21 Turbot in Subarea 4

This report presents the stock assessment carried out for turbot (*Scophthalmus maxima*) in Subarea 4 in 2021. Following an inter-benchmark procedure for this stock in 2015, a state-space assessment model SAM (Nielsen and Berg, 2014) is used (ICES 2016). During WGNSSK 2017 questionable model settings used since the 2015 Inter-benchmark were detected. This led to the decision that a further inter-benchmark was needed in 2017 (ICES, 2017), screening all available input data, including a new LPUE index from UK, a Delta-GAM survey index combining several BTS surveys and, for the first time, age-based catch data from Denmark for most recent years.

During WGNSSK 2018 a mistake was found in the inter-benchmark 2017 results. The mistake related to how one of the surveys was being treated, i.e. as an index of SSB instead of exploitable biomass. The mistake led to questions on the persistence of the retrospective pattern on F and assessment category used to provide advice. Therefore, an inter-benchmark was organised in 2018. This inter-benchmark corrected the mistake in the 2017 inter-benchmark settings, checked the plus-group settings of the catch as well as surveys and re-evaluated the parameter bindings in the assessment configuration (ICES, 2018).

Under the new assessment resulting from the 2018 inter-benchmark, the retrospective has improved substantially and F was deemed to be estimated reliably. Therefore, the inter-benchmark decided to upgrade turbot in 27.4 to a Category 1 stock. In this context, the inter-benchmark also estimated reference points for a Category 1 stock and provided a short-term forecast. During WGNSSK 2019, the assessment was conducted and advice for turbot in 27.4 was provided for 2020 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, 2012a) 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, sandeels, 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%). In most countries, turbot is caught in trawls of mixed fisheries, with most of the landings in the Netherlands coming from the 80 mm beam trawl fleet (BT2) fishing for sole and plaice. In Denmark, the second largest contributor to the landings in recent times, there is a directed fishery for turbot using gillnets (~4 % of the total landings in 2019 and 2020).

See the Stock Annex for more details.

21.1.3 Management

A combined EU TAC for turbot and brill is set for EU waters in areas 2.a and 4. This TAC only applies to the EU fisheries. This management area (particularly the inclusion of Area 2.a) does not correspond to either of the stock areas defined by ICES for turbot and brill.

No specific management objectives or plans are known to ICES.

As a primarily bycatch species, regulations relating to effort restrictions for the primary métiers catching turbot (e.g. beam trawlers) are likely to impact on 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}. During 2018, the PO measures were relaxed due to the sufficiently available quota and were continued in 2019 and 2020.

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

21.1.4 Data used

Following the inter-benchmark conducted in the summer of 2018 (ICES, 2018), 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.

21.1.5 Catch data

Figure 21.2.1 shows the trend in total landings (InterCatch) and discards (InterCatch) over time. ICES estimated landings of turbot decreased during the 1990s and 2000s, and for the last ten years have been around 3000 tonnes. In this period, effort by the Dutch beam trawl fleet, which contributes most to the landings (ca. 45%), has decreased notably. Since turbot is primarily a bycatch species, this indicates that abundance of turbot has likely increased over this period. In 2016 and 2017, landings have been slightly higher, exceeding 3400 tonnes. Since 2018, official landings in Subarea 4 decreased slightly. In 2020, 3187tonnes has been officially reported in Division 2a and Subarea 4. In the last 4 years, the combined TAC for turbot and brill has not been fully utilized. In 2020, only 67% of the combined TAC (6498 tonnes) was taken of which turbot had the largest share (49%).

Landings in numbers at age are presented in Table 21.2.1 and Figure 21.2.2. 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 year classes in 2012, 2013 and 2016. 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 2020, there is a decrease in landings of age 5 which may result from the weak 2016-year class. In 2020, age 2 and 3 are the dominant age classes in the landings coming from relatively good year classes in 2018 and 2019.

The weights at age in the landings of turbot in Subarea 27.4 (Table 21.2.2a) 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 21.2.3a) 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 21.2.2b and 21.2.3b).

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

21.1.6 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. In 2019 and 2020, no age structure information was submitted for the discard estimates. Sample sizes were too low 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: 198 715 / (discards + landings: 3 303 033) was 6% in 2020. This is lower compared to the period 2016–2018 with an average of 14%. The discard rate in 2019 and 2020 is more in line with the discard rate observed in the period 2013–2015, when discard ratios were approximately 5%.

In 2020, BMS landings were reported by the UK (England); however, the submitted values were very low (46 kg) and were therefore not raised in InterCatch.

21.1.7 Logbook registered discards

In 2020, no logbook registered discards were reported to InterCatch. They are not raised.

21.1.8 InterCatch

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

In 2020, most countries provided estimates of discards to InterCatch. 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 which did not fit in any of the above groups or, were then raised with all available discard estimates.

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

*** 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 199 tonnes of estimated discards, 145 tonnes (73%) was reported data and 53 tonnes are raised in InterCatch. The proportion of landings with discards associated (same strata) is 68%.

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 of the landings (5750) increased compared to 2018 (2267) and 2019 (4186) and is mainly due to an increase in sampling of landings in different Danish métiers. In total, Denmark supplied 5169 samples collected in various metiers, while the Dutch (479) and Belgian (102) samples mainly 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 21.2.3 shows the métiers with numbers at age samples for the landings in 2020. Approximately 57% of the landings in weight are sampled in Subarea 4. 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 2020, the allocation for discards were done separately, making use of available age samples of the landings.

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

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

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

21.1.9 Survey data and commercial LPUE

Two survey abundance indices, the Sole Net Survey (SNS (B3498)) and the 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 21.3.1–3 and Figure 21.2.4).

All abundance indices indicate an increase in the number of fish aged 4 and since 2005. An increase in the amount of older fish would indicate either strong recruitment or a decrease in mortality (e.g. fishing pressure) exerted on the stock. Before 2015 no strong year classes have been observed. Since 2015, with the exception of 2016, relatively strong year classes are seen, resulting in an increase of fish of age 2, 4 and 6 to appear in the survey catches. In 2020 a slightly lower recruitment (age 1) compared to 2019 is observed. Recruitment however is still larger compared to the long-term mean. The Dutch BT2 LPUE index shows a continuous gradual increase since 2000. After two years of decline (2017 and 2018), the LPUE increases slightly in 2020. The LPUE is higher compared to the LPUE's observed before 2012.

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 21.2.5). The SNS survey is particularly poor at picking up cohort signals, with low R^2 values for cohort 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.

21.1.10 Biological data

All biological data used in the assessment are presented in Tables 21.2.3–5.

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 21.2.6). 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 Interbenchmark, 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. Since then, weights at age have decreased again and are slightly lower than the weights observed in the 1970s.

Maturity

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 Stock assessment model

After the inter-benchmark protocol of 2017 and 2018, a new assessment model (SAM, FLSAM) is used. 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).

21.2.1 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, 2018).

Assessment settings used in the final assessment

Year	**2020**
FLSAM version	2.1.1
FLCORE version	2.6.15
R version	4.0.2 (2020-06-02)
Platform	x86_64-w64-mingw32
Run date	2021-04-24

Model	SAM
First tuning year	1981
Last data year	2020
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)	1 2 3 4 5 6 7 7
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)	1 1 2 3 3 3 0 0 4 4 5 5 6 6 6 0 7 0 0 0 0 0 0 0
Coupling of fishing mortality RW VARIANCES	1 2 3 3 4 4 5 5
Coupling of log N RW VARIANCES	1 2 2 2 2 2 2 2
Coupling of OBSERVATION VARIANCES (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	1 2 3 3 4 4 5 5 6 6 7 8 8 8 0 0 9 9 9 10 11 11 11 0 12 0 0 0 0 0 0 0
Coupling of Survey Correlation correction by age (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
LPUE time-series indicator (0=SSB, 1 = catch, 2 = exploitable biomass)	2
Stock-recruitment model code (0=RW, 1=Ricker, 2=BH)	0
Fbar ranges	2–6

21.3 Assessment model results

The stock summary is given in Table 21.4.1a-c, while fishing mortality at age and abundance at age estimated by the assessment model are presented in Tables 21.4.2 and 21.4.3, respectively.

21.3.1 Status of the stock

Fishing mortality has been below 0.36 (F_{MSY}) since 2012. In 2018 and 2019, fishing mortality was estimated at 0.363 and 0.367, respectively, being just above F_{MSY}, but well below the long-term geometric mean (0.51). In 2020, fishing mortality dropped to 0.350. The SSB in 2020 was estimated to be 8343 tonnes, a very minor decrease (0.91%) from 2019 which was estimated at 8420 tonnes (Table 21.4.1b). SSB has been above MSY $B_{trigger}$ (6353 tonnes) since 2013. The estimated recruitment (age 1) for 2020 (6374 thousand). The 2019 recruitment estimate was revised downward from 8095 to 7094, but still remain the second highest recruitment in the time-series (9134 in 2015). The estimated recruitment is well above the geometric mean of the time series (4566 thousand) (Table 21.4.1c). However, this estimate is based on limited amount of data and is unlikely to be a reliable estimate.

21.3.2 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 and F increased gradually (Figure 21.4.1). The lowest estimated SSB was in 2004; SSB subsequently increased and has continued to increase since. Recruitment has been variable over the time-series without a clear trend. Recent recruitment (2014 and 2015) have been well above the long term mean and do now contribute to the increase in SSB.

Mean F peaked in 1994 at 0.83, but then declined to 0.62 in 1999, before rapidly increasing again to 0.76 in 2002. After 2002, there is a steep decline in F to 0.41 in 2010. Between 2012 and 2017, F has fluctuated around 0.34. In the last two years F has slightly increased to F_{MSY} level. These trends correspond well with the trends in fishing effort of the beam trawl fleet.

There are no clear patterns in recruitment, though values are estimated at a slightly higher level, but with more uncertainty, during the years of missing landings at age data (1990s). Since 2017, recruitment has been above the long-term geometric mean of the time series.

21.3.3 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 21.4.2–4. The retrospective plots in SSB, F and recruitment do not exhibit a strong negative or positive pattern. The Mohn's rho associated with this retrospective is -9.0% on SSB, 6.5% on F and -15.6% on recruitment, all considered to be low.

21.4 Model diagnostics

Model diagnostics are provided in Tables 21.5.1–6 and Figures 21.5.1–7.

The stability and estimatability 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 21.5.1).

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 21.5.2). 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 21.5.3).

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 (see also Figure 21.5.4).

The estimated selectivity at age from 1981 to 2020 is shown in Figure 21.5.5. The selectivity at-age do show some trend in the past decade, whereby after 2013 the selectivity has shifted slightly towards older ages (i.e. age 4). The values presented in Figure 21.4.5 are the actual F-at-age.

Residual plots of landings as well as of the SNS and BTS-ISIS survey do not show clear systematic patterns in either positive or negative residuals (Figure 21.5.6 and 21.5.7).

21.5 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 21.6.1). Productivity and stock-recruit pairs over time are shown in Figures 21.6.2–3.

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 precautionary 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

21.6 Short-term-forecast

The short-term forecast was implemented in FLR using the fwd-routines. Terminal year estimates from the SAM assessment were used as starting conditions. Since there is no clear relationship between SSB and Rec, it was decided to assume 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.

In the past 4 years, the TAC has not been exhausted, i.e. on average 68% of the combined TAC was used, therefore, using a % TAC was 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. This was also supported by the recent years in which F has been relatively stable at around 0.36.

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

Variable	Value	Notes
$F_{ages\ 2–6}$ (2021)	0.36	F_{sq} = $F_{average}$ of F (2018–2020)
SSB (2022)	9336	Short-term forecast (STF) at *status quo* (F_{sq})
R_{age1} (2021, 2022)	4566	Geometric mean (GM, 1981–2020)
Projected landings (2021)	3328	STF assuming an F *status quo* (F_{sq})

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 * (2022)	Projected landings ** (2022)	Projected discards *** (2022)	F (2-6) (2022)	SSB (2023)	% SSB change ^	% advice change ^^
MSY approach: F_{MSY}	3609	3291	318	0.361	9012	-3.5	-8.6
F_{MSY} upper = 0.48	4564	4162	402	0.482	8095	-13.3	15.6
F_{MSY} lower = 0.25	2634	2401	232	0.252	9957	6.6	-33
F = 0	0	0	0	0	12545	34	-100
F_{pa} ($F_{p.05}$ with AR)	6984	6368	616	0.856	5821	-38	77
$F_{p.05}$ without AR	4489	4093	396	0.473	8167	-12.5	13.7
F_{lim}	5487	5003	484	0.606	7219	-23	39
F_{sq}	3609	3291	318	0.360	9012	-3.5	-8.6
SSB (2022) = B_{lim}	10180	9282	897	1.70	2974	-68	158
SSB (2022) = B_{pa}	8812	8035	777	1.27	4163	-55	123
SSB (2022) = MSY $B_{trigger}$	6410	5845	565	0.76	6353	-32	62
Rollover advise	3948	3600	348	0.40	8686	-7	0
Multi-options table							
F = 0	0	0	0	0	12648	34	-100
F= 0.05	583	532	51	0.05	12070	28	-85
F = 0.10	1139	1039	100	0.10	11522	22	-71
F = 0.15	1669	1522	147	0.15	11001	16.8	-58
F = 0.20	2174	1982	192	0.20	10507	11.5	-45
F = 0.25	2656	2421	234	0.25	10037	6.6	-33
F = 0.30	3115	2840	275	0.30	9591	1.82	-21
F = 0.35	3553	3240	313	0.35	9166	-2.7	-10
F = 0.40	3972	3622	350	0.40	8763	-7.0	0.6
F = 0.45	4371	3986	385	0.45	8380	-11.0	10.7
F = 0.50	4752	4333	419	0.50	8015	-14.9	20

*** (projected landings) / (1 – average discard rate); average discard rate 2018–2020 = 8.8%**

**** Marketable landings**

***** Including BMS landings (EU stocks), assuming recent discard rate.**

^ SSB 2023 relative to SSB 2022.

^^ Total catch in 2022 relative to advice value for 2021 (3948 t).

21.7 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 in 2020 for turbot caught by TBB gears with a cod end more than 80 mm in ICES Subarea 4 (Commission Delegated Regulation (EU) 2019/2238).

21.7.1 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.

21.7.2 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.

21.7.3 Combined TAC

At present the EU provides a combined TAC for turbot and brill in the North Sea. This TAC seems largely ineffective at reducing F: increases in the stock at similar TACs lead to increased discarding. In addition, it is unclear how the quantitative single species advice for turbot and the qualitative single species advice for brill can/will be used to formulate a combined TAC for these two stocks. In this situation, improving the brill assessment may be necessary in order to ensure efficient management of both of these stocks. Ideally, a combined TAC should not be used.

21.8 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 update of the survey was provided in WGNSSK 2020 and 2021.

In 2020, 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).

Due to COVID-19 restrictions it was not possible for researchers to board the participating vessels. An alternative method was used, whereby, the survey fish were sorted from the catches and then labelled per station and stored by the vessel's crews. At the end of the survey week all collected survey fish was handed over to a team of researchers for processing in the fish auction. This method proved to be practically feasible and there were no indications of (noticeable) irregularities in sample collection.

The procedure for the random selection of survey stations and their assignment to the vessels remained unchanged from 2019 except for the number of selected stations. Instead of selecting the required 60 stations, a total of 75 stations were selected (Figure 21.8.1). Sixty stations were manually assigned to the vessels (20 each) and the remaining 15 stations were kept as 'spares', undisclosed to the skippers in case some of the stations were deemed unsuitable.

