in estuaries and in lower salinity fjords and lagoons. (Hempel and Nellen, 1974). In the western Baltic cod, herring, and sprat comprise the large majority of the fish community in both biomass and numbers. In the western Baltic cod is the main predator on herring and sprat, and there is also some cannibalism on small cod as in the eastern Baltic (Köster *et al.*, 2003). A predation on cod eggs by sprat and herring has been described in the southern Baltic and especially for the Bornholm Basin. This interaction is operative also in the western Baltic in the most important spawning areas. However the cod egg predation by clupeids appears to be less import in the western spawning areas than in the eastern Baltic. This has been explained by a more limited vertical overlap between predator and prey in these areas (STORE 2003).

The biological characteristics and population abundance of the three species are rather different between geographical areas within the stock units presently assessed and are also rather variable in time. The passive transport of youngest life stages of cod and migration by juveniles into/out of their nursery areas as well as spawning migrations of adults between different sub-divisions and between stocks are likely to occur and it is variable between seasons and years. For cod, separation and mixing between different stocks and components is presently not clear and worthwhile considering.

Present multispecies interaction models in use do not permit incorporation of migration (if not independently measured migration rates are available for the entire time period covered) while other statistically based methods are able to model migration rates utilizing different kind of spatially disaggregated data available. However, the trophic interactions between cod, herring, and sprat may periodically exert a strong influence on the state of the stocks in the western Baltic especially with respect to cod egg predation by clupeids as well as environmental conditions.

B. Data

B.1 Commercial catch

National landings and estimates of catch composition in numbers and weights-at-age data are available from sampling programs back to 1970. Since mid-1990s national landing information is provided by quarter, Sub-division and gear (active gear and passive gear) and documented in the WG report.

Landings

CANUM, WECA and CATON for landings are up to the national level compiled by the national institutes. Data are in this stage nationally aggregated to quarter, sub-division and gear type (Active, passive) even though the sampling in each country often is stratified on several fisheries (metiers). Not all landings strata have matching biological information (otoliths and length measurements) and biological information must therefore be extrapolated from other sub-divisions, quarters or fisheries. On the national level, data extrapolations of biological data are only done for strata for which additional biological information from other countries are not relevant. If additional biological information from other countries is relevant, only total landings in tonnes are given. The national data are submitted to the data coordinator and compiled in an EXCEL sheet format. The remaining extrapolations of age distributions and mean weight-at-age are made by applying the compiled data based on the countries which have performed sampling in the strata. All data extrapolations are logged for later documentation.

The amounts of cod discarded by the fishermen are estimated based on data collected by observers onboard commercial fishing vessels. All relevant biological information concerning discards is recorded by observes. Discard data are available from 1996 and onwards.

Discards data follows two alternative compilations methods depending if disaggregated sampling data are uploaded to FishFrame or not. If data are uploaded to FishFrame the estimation of the weight based discard rate is done centrally and the output is imported to EXCEL for further compilation. The stratification is the same as for the landings and the discards are raised by the landings. Because not all countries, which have uploaded discard data have uploaded landings statistics in FishFrame, the landings statistics used for raising are taken from the submitted spreadsheets (inclusive added misreporting).

In strata with landings but where no biological information exists on discard, data from other strata have been applied.

The following priorities were used when extrapolating the available biological information:

1) Same country, same quarter, adjacent Subdivision.
2) Same quarter, another country.
3) Another country, same quarter, adjacent Subdivision.

Discard data are included in the assessment as standard. Thus, CANUM input for the model consist of the sum of the landings and the discards. The estimated discard numbers for years prior to 1996 (where sampling commenced) are based on average proportions discarded by age in the period 1996 to 2003.

B.2 Biological information

Weight information:

- Catch weights are derived from the landings and the discard (weighted by numbers). Before 1982 weight-at-age in the catch were set constant.
- Weight-at-age in the stock for ages 1–3 have been updated from survey data (DATRAS) for years 1992 to present. Weights-at-ages 4–11 in the stock were set equal to the annual weights in catches from 1982 to present.
- Mean weights-at-age in discard was before 2007 set constant based on the estimates from 2002. Due to the large variance in discard weights between years it was in 2007 decided to use a weighted average of the weight-at-age in discards from 2001–2006 as discard weight data were not available before 2001. In 2008 the mean discard weight included 2001–2007 data.

Maturity information

Maturity ogives have been updated annually since 1992. At the Benchmark Workshop in 2009 a new maturity ogive, using all available data in DATRAS and taking mature but resting spawners into account for combined sexes, was accepted. Maturity ogive in the time frame 1992–2007 has been included. In 1997 maturity-at-age were updated back in time and this new maturity estimation was adopted by the Working Group.

Maturity ogives for 1992–2007 were estimated from BITS 1st quarter survey data (Paulsen *et al.*, in prep).

B.3 Surveys

In 2008 four different surveys has been available for the Western Baltic stock assessment. Two German surveys; the Solea 1st and 4th quarter. Furthermore, Denmark has conducted two surveys in the area with “Havfisken” 1st and 4th quarter. The Danish surveys were introduced in the final assessment in 2007 (Figure 3).

Danish ‘Havfisken’ surveys in SD 22-23 in 1st and 4th quarter.

The KASU (Kattegat Survey) survey is conducted twice a year in The Sound (SD 23) and Western Baltic (SD 22, 24) in February and November by a Danish vessel, "Havfisken" from DTU Aqua (formerly DIFRES). KASU is a part of BITS, and designed to provide annual abundance indices for cod, plaice and sole. The trawl is a standard TV3-520 with rubber discs of 10cm diameter on the groundrope and with a trawl speed at 3 knots. Time series from KASU start in 1995 for the first quarter and in 1994 for the fourth quarter. The spatial coverage has changed throughout time; in the period 1994–2000 the survey covered SD 23 and 22 down to Mecklenburg Bay, in 2001 the survey covered SD 23 and 22 to the Kiel Bay and since 2004 the survey has covered SD 23 and from Little Belt and Great Belt to the Northern part of SD 22 (Figure 3).

The surveys were in 2007 implemented in the assessment for the first time, due to the high internal consistency between age groups and analysis of the catchability residuals. Previously the surveys were rejected because of a small cover of the stock area, but since the survey is covering an area not included in the "Solea" survey-Northern part of SD 22 and SD 23 it was decided to include the survey in the assessment. Age group 3+ had S.E in the log residuals above 0.8 and was for this reason excluded from the tuning.

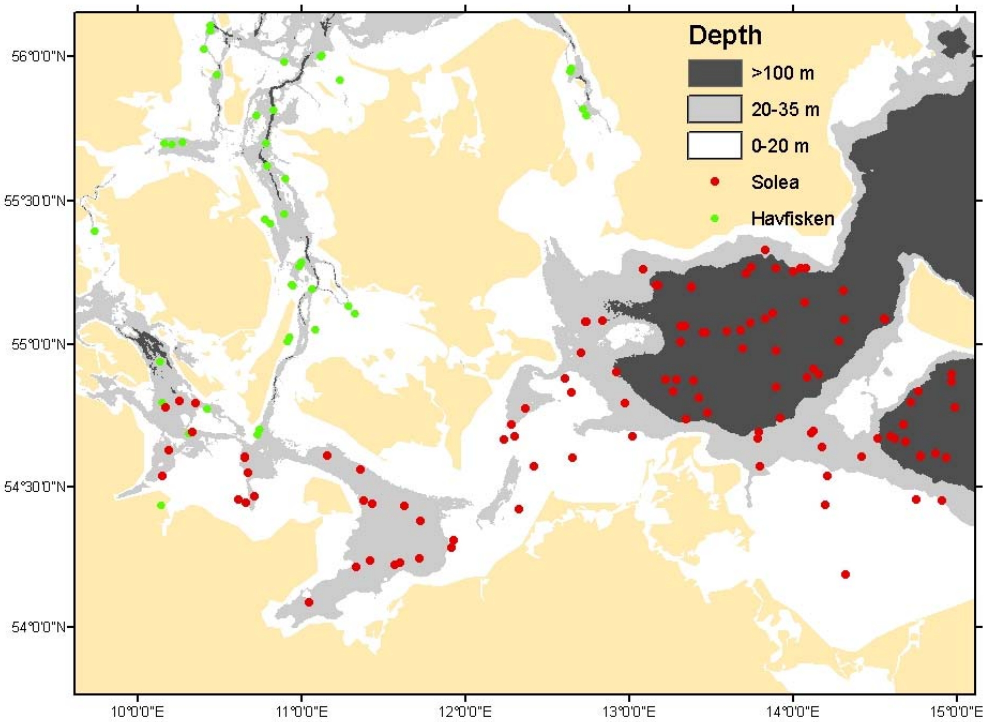


Figure 3. Area distribution of the 2 surveys Solea and Havfisken in both quarters.

German "Solea" survey in SD22-24. 1st and 4th quarter.

The time series covers the period 1978 from the 4th, and 1979 from the 1st quarter to present. Since 1997 until 2006 data from the 1st quarter survey has been used in the assessment, although with changes in age groups and timeframe. In 2007 it was decide to exclude the survey from the final run as the data showed a low internal consistency for age group 1–2 and a very high S.E in the log residuals from the XSA output for larger age groups. The 4th quarter survey was used for age 1–3.

Stock indices were derived from survey data as was done in the previous years, applying a stratified sampling design using Sub-division and depth as strata. The stratified mean cpue and the variation in the means were calculated by:

$$E(\bar{y}_{st}) = \sum_{i=1}^{L} W_i \bar{Y}_i$$

$$V(\bar{y}_{st}) = \sum \frac{W_i^2 S_i^2}{n_i}$$

where Y_i and S_i are the estimated means and standard deviations found in stratum i, W_i is the stratum weight (stratum area/total area) and n_i is the number of hauls in the stratum. The strata areas were calculated using topographical data from the Institute of Baltic Sea Research in Warnemünde. No corrections has been made for the change of gear in surveys since 2000, however inter-comparisons indicate that the efficiency of the two gears is very similar.

Combined survey

In the benchmark workshop in 2009 indices with a combined survey were presented. As the two surveys covers different areas but with the same trawl and fishing speed it has been suggested to combined the two first quarter surveys and the two fourths quarter surveys (Figure 4). Two different approaches were tried. The GAM model taking the depth, area and vessel effect into account and an ICES combined survey indices taking depth and ICES square into account.

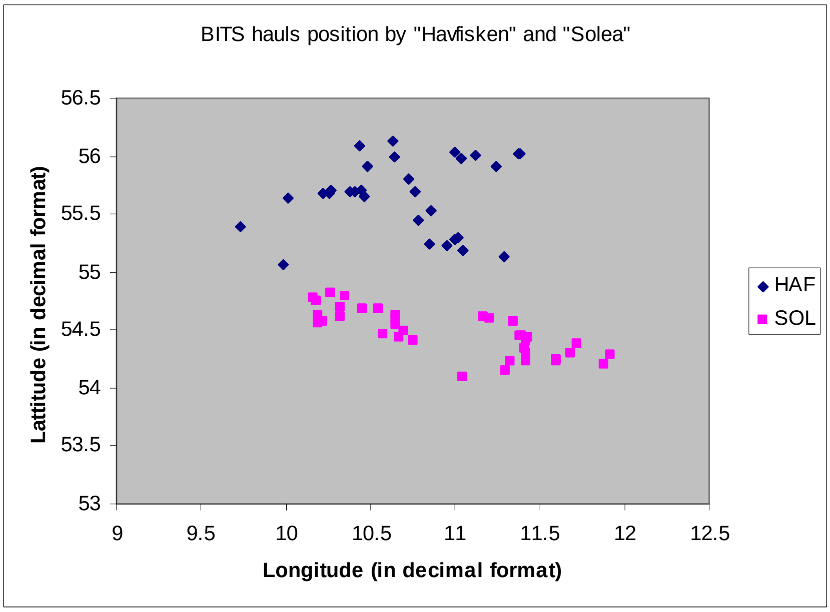


Figure 4. Station allocation from the Solea and Havfisken in correlation to latitude and longitude.

The indices showed a very different catchability in the two ships within the same subdivisions. This could be caused by an area effect as there is very little spatial overlap between ships but it could also be caused by a vessel effect. For this reason the combined surveys were not included in the final assessment. To use the combined surveys in future assessment, a larger spatial overlap between vessels is necessary to take into account for the vessel affect. A combined survey indices should not be used for assessment before this exercise.

B.4 Commercial cpue

In 2009 at the benchmark assessment a new tuning fleet was introduced for the western and Eastern Baltic cod. The gillnetters were excluded due to a bad internal consistency. The commercial tuning fleets used in this assessment are all from the Danish fishery.

In 2009 a new trawler tuning series was introduced to standardize the calculation methods between the Western and Eastern Baltic stock.

The selection procedure was based on the following criteria: (i) to subset the cod-specialist activity i.e. all activities exclusively directed to cod catches in order to get an unbiased cpue time series based on the effort targeting cod (otherwise, possible under-estimation of the cod cpue in case of effort directed toward other species); (ii) to subset all activities acting with a given and unique fishing gear combination because first the variance in catch rates per species is mainly impacted by the gear used, and second the use of the similar combination of gears is likely to reflect a homogeneous fishing behaviour pattern; (iii) to subset all activities exclusively included in area delimitation of the stock reflecting similar fishing behaviour pattern; (iv) to remove all activities subject to misreported landings and discarding for which effort and catch data are not reliable. Using these criteria, we expect to get the most homogeneous subset of activities (especially in terms of fishing behaviour pattern) relevant for tuning the cod assessment. The available data to run the subset is the trip-based Danish DFAD database merging logbook information with sales slip. The database lists the catches trip by trip for each vessel and by ICES squares. The point (iv) has not been undertaken due to lack of data on the misreporting aspect. The same arrangement is run for each year over the desired year range of the tuning fleets. Note that, processing by year, a fleet may not be constituted by the same vessels over the years. The total cod landings of each trip were then converted to landings-per-age using an allocation key from the data analysis. The decomposition of landings-in-age group is deduced from harbour sampling of fish length and fish ageing from otolith reading after building an age-length key.

Cpue standardisation

Inside each selected fleet, a standardisation procedure is applied to extract the year effect on which index of abundance can be based using a Generalized Linear Models (GLMs) with log-link. The minimal efficient model found in the model selection was for the trawler fleet was:

Cpue = year + kw + year:age

The time series cover the period 1987–present, whereas only data from 1992 to the present were used. The cpue information for the commercial fisheries was extracted from the Danish log-book database. This database provides information by vessel size, kwatt, fishing gear and mesh-size, effort measured as days-at-sea and catches separated into five market categories (i.e., size groups) on a trip-by-trip basis. The age composition in the catches is derived by linking the landings in each market category with information on age composition by market category (a market category-age key). Cpue were standardised to fleets by the ANOVA ln(cpue)=Year*month + Vessel size + kwatt. The estimated vessel size effect were re-transformed and used to correct the fishing power of different vessel sizes to a common size standard. The input data is presented as catch-in-numbers in age groups 1 to 6 and standardised effort unit by fleet. Selectivity in age 1 and 2 in this fleet is believed to have changed after the introduction of the BACOMA window.

B.5 Other relevant data

VMS data are available for the Danish fleet since 2006. An example is shown in Figure 5. The VMS signal is transmitted once an hour for vessels above 15 meters and is combined with the Danish logbooks, thereby providing the gear used. However, it is at present not possible to use the catch data as the Danish logbooks are given on a daily basis and the catch-by-haul can therefore not be applied. The VMS data has been used to estimate the effort reported in the Western Baltic compared to the effort observed in areas outside the Western Baltic. The level of misreporting from Danish vessels above 15 meters is below 3% to both the Eastern Baltic and to Kattegat.

