BENCHMARK WORKSHOP ON SELECTED ELASMOBRANCH STOCKS (WKBELASMO)

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Contents

i Executive summary

A Benchmark Workshop for selected elasmobranch stocks (WKBELASMO) was convened to evaluate the appropriateness of data and methods to assess and provide short-term forecast for three rays stocks in the greater North Sea: thornback ray in the North Sea, Skagerrak, Kat-tegat, and eastern English Channel (rjc.27.3a47d), spotted ray in the North Sea, Skagerrak, Kattegat, and eastern English Channel (rjm.27.3a47d), and blonde ray in the southern North Sea and eastern English Channel (rjh.27.4c7d).

For thornback ray in the North Sea, Skagerrak, Kattegat, and eastern English Channel, a SPiCT assessment using removals since 1999 and two series of biomass indices (NS-IBTS-Q1 and FR-CGFS-Q4 combined, and NS-IBTS-Q3, BTS-ENG-Q3, BTS-BEL-Q3 combined) since 1989 was accepted. The workshop also agreed on the settings for the short-term forecast, allowing the stock to be assessed as category 2. This stock is estimated to be harvested well below Fmsy with a biomass just above B_{MSY}. The 15th percentile of the removals at Fmsy is slightly below MSY and corresponds to landings higher (~3 times) than the previous landings advice.

For spotted ray in the North Sea, Skagerrak, Kattegat, and eastern English Channel, a SPiCT assessment using removals since 1999 and two series of biomass indices (NS-IBTS-Q1 and FR-CGFS-Q4 combined, and NS-IBTS-Q3, BTS-ENG-Q3, BTS-BEL-Q3 and BTS-NL-Q3 com-bined) since 1989 was accepted. The workshop also agreed on the settings for the short-term forecast, allowing the stock to be assessed as category 2. This stock is estimated to be harvest-ed well below Fmsy with a biomass above B_{MSY}. The 15th percentile of the removals at Fmsy is just above MSY and corresponds to landings higher (~5 times) than the previous landings advice.

For blonde ray in the North Sea and eastern English Channel, a synthesis of stock ID infor-mation (tagging, surveys) was presented, indicating that the stock unit for blonde ray should cover Division 4.b. Therefore, WKBELASMO has considered a new stock unit (rjh.27.4bc7d) for the assessment. A SPiCT assessment using removals since 1999 and one series of biomass indices (NS-IBTS-Q1, Q3 and FR-CGFS-Q4 combined) since 1997 was accepted. The workshop also agreed on the settings for the short-term forecast, allowing the stock to be assessed as category 2. This stock is estimated to be harvested well below Fmsy with a biomass above B_{MSY}, both with a relatively wide confidence interval. The 15th percentile of the removals at F_{MSY} is above MSY and corresponds to landings largely higher (~6 times) than the previous advice.

ii Expert group information

Expert group name	Benchmark Workshop for selected elasmobranch stocks 2023 (WKBELASMO 2023)
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chairs	Alain Biseau, France
	Manuela Azevedo, Portugal
Meeting venues and dates	Data Evaluation Workshop: 28 November – 1 December 2022, Online meeting (17 participants)
	Benchmark Workshop: 20 – 24 March 2023, ICES headquarters, Copenhagen (18 participants)

1 Introduction

1.1 Terms of reference

2022/2/FRSG41 A Benchmark Workshop for selected elasmobranch stocks (WKBELASMO 2023), chaired by ICES Chair Alain Biseau* (France), and attended by invited external experts Manuela Azevedo (External Chair, Portugal), Casper Berg (Denmark) and Henning Winker ((JRC, Italy), will be established and will meet online 28 November - 2 December 2022 for a data evaluation meeting and in ICES HQ, Copenhagen, Denmark, for a 5-day Benchmark meeting 20-24 March 2023 to:

a) Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short term outlook taking agreed or proposed management plans into account for the stocks listed in the text table below. The evaluation shall include consideration of:

i. Stock identity and migration issues;

ii. Life-history data.

iii. Review current sampling levels and adjust stratification levels for landings and discards accordingly;

iv. Inclusion of recent scientific fishing surveys not yet considered in the assessment;

v. Examine alternative assessment models to the current model;

vi. Explore impact of all tuning fleets on assessment estimates;

b) Agree and document the most appropriate method for evaluating stock status and (where applicable) short term forecast and update the stock annex as appropriate. If no analytical assessment method can be agreed, then an alternative method for providing advice (the former single stock methods, or following the ICES data-limited stock approach (see WKLIFE X (https://doi.org/10.17895/ices.pub.5985)) should be put forward;

c) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);

d) Develop recommendations for future improvements of the assessment methodology and data collection;

e) As part of the evaluation:

i) Conduct a 5-day data evaluation workshop. Stakeholders are invited to contribute data (including data from non-traditional sources) and to contribute to data preparation and evaluation of data quality. As part of the data compilation workshop, consider the quality of data including discard and estimates of misreporting of landings;

ii) Following the Data evaluation, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting.

WKBELASMO will report by 7 April 2023 for the attention of ACOM.

1.2 Conduct of the Benchmark

The list of participants and the agenda for the benchmark workshop meetings are presented in Annex 1 and Annex 2, respectively.

The ICES benchmark for some elasmobranch stocks included the following steps:

1) A data call was issued 15 October
2) A data compilation workshop was held online 28 November – 2 December 2022. The main focus of this meeting was to review the relevant data and consider information and issues for each stock, and especially considerations on stock identity. The plan of actions by stock was decided to prepare the actual benchmark (Annex 3).
3) The examination of the information regarding the stock identity for blonde ray leads to the conclusion that Division 4b should be included in the stock definition. The proposal for a new stock unit definition (Annex 4) was sent to ACOM-LS 01 December and a positive response was received the 6th of December.
4) An iintersessional meeting was held online on the 15th of February, and the benchmark meeting 20-24 March with 18 participants, 9 in person and 9 online.
5) The working documents to be discussed were provided to meeting participants in advance of the final meeting. The following working documents were prepared before the meeting:

Title	Description	Contributors
1. CGFS-FR_indices_rjc.27.3a47d	Calculation of biomass indices for rjc.27.3a74d	Pascal Lorance
2. Ribeiro Santos_2022_UK-Eng_Discards methodology	Description of data handling and estimation procedures for discards and length distributions for the English and Wales fleets	Ana Ribeiro Santos
3. Silva_2022_Rajidae in 4c7d_BTS_Eng_Q3 survey	Rajidae in the eastern English Channel (ICES Division 7.d) and southern North Sea (ICES Division 4.c)	Joana Silva
4. Ellis *et al*_2023 WD_Life history parameters for RJC RJM RJH	An overview of the life-history parameters for North Sea stocks of thornback ray Raja clavata (rjc.27.3a47d), spotted ray R. montagui (rjm.27.3a47d) and blonde ray R. brachyura (rjh.27.4bc7d)	Jim Ellis *et al*
5. WD on the use of INLA for RJC WKBELASMO 2023	Generate Biomass Indices for Raja clavata stock 3a47d using INLA	Timo Stäudle
6. Ellis *et al*_2023 WD_Management applicable for skates and rays_North Sea ecoregion	An overview of the management measures that apply to skates and rays in the North Sea ecoregion	Jim Ellis *et al*
7. Working document on discard survival	Discard mortality: Merging data from SUMARiS, FROM NORD (French Flyshoot) and WMR.	Damian Villagra
8. Working document on catch reconstruction_3 stocks	WD on catches for selected Elasmobranch stocks	Jurgen Batsleer & Katinka Bleeker
9. Working document on surveys and biomass indices_3 stocks	WD on fisheries independent surveys and biomass index calculations for selected Elasmobranch stocks	Katinka Bleeker & Jurgen Batsleer

Title	Description	Contributors
10. rjc_WDStock summary	WD on the stock summary of Thornback ray (Raja clavata) in the North Sea	Jurgen Batsleer, Katinka Bleeker, Timo Städle
11. rjh_WDStock summary	WD on the stock summary of Blonde ray (Raja brachyura) in the North Sea	Jurgen Batsleer, Katinka Bleeker, Timo Städle
12. rjm_WDStock summary	WD on the stock summary of spotted ray (Raja montagui) in the North Sea	Jurgen Batsleer & Katinka Bleeker

1.3 Conduct of the meetings

The working documents were received prior to the meeting and presentations were made by the participants, which subsequently formed the basis of the workshop's investigations during the two meetings.

To ensure credibility, salience, legitimacy, transparency and accountability in ICES' work, to avoid CoI and to safeguard the reputation of ICES as an impartial knowledge provider, all contributors to ICES' work are required to abide by the ICES' Code of Conduct. The ICES' Code of Conduct document dated October 2018 was brought to the attention of participants at the workshop and no CoI was reported.

1.4 Recommendations

To WGEF:

Spotted ray 3a47d: The fisheries locations show two separate grounds (North West of the North Sea (division 4a) and the Central/Southern North Sea (mostly division4b). Survey information also indicate separate areas of higher biomass, with different trends in recent years. Further work on the stock identity must be encouraged, especially genetic studies.

To WKLIFE:

While most of the simulation testing carried out by WKLIFE consider recovering stocks, future work should consider the appropriateness of an ICES rule for stocks that are currently exploited far below Fmsy (and at or above Bmsy), since even a low fractile (e.g. 15^{th}) of the catches at Fmsy would lead to a large increase in short term fishing opportunities, above MSY, with a risk of reduction in the near future. Given the uncertainty around the MSY value, it would be relevant to test a constraint in the increase in the catch advice to the lower limit of the confidence interval around MSY.

To ACOM:

While a cap in the inter-annual variation of a TAC would remain a management decision, it is suggested that ACOM consider showing the trade-off between a big increase in a catch advice with a risk of mining and consequently a decrease in future catch advice, and a lower catch advice which would be more stable for some years.

1.5 Historical landings series

Most landings of skates and rays were not reported to species-level before 2009, resulting in short time-series for all assessments. Reconstruction of landings before 2009 was achieved for all three stocks back to 1999. Nevertheless, previous landings reported at higher taxonomic levels allow appraising the magnitude of the landings in earlier periods. ICES landings data from the early 1900s to the late 1970s included one single item for Rajiformes, labelled "Raja rays nei". From 1978, a variable (0 to 8 %) fraction of annual landings was reported as blue skate and a similar fraction as thornback ray. However, only one country reported thornback ray before 2008 (with unknown reliability of the species identification). Therefore, only data for aggregated skates "Raja rays nei" can be considered to get an overall view of the longer-term trend in Rajiformes landings.

The time-series of Rajiformes landings was extracted for Subarea 4 and divisions 3.a and 7.d. It showed landings levels reaching approximately 17 000 tonnes in a few years up to the early 1950s followed by a long-term decline during the second half of the 20th Century (Figure 1.5.1). A similar compilation was done previously by Heessen (2003 Ed) for the North Sea, Subarea 4, only (Figure 1.5.2). The addition of the Eastern English Channel (in order to match the benchmarked stocks areas) resulted in substantially higher landings levels than the previous compilation, especially in the recent part of time-series in the 1970s to the 1990s. This may suggest that landings from Division 7.d may have been poorly reported earlier, possibly as this stretch of coastline may have had more landings from inshore vessels for which data may have been incomplete.

Landings in earlier years are considered incomplete, especially for coastal fisheries, which occasionally target skates, so that a crude average of Rajiformes landings from the 1910s to the 1950s may have been in the region of 15 000 tonnes per year or more, although the species composition would be expected to have changed over time.

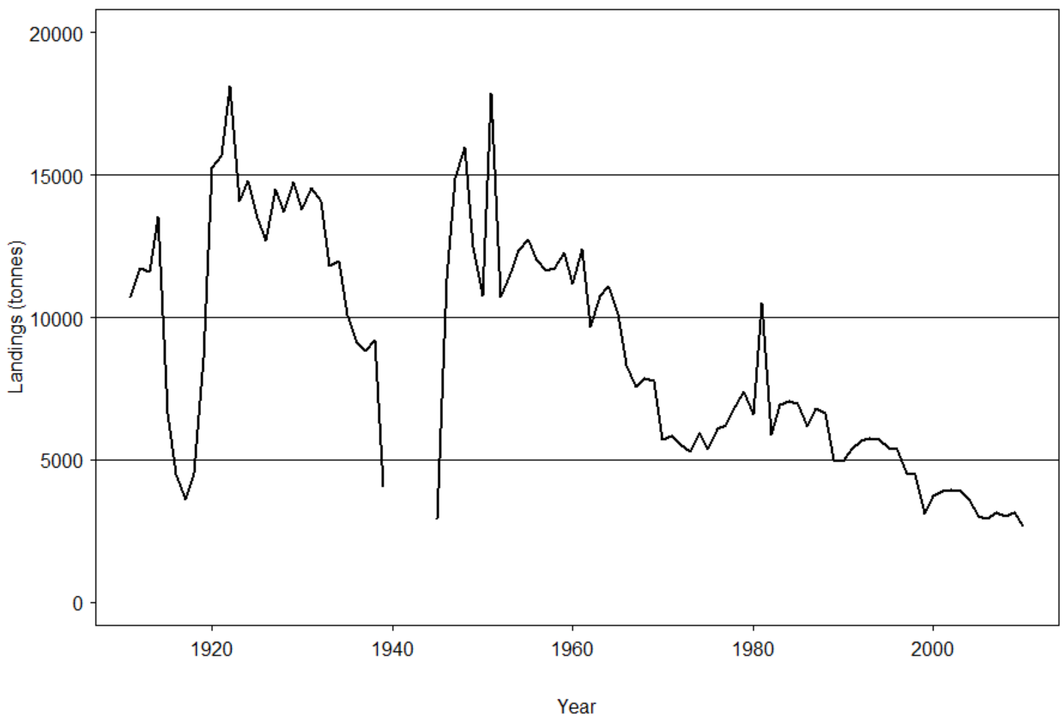

Figure 1.5.1. International landings of rays and skates from ICES Subarea 4 and Division 3.a and 7.d from 1911 to 2010, from ICES historical catch statistics.

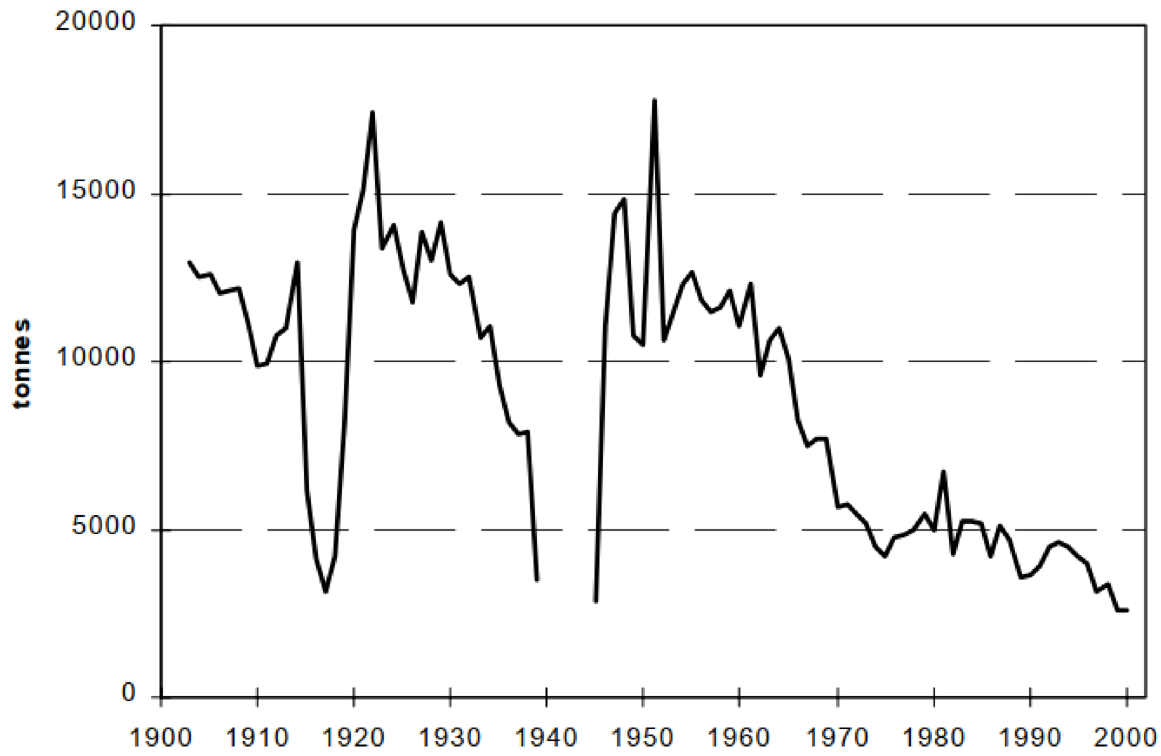

Figure 1.5.2. International landings (t) of rays and skates from the North Sea, 1906 - 2000 (ICES Fisheries Statistics, redrawn from Heessen, 2003).

1.6 Reviewers´ report

The reviewers´ report regarding details on the stock specific assessments is included in the section of each stock.

Henning Winker (GFCM-FAO) and Casper Berg (DTU-AQUA, Denmark)

This report presents the reviewers' assessments of the Benchmark Workshop the following three selected elasmobranch stocks (WKBELASMO 2023):

- Thornback ray (*Raja clavata*) in Subarea 4 and in divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel)
- Blonde ray (*Raja brachyura*) in divisions 4.c and 7.d (southern North Sea and eastern English Channel)
- Spotted ray (*Raja montagui*) in Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel)

WKBELASMO (2023) chaired by ICES Chair Alain Biseau* (France) and External Chair Manuela Azevedo* (Portugal) and comprised of an online data evaluation meeting (08 November - 2 December 2022) and a 5-day Benchmark meeting in ICES HQ, Copenhagen, Denmark (20-24 March 2023).

This reviewer report was jointly prepared by the invited external reviewers Casper Berg (Denmark) and Henning Winker (FAO, GFCM).

For all three stocks, a SPiCT base-case model was endorsed as being adequate and sufficiently robust as benchmark model for Category 2 stocks by both external reviewers. A detailed evaluation of benchmark process is presented in the following section.

1.6.1 Benchmark process

The benchmark process sets a very high standard compared to previous experiences. Highly beneficial was that the three Rajidae species under assessment were feasible to evaluate in great detail, and that they formed part of a species complex with an overlapping spatial distribution. The input data preparation could build on largely harmonized processes with respect to bycatch estimation, catch reconstructions and survey index standardization. Noting that surplus production models, such as SPiCT, are strongly driven by the trends in the indices in response to catch removal, it is critical that both data sources are prepared with high scrutiny. The benchmark process involved thorough examination of the sensitivities of assumption made during the data preparation, which were in several cases propagated as sensitivities into the assessment runs with SPiCT. Furthermore, the data preparation process was well documented and transparent, and went through several iterations of reviews by the Group.

There remains a need to build further capacity on good practices in applying SPiCT with respect to choosing the most appropriate settings for the stock under assessment and interpretation of the diagnostics to inform these choices. In particular, the options for setting up the variance parameters can be highly influential on the assessment outcome and the advice. An important aspect is to increase continuously the empirical knowledge base by building on the evolving practices from previous benchmarks with SPiCT. WKBELASMO, for example, could build on guidelines and recommendations. These were initially put forward in WKMSYSPICT1 and were further refined during WKBMSYSPICT2. A continuity of knowledge transfer among experts of these benchmark meetings is recommended.

1.6.2 Commercial data

Species-specific commercial catches were only available from 2009, because earlier data were only recorded at higher order family grouping. Some discard data were missing or incompletely reported in the period 2009-2021. These were imputed using a published multiple regression model based on the relation between discard and fishing effort by metier (Amelot *et al*., 2021). While this method generally was deemed appropriate to use for this purpose, it was noted that this model implicitly assumes that abundance is constant. It is therefore recommended that this model is continuously checked for residual trends over time in the future to avoid potential bias in case reconstruction of discards remains necessary.

Discard survival was accounted for by applying métier specific estimates of survival probability to the discards. The results of several studies were combined to obtain the survival probabilities. Discard and survival rates are fairly high for rays, so having data on survival to actually account for this was a benefit.

Species-specific landings for the period 1999-2008 were reconstructed from the total Rajidae landings and the observed landing proportions by species from later period. Different options for computing average proportions as input for the early time period were explored, and included in sensitivity analysis. Similarly, dead discards in the period 1999-2008 were also reconstructed based on average ratios from the observed period 2009-2021.

Extending the time series of catches back in time is helpful for the SPiCT model, as it informs about exploitation history and provides contrast in the data, which is crucial for reference point estimates. Although some assumptions are needed to reconstruct the time series back in time, the increased uncertainty is accounted for in the model by increasing the observation error variance for the reconstructed part in the model.

It could be helpful in the future to have variance estimates for the total catch by year, which could be used as input to SPiCT. While it is not standard to produce such estimates for ICES assessments, it should be possible to compute them for example using bootstrapping. This would for instance ensure that changes in the discard sampling programme leading to varying precision in the discard estimates would be reflected in the assessment.

1.6.3 Survey indices

Prior to WKBELASMO (2023) a design-based approach was used to derive survey-based stock trends for all three stocks. Survey indices were calculated independently for different combinations of quarter, gear, and area, and finally a single index was produced by taking average across each sub-index (normalized). The design-based results were initially prepared for the preparation meeting for the benchmark, where a model-based alternative was subsequently presented and adopted for the benchmark. The model-based indices were estimated using the "surveyIndex" R package (Berg *et al*., 2014). This approach gives more appropriate weighting to each sub-index compared to the designed-based approach, which implicitly assigned equal weighting. Furthermore, the model-based approach can account for changes in sampling design as well as quantify the change in uncertainty due to such changes.

Several combinations of surveys, error distributions (Tweedie and Delta-Lognormal), and length thresholds (>= 30 and >= 50 cm) were explored and the indices were checked for consistency with the design-based approaches. There were generally good agreement in survey trends between the different models and datasets, which corroborated the trends in the model-based indices. However, the interannual precision estimates for the model-based index were generally deemed more reliable.

It was helpful for the review process that all stocks used the same standard methodology for the survey indices, because similar model configurations and diagnostics could be applied and compared across all stocks. For all three stocks, a delta-lognormal error distribution was judged to be the most appropriate for the survey index standardization.

1.6.4 SPICT model configuration

If used in benchmark process, the adequate configuration of SPiCT requires careful considerations of the stock's biology, the available data and the emergent properties of time series. Due to the similarities among the three Rajidae species the following configurations and guiding principles were transferable among the assessments:

- The uncertainty about the catches was assumed to have a log.sd=0.1 for the reported catch period (typically from 2009) and a larger uncertainty of log.sd=0.2 for the reconstructed catch period.
- The observation error for the indices was informed through priors that were formulated on the basis of annual standard error estimates from the index standardisation model, both in terms of interannual and absolute precision.
- Process errors on log biomass (*logsdb*) were formulated as informative priors. A fairly low mean value of process error deviation of 0.07 was assumed for all three species considering the moderately long generation times and the associated inertia on log biomass, which was also informed by preliminary simulation trials. The precision about the process error prior was kept fairly vague (typically CV=0.5). In addition, sensitivity trials

were routinely conducted for various combinations of process error mean and precision settings, indicating that the “default” assumption can be considered reasonably robust.

- All assessment models assumed a Schaefer production function, which was generally deemed adequate considering the life history of the species. Priors on r were formulated based on a Leslie matrix approach to generate prior knowledge about the stocks productivity. The required input parameters for somatic growth, maturation, natural mortality and fecundity were reviewed and agreed by the group. Sensitivity trials were routinely conducted for various combinations of r mean and precision settings. The guiding principle was such that the precision on the r prior as low as possible, so as to keep r estimates within biological plausible limits, achieve adequate model convergence and consistency in terms of retrospective bias, while still maintaining the model’s ability to efficiently update to the prior information given the data.

1.6.5 Model diagnostics

Model diagnostics of all candidate models were extensively evaluated using the comprehensive diagnostic toolbox that is available in SPiCT. These included:

- Fits to the catch and abundance indices data on the basis of one-step ahead residuals
- Evaluation of process error deviations on log biomass and F
- Prior and posterior distributions
- Retrospective consistency
- Prediction skill based on hindcast cross-validation
- Sensitivity runs, including alternative prior assumptions for the mean and precision assumptions for process error (*logsdb*), productivity (*logr*) and initial biomass depletion (*logbkfrac*).

1.6.6 Recommendations for future work

There is a need for further simulation testing, e.g. through WKLIFE. One aspect is the evaluation of the behaviour of SPiCT to different properties of the time series. The three ray species under assessment had, for example, longer time series for surveys than for species-specific catch data and showed a continuous increase over the available catch horizon. Model performance and robustness of advice under the emergent properties of a rebuilding stock in the absence of historical catch data currently lack formal simulation testing, considering that this “one-way uphill trip” may be associated with similar challenges to the well documented “one-way downhill trip”.

Furthermore, there is need to reflect on the interpretation of key model diagnostics, such as retrospective analysis in the context of SPiCT assessments. The prevailing paradigm is that the least retrospective bias is the most desirable diagnostic outcome. In SPiCT, retrospective bias can, for example, be reduced by increasing the precision of priors for key model quantities, such as *logr* and *logbkfrac*. However, this may effectively reduce the model’s ability to effectively update to new data in terms of the stock’s productivity. In particular during rebuilding, every new data can be highly informative about the population growth r at low abundance. In general, retrospective bias represents a larger challenge in situations where reference points of, e.g., F_{MSY}, B_{pa} or B_{lim} are benchmarked as absolute values and fixed until next benchmark, but potentially less so within the SPiCT advice framework where key quantities are presented as relative quantities F/F_{MSY}, B/B_{MSY} and B/B_{lim} and re-estimated each time advice is given. Nevertheless, too large retrospective bias in SPiCT models may still lead to poor model consistency and spurious advice. The primary diagnostics used to compare models has been to examine residuals patterns to check goodness-of-fit and to conduct retrospective analysis. However, residual patterns can be removed by adding more parameters than justified by the data, and retrospective patterns removed by ignoring the data (Kell *et al*., 2021). Therefore, further research is recommended towards refining the model diagnostics guidelines for evaluating the optimal trade-offs between model consistency and its flexibility to update to new data. The added hindcast cross-validation diagnostic for evaluating prediction skill could provide additional utilities to achieve this.

The survey data indicated two spatially separated hot spots of rays, one in the North and one in the Southern part of the North Sea. Due to lack of genetic evidence it was not possible to evaluate whether these two hot spots are part of the same population or not. It is therefore recommended to perform further genetic and/or tagging studies to inform about stock structure of rays in the North Sea.

All three assessments show stocks that have recovered from bad states with low biomass and high fishing pressure to good states with biomass around BMSY and fishing pressure well below FMSY. The result of this is that the models suggest substantial increase in the advised TACs (2-4 times current catch levels) even surpassing the MSY estimates because some biomass levels are above BMSY. Statistical models including production models generally have better predictive power when confronted with new data within the range of what was previously observed. Thus, increasing catch levels substantially beyond previously observed values involves some risk of unpredicted results. Such risks can be avoided by increasing the TAC gradually over several years, while monitoring the stock biomass development as the result of this. More conservative TACs could also be obtained by using lower than default values for the uncertainty buffer fractiles in the SPiCT forecast procedure. Given that catches above MSY cannot be sustained in principle, an upper catch limit that accounts for the uncertainty about MSY (e.g. 35% fractile of MSY) could be considered, if otherwise predictable TAC reductions to levels below MSY are to be avoided in future. While ultimately a management decision, and more simulation testing of recovering stocks is needed for guidance, the reviewers recommend that sudden large increases in catch advice for these stocks should be avoided.

1.7 References

Amelot, M., Batsleer, J., Foucher, E., Girardin, R., Marchal, P., Poos, J. J., & Sys, K. (2021). Evidence of difference in landings and discards patterns in the english channel and north sea

rajidae complex fishery. Fisheries Research, 242, 106028. https://doi.org/10.1016/j.fishres.202

1.106028

Berg, C. W., Nielsen, A. and Kristensen, K. (2014). Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. Fisheries Research 151: 91-99.

Heessen, H.J.L. (Ed.) 2003. Development of elasmobranch assessments DELASS. Final report of DG Fish Study Contract 99/055, 605 p.

Kell, L. T., Sharma, R., Kitakado, T., Winker, H., Mosqueira, I., Cardinali, M., Fu, D. (2021). Validation of stock assessment methods: is it me or my model talking? ICES Journal of Marine Science, 78 (6): 2244–2255. https://doi.org/10.1093/icesjms/fsab104

2 Thornback ray (*Raja clavata*) in Subarea 4 and in divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) (rjc.27.3a47d)

2.1 Introduction

Thornback ray (*Raja clavata*) is the most common skate species in the Greater North Sea area. It occurs from coastal waters including estuaries to offshore seabed down to at least 300 m. It is a medium-size bodied species which reaches a maximum length of about 1 m. While fisheries measures and species-specific data collection have improved over time, there are still knowledge gaps regarding its life-cycle and population structure.
ICES considers seven assessment units of the species. In 2022 thornback ray in Subarea 8 (Bay of Biscay) was benchmarked and split into a Bay of Biscay (rjc.27.8abd) and a Cantabrian Sea (rjc.27.8c) component. The split demonstrated the importance of reviewing available genetic data as well as tagging and fisheries (in)dependent data to delineate the stock structure. In this document we focus on outlining the stock unit of thornback ray in the North Sea by reviewing tagging and catch data as well as recent outcomes of a genetic study to evaluate the stock structure in European waters. Furthermore, management measures and information on fishing effort over time by métier are collected. Such data may provide insight in what is driving fisheries behavior and thus potential changes in catches of this stock.

Thornback ray in the North Sea, Skagerrak, Kattegat and eastern English Channel is currently assessed as a Category-3 stock using the ICES 2/5 rule, and its management follows the precautionary approach. The assessment has been based on a single exploitable biomass (individuals ≥50 cm) index from the NS-IBTS-Q1, NS-IBTS-Q3, BTS-Eng-Q3, BTS-BEL-Q3 and FR-CGFS-Q4 surveys. During the benchmark workshop WKBELASMO, the relevance of the assessment of this stock using the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg 2017) was evaluated.

2.2 Stock Identity

Assessing the appropriateness of current stock units used in ICES advisory process is fundamental to conducting robust stock assessments and ensuring that management measures apply over appropriate geographic areas (Pawson & Jennings, 1996). Here we evaluate the stock structure based on genetic and tagging data.

2.2.1 Genetics

An EMFF-funded project INNORAYS determined the population structure for thornback ray (*Raja clavata*) in Western Europe (Poos *et al.,* 2022). Tissue samples collected in the Netherlands and by France (IFREMER) were analysed. As such, the population structure in a wider range than only the North Sea could be determined. Six areas were used which are based on ICES areas: Central North Sea, Southern North Sea, English Channel, Irish Sea, Bristol Channel & Celtic Sea, and Bay of Biscay. The population structure was then determined using two methods: using admixture models through fastSTRUCTURE (Raj *et al.,* 2014), and using pairwise θST (Weir & Cockerham, 1984) and FST values (Nei, 1987).

The admixture models were analysed for different cluster values, with 3 or 4 clusters being evaluated as best models based on their BIC values. The distribution of the four clusters in the respective model indicates that the Bay of Biscay is clearly different from the other areas. The North Sea and English Channel on the other hand were dominated by a second cluster, while within these areas there were less obvious differences in cluster composition. The admixture models thus gave a clear first indication that there is structure within the different thornback ray populations within north-western Europe but less so within the North Sea and English Channel.

Pairwise F_{ST} values were calculated between sample locations to estimate genetic differentiation between areas. The F_{ST} values for the Bay of Biscay are higher compared to the other areas as compared to the areas among each other. The F_{ST} values for all areas differ significantly from 0, except for the Bristol Channel - Irish Sea pair. The values for paired areas within the larger North Sea ecosystem (i.e. Central North Sea, Southern North Sea and English Channel), however, are substantially lower than the other values for the other pairs. This indicates that relatively few genetic differences can be found within the North Sea between the subregions (Figure 2.2.1).

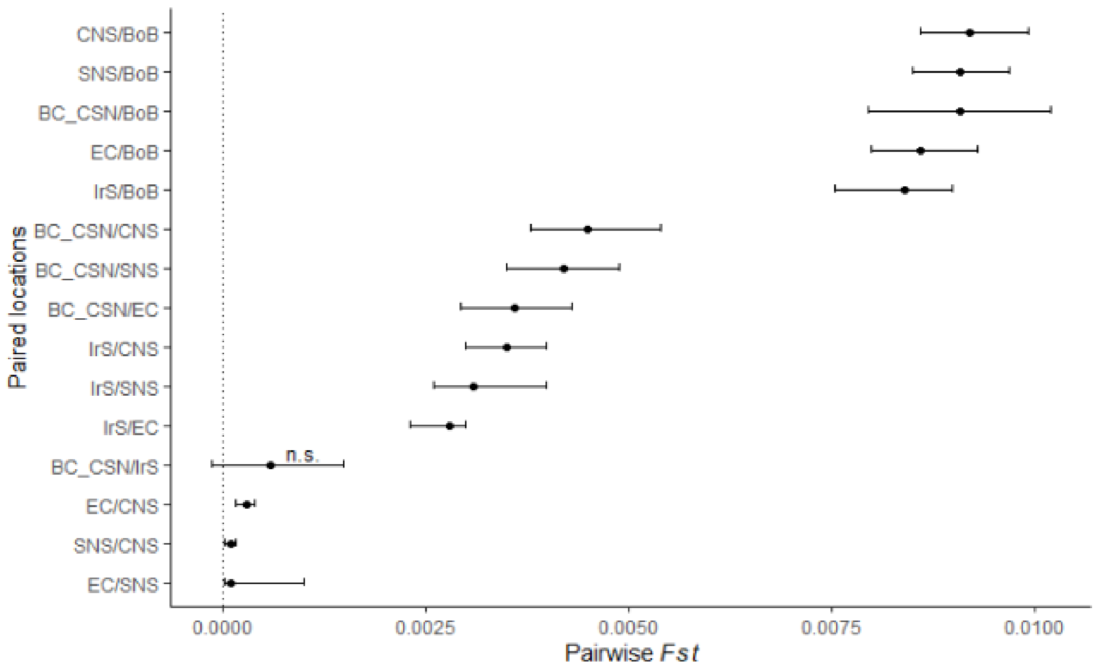

Figure 2.2.1 Nei's (1987) FST values for paired areas, with corresponding 95% confidence intervals. Dots indicate the estimated FST value per pair. Horizontal lines indicate the 95% confidence intervals. The vertical line indicates an FST value of 0. N.s.: not significantly different from 0 (obtained from Poos *et al*. 2022).

2.2.2 Tagging

Bird *et al.* (2020) compiled and reviewed 50 years of tagging data, including release and return information, for several skate and ray species including thornback ray. Thornback ray is the most frequently tagged ray species in European Waters (Bird *et al.*, 2020). Several tagging studies were done in the southern North Sea (i.e. Outer Thames) demonstrating the importance of the estuary in the life-cycle of this stocks (Walker *et al.*, 1997; Hunter *et al.*, 2006). While the Thames Estuary is an important area for the stock, individuals are not restricted to the estuary, but move throughout the southern North Sea (Hunter *et al.*, 2006). Annual migration patterns were observed whereby individuals move in autumn from the spawning grounds in the Thames estuary to the central North Sea for winter, followed by a return to the estuary in spawning season.

Overall, for individuals tagged in the North Sea over 99% of the tag returns came from within the current stock unit of thornback ray, i.e. there is a clear exchange of thornback ray within divisions 4.b–c and 7.d. Yet, information on the exchange with division 3.a (Skagerrak) and 4.a (Northern North Sea) is very limited (Figure 2.2.2 and Table 2.2.1). Furthermore, more distant movements to other stock units were also observed. However, it remains unclear whether these are regular or occasional movements. As such, based on available tagging data there is no evidence to update the current North Sea stock unit for thornback ray.

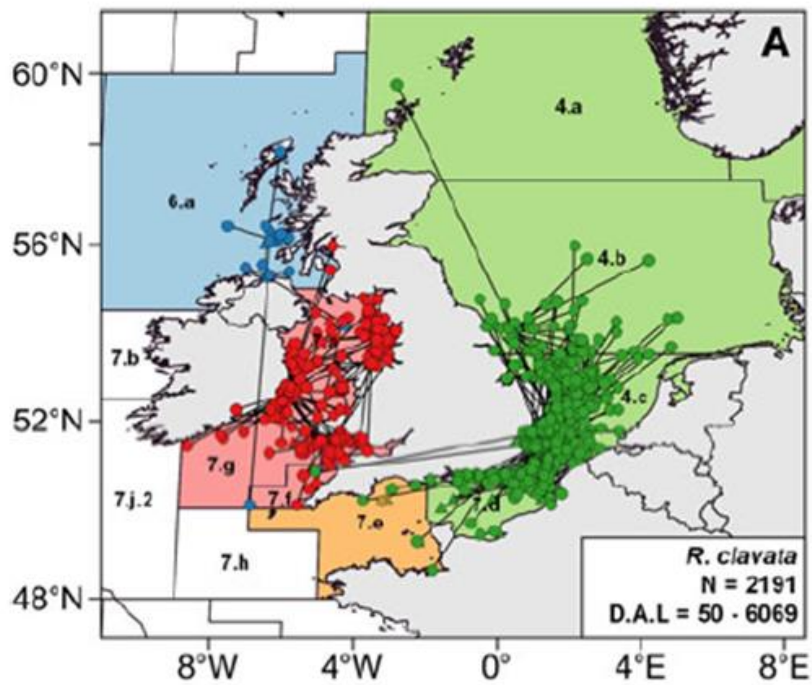

Figure 2.2.2: Tag releases, returns and straight-line distances for thornback ray (Raja clavata). The colours depict the stock units, with the green stock unit being thornback ray in subarea 4, and divisions 3.a and 7.d. Retrieved from Bird *et al*., 2020.

Table 2.2.1: Exchange of thornback ray (Raja clavata) (≥50 D.A.L.; N = 2191) between ICES divisions, showing the original release division, the total number released (NRel), the number recaptured (NRec), and the proportion of these recaptured in each ICES division. Obtained from Bird *et al.*, 2020.

Release Division	NRel	NRec	Recapture Division									
			3.a	4.a	4.b	4.c	7.d	6.a–b	7.a	7.f	7.g	7.e
3.a	0	0	–	–	–	–	–	–	–	–	–	–
4.a	0	0	–	–	–	–	–	–	–	–	–	–
4.b	123	31	–	0.032	0.871	0.097	–	–	–	–	–	–
4.c	9931	1558	–	–	0.021	0.938	0.039	–	–	0.001	–	0.001
7.d	860	129	–	–	–	0.155	0.814	–	–	–	–	0.031
6.a–b	68	19	–	–	–	–	–	0.895	0.053	0.053	–	–
7.a	2318	385	–	–	–	–	–	0.005	0.953	0.021	0.018	0.003
7.f	598	55	–	–	–	–	–	–	0.073	0.745	0.182	–
7.g	130	13	–	–	–	–	–	–	0.154	0.231	0.615	–
7.e	3	1	–	–	–	–	–	–	–	–	–	1

2.3 Input data for stock assessment

2.3.1 Catch data

In September 2022 a data call was send out specifically requesting landings and discards (catch) for the selected stocks in the WKBELASMO 2023. Catch data of thornback ray (*Raja clavata*) in Subarea 4 and divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat and eastern English Channel) for the period 2009-2021 were extracted from InterCatch. Data before 2009 were obtained from the WGEF landings and discard table (ICES, 2021). BMS landings are available since 2018, but have only been submitted by the UK. Overview of the catches are shown in Figure 2.3.1.

Thornback ray is the main commercial skate species in the North Sea and eastern English Channel, straddling two TAC management units. Since 2013, thornback ray could no longer be landed from Division 3.a (prohibited species list), although thornback ray has limited occurrence in that area. The majority of thornback ray catches come from division 7.d, with landings increasing over time. Catches in subarea 4 are mainly realised in division 4.c, however, some member states have not provided the data by division but have aggregated the catches into subarea 4. These cannot be allocated to a specific division. Given the majority of the fishing activities occur in division 4.c it is likely that most of the catches could be allocated to 4.c.

Landings and discard data have been submitted by Belgium, Germany, Denmark, France, the UK (2009-2021), Ireland (landings only), Netherlands and Sweden. Catches are highest for France, but The Netherlands has the highest discard rate (~60%) compared to the other countries such as France (~20%). A potential reason for the high discard rate could be the smaller share of the TAC for the Netherlands (9%) compared to France (~36%) and UK (~41%), constraining the landings in the Dutch fisheries, and thus incentivising discarding.

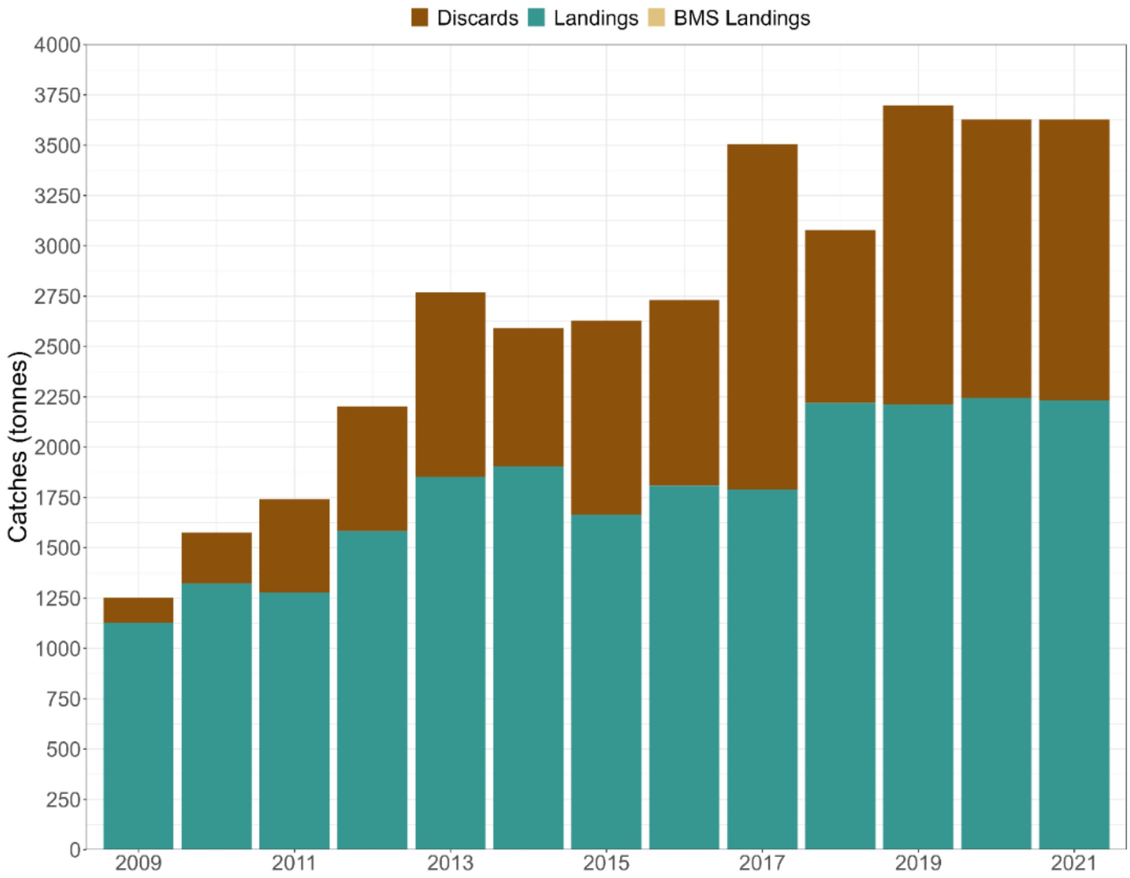

Figure 2.3.1: Thornback ray, annual landings, discards and BMS landings (catch) in subarea 4, and division 3.a and 7.d.

The data call requested landings and discards to be submitted by metier (kW.Days, Days being fishing days) level 4 (gear group) or finer. All metiers have been aggregated to level 4 metiers. Landings have been submitted for seven metiers showing thornback ray is mainly and increasingly been landed by bottom trawls, followed by beam trawls and netters. In recent years more landings are observed in the seine fisheries, which corroborates with the increase in effort observed for this fishery. Compared to the landing´s discards have only been submitted for three metiers (i.e. bottom trawls, beam trawls and netters). Beam trawlers have the highest discard rate being ~ 65% in recent 5 years.

Surplus production models such as SPiCT and JABBA require a time series of catches as input data. Preferably the time series of catches is long enough to cover one generation time (~10 years) and includes contrasted periods in terms of stock biomass and fishing mortality. Such contrasts provide valuable information to the model, improving the quality of the estimation of various model parameters. As submitted data cover the period 2009-2021, we explored the potential of extending the time series by reconstructing landings and discards for the period 1999-2008. In addition, catches, as input data for the models, should preferably consist of dead catch. Dead catch are the landings plus the part of discards which do not survive the catching process (i.e. dead discards). Dead discards were calculated applying the outcomes of several ray discard survival studies to the submitted as well as reconstructed discards. Information on thornback ray catches can be found in Working document 10, with the reconstruction of landings, discards and removals found in Working document 8.

2.3.1.1 Landings

Before 2008, commercial ray landings in the EU were mainly recorded at a family level, making species-specific catch data before 2009 highly uncertain. As such, landings data before 2009 are lower and more uncertain compared to the landings submitted from 2009 onwards.

To expand the time series of catches landings in the period 1999-2008 have been reconstructed. Reconstruction is possible by applying a species-specific ratio to the total landings of the species part of the group-TAC in the greater North Sea ecoregion (i.e. Rajidae, starry ray, cuckoo ray, thornback ray, spotted ray and blonde ray). Total landings in the period 1999-2008 were extracted from the Historical Nominal Catches 1950-2010 database. Using the species-specific data from 2009–2021 a species-specific landing ratio, being the proportion of landings of each stock within the total Rajidae landings, was calculated. Same species as for the 1999-2008 Rajidae composition was used.

