21 Turbot in the North Sea

tur.27.4 – *Scophthalmus maximus* in Subarea 4

This report presents the stock assessment carried out for turbot (*Scophthalmus maximus*) in Subarea 4 in 2024. Turbot in 27.4 was upgraded to a Category 1 stock including reference points and a short-term forecast during the 2018 inter-benchmark (ICES, 2018b). Since WGNSSK 2019, the assessment is conducted and advice for turbot in 27.4 is provided based on the assessment configuration, reference points and short-term forecast derived during the 2018 inter-benchmark.

21.1 General

21.1.1 Biology and ecosystem aspects

Turbot is broadly distributed from Iceland in the North, along the European coastline, to the Mediterranean and Adriatic Sea in the south. In general, turbot is a rather sedentary species, but there are some indications of migratory patterns. For example, in the North Sea, migrations from the nursery grounds in the south-eastern part to more northerly areas have been recorded. IBPNEW (ICES, 2012) concluded that turbot in the North Sea (Subarea 4) can be considered as a distinct stock for management purposes. However, recent genetic studies and species distribution mapping show that the Skagerrak part of the stock could potentially be merged with the North Sea stock and the Kattegat with the Baltic Sea stock (ICES, 2020).

Turbot is typically found at a depth range of 10 to 70 m, on sandy, rocky or mixed bottoms and is one of the few marine fish species that inhabits brackish waters. It is a typical visual feeder and could be regarded as a top predator. Turbot feeds mainly on bottom living fishes (e.g. common gadoids, sandeel, gobies, sole, dab, dragonets, sea breams, etc.) and small pelagic fish (e.g. herring, sprat, boarfish, sardine) but also, to a lesser extent, on larger crustaceans and bivalves.

21.1.2 Fisheries

In the 1950s, the UK was the biggest contributor to the landings (~50% of the landings). In recent years, most of the landings stem from the Netherlands (~60%). Turbot is mostly caught in trawls of mixed fisheries, such as the 80 mm beam trawl fleet (BT2) fishing for sole and plaice (representing 69% of Dutch turbot landings in 2023). In Denmark, the second largest contributor to the landings in recent times, there is a directed fishery for turbot using gillnets (19 % of the total landings in 2023).

See the Stock Annex for more details.

21.1.3 Management

The turbot stock was previously managed using a combined TAC for turbot and brill is set in Subarea 4 and in UK waters of Division 2.a. This management area (particularly the inclusion of a part of Division 2.a) did not correspond to either of the stock areas defined by ICES for turbot and brill.

As of 2024, the combined turbot and brill TAC technically remains in place for Subareas 2.a (UK only) and 4 (EU + UK). However, the TAC is now divided into separate allocations for the UK and EU member states for both species, with 400 tonnes of turbot allocated to the UK and 1638

tonnes allocated to the EU in 2024 (EU, 2023). This updated approach, effectively abolishes the combined TAC in practical terms.

As a primarily bycatch species, regulations relating to effort restrictions for the primary métiers catching turbot (e.g. beam trawlers) are likely to impact the stock. Fishing effort has been restricted in the past for demersal fleets in a number of EC regulations (e.g. EC Council Regulation Nos. 2056/2001, 51/2006, 41/2007, and 40/2008).

The Dutch Producer Organisations (POs) have introduced a minimum landings size of 27 cm in 2013. In 2016 catches of turbot increased substantially and the minimum landing size was increased to 30 cm at first, followed by a further increase to 32 cm in May 2016. In the summer of 2016, the POs decided to prohibit landing the smallest market category and in October and November the weekly landings were capped to respectively 375 kg and 600 kg wk^{-1}. These measures were taken to keep the landings in line with the available national quota. In 2018, the TAC for turbot and brill was substantially increased; however, Dutch PO measures were still in place with a minimum landing size of 30 cm and limiting the landings to 2000 kg wk^{-1}. Since 2019, the PO measures were relaxed due to the sufficiently available quota.

Measures taken by the Dutch Producer Organisations from 2016 up to present.

Dutch PO-measures			
Year	**Date**	**Max kg per week/trip**	**MLS**
2016	January - March	-	27 cm
2016	April – May	-	30 cm
2016	May – September	-	32 cm
2016	October – November	375 kg	32 cm
2016	November – December	600 kg	32 cm
2017	January – February	-	32 cm
2017	March – October	800 kg	32 cm
2017	November - December	2000 kg	30 cm
2018	January – August	2000 kg	30 cm
2018	September - October	2500 kg	30 cm
2018	October - December	3000 kg	27 cm
2019	January – December	3000 kg	27 cm
2020	January - December	3000 kg	27 cm
2021	January – December	3000 kg	27 cm
2022	January – December	3000 kg	27 cm
2023	January – December	3000 kg	27 cm

21.2 Data used in the assessment

Following the inter-benchmark conducted in the summer of 2018 (ICES, 2018b), the assessment of North Sea turbot requires three main types of data:

Catch data: estimates of removals of turbot by the fishery.

Survey data and commercial LPUE (landings per unit effort): indices of trends in population abundance over time from fisheries independent and fisheries dependent sources, respectively.

Biological data: estimates and/or assumptions on growth, maturation and natural mortality.

Since the assessment is age-based, data for the above is required for each age. See the Stock Annex for more details on the data used in the assessment, sources and historical values.

21.2.1 Catch data

Figure 21.1 and Table 21.2 show the trend in total landings (InterCatch) and discards (InterCatch) over time. ICES estimated landings of turbot decreased during the 1990s and 2000s. From 2012 – 2020 landings fluctuated around 3000 tonnes but have declined consecutively in 2021 (2659 t), 2022 (1697 t), and 2023 (1656 t). In this period, effort by the Dutch beam trawl fleet, which contributes most to the landings (ca. 45%), has decreased notably. In 2016 and 2017, landings were slightly higher, exceeding 3400 tonnes.

Since 2018, official landings in Subarea 4 decreased gradually from 3228 tonnes to 1648 tonnes in 2023 (Table 21.3). Since 2016, the combined TAC for turbot and brill has not been fully utilized. In 2023, ~57% of the combined TAC (3747 tonnes) was taken, of which turbot had the largest share (77%).

Landings in numbers-at-age are presented in Table 21.1 and Figure 21.2. Following a decrease in minimum market size for turbot in the Netherlands in 2002, there has been a notable increase in the amount of age 1 and 2 turbot landed, accounting for half of the landings in some years. This proportion has been decreasing in recent years due to some poor recruitment in 2012, 2013, 2016, and 2021. Since turbot are only fully mature-at-age 4, a high proportion of immature fish are in the landings. Since 2015, however, a larger proportion of age 5+ fish in the landings is observed; these are now of the same order of magnitude as the estimates in the 1980s. This could reflect the recent reduction in F leading to an increasing proportion of older fish in the landings. However, since the landing data up to 2016 are raised using only the Dutch 80 mm TBB fleet, signals in landings-at-age data may not be accurate reflections of true removals from the population over time. In 2021, there were no landings of age 1 suggesting a weak year class. The landings of age 1 fish in 2022 and 2023 were similar to those of the 2018-2020-year classes, suggesting a stronger year class coming through.

The weights-at-age in the landings of turbot in Subarea 27.4 (Table 21.3) come from the "weca" file of the InterCatch landings export. These are measured weights from the various national catch and market sampling programmes. Mean stock weights-at-age (Table 21.6) are the average weights from the 2nd quarter landings and are derived from the "Catch and Sample Data Table" file from InterCatch. As discards are not included in this assessment, discard weight-at-age are not imported. Given the lack of weight data in the period 1991–2003, modelling[1] was required to infer the trend in stock and landings weight-at-age data (Table 21.5 and 21.7).

[1] see Stock Annex for turbot 27.4 for full details

21.2.2 Discards

The assessment of this stock does not include discards as there is very limited age sampling of the discards. In 2018, 4% of the imported discard data were sampled, coming from discards of some Danish (< 8 fish per métier) and Belgian beam trawl fleet (138 fish). These data were considered insufficient to be used in the age allocation of international discards. Since 2019, no age structure information was submitted for the discard estimates as sample sizes were too low for raising and to be submitted to InterCatch.

There was a sudden increase in the landing of age two turbot following the decrease in minimum market size in the Netherlands in 2002. Given that there was no known change in the fishing behaviour of the main fleets at this time, this could indicate that, previously, more age 1 fish must have been caught than were actually landed. These were either discarded or, as a much-sought-after fish, kept by the fishermen for personal use. This would mean that the discards could be underestimated in the period up to 2002 relative to the period following this. Alternatively, subsequent to the change in MLS, more targeting of small turbot may have occurred. Without a useable time-series of discards before and after this change it is difficult to determine which of these explanations holds.

The discard rate (discards: 187 t / (discards + landings: 1 656 t)) was 10.1% in 2023 marking an increase in turbot discards compared to 2022 (2.9%). Since 2019, the discard ratio has been lower (~6%) compared to the period 2016–2018 that featured an average of 14%. The discard rate in the most recent three years is more in line with the discard rate observed in the period 2013–2015, when discard ratios were approximately 5%.

In 2023, BMS landings were reported by the UK. However, the submitted values were negligible (40 kg) and were not raised in InterCatch.

21.2.3 Logbook registered discards

In 2023, no logbook registered discards were reported to InterCatch. They are not raised.

21.2.4 InterCatch raising and allocation procedures

InterCatch was used for the first time for the North Sea turbot stock at WGNSSK 2014, and has been used since.

In 2023, six countries provided imported estimates of discards to InterCatch with only Belgium, the Netherlands and Scotland providing non-zero values. Where possible, discards were raised within métier by quarter. In the towed gear group, a distinction was made between otter trawlers, seines, and beam trawlers. Beam trawlers and otter trawlers targeting crustaceans (CRU) with a mesh size smaller than 99 mm were grouped together. The remainder, which consisted of métiers that did not fit in any of the above groups, were then raised with all available discard estimates (see table below).

Unsampled fleet*	Sampled fleet**
TBB < 100 mm	Within métier, by quarter
TBB > 100 mm	Within métier, by quarter
OTB/TBB < 70 mm (DEF and CRU)	Within métier, all quarters
OTB < 100 mm	Within métier, all quarters
OTB > 100 mm	Within métier, all quarters
SSC/SDN > 100 mm	All métiers, all quarters
SSC/SDN < 100 mm	All métiers, all quarters
Passive gears (GNS/GTR)	All métiers, all quarters
Others	All métiers, all quarters

*** Unsampled fleet are those fleets for which no discards are submitted.**

**** Sampled fleet are those fleets for which discards ratios are known.**

Out of the 187 tonnes of estimated discards, 74 tonnes (40%) were reported data and 113 tonnes (60%) were raised in InterCatch. The proportion of landings with discards associated (same strata) was 54%.

For the landings, Dutch (for data from 2004–present), Danish (2014–present) and Belgian (2017–present) samples, accounting for auctions, quarters and market categories, are provided. The number of age samples gradually increased from 2018 (2359), to having 11027 samples in 2023. This increase is due to an expansion in the sampling effort of landings across different Danish métiers. In total, Denmark supplied 10588 samples collected in various metiers in 2023, while the Dutch (439) samples only consist of the TBB_DEF_70-99 fleet. All data are used for estimating the age structure of the landings. Prior to 2004, the landings-at-age information is from an old Dutch monitoring scheme from the 1980s. Figure 21.3 shows the métiers with age distributions for the landings in 2023. Allocations to calculate the age structure were done separately for discards and landings and were done within métier per quarter where possible. If by quarter was not possible, available quarters were grouped. As no age structure information for discards was available in 2023, the allocation for discards were done separately, making use of available age samples of the landings, although not used in the assessment.

Unsampled fleet*	Sampled fleet**
TBB < 100mm	Within métier, all quarters
TBB > 100 mm	Within métier, all quarters
OTB < 100 mm	Within métier, all quarters
OTB > 100 mm	Within métier, all quarters
SSC/SDN < 100 mm	All métiers, all quarters
SSC/SDN > 100 mm	All métiers, all quarters
Passive gears (GNS/GTR)	All métiers, all quarters
Others	All métiers, all quarters

*** Unsampled fleet are those fleets for which no age structure is known.**

**** Sampled fleet are those fleets for which age structure is known.**

21.2.5 Biological data

All biological data used in the assessment are presented in Tables 21.6-8.

Weight at age

Constant annual catch and stock weights-at-age (long term means of all available data) were previously used in the assessment because of large gaps in the time series of weight-at-age data for turbot in the North Sea (Figure 21.6). What data is available is also very noisy, due to low sample sizes for most ages. The data that are available, and trends in other flatfish species in the same areas, suggest that there have been potentially significant changes in weight-at-age over time. At the 2015 inter-benchmark, a method was developed to model the growth parameters over time, allowing smooth changes over the time series (see Stock Annex for full details) (ICES, 2016). The results indicate an increase in weight-at-age from the start of the time series, peaking in the early 1990s. Following this period, weights-at-age showed a declining trend until 2019 but have been gradually increasing since then (Figure 21.6).

Maturity

In this assessment individuals are assumed to be 100% mature at age 5, 95% at age 4, 47% at age 3, 4% at age 2 and 0% for ages 1 and 0. See Stock Annex for full details.

