Annex 06 – Stock Annex – Sole in 20-24

Quality Handbook **ANNEX: WGBFAS_Sole in 20-24**

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Sole in Division 3a and subdivisions 22-24

Working Group: Baltic Fisheries Working Group

Date: 29 May 2020 ; small editorial issues, Jesper

Latest benchmark: Autumn 2015

A. General

A.1. Stock definition

Division 3a represents the Skagerrak (ICES Subdivision 20) and Kattegat (ICES Subdivision 21), and is therefore part of the transition area between the North Sea and Baltic Sea. Sole are more abundant in the Kattegat than Skagerrak and spawning areas are believed to be located in the Kattegat and Skagerrak. Distribution of sole beyond the Kattegat into the Baltic Sea is limited by salinity which decreases further eastward. Sole are therefore found only in low abundances in the Belt Sea (ICES Subdivision 22) and the Øresund (ICES Subdivision 23). However, since 2004 the fishery for sole indicates that the share of the population inhabiting the Belts has been increasing, and therefore since 2010 sole in the Belts (Subdivs. 22-24) are included in this assessment (WKFLAT 2010).

Sole in the Skagerrak and Kattegat are geographically close to the northern limit of the long-term geographical distribution of the species (Muus and Nielsen, 1999), which ranges from Scotland and southern Norway south to the Mediterranean and Black Sea. Sole in IIIa typically spawn in late May/early June, which is later than spawning times for sole in the southern North Sea (April-June) and the Mediterranean (February; (Muus and Nielsen, 1999).

Interactions and exchanges between sole in IIIa and Subdivs 22-24 and neighboring stocks, or within IIIa (i. e. between Kattegat and Skagerrak) may occur but are poorly documented. The former stock boundary in the east (i. e., limit at border between Kattegat and Subdivisions 22-23) were biologically based on the scarcity beyond the Kattegat. The boundary to the west (i. e., between Skagerrak and the North Sea) is likely porous to some extent due to migration of adults and/or drift of sole eggs and larvae. However, neither the direction nor magnitudes of exchanges have been described. It is more likely that there is exchange within the stock (between Skagerrak and Kattegat) because hydrographic conditions influence drift of eggs and larvae of another flatfish species (plaice) from Skagerrak to Kattegat (Nielsen *et al.*, 1998). Muus and Nielsen (1999) state that sole in the Kattegat is separated from the North Sea and better adapted for hard winters. New genetic studies are helping to clarify the genetic and biological basis for population differences (Draisma *et al.*, 2003).

Sole for assessment purposes in IIIa+22-24 are assumed to mature at age 3 although there is little empirical data and no time series to support this assumption. A similar assumption is used for assessment of North Sea sole and is consistent with Muus and Nielsen (1999) who state that sole mature between ages 3-5 and at sizes of 25-35 cm.

Sole in IIIa is a small stock compared with other sole stocks in the ICES area (e. g., North Sea, Bay of Biscay). Sole are nocturnal predators (Muus and Nielsen, 1999) and therefore more susceptible to capture by fisheries at night than in daylight.

A.2. Fishery

Sole has been one of the most important species in the late 1990s in the Danish Kattegat fisheries and accounted for about 25% of the total value of the human consumption fisheries. The economic importance of sole is more limited in Skagerrak where it accounts for less than 5% of the total value of the Danish human consumption fisheries.

A.2.1. Changes in regulations in the recent past

The major part of the sole catches in Kattegat and Skagerrak (3a) are prior to 2005 taken in the mixed species trawl fishery using mesh sizes 70–105 mm in the cod end and with gill nets using mesh sizes of 90–120 mm. Since then mostly mesh sizes 90-105 mm have been used. Minimum legal landing size is 24.5 cm.

Kattegat is traditionally the most important area accounting for 70–80% of the annual catches of this stock. Since 2004 the Belts accounts for a larger part of the total catches and in most recent years also Skagerrak have accounted for a higher share (Fig. 1). The fishery that lands sole from IIIa and 22-24 is almost entirely a Danish fishery.

