Stock Annex: Plaice (*Pleuronectes platessa*) in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Plaice (*Pleuronectes platessa*) in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak)
Working Group:	Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
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A. General

A.1. Stock definition

Genetic analysis of plaice population structure in northern Europe using microsatellites and mitochondrial DNA data (Hoarau *et al.*, 2004) reveals relatively strong differentiation between "shelf" plaice and those from Iceland and Faeroe, suggesting that deep water may serve as a barrier to movement between these populations. However, within the area of the European continental shelf, only weak differentiation could be detected between North Sea-Irish Sea and other areas (Norway, the Baltic and the Bay of Biscay, Hoarau *et al.*, 2004). Although the spatial location of sampling within the North Sea was not sufficient to reveal any sub-structure. The lack of any genetic differentiation between Irish Sea and North Sea plaice populations (Hoarau *et al.*, 2004) despite the evidence from mark-recapture studies that indicate extremely low transfer of individuals between these sea areas (0.36% over 17 years, calculated from (Dunn and Pawson, 2002)) shows how differently genetic and tagging studies provide an understanding fish population structure. Nonetheless, it seems unlikely that Irish Sea and North Sea plaice are a single "stock", at least in a fisheries management sense.

Plaice in the Skagerrak is considered to have two components: an Eastern and Western. The latter occurs in a mix with plaice migrating in from the North Sea (Ulrich *et al.*, 2013) and the predominance of catches occurs on summer feeding aggregations in the Western Skagerrak. In a benchmark (WKPLE 2015, ICES 2015) it was decided that plaice in the Skagerrak would be assessed together with the North Sea stock.

Data from data storage tag experiments reveal that about one third of plaice released in the Southern Bight of the North Sea visit the eastern English Channel in December and January. In contrast, analysis of the movements of mark-recapture experiments with plaice of a similar size and released at similar times indicates that only 13% of plaice released in the Southern Bight visit the eastern English Channel at this time (Hunter *et al.*, 2004). This difference between DST and mark-recapture experiments is not observed in the central North Sea and German Bight, where the movements of plaice derived from the two approaches are relatively similar (Bolle *et al.*, 2005). The differences may possibly be due to the fact that these fish migrate to their spawning grounds by selective tidal stream transport. Studies (Kell *et al.*, 2004) have shown that the migration between North Sea and the adjacent areas is more problematic for the smaller adjacent areas than it is for management in subarea 4.

A.2. Fishery

Plaice in Subarea 4 is taken mainly in a mixed flatfish fishery by beam trawlers in the southern and south-eastern North Sea. Directed fisheries are also carried out with seines, gill nets, and twin trawls, and by beam trawlers in the central North Sea. Due to the minimum mesh size enforced (80 mm in the mixed beam trawl fishery), large numbers of (undersized) plaice are discarded. Fleets exploiting North Sea plaice have generally decreased in number of vessels in the last 10 years. However, in some instances, reflagging vessels to other countries has partly compensated these reductions. For example, approximately 85% of plaice landings from the UK (England and Scotland) is landed into the Netherlands by Dutch vessels fishing on the UK register. Vessels fishing under foreign registry are referred to as flag vessels, which may have different fishing patterns from the rest of the fleet. Besides having reduced in number of vessels, the fleets have also shifted towards two categories of vessels: 2000HP (the maximum engine power allowed) and 300 HP (the maximum engine power for vessels that are allowed to fish within the 12 mile coastal zone and the plaice box). Also, the decrease in fleet size may partially have been compensated by slight increases in the technical efficiency of vessels. In the Dutch beam trawl fleet indications of an increase of technical efficiency of around 1.65% by year was found over the period 1990 – 2004 (Rijnsdorp *et al*., 2006). Because the commercial tuning series are not currently used in the assessment, these estimates do not affect the current assessment.