Natural mortality

A constant value of M = 0.2 for all ages and years is applied for this stock. See Stock Annex for full details.

21.2.6 Survey data and commercial LPUE

Two survey abundance indices, the Dutch Sole Net Survey (SNS [B3498]) and the Dutch Beam Trawl Survey (BTS ISIS [B2453]), and one standardised commercial LPUE unstructured abundance index based on the Dutch 80 mm beam trawl fleet (BT2), are used to tune the assessment (Table 21.10-12 and Figure 21.4).

All abundance indices indicate an increase in the amount of older fish since 2015, which would indicate either strong recruitment or a decrease in mortality (e.g. fishing pressure) exerted on the stock. Between 2005 and 2015 no stronger year classes have been observed. Within the last decade, relatively strong recruitment were observed in 2015, 2017, 2018 and 2019. In 2021, the recruitment (age 1) was the lowest observed since the late 1980s and is well below the long-term mean. The Dutch BT2 LPUE index shows a gradual increase from 1998 to 2016. The index then showed a general decline up to 2022. However, 2023 exhibited a 36% increase compared to the previous year.

There is fairly close agreement between the two survey indices regarding general trends in abundance at age, but the data are noisy from year to year. This can be seen in the low R^2 values in the internal consistency correlations in the BTS_ISIS and SNS surveys (Figure 21.5). The SNS survey is particularly poor at picking up cohort signals, with low R^2 values for cohorts from one age to the next. Though all correlations between successive ages are positive, estimated numbers at age, particularly for the younger ages, fluctuate a lot from year to year. The BTS-ISIS is more internally consistent for ages 3 and up, but is still lacking sufficient older fish leading to a poor tracking of the cohorts over time.

Noisy indices that are more indicative of general trends are best used in an assessment model that is able to smooth over the noise in the data. The SAM model used for this stock is able do this, but nevertheless, inputting noisy data into the assessment will increase uncertainty in the outputs.

By removing the age-structure from the NL BT2 LPUE index, the clearest cohort signals in the assessment of this stock are coming from the catch-at-age matrix. The Dutch BT2 LPUE time-series is now standardised by building a statistical model that includes interactions in space, time and gear. Raw LPUEs are calculated per trip and per ICES rectangle. The fishing effort per rectangle is then taken as a weighting factor in the analysis. Only those rectangles where fishing occurred in eleven or more years are then used. This dataset amounted to 99% of all turbot catches since 1995. There is a possibility of excluding ages 1–2 from the Dutch LPUE data. However, currently, this would mean shortening the time-series of the LPUE-index considerably, because disaggregated data to distinguish market categories/ages are not available before 2002. Work on providing such data further back in time could be beneficial for the assessment.

21.3 Stock assessment model

After the inter-benchmark protocol of 2017 and 2018, a new assessment model (SAM, FLSAM; Nielsen and Berg, 2014; Berg and Nielsen, 2016) is used using an observation correlation structure. More details on the data used, assumptions made and the assessment model settings can be found in the Stock Annex, in the inter-benchmark protocol report (ICES, 2018a and b) as well as on the github website (https://github.com/ices-eg/wg_IBPTur.27.4).

21.3.1 Model settings

The assessment model was conducted using the settings and configuration given below. Details of the assessment model can be found in the Stock Annex and 2018 Inter-benchmark report (ICES, 2018b).

Model settings used in the final assessment

Year	2024
FLSAM version	2.1.1
FLCore version	2.6.19.9105
R version	4.2.2 (2022-10-31)
Platform	x86_64-w64-mingw32
Run date	2024-04-11
Model	SAM
First tuning year	1981
Last data year	2023
Ages	1–8+
Plus group	Yes
Stock weights-at-age	Von Bertalanffy growth curve with time varying Linf
Catch weights-at-age	Von Bertalanffy growth curve with time varying Linf
Total Landings	Not used
Landings at age	1981–1990, 1998, 2000–present
Discards	Not used (assumed 0)
Abundance indices	BTS-ISIS 1991–present SNS 2004–present
	Standardized NL-BT2 LPUE age-aggregated catchable biomass 1995– present
Catchability in catch-at-age matrix independent of age for ages >=	7
Coupling of fishing mortality STATES (Row represent Catch, columns represent ages)	0 1 2 3 4 5 6 6
Use correlated random walks for the fishing mortalities (0 = independent, 1= correlation estimated)	2
Coupling of catchability PARAMETERS (Surveys)) Row represent fleets (SNS and BTS-only, LPUE age-aggregated), Columns represent ages)	0 0 1 2 2 2 -1 -1 3 3 4 4 5 5 5 -1 6 -1 -1 -1 -1 -1 -1 -1
Coupling of fishing mortality RW VARIANCES	0 1 2 2 3 3 4 4
Coupling of log N RW VARIANCES	0 1 1 1 1 1 1 1

Year	2024
Coupling of OBSERVATION VARIANCES (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	0 1 2 2 3 3 4 4 5 5 6 7 7 7 -1 -1 8 8 8 9 10 10 10 -1 11 -1 -1 -1 -1 -1 -1 -1
Coupling of Survey Correlation correction by age (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	-1 -1 -1 -1 -1 -1 -1 -1 0 0 0 0 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
LPUE time-series indicator (0=SSB, 1 = catch, 2 = exploitable biomass)	2
Stock-recruitment model code (0=RW, 1=Ricker, 2=BH)	0
F_{bar} ranges	2–6

21.4 Assessment model results

The stock summary is given in Table 21.13-15, while fishing mortality-at-age and abundance-at-age (stock numbers at age) estimated by the assessment model are presented in Tables 21.16 and 21.17, respectively.

21.4.1 Status of the stock

Fishing mortality in 2023 was 0.302 which is below F_{MSY} (0.361). From 2019-2021, Fbar (ages 2-6) was estimated slightly higher than F_{MSY}, but lower in the period from 2012-2018.

The SSB in 2023 was estimated at 6841 tonnes, which is 3.5% lower than the SSB in 2022 which was estimated at 7088 tonnes (Table 21.14). SSB has been above MSY $B_{trigger}$ (6353 tonnes) since 2013.

During WGNSSK 2024, the 2021 recruitment estimate, once thought of as the lowest recruitment in the time series was revised upward from 2039 thousand (in 2023 WGNSSK) to 2618 thousand in the current assessment. An additional upward revision was seen in recruitment in 2022 of the 2021 year-class from 3896 thousand at WGNSSK 2023 to 4389 in 2024, leading to the positive advice change (18.2%) for 2025.

21.4.2 Historic stock trends

SSB was at its highest in the early 1980s (possibly higher before that time for which no reliable data is available). From the mid–1980s up until the early 2000s, SSB declined gradually while F increased (Figure 21.7). The lowest estimated SSB was in 2004. SSB subsequently increased and has continued to increase to >9000 t in 2018. The SSB has shown a gradual decline since then, and is currently estimated at 6841 t.

Recruitment has been variable over the time-series without a clear trend. The large recruitment in 2014 and 2015 have been well-above the long term mean and contributed to the increase in SSB in 2017 and 2018 while the lowest estimated recruitment in the time series was measured in 1985 at 2490 thousand. During the years of missing landings-at-age data (1990s), recruitment values are estimated at a slightly higher level, but with more uncertainty. The years 2020-2021

were marked with low recruitment (below the long-term geometric mean of the time series), before showing an increase in 2022 and 2023.

Mean F peaked in 1994 at 0.83, but then declined to 0.62 in 1999, before rapidly increasing again to 0.77 in 2002. After 2002, there is a steep decline in F to 0.39 in 2008. Between 2012 and 2017, F has fluctuated around 0.34. In the years following, F increased to 0.39 in 2021 but is now estimated to be 0.30 in 2023. These trends correspond well with the trends in fishing effort of the beam trawl fleet.

21.4.3 Retrospective assessments

The results of five retrospective assessments, using the same model settings but removing one year of data from the end of the time series, are plotted in Figures 21.8-10. The retrospective plots in SSB, F and recruitment do not exhibit a strong negative or positive pattern. However, the retrospective pattern on SSB shows a trend of overestimating SSB. Nevertheless, the Mohn's rho's associated with this retrospective analysis are within acceptable limits: -11.7% on SSB and 6.3% on F, and -19.0% on recruitment.

21.5 Model diagnostics

Model diagnostics are provided in Tables 21.17-25 and Figures 21.11-17.

The stability and estimability of a stock assessment model depends on the degree of collinearity between the parameters. When parameters are co-linear or correlated, the model can be sensitive to minor changes. A parameter correlation plot helps to identify the correlation between parameters. The correlation coefficient (varying between -1 and 1) is shown as a colour intensity as a function of the corresponding parameters. Ideally, the correlation between the parameters (except for a parameter with itself) should be 0, indicating the parameters are independent of each other. The parameter correlation plot for turbot shows some positive correlation between the catchability parameters (F_{par}), but no strong correlation between the other parameters (Figure 21.11).

To see how the SAM model has converged on the observation variances, the estimated observation variance (CV) of each data source in the assessment is plotted against the coefficient of variance of the estimate (Figure 21.12). Ideally all parameters should have a low CV. For turbot, the observation variance of the Dutch LPUE index as well as the landing-at-age 3 and 4 is lowest, while the associated CVs are highest. As such, the model assumes most information is available in these parameters giving them more weight in the assessment (Figure 21.13).

Please refer to the Turbot inter-benchmark 2017 and 2018 reports for more detailed specifications on the model diagnostics, in particular, for the configuration on the survey catchabilities for all surveys with more than 1 age group (ICES, 2018a, b; see also Figure 21.14).

The estimated selectivity-at-age from 1981 to 2023 is shown in Figure 21.15. The selectivity at-age do show some trends in the past decade, with decreasing selectivity for older ages (*i.e.,* age 6 and above). The values presented in Figure 21.10 are the actual F-at-age.

Residual plots of landings shows a residual pattern in the plusgroup (8+), which is acceptable. TDutch LPUE index shows consistent overestimation in the period 2000-2020. The SNS does not show clear systematic patterns in either positive or negative residuals. The BTS-ISIS survey shows some consistent negative residuals for the ages 2, 4, 5 and 6 (Figure 21.16 and 21.17).

21.6 Reference Points

Reference points were estimated during the 2018 inter-benchmark using the R-script template provided by ICES, which was developed during early 2018 to ensure that a correct procedure in estimating reference points was followed.

The simulations were executed during IBPTurbot (ICES, 2018b) with the entire time-series of SR-pairs (1981–2017) and were run with 2000 iterations and applying a mixture of two SR-models, namely Segmented Regression and Ricker (sampling from 2000 fits) (Figure 21.18). Productivity and stock-recruit pairs over time are shown in Figures 21.19 and 21.20.

In 2020, ACOM decided that the basis of F_{pa} should be $F_{P.05}$ (with Advice rule). $F_{P.05}$ is the value of F, including modification with biomass criteria that, if applied as target in the advice rule would lead to SSB ≥ B_{lim} with a 95% probability. $F_{P.05}$ provides an upper F limit that is considered pre-cautionary for management plans and MSY rules. However, for turbot the $F_{P.05}$ value (0.856) is well above the value of F_{lim} (0.606).

The table below shows the estimated reference points using the final IBP 2018 assessment. [See the IBPTurbot report (ICES, 2018b) for more details.]

Reference point	Estimate
1. MSY $B_{trigger}$	6353
2. B_{pa}	4163
3. B_{lim}	2974
4. F_{lim}	0.606
5. F_{pa} = $F_{P.05}$ with AR	0.856
6. $F_{P.05}$ without AR	0.473
7. F_{MSY}	0.361
8. $F_{MSY\ lower}$	0.252
9. $F_{MSY\ upper}$	0.482

21.7 Short-term-forecast

The short-term forecast was implemented in FLR (Kell *et al.*, 2007) using the routines available in the Flasher package (https://flr-project.org/FLasher). Terminal year estimates from the SAM assessment were used as starting conditions. Since there is no clear relationship between SSB and recruitment (Figure 21.20), it was decided to set recruitment to follow a geometric mean for the entire time-series, including the latest estimate.

Since stock and catch weight-at-age are modelled, we assume in the forecast that weights are identical to the weights used in the final assessment year. As such, we do not introduce a break in the smoothness of the weight-at-age time-series. Maturity-at-age and time of spawning are fixed over time, and these values are used in the forecast. Selectivity-at-age is with minimal trends in recent years, but has changed in the past decade. Hence, a 3-year average was used for future years in the simulations.

The TAC has not been exhausted since 2016, and in 2023 57% of the combined TAC was used. Using a % TAC was, therefore, deemed inappropriate. Hence, the assumption for the intermediate year was made to not use a catch constraint but a status-quo F (F_{sq}) instead.