Several options were explored to average the yearly ratios and applied to total landings of Rajidae from 1999 to 2008 in order to get an estimate of the landings for these years. Given the changes in the TACs over time three scenarios to average yearly ratios were explored,

1. Average over entire time series applied over 1999-2008
2. Average of 2009-2011 applied over 1999-2008
3. Average of 2009-2011 applied over 2005-2008, and average of 2018–2021 applied over 1999-2004.

whereby scenario 3 takes the similarity in TAC setting between the years 1999-2004 and 2018 and 2021, and 2005-2008 and the three following years (2009-2011) into account.

The landings ratio of thornback ray increased from 38.6% in 2009 to 68.1% in 2021 (Table 2.3.1). Using the full time series a landings ratio of 60.9% is applied resulting in relatively high landings of the species in the reconstructed year. More specifically in the period 2006-2008 when the TAC has been the lowest in the entire time series.

Scenario 2 resulted in an average landings ratio of 44.7%. Consequently, the landings in the period 2005-2008 are in line with the landings observed in 2009-2011. However, reconstructed landings in the earliest years (1999-2004), when the TAC and Rajidae landings were highest, are low. For example comparing the reconstructed landings in 2001 (1728 tonnes) with the 2020 landings (2242 tonnes), whereby the TAC and total Rajidae landings in 2001 were higher compared to 2020.

To correct for this mismatch, scenario 3 was explored with the landings ratio of 2009-2011 (44.7%) applied to the 2005-2008 total Rajidae landings and the landings ratio of 2018-2021 (66.8%) applied to the earliest years when the TAC and Rajidae landings were highest in the time-series and more equal to the recent time period.

Extending the time series is providing valuable information to the assessment models, especially when contrasted periods in the time series are observed. Such contrast is observed in thornback ray for scenario 1 and 3, with a sudden decrease in landings in 2009 and 2005 respectively. This sudden decrease in landings was deemed unrealistic as such changes would require a major shift in fishing activities or abrupt changes in the population. In this context, it was decided to include scenario 2 as the basis for catches in the assessment demonstrating a more gradual decrease in landings in the period 1999-2008, being more in line with landings observed in the succeeding period, i.e. 2009-2011.

Table 2.3.1: Thornback ray overview of the yearly landings ratio and reconstructed time series (orange) in the period 1999-2008 under 3 scenarios (tonnes).

Year	Agreed TAC	Rajidae landings	RJC proportion	Average time series	Average 2009-2011	Average combined
1999	6060	3087		1882	1381	2064
2000	6060	3644		2221	1630	2436
2001	4848	3862		2354	1728	2582
2002	4848	3878		2364	1735	2592
2003	4121	3864		2356	1729	2583
2004	3503	3556		2168	1591	2377
2005	3220	2988		1822	1337	1337
2006	2737	2910		1774	1302	1302
2007	2190	3118		1901	1395	1395
2008	1643	2998		1828	1341	1341
2009	3367	2917	0.386	1127	1127	1127
2010	2864	2812	0.471	1323	1323	1323
2011	2864	2633	0.486	1278	1278	1278
2012	2862	2753	0.575	1584	1584	1584
2013	2574	2931	0.632	1852	1852	1852
2014	2524	2790	0.683	1905	1905	1905
2015	2650	2488	0.669	1665	1665	1665
2016	2749	2616	0.691	1808	1808	1808
2017	2911	2716	0.659	1789	1789	1789
2018	3400	3429	0.647	2219	2219	2219
2019	3528	3408	0.649	2211	2211	2211
2020	3681	3215	0.697	2242	2242	2242
2021	3500	3279	0.681	2231	2231	2231

2.3.1.2 Discards

Discard data per stock, country, year, métier, and fishing area (in tonnes) were extracted from InterCatch for the period 2009-2021. Discards are available since 2009 and have increased until 2019 where discards have been close to 1400t per year. Yet, the time series of discards is incomplete as some countries only submitted discard data from 2011 onwards (e.g. The Netherlands).

Since 2015 the discard rate is 38% on average with a peak in 2017 (49%) and low in the following year (28%).

Here we describe the use of a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) to fill the gaps in the discard data series in the period 2019 – 2021. Next, the reconstruction of dead discards in the period 1999 – 2008 is presented.

Fishing effort data was extracted from the ICES Working Group of Mixed Fisheries (WGMixFish) for the period 2009-2021. Data consisted of effort by kw.days by year, country, metier, and size class of the vessels. Four size classes were noted ranging from below or equal to 10 (<=10m), between 10 and 24m (10<24m), between 24 and 40m (24-<40m) and vessels larger or equal to 40m (>=40m). Effort data were aggregated to metier level 4, keeping the size-classes information of the vessels (Figure 2.3.2).

Data show fishing effort is dominated by the beam trawlers and bottom trawls (i.e. OTB and OTM). There is a decrease in the effort of both the 10<24m and 24<40m beam trawlers, while the effort of the largest size classes is decreasing in the first years of the time series, but stabilizing in recent years. Conversely, fishing effort of the bottom trawls and seine fisheries increases. Especially fishing effort in the seines of 24<40m vessel size class increases rapidly over time. This is in line with observation in the Dutch and French fishing fleet where vessels shift from using conventional beam trawls or otter trawls to the use of (Scottish or Danish) seines.

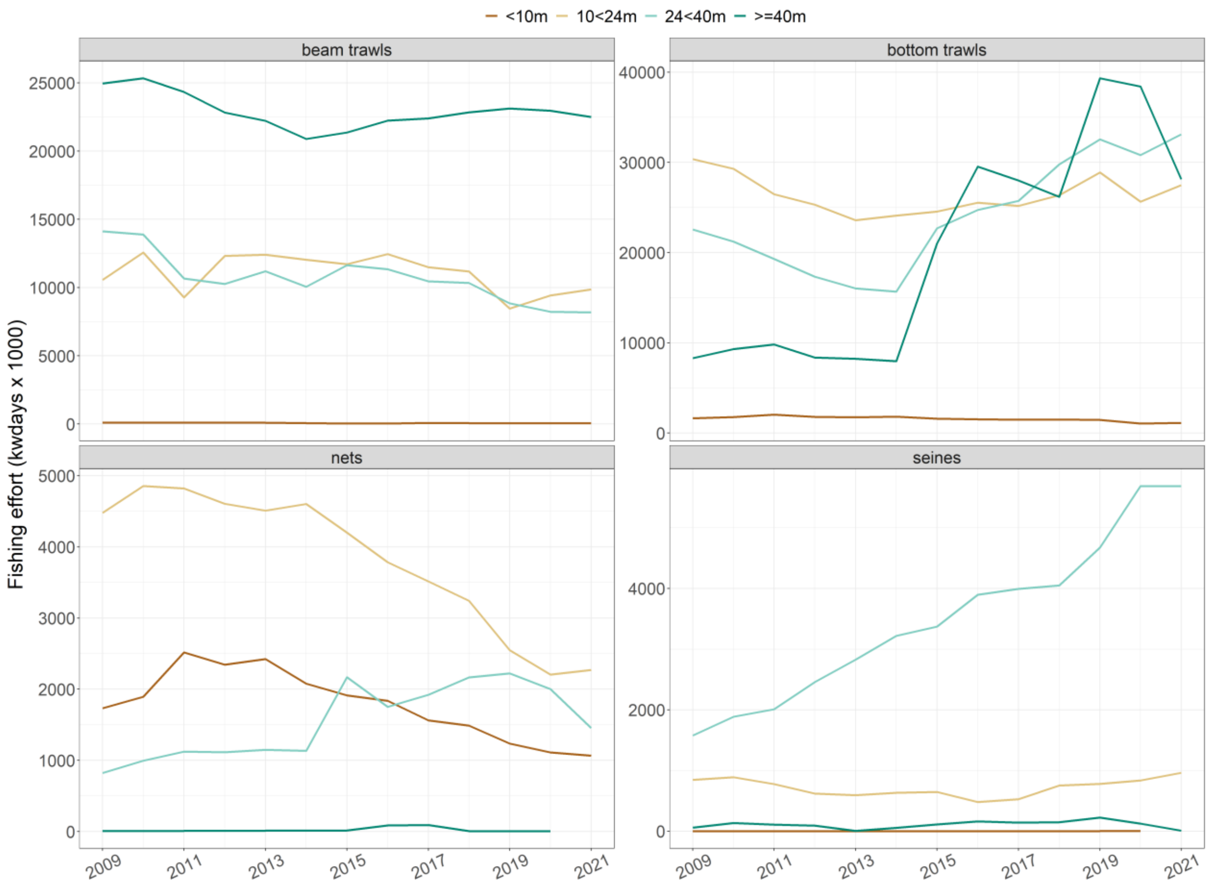

Figure 2.3.2: Effort in KW.days by fishing gear and vessel length in the period 2009-2021. Data extracted from WGMIXFISH.

Both discard values and fishing effort were aggregated to the lowest level of detail as submitted by Member States (i.e. métier level 4) in the WKBELASMO data call. Some Member States provided the discard data at subarea level, i.e. 27.4. Consequently, discard and fishing effort data of division 4a, b and c were aggregated to subarea level 27.4. For some combinations of year, métier, fishing area discard data were not available. Discard values of missing combinations were inferred using a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) using the model (Amelot *et al.* 2021):

Discards (in tonnes) ~ kWdays: Fishing Fleet: Fishing Area.

For thornback ray discard data were available for beam trawls, bottom trawls, netters, hooks and lines and seines, whereby bottom trawls is the only métier covering subarea 27.4 and division 3a and 7d. The relation between discard values and fishing effort (KW-days) per area is presented in Figure 2.3.3. Only métiers for which data are available were included in the model. Consequently, the hooks and lines, seines, midwater and pelagic trawls, unspecified and all other bottom trawl gears segments were excluded from the analysis. This means we assume these métiers do not contribute to the discards, resulting in an underestimation of the discarded part of the catch.

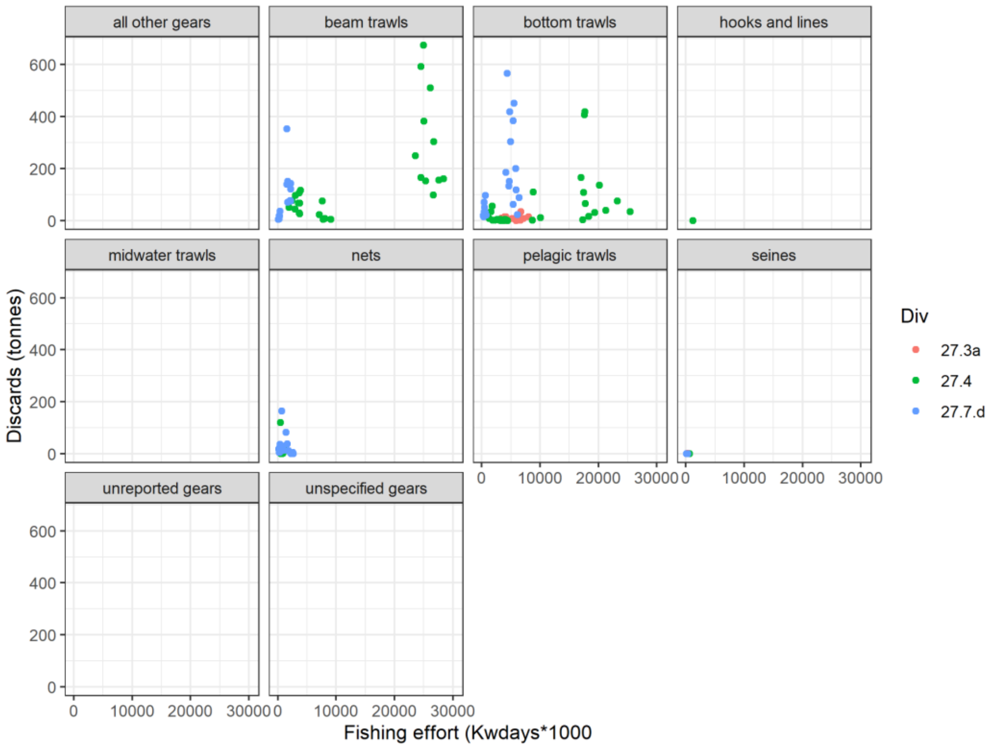

Figure 2.3.3: thornback ray, correlation between fishing effort by métier, area and discarding.

The results of the regression for thornback ray showed that the model was a significant predictor of discards F(12,163) = 21.67, P < .001. Coefficients of beam trawls in subarea 4 (1.1712×10^{-05}, P < .001), division 7.d (6.527×10^{-06}, P < .001) and bottom trawls in subarea 4 (5.727×10^{-06}, P < .001) and division 7d (4.313×10^{-06}, P < .001) was shown to have contributed significantly to the model. Thus, having a significant impact on the discards. These values were then used to predict missing discard values of thornback ray (Figure 2.3.4).

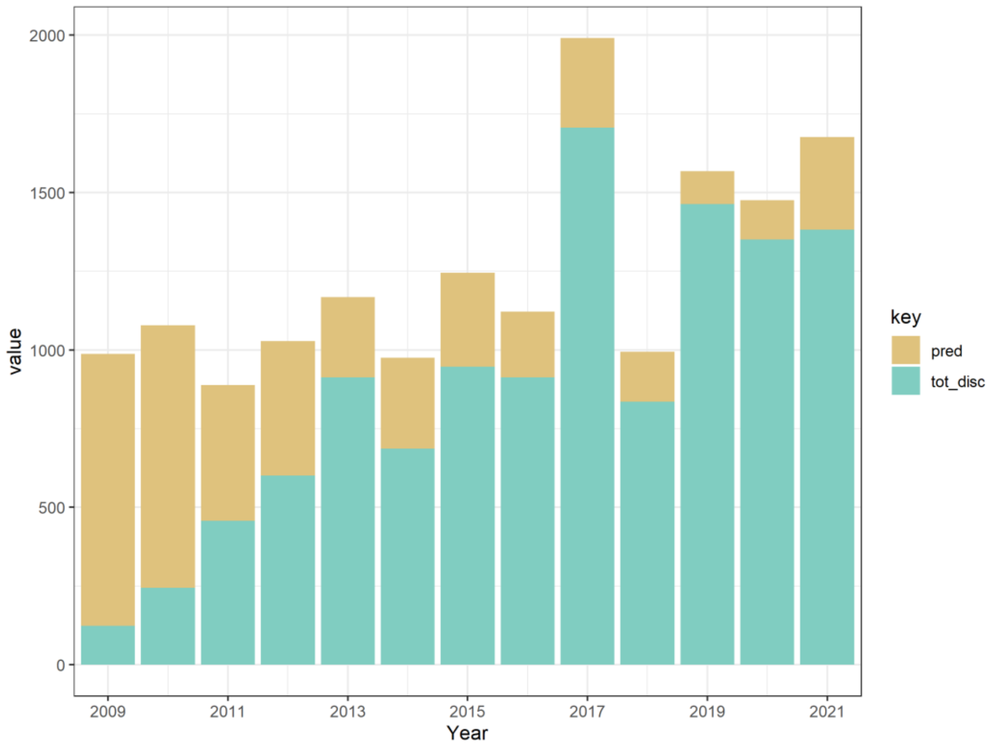

Figure 2.3.4: thornback ray, the total reconstructed discards of the stock (tonnes) showing the submitted values (green) and reconstructed part (brown). These values do not account for discard survival.

The reconstructed discards do not account for discard survival. To do so, discard survival studies for thornback ray by FromNord, Wageningen Marine Research and the Sumaris project have been merged to obtain a single survival value per métier (Villagra, 2023 (WD7 on discard survival)). These values do not take possible difference in the survivability of length classes into account. Quota have been and are still constraining the landings of the species for most fleets. Consequently, all size classes are observed in the discards, justifying the use of a single survival estimate per métier.

For thornback ray, survival is highest in trammel net fisheries (99.1%) and lowest in the beam trawl fishery (59.7%) (Table 2.3.2). These values are applied to the total discards by métier and summed to get an estimate of the dead discards in the period 2009-2021 (Table 2.3.3).

Table 2.3.2: Discard mortality rates for thornback ray in the North Sea (Villagra, 2023 WD7).

	GTR	OTB	TBB
Discard mortality (%)	0.66	28.43	45.54

Table 2.3.3: thornback ray (rjc.27.3a47d), overview of discard data submitted to InterCatch (Submitted), after reconstruction using the multiple regression (Reconstructed), and correction using discard survival estimates (Dead) (all values in tonnes).

Year	Submitted	Reconstructed	Dead
2009	123.1	987.0	362.4
2010	244.5	1078.9	388.4
2011	456.7	888.4	298.9
2012	600.9	1027.8	293.2
2013	913.2	1168.2	367.3
2014	686.2	974.7	341.7
2015	946.3	1244.3	413.3
2016	912.9	1121.5	355.5
2017	1705.7	1991.0	652.8
2018	836.0	994.1	311.5
2019	1463.7	1567.0	513.1
2020	1350.6	1475.7	498.3
2021	1381.4	1676.1	595.3

2.3.1.3 Removals

To reconstruct the removals (i.e. dead catch) in the period 1999 – 2008, the ratio between landings and dead discards for the 2009-2021 time period was calculated. Dead discards include the total discards resulting from the regression and corrected for discard survival. This ratio was then applied to the reconstructed landings in order to get an estimate of the dead discards for the period 1999-2008. Note that we assume that discards remained stable over this time period. Calculations were done for the three scenarios described in section 2.3.1.1. For thornback ray the average (dead) discard rate over the period 2009-2021 is 19.7%. This value is applied to the reconstructed landings in the period 1999-2008 using the equation:

Total reconstructed catch = reconstructed Landings/(1 – average discard ratio)

Removals of thornback ray for the 1999-2021 period are shown in Figure 2.3.5. Outcomes, show a sudden decrease in catches in 2009 and 2005, using either scenario 1 and 3 to reconstruct the landings. Such decrease is questionable when looking at the trends in known catches of thornback ray. Unless there is evidence of management measures or sudden changes in the abundance of the stock we would argue these scenarios could be valid and used. Yet no such evidence is available and the group decide to use the removals in scenario 2 in which the landings are reconstructed using the ratio of thornback ray in the total Rajidae landings observed in the period 2009 – 2011. In addition, the group decided to keep the full time-series as input for the assessment (Table 2.3.4).

Figure 2.3.5: thornback ray, dead catch in the period 1999-2021, with reconstructed dead catch for 1999-2008. Three scenarios using the average landings ratio of the full time series (left), the period 2009-2011(middle) and combination of 2009-2011 and 2018-2021 (right). Lighter coloration denotes the dead discards.

Table 2.3.4: thornback ray, landings, dead discards and removals resulting from the reconstruction and used as input in the assessment model (all values in tonnes).

Year	Landings	Dead discards	Removals
1999	1381	324	1705
2000	1630	382	2012
2001	1728	405	2133
2002	1735	407	2142
2003	1729	405	2134
2004	1591	373	1964
2005	1337	313	1650
2006	1302	305	1607
2007	1395	327	1722
2008	1341	314	1656
2009	1127	362	1489
2010	1323	388	1712
2011	1278	299	1577
2012	1584	293	1877

Year	Landings	Dead discards	Removals
2013	1852	367	2220
2014	1905	342	2246
2015	1665	413	2078
2016	1808	355	2164
2017	1789	653	2442
2018	2219	311	2530
2019	2211	513	2724
2020	2242	498	2740
2021	2231	595	2827

2.3.2 Survey biomass index

In the current assessment of thornback ray, several surveys indices are combined into a single index using a design-based approach. Surveys that are included for this stock are NS-IBTS-Q1, NS-IBTS-Q3, BTS-BEL-Q3, BTS-Eng-Q3 and FR-CGFS-Q4. The inclusion of surveys for this stock was evaluated during WKSKATE (ICES, 2021b). For this benchmark, a model-based approach was chosen to combine surveys. Different combinations of surveys were explored using a gam model with either a Tweedie or delta lognormal distribution. Furthermore, models were tested combining all surveys or splitting the surveys based on seasonality. In this section we only describe the models that were chosen to be used in the exploratory SPiCT assessment runs. More detailed information can be found in Working document 9 on surveys and biomass indices.

Instead of using exploitable biomass (individuals ≥50 cm), it was chosen to use a biomass index of individuals ≥30 cm as these individuals represent a significant part of thornback ray catches. From the different model runs, two options were chosen to use in the exploratory assessment runs using SPiCT (Table 2.3.5). For both options a delta lognormal distribution model was chosen as they had a better fit to the data, despite having higher AIC scores when splitting the surveys into two indices. However, QQ-plots for the second model showed a better distribution of quantiles for the delta lognormal as compared to the Tweedie distribution.

Table 2.3.5 Model runs for thornback ray with different survey combinations for years 1989-2021 using biomass of individuals ≥30 cm resulting in either 1 or 2 survey indices.

	Survey index 1	Survey index 2
1	NS-IBTS-Q1 and Q3, FR-CGFS-Q4, BTS-Eng-Q3 and BTS-BEL-Q3 combined	
2	NS-IBTS-Q1 and FR-CGFS-Q4 combined*	NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined^

Both index options have been explored in exploratory SPiCT runs and ultimately it was chosen to use the second model with two survey indices in the final SPiCT assessment. The biomass indices are shown in Figure 2.3.6 where both indices show an increase in biomass since 2011 up until 2020 and a decrease in 2021.

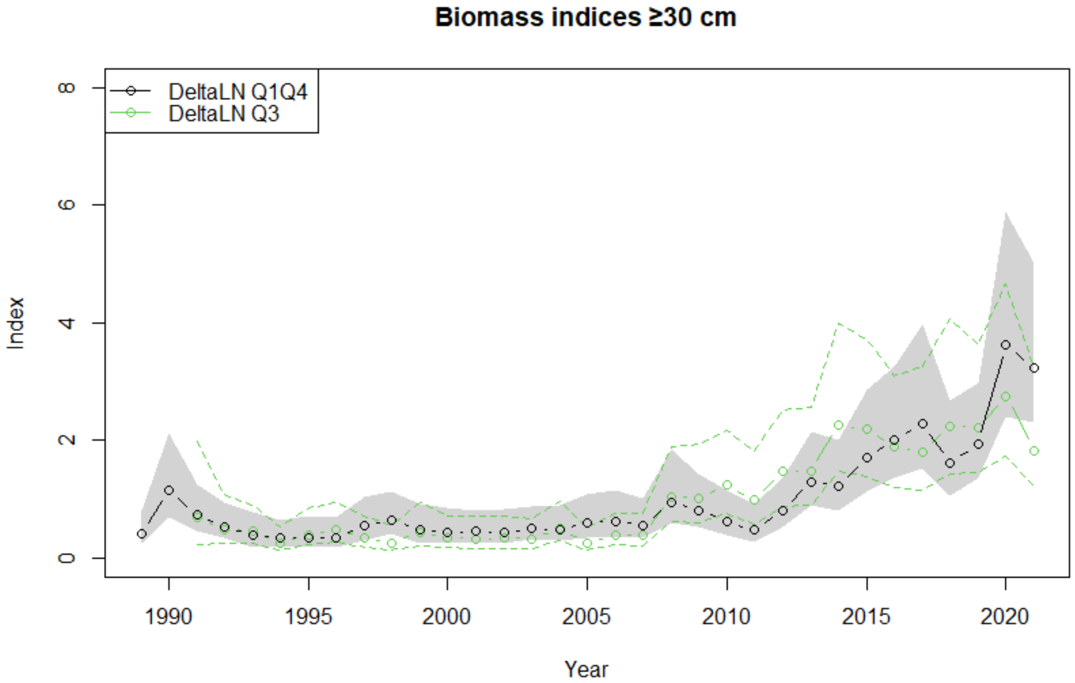

Figure 2.3.6: Thornback ray relative biomass (≥30 cm) indices with 95% confidence intervals for NS-IBTS-Q1 and FR-CGFS-Q4 combined (black line) and NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined (green line).

2.3.3 Life-history parameters

Key life-history parameters, namely the length-weight relationship, length-at-maturity, growth rates and annual fecundity of thornback ray have been collated in Ellis *et al*. 2023 (Working document 4). Below we summarize the selected parameters used as input in the assessment.

For the purposes of the 2023 benchmark assessment, it was agreed to use the length-weight relationship provided by Silva *et al*. (2013): $W = 0.0045\ L^{3.0961}$ ($r^2 = 0.9921$). This study included individuals from the North Sea and eastern English Channel stock and covered a large sample size (n=2417) and length range (10-94cm).

Estimates of the length at which 50% of the population is mature ($L_{50\%}$) for thornback ray in the stock area are given by Walker (1999) and McCully *et al*. (2012). Given the former study had a limited sample size, it was agreed to use a length-at-maturity of 73.7 cm, based on data for female thornback ray in the North Sea ecoregion (McCully *et al*., 2012). The length at which 95% of the population is mature ($L_{95\%}$) was derived from the same study, using the largest size of immature female encountered (82.0 cm).

Thornback ray is one of the best-studied skates in the North-east Atlantic, and consequently a range of studies have examined the growth of this species. The averaged VBGP provided for female thornback ray from seven studies (Taylor and Holden, 1964; Holden, 1972; Fahy, 1989 (mean value from different areas); Walker, 1999; Gallagher *et al*., 2005; Whittamore and McCarthy, 2005; Serra-Pereira *et al*., 2008) were L_{inf} = 123.62 cm, K = 0.129 y^{-1} and t_0 = –1.154. These published values and the averaged values gave growth curves (Figure 2.3.7) that were above the corresponding curve derived from the parameters for thornback ray given on FishBase (L_{inf} =

94.5 cm, K = 0.19 y^{-1} and t_0 = –0.65; Froese and Pauly, 2022).

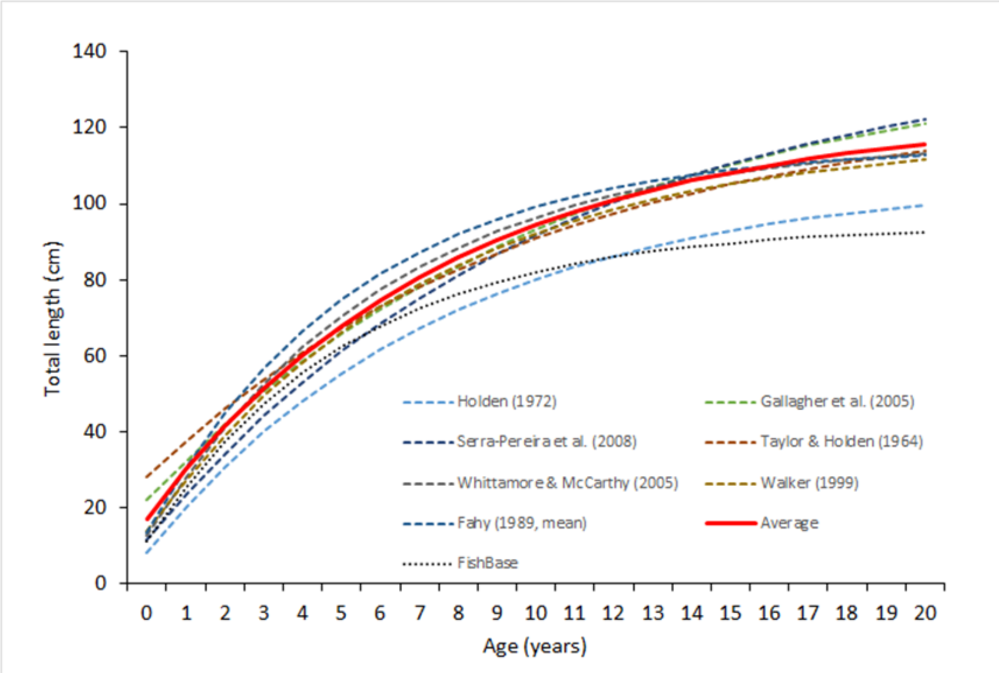

Figure 2.3.7: Estimated length-at-age for thornback ray (RJC) from published studies, including the growth for the averaged VBGP and that given by FishBase. Data extrapolated to age 20, given that Walker (1999) observed fish up to 14 years of age (See WD4, Ellis *et al*. 2023).

Several studies have collected data to help estimate the fecundity of thornback ray, including estimates of ovarian fecundity (based on counting the number of yolk-filled follicles for samples from certain months or from samples collected over the course of the year), egg-laying observations from captive-held specimens, and by combining monthly data on the proportions of females with egg-cases with egg-laying rate data. These methods provide slightly different estimates whereby studies using ovarian counts or observed egg-laying behaviour, have indicated 47–115 follicles (Holden, 1975), 62–74 follicles (Ryland and Ajayi, 1984), 32–69 follicles (Walker, 1999), and 27–60 follicles (Saglam and Ak, 2012). These values are in line with observed egg production of captive-held thornback ray (Ellis and Shackley: 48 eggs; Cefas unpublished: 38–74 eggs). For the purposes of the 2023 benchmark assessment, it is proposed to consider that the annual fecundity of thornback ray would generally be <100 eggs per year. More specifically, fecundity was set at 70 eggs per year based on two North Sea studies (Walker 1999 and the observed egg-production of captive-held specimen (Cefas unpublished)).

2.4 Stock assessment

The benchmark focussed on evaluating the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg 2017) on thornback ray in subarea 4, and division 3a and 7d.

2.4.1 Priors

A prior probability distribution has been defined for the intrinsic rate of biomass increase (*r*). To estimate *r* the only considered source of mortality was natural mortality (*M*). Parameters *K* and L_{inf} were used to generate an estimate of M following Then *et al*., (2015) in their review of multiple procedures for calculating it. A single natural mortality value across all ages (M = 0.19) was calculated as follows:

$$M = 4.118 * K^{0.73} * L_{inf}^{-0.33}$$

A value for the maximum age (t_{max}) was extracted from the database of life history correlations available in the FishLife R package (Thorson, 2019). The maximum value from those available for thornback ray was chosen, with t_{max} = 17. Values for a range of biological variables were extracted from the data available for the stock.

A Leslie matrix was built using the biological variables available for thornback ray (Table 2.4.1) to obtain a mean prior value for the intrinsic rate of increase (r). The *jbleslie* function in the R package JABBA was used to return a value of r = 0.29. This value was considered rather high when compared to the median estimate of r for thornback ray in the Bay of Biscay, of 0.18 (rjc.8abd, ICES, 2022). A vague prior for r with mean value of 0.15 was adopted for the SPICT assessment trials.

Table 2.4.1 Biological variables used in the call to JABBA::jbleslie() to obtain a mean prior for the intrinsic rate of biomass increase (r) using a Leslie matrix calculation of female net reproductive rate.

Min age	Max age	L_{inf}	k	t_0	LWR a	LWR b	M	Fec	$L_{50\%}$	$L_{95\%}$
0	17	123.62	0.129	-1.154	0.0045	3.096	0.188	70	73.7	82

2.4.2 Exploratory assessments

Various simulation scenarios were tested, differing in terms of the time series considered for removals, the introduction of informative priors on parameters *r*, *bkfrac* and *sdb.* First input in the SPiCT reference run are the annual catches. It was decided to use the entire time series of removals (1999-2021). Observation errors on removals in years 1999-2008 were higher (x2) than those associated with years from 2009 onwards. This resulted in a CV of 0.2 for the removals in years prior to 2009 and a CV of 0.1 from 2009 onwards. The *logsdc* was fixed by setting the log.sd to the reference value for later years (0.1), assuming a low CV of 0.1.

The biomass index (individuals ≥30 cm) of the FR-CGFS-Q4, NS-IBTS-Q1, NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined was used and the corresponding CV values were normalized using the long-term mean. For the reference run, a short time-series of the index was used (1999-2021). A mean observation error (*sdi*) was included using the log mean of the CV of the short time-series, resulting a prior for *sdi* of -0.706 with a CV of 0.2.

The r prior was set to 0.15 and a log-normal bias correction was used. The initial r prior in the SPiCT model resulted in: -1.942 with a CV of 0.3.

The shape parameter n was fixed to a Schaefer model (n = 2) and log-transformed, resulting in a prior for n of 0.693 with a CV of 0.001.

Simulations show that high process error can be expected for a relatively long-lived species (Winker, 2018). A process error (*sdb*) of 0.07 was used in the first base run. A log-normal bias correction was used resulting in a *sdb* of -2.78426 with a CV of 0.5.

The dteuler was set at ¼. Furthermore, no informative priors on the alpha and beta parameters were set.

Outcomes of the reference run for North Sea spotted ray are shown in Figures 2.4.1-2.4.6. The retrospective bias fails to fall within the acceptable range for long-lived species (Mohn's ρ = −0.15–0.2). Furthermore, the prediction skill is evaluated using the new hindcast cross-validation

(Figure 2.4.6). A Mean Absolute Scaled Error (MASE) smaller 1 would indicate that the model has prediction skill for the index. The MASE for the reference scenario equals 0.95, indicating the model has prediction skill for the index.

To potentially resolve the strong retrospective pattern on B/B_{MSY}, a revised reference run was considered. In this revised reference run, an informative prior on the initial depletion *bkfrac* was used and set as a mean of 0.1 with a CV of 0.5. Other parameters were kept similar as the first reference run. The retrospective analysis of the revised reference falls within the acceptable range for long-lived species (Figure 2.4.7). Output from the comparison of both reference runs can be found in Figure 2.4.8. The revised reference run was used for further sensitivity analyses. A summary of the exploratory assessment scenarios and parameter settings is found in Table 2.4.2.

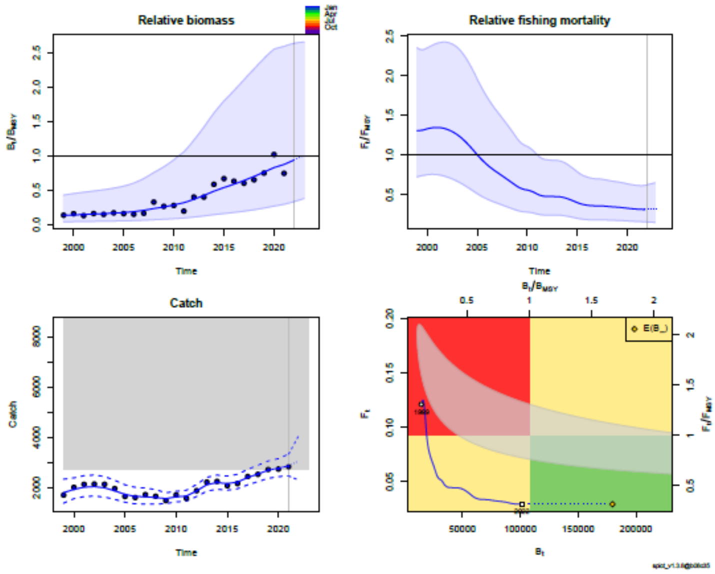

Figure 2.4.1 Results plot of the reference run.

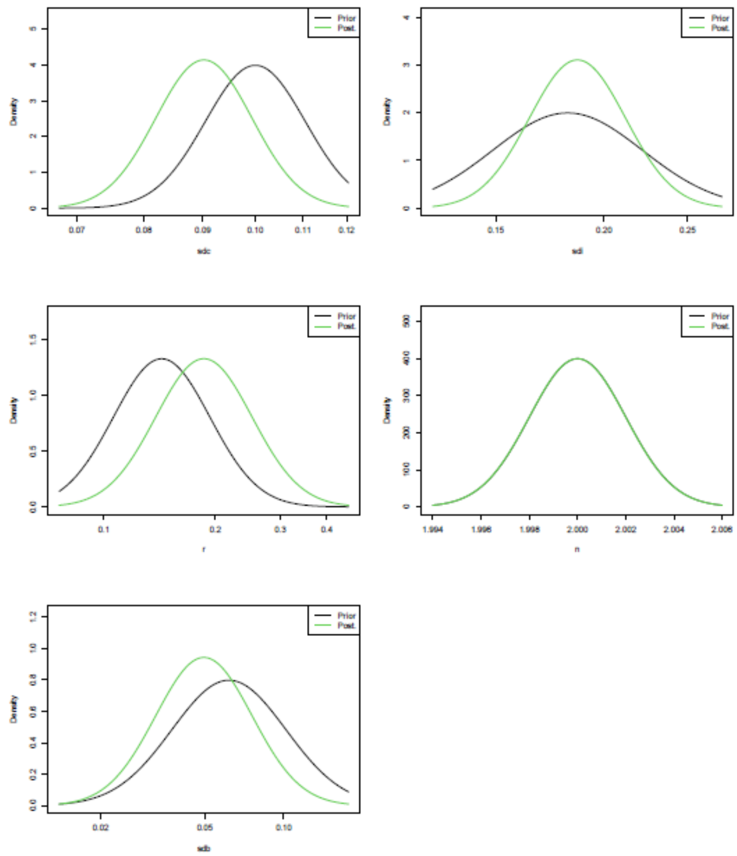

Figure 2.4.2 Plot showing the estimated priors and posteriors for the reference run.

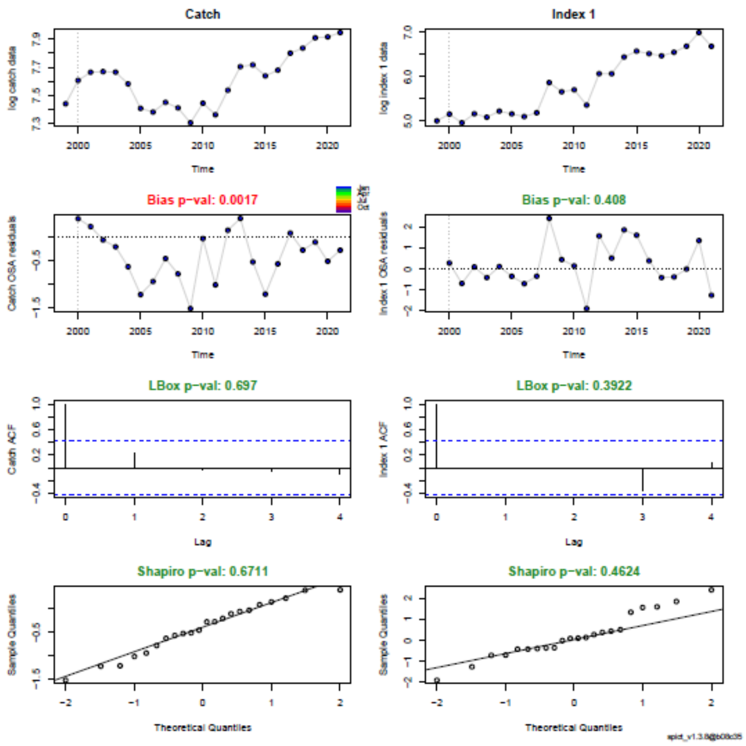

Figure 2.4.3 Diagnostics of one-step-ahead residuals for the reference scenario.

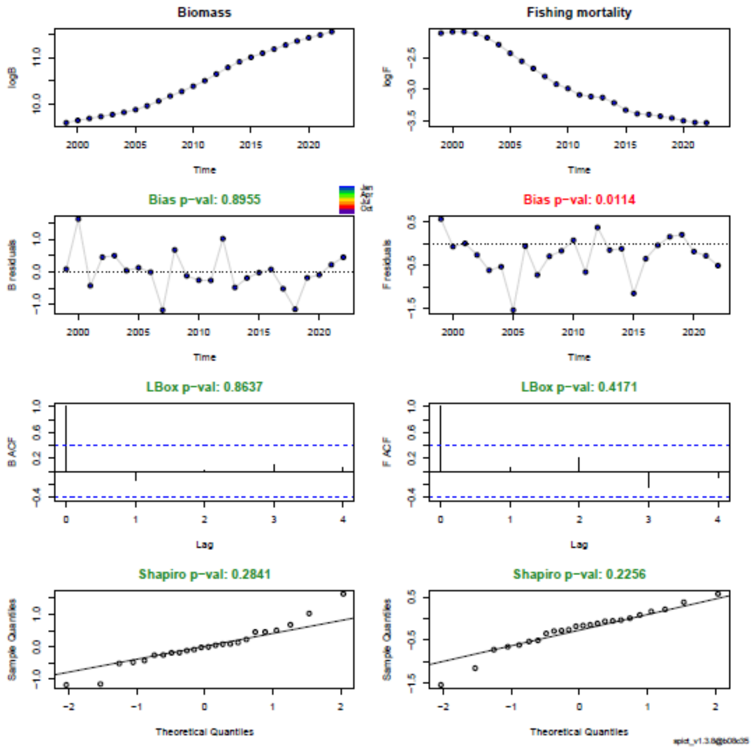

Figure 2.4.4 Diagnostics of process error deviations for the reference scenario.

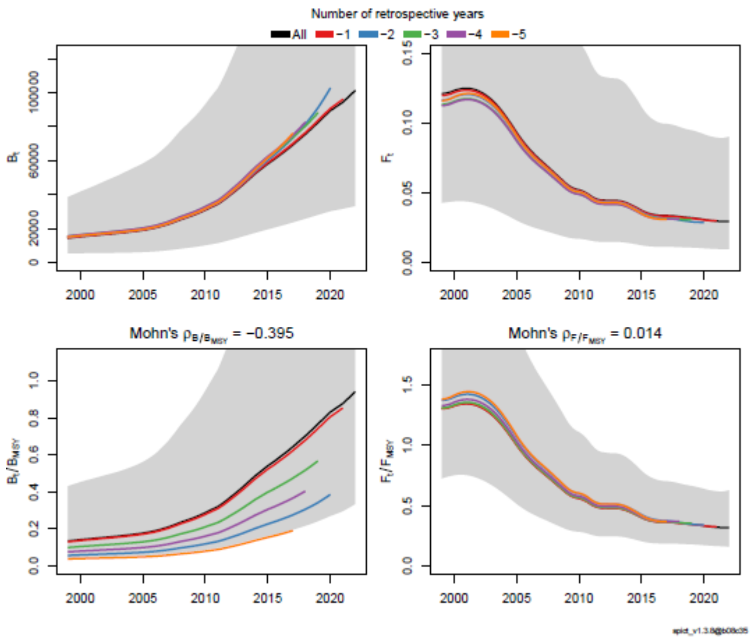

Figure 2.4.5 Retrospective analysis for the reference scenario.

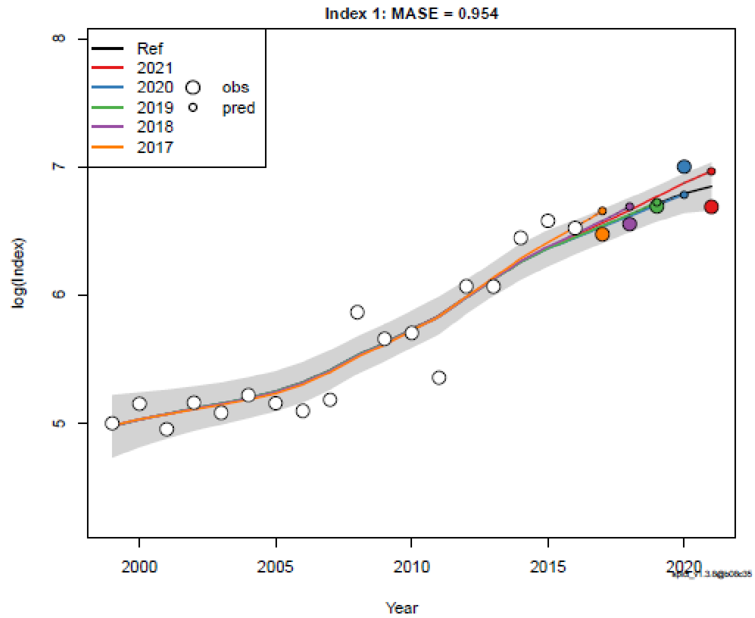

Figure 2.4.6 Hindcast cross-validation results for the reference scenario.

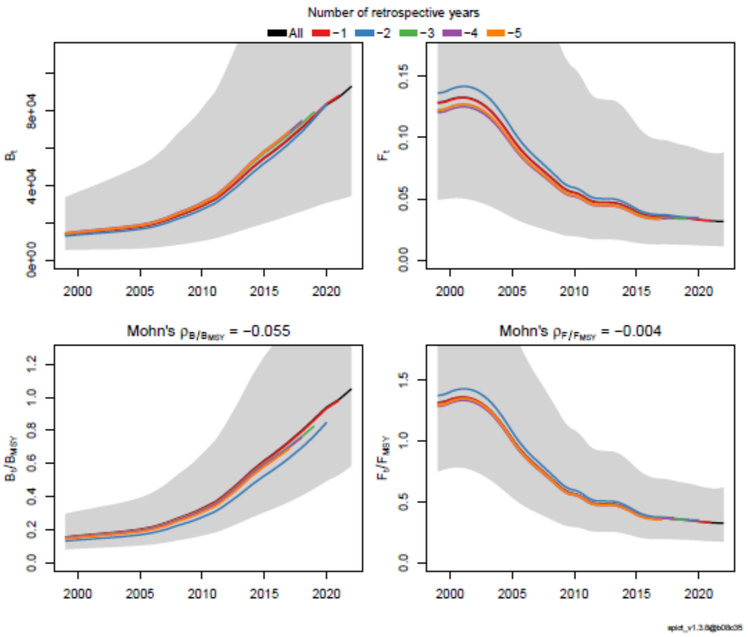

Figure 2.4.7 Retrospective analysis for the revised reference scenario.

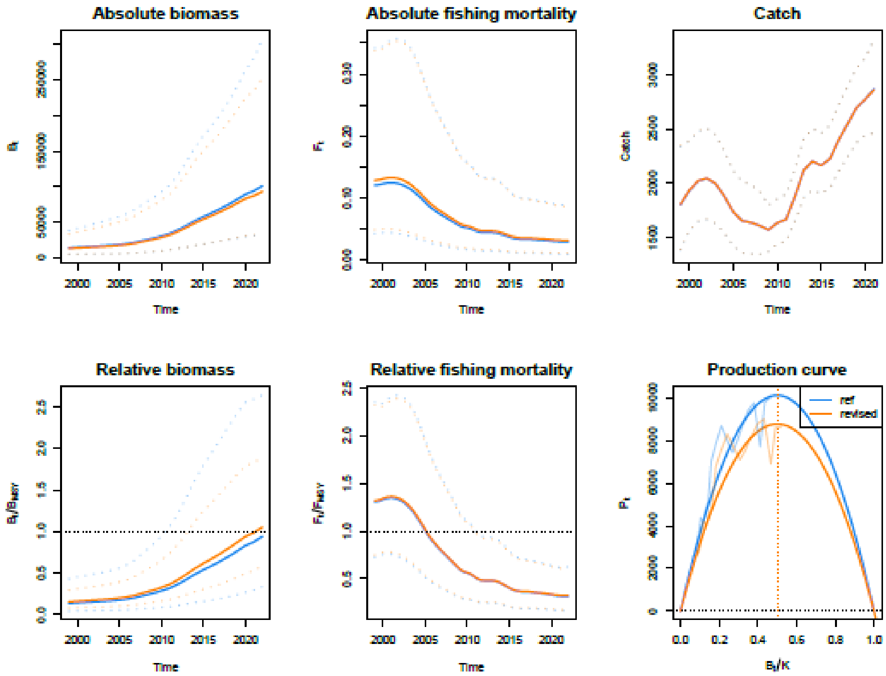

Figure 2.4.8 Comparison plots between the reference scenario and revised reference scenario.