The Dutch beam trawl fleet, one of the major operators in the mixed flatfish fishery in the North Sea, has seen a shift towards more inshore fishing grounds, changing the catchability of the fleet. This shift may be caused by a number of factors, such as the implementation of fishing effort restrictions, the increase in fuel prices and changes in the TAC for the target species (Quirijns, 2008). However, the contribution of each of these factors is yet unknown. Other factors affecting the catchability of the fleet include the changes in the fishing speed of the vessels, and discarding marketable fish in certain seasons and areas, as a result of the TAC management (Rijnsdorp, 1991).

In recent years, the adoption of innovative gears – which are often aimed at reduction of fuel consumption and reduction of bottom disturbance – may be contributing to changes in fishing patterns however. In 2011, approximately 30 derogation licenses for Pulse trawls were taken into operation, which increased to 42 in 2012. An additional 42 derogation licenses have been extended in spring 2014. At the same time, possible amendments to EU regulations which would permanently legalize the use of pulse gears for the whole fleet are ongoing. Potential future impact either on the plaice stock itself or the stock assessment is unknown. ICES recommends that further studies aimed at investigating catch composition of these innovative gears in comparison to traditional beam trawls are undertaken.

Conservation schemes and technical conservation measures

Fishing effort has been restricted for demersal fleets in a number of EC regulations (EC Council Regulation No. 2056/2001; EC Council Regulation No 51/2006; e.g N°40/2008, annex IIa). For example, for 2007, Council Regulation (EC) No 41/2007 allocated different days at sea depending on gear, mesh size, and catch composition: Beam Trawls could fish between 123 and 143 days per year. Trawls or Danish seines could fish between 103 and 280 days per year. Gillnets could allowed to fish between 140 and 162 days per year. Trammel nets could fish between 140 and 205 days per year.

Several technical measures are applicable to the plaice fishery in the North Sea: mesh size regulations, minimum landing size, gear restrictions and a closed area (the plaice box).

Mesh size regulations for towed trawl gears require that vessels fishing North of 55 N (or 56°N east of 5°E, since January 2000) should have a minimum mesh size of 100 mm, while to the south of this limit, where the majority the plaice fishery takes place, an 80 mm mesh is allowed. In the fishery with fixed gears a minimum mesh size of 100 mm is required. In addition to this, since 2002 a small part of North Sea plaice fishery is affected by the additional cod recovery plan (EU regulation 2056/2001) that prohibits trawl fisheries with a mesh size < 120 mm in the area to the north of 56°N.

The minimum landing size of North Sea plaice is 27 cm. The maximum aggregated beam length of beam trawlers is 24 m. In the 12 nautical mile zone and in the plaice box the maximum aggregated beam-length is 9m. A closed area has been in operation since 1989 (the plaice box). Since 1995 this area was closed in all quarters. The closed area applies to vessels using towed gears, but vessels smaller than 300 HP are exempt from the regulation. An evaluation of the plaice box has indicated that: From trends observed it was inferred that the Plaice Box has likely had a positive effect on the recruitment of Plaice but that its overall effect has decreased since it was established. There are two reasons to assume that the Plaice Box has a positive effect on the recruitment of Plaice: 1) at present, the Plaice Box still protects the majority of undersized Plaice. Approximately 70 % of the undersized Plaice are found in the Plaice Box and Wadden Sea, and despite the changed distribution, densities of juvenile Plaice inside the Box are still higher than outside; 2) In the 80 mm fishery, discard percentages in the Box are higher than outside. Because more than 90 % of the Plaice caught in the 80 mm fishery in the Box are discarded, any reduction in this fishery would reduce discard mortality. There is, however, no proof of a direct relationship between total discard mortality and recruitment.

Generally, it is assumed that the majority of discarded animals do not survive (Beek *et al*. 1990; Chopin *et al*. 1996). Reviews of studies that have tested this assumption acknowledge that discard mortality is determined by a range of biological, technical, or environmental factors or 'stressors' (Broadhurst *et al*. 2006). Biological factors relate to e.g. the species, physiology, size, catch weight/ volume, composition; technical stressors relate to e.g. gear design, deployment duration, fishing speed; environmental stressors relate to e.g. temperature, hypoxia, depth, wind force, availability of sunlight.