Assumptions made for the interim year and in the forecast. All weights are in tonnes, recruitment in thousands:

Variable	Value	Notes
$F_{ages\ 2–6}$ (2024)	0.302	F_{sq} = Average exploitation pattern (2021–2023), scaled to $F_{ages\ 2–6}$ 2023
SSB (2025)	7223	Short-term forecast (STF) at *status quo* (F_{sq})
R_{age1} (2024, 2025)	4372	Geometric mean (GM, 1981–2023); thousands
Projected landings (2024)	1864	STF assuming an F *status quo* (F_{sq})
Catch (2024)	1981	(Projected landings)/(1–average discard rate); average discard rate by weight 2021–2023 = 5.9%.

The options table summarizes the outcomes of the short-term forecast. The numbers presented are the rounded values; actual calculations are performed with the exact numbers.

Basis	Total catch * (2025)	Projected landings ** (2025)	Projected discards *** (2025)	$F_{projected\ landings}$ (ages 2-6) (2025)	SSB (2026)	% SSB change ^	% advice change ^^
MSY approach: F_{MSY}	2426	2284	142	0.361	7150	-1.00	18.2
F_{MSY} upper = 0.48	3068	2888	180	0.482	6543	-9.4	50
F_{MSY} lower = 0.25	1781	1678	104	0.252	7767	7.5	-13.0
F = 0	0	0	0	0	9500	32	-100
F_{pa} ($F_{p.05}$ with AR)	4658	4385	273	0.856	5071	-30	127
F_{lim}	3655	3441	214	0.61	5993	-17	78
$F=F_{2024}$	2088	1965	122	0.30	7473	3.5	1.80
SSB (2026) = B_{lim}	7069	6654	414	1.82	2974	-59	240
SSB (2026) = B_{pa}	5674	5341	333	1.18	4163	-42	177
SSB (2026) = MSY $B_{trigger}$	3270	3078	192	0.52	6353	-12.1	-59
Rollover advice	2052	1932	120	0.30	7507	3.9	0
Multi-options table							
F = 0	0	0	0	0	9500	32	-100
F= 0.05	390	367	23	0.05	9118	26	-81
F = 0.10	760	716	45	0.10	8756	21	-63
F = 0.15	1113	1048	65	0.15	8413	16.5	-46

Basis	Total catch * (2025)	Projected landings ** (2025)	Projected discards *** (2025)	$F_{projected\ landings}$ (ages 2-6) (2025)	SSB (2026)	% SSB change ^	% advice change ^^
F = 0.20	1449	1364	85	0.20	8088	12.0	-29
F = 0.25	1769	1665	104	0.25	7779	7.7	-13.8
F = 0.30	2074	1952	122	0.30	7487	3.7	1.05
F = 0.35	2364	2225	139	0.35	7210	-0.180	15.2
F = 0.40	2641	2486	155	0.40	6946	-3.8	29
F = 0.45	2905	2735	170	0.45	6696	-7.3	42
F = 0.50	3157	2972	185	0.50	6459	-10.6	54

*** (projected landings) / (1 – average discard rate); average discard rate 2021–2023 = 5.9%**

**** Marketable landings**

***** Including BMS landings, assuming recent discard rate (5.9%).**

^ SSB 2026 relative to SSB 2025.

^^ Total catch in 2025 relative to advice value for 2024 (2052 t).

21.8 Management considerations

There are a number of EC regulations that affect the flatfish fisheries in the North Sea, e.g. as a basis for setting the TAC, limiting effort, and minimum mesh size. Since 2019, turbot falls under the landing obligation. The joint recommendation suggests a survivability exemption until 2028 for turbot caught by TBB gears with a cod end more than 80 mm in ICES Subarea 4 (Commission Delegated Regulation (EU) 2023/2459).

21.8.1 Effort regulations

The overall fleet capacity and deployed effort of the North Sea beam trawl fleet has been substantially reduced since 1995, due to a number of reasons, including the effort limitations for the recovery of the cod stock. In 2008, 25 vessels were decommissioned. In 2022, an increase in fuel prices resulted in reduced fishing effort, leading to a larger number of vessels remaining in the harbour. Additionally, the Dutch beam trawl fleet experienced substantial vessel decommissioning during the same year and this pattern is expected to continue in the following years.

21.8.2 Technical measures

Turbot is mainly taken by beam trawlers in a mixed fishery directed at sole and plaice in the southern and central part of the North Sea. Technical measures (EC Council Regulation 1543/2000) applicable to the mixed flatfish fishery affect the catching of turbot. The minimum mesh size of 80 mm in the beam trawl fishery selects sole at the minimum landing size (24 cm); however, this mesh size is likely to catch immature turbot (age 1 and 2 fish). Mesh enlargement would reduce the catch of smaller turbot, while at the same time potentially increasing the yield per recruit, but would also result in loss of marketable sole catches.

A closed area has been in operation since 1989 (the plaice box), and since 1995 this area has been closed in all quarters. The closed area applies to vessels using towed gears, but vessels smaller

than 300 HP are exempted from the regulation. An additional technical measure concerning the fishing gear is the restriction of the aggregated beam length of beam trawlers to no more than 24 m. In the 12 nautical mile zone and in the plaice box, the maximum aggregated beam-length is 9 m.

21.8.3 Changes in TAC regulations

In 2023, the TAC for turbot and brill in the North Sea was combined as in previous years. In 2024, a regulatory amendment was introduced resulting in separate TAC allocations for turbot and brill to countries adjacent to the North Sea, effectively abolishing the combined TAC (EU, 2023). This change marks and improvement in the management for turbot and brill in the North Sea as the previous combined TAC was deemed largely ineffective by ICES at reducing F due to species-specific changes in stock dynamics.

21.9 Industry Survey turbot and brill

The available scientific surveys used for the assessment of turbot in 27.4 generally have a weak internal consistency, especially for older ages, leading to a poor ability to track cohorts over time. Because of this, the assessment is strongly influenced by the Dutch LPUE index. A scientific survey with higher catch rates for turbot and a better internal consistency would be preferable. In this context, the Dutch producer organization VisNed and Wageningen Marine Research initiated an industry-based survey to monitor large flatfish such as brill and turbot in the North Sea. The survey started in 2018, and the set up and first results were presented during the 2019 WGNSSK. The group considered the survey valuable, but provided recommendations to make the survey more adequate for future use in the assessment; therefore, the first year of the survey (2018) is seen as a pilot year. An annual update of the survey was provided since WGNSSK 2020.

In 2021, the survey took place in quarter 3, and 3 traditional beam trawl vessels were selected. The survey area is based on LPUE data over a 6-year period (2007–2009 (before pulse) and 2012–2014 (first years with pulse fisheries)). By defining the positions were 60% of the LPUE is realized, the survey area covers the main high LPUE areas but also some areas around these. Inaccessible areas such as wind parks, Natura 2000 closures, etc were removed from the survey area following discussions with the participating fishermen. A 5x5 km grid was overlaid onto the survey area.

Each grid cell in the survey area is a potential survey station. Each year 60 grid cells are to be randomly selected using an R-script. Because the cutting out of unfishable areas resulted in some cells having irregular shapes and smaller surface areas than regular 5x5 km grid cells, the probability of being randomly selected as survey station was made proportional to their surface areas. The selected survey stations are then equally distributed over the three participating vessels (~20 survey stations each) on the basis of their normal fishing grounds. Survey hauls are carried out similar to commercial hauls, taking approximately 100 to 120 minutes. Hauls may start anywhere in a designated grid cell, may then follow any route, and may exit the grid cell during the haul. Data collected include fishing conditions (e.g. haul list, gear description), and for each haul: counts of all turbot and brill; length, weight, and sex of all turbot and brill; a specified number of otoliths per length class (Schram *et al.,* 2021).

In 2020, the survey could not be carried out using on-board observers due to COVID restrictions. To avoid the survey to have a data gap the standard sampling protocol was replaced using a self-sampling protocol. Self-sampling survey trips are not attended by researchers. Catches from survey stations are processed according to the vessel's regular catch sorting process. During this process the vessel's crew collects all turbot and all brill (thus including fish below minimum

landing size) from the sorting belt. Sampled fish above minimum landing size are gutted, bled, packed in labelled plastic bags (stating species and survey station number) and stored on ice. Upon return in the harbour, the sampled fish are handed over to the researchers in the fish auction. A team of researchers processes the samples by collecting the same data as according to the regular survey protocol (counts per species per survey station, individual length, weight (to be corrected for gutting) and sex, otoliths from a subset). Fish above minimum landing size are sold on the auction on behalf of the vessel owners. Fish below minimum size are discarded. After completion of the three annual trips, age is read from the collected otoliths and all collected data is entered in a database.

The protocol for using self-sampling was presented during the 2023 WGNSSK and was accepted by the group. Such protocol is useful in situations in which for any reason researchers cannot join (part of) the annual survey trips and prevent potential data gaps in the survey. Since 2021, the survey was carried out as usual, i.e., with on board observers.

The potential of extending the survey to include other Member States was presented to the group. The group agreed this could be useful but requires funding and more insight into the stock boundaries and management units (e.g. brill covering multiple ICES divisions).

During the 2023 survey, 62 hauls were sampled (Figure 21.21), catching 633 brill and 1578 turbot which are higher compared to 2021 and 2022. The numbers of turbot and brill caught during this survey are always higher compared to the BTS-ISIS survey (~100/yr) or the SNS (~30/yr) (Figure 21.22). Length measurements ranged from 17 cm to 69 cm for turbot and 18 cm to 58 cm for brill in 2023 (Figure 21.22). Currently, ageing has been conducted over 1 cm-classes for 2445 brill and 7242 turbot in the survey since 2019, showing that most of the fish caught are within ages 1 to 3 (Figure 21.23). Further analysis of the survey data is needed to update the new information and align these with existing commercial sampling and independent fisheries survey data.

The aim of the survey is to become an additional index, strengthening the fisheries independent surveys for turbot. Once a period of 5 years is covered, the index of this new survey is a potential candidate to include in the turbot as well as the brill assessments in the North Sea. In this context, it is important to develop the age-structured index in advance and make a trial assessment including the "new" index into the assessment.

21.10 Issues for future benchmarks

21.10.1 Data

The available scientific surveys (SNS and BTS-ISIS Q3) have weak internal consistency, especially for older ages, leading to a poor ability to track cohorts over time. Because of this, the assessment is strongly influenced by the Dutch LPUE index. A scientific survey with higher catch rates for turbot and a better internal consistency would be preferable (See Section 21.9).

The assessment is strongly influenced by the Dutch LPUE index. This is apparent upon examining the leave-one-out runs with the 3 indices used in the assessment model for SSB, Fbar and recruitment (Figure 21.24-26). More work should be done on getting LPUE data from other Member States. In the future, the use of these data may be possible after standardization or weighting of the original values to account for the difference in gear and location. Obtaining standardised Belgian, UK and Danish LPUE data for use in the assessment model should be investigated.

Estimates of discards are available (e.g. Dutch discards are available for 1999-present); however, age-length information is very limited. Age-information is based on a few fish sampled in the discards of some of the Danish and Belgian fleets (at-sea sampling). As a result, estimates of

discards are highly uncertain, and not included in the current assessment. Future sampling effort needs to ensure a proper sampling coverage over the main fleets and countries for both landings and discards. Sampling should include age information for discards from all countries.

Currently, estimates of mean weights-at-age from the fishery and for the stock (from surveys) cannot be used directly in assessments without first smoothing these estimates, because of data gaps and poor sample sizes (the latter leading to highly variable and inconsistent estimates, particularly at the older ages). The smoothing techniques currently used add to any retrospective patterns present, because they re-estimate the entire time-series of smoothed weights whenever new data are added. It is therefore recommended that methods that produce more stable estimates of mean weights be investigated and their performance be compared to current methods, or sampling be improved to allow raw weights to be used directly in assessments, or to appropriately deal with smoothing of raw weights within the stock assessment model.

A delta GAM index combining different BTS surveys was tested. Currently, such an index could not improve the assessment. However, age information in DATRAS was not available for the whole time-series, and errors seem to have occurred during the upload of additional data. Once the whole time-series of age information is available, a detailed analysis of delta GAM indices with various settings should be carried out.

The procedure to create an age-structured index series from the BTS-ISIS needs to be checked. Currently, the procedure first links the individual fish from which otoliths are taken to the length sample. This allows direct ageing of the fish in the index. Those fish for which no direct age sample is available are then assigned to ages using the age–length key based on all fish in the period 1991–present. This method may be flawed as combining an ALK over many years, so that the same ALK is used each year may smear any cohort signals in the data.

The 2023 WGNSSK meeting revealed increasing proportions of older fish (plus group 8+) in the turbot population (Figure 21.27). This cryptic biomass may be valid due to a number of reasons. First, as the commercial fleets show declining selectivity for older ages (Figure 21.28), leading to a lower likelihood of catching older individuals. Second, older and larger fish are regularly caught when turbot is targeted in the Dutch industry survey (Figure 21.22-23). Additionally, turbot is a bycatch species in the North Sea, which may allow older aged turbot to persist. Nevertheless, further investigation is needed to better understand the dynamics and validity of this cryptic biomass.

21.10.2 Assessment

The Dutch LPUE data series receives a high weight in the assessment (higher than any other data source, and much higher than the survey indices of abundance); this weighting is, arguably, unrealistically high. The Dutch LPUE data are standardised by applying a statistical model that includes interactions in space, time and gear, and it may be possible to extract CVs associated with the estimates from this model. It is recommended that the use of such CVs in the SAM assessment be investigated to better deal with the weighting of the LPUE data series.