In total, 59 hauls were sampled in the 2020 survey, catching 454 brill and 1415 turbot. The numbers of turbot caught during this survey were approximately 9 times higher than caught during the BTS-ISIS survey. Length measurements ranged from 17 cm to 68 cm for turbot and 21 cm to 54 cm for brill in both 2019 and 2020 survey (Figure 21.8.2). Ageing was done over 1 cm-classes for 126 brill and 148 turbot, showing that most of the fish caught are within ages 1 to 3 (Figure 21.8.3.). 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 brill assessments. In this context, it is import to develop the age-structured index in advance and make a trial assessment including the "new" index into the assessment.

21.9 Issues for future benchmarks

21.9.1 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. More work should be done on getting LPUE data from other Member States. In 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.

21.9.2 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.

21.9.3 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.

21.10 References

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Table 21.2.1. Turbot in Area 4. Observed landings in numbers (units: thousands) SOP corrected.

Year	Age							
	1	2	3	4	5	6	7	8
1981	0	282.330	712.906	502.339	432.465	165.243	63.264	101.034
1982	0	149.504	925.331	236.198	147.734	258.314	86.694	137.119
1983	0	357.292	598.153	425.728	97.766	100.433	159.981	180.423
1984	0	1186.851	1119.999	284.808	143.777	54.947	52.199	178.577
1985	0	618.015	1877.367	508.405	139.151	84.734	20.212	124.380
1986	0	320.569	1270.178	602.254	158.124	57.892	25.058	107.144
1987	12.619	629.016	530.004	656.196	153.371	50.477	18.443	67.949
1988	32.245	970.934	803.439	159.434	157.642	80.613	25.079	68.969
1989	0	668.968	1167.878	354.756	156.543	82.213	31.534	68.699
1990	44.560	991.727	1069.449	316.068	165.806	75.649	101.556	113.992
1991–1997				NO DATA				
1998	0	404.599	867.639	356.646	72.678	29.446	8.467	14.243
1999–2002				NO DATA				
2003	209.891	1909.456	460.659	297.149	70.750	32.938	20.675	20.517
2004	435.038	1980.187	792.429	138.276	82.434	9.662	7.534	6.072
2005	343.884	1982.262	721.789	230.358	24.808	21.854	2.599	19.197
2006	888.352	1651.577	810.682	119.588	35.247	7.931	16.239	18.203
2007	79.305	2807.922	622.328	287.839	40.695	29.379	8.337	16.069
2008	179.475	1365.758	830.739	222.762	197.471	47.665	13.035	10.340
2009	121.514	1118.472	1044.670	451.131	95.631	26.922	11.850	19.916
2010	279.068	1405.944	386.546	309.944	172.060	88.269	30.641	19.587
2011	213.741	1967.663	610.688	112.187	139.502	78.043	32.681	23.910
2012	0.000	1920.526	781.619	268.323	42.709	64.285	73.448	24.867
2013	173.657	1590.229	1088.182	327.401	91.533	26.143	42.265	26.046
2014	65.496	372.461	618.447	650.101	130.768	115.918	36.152	99.928
2015	39.278	1213.722	464.183	325.938	315.920	109.598	43.122	79.630
2016	0.000	1032.477	986.958	331.150	355.737	186.039	44.817	70.107
2017	6.834	326.483	1643.832	593.509	137.326	61.989	97.075	60.062
2018	178.575	699.012	471.674	904.819	251.281	67.844	45.107	71.201
2019	171.184	1055.714	876.447	261.154	356.688	121.478	22.750	63.521
2020	211.476	1565.534	830.666	389.777	142.518	144.393	41.958	41.116

Table 21.2.1b. ICES estimated landings (tonnes) SOP corrected and discards of turbot in Area 4.

Year	Landings	Landing SOP	Discards	Year	Landings	Landing SOP	Discards
1981	4755	1		2020	3104	1	199
1982	4453	1					
1983	4575	1					
1984	5297	1					
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					
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 21.2.2a. Turbot in Area 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
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

Table 21.2.2b. Turbot in Area 4. Modelled weights at age in the catch (units: kg).

Year	Age 1	2	3	4	5	6	7	8
1981	0.355	0.757	1.303	1.964	2.709	3.508	4.333	5.947
1982	0.368	0.785	1.351	2.036	2.809	3.638	4.494	6.275
1983	0.380	0.812	1.397	2.106	2.906	3.763	4.648	6.357
1984	0.392	0.838	1.441	2.173	2.997	3.881	4.794	6.584
1985	0.404	0.861	1.482	2.234	3.082	3.991	4.931	6.996
1986	0.414	0.883	1.520	2.291	3.161	4.093	5.056	7.520
1987	0.423	0.903	1.554	2.343	3.232	4.185	5.169	7.867
1988	0.431	0.920	1.584	2.387	3.293	4.265	5.268	7.038
1989	0.438	0.935	1.609	2.425	3.345	4.332	5.351	7.482
1990	0.443	0.947	1.629	2.455	3.387	4.386	5.417	7.285
1991	0.447	0.955	1.643	2.477	3.417	4.424	5.465	7.528
1992	0.450	0.960	1.652	2.490	3.435	4.448	5.494	7.568
1993	0.450	0.961	1.654	2.494	3.440	4.455	5.503	7.580
1994	0.449	0.959	1.650	2.488	3.433	4.445	5.491	7.563
1995	0.447	0.953	1.640	2.473	3.412	4.418	5.457	7.517
1996	0.442	0.944	1.624	2.448	3.377	4.373	5.402	7.441
1997	0.436	0.931	1.601	2.414	3.330	4.312	5.326	7.336
1998	0.428	0.914	1.572	2.370	3.269	4.233	5.229	7.091
1999	0.418	0.893	1.537	2.317	3.197	4.139	5.113	7.043
2000	0.408	0.871	1.498	2.258	3.115	4.033	4.982	6.863
2001	0.396	0.846	1.455	2.194	3.026	3.918	4.840	6.667
2002	0.384	0.820	1.410	2.126	2.932	3.797	4.690	6.461
2003	0.371	0.793	1.364	2.056	2.836	3.672	4.536	6.261
2004	0.358	0.765	1.317	1.985	2.738	3.546	4.380	5.750
2005	0.346	0.738	1.270	1.915	2.641	3.420	4.225	5.413
2006	0.333	0.712	1.224	1.846	2.546	3.297	4.073	6.001
2007	0.321	0.686	1.180	1.779	2.455	3.179	3.926	5.263
2008	0.310	0.662	1.138	1.716	2.367	3.065	3.787	5.313
2009	0.299	0.639	1.099	1.657	2.285	2.959	3.655	5.100
2010	0.289	0.617	1.062	1.601	2.209	2.861	3.534	4.872
2011	0.280	0.598	1.029	1.551	2.140	2.771	3.423	4.416
2012	0.272	0.581	0.999	1.506	2.077	2.690	3.323	4.359
2013	0.265	0.565	0.973	1.466	2.023	2.619	3.236	4.148
2014	0.259	0.552	0.950	1.433	1.976	2.559	3.161	4.230
2015	0.254	0.542	0.932	1.405	1.939	2.510	3.101	4.300
2016	0.250	0.534	0.918	1.384	1.910	2.473	3.055	4.288
2017	0.248	0.528	0.909	1.371	1.891	2.448	3.025	4.224
2018	0.246	0.526	0.905	1.364	1.882	2.437	3.010	4.115
2019	0.247	0.527	0.906	1.366	1.884	2.440	3.014	4.092
2020	0.249	0.531	0.913	1.376	1.899	2.459	3.037	4.206

Table 21.2.3a. Turbot in Area 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
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

Table 21.2.3b. Turbot in Area 4. Modelled weights at age in the stock (units: kg)

Year	Age 1	2	3	4	5	6	7	8
1981	0.355	0.757	1.303	1.964	2.709	3.508	4.333	5.947
1982	0.368	0.785	1.351	2.036	2.809	3.638	4.494	6.275
1983	0.380	0.812	1.397	2.106	2.906	3.763	4.648	6.357
1984	0.392	0.838	1.441	2.173	2.997	3.881	4.794	6.584
1985	0.404	0.861	1.482	2.234	3.082	3.991	4.931	6.996
1986	0.414	0.883	1.520	2.291	3.161	4.093	5.056	7.520
1987	0.423	0.903	1.554	2.343	3.232	4.185	5.169	7.867
1988	0.431	0.920	1.584	2.387	3.293	4.265	5.268	7.038
1989	0.438	0.935	1.609	2.425	3.345	4.332	5.351	7.482
1990	0.443	0.947	1.629	2.455	3.387	4.386	5.417	7.285
1991	0.447	0.955	1.643	2.477	3.417	4.424	5.465	7.528
1992	0.450	0.960	1.652	2.490	3.435	4.448	5.494	7.568
1993	0.450	0.961	1.654	2.494	3.440	4.455	5.503	7.580
1994	0.449	0.959	1.650	2.488	3.433	4.445	5.491	7.563
1995	0.447	0.953	1.640	2.473	3.412	4.418	5.457	7.517
1996	0.442	0.944	1.624	2.448	3.377	4.373	5.402	7.441
1997	0.436	0.931	1.601	2.414	3.330	4.312	5.326	7.336
1998	0.428	0.914	1.572	2.370	3.269	4.233	5.229	7.091
1999	0.418	0.893	1.537	2.317	3.197	4.139	5.113	7.043
2000	0.408	0.871	1.498	2.258	3.115	4.033	4.982	6.863
2001	0.396	0.846	1.455	2.194	3.026	3.918	4.840	6.667
2002	0.384	0.820	1.410	2.126	2.932	3.797	4.690	6.461
2003	0.371	0.793	1.364	2.056	2.836	3.672	4.536	6.261
2004	0.358	0.765	1.317	1.985	2.738	3.546	4.380	5.750
2005	0.346	0.738	1.270	1.915	2.641	3.420	4.225	5.413
2006	0.333	0.712	1.224	1.846	2.546	3.297	4.073	6.001
2007	0.321	0.686	1.180	1.779	2.455	3.179	3.926	5.263
2008	0.310	0.662	1.138	1.716	2.367	3.065	3.787	5.313
2009	0.299	0.639	1.099	1.657	2.285	2.959	3.655	5.100
2010	0.289	0.617	1.062	1.601	2.209	2.861	3.534	4.872
2011	0.280	0.598	1.029	1.551	2.140	2.771	3.423	4.416
2012	0.272	0.581	0.999	1.506	2.077	2.690	3.323	4.359
2013	0.265	0.565	0.973	1.466	2.023	2.619	3.236	4.148
2014	0.259	0.552	0.950	1.433	1.976	2.559	3.161	4.230
2015	0.254	0.542	0.932	1.405	1.939	2.510	3.101	4.300
2016	0.250	0.534	0.918	1.384	1.910	2.473	3.055	4.288
2017	0.248	0.528	0.909	1.371	1.891	2.448	3.025	4.224
2018	0.246	0.526	0.905	1.364	1.882	2.437	3.010	4.115
2019	0.247	0.527	0.906	1.366	1.884	2.440	3.014	4.092
	0.249	0.531	0.913	1.376	1.899	2.459	3.037	4.206

Table 21.2.4. Turbot in Area 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 21.2.5. Turbot in Area 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 21.3.1. Turbot in Area 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							
2006	196.15	97.47	14.87	3.61	1.09	0.00							
2007	89.74	55.60	33.78	11.84	1.32	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 21.3.2. Turbot in Area 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
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

Table 21.3.3. Turbot in Area 4. Dutch_BT2_LPUE survey index (biomass)

Year	
1995	0.0426
1996	0.0371
1997	0.0375
1998	0.0347
1999	0.0349
2000	0.0444
2001	0.046
2002	0.0456
2003	0.0472
2004	0.0483
2005	0.0479
2006	0.049
2007	0.0652
2008	0.0681
2009	0.0671
2010	0.0584
2011	0.0604
2012	0.0744
2013	0.0767
2014	0.0747
2015	0.0859
2016	0.0954
2017	0.0936
2018	0.0786
2019	0.0834
2020	0.0860

Table 21.4.1a. Fbar (Ages 2–6) of turbot in Area 4.

Year	Fbar	Low	High	Year	Fbar	Low	High
1981	0.388	0.314	0.480	2020	0.350	0.279	0.440
1982	0.377	0.308	0.460				
1983	0.413	0.341	0.500				
1984	0.458	0.379	0.553				
1985	0.498	0.412	0.603				
1986	0.479	0.393	0.583				
1987	0.488	0.400	0.596				
1988	0.475	0.385	0.586				
1989	0.589	0.486	0.715				
1990	0.711	0.573	0.884				
1991	0.759	0.604	0.952				
1992	0.792	0.629	0.997				
1993	0.822	0.657	1.028				
1994	0.832	0.670	1.033				
1995	0.817	0.661	1.009				
1996	0.746	0.614	0.907				
1997	0.684	0.550	0.850				
1998	0.652	0.528	0.805				
1999	0.619	0.503	0.763				
2000	0.640	0.521	0.787				
2001	0.697	0.572	0.850				
2002	0.761	0.612	0.947				
2003	0.716	0.599	0.856				
2004	0.638	0.533	0.764				
2005	0.566	0.469	0.682				
2006	0.443	0.362	0.543				
2007	0.410	0.335	0.502				
2008	0.380	0.312	0.462				
2009	0.429	0.352	0.521				
2010	0.410	0.338	0.497				
2011	0.368	0.300	0.452				
2012	0.348	0.285	0.425				
2013	0.330	0.270	0.402				
2014	0.325	0.271	0.402				
2015	0.324	0.270	0.406				
2016	0.348	0.289	0.442				
2017	0.350	0.291	0.438				
2018	0.363	0.298	0.454				
2019	0.367	0.288	0.468				

Table 21.4.1b. Total and Spawning stock Biomass of turbot in Area 4 (tonnes).