In the past two decades the Danish fishery has undergone major changes in management regulations in Kattegat and Skagerrak. The main reason for the different regulations have been to protect the low cod stock in Kattegat, however most of the initiatives have also had an effect on the other stocks as the fishery in the Kattegat/ Skagerrak area mainly consist of a mix fishery. In the following is given a historic overview of the main changes.

The Danish TAC regulation was prior to 2002 regulated both by a non-restrictive effort scheme and later by non-constraining rations (Hovgård 2005) (illegal landings). The "ration" system stipulated catch ceilings for individual vessels in predetermined periods, typically weeks or 1/2 months.

In the early 2000s the fishery became increasingly limited by quota restrictions. Ration size decreased remarkably from no constraints in the start of 2000 to low levels in the last years of this regime. The high level of the ration utilization since 2001 indicated that the ration levels were restrictive and Hovgård (2005) indicated that there was considerable economic incentive to misreport landings in 2002-2004 as the entire two week ration in many cases could be taken in just a few hauls.

A major shift in fishing gears occurred between 2003 and 2004 when the use of 70–89 mm trawls without sorting grids was banned. This caused an increase in the 90-99 mm trawl fishery in 2004. The effort of 90–99 mm trawls was stable in 2006–2010.

In 2004 Sweden is moving the trawl border in Kattegat from 2 to 4 nautical miles and in Skagerrak from 3-4 nautical miles. This has mainly an effect on the Swedish fleet.

A new rights-based regulation (FKA – Vessel Quota Share) was put in force in Denmark from the 1st January 2007 to replace the 2 week ration regulation. With the new system, individual vessels are allocated a yearly share of the Danish quota, which can be taken at any time of the year. There is also a possibility to trade it, exchange it, or pool it with other fishers. The old regulation had a system with 14-day quotas, which continuously adjusted to the amount of national quota left. The new system gives the industry a possibility to plan better and is expected to lead to a more efficient fishery with less discards.

In 2007 fishermen were allocated additional fishing days when using trawls with an exit-window with square-meshes at a minimum 120 mm. Since 1st of February 2008, the usage of the exit-window in trawls is mandatory in Denmark, but not in Swedish fishery.

In 2008, in order to restrict the targeted Kattegat cod fisheries, each fishing day during the period between 1 February and 30 April was further counted as 2.5 days.

In 2009, following the introduction of the new management plan (EC No. 1342/2008) for North Sea (incl. Kattegat and Skagerrak) cod a new effort system was introduced. In this system each Member State (MS) is given amounts of kWdays for different gear groups. It was then up to the MS to distribute the kWdays among the fishing vessels. The amount of kWdays for gear groups catching cod will be subject to yearly cuts as long as the cod stock is below reference points in the management plan. MS can apply for derogation from the kWdays system if the catches in a certain part of the fleet can be shown (after evaluation by STECF) to consist of less than 1.5% cod (article 11(2)(b)). In 2009 Sweden got derogation from the kWdays system for Nephrops trawlers using the Swedish grid. This effort regulation could potentially have restricted some of the segments in the fisheries for sole in Kattegat in 2010 rather than the VQS's, as 98% of the KW-days were utilized for one of the principal trawler fleets.

In 2009, as a part of the attempts to rebuild of the cod stock in Kattegat, Denmark and Sweden, introduced protected areas on historically important spawning grounds. The protected zone consists of three different areas in Kattegat in which the fisheries are either completely forbidden or limited to certain selective gears (Swedish grid and Danish SELTRA trawl) during all or different periods of the year.

Denmark introduced a cod avoidance plan in 2010 and as a part of this plan since 2011 Danish fishermen is obligated to use the SELTRA trawl the first 9 month of the year, in accordance with the derogation under article 13 in the cod recovery plan (EU) nr. 1342/2008.