Table 2.4.2 Thornback ray SPiCT scenarios with input parameter settings. For all scenarios a Schaefer production curve was used.

Scenario	Removals time series	Surveys time series	*r* prior (with CV)	Initial depletion rate *bkfrac* (with CV)	Process error *sdb* (with CV)
Reference	Catches 1999-2021	Short biomass index* 1999-2021	0.15 (0.3)	-	0.07 (0.5)
Revised reference	Catches 1999-2021	Short biomass index* 1999-2021	0.15 (0.3)	0.1 (0.5)	0.07 (0.5)
1 – Separate indices	Catches 1999-2021	Index 1: FR-CGFS-Q4 and NS-IBTS-Q1 combined. Time series 1991-2021 Index 2: NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined. Time series 1991–2021.	0.15 (0.3)	0.1 (0.5)	0.07 (0.5)
2 – Biomass indices full time-series	Catches 1999-2021	Full biomass index* 1989-2021	0.15 (0.3)	0.2 (0.5)	0.07 (0.5)
3 – Catch time series	Catches 2009-2021	Short biomass index* 1999-2021	0.15 (0.3)	0.1 (0.5)	0.07 (0.5)
4 – Low vs. high *r* prior	Catches 2009-2021	Short biomass index* 1999-2021	0.1, 0.25 (0.3, 0.3)	0.1 (0.5)	0.07 (0.5)
5 – *bkfrac* prior sensitivities	Catches 1999-2021	Short biomass index* 1999-2021	0.15 (0.3)	0.05, 0.1, 0.5, 0.7 (0.3, 0.5, 0.7)	0.07 (0.5)

*** Combined survey index of FR-CGFS-Q4, NS-IBTS-Q1, NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3, using a delta-gam modelling approach.**

A comparison plot of the revised reference run with scenarios 1-4 is shown in Figure 2.4.9. Although the scenario 4 (rlo) and scenario 3 (C2009) indicated similar results about the stock status, the associated precision was very low. In addition, both runs resulted in considerable higher surplus production (*MSY*) estimates, indicating that the catch forecast would be most optimistic. The remaining scenario's (1-2, 4 rhi) were further explored on estimated priors and posteriors, diagnostic plots, retrospective bias and hind-cast validation. All scenario's fall within the acceptable range for Mohn's ρ, and the MASE for each scenario was smaller than 1, indicating that the models have prediction skill for the index. Further sensitivity analyses were performed on varying priors for *bkfrac* and its CV (scenario 5). Comparison plots of these sensitivity runs are shown in Figure 2.4.10.

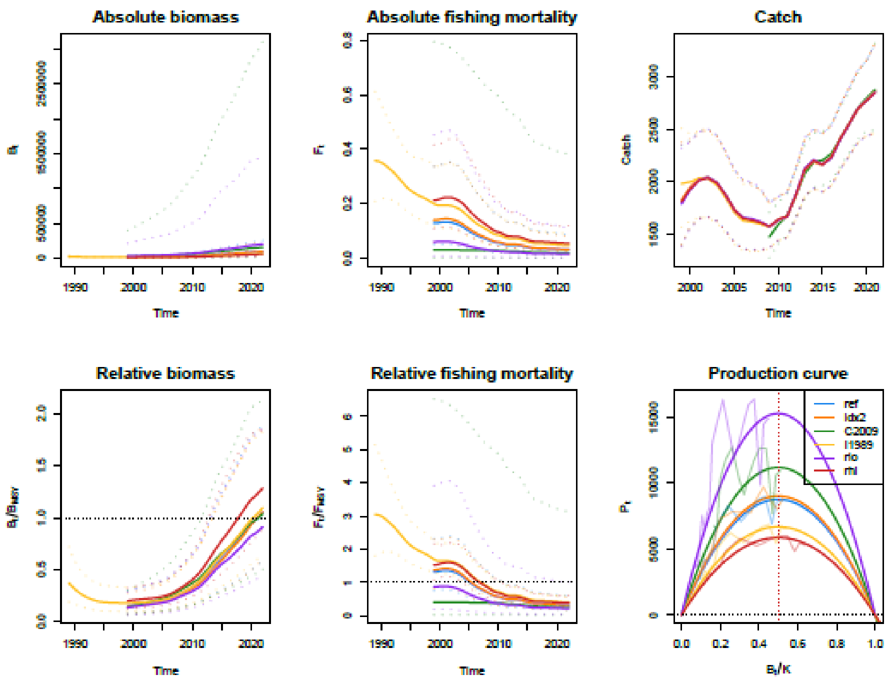

Figure 2.4.9 Comparison plots between the revised reference scenario (ref) and scenario's 1-4 (scenario 1 = idx2, scenario 2 = I1989, scenario 3 = C2009, scenario 4 = rlo (low r prior) and rhi (high r prior).

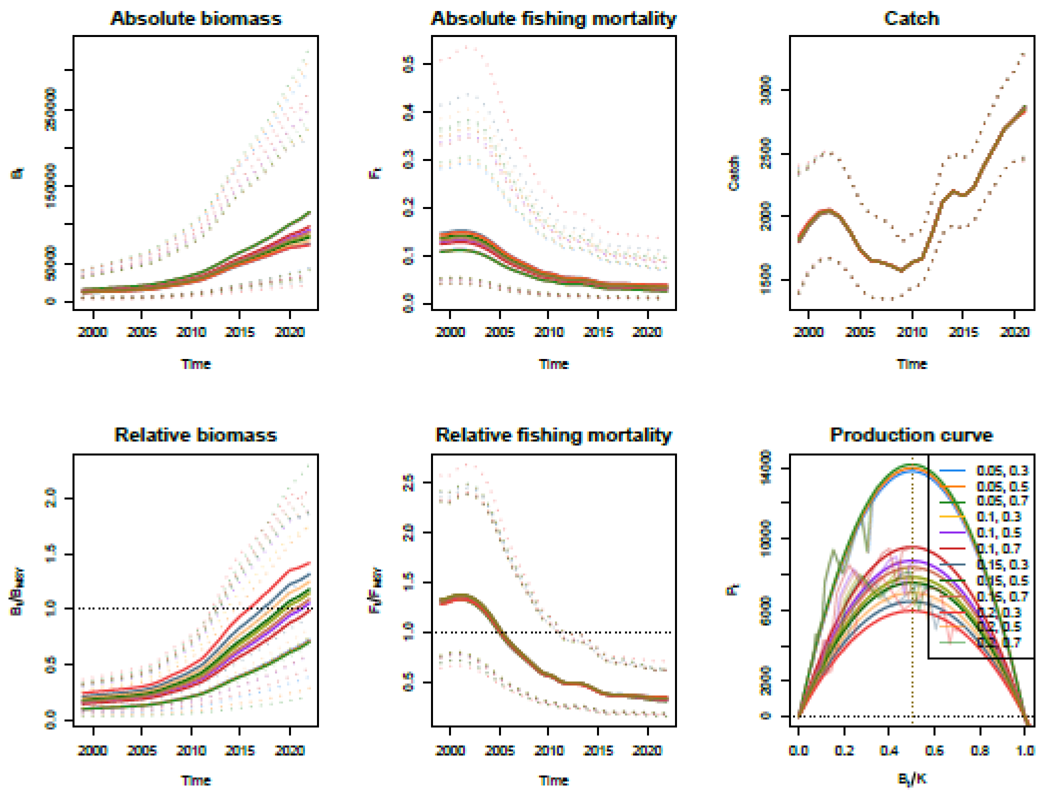

Figure 2.4.10 Comparison plots between the revised reference scenario (0.1, 0.5) and scenario 5, including varying bkfrac rates and CVs.

2.4.3 Final assessment

The scenario that was chosen as final assessment included informative priors on parameters *r*, *n* and *bkfrac*. The parameter settings agreed for the final assessment are found in Table 2.4.3. Diagnostic plots corresponding to the final assessment can be found in Figure 2.4.11.

Table 2.4.3 Parameter settings for the final assessment of thornback ray using SPiCT.

Parameter	Agreed setting
Catches	1999-2021 using reconstruction scenario 2 (2009-2011). 2x higher uncertainty in 1999-2010
Surveys	Index 1: biomass (individuals ≥30 cm) FR-CGFS-Q4 and NS-IBTS-Q1 combined. Time series 1989-2021 Index 2: biomass (individuals ≥30 cm) NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined. Time series 1991–2021.
r. prior	*r* = 0.15, CV = 0.3
Shape.prior	Schaefer model (*n* = 2)
Initial depletion prior	*bkfrac* = 0.15, CV = 0.5
Process error	*sdb* = 0.07, CV = 0.5

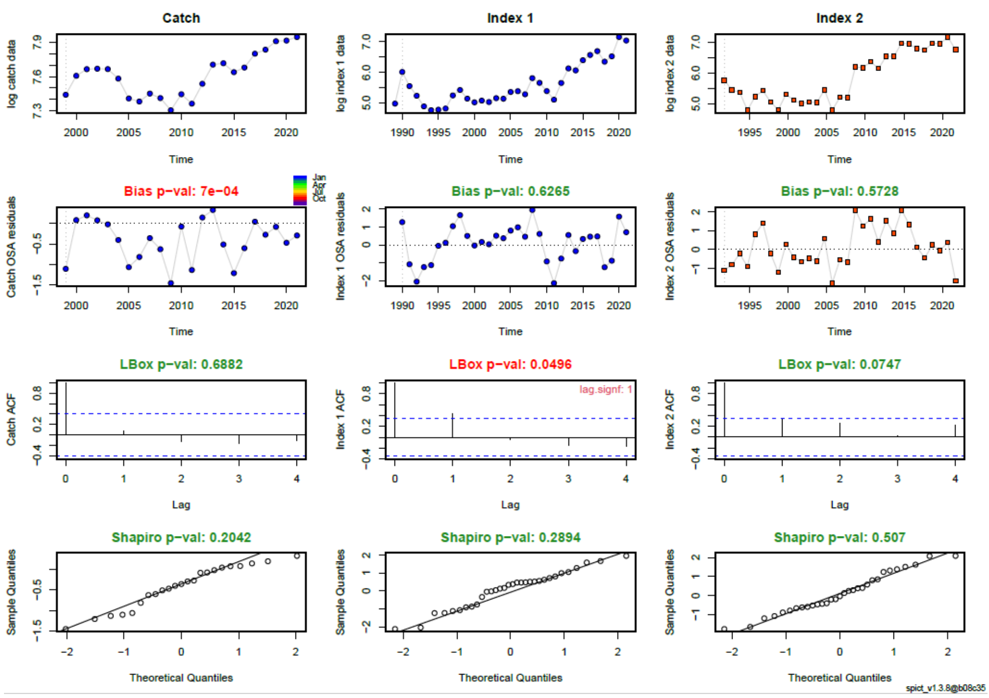

Figure 2.4.11 Diagnostic plots corresponding to the final assessment.

The retrospective analysis was done using 5 retro-years and showed *consistent patterns (Figure 2.4.12). Mohn's rho of Bcurrent/BMSY and Fcurrent/FMSY were -0.088 and 0, respectively*, which is in between the thresholds of -0.15 and 0.20 for long-lived species (ICES, 2020).

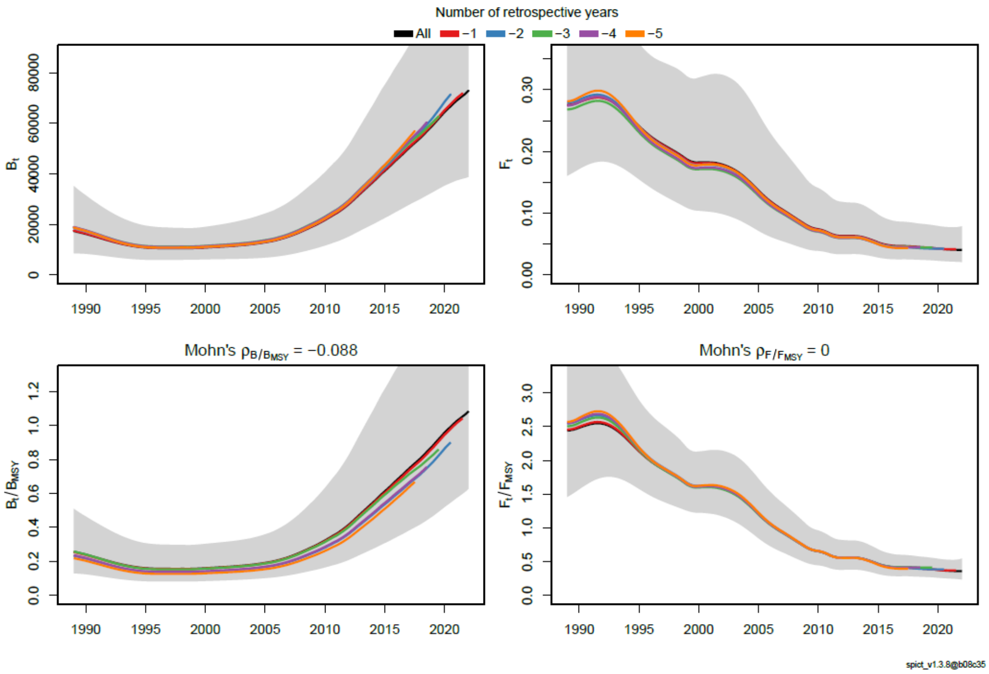

Figure 2.4.12 Plots of the retrospective analysis corresponding to the final assessment.

A hindcast cross-validation was done for the final assessment for hindcasts to 5 years. A Mean Absolute Scaled Error (MASE) smaller than 1 would indicate that the model has prediction skill for in the index. In the hindcast cross-validation using 5 years, the prediction skill was 0.859 for index 1 and 0.897 for index 2 (Figure 2.4.13).

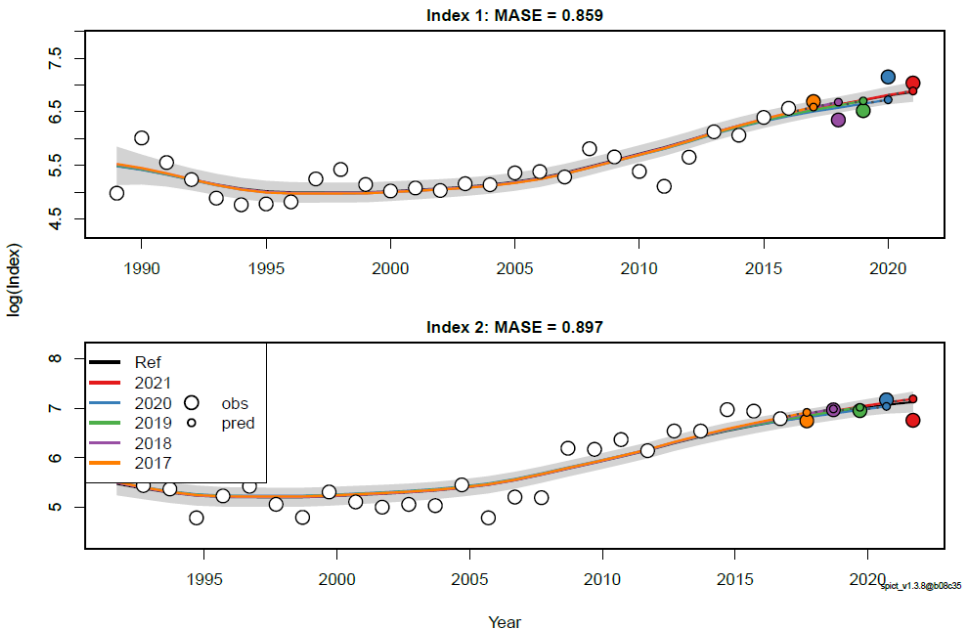

Figure 2.4.13 Hindcast cross-validation results for 5 years corresponding to the final assessment.

Result plots for the final assessment can be found in Figure 2.4.14. The output of the model indicates an overexploited stock with a biomass well below *BMSY* for most of the time series. Fishing mortality was above *FMSY* but decreasing at the start of the time series and has been below *FMSY* since 2006. The reduction in fishing mortality allowed the stock to rebuild and biomass had reached to above *BMSY* since 2020. MSY is estimated to be 7672 tonnes with a wide confidence interval [3996-14730].

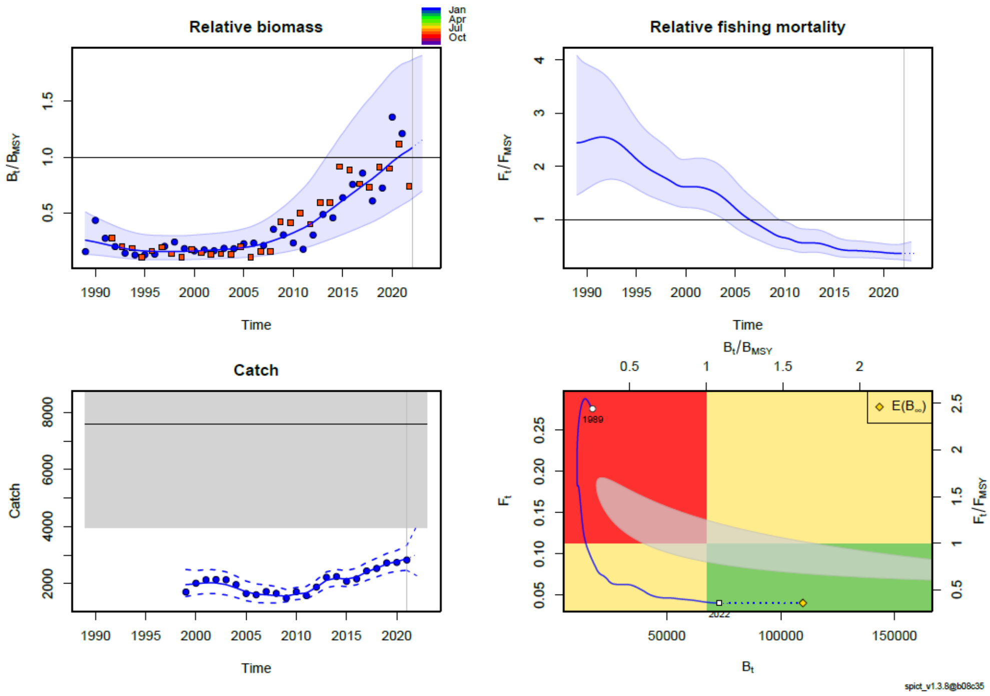

Figure 2.4.14 Result plots for the final assessment.

2.4.4 Forecast

With the final assessment model, a short-term forecast was carried out assuming a status quo harvest rate for the interim year. A two-year projection (2023-2024) was made including different management options:

1. ICES advice rule, corresponding to the 35th percentile of the removals
2. 15th percentile of the catch
3. 25th percentile of the catch, biomass and fishing mortality
4. Current ICES Category 3 precautionary approach (i.e. increase in advice cannot be higher than 20%).
5. Increase realized removals with 20%

The advised removals of thornback ray for 2023 corresponding to the ICES advice rule is 8051 tonnes. This advice is a 2.9-fold increase compared to the average annual removals derived for the period 2020-2021 (2783 tonnes) and a 3-fold increase compared to what should have been an advice for removals derived from the current 2246 tonnes landings advice (2681 tonnes given a dead discard rate of 0.19 (average of 2019-2021)). Given the change of perception of the state of the stock (formerly considered depleted and now estimated to be harvested well below F_{MSY} with a biomass above B_{MSY}) and the use of a forecast and reference points, the workshop considered that this substantial increase of the forecasted removals was sensible. If this advice were to be followed, B/B_{MSY} would be expected to be 1.14 and F/F_{MSY} would be expected to be 0.92 at the beginning of 2024. For illustration, when following the current ICES Category 3 precautionary approach, the advice on removals for the stock would be 3217 tonnes with corresponding B/B_{MSY} of 1.21 and F/F_{MSY} of 0.36. Increasing the realized removals by 20% gives an advice on removals of 3441 tonnes. The five predicted trajectories are presented in Table 2.4.4. and in Figure 2.4.15.

Table 2.4.4. Scenario outputs for 2023.

Scenario	Removals (tonnes)	F/Fmsy	B/Bmsy
35th percentile of catch at Fmsy	8051	0.92	1.14
15th percentile of catch at Fmsy	7074	0.81	1.16
25th percentile of the catch, biomass and fishing mortality	6447	0.73	1.17
Increase advice (current ICES category 3 (+20%))	3217	0.36	1.21
Increase realized removals +20%	3441	0.39	1.21

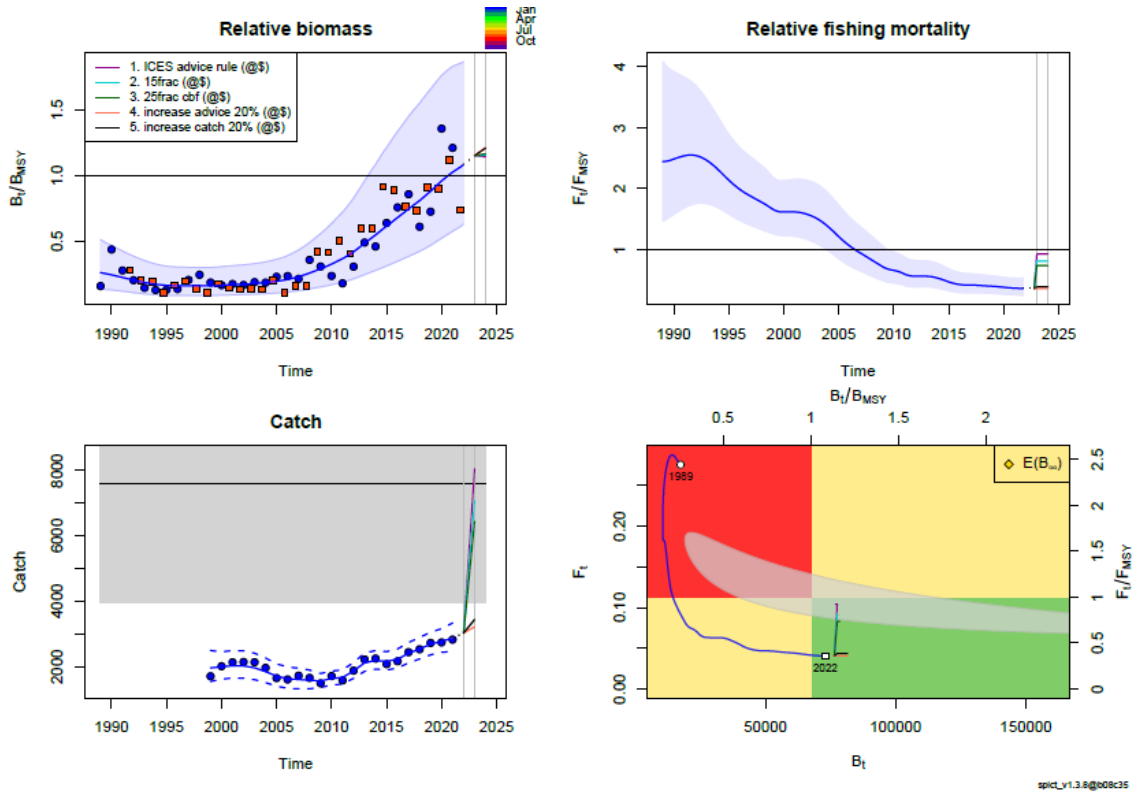

Figure 2.4.15 Predicted trajectories of thornback ray (rjc.27.3a47d) for the management period 2023-2024.

It should be noted that when applying the ICES rule (35th of the predicted catch [removals] at Fmsy) the resulting catches (removals) are above the estimated MSY (7672 tonnes), while considering the 15th percentile results in a fishing opportunity slightly below.

2.5 Future considerations/recommendations

The forecasted value of the advice on removals when applying the ICES rule (8051 tonnes) is greater than the recent annual catch (2020-2021 average: 2237 tonnes) or recent removals (2020-2021 average: 2784 tonnes) and, also much greater than the current advice on total catch (2246 tonnes).

Given the increase in advice using SPiCT, the average dead discard rate observed in the current time series may change. Using the usual procedure to convert removals to landings by using the recently observed dead discard rate would potentially not be appropriate. It is very unlikely that this discard rate would remain similar if more landings were to be allowed. If the advised removals were directly used to fix the allowed landings, this would imply some degree of targeting for fishers to reach this quantity (i.e. some increase in effort dedicated to this fishery).

While most of the simulation testing were carried out for recovering stocks, WKLIFE should consider what could be an ICES rule for stocks which are far below Fmsy (and at or above Bmsy). Even a low fractile (e.g. 15th) of the catches at Fmsy would lead to a large increase in short term fishing opportunities, above MSY, with a risk of reduction of the biomass in the near future. Given the uncertainty around the MSY value, it would be relevant to test a constraint in the increase in the catch advice to the lower limit of the confidence interval around MSY.

Thornback ray is one of the most studied skate species in the North Sea. Tagging and genetic studies suggest the current stock unit is appropriate. However, data on the exchange of individuals from division 3.a (Skagerrak) and 4.a (Northern North Sea) is limited and requires further research.

It is recommended that the survey indices related to biomass (individuals ≥30 cm) are used in subsequent assessments, rather than exploitable biomass (individuals ≥50 cm) as was done in previous assessments. Within the surveys used in the assessment, especially in surveys using the 'GOV' gear type, a large part of the catch fraction are individuals ≥30 cm.

2.6 Reviewers´ report

A wide range of SPiCT scenarios were initially explored with respect to input time series of catches and survey indices. The final model included catches from 1999-2021, with a two times higher catch uncertainty admitted for the reconstructed catches 1999-2010 than for recent catches 2011-2021. The following two survey indices were fitted, which extended back to 1989:

- Index1: FR-CGFS-Q4 and NS-IBTS-Q1 combined (1989-2021)
- Index2: NS-IBTS-Q3, BTS-Eng-Q3 and BTS-BEL-Q3 combined (1991–2021)

Index1 was associated with slightly higher precision estimates than Index2, but both indices showed consistent trends, indicating no evident conflicts. It was noted that fitting of the separate, yet consistent indices, as recommended by WKBMSYSPICT2, is likely to improve the model's ability to more effectively separate observation error from process error and thus estimate both quantities more reliably.

Both indices showed a slight initial decrease until the late 1990s and started to increase strongly from about 2005 onwards through 2021. The initial decrease prior to the start of the catch series, which was then followed by an increase, provided additional contrast for estimating productivity. The high ratio of F/Fmsy > 2 in the absence of catch data during this early period was considered broadly consistent with exploration history and the historical landing records for rays and skates combined, which were substantially higher in the past.

The maximum likelihood estimate (MLE) for the initial depletion ratio B_{1991}/K was estimated without prior constrains at around 0.15, which corresponds to stock levels around Blim = 0.3B/Bmsy, but subsequently biomass decreased further below Blim in the 2000s. However, retrospective analysis indicated some model instability, and it was therefore agreed to use the MLE estimate as a basis to set vaguely informative *logbkfrac* with a *logsd* = 0.5 to ensure model consistency in view of updating the model to new data in future. The evaluation of prior and posterior plots indicated that the model effectively updated posterior distributions relative to the priors. The estimate for r = 0.227 was higher relative to the prior mean of 0.15, but it was generally considered well within the plausible biological range for this stock.

Evaluation of model diagnostics indicated some violation of normality on in the OSA residuals of the catch time series, which appeared to originate in the reconstructed period of the catches. It was noted, however, that fit to the observed catches was still precise and that the impact on the model estimates for recent years was likely minimal. In addition, a significant autocorrelation lag of 1 was noted for the residuals of Index1. Considering that the overall fit to the data was satisfying with no apparent data conflicts, that the model was consistent retrospectively and that hindcast cross-validations indicated that the model had prediction skill for both indices (MASE < 1), the model was deemed overall appropriate for being benchmarked.

2.7 References

Amelot, M., Batsleer, J., Foucher, E., Girardin, R., Marchal, P., Poos, J.J., and Sys, K. (2021). Evidence of difference in landings and discards patterns in the English Channel and North Sea Rajidae complex fishery. Fisheries Research, 242. https://doi.org/10.1016/j.fishres.2021.106028

Bird, C., *et al*. (2020). "Fifty years of tagging skates (Rajidae): using mark-recapture data to evaluate stock units." Journal of the Marine Biological Association of the United Kingdom 100(1): 121-131.

Ellis, J.R. and Shackley, S.E. (1995). Observations on egg-laying in the thornback ray. Journal of Fish Biology, 46: 903–904.

Ellis, J.R., Silva, J.F., McCully Phillips, S.R., Bleeker, K. and Batsleer, J. (2023). An overview of the life-history parameters for North Sea stocks of thornback ray Raja clavata (rjc.27.3a4d7), spotted ray R. montagui (rjm.27.3a47d) and blonde ray R. brachyura (rjh.27.4bc7d). WKBELASMO 2023 Working Document.

Fahy, E. (1991). The south-eastern ray Raja spp. fishery, with observations on the growth of rays in Irish waters and their commercial grading. Irish Fisheries Investigations, Series B (Marine), 37: 18 pp.

Froese, R. and Pauly, D. (Editors) (2022). FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2022).

Gallagher, M.J., Nolan, C.P. and Jeal, F. (2005). Age, growth and maturity of the commercial ray species from the Irish Sea. Journal of Northwest Atlantic Fishery Science, 35: 47–66.

Holden, M.J. (1972). The growth rates of Raja brachyura, R. clavata and R. montagui as determined from tagging data. ICES Journal of Marine Science, 34: 161–168.

Hunter, E., *et al*. (2005). "repeated seasonal migration by a thornback ray in the southern north sea." Journal of the Marine Biological Association of the United Kingdom 85(5): 1199-1200

ICES (2020). ICES. 2020. Workshop on Catch Forecast from Biased Assessments (WKFORBIAS; outputs from 2019 meeting). ICES Scientific Reports. 2:28. 38 pp. http://doi.org/10.17895/ices.pub.5997

ICES (2021). Working Group on Elasmobranch Fishes (WGEF). ICES Scientific Reports, 3:59. http://doi.org/10.17895/ices.pub.8199.

ICES (2021b). Workshop on the use of surveys for stock assessment and reference points for rays and skates (WKSKATE; outputs from 2020 meeting). ICES Scientific Reports. 3:23. 183 pp. https://doi.org/10.17895/ices.pub.7948

ICES (2022). Benchmark Workshop for selected elasmobranch stocks (WKELASMO). ICES Scientific Reports. 4:47. 136 pp. http://doi.org/10.17895/ices.pub.21025021

McCully, S. R., Scott, F. and Ellis, J. R. (2012). Length at maturity and conversion factors for skates (Rajidae) around the British Isles, with a critique of earlier studies. ICES Journal of Marine Science, 69: 1812–1822.

Nei, M. (1987). Molecular Evolutionary Genetics. Columbia University Press. https://doi.org/doi:10.7312/nei-92038

Pawson, M. G. and S. Jennings (1996). "A critique of methods for stock identification in marine capture fisheries." Fisheries Research 25(3): 203-217.

Pedersen, M.W., and Berg, C.W. 2017. A stochastic surplus production model in continuous time. Fish

Fish. 18(2): 226–243. doi:10.1111/faf.12174.

Poos, J. J., Stäudle, T., & Megens, H-J. (2022). Genetische analyses voor stekelrog en blonde rog. Wageningen University & Research. https://doi.org/10.18174/582408

Raj, A., Stephens, M., Pritchard, J.K. (2014) FastSTRUCTURE: Variational inference of population structure in large SNP data sets. Genetics 197(2), pp. 573-589.

Ryland, J.S. and Ajayi, T.O. (1984). Growth and population dynamics of three Raja species (Batoidei) in Carmarthen Bay, British Isles. Journal du Conseil internationale pour l'Exploration de la Mer, 41: 111–120.

Saglam, H. and Ak, O. (2012). Reproductive biology of Raja clavata (Elasmobranchii: Rajidae) from southern Black Sea coast around Turkey. Helgoland Marine Research, 66: 117–126.

Serra-Pereira, B., Figueiredo, I., Farias, I., Moura, T. and Gordo, L.S. (2008). Description of dermal denticles from the caudal region of Raja clavata and their use for the estimation of age and growth. ICES Journal of Marine Science, 65: 1701–1709.

Silva, J. F., Ellis, J. R. and Ayers, R. (2013). Length-weight relationships of marine fish collected from around the British Isles. Science Series Technical Report, CEFAS, 150: 109 pp.

Taylor, A.J. and Holden, M.J. (1964). The preparation and use of vertebrae for age determination in rays. ICES CM, 145, pp.1–3.

Then, A.Y., Hoenig, J.M., Hall, N.G., Hewitt, D.A., and Handling editor: Ernesto Jardim. (2015).

Evaluating the predictive performance of empirical estimators of natural mortality rate using

information on over 200 fish species. ICES J. Mar. Sci. 72(1): 82–92.

doi:10.1093/icesjms/fsu136.

Thorson, J. T. (2019). Predicting recruitment density dependence and intrinsic growth rate for all fishes worldwide using a data-integrated life-history model. Fish and Fisheries.

Villagra, D. (2023). Discard mortality: merging from SUMARiS, FROM NORD and WMR. WKBELASMO 2023 Working Document.

Walker, P.A. 1999. Fleeting images: dynamics of North Sea ray populations. PhD dissertation, Faculteit Biologie, Universiteit van Amsterdam.

Weir, B. S., Cockerham, C. C. (1984). Estimating F-statistics for the analysis of population structure. Evolution, 1358–1370.

Whittamore, J.M. and McCarthy, I.D. (2005). The population biology of the thornback ray, Raja clavata in Caernarfon Bay, north Wales. Journal of the Marine Biological Association of the United Kingdom, 85: 1089–1094.

Winker, H., (2018). Investigation into the process error in biomass dynamics of fishes. MARAM/IWS/2018/Linefish/P3

3 Spotted ray (*Raja montagui*) in Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) (rjm.27.3a47d)

3.1 Introduction

Spotted ray (*Raja montagui*) is a smaller-bodied skate species reaching a maximum total length of 80cm. The species is widespread in the North-east Atlantic, ranging from Morocco in the south to the Shetland Isles and Skagerrak in the northern North Sea, including the Mediterranean Sea (Ellis *et al*., 2007). This species is found in shelf seas at depths of up to 400m, but is most commonly found in waters less than 150m (Ellis *et al*., 2005). Juveniles tend to occur closer inshore on sandy sediments, with adults more common further offshore on sand and coarse sand-gravel substrates. Data for spotted ray may be confounded with the similar-looking blonde ray (*R. brachyura)*. Information on the reproductive biology, migration patterns and stock structure are limited.

ICES considers five stock units of the species of which one covers the greater North Sea area. In this document we focus on outlining the stock unit of spotted ray in the North Sea by reviewing tagging and catch data. Furthermore, information on fishing effort over time by métier are collected from the mixed fisheries working group. In addition, an overview of (inter)national management measure is provided in a separate working document. These data may provide insight in what is driving fisheries behavior and thus potential changes in catches of this stock.

Spotted ray in the North Sea, Skagerrak, Kattegat and eastern English Channel is currently assessed as a Category-3 stock using the ICES 2/5 rule, and its management follows the precautionary approach. The assessment has been based on a single exploitable biomass (individuals ≥50 cm) index from the NS-IBTS-Q1 and NS-IBTS-Q3 surveys. During the benchmark workshop WKBELASMO, the relevance of the assessment of this stock using the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg 2017) was evaluated.

3.2 Stock Identity

Compared to the other two stocks in the benchmark, the stock structure of spotted ray was only evaluated based on tagging data. While an ongoing Dutch EMFF funded project is exploring the stock structure and size using innovative genetic tools, results are not available yet, and cannot be used to infer stock structure of spotted ray.

Bird *et al*, (2020) compiled and reviewed 50 years of tagging data, including release and return information, for several skate and ray species including spotted ray in the North Sea ecoregion. In total 2471 individuals were tagged and released across 10 ICES units with a tag return of 15.2%. The majority of the fish (n=726) were tagged in the southern North Sea (division 4.c) and (n=216) eastern English Channel (division 7.d) (Table 3.1). Furthermore, 30 individuals were tagged in the central North Sea (division 4.b) and 101 in the Northern North Sea of which no tags have been returned. In general all of the recaptures were within the stock unit of release, showing some movement between Division 4.c and 4.b and between Division 7.d. and 4.c (Figure 3.1). No information is available to confirm the inclusion of Division 4.a in the stock unit.

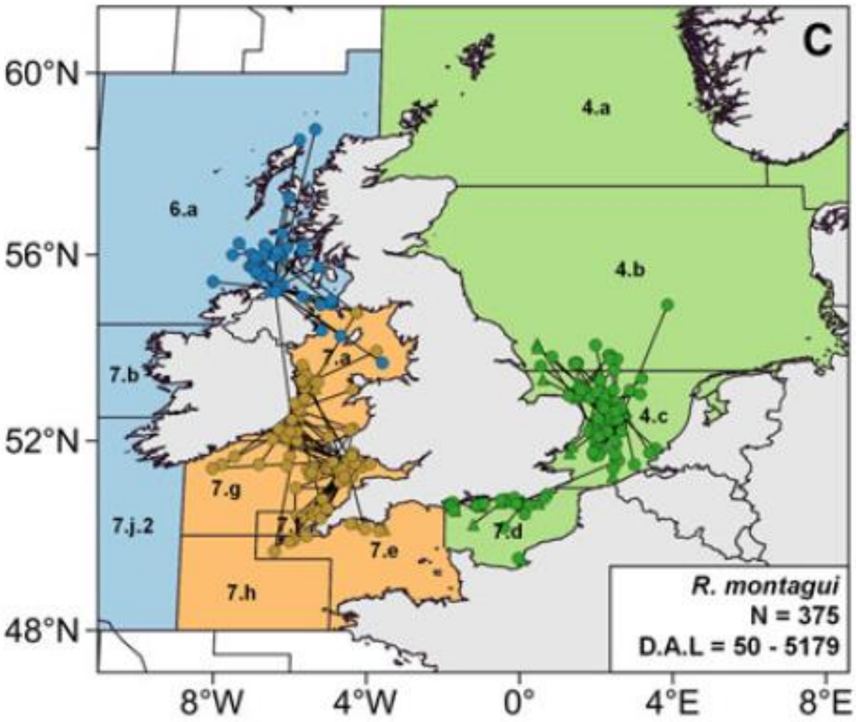

Figure 3.1: Tag releases, returns and straight-line distances for spotted ray (Raja montagui). The colors depict the stock units, with the green stock unit being spotted ray in subarea 4, and divisions 3.a and 7.d. Retrieved from Bird *et al*. 2020.

Table 3.1: Exchange of spotted ray (Raja montagui) (≥50 D.A.L.; N = 2191) between ICES divisions, showing the original release division, the total number released (NRel), the number recaptured (NRec), and the proportion of these recaptured in each ICES division. Obtained from Bird *et al*. 2020.

Release Division	NRel	NRec	Recapture Division										
			3.a	4.a	4.b	4.c	7.d	6.a	7.b.j	7.a	7.e	7.f	7.g
3.a	0	0	–	–	–	–	–	–	–	–	–	–	–
4.a	101	0	–	–	–	–	–	–	–	–	–	–	–
4.b	30	2	–	–	–	1	–	–	–	–	–	–	–
4.c	726	71	–	–	0.169	0.831	–	–	–	–	–	–	–
7.d	216	28	–	–	–	0.036	0.964	–	–	–	–	–	–
6.a	445	77	–	–	–	–	–	0.896	–	0.104	–	–	–
7.b.j	0	0	–	–	–	–	–	–	–	–	–	–	–
7.a	313	77	–	–	–	–	–	–	–	0.896	0.013	0.026	0.065
7.e	18	2	–	–	–	–	–	–	–	–	1	–	–
7.f	583	111	–	–	–	–	–	–	–	0.117	0.063	0.703	0.117
7.g	38	7	–	–	–	–	–	–	–	0.286	–	0.571	0.143
7.h	1	0	–	–	–	–	–	–	–	–	–	–	–

3.3 Input data for stock assessment

Data series of dead catch and biomass (individuals ≥30 cm) indices from scientific surveys FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3, and all BTS-Q3 surveys were used as inputs for the SPiCT runs. Furthermore, specific life-history parameters were used to produce the population model, which are further discussed in section 3.3.3.

3.3.1 Catch data

Prior to the benchmark, a data call was issued requesting time series of landings and discard data of the relevant stocks. Data for the period 2009-2021 were received. Earlier data are missing as it is likely that before 2008, misidentification has occurred, especially for spotted ray (*R. montagui*) and blonde ray (*R. brachyura*). Misidentification probably affects the landings data of most nations reporting these two species. Before 2008, commercial ray landings in the EU were mainly recorded on a family level, making species-specific landings data before 2009 highly uncertain. Since 2009, all EU countries are obliged to register species-specific landings for the main skate species, resulting in improved species-specific landings to WGEF since 2009. In this context landings and discard data before 2009 submitted to ICES WGEF are uncertain or incomplete and will not directly be used in the assessments.

Spotted ray is the second most important commercial skate species in the North Sea. The stock is straddling the three North Sea TAC management units, with most catches realised in ICES subarea 4. Spotted ray is mainly caught in beam trawls and bottom trawls with an increase of landings in the seine fisheries. For the latter metier, no discard data are available due to a low observer/sample coverage. Important to note is that discards are an important component of the catch, constituting more than 70% of catches in the last 5 years (Figure 3.2). The Netherlands and the UK have the largest share of catches, with a vast majority (>70%) of Dutch catches being discards (see working document 12 on the stock summary of spotted ray).

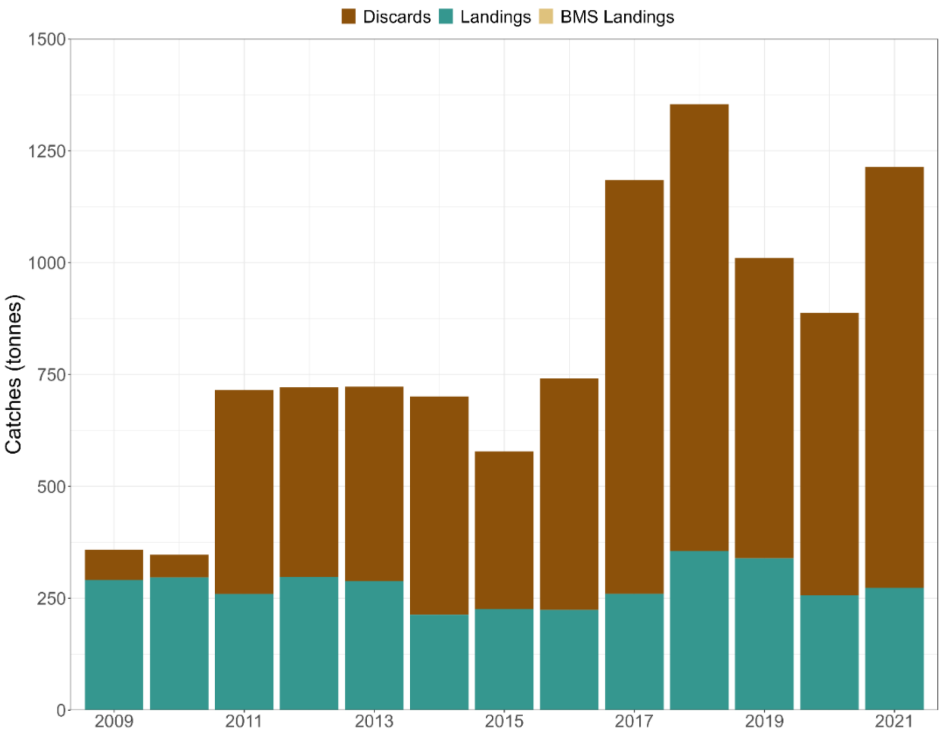

Figure 3.2: Spotted ray, annual landings, discards and BMS landings (catch) in subarea 4, and division 3.a and 7.d.

Surplus production models such as SPiCT and JABBA require a time series of catches as input data. Preferably the time series of catches is long enough to cover one generation time (~10 years) and includes contrasted periods in terms of stock biomass and fishing mortality. Such contrasts provide valuable information to the model, improving the quality of the estimation of various model parameters. As submitted data cover the period 2009-2021, the time series of catches was extended by reconstructing the landings and discards for the period 1999-2008 (see working document 8 on catch reconstruction). In addition, catches, as input data for the assessment models, should preferably consist of removals, i.e. dead catch. Dead catch are the landings plus the part of the discards which do not survive the catching process (i.e. dead discards). Dead discards were calculated applying the outcomes of several discard survival studies (see working document 7 on discard survival) to the submitted as well as reconstructed discards.

3.3.1.1 Landings

Landings have been submitted by six countries. Landings have been relatively stable around 275t, only increasing over 300t in the years 2018 and 2019 (Table 3.3.1). In both years landings have been well above the ICES advice (Figure 3.3.1). Most landings are realised in subarea 4; it should be noted that some countries (e.g. Scotland) report landings from subarea 4, while most of them occur in 4a. A slight increase of landings in Division 7d is noted since 2017. Spotted ray is mainly caught as bycatch in mixed demersal fisheries using trawls (i.e. beam and bottom trawls). In recent years an increase in landings is observed in the seine fisheries, which corroborates with the increase in effort in these fisheries.