Year	TSB	Low	High	SSB	Low	High
1981	19641	15965	24164	15393	11941	19842
1982	18334	14836	22658	13728	10488	17969
1983	18454	15094	22563	12331	9341	16278
1984	19434	16196	23318	11333	8632	14878
1985	18749	15817	22226	11448	8996	14568
1986	16266	13614	19434	10915	8600	13852
1987	14757	12276	17740	9716	7522	12550
1988	13887	11634	16576	8014	6113	10506
1989	14233	11923	16990	7989	6136	10402
1990	14115	11456	17392	6934	5211	9226
1991	13967	10669	18286	5769	4115	8089
1992	13283	10085	17495	5394	3893	7474
1993	12090	9324	15678	4891	3603	6639
1994	10812	8543	13684	4106	3062	5506
1995	9970	8219	12095	3724	2935	4724
1996	9221	7729	11001	3240	2573	4080
1997	8856	7551	10388	3504	2901	4231
1998	8740	7487	10203	3749	3193	4401
1999	8894	7280	10865	3619	2848	4599
2000	9878	8139	11990	3999	3184	5024
2001	9602	7989	11540	3817	3075	4739
2002	9321	7903	10994	3656	3046	4389
2003	8797	7730	10011	3042	2593	3569
2004	8532	7546	9647	2851	2407	3377
2005	8331	7326	9473	2905	2430	3473
2006	8703	7641	9912	3162	2606	3837
2007	9960	8830	11235	3961	3301	4753
2008	10007	8833	11337	4830	4019	5803
2009	10009	8738	11466	5954	4963	7141
2010	9685	8352	11232	5681	4606	7007
2011	10415	8895	12194	5322	4231	6694
2012	11238	9631	13113	5854	4691	7306
2013	11288	9668	13179	6863	5586	8432
2014	12159	10401	14215	8141	6663	9948
2015	13945	11841	16423	8101	6442	10187
2016	14580	12448	17078	8362	6670	10485
2017	14131	12113	16484	9272	7596	11317
2018	13383	11359	15767	9187	7444	11338
2019	13640	11535	16128	8420	6677	10619
2020	14035	11646	16913	8343	6529	10662

Table 21.4.1c. Recruitment (Age 1) of turbot in Area 4. (Thousands)

Year	Value	Low	High	Year	Value	Low	High
1981	2559.23	1850.64	3539.13	2018	5829.87	4434.50	7664.30
1982	4205.67	3111.83	5684.02	2019	7094.35	5111.81	9845.78
1983	6446.80	4726.48	8793.28	2020	6374.03	3799.60	10692.78
1984	5010.25	3620.87	6932.74				
1985	2487.28	1790.65	3454.92				
1986	3395.51	2514.63	4584.96				
1987	3972.87	2933.69	5380.16				
1988	3748.36	2734.84	5137.48				
1989	4502.16	2971.49	6821.31				
1990	5778.43	3602.16	9269.49				
1991	5008.73	3233.42	7758.79				
1992	4413.22	2849.21	6835.76				
1993	4899.31	3253.24	7378.26				
1994	3794.25	2517.67	5718.10				
1995	4754.23	3358.77	6729.46				
1996	3310.14	2405.46	4555.05				
1997	2839.96	2039.57	3954.44				
1998	4050.76	2856.11	5745.10				
1999	3442.49	2355.61	5030.87				
2000	5433.53	3836.58	7695.19				
2001	3586.80	2424.32	5306.68				
2002	5862.00	4325.24	7944.76				
2003	4836.85	3635.57	6435.07				
2004	5905.79	4516.50	7722.43				
2005	4505.88	3466.47	5856.96				
2006	6355.54	4879.88	8277.45				
2007	5278.08	4050.23	6878.16				
2008	3253.31	2419.99	4373.59				
2009	3970.37	3008.51	5239.76				
2010	5425.11	4181.33	7038.87				
2011	6838.45	5092.24	9183.47				
2012	4181.95	3148.94	5553.85				
2013	3300.38	2497.51	4361.33				
2014	6713.69	5114.09	8813.61				
2015	9134.54	6802.49	12266.06				
2016	3114.57	2316.26	4188.01				
2017	5044.40	3846.96	6614.57				

Table 21.4.2. Turbot in Area 4. Estimated fishing mortality

Year	Age							
	1	2	3	4	5	6	7	8
1981	0.002	0.118	0.615	0.532	0.358	0.316	0.229	0.229
1982	0.002	0.112	0.575	0.513	0.358	0.324	0.243	0.243
1983	0.003	0.135	0.607	0.560	0.402	0.360	0.278	0.278
1984	0.004	0.178	0.673	0.611	0.442	0.385	0.289	0.289
1985	0.005	0.206	0.728	0.669	0.484	0.405	0.290	0.290
1986	0.005	0.211	0.687	0.634	0.470	0.392	0.279	0.279
1987	0.006	0.244	0.725	0.628	0.464	0.381	0.273	0.273
1988	0.007	0.259	0.725	0.573	0.443	0.374	0.281	0.281
1989	0.009	0.328	0.909	0.710	0.553	0.448	0.360	0.360
1990	0.012	0.383	1.05	0.846	0.698	0.579	0.536	0.536
1991	0.014	0.409	1.103	0.906	0.754	0.621	0.596	0.596
1992	0.016	0.440	1.143	0.940	0.786	0.649	0.652	0.652
1993	0.019	0.483	1.190	0.968	0.804	0.662	0.692	0.692
1994	0.022	0.508	1.217	0.975	0.803	0.656	0.701	0.701
1995	0.023	0.505	1.186	0.960	0.789	0.644	0.707	0.707
1996	0.017	0.398	1.038	0.888	0.767	0.641	0.743	0.743
1997	0.014	0.321	0.890	0.814	0.746	0.649	0.797	0.797
1998	0.013	0.298	0.821	0.765	0.727	0.649	0.849	0.849
1999	0.015	0.318	0.778	0.724	0.675	0.602	0.801	0.801
2000	0.025	0.440	0.842	0.741	0.646	0.533	0.646	0.646
2001	0.040	0.588	0.929	0.800	0.660	0.509	0.572	0.572
2002	0.067	0.821	1.006	0.846	0.662	0.473	0.487	0.487
2003	0.072	0.824	0.934	0.789	0.610	0.425	0.412	0.412
2004	0.074	0.796	0.864	0.699	0.498	0.333	0.275	0.275
2005	0.063	0.673	0.788	0.616	0.440	0.312	0.269	0.269
2006	0.047	0.530	0.605	0.457	0.346	0.277	0.264	0.264
2007	0.040	0.510	0.542	0.416	0.319	0.264	0.244	0.244
2008	0.036	0.457	0.496	0.384	0.306	0.255	0.221	0.221
2009	0.050	0.603	0.577	0.415	0.304	0.245	0.208	0.208
2010	0.045	0.558	0.549	0.398	0.296	0.247	0.210	0.210
2011	0.035	0.477	0.494	0.368	0.272	0.230	0.193	0.193
2012	0.028	0.417	0.463	0.369	0.266	0.224	0.183	0.183
2013	0.024	0.376	0.427	0.362	0.264	0.220	0.169	0.169
2014	0.015	0.290	0.403	0.378	0.298	0.257	0.211	0.211
2015	0.011	0.259	0.391	0.386	0.319	0.264	0.205	0.205
2016	0.010	0.242	0.411	0.437	0.367	0.286	0.210	0.210
2017	0.009	0.229	0.417	0.447	0.372	0.283	0.201	0.201
2018	0.014	0.263	0.435	0.453	0.380	0.286	0.192	0.192
2019	0.019	0.304	0.447	0.446	0.369	0.269	0.167	0.167
2020	0.021	0.310	0.425	0.419	0.347	0.249	0.146	0.146

Table 21.4.3. Turbot in Area 4. Estimated population abundance (units: thousands)

Year	Age 1	2	3	4	5	6	7	8
1981	2559.23	3105.04	1612.05	1319.61	1764.83	714.68	361.13	600.79
1982	4205.67	2019.03	2292.67	673.44	628.24	1023.88	429.87	637.14
1983	6446.80	3453.25	1479.90	1061.78	328.09	362.60	614.33	693.78
1984	5010.25	5522.17	2518.12	684.82	486.80	178.98	208.75	804.65
1985	2487.28	4217.49	3770.16	1083.14	318.16	254.10	98.65	617.96
1986	3395.51	1887.94	2959.08	1404.15	442.15	163.55	136.14	442.83
1987	3972.87	2797.07	1168.95	1373.87	576.47	219.13	90.24	358.52
1988	3748.36	3312.00	1781.05	454.36	594.93	288.71	122.00	284.54
1989	4502.16	2978.42	2043.50	740.26	238.51	317.95	158.49	254.33
1990	5778.43	3634.89	1746.74	628.82	302.54	119.96	174.03	241.32
1991	5008.73	4833.35	2036.46	485.38	216.42	122.59	55.71	199.14
1992	4413.22	4134.29	2651.21	550.54	159.22	82.06	53.65	115.04
1993	4899.31	3517.16	2201.78	683.42	177.65	58.75	34.38	72.01
1994	3794.25	4023.95	1687.96	556.34	211.59	64.63	24.96	43.68
1995	4754.23	2854.20	1949.14	399.98	177.13	78.50	27.51	27.96
1996	3310.14	3915.24	1317.21	486.62	125.87	68.19	34.48	22.46
1997	2839.96	2742.63	2145.43	367.51	163.71	47.26	30.49	22.40
1998	4050.76	2271.72	1638.44	733.94	131.74	63.10	19.71	20.09
1999	3442.49	3304.19	1388.60	576.03	287.15	51.44	26.65	13.90
2000	5433.53	2642.53	2031.19	551.49	229.65	126.80	23.09	14.91
2001	3586.80	4317.35	1293.88	702.88	220.84	97.42	63.09	16.34
2002	5862.00	2672.46	1982.13	402.14	255.30	96.78	47.58	37.21
2003	4836.85	4553.82	895.89	596.74	134.73	105.34	50.45	43.86
2004	5905.79	3592.19	1589.01	286.34	221.15	55.29	54.88	49.13
2005	4505.88	4429.05	1308.74	527.42	108.42	106.72	30.15	67.24
2006	6355.54	3478.48	1871.79	415.36	219.31	54.97	64.48	62.26
2007	5278.08	5123.76	1715.84	894.10	217.42	132.35	34.63	78.82
2008	3253.31	4371.17	2515.11	806.45	476.87	132.92	84.40	71.17
2009	3970.37	2448.42	2408.79	1392.12	472.92	262.83	81.35	102.55
2010	5425.11	3264.90	1001.42	1077.09	750.94	297.46	164.63	119.55
2011	6838.45	4241.66	1648.69	435.12	603.91	455.03	186.01	179.12
2012	4181.95	5746.57	2221.94	900.48	252.95	387.40	307.56	233.72
2013	3300.38	3385.67	3479.51	1161.46	521.59	168.40	264.59	357.24
2014	6713.69	2388.79	2007.12	2142.17	685.82	351.31	118.72	461.13
2015	9134.54	5546.04	1574.84	1162.53	1293.74	433.32	225.82	405.85
2016	3114.57	7735.89	3374.36	943.99	680.49	766.30	268.43	419.04
2017	5044.40	2316.67	5181.65	1746.06	490.04	368.97	465.91	436.20
2018	5829.87	4010.77	1479.34	2662.57	892.97	276.00	229.31	564.31
2019	7094.35	4694.91	2575.89	789.99	1402.99	501.18	168.45	522.99
2020	6374.03	5666.68	2778.41	1288.28	424.65	787.51	316.44	464.85

Table 21.5.1a. Turbot in Area 4. Predicted catch numbers at age (units: thousands)

Year	Age 1	2	3	4	5	6	7	8
1981	5.01	314.72	677.97	498.11	484.10	176.53	67.28	5.01
1982	7.66	194.57	917.78	247.09	172.52	258.42	84.50	7.66
1983	15.00	394.83	616.73	416.33	99.00	100.05	135.82	15.00
1984	17.03	818.14	1130.32	286.81	158.71	52.18	47.65	17.03
1985	10.30	713.06	1789.17	484.25	111.52	77.14	22.62	10.30
1986	14.51	326.17	1348.02	603.65	151.47	48.35	30.15	14.51
1987	20.68	550.74	553.10	586.99	195.41	63.27	19.61	20.68
1988	22.55	687.89	842.45	181.24	194.39	82.24	27.24	22.55
1989	37.84	758.55	1122.12	345.05	92.66	104.84	43.71	37.84
1990	60.98	1055.77	1047.10	330.01	139.32	48.25	66.00	60.98
1991	61.22	1481.53	1255.24	266.05	105.15	51.91	22.90	61.22
1992	63.11	1344.06	1667.68	308.84	79.60	35.91	23.55	63.11
1993	84.17	1231.93	1415.22	390.36	90.14	26.07	15.74	84.17
1994	73.93	1464.07	1098.08	319.05	107.26	28.50	11.53	73.93
1995	96.99	1033.69	1250.67	227.23	88.73	34.12	12.78	96.99
1996	51.97	1172.49	784.15	263.41	61.88	29.56	16.58	51.97
1997	35.38	685.65	1162.94	188.06	78.98	20.67	15.38	35.38
1998	48.48	533.70	842.80	360.13	62.45	27.59	10.37	48.48
1999	47.67	819.12	689.05	272.14	129.15	21.31	13.49	47.67
2000	123.73	858.04	1062.65	264.89	100.13	47.90	10.06	123.73
2001	128.65	1755.65	720.40	355.33	97.73	35.53	25.16	128.65
2002	344.69	1374.59	1158.31	210.93	113.26	33.31	16.77	344.69
2003	303.50	2348.45	500.38	298.89	56.30	33.26	15.54	303.50
2004	382.57	1811.07	845.15	132.03	79.28	14.26	12.00	382.57
2005	248.83	1989.10	655.34	221.98	35.22	26.04	6.47	248.83
2006	262.57	1309.31	778.07	139.15	58.45	12.11	13.63	262.57
2007	189.72	1870.27	656.98	277.61	54.13	27.94	6.81	189.72
2008	104.18	1463.65	899.31	234.40	114.54	27.28	15.21	104.18
2009	174.64	1015.45	965.90	431.27	112.83	51.94	13.88	174.64
2010	214.75	1277.33	387.14	322.59	175.40	59.29	28.39	214.75
2011	210.90	1468.81	587.02	122.09	130.97	85.00	29.72	210.90
2012	105.71	1787.22	752.71	253.64	53.87	70.67	46.64	105.71
2013	71.20	968.28	1103.95	321.72	110.05	30.23	37.45	71.20
2014	87.73	547.38	607.49	615.32	160.97	72.49	20.50	87.73
2015	91.73	1151.44	465.01	339.58	321.81	91.51	38.02	91.73
2016	28.37	1511.45	1038.23	305.17	190.53	173.37	46.24	28.37
2017	42.33	430.82	1611.31	575.05	138.95	82.83	77.27	42.33
2018	74.14	844.61	475.97	885.45	257.62	62.50	36.47	74.14
2019	122.67	1121.05	847.53	259.48	394.73	107.60	23.50	122.67
2020	121.49	1376.05	877.40	402.25	113.62	158.09	39.15	121.49

Table 21.5.1b. Turbot in Area 4. Catch at age residuals

Year	Age							
	1	2	3	4	5	6	7	8
1981	0.000	-2.011	0.028	3.131	0.594	0.139	0.979	2.839
1982	0.000	1.548	0.204	-1.282	-1.574	-1.426	-0.396	0.100
1983	0.000	1.356	-0.003	0.946	0.368	-0.096	0.127	-0.043
1984	0.000	2.226	0.016	0.580	-0.081	-0.098	-0.268	-0.908
1985	0.000	-0.436	-0.246	0.605	0.968	-0.178	-0.771	-0.907
1986	0.000	-1.101	-0.435	-0.982	-0.060	0.189	-0.727	-0.192
1987	0.340	0.783	-1.856	1.356	-1.022	-1.133	-0.080	-0.686
1988	0.740	0.937	-0.740	-1.477	-0.048	-0.044	0.083	0.070
1989	0.000	-0.466	0.234	0.838	2.581	-0.327	-0.334	-0.025
1990	0.595	0.316	-0.157	-1.377	0.747	1.864	1.960	0.314
1991–1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	-0.104	-0.294	0.437	0.611	0.054	-0.403	0.905
1999–2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	1.297	0.495	-2.586	-0.352	-0.613	-1.216	0.178	0.930
2004	0.903	0.142	-1.170	-0.363	-0.485	-2.416	-2.205	-1.910
2005	0.162	-0.512	0.349	-0.694	-1.579	-0.503	-2.383	1.487
2006	1.360	0.509	-0.775	-3.060	-1.692	-0.873	1.213	0.949
2007	-1.299	1.221	-0.933	0.932	-0.391	0.941	0.584	-0.481
2008	0.015	-0.111	-0.657	-0.406	1.577	1.568	-0.686	-0.946
2009	-0.067	0.313	1.164	1.130	-0.488	-2.348	-0.499	0.333
2010	0.692	1.007	-1.285	-0.603	-0.014	1.556	0.036	-0.314
2011	-0.127	0.551	0.935	-1.158	0.114	-0.300	0.065	-0.806
2012	0.000	-0.053	0.217	1.583	-0.657	-0.062	1.165	-1.618
2013	0.062	0.509	0.691	0.520	-0.281	0.109	0.290	-2.165
2014	-0.756	-2.388	0.545	1.931	0.152	2.088	1.919	0.564
2015	-0.937	0.480	0.919	0.452	0.705	0.526	-0.157	0.220
2016	0.000	-1.497	-0.209	1.931	2.297	0.036	-0.555	-0.229
2017	-1.403	-0.976	1.204	-0.050	-0.048	-1.032	0.439	-0.709
2018	1.802	-0.655	-0.318	-0.394	0.004	0.341	0.336	-1.079
2019	1.047	0.119	0.106	-0.191	-0.172	0.157	-0.619	-0.790
2020	0.662	0.159	-1.043	-0.807	0.743	-0.467	-0.039	-1.215

