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Stock Annex: West of Scotland cod (Division VIa)

Stock-specific documentation of standard assessment procedures used by the International Council for Exploration of the Sea (ICES).

Stock	Cod (*Gadus Morhua*) in West of Scotland (Division VIa); cod-scow_SA
Working group	Celtic Seas Ecoregion (WGCSE)
Date	March 2015
Revised by	Rui Catarino (IBPWSRound 2015)
Last Benchmarked	WKROUND 2012

A General

A.1 Stock definition

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

A.2 Fishery

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

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

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

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

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

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

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

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

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

For stocks below B_{lim} the Regulation requires:

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

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

In addition the plan states:

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

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

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

A.2.1 General description

In recent years the countries involved in this fishery are Scotland, Northern Ireland, Republic of Ireland, England and Wales, Norway and France.

A.2.2 Fishery management regulations

Regulations and cod avoidance schemes relevant to Division VIa cod

Area closures

- Clyde Sea area closure – STECF (2007) noted that the Clyde closure includes the main spawning area of a reproductively isolated aggregation of cod and concluded that the closure is likely to have a positive effect in reducing targeting of high densities of mature cod.
- Windsock closed area – STECF (2007) concluded that the extent of the Windsock closure is unlikely to be large enough to greatly reduce fishing mortality on cod, and its boundaries should be reconsidered. However, its removal would not help improve cod recovery.
- Since 2009, the Irish authorities introduced a seasonal closure in Division VIa. The closure covers ICES statistical rectangle 39E3 and is in force from October 31 to March 31. Historically, over 40% of Irish cod landings from ICES Division VIa are from the closed area. For contrast, standardized cpue rates observed from a dedicated survey conducted inside the closed area in 2006 were on average 26.8 kg hr^{-1} while cpue rates estimated from observer trips outside the closure gathered in the same period were 0.015 kg hr^{-1}. STECF (2012) concluded that, in accordance with the provisions of article 13 (Reg. (EC) 1342/2008), the partial cod mortality associated with the Irish fleet had declined considerably (>50%) since the introduction of the cod closure and other measures, although it is not possible to disentangle the effects of the Cape closure from other measures.

Mesh sizes and catch composition rules

- Catch composition rules related to days-at-sea allowances (Reg. (EC) 850/1998 Annex I and Reg. (EC) 2056/2001) – These rules legislate for landings compositions, but do not restrict discards.
- Emergency measures introduced in EC regulation 43/2009 (Annex III) (and rolled forward into 2010 and 2011) prohibited all fishing activity to the east of the West of Scotland Management (French) line in Division VIa, with the exception of a number of derogated fisheries. These measures have been incorporated into a new EC regulation 227/2013. For demersal otter trawlers targeting whitefish this required an increase in mesh size to 120 mm and the inclusion of a 120 mm square-meshed panel (SMP). Vessels targeting *Nephrops* also require the 120 mm SMP or a sorting grid. More stringent catch composition rules have also been introduced. For *Nephrops*-directed fisheries, no more than 10% of the retained catch can consist of cod, haddock, and whiting, where the limit is no more than 30% for whitefish targeted vessels. For 2012 a zero TAC for cod and a 1.5% bycatch by live weight limit was introduced and this was carried through to 2013, but in 2012 the catch composition limit on haddock was removed (Reg. (EC) 161/2012).

Effort limitations

- Between 2003 and 2011 STECF (2012) reported that the fishing effort (in kW-days) of trawlers using >100 mm mesh declined by 59%. These vessels primarily targeted roundfish, including cod. Over the same period effort for trawlers using 70–99 mm mesh declined by 16%. These vessels primarily target *Nephrops* and in 2011 22% of the effort in this category was exempt from effort controls because of less than 1.5% of cod in the catch (article 11).
- Annex IIa of Reg. (EC) 39/2013 does not require effort reduction compared to 2012 except for French trawlers using >100 mm mesh (20% reduction).

Supply chain traceability

Unreported landings are expected to have reduced under the UK "Buyers and Sellers" and Irish "Sales Note" regulations. Observer data, however, show an increase in discards starting in 2006. The amount of discards relative to landings has increased and the age pattern of discarding has changed. Currently discards of fish aged 3 and above are being recorded.

Cod avoidance measures

In 2008, Scotland introduced a voluntary programme known as "Conservation Credits", which involved seasonal closures, real-time closures (RTCs), and various selective gear options. This was designed to reduce mortality and discarding of cod. The number of RTCs west of Scotland were four in 2008, twenty in 2009, nineteen in 2010, four in 2011, and nine in 2012, representing 27%, 14%, 12%, 2%, and 5% of the total RTCs in each year. RTCs are determined by lpue, based on fine-scale VMS data and daily logbook records, and also by on-board inspections. The low number of RTCs west of Scotland result from few instances of high lpue in the area. Estimates of continuing high discard rates in Division VIa indicate the scheme has not been effective west of Scotland. *ICES Advice 2014 Book 5* 11.

EU management plan

The European Commission has adopted Council Regulation (EC) No. 1342/2008 which establishes measures for the recovery and long-term management of cod stocks. The stated objective of the plan is to ensure the sustainable exploitation of the cod stocks on the basis of maximum sustainable yield while maintaining a fishing mortality of 0.4. Articles 7–9, describing aspects of the plan relevant to west of Scotland cod, are reproduced below:

Article 7

Procedure for setting TACs for cod stocks in the Kattegat the west of Scotland and the Irish Sea

1) Each year, the Council shall decide on the TAC for the following year for each of the cod stocks in the Kattegat, the west of Scotland and the Irish Sea. The TAC shall be calculated by deducting the following quantities from the total removals of cod that are forecast by STECF as corresponding to the fishing mortality rates referred to in paragraphs 2 and 3: (a) a quantity of fish equivalent to the expected discards of cod from the stock concerned; (b) as appropriate a quantity corresponding to other sources of cod mortality caused by fishing to be fixed on the basis of a proposal from the Commission.