Table 3.3.1 Spotted ray landings (tonnes) from 2009-2021 per ICES subarea/division.

Landings							
Year	**27.3.a.20**	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.4**	**27.7.d**
2009			0.0	21.3	32.9	200.7	35.9
2010				15.8	27.9	216.2	36.7
2011			0.0	31.5	18.0	174.2	36.2
2012			0.1	20.6	6.1	238.6	32.3
2013			0.0	44.6	4.5	204.2	35.2
2014			0.2	28.8	7.0	143.8	33.3
2015		0.0	0.6	22.3	4.3	179.8	19.4
2016		0.0	0.9	25.7	7.6	166.6	23.1
2017			0.7	20.9	11.7	182.2	44.6
2018		0.0	0.1	31.4	21.6	272.3	30.7
2019		0.1	0.0	31.7	31.5	228.1	48.1
2020		0.4	0.8	11.1	31.9	164.0	48.4
2021	0.0	0.0	0.1	26.1	24.8	166.3	55.5

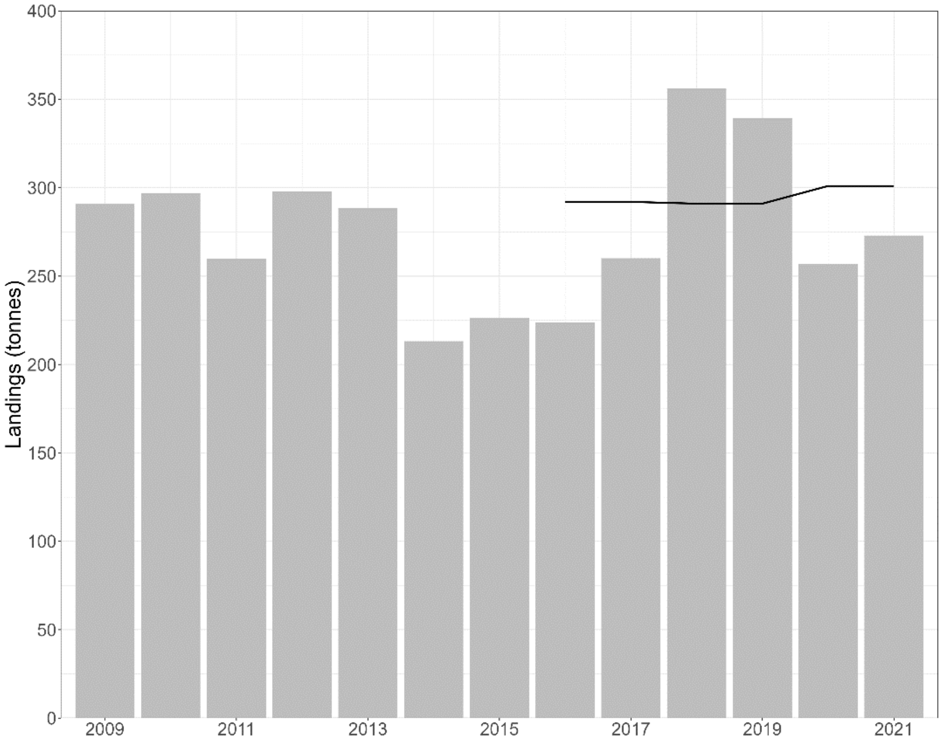

Figure 3.3.1: Spotted ray, annual landings (bars) and advice (line) in subarea 4, and divisions 3.a and 7.d.

To reconstruct landings in the period 1999-2008, landings of the species part of the group-TAC in the greater North Sea ecoregion (i.e. Rajidae, starry ray, cuckoo ray, thornback ray, spotted ray and blonde ray) were extracted from the Historical Nominal Catches 1950-2010 database. Using the species-specific data from 2009–2021 a species-specific landing ratio, being the proportion of landings of each stock within the total Rajidae landings, was calculated. The same species as for the 1999-2008 Rajidae composition was used.

Several options were explored to average the yearly ratios and applied to total landings of Rajidae from 1999 to 2008 in order to get an estimate of the landings for these years. Given the changes in the TACs over time three scenarios to average yearly ratios were explored,

1. Average over entire time series applied over 1999-2008
2. Average of 2009-2011 applied over 1999-2008
3. Average of 2009-2011 applied over 2005-2008, and average of 2018–2021 applied over 1999-2004.

whereby scenario 3 takes the similarity in TAC setting between the years 1999-2004 and 2018 and 2021, and 2005-2008 and the three following years (2009-2011) into account.

The landings ratio of spotted ray has been fluctuating around 9.4% of the total Rajidae landings, with somewhat higher ratio observed in the period 2009 -2011 (Table 3.3.2). The minor reduction in landings ratio in the most recent years of the time series could be explained by the shift in landings of spotted ray towards blonde ray (Figure 3.3.2).

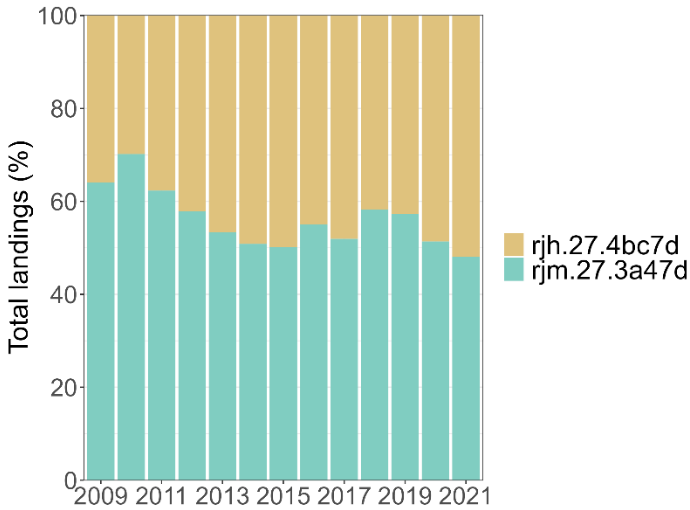

Figure 3.3.2: Proportion of blonde ray (rjh.27.4bc7d) and spotted ray (rjm.27.3a47d) in total landings of both species in the period 2009 – 2021.

Applying the average landings ratio of the full time series (9.4%) results in reconstructed landings ranging from 274t in 2006 to 366t in 2002. Given the relatively stable landings ratio in the time series, reconstructed landings are in line with the landings observed in the period 2009-2021. Using the average ratio of 2009-2011 (10.1%) results in slightly higher reconstructed landings. Using the third scenario with a ratio of 10.1% (2009-2011) and 9.2% (2018-2021) applied to the 2005-2008 and 1999-2004 Rajidae landings respectively, yields lowest landings in the earliest time-period. Yet, differences in the reconstructed landings between the three scenarios are minimal.

Table 3.3.2: spotted ray overview of the yearly landings ratio and reconstructed time series (orange) in the period 1999-2008 under the three scenarios (values in tonnes).

Year	Agreed TAC	Rajidae landings	RJM proportion	Average time series	Average 2009-2011	Average combined
1999	6060	3087		291	313	283
2000	6060	3644		344	369	334
2001	4848	3862		364	391	354
2002	4848	3878		366	393	355
2003	4121	3864		364	391	354
2004	3503	3556		335	360	326
2005	3220	2988		282	303	303
2006	2737	2910		274	295	295
2007	2190	3118		294	316	316
2008	1643	2998		283	304	304
2009	3367	2917	0.100	291	291	291

Year	Agreed TAC	Rajidae landings	RJM proportion	Average time series	Average 2009-2011	Average combined
2010	2864	2812	0.106	297	297	297
2011	2864	2633	0.099	260	260	260
2012	2862	2753	0.108	298	298	298
2013	2574	2931	0.098	289	289	289
2014	2524	2790	0.076	213	213	213
2015	2650	2488	0.091	226	226	226
2016	2749	2616	0.086	224	224	224
2017	2911	2716	0.096	260	260	260
2018	3400	3429	0.104	356	356	356
2019	3528	3408	0.100	339	339	339
2020	3681	3215	0.080	257	257	257
2021	3500	3279	0.083	273	273	273

3.3.1.2 Discards

Discard data for spotted ray by country, year, métier, and fishing area (in tonnes) were extracted from InterCatch for the period 2009-2021. Discards are available since 2009 and have increased over time, being over 600t since 2017, reaching a maximum of 998t in 2018. In this context, discards are an important component of the catch, constituting more than 70% of catches in the last 5 years. The Netherlands have the highest discard rate (~70%) compared to the other countries, which could be explained by the lower quota share. Discards in 2009 and 2010 are much lower compared to the rest of the time series because several countries, including the Netherlands, have not submitted discard data in those years.

As discard data are incomplete, i.e. missing countries or gears, a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) was used to fill those gaps for the period 2019 – 2021. To do so, fishing effort data were extracted from the ICES Working Group of Mixed Fisheries (WGMixFish) for the period 2009-2021. Data consisted on effort by kw.days by year, country, metier, and size class of the vessels. For the reconstruction effort data were aggregated to metier level 4 similar to the metier level at which discard data have been submitted.

Some Member States provided the discard data at subarea level (i.e. 27.4). Therefore, discard and fishing effort data by division (i.e. 4a, b and c) were merged to subarea level. Discard data were not available for some combinations of year, métier and fishing area (Figure 3.3.3). Consequently, the hooks and lines, seines, midwater and pelagic trawls, unspecified and all other bottom trawl gears segments were excluded from the regression analysis. As such, we assume these métiers do not contribute to the discards, resulting in an underestimation of the discarded part of the catch. Only the discard values of missing combinations were inferred using a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) using the model (Amelot *et al.* 2021):

Discards (in tonnes) ~ kWdays: Fishing Fleet: Fishing Area.

The results of the regression showed that the model was a significant predictor of discards ($F(7,77) = 44.42$, $P < .001$). Coefficients of beam trawls in subarea 4 (1.578×10^{-05}, $P < .001$) and bottom trawls in subarea 4 (4.480×10^{-06}, $P < .001$) were shown to have contributed significantly to the model.

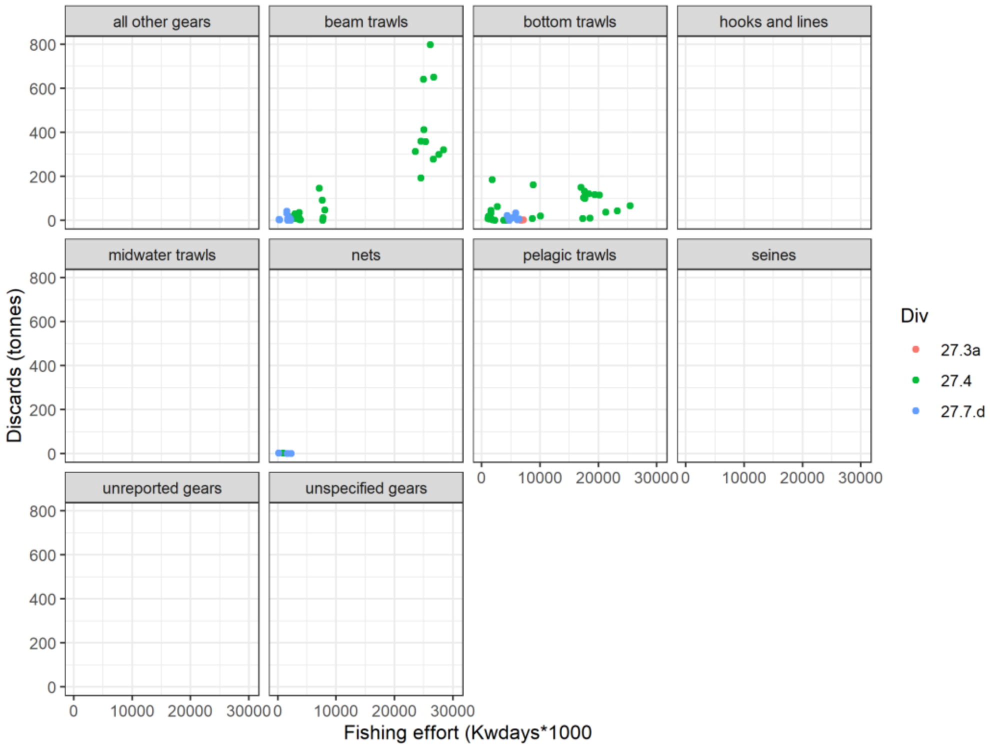

Figure 3.3.3: Spotted ray, correlation between fishing effort by métier, area and discarding.

For the UK, discard data in 2020 and 2021 were exceptionally low (< 15t) compared to previous years (average of 125t since 2012). This difference potentially arises due to a lower sampling coverage or the influence of a reduction in fishing effort due to COVID-19. The latter is negated because fishing effort data of 2020 and 2021 do not show a major decrease compared to previous years. The group discussed to option of replacing the submitted discard values by the predicted discard values for the UK in both 2020 and 2021. The predicted values are more in line with the observed discards in previous years (Figure 3.3.4) and are in agreement with previously observed discard rates for the UK (Figure 3.3.5). The group decided to update the discard value for the UK in the years 2020 and 2021 with the predicted values resulting from the regression analysis. Total discard estimates for spotted ray are shown in Figure 3.3.6.

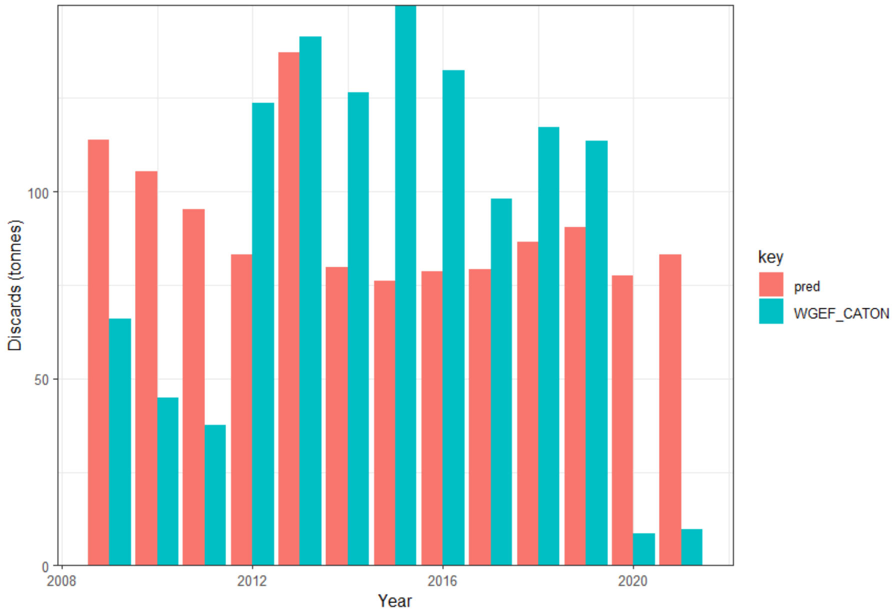

Figure 3.3.4: Spotted ray, comparison of the predicted discard values (red) with the submitted values available in Inter-Catch (blue).

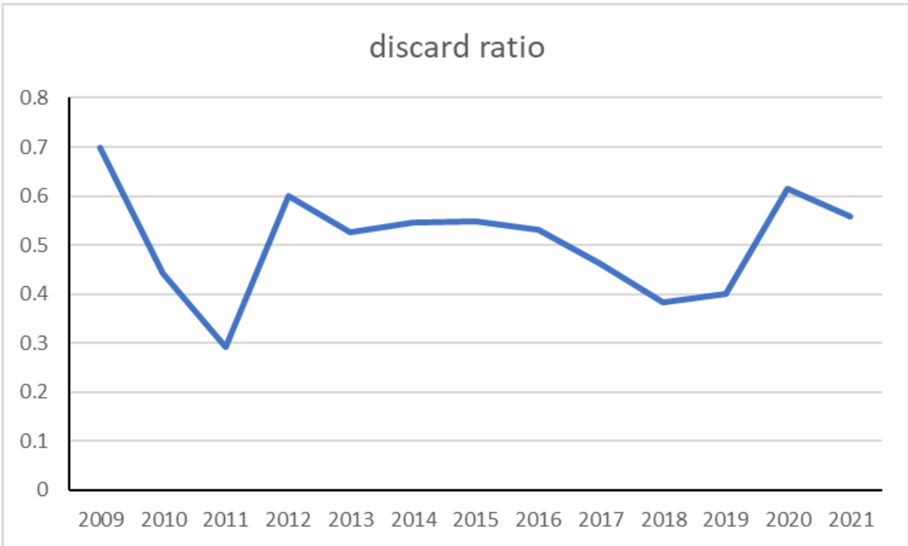

Figure 3.3.5 UK discard ratio in the period 2009-2021. For 2020 and 2021 the predicted values are used.

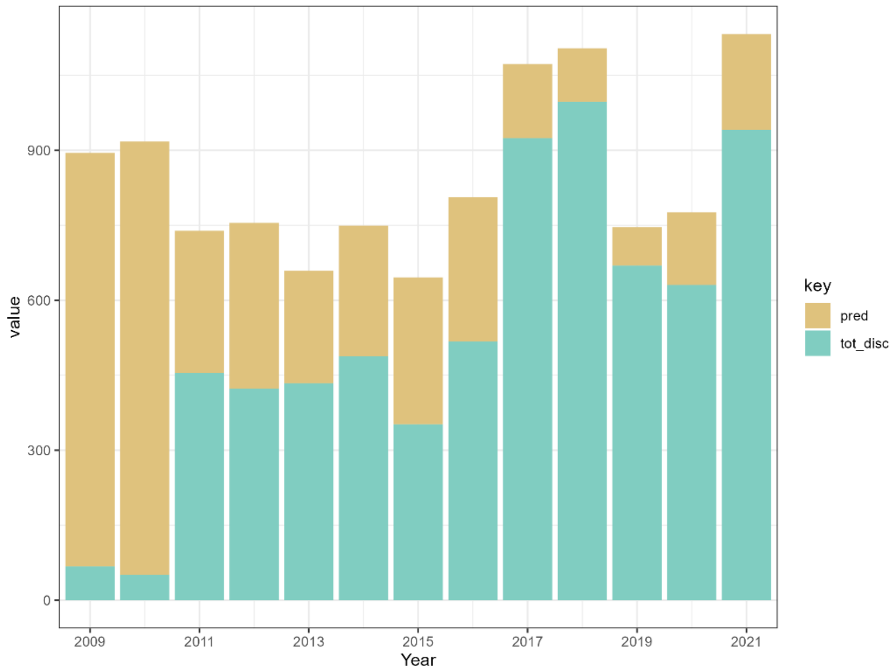

Figure 3.3.6 spotted ray, the total reconstructed discards of the stock (tonnes) showing the submitted values (green) and reconstructed part including the full reconstructed UK discards for 2020 and 2021 (brown). These values do not account for discard survival.

The reconstructed discards do not account for discard survival. To do so, discard survival studies for thornback ray by FromNord, Wageningen Marine Research and the Sumaris project have been merged to obtain a single survival value per métier (Villagra *et al*, 2023 (WD on discard survival)). These values do not take possible difference in the survivability of length classes into account. Quota have been and are still constraining the landings of the species for most fleets. Consequently, all size classes are observed in the discards, justifying the use of a single survival estimate per métier.

For spotted ray survival is highest in flyshoot fisheries (71.6%) and lowest in the beam trawl fishery (48.7%). No information on the survival of spotted ray in the OTB segment was available. The ratio between discard survival estimates of spotted ray with both thornback ray and blonde ray in the TBB fisheries was calculated. These ratios were applied to known values of survival estimates in the OTB fisheries of the latter two species and averaged. This resulted in a survival estimate of 60% for spotted ray in the OTB fisheries. These survival estimates are applied to the total discards by métier and summed to get an estimate of the dead discards in the period 2009-2021 (Table 3.3.3).

Table 3.3.3 spotted ray (rjm.27.3a47d), overview of discard data submitted to InterCatch (Submitted), after reconstruction using the multiple regression (Reconstructed), and correction using discard survival estimates (Dead) (values in tonnes).

Year	Submitted	Reconstructed	Dead
2009	67.6	894.9	442.0
2010	50.5	917.5	455.4
2011	455.1	739.0	355.7
2012	423.5	754.8	364.8

Year	Submitted	Reconstructed	Dead
2013	434.1	658.9	317.2
2014	487.7	749.3	358.7
2015	352.2	646.0	305.0
2016	517.4	806.6	388.8
2017	924.3	1072.6	528.2
2018	997.1	1104.1	528.8
2019	669.5	746.3	363.6
2020	630.6	775.7	378.2
2021	940.9	1132.6	543.8

3.3.1.3 Removals

To reconstruct the removals (i.e. dead catch) of spotted ray in the period 1999 – 2008, the ratio between landings and dead discards for the 2009-2021 time period was calculated. Dead discards include the total discards resulting from the regression and corrected for discard survival. This ratio was then applied to the reconstructed landings in order to get an estimate of the dead discards for the period 1999-2008. Note that we assume that discards remained stable over this time period. Calculations were done for the three scenarios described in section 3.3.1.1. For spotted ray the average (dead) discard rate over the period 2009-2021 is 66.9%. This value is applied to the reconstructed landings in the period 1999-2008 using the equation:

Total reconstructed catch = reconstructed Landings/(1 – average discard ratio)

Removals of spotted ray for the 1999-2021 period are shown in Figure 3.3.7. Outcomes, show a decrease in catches until 2015. There are only minor differences in the catches between the three scenarios, with higher catches in the initial period using scenario 2 (i.e. 2009-2011 landings ratio). Given the minor differences, the group decided to be consistent between the species and opt for scenario 2 as the final catches to be used as input in the SPiCT assessment for spotted ray (Table 3.3.4).

Figure 3.3.7 Spotted ray, dead catch in the period 1999-2021, with reconstructed dead catch for 1999-2008. Three scenarios using the average landings ratio of the full time series (left), the period 2009-2011(middle) and combination of 2009-2011 and 2018-2021 (right). Lighter coloration denotes the dead discards.

Table 3.3.4 Spotted ray, landings, dead discards and removals resulting from the reconstruction and used as input in the assessment model (values in tonnes).

Year	Landings	Dead discards	Removals
1999	313	461	773
2000	369	544	913
2001	391	576	967
2002	393	579	971
2003	391	576	968
2004	360	531	891
2005	303	446	748
2006	295	434	729
2007	316	465	781
2008	304	447	751
2009	291	442	733
2010	297	455	752
2011	260	356	616
2012	298	365	663

Year	Landings	Dead discards	Removals
2013	289	317	606
2014	213	359	572
2015	226	305	531
2016	224	389	613
2017	260	528	788
2018	356	529	885
2019	339	364	703
2020	257	378	635
2021	273	544	817

3.3.2 Survey biomass index

In the current assessment of spotted ray, the exploitable biomass (individuals ≥50 cm) indices of NS-IBTS-Q1 and NS-IBTS-Q3 are used and combined into a single index using a design-based approach. For this benchmark, a model-based approach was chosen to combine different surveys into a single index or in two indices by combining surveys based on seasonality (e.g. all survey carried out in Q3 combined). Different combinations of surveys were explored using a gam model with either a Tweedie or delta lognormal distribution. AIC scores were used to compare the two distributions. In this section, we only describe the models that were chosen to be used in the exploratory SPiCT assessment runs. More detailed information can be found in Working document 9 on surveys and biomass indices.

A biomass index of individuals ≥30 cm was chosen, instead of exploitable biomass, as these individuals represent a significant part of spotted ray catches. Furthermore, the proportion of discards in the catch is higher than the proportion of landings. From the different model runs, two options were chosen to use in the exploratory assessment runs using SPiCT (Table 3.3.5). For both options a delta lognormal distribution model was chosen as they had a better fit to the data. In the first model, where only the NS-IBTS surveys were combined, AIC scores from the tweedie model were slightly lower than those from the delta lognormal model. However, QQ-plots for this model showed a better distribution of quantiles for the delta lognormal distribution.

Table 3.3.5 Model runs for spotted ray with different survey combinations for years 1989-2021 or 1991-2021^ using biomass of individuals ≥30 cm resulting in either 1 or 2 survey indices.

	Survey index 1	Survey index 2
1	NS-IBTS-Q1 and NS-IBTS-Q3 combined	
2	NS-IBTS-Q1 and FR-CGFS-Q4 combined*	NS-IBTS-Q3 and all BTS-Q3* surveys combined (excl. DE)^

^ Years 1991-2021 due to surveys not being available prior to 1991.
*** BTS-Eng-Q3, BTS-BEL-Q3, BTS-NL-ISI-Q3 and BTS-NL-TRI-Q3**

Both index options have been explored in exploratory SPiCT runs and ultimately it was chosen to use the second model with two survey indices in the final SPiCT assessment. The biomass indices are shown in Figure 3.3.8. There is variation in the trends of both indices, with a slight increasing trend since 2006 up until 2015. Between 2015 and 2018, both indices show a more stable trend, and have been decreasing since then.

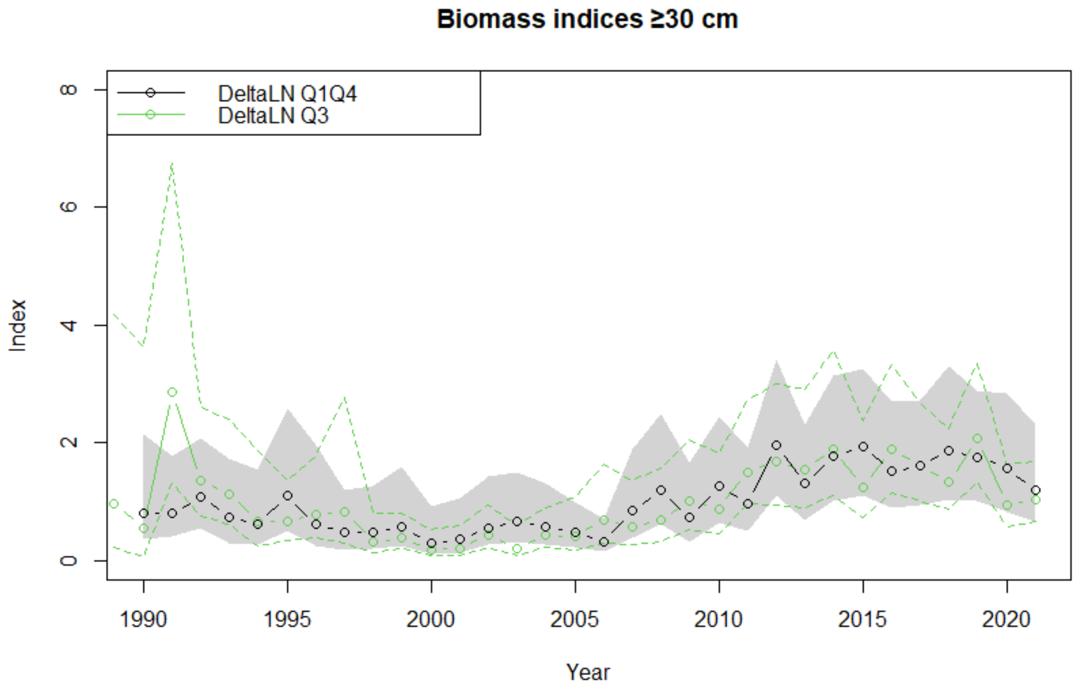

Figure 3.3.8 Spotted ray relative biomass (≥30 cm) indices with 95% confidence intervals for NS-IBTS-Q1 and FR-CGFS-Q4 combined (black line) and NS-IBTS-Q3, and all BTS-Q3 surveys (excl. DE) combined (green line).

During the benchmark workshop, output from the delta-gam model was discussed including the spatial distribution of biomass of each species. It was noted that the biomass of spotted ray in the Northern part of the North Sea has substantially increased since the early 2000s (Figure 3.3.9). This increase is also seen in the Southern North Sea, though less substantial. Since there is little information on the genetic structure of spotted ray in the North Sea, there is no evidence available for dividing the stock unit into different regions. To explore this further, the survey index was split among the three divisions of the North Sea (4.a, 4.b and 4.c) using the *redoSurveyIndex()* function from the surveyIndex package in R. Figure 3.3.10 shows the biomass indices for each division. In later years, the index from Division 4.a is substantially higher as compared to the other indices. This might affect the overall index when these divisions are not taking into account. However, the indices follow similar trends and using separated indices in the model does not improve the assessment; therefore, it was decided to keep the overall index in the assessment. Further genetic and tagging studies can provide more insight in the population structure of spotted ray in the North Sea.

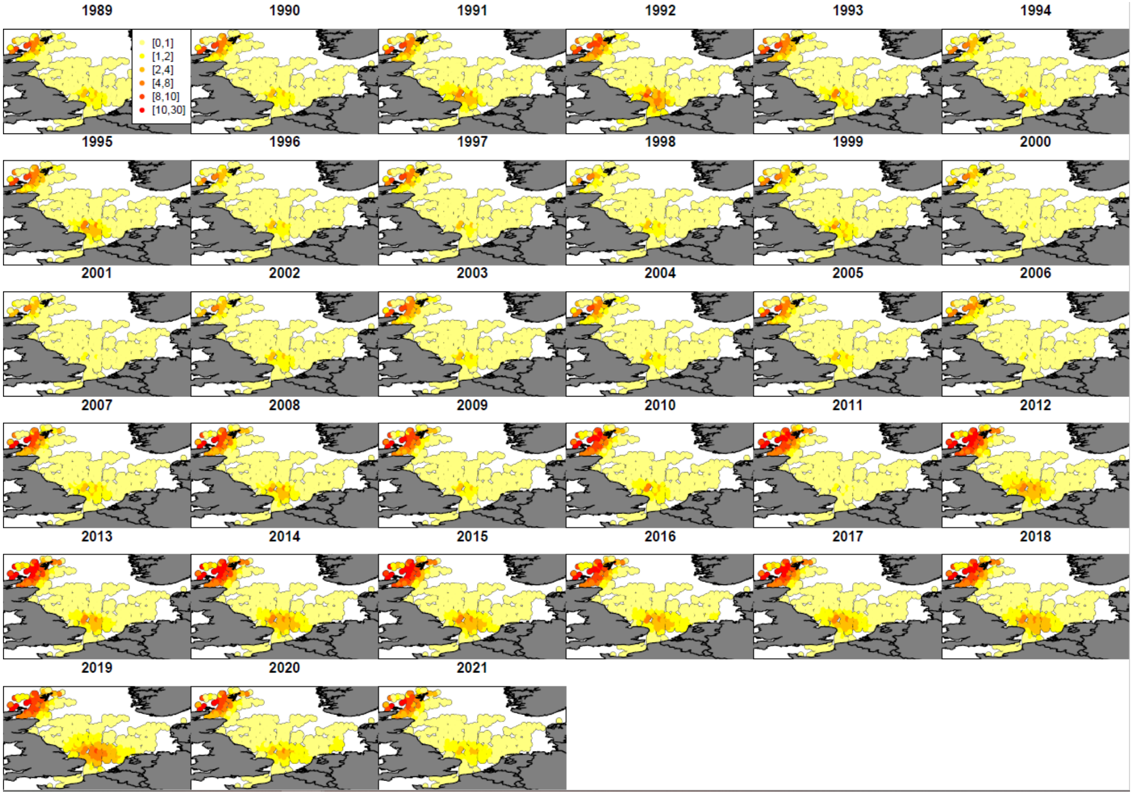

Figure 3.3.9 Heatmap of the spatio-temporal distribution of spotted ray in the North Sea from the combined index of the NS-IBTS-Q1 and NS-IBTS-Q3 for years 1989-2021.

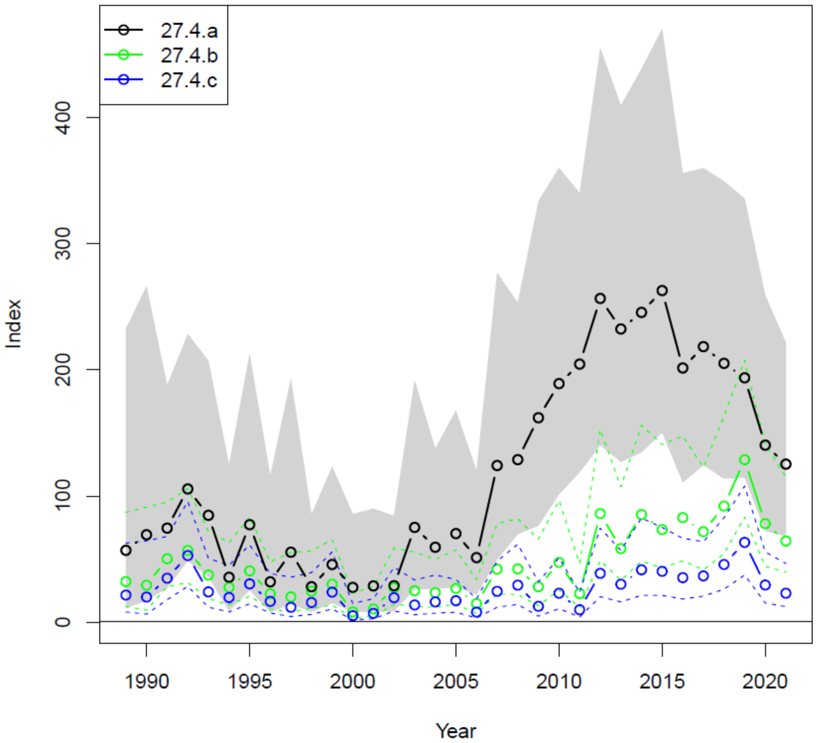

Figure 3.3.10 Spotted ray biomass (≥30 cm) indices with 95% confidence intervals for NS-IBTS-Q1 and NS-IBTS-Q3 combined for each division in the North Sea (4.a = black line, 4.b = green line, 4.c = blue line).

3.3.3 Life-history parameters

Key life-history parameters, namely the length-weight relationship, length-at-maturity, growth rates and annual fecundity of spotted ray have been collated in Ellis *et al*. 2023 (Working document 4). Below we summarize the selected parameters used as input in the assessment.

For the purposes of the 2023 benchmark assessment, it was agreed to use the length-weight relationship provided by Silva *et al*. 2013: $W = 0.0041\ L^{3.1152}$ ($r^2 = 0.9889$). This study included individuals from the British Isles, including samples from the North Sea and eastern Channel stock, and was based on a large sample size (n=1695) and covered a length range of 10-69 cm.

Estimates of the length at which 50% of the population is mature ($L_{50\%}$) for spotted ray in the stock area are given by Walker (1999) and McCully *et al.* (2012). Whilst the sample size of Walker (1999) was lower, the reported length-at-maturity for females was very similar in both studies: 62.2 cm (Walker, 1999) and 62.5 cm (McCully *et al.*, 2012), of which the latter was proposed to use for the purpose of the benchmark. The length at which 95% of the population is mature ($L_{95\%}$) was derived from the same study, using the largest size of immature female encountered (70 cm).

Growth of spotted ray has been studied for both North Sea (Walker, 1999) and Celtic Seas (Holden, 1972; Ryland and Ajayi, 1984; Fahy 1989; Gallagher *et al.*, 2005) populations. There are no published estimates for stocks in the Biscay-Iberian ecoregion.

The averaged VBGP provided for female spotted ray by Holden (1972), Walker (1999) and Gallagher *et al.* (2005) were L_{inf} = 76.81 cm, K = 0.21 y^{-1} and t_0 = –0.816. Growth curves for the published values, the averaged values and the values for spotted ray given on FishBase (L_{inf} = 78.4 cm, K = 0.26 y^{-1} and t_0 = –0.49; Froese and Pauly, 2022), were broadly similar (Figure 3.3.11).

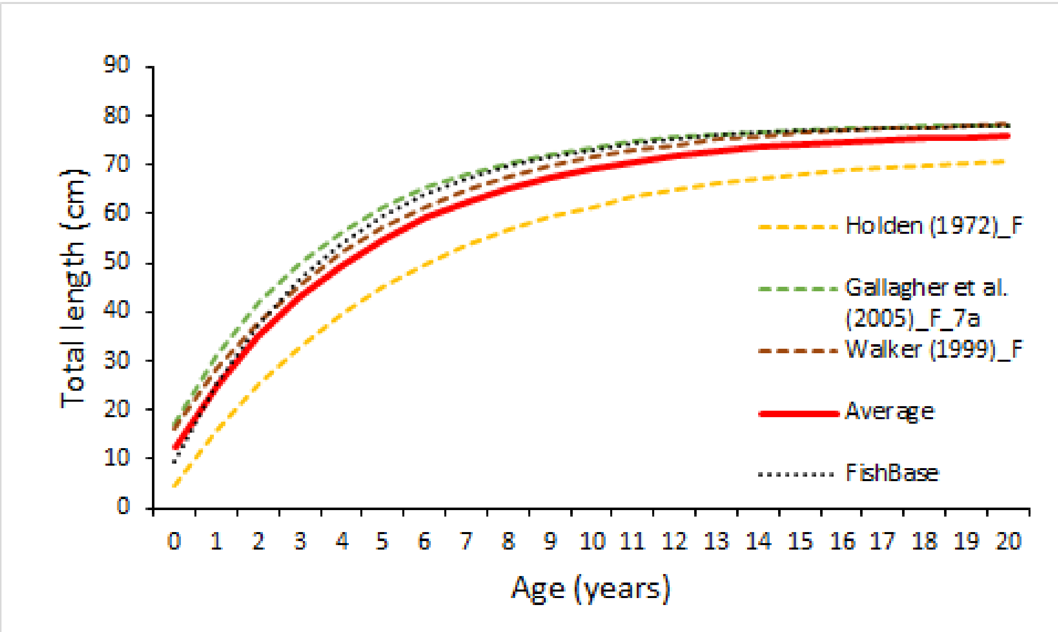

Figure 3.3.11 Estimated length-at-age for spotted ray (RJM) from published studies, including the growth for the averaged VBGP and that given by FishBase. Data extrapolated to age 20, given that Walker (1999) observed fish up to 12 years of age (See working document 4, Ellis *et al*., 2023).

There are limited data available relating to the potential fecundity of spotted ray. Ovarian fecundity was estimated to be 13-27 (mean count at length) with an estimated fecundity of 70 eggs per year (Walker, 1999). Holden *et al.* (1971) estimated annual fecundity to be around 60 eggs. For the purpose of the 2023 benchmark assessment, it is proposed to consider that the annual fecundity of spotted ray would be <100 eggs per year.

3.4 Stock assessment

The benchmark focussed on evaluating the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg 2017) on spotted ray in subarea 4 and divisions 3.a and 7.d.

3.4.1 Priors

A prior probability distribution has been defined for the intrinsic rate of biomass increase (r). To estimate r, the only considered source of mortality was natural mortality (M). Parameters K and L_{inf} were used to generate an estimate of M following Then *et al.* (2015) in their review of multiple procedures for estimating M. A single natural mortality value across all ages (M = 0.315) was calculated as follows:

$$M = 4.118 * K^{0.73} * L_{inf}^{-0.33}$$

A value for the maximum age (t_{max}) was extracted from the database of life history correlations available in the FishLife R package (Thorson, 2019). The maximum value from those available for spotted ray was chosen, with t_{max} = 13.

A Leslie matrix was built using the biological variables available for spotted ray (Table 3.4.1) to obtain a mean prior value for the intrinsic rate of increase (r). The *jbleslie* function in the R package JABBA was used to return a value of r = 0.3099494. The function included a steepness parameter h (0.7466) extracted from the database of life history correlations available in the FishLife R package (Thorson, 2019) instead of a fecundity parameter. Using the fecundity parameter resulted in a negative value for r.

Table 3.4.1 Biological variables used in the call to JABBA::jbleslie() to obtain a mean prior for the intrinsic rate of biomass increase (r) using a Leslie matrix calculation of female net reproductive rate.

Min age	Max age	L_{inf}	k	t_0	LWR a	LWR b	M	h	$L_{50\%}$	$L_{95\%}$
0	13	76.8	0.21	-0.816	0.0041	3.1152	0.315	0.7466	62.5	70

3.4.2 Reference run

First input in the SPiCT reference run are the annual catches. It was decided to use the entire time series of removals (1999-2021), applying higher (x2) observation errors on removals in years 1999-2010 than those associated with years 2011-2021. This resulted in a CV = 0.2 for the reconstructed catch years prior to 2011 and a CV = 0.1 from 2011 onwards. The logsdc was fixed by setting the log.sd to the reference value for 2009+ and assuming a small CV = 0.1.

SPiCT uses a two-step approach to specify observation errors on the indices. For the reference run a single survey index including both NS-IBTS Q1 and Q3 surveys of individuals ≥30cm and a Delta-Gam approach was used. The survey is assumed to take place in the middle of the year. The interannual variability is specified from the log.sd estimates of the joint index and scaled to 1 by normalizing by the mean. Observation error is specified by taking the mean across the time series. Additional uncertainty was added by allowing to estimate observation error with a prior given by the mean survey SE and a CV = 0.2.

The *r* prior obtained from the Leslie Matrix was set, including a CV of 0.3. A log-normal bias correction was used. The initial *r* prior in the SPiCT model resulted in: -1.216346 with a CV of 0.3.

The shape parameter *n* was fixed to a Schaefer model (*n* = 2) and log-transformed, resulting in a prior for *n* of 0.6931472 with a CV of 0.001.

Simulations show that moderate process error can be expected for a relatively long-lived species (Winker, 2018). A process error (*sdb*) of 0.07 was used in the first base run. A log-normal bias correction was used resulting in a *sdb* of -2.78426 with a CV of 0.5.

The dteuler was set at ¼. Furthermore, no informative priors on the initial depletion ratio (*bkfrac)*, alpha and beta parameters were set.

Outcomes of the reference run for North Sea spotted ray are shown in Figures 3.4.1-3.4.6. The retrospective bias falls within the acceptable range for long-lived species (Mohn's ρ = −0.15−0.2). Furthermore, the prediction skill is evaluated using the new hindcast cross-validation (Figure 3.4.5). A Mean Absolute Scaled Error (MASE) smaller 1 would indicate that the model has prediction skill for the index. The MASE for the reference scenario equals 1.54, indicating the model has difficulties predicting the index (Figure 3.4.6).

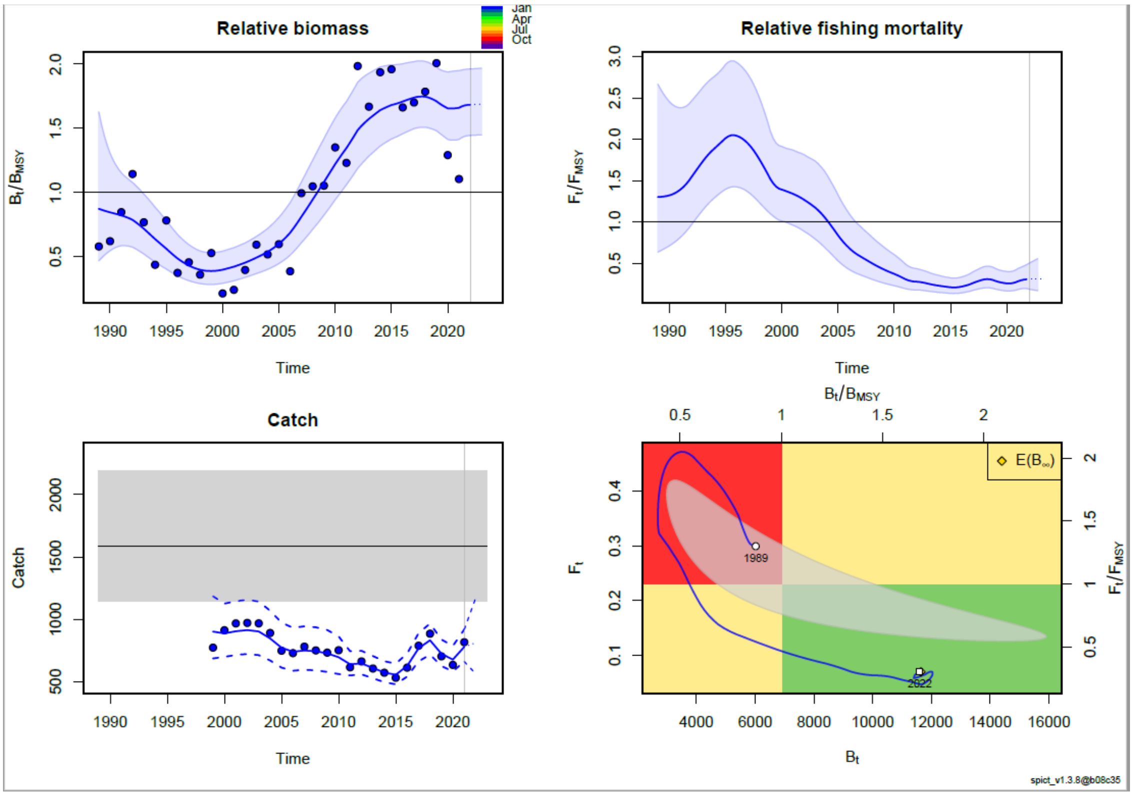

Figure 3.4.1 Fit and stock trajectories for the reference run for North Sea spotted ray.