Since 2009 there are a substantial number of gears used in the Kattegat. Some of these gears are considered highly selective and are therefore allowed in parts of the Kattegat closed areas:

- A 70 mm square mesh cod-end with a 35 mm grid (Scandinavian grid cod-end)
- A four panel 90 mm diamond mesh cod-end with a 300 mm square mesh window (SELTRA300)
- A Topless trawl with a four panel 90 mm diamond mesh cod-end with a 175 mm square mesh window (Topless SELTRA175)

Outside the closed areas, the Danish fishermen use SELTRA270/SELTRA180, SELTRA300, and 120SMP (square mesh panel). Swedish fishermen use the standard grid or 90DMC (diamond mesh in codend). In recent years, the use of trawls equipped with a sorting grid in the Nephrops fishery has increased in the Swedish fishery and now dominates Swedish trawl effort.

EU and Norway have in 2013 introduced more selective gears in Skagerrak. The gears used in Kattegat are allowed in Skagerrak as well, however, not entirely appliance as a 140 mm square mesh SELTRA is also allowed in Skagerrak.

There is seasonality in sole fishery with both gill net and trawl. The low season for trawl is from May to September. In average more than 75% of the annual sole catches with trawl are caught outside the summer season. During summer the trawl fishery that catches sole is directing their effort towards *Nephrops*. The season for gill net fishery for sole is from April to September. During this season, about 80 % of the gill net landings are sole.

These gradually introduced regulations over decades have had a high influence on the sole fishery and are assumed to have resulted in a reduced selection of younger sole. Madsen and Valentinsson (2010) and Madsen et al. (2010) have provided useful descriptions of the changes and the impact in selectivity for many of the fisheries. The impact on sole catches is however not quantified.

A.2.2. Fishery distribution and landings

Denmark takes more than 90% of the total Kattegat-Skagerrak catch. Kattegat is traditionally the most important area accounting for 70–80% of the annual catches. Since 2004 the Belts accounts for a larger part of the total catches (approx 20% of IIIa and 22+23 catches in 2007-2008 but since then about 10%). Sweden and Germany are the other nations participating in the fishery.

Sole have been exploited in the Kattegat and Skagerrak since at least 1952. The fishery fluctuated between 200 and 500 t annually prior to the mid-1980s. Landings increased to a maximum of 1400 t in 1993 and since then have decreased almost every year to a level about 600 t by the end of the 1990'ties. In 2002-2005 the fishery has became increasingly limited by quota restrictions, which gave an incentive for substantial misreporting. Analyses of private logbooks (Christensen, 2005), survey data (Jørgensen, 2005) and observer data Hovgård (2005) indicated that there was considerable economic incentive to misreport landings in 2002-2004 as the entire two week ration in many cases could be taken in just a few hauls. However, it is not known to what extend the catches were discarded, landed as black landings (i.e. excluding both catch and effort data from the official statistics), or distributed to and landed by vessels not having caught their rations, i.e. the catch data would be correct but the corresponding effort would (most likely) be overestimated. Based on information from the industry mis- or non-reporting and discarding (see section 3.1.3), is believed to have been in the order of magnitude of 50% in 2002 and about 100 % in 2003 and 2004. In 2005 misreporting was assumed to have taken place until June when quotas were raised and therefore did not limit the fishery. The assumption is 20% misreporting in 2005. A revision of the perception of the stock in 2005 resulted in higher TACs that no longer limited the fishery and the incentive for misreporting was no longer present.

In 2000 and 2001, some catches from the North Sea were reported as being caught in the Skagerrak. These reported landings have been subtracted from working group estimates for these years and assessments from 2003 and onwards are based on the revised landings and catch numbers-at-age.

Danish discard sampling at sea is carried out within EU programmes that began in 1995 in both Kattegat and Skagerrak. However, the data from this programme is only complete in later years and not applied in the assessment.

Discard levels are in general believed to be negligible when measured relative to the sole landings, due to the high price of sole. Since 2010 discard sampling are considered sufficient and discard rates are estimated about 2% by weight on average since then.

Mean fishing mortality (ages 4 - 8) has usually been 0.3–0.5 for all years (ICES, 2003), but in recent years (since 2009) consistently underestimated.