2) The TAC shall, based on the advice of STECF, satisfy all of the following conditions: (a) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be below the minimum spawning biomass level established in Article 6, the fishing mortality rate shall be reduced by 25% in the year of application of the TAC as compared with the fishing mortality rate in the previous year; (b) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be below the precautionary spawning biomass level set out in Article 6 and above or equal to the minimum spawning biomass level established in Article 6, the fishing mortality rate shall be reduced by 15 % in the year of application of the TAC as compared with the fishing mortality rate in the previous year; and (c) if the size of the stock on 1 January of the year of application of the TAC is predicted by STECF to be above or equal to the precautionary spawning biomass level set out in Article 6, the fishing mortality rate shall be reduced by 10% in the year of application of the TAC as compared with the fishing mortality rate in the previous year.

3) If the application of paragraph 2(b) and (c) would, based on the advice of STECF, result in a fishing mortality rate lower than the fishing mortality rate specified in Article 5(2), the Council shall set the TAC at a level resulting in a fishing mortality rate as specified in that Article.

4) When giving its advice in accordance with paragraphs 2 and 3, STECF shall assume that in the year prior to the year of application of the TAC the stock is fished with an adjustment in fishing mortality equal to the reduction in maximum allowable fishing effort that applies in that year.

5) Notwithstanding paragraph 2(a), (b) and (c) and paragraph 3, the Council shall not set the TAC at a level that is more than 20% below or above the TAC established in the previous year.

Article 9

Procedure for setting TACs in poor data conditions

Where, due to lack of sufficiently accurate and representative information, STECF is not able to give advice allowing the Council to set the TACs in accordance with Articles 7 or 8, the Council shall decide as follows: (a) where STECF advises that the catches of cod should be reduced to the lowest possible level, the TACs shall be set according to a 25% reduction compared to the TAC in the previous year; (b) in all other cases the TACs shall be set according to a 15% reduction compared to the TAC in the previous year, unless STECF advises that this is not appropriate.

Article 10

Adaptation of measures

1) When the target fishing mortality rate in Article 5(2) has been reached or in the event that STECF advises that this target, or the minimum and precautionary– spawning biomass levels in Article 6 or the levels of fishing mortality rates given in Article 7(2) are no longer appropriate in order to maintain a low risk

of stock depletion and a maximum sustainable yield, the Council shall decide on new values for these levels.

2) In the event that STECF advises that any of the cod stocks is failing to recover properly, the Council shall take a decision which: (a) sets the TAC for the relevant stock at a level lower than that provided for in Articles 7, 8 and 9; (b) sets the maximum allowable fishing effort at a level lower than that provided for in Article 12; (c) establishes associated conditions as appropriate.

Ecosystem aspects

Geographic location and timing of spawning

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

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

Fecundity

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

B Data

B.1 Commercial catch

B.1.1 Landings data

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

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

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

Norway	X

B.2 Biological sampling

B.2.1 Maturity

Maturities-at-age are given by

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

B.2.2 Natural mortality

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

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

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

B.2.3 Length and age composition of landed and discarded fish in commercial fisheries

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

B.3 Surveys

B.3.1 Survey design and analysis

ScoGFS – WIBTS – Q1: Fixed station design

ScoGFS – WIBTS – Q4: Fixed station design

IGFS – WIBTS – Q4: Random stratified design

UKSGFS – WIBTS – Q1: Random stratified design

UKSGFS – WIBTS – Q4: Random stratified design

B.3.2 Survey data used

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

UKSGFS – WIBTS – Q1: 2011– . Ages 1 to 6 where oldest age is a true age.

ScoGFS – WIBTS – Q4: 1996–2009. Ages 1 to 6 where oldest age is a true age.

Modest to poor self-consistency (a weak ability to track cohorts) and very limited influence on exploratory assessment runs means not included in assessment.

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

UKSGFS – WIBTS – Q4: 2011– . Ages 1 to 6 where oldest age is a true age. Random stratified design. Replaced ScoGFS – WIBTS – Q4. ICES will consider inclusion as a tuning index through an inter-benchmark procedure when 4+ years of data have been gathered.

B.4 Commercial cpue

Not used.

B.5 Other relevant data

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

C Assessment methods and settings

C.1 Choice of stock assess model

Model used: TSA

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

C.2 Model used of basis for advice

Model Options chosen:

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

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

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

Commercial data

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

Points given greater variance at WKROUND 2012

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

Discard model

- step model: random walk for each age, with a step function allowed

- 1981–2005: ages 1and 2 modelled
- 2006–2010: ages 1 to 4 modelled, with a step function for ages 1 and 2

Stock–recruit model

- Ricker
  - Numbers-at-age 1 assumed to be independent and normally distributed with mean η1 S exp(−η2 S), where S is the spawning–stock biomass at the start of the previous year. To allow recruitment variability to increase with mean recruitment, a constant coefficient of variation is assumed.
- Large year class: 1986
  - Mean in Ricker model replaced by 5η1 S exp(−η2 S). The factor of 5 was chosen by comparing maximum recruitment to median recruitment from 1966–1996 for VIa cod, haddock, and whiting in turn using previous XSA runs. The coefficient of variation is again assumed to be constant.