The Dutch LPUE data series (an aggregated biomass index) is associated with 60–70% of the total catch for turbot, but the current SAM assessment uses the selectivity estimated for the total catch to build an exploitable biomass estimate used to fit the Dutch LPUE data. This is not entirely representative and likely introduces some model misspecification. There is a fleet-based version of SAM that, given fleet-based data, could be used to deal with this problem. It is therefore recommended that the use of such fleet-based data and a fleet-based SAM version be investigated to provide a more appropriate fit to the Dutch LPUE data.

When comparing results from WGNSSK 2024 to WGNSSK 2023, revised data from the 2024 meeting provide slightly higher estimates for numbers and biomass-at-age of 1 to 6-year-old fish (Figure 21.29 and Table 21.27) for the period of 2016 – 2025. Contrary to the 2023 assessment year, estimates for the plus group (8+) have slightly decreased (Figure 21.29). Higher estimates in 2024 are largely influenced by the upward revision of recruitment in 2021-2022 (Figure 21.30). Weight at age and biomass-at-age, as assessed in WGNSSK 2024, are estimated to be slightly higher than in 2023, following a modest increase in observed weights-at-age in recent years (Figure 21.31 and 21.32). It is recommended that this information be continually monitored between assessment years and that any large disparities be investigated to determine the underlying reasons.

21.10.3 Short term forecast

The forecast is performed using future landings. Catch advice is derived by dividing the estimated landings with one minus the average discard rate observed in the previous three years.

21.11 References

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21.12 Tables and figures

Table 21.1. Turbot in Subarea 4. Observed landings in numbers (units: thousands) SOP corrected.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0	281.701	711.317	501.220	431.501	164.875	63.124	100.809
1982	0	149.128	923.008	235.605	147.364	257.666	86.477	136.775
1983	0	356.364	596.599	424.622	97.512	100.172	159.566	179.955
1984	0	1178.913	1112.508	282.903	142.816	54.579	51.850	177.383
1985	0	613.528	1863.735	504.713	138.140	84.119	20.065	123.477
1986	0	319.058	1264.190	599.415	157.379	57.620	24.940	106.639
1987	12.576	626.886	528.210	653.974	152.852	50.306	18.381	67.719
1988	32.152	968.144	801.130	158.976	157.189	80.381	25.007	68.770
1989	0	668.852	1167.677	354.694	156.516	82.199	31.528	68.687
1990	44.709	995.044	1073.025	317.125	166.361	75.902	101.896	114.373
1991–1997	NO DATA							
1998	0	405.774	870.16	357.682	72.889	29.531	8.491	14.285
1999–2002	NO DATA							
2003	208.732	1898.915	458.116	295.508	70.359	32.756	20.560	20.404
2004	430.765	1960.734	784.645	136.918	81.624	9.567	7.460	6.012
2005	339.954	1959.609	713.541	227.726	24.524	21.605	2.569	18.977
2006	876.209	1629.002	799.601	117.954	34.765	7.822	16.017	17.954
2007	78.127	2766.209	613.084	283.563	40.090	28.943	8.214	15.831
2008	177.079	1347.527	819.650	219.789	194.835	47.029	12.861	10.202
2009	119.842	1103.077	1030.290	444.921	94.315	26.552	11.687	19.642
2010	275.441	1387.674	381.523	305.916	169.824	87.122	30.243	19.332
2011	210.718	1939.836	602.051	110.600	137.529	76.939	32.218	23.572
2012	0	1896.797	771.962	265.008	42.181	63.491	72.540	24.560
2013	171.757	1572.827	1076.275	323.818	90.531	25.857	41.803	25.761

Year	Age							
	1	2	3	4	5	6	7	8+
2014	65.360	371.685	617.157	648.745	130.496	115.677	36.077	99.719
2015	39.288	1214.035	464.302	326.022	316.001	109.627	43.133	79.650
2016	0.000	1037.435	991.697	332.740	357.445	186.932	45.032	70.443
2017	6.902	329.725	1660.160	599.404	138.690	62.605	98.039	60.658
2018	181.724	711.338	479.991	920.775	255.712	69.040	45.902	72.456
2019	175.431	1081.906	898.192	267.633	365.538	124.492	23.315	65.097
2020	218.412	1616.876	857.908	402.560	147.192	149.128	43.334	42.465
2021	0	645.329	926.201	477.198	180.232	59.850	60.631	54.620
2022	225.980	472.414	508.516	271.730	148.611	32.465	12.289	41.615
2023	170.026	824.691	484.233	189.203	115.363	56.648	15.738	16.923

Table 21.2. Turbot in Subarea 4. ICES estimated landings (tonnes) SOP corrected and discards of turbot.

Year	Landings	Landing SOP	Discards	Year	Landings	Landing SOP	Discards
1981	4755	1		2020	3104	1	199
1982	4453	1		2021	2659	1	129
1983	4575	1		2022	1697	1	49
1984	5297	1		2023	1656	1	187
1985	6188	1					
1986	5263	1					
1987	4271	1					
1988	4041	1					
1989	4927	1					
1990	5750	1					
1991	6340	-0.007					
1992	5933	-0.007					
1993	5546	-0.008					
1994	5244	-0.008					
1995	4671	-0.009					

Year	Landings	Landing SOP	Discards	Year	Landings	Landing SOP	Discards
1996	3644	-0.011					
1997	3382	-0.012					
1998	3086	1					
1999	3187	-0.012					
2000	4025	-0.009					
2001	4100	-0.009					
2002	3749	-0.010					
2003	3374	1					
2004	3317	1					
2005	3195	1					
2006	2976	1					
2007	3509	1					
2008	3005	1					
2009	3089	1					
2010	2692	1					
2011	2771	1					
2012	2914	1					
2013	2982	1	97				
2014	2834	1	158				
2015	2922	1	112				
2016	3493	1	666				
2017	3441	1	496				
2018	3140	1	486				
2019	3046	1	230				

Table 21.3. Turbot in Subarea 4. Official estimated landings (tonnes) for each country participating in the fishery.

Year	Netherlands	UK	Denmark	Belgium	France	Germany	Norway	Other	Total
1975	3349	503	387	158	21	169	0	1	4588
1976	3253	631	588	146	38	156	0	2	4814
1977	2973	683	474	145	37	172	0	0	4484

Year	Netherlands	UK	Denmark	Belgium	France	Germany	Norway	Other	Total
1978	3196	752	693	170	50	173	0	< 1	5034
1979	3999	838	1164	187	22	151	0	3	6364
1980	3241	559	1360	162	17	146	0	0	5485
1981	3073	404	1044	142	6	86	0	0	4755
1982	3029	335	880	153	14	42	0	< 1	4453
1983	3163	277	893	174	24	44	0	< 1	4575
1984	3800*	282	886	242	40	46	0	1	5297
1985	4600*	312	983	222	37	34	0	0	6188
1986	3810*	287	997	133	5	31	0	0	5263
1987	2760*	345	988	130	21	27	0	0	4271
1988	2660	328	858	129	24	41	0	1	4041
1989	3666	333	637	176	30	85	0	0	4927
1990	3732	437	1046	292	52	184	0	7	5750
1991	3780	688	1233	350	64	186	30	9	6340
1992	3495	902	907	317	81	163	65	3	5933
1993	2939	1013	817	355	123	252	47	0	5546
1994	2724	882	862	330	141	263	42	0	5244
1995	2476	703	761	315	108	275	33	0	4671
1996	1776	687	618	210	160	157	36	0	3644
1997	1854	619	479	169	1	215	45	0	3382
1998	1695	582	392	198	22	164	33	< 1	3086
1999	1808	488	411	224	0	224	32	0	3187
2000	2280	549	469	302	21	349	55	0	4025
2001	2226	642	506	333	17	297	79	0	4100
2002	1898	551	677	243	15	280	85	0	3749
2003	1893	431	486	192	18	289	65	0	3374
2004	1762	463	518	207	15	278	74	0	3317
2005	1903	347	429	159	18	274	65	0	3195
2006	1828	381	338	147	22	221	40	< 1	2976

Year	Netherlands	UK	Denmark	Belgium	France	Germany	Norway	Other	Total
2007	2263	485	310	173	32	203	43	0	3508
2008	1744	370	457	182	21	199	32	< 1	3005
2009	1698	421	548	172	24	198	29	< 1	3090
2010	1469	386	467	118	37	191	26	< 1	2695
2011	1540	396	548	122	33	144	28	< 1	2811
2012	1740	366	481	150	30	187	37	< 1	2991
2013	1763	374	498	161	40	219	29	< 1	3085
2014	1594	391	433	176	42	197	38	< 1	2872
2015	1739	336	392	215	46	236	10	4	2978
2016	1854	404	505	339	38	273	8	1	3422
2017	2118	397	486	336	40	252	13	1	3641
2018	1914	368	331	267	27	306	15	1	3231
2019	1901	362	273	228	14	326	13	1	3121
2020	2099	354	257	161	5	297	17	1	3192
2021	1676	324	326	132	3	221	13	1	2696
2022	922	210	332	90	1	125	15	1	1697
2023	829	238	255	125	< 1	172	28	1.20	1648

Table 21.4. Turbot in Subarea 4. Raw weights-at-age in the landings (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0	0.90	1.00	1.70	2.60	3.60	4.40	6.90
1982	0	0.90	1.10	1.80	2.60	3.20	4.50	5.50
1983	0	0.90	1.20	2.00	2.80	3.60	4.00	5.53
1984	0	0.80	1.30	2.20	3.20	3.80	4.50	6.17
1985	0	0.70	1.10	2.00	3.20	4.20	5.00	6.33
1986	0	1.00	1.30	2.10	3.00	3.70	6.30	5.87
1987	0.70	1.10	1.60	2.10	3.80	4.60	6.10	7.83
1988	0.70	1.00	1.60	2.80	3.10	4.60	6.00	6.90

Year	Age							
	1	2	3	4	5	6	7	8+
1989	0	1.00	1.50	2.70	3.90	4.70	6.90	8.00
1990	0.90	1.00	1.60	2.70	3.40	5.40	5.60	7.30
1991–1997	NO DATA							
1998	0	0.830	1.26	2.12	3.34	4.92	5.38	6.78
1999–2002	NO DATA							
2003	0.50	0.62	1.15	1.78	2.24	2.74	2.59	3.72
2004	0.43	0.69	1.20	2.12	3.17	3.76	5.15	7.71
2005	0.44	0.62	1.13	1.89	2.89	3.47	4.60	5.87
2006	0.41	0.66	1.31	1.92	3.37	5.09	2.70	3.31
2007	0.34	0.70	1.25	1.75	3.27	3.72	4.17	2.92
2008	0.37	0.68	1.27	1.78	1.79	2.76	4.91	5.69
2009	0.41	0.62	1.25	1.76	2.95	4.83	5.47	5.06
2010	0.35	0.61	1.07	1.62	2.19	2.67	2.65	5.19
2011	0.48	0.55	1.06	1.79	1.97	3.25	4.48	4.64
2012	0	0.60	0.91	1.46	2.58	3.01	3.47	5.28
2013	0.61	0.61	1.00	1.64	2.23	3.41	2.27	5.19
2014	0.41	0.59	1.07	1.42	1.67	1.85	3.03	3.40
2015	0.41	0.59	1.10	1.30	1.67	2.12	2.78	3.23
2016	0	0.66	0.93	1.33	1.22	1.94	2.93	4.01
2017	0.54	0.98	1.18	1.74	2.15	2.37	3.07	3.68
2018	0.34	0.59	0.98	1.36	1.41	1.90	2.86	3.18
2019	0.44	0.58	0.94	1.50	1.77	2.11	3.63	2.46
2020	0.44	0.63	0.96	1.29	1.48	2.01	2.87	3.18
2021	0	0.57	0.97	1.38	1.53	1.59	2.65	2.36
2022	0.48	0.79	1.14	1.54	1.66	2.36	2.93	3.04
2023	0.37	0.61	0.91	1.34	1.84	1.77	2.93	2.96