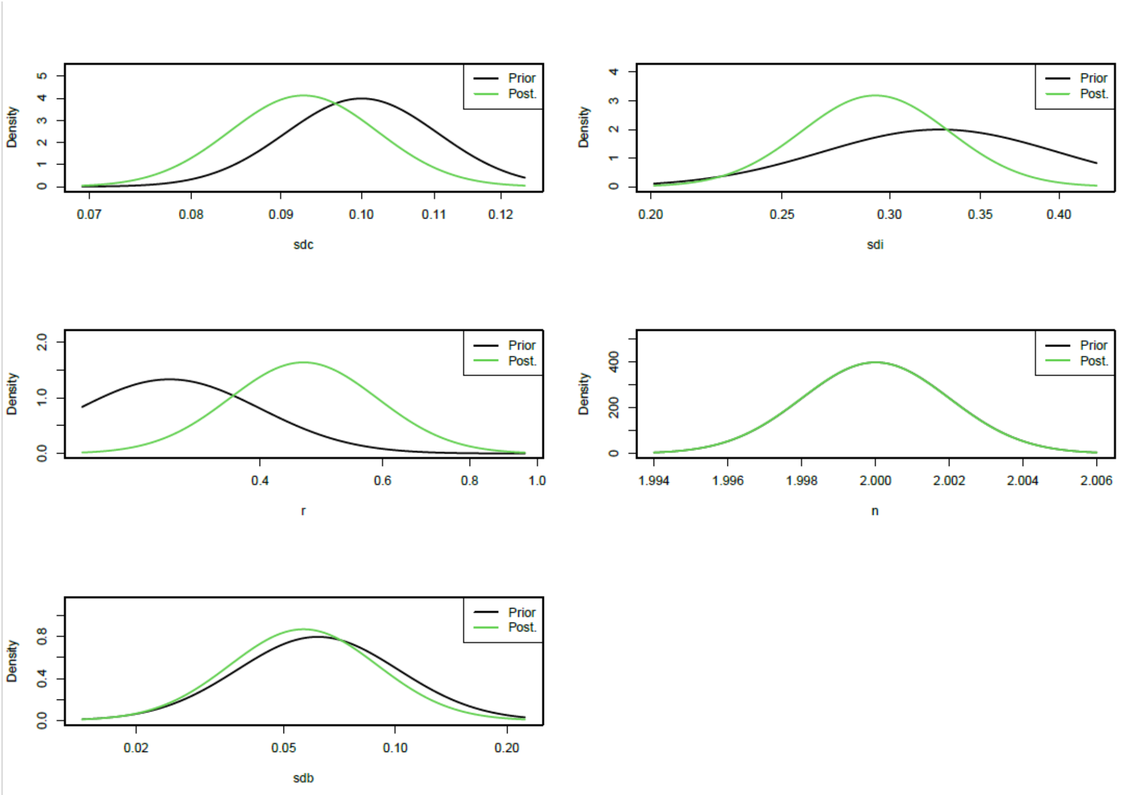

Figure 3.4.2 The estimated priors and posteriors for the reference case.

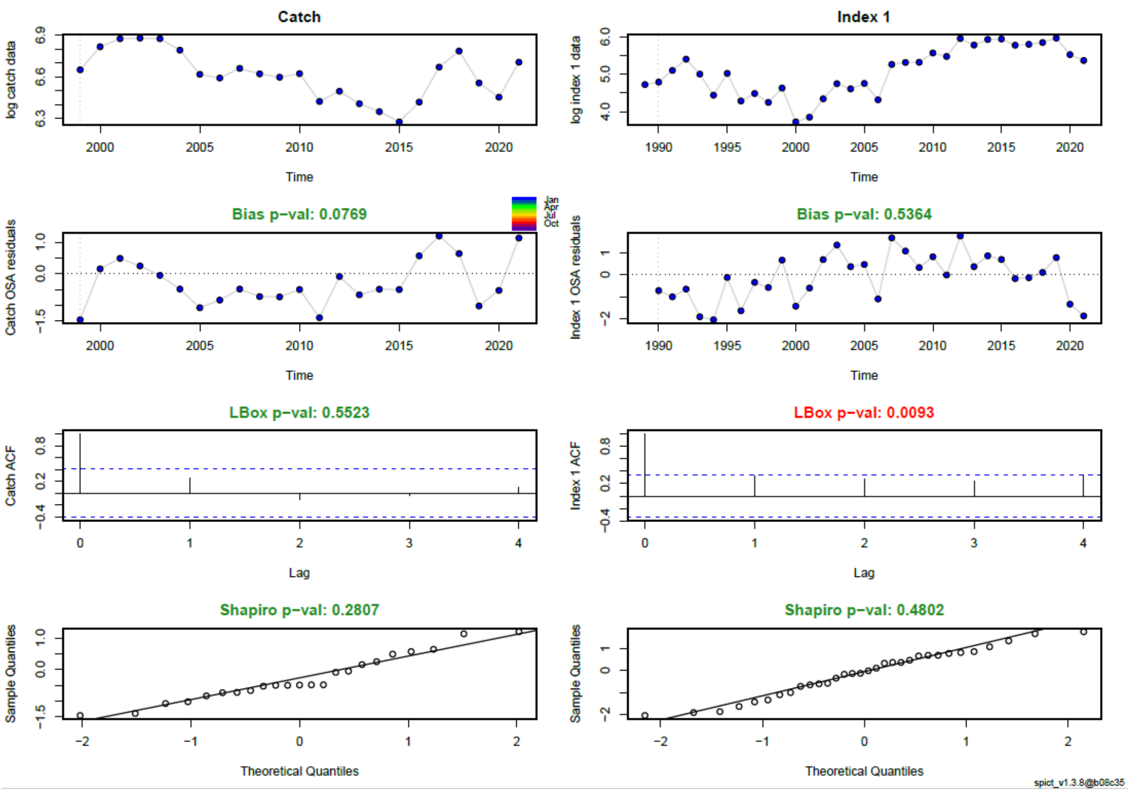

Figure 3.4.3 Diagnostics of one-step-ahead residuals for the 'reference' scenario.

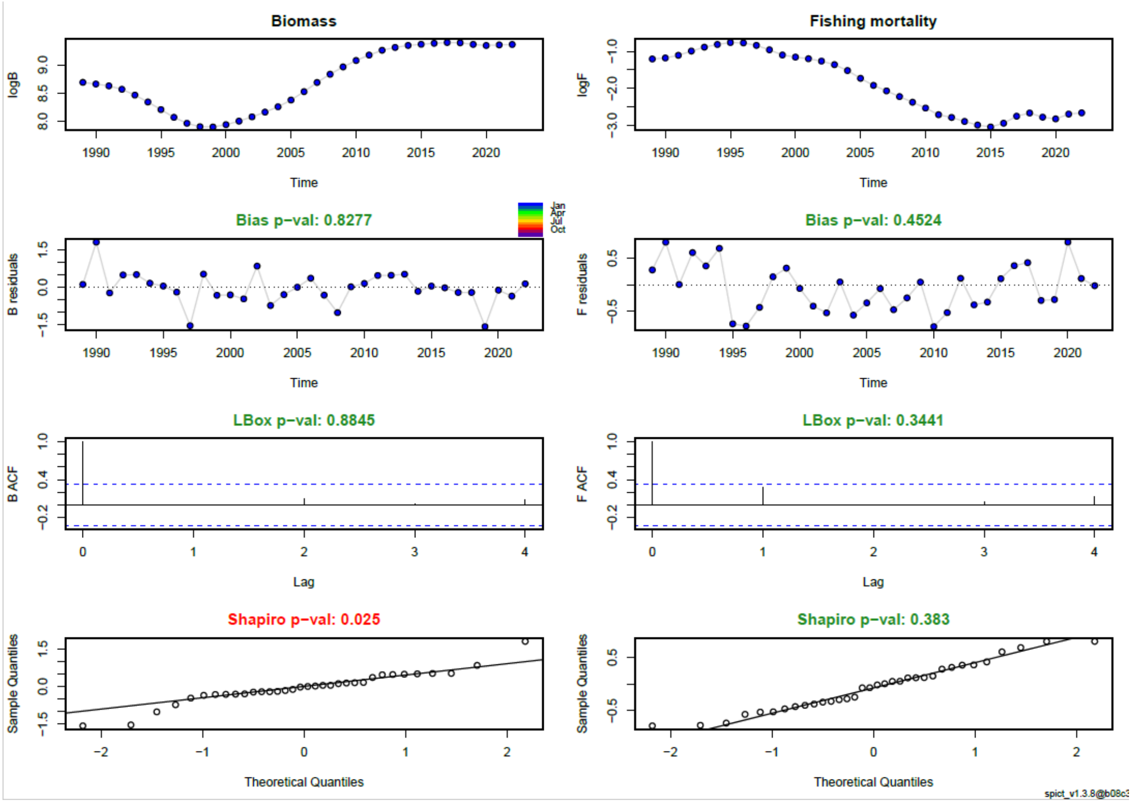

Figure 3.4.4 Diagnostics process error deviations for the reference scenario.

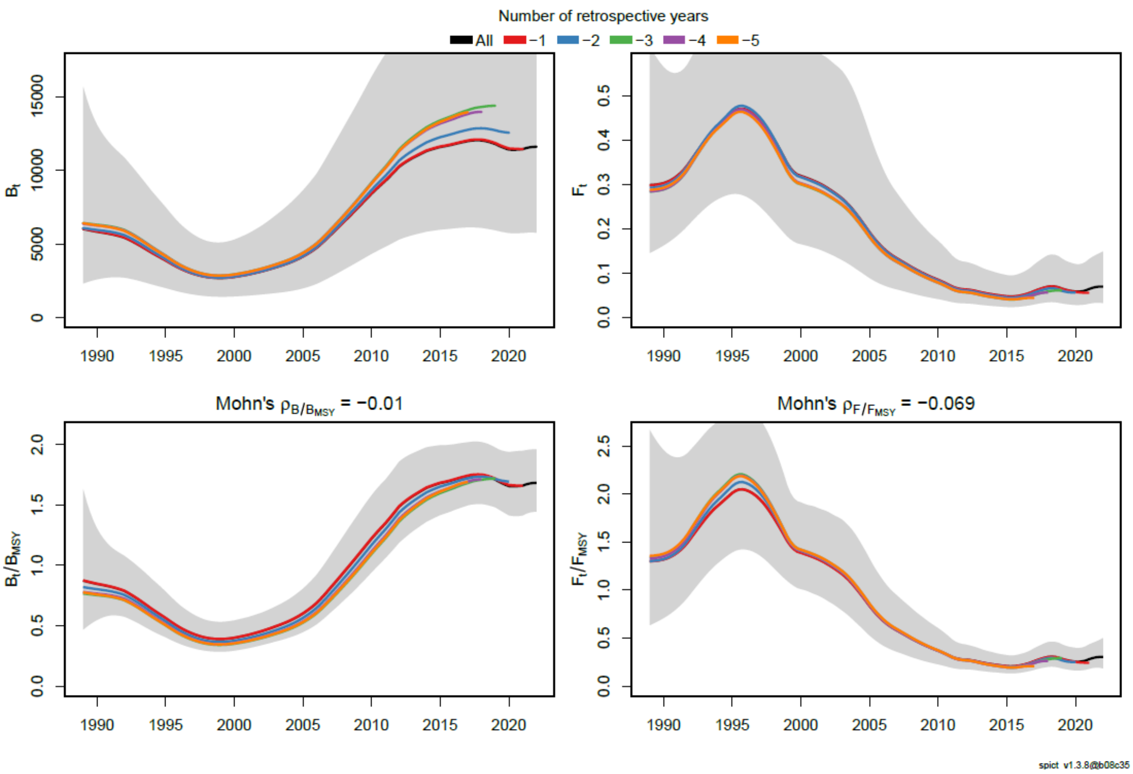

Figure 3.4.5 Retrospective analysis for the reference scenario

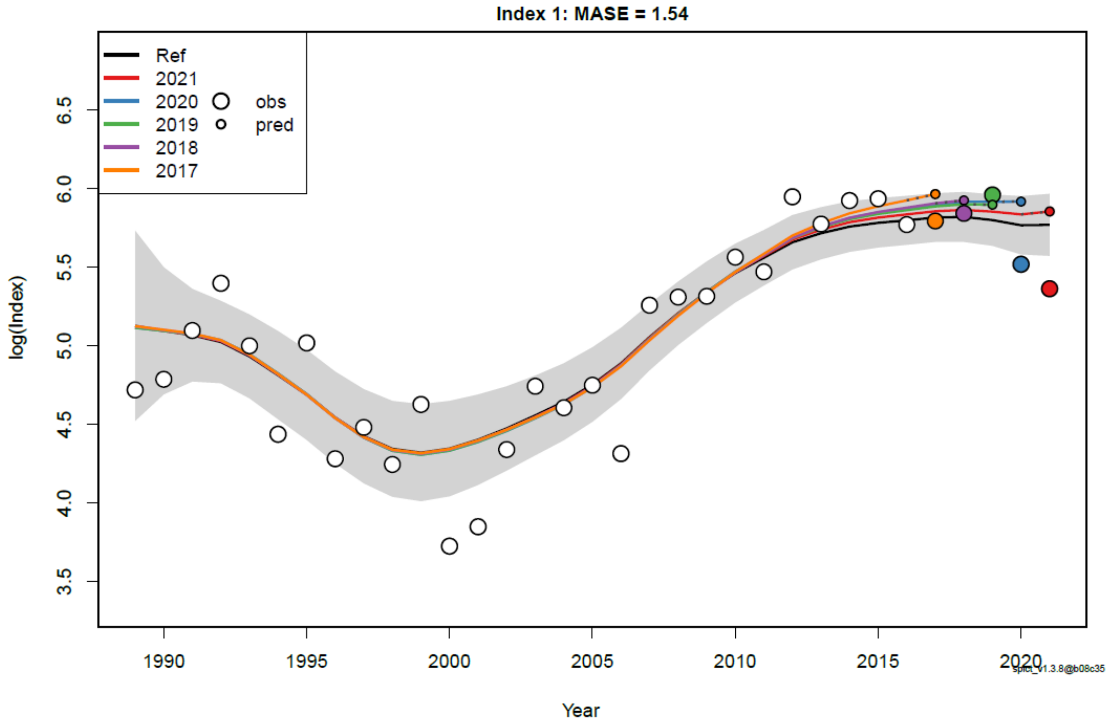

Figure 3.4.6 Hindcast cross-validation results for the ‘reference‘ scenario.

3.4.3 Exploratory assessments

Various simulation scenarios were tested, differing in terms of the time series considered for index, the use of multiple survey indices, the introduction of informative priors on parameter *r*, *bkfrac*, and *sdb*. A summary of the exploratory assessment runs is found in Table 3.4.2.

Table 3.4.2 SPiCT scenarios with input variable settings. For all scenarios a Schaefer production curve was used.

Scenario	Removals time series	Surveys time series	*r* prior (with CV)	Initial depletion rate *bkfrac* (with CV)	Process error *sdb* (with CV)
Reference (ref)	Catches 1999-2021	Single NS-IBTS-Q1 and Q3 biomass index (1989-2021)*	0.309^ (0.3)	-	0.07 (0.5)
1 – bkfrac prior (refr)	Catches 1999-2021	Single NS-IBTS-Q1 and Q3 biomass index (1989-2021)*	0.309^ (0.3)	0.1 (0.5)	0.07 (0.5)
2 – Shorter survey (sidx)	Catches 1999-2021	Single NS-IBTS-Q1 and Q3 biomass index (1999-2021)*	0.309^ (0.3)	-	0.07 (0.5)
3 – All surveys (idxa)	Catches 1999-2021	Single biomass index including all surveys (1989-2021)**	0.309^ (0.3)	-	0.07 (0.5)
4 – 2 surveys (idx2)	Catches 1999-2021	2 survey indices:	0.309^ (0.3)	-	0.07 (0.5)

		Q14*** and a Q3**** survey (1989-2021)			
5 – excl 1991 in Q3 index (idx91)	Catches 1999-2021	2 survey indices but excluding 1991 in Q3 index	0.309^ (0.3)	-	0.07 (0.5)
6 – *r* prior vs. logsdb	Catches 1999-2021	2 survey indices but excluding 1991 in Q3 index	0.2, 0.3, 0.4 (0.3)	-	0.05, 0.07, 0.1, 0.15 (0.5)
7 – CV in process error	Catches 1999-2021	2 survey indices but excluding 1991 in Q3 index	0.309^ (0.3)	-	0.07 (0.3, 0.5)

*** Combined survey index of NS-IBTS-Q1 and NS-IBTS-Q3 for ≥30cm individuals and a delta-gam modelling approach.**

**** Combined survey index of all surveys (NS-IBTS, CGFS and BTS) for ≥30cm individuals and delta-gam modelling**

***** Combined survey index of NS-IBTS-Q1 and CGFS Q4 for ≥30cm individuals and a delta-gam modelling approach.**

****** Combined survey index of NS-IBTS-Q3 and all BTS-Q3 surveys in the North Sea for ≥30cm individuals and delta-gam modelling**

^ *r* prior is rounded for reading purposes. In the models the unrounded *r* prior of = 0.3099494 was used (see section 4.4.1).

First, an exploratory run was done using the reference settings, but including an informative prior of 0.1 with a CV of 0.5 on the initial depletion ratio (*bkfrac*). Adding the *bkfrac* prior did not improve the fit, but resulted in a minor change in the perception of the stock with a lower biomass and lower F in the initial years of the time-series (Figure 3.4.7). The retrospective analysis is still within the acceptable bounds (Mohn's ρ B/Bmsy = −0.019 and Mohn's ρ F/Fmsy = -0.078) but performs less well compared to the reference run. Similarly, the hindcast (MASE=1.81) deteriorated as well with the addition of a *bkfrac* prior (Figure 3.4.8). The group decided not to set an initial depletion in the rest of the exploratory runs.

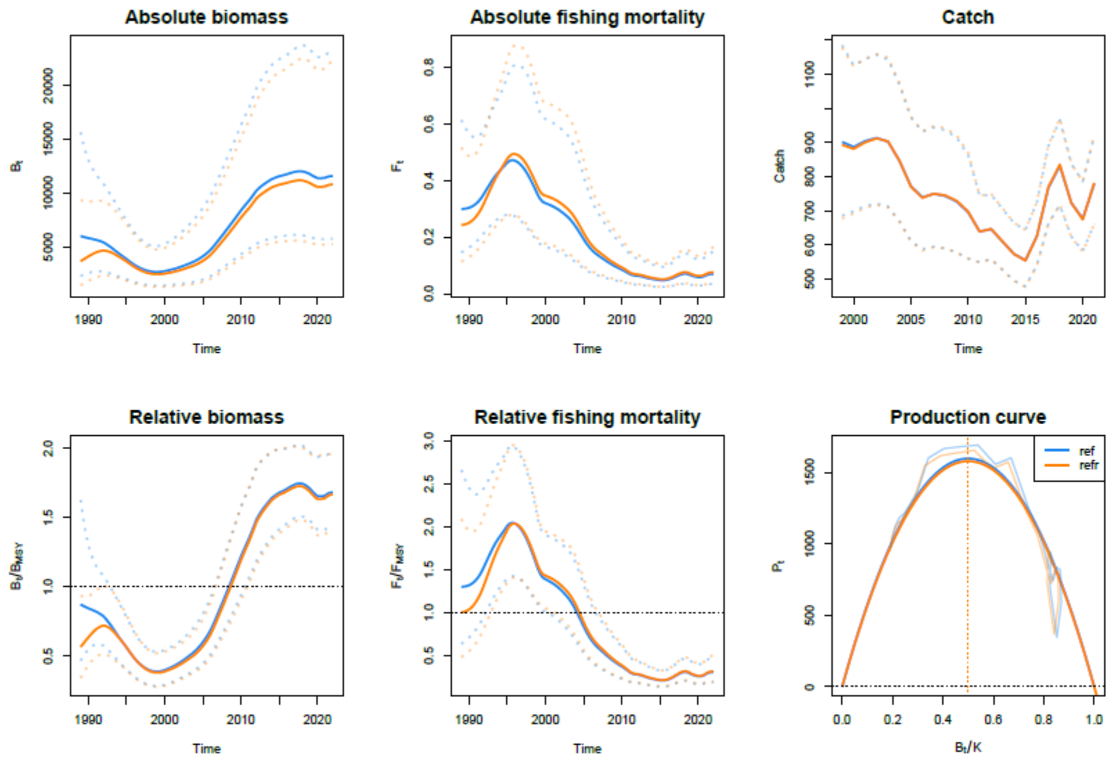

Figure 3.4.7 comparison plots of the reference run with the revised run using a bkfrac of 0.1 and CV=0.5.

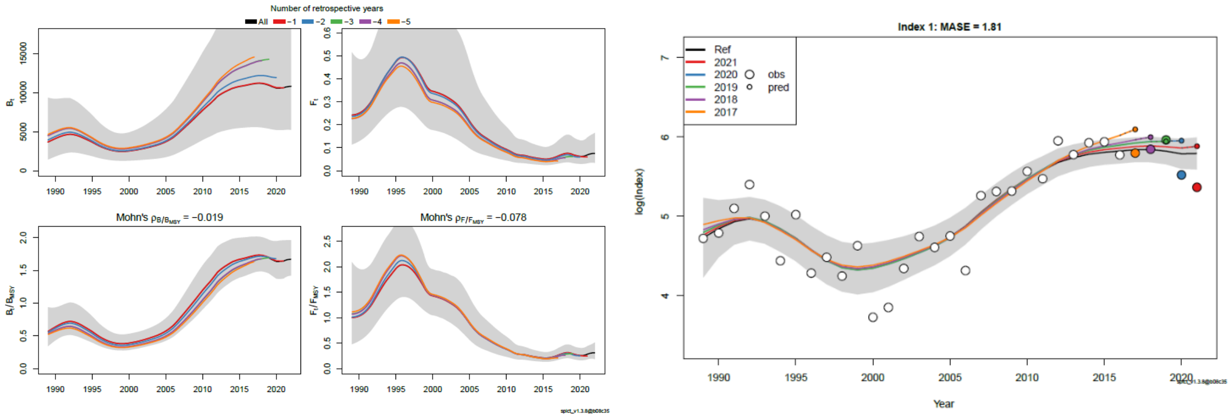

Figure 3.4.8: Retrospective analysis (left) and hindcast (right) for the revised run using a bkfrac prior.

In the following steps several exploratory runs were used to understand the effects of choices regarding the surveys:

- sidx (scenario 2): Single survey index of the NS-IBTSQ1 and Q3 with a truncated time-series to match the time-series of catches (1999-2021)
- idxa (scenario 3): Single survey index with all surveys in the North Sea (1989-2021)
- idx2 (scenario 4): Two survey indices with one index for the CGFS-Q4 and NS-IBTS-Q1, and a second index for a combination of the NS-IBTS-Q3 and all BTS-Q3 surveys (i.e. BTS-Eng-Q3, BTS-BEL-Q3, BTS-NL-ISI-Q3 and BTS-NL-TRI-Q3) (1989-2021). The Q3 survey is set to start later in the year (year +0.75) to match the timing of the surveys.
- idx91 (scenario 5): Two survey indices, but for the Q3 survey index, year 1991 was excluded (exceptional catch of larger individuals of spotted ray in the Dutch beam trawl survey). The Q3 survey is set to start later in the year (year +0.75) to match the timing of the surveys.

Outputs of the surveys scenarios and reference run are shown in Figure 3.4.9. All scenarios indicate similar results about the stock status, i.e. stock recovering from low biomass to being well above Bmsy and F being above Fmsy until the early 2000s. Using a short time-series for the index (sidx) does not improve the assessment. While the result is in line with the other scenarios, there is a lower precision, with a considerable higher estimated surplus production (MSY). The latter could result in more optimistic catch forecast. The group agreed that a shorter time series does not improve the assessment.

All exploratory runs appear to be more optimistic about the biomass in the initial years of the assessment compared to the reference run. Only the idx91 run (scenario 5) is also estimating the stock to be below Bmsy at the start of the time series, recovering to Bmsy around 2006. The idxa (scenario 3) and idx2 (scenario 4) runs estimate the stock to be above Bmsy in the first years, decreasing below Bmsy in the early 1990s.

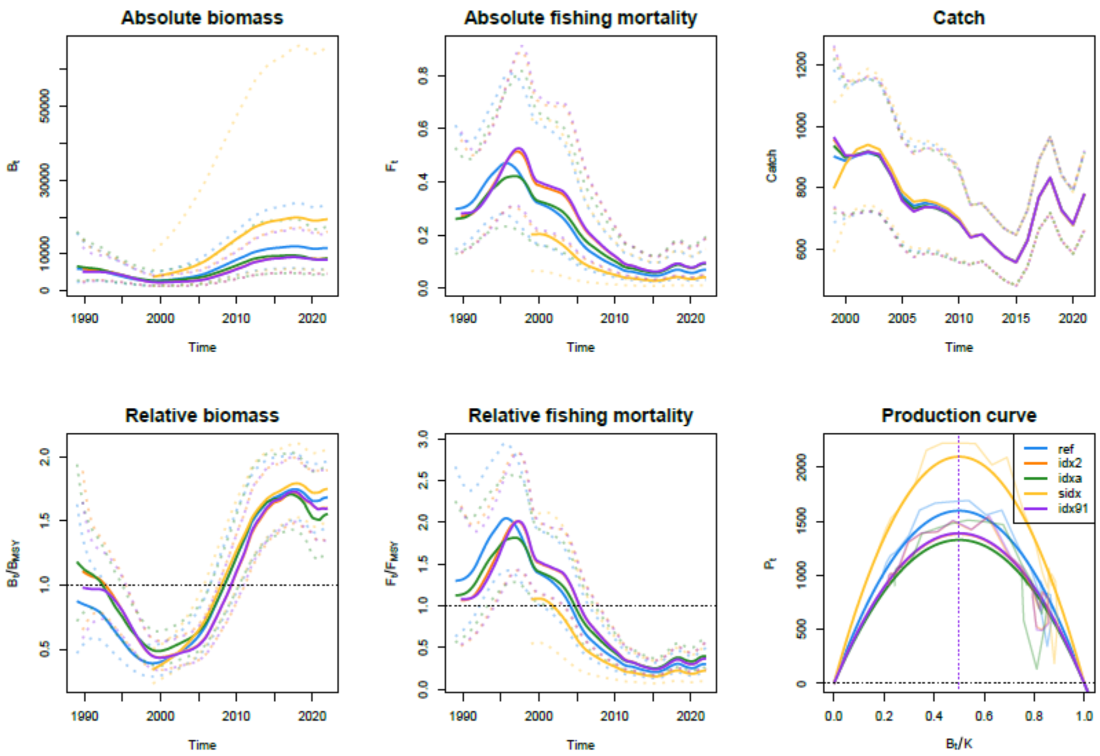

Figure 3.4.9 comparison plots of the reference run with the revised runs adjusting survey indices.

When using a single survey index in the model (ref and idxa) hindcasting cross-validation showed a relatively low prediction skill with MASE values deviating from 1, i.e. a MASE of 1.54 and 1.43 for the ref and idxa run, respectively. As such, an exploratory run using two surveys indices split by quarter (Q14, and Q3) was considered (idx2, scenario 4). The predictive skill of this model, quantified through a five-year hindcasting, showed a much improved prediction skill with MASE values close to 1 (Figure 3.4.14, left panel).

While the stock trajectory of the idx2 run is similar to the reference run, MSY is estimated to be lower and the stock is estimated to recover less rapidly achieving Bmsy a bit later. In the relative biomass plot an outlier in 1991 for the Q3 index is visible. This outlier relates to an exceptional catch of larger individuals of spotted ray in the Dutch beam trawl survey conducted by the RV ISIS. To investigate the influence of this outlier a run excluding year 1991 from the quarter 3 survey index was evaluated (idx91, scenario 5). Model fit and trajectories as well as diagnostics of the idx2 (scenario 4) and idx91 (scenario 5) runs are presented in Figures 3.4.10 – 3.4.15. The idx91 run does not result in a large change in the perception of the stock, but indicates the stock has been below Bmsy at the start of the time-series. This is different compared to the other scenarios, where the stock is estimated to be above Bmsy in the initial years of the assessment. This is also true for the idx2 run, being about the only difference between the two runs using 2 survey indices. The surplus production of the idx2 and idx91 runs are similar and estimated at 1384 and 1389, respectively. Comparing the diagnostics shows no major differences, with Mohns rho within the acceptable bounds (Figure 3.4.14). The predictive skill of the idx91 run, quantified through a five-year hindcasting, showed an improvement for the quarter 3 survey with a MASE value below 1 (Figure 3.4.15). Based on the diagnostics the model using 2 surveys, leaving out the 1991 outlier in the quarter 3 survey (idx91) was chosen as a base to continue exploratory runs.

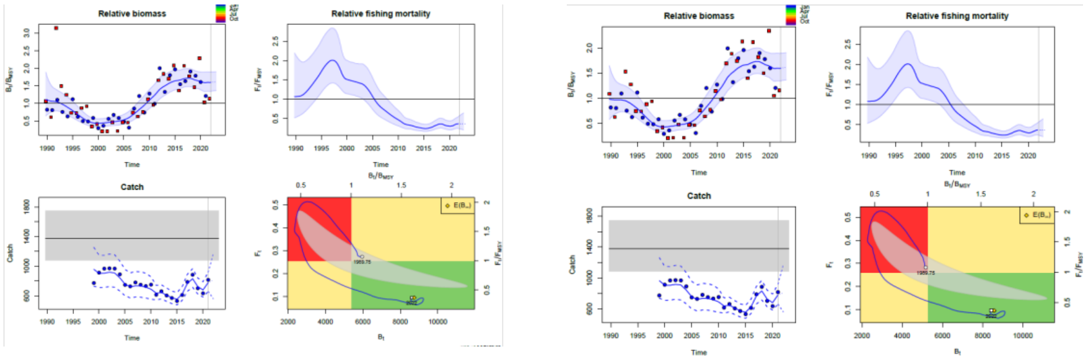

Figure 3.4.10 Fit and stock trajectories for scenario 4 (idx2, left) and scenario 5 (idx91, right).

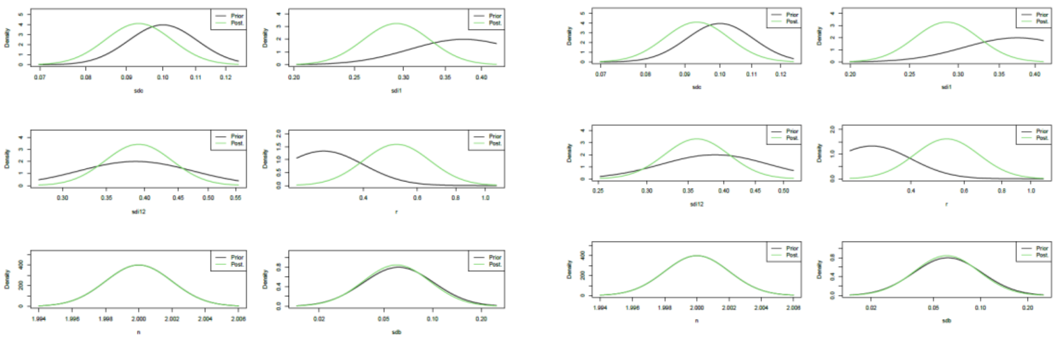

Figure 3.4.11 The estimated priors and posteriors for scenario 4 (idx2, left) and scenario 5 (idx91, right)

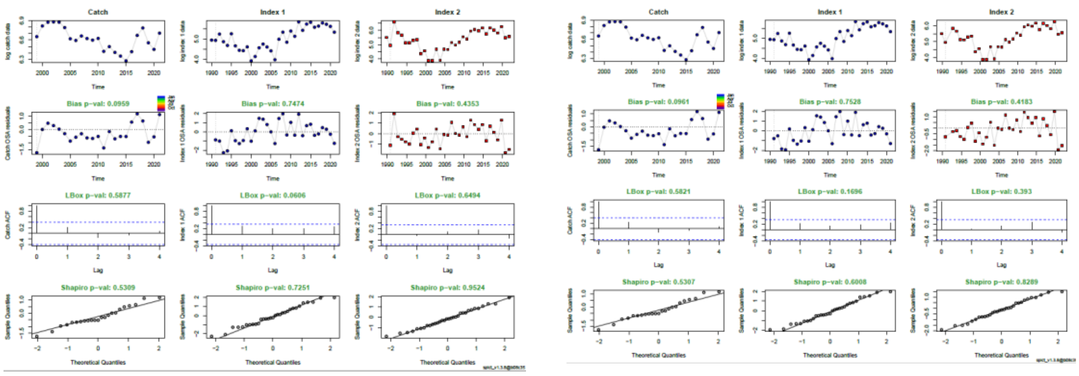

Figure 3.4.12 Diagnostics of one-step-ahead residuals for scenario 4 (idx2, left) and scenario 5 (idx91, right)

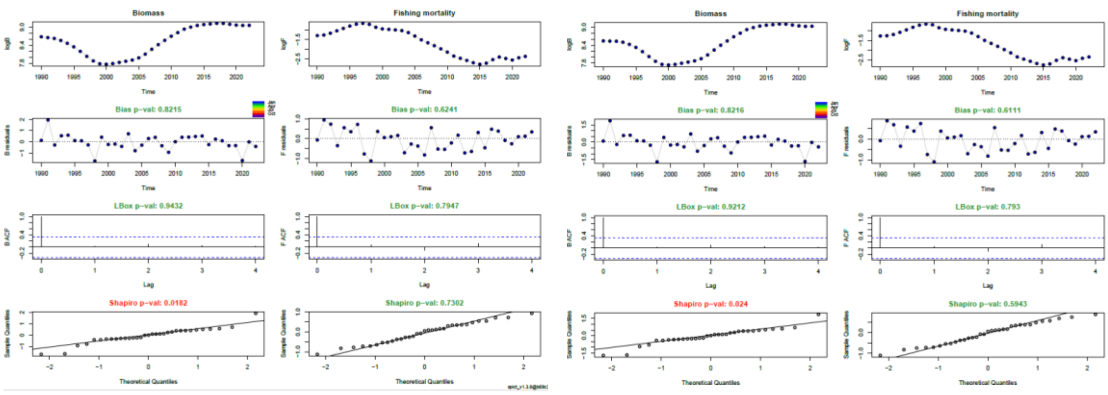

Figure 3.4.13 Diagnostics process error deviations for scenario 4 (idx2, left) and scenario 5 (idx91, right)

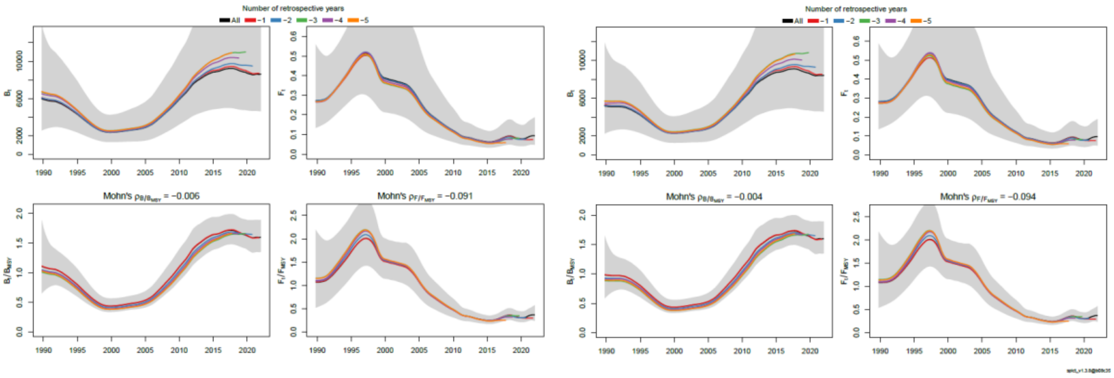

Figure 3.4.14 Retrospective analysis for scenario 4 (idx2, left) and scenario 5 (idx91, right)

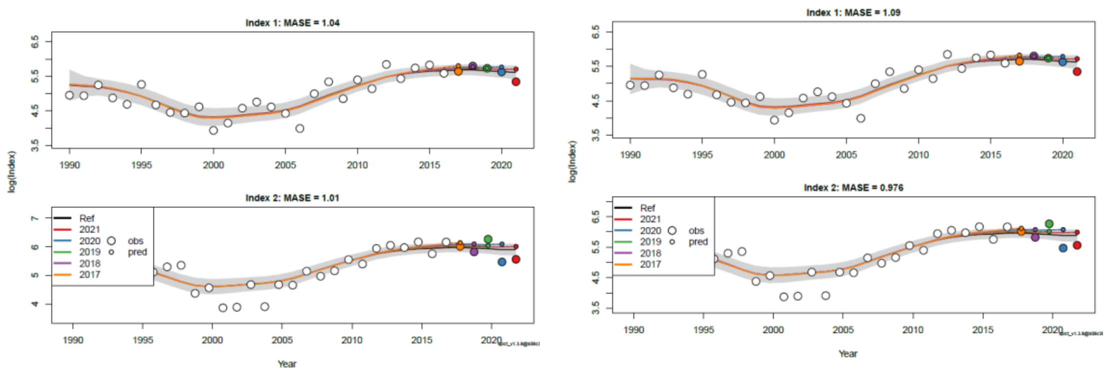

Figure 3.4.15 Hindcast cross-validation results for scenario 4 (idx2, left) and scenario 5 (idx91, right). A Mean Absolute Scaled Error (MASE) smaller than 1 would indicate that the model has prediction skill for the index.

The next step in exploratory assessments was to test the sensitivity of setting an informative *r* prior in combination with adjusting the prior on process error (scenario 6). The initial *r* prior obtained from the Leslie matrix was 0.309 with a CV of 0.3, while process error was set at 0.07 with a CV of 0.5. In total 12 combinations were tested using 3 different *r* priors (0.2, 0.3 and 0.4 with a fixed CV of 0.3) and 4 different process error (*sdb*) priors (0.05, 0.07, 0.1 and 0.15 with a fixed CV of 0.5). Comparison plots of the different prior settings in scenario 3 can be found in Figures 3.4.16 and 3.4.17. Changing the *r* prior has a limited effect on the stock trajectories and shows the stock is below Bmsy and above Fmsy at the start of the time-series in all *r* prior runs. Lowering the *r* prior to 0.2 slight affects the production curve estimating a higher MSY-value. In addition, the model estimates a larger biomass and lower fishing mortality on the stock, however, uncertainty is much larger. Overall, in all 3 runs the *r* prior is updated to larger values (Figure 3.4.16) and model diagnostics of a lower of higher *r* prior do not improve compared to using a value of 0.3 (i.e. the idx91 scenario). In contrast using a lower *r* prior, the retrospective analysis and hindcast cross validation worsen.

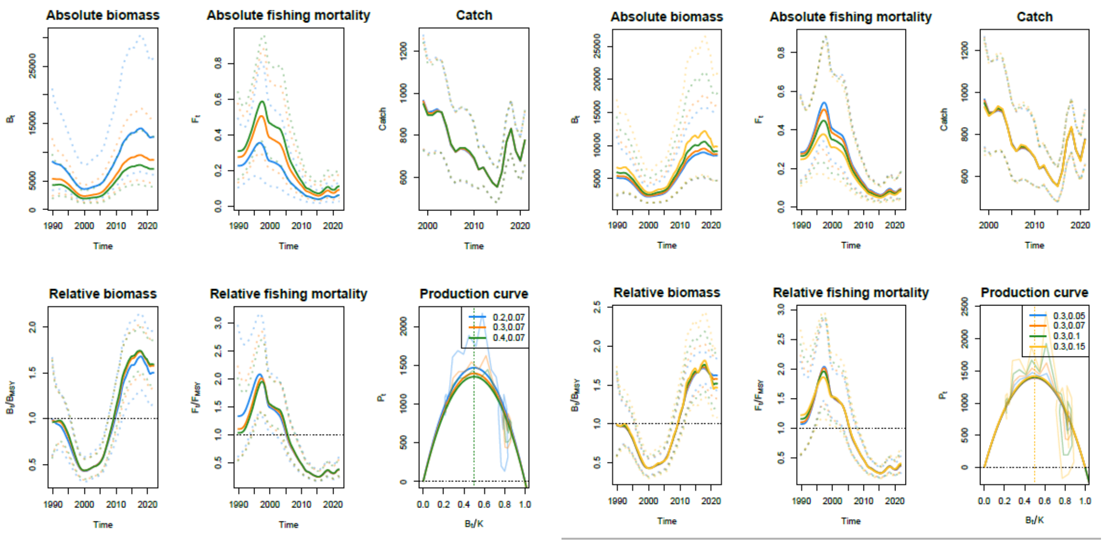

Figure 3.4.16 comparison plots of updating the r prior keeping process error (sdb) fixed (left) and the runs varying the process error (sdb) keeping the r prior fixed at 0.3 (right).

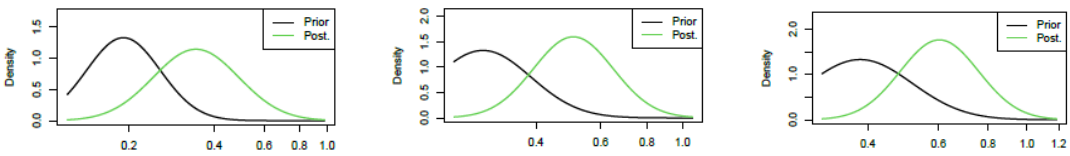

Figure 3.4.17 The estimated r prior and posterior using an r prior of 0.2 (left), 0.3 (middle) and 0.4 (right), all with a fixed CV of 0.3 and sdb of 0.07 (CV=0.5).

Simulating the prior on the process error did not seem to have a direct effect on biomass, fishing pressure or the production curve (Figure 3.4.16). In all runs the stock starts below Bmsy and above Fmsy. Retrospective analyses and hindcasts cross-validations with a prior of 0.1 seemed to improve the model fit and diagnostics and it was decided to keep the *r* prior from the reference run (0.309, CV=0.3) and an *sdb* prior of 0.1.

As a final validation, the CV of the process error (0.1) was tested by comparing a reference CV of 0.5 with a lower CV value of 0.3. Comparison outputs are shown in Figure 3.4.18. Changing the CV value has no influence on the model fits and diagnostics. As such, the group decided to use a process error of 0.1 with a CV of 0.5 in the final model for spotted ray.

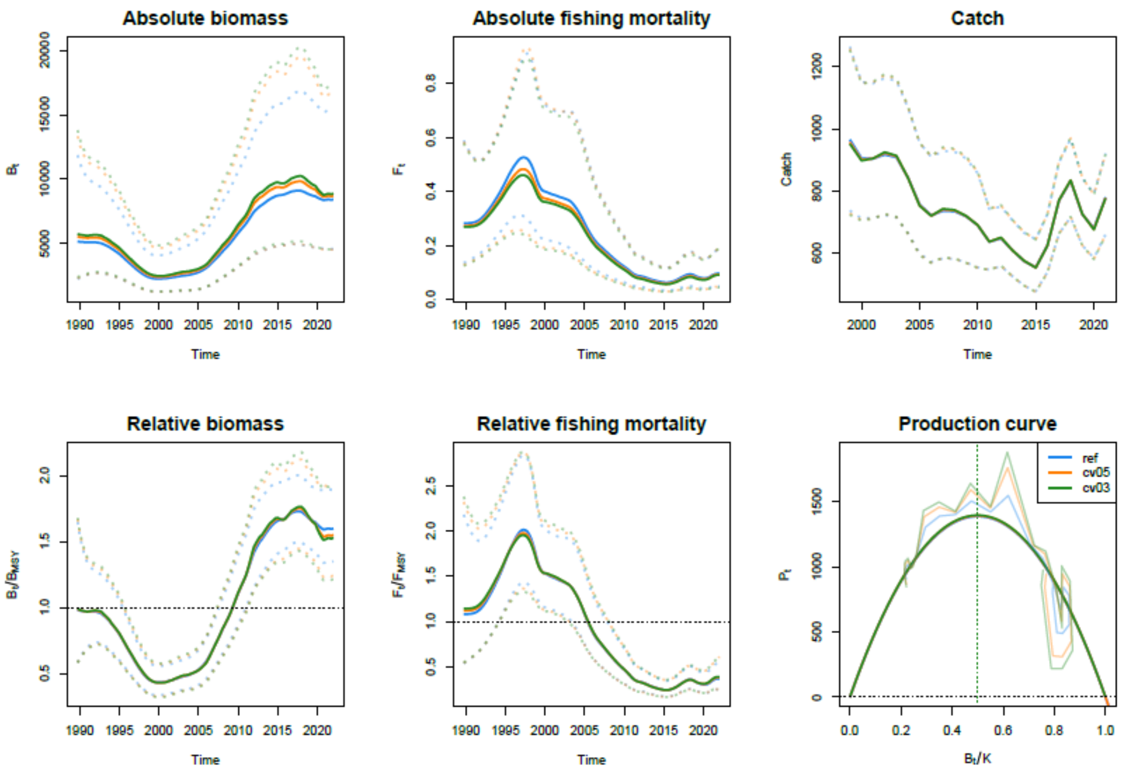

Figure 3.4.18 Comparison plots of the reference run with the revised runs adjusting survey indices.

3.4.4 Final assessment

The scenario that was chosen as final assessment included informative priors on parameters *r* and *n*. The parameter settings agreed for the final assessment are found in Table 3.4.3. Diagnostic plots corresponding to the final assessment are presented in Figures 3.4.19-3.4.23.

Table 3.4.3 Parameter settings for the final assessment of spotted ray with SPiCT.

Parameter	Agreed setting
Catches	1999-2021 using reconstruction scenario 2 (2009-2011). 2x higher uncertainty in 1999-2010
Surveys	Index 1: FR-CGFS-Q4 and NS-IBTS-Q1 combined. Time series 1989-2021 Index 2: NS-IBTS-Q3 and all BTS-Q3 surveys combined. Time series 1989–2021 (excluding 1991).
r. prior	*r* = 0.309, CV = 0.3
Shape.prior	Schaefer model (*n* = 2)
Process error	*sdb* = 0.1, CV = 0.5

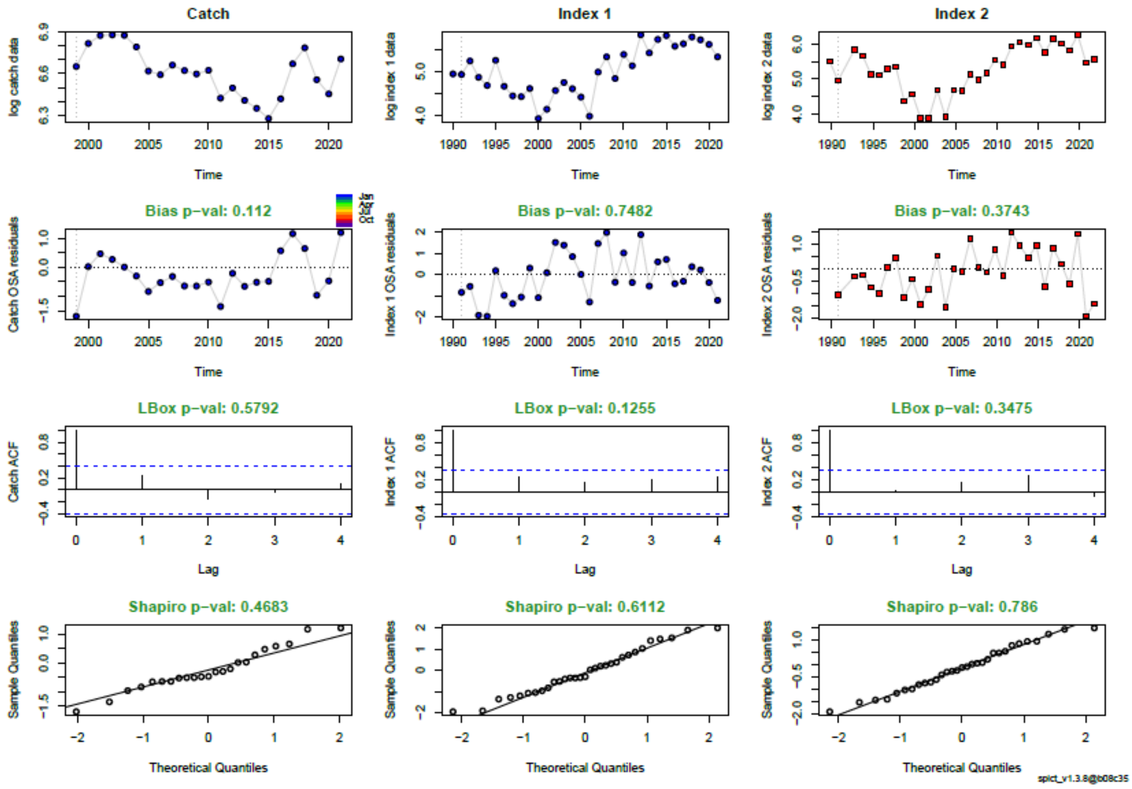

Figure 3.4.19 Diagnostics of one-step-ahead residuals for the final assessment of spotted ray.