Table 21.5.2a. Turbot in Area 4. Predicted index at age SNS

Year	Age					
	1	2	3	4	5	6
2004	101.9713758	37.27367	10.39421	0.98663	0.878012	0.246618
2005	78.4203839	50.11841	9.031047	1.927375	0.448503	0.483163
2006	111.8808308	43.53593	14.69522	1.697349	0.969329	0.255064
2007	93.3190143	65.07126	14.08081	3.761427	0.979238	0.619744
2008	57.702534	57.62735	21.32104	3.470473	2.16756	0.626101
2009	69.741006	29.10799	19.29649	5.861288	2.153241	1.247414
2010	95.636122	40.07481	8.178085	4.588868	3.436935	1.409369
2011	121.40602	55.14558	14.00279	1.893667	2.811617	2.182516
2012	74.575881	77.92917	19.27814	3.914247	1.182319	1.866035
2013	59.0291537	47.24071	30.97389	5.074878	2.442759	0.813454
2014	120.890327	35.42543	18.17231	9.254036	3.135176	1.652959
2015	164.873924	84.06128	14.37909	4.994649	5.827962	2.028981
2016	56.257636	118.6818	30.37531	3.912172	2.963522	3.533791
2017	91.166999	35.86981	46.46704	7.184153	2.125656	1.704576
2018	105.004822	60.6107	13.09959	10.91294	3.852159	1.272469
2019	127.318811	68.93351	22.61299	3.25379	6.100735	2.338492
2020	114.231177	82.84973	24.77583	5.408684	1.874693	3.726025

Table 21.5.2b. Turbot in Area 4. Index at age residuals SNS

	Age					
Year	1	2	3	4	5	6
2004	0.417	-1.468	1.155	0.991	1.062	1.637
2005	-0.619	2.058	0.365	0.000	0.000	0.000
2006	1.032	1.107	-0.334	0.849	-0.299	0.000
2007	0.044	-0.074	1.804	0.669	-0.173	0.000
2008	-0.622	1.698	0.454	0.778	0.893	-0.183
2009	-1.286	-0.503	-1.249	2.015	0.586	0.000
2010	0.608	0.011	0.000	0.114	-0.009	1.581
2011	0.382	-0.593	0.000	0.000	0.000	-0.211
2012	-1.208	-0.082	-0.279	-0.697	0.000	0.000
2013	0.497	-1.824	0.383	-2.183	0.000	0.000
2014	1.046	-1.282	-0.233	0.086	0.673	-0.530
2015	1.718	-1.283	-2.202	0.467	0.000	0.000
2016	-1.406	0.962	-0.362	-0.675	-0.557	-1.605
2017	2.202	-0.765	0.031	-3.098	0.000	-0.543
2018	-0.215	0.405	0.056	0.542	0.458	0.513
2019	0.207	0.056	-0.488	-0.526	0.090	-0.936
2020	-0.867	-0.245	1.569	-0.612	0.134	0.255

Table 21.5.3a. Turbot in Area 4. Predicted index at age BTS-ISIS

Year	Age						
	1	2	3	4	5	6	7
1991	1.657	1.209	0.192	0.052	0.019	0.012	0.005
1992	1.457	1.012	0.243	0.058	0.014	0.008	0.005
1993	1.614	0.835	0.195	0.071	0.015	0.005	0.003
1994	1.248	0.940	0.147	0.057	0.018	0.006	0.002
1995	1.562	0.668	0.173	0.042	0.015	0.007	0.002
1996	1.092	0.988	0.130	0.053	0.011	0.006	0.003
1997	0.939	0.731	0.235	0.042	0.014	0.004	0.003
1998	1.340	0.615	0.188	0.088	0.012	0.006	0.002
1999	1.137	0.882	0.164	0.071	0.027	0.005	0.002
2000	1.782	0.647	0.230	0.067	0.022	0.013	0.002
2001	1.164	0.953	0.138	0.082	0.021	0.010	0.006
2002	1.867	0.500	0.200	0.045	0.024	0.010	0.005
2003	1.536	0.851	0.095	0.070	0.013	0.012	0.006
2004	1.872	0.684	0.177	0.036	0.023	0.006	0.007
2005	1.440	0.920	0.154	0.070	0.012	0.013	0.004
2006	2.054	0.799	0.250	0.062	0.026	0.007	0.008
2007	1.713	1.195	0.240	0.137	0.026	0.016	0.004
2008	1.059	1.058	0.363	0.126	0.057	0.016	0.011
2009	1.280	0.534	0.329	0.213	0.057	0.033	0.010
2010	1.756	0.736	0.139	0.167	0.091	0.037	0.021
2011	2.229	1.012	0.238	0.069	0.074	0.057	0.024
2012	1.369	1.431	0.328	0.142	0.031	0.049	0.040
2013	1.084	0.867	0.527	0.184	0.064	0.021	0.035
2014	2.219	0.650	0.309	0.336	0.083	0.044	0.015
2015	3.027	1.543	0.245	0.181	0.153	0.053	0.029
2016	1.033	2.179	0.517	0.142	0.078	0.093	0.034
2017	1.674	0.658	0.791	0.261	0.056	0.045	0.060
2018	1.928	1.113	0.223	0.396	0.101	0.034	0.030
2019	2.337	1.265	0.385	0.118	0.161	0.062	0.022
2020	2.097	1.521	0.422	0.196	0.049	0.098	0.042

Table 21.5.3b. Turbot in Area 4. Index at age residuals BTS-ISIS

Year	Age						
	1	2	3	4	5	6	7
1991	-0.590	0.734	-1.027	-2.236	-0.958	0.000	0.197
1992	-0.085	0.517	0.207	-1.291	-0.390	-0.290	-1.036
1993	0.246	0.800	-0.474	-0.776	0.901	-1.594	-1.741
1994	0.168	0.783	-1.571	-0.678	-0.931	-0.389	0.650
1995	0.015	-1.099	-0.984	-1.188	0.252	-0.191	0.000
1996	-1.544	1.877	-0.214	1.228	1.846	0.000	1.391
1997	-0.500	1.762	1.450	-0.463	1.273	1.198	1.701
1998	1.386	0.764	0.728	0.988	-1.026	0.000	-0.392
1999	-0.167	0.428	0.159	0.606	-0.235	-0.505	-0.636
2000	1.780	-0.671	0.780	1.251	1.112	1.917	0.000
2001	-1.348	-0.147	-1.651	0.357	0.000	0.000	2.313
2002	1.085	-1.688	-1.775	-0.674	-0.006	0.816	-1.498
2003	-0.531	-0.280	0.078	-0.575	0.000	-0.051	0.930
2004	-0.209	-0.288	1.470	0.000	1.012	0.727	0.000
2005	-0.720	0.592	2.399	0.503	1.055	-0.860	1.113
2006	-0.384	-0.010	0.867	1.164	-1.720	0.000	0.000
2007	-0.268	-0.133	2.720	1.337	1.552	1.483	0.000
2008	0.022	0.403	0.602	0.167	0.119	-0.032	2.228
2009	0.059	-1.022	0.236	0.582	1.262	0.426	-0.868
2010	0.476	-1.078	-0.725	-1.153	0.036	-1.060	-0.497
2011	0.005	0.158	-0.305	0.007	-0.079	-1.327	0.000
2012	-0.548	0.213	-0.057	1.036	-0.210	0.018	0.752
2013	-1.753	0.175	0.713	0.123	-1.192	0.786	0.183
2014	1.154	-2.357	-0.022	0.271	0.518	0.163	-0.007
2015	1.032	-0.083	0.146	-0.764	-0.350	0.000	-0.878
2016	-1.540	0.253	-0.364	-1.407	-0.933	-0.971	-0.369
2017	0.708	-1.461	-0.149	-2.335	-1.635	-1.269	-0.546
2018	-0.684	-0.129	0.327	-0.493	0.515	-0.091	0.000
2019	0.275	-0.549	0.016	-1.587	-0.315	-1.401	0.000
2020	-0.449	-0.459	-0.116	-0.603	-0.426	-0.607	-0.011

Table 21.5.4. Turbot in Area 4. Predicted index and residuals of the Dutch LPUE

year	Index	Residuals
1995	0.042	0.380
1996	0.038	-0.963
1997	0.038	-1.515
1998	0.035	-0.359
1999	0.036	-0.311
2000	0.044	0.026
2001	0.047	-0.283
2002	0.045	0.112
2003	0.046	0.927
2004	0.048	-0.813
2005	0.050	-2.661
2006	0.052	-0.725
2007	0.064	0.732
2008	0.069	-0.016
2009	0.066	0.189
2010	0.057	1.461
2011	0.062	0.354
2012	0.075	1.795
2013	0.078	2.052
2014	0.074	2.313
2015	0.079	2.708
2016	0.090	1.308
2017	0.092	-0.263
2018	0.082	-1.335
2019	0.081	0.933
2020	0.085	0.492

Table 21.5.5. Turbot in Area 4. Fit parameters

Name	value	std.dev
logFpar	-3.866	0.135
logFpar	-4.279	0.195
logFpar	-5.037	0.247
logFpar	-7.864	0.073
logFpar	-8.352	0.088
logFpar	-8.674	0.164
logFpar	-9.762	0.089
logSdLogFsta	-0.802	0.400
logSdLogFsta	-1.405	0.233
logSdLogFsta	-1.982	0.217
logSdLogN	-1.900	0.273
logSdLogN	-1.527	0.291
logSdLogObs	-0.866	0.166
logSdLogObs	-2.194	0.334
logSdLogObs	-0.174	0.225
logSdLogObs	-1.205	0.276
logSdLogObs	-2.265	0.369
logSdLogObs	-1.130	0.139
logSdLogObs	-1.066	0.157
logSdLogObs	-0.505	0.147
logSdLogObs	-0.227	0.172
transfIRARdist	0.086	0.122
itrans_rho	-0.906	0.091

Table 21.5.6. Turbot in Area 4. Negative Log-Likelihood

414.262

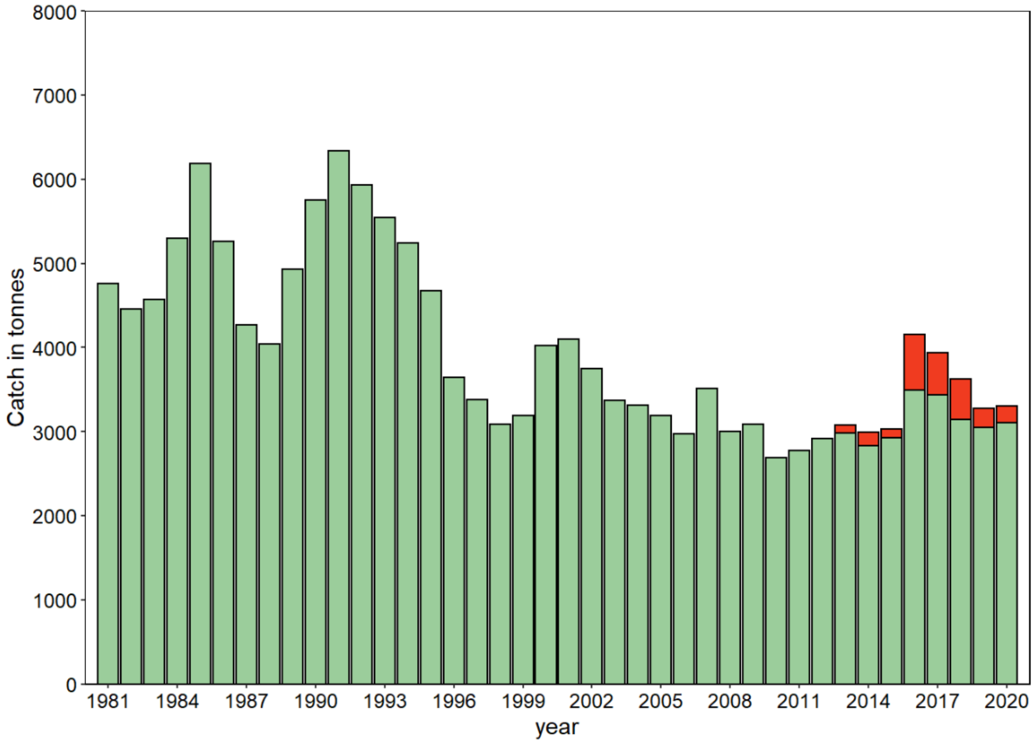


Figure 21.2.1. Turbot in 27.4.20. Total catches 1981–2020. ICES estimated landings (green) and discards (red).

Figure 21.2.2. Turbot in 27.4.20. Landings at age for the years with available data between 1975–2020. Data for 1991–1997 and 1999–2002 are missing.

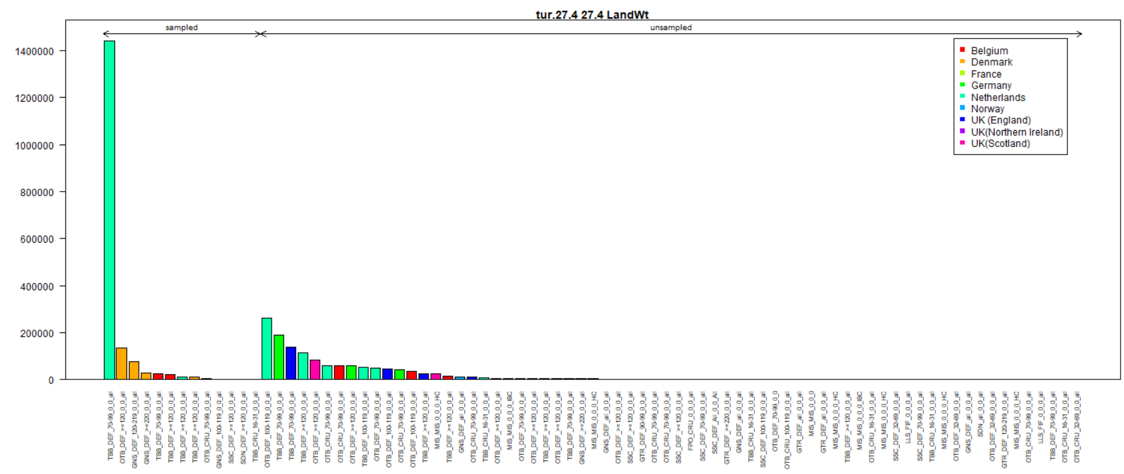


Figure 21.2.3. Turbot in 27.4.20: Total landings by métier in 2020 sorted by sampled/unsampled for numbers at age in InterCatch.