A.3. Ecosystem aspects

Both salinity and temperature probably influence sole distribution and production in IIIa because the species' geographical distribution is confined to relatively warm, saline water (Muus and Nielsen, 1999). Large variations in either factor will therefore influence stock productivity and therefore availability to the fishery.

The Kattegat has also been eutrophied over the past 50 years and eutrophication has influenced many aspects of the Kattegat ecosystem, including occasional severe anoxia periods (Pihl, 1994; Isaksson *et al.*, 1994), increased primary production and possibly a change in fish productivity and species composition (Nielsen and Richardson, 1996). The specific effects of eutrophication on sole have not been investigated.

The large increase in landings in the early 1990s compared to long-term historical levels (1950s-1980s) may represent both changes in environmental conditions and fishery developments (e. g., increased effort) but the relative importance of the two factors is not known.

B. Data

B.1. Commercial catch

Denmark collects biological information (lengths, weights, ages) on a quarterly basis from commercial fisheries which is used for stock assessment. Landings data are supplied by Sweden, Norway, Netherland and Germany by quarter separately for Kattegat, Skagerrak and the Belts.

B.2. Biological

Weight at age in the stock is only available from a survey in November and thus not representative for the stock over the year. Therefore weight at age in the stock is assumed to be the same as weight at age in the catch.

A fixed natural mortality of 0.1 is used both in the assessment and the forecast.

Both the proportion of natural mortality before spawning (Mprop) and the proportion of fishing mortality before spawning (Fprop) have been historically set to 0.

No time series of maturity information is available for sole in IIIA. Danish sampling started in 2004 with a survey targeting sole, but since the survey period is in November maturity information is not considered of value. Therefore, knife-edge maturity at age 3 is used for this stock. This is the same assumption as used for the North Sea sole.

B.3. Surveys

Previously, four surveys were conducted, but since 2014 only one survey is used in the assessment.

Cooperative Fishermen-DTU Aqua Sole Survey

In 2004 National Institute of Aquatic Resources (DTU Aqua) initiated a survey series targeting sole in Skagerrak and Kattegat in cooperation with The Danish Fishermen's Association. The purpose is to establish a time series of catch and effort data independent of the commercial fishery in order to strengthen the scientific advice on the sole stock in ICES Div. IIIa. However, data on all commercial species are recorded. In 2005 the survey design was changed slightly in order to allow estimation of trawlable biomass and abundance. Two commercial trawlers conduct the survey without any restrictions in the vessels quota and with dispensation from all by-catch regulations. Staff from DTU Aqua are on board the vessels during the surveys. The survey ceased in 2011-12 due to economic reasons, but resumed in 2014.

The survey was originally designed in order to establish fisheries independent CPUE indices by means of annual fishing at 120 fixed stations. In 2005 the survey design was changed slightly: the number of stations selected by the fishermen was reduced by 10 from 60 to 50, while the number of stations selected randomly by DTU AQUA was increased to 70. These 70 randomly distributed stations allow an estimation of the trawlable biomass and abundance for the entire survey area. As there are no stations deeper than 90 m the biomass and abundance are estimated for depths between 10 and 90 m. The survey area is stratified by ICES squares and the area between 10 and 90 m is estimated. There is at least 5 mile between each station in order to spread out the stations (there are a few stations with lesser distance between, but then there is great difference in the depth).

Since the 2010 assessment, the survey abundance by age has been used to calibrate the assessment as a fishery independent tuning series. The survey is documented in a WD to the WGBFAS each year.

At the benchmark in 2015 (WKSOLKAT2015), it was decided to change the index estimation method and also include age 1 as an index (previously only ages 2-9 were used). The estimation of indices for all ages 1-9 is now conducted by means of a GAM analysis (Spatial Continuation logit reduced (Berg and Kristensen 2012, Vinther and Boje, 2015).

B.4. Commercial CPUE

Assessments prior to 2005 used overall CPUE averages from two trawl fisheries to calibrate the XSA. However, these CPUE indices were compromised due to lack of knowledge of fishers' targeting behavior and the effect of misreporting in the period 2002 to 2004 when the Danish quotas were particularly restrictive.