Fishing selection model

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

Survey model (ScoGFS – WIBTS – Q1)

- full model: separate catchability for each age
- ages 1 to 6 modelled
- transitory and persistent changes in catchability not allowed

Survey model (UKSGFS – WIBTS – Q1)

- full model: separate catchability for each age
- ages 1 to 6 modelled
- transitory changes in catchability allowed, persistent changes in catchability not allowed

Points given greater variance at WKROUND 2012

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

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

Seal feeding model (supplementary model run only)

$$M2(y,a) = qaSyB_y^{\alpha}$$

where

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

C.3. Assessment model configuration

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

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	ScoGFS – WIBTS – Q1	1985–2010	1 to 6
Tuning fleet 2	UKSGFS – WIBTS – Q1	2011–2015	1 to 6
Tuning fleet 3	ScoGFS – WIBTS – Q4	Not used	1 to 6
Tuning fleet 4	IGFS – WIBTS – Q4	Not used	1 to 2

D Short-term prediction

Model used: Age structured

Software used: MFDP prediction with management option table and yield-per-recruit routines. MLA suite (WGFRANSW) used for sensitivity analysis and probability profiles.

The following configuration was agreed at WGNSDS 2008

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

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

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

Maturity: The same ogive as in the assessment is used for all years.

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

Exploitation pattern: Average of the three last years.

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

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

E Medium-term prediction

Not considered at the WKROUND benchmark.

F Long-term prediction

Not considered at the WKROUND benchmark.

G Biological reference points

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

(unchanged since: 2010).

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

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

The F_{MSY} estimate was derived by WGCSE 2010 using the srmsymc package. Figures showing stochastic fits to three stock–recruit relationships, estimates of F_{MSY} and F_{crash} and estimates of yield-per-recruit, together with descriptive text, are given in Appendix 1.

H Other issues

H.1. Change of Scottish Research Survey

For 2011 the rig and sampling design of the ScoGFS-WIBTS-Q1 survey was changed. A new groundgear capable of tackling challenging terrain was introduced broadly modelled around the rig used by Ireland for the IRGFS-WIBTS-Q4. The move to a more robust groundgear also allowed a move to a random stratified survey (which is again consistent with the IRGFS-WIBTS-Q4) as the previous repeat station survey format consisting of the same series of survey trawl positions being sampled at approximately the same temporal period every year was considered a bias prone method for surveying the area. It is hoped the greater compatibility between Scottish and Irish surveys will facilitate both being used to assess gadoids west of Scotland.

New survey strata were designed using cluster analysis on aggregated data from the previous ScoGFS-WIBTS-Q1 data (1999–2010) as well as the data collected from a dedicated gadoid survey which took place during quarter 1 of 2010. Species considered were cod, haddock, whiting, saithe and hake. Cluster analysis yielded four specific clusters. Two additional strata were added; the Clyde area and the 'windsock' which is an area that has been designated as a recovery zone since 2002 and has therefore experienced no mobile gear exploitation during this time. The new strata are shown in Figure H.1. Each individual polygon was treated as a separate stratum and the number of survey stations for each was allocated according to polygon size and the variability of indices within each stratum. Strata were weighted by surface area to build the final indices.

H.2 Biology of species

H.3 Stock dynamics, regulations in 20th century, historic overview

2004 to 2011.

Model used: TSA

Software used: Compaq visual FORTRAN using NAG library.

Model Options chosen:

Natural mortality (M) 0.2 at all ages.

Commercial data

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

Discard model

- 1978–1994: ages 1and 2 modelled

- 1995–AY-1: omitted

Stock–recruit model

- Ricker
- large year class: 1986

Fishing selection model

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

Survey model (IBTS Q1)

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

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

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

AY – Assessment year.

H.4 Current fisheries

H.5 Management and advise

H.6 Others (e.g. age terminology)

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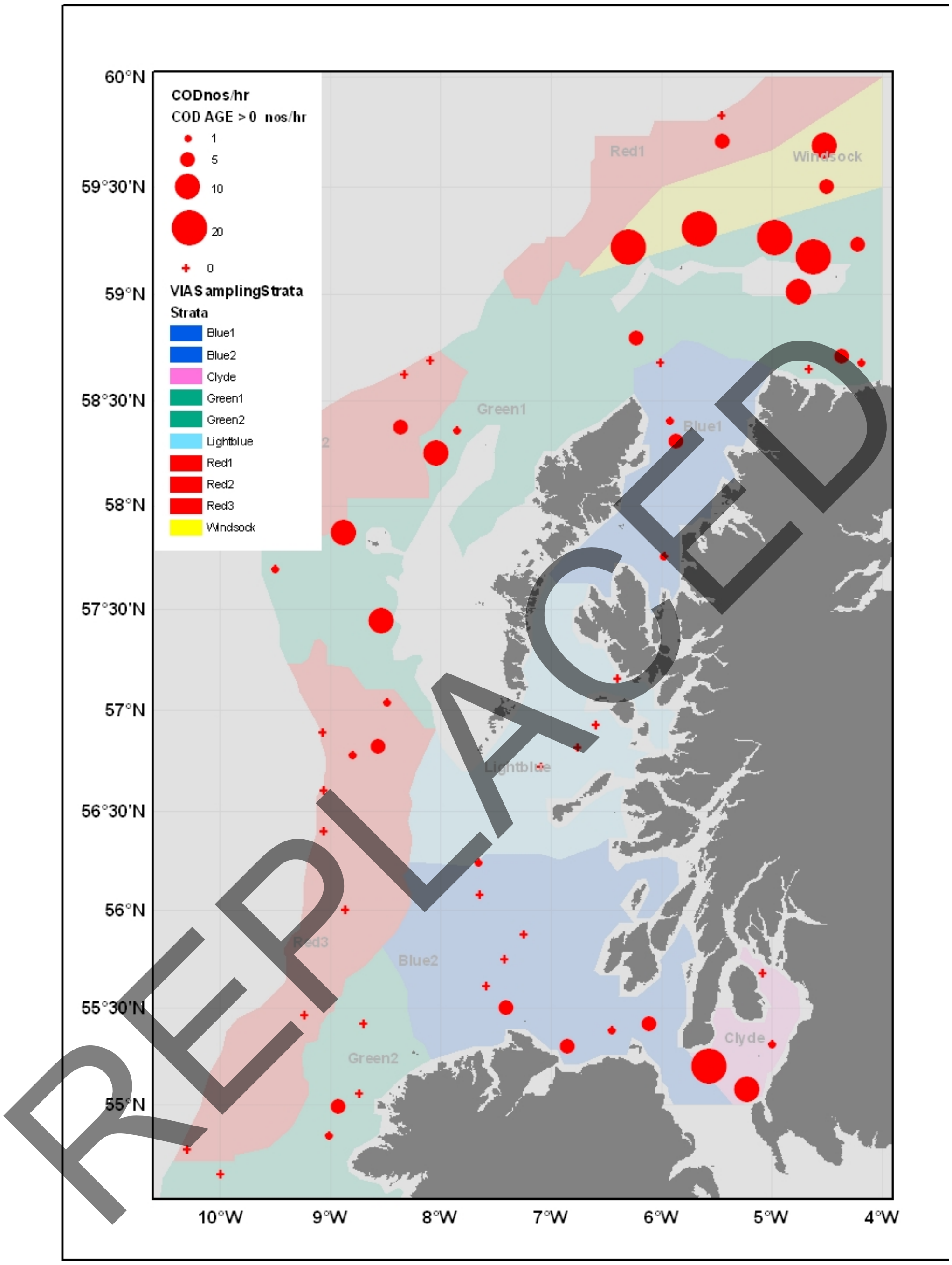