For the beam trawl fishery, discard mortality is influenced by the duration the organisms are confined in the codend and concurrent injuries (Beek *et al*. 1990; Broadhurst *et al*. 2006). If the fish were brought on board alive, then the processing of the catch on board would also matter. It is estimated based on experimental studies on board commercial vessels that less than 10% of the plaice and sole discards in the beam trawl fisheries survive the process of discarding (Bult and Schelvis-Smit 2007; Beek *et al*. 1990). In the pulse fishery, overall survival for plaice was assessed as 15% [95% CI: 11–19%] (van der Reijden *et al.*, 2017).

A.3 Ecosystem aspects

Adult North Sea plaice have an annual migration cycle between spawning and feeding grounds. The spawning grounds are located in the central and southern North Sea, overlapping with the distribution area of Sole. The feeding grounds are located more northerly than the sole distribution areas. Juvenile stages are concentrated in shallow inshore waters and move gradually off-shore as they become larger. The nursery areas on the eastern side of the North Sea contribute most of the total recruitment. Sub-populations have strong homing behaviour to specified spawning grounds and rather low mixing rate with other sub-populations during the feeding season (de Veen, 1978, Rijnsdorp and Pastoors, 1995). Genetically, North Sea and Irish Sea plaice are weakly distinguishable from Norway, Baltic and Bay of Biscay stocks using mitochondrial DNA (Hoarau *et al*., 2004).

Juvenile plaice were distributed more offshore in recent years. Surveys in the Wadden Sea have shown that 1-group plaice is almost absent from the area where it was very abundant in earlier years (van Keeken *et al*., 2007). The Wadden Sea Quality Status Report 2004 (Vorberg *et al*., 2005) notes that increased temperature, lower levels of eu-trophication, and de-cline in turbidity have been suggested as causal factors, but that no conclusive evidence is available; taking into account the temperature tolerance of the species there is ground for the hypothesis that a temperature rise contributes to the shift in distribution.

A shift in the age and size at maturation of plaice has been observed (Grift *et al*., 2007, Grift *et al*., 2003): plaice become mature at younger ages and at smaller sizes in recent years than in the past. This shift is thought to be a genetic fisheries-induced change: Those fish that are genetically programmed to mature late at large sizes are likely to have been removed from the population before they have had a chance to reproduce and pass on their genes. This results in a population that consists ever more of fish that are genetically programmed to mature early at small sizes. Reversal of such a genetic shift may be difficult. This shift in maturation also leads to mature fish being of a smaller size at age, because growth rate is reduced after maturation.

B. Data

B.1 Commercial catch

Discard sampling programmes started in the late 1990s to obtain discard estimates from several fleets fishing for flatfish. These sampling programmes give information on discard rates from 1999 but not for the historical time series. Observations indicate that the proportions of plaice catches discarded are high and variable (80% in numbers and 50% in weight: (van Keeken *et al*., 2004)), but that they have been decreasing since 2005 to approximately 30%. For the period prior to 2000, a reconstructed discard time series for 1957–1999 exists, based on a reconstructed population and selection and distribution ogives (ICES, 2005a).

Discard data from the sampling programmes in the individual countries are provided as raised totals, based on samples from onboard observers and self-sampling. These programs generally provide length structured samples of which a subsample is aged through otolith readings.

In the period 2000–2010, discards at age were raised from the Dutch and UK sampling programmes by effort ratio (based on hp days at sea for the Dutch fleets, and on trips for the UK fleets). Discards at age from the Danish and German sampling programs were raised by landings. Discards at age for the other fleets for which no estimates were available, were calculated as a weighted average of the Dutch, Danish, German and UK discards at age and raised to the proportion in landings (tonnes). Since 2012, Intercatch was used to estimate discards at age, with an increasing number of countries contributing to the samples.

A self sampling programme for discards was started by the Dutch beam trawl fishery in 2004, and is still running. This sampling program has a high number of samples, taken on board by the fishermen, estimating the percentage of discards by volume. The program indicates a strong spatial pattern in the discarding of the fleet.