From 2005 to 2009 the sole assessment has been calibrated with CPUE series based on 1) private logbook data from gill net and trawl fishery in the main sole seasons; 2) official logbook data outside the main sole season; and 3) scientific survey data (Havfisken 1st quarter). From 2010 assessment a number of adjustments have been made to the commercial tuning series as follows below.

Official logbooks

Prior to 2005 the sole assessment was calibrated by catch rate indices from two commercial trawl fisheries (using 70-90mm and 90-104mm mesh size respectively). However, ICES (ICES, 2004) considered that these CPUE indices could be compromised due to lack of knowledge of fisherman targeting behavior and the effect of misreporting, particularly in years with restricting quotas and TACs.

Since 2007 large trawlers (12-20 m) fishing outside the season (April-August) has been used in the assessment among official logbook information. At the interbenchmark in 2015 it was decided to reject the commercial series due to the significant changes in regulations and gear use as described in section A.2.1.

Private logbooks

Due to the lack of unbiased catch rate indices, DTU Aqua, in collaboration with the Danish Fishermen Organisation, in 2004 established a database with data from private logbooks for calibration of the sole assessment. The private logbooks covers the period from 1987 to 2008 and provides information on effort (number of hours trawling / number of nets) catches (kg by major species or species group) and location (name of fishing ground) from 7 trawlers and 3 gill netters.

During the benchmark assessment in 2010, the consistency and reliability of private logbooks collected annually were discussed. Whereas WKFLAT considered the historical data likely to be unbiased the group was concerned that given a future situation with incentive to misreport catches, also the private logbooks might be compromised. As, furthermore, the number of vessels participating in the voluntary logbook programme has declined over time, in 2010 WKFLAT concluded that the tuning series should be maintained in the assessment without being updated in future.

An evaluation at the interbenchmark in 2015 resulted in continuing keeping these historical series in the assessment, since they stabilized the F and SSB estimation in a period with no other tuning series (1987-2004).

C. Historical Stock Development

Model used until 2009 assessment: XSA under following conditions:

Software used: IFAP / Lowestoft VPA suite
Model Options chosen for the final assessment by WGBFAS since 2006:
Tapered time weighting applied, power = 3 over 20 years
Catchability independent of stock size for all ages
Catchability independent of age for ages >= 7
Survivor estimates shrunk towards the mean F of the final 5 years or the 5 oldest ages
S.E. of the mean to which the estimate are shrunk = 1.500
Minimum standard error for population estimates derived from each fleet = 0.300
Prior weighting not applied

Model agreed on WKFLAT 2010 to be implemented at WGBFAS 2010: A **S**tate-space **A**ssessment **M**odel (SAM) (reviewed at WGMG 2009 at http://www.ices.dk/reports/SSGSUE/2009/WGMG09.pdf) under the following conditions:

Software used: AD model-builder implemented into internet user-interface (http://www.sole3a.stockassessment.org), requires password.
Model options are conceptually different from options in previous XSA and therefore not provided here, but available at internet address above (see model.cfg file).
All input data equal to previous XSA apart from these changes adopted at WKFLAT 2010

At the interbenchmark 2015 (IBPSOLKAT2015) changes was decided on input to the model as follows:

- A tuning fleet , commercial trawlers were discarded and age 1 was included for recruitment purposes from the survey even though age 1 is not in canum.