Figure H.1. Sampling strata of UKSGFS-WIBTS-Q1 survey. Figure also shows cpue numbers for fish aged at 1+ by haul for cod in 2011 (numbers standardised to 60 minutes towing).

Appendix 1 Investigations of F_{MSY} using the srmsymc package

The same input data files as used for the short-term forecast were used. An alternative run using ten year means for stock weights-at-age and mortality-at-age showed there to be little sensitivity to the averaging period used. Figure A.1 shows the three stock–recruit relationships fitted by the package; Ricker, Beverton–Holt and smooth hockey-stick. Models were fitted using 1000 MCMC resamples. For all three stock–recruit relationships all resamples allowed F_{MSY} and F_{crash} values to be determined. As such, there was no basis to reject any of the recruitment models as unsuitable for this stock. For each of the stock–recruit relationships (SRR) Figures A.2 to A.4 show box plots of F_{MSY} and F_{crash} together with the values of F_{PA} and F_{lim}. For the Ricker and Beverton–Holt SRR the estimated value of F_{crash} is very close to F_{lim}. For the smooth hockey-stick SRR F_{crash} is estimated between F_{lim} and F_{PA}. For all three SRR the current level of Z-02 is higher than the median F_{crash} value. Also the value of F_{MSY} is well defined and considerably lower than F_{PA} for all three SRR. The level of removals possible at the estimated F_{MSY} is poorly defined however. Circles showing the datapoints show values of Z-0.2 repeatedly in excess of the upper percentile for F_{crash}. As expected removals and SSB have declined such that values for both are now inside confidence limits for these metrics at the estimated Z-0.2 mortality rates.

Figure A.5 shows estimation of yield-per-recruit. F_{MAX} is well defined for this stock. Comparison of F_{MAX} to F_{MSY} estimated using the three SRRs (Figures A.2–4) shows F_{MSY} estimated as lower than F_{MAX} for the Beverton–Holt model, equal for the smooth hockey-stick, and higher than F_{MAX} in the Ricker model reflecting the downward slope of the stock–recruit relationship at higher SSBs.

In conclusion mortalities from removals in the range 0.17 to 0.33 were considered consistent with F_{MSY}.