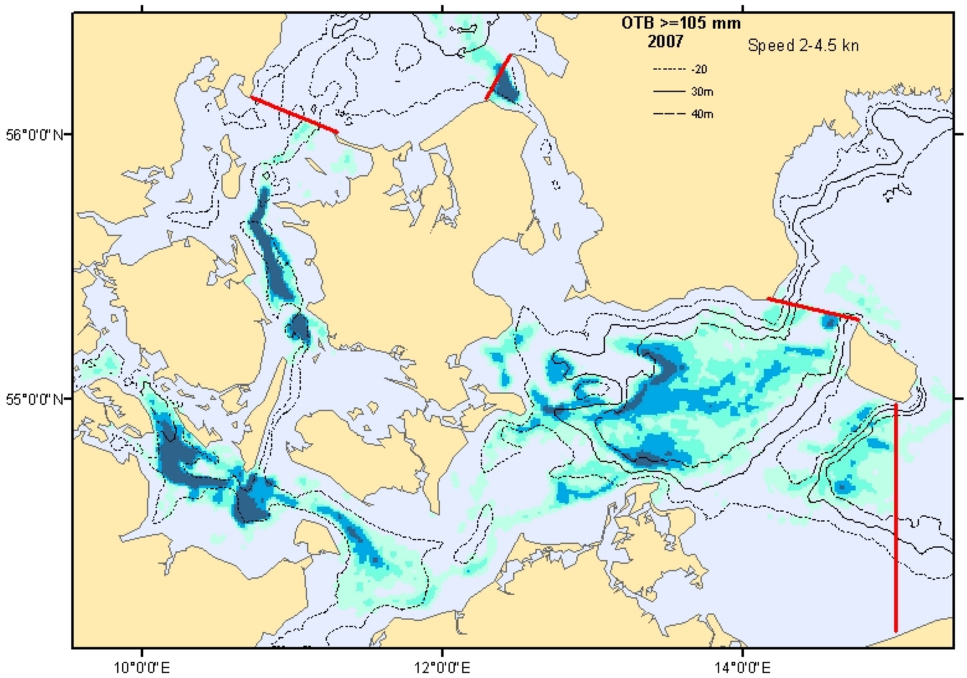


Figure 5. VMS from the Danish bottom trawlers in 2007. Only signals operating with fishing speed (2–4.5kn) and with a mesh size >= 105 mm where landings have been reported in the Western Baltic Sea has been included.

C Historical stock development

Model used: SAM. The State-Space Assessment Model (Nielsen, 2008, 2009). This model was run using the web interface that can be viewed at www.wbcod.stockassessment.org. Details concerning input data and model configurations can be found on this webpage. Some model configurations are shown below.

Software used: R (an integrated suite of software facilities for data manipulation, calculation and graphical display)

Model Options chosen:

Fishing mortality is assumed constant for ages 5+

Variance parameter is estimated separately for age 1 (in catch and in all surveys) and for ages 2+

Catchability dependent on stock size for ages < 2

Catchability independent of age for ages >= 4

Input data types and characteristics

Type	Name	Year range	Available Age range	Used Age range	Variable from year to year Yes/No
Caton	Catch-in-tonnes	1970–last data year	1+	1+	Yes
Canum	Catch-at-age in numbers	1970–last data year	1–11+ (–1996) 1–10+ (1997–)	1–7	Yes
Weca	Weight-at-age in the commercial catch and discard	1970–last data year	1–11+ (–1996) 1–10+ (1997–)	1–7	Yes (constant 1970–1981)
West	Weight-at-age of the spawning stock at spawning time.	1970–last data year	1–11+	1–7	Yes (constant during different periods: 1966–1984; 1990–1994; 1995–present) for age 1–3. For age 4–11 weights in catch
Mprop	Proportion of natural mortality before spawning	1970–last data year	1–11+	1–7	No - set to 0 for all ages and all years
Fprop	Proportion of fishing mortality before spawning	1970–last data year	1–11+	1–7	No - set to 0 for all ages and all years
Matprop	Proportion mature-at-age	1970–last data year	1–11+	1–7	Yes – ocassionally revised, new data in 2009
Natmor	Natural mortality	1970–last data year	1–11+	1–7	No- from AG 2 set to 0.2 for all ages and all years Y-AG 1 according to MSVPA, but unchanged since 1997

Tuning data

Type	Name	Year range	Age range
Tuning fleet 1	”Solea”, Q1, SD24	Excluded in 2006	AG 1–3
Tuning fleet 2	”Solea”, Q4, SD22–24	1981–present	AG1–3
Tuning fleet 4	Danish Trawlers	Revised in 2009	AG 3–6
Tuning fleet 5	“Havfisken”, 1Q SD22–23	1995–present	AG1–3
Tuning fleet 6	“Havfisken”, 4Q SD22–23	1994–present	AG1–3

D Short-term projection

Short term forecast in the future will be based on the SAM short term forecast module output. Selected, sensible scenarios will be simulated forward in time starting from estimates from the last data year. The forward simulations will carry through estimated uncertainties and correlations to the projections and calculated quantities (TAC, SSB, Fbar).

The general rules and standard settings for short term projection should be based on following general rules:

Model to be used: SAM age structured prediction module

Software in use: R (an integrated suite of software facilities for data manipulation, calculation and graphical display)

Initial stock size: Final year estimates from SAM.

Recruitment estimates: For year class 2009 and onwards-samples from the recent (for instance 5) years.

Natural mortality will be set consistent with model assumptions (e.g. 0.2 for all ages).

Other necessary future values of natural mortality, stock weights, catch weights and proportions mature will be calculates as (possibly weighted) averages of data values in recent years (e.g. three years).

E Medium-term projections

Has not been considered appropriate for this stock.

F Long-term projections

Has not been considered appropriate for this stock.

G Biological reference points

ICES has since 1996 recommended a $\mathbf{B}_{pa}$ at 23 000 t. WKROUND did not find basis for changes.

The S-R relationship has previously been analysed and the calculation of MBAL with updated data points has been found unrealistic, because it is 60% higher than the largest SSB observed in the time series. It has also been pointed out that establishing meaningful stock-recruitment relationship for this stock is difficult due to inflow of recruits from adjacent areas (Cardinale and Svedäng, 2004). Therefore, current stock-recruitment data are considered uninformative of change level in recruitment.

The exploitation level has been considered high for most of the time series and around 1.0 or higher in the latest two decades. The F_{lim} at 1.0 is therefore considered invalid. As the estimation of F_{pa} is linked to F_{lim}, F_{pa} is invalidated as well.

A yield-per-recruit estimate assumes a closed stock structure. Stock identity in the Western Baltic has not been solved, and there are strong indications on mixing of stocks (eastern Baltic cod/western Baltic cod and western Baltic cod/Kattegat cod) and homing migration of adult fish back to the original stock is documented. Furthermore the western Baltic cod stock has sustained an average F above 1 at least last two decades, which is seems to be unrealistically high. Therefore standard yield-per-recruit F reference point estimates are misleading. In present situation a yield-per-recruit analysis will not give any sensible results on F reference points.

The present reference points are as follows:

	Type	Value	Technical basis
Precautionary approach	Blim	not defined	
	Bpa	23 000 t	MBAL
	Flim	not defined	
	Fpa	not defined	
Targets	Fy	0.6	EU management plan 2007

(unchanged since: 2008)

Yield and spawning biomass per Recruit F-reference points

	Fish Mort	Yield/R	SSB/R
	Ages 3–6		
Average last 3 years	0.959	0.684	0.661
Fmax	0.271	0.885	3.429
F0.1	0.163	0.829	5.398
Fmed	1.375	0.633	0.399

(WGBFAS 2008)

H Other issues

None.

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8 Eastern Baltic cod

8.1 Current stock status and assessment issues

For Eastern Baltic cod stock traditionally has been assessed by XSA. Recent assessments reveal an increase in spawning-stock biomass is observed since 2005 although it is still at a historic low level. Based on the most recent assessments, fishing mortality has decreased. The two recent year-classes (2003 and 2005) are estimated to be above the average of the last 15 years.

The assessment is based on long-term catch data, fishery-independent data from two scientific surveys, and three indices of commercial catch per unit effort.

There is information on substantial underreporting of catch in 1993–1996, and this has also been the case since 2000. In such a situation the use official data only would result in very poor or heavily biased assessments. In this situation it was decided to include mis- and non-reportings in the assessment based on national expert knowledge. Estimates on the amount of misreporting are available from the national industries and control agencies. These indicate that recent catches have been around 32–45% higher than the reported figures. By nature this information is highly uncertain, and also incomplete, with no information available for some of the nations where misreporting is suspected to occur. Since 2007 EC has put effort to reduce unreported landings.

It is also considered that the age composition data in both the catches and the survey suffer from severe inconsistencies which appear to differ between countries and between years.

In summary the main problems that need to be solved in the Eastern Baltic cod assessment are:

1. Unreported/misreported landings,
2. Improvement of discard estimates,
3. Age reading inconsistence,
4. Mean weight-at-age in the stock,
5. Maturity ogive estimation,
6. Commercial tuning fleet indices estimation.

The WKROUND 2009 for Eastern Baltic cod stock was in position to correct the estimates mentioned under points 4 and 6.

List of Working documents:

WD 7. Francois Bastardie. Defining new commercial tuning fleets for improving the Baltic cod assessment.

WD 8. Francois Bastardie. Defining new commercial Danish tuning fleets for the eastern Baltic cod assessment.

WD 14 Anders Nielsen. State-space fish stock assessment model as alternative to (semi-) deterministic approaches and stochastic models with a high number of parameters

8.2 Compilation of available data

8.2.1 Catch/landings data

No new information (See stock annex).

8.2.1.1 Evaluation of the quality of the catch data

Landings data are considered uncertain for period since 1990-ie due to mis- and under-reporting. This leads to substantial uncertainty associated with the estimates of total landings. In recent years the WGBFAS has attempted to correct for such misreporting by applying raising factors to national catches based on the available information on misreporting by each national fleet. By nature this information is highly uncertain, and also incomplete, with no information available for some nations where nonetheless misreporting is suspected to occur. This means that the corrected landings values derived by the WG can at best be considered to be approximate minimum values.

The amount of discard estimated is sensitive to extrapolation of discard data into strata where no data exist. Particularly, taking into account the low number of discard samples and the large fractions of strata where it has been necessary to borrow data from other strata, the discard estimates for both passive and active gears have to be taken with a great caution. This is a case mainly for gillnet fleet in some years and Sub-divisions.

8.2.2 Survey data

Relative abundance indices available and used in the assessment are the following:

BITS q1 1991–2008 ages 1–6

BITS q4 2001–2007 ages 0–4

The longest survey series has an apparent break in 2001 when the survey design was altered and new standard survey trawl introduced. Therefore BITS Q1 survey is divided into two parts 1991–2000 and 2001–2008. The survey indices are back shifted from 1 qtr to the 4 qtr of previous year that allows using the most recent assessment year survey.

The following tuning data series from both surveys are used in the assessment:

TYPE	NAME	YEAR RANGE	AGE RANGE
Tuning fleet 1	BITS Q1 3–9_Backshifted	1990–2000	2–5
Tuning fleet 2	BITS Q1 3–9_Backshifted	2001–2008	2–5
Tuning fleet 3	BITS Q1_2_raw	1991–2000	2
Tuning fleet 4	BITS Q1_2_raw	2001–2007	2
Tuning fleet 5	BITS Q4_raw	2002–2007	2–5

This selection of tuning indices has been used on previous assessments and no change to this was made during benchmark workshop.

8.2.2.1 Evaluation of data quality

Quality of survey data was evaluated based on consistency analyses within and between the surveys. For younger age-groups (1–4) the consistency for both surveys is quite sufficient (R^2- value in range of 0.32–0.72). For eldest age groups it appears to be very noisy, that probably is caused also age reading inconsistencies between countries.

According to EU Decision 949/2008 (Precision of biological sampling in DCR requirements by EU Commission) the national sampling programmes shall include estimation of precision on the collected data, if the sampling cannot be defined by a quantitative target, such as sample size or sampling rate. Details are available in in:

COMMISSION DECISION of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy (2008/949/EC).

Where reference is made to precision the following levels shall apply:

Level 1) +/- 40% for a 95% confidence level or CV of 20%

Level 2) +/- 25% for a 95% confidence level or CV of 12.5%

Level 3) +/- 5% for a 95% confidence level or CV of 2.5%

The COST (Common Open Source Tool) is addressing how to estimate precision in an EU project running from 1 July 2007 until 31 December 2008 (They will develop methods to investigate and estimate sampling indicators for discards, length and age structure of catches and landings and biological parameters such as growth, maturity and sex- ratio from all the regions covered by the DCR.

The outcome of COST will be implemented by national sampling programmes in future and the procedure for implementing will be evaluated in future benchmark assessments.

8.2.3 Commercial tuning data

Two commercial Danish tuning fleets are currently used as tuning indexes for the Eastern Baltic cod assessment (Den_Trawl_>90 mm and Den_Gillnet_<160 mm) together with a Swedish commercial fleet (Swe_Trawl). The selection of the fleets and the methodology for the estimation of the indices should aim at finding a subset of the total fishing activity for which a proportional relationship between cpue and the abundance of the stock can be assumed. Potential biases is usually related to the unequal and changing nature of the spatial distribution of the fishing effort (Campbell, 2004), the effect of increased fishing power of the fleet (Bishop, 2006) and targeting (Quirijns *et al*., 2008). Historically commercial tuning indexes have not been standardised to take into account for any of those factors. Standardization, accounting for factors affecting both relative abundance and fishing efficiency, results in time series of catch and effort data that are more representative of trends in population abundance.

The selection procedure was based on the following criteria:

1. to subset the cod-specialist activity i.e. all activities exclusively directed to cod catches in order to get an unbiased cpue time series based on the effort targeting cod (otherwise, possible under-estimation of the cod cpue in case of effort directed toward other species);
2. to subset all activities acting with a given and unique fishing gear combination because first the variance in catch rates per species is mainly impacted by the gear used, and second the use of the similar combination of gears is likely to reflect a homogeneous fishing behaviour pattern;
3. to subset all activities exclusively included in area delimitation of the stock reflecting similar fishing behaviour pattern;
4. to remove all activities subject to misreported landings and discarding for which effort and catch data are not reliable.

Using these criteria, we expect to get the most homogeneous subset of activities (especially in terms of fishing behaviour pattern) relevant for tuning the cod assessment. The available data to run the subset is the trip-based Danish DFAD database merging logbook information with sales slip. The database lists the catches trip by trip for each vessel and by ICES squares. The point (iv) has not been undertaken due to lack of data on the misreporting aspect. The same arrangement is run for each year over the desired year range of the tuning fleets. Note that, processing by year, a fleet may not be constituted by the same vessels over the years. The total cod landings of each trip were then converted to landings-per-age using an allocation key from the data analysis. The decomposition of landings in age group is deduced from harbour sampling of fish length and fish ageing from otolith reading after building an age-length key.

Cpue standardisation

Inside each selected fleet, a standardisation procedure is applied to extract the year effect on which index of abundance can be based using a Generalized Linear Models (GLMs) with log-link. The minimal efficient model found in the model selection was for the trawler fleet was:

Cpue = year + kw + year:age

The model fit for the gillnetter fleet was:

Cpue = year + meshsize + year:age

The landings decomposition by age group was possible from 2007 to 1997 backward, data from previous years being considered less reliable by experts. This conditions the final range of years of the time series of the abundance indices. The main result of the effort standardization is that the correction is low and this could be explained by the fact that the fleet selection had already succeed in setting up homogeneous fleets. For trawlers, the fleet selection procedure enabled to set a fleet with homogeneous vessels as the low effort correction demonstrated. Further, the visual inspection of the internal consistency of the proposed fleets (Den_Trawl_bchmk09) suggests that this fleet is consistent (Figure 8.1).

The good consistency of the existing gillnetter fleet (i.e. Den_Gillnet_<160 mm) could not have been reproduced by the proposed one (Den_Gillnet_bchmk09). Therefore, the proposed tuning fleet should not be used considering its lower internal consistency. The difference of design with the existing one is however unknown (Figure 8.2).

8.2.3.1 Evaluation of data quality

The cpue indices obtained here were first based on the assumption that the catch rate is proportional to the stock abundance. Cpue may however decrease less than expected (i.e. hyperstability) when effort is reduced because of fish schooling, sedentary stock, active fishermen search, etc. Second, indices assumed no change in the discard and selectivity patterns over the time and equally no technical improvement of vessels during the span of the time series (1997–2007) over what is already accounted in the changes in vessel power (kwh). Further, it should keep in mind that it is only if there are between vessels difference in catching power that are measurable characteristic that the GLM method is able to distinguish between abundance changes and catching power changes.

The present work delivers a unified R code (data analysis + graphics) to test new definition for tuning fleets, also possibly to test some limitations (technological improvement, etc.) affecting the stationary of catch rates over the time series. This constitutes also a generic R code to apply on the west cod stock as well.