Input data types and characteristics since 2015:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1984-last data year	1-9+	Yes
Canum	Catch at age in numbers	1984-last data year	1-9+	Yes
Weca	Weight at age in the commercial catch	1984-last data year	1-9+	Yes
West	Weight at age of the spawning stock at spawning time.	1984-last data year	1-9+	Yes/No – assumed to be the same as weight at age in the catch
Mprop	Proportion of natural mortality before spawning	1984-last data year	1-9+	No – set to 0 for all ages in all years

Fprop	Proportion of fishing mortality before spawning	1984-last data year	1-9+	No – set to 0 for all ages in all years
Matprop	Proportion mature at age	1984-last data year	1-9+	No
Natmor	Natural mortality	1984-last data year	1-9+	No – set to 0.1 for all ages in all years

Tuning data for assessment of sole since 2015

Type	Name	Source of data	Year range	Age range
Tuning fleet 1	6 trawlers	Private logbooks	1987-2008	2-6
Tuning fleet 2	3 gill netters	Private logbooks	1994- 2007	2-9
Tuning fleet 3	Fisherman-DTU Aqua	Scientific survey	2004-2011,2014-	1-9

Model assumptions on recruitment estimation

In the SAM model an option on estimation of recruitment (youngest age group) can be either random walk (dependence on previous years recruitment) or dependent on a stock-recruitment relationship, i.e. Ricker or Beverton-Holt. The benchmark 2010 revealed that the Ricker function improves the model significantly based on AIC and Ricker model is therefore the assumption in the estimation of recruitment in the SAM model.

D. Short-Term Projection

Model used: Age structured

Software used: SAM since benchmark 2015. Prior to that a deterministic forecast was conducted by use of MFDP1a software.

Initial stock size. Taken from the SAM age 3 and older.

Recruitment: Age 1 (recruit) abundance in forecast years is randomly sampled from 2004 onwards corresponding to a period when recruitment has been low.

Natural mortality: Set to 0.1 for all ages in all years

Maturity: Knife-edge 3+ for all years

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

Weight at age in the stock: Assumed to be the same as weight at age in the catch

Weight at age in the catch: Average of recent three years

Exploitation pattern: randomly Sampled recent three years.

Intermediate year assumptions: Previously Fsq, either scaled or unscaled depending on F trend and expected development in fishery, but since 2015 a TAC constraint are used as the most reliable expectation.

For a number of years in the recent decade the TAC has not been fully utilized even though TACs were constantly reduced. One of the assumed reasons for this was that the *Nephrops* fishery in which sole is a valuable by-catch has used more effort to target *Nephrops* due to high market prices.

Stock recruitment model used: Random walk for age 1 based on the period 2004-latest data year.

Procedures used for splitting projected catches: Not relevant

E. Medium-Term Projections

No medium term analysis has been carried out since 2006 (no request).

F. Long-Term Projections

Standard yield-per-recruit analyses are conducted as part of stock assessment using long-term average (15 yrs) as input and conducted by means of SAM.

G. Biological Reference Points

ACOM in 2010 defined the following reference points:

	Type	Value	Technical basis
MSY Approach	MSY $B_{trigger}$	2000 t	lowest observed SSB excluding 1984-85 low SSB's
	F_{MSY}	0.38	Provisional value based on Stochastic simulations. F associated with highest yield and low prob. of SSB<Btrigger
Precautionary Approach	B_{lim}	undefined	
	Bpa	undefined	
	F_{lim}	0.47	F_{med} 98 excluding the abnormal years around 1990
	F_{pa}	0.30	consistent with F_{lim}

The suggested Fmsy reference point of 0.38 was based a MPE framework where p(SSB>Btrigger; 20%). Btrigger was adopted at 2000 t and all previous biomass reference points rejected.

Since WKMSYREF2 in 2014 reference points was defined as follows:

	Type	Value	Technical basis
MSY Approach	MSY $B_{trigger}$	2000 t	lowest observed SSB, excluding low SSBs in 1984–1985 (ICES, 2010).
	F_{MSY}	0.32	equilibrium scenarios constrained by prob(SSB<Blim)<5% w. stochastic recruitment (WKMSYREF2 2014)
Precautionary Approach	B_{lim}	1200 t	Bloss and segmented regression (WKMSYREF2 2014)
	B_{pa}	2000 t	Blim*e 1.645σ , σ=0.30 (WKMSYREF2 2014)
	F_{lim}	0.92	Flim replacement line; Consistent with Blim (WKMSYREF2 2014)
	F_{pa}	0.47	Bpa replacement line; Consistent with Bpa and Flim (WKMSYREF2 2014)