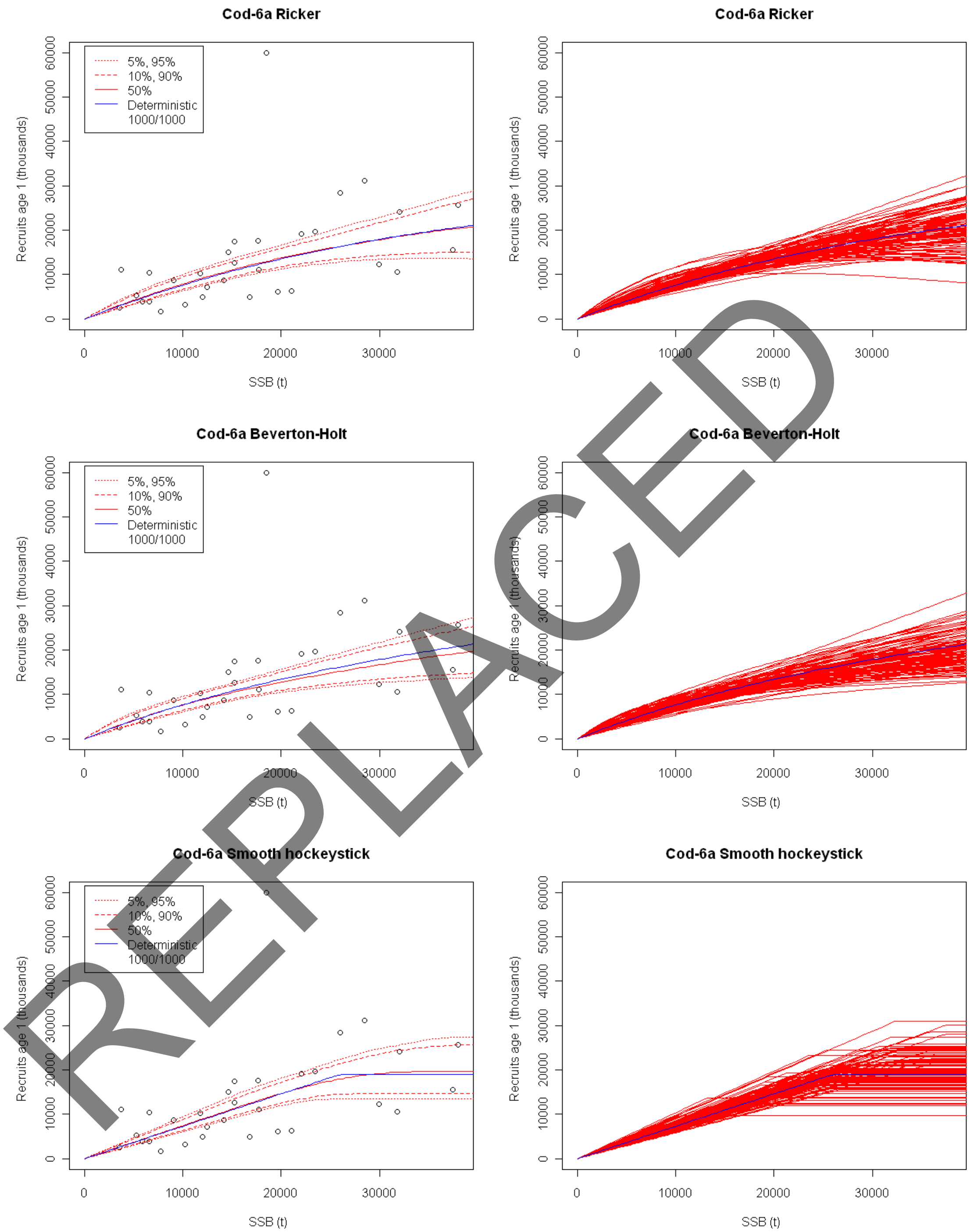

Figure A.1. Cod in Division VIa. Stock–recruit relationships fitted by srmsymc package. Models were fitted using 1000 MCMC resamples. Left hand panels illustrate confidence intervals. Right hand panels present curves plotted from the first 100 resamples for illustration. The blue line indicates a deterministic estimate, separate from the MCMC chain. The legends for each recruitment model show it was possible to converge on a value of F_{MSY} and F_{crash} for all 1000 iterations in each case.

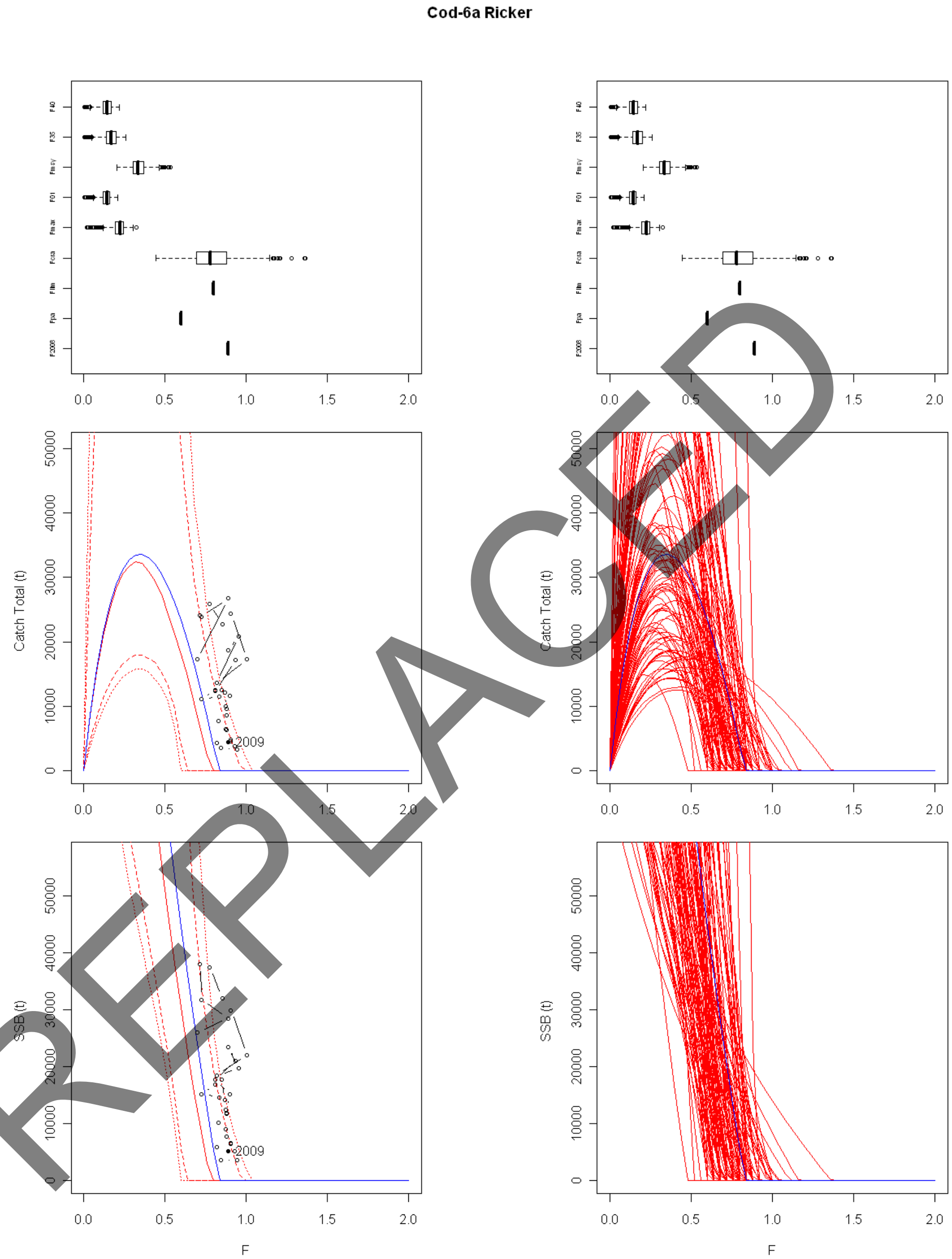

Figure A.2. Cod in Division VIa. srmsymc package. Estimation of F reference points and equilibrium yield and SSB against mortality using Ricker recruitment model. For yield and SSB plots left hand panels illustrate confidence intervals. Right hand panels present curves plotted from the first 100 resamples for illustration. The blue line indicates a deterministic estimate, separate from the MCMC chain. Circles show datapoints with the most recent year labelled. For VIa cod the model has been run using total removals over and above natural mortality, i.e. the x-axis represents Z-0.2.