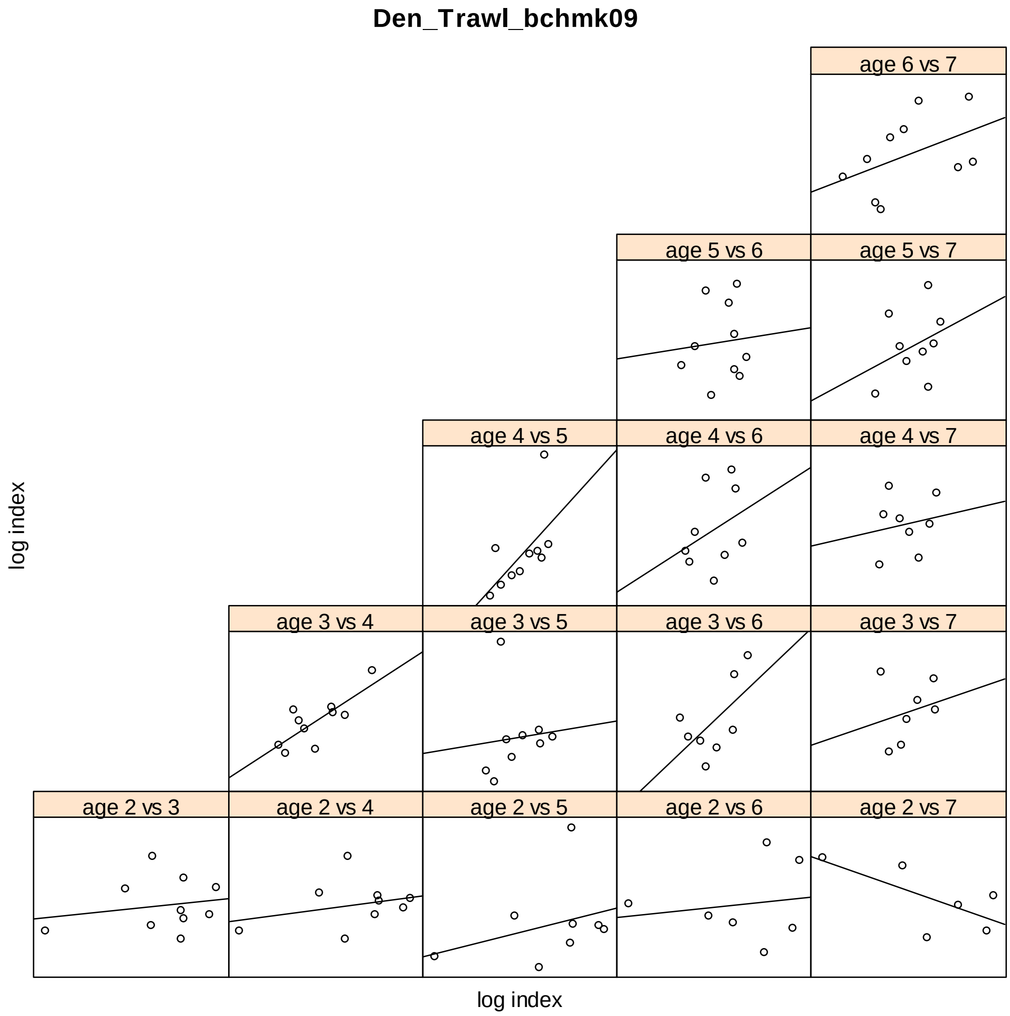


Figure 8.1. Internal consistency of the suggested tuning fleets Den_Trawl_bchmk09.

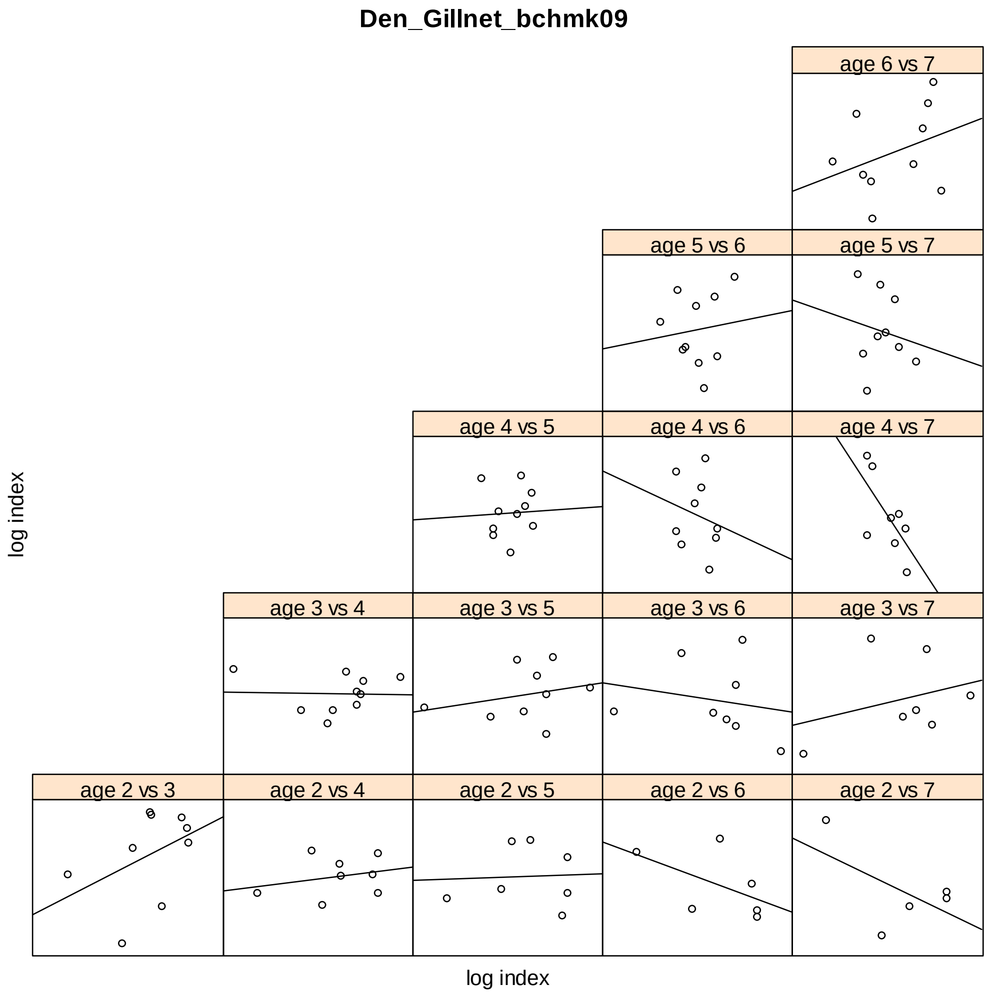


Figure 8.1. Internal consistency of the suggested tuning fleets Den_Gillnet_bchmk09.

8.2.4 Biological data

Estimates of the mean weight-at-age in the stock since 1995 are based on data from the first quarter BITS survey data. The values are calculated from the mean weight-at-age in each Subdivision weighted by survey estimates of the relative abundance of cod in each Subdivision.

Mean weight in stock for 2005–2007 were not available at the WG meeting, as the survey database DATRAS was not designed for such purpose. Therefore these values were estimated by applying the ratio between stock weight-at-age and catch weights-at-age as average over 2002–2004 to the 2005, 2006 and 2007 catch weights-at-age. In WG was pointed that presently used method to obtain mean weight-at-age data for 2005–2007 as a ratio between stock weight and catch weights-at-age may not be appropriate for recent three years because of significant changes in Eastern Baltic fishery technical regulations e.g. increase of minimal landing size and gear mesh size (Suuronen *et al.*, 2007).

As the recently DATRAS database development include calculation of mean weight-at-age taking into account the length distribution, also for 2005–2007 weight-at-age in stock was estimated using the mean weight-at-age per Sub-division (download option: SMALK) weighted by survey estimates of the relative abundance of cod among Sub-divisions 25, 26 and 28 (download option: cpue per age per area).

The maturity ogive data is still not available from DATRAS database. According to information from ICES representatives it will be made available in at latest March 2009.

8.2.5 Industry/stakeholder data inputs

Fish processing company A. Espersen A/S has proposed to consider data extracted from EURO Stat numbers for import and export of cod for calculating cod overfishing in the Baltic. Together with Sustainable Fisheries Partnership A. Espersen A/S has conducted a preliminary analysis of the levels of Baltic Sea overfishing using the adjustment method developed by Tony Pitcher. The adjustment method uses statistical analysis to compare multiple sources of information, highlights variation and uncertainties and provides upper and lower limits of IUU. The process requires information on trends over time and regulatory incentives/disincentives to misreporting. Consequently there is an attempt to include data on recent or historical assessments/estimates of IUU. Unfortunately for present time constrains it was not possible to present some preliminary results at WKROUND meeting, but the analysis is expected to be available within the next couple of months.

8.3 Stock identity and migration issues

There was no new information available for this group (c.f. Stock Annex).

8.4 Spatial changes in fishery or stock distribution

Spatial changes in fishery or stock distribution is currently not considered an issue for assessment.

8.5 Environmental drivers of stock dynamics

The main drivers in the Kattegat, western Baltic and eastern Baltic vary somewhat between regions, but all sub-systems in the Baltic Sea from south to north include the increasing temperature, decreasing salinity and in the Baltic Main Proper deep basins the oxygen. The primary driving forces of the observed regime shift in all Baltic sub-regions, decreasing salinity and increasing temperature, are both consequences of climate change. These are influenced largely by atmospheric forcing illustrated by the Baltic Sea Index (BSI), a regional calibration of the North Atlantic Oscillation index (NAO) (Lehmann *et al*., 2002). The change from a generally negative to a positive index in the late 1980s was associated with more frequent westerly winds, warmer winter and eventually a warmer climate over the area. Further, the absence of major inflow events has been hypothesized to be related to the high NAO period (Hänninen *et al*., 2000).

For the Baltic Sea, future climatic change involves decreased frequency of inflow of saline water from the North Sea and increasing run-off due to precipitation. Both of these have contributed, and will continue to contribute, to the decreasing salinity in the Baltic Sea.

In Kattegat, western Baltic (SD 22–24) and eastern Baltic cod (SD 25–32) stocks environmental drivers influencing stock dynamics exist, but the only stock with clear documentation of the impact of environmental drivers is eastern Baltic cod stock.

The following drivers have been considered, but not included into the assessment models except cannibalism into the SMS multispecies model.

1. Due to the increased salinity after the 1993 major Baltic inflow (Matthäus and Lass, 1995), cod eggs were floating in shallower water lay-

ers, while clupeids occurred deeper, due to enhanced oxygen concentration in the bottom water (Köster and Möllmann, 2000). Thus, predation pressure on cod eggs appears to be higher in stagnation periods.

2. A substantial predation on cod eggs by sprat and herring has been described for the Bornholm Basin presently the most important spawning area due to adverse hydrograhic condition in the Gotland Deep and Gdansk Deep. Egg predation is most intense at the beginning of the cod spawning season, with sprat being the major predator (Köster and Möllmann, 2000). The shift of cod peak spawning time from spring to summer (Wieland *et al*., 2000) resulted in a decreasing predation pressure on cod eggs by sprat, due to a reduced temporal overlap between predator and prey.
3. Cod egg predation by clupeids appears to be less important in the more eastern spawning areas. This has been explained by a more limited vertical overlap between predator and prey in these areas (STORE 2003).
4. *Copepod nauplii* and *copepodites* are the dominating prey organisms of cod larvae in the Central Baltic (Voss *et al*., 2003). The composition and distribution of the zooplankton is important for larval survival and growth and thus survival. The copepod *Pseudocalanus* elongates that is related to more saline water is preferable to *Temora longicornis* and *Acartia spp*. which dominate at low salinities. Using a coupled hydrodynamic-trophodynamic model to analyse intra- and inter-annual variability in growth and survival of cod larvae in the Eastern Baltic, it was identified that the strong decline in *P. elongatus* abundance during the last two decades as a result of low salinities (Möllmann *et al.*, 2000), meant that early cod larvae changed from a non-food limited to a food limited state.
5. If *P. elongatus nauplii* are present in the model, high survival rates occurred during spring and early summer, whereas omitting P. *elongatus* resulted in high mortality rates and only late hatched larvae or larvae transported rapidly out of the basins into shallow water areas survived (Hinrichsen *et al*., 2002a). Thus, low *P. elongatus* availability is likely to have contributed to the reduced recruitment of cod since the late 1980s.
6. After settling fish increased in the diet of cod and sprat and herring become the main food for the larger cod. At the present low stock size cod seems not be food limited, however this may not have been the case in the 1980s, when the cod stock was at a high level relative to the clupeid abundance. Juvenile cod also suffer from cannibalism (Sparholt, 1994; Neuenfeldt and Köster, 2000). As in other cod stocks, the intensity of cannibalism is related to predator abundance, but also the juvenile concentrations, which depend upon the habitat volume occupied and the overall abundance of cod. Apart from medium- to long-term distribution changes related to stock size, inter-annual variability in cannibalism may be influenced by changing hydrographic conditions as well (Uzars and Pliksh, 2000).

8.6 Role of multispecies interactions

The multispecies assessment for the Central Baltic Sea has been updated using SMS (WGSAM 2008). SMS is a stochastic multispecies model describing stock dynamics of interacting stocks linked together by predation.

The updated key run shows that herring predation mortalities appeared to increase slightly in 2005 to 2007. This was probably an effect of excluding the Gulf of Riga in this period. This is, however, not an artefact in the sense that predation is over - estimated in the last 3 years of the assessment, but that predation is probably under-estimated in the years before. Excluding the Gulf of Riga herring also for previous years would probably increase predation mortality estimates for herring for the earlier period. On the other hand, the cod stock actually has increased slightly since 2004, which resulted in an increased predation on sprat. Again, this effect is probably amplified by the exclusion of Gulf of Riga herring, which decrease the biomass of total available food, increasing the suitability for sprat as prey. All key run details and results are available in WGSAM 2008.

8.7 Impacts of fishing on the ecosystem

There was no new information available for this group (see the Baltic Sea overview).

8.8 Stock assessment methods

8.8.1 Models

XSA was used for assessing cod in the Eastern Baltic with 8 tuning fleets (5 survey fleets and 3 commercial-see Sections 8.2.2 and 8.2.3). During the WKROUND 2009 the new SAM model was tested.

8.8.2 Sensitivity analyses

8.8.2.1 XSA

During WKROUND 2009 there was made corrections in the mean weight-at-age in the stock data input file for 2005–2007 and all three commercial tuning fleets replaced by one Den_trawl_bench_09. Based on this the following runs were explored and compared with ACOM accepted XSA run in 2008:

1) New tuning fleet set plus old west data;
2) New tuning fleet set and new west data;
3) Survey fleets only plus new west data;
4) Updated tuning and mean weight-at-age data with shrinkages 0.5 (standard) and 2.0.

The options 1 and 2 were performed in order to evaluate the impact of change of mean weight in the stock.

The terminal year SSB and F estimate comparison is shown in Figure 8.3. Similar to WGBFAS 2008 for last 3 years is observed the increase trend in SSB and decrease trend in F. However, the new runs show slightly higher F and lower estimate of SSB. The influence of change in the mean weight-at-age in stock that is significant for younger age groups (2 and 3) is small (approximately 5000 t). However new estimate of SSB is smaller because of decrease stock numbers-at-age in eldest ages. It is considered as an effect of changes of commercial tuning fleet.

The run with survey fleets only produced different results. The differences were most significant in the fishing mortality and in the spawning biomass estimates for the last year. Diagnostics are quite similar for both runs, but the results from the run with all survey fleets seems to be slightly better with lower residuals, higher R^2 values and lower SE of log(q). The similar differences were reported during WGBFAS 2008.

The decrease of shrinkage shows higher SSB and lower F values but maintaining the similar stock development trends (Figure 8.4).

It should be also pointed out that for ages 6 and 7 have increased scaled weights of shrinkage in comparison with WGBFAS. It is also considered as an effect of change in commercial tuning fleet. The Log catchability residuals are shown in Figure 8.5.

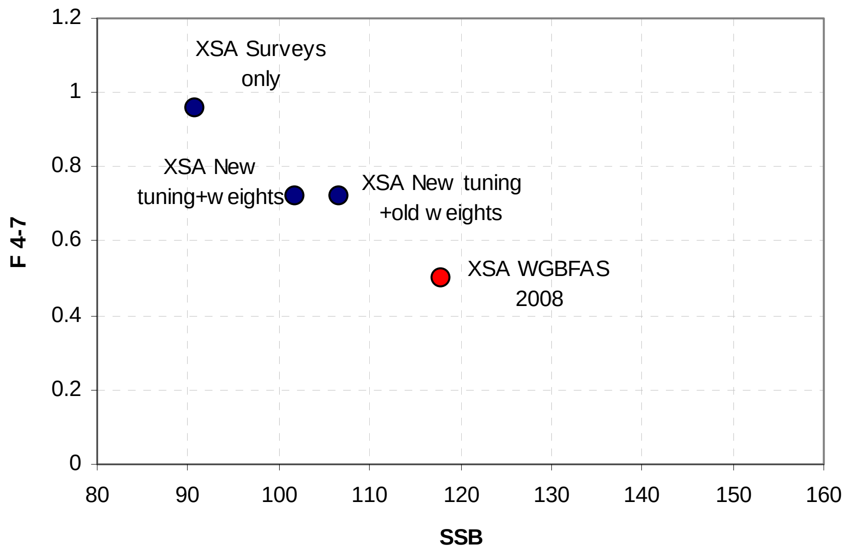


Figure 8.3. Comparison of new XSA runs with final run of WGBFAS 2008.