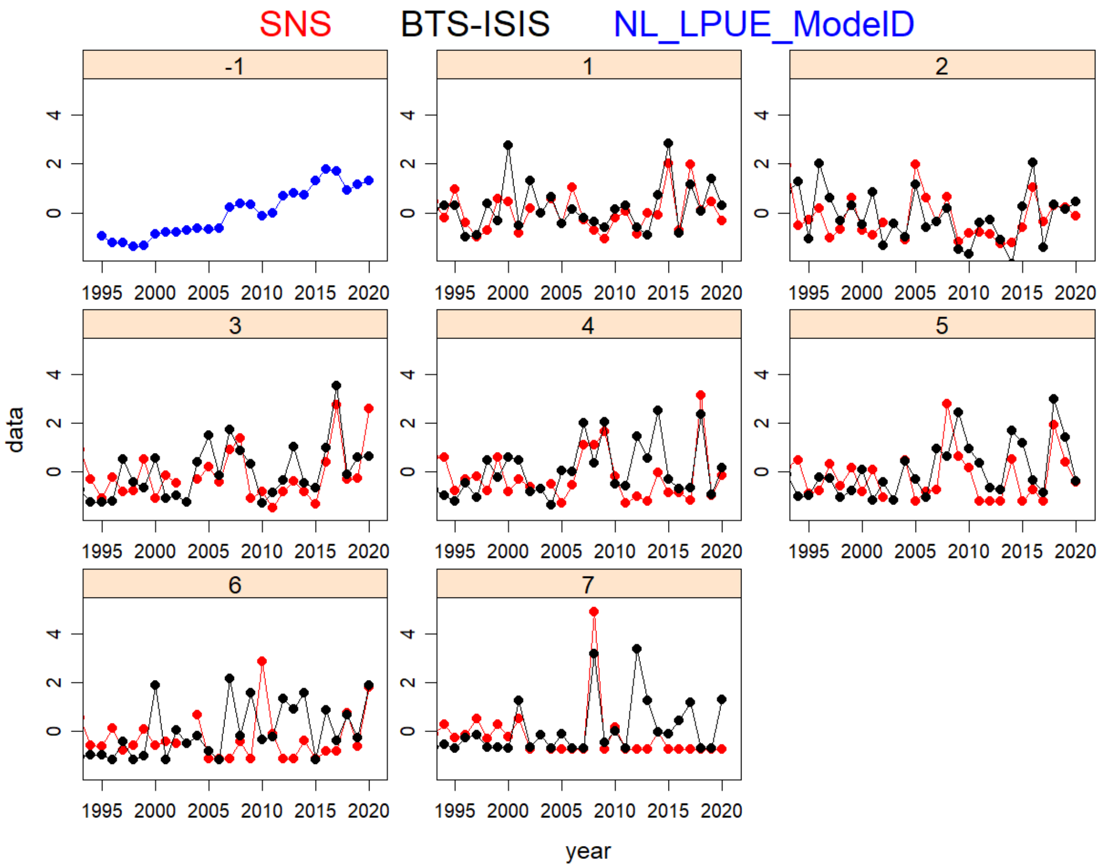
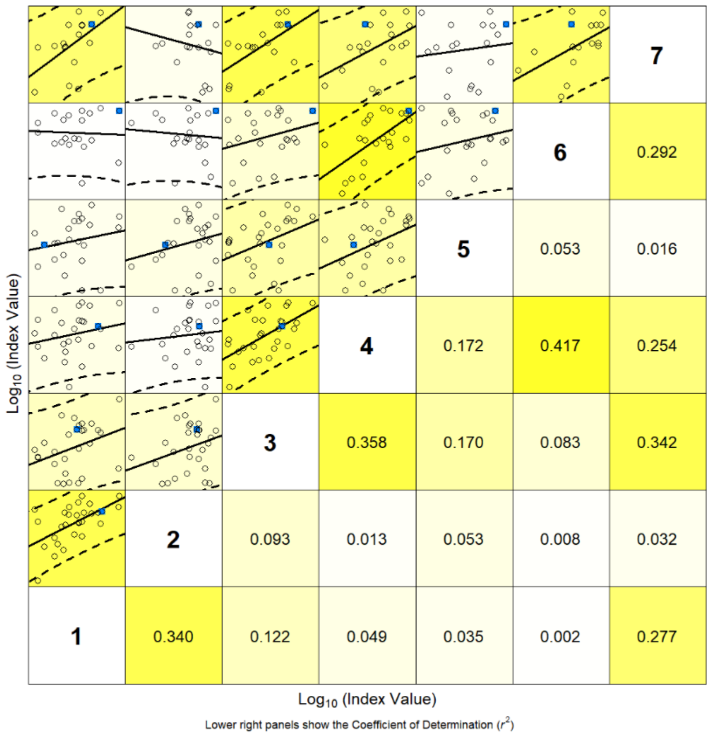


Figure 21.2.4. Turbot in 27.4.20. Time series of the standardized indices for ages 1 to 7 from the three tuning fleets available for the assessment: BTS-ISIS (black), SNS (red) and NL beam trawl LPUE (shown in the "-1" panel).



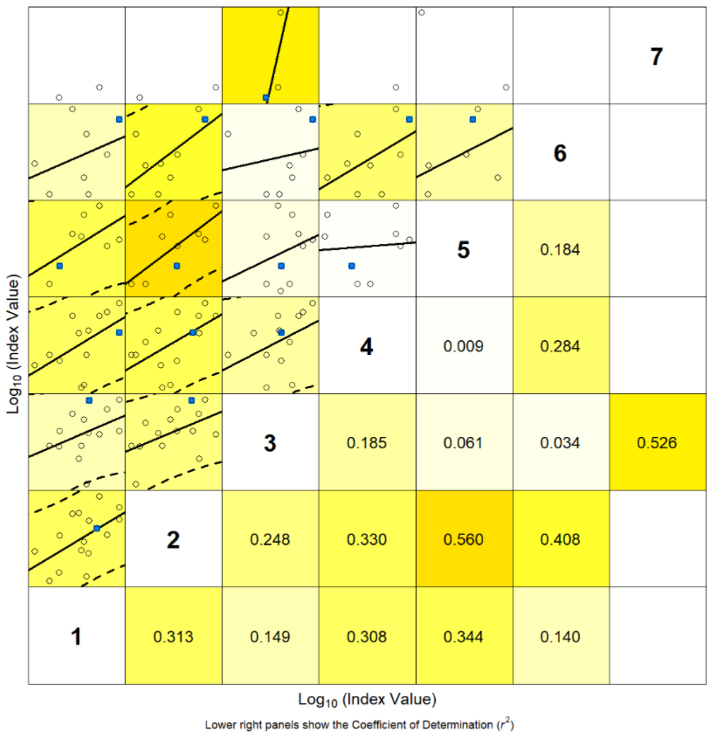


Figure 21.2.5. Turbot in 27.4.20. Internal consistency of the two tuning indices available for the assessment: BTS-ISIS from 1991–2020 (top), and SNS 2004–2020 (bottom).

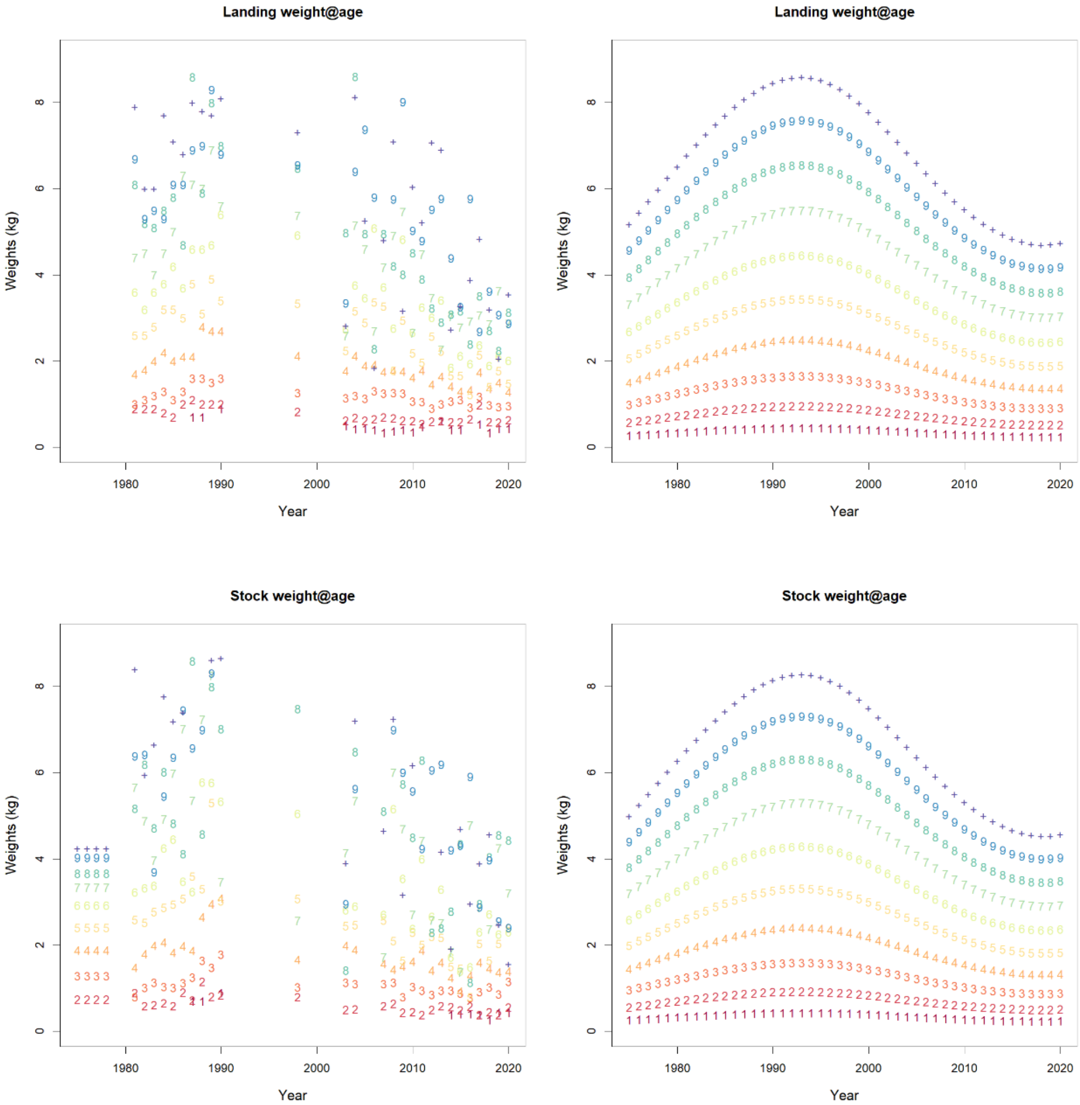


Figure 21.2.6. Raw landings (top-left), modelled landings (top right) and raw stock (bottom left) and modelled (bottom right) weight at age.

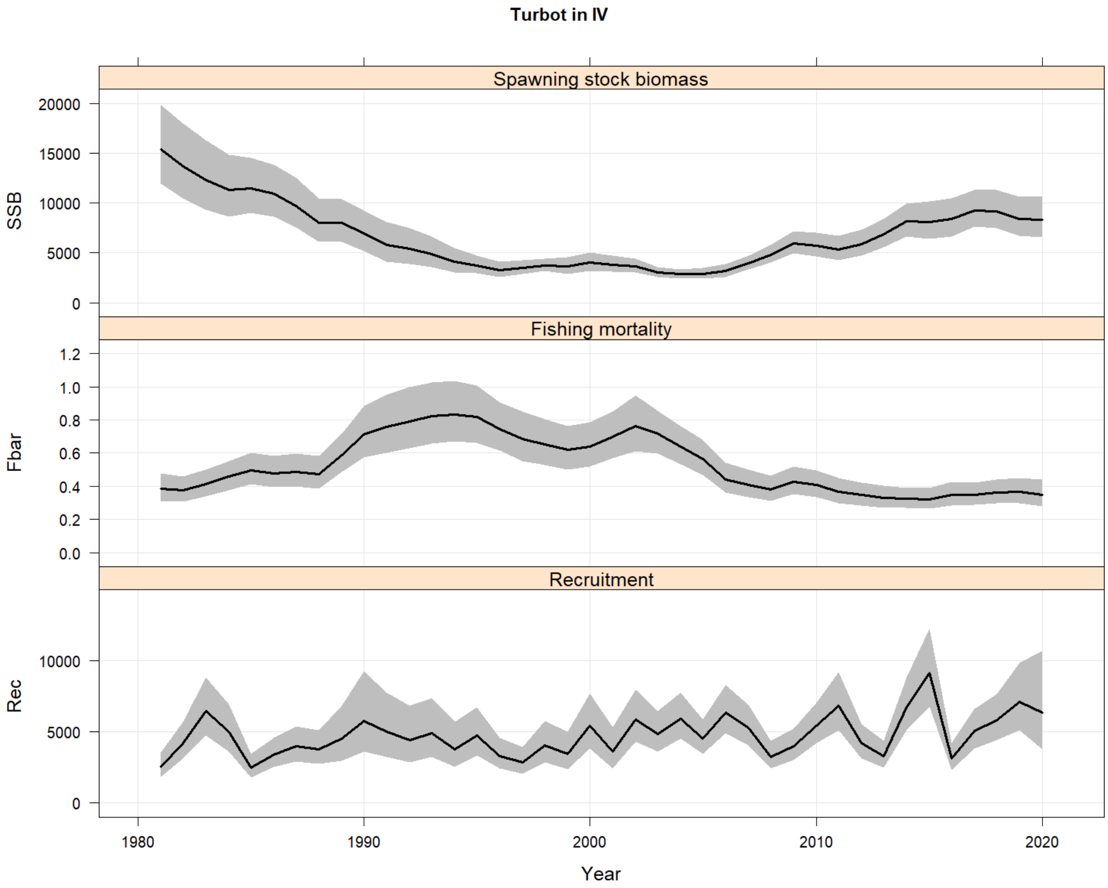


Figure 21.4.1. Summary plot of SSB, F and Recruitment, including the uncertainty bounds.