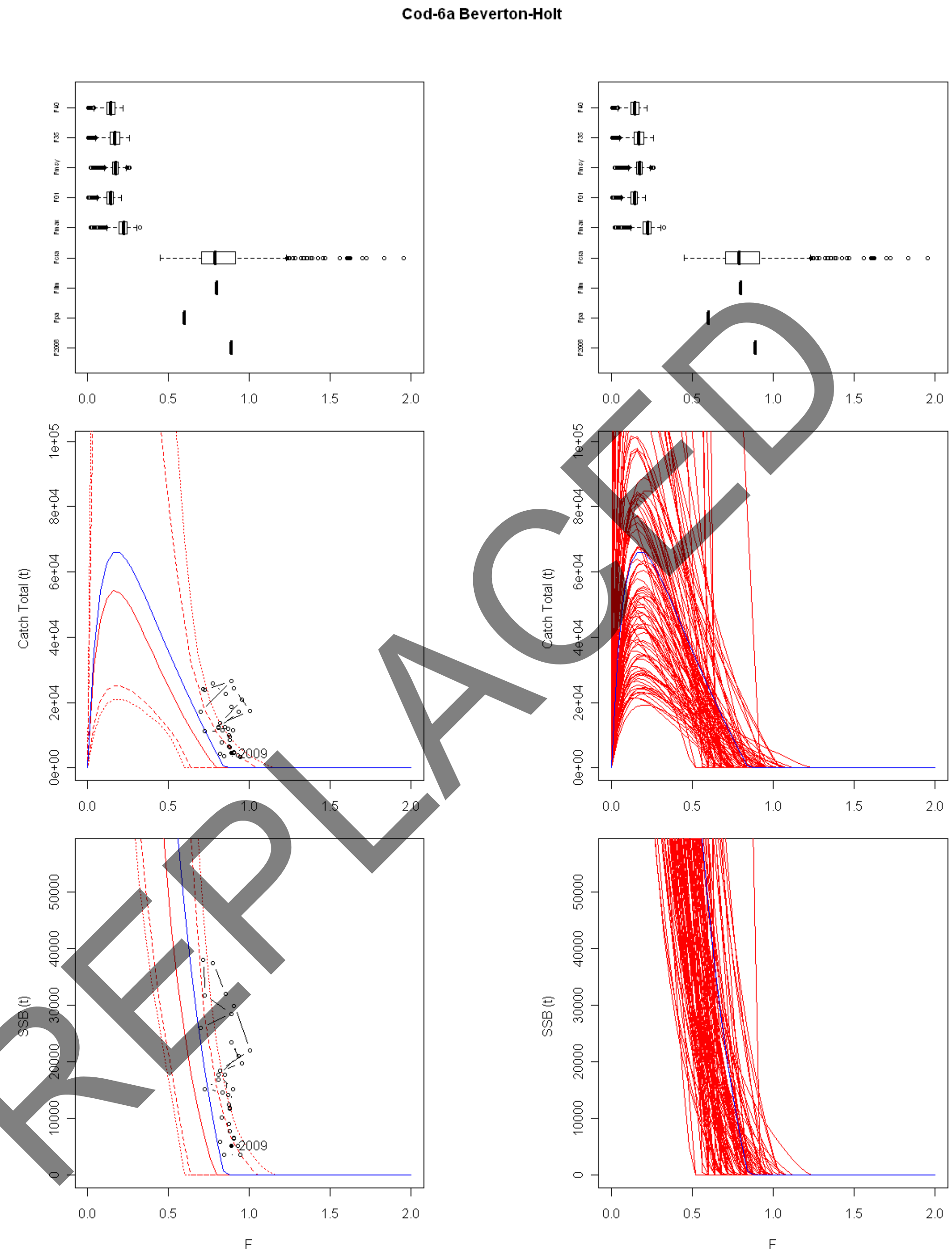

Figure A.3. Cod in Division VIa. srmsymc package. Estimation of F reference points and equilibrium yield and SSB against mortality using Beverton–Holt recruitment model. For yield and SSB plots left hand panels illustrate confidence intervals. Right hand panels present curves plotted from the first 100 resamples for illustration. The blue line indicates a deterministic estimate, separate from the MCMC chain. Circles show datapoints with the most recent year labelled. For VIa cod the model has been run using total removals over and above natural mortality, i.e. the x-axis represents Z-0.2.