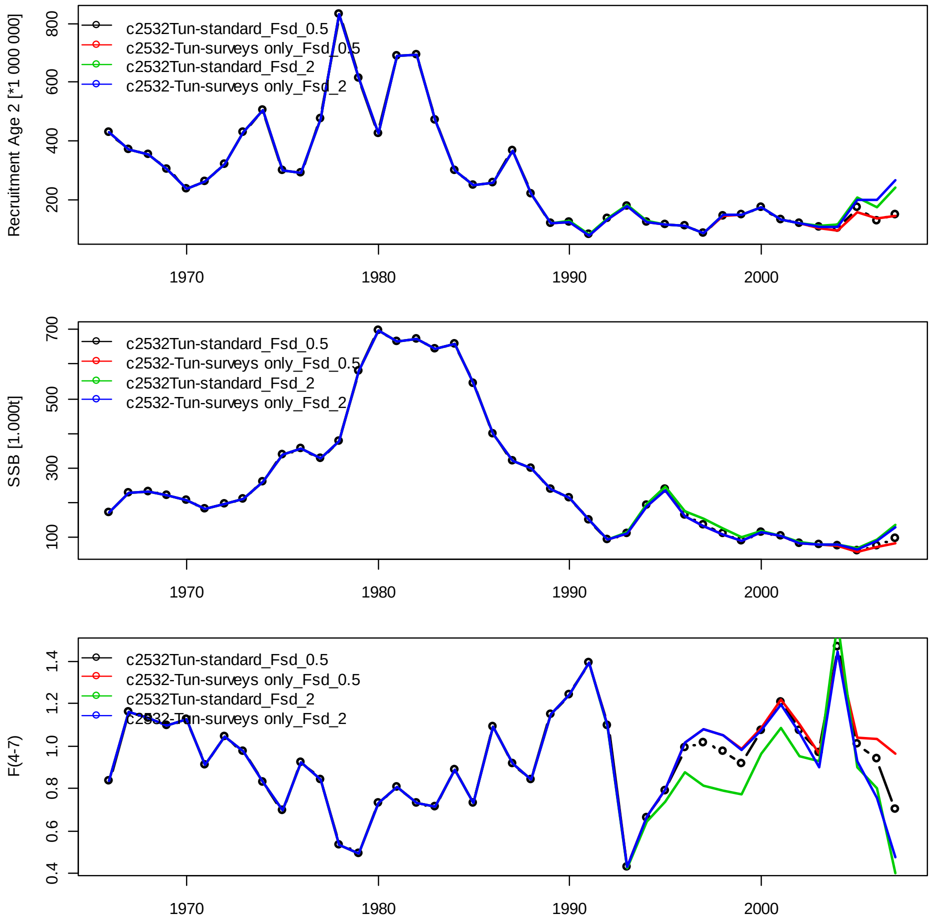


Figure 8.4. XSA time series.

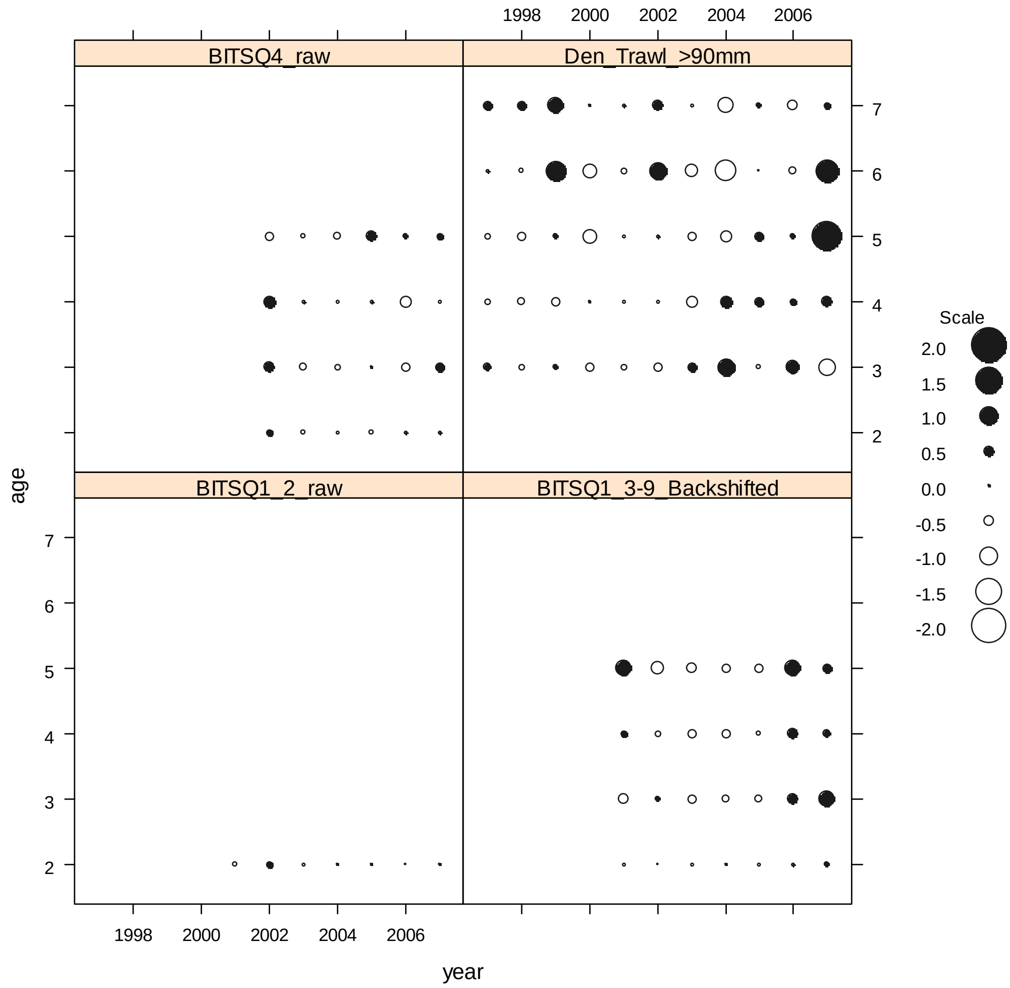


Figure 8.5. Log catchability residuals of new tuning fleet set.

8.8.2.2 SAM model

The SAM model was configured using the revised time series of mean weight in the stock and using the "Danish trawlers" as the only commercial tuning fleet. The model was configured as presented in the table below:

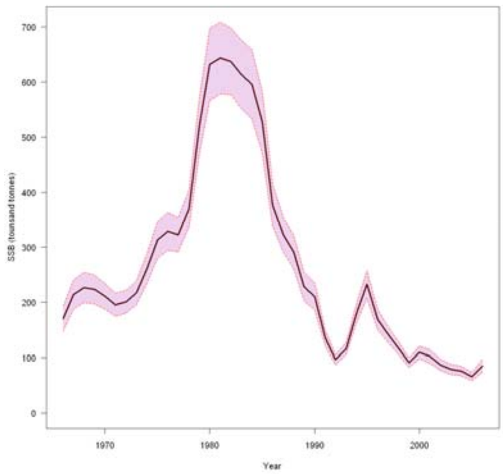
	Grouping of states and parameters
F-processes	Age 2, age 3, age 4, age 5, ages 6-8
F random walk variance parameters	Ages 2–8
N process variance parameters	Age 2, ages 3–8
Observation variance of catches	Age 2, ages 3–8
Catchability, surveys	
BITSQ1_3-9_Backshifted, 1990-2000	Age 2, age 3, ages 4–5
BITSQ1_2_raw	Age 2
BITSQ1_3-9_Backshifted	Age 2, age 3, ages 4–5
BITSQ1_2_raw	Age 2
BITSQ4_raw	Age 2, age 3, ages 4–5
Den_Trawl_bench_09	Age 3, ages 4–5, ages 6–7
Variance of catchability, surveys	

	Grouping of states and parameters
BITSQ1_3-9_Backshifted, 1990-2000	Age 2, ages 3–5
BITSQ1_2_raw	Age 2
BITSQ1_3-9_Backshifted	Age 2, ages 3–5
BITSQ1_2_raw	Age 2
BITSQ4_raw	Age 2, ages 3–5
Den_Trawl_bench_09	Age 3, ages 4–7

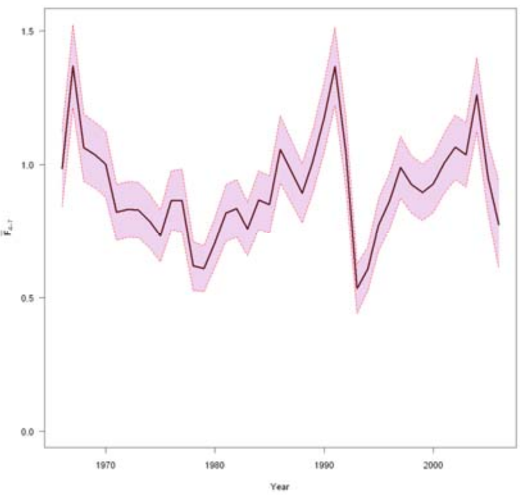
An overview of the results is presented in Figure 8.6. Estimated SSB, mean F and recruits show the same trend as estimated from the XSA output. However, SAM estimates of F for terminal year is lower, but SSB-higher (Figure 8.7).

Leaving out one tuning fleet at time (Figure 8.8) has almost no effect on the estimated SSB and F, indicating a consistent signal from all data sources.

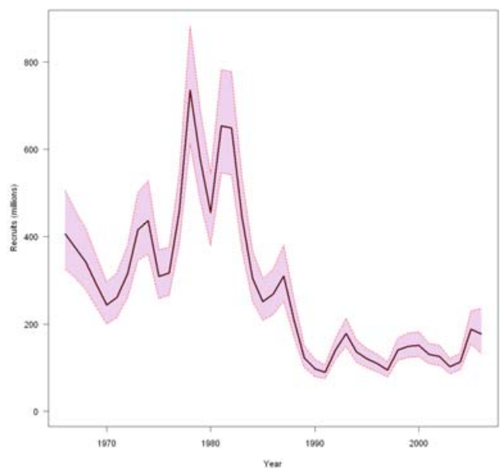
Spawning Stock Biomass



Mean Fishing mortality (age 4-7)



Recruitment estimate



Standardized Residuals, catch and surveys

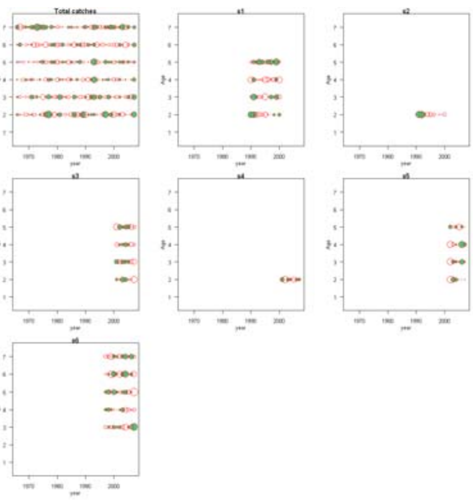


Figure 8.6. Output of the SAM model, Eastern Baltic cod. For SSB, mean F and recruits the figure show the median and the point wise 95% confidence intervals. For the residuals, red circles indicate a positive residual and filled green circle indicate a negative residual.

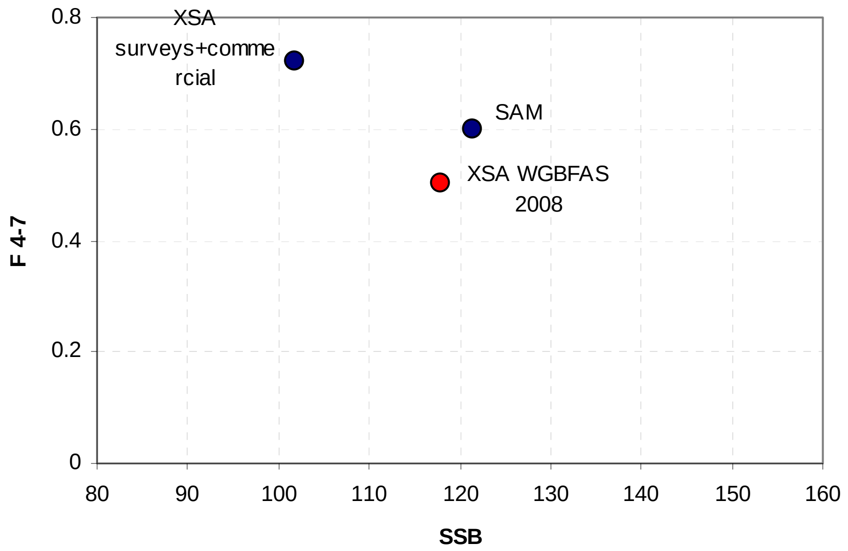


Figure 8.7. Comparison SSB and F estimates of terminal year for XSA and SAM.

Mean Fishing mortality (age 4-7) **Spawning Stock Biomass**

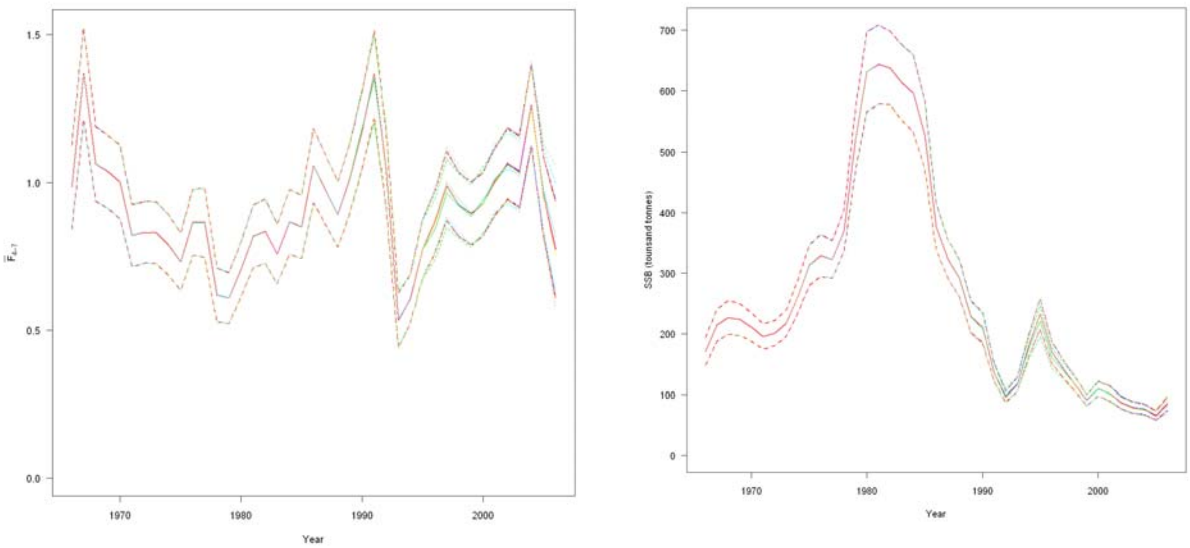


Figure 8.8. SAM, Sensitivity analysis. Results of leaving out one tuning fleet at time. The graphs show median and 95% confidence limits.

8.8.3 Retrospective patterns

Due to the very short time series of survey indices, it was just possible to make the retrospective analysis for some years back in time in both models. The SAM model results show a very consistent estimate of SSB, but a possible tendency to overestimate F (Figure 8.9). The same pattern is seen for the XSA runs (Figure 8.10).