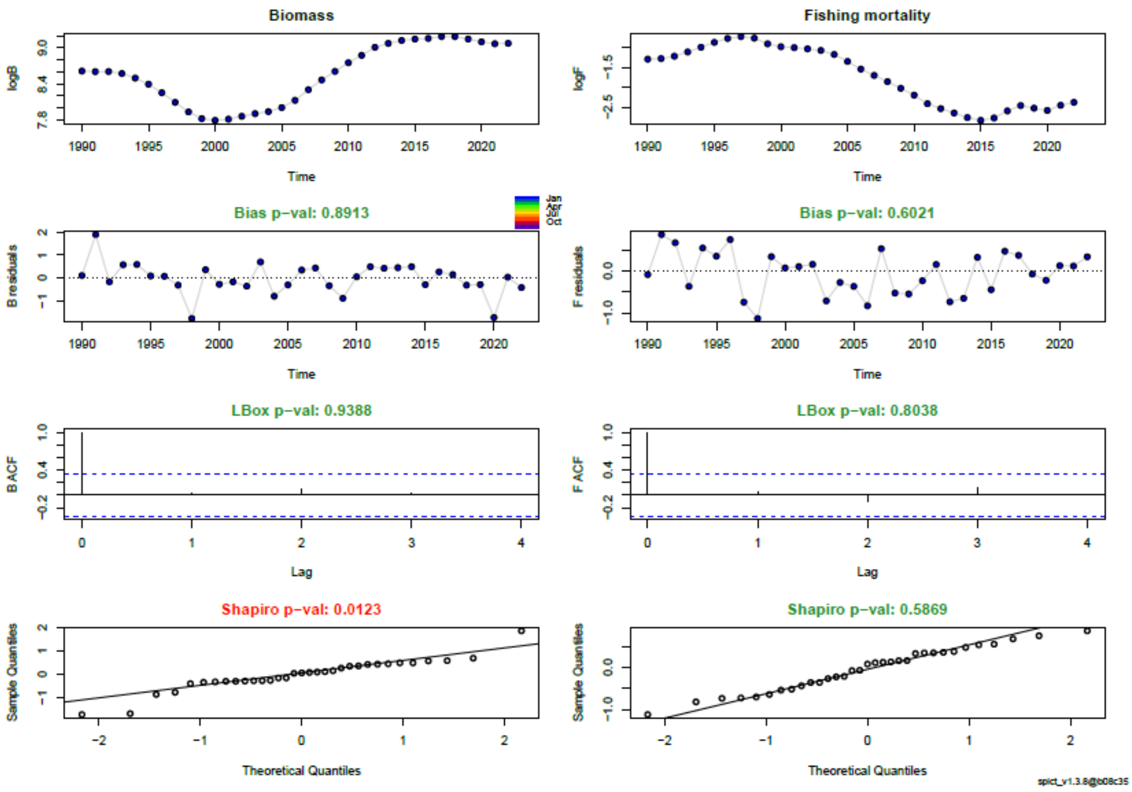

Figure 3.4.20 Diagnostics of process error deviations for the final assessment of spotted ray.

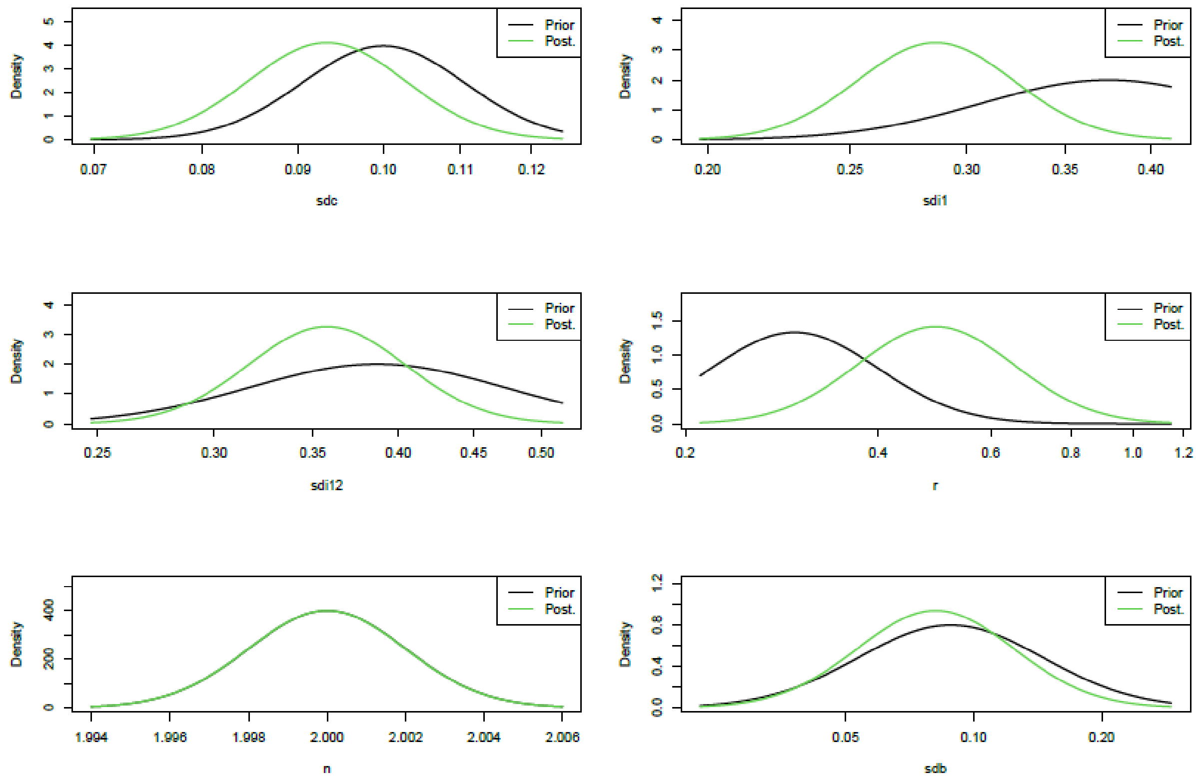

Figure 3.4.21 Plot showing the estimated priors and posteriors for the final assessment of spotted ray.

The retrospective analysis was done using 5 retro-years and showed consistent patterns (Figure 3.4.22). Mohn's rho of $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ were -0.012 and -0.093, respectively, which is in between the thresholds of -0.15 and 0.20 for long-lived species (ICES, 2020).

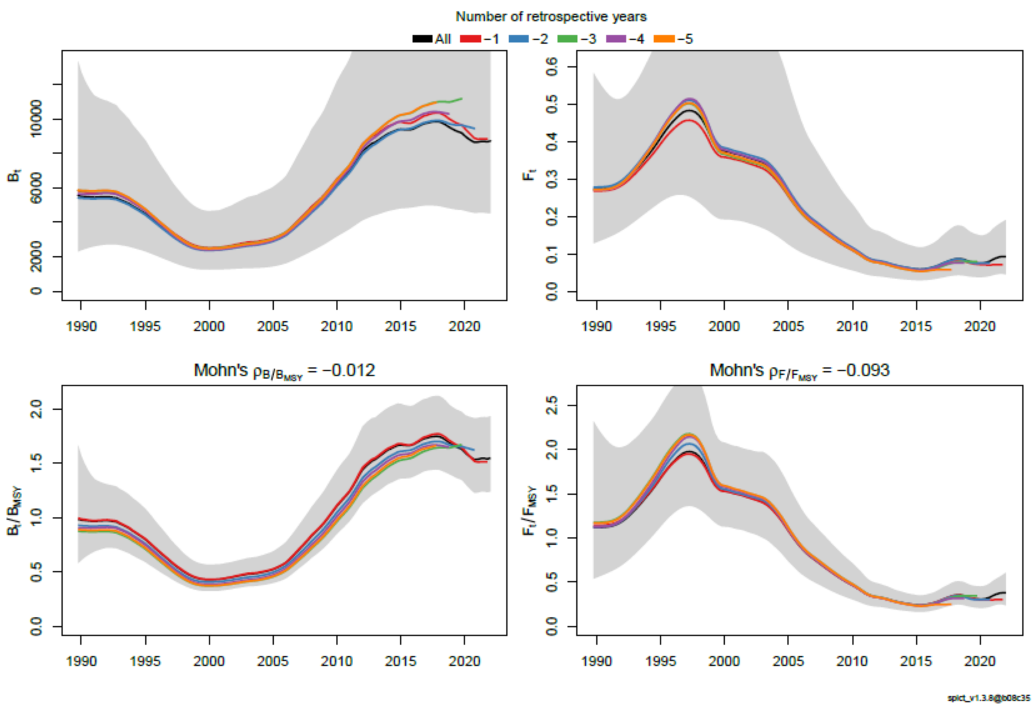

Figure 3.4.22 Retrospective analysis for the final assessment of spotted ray.

A hindcast cross-validation was done for the final assessment for hindcasts to 5 years. A Mean Absolute Scaled Error (MASE) smaller than 1 would indicate that the model has prediction skill for the index. In the hindcast cross-validation using 5 years, the prediction skill was a bit higher than 1: MASE = 1.06 for index Q14 (Figure 3.4.23, upper graph) and 0.981 for index Q3 (Figure 3.4.23, lower graph).

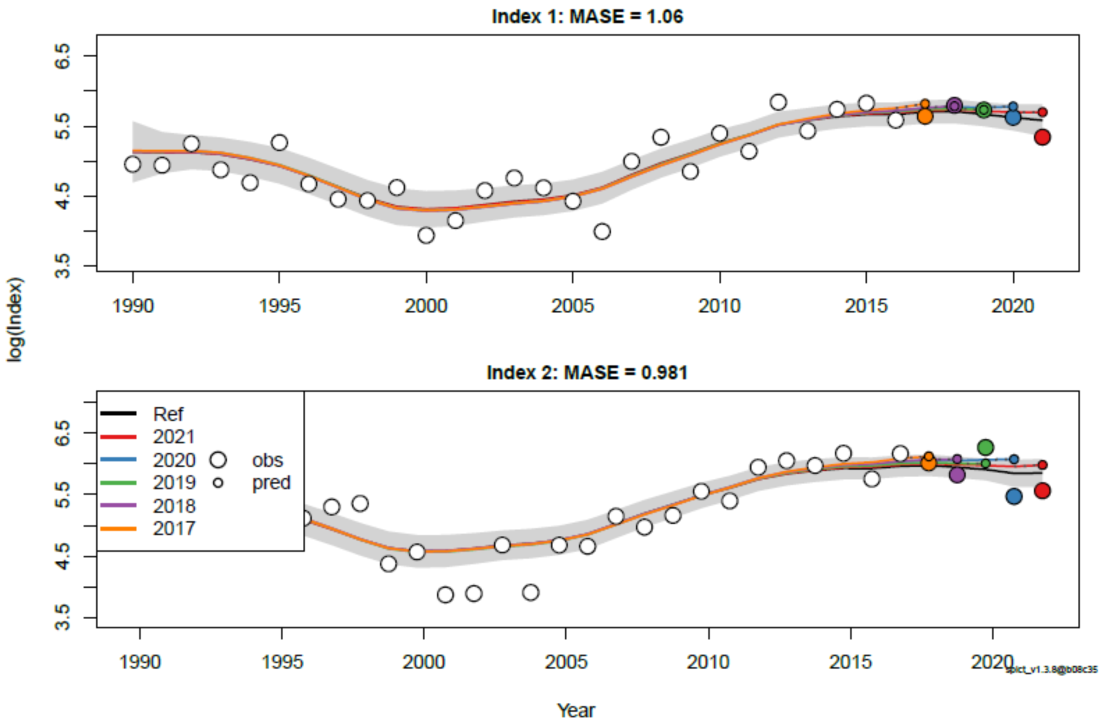

Figure 3.4.23 Hindcast cross-validation for the final assessment of spotted ray (Index1: Q14; Index2: Q3).

Result plots for the final assessment can be found in Figure 3.4.24. The output of the model indicates an overexploited stock with a biomass well below B_{MSY} in 1997. Fishing mortality was stable but above F_{MSY} in earlier years following a decreasing trend and remaining below F_{MSY} since 2006, allowing the stock to rebuild. Since 2018 biomass is above B_{MSY}. MSY is estimated to be 1394 tonnes with confidence interval [1076-1806] tonnes.

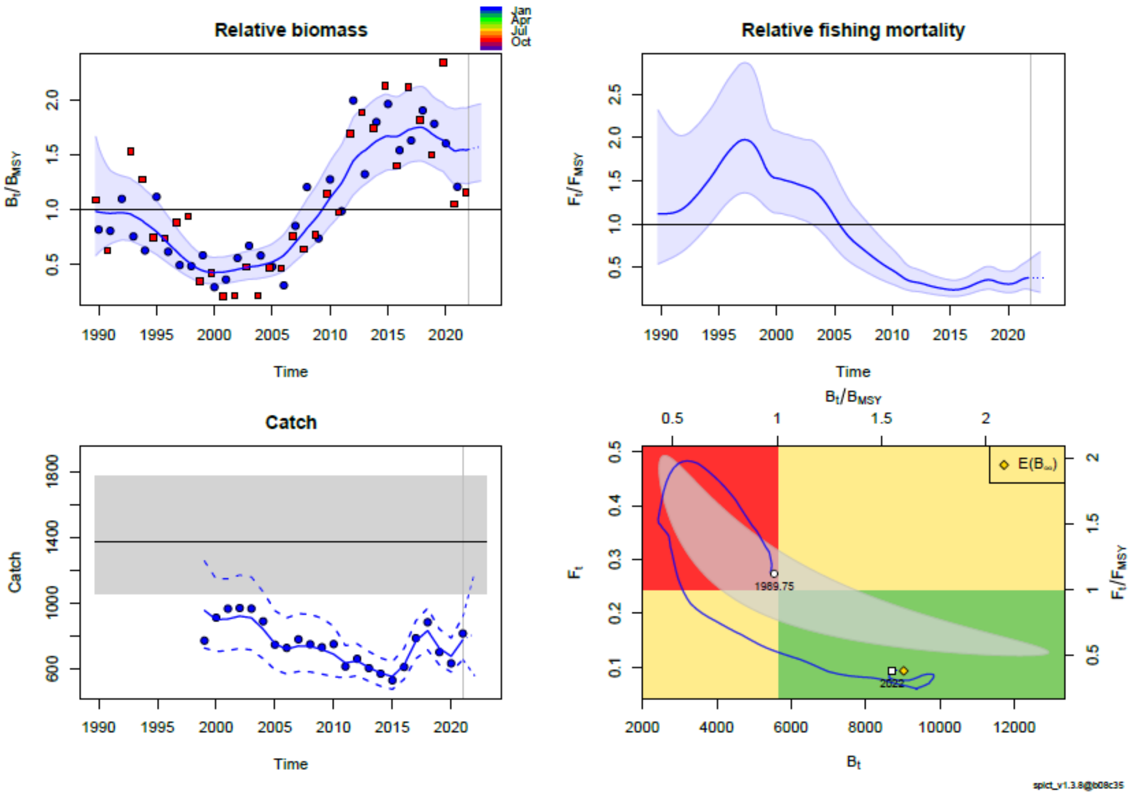

Figure 3.4.24 Fit and trajectories plots for the final assessment of spotted ray.

3.4.5 Forecast

With the final assessment model, a short-term forecast was carried out assuming status quo harvest rate for the interim year. A two-year projection (2023-2024) was made including different management options:

1. ICES advice rule, corresponding to the 35th percentile of the catch
2. 15th percentile of the catch
3. 25th percentile of the catch, biomass and fishing mortality
4. Current ICES Category 3 precautionary approach (i.e. increase in advice cannot be higher than 20%).
5. Increase realized removals with 20%

The advised removals of spotted ray for 2023 corresponding to the ICES advice rule is 1865 tonnes. This advice is a 2.5-fold increase compared to the average annual removals derived for the period 2020-2021 (726 tonnes) and a 5-fold increase compared to what should have been an advice for removals derived from the current 232 tonnes landings advice (370 tonnes given a dead discard rate of 0.59 (average rate of 2019-2021)). Given the change of perception of the state of the stock (formerly considered depleted and now estimated to be harvested well below F_{MSY} with a biomass above B_{MSY}) and the use of a forecast and reference points, the workshop considered that this substantial increase of the forecasted removals was sensible. If this advice were to be followed, B/B_{MSY} would be expected to be 1.42 and F/F_{MSY} would be expected to be 0.90 at the beginning of 2024. For illustration, when following the current ICES Category 3 precautionary approach, the advice for the stock would be 443 tonnes with corresponding B/B_{MSY} of 1.65 and F/F_{MSY} of 0.20. Increasing the realized removals by 20% gives an advice on removals of 934 tonnes. The five predicted trajectories are presented in Table 3.4.4 and Figure 3.4.25.

Table 3.4.4. Scenario outputs for 2023.

Scenario	Removals (tonnes)	F/Fmsy	B/Bmsy
35th percentile of catch at Fmsy	1865	0.90	1.42
15th percentile of catch at Fmsy	1578	0.75	1.47
25th percentile of of the catch, biomass and fishing mortality	1423	0.67	1.50
Increase advice (current ICES Category 3 (+20%))	443	0.20	1.65
Increase realized removals (+20%)	934	0.43	1.57

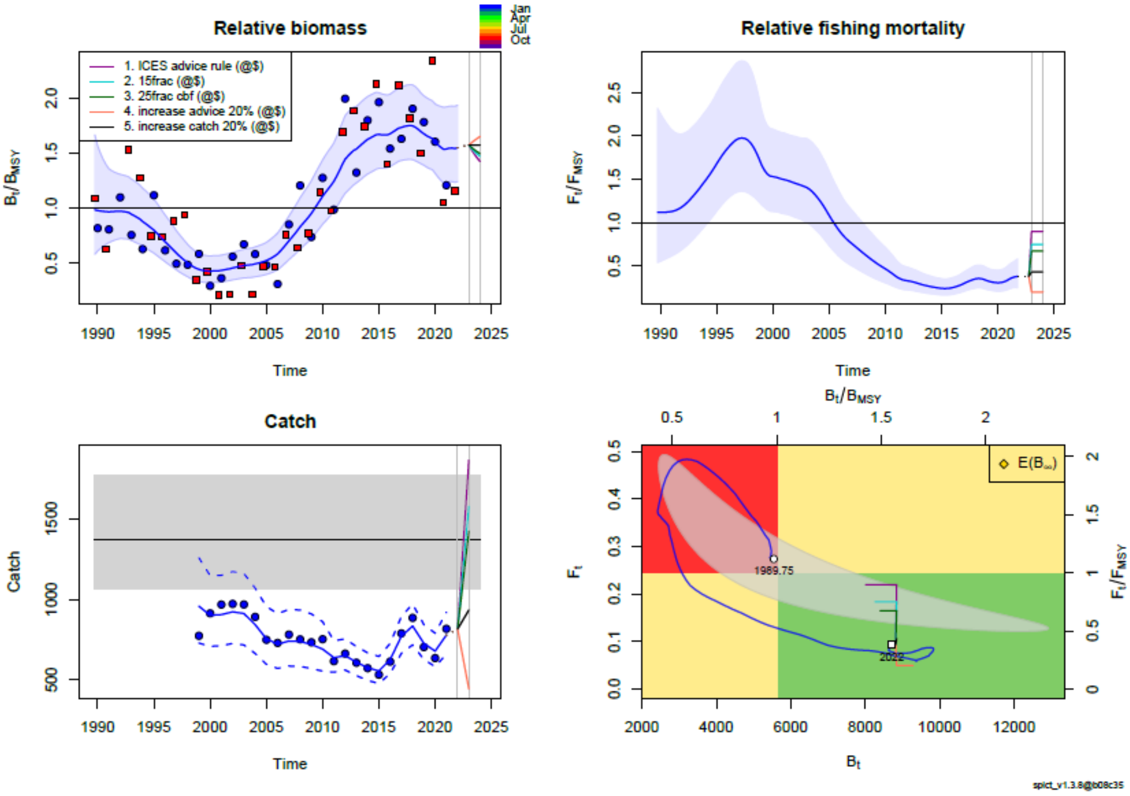

Figure 3.4.25 Predicted trajectories of spotted ray (rjm.27.3a47d) for the management period 2023-2024.

It should be noted that when applying the ICES rule (35th of the predicted catch [removals] at Fmsy) the resulting catches (removals) are well above the estimated MSY (1394 tonnes, i.e. greater than the upper bound of the confidence interval), while considering the 15th percentile results in a fishing opportunity slightly below.

3.5 Future considerations/recommendations

The forecasted value of the advice on removals when applying the ICES rule (1865 tonnes) is greater than the recent annual catch (2020-2021 average: 265 tonnes) or recent removals (2020-2021 average: 726 tonnes) and, also much greater than the current advice on total catch (232 tonnes).

Given the increase in advice using SPiCT, the average dead discard rate observed in the current time series may change. Using the usual procedure to convert removals to landings by using the recently observed dead discard rate would potentially not be appropriate. It is very unlikely that this discard rate would remain similar if more landings were to be allowed. If the advised removals were directly used to fix the allowed landings, this would imply some degree of targeting for fishers to reach this quantity (i.e. some increase in effort dedicated to this fishery).

While most of the simulation testing were carried out for recovering stocks, WKLIFE should consider what could be an ICES rule for stocks which are far below Fmsy (and at or above Bmsy). Even a low fractile (e.g. 15th) of the catches at Fmsy would lead to a large increase in short term fishing opportunities, above MSY, with a risk of reduction of the biomass in the near future. Given the uncertainty around the MSY value, it would be relevant to test a constraint in the increase in the catch advice to the lower limit of the confidence interval around MSY.

Information on the genetic structure of spotted ray in the North Sea, Skagerrak and English Channel is not yet available. An ongoing Dutch EMFF funded project is evaluating this stock structure in European waters and results are expected in 2024. This will potentially give more insight into the distribution of the stock and define the appropriate stock unit. Furthermore, an analysis on the survey data using INLA (see blonde ray chapter) could help address whether mixing between division 4a, 4b and 4c occurs.

It is recommended that the survey indices related to biomass (individuals ≥30 cm) are used in subsequent assessments, rather than exploitable biomass (individuals ≥50 cm) as was done in previous assessments. Spotted ray is a smaller bodied ray species and though the highest numbers at length caught are individuals ≥50 cm in surveys using 'GOV' gear type (FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3), in other surveys (BTS surveys) the catchability of individuals <50 cm is higher. Furthermore, a large fraction (2019-2021 average: 0.59) of the removals consist of dead discards.

3.6 Reviewers´ report

A wide range of SPiCT scenarios were initially explored with respect to input time series of catches and survey indices. The final model included catches from 1999-2021, with a two times higher catch uncertainty admitted for the reconstructed catches 1999-2010 than for recent catches 2011-2021. For spotted ray the average (dead) discard rate was highest among the three species and was estimated at 66.9% over the period 2009-2021. The following two survey indices were fitted, which extended back to 1989:

- Index1 : FR-CGFS-Q4 and NS-IBTS-Q1 combined (1989-2021)
- Index2: NS-IBTS-Q3 and all BTS-Q3 surveys combined (1989–2021, excl. 1991)

For spotted ray the length threshold for the biomass indices was changed from the previously used value of >= 50 cm to >=30 cm because a significant part of the catches (including discards) are between 30 and 50 cm for this species.

The two survey indices had similar estimates of uncertainty, and both indices showed consistent trends, indicating no evident conflicts. However, the Q3 index had an extreme high value in 1991 due to an exceptional catch in the BTS survey that year. Based on improved diagnostics of a comparative run with this data point removed it was agreed to remove this outlier from the final model.

The abundance maps from the survey data indicated two hotspots, one in the North and one in the South similar to the other ray species. However, unlike the other ray species, spotted ray appears clearly more abundant in the North, particularly in the later years. The commercial catches by subarea was in line with this, the majority stems from the Northern part. It should be noted that there is currently no genetic or tagging information available to confirm that the two hotspots are part of the same population to support the assumption of a single stock for this benchmark.

It was noted that fitting of the separate, yet consistent indices, as recommended by WKBM-SYSPICT2, is likely to improve the model's ability to more effectively separate observation error from process error and thus estimate both quantities more reliably. The MASE scores from the hindcast cross-validation were improved considerably when using two separate indices compared to a single combined index.

The assessment results appeared very robust to various model settings. Thus, a prior on the initial depletion level was not needed for this stock. Although the model results showed that the stock was in an overexploited state with a biomass below 0.5BMSY in 1997, the initial stock status depletion estimate was less severe than for the two other species. It was noted that this could be attributed to spotted ray being likely less vulnerable to fishing, because it is selected later due its smaller body size and because it is the least targeted species associated with high proportions of discards and fairly high discard survival rate estimates depending on the fishing operation (46.7%-71.6%). Priors were used for *r*, observation variances, and *logsdb*, while the shape parameter was fixed to n = 2 (Schaefer model). The evaluation of prior and posterior plots indicated that the model effectively updated posterior distributions relative to the priors.

The estimate for *r* was higher relative to the prior mean, but it was generally considered within the plausible biological range for this stock. The final model passed all OSA residual tests. Only the biomass process error normality test failed, but the p-value was close to 5% so this was not considered a serious problem and the model could thus be accepted.

3.7 References

Amelot, M., Batsleer, J., Foucher, E., Girardin, R., Marchal, P., Poos, J.J., and Sys, K. (2021). Evidence of difference in landings and discards patterns in the English Channel and North Sea Rajidae complex fishery. Fisheries Research, 242. https://doi.org/10.1016/j.fishres.2021.106028

Bird, C., *et al*. (2020). "Fifty years of tagging skates (Rajidae): using mark-recapture data to evaluate stock units." Journal of the Marine Biological Association of the United Kingdom 100(1): 121-131.

Ellis, J. R., Cruz-Martinez, A., Rackham, B. D. and Rogers, S. I. 2005. The distribution of chondrichthyan fishes around the British Isles and implications for conservation. Journal of Northwest Atlantic Fishery Science, 35, 195–213.

Ellis, J., Ungaro, N., Serena, F., Dulvy, N., Tinti, F., Bertozzi, M., Pasolini, P., Mancusi, C., and Noarbar-tolo di Sciara, G. 2007. Raja montagui. The IUCN Red List of Threatened Species 2007:e.T63146A12623141. https://dx.doi.org/10.2305/IUCN.UK.2007.RLTS.T63146A12623141.en.

Ellis, J.R., Silva, J.F., McCully Phillips, S.R., Bleeker, K. and Batsleer, J. (2023). An overview of the life-history parameters for North Sea stocks of thornback ray Raja clavata (rjc.27.3a4d7), spotted ray R. montagui (rjm.27.3a47d) and blonde ray R. brachyura (rjh.27.4bc7d). WKBELASMO 2023 Working Document.

Fahy, E. (1989). Growth parameters of rays (Batoidei) in Irish waters, from material examined in commercial catches. ICES CM 1989/G:59; 12 pp.

Fahy, E. (1991). The south-eastern ray Raja spp. fishery, with observations on the growth of rays in Irish waters and their commercial grading. Irish Fisheries Investigations, Series B (Marine), 37: 18 pp.

Froese, R. and Pauly, D. (Editors) (2022). FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2022).

Gallagher, M.J., Nolan, C.P. and Jeal, F. (2005). Age, growth and maturity of the commercial ray species from the Irish Sea. Journal of Northwest Atlantic Fishery Science, 35: 47–66.

Holden, M.J., Rout, D.W. and Humphreys, C.N. (1971). The rate of egg laying by three species of ray. Journal du Conseil internationale pour l'Exploration de la Mer, 33: 335–339.

Holden, M.J. (1972). The growth rates of Raja brachyura, R. clavata and R. montagui as determined from tagging data. ICES Journal of Marine Science, 34: 161–168.

McCully, S. R., Scott, F. and Ellis, J. R. (2012). Length at maturity and conversion factors for skates (Rajidae) around the British Isles, with a critique of earlier studies. ICES Journal of Marine Science, 69: 1812–1822.

Pedersen, M.W., and Berg, C.W. 2017. A stochastic surplus production model in continuous time. Fish

Fish. 18(2): 226–243. doi:10.1111/faf.12174.

Ryland, J.S. and Ajayi, T.O. (1984). Growth and population dynamics of three Raja species (Batoidei) in Carmarthen Bay, British Isles. Journal du Conseil internationale pour l'Exploration de la Mer, 41: 111–120.

Silva, J. F., Ellis, J. R. and Ayers, R. (2013). Length-weight relationships of marine fish collected from around the British Isles. Science Series Technical Report, CEFAS, 150: 109 pp.

Then, A.Y., Hoenig, J.M., Hall, N.G., Hewitt, D.A., and Handling editor: Ernesto Jardim. (2015).

Evaluating the predictive performance of empirical estimators of natural mortality rate using

information on over 200 fish species. ICES J. Mar. Sci. 72(1): 82–92.

doi:10.1093/icesjms/fsu136.

Thorson, J. T. (2019). Predicting recruitment density dependence and intrinsic growth rate for all fishes worldwide using a data-integrated life-history model. Fish and Fisheries.

Walker, P.A. 1999. Fleeting images: dynamics of North Sea ray populations. PhD dissertation, Faculteit Biologie, Universiteit van Amsterdam.

Winker, H., 2018. Investigation into the process error in biomass dynamics of fishes. MARAM/IWS/2018/Linefish/P3

4 Blonde ray (*Raja brachyura*) in divisions 4.bc and 7.d (North Sea and eastern English Channel) (rjh.27.4bc7d)

4.1 Introduction

Blonde ray (*Raja brachyura*) occurs within the Northeast Atlantic and western Mediterranean Sea. In the Northeast Atlantic the species has a patchy distribution and is most commonly found in inshore and shelf waters. Its distribution ranges from the English and Bristol Channel as well as Irish Sea, where it is most abundant, to the North Sea and Celtic Sea where numbers are lower. Blonde ray occurs on soft substrates to depths of about 150 m (Ellis *et al*, 2005). It is a relatively large-bodied skate which reaches a maximum size of 120cm (Stehmann and Burkel, 1984). While species-specific data collection have improved over time, blonde ray is often confounded with spotted ray (*Raja montagui*), which probably affects the reporting of these two species. Furthermore, information on the reproductive biology, migration patterns and stock structure are limited.

ICES considers five stock units of the species, of which two are defined in the North Sea. One stock unit comprises the population in the southern North Sea and English Channel (rjc.27.4c7d) and is defined as and ICES category 3 stock. The second North Sea stock unit comprises of the northern North Sea and West of Scotland (rjc.274a6) and is classified as an ICES category 5 stock. Furthermore, individuals reported in the central North Sea (27.4.b) are assigned to the other ray and skate stock in the North Sea (raj.27.3a47d).

During the data evaluation workshop of WKBELASMO, it was recommended to extend the stock unit of blonde ray in the North Sea to division 4.b, as an analysis of survey data showed a clear spill-over from the north of division 4.c to the south of division 4.b in recent years (see chapter 4.2 stock identity). The recommendation was accepted by ACOM-LS and from 2023 onwards the stock unit includes division 4.b.

Blonde ray in the North Sea and eastern English Channel is currently assessed as a Category-3 stock using the ICES 2/5 rule, and its management follows the precautionary approach. The assessment has been based on a single exploitable biomass (individuals ≥50 cm) index from the FR-CGFS survey carried out in the autumn in division 7.d. During the benchmark workshop WKBELASMO, the relevance of the assessment of this stock using the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg 2017) was evaluated.

4.2 Stock Identity

For blonde ray in the North Sea ecoregion, the stock boundaries are not well known, and currently there are two stock units defined in this ecoregion (rjh.27.4a6 and rjh.27.4bc7d). Assessing the appropriateness of current stock units used in ICES advisory process is fundamental to conducting robust stock assessments and ensuring that management measures apply over appropriate geographic areas (Pawson & Jennings, 1996).

4.2.1 Genetics (preliminary analysis)

To assess the genetic population structure of blonde ray, 934 samples (fin clips) were collected from the North Sea and the Celtic Sea. Samples were genotyped using DArTseq Diversity Arrays Technology (DArT), resulting in 855 samples and 2,083 SNPs after quality control filtering for further analyses. A discriminant analysis of principle components (DAPC) was performed with both spatial information provided and without prior information. The DAPC allows to cluster samples with or without prior information based on the genetic variation observed in the SNPs. An admixture model was used to investigate what proportion of ancestral clusters has informed the genetic variance observed in the SNPs across samples without using prior knowledge on the spatial locations of the samples taken.

The DAPC with prior spatial information did not identify a clear difference in clustering between samples from the North Sea and Celtic Sea (Figure 4.2.1). Samples from divisions 4.b and 4.c appear to cluster together, however the number of samples from 4.b was low (n = 7). The best DAPC model without prior grouping appears to be the model with 3 clusters assigned. The differentiation of these 3 clusters is shown in Figure 4.2.2, however there is no apparent spatial clustering suggested by this model and samples from both locations appear in all three clusters.

The admixture model, using the 3 clusters, indicates some population structure between the Celtic Sea and the North Sea, with one of the clusters contributing a greater proportion to the samples taken from the Celtic Sea (Figure 4.2.3). Some minor population structure appears to be present both within the Celtic Sea and the North Sea.

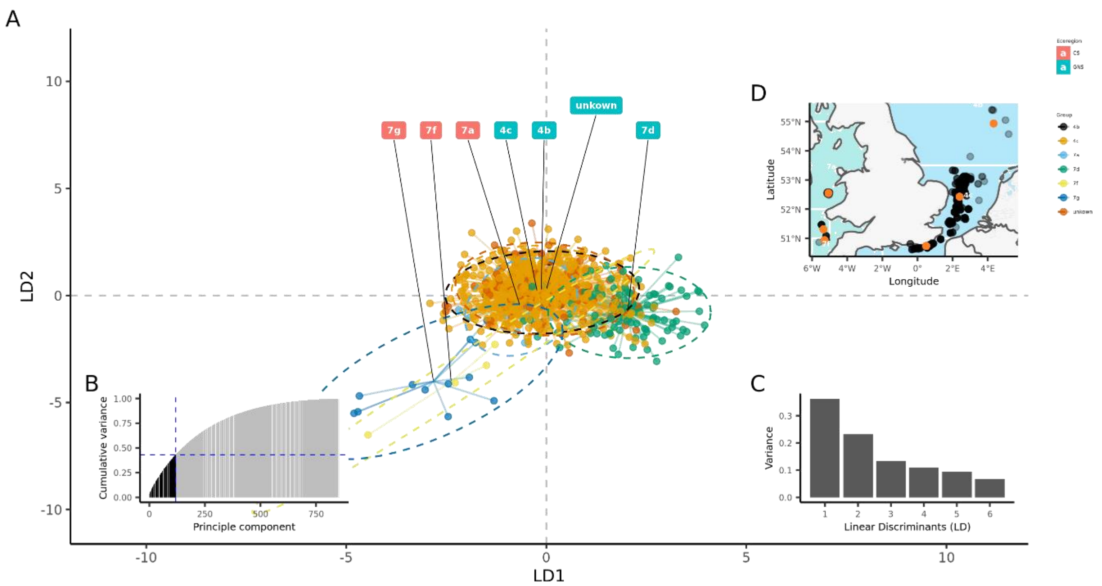

Figure 4.2.1 Discriminant analysis of principle components with grouping Prior based on Area27 sample locations (A). Cumulative variance of optimal number of 83 PCs retained for DAPC (B). Variance of linear discriminants retained in DAPC (C). Sample locations of individuals colour coded by cluster results of DAPC (D).

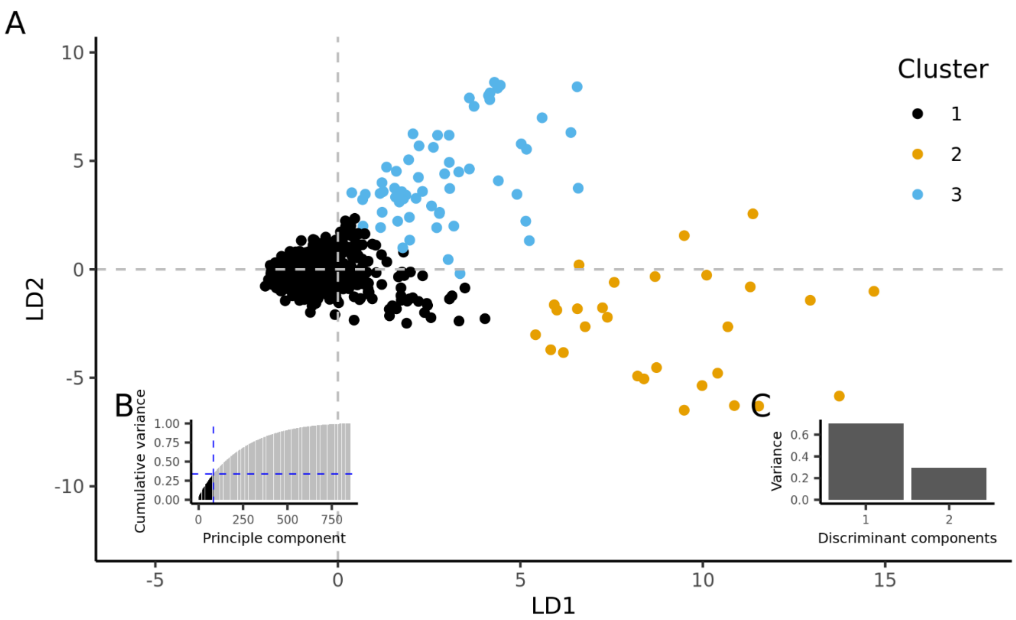

Figure 4.2.2 DAPC without prior for Raja brachyura with 3 clusters (A), cumulative variance of optimal 83 PCs (B), and Variance of Linear Discriminants in the DAPC (C).

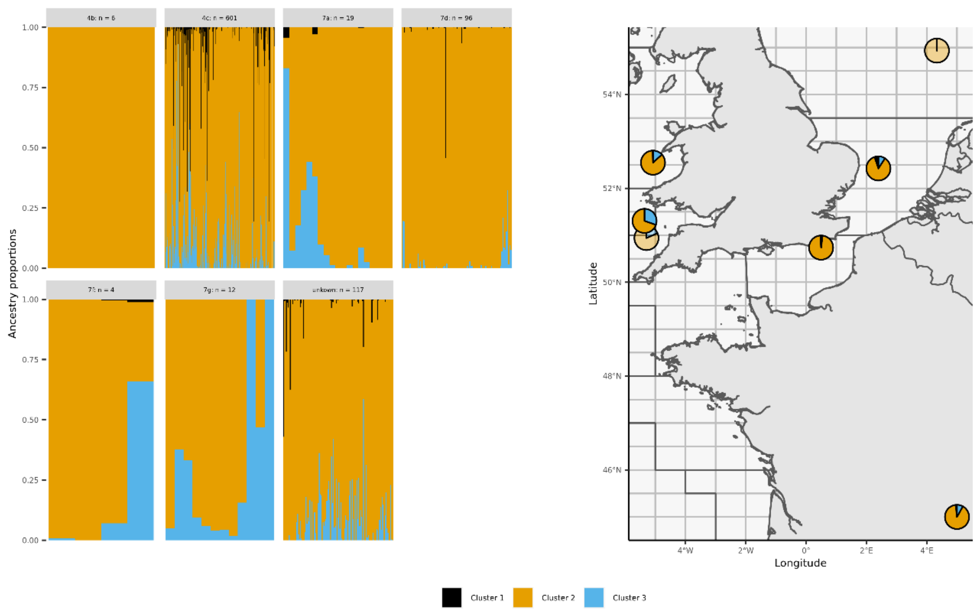

Figure 4.2.3 Ancestry proportions per sample (left) and average ancestry proportions by Area27(right) for K=3. Transparent pie charts indicate sub-populations with sample size < 10 samples. The pie chart in the South-East of France represents the combined 120 samples from the Greater North Sea ecoregions for which no clear spatial location could be determined.

4.2.2 Tagging

Bird *et al*. (2020) compiled and reviewed 50 years of tagging data, including release and return information, for several skate and ray species including blonde ray in the North Sea. In total, 1349 rays were tagged and released across nine ICES divisions. In the North Sea ecoregion 62 individuals were tagged in ICES division 4.c, 2 in ICES division 4.b and none in division 7.d. Of those tagged in ICES division 4.c. three individuals were recaptured in division 4.b indicating movement between the southern and central North Sea (Figure 4.2.4 and Table 4.1). No movement between the southern North Sea and English Channel and northern North Sea is observed. The movement of blonde rays between the southern and central North Sea is also observed in a recent tagging study by Wageningen University and Research (Figure 4.2.5) (Greenway *et al*. unpublished). This study is ongoing and several individuals have been tagged in the English Channel, with one recapture in the western Channel. The outcomes of tagging studies suggest the current stock unit extends further North and led to the recommendation to include division 4.b in the stock unit. Yet, further research is needed to evaluate the movements of individuals from the Channel and northern North Sea into the central and southern North Sea.

The most convincing evidence to merge the central North Sea into the stock unit is provided by analyses of surveys data using INLA (see survey working document 5) (Stäudle *et al*., unpublished). The analysis shows a clear spill-over from the north of 4.c to the south of 4.b in recent years (Figure 4.2.6). If this continues, then not accounting for catches in 4.b in the future could lead to more uncertain assessments.

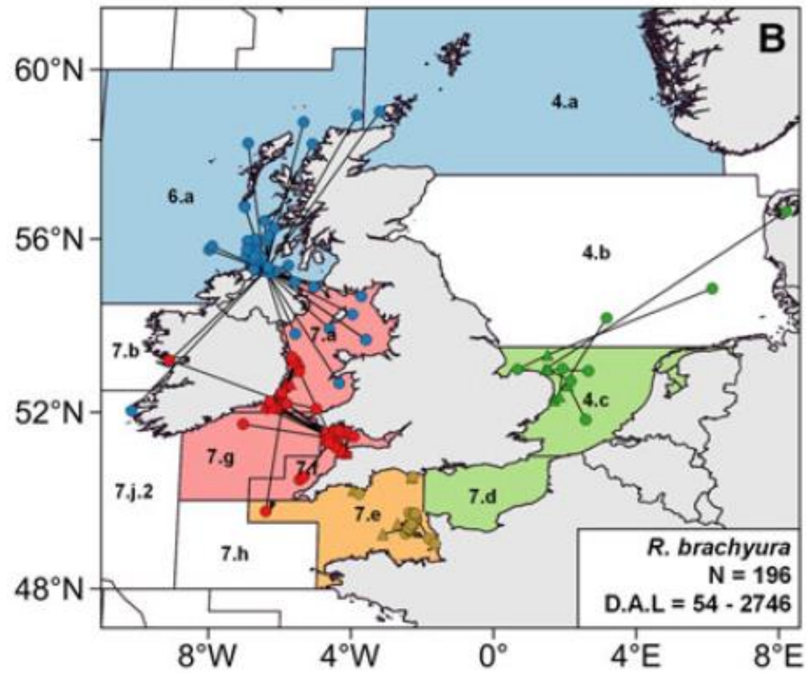

Figure 4.2.4: Tag releases, returns and straight-line distances for blonde ray (Raja brachyura). The colors depict the stock units, with the green stock unit being blonde ray in subarea 4, and divisions 3.a and 7.d. Retrieved from Bird *et al*. 2020.

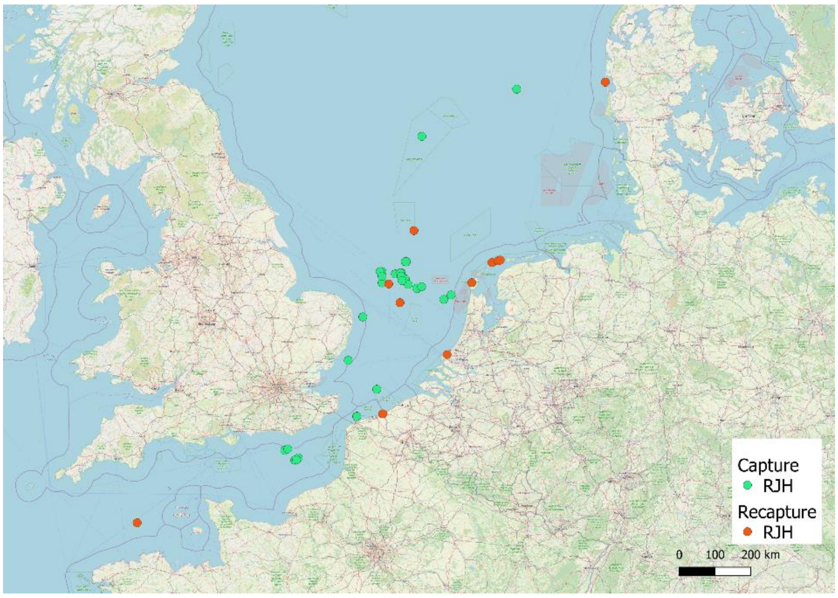

Figure 4.2.5: Release and recapture locations of blonde ray (Raja brachyura) in the North Sea ecoregion (Greenway *et al*. unpublished).