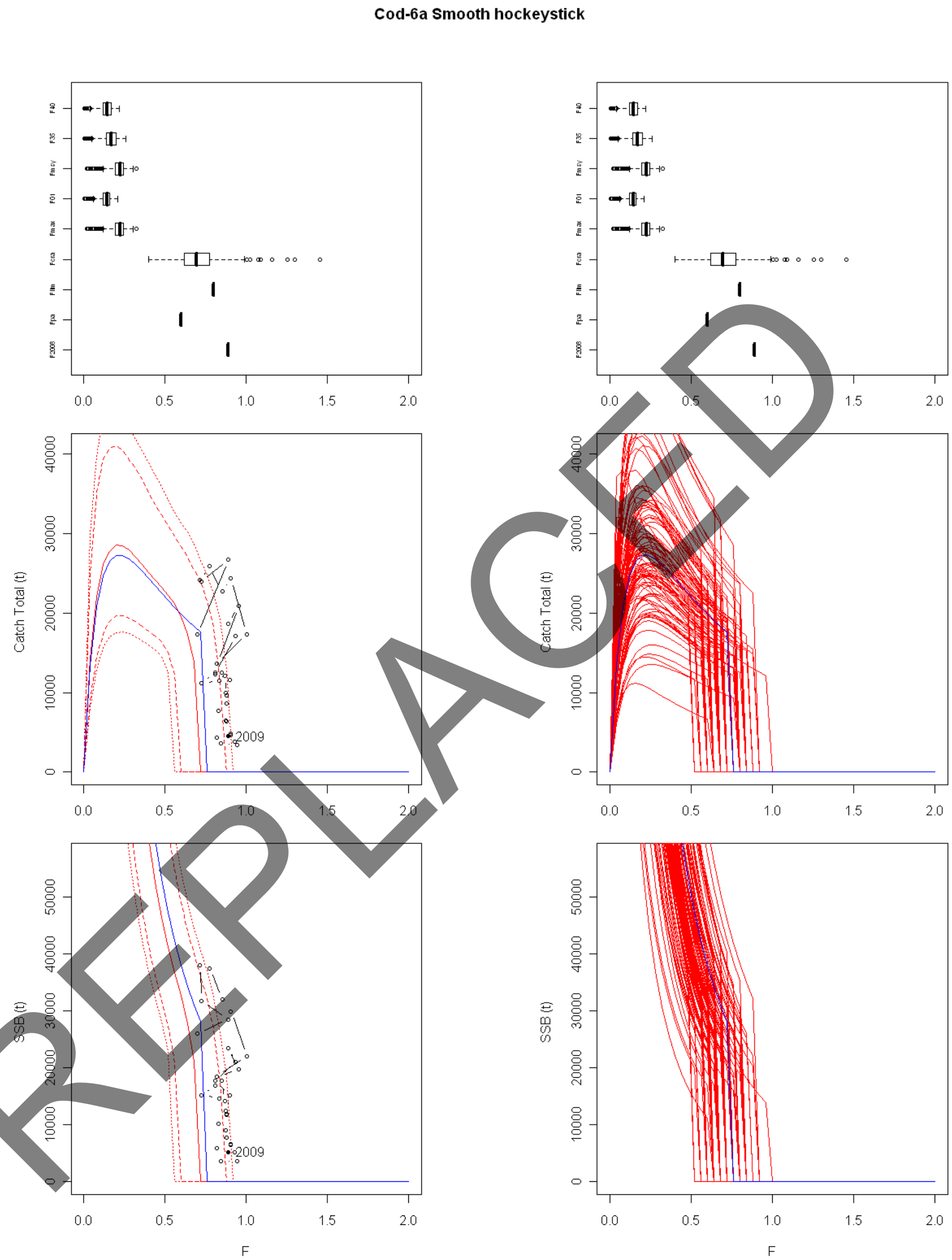

Figure A.4. Cod in Division VIa. srmsymc package. Estimation of F reference points and equilibrium yield and SSB against mortality using smooth hockey-stick recruitment model. For yield and SSB plots left hand panels illustrate confidence intervals. Right hand panels present curves plotted from the first 100 resamples for illustration. The blue line indicates a deterministic estimate, separate from the MCMC chain. Circles show datapoints with the most recent year labelled. For VIa cod the model has been run using total removals over and above natural mortality, i.e. the x-axis represents Z-0.2.