Mean Fishing mortality (age 4-7) **Spawning Stock Biomass**

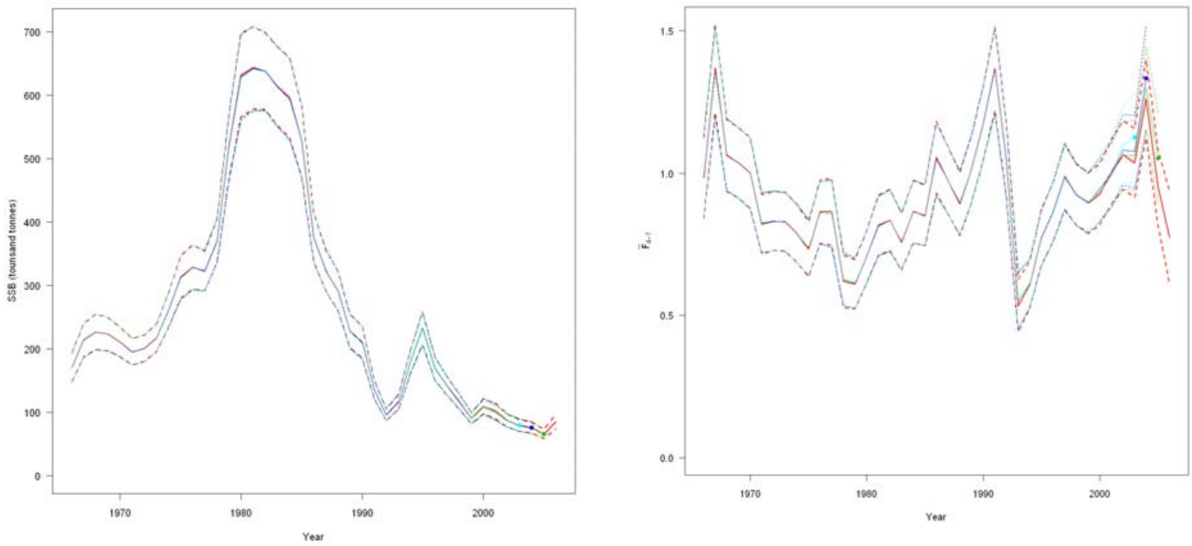


Figure 8.9. SAM, Retrospective analysis. For each year the median and the 95% confidence limits are shown.

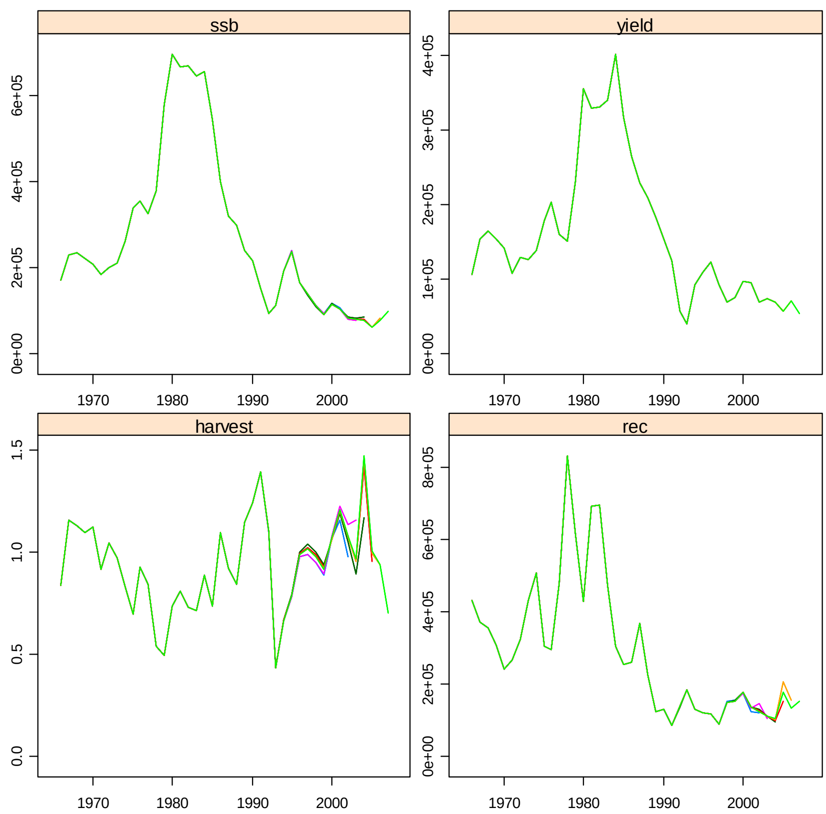


Figure 8.10. XSA, retrospective analyses.

8.8.4 Evaluation of models

For XSA analyses from diagnostic point of view were not detected significant differences from last year's assessment. Therefore WGROUND 2009 accepted the data corrections.

SAM provides several advanced features like the confidence intervals of F, SSB and R estimates. The XSA estimates were in the confidence intervals of SAM, however WGROUND was not in a position to evaluate which model is the best for the stock assessment of Eastern Baltic cod. More exploratory runs with SAM will be conducted during next WG meeting. As WG has traditionally used the XSA analyses it was recommended that until next benchmark assessment WG base assessment on XSA.

WKROUND 2009 decided that until next benchmark assessment the age structured models are used for this stock.

8.9 Stock assessment

The differences from most recent assessment are listed in Chapter 8.2.

8.10 Recruitment estimation

Recruitment estimation for this stock should be based on regression between XSA Age 2 estimate and 1st and 4th quarter survey estimates.

8.11 Short-term and medium-term forecasts

Short term projections for this stock should be based on XSA assessment.

8.12 Biological reference points

Reference points (up to 2008)

	Type	Value	Technical basis
Precautionary approach	Blim	160 000 t *	Bpa*exp(-1.645*σ), with σ = 0.25
	Bpa	240 000 t *	MBAL
	Flim	0.96	Fmed (estimated in 1998)
	Fpa	0.6	5th percentile of Fmed
Targets	Fy	0.3	EU management plan 2007

(changed in 2008) *** Recent integrated ecosystem assessment (ICES CM 2008/BCC:04) has demonstrated a major shift in food web composition and in environmental drivers, and therefore the existing biomass reference points were not used in assessing stock status or advice (and will be re-evaluated in the future).**

Yield and spawning biomass per Recruit

F-reference points

	Ages 4–7	Yield/R	SSB/R
Average last 3 years	0.71	0.60	0.99
Fmax	0.27	0.70	2.50
F0.1	0.16	0.66	3.67
Fmed	0.79	0.58	0.89

WGBFAS 2008

There is a relation between SSB and R. However its magnitude depends on the environmental condition and recruitment has been apparently independent of SSB since 1987 owing to unfavourable environmental conditions.

The Workshop on Reference Points in the Baltic Sea (WKREFBAS 2008) performed simulations to derive range of sustainable fishing mortalities for cod. The workshop concluded that sustainable F range of 0.3 to 0.4 are still appropriate for describing the long-term dynamics of the stock and investigating long-term fishing mortalities. Only with a substantial reduction of errors in assessment and implementation errors, a higher F might be possible. WKREFBAS also concluded that sustainable F between 0.3–0.4, obtained by ALTA (ICES 2005), is still valid. In this context the estimated Blim is now considered inappropriate, in particular as it was elaborated under environmental conditions which have been verified to be very different from the present environmental condition (Figure 8.11) (WGIAB 2008; WKREF 2007).

WKROUND benchmark workshop in 2009 thus recommends that present reference points should be removed and only the sustainable F between 0.3–0.4, obtained by ALTA (ICES 2005), is kept.

Reference points (present)

	Type	Value	Technical basis
Precautionary approach	Blim	Not defined	
	Bpa	Not defined	
	Flim	Not defined	
	Fpa	Not defined	
Targets	Fy	0.3–0.4	AGALTA 2005, WKREFBAS 2008, simulations

(changed in 2009)

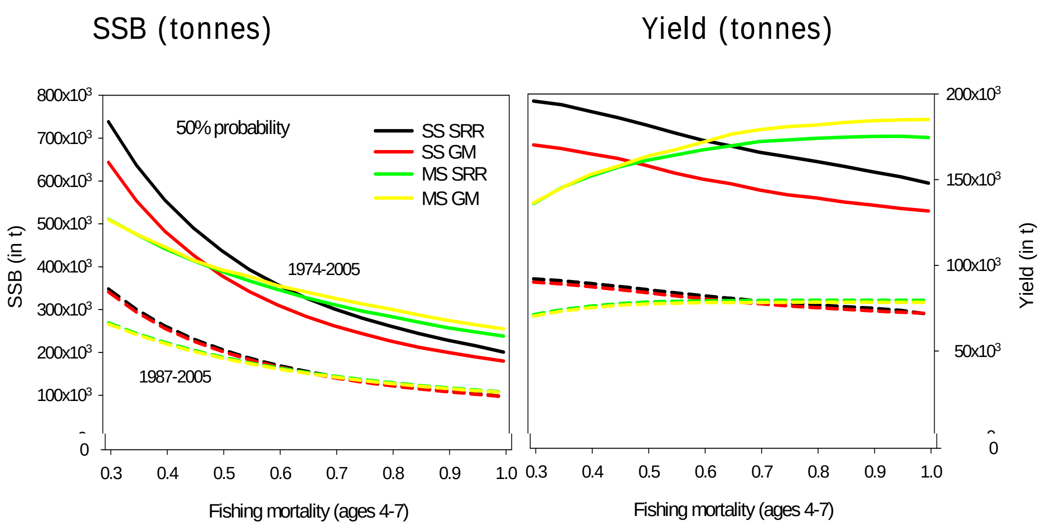


Figure 8.11. Single species (SS) and multispecies (MS) SSB and yield projections using stock-recruitment relationships (SRR) or geometric mean (GM) for whole observation period (1974–005) and period after the change in environmental conditions (1987–2005).

8.13 Recommended modifications to the stock annex

A new procedure for calculating mean weight-at-age in the stock and a calculation procedure for the commercial tuning fleet needs to be included.

8.14 Recommendations on the procedure for assessment updates

No new information was provided.

8.15 Industry-supplied data

No new information was provided at WKROUND, but the fish processing company A. Espersen A/S has proposed considering data extracted from EURO Stat numbers for import and export of cod for calculating cod overfishing in the Baltic (see Chapter 8.2.5) and to include data on recent or historical assessments/estimates of IUU. The analysis is expected to be available within the spring 2009 for consideration of WGBFAS in April 2009.

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Stock Annex Cod in Subdivisions 25–32

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Cod in Subdivisions 25–32

Working Group: Baltic Fisheries Working Group

Date: 21 January 2009

By: Maris Plikshs

A General

A.1 Stock definition

The distribution area of the Eastern Baltic cod stock is defined as the ICES Subdivisions 25–32 of the Baltic Sea. The stock is biologically distinct from the adjacent Western Baltic cod stock distributed Sub-divisions 22–24, although the stocks overlap in the border area. The stock separation that has recently been confirmed by genetic studies (Nielsen *et al*., 2001) is maintained primary trough differences in spawning areas, spawning time and egg characteristics. The timing of spawning differs between the two stocks with little the overlap in time, which is reproductively separating the stocks. Spawning of the eastern stock is confined to the deep areas where salinities in the deeper water are sufficiently high to allow egg fertilisation and to keep the fertilised eggs float. The eggs of Baltic cod reach neutral buoyancy at lower salinities (app. 12–14 PSU) than other cod stocks, which is an essential adaptation to living in a brackish water area. Sufficient oxygen contents in the deep saline water layer where the fertilised eggs float, is crucial to egg survival and recruitment success. Limited inflow of oceanic water from the North Sea has in oxygen depletion in the deep saline water and since the mid-1980s and cod reproduction has only been successful in the southern spawning areas Bornholm Basin and Slupsk Furrow located mainly in Sub-division 25. The reproduction failure in Gotland Deep (Sub-divisions 28 and 26 north) and to some extent Gdansk Deep (Sub-division 26 south) has reduced recruitment to the northern areas (Sub-division 28–32), which do not have any cod spawning areas. The stock distribution is presently limited to Sub-division 25, 26 and the southern part of Sub-division 28.

A.2 Fishery

Cod in the eastern Baltic have traditionally been taken in a directed fishery while catches of cod as bycatch in pelagic fisheries have been very limited. The main fisheries for cod in the Eastern Baltic use demersal trawls, pelagic trawls and gillnets. The cod fishery was intensified the early 1980s when the stock biomass substantially increased due to favourable reproduction conditions with particularly abundant year classes in 1976, 1977 and 1980 and landings increased to 350–400 000 tons in the mid 1980s. During this time, a considerable share of the catches was taken in Sub-divisions 28–32. However, the spawning stock declined from the highest level on record (1982–1983) to an extremely low level in the early 1990s as a result of the increased effort of the traditional bottom trawl fishery, introduction of gillnet fishery, and decreased egg survival due to oxygen depletion of deep water layers. During the 1990s when the proportion of older cod in the stock was large, the gillnet fisheries expanded. However, with the change in the stock age composition in the late 1990s and early 2000 towards younger ages, the share of the total catch of cod taken by gillnets has decreased while that of demersal trawl increased. During the most recent years, the cod catches are largely taken in Subdivisions 25 and 26 with approximately 30–40% being taken by gillnets. The cod fishery with long-lines has been developed in the recent years in some countries. The landings ranges between 50 000 and 100 000 t, however the landing estimates are presently inaccurate due to landing misreporting.

A.3. Ecosystem aspects

The eastern Baltic Sea is a brackish water area with an estuarine circulation with a low salinity surface layer (app. 7 PSU) and deeper saline layer (between 12–18 PSU). A permanent halocline separates to the low and high saline layers. The salinity and oxygen contents largely depend on the frequency and intensity of inflows of saline oxygenated water from the North Sea. The water volume suitable for egg fertilisation and development is defined as the volume of water with a PSU > 12 PSU and oxygen content > 2 ml/l, i.e. the reproductive volume. The critical stages for the recruitment success are the egg and early larval stage (Köster *et al.*, 2003a). Low oxygen contents in ambient water increases egg mortality and predation by clupeids is another mortality factor while prey availability is crucial to the survival at the first feeding larval stage.

A substantial predation on cod eggs by sprat and herring has been described for the Bornholm Basin the most important spawning area due to adverse hydrograhic condition in the Gotland Deep and Gdansk Deep. Egg predation is most intense at the beginning of the cod spawning season, with sprat being the major predator (Köster and Möllmann, 2000). The shift of cod peak spawning time from spring to summer (Wieland *et al.*, 2000) resulted in a decreasing predation pressure on cod eggs by sprat, due to a reduced temporal overlap between predator and prey. Due to the increased salinity after the 1993 major Baltic inflow (Matthäus and Lass, 1995), cod eggs were floating in shallower water layers, while clupeids occurred deeper, due to enhanced oxygen concentration in the bottom water (Köster and Möllmann, 2000). Thus, predation pressure on cod eggs appears to be higher in stagnation periods. Cod egg predation by clupeids appears to be less import in the more eastern spawning areas. This has been explained by a more limited vertical overlap between predator and prey in these areas (STORE 2003).

Copepod *nauplii* and copepodites are the dominating prey organisms of cod larvae in the Central Baltic (Voss *et al.*, 2003). In contrast to cod stocks outside the Baltic, phytoplankton does not contribute a relevant proportion to the cod larval diet. The composition and distribution of the zooplankton is important for larval survival and growth. The calanoid copepod *Pseudocalanus elongates* that is related to more saline water is preferable to *Temora longicornis* and *Acartia* spp. which dominate at low salinities. Using a coupled hydrodynamic-trophodynamic model to analyse intra- and inter-annual variability in growth and survival of cod larvae in the Eastern Baltic, it was identified that the strong decline in *P. elongatus* abundance during the last two decades as a result of low salinities (Möllmann *et al.*, 2000), meant that early cod larvae changed from a non-food limited to a food limited state. If *P. elongatus nauplii* are present in the model, high survival rates occurred during spring and early summer, whereas omitting *P. elongatus* resulted in high mortality rates and only late hatched larvae or larvae transported rapidly out of the basins into shallow water areas survived (Hinrichsen *et al.*, 2002a). Thus, low *P. elongatus* availability is likely to have contributed to the reduced recruitment of cod since the late 1980s.

After cod settles, the share of fish in their diet increases and sprat and herring become the main food for the larger cod. At the present low stock size cod seems not be food limited, however this may not have been the case in the 1980s, when the cod stock was at a high level relative to the clupeid abundance. Juvenile cod also suffer from cannibalism (Sparholt, 1994; Neuenfeldt and Köster, 2000). As in other cod stocks, the intensity of cannibalism is related to predator abundance, but also the juvenile concentrations, which depend upon the habitat volume occupied and the overall abundance of cod. Apart from medium- to long-term distribution changes related to stock size, inter-annual variability in cannibalism may be influenced by changing hydrographic conditions as well (Uzars and Plikshs, 2000).