Table 21.5. Turbot in Subarea 4. Modelled weights-at-age in the catch (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.363	0.770	1.317	1.975	2.713	3.499	4.307	5.874
1982	0.378	0.800	1.368	2.052	2.818	3.635	4.475	6.206
1983	0.391	0.828	1.416	2.124	2.917	3.763	4.632	6.295
1984	0.403	0.854	1.460	2.191	3.009	3.881	4.778	6.520
1985	0.414	0.878	1.501	2.252	3.093	3.989	4.910	6.918
1986	0.424	0.899	1.537	2.306	3.167	4.086	5.029	7.419
1987	0.433	0.917	1.569	2.353	3.233	4.170	5.132	7.745
1988	0.440	0.933	1.596	2.393	3.288	4.240	5.220	6.932
1989	0.446	0.945	1.617	2.426	3.332	4.297	5.290	7.346
1990	0.451	0.955	1.633	2.450	3.365	4.340	5.342	7.142
1991	0.454	0.961	1.644	2.466	3.387	4.368	5.377	7.359
1992	0.455	0.964	1.649	2.473	3.397	4.382	5.393	7.381
1993	0.455	0.964	1.648	2.472	3.396	4.380	5.391	7.378
1994	0.453	0.960	1.642	2.463	3.383	4.363	5.371	7.350
1995	0.450	0.953	1.630	2.445	3.359	4.332	5.332	7.298
1996	0.445	0.943	1.613	2.420	3.323	4.287	5.276	7.221
1997	0.439	0.930	1.591	2.386	3.278	4.228	5.204	7.122
1998	0.432	0.914	1.564	2.346	3.222	4.155	5.115	6.894
1999	0.423	0.896	1.532	2.298	3.156	4.071	5.011	6.858
2000	0.413	0.875	1.496	2.244	3.082	3.975	4.893	6.697
2001	0.402	0.852	1.457	2.185	3.001	3.871	4.765	6.521
2002	0.391	0.827	1.415	2.122	2.915	3.760	4.628	6.334
2003	0.379	0.802	1.371	2.057	2.826	3.645	4.487	6.153
2004	0.366	0.776	1.327	1.991	2.735	3.527	4.342	5.669
2005	0.354	0.750	1.283	1.925	2.644	3.410	4.197	5.351
2006	0.342	0.725	1.239	1.859	2.553	3.293	4.054	5.925
2007	0.330	0.700	1.196	1.795	2.465	3.180	3.914	5.215
2008	0.319	0.675	1.155	1.733	2.380	3.070	3.779	5.267

Year	Age							
	1	2	3	4	5	6	7	8+
2009	0.308	0.653	1.116	1.674	2.299	2.966	3.651	5.059
2010	0.298	0.631	1.079	1.619	2.223	2.868	3.530	4.836
2011	0.288	0.611	1.045	1.567	2.152	2.776	3.417	4.387
2012	0.280	0.592	1.013	1.520	2.087	2.692	3.314	4.324
2013	0.272	0.576	0.985	1.477	2.029	2.617	3.221	4.109
2014	0.265	0.561	0.959	1.439	1.977	2.550	3.138	4.175
2015	0.259	0.548	0.938	1.406	1.932	2.492	3.067	4.225
2016	0.254	0.538	0.919	1.379	1.894	2.443	3.008	4.192
2017	0.250	0.529	0.905	1.358	1.865	2.405	2.961	4.107
2018	0.247	0.523	0.895	1.342	1.843	2.378	2.927	3.976
2019	0.245	0.519	0.889	1.333	1.831	2.361	2.907	3.922
2020	0.245	0.519	0.887	1.330	1.827	2.357	2.901	3.991
2021	0.246	0.520	0.890	1.335	1.834	2.366	2.912	3.896
2022	0.248	0.525	0.899	1.348	1.852	2.388	2.940	3.930
2023	0.252	0.534	0.913	1.370	1.881	2.427	2.987	4.139

Table 21.6. Turbot in Subarea 4. Raw weights-at-age in the stock estimated as the catch weights in Q2 (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0	0.9	0.8	1.48	2.59	3.23	5.66	6.52
1982	0	0.59	1.01	1.8	2.53	3.33	4.88	6.19
1983	0	0.61	1.13	1.99	2.77	3.38	3.97	4.88
1984	0	0.66	1.04	2.07	2.87	4.25	4.93	6.34
1985	0	0.59	1.02	1.83	2.95	4.46	5.99	6.04
1986	0	0.91	1.12	1.98	3.08	3.48	7.02	6.10
1987	0.7	0.72	1.25	1.87	3.6	3.24	5.36	8.19
1988	0.7	1.16	1.65	2.65	3.31	5.78	7.24	7.38
1989	0	0.81	1.48	2.96	5.3	5.77	8.26	8.31

Year	Age							
	1	2	3	4	5	6	7	8+
1990	0.9	0.84	1.79	3.09	3.02	5.34	3.47	8.65
1991–1997	NO DATA							
1998	0	0.8	1.03	1.67	3.08	5.06	2.57	7.49
1999–2002	NO DATA							
2003	0	0.5	1.14	1.99	2.45	2.82	4.14	2.54
2004	0	0.52	1.1	1.9	2.47	2.91	5.35	6.41
2005–2006	NO DATA							
2007	0	0.59	1.1	1.57	2.58	2.71	1.72	4.87
2008	0	0.65	1.14	1.44	2.1	5.16	6.01	7.12
2009	0	0.44	0.80	1.51	1.65	3.55	4.70	4.78
2010	0	0.45	1.04	1.62	2.3	2.38	2.71	5.37
2011	0	0.39	0.95	1.88	2.01	4.00	4.42	5.16
2012	0	0.51	0.85	1.42	2.2	2.67	2.58	3.73
2013	0	0.59	0.95	1.60	2.18	3.30	2.51	3.95
2014	0.38	0.57	0.95	1.24	1.50	1.72	1.84	2.82
2015	0.41	0.49	0.89	0.93	1.46	1.4	1.37	4.45
2016	0.41	0.58	0.78	1.3	0.8	1.49	4.78	2.71
2017	0.39	0.38	0.92	1.6	2.04	2.31	2.87	3.21
2018	0.27	0.45	1.03	1.46	1.64	2.72	2.37	4.19
2019	0.44	0.39	0.86	1.37	2.04	2.25	4.25	3.07
2020	0.44	0.56	1.16	1.39	2.39	2.31	3.21	2.80
2021	0	0.41	0.89	1.49	1.71	1.82	2.85	2.44
2022	0.48	0.71	1.05	1.54	1.97	2.27	2.68	3.16
2023	0.37	0.60	1.00	1.48	1.73	1.87	3.06	3.24

Table 21.7. Turbot in Subarea 4. Modelled weights-at-age in the stock (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.352	0.746	1.275	1.913	2.627	3.389	4.171	5.688
1982	0.366	0.774	1.325	1.987	2.729	3.520	4.333	6.010
1983	0.378	0.802	1.371	2.057	2.825	3.644	4.485	6.096
1984	0.390	0.827	1.414	2.122	2.914	3.759	4.627	6.314
1985	0.401	0.850	1.454	2.180	2.995	3.863	4.755	6.700
1986	0.411	0.870	1.489	2.233	3.067	3.956	4.870	7.185
1987	0.419	0.888	1.519	2.279	3.130	4.038	4.970	7.500
1988	0.427	0.903	1.545	2.318	3.184	4.106	5.055	6.713
1989	0.432	0.916	1.566	2.349	3.226	4.162	5.123	7.114
1990	0.437	0.925	1.582	2.372	3.259	4.203	5.174	6.916
1991	0.439	0.931	1.592	2.388	3.280	4.230	5.207	7.126
1992	0.441	0.933	1.597	2.395	3.290	4.243	5.223	7.148
1993	0.441	0.933	1.596	2.394	3.288	4.241	5.221	7.145
1994	0.439	0.930	1.590	2.385	3.276	4.225	5.201	7.118
1995	0.436	0.923	1.579	2.368	3.252	4.195	5.164	7.067
1996	0.431	0.913	1.562	2.343	3.218	4.151	5.110	6.993
1997	0.425	0.901	1.540	2.311	3.174	4.094	5.039	6.897
1998	0.418	0.885	1.514	2.271	3.120	4.024	4.953	6.676
1999	0.409	0.867	1.483	2.225	3.056	3.942	4.853	6.641
2000	0.400	0.847	1.449	2.173	2.985	3.850	4.739	6.485
2001	0.389	0.825	1.411	2.116	2.906	3.749	4.614	6.315
2002	0.378	0.801	1.370	2.055	2.823	3.641	4.482	6.134
2003	0.367	0.777	1.328	1.992	2.736	3.530	4.345	5.958
2004	0.355	0.752	1.285	1.928	2.648	3.416	4.205	5.490
2005	0.343	0.726	1.242	1.864	2.560	3.302	4.064	5.182
2006	0.331	0.702	1.200	1.800	2.473	3.189	3.926	5.738
2007	0.320	0.677	1.159	1.738	2.387	3.079	3.790	5.050
2008	0.309	0.654	1.119	1.678	2.305	2.973	3.660	5.101

Year	Age							
	1	2	3	4	5	6	7	8+
2009	0.298	0.632	1.081	1.621	2.227	2.872	3.535	4.899
2010	0.288	0.611	1.045	1.567	2.153	2.777	3.418	4.683
2011	0.279	0.591	1.012	1.518	2.084	2.689	3.309	4.248
2012	0.271	0.574	0.981	1.472	2.021	2.607	3.209	4.187
2013	0.263	0.558	0.954	1.430	1.965	2.534	3.119	3.979
2014	0.256	0.543	0.929	1.394	1.914	2.469	3.039	4.043
2015	0.251	0.531	0.908	1.362	1.871	2.413	2.970	4.091
2016	0.246	0.521	0.890	1.336	1.834	2.366	2.913	4.059
2017	0.242	0.512	0.876	1.315	1.806	2.329	2.867	3.977
2018	0.239	0.507	0.866	1.300	1.785	2.302	2.834	3.850
2019	0.238	0.503	0.860	1.291	1.773	2.287	2.815	3.798
2020	0.237	0.502	0.859	1.288	1.770	2.282	2.810	3.865
2021	0.238	0.504	0.862	1.293	1.776	2.291	2.820	3.773
2022	0.240	0.509	0.870	1.305	1.793	2.313	2.847	3.806
2023	0.244	0.517	0.884	1.326	1.822	2.350	2.893	4.009

Table 21.8. Turbot in Subarea 4. Natural mortality-at-age and maturity at age.

Age	1	2	3	4	5	6	7	8+
natural mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
maturity	0	0.04	0.47	0.95	1	1	1	1

Table 21.9. Turbot in Subarea 4. Fraction of harvest before spawning and fraction of natural mortality before spawning.

Age	1	2	3	4	5	6	7	8+
Harvest	0	0	0	0	0	0	0	0
Natural mortality	0	0	0	0	0	0	0	0

Table 21.10. Turbot in Subarea 4. SNS survey index

	Age							Age					
Year	**1**	**2**	**3**	**4**	**5**	**6**	**Year**	**1**	**2**	**3**	**4**	**5**	**6**
2004	186.52	27.029	18.76	4.09	3.00	3.42	2020	85.59	65.38	57.96	5.55	2.14	5.00
2005	75.39	155.55	23.66	0.00	0.00	0.00	2021	23.21	28.86	12.68	7.35	0.00	0.00
2006	196.15	97.47	14.87	3.61	1.09	0.00	2022	116.40	14.28	7.14	0.00	0.00	0.00
2007	89.74	55.60	33.78	11.84	1.32	0.00	2023	95.61	25.89	6.62	1.10	0.00	0.00
2008	52.09	99.74	40.83	11.87	10.92	1.20							
2009	26.27	20.31	5.65	14.47	5.09	0.00							
2010	96.02	35.81	9.27	5.37	3.70	6.76							
2011	116.69	36.89	0.00	0.00	0.00	1.69							
2012	39.86	33.51	9.46	1.23	0.00	0.00							
2013	110.16	16.12	15.64	0.44	0.00	0.00							
2014	102.71	18.31	9.45	6.16	4.74	1.20							
2015	273.79	45.87	2.00	2.00	0.00	0.00							
2016	52.83	115.69	26.71	2.00	1.31	0.50							
2017	271.90	54.70	60.34	0.50	0.00	0.50							
2018	118.21	84.25	16.84	21.94	8.64	3.18							
2019	148.66	81.43	17.07	1.53	4.37	0.83							

Table 21.11. Turbot in Subarea 4. BTS survey index

	Age						
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1991	1.227	1.665	0.217	0.024	0.014	0.000	0.012
1992	1.361	1.178	0.320	0.034	0.015	0.011	0.003
1993	1.680	1.406	0.185	0.052	0.045	0.002	0.001
1994	1.830	1.580	0.102	0.031	0.006	0.003	0.003
1995	1.833	0.607	0.101	0.012	0.009	0.003	0.000
1996	0.615	1.901	0.113	0.075	0.040	0.000	0.009
1997	0.669	1.308	0.378	0.026	0.038	0.013	0.012
1998	1.915	0.916	0.233	0.152	0.005	0.000	0.001

	Age						
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1999	1.243	1.181	0.195	0.095	0.017	0.003	0.001
2000	4.214	0.847	0.386	0.164	0.054	0.055	0.000
2001	1.044	1.410	0.129	0.152	0.000	0.000	0.040
2002	2.814	0.493	0.146	0.046	0.032	0.022	0.001
2003	1.543	0.875	0.101	0.054	0.000	0.012	0.011
2004	2.166	0.640	0.359	0.000	0.069	0.017	0.000
2005	1.143	1.538	0.526	0.116	0.036	0.006	0.012
2006	1.705	0.799	0.273	0.114	0.005	0.000	0.000
2007	1.342	0.902	0.563	0.280	0.090	0.060	0.000
2008	1.196	1.125	0.431	0.143	0.076	0.017	0.080
2009	0.972	0.420	0.346	0.281	0.152	0.050	0.005
2010	1.691	0.348	0.099	0.070	0.089	0.015	0.015
2011	1.840	0.892	0.163	0.063	0.065	0.017	0.000
2012	0.977	0.930	0.240	0.236	0.021	0.045	0.084
2013	0.668	0.585	0.456	0.158	0.018	0.037	0.041
2014	2.270	0.176	0.225	0.321	0.120	0.050	0.014
2015	4.279	1.163	0.192	0.088	0.099	0.000	0.012
2016	0.774	1.909	0.451	0.056	0.035	0.037	0.024
2017	2.654	0.460	0.843	0.058	0.013	0.014	0.039
2018	1.622	1.190	0.281	0.309	0.176	0.033	0.000
2019	2.899	1.116	0.386	0.036	0.110	0.016	0.000
2020	1.836	1.241	0.392	0.128	0.032	0.055	0.041
2021	0.533	0.733	0.436	0.180	0.062	0.021	0.000
2022	1.377	0.443	0.456	0.076	0.046	0.000	0.008
2023	0.983	1.026	0.167	0.245	0.056	0.016	0.000

Table 21.12. Turbot in Subarea 4. Dutch_BT2_LPUE survey index (biomass)

Year	Index
1995	0.0425
1996	0.0367
1997	0.0374
1998	0.0346
1999	0.0353
2000	0.0447
2001	0.0458
2002	0.0449
2003	0.0467
2004	0.0476
2005	0.0478
2006	0.0492
2007	0.0653
2008	0.0677
2009	0.0669
2010	0.0588
2011	0.0618
2012	0.076
2013	0.0813
2014	0.0776
2015	0.0893
2016	0.1019
2017	0.097
2018	0.0875
2019	0.0876
2020	0.0926
2021	0.0793
2022	0.0503
2023	0.0682

Table 21.13. Turbot in Subarea 4. Fbar (Ages 2–6) estimates from the assessment model.