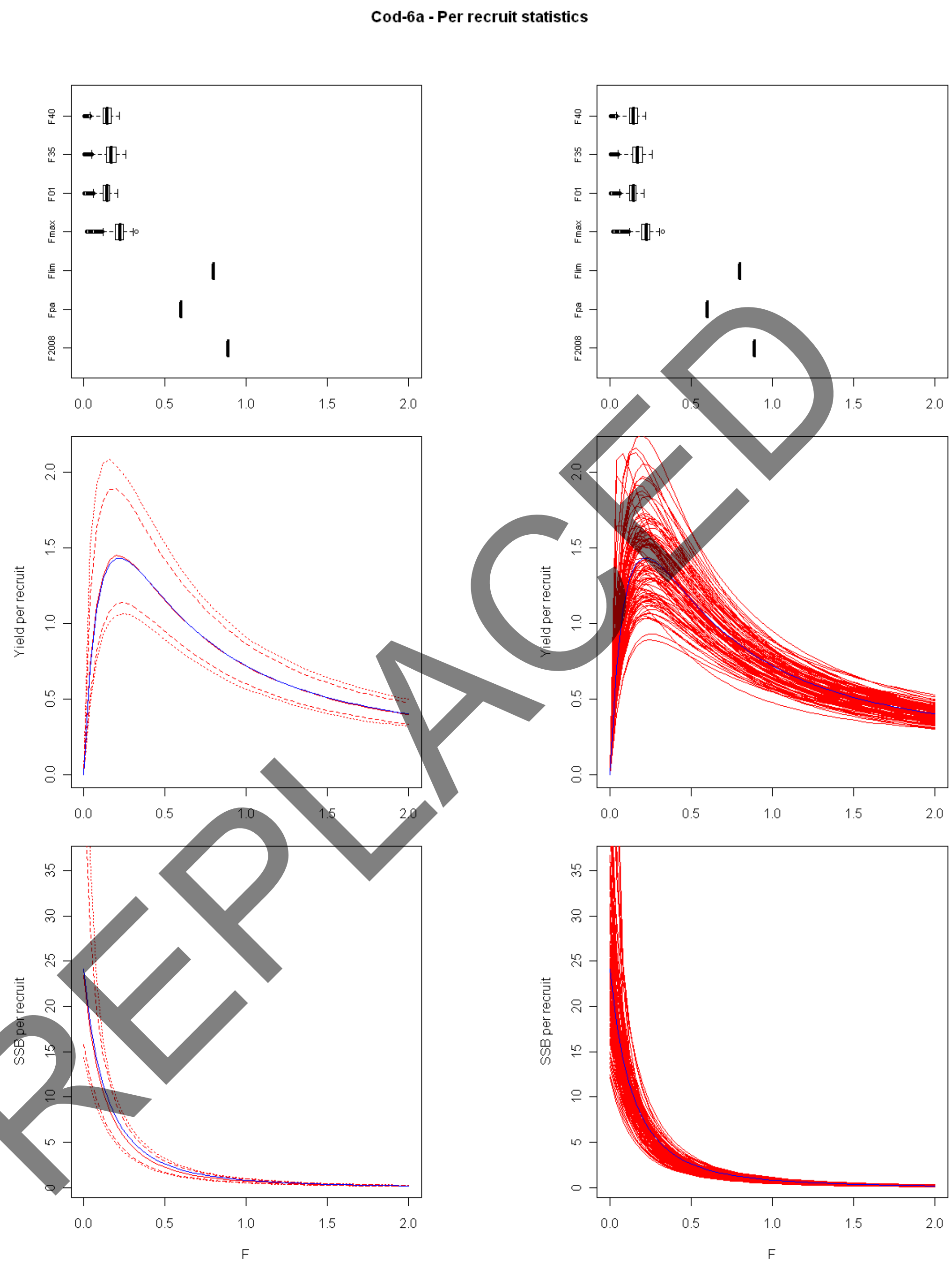

Figure A.5. Cod in Division VIa. srmsymc package. F reference points and yield-per-recruit and SSB per recruit against mortality. For VIa cod the model has been run using total removals over and above natural mortality, i.e. the x-axis represents Z-0.2.

Table A.1. Cod in Division VIa. Output from srmsymc ADMB package.

Stock name									
Cod-6a									
Sen filename									
sum_and_sen_files/codvia10runspalyhf075hf0563.sen									
pf, pm									
0	0								
Number of iterations									
1000									
Simulate variation in Biological parameters									
TRUE									
SR relationship constrained									
TRUE									
Ricker									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AIC
Deterministic	0.83	0.35	107615.00	33631.40	0.77	0.32	0.86	1.22E-05	64.52
Mean	0.79	0.34	248654.55	80885.39	0.78	0.38	0.93	1.45E-05	
5%ile	0.59	0.26	42534.56	16130.92	0.61	0.05	0.68	1.73E-06	
25%ile	0.69	0.30	64432.03	23129.35	0.70	0.18	0.80	7.03E-06	
50%ile	0.78	0.33	94637.85	32832.15	0.77	0.35	0.90	1.35E-05	
75%ile	0.88	0.37	176432.50	56775.68	0.85	0.53	1.04	2.02E-05	
95%ile	1.03	0.42	692590.35	217198.55	0.97	0.82	1.32	3.16E-05	
CV	0.17	0.15	3.43	3.41	0.14	0.65	0.21	0.65	

Table A.5. (cont): Cod in Division VIa. Output from srmsymc ADMB package.

Beverton–Holt									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AIC
Deterministic	0.85	0.18	401035.00	66296.50	0.39	1.31	53828.10	60405.70	64.48
Mean	0.83	0.17	830128.89	113018.89	0.54	1.41	91481.79	119568.27	
5%ile	0.59	0.11	110359.80	21448.08	0.07	1.10	18394.14	11822.00	
25%ile	0.70	0.15	195133.00	35526.05	0.28	1.26	28078.33	26150.93	
50%ile	0.79	0.17	322891.50	55212.35	0.48	1.40	44006.65	47156.45	
75%ile	0.91	0.19	630754.50	96558.98	0.76	1.55	76202.40	97400.13	
95%ile	1.15	0.21	2769898.00	341061.90	1.15	1.78	298192.60	417604.45	
CV	0.25	0.21	2.78	1.97	0.65	0.15	2.22	2.75	
Smooth hockey stick									
1000/1000 Iterations resulted in feasible parameter estimates									
	Fcrash	Fmsy	Bmsy	MSY	ADMB Alpha	ADMB Beta	Unscaled Alpha	Unscaled Beta	AIC
Deterministic	0.75	0.22	135085.00	27314.90	0.45	1.54	0.37	26047.10	64.56
Mean	0.70	0.21	173441.36	30090.20	0.47	1.58	0.38	26727.73	
5%ile	0.53	0.13	68545.05	17722.69	0.37	0.99	0.30	16778.00	
25%ile	0.62	0.19	98326.80	23808.10	0.42	1.33	0.34	22442.08	
50%ile	0.69	0.22	129465.50	28856.20	0.46	1.58	0.37	26719.35	
75%ile	0.77	0.24	171332.00	34618.58	0.50	1.87	0.41	31474.53	
95%ile	0.89	0.27	306434.25	46886.99	0.58	2.17	0.47	36539.60	
CV	0.16	0.22	1.38	0.31	0.16	0.23	0.16	0.23	

Table A.5 (cont). Cod in Division VIa. Output from srmsymc ADMB package.

Per recruit								
	F35	F40	F01	Fmax	Bmsypr	MSYpr	Fpa	Flim
Deterministic	0.18	0.15	0.14	0.22	7.10	1.44	0.60	0.80
Mean	0.16	0.14	0.13	0.21	8.70	1.51		
5%ile	0.06	0.05	0.06	0.13	3.97	1.07		
25%ile	0.14	0.12	0.12	0.19	5.23	1.27		
50%ile	0.17	0.14	0.14	0.22	6.48	1.47		
75%ile	0.20	0.17	0.16	0.24	8.31	1.66		
95%ile	0.23	0.19	0.18	0.27	15.11	2.16		
CV	0.31	0.31	0.28	0.22	1.36	0.22		