B Data

B.1 Commercial catch

National landings and estimates of catch composition-in-numbers and weights-at-age data are available from national sampling programs back to 1966, although data prior to about 1970 are of unknown and possibly poor quality. Since mid 1990s, national CANUM, WECA and CATON for landings are compiled by the national institutes. Data are in this stage nationally aggregated to quarter, sub-division and gear type (Active, passive) even though the sampling in each country often is stratified on several fisheries (metiers). Not all landings strata have matching biological information and biological information must therefore be extrapolated from other sub-divisions, quarters or fisheries. On the national level, data extrapolations of biological data are only done for strata for which additional biological information from other countries are not relevant. If additional biological information from other countries is relevant, only total landings in tons are given. The national data are submitted to the data coordinator in a fixed EXCEL sheet format. The national data sheets are aggregated to stock level by quarter and sub-division. The remaining extrapolations of age distributions and mean weight-at-age are made by applying the compiled data based on the countries which have performed sampling in the strata. All data extrapolations are logged for later documentation.

Misreporting has been a significant problem from 1993–1996 and over the last years (2000–2006) and the reported catches been increased by 35–40%. Catch misreporting, mostly in the form of unreported landings, tends to result from a combination of restrictive quotas, the absence of other fishing opportunities and inadequate inspection. However, the precise circumstances can differ between countries, so information is obtained from representatives of each of the countries contributing data to the WG. The information supplied by each country is summarised to illustrate the nature of the information available, and to allow the reliability of the estimates to be evaluated.

Hence the raising factor (RF) that implies that the WG estimate of landings is higher than the officially reported figure was obtained by WG experts. For 1993–1996 and 2000–2005 the RF was applied to the overall CANUM. Since 2006 country specific RF's were applied to the national CANUM data. If information about misreporting is available then the landings are adjusted by applying the same factor to all age groups in the landings. The resolution for the misreporting is by quarter, sub-division, gear type and country.

Information about discard data that is available from internationally co-ordinated sampling since 1996 was introduced in the assessment in 2001. Discard data follows two alternative compilation methods depending if disaggregated sampling data are uploaded to FishFrame or not. If data are uploaded to FishFrame the estimation of the weight based discard rate is done centrally and the output is imported to EXCEL for further compilation by the data coordinator. The stratification follows the same stratification as the landings and the discard is raised by the landings. Because not all countries, which have uploaded discard data have uploaded landings statistics in FishFrame, the landings statistics used for raising are taken from the spreadsheets submitted for landings (including added misreporting). Only age groups below 3 years are adjusted with the misreporting factor assuming that the increased discard induced by the misreporting mostly is due to high grading. No extrapolation module is available in FishFrame version 4.3 and the necessary data extrapolation is done manually in the spreadsheet. The extrapolation of age distributions and mean weight-at-age are made taking into account the following priorities:

1. Same country, same quarter, adjacent Sub-division.
2. Same quarter, same Sub-division, another country.
3. Another country, same quarter, adjacent Subdivision.

All data extrapolations are logged for later documentation.

If a country does not to upload discard information into FishFrame, all data compilation of discard to national level must be done before the data are submitted to the data coordinator. All data from both sources are then aggregated to stock level on the same stratification as for the landing data. Landing and discard data are finally aggregated to stock catch level and extracted to XSA input format. All data extrapolations are logged for later documentation.

FishFrame version 5.0 has been released. This version includes the possibility for data extrapolation and raising. It is now possible to do all data processing from dis-aggregated data to final stock estimates for both landings and discards within FishFrame. This means that the use of EXCEL for data processing is no longer necessary if each country uploads data to FishFrame. At the same time it is now possible to do the data extrapolation of discard data on a sufficient low aggregation level which allows a more precise extrapolation based on fisheries having similar discard patterns. In each extrapolation the data coordinator are able to judge the data based on information of extrapolated data. This system will make it possible by time to update and quality improve the whole discard data serial and result in a general improvement of the assessment.

The discard in numbers-by-ages estimates for years previous 1996 have been raised assuming fixed discarding rates at age based on the mean values for the period 1996 to 2001.

B.2 Biological

Data on weight-at-age in the stock are available from 1995–2004 based on data from the first quarter BITS survey in Sub-divisions 25, 26 and 28. The weight-at-age is estimated using the mean weight-at-age per Sub-division weighted by survey estimates of the relative abundance of cod among Sub-divisions.

Mean weight in stock for 2005–2007 are available from the DATRAS database. The weight-at-age is estimated using the mean weight-at-age per Sub-division (download option: SMALK) weighted by survey estimates of the relative abundance of cod among Sub-divisions 25, 26 and 28 (download option: cpue-per-age per area).

Mean weight-at-age used in assessment is verified by the WG. Outlier values by country, SD, etc. can be excluded from given strata for the final estimates. This should be documented in the WG report.

In 1998, variable combined maturity ogives were introduced for the period 1966–1997 based on national data from the first quarter BITS survey. The ogives were based on compiled national sex-specific data, sex ratios, and number sampled at age per Sub-division (Tomkiewicz *et al.*, 1997). Data for the period 1980–1994 were averaged over 5 year periods due to low sample sizes, while the years 1995–1998 were annual estimates. The average for the period 1980–1984 was used for the period prior to 1980. The annual was updated in 1998 and 1999, but not subsequently and the average maturity-at-age for the years 1997 to 1999 has been used for 2000–2007. The assessment presently uses a combined female and male maturity ogive, but sex-specific ogives and sex ratios are available. Maturation is dimorphic with females maturing on average one year later than males in this stock, which makes the female-only SSB is a more reliable estimator of the egg production (Köster *et al.*, 2003) than the SSB due to the large changes in age composition stock. A fecundity time series and model also exists for the Eastern Baltic cod base on relative fecundity estimates and prey availability.

A constant natural mortality of 0.2 is assumed for all years and ages. Predation mortalities (cannibalism) have been estimated by the Multi-species VPA for the Baltic Sea, but are presently not used in the stock assessment.

Otoliths from cod in the Eastern Baltic generally do not show well-defined seasonal growth zones. Recent investigations show that the development of winter rings differs between the eastern and western Baltic Sea probably due to differences in the ambient water temperature. The later spawning time in the eastern Baltic compared with the western Baltic and Kattegat is reflected in a smaller nucleus and a less evident juvenile ring as the growth period during the winter is shorter (Hüssy *et al.*, 2003). These features causes age substantial reading problems for this stock. In 2007 the new EU funded study project DECODE was started with the aim to resolve age reading inconsistencies between countries based on otolith weight analyses.

B.3. Surveys

Stock abundance indices are available from Baltic international Trawl Surveys (BITS) conducted in 1st quarter of the year from 1991 and additionally in 4th quarter (since 2001). Denmark, Germany, Latvia, Poland, Russia and Sweden participate with research vessels. The survey has been internationally coordinated since 2001, when major changes in survey and gear design were introduced. Previously, all research vessels used different trawls and the change to a standardised trawl implies that indices from the period 2001–2008 are not directly comparable with indices from earlier surveys. Consequently, inter-comparison trials were made before the new gear was implemented as the survey standard gear and the results have been used to estimate conversion factors among gears. The issue of estimating conversion factors is considered by WGBIFS (ICES CM 2003/G:05).

Survey indices at age for tuning fleets are available from DATRAS database. The BITS Q1 survey has an apparent break in 2001 when the survey design was altered and new standard survey trawl introduced. Therefore this survey is divided into two parts 1991–2000 and 2001–2008. The survey indices of ages 3–6 are back shifted from 1st quarter to the 4th quartetr of previous year that allows using the most recent assessment year survey.

In case of non adequate survey conditions it could be excluded from cod abundance index calculation. This should be verified by WGBIFS and reason documented in WG report.

Ichthyoplankton surveys exist from the spawning area in the Bornholm Basin, the Gdansk Deep and the Gotland Basin. The time series for Bornholm Basin based on German and Polish surveys during the spawning period is comprehensive and allow estimation of the average daily egg production indices and the seasonal egg production. These time series have been use to validate estimates the egg production of Baltic cod (Kraus *et al*., 2002, Köster *et al*., 2002). Ichthyplankton data also exist for the Gdansk Deep and the Gotland Deep but survey frequency and coverage is more limited. These data are not used in the standard assessment.

B.4 Commercial cpue

Age disaggregated tuning data since 1997 are available from Danish Trawlers The Danish vessels take the majority of their catch in SD 25, with a smaller proportion taken in SD 26.

Standardization of Danish Trawler fleet cpue indices, accounting for factors affecting both relative abundance and fishing efficiency, results in time series of catch and effort data that are more representative of trends in population abundance.

The standardization procedure was based on the following criteria:

- to subset the cod-specialist activity i.e. all activities exclusively directed to cod catches in order to get an unbiased cpue time series based on the effort targeting cod (otherwise, possible under-estimation of the cod cpue in case of effort directed toward other species);
- to subset all activities acting with a given and unique fishing gear combination because first the variance in catch rates per species is mainly impacted by the gear used, and second the use of the similar combination of gears is likely to reflect a homogeneous fishing behaviour pattern;
- to subset all activities exclusively included in area delimitation of the stock reflecting similar fishing behaviour pattern;
- to remove all activities subject to misreported landings and discarding for which effort and catch data are not reliable.

Using these criteria, we expect to get the most homogeneous subset of activities (especially in terms of fishing behaviour pattern) relevant for tuning the cod assessment. The available data to run the subset is the trip-based Danish DFAD database merging logbook information with sales slip. The database lists the catches trip by trip for each vessel and by ICES squares. Before 2009, point (iv) has not been undertaken due to lack of data on the misreporting aspect.

The same arrangement is run for each year over the desired year range of the tuning fleets. Note that, processing by year, a fleet may not be constituted by the same vessels over the years. The total cod landings of each trip were then converted to landings-per-age using an allocation key from the data analysis. The decomposition of landings in age group is deduced from harbour sampling of fish length and fish ageing from otolith reading after building an age-length key.

Cpue standardisation

Inside each selected fleet, a standardisation procedure is applied to extract the year effect on which index of abundance can be based using a Generalized Linear Models (GLMs) with log-link. The minimal efficient model found in the model selection was for the trawler fleet was:

Cpue = year + kw + year:age

The landings decomposition by age group was possible from 2007 to 1997 backward, data from previous years being considered less reliable by experts. This conditions the final range of years of the time series of the abundance indices. The main result of the effort standardization is that the correction is low and this could be explained by the fact that the fleet selection had already succeed in setting up homogeneous fleets. For trawlers, the fleet selection procedure enabled to set a fleet with homogeneous vessels as the low effort correction demonstrated. Further, the visual inspection of the internal consistency of the proposed fleets (Den_Trawl_bchmk09) suggests that this fleet is consistent.

No cpue data of other countries available.

B.5 Other relevant data

Historic information on cod migrations patterns within and between the eastern and western Baltic exists from comprehensive tagging programs. Detailed studies of cod migration and behaviour using data-storage tags is available within the EU-funded research project CODYSSEA.

While the standard stock assessment is performed by an XSA covering age-groups 2-8+, a Baltic multi species VPA exist that provides recruitment estimates for the same stock units from age-group 0 onwards (ICES 2003). To establish time series of spawning stock sizes and recruitment in the different spawning areas of the Central Baltic area-disaggregated MSVPA's are available for Sub-division 25, 26 and 28 (Köster *et al*., 2001, ICES 2001).

Comprehensive hydrography databases exist as well as 3D hydrodynamic models describing the changes in the cod habitat, suitability of spawning areas (spawning volume) and larval drift. Also zooplankton time series exist for different areas of the Baltic.

An environmentally sensitive and spatially explicit stock-recruitment relationship has been established (Köster *et al*., 2001, Köster *et al*., 2003). The most recent statistical model includes: the potential egg production based on the female-SSB and relative fecundity time series, oxygen related egg survival factors in each spawning area, and prey availability for first feeding larvae as the product of *P. elongatus* nauplii abundance and turbulent velocity. If predicting recruitment at age 1 and 2, additionally area specific cannibalism rates on 0- and 1-group specimen are applied. The statistical model is highly significant and explains 73% of the variability in age-group 0 recruitment.

C Historical stock development

Model used: XSA, test runs with SAM model will be performed parallel every year and evaluated at next benchmark assessment.

Software used: VPA-95 (Darby and Flatman, 1994)

Model Options chosen:

Tapered time weighting applied, power = 3 over 20 years

Catchability independent of stock size for all ages

Catchability independent of age for ages >= 6

Survivor estimates shrunk towards the mean F of the final 5 years or the 3 oldest ages

S.E. of the mean to which the estimate are shrunk = 0.5

Minimum standard error for population estimates derived from each fleet = 0.300

Prior weighting not applied

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1966–	2–8+	Yes
Canum	Catch-at-age in numbers	1966–2007	2–8+	Yes
Weca	Weight-at-age in the commercial catch	1966–2007	2–8+	Yes (constant at age 2–7 from 1966–1980
West	Weight-at-age of the spawning stock at spawning time.	1966–2007	2–8+	Yes (constant at age 2–7 from 1966–1982)
Mprop	Proportion of natural mortality before spawning	1966–2007	2–8+	No-set to 0 for all ages and all years
Fprop	Proportion of fishing mortality before spawning	1966–2007	2–8+	No-set to 0 for all ages and all years
Matprop	Proportion mature-at-age	1966–2007	2–8+	Yes (constant at age 2–8+ from 1966–1984 and 2000 onwards)
Natmor	Natural mortality	1966–2007	2–8+	No-set to 0.2 for all ages and all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	BITS Q1 3-9_Backshifted	1990–2000	2–5
Tuning fleet 2	BITS Q1 3-9_Backshifted	2001–2008	2–5
Tuning fleet 3	BITS Q1_2_raw	1991–2000	2
Tuning fleet 4	BITS Q1_2_raw	2001–2007	2
Tuning fleet 5	BITS Q4_raw	2002–2007	2–5
Tuning fleet 7	Den_Trawl_bchmk09	1997–2007	3–7

D Short-term projection

Model used: age structured based on XSA outputs

Software used: MFDP

Initial stock size: survivors from XSA run for ages 3+. Recruitment-at- age 2 for next year class is estimated by RCT3, for following two year classes-GM for period that is representative for recent recruitment pattern. In RCT3 analyses the XSA estimates of Age 2 is correlated with Age groups 1 and 2 abundance indices from BITS survey in first quarter and age group 0, 1 and 2 indices from BITS survey in fourth quarter.

Natural mortality: Set to 0.2 for all ages in all years

Maturity: Average of last 3 year if no time trend, otherwise-average of last 3 years scaled to the last year.

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

Weight-at-age in the stock: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Weight-at-age in the catch: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Exploitation pattern: Average of last 3 year if no time trend, otherwise-last year, separated for landings and discards

Intermediate year assumptions: F = average of last 3 years scaled or not depending on the trend in F

Procedures used for splitting projected catches: Discards and landing split based on F by ages.

E. Medium-term projections

Not considered relevant for this stock

F. Long-term projections

Not done for this stock

G. Biological reference points

The reference points were considered in the 2009 benchmark. Biomass reference points were deleted because the relation between SSB and R has altered and depends on the environmental conditions which have been unfavourable since 1987. The F reference points have been recalculated on the same basis as before:

	Type	Value	Technical basis
Precautionary approach	Blim	Not defined	
	Bpa	Not defined	
	Flim	0.8	Fmed (estimated in 2009)
	Fpa	0.63	5th percentile of Fmed
Targets	Fy	0.3-0.4	AGALTA 2005, WKREFBAS 2008, simulations
	F mgt	0.3	EU management plan 2007

Yield and spawning biomass per Recruit

F-reference points (2009):

	Ages 4–7	Yield/R	SSB/R
Average last 3 years	0.72	0.63	1.03
Fmax	0.27	0.72	2.67
F0.1	0.16	0.67	3.83
Fmed	0.80	0.61	0.92

Further consideration for future reference: There is a relation between SSB and R. However its magnitude depends on the environmental condition and recruitment has been apparently independent of SSB since 1987 owing to unfavourable environmental conditions.

The Workshop on Reference Points in the Baltic Sea (WKREFBAS 2008) performed simulations to derive range of sustainable fishing mortalities for cod. The workshop concluded that sustainable F range of 0.3 to 0.4 are still appropriate for describing the long-term dynamics of the stock and investigating long-term fishing mortalities. Only with a substantial reduction of errors in assessment and implementation errors, a higher F might be possible. WKREFBAS also concluded that sustainable F between 0.3–0.4, obtained by ALTA (ICES 2005), is still valid. In this context the estimated Blim was considered inappropriate, in particular as it was elaborated under environmental conditions which have been verified to be very different from the present environmental condition (WGIAB 2008; WKREF 2007).