For the period before 2000 assessment, discards numbers at age are calculated from fishing mortality at age corrected for discard fractions, using a reconstructed population and selection and distribution o-gives (ICES, 2005a).

Landings

The landings by country are collected by different countries, segregated by sex for the Netherlands and Belgium (accounting for approximately 50 % of the landings). Age structure is available for the Netherlands, France, Germany, Denmark and Belgium (accounting for > 50% of the landings). The total age structured landings are estimated using a weighed procedure for the age structure by country, based on the proportionality of the weight of the total landings.

During the benchmark of the eastern channel (7.d) plaice stock (WKFLAT ICES, 2010) it was decided that 50% of mature Q1 landings and discards taken in the eastern channel are actually plaice from the North Sea stock migrating in and out of the area. The impact was found to be minimal, given that as a percentage of the total catch, these eastern channel landings, available back to 1980, account for less than 1% each year. Since 2012, 50% of the Q1 eastern channel (7.d) mature plaice landings and discards are included in the assessment of the North Sea plaice stock. See the stock annex for plaice in division 7.d for further details.

1.1.1 B.2 Biological

Weight at age

Since the use of intercatch for this stock, stock weights at age are based on the catch samples in the first quarter. Stock weight at age have varied considerably over time, especially for the older ages. Landing weights at age are derived from market sampling programmes. Discards weights are derived from observer programs and self-sampling programs. Catch weights at age are calculated as the weighted average of the discard and landing weights at age in intercatch. There appear to be cohort effects on landings weight at age, which are also reflected in the stock weights at age. In addition to the cohort effects, there is a long term decline in weight at age for the older ages. The stock weights of the older ages are based on the market samples in the first quarter. In these market samples, the sex ratio for the older ages may be skewed towards one of the sexes.

Natural mortality

Natural mortality is assumed to be 0.1 for all age groups and constant over time. These values are probably derived from war-time estimates (Beverton and Holt, 1957; Beverton 1964).

Maturity

A fixed maturity ogive is used for the estimation of SSB from the assessment in North Sea plaice, assuming maturity-at-age 1 is 0, maturity-at-age 2 and 3 are 0.5, and older ages are fully mature. However maturity at-age is not likely to be constant over time (Grift *et al*. 2003, Grift *et al*. 2007) (Grift *et al*., 2007, Grift *et al*., 2003). The effects of assuming a constant maturity-at-age on the management advice was discussed in a study by (Kell and Bromley, 2004). However, a study of the effect of the fluctuations of natural mortality on the SSB by WKNSEA in 2017 showed that incorporating the historic fluctuations had little effect on SSB estimates (ICES, 2017).

B.3 Surveys

The stock assessment of North Sea plaice uses indices from different surveys. (1) the Beam Trawl Surveys from NL, GE, UK, and BE, (2) the Sole Net Survey (SNS), and the IBTS surveys. The Beam Trawl Survey RV Isis (BTS-Isis) was initiated in 1985 and was set up to obtain indices of the younger age groups of plaice and sole, covering the south-eastern part of the North Sea (RV Isis). Since 1996 the BTS-Tridens covers the central part of the North Sea, extending the survey area of the surveys. Both vessels use an 8-m beam trawl with 40 mm stretched mesh codend, but the Tridens beam trawl is rigged with a modified net. Owing to the spatial distribution of both BTS surveys, considerable numbers of older plaice and sole are caught. Besides the Dutch survey time series there exist also a Belgian, U.K. and a German beam trawl survey data. The Belgian and U.K. beam trawl surveys cover additional parts of area 4.c and 4.b. The German beam trawl survey started to survey the area west of Jutland since 1994 (Area 4.b). This survey overlaps with some of the area covered by RV Isis and RV Tridens but it also adds some areas to the survey area. The spatial distributions of the BTS surveys are given in Figure 1.