Year	Low	Fbar	High
1981	0.309	0.384	0.476
1982	0.303	0.372	0.457
1983	0.336	0.410	0.500
1984	0.374	0.455	0.553
1985	0.406	0.495	0.604
1986	0.387	0.475	0.583
1987	0.393	0.483	0.593
1988	0.378	0.468	0.580
1989	0.479	0.583	0.710
1990	0.572	0.714	0.893
1991	0.604	0.762	0.962
1992	0.628	0.796	1.008
1993	0.655	0.825	1.040
1994	0.665	0.832	1.040
1995	0.646	0.803	0.997
1996	0.592	0.725	0.887
1997	0.531	0.663	0.829
1998	0.517	0.638	0.787
1999	0.498	0.617	0.764
2000	0.520	0.642	0.794
2001	0.577	0.708	0.868
2002	0.620	0.770	0.956
2003	0.611	0.728	0.867
2004	0.533	0.637	0.762
2005	0.470	0.569	0.687
2006	0.365	0.449	0.551
2007	0.339	0.415	0.509
2008	0.320	0.390	0.476
2009	0.363	0.441	0.535

Year	Low	Fbar	High
2010	0.347	0.420	0.509
2011	0.306	0.375	0.459
2012	0.290	0.354	0.432
2013	0.274	0.335	0.410
2014	0.278	0.338	0.411
2015	0.276	0.337	0.412
2016	0.289	0.358	0.443
2017	0.282	0.348	0.429
2018	0.292	0.360	0.443
2019	0.302	0.375	0.465
2020	0.302	0.377	0.472
2021	0.308	0.387	0.486
2022	0.252	0.318	0.401
2023	0.234	0.302	0.390

Table 21.14. Turbot in Subarea 4. Total and Spawning Stock Biomass estimates from the assessment model (tonnes).

Year	Low	TSB	High	Low	SSB	High
1981	16179	19895	24465	12085	15565	20046
1982	15092	18650	23048	10668	13955	18255
1983	15380	18810	23005	9508	12545	16552
1984	16454	19772	23758	8733	11480	15091
1985	16018	19045	22643	9090	11609	14825
1986	13779	16535	19843	8673	11075	14141
1987	12445	15036	18167	7573	9862	12843
1988	11819	14174	16998	6164	8153	10785
1989	12088	14486	17359	6211	8144	10680
1990	11567	14290	17653	5262	7055	9460
1991	10609	13944	18326	4035	5746	8184
1992	9919	13104	17312	3792	5299	7406

Year	Low	TSB	High	Low	SSB	High
1993	9013	11764	15353	3480	4751	6486
1994	8089	10391	13349	2908	3927	5304
1995	7769	9609	11884	2717	3518	4554
1996	7539	9114	11017	2444	3110	3957
1997	7600	8944	10525	2873	3491	4242
1998	7677	8937	10404	3256	3818	4478
1999	7476	9178	11268	2966	3764	4777
2000	8087	9995	12353	3228	4096	5198
2001	7821	9608	11803	3081	3876	4877
2002	7577	9015	10725	2980	3609	4371
2003	7394	8435	9622	2533	2951	3438
2004	7399	8404	9547	2329	2747	3240
2005	7464	8505	9693	2397	2859	3409
2006	7704	8812	10080	2593	3137	3795
2007	8645	9854	11232	3238	3896	4688
2008	8660	9868	11244	3908	4716	5691
2009	8482	9737	11178	4767	5734	6898
2010	8127	9458	11007	4397	5432	6711
2011	8817	10318	12074	4066	5108	6418
2012	9494	11092	12958	4546	5648	7017
2013	9493	11082	12937	5419	6635	8124
2014	10006	11739	13772	6366	7788	9526
2015	11219	13234	15611	5981	7501	9409
2016	11817	13941	16448	6168	7762	9769
2017	11652	13748	16221	7135	8820	10901
2018	11105	13235	15772	7214	9029	11301
2019	10773	12977	15631	6328	8160	10523
2020	10123	12385	15152	6026	7934	10447
2021	8892	11109	13878	5921	7896	10529

Year	Low	TSB	High	Low	SSB	High
2022	7682	9908	12777	5102	7088	9848
2023	7922	10303	13399	4823	6841	9704

Table 21.15. Turbot in Subarea 4. Recruitment (Age 1) estimates from the assessment model (units: thousands).

Year	Low	Value	High
1981	1831.84	2542.24	3528.13
1982	3080.95	4179.79	5670.56
1983	4718.96	6451.00	8818.76
1984	3592.54	4975.52	6890.88
1985	1798.24	2489.79	3447.28
1986	2515.30	3406.85	4614.41
1987	2953.94	4007.08	5435.70
1988	2738.11	3758.25	5158.46
1989	2954.80	4462.90	6740.72
1990	3578.22	5719.67	9142.72
1991	3182.00	4916.61	7596.82
1992	2743.92	4259.49	6612.15
1993	3081.59	4702.02	7174.56
1994	2425.14	3670.35	5554.92
1995	3334.18	4762.42	6802.46
1996	2419.51	3331.21	4586.45
1997	2065.71	2876.86	4006.52
1998	2866.67	4125.95	5938.40
1999	2309.95	3415.05	5048.83
2000	3683.71	5363.46	7809.15
2001	2284.32	3373.31	4981.45
2002	3987.87	5432.06	7399.27
2003	3450.89	4595.01	6118.45
2004	4574.66	5989.92	7843.01

Year	Low	Value	High
2005	3509.33	4585.54	5991.80
2006	4716.59	6215.79	8191.53
2007	3902.67	5113.61	6700.28
2008	2367.89	3159.27	4215.12
2009	2875.74	3830.22	5101.50
2010	4166.24	5438.57	7099.47
2011	4990.32	6759.39	9155.58
2012	3104.28	4140.66	5523.04
2013	2415.81	3199.76	4238.11
2014	4896.64	6426.86	8435.29
2015	6645.28	8944.96	12040.48
2016	2336.52	3124.88	4179.24
2017	3863.12	5073.18	6662.28
2018	4323.70	5646.32	7373.51
2019	4443.92	5893.92	7817.03
2020	2919.81	3870.79	5131.50
2021	1957.29	2618.01	3501.75
2022	3141.42	4389.09	6132.28
2023	2600.19	4370.40	7345.77

Table 21.16. Turbot in Subarea 4. Fishing mortality-at-age as estimated by the assessment model.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.002	0.118	0.612	0.529	0.348	0.310	0.219	0.219
1982	0.002	0.112	0.572	0.509	0.349	0.319	0.238	0.238
1983	0.002	0.135	0.605	0.557	0.396	0.359	0.279	0.279
1984	0.003	0.178	0.671	0.607	0.436	0.382	0.284	0.284
1985	0.004	0.205	0.726	0.664	0.480	0.399	0.279	0.279
1986	0.004	0.211	0.684	0.630	0.465	0.385	0.265	0.265

Year	Age							
	1	2	3	4	5	6	7	8+
1987	0.005	0.244	0.721	0.622	0.456	0.371	0.255	0.255
1988	0.006	0.261	0.720	0.564	0.432	0.363	0.263	0.263
1989	0.009	0.328	0.905	0.699	0.547	0.436	0.345	0.345
1990	0.011	0.386	1.055	0.840	0.709	0.582	0.567	0.567
1991	0.013	0.413	1.110	0.898	0.767	0.624	0.640	0.640
1992	0.016	0.444	1.152	0.931	0.800	0.653	0.711	0.711
1993	0.019	0.488	1.201	0.957	0.816	0.664	0.759	0.759
1994	0.022	0.511	1.227	0.960	0.809	0.651	0.755	0.755
1995	0.022	0.494	1.176	0.933	0.782	0.629	0.747	0.747
1996	0.016	0.388	1.019	0.852	0.749	0.616	0.770	0.770
1997	0.012	0.315	0.872	0.780	0.726	0.623	0.833	0.833
1998	0.011	0.294	0.805	0.738	0.716	0.635	0.935	0.935
1999	0.014	0.327	0.781	0.713	0.672	0.592	0.884	0.884
2000	0.024	0.439	0.843	0.739	0.656	0.535	0.722	0.722
2001	0.041	0.592	0.941	0.809	0.681	0.515	0.631	0.631
2002	0.066	0.783	1.011	0.864	0.700	0.491	0.549	0.549
2003	0.070	0.785	0.944	0.815	0.652	0.445	0.461	0.461
2004	0.073	0.763	0.866	0.713	0.511	0.333	0.267	0.267
2005	0.068	0.683	0.793	0.620	0.439	0.307	0.260	0.260
2006	0.051	0.552	0.612	0.460	0.342	0.276	0.273	0.273
2007	0.041	0.514	0.547	0.422	0.322	0.272	0.263	0.263
2008	0.037	0.470	0.507	0.394	0.314	0.266	0.234	0.234
2009	0.053	0.615	0.592	0.428	0.312	0.256	0.225	0.225
2010	0.047	0.565	0.563	0.410	0.303	0.260	0.232	0.232
2011	0.037	0.487	0.504	0.376	0.273	0.236	0.206	0.206
2012	0.030	0.424	0.472	0.378	0.266	0.228	0.193	0.193
2013	0.026	0.384	0.438	0.371	0.262	0.222	0.173	0.173
2014	0.015	0.292	0.418	0.397	0.309	0.274	0.243	0.243

Year	Age							
	1	2	3	4	5	6	7	8+
2015	0.010	0.253	0.405	0.407	0.335	0.284	0.240	0.240
2016	0.009	0.232	0.419	0.454	0.385	0.302	0.241	0.241
2017	0.009	0.216	0.414	0.448	0.375	0.287	0.221	0.221
2018	0.016	0.259	0.437	0.448	0.373	0.280	0.201	0.201
2019	0.027	0.319	0.473	0.450	0.367	0.264	0.170	0.170
2020	0.040	0.368	0.488	0.439	0.351	0.241	0.141	0.141
2021	0.047	0.386	0.527	0.445	0.347	0.228	0.124	0.124
2022	0.039	0.326	0.465	0.360	0.268	0.170	0.077	0.077
2023	0.040	0.326	0.461	0.335	0.242	0.150	0.059	0.059

Table 21.17. Turbot in Subarea 4. Population abundance (stock numbers at age) as estimated by the assessment model (units: thousands).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	2542.24	3098.46	1615.14	1322.14	1767.24	719.89	370.38	610.90
1982	4179.79	2004.85	2292.89	674.90	630.65	1034.30	435.75	655.73
1983	6451.00	3432.36	1475.38	1064.16	329.89	367.01	623.14	712.01
1984	4975.52	5540.36	2506.13	685.60	488.47	180.85	211.77	818.27
1985	2489.79	4188.88	3765.93	1082.10	321.79	256.44	99.99	630.19
1986	3406.85	1888.54	2947.74	1401.84	443.71	166.68	138.00	456.51
1987	4007.08	2808.08	1169.26	1378.20	574.87	220.70	92.72	372.28
1988	3758.25	3346.84	1784.79	457.54	597.53	289.37	124.24	299.46
1989	4462.90	2979.70	2054.88	747.20	244.68	321.81	159.80	268.25
1990	5719.67	3601.64	1747.93	633.46	308.45	124.27	178.19	252.43
1991	4916.61	4793.30	2011.44	482.73	219.39	123.66	57.61	200.02
1992	4259.49	4067.77	2621.00	540.09	159.80	82.11	53.97	111.33
1993	4702.02	3386.60	2160.42	669.83	176.24	58.21	34.25	66.52
1994	3670.35	3850.42	1605.05	541.00	209.87	63.35	24.72	38.68
1995	4762.42	2742.29	1843.05	373.64	175.38	77.54	27.10	24.45