H Other issues

None

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9 Recommendations for future work

Recommendations from the Plenary

Recommendation	To whom
Intersessional Benchmark Change Protocol Ideally, changes to Stock Annexes will be evaluated and agreed only at Benchmark workshops every 3–5 years, with simple assessment updates taking place in the intervening years based on the Stock Annexes agreed during the Benchmark workshops. However, it would be unreasonable to require assessment WGs to adhere to a benchmark that was subsequently found to be incorrect, or was superseded by superior methodology. When it is essential to make substantive changes to assessment models, methods or inputs between Benchmark workshops, the WK recommends that the minimum number of relevant sections of the Stock Annex (e.g. only those parts of Section C concerned with model choice) be modified appropriately and added to the agenda of the next associated benchmark meeting on related stocks (e.g. the next roundfish benchmark workshop).	ICES Secretariat, ACOM
Commercial Tuning Fleets Currently standardised research survey cruises are the method of choice for tuning stock assessment models and are used in the North Sea. In the Baltic and Kattegat cod stock assessments a combination of commercial fleets and research surveys are used for tuning. However, research surveys have better spatial coverage and attempt to ensure that catchability is constant from year to year. Commercial fleets tend to have higher catches of larger fish, but suffer from poor spatial coverage, difficult to estimate technology-creep improvements in catchability, difficulties in standardising gear types and cross-correlation issues. To improve transparency with the industry and to guide working groups, the WK recommended that a group be struck to provide reference criteria on the use of commercial fleets in tuning assessments.	PGCCDBS
Use of Commercial cpue and VMS A future workshop should be set up to develop guidelines on the types of data and information that need to be supplied, and the relevant factors that need to be taken into account, in order to maximise the utility of commercial cpue and VMS data as inputs to assessment models, or as ancillary information to evaluate the credibility of assessment results. Substantial input from fishing industry representatives, including active participation in such a working group, is required for such a workshop to be successful.	PGCCDBS
Fishery-Independent Abundance Indices The ICES DATRAS database delivers fishery-independent abundance indices for tuning stock assessments. It is possible to download the raw data on the survey catches along with information on the various standardisation and raising factors. Documentation is provided in a report to the Commission (http://datras.ices.dk/Documents/Manuals/Workshop%20report%20on%20variance%20estimation.doc) that includes methods and equations, and there is a manual for use during survey data collection (http://datras.ices.dk/Documents/Manuals/Manual%20BITS.doc). The WK recommends that the computer source code used to combine survey indices into composite indices should also be made available to assessment scientists, in order to facilitate investigation of possible anomalies in survey trends (a need identified during the current workshop).	ICES Data Centre (DATRAS)

Recommendation	To whom
Multispecies Interactions International coordinated stomach sampling from the North Sea has not been conducted since 1991. Since then the North Sea environment and ecosystem has changed considerably. Predator assemblages are now less dominated by gadoids and the predator-prey overlap for all species might have changed. For the Baltic multispecies interactions, the stomach content data-base contains mainly information for the period 1977–1993. Stomach sampling continued from 1994 to 2004, but at a much lower intensity than in the 1977–1993 period. A new international coordinated stomach sampling program is recommended both in the North Sea and the Baltic Sea to track changes in the food web, to be used for estimation of predation mortalities and to facilitate an ecosystem approach to management.	ICES member states PGCCDBS
Evaluation of Assessment Models ICES should develop protocols for the evaluation and acceptance of new stock assessment models. In many cases, it may be adequate to refer such models to the Stock Assessment Methods WG. However, in the case of a new method that is not in widespread use or that is not familiar to Stock Assessment Methods WG members, it may be necessary to form an ad hoc group of selected experts to conduct the evaluation. In either case, a single meeting to determine whether or not a new model should be accepted is probably not adequate because, in such a meeting, it may only be possible to consider the theoretical attributes of the model and to examine a few example runs. This may be adequate to determine that a particular model is worthy of further exploration but a minimum of 2–4 years further evaluation should be undertaken before accepting a given model for wider use. During this evaluation period, the new model should be run alongside existing models. It is also essential to ensure that the number of assessment models in use for ICES stocks does not escalate to unmanageable levels. In this regard, new models should only be accepted if it can be demonstrated that they solve problems that are not able to be addressed by existing models; e.g. problems related to bias, precision, unrealistic estimates of model parameters, divergent tuning series, and fishing mortality-at-age trends that do not seem to be consistent with knowledge of fishing operations.	WGMG
Documentation of Assessment Models Better documentation of most, if not all, stock assessment models currently used by ICES is required to enable assessment analysts to readily replicate assessment results without the need to have been previously involved in such assessments.	WGMG
Biological Reference Points The WK recommended that the stock annexes should include the methodologies or software used to calculate the usual biomass and fishing mortality limit and precautionary approach reference points (Blim, Bpa, Flim, Fpa) along with standard reference points from yield-per-recruit and spawning biomass-per-recruit analyses (e.g. F0.1, Fmax, Fmed and F35%), provided that these are considered meaningful for the stock in question. Note that F35% is a standard output of the ICES yield-per-recruit software, but is usually not presented in assessment reports. The WK recommended that it should be presented as a potential proxy for FMSY that is in line with the estimates of F30%–F40% used in many other parts of the world. If numeric estimates for any of these reference points are not presented, reasons why they cannot be calculated or are not considered valid should be given. If changes to stock-recruitment data, maturity ogives, weights-at-age and other factors are likely to result in changes to estimates of reference points, these should be updated as necessary, including during update assessments.	ACOM, Reference point WKs

Recommendation	To whom
Voluntary Data Provision from Industry Nationally reported landings are used to estimate total catch and usually include raising factors to account for misreporting and discarding. The successful partnerships established with industry have lead to improved estimates of misreporting and discarding, and there are various self-sampling protocols in existence to encourage this data collection. These voluntary schemes work well and need to be better integrated into the overall national data collection programmes necessary for stock assessment. The WK recommends that ICES further collaborates with industry to provide a stock-by-stock list of data requirements that can be incorporated into national data collection programmes.	MIRAC, PGCCDBS
Involvement of Industry members in stock assessments WK participants agreed there is benefit to have industry represented in most, if not all, stock assessment working groups, because this will enhance opportunities for data input and interpretative data analyses, promote understanding and awareness of role of science in ICES advice and subsequent management decisions and, as a result of these advantages, promote buy-in to stock assessment results. The WK therefore recommends that ICES considers involving industry (and other stakeholders) more fully in stock assessment meetings. At the least, the WK recommends considering setting aside a day prior to key assessment meetings for industry and assessment scientists to discuss developments in fisheries and interpretations of data.	Council, ACOM, MIRAC
Archiving of Working Documents Working Documents presented at WG or WK meetings should be numbered and archived by ICES in a database that is accessible to present or future WG or WK members. Numbered documents can be referenced in the text of WG or WK reports when the information in the WG or WK reports is not available in published form.	ICES Secretariat
Recommendations for future Benchmark Workshops • Participants of WKROUND 2009 considered that the following issues should be considered in future benchmark workshops: • benchmark workshops need to be announced much further ahead of time in order to allow more preparatory work to be undertaken; such announcements should be accompanied by detailed terms of reference; • benchmarks would benefit from having analyses and papers prepared in advance of the meeting rather than almost all analyses being undertaken at the benchmark itself; • Working Papers should be numbered and archived as part of the meeting process; • consideration should be given to holding a coordination meeting several weeks prior to the WK, with such a meeting involving industry participants; • consideration should be given to splitting the data compilation and benchmark parts of the workshop in order to enable more work to be done ahead of time; • mixing together of different, but related, assessment working groups at the same meeting promoted cross-fertilisation and should be continued in the future; the number of assessment working groups (3) and the number of stocks (6) was considered to be about the right amount to be considered in the timeframe allowed; and • industry representatives and other stakeholders have valuable input to contribute to stock assessments, including data and alternative interpretations of assessment results; ICES should consider allowing industry representatives to attend all stock assessment-related meetings.	Benchmark Workshops

Recommendations from the Baltic Sea sub-group

Future research on cod stock identities in the Kattegat and Baltic Sea

A stock in ICES' assessment process is defined as an operational entity in fisheries management with such criteria that the differences within the group as well as the exchange with other stocks can usually be ignored without disturbing the conclusions. Usually a stock concept is applied to define a sub-unit or sub-population of a species occupying a certain geographical area, showing some mixing with adjacent groups and in a sub-unit possessing similar growth and mortality parameters and similar fishery.

Cod stocks in Kattegat, western Baltic and eastern Baltic form a stock complex, which is presently referring to three adjacent stocks, which may mix during the feeding period but are less likely to mix during the spawning period. The mixing of stocks is obvious between Kattegat/Skagerrak-North Sea, Kattegat/western Baltic and western Baltic/eastern Baltic. All these stocks have in their distribution area transitional areas, in which there is a match-mismatch between management areas and stock/population distribution areas. The main problem is that presently the mixing of stocks in time and space is not well known, especially concerning the amount of inflowing recruits from one area to another and the following return migration to their natal spawning ground and mixing in catches.

The most common methods to overcome this difficulty and separate fish stocks or races, is to determine their distribution and estimate their overlap in time and space. To judge whether the influence of these sub-units/sub-populations on estimated age compositions (and consequently on estimates on recruitment and mortality), the variation in one or several of the following parameters should be investigated.

1. Genetic characters: DNA analyses (mitochondrial DNA): Methods to investigate differences in DNA sequences, e.g. analyses of micro-satellite markers. The observed differences in gene frequencies are used to describe the genetic composition and to investigate relationships.
2. Distribution and migration patterns: Tagging experiments with exterior and interior tags are applied to determine distribution and migration patterns between areas within and outside the spawning period giving mainly qualitative measure rather than quantitative analysis.
3. Spawning areas and times: Identification of specific spawning areas to which the individuals are returning year after year (homing). Identification of spawning areas and times together with migration patterns may indicate reproductively isolated sub-populations.
4. Otolith structure and form: Analysis of growth patterns in the otoliths of the balance organs are applied to estimates the age of individual fishes, but differences in growth patterns can also be used to characterise differences between sub-populations and to separate stocks.

Each of these methods has its strengths and limitations, but in combination they provide good opportunities to characterise the mixing between separate stocks cod stocks in the Baltic and Kattegat, especially in younger age groups.

WKROUND recommends that a new internationally coordinated stock identification program is initiated in order to track cod stock mixing and annual and spatial changes to be used for in stock assessments and to facilitate an ecosystem approach to management for these stocks.

Annex 1. WKROUND Terms of Reference

2008/2/ACOM32 A **Benchmark Workshop on Roundfish** (Chair: Pamela Mace (New Zealand) and ICES coordinators: Chris Darby (UK) and Eero Aro (Finland) and two invited external experts) will be established and will meet at ICES HQ, Copenhagen, Denmark, 16–23 January 2009 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, and life history data currently being collected for use in the current assessment work and the proposed assessment;

b) Agree and document preferred method for evaluating stock status and (where applicable) short term outlook and update the assessment handbooks as appropriate;

c) Develop recommendations for future improving assessment methodology and data collection;

d) 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 the possible inclusion of environmental drivers for stock dynamics in the assessments and outlook;

   iii) evaluate the role of stock identity and migration;

   iv) evaluate the role of multispecies interactions on the assessments.

STOCK	ASSESSMENT LEAD
North Sea whiting	Colin Millar
North Sea cod	Jose de Oliveira
Kattegat cod	Margit Eero
Western Baltic cod	Marie Storr-Paulsen
Eastern Baltic cod	Maris Pliksh
Celtic Sea cod	Robert Belail

The Benchmark Workshop will report for the attention of ACOM by 20 February 2009.

Annex 2. List of participants

NAME	ADDRESS	PHONE/FAX	EMAIL
Michael Andersen NSRAC and BSRAC	Danish Fishermen's Association København H.C. Andersens Boulevard 37, 1. DK-1553 Copenhagen V Denmark	Phone +45 70 10 40 40 Fax +45 33 32 32 38	ma@dkfisk.dk
Eero Aro ICES Coordinator	Finnish Game and Fisheries Research Institute PO Box 2 FI-00791 Helsinki Finland	Phone +358-205751253 Cell +358 40 7389132 Fax +358-205751202	eero.aro@rktl.fi
François Bastardie Expert	The National Institute of Aquatic Resources Jægersborgvej 64–66 DK-2800 Kgs. Lyngby Denmark	Phone +45 3396 3395 Fax +45 3396 3333	fba@aqua.dtu.dk
Robert Bellail Expert	IFREMER Lorient Station 8 rue François Toullec F-56100 Lorient France	Phone +33 2 97 87 3819 Fax +33 2 97 87 3836	robert.bellail@ifremer.fr
Casper Willestofte Berg Expert	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33963433 Fax +45	cbe@aqua.dtu.dk
Noel Cadigan Invited Expert	Fisheries and Oceans Canada Northwest Atlantic Fisheries Center P.O. Box 5667 St John's NF A1C 5X1 Canada		cadiganN@dfo-mpo.gc.ca

Name	Address	Phone/Fax	Email
Max Cardinale Expert	Swedish Board of Fisheries Institute of Marine Research Lysekil P.O. Box 4 SE-453 21 Lysekil Sweden	Phone +46 523 18 750 / 700 Fax +46 523 13977	massimiliano.cardinale@fiskeriverket.se
Sally Clink BSRAC	Baltic Sea Regional Advisory Council H.C. Andersens Blvd 37 III 1553 Copenhagen K Denmark	Phone +45 Fax +45	sc@bsrac.org
Luc Corbisier Stakeholder	SDVO Belgium	Phone +32 Fax +32	Luc.corbisier@sdvo.be
Chris Darby ICES Coordinator	Centre for Environment, Fisheries & Aquaculture Science Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 1502 524329 /+44 7909 885 157 Fax +44 1502 513865	chris.darby@cefas.co.uk
Barrie Deas NSRAC	National Federation of Fishermen's Org., NFFO 30 Monkgate YO31 7PF York United Kingdom	Phone +44 Fax +44	barrie@nffo.org.uk
Henrik Degel Expert	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33963386 Fax +45 33 96 3333	hd@aqua.dtu.dk
Margit Eero Expert	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33963318 Fax +45 33963333	mee@aqua.dtu.dk

NAME	ADDRESS	PHONE/FAX	EMAIL
Yuri Efimov Expert	Russian Federal Research Institute of Fisheries & Oceanography (VNIRO) 17 Verkhne Krasnoselskaya Street RU-107140 Moscow Russian Federation	Phone +7 499 264 9129 Fax +7 499 264 9129	efimov@vniro.ru
Steven Holmes Expert	Fisheries Research Services FRS Marine Laboratory P.O. Box 101 AB11 9DB Aberdeen United Kingdom	Phone +44(0) 1224 29 5507 Fax +44(0) 1224 29 5511	s.holmes@marlab.ac.uk
Tore Jakobsen Expert	Institute of Marine Research P.O. Box 1870 N-5817 Bergen Norway	Phone +47 5523 8577 Fax +47 5523 8687	tore.jakobsen@imr.no
Alexander Kempf Expert	Johann Heinrich von Thünen-Institute Palmaille 9 D-22767 Hamburg Germany	Phone +49 40 38905 194	alexander.kempf@vti.bund.de
Julien Lamothe NWWRAC	ANOP France	Phone +33 298 101111 Fax +33 298 103610	anoprod@wanadoo.fr
Colm Lordan Expert	Marine Institute Rinville Oranmore Co. Galway Ireland	Phone +353 91 387200 Fax +353 91 387201	colm.lordan@marine.ie
Pamela Mace Chair/Invited Expert	Ministry of Fisheries New Zealand PO Box 1020 Wellington New Zealand	Phone +64 4 819 4266 Fax +64 4 819 4261	Pamela.Mace@fish.govt.nz
Julian Metcalfe Expert	Centre for Environment, Fisheries & Aquaculture Science Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 1502 524352 Fax +44 1502 513865	julian.metcalfe@cefas.co.uk