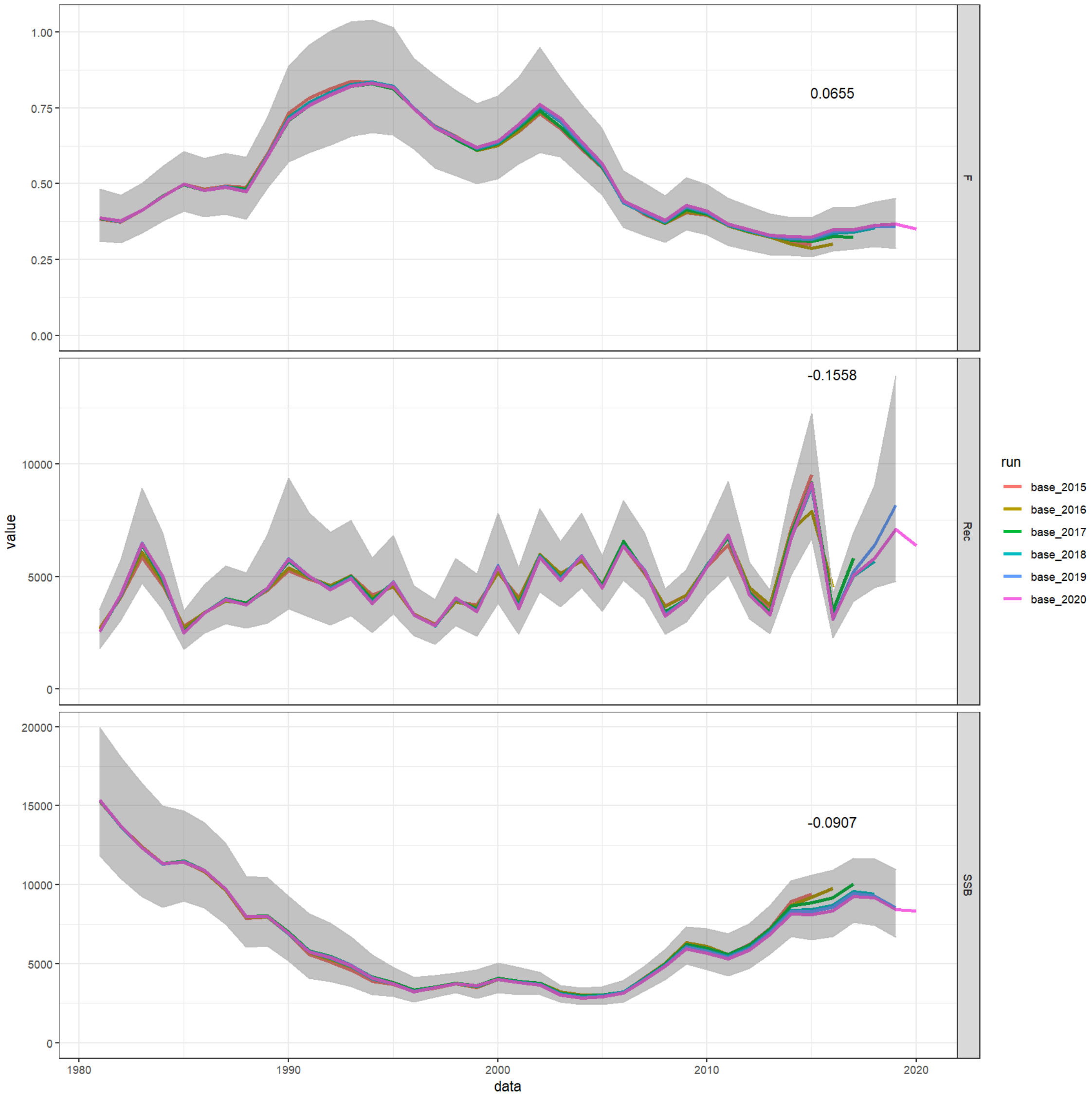


Figure 21.4.2. Retrospective analysis plot on SSB, F and R including confidence band last year assessment and Mohn's rho values.

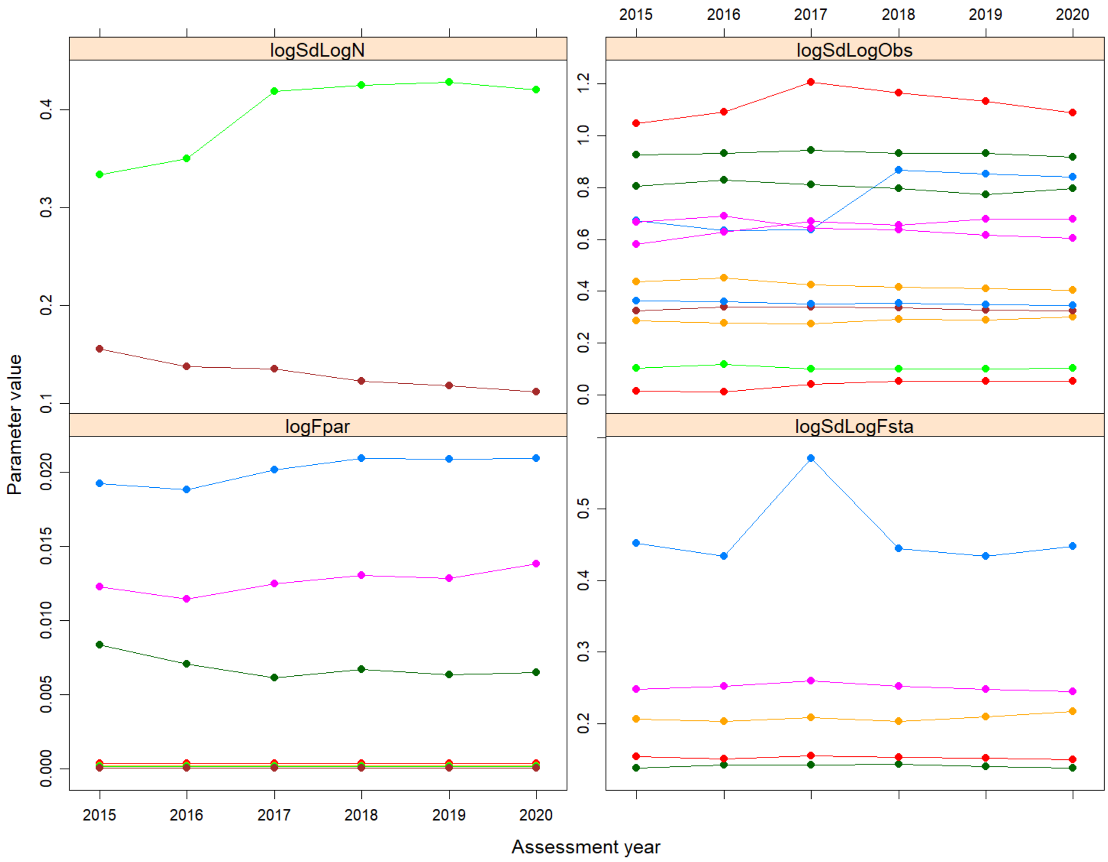


Figure 21.4.3. Retrospective analysis plot on the value of the estimated parameters, ideally, all show a flat line indicating that with reducing the model with a year's worth of data does not affect the parameters to be estimated: logSdLogN = the random walk in N, logSdLogObs is the observation variance in the surveys and catch, logFpar are the catchability parameters and logSdLogFsta are the sd's of the random walks in F.

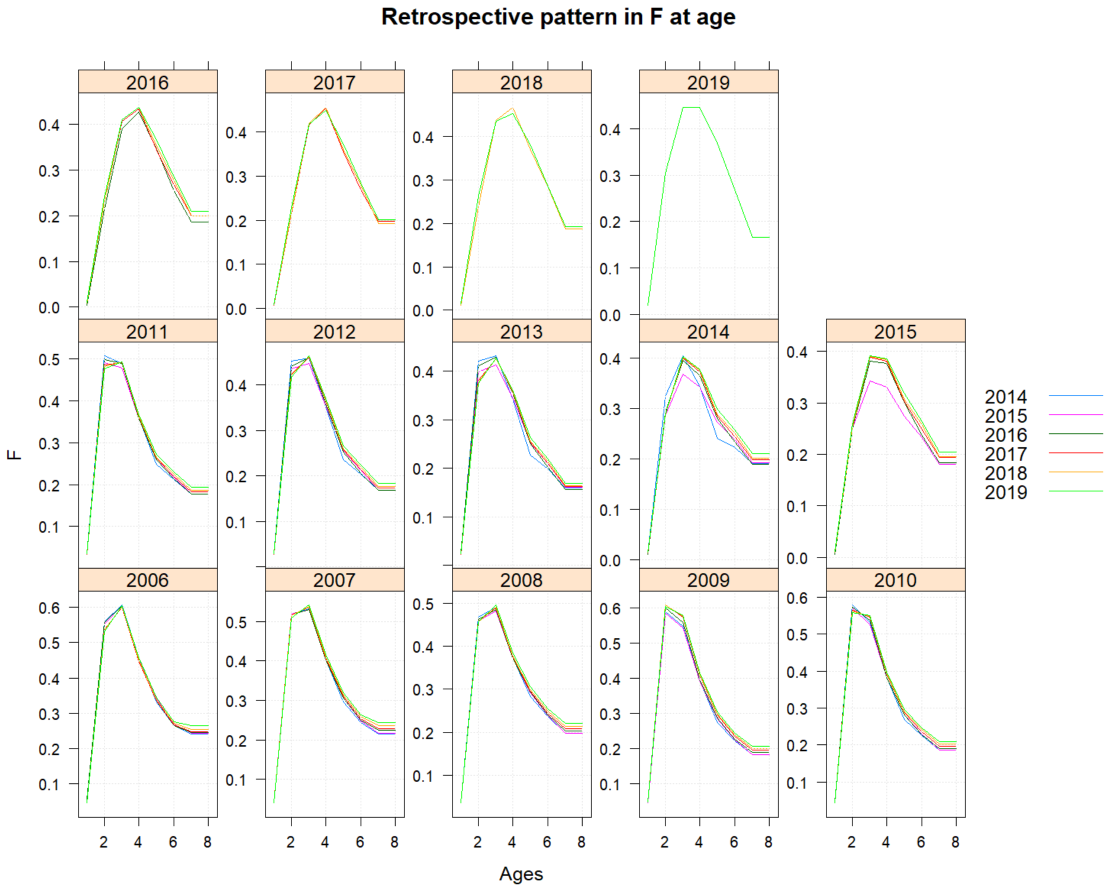


Figure 21.4.4. Retrospective analysis plot of selectivity pattern.

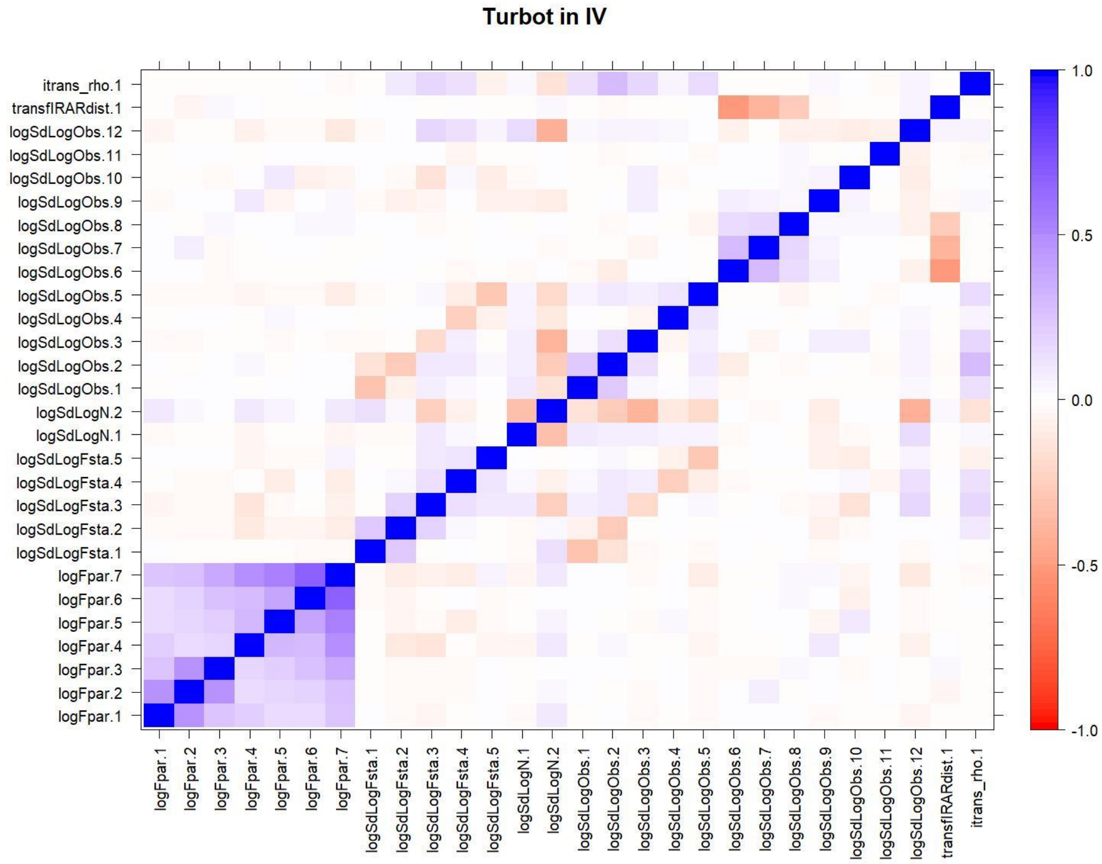


Figure 21.5.1. Parameter-correlation plot. It shows the correlation among all parameters that are estimated in the model. Fpar parameters refer to catchabilities, Fstates to the random walk in F, logN to the random walk in N, logObs to the observation variances, fRARdist to the auto-correlation in the surveys and trans_rho to the correlation in the F-random walks.

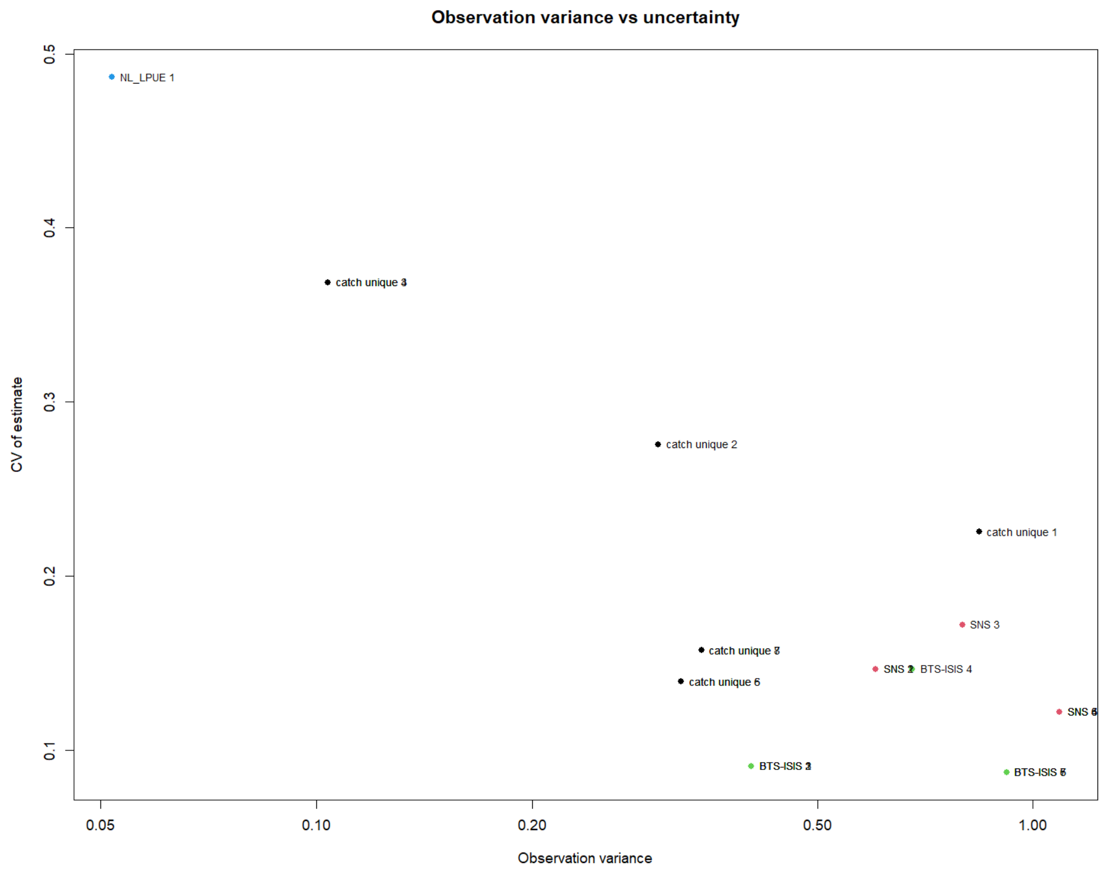


Figure 21.5.2. Plot showing the observation variance vs the CV of that estimate.