Year	Age							
	1	2	3	4	5	6	7	8+
1996	3331.21	3940.84	1277.17	467.03	120.55	68.33	34.67	20.06
1997	2876.86	2778.16	2186.67	363.32	163.55	45.86	31.48	20.97
1998	4125.95	2313.62	1672.09	760.58	134.83	64.45	19.48	19.30
1999	3415.05	3384.79	1438.02	602.84	308.44	53.24	27.63	12.44
2000	5363.46	2616.50	2038.58	565.55	242.28	136.76	24.13	13.56
2001	3373.31	4269.04	1288.87	711.07	227.28	101.82	68.12	15.01
2002	5432.06	2493.73	1918.06	394.65	256.01	97.31	49.41	36.71
2003	4595.01	4195.00	872.68	577.56	130.21	102.09	49.78	41.99
2004	5989.92	3403.40	1540.74	277.64	210.60	51.47	52.46	45.78
2005	4585.54	4543.03	1302.28	516.97	103.75	101.26	28.05	65.04
2006	6215.79	3542.21	1876.35	408.03	212.96	52.47	61.60	60.25
2007	5113.61	4942.78	1679.50	875.15	211.73	128.42	32.99	74.59
2008	3159.27	4248.96	2432.99	780.41	462.26	128.88	80.91	65.96
2009	3830.22	2362.87	2302.56	1328.30	451.65	248.68	77.27	95.13
2010	5438.57	3142.16	964.41	1026.08	710.55	282.78	153.58	109.65
2011	6759.39	4277.10	1607.08	418.46	578.89	432.88	174.79	162.65
2012	4140.66	5668.12	2185.24	874.29	242.31	372.72	292.17	212.30
2013	3199.76	3360.39	3414.39	1129.91	503.39	161.87	254.31	327.24
2014	6426.86	2297.31	1952.66	2061.69	656.06	338.33	113.73	425.05
2015	8944.96	5273.20	1512.69	1106.26	1195.68	405.22	211.36	359.32
2016	3124.88	7593.59	3294.91	914.23	646.23	707.26	246.06	367.01
2017	5073.18	2332.84	5250.35	1741.99	475.94	349.21	431.29	383.23
2018	5646.32	4060.32	1521.85	2799.00	916.10	272.60	219.39	516.07
2019	5893.92	4548.95	2561.10	809.82	1448.89	513.59	167.13	480.95
2020	3870.79	4623.75	2686.65	1257.56	442.01	810.26	324.45	433.33
2021	2618.01	2859.39	2442.47	1395.76	643.81	257.31	510.12	520.25
2022	4389.09	2040.00	1518.46	1040.62	696.90	354.64	164.45	682.44
2023	4370.40	3459.38	1339.52	762.24	600.69	434.11	251.39	601.38

Table 21.18. Turbot in Subarea 4. Predicted catch numbers-at-age (units: thousands).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	3.91	312.53	677.17	496.68	473.98	174.80	66.34	109.42
1982	5.92	192.36	913.75	246.18	169.44	257.72	83.88	126.22
1983	12.20	392.72	613.44	415.69	98.37	100.85	138.27	158.00
1984	14.52	822.10	1122.48	285.53	157.58	52.32	47.74	184.47
1985	9.04	706.62	1782.12	481.29	112.03	77.03	22.20	139.89
1986	12.87	326.17	1338.44	599.99	150.83	48.63	29.29	96.88
1987	19.01	553.63	551.02	584.78	192.25	62.35	18.99	76.24
1988	21.31	699.81	840.51	180.47	191.46	80.40	26.15	63.04
1989	35.93	758.87	1125.35	344.69	94.26	103.88	42.49	71.33
1990	59.16	1051.98	1050.73	330.88	143.62	50.17	70.58	99.98
1991	59.43	1478.77	1244.18	263.14	107.85	52.56	24.93	86.56
1992	60.80	1331.44	1655.38	301.07	80.80	36.08	25.18	51.95
1993	81.80	1195.51	1395.48	379.95	90.30	25.89	16.72	32.46
1994	72.35	1408.27	1048.84	307.42	106.89	27.77	12.02	18.81
1995	93.31	976.47	1177.13	208.52	87.34	33.14	13.08	11.80
1996	47.50	1155.81	752.02	246.23	58.32	28.79	17.09	9.89
1997	31.44	683.87	1170.10	180.65	77.42	19.48	16.35	10.89
1998	42.75	536.77	849.30	364.08	63.25	27.74	10.89	10.79
1999	44.08	859.51	715.52	281.89	138.29	21.77	14.91	6.71
2000	114.99	848.49	1066.65	271.00	106.83	51.79	11.38	6.40
2001	121.74	1745.16	723.31	362.23	102.91	37.48	29.19	6.43
2002	312.99	1243.32	1124.40	209.88	118.14	34.47	19.09	14.18
2003	282.13	2094.28	490.84	295.75	57.12	33.46	16.79	14.16
2004	384.83	1667.36	820.70	129.79	77.04	13.28	11.21	9.78
2005	272.33	2060.40	654.96	218.82	33.67	24.37	5.85	13.58
2006	282.15	1375.05	786.33	137.37	56.25	11.54	13.40	13.11
2007	185.25	1817.00	647.17	274.87	53.14	27.82	6.94	15.68
2008	105.06	1456.63	884.95	231.97	113.41	27.38	15.38	12.54

Year	Age							
	1	2	3	4	5	6	7	8+
2009	179.45	993.41	942.14	422.43	110.28	51.07	14.17	17.44
2010	227.83	1241.01	379.92	315.18	169.41	58.88	28.95	20.67
2011	221.74	1506.24	581.06	119.54	125.79	82.78	29.58	27.53
2012	111.30	1787.32	751.42	250.73	51.45	69.24	46.65	33.90
2013	74.58	976.44	1105.34	319.64	105.53	29.30	36.68	47.20
2014	84.17	530.12	608.95	616.74	158.92	73.79	22.29	83.31
2015	84.13	1074.00	459.58	337.54	310.41	91.26	40.96	69.64
2016	26.37	1428.27	1028.92	304.65	188.19	167.94	47.91	71.46
2017	39.34	411.70	1624.57	574.57	135.65	79.30	77.73	69.07
2018	81.79	842.52	492.27	923.27	260.35	60.66	36.34	85.48
2019	143.73	1133.18	882.01	267.89	405.89	108.38	23.77	68.39
2020	138.48	1299.53	947.83	407.90	119.21	157.66	38.66	51.64
2021	109.44	835.39	914.22	457.57	172.26	47.69	54.16	55.23
2022	153.35	516.89	515.35	286.72	149.32	50.42	11.11	46.12
2023	155.03	876.09	451.49	197.66	117.34	54.82	13.07	31.26

Table 21.19. Turbot in Subarea 4. Catch-at-age residuals.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.000	-1.450	1.819	1.750	0.896	0.733	0.893	2.200
1982	0.000	0.177	0.622	-1.068	-1.148	-1.764	-0.920	0.045
1983	0.000	-0.492	1.179	2.014	2.061	0.138	0.247	2.705
1984	0.000	0.052	0.291	-0.774	-1.971	-0.640	-1.717	0.030
1985	0.000	1.376	0.012	0.926	0.364	-0.105	0.107	-0.090
1986	0.000	2.229	-0.041	0.571	-0.115	-0.117	-0.292	-0.931
1987	0.000	-0.475	-0.340	0.629	0.988	-0.190	-0.764	-0.860
1988	0.000	-1.108	-0.424	-0.982	-0.048	0.209	-0.629	-0.109
1989	0.340	0.809	-1.833	1.336	-1.053	-1.144	0.027	-0.671

Year	Age							
	1	2	3	4	5	6	7	8+
1990	0.766	0.918	-0.813	-1.474	-0.061	-0.022	0.169	0.050
1991–1997	0.000	-0.505	0.217	0.842	2.636	-0.379	-0.325	-0.098
1998	0.584	0.316	-0.124	-1.364	0.736	1.876	1.934	0.082
1999–2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	0.000	-0.050	-0.275	0.472	0.663	0.081	-0.541	0.994
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2014	1.257	0.484	-2.489	-0.063	-0.484	-1.111	0.043	1.015
2015	0.863	0.169	-1.107	-0.178	-0.410	-2.208	-2.094	-1.760
2016	0.118	-0.504	0.237	-0.662	-1.538	-0.318	-2.120	1.825
2017	1.365	0.441	-1.092	-3.161	-1.644	-0.744	1.456	1.047
2018	-1.399	1.250	-0.893	0.860	-0.343	0.984	0.552	-0.532
2019	0.034	-0.056	-0.369	-0.401	1.631	1.514	-0.889	-0.969
2020	-0.093	0.302	1.298	1.170	-0.497	-2.457	-0.499	0.441
2021	0.657	1.011	-1.116	-0.413	0.071	1.636	-0.011	-0.405
2022	-0.191	0.533	1.169	-0.980	0.257	-0.209	0.060	-0.875
2023	0.000	-0.093	0.138	1.676	-0.575	0.038	1.220	-1.716

Table 21.20. Turbot in Subarea 4. Predicted index-at-age SNS.

Year	Age					
	1	2	3	4	5	6
2004	102.553	35.832	9.696	0.952	0.832	0.231
2005	78.827	50.617	8.627	1.892	0.431	0.462
2006	108.091	43.268	14.126	1.672	0.948	0.245
2007	89.589	62.012	13.236	3.684	0.956	0.601
2008	55.483	54.984	19.717	3.349	2.100	0.606
2009	66.527	27.622	17.574	5.565	2.054	1.177
2010	94.846	38.037	7.514	4.354	3.251	1.334
2011	118.751	54.714	13.060	1.819	2.707	2.077
2012	73.091	75.801	18.153	3.797	1.139	1.798
2013	56.644	46.234	29.061	4.928	2.372	0.784
2014	114.697	33.711	16.853	8.829	2.990	1.581
2015	160.101	79.529	13.178	4.705	5.349	1.879
2016	55.973	116.292	28.424	3.762	2.792	3.239
2017	90.920	36.129	45.444	7.197	2.071	1.617
2018	100.657	61.004	12.957	11.564	3.990	1.268
2019	104.248	65.484	21.262	3.342	6.339	2.417
2020	67.840	64.296	22.074	5.230	1.956	3.875
2021	45.660	39.271	19.528	5.780	2.856	1.242
2022	76.976	29.234	12.683	4.576	3.268	1.783
2023	76.615	49.581	11.221	3.411	2.871	2.214

Table 21.21. Turbot in Subarea 4. Index-at-age residuals SNS

Year	Age					
	1	2	3	4	5	6
2004	0.466	-1.409	1.310	1.011	1.175	1.747
2005	-0.582	2.073	0.534	0.000	0.000	0.000
2006	1.020	1.127	-0.261	0.831	-0.278	0.000
2007	0.087	-0.110	1.964	0.624	-0.146	0.000

Year	Age					
	1	2	3	4	5	6
2008	-0.552	1.754	0.606	0.733	0.905	-0.159
2009	-1.239	-0.485	-1.276	2.025	0.622	0.000
2010	0.699	0.128	0.139	0.110	0.031	1.601
2011	0.479	-0.480	0.000	0.000	0.000	-0.113
2012	-1.167	-0.050	-0.216	-0.675	0.000	0.000
2013	0.569	-1.747	0.471	-2.192	0.000	0.000
2014	1.147	-1.252	-0.334	0.394	0.718	-0.531
2015	1.805	-1.180	-2.201	0.498	0.000	0.000
2016	-1.321	1.034	-0.228	-0.657	-0.497	-1.536
2017	2.240	-0.666	0.131	-3.093	0.000	-0.486
2018	-0.283	0.451	0.155	0.533	0.516	0.590
2019	0.117	0.002	-0.530	-0.578	0.023	-0.946
2020	-0.856	-0.238	1.679	-0.656	0.127	0.246
2021	-1.855	-0.394	-0.598	0.687	0.000	0.000
2022	1.076	-1.682	-0.502	0.000	0.000	0.000
2023	0.321	-1.174	-0.159	-0.765	0.000	0.000

Table 21.22. Turbot in Subarea 4. Predicted index-at-age BTS-ISIS

Year	Age						
	1	2	3	4	5	6	7
1991	1.652	1.216	0.195	0.054	0.019	0.012	0.005
1992	1.429	1.009	0.247	0.059	0.013	0.008	0.005
1993	1.573	0.814	0.196	0.072	0.014	0.005	0.003
1994	1.226	0.911	0.143	0.058	0.017	0.006	0.002
1995	1.591	0.657	0.171	0.041	0.015	0.007	0.002
1996	1.117	1.017	0.132	0.054	0.010	0.006	0.003
1997	0.968	0.755	0.251	0.044	0.014	0.004	0.003
1998	1.388	0.638	0.201	0.096	0.012	0.006	0.001