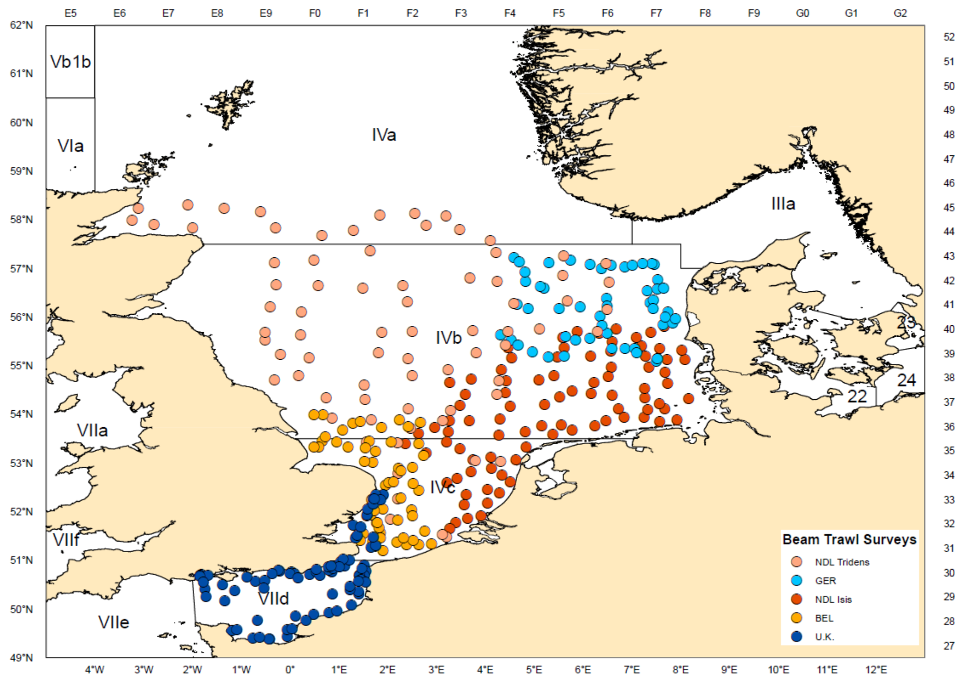

Figure 1: Spatial coverage of the different off shore beam trawl surveys in the North Sea (3rd Quarter). Displayed are exemplarily the realized stations from 2012.

The formerly separated plaice stocks of area 4 (North Sea) and 3.aN (Skagerrak) were combined and assessed as a single stock unit since 2015 (WGNSSK, 2015; WKPLE, 2015). The beam trawl surveys do not provide any information for area 3.aN, but the International Bottom Trawl Survey (IBTS, Figure 2) covers area 4 and 3.aN in a standardized way in quarter 1 (since 1983) and quarter 3 (since 1991). However, plaice was historically not one of the main target species of these surveys and biological data (age, weight) were not taken in a consistent way in area 4 before 2007. But in recent years plaice was sampled more regularly and consistent on the IBTS (Q1 and Q3). Further, in general there is a good coverage of sampling for area 3.a for most years of the time series. Therefore, the IBTS is potentially a suitable survey for the estimation of an abundance index covering the North Sea and the Skagerrak. Consistent age sampling for plaice in IBTS Q1 started in 2007, and in IBTS Q3 started in 1997. The spatial coverage of the IBTS Q1 survey is given in Figure 2.