In December 2014 WKMSYREF3 workshop recalculated Fmsy with upper and lower ranges. The workshop considered that the low recruitment regime since 1994 (SSB since 1992) is likely the representative regime forward and therefore to be used as SR relation in the Fmsy estimation. Also the observed decreasing mean weight at age for age groups 7-8 compared to age 6, was not believed and ages 7-8 was therefore set equal to age 6. The new Fmsy with ranges was adopted as follows:

	Type	Value	Technical basis
MSY Approach	F_{MSY} $F_{MSY\ upper}$ $F_{MSY\ lower}$	0.22 0.26 0.17	equilibrium scenarios constrained by prob(SSB<Blim)<5% w. stochastic recruitment for the short period 1992-2013 (WKMSYREF3 2014)

At the WKSOLKAT2015 benchmark, that produced a revised assessment with a new perception of the stock, reference points were defined based on the guidelines from WKMSYREF4.

The 1984-1985 SSB estimates have produced a substantive high recruitment given their low biomass. The two estimates are therefore considered outliers and are suggested to be rejected for Blim and Bloss considerations. In addition, given the above MSY considerations on the S/R relation of a changed productivity regime, Blim is suggested to be revised from 1200 t to 1850 t (equal to Bloss excluding low SSBs in 1984–1985). Bpa was formerly 2000 t based on a buffer from Blim ($B_{lim} \times e^{1.645\sigma}$, σ=0.30), where σ (stderr of log(ssb) terminal year) was considered 0.30. The present assessment (WD4) have estimated σ to 0.15 for the terminal year log(ssb). However, this is considered an unrealistic low value, and was rounded up to 0.2. Assuming σ=0.20 results in Bpa estimated to 2600 t. This is suggested the new defined Bpa under the present productivity regime. Bpa is a potential candidate for MSY Btrigger. The proposed new biomass reference points are summarized below in table of adopted reference points.

The following settings were used in the Eqsim simulations for calculations of F reference points.

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Reduced data series reflection recent poor recruitment regime (1992-2014)	Based on consistent higher productivity 1984 -1991 and on evaluation by WKMSYREF3 Additional analyses conducted with full time series
Mean weights and proportion mature	2010-2014	Short period to reflect recent regime
Exploitation pattern	2010-2014	Short period to reflect recent fishery
Assessment error in the advisory year. Fcv	0.25	Based on evaluation of F forecasted (intermediate year) and realized F estimated next year for the period 2003-2014
Autocorrelation in assessment error of the advisory year, Fphi	0.45	Based on evaluation of F forecasted (intermediate year) and realized F estimated next year for the period 2003-2014

Flim is defined from the Eqsim simulations as FP0.5 (Median from equilibrium scenarios, prob(SSB<Blim)<50% w. stochastic recruitment, Fcv=Fphi=0 and without Btrigger). Flim is calculated to 0.32. Fpa is revised accordingly as Flim / e 1.645σ, where σ=0.18 as obtained from the assessment ((ln(f) in the last assessment year). Fpa is estimated to 0.23.

Fmsy is estimated to 0.26 with ranges of 0.20-0.29, from an Eqsim run without Btrigger and with the Fcv and Fphi >0. The Fp.05 (5% risk to Blim) is calculated with Btrigger=1853 and also Fcv and Fphi>0 at their estimated values. Fp.05 is calculated to 0.26 and do thus not constrain Fmsy. However, since Fpa is lower than Fmsy, Fmsy is then capped by Fpa at 0.23.

Reference points adopted in 2015 (WKSOLKAT2015).