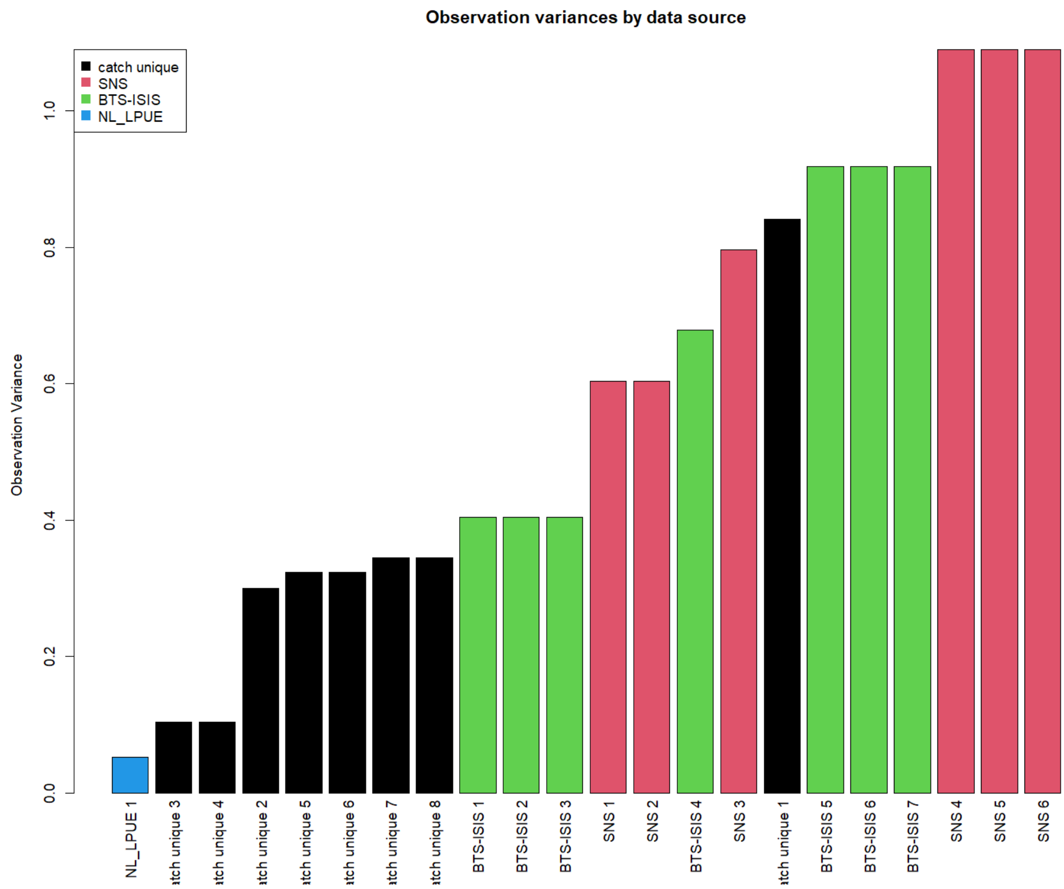


Figure 21.5.3. Estimated observation variances (scaling factor for each of the surveys), ordered from the best to the worst survey fit and has colour coding to show which bars belong to one dataset.

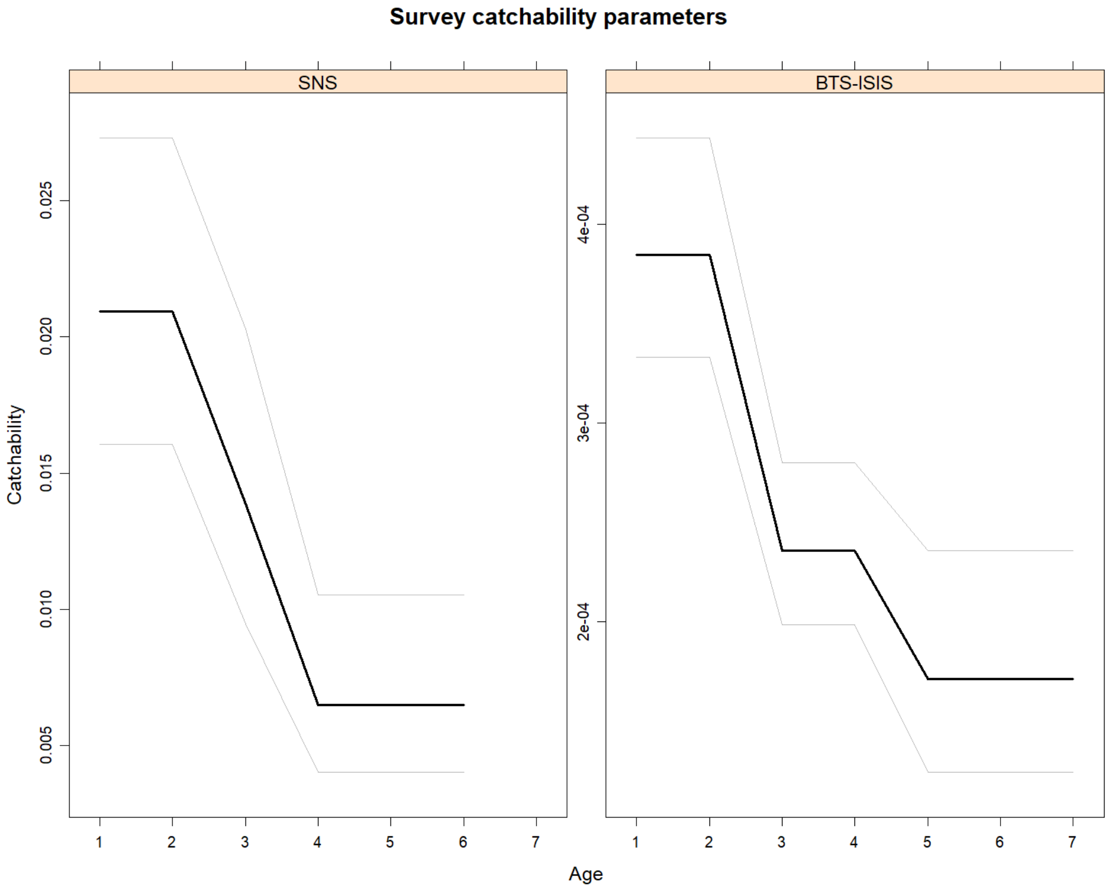


Figure 21.5.4. Catchabilities of the surveys for all surveys with more than 1 age-group.

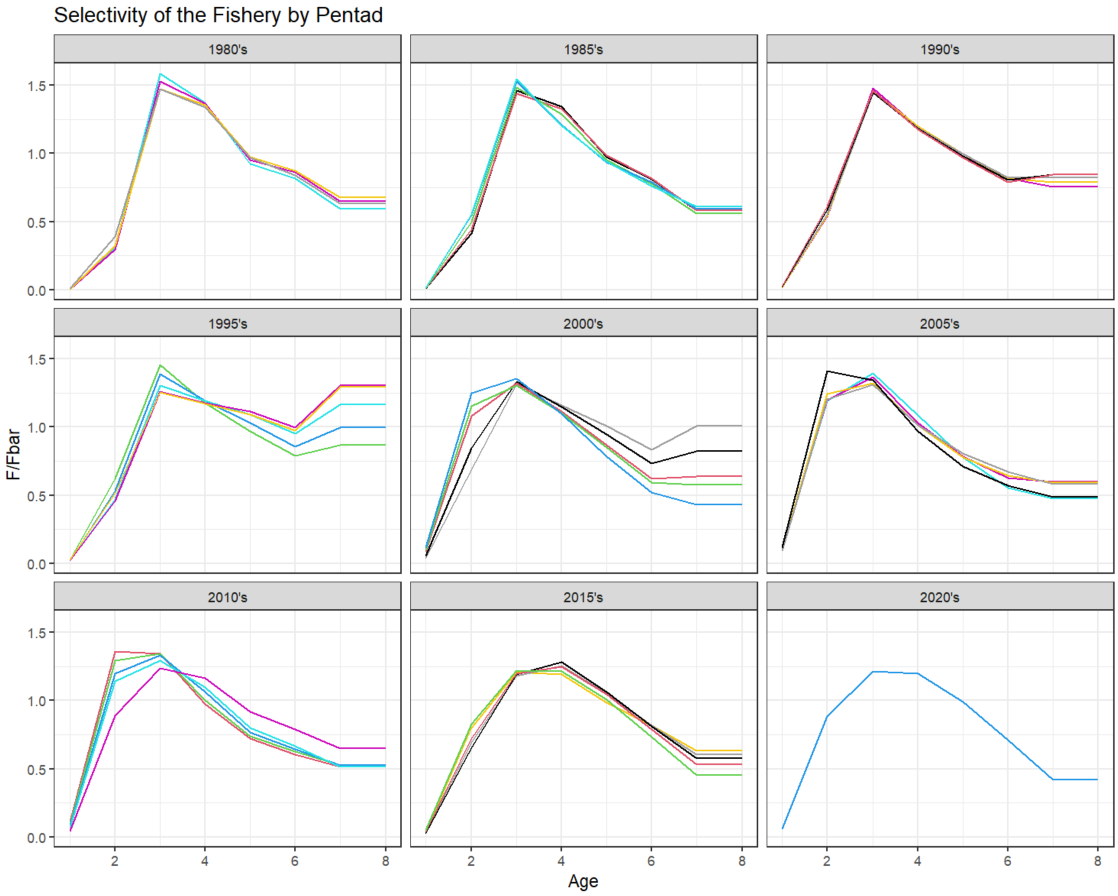


Figure 21.5.5. Estimated selectivity from 1981 to 2020, grouped by a 5-year period. Note the 1980s are 1981 up to 1984, 2015s is 2015 up to 2019. Values represent actual F-at-age.

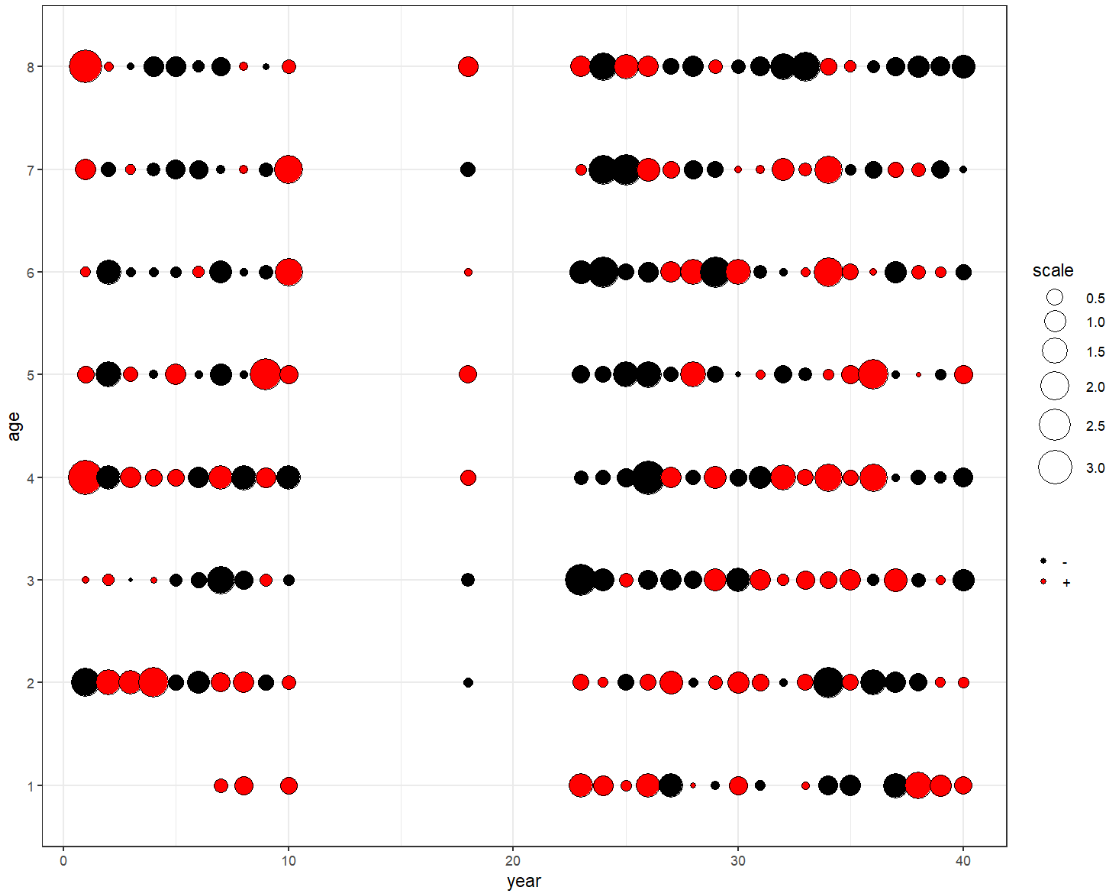


Figure 21.5.6. Residual bubble plot of landings

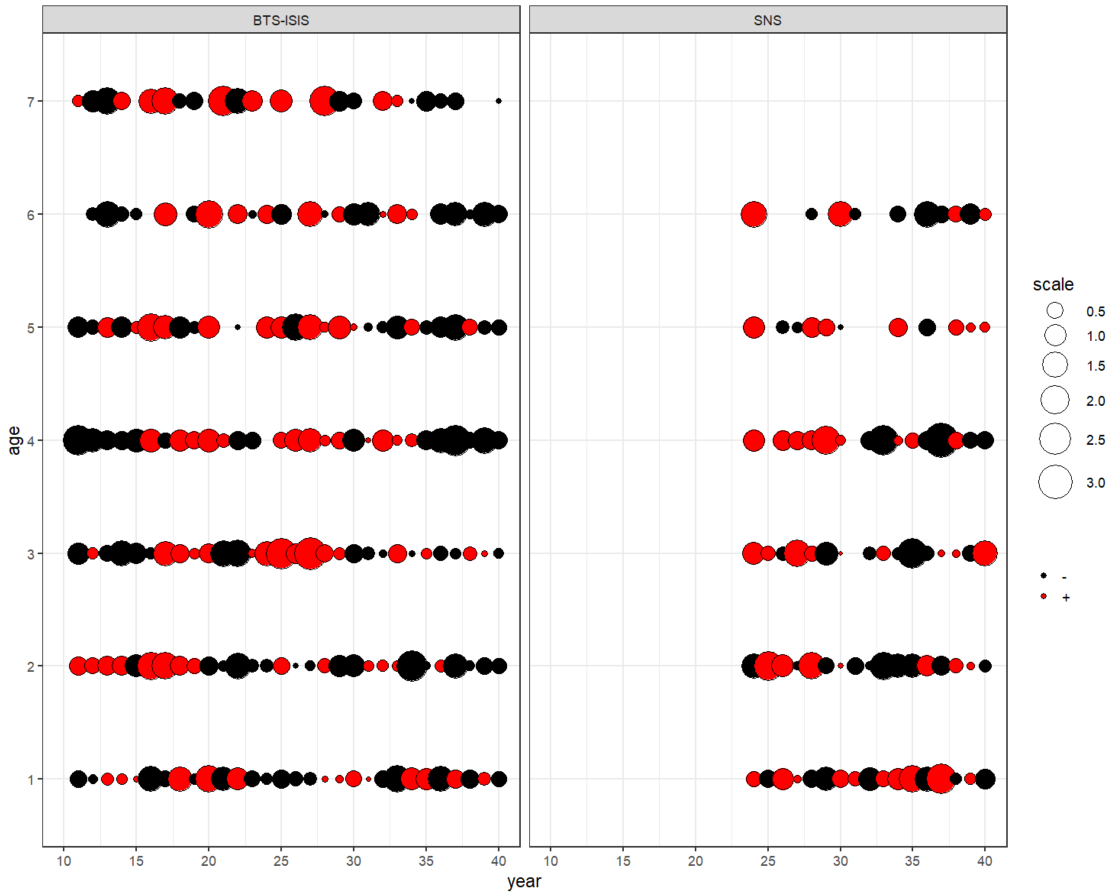


Figure 21.5.7. Residual bubble plot of SNS and BTS-ISIS survey.