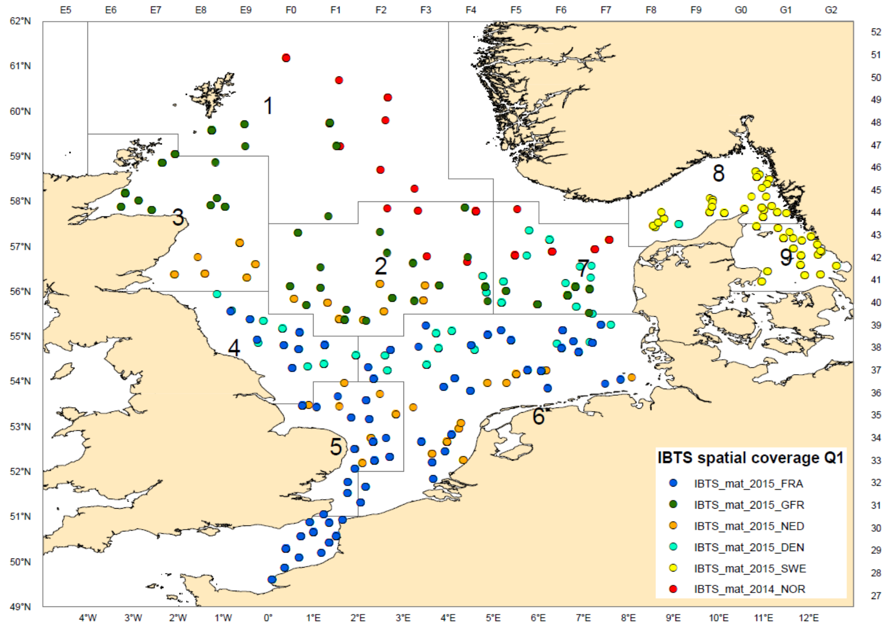

Figure 2: Spatial coverage of the IBTS (1st quarter) and stratification by roundfish areas. Displayed are stations from 2015 where plaice age and maturity data were collected.

A GAM model approach by Berg et al. (2014) is used to combine the BTS surveys from 1997 onwards, to combine the IBTS Q1, and to combine the IBTS Q3.

The assessment is conducted using the combined BTS-indices, while maintaining the early part of the BTS-Isis index in the assessment separately (since this survey started 11 years before the BTS-Tridens and so only part of the time series can be combined). The survey areas of the different BTS indices are shown in Figure 1.

The Sole Net Survey (SNS) was carried out with RV Tridens until 1995 and then continued with the RV Isis. Until 1990 this survey was carried out in both spring and autumn, but after that only in autumn. The gear used is a 6 m beam trawl with 40 mm stretched mesh cod-ends. The stations fished are on transects along or perpendicular to the coast. This survey is directed to juvenile plaice and sole. Ages 1 to 3 are used for tuning the North Sea plaice assessment; the 0-group index is used in the RCT3. In an attempt to solve the problem of not having the survey indices in time for the WG, the SNS was moved to spring in 2003. However, because of the gap in the spring series these data could not be used in the plaice assessment or in RCT3. In 2004, the SNS was moved back to autumn as before, based on the recommendation of the WGNSSK in 2004.

The three different survey indices used are:

- Beam Trawl Survey RV Isis (BTS-Isis) for the older part of the time series; (1985–1995, ages 1–8)
- Beam Trawl Survey combined (BTS-combined); (1996–now, ages 1–9)
- Sole Net Survey (SNS1); (1970–1999, 1–6)
- Sole Net Survey (SNS2); (2000–now, 1–6)

- International Bottom Trawl Survey Q1 (IBTS Q1); (2007–now, ages 1–7)
- International Bottom Trawl Survey Q3 (IBTS Q3); (1997–now, ages 1–9)

An additional Survey index that can be used for recruitment estimates are:

- Demersal Fish Survey (DFS)

The Demersal Fish Survey (DFS) is the more coastal of the surveys, conducted by several countries. This survey is not used in the assessment, but rather used to estimate the recruitment of juvenile fish in the RCT3 analysis. The survey estimates abundances for North Sea plaice age 0 and age 1. However, the age 1 has not been used for recruitment estimation since a number of years, and the time series for this age was stopped in 2005. Since 2013, a revised time series from 1990 onwards is used, because the UK survey was terminated and thus removed from the international combined index (ICES, 2012).

B.4 Commercial LPUE

Commercial age structured LPUE series (consisting of an effort series and landings-at-age series) that are available to be used (but are currently not included in the assessment anymore) as tuning fleets are:

- The Dutch beam trawl fleet (since 1989)
- The Dutch beam trawl fleet corrected for spatial effort allocation (since 1997)
- The UK beam trawl fleet excluding all flag vessels (between 1990 and 2002)

Effort has decreased in the Dutch beam trawl fleet since the early/mid 1990s. Up until 2002, the age-classes available in both the Dutch and the UK fleets generally show equal trends in LPUE through time.