- Table 4.1: Exchange of blonde ray (Raja brachyura) (≥50 D.A.L.; N = 2191) between ICES divisions, showing the original release division, the total number released (NRel), the number recaptured (NRec), and the proportion of these recaptured in each ICES division. Obtained from Bird *et al*. 2020.

Release Division	NRel	NRec	Recapture Division											
			6.a	4.a	4.b	4.c	7.d	7.a	7.f	7.g	7.e	7.h	7.b	7.j
6.a	609	110	0.873	0.009	–	–	–	0.1	–	–	–	–	0.009	0.009
4.a	0	–	–	–	–	–	–	–	–	–	–	–	–	–
4.b	2	0	–	–	–	–	–	–	–	–	–	–	–	–
4.c	62	7	–	–	0.286	0.714	–	–	–	–	–	–	–	–
7.d	24	0	–	–	–	–	–	–	–	–	–	–	–	–
7.a	91	19	–	–	–	–	–	0.895	–	–	0.053	–	0.053	–
7.f	284	34	–	–	–	–	–	0.294	0.676	0.029	–	–	–	–
7.g	25	1	–	–	–	–	–	1	–	–	–	–	–	–
7.e	250	25	–	–	–	–	–	–	–	–	1	–	–	–
7.h	1	0	–	–	–	–	–	–	–	–	–	–	–	

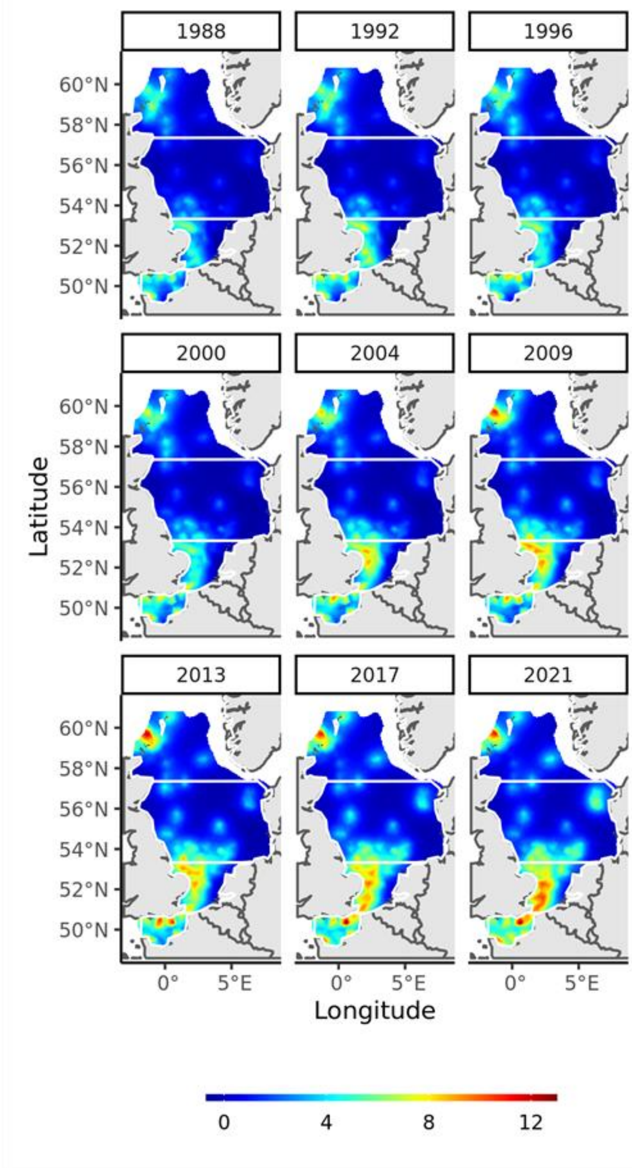

Figure 4.2.6: Spatial distribution of blonde ray (Raja brachyura) in the North Sea ecoregion using an Integrated Nested Laplace Approximation (INLA) (Städle *et al*. Unpublished). Also see working document 5 (the use of INLA for RJC).

Given the evidence provided above, the group proposed to include Division 4.b in the stock unit definition (see Annex 4). This was agreed by BOG/ACOM before the benchmark meeting, and the rest of the section refers to rjh.27.4bc7d.

4.3 Input data for stock assessment

Data series of dead catch and exploitable biomass (individuals ≥50 cm) indices from scientific surveys FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 were used as inputs for the SPiCT runs. Furthermore, specific life-history parameters were used to produce the population model, which are further discussed in section 4.3.3.

4.3.1 Catch data

Prior to the benchmark, a data call was issued requesting time series of landings and discard data of the relevant stocks. Data for the period 2009-2021 were received. Earlier data are missing as it is likely that before 2008, misidentification has occurred, especially for spotted ray (*R. montagui*) and blonde ray (*R. brachyura*). Misidentification probably affects the landings data of most nations reporting these two species. Before 2008, commercial ray landings in the EU were mainly recorded on a family level, making species-specific landings data before 2009 highly uncertain. Since 2009, all EU countries are obliged to register species-specific landings for the main skate species, resulting in improved species-specific landings to WGEF since 2009. In this context landings and discard data before 2009 submitted to ICES WGEF are uncertain or incomplete and will not directly be used in the assessments.

Surplus production models such as SPiCT and JABBA require a time series of catches as input data. Preferably the time series of catches is long enough to cover one generation time (~10 years) and includes contrasted periods in terms of stock biomass and fishing mortality. Such contrasts provide valuable information to the model, improving the quality of the estimation of various model parameters. As submitted data cover the period 2009-2021, the time series of catches was extended by reconstructing the landings and discards for the period 1999-2008 (see working document 8 on catch reconstruction). In addition, catches, as input data for the assessment models, should preferably consists of dead catch. Dead catch are the landings plus the part of the discards which do not survive the catching process (i.e. dead discards). Dead discards were calculated applying the outcomes of the discard survival work (see working document 7 on discard survival) to the submitted as well as reconstructed discards.

4.3.1.1 Landings

Landings have been submitted by seven countries. In the early years of the time series (2009-2011) landings have fluctuated around 150t, increasing gradually to above 250t since 2018 (Table 4.3.1). In division 7.d, landings have been increasing rapidly since 2016, whereas those from division 4.c have been fluctuating over time. Landings of this stock have been well above the ICES advice (Figure 4.3.1). Blonde ray is mainly caught in areas where it is locally abundant and taken as bycatch in mixed demersal fisheries using trawls (i.e. beam and bottom trawls). It is also caught in nets (gillnets) and longlines. In recent years an increase in landings is observed in the seine fisheries, which corroborates with the increase in effort in these fisheries.

Table 4.3.1 Blonde ray landings (tonnes) from 2009-2021 per ICES division.

Landings			
Year	27.4.b	27.4.c	27.7.d
2009	7.3	93.2	62.5
2010	11.9	57.2	56.9

	Landings		
2011	12.3	53.0	92.0
2012	23.6	109.7	83.5
2013	15.9	146.8	90.1
2014	27.3	91.0	87.8
2015	37.0	104.1	84.2
2016	33.6	64.9	84.5
2017	37.7	86.7	116.4
2018	1.9	111.3	141.7
2019	0.7	98.1	154.3
2020	2.1	66.6	174.4
2021	20.3	61.5	213.2

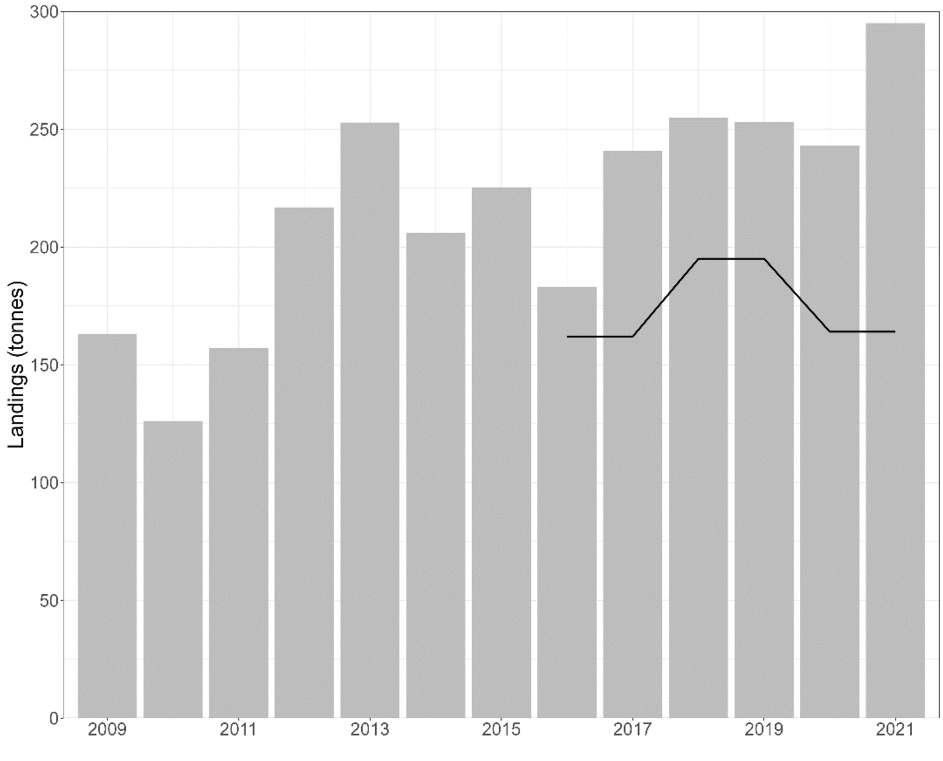

Figure 4.3.1 Blonde ray, annual landings (bars) and advice (line) in divisions 4.b, 4.c and 7.d.

To reconstruct landings in the period 1999-2008, landings of the species part of the group-TAC in the greater North Sea ecoregion (i.e. Rajidae, starry ray, cuckoo ray, thornback ray, spotted ray and blonde ray) were extracted from the Historical Nominal Catches 1950-2010 database. Using the species-specific data from 2009–2021 a species-specific landing ratio, being the proportion of landings of each stock within the total Rajidae landings, was calculated. The same species as for the 1999-2008 Rajidae composition was used.

Several options were explored to average the yearly ratios and applied to total landings of Rajidae from 1999 to 2008 in order to get an estimate of the landings for these years. Given the changes in the TACs over time three scenarios to average yearly ratios were explored,

1. Average over entire time series applied over 1999-2008
2. Average of 2009-2011 applied over 1999-2008
3. Average of 2009-2011 applied over 2005-2008, and average of 2018–2021 applied over 1999-2004.

whereby scenario 3 takes the similarity in TAC setting between the years 1999-2004 and 2018 and 2021, and 2005-2008 and the three following years (2009-2011) into account.

The landings ratio of blonde ray increased from 5.3% in 2009 to 9.0% in 2021 (Table 4.3.2). The increase in landings ratio over time could be explained by the shift in landings of spotted ray towards blonde ray (Figure 3.3.2).

Applying the average landings ratio of the full time series (7.4%) results in reconstructed landings ranging from 287t in 2002 to 221t in 2005. Reconstructed landings between 2005-2008 are relatively high compared to the landings in 2009-2011, which are similar in terms of TAC and total Rajidae landings. Using scenario 2, with a landings ratio of 5.3% brings the reconstructed landings in 2005-2008 more in line with the period 2009-2011. Conversely, reconstructed landings in the earliest period of the times series are probably too low.

Table 4.3.2 Blonde ray overview of the yearly landings ratio and reconstructed time series (orange) in the period 1999-2008.

Year	Agreed TAC	Rajidae landings	RJH proportion	Average time series	Average 2009-2011	Average combined
1999	6060	3087		229	165	242
2000	6060	3644		270	195	286
2001	4848	3862		286	207	303
2002	4848	3878		287	207	305
2003	4121	3864		286	207	303
2004	3503	3556		263	190	279
2005	3220	2988		221	160	160
2006	2737	2910		215	156	156
2007	2190	3118		231	167	167
2008	1643	2998		222	160	160
2009	3367	2917	0.056	163	163	163
2010	2864	2812	0.045	126	126	126
2011	2864	2633	0.060	157	157	157
2012	2862	2753	0.079	217	217	217
2013	2574	2931	0.086	253	253	253

Year	Agreed TAC	Rajidae landings	RJH proportion	Average time series	Average 2009-2011	Average combined
2014	2524	2790	0.074	206	206	206
2015	2650	2488	0.091	225	225	225
2016	2749	2616	0.070	183	183	183
2017	2911	2716	0.089	241	241	241
2018	3400	3429	0.074	255	255	255
2019	3528	3408	0.074	253	253	253
2020	3681	3215	0.076	243	243	243
2021	3500	3279	0.090	295	295	295

4.3.1.2 Discards

Discard data for blonde ray by country, year, métier, and fishing area (in tonnes) were extracted from InterCatch for the period 2009-2021. Discards are available since 2010 and are highly variable by year ranging from 19.5 t to 269.3 t. The time series of discards is incomplete and many countries provided discard data for only a few years and gears. Only Belgium has submitted discard data for blonde ray in the beam trawls annually since 2013. In this context, discard data for this stock are highly uncertain. Furthermore, discard data in 2020 and 2021 are lower (<100t) compared to the three previous years.

As discard data are incomplete, i.e. missing countries or gears, a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) was used to fill those gaps for the period 2019 – 2021 (Figure 4.3.2). To do so, fishing effort data were extracted from the ICES Working Group of Mixed Fisheries (WGMixFish) for the period 2009-2021. Data consisted on effort by kw.days by year, country, metier, and size class of the vessels. For the reconstruction effort data were aggregated to metier level 4 similar to the metier level at which discard data have been submitted.

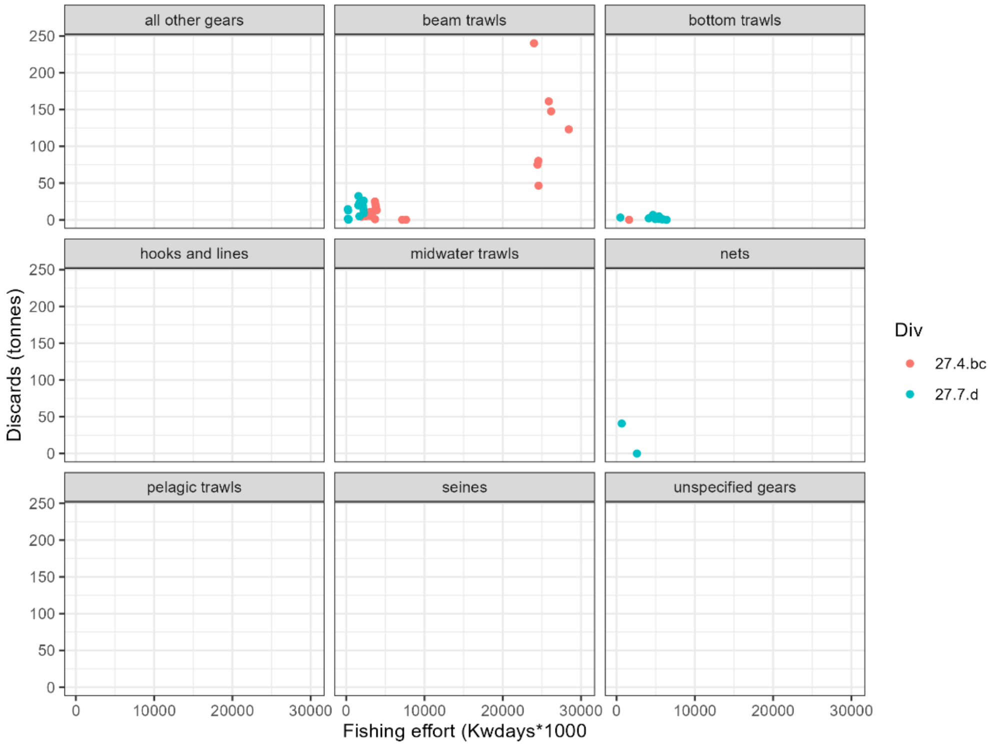

Figure 4.3.2 Blonde ray, correlation between fishing effort by métier, area and discarding.

For blonde ray all discard data are available at ICES division level, being divisions 27.4.b-c and 7.d. Therefore, discard and fishing effort data by division were used. Discard data were not available for some combinations of year, métier and fishing area. Consequently, the hooks and lines, seines, midwater and pelagic trawls, unspecified and all other bottom trawl gears segments were excluded from the regression analysis. As such, we assume these métiers do not contribute to the discards, resulting in an underestimation of the discarded part of the catch. Only the discard values of missing combinations were inferred using a multiple regression based on the relation between the amount of discards and fishing effort by métier (level 4) using the model (Amelot *et al.* 2021):

Discards (in tonnes) ~ kWdays: Fishing Fleet: Fishing Area.

The results of the regression showed that the model was a significant predictor of discards ($F(5,45) = 31.56$, $P < .001$). Coefficients of beam trawls in divisions 4.bc (4.754×10^{-06}, $P < .001$) and division 7.d (9.690×10^{-06}, $P < .05$) was shown to have contributed significantly to the model.

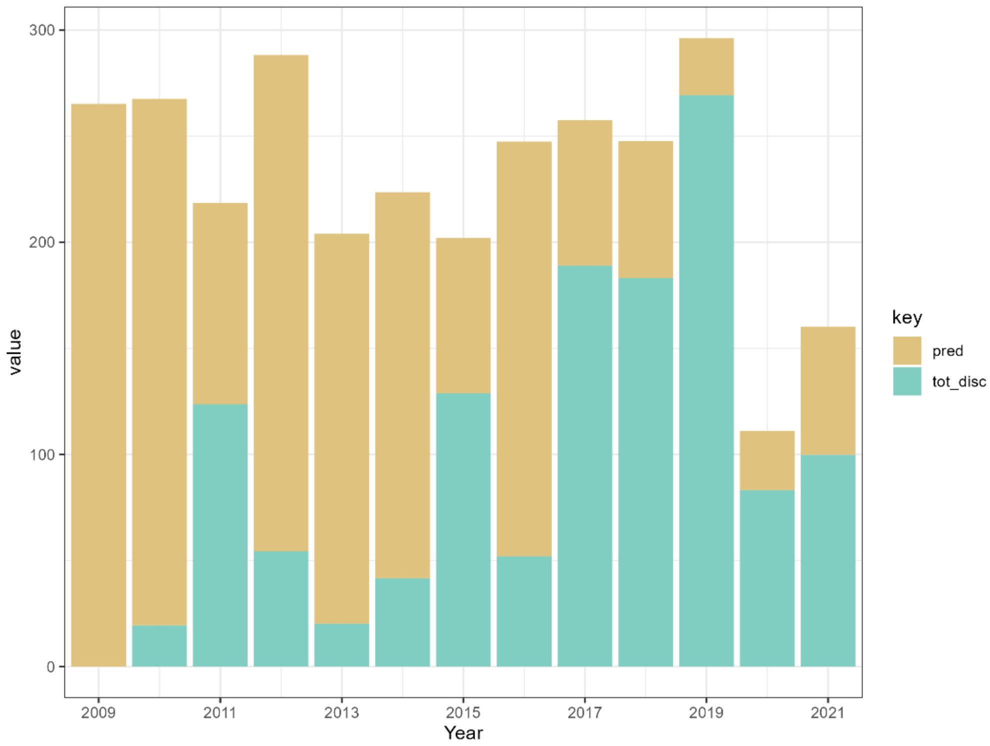

Figure 4.3.3 Blonde ray, the total reconstructed discards (tonnes) of the stock showing the submitted values (green) and reconstructed part (brown). These values do not account for discard survival.

The reconstructed discards (Figure 4.3.3) do not account for discard survival. To do so, discard survival studies for thornback ray by FromNord, Wageningen Marine Research and the Sumaris project have been merged to obtain a single survival value per métier (Villagra *et al*, 2023 (WD on discard survival)). These values do not take possible difference in the survivability of length classes into account. Quota have been and are still constraining the landings of the species for most fleets. Consequently, all size classes are observed in the discards, justifying the use of a single survival estimate per métier.

For blonde ray survival is highest in bottom trawl fisheries (85.3%) and lowest in the beam trawl fishery (63%). These survival estimates are applied to the total discards by métier and summed to get an estimate of the dead discards in the period 2009-2021.

The group discussed the low discard data in 2020 and 2021 and decided to evaluate the option of replacing the discard data in 2020 and 2021 using the predicted values from the regression analysis. However, the predicted values still resulted in lower discard estimates in both years. Therefore, an alternative was explored which applies an average dead discard ratio on the known landings in 2020 and 2021. Two ratios were calculated, one for the period 2009-2019 (0.31) and one for the period 2011-2019 (0.29) to account for the high uncertainty in the discard estimates in 2009 and 2010. Given, the minor difference between the two ratios the group decided to use the average dead discard ratio over the full time-series. Using this ratio ensures that the dead discard values in both years are more in line with previous years (Figure 4.3.4). Final outcomes of the discard reconstruction are presented in table 4.3.3.

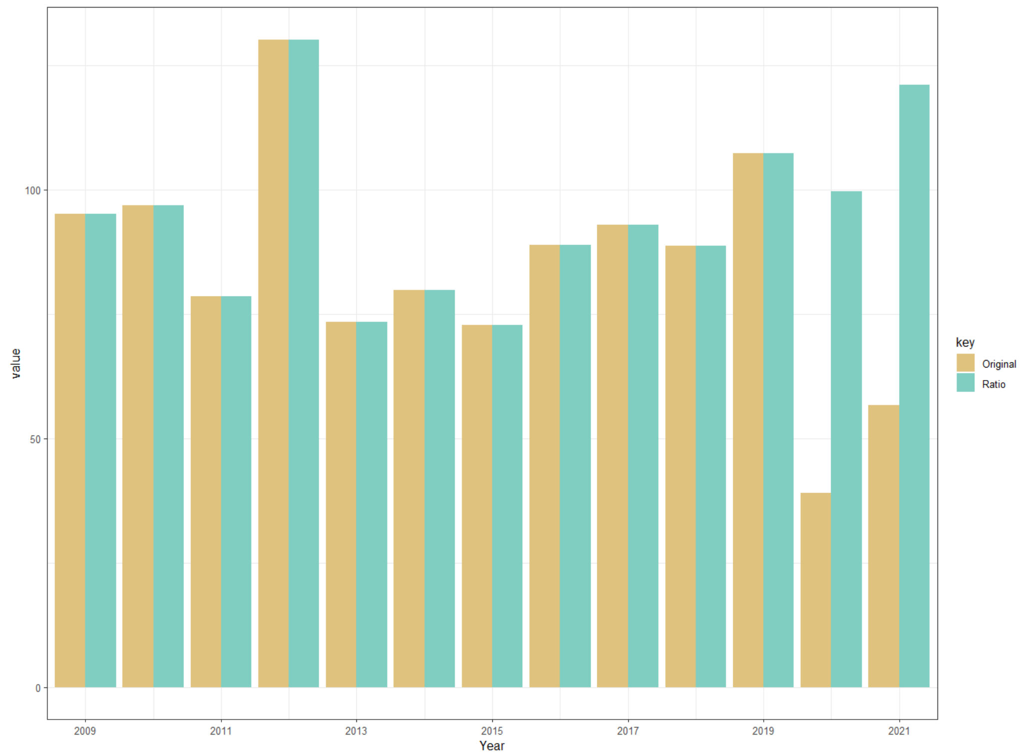

Figure 4.3.4: Spotted ray, comparison of dead discards calculated from original data versus the values obtained using the average dead discard ratio in the period 2009-2019. Only the 2020 and 2021 value have been altered (all value in tonnes).

Table 4.3.3: Blonde ray (rjh.27.4bc7d), overview of discard data submitted to InterCatch (Submitted), after reconstruction using the multiple regression (Reconstructed), and correction using discard survival estimates (Dead) (all values in tonnes).

Year	Submitted	Reconstructed	Dead
2009	0.0	265.2	95.1
2010	19.5	267.6	96.9
2011	123.6	218.5	78.5
2012	54.4	288.2	130.1
2013	20.3	204.0	73.4
2014	41.6	223.5	79.8
2015	128.7	202.1	72.7
2016	52.0	247.4	88.8
2017	189.0	257.5	93.0
2018	183.1	247.6	88.6
2019	269.3	296.2	107.3
2020	83.2	111.0	39.0
2021	99.8	160.2	56.7

4.3.1.3 Removals

To reconstruct the removals (i.e. dead catch) of blonde ray in the period 1999 – 2008, the ratio between landings and dead discards for the 2009-2021 time period was calculated. Dead discards include the total discards resulting from the regression and corrected for discard survival. This ratio was then applied to the reconstructed landings in order to get an estimate of the dead discards for the period 1999-2008. Note that we assume that discards remained stable over this time period. Calculations were done for the three scenarios described in section 4.3.1.1. For blonde ray the average (dead) discard rate over the period 2009-2021 is 26.7%. This value is applied to the reconstructed landings in the period 1999-2008 using the equation:

Total reconstructed catch = reconstructed Landings/(1 – average discard ratio)

The outcomes of blonde ray (Figure 4.3.5) are similar to those described under thornback ray. The landings ratio of both stocks show an increase over time making an average over the entire known time series unlikely to reflect historic landings of the stock. While scenario 1 and 3 would provide contrasting periods in catches, with high catches at the start of the time series, the values are questionable. The group agreed that a catches reconstruction using scenario 2 (i.e. 2009-2011 landings ratio) is more appropriate as there is a smoother transition over time compared to both other scenarios. Final catches used as input in the SPiCT assessment for blonde ray are shown in Table 4.3.4.

Figure 4.3.5: Blonde ray, dead catch in the period 1999-2021, with reconstructed dead catch for 1999-2008. Three scenarios using the average landings ratio of the full time series (left), the period 2009-2011(middle) and combination of 2009-2011 and 2018-2021 (right). Lighter coloration denotes the dead discards.

Table 4.3.4: Blonde ray, landings, dead discards and removals resulting from the reconstruction and used as input in the assessment model (all values in tonnes).

Year	Landings	Dead discards	Removals
1999	165	73	238
2000	195	87	282
2001	207	92	298
2002	207	92	300
2003	207	92	299
2004	190	85	275
2005	160	71	231
2006	156	69	225
2007	167	74	241
2008	160	71	232
2009	163	95	258
2010	126	97	223
2011	157	79	236
2012	217	130	347
2013	253	73	326
2014	206	80	286
2015	225	73	298
2016	183	89	272
2017	241	93	334
2018	255	89	343
2019	253	107	360
2020	243	100	343
2021	295	121	416

4.3.2 Survey biomass index

In the current assessment of blonde ray, the exploitable biomass (individuals ≥50 cm) index of only the FR-CGFS-Q4 survey is used. For this benchmark, a model-based approach was chosen to combine different surveys into a single index or in two indices by combining surveys based on seasonality (e.g. all surveys carried out in Q3 combined). Different combinations of surveys were explored using a gam model with either a Tweedie or delta lognormal distribution. AIC scores were used to compare the two distributions. In this section, we only describe the models that were chosen to be used in the exploratory SPiCT assessment runs. More detailed information can be found in Working document 9 on surveys and biomass indices.

Blonde ray is one of the larger ray species in the North Sea and it was chosen to keep an exploitable biomass of individuals. The FR-CGFS-Q4 survey covers division 7.d and has limited coverage in division 4.c. Different models runs were carried out including surveys that cover both division 4.b and 4.c, like the NS-IBTS surveys in both Q1 and Q3. A single exploitable biomass index with the FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined was chosen from the different model runs to use in the exploratory and final assessment runs using SPiCT. The delta lognormal distribution model was chosen, even though the AIC score was higher as compared to the Tweedie distribution. QQ-plots showed a better distribution of quantiles for the delta lognormal distribution. The relative exploitable biomass index is shown in Figure 4.3.6. The exploitable biomass is low in earlier years of the time series and shows an increasing trend since 2010. Furthermore, in some years prior to 1997, catches in the surveys have been very low to zero, resulting in estimates of zero for these years. Furthermore, the uncertainty in the exploitable biomass index is high, as shown by the (upper) confidence intervals.

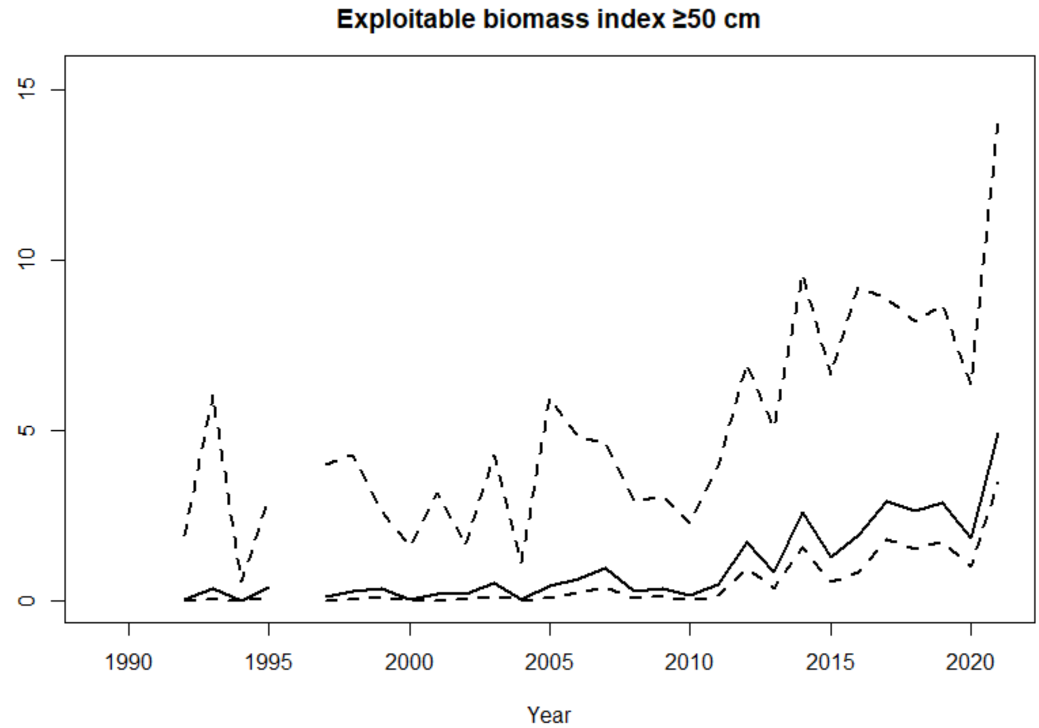

Figure 4.3.6 Blonde ray relative exploitable biomass (≥50 cm) index with 95% confidence intervals for FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined.

4.3.3 Life-history parameters

Key life-history parameters, namely the length-weight relationship, length-at-maturity, growth rates and annual fecundity of blonde ray have been collated in Ellis *et al*. 2023 (Working document 4). Below we summarize the selected parameters used as input in the assessment.

For the purposes of the 2023 benchmark assessment, it was agreed to use the length-weight relationship provided by Silva *et al*. 2013: $W = 0.0027 L^{3.258}$ ($r^2 = 0.9888$). This study included individuals from the British Isles and was based on a sample size of 352 individuals and length range of 13-108 cm.

Estimates of the length at which 50% of the population is mature ($L_{50\%}$) for blonde ray in the stock area are not available. There are published estimates for the British Isles as a whole (McCully *et al.*, 2012), though most samples would have been from the Celtic Seas ecoregions. Furthermore, there are published estimates from the Irish Sea (Gallagher *et al.*, 2005) and from Divisions 7.a, 7.f-g, 7.d and 7.e (Lemey *et al.*, 2022). It was agreed to use a length-at-maturity of 82.7 cm, based on data for female blonde ray from Gallagher *et al.*, (2005), McCully *et al.*, (2012) and Lemey *et al.*, 2022. The length at which 95% of the population is mature ($L_{95\%}$) was derived from McCully *et al.* (2012), using the largest size of immature female encountered (93.0 cm).

There are few studies that have examined the growth of blonde ray, but there have been studies from the North Sea and Celtic Seas ecoregions. The averaged VBGP provided for female blonde ray from three studies (Holden, 1972; Fahy, 1989 (mean value from four different study areas) and Gallagher *et al.*, 2005) were L_{inf} = 134.31 cm, K = 0.182 y^{-1} and $t_0 = -0.56$. The published values and the averaged values gave growth relationships (Figure 4.3.7) that were higher than the growth curve derived from the values for blonde ray given on FishBase (L_{inf} = 110.5 cm, K = 0.12 y^{-1} and $t_0 = -1.00$; Froese and Pauly, 2022).

There is limited data available to help estimate the fecundity of blonde ray. Holden *et al.* (1971) indicated annual fecundity may be about 90 eggs in the British Isles. Porcu *et al.* (2015) estimated ovarian fecundity on 37-44 in the Mediterranean. For the purpose of the benchmark, it is proposed to consider that the annual fecundity of blonde ray would generally be <100 per year.

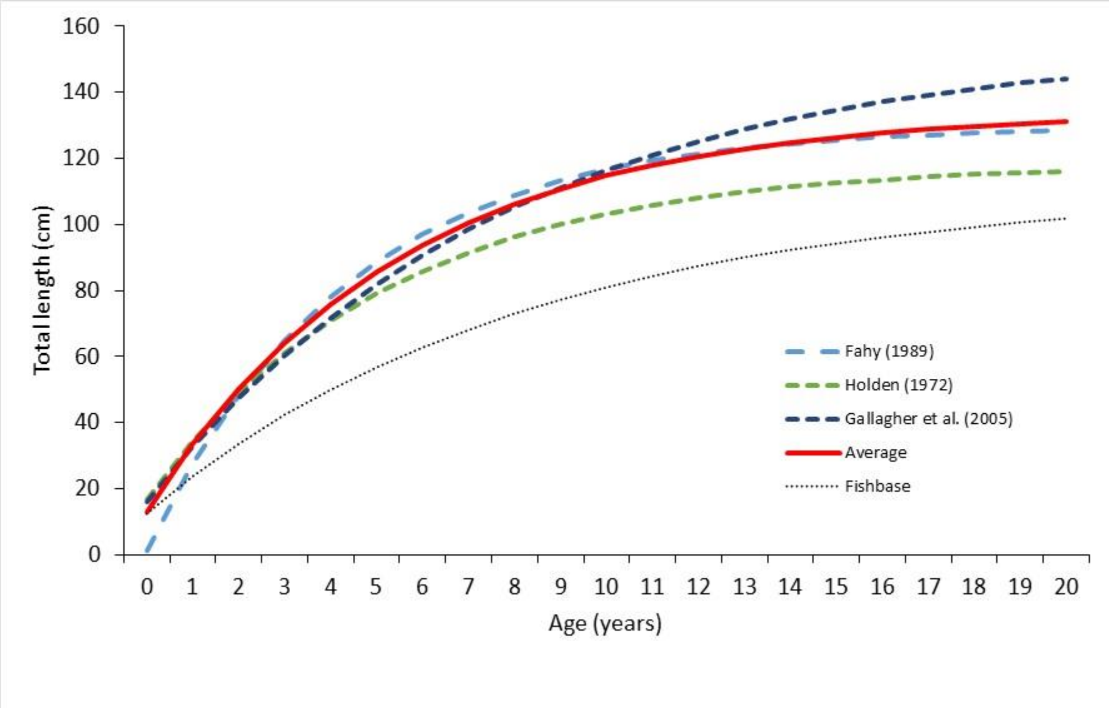

Figure 4.3.7 Estimated length-at-age for blonde ray (RJH) from published studies, including the growth for the averaged VBGP and that given by FishBase. Data extrapolated to age 20, given that Porcu *et al*. (2015) observed fish up to 16 years of age (See working document 4, Ellis *et al*., 2023).

4.4 Stock assessment

The benchmark focussed on evaluating the surplus production model SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg, 2017) on blonde ray in divisions 4.b, 4.c and 7.d.

4.4.1 Priors

A prior probability distribution has been defined for the intrinsic rate of biomass increase (*r*). To estimate *r,* the only considered source of mortality was natural mortality (*M*). Parameters *K* and L_{inf} were used to generate an estimate of M following Then *et al.* (2014) in their review of multiple procedures for estimating *M.* A single natural mortality value across all ages (*M* = 0.24) was calculated as follows:

$$M = 4.118 * K^{0.73} * L_{inf}^{-0.33}$$

A value for the maximum age (t_{max}) was extracted from the database of life history correlations available in the FishLife R package (Thorson, 2019). The maximum value from those available for blonde ray was chosen, with t_{max} = 17.

A Leslie matrix was built using the biological variables available for blonde ray (Table 4.4.1) to obtain a mean prior value for the intrinsic rate of increase (*r*). The *jbleslie* function in the R package JABBA was used to return a value of *r* = 0.3367429.

Table 4.4.1 Biological variables used in the call to JABBA::jbleslie() to obtain a mean prior for the intrinsic rate of biomass increase (r) using a Leslie matrix calculation of female net reproductive rate.

Min age	Max age	L_{inf}	*k*	t_0	LWR a	LWR b	*M*	Fec	$L_{50\%}$	$L_{95\%}$
0	17	134.31	0.182	-0.56	0.0027	3.258	0.2356474	90	82.7	93

4.4.2 Exploratory assessments

Various simulation scenarios were tested, differing in terms of the time series considered for removals, the introduction of informative priors on parameter *r*, *bkfrac*, and *sdb*. First input in the SPiCT reference run are the annual catches. It was decided to use the entire time series of removals (1999-2021). Observation errors on removals in years 1999-2010 were higher (x2) than those associated with years 2011-2021. This resulted in a CV of 0.2 for the removals in years prior to 2011 and a CV of 0.1 from 2011 onwards. The *logsdc* was fixed by setting the *log.sd* to the reference value for later years (0.1) assuming a low CV of 0.1.

For blonde ray, the exploitable biomass index of the FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined was used and the corresponding CV values were normalized using the long-term mean. Due to zero values in the index, it was decided to remove all years prior to 1997. A mean observation error (*sdi*) was included using the log mean of the CV of the entire time series resulting in a prior for *sdi* of -0.2338901 with a CV of 0.2.

The *r* prior was set with a CV of 0.3 and a log-normal bias correction was used. The initial *r* prior in the SPiCT model resulted in: -1.133436 with a CV of 0.3.

In the first base runs, the initial depletion ratio (*bkfrac*) was compared by not including any information on *bkfrac,* and using an initial depletion ratio of 0.1 with a CV of 0.5. For this ratio, also a log-normal bias correction was used, resulting in a *bkfrac* of -2.427585 with a CV of 0.5.

The shape parameter *n* was fixed to a Schaefer model (*n* = 2) and log-transformed, resulting in a prior for *n* of 0.6931472 with a CV of 0.001.

Simulations show that high process error can be expected for a relatively long-lived species (Winker, 2018). A process error (*sdb*) of 0.07 was used in the first base run. A log-normal bias correction was used resulting in a *sdb* of -2.78426 with a CV of 0.5.

The dteuler was set at ¼. Furthermore, no informative priors on the alpha and beta parameters were set.

A summary of the exploratory assessment scenarios and parameter settings is found in Table 4.4.2. First, two reference runs were compared for which reference 0 had no prior for *bkfrac* and reference 1 included a prior of 0.1 with CV=0.5 for *bkfrac.* All further exploratory runs were simulated with both reference runs, however during benchmark discussions it was decided to continue further exploratory runs without a prior for *bkfrac*. In this report, only outputs from these exploratory runs are given.

Table 4.4.2 SPiCT scenarios with input parameter settings. For all scenarios a Schaefer production curve was used.

Scenario	**Removals time series**	**Surveys time series**	***r* prior (with CV)**	**Initial depletion rate *bkfrac* (with CV)**	**Process error *sdb* (with CV)**
Reference 0	Catches 1999-2021	Expl. biomass index 1997-2021*	0.337^ (0.3)	-	0.07 (0.5)
Reference 1	Catches 1999-2021	Expl. biomass index 1997-2021*	0.337^ (0.3)	0.1 (0.5)	0.07 (0.5)
1 – landings	Landings 1999-2021	Expl. biomass index 1997-2021*	0.337^ (0.3)	-	0.07 (0.5)
2 – CV on *r* prior	Catches 1999-2021	Expl. biomass index 1997-2021*	0.337^, (0.4, 0.5, 0.6, 0.7)	-	0.07 (0.5)
3 – *r* prior vs. *sdb*	Catches 1999-2021	Expl. biomass index 1997-2021*	0.2, 0.337^, 0.4 (0.3)	-	0.05, 0.07, 0.1, 0.15 (0.5)
4 – No priors on *r*	Catches 1999-2021	Expl. biomass index 1997-2021*	-	-	0.07 (0.5)
5 – Catch time series	Catches 2009-2021	Expl. biomass index 1997-2021*	0.337^ (0.3)	-	0.07 (0.5)

*** Combined survey index of FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 using a delta-gam modelling approach.**

^ *r* prior is round for reading purposes. In the models the unrounded *r* prior of 0.3367429 was used (see section 4.4.1).

In the first exploratory run the scenarios reference 0 and reference 1 were compared to explore the potential effect of providing the model with an initial depletion prior. Figure 4.4.1 shows a comparison plot of the two scenarios. Including the *bkfrac* prior resulted in minor changes in both absolute biomass and fishing mortality. Furthermore, the retrospective analysis remains within acceptable bounds (Mohn's rho B/B_{MSY} = 0.137 and F/F_{MSY} = -0.05). The hindcast performed better using a prior on *bkfrac*. Even though reference 1 (Figure 4.4.2, lower panel) deemed better as compared to reference 0 (Figure 4.4.2, upper panel), during discussions in the benchmark it was decided to not set an initial depletion prior and continue exploratory assessment runs with reference 0.

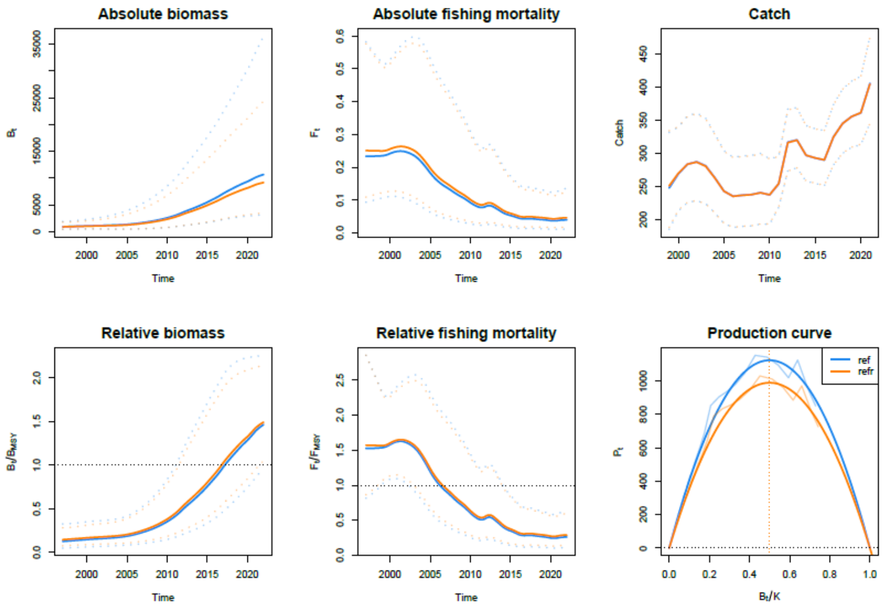

Figure 4.4.1 Comparison plot of the two reference runs. Reference 0 without a prior on bkfrac and reference 1 including a prior on bkfrac.

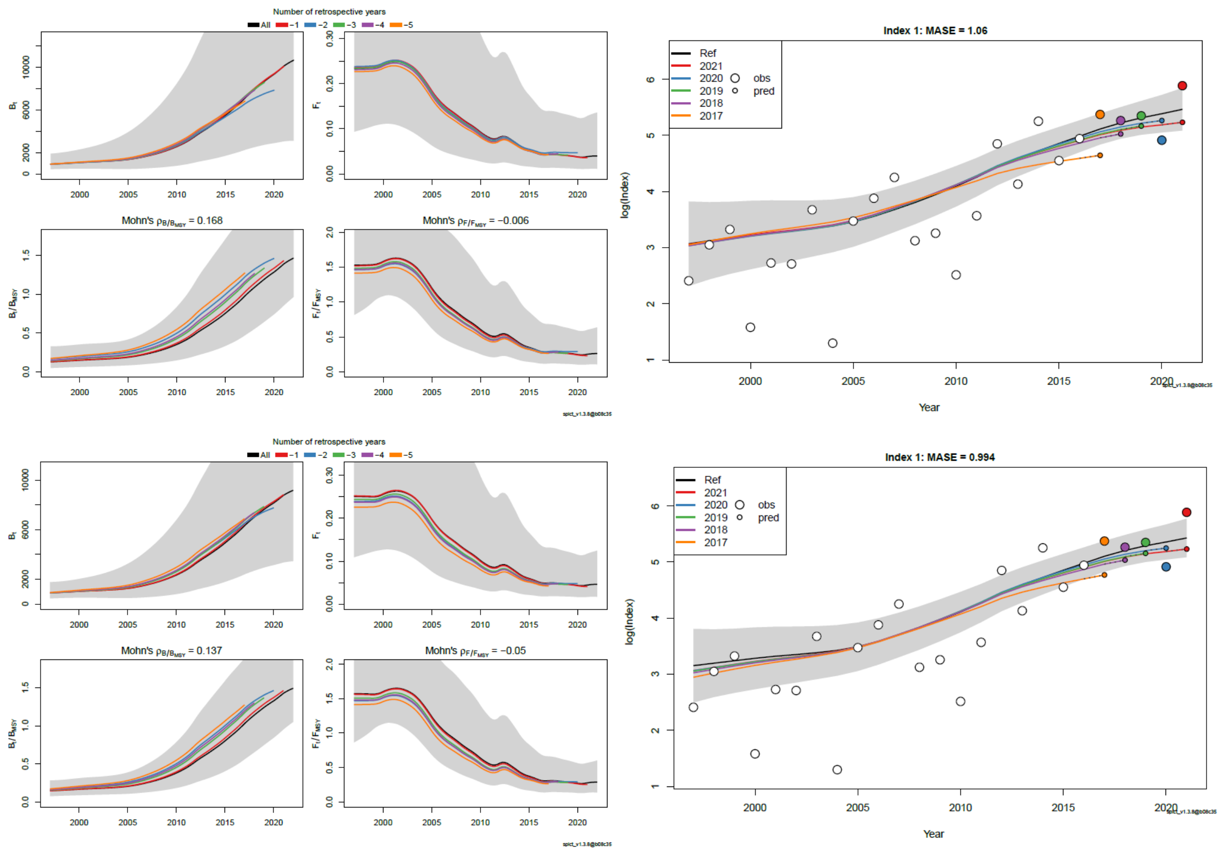

Figure 4.4.2 Retrospective analysis and hindcast with 5 years for reference 0 (upper panel) and reference 1 (lower panel).