Year	Age						
	1	2	3	4	5	6	7
1999	1.147	0.912	0.176	0.077	0.028	0.005	0.002
2000	1.789	0.651	0.239	0.071	0.022	0.014	0.002
2001	1.112	0.954	0.141	0.085	0.020	0.010	0.006
2002	1.759	0.487	0.199	0.046	0.023	0.010	0.005
2003	1.483	0.818	0.095	0.069	0.012	0.011	0.005
2004	1.929	0.674	0.177	0.036	0.021	0.006	0.006
2005	1.483	0.952	0.158	0.071	0.011	0.012	0.003
2006	2.033	0.814	0.258	0.063	0.024	0.006	0.007
2007	1.685	1.167	0.242	0.138	0.025	0.015	0.004
2008	1.044	1.034	0.361	0.125	0.054	0.016	0.010
2009	1.252	0.520	0.322	0.208	0.053	0.030	0.010
2010	1.784	0.716	0.137	0.163	0.083	0.034	0.019
2011	2.234	1.029	0.239	0.068	0.069	0.053	0.022
2012	1.375	1.426	0.332	0.142	0.029	0.046	0.037
2013	1.066	0.870	0.532	0.184	0.061	0.020	0.033
2014	2.158	0.634	0.308	0.330	0.077	0.041	0.014
2015	3.012	1.496	0.241	0.176	0.137	0.048	0.026
2016	1.053	2.188	0.520	0.141	0.072	0.083	0.030
2017	1.710	0.680	0.831	0.269	0.053	0.041	0.054
2018	1.894	1.148	0.237	0.433	0.102	0.033	0.028
2019	1.961	1.232	0.389	0.125	0.162	0.062	0.022
2020	1.276	1.210	0.404	0.196	0.050	0.099	0.043
2021	0.859	0.739	0.357	0.216	0.073	0.032	0.068
2022	1.448	0.550	0.232	0.171	0.084	0.046	0.023
2023	1.441	0.933	0.205	0.128	0.074	0.057	0.035

Table 21.23. Turbot in Subarea 4. Index-at-age residuals BTS-ISIS.

Year	Age						
	1	2	3	4	5	6	7
1991	-0.596	0.736	-1.067	-2.232	-0.872	0.000	0.279
1992	-0.080	0.535	0.197	-1.281	-0.302	-0.214	-0.955
1993	0.251	0.817	-0.493	-0.781	0.988	-1.540	-1.639
1994	0.168	0.795	-1.601	-0.675	-0.862	-0.311	0.787
1995	0.015	-1.108	-1.001	-1.185	0.329	-0.139	0.000
1996	-1.541	1.904	-0.193	1.253	1.932	0.000	1.464
1997	-0.495	1.783	1.361	-0.532	1.322	1.214	1.731
1998	1.374	0.756	0.646	0.867	-1.046	0.000	-0.354
1999	-0.182	0.421	0.147	0.573	-0.249	-0.481	-0.553
2000	1.775	-0.684	0.740	1.213	1.149	1.904	0.000
2001	-1.369	-0.164	-1.653	0.361	0.000	0.000	2.330
2002	1.096	-1.690	-1.779	-0.613	0.066	0.837	-1.441
2003	-0.507	-0.242	0.162	-0.498	0.000	0.085	1.084
2004	-0.217	-0.296	1.516	0.000	1.138	0.849	0.000
2005	-0.744	0.605	2.383	0.500	1.132	-0.809	1.201
2006	-0.454	-0.044	0.757	1.118	-1.716	0.000	0.000
2007	-0.292	-0.217	2.636	1.262	1.567	1.495	0.000
2008	0.038	0.462	0.589	0.134	0.137	-0.010	2.295
2009	0.083	-1.008	0.273	0.596	1.335	0.471	-0.861
2010	0.518	-0.992	-0.608	-1.069	0.163	-0.981	-0.411
2011	0.058	0.258	-0.118	0.144	0.090	-1.184	0.000
2012	-0.539	0.249	-0.009	1.116	-0.077	0.161	0.895
2013	-1.731	0.231	0.817	0.189	-1.073	0.937	0.316
2014	1.207	-2.266	0.058	0.332	0.638	0.279	0.143
2015	1.092	-0.003	0.284	-0.681	-0.210	0.000	-0.717
2016	-1.494	0.362	-0.212	-1.283	-0.758	-0.765	-0.157
2017	0.699	-1.443	-0.124	-2.258	-1.469	-1.081	-0.338
2018	-0.790	-0.144	0.304	-0.493	0.612	0.025	0.000

Year	Age						
	1	2	3	4	5	6	7
2019	0.142	-0.692	-0.219	-1.723	-0.357	-1.407	0.000
2020	-0.303	-0.486	-0.208	-0.653	-0.323	-0.566	0.009
2021	-1.293	-0.534	-0.191	-0.436	-0.287	-0.456	0.000
2022	-0.075	-0.177	1.340	-1.384	-0.800	0.000	-1.139
2023	-0.956	0.664	-0.233	1.136	-0.259	-1.353	0.000

Table 21.24. Turbot in Subarea 4. Predicted index and residuals of the Dutch LPUE.

Year	Index	Residuals
1995	0.042	0.302
1996	0.038	-1.001
1997	0.04	-1.606
1998	0.036	-0.552
1999	0.038	-0.237
2000	0.045	-0.175
2001	0.049	-0.432
2002	0.044	0.057
2003	0.044	0.731
2004	0.048	-0.96
2005	0.054	-2.456
2006	0.055	-0.958
2007	0.066	-0.035
2008	0.071	-0.422
2009	0.066	-0.169
2010	0.057	1.156
2011	0.064	0.552
2012	0.077	1.412
2013	0.08	1.958
2014	0.074	2.047

Year	Index	Residuals
2015	0.076	2.471
2016	0.088	1.956
2017	0.094	0.561
2018	0.087	0.017
2019	0.083	0.741
2020	0.081	0.832
2021	0.072	-0.066
2022	0.06	-1.702
2023	0.061	1.431

Table 21.25. Turbot in Subarea 4. Fit parameters.

Name	value	std.dev
logFpar	-3.875	0.125
logFpar	-4.317	0.172
logFpar	-5.032	0.234
logFpar	-7.848	0.07
logFpar	-8.318	0.086
logFpar	-8.696	0.16
logFpar	-9.71	0.089
logSdLogFsta	-0.687	0.375
logSdLogFsta	-1.412	0.223
logSdLogFsta	-1.953	0.214
logSdLogFsta	-1.802	0.263
logSdLogFsta	-1.316	0.224
logSdLogN	-0.856	0.156
logSdLogN	-2.171	0.33
logSdLogObs	-0.253	0.236
logSdLogObs	-1.256	0.264
logSdLogObs	-2.273	0.387

Name	value	std.dev
logSdLogObs	-1.173	0.14
logSdLogObs	-1.123	0.166
logSdLogObs	-0.511	0.136
logSdLogObs	-0.292	0.158
logSdLogObs	0.07	0.118
logSdLogObs	-0.922	0.09
logSdLogObs	-0.397	0.14
logSdLogObs	-0.099	0.086
logSdLogObs	-2.306	0.292
transfIRARdist	0.014	0.293
itrans_rho	0.973	0.178

Table 21.26. Turbot in Subarea 4. Negative Log-Likelihood.

459.2012

Table 21.27. Comparison between the WGNSSK 2024 and 2023 estimates for recruitment, catch, fishing pressure (F) and targeted fishing pressure for total allowable catch (Target F for TAC).

Parameter	Year*	Current Assessment (2024)	Previous assessment (2023)
Assumed recruitment	2023	4370 thousand	4313 thousand
	2024	4372 thousand	4314 thousand
Catch	2023	1843 t	1762 t
F	2023	0.302	0.340
Target F for TAC	2024	0.361	0.361

*'2023' = Intermediate year in the previous assessment; '2024' = advice year in the previous assessment

Figure 21.1. Turbot in Subarea 4. Total catches 1981–2023. ICES estimated landings (green) and discards (red).

Figure 21.2. Turbot in Subarea 4. Landings-at-age for the years with available data between 1975–2023. Data for 1991–1997 and 1999–2002 are missing.

Figure 21.3. Turbot in Subarea 4. Total landings by métier in 2023 sorted by sampled/unsampled age distributions in InterCatch.

Figure 21.4. Turbot in Subarea 4. Time series of the standardized indices for ages 1 to 7 from the three tuning fleets available for the assessment: BTS-ISIS (black), SNS (red) and NL beam trawl LPUE (shown in the "-1" panel).

Figure 21.5. Turbot in Subarea 4. Internal consistency of the two tuning indices available for the assessment: BTS-ISIS from 1991–2023 (top), and SNS 2004–2023 (bottom).

Figure 21.6. Turbot in Subarea 4. Raw landings (top-left), modelled landings (top right) and raw stock (bottom left) and modelled (bottom right) weight at age.

Figure 21.7. Turbot in Subarea 4. Summary plot of SSB, F and Recruitment, including the uncertainty bounds.

Figure 21.8. Turbot in Subarea 4. Retrospective analysis plot on SSB, F and R including the confidence band of the most recent assessment and Mohn's rho values.

Figure 21.9. Turbot in Subarea 4. Retrospective analysis plot on the value of the estimated parameters, ideally, all show a flat line indicating that with reducing the model with a year's worth of data does not affect the parameters to be estimated: logSdLogN = the random walk in N, logSdLogObs is the observation variance in the surveys and catch, logFpar are the catchability parameters and logSdLogFsta are the sd's of the random walks in F.

Figure 21.10. Turbot in Subarea 4. Retrospective analysis plot of selectivity pattern.

Figure 21.11. Turbot in Subarea 4. Parameter-correlation plot. It shows the correlation among all parameters that are estimated in the model. Fpar parameters refer to catchabilities, Fstates to the random walk in F, logN to the random walk in N, logObs to the observation variances, fRARdist to the auto-correlation in the surveys and trans_rho to the correlation in the F-random walks.

Figure 21.12. Turbot in Subarea 4. Plot showing the observation variance vs the CV of that estimate.

Figure 21.13. Turbot in Subarea 4. Estimated observation variances (scaling factor for each of the surveys), ordered from the best to the worst survey fit and has colour coding to show which bars belong to one dataset.

Figure 21.14. Turbot in Subarea 4. Catchabilities of the surveys for all surveys with more than 1 age-group.

Figure 21.15. Turbot in Subarea 4. Estimated selectivity from 1981 to 2023, grouped by a 5-year period. Note the 1980s are 1981 up to 1984, 2015s is 2015 up to 2019. Values represent actual F-at-age.

Figure 21.16. Turbot in Subarea 4. Residual bubble plot of landings.

Figure 21.17. Turbot in Subarea 4. Residual bubble plot of SNS, BTS-ISIS survey and the Dutch LPUE index.

Figure 21.18. Turbot in Subarea 4. Stock recruitment pairs over time which were used to calculate the reference points.

Figure 21.19. Turbot in Subarea 4. Productivity over time.

Figure 21.20. Turbot in Subarea 4. Stock recruitment pairs over time.

Figure 21.21. Turbot in Subarea 4. Maps showing the area survey stations monitored during the Dutch industry-based survey in the period 2021 to 2023.

Figure 21.22. Turbot in Subarea 4. Length composition (1cm-classes) of individuals of turbot and brill sampled from the Dutch industry survey in 2019 – 2023.

Figure 21.23. Turbot in Subarea 4. Age-length distribution of turbot from samples obtained during the 2019 – 2023 industry survey.

Figure 21.24. Turbot in Subarea 4. Leave-one-out analysis showing the effects from the three indices on spawning stock biomass (SSB).

Figure 21.25. Turbot in Subarea 4. Leave-one-out analysis showing the effects from the three indices on fishing pressure (Fbar).

Figure 21.26. Turbot in Subarea 4. Leave-one-out analysis showing the effects from the three indices on recruitment (age 1) of turbot in Subarea 4.

Figure 21.27. Turbot in Subarea 4. Model estimated absolute SSB-at-age (spawning stock biomass; *left*) and the estimated proportion of SSB-at-age (*right*).

Figure 21.28. Turbot in Subarea 4. The 3, 5, 10 and 20 year averages for selectivity-at-age in commercial catches (left) and modelled stock weights-at-age (*right*).

Figure 21.29. Turbot in Subarea 4. Ratios of numbers-at-age (left) and biomass-at-age (right) for WGNSSK 2024 to WGNSSK 2023 from years 2016 – 2025 (assessment and forecast).

Figure 21.30. Turbot in Subarea 4. Comparison of abundances-at-age between WGNSSK 2023 and WGNSSK 2024 data and intermediate year forecasts for 2022-2024 as well as the 2025 advice year forecast from WGNSSK 2024.

Figure 21.31. Turbot in Subarea 4. Comparison of biomass-at-age between WGNSSK 2023 and WGNSSK 2024 data and intermediate year forecasts for 2022-2024 as well as the 2025 advice year forecast from WGNSSK 2024.

Figure 21.32. Turbot in Subarea 4. Ratios of weight-at-age for WGNSSK 2024 to WGNSSK 2023 from years 2016–2025 (assessment and forecast).

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