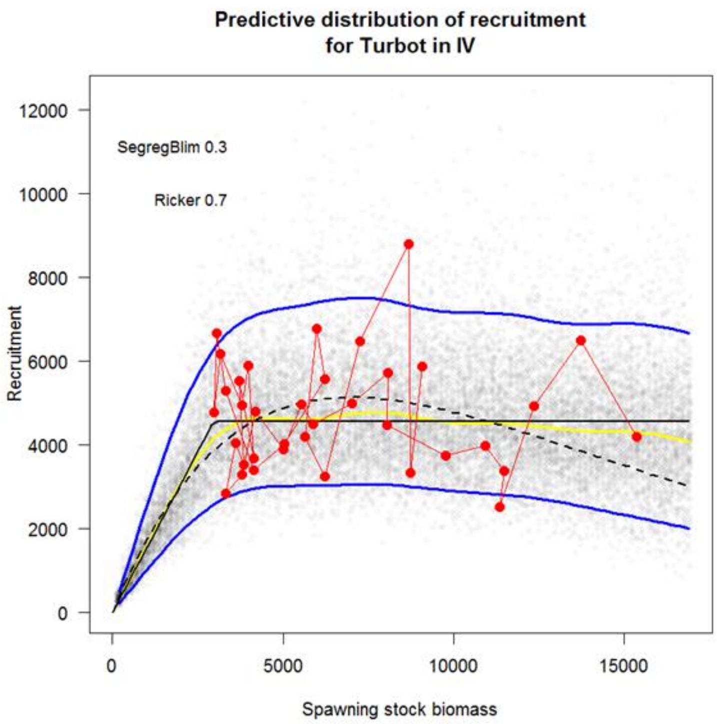


Figure 21.6.1. Stock recruitment pairs over time.

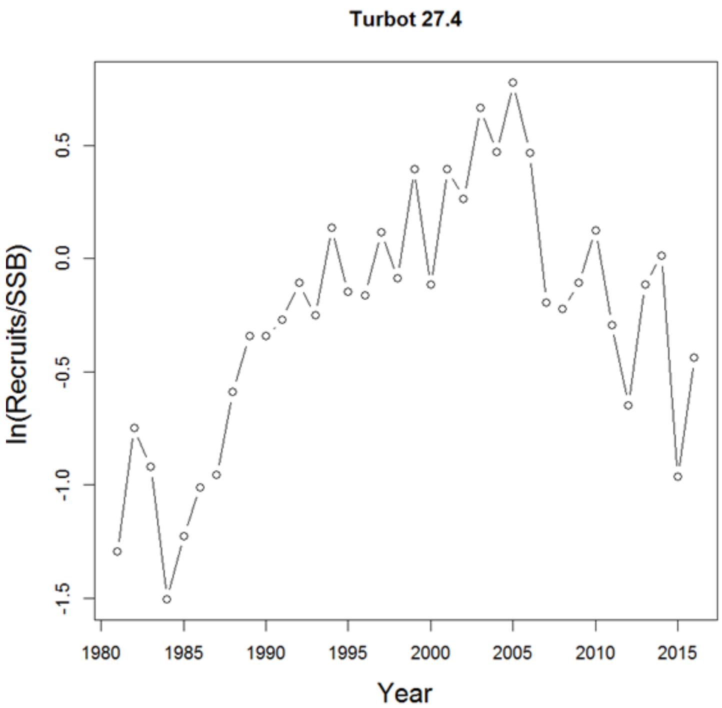


Figure 21.6.2 Productivity over time

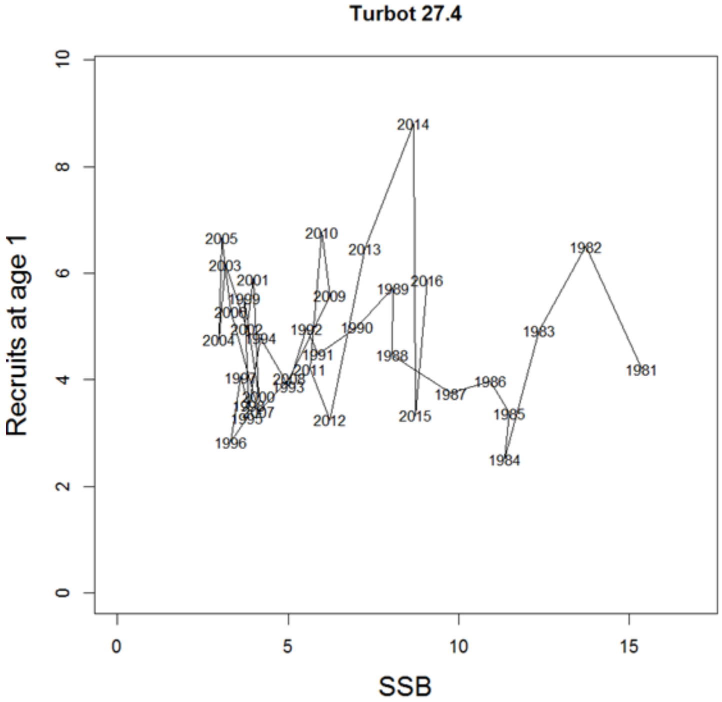


Figure 21.6.3. Stock recruitment pairs over time

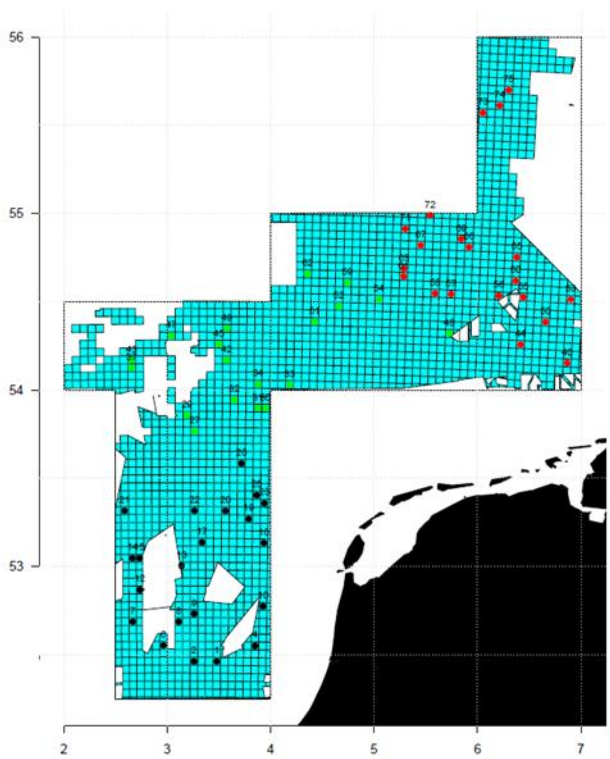


Figure 21.8.1. Map showing the area survey design to be monitored during the new Dutch industry-based survey. The squares are 5 x 5 km zones. Map showing the 75 randomly selected monitored stations during the 2020 survey.

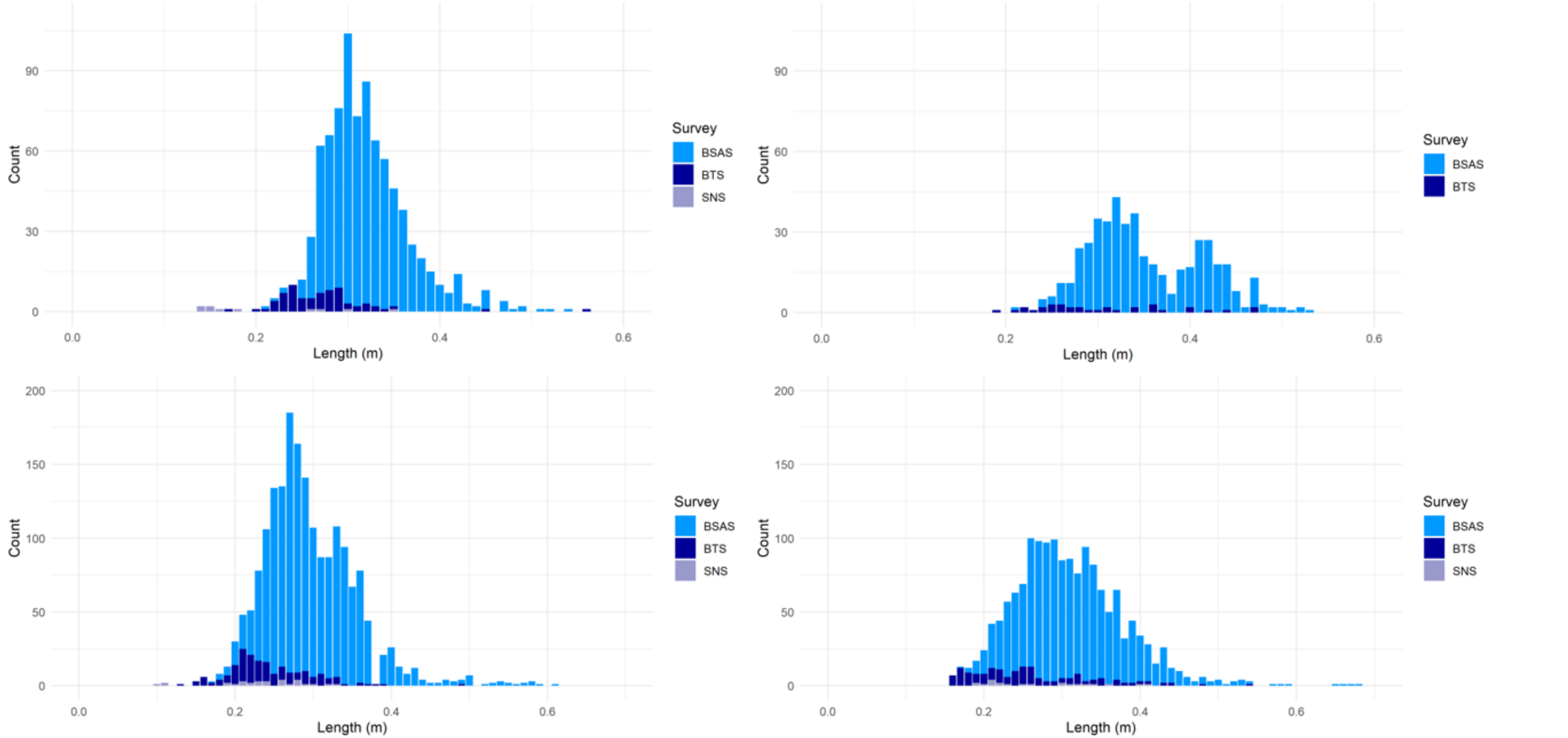


Figure 21.8.2 Length composition (1cm-classes) of individuals of brill (top) and turbot (lower) sampled within the Dutch industry survey compared to the BTS and SNS in 2019 (left) and 2020 (right).

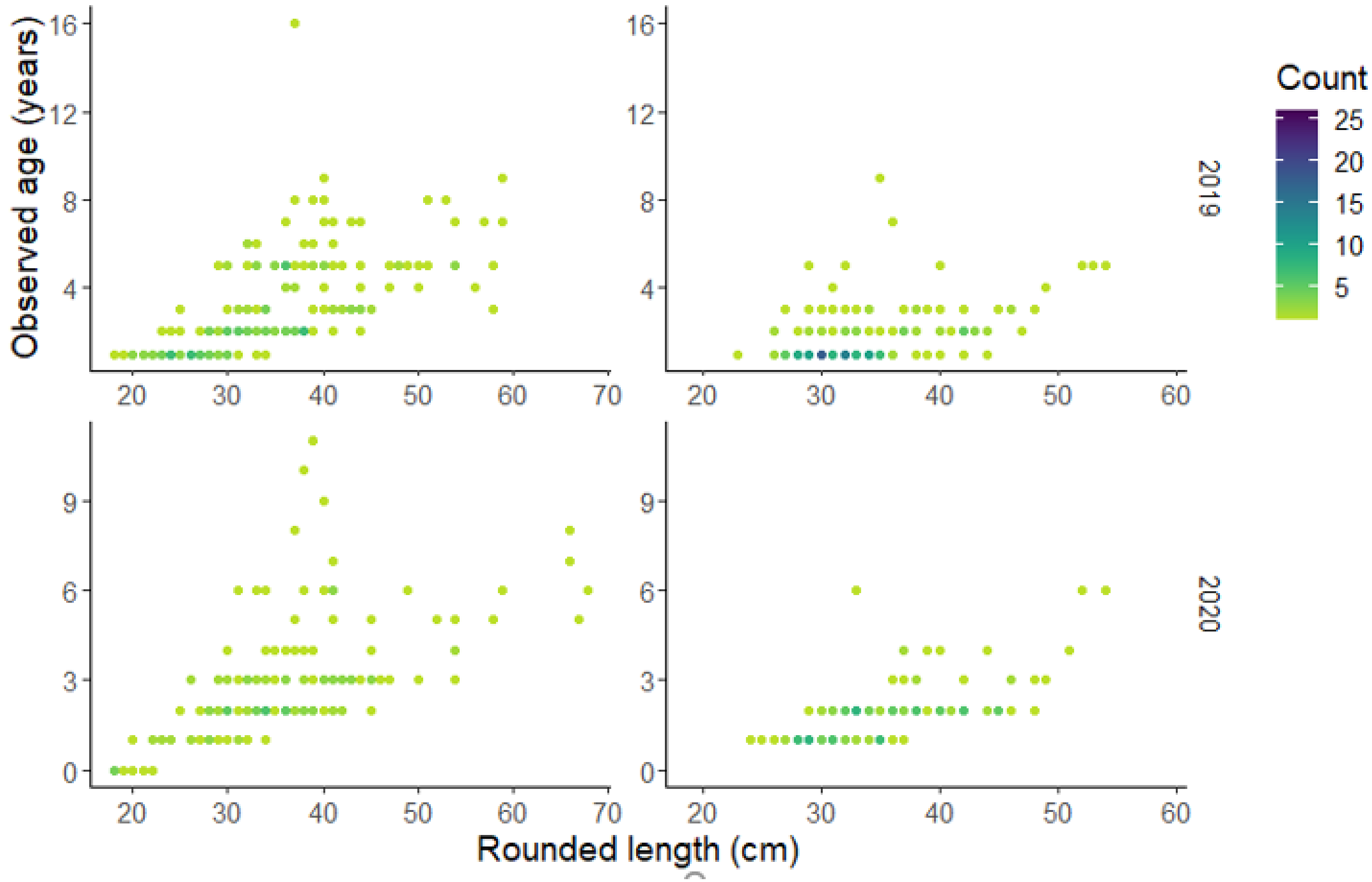


Figure 21.8.3 age-length distribution of turbot (left) and brill (right) sampled in the 2019 and 2020 industry survey.