REFERENCE POINT	VALUE	TECHNICAL BASIS
F_{MSY}	0.23	Equilibrium scenarios, capped at Fpa
F_{LIM}	0.32	Equilibrium scenarios prob(SSB< Blim)< 50% with stochastic recruitment

F_{PA}	0.23	$F_{lim} / e^{1.645\sigma}$, $\sigma=0.18$
B_{LIM}	1850 t.	B_{loss}, recent S/R regime 1992-2014
B_{PA}	2600 t	$B_{lim} \times e^{1.645\sigma}$, $\sigma=0.20$
MSY $B_{trigger}$	2600 t.	B_{PA}

H. Other Issues

Reference List

Boje, J, O A Jørgensen, S Christensen, M. Vinther 2010. Performance of a new sole survey in Div. IIIa as tuning series for stock assessment. WD #5.1 WKFLAT 2010.

Boje, J. 2010. Potential candidates for Fmsy. WD # 5.3 WKFLAT 2010.

Boje, J. 2010. Inclusion of the Belts (area 22) in the assessment for sole in IIIa. WD # 5.4 WKFLAT 2010.

Boje, J. 2015. Recruitment indices from the Danish sole survey. Working doc 3, IBPSOLKAT 2015.

Berg, C.W. and Kristensen, K. 2012. Spatial age-length key modelling using continuation ratio logits. Fisheries Research, 129:119-126.

Christensen, S. 2010. Private logbooks for calibration of the sole in IIIa assessment. WD # 5.2 WKFLAT 2010.

Christensen, S. 2005. Identification of commercial tuning fleets for assessment of sole in ICES subdivision IIIa based on private logbooks. ICES WG Document 7, 2005 Baltic Fisheries Assessment Working Group 7.

Draisma, S. G. A., Volkaert, F. M. A., Hellemans, B., and Brossier, P. 2003. Gene flow among European populations of Dover sole (*Solea solea* Teleostei). Poster (pers. comm.).

Hovgård, H. 2005. Regulations of the sole fisheries in IIIa and the incentives for non-compliance to catch regulations. ICES WG Document 9, 2005 Baltic Fisheries Assessment Working Group 9.

Hovgård, H., Hartmann, M., and Lassen, H. 1998. Standardisering af effort- og dødelighedesmål for de demersale fiskerier i Kattegat. Danmarks Fiskeriundersøgelser Report Series.

ICES 2002. Report of the Baltic Fisheries Assessment Working Group. ICES CM 2002/ACM: 17.

ICES 2003. Report of the Baltic Fisheries Assessment Working Group. ICES ACFM/Assess.Isaksson, I., Pihl, L., and van Montfrans, J. 1994. Eutrophication-related changes in macrovegetation and foraging of young cod (Gadus morhua L.): a mesocosm experiment. J. Exp. Mar. Biol. Ecol. 177: 203-217.

Jørgensen, O. 2005. Argos IBTS surveys as a tuning fleet for sole assessment in Subdivision 3A. ICES WG Document 8, 2005 Baltic Fisheries Assessment Working Group 8:.

MacKenzie, B. R., Nielsen, E., Hovgård, H., and Folmer, O. 2005. Danish survey estimates of sole abundance in the Kattegat-Belt Sea. ICES WG Document 10, 2005 Baltic Fisheries Assessment Working Group 10: 1-20.

Muus, B. J. and Nielsen, J. G. 1999. Sea fish. Scandinavian Fishing Year Book, Hedehusene, Denmark.

Nielsen, E., Bagge, O., and MacKenzie, B. R. 1998. Wind-induced transport of plaice (*Pleuronectes platessa*) early life-history stages in the Skagerrak-Kattegat. J. Sea Res. 39: 11-28.

Nielsen, E. and Richardson, K. 1996. Can changes in fisheries yield in the Kattegat (1950-1992) be linked to changes in primary production? ICES J. Mar. Sci. 53: 988-994.

Pihl, L. 1994. Changes in the diet of demersal fish due to eutrophication - induced hypoxia in the Kattegat, Sweden. Can. J. Fish. Aquat. Sci. 51: 321-336.

Vinther, M. and J. Boje. 2015. Sole survey indices. Working doc 2, IBPSOLKAT 2015.

Vinther, M. 2008. Sole in area IIIa. Evaluation of F-reference points consistent with high long-term yield and low risk of stock depletion.WD to WGBFAS meeting 2008.