The WG used both survey data and commercial LPUE data for tuning until the mid-1990s. The commercial LPUE was calculated as the ratio of the annual landings over the total number of fishing days of the fleet. At that time, however, it was realised that the commercial LPUE data of the Dutch beam trawl-fleet, which dominated the fishery, were likely to be biased due to quota restrictions. Vessels were reported to adjust their fishing patterns in accordance to the individual quota available for that year. Fishers reported to leave productive fishing grounds because they lacked the fishing rights and moved to areas with lower catch rates of the restricted species with a bycatch of non-quota, or less restricted species.

A method that corrects for the spatial effort allocation is to calculate LPUEs at a smaller spatial scale, e.g. ICES rectangles, and then calculate the average of these ICES rectangle-specific LPUEs. Age-information is available at this spatial level since 1997, and LPUE series could be used for tuning an age structured assessment method (alternatively, age-aggregated tuning series could be used in other analytical assessment methods than AAP). Only under the assumption that discarding is negligible for the older ages, the LPUE represents CPUE, and this time-series could be used to tune age structured assessment methods.

C. Historical Stock Development

A number of assessment runs were done using different formulations of a smoother-based age structured stock assessment, based on Aarts and Poos (2009). The assessments were based on combinations of surveys, and methods for combining survey information (WD 4). The current assessment uses discards data from 2000 onwards: The discards time series used in the assessment includes Dutch, Danish, German and UK discards observations for 2000–2015. To reconstruct the number of plaice discards at age before 2000, catch numbers at age data was reconstructed in 2005 based on a model-based analysis of growth, selectivity of the 80-mm beam trawl gear, and the availability of undersized plaice on the fishing grounds. This reconstruction was done in 2004 (van Keeken *et al.* 2004). The benchmark decided to continue this procedure.

The assessment is similar in structure to that in Aarts and Poos (2009), but the F-at-age matrix is generated using a tensor spline (with a design matrix taken from mgcv (Wood, 2006)). The number of knots in this tensor spline are controlled by means of a vector of length 2, one for the knots in the age dimension, and one for the number of knots in the year dimension of the assessment. Rather than using the discards and landings-at-age as separate data sources as in Aarts and Poos (2009), the final assessment uses the catches (the sum of landings and discards) as data and the basis for the likelihood fitting. After fitting the catches, landings and discards in the model fit are separated using the observed proportionality between landings and discards.

The final model used the following data and settings:

STOCK	NORTH SEA AND SKAGERRAK COMBINED
Catch at age	Landings + (reconstructed) discards based on NL, DK + UK + DE fleets and BE (since 2012)
Fleets (years; ages)	BTS-Isis-early 1985–1995; 1–8 BTS-combined 1996–now; 1–9 SNS1 1970–1999; 1–6 SNS2 2000-now (excl. 2003); 1–6 IBTS Q1 2007-now; 1-7 IBTS Q3 1997-now ; 1-9
Plus group	10
Catchability independent of ages for ages >=	6
Age at which the catchability for the F-at-age reaches a plateau >=	9
F tensor spline age knots	6
F tensor spline year knots	26

D. Short-term Projection

The short term projection is done deterministically in FLR. Weight-at-age in the stock and weight-at-age in the catch are taken to be the average over the last 3 years. The exploitation pattern was taken to be the mean value of the last three years, scaled to the intermediate year F. The proportion of landings at age was taken to be the mean of the last three years, this proportion was used for the calculation of the discard and human consumption partial fishing mortality.

Population numbers at ages 3 and older are AAP survivor estimates. Numbers at age 2 are based on RCT3 estimates if the estimates from RCT3 show sufficient consistency. Numbers at age 1 and recruitment of the incoming year-class are taken from the long-term geometric mean of age 1 assessment estimates, where the most recent years are removed from the time-series, or are based on RCT3 estimates if the estimates from RCT3 show sufficient consistency.

The management options are given for two different assumptions on the F values in the intermediate year;

a) F is assumed to be equal to the estimate for F in the final year of the assessment,

b) F is set such that the landings in the intermediate year are equal to the TAC of that year.