Name	Address	Phone/Fax	Email
Colin Millar Expert	Fisheries Research Services FRS Marine Laboratory P.O. Box 101 AB11 9DB Aberdeen United Kingdom	Phone +44 1224 295575 Fax +44 1224 295511	millarc@marlab.ac.uk
Anders Nielsen Expert	The National Institute of Aquatic Resources Jægersborgvej 64–66 DK-2800 Kgs. Lyngby Denmark	Phone +45 Fax +45	an@aqua.dtu.dk
Fred Normandale NSRAC	National Federation of Fishermen's Org., NFFO 30 Monkgate YO31 7PF York United Kingdom	Phone +44 7802 940666 Fax +44	fred@nffo.org.uk
Jose de Oliveira Expert	Centre for Environment, Fisheries & Aquaculture Science Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 1502 527 7 27 Fax +44 1502 524 511	jose.deoliveira@cefas.co.uk
Michael Park NSRAC	North Lodge 11, Bath St. AB39 2DH Stonehaven United Kingdom	Phone +44 7710504773	m.park@btconnect.com
Lionel Pawlowski Expert	IFREMER Lorient Station 8 rue François Toullec F-56100 Lorient France	Phone +33 2 9787 3846 Fax +33 2 9787 3836	lionel.pawlowski@ifremer.fr
Maris Plikshs Expert	Latvian Fish Resources Agency 8 Daugavgrivas Str. LV-1048 Riga Latvia	Phone +371 67610766 Fax +371 67616946	Maris.Plikss@lzra.gov.lv

Name	Address	Phone/Fax	Email
Barbara Schoute ICES Secretariat	International Council for the Exploration of the Sea H.C. Andersens Boulevard 44–46 DK-1553 Copenhagen V Denmark	Phone +45 33 38 67 56 Fax +45 33 93 42 15	barbara@ices.dk
Marie Storr-Paulsen Expert	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 3396 3442 Fax +45 3396 3333	msp@aqua.dtu.dk
Henrik Svedäng Expert	Swedish Board of Fisheries Institute of Marine Research, Lysekil P.O. Box 4 SE-453 21 Lysekil Sweden	Phone +46 52318723 Fax +46 523 13977	henrik.svedang@fiskeriverket.se
Anthony Thompson Invited Expert	Northwest Atlantic Fisheries Organization PO Box 638 Dartmouth NS B2Y 3Y9 Canada	Phone +1 902 468 5271 Fax +1 902 468 5538	athompson@nafo.int
Paul Trebilcock NWWRAC	Cornish Fish Producers Organisation Ltd. 1 The Strand TR18 5JH Newlyn Penzance United Kingdom	Phone +44 1736 351050 Fax +44	paul@cornishfpo.org.uk
Willy Vanhee Expert	Institute for Agricultural and Fisheries Research (ILVO) Ankerstraat 1 B-8400 Oostende Belgium	Phone +32 5 956 9829 Fax +32 5 933 0629	willy.vanhee@ilvo.vlaanderen.be

NAME	ADDRESS	PHONE/FAX	EMAIL
Morten Vinther Expert	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33 96 33 50 Fax +45 33 96 33 33	mv@aqua.dtu.dk
Michael Walsh Stakeholder	Irish South and East Fisheries Producers' Organization Ireland	Phone +353 51 383 170/+353 87 258 2842 Fax +353	isefpomichael@eircom.net
Yvonne Walther Expert	Swedish Board of Fisheries Institute of Marine Research Utövägen5 SE-371 37 Karlskrona Sweden	Phone +46 455 362 852	yvonne.walther@fiskeriverket.se
Kai Ulrich Wieland Expert	The National Institute of Aquatic Resources The North Sea Centre P.O. Box 101 DK-9850 Hirtshals Denmark	Phone +45 3396 3276 Fax +45 3396 3260	kw@aqua.dtu.dk

Annex 3. List of Working Documents

Working document #1: Cod Celtic Sea Irish Survey. Colm Lordan

Working document #2: Cod Celtic Sea Recruitment and Environment. Colm Lordan

Working document #3: Cod Celtic Sea Sensitivity to under-reporting. Colm Lordan

Working document #4: Cod Celtic Sea Sensitivity to new Ogive. Lionel Pawlowski

Working document #5: North Sea cod: The role of predation. Alexander Kempf

Working document #6: North Sea Cod biomass based on REX and IBTS. Kai Wieland

Working document #7: Baltic cod: Defining new commercial tuning fleets for improving the assessments. François Bastardie

Working document #8: Eastern Baltic cod: Defining new commercial Danish tuning fleets for the assessment. François Bastardie

Working document #9: Kattegat Cod survey. Max Cardinale, Ole Jørgensen

Working document #10: NFFO Fishermen report AFR 15 m TRAWLERS April 2008. Paul Trebilcock

Working document #11: NFFO Fishermen report AFR 24 m Beam TRAWLERS Oct 2008. Paul Trebilcock

Working document #12: NFFO Fishermen report AFR over 15m Netters Oct 2008. Paul Trebilcock

Working document #13: NFFO Fishermen report AFR under 10 m fleet Oct 2007. Paul Trebilcock

Working document #14: State-space fish stock assessment model as alternative to (semi-) deterministic approaches and stochastic models with a high number of parameters. Anders Nielsen

Annex 4. Industry Participation

Assessment analysts and other members of the WK welcomed the participation of industry representatives, and concluded that the Workshop would have benefited from even greater industry participation.

For example, the issue of perceived inconsistencies in estimates of large cod in the North Sea was raised, with the industry believing that there are more large cod than indicated in the assessments. It was noted that the IBTS used to tune North Sea assessments deploys gears designed to catch smaller cod, thus underestimating larger cod. This contrasts with the industry which uses gears designed to catch larger cod, thus underestimating small cod. For several reasons, commercial catch data cannot be used to tune the analysis, and the use of the IBTS survey to tune the assessment appears to result in an under-estimation of the true number of large cod in the population in the most recent years. This has led to widespread distrust of the assessment results by the industry, and has had undesirable consequences at every level of the fishery management process.

Several discussions during the first two days of the Workshop concerned the involvement of the industry in providing data to assist in enhancing the credibility and robustness of stock assessments. It was noted that the current Fishery-Science-Partnerships were supported and appreciated by both industry and scientists, and there was every wish to continue these. However, it was also noted that these tended to occur in small areas and/or operate for only a few years, and results are often difficult to incorporate into the assessment process.

The industry provided the workshop with examples of the types of information they could potentially supply:

- Annual reports highlighting major trends in spatial fishing patterns, technology and gear developments, and market measures derived from structured interviews. Some examples of this were provided by Fishery-Science-Partnerships in south-western England (Working documents #10–13);
- Interpretation of VMS data would be greatly enhanced by partnerships with industry, subject to any relevant confidentiality restrictions;
- Time series of catches and cpue though collaborative surveys that could be self-sampling by crew or have on-board assistance from scientists. It was noted that validation was important and there was a suggestion that CCTV could be used instead of costly on-board observer programmes;
- More dialogue and dissemination of information between industry and scientists on the biology of cod, noting for example the interest generated at the meeting in the results of the North Sea cod behaviour data tagging programme; and
- Input into the design and possibly the evaluation of management measures (although it was realised that this may be outside the scope of assessment groups).

Assessment scientists suggested that industry provision of the following types of information would be most useful for improving the validity and credibility of assessments:

- Improved information on discards;
- Improved information on misreporting;

- Changes in fishing patterns and the distribution of catch in response to regulations, markets and other relevant factors;
- Adoption of new technology that affects fishing success; and
- A continuation and expansion of fisheries-science partnerships, and of meetings such as the recent ICES WKSC (2008) and WKUFS (2007) catch sampling workshops.

Collaborative programmes that forge closer links between assessment scientists and the industry could improve assessments through more complete, or complementary, data. Care needs to be taken to avoid a mismatch in what industry can offer and what scientists are able to incorporate into assessments. Annual reports of the type presented to the WK by industry (Working documents #10–13) provide valuable information that may lead to more successful management measures through a better understanding of the operation and evolution of fisheries, and may aid in the interpretation of assessment results. However, they may sometimes be too qualitative and too local to be of direct use in stock assessments. The wider the area of coverage, the greater the potential utility of such information. Similarly, requests to improve catch reporting and discard estimates may be too sensitive on a large scale to create a satisfactory starting point for collaborative work between assessment scientists and industry (although this has been successful for local estimates as illustrated in the recent ICES WKSC (2008) workshop).

The possibility of the inclusion of commercial vessel surveys into the IBTS (or similar) surveys warrants further investigation. It is unlikely that the information could be used initially in the assessments, especially for tuning purposes, but even in the short term it could achieve two important objectives:

- to involve industry directly in the collection of data of a type that could be used in the assessment process in the future (as opposed to smaller scale FSP that are difficult to include in the assessment process) and may even be able to be used immediately to check and adjust size-related biases seen in the IBTS surveys; and
- to facilitate industry-science meetings to discuss the interpretation of the spatial distribution of roundfish stocks and landings. This should result in an improved interpretation of indices related to the distribution and abundance of roundfish used to tune assessments.

A programme such as this would require considerable effort both to set it up and to ensure its continuation in a consistent manner. Careful vessel selection would be essential to ensure standardisation of commercial gears among fleets. As well as developing a survey design, a self-sampling or an assisted-sampling programme on board commercial vessels would be required. A potential advantage of such a programme is that it could have wide spatial and temporal coverage and could provide additional information on the abundance and distribution of large fish. Data collected would be of a basic nature and could be as simple as weights of fish in various size classes followed by conversion to numbers-at-age using age-weight and age-length keys. It is likely that scientific observers would need to spend some time on-board to conduct sampling and to discuss findings with skippers and crew. The results would probably not provide quantitative spatial estimates of abundance, but could facilitate better interpretation of the IBTS results.

Annex 5. A State-space Assessment model (SAM)

SAM is a statistical state-space model in which all observations (catches, indices, and possibly more) have measurement error, and population processes are stochastic. The amount of variability in observation and process errors is estimated in SAM. Model parameters are estimated using maximum likelihood methods based on the marginal likelihood function. This likelihood function is integrated over process errors, and is considered to provide better estimates of model parameters compared to other approximate approaches (de Valpine and Hilborn, 2005). Estimation of uncertainties for all quantities of interest ($\bar{F}$, SSB, and stock sizes) is an integral feature of the model. It assumes stochastic survival from one year to the next and models fishing mortality as a random walk, thus enabling selectivity to drift over time throughout the modelling period. It also handles missing observations in both catch and surveys. It should be noted that this approach does not have the convergence properties typical of backwards VPAs such as XSA and ADAPT.

SAM incorporates new software (the random effects module for AD Model Builder http://www.admb-project.org), which uses a combination of automatic differentiation and the Laplace approximation (MacKay, 2003) to solve high dimensional non-linear models with unobserved random variables efficiently. It is based on all the standard assessment equations (such as the catch equation, the stock equation, and standard stock-recruitment relationships). The combined set ($N_1,...N_A, F_1,..., F_A$) are considered as unobserved random variables. Observations are time series of catches in numbers and survey indices. WKROUND WD 14 contains a mathematical description of the model and outlines the key model features in more detail.

The benchmark WK considered the utility of SAM, as detailed below.

Benefits

- it includes more realistic treatment of catches (e.g. observation errors) and population dynamics (process errors), compared to more traditional assessment models (e.g. XSA, ADAPT);
- it can provide more realistic measures of uncertainty on model outputs;
- it can estimate biases in reported landings over time; these biases can potentially be age- or age-group-specific;
- it does not require selectivity to be constant over time in that it models fishing mortality as a random walk, thus allowing selectivity to drift in a constrained manner;
- it explicitly provides estimates of recruitment and survival process errors which should be included in medium or longer-term stochastic stock projections.

Drawbacks

- it has not yet been adequately tested on a sufficiently large number of assessments (currently five, but all very recent implementations);
- it is difficult for a non-expert to implement from scratch (although relatively easy to update);
- other similar approaches have difficulties with confounding in variance parameters, and the amount of smoothness in some model outputs can be very uncertain; this may also apply to SAM;

- it is restricted in its ability to model radical changes in fishing mortality functionally-related variables in terminal assessment years and when these follow long periods of relative stability-this means that it may not quickly detect a rapidly collapsing or rapidly recovering stock; and
- as a result of the latter it may exhibit strong retrospective patterns.

Recommendations

The Benchmark WK recommended that SAM be used to provide:

- a comparative model for North Sea cod, with the potential long term goal of becoming a primary assessment model for this stock;
- exploratory assessments for future benchmarks for North Sea whiting;
- the primary assessment model used in updates for Kattegat and Western Baltic cod; and
- an exploratory assessment model for Eastern Baltic cod.

The Benchmark WK recommended that further review of SAM should be a priority for 2009 (as should other new stock assessment models), including case studies and comparisons with other models, sensitivity of model assumptions including process error structure, and recommendations on the types of stocks and data where this model should or should not be used. It should be noted that lognormal process error in a cohort model can lead to infeasible results in that cohorts can increase with age. Documentation of the user interface should be provided to enable assessment scientists who have not previously used the software to be able to construct models for new stocks.

If the Methods Working Group (WGMG), or some other appropriate forum, determines that SAM should be the preferred model for one or more stocks, consideration should be given to conducting an early benchmark workshop for those stocks or, more simply, to amending the modelling sections of the stock annexes for those stocks and adopting them at the next associated benchmark meeting on related stocks (e.g. the next Roundfish Benchmark Workshop).

References

de Valpine, P., Hilborn, R., 2005. State-space likelihoods for nonlinear fisheries time-series. *Canadian Journal of Fisheries and Aquatic Science* 62, 1937–1952.

MacKay, D. J. C. (2003). Information Theory, Inference, and Learning Algorithms. Cambridge University Press, Cambridge.

Brief introduction to web-interface for SAM

The State-space Assessment Model (SAM) can be run via a web-interface for a number of stocks for which the data has been uploaded and the model has been configured. The page is located at: http://www.stockassessment.org and also includes results from four example stock assessments. The page allows user with a personal user account to modify the configuration of the model, change the input data, and re-run the model. Without a user account it is possible to browse the pages, but not to modify anything.

To request a personal user account send an e-mail to one of the maintainers (e-mail addresses are listed on the page). A password will be returned by e-mail. The password can be modified after the fist login. When a user enters the system for a specific stock three main pages are available 'Data', 'Configuration', and 'Results'.

The data page lists a number of data files all in the standard format suitable for XSA input. This format is chosen, as it is familiar to most of the intended users of the model. When a user clicks on one of the data files the content of that file is shown in the editor window on the page. The user can edit the desired values. After editing a file it can be saved or the original can be restored. In addition to the data files there are two more files in R-script (datascript.R): one is a program that transforms the data to match the SAM model, and the other is the complete source code written in AD Model Builder for the SAM model (ssass.tpl). These two files cannot be edited via the web interface, but are listed to allow for peer review of all details including the model implementation. At the very bottom of the data page is a 'save and go' or a 'go' button. If the latter is pressed, the model will start running with the currently saved data files.

The configuration page allows the user to modify the model settings by editing the file 'model.cfg', and add titles and captions to the graphs displayed on the results page by editing the file 'titles.cfg'. The configuration file consists of a number of sections where different aspects of the model can be configured. For instance the default file for North Sea cod contains:

```
# Min Age (should not be modified unless data is modified accordingly)

1

# Max Age (should not be modified unless data is modified accordingly)

7

# Max Age considered a plus group (0=No, 1=Yes)

1

# The following matrix describes the coupling

# of fishing mortality STATES

# Rows represent fleets.

# Columns represent ages.

 1 2 3 4 5 6 6

 0 0 0 0 0 0 0

 0 0 0 0 0 0 0
```

The first three sections are straightforward. The two first should only be modified if the user has also changed the input data accordingly. The third specifies whether the last age group should be considered a plus group. Section four requires a bit of explaining. The table has a row for each fleet, where the first contains the total catches, and the following rows are survey fleets sorted in the same order as they appear in the input file. The numbers indicate an indexing of the random walks that represent the fishing mortalities. The configuration above gives a separate random walk to each of the first five age groups, but uses the same for age groups 6 and 7+. The two rows of zeroes indicate that the two surveys available for this stock are assumed to have constant catchabilities (in time), and the age-coupling of these is specified in one of the following sections in the configuration file.

It is entirely the user’s responsibility to ensure that the supplied data and configuration gives a sensible model run. Certain combinations of data and configurations will make SAM crash, and currently very few automatic checks are implemented via the interface.

The results page shows a selection of graphs and tables. Two model runs are always stored in the users account (possibly identical). These two stored runs are called base and current, where current is the latest model run. The graphs show both, so that they can be easily compared. At any time the current run can be saved as the base run by pressing the 'upgrade to base run' button so a new model run can be compared to the old current run.

This brief introduction to the system should enable users to get started with the interface. If questions occur the maintainers will assist (e-mail addresses are listed on the page). The source code for the model is also available on the page, so it is possible for the user to run and improve the model independently.