E. Medium-Term Projections

Generally, no medium term projections are done for this stock.

F. Long-Term Projections

Generally, no medium term projections are done for this stock.

G. Biological Reference Points

The current reference points were established by WKNSEA 2017 (ICES, 2017). Data used for the reference point estimation were derived from the final assessment as defined in section 4.6.4. The SSB and R pairs can be found in assessment summary table 4.7.2.1. The fishing mortalities-at-age can be found in Table 4.7.2.2. Weights-at-age for the stock, landings, discards and catches have not changed and can be found in the ICES WGNSSK 2016 report.

Stock–recruitment relationship and new B_{lim} and B_{PA} reference points

The stock-recruit fits for a pure segmented regression and for a mixture of Stock-recruitment relationships are shown in Figures 4.7.3.1 and 4.7.3.2, respectively. The SR scatter for North Sea plaice shows no clear patterns with both high and low recruitments found across the whole range of observed SSB. There is a single outlier (1985 year class) near the middle of the observed SSB range.

In the Eqsim method, the segmented regression estimates a breakpoint in the data at 207 287 tonnes. This is just above the B_{loss} of 20 2100 tonnes observed in 1997. This 207 288 is thus the proposed B_{lim} reference point. Using the default multiplier (of 1.4) to calculate B_{pa} from B_{lim}, results in a B_{pa} reference point of 290 203 tonnes.

Methods and settings used to determine ranges for FMSY

The Eqsim methods were applied to estimate the remainder of the reference points. Runs with and without MSY $B_{trigger}$ were done for the Eqsim method. The total (catch) F was optimised for maximum landings. The EQ sim runs were based on the S-R fits. For each run, 3000 draws were taken from the S-R results.

The resulting F_{lim} estimate is 0.516 year-1. Using the default multiplier (of 1/1.4) between F_{lim} and F_{pa} results in a corresponding F_{pa} estimate of 0.369 year-1.

In order to get the initial F_{MSY} and $F_{0.5}$ estimates, a run was done with all S-R relationships. The resulting median F_{MSY} estimate is 0.210 year-1 and the resulting $F_{0.5}$ is 0.425 year-1.

Next, a run was done to determine the $B_{trigger}$. The estimates of this trigger were 79 3905 tonnes. This is larger than the current $B_{trigger}$, larger than B_{pa}, and larger than the 5%ile of the most recent SSB estimate in the model (based on SSB2015/1.4= 564 599). Because the SSB has climbed so steeply in recent years, and the effects in terms of density dependent growth and mortality cannot (yet) be evaluated, the benchmark decided to propose a trigger that is based on historic observations, from the time period when fishing mortality was substantially lower, and abundances high: the peak in abundance of 481.5 thousand tonnes in the first ten years of the assessment. This $B_{trigger}$ means a substantial increase compared to the current $B_{trigger}$, and is substantially higher than B_{pa}. The next benchmark can then re-evaluate the trigger, once the population processes and dynamics that govern the stock when fishing at F around F_{MSY} have been evaluated.

The final reference points table from the EQSIM runs were

Reference point	Value
F_{MSY} without $B_{trigger}$	0.21
$F_{MSY\ lower}$ without $B_{trigger}$	0.15
$F_{MSY\ upper}$ without $B_{trigger}$	0.30
$F_{P.05}$ (5% risk to B_{lim} without $B_{trigger}$)	0.43
F_{MSY} with $B_{trigger}$	0.21
$F_{MSY\ lower}$ with $B_{trigger}$	0.146
$F_{MSY\ upper}$ with $B_{trigger}$	0.30
$F_{P.05}$ (5% risk to B_{lim} with $B_{trigger}$)	0.77
MSY	104 113 t
Median SSB at F_{MSY}	1 104 120 t
Median SSB lower precautionary (median at $F_{MSY\ upper}$ precautionary)	690 328 t
Median SSB upper (median at $F_{MSY\ lower}$)	1 616 173 t

H. Other Issues

None identified

I. References

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