Scenarios 1 and 5 included an update of the removals, for which only landings from 1999-2021 were included in scenario 1 and a shorter time series of catches (2009-2021) was used in scenario 5. All other input parameters remained the same as for reference 0. Retrospective analysis and hindcast cross-validations resulted in similar outcomes as for reference 0. It was decided to continue with catches from 1999-2021 as this includes more information on the stock harvest rates and a catch advice rather than a landings advice can be given.

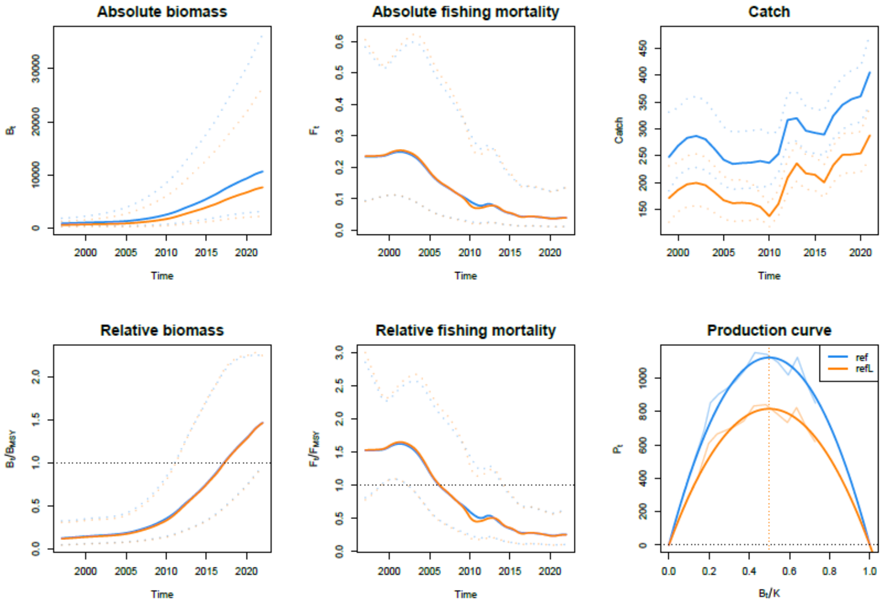

Figure 4.4.3 Comparison plot of reference 0 using catches 1999-2021 versus scenario 1 using landings 1999-2021.

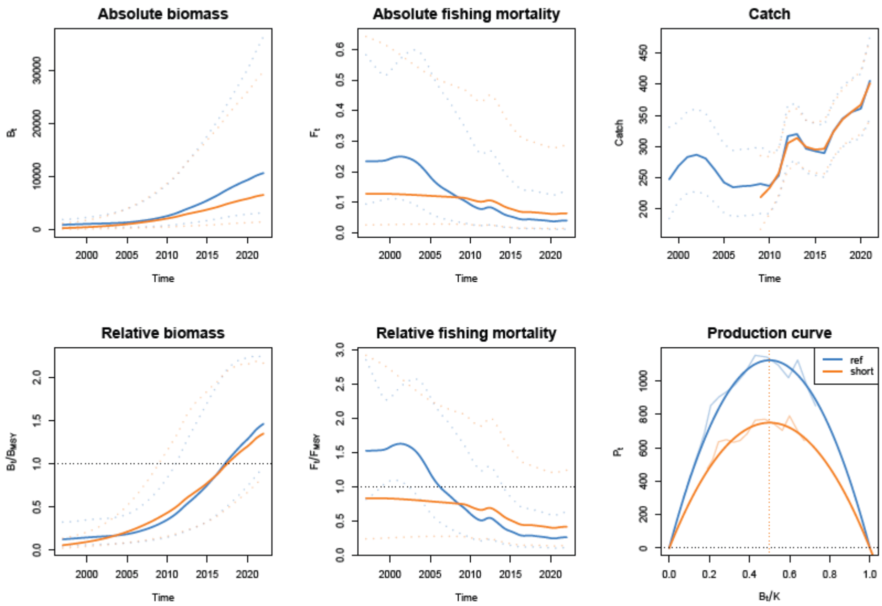

Figure 4.4.4 Comparison plot of reference 0 using catches 1999-2021 versus scenario 5 using a shorter catch time-series of 2009-2021.

In scenario 2, we tested the effect of the CV on the *r* prior by comparing a reference CV of 0.3 with higher CV values of 0.4, 0.5, 0.6 and 0.7 (Figure 4.4.5). The higher CV levels did not pass validation criteria for a SPiCT assessment as the retrospective analyses were outside the acceptable bounds for long-lived species. Similarly, the hindcast deteriorated as well with higher CVs on the *r* prior.

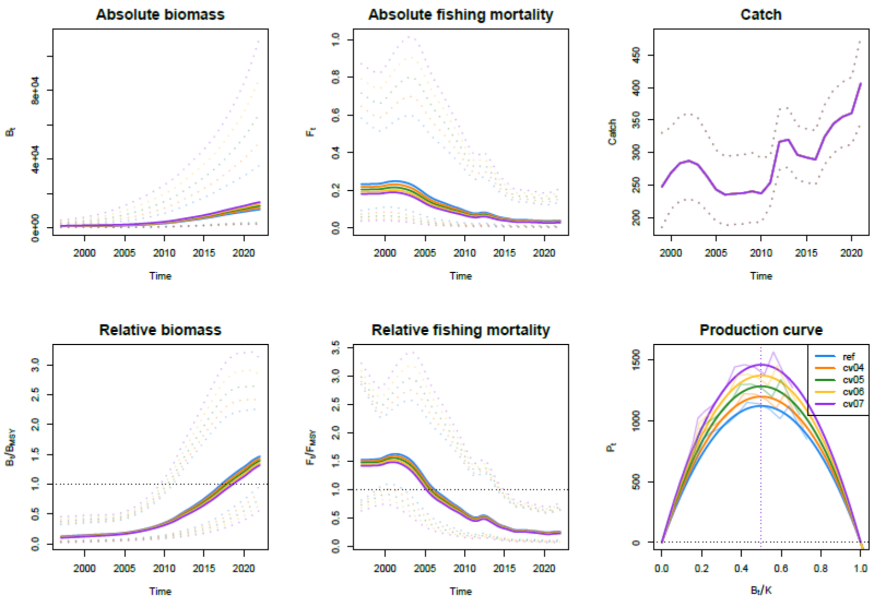

Figure 4.4.5 Comparison plot of reference 0 with a CV on the r prior of 0.3, versus scenario 2 in with ranging r prior CVs of 0.4, 0.5, 0.6 and 0.7.

In scenario 3, different simulations were tested with updating the *r prior* and simultaneously test the effect of the process error *sdb.* In total 12 combinations were tested using 3 different *r* priors and 4 different *sdb* priors. The CVs on both priors were kept the same. Comparison plots of the different prior settings in scenario 3 can be found in Figures 4.4.6 and 4.4.7. Lowering the *r* prior to 0.2 increased the production curve of the stock to >2 times larger and resulted in a biomass below B_{MSY} in the entire time series (Figure 4.4.6). Simulating the prior on the process error did not seem to have a direct effect on biomass, fishing pressure or the production curve (Figure 4.4.7). Retrospective analyses and hindcasts cross-validations did not seem to improve the model and it was decided to keep both the *r* prior and *sdb* prior as in the reference 0 scenario.

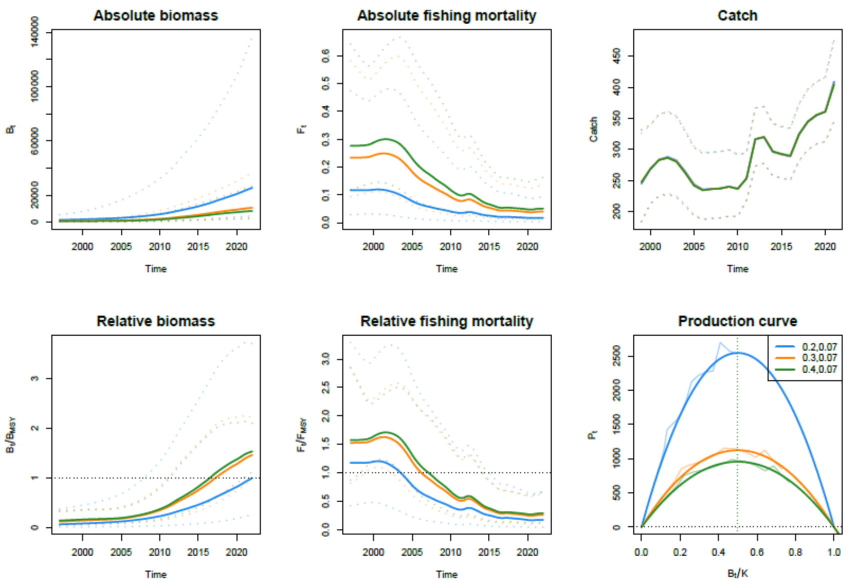

Figure 4.4.6 Comparison plot of reference 0 with r prior of 0.337 and process error sdb prior of 0.07, versus scenario 3 with a lower and higher r prior (0.2, 0.4).

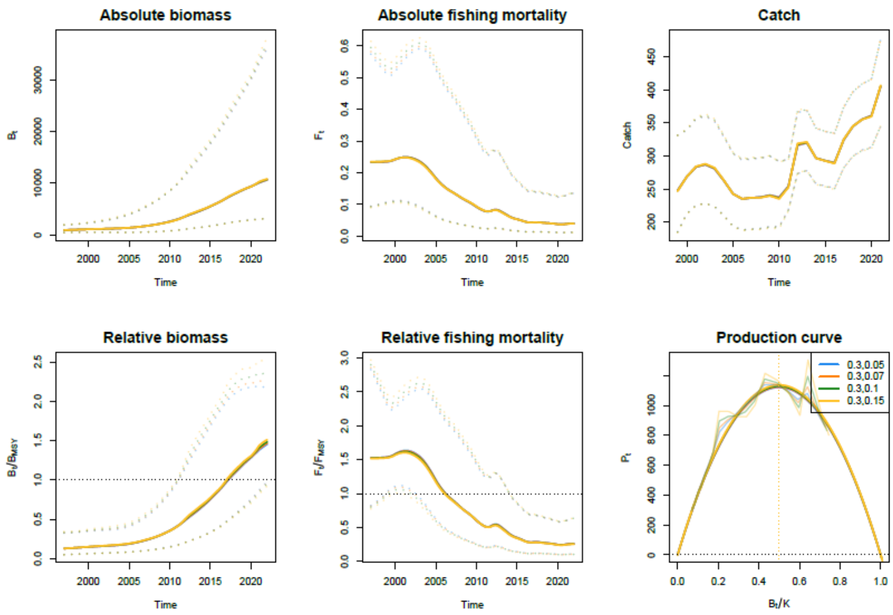

Figure 4.4.7 Comparison plot of reference 0 with r prior of .337 and process error sdb prior of 0.07, versus scenario 3 with sdb priors of 0.05, 0.1 and 0.15.

Furthermore, we ran scenario 4 in which no priors on *r* and *bkfrac* were used. This scenario was not validated and all retrospective analyses failed.

4.4.3 Final assessment

The scenario that was chosen as final assessment included informative priors on parameters *r* and *n*. The parameter settings agreed for the final assessment are found in Table 4.4.3. Diagnostic plots corresponding to the final assessment are presented in Figure 4.4.8.

Table 4.4.3 Parameter settings for the final assessment of blonde ray with SPiCT.

Parameter	Agreed setting
Catches	1999-2021 using reconstruction scenario 2 (2009-2011). 2x higher uncertainty in 1999-2010
Surveys	FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined. Time series 1997-2021
r. prior	*r* = 0.337, CV = 0.3
Shape.prior	Schaefer model (*n* = 2)
Initial depletion prior	-
Process error	*sdb* = 0.07, CV = 0.5

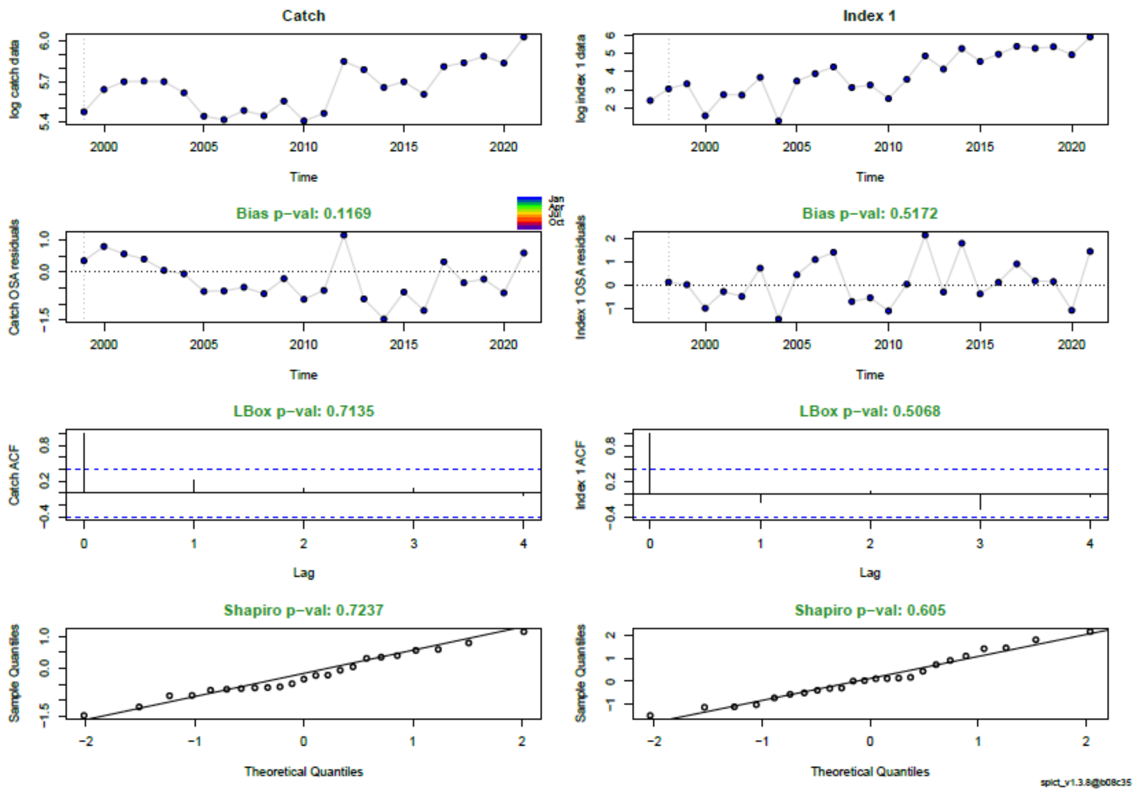

Figure 4.4.8 Diagnostic plots corresponding to the final assessment. Scenario reference 0 with informative priors for r and n, removals 1999-2021, and an exploitable biomass index from FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined.

The retrospective analysis was done using 5 retro-years and showed consistent patterns (Figure 4.4.9). Mohn's rho of $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ were 0.168 and -0.006, respectively, which is in between the thresholds of -0.15 and 0.20 for long-lived species (ICES, 2020).

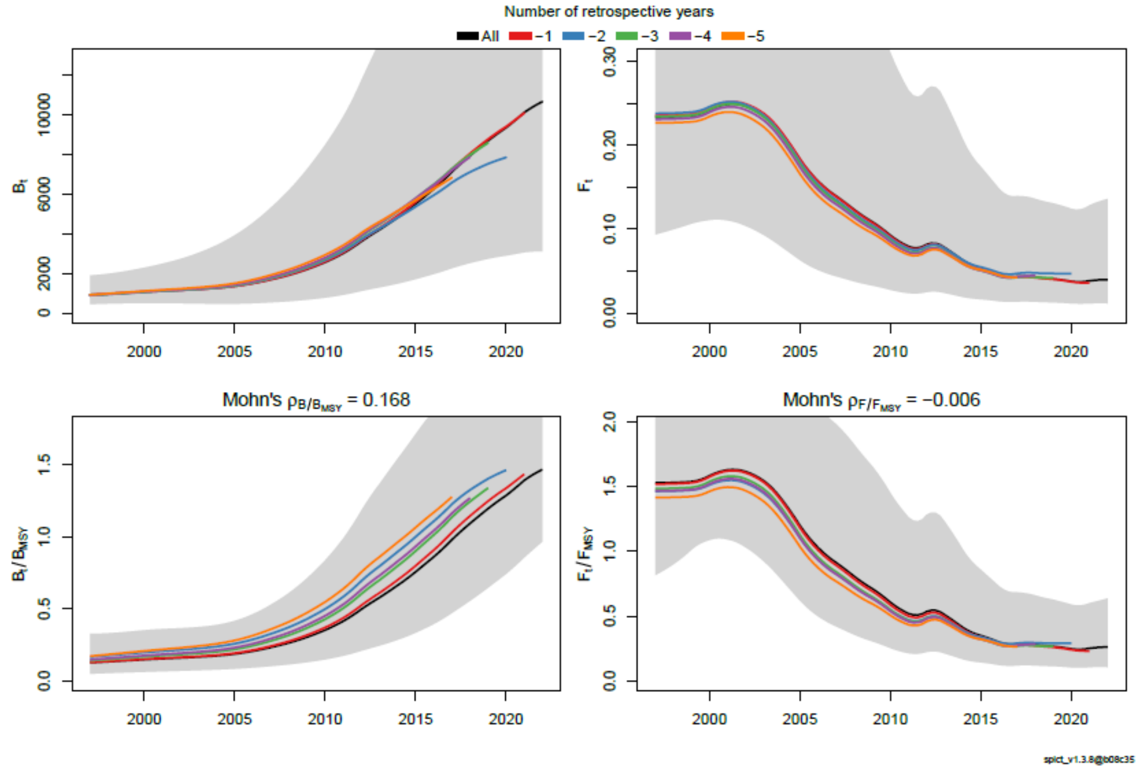

Figure 4.4.9 Plots of the retrospective analysis corresponding to the final assessment. Scenario reference 0 with informative priors for r and n, removals 1999-2021, and an exploitable biomass index from FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined.

A hindcast cross-validation was done for the final assessment for hindcasts to 5 years. A Mean Absolute Scaled Error (MASE) smaller than 1 would indicate that the model has prediction skill for in the index. In the hindcast cross-validation using 5 years, the prediction skill was a bit higher than 1: MASE = 1.06 (Figure 4.4.10, upper panel). During benchmark discussions it was decided to also run a hindcast using 3 years which resulted in a MASE of 0.795 (Figure 4.4.10, lower panel). This was within the boundaries of acceptance.

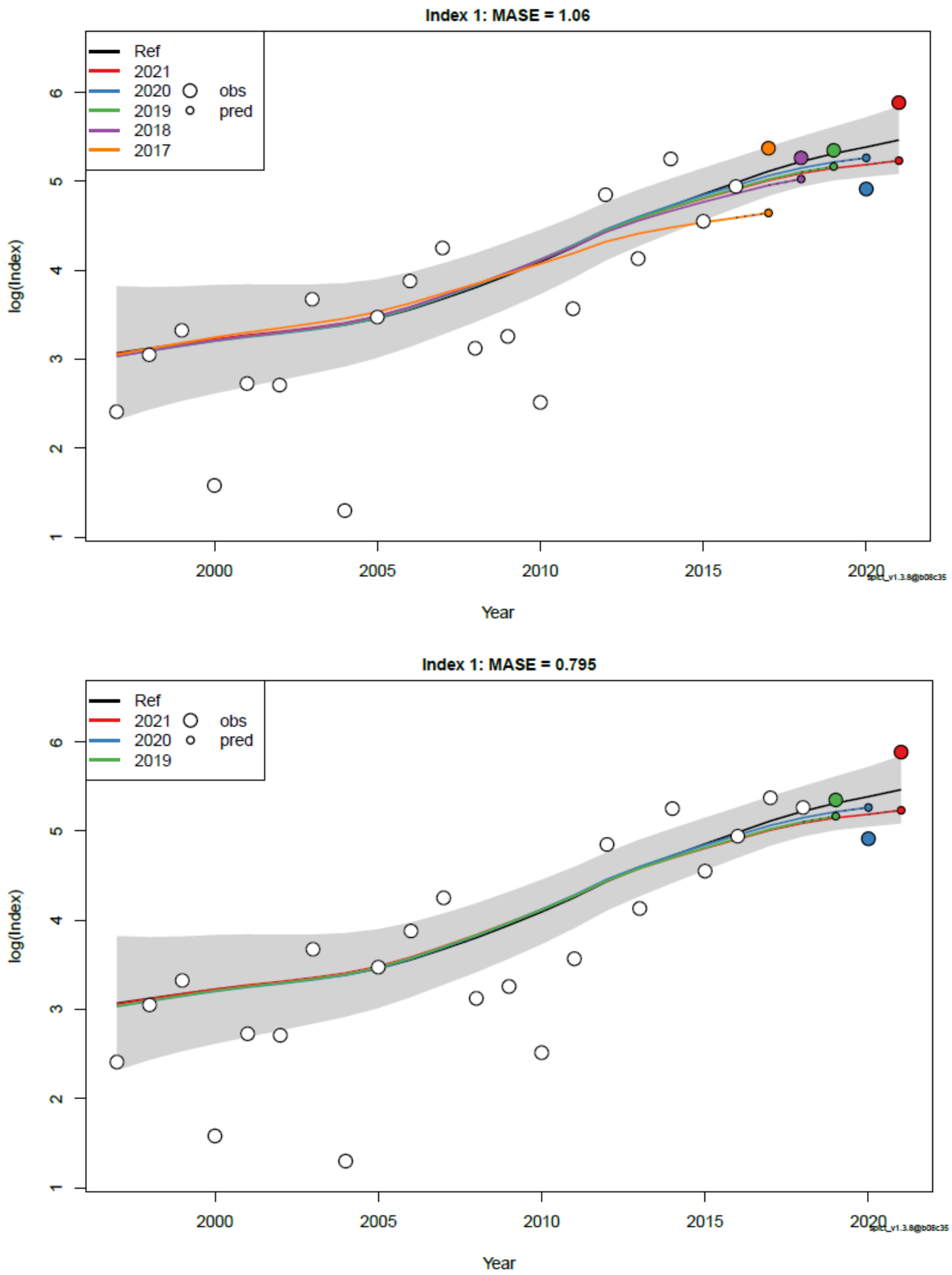

Figure 4.4.10 Hindcast cross-validation results for 5 years (upper graph) and 3 years (lower graph) corresponding to the final assessment. Scenario reference 0 with informative priors for r and n, removals 1999-2021, and an exploitable biomass index from FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined.

Result plots for the final assessment can be found in Figure 4.4.11. The output of the model indicates an overexploited stock with a biomass well below B_{MSY} in 1997. Fishing mortality was stable but above F_{MSY} in earlier years following a decreasing trend and remaining below F_{MSY} since 2006, allowing the stock to rebuild. Since 2018 biomass is above B_{MSY}. MSY is estimated to be 1124 tonnes with a wide confidence interval, of [434-2908] tonnes.

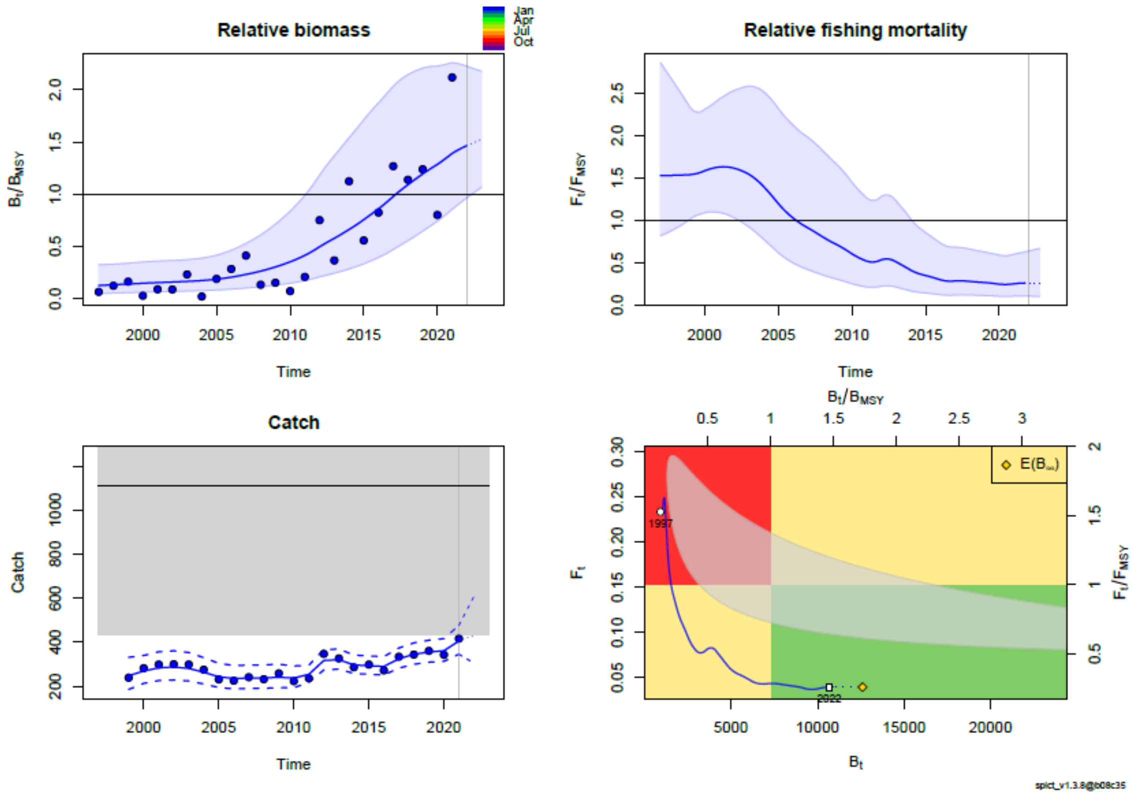

Figure 4.4.11 Result plots for the final assessment scenario: reference 0 with informative priors for r and n, removals 1999-2021, and an exploitable biomass index from FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3 combined.

4.4.4 Forecast

With the final assessment model, a short-term forecast was carried out assuming status quo harvest rate for the interim year. A two-year projection (2023-2024) was made including different management options:

1. ICES advice rule, corresponding to the 35th percentile of the catch
2. 15th percentile of the catch
3. 25th percentile of the catch, biomass and fishing mortality
4. Current ICES Category 3 precautionary approach (i.e. increase in advice cannot be higher than 20%).
5. Increase realized removals with 20%

The advised removals of blonde ray for 2023 corresponding to the ICES advice rule is 1498 tonnes. This advice is a 3.9-fold increase compared to the average annual removals derived for the period 2020-2021 (379 tonnes) and a 6-fold increase compared to what should have been an advice for removals derived from the current 191 tonnes landings advice (247 tonnes given a dead discard rate of 0.29 (average of 2019-2021). Given the change of perception of the state of the stock (formerly considered depleted and now estimated to be harvested well below F_{MSY} with a biomass above B_{MSY}) and the use of a forecast and reference points, the workshop considered that this substantial increase of the forecasted removals was sensible. If this advice were to be followed, B/B_{MSY} would be expected to be 1.44 and F/F_{MSY} would be expected to be 0.90 at the beginning of 2024. For illustration, when following the current ICES Category 3 precautionary approach, the advice for the stock would be 296 tonnes with corresponding B/B_{MSY} of 1.68 and F/F_{MSY} of 0.08. Increasing the realized removals by 20% gives an advice on removals of 486 tonnes. The five predicted trajectories are presented in Table 4.4.4. and in Figure 4.4.12.

Table 4.4.4. Scenario outputs for 2023.

Scenario	Removals (tonnes)	F/Fmsy	B/Bmsy
35th percentile of catch at Fmsy	1498	0.90	1.44
15th percentile of catch at Fmsy	1275	0.76	1.46
25th percentile of the catch, biomass and fishing mortality	1018	0.60	1.50
Increase advice (current ICES Category 3 (+20%))	296	0.08	1.68
Increase realized removals +20%	487	0.28	1.57

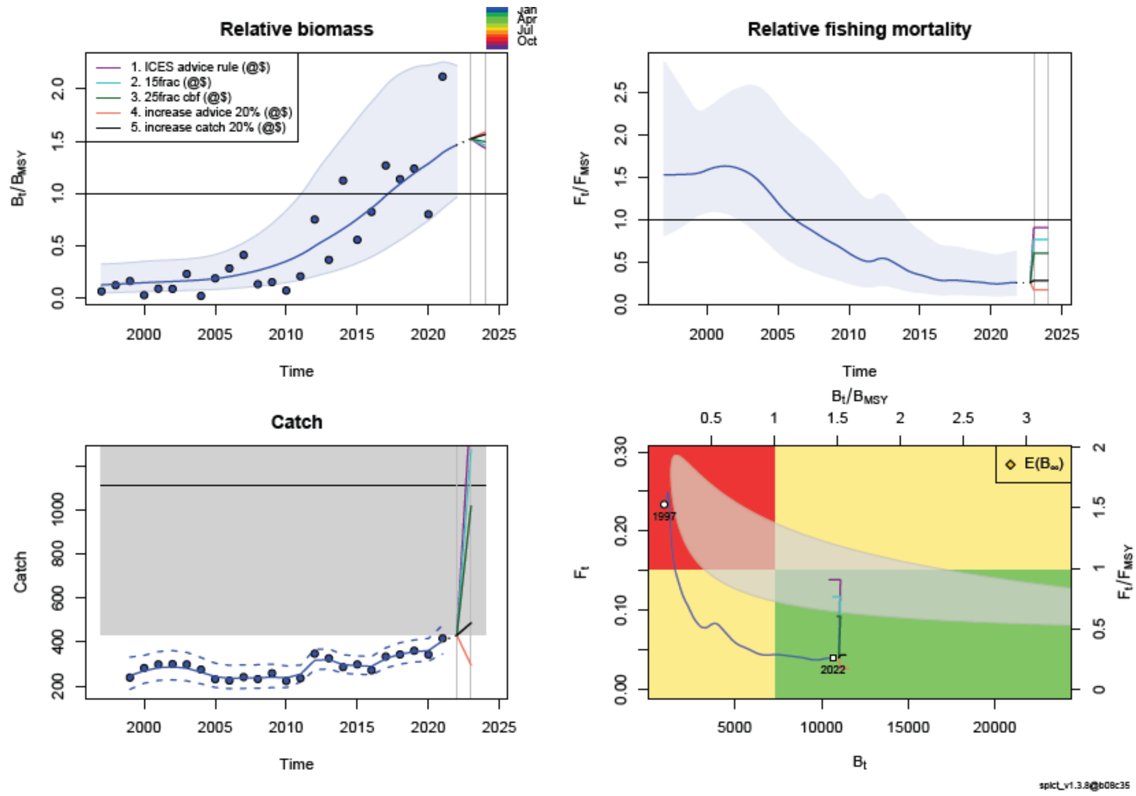

Figure 4.4.12 Predicted trajectories of blonde ray (rjh.27.4bc7d) for the management period 2023-2024.

It should be noted that when applying the ICES rule (35th of the predicted catch [removals] at Fmsy) or considering the 15th percentile, the resulting catches (removals) are well above the estimated MSY (1124 tonnes).

4.5 Future considerations/recommendations

The forecasted value of the advice on removals when applying the ICES rule (1498 tonnes) is greater than the recent annual catch (2020-2021 average: 269 tonnes) or recent removals (2020-2021 average: 380 tonnes) and, also much greater than the current advice on total catch (191 tonnes).

Given the increase in advice using SPiCT, the average dead discard rate observed in the current time series may change. Using the usual procedure to convert removals to landings by using the recently observed dead discard rate would potentially not be appropriate. It is very unlikely that this discard rate would remain similar if more landings were to be allowed. If the advised removals were directly used to fix the allowed landings, this would imply some degree of targeting for fishers to reach this quantity (i.e. some increase in effort dedicated to this fishery).

While most of the simulation testing were carried out for recovering stocks, WKLIFE should consider what could be an ICES rule for stocks which are far below Fmsy (and at or above Bmsy). Even a low fractile (e.g. 15th) of the catches at Fmsy would lead to a large increase in short term fishing opportunities, above MSY, with a risk of reduction of the biomass in the near future. Given the uncertainty around the MSY value, it would be relevant to test a constraint in the increase in the catch advice to the lower limit of the confidence interval around MSY.

The addition of division 4.b to the stock unit is mainly supported by results on survey analysis using INLA showing a spill-over effect of division 4.c into 4.b. The genetic work is ongoing and preliminary data shows similar results.

It is recommended that the survey indices related to exploitable biomass (individuals ≥50 cm) are, like in previous assessments, used in subsequent assessments. Within the FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3, the majority of individuals caught is within this range.

4.6 Reviewers´ report

A wide range of SPiCT scenarios were initially explored with respect to input time series of catches and survey indices for blonde ray. The final model included catches from 1999-2021, with a two times higher catch uncertainty admitted for the reconstructed catches 1999-2010 than for recent catches 2011-2021. For blonde ray the only index fitted combined FR-CGFS-Q4, NS-IBTS-Q1 and NS-IBTS-Q3, which extended back to 1997. Generating a separate index for NS-IBTS-Q3 was not deemed feasible because of the low encounter rates and small proportion of positive catch rates. The previous design-based index considering only the FR-CGFS-Q4 data was replaced by the new combined model-based index and the length threshold was kept at >=50 cm.

The number of blonde rays caught in the surveys is significantly lower compared to the two other ray species – in some of the early years no individuals were caught at all, but the numbers have increased substantially since 2010 and reaching the highest value in the last year. The high proportion of zeroes makes the uncertainty of the index much larger compared to the indices of the other two rays (average CV around 0.8).

The sensitivity runs showed that model results were consistent when using various input time series and prior settings. The uncertainty of the assessment is larger compared to those for the other rays, reflecting the higher uncertainty of the indices for this stock. Still, the fishing pressure in the final year is estimated to be significantly below FMSY and significantly above Blim, so the uncertainty was not deemed too excessive to use for management. Mohn's rho for B/BMSY was also somewhat higher for this stock compared to the others, but still in the acceptable range (0.168). While this value could be reduced by imposing a prior on the initial depletion level, it was agreed that the final model should not use it, since there was no real prior information to support it.

The final model passed all diagnostic tests and was therefore accepted.

4.7 References

Amelot, M., Batsleer, J., Foucher, E., Girardin, R., Marchal, P., Poos, J.J., and Sys, K. (2021). Evidence of difference in landings and discards patterns in the English Channel and North Sea Rajidae complex fishery. Fisheries Research, 242. https://doi.org/10.1016/j.fishres.2021.106028

Bird, C., *et al*. (2020). "Fifty years of tagging skates (Rajidae): using mark-recapture data to evaluate stock units." Journal of the Marine Biological Association of the United Kingdom 100(1): 121-131.

Ellis, J. R., Cruz-Martinez, A., Rackham, B. D. and Rogers, S. I. 2005. The distribution of chondrichthyan fishes around the British Isles and implications for conservation. Journal of Northwest Atlantic Fishery Science, 35, 195–213.

Fahy, E. (1989). Growth parameters of rays (Batoidei) in Irish waters, from material examined in commercial catches. ICES CM 1989/G:59; 12 pp.

Froese, R. and Pauly, D. (Editors) (2022). FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2022).

Gallagher, M.J., Nolan, C.P. and Jeal, F. (2005). Age, growth and maturity of the commercial ray species from the Irish Sea. Journal of Northwest Atlantic Fishery Science, 35: 47–66.

Holden, M.J. (1972). The growth rates of Raja brachyura, R. clavata and R. montagui as determined from tagging data. ICES Journal of Marine Science, 34: 161–168.

Lemey, L., Sys, K., Torreblanca, E., Villagra Villanueva, D. and Plevoets, T. (2022). Raywatch: Streven naar een uitgebreidere en efficiëntere verzameling van lange-termijn gegevens voor roggen ter ondersteuning van de "Roadmap for rays and skates. Finaal rapport, ILVO, 154 pp.

McCully, S. R., Scott, F. and Ellis, J. R. (2012). Length at maturity and conversion factors for skates (Rajidae) around the British Isles, with a critique of earlier studies. ICES Journal of Marine Science, 69: 1812–1822.

Pawson, M.G. and Jennings, S. (1996). A critique of methods for stock identification in marine capture fisheries. Fish. Res., 25. 203-217 pp.

Pedersen, M.W., and Berg, C.W. 2017. A stochastic surplus production model in continuous time. Fish

Fish. 18(2): 226–243. doi:10.1111/faf.12174. https://doi.org/10.1016/0165-7836(95)00441-6.

Porcu, C., Bellodi, A., Cannas, R., Marongiu, M.F., Mulas, A. and Follesa, M.C. (2015). Life-history traits of a commercial ray, Raja brachyura from the central western Mediterranean Sea. Mediterranean Marine Science, 16: 90–102.

Silva, J. F., Ellis, J. R. and Ayers, R. (2013). Length-weight relationships of marine fish collected from around the British Isles. Science Series Technical Report, CEFAS, 150: 109 pp.

Stehmann, M. and Bürkel, D.L. (1984). Rajidae. In: Fishes of the North-eastern Atlantic and Mediterranean. Vol. 1.

Then, A.Y., Hoenig, J.M., Hall, N.G., Hewitt, D.A., and Handling editor: Ernesto Jardim. (2015).

Evaluating the predictive performance of empirical estimators of natural mortality rate using

information on over 200 fish species. ICES J. Mar. Sci. 72(1): 82–92.

doi:10.1093/icesjms/fsu136.

Thorson, J. T. (2019). Predicting recruitment density dependence and intrinsic growth rate for all fishes worldwide using a data-integrated life-history model. Fish and Fisheries.

Winker, H., 2018. Investigation into the process error in biomass dynamics of fishes. MARAM/IWS/2018/Linefish/P3

Annex 1: List of participants

DEWK: Data Evaluation workshop: 28 November – 1 December 2022
WP: Meeting on Work progress (15 February 2023)
ABWK: Benchmark workshop: 20 – 24 March 2023

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Annex 2: Workshop agendas

WKBELASMO 2023, 28 November - 01 December 2022

(Online meeting)

Data Evaluation

Agenda

28 Nov (Monday)

09:00-09:15 (CPH TIME))

- Opening of the meeting, code of conduct, introduction participants & meeting ToRs.

09:15-11:30

Thornback ray (*Raja clavata*) in Subarea 4 and in divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) (**rjc.27.3a47d**) – Category 3 stock

Presentations and plenary discussions:

- Catch data, discard survival, surveys, life-history parameters and potential models for stock assessment - Jurgen Batsleer and Katinka Bleeker

11:30-11:45 health break

11:45-13:00

- Genetic population structure & kinship – Timo Staeudle
- Data handling and estimation procedures for discards and length distributions for the English and Wales fleets – Ana Ribeiro Santos
- BTS-Eng–Q3 survey indices in 4.c and 7.d – Joana Silva
- Modelling abundance and biomass from the surveys with INLA - Timo Staeudle

29 Nov (Tuesday)

Spotted ray (*Raja montagui*) in Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) (**rjm.27.3a47d**) – Category 3 stock

09:00-12:00

Presentations and plenary discussions:

- Catch data, discard survival, surveys, life-history parameters and potential models for stock assessment - Jurgen Batsleer and Katinka Bleeker

30 Nov (Wednesday)

Blonde ray (*Raja brachyura*) in divisions 4.c and 7.d (southern North Sea and eastern English Channel) (**rjh.27.4c7d**) – Category 3 stock

09:00-13:30

Presentations and plenary discussions:

- Catch data, discard survival, surveys, life-history parameters and potential models for stock assessment - Jurgen Batsleer and Katinka Bleeker
- Genetic population structure & kinship – Timo Staeudle
- Biomass and abundance indices – Pascal Lorence
- Modelling abundance and biomass from the surveys with INLA - Timo Staeudle
- Exploratory stock assessment with JABBA – Nana Afranewaa

01 Dec (Thursday)

09:00-12:00

- **Adopted workplan** for Thornback ray, Spotted ray & Blonde ray.

WKBELASMO 2023, 20-24 March 2023

Benchmark meeting

Venue: ICES headquarters

Agenda

Daily schedule: 09:00-17:00

Health breaks: 11:30-11:45; 15:30-15:45

Lunch break: 13:00-14:00

20 March (Monday)

09:00-09:15

- Opening of the meeting, code of conduct, introduction participants & meeting ToRs.

09:15-13:00

- Thornback ray (*Raja clavata*) (rjc.27.3a47d): input data for stock assessment and exploratory assessment runs with SPICT and JABBA) - Jurgen Batsleer, Katinka Bleeker, Liese Carleton & Iago Mosqueira
- Discard survival for rays and skates: merging SUMMARiS, French Flyshoot fleet (FROM Nord) and Dutch Fleet (WMR) data – Damian Villagra Villanueva

14:00-18:00

- Thornback ray exploratory assessment runs with SPICT and JABBA (Jurgen *et al*, cont.)
- Age-structured rebuilding simulation evaluation for Thornback ray with Spict - Henning Winker
- Investigation into the process error in biomass dynamics of fishes - Henning Winker

Plenary discussions and agreement on input data, SPICT base-case run and set of sensitivity analysis to be carried out for Thornback ray

21 March (Tuesday)

09:00-10:30

- Sub-group work

10:30-13:00

- Thornback ray: revised catch data and updated survey indices; SPICT base-case run and sensitivity analysis - Jurgen Batsleer, Katinka Bleeker
- Sub-group work

14:00-16:30

- Spotted ray (*Raja montagui*) (rjm.27.3a47d): input data and SPICT exploratory runs - Jurgen Batsleer, Katinka Bleeker

Plenary discussions and agreement on input data, SPICT base-case run and set of sensitivity analysis to be carried out for Spotted ray

16:30-18:00

Plenary discussions and adoption of final assessment run for Thornback ray; short-term forecasts with SPICT

22 March (Wednesday)

09:00-10:15

- Sub-group work

10:15-13:00

- Spotted ray: plenary adoption of the approach to estimate/reconstruct GBR discards for 2020-2021; SPICT exploratory runs.

14:00-15:30

- Sub-group work

15:30-17:00
Plenary discussions and adoption of base-case run for Spotted ray and short-term forecasts with SPICT for Thornback ray.

23 March (Thursday)

09:00-10:00

- Sub-group work

10:00-10:30

- Blonde ray (*Raja brachyura*) (**rjh.27.4c7d**): input data for stock assessment and exploratory assessment runs - Jurgen Batsleer, Katinka Bleeker

10:30-13:00

- Sub-group work

14:00-16:00

- Blonde ray: input data for stock assessment and exploratory assessment runs - Jurgen Batsleer, Katinka Bleeker (cont.)

16:00-17:00

- Sub-group work

17:00-18:30
Plenary discussions on the set of sensitivity runs for Spotted ray and Blonde ray

24 March (Friday)

09:00-10:00

- Sub-group work

10:30-13:30
Plenary discussions and adoption of final assessment run for Spotted ray and Blonde ray; short-term forecasts with SPICT for Spotted ray.

14:30-17:00
Plenary discussions and adoption of short-term forecasts with SPICT for Blonde ray; Summary of WKBELASMO main conclusions and recommendations.

- Probabilistic HCRs for Thornback ray within an MSE framework – Tobias K. Mildenberger

Annex 3: List of tasks by stock

Workplan WKBELASMO 2023

Intersessional meeting: morning session in the week of **13-17 February**

Benchmark meeting: **20-24 March**

	Deadline (all three stocks)
WD stock summary	**Prior to intersessional meeting**
WD catches	**Prior to intersessional meeting**
WD surveys	**Prior to intersessional meeting**
WD assessment models	**10th of March**

Workplan WKBELASMO 2023																
	December				January					February				March		
	5 - 9	12 - 16	19 - 23	26 - 30	2 - 6	9 - 13	16 - 20	23 - 27	30 - 3	6 - 10	13 - 17	20 - 24	27 - 3	6 - 10	13 - 17	20 - 24
Document rjh.27.4c7d																
Stock summary																
Catches																
Surveys																
Assessment models																
Intersessional meeting																
Benchmark																

Workplan rjc.27.3a47d, rjm.27.3a47d, rjh.27.4c7d

- Document to ACOM leadership for **rjh.27.4c7d** about extending the stock with division 4.b.

- Working document for stock summary
  - Description of stock in terms of catches and TAC setting
  - Management measures overview (timeline)
  - Development of fishing effort over time
  - Synthesis of information from tagging
  - Synthesis of information from genetics
  - Life history parameters

- Working document on catches
  - Description of the fishery
  - Description of available length data
  - Estimations of landings back in time
    - Reconstruction following Amelot *et al.* (2021); using the (average) species-specific ratio of landings from 2009 onwards. Common approach for all three stocks.
    - Reconstruction using species specific ratios including area and gear type where possible (maximum backwards to 2005).
  - Estimations of discards back time
    - Reconstruction using the correlation between fishing effort and discards. Uncertain how far back in time given knowledge on management.
    - Optional: explore methods used in undulate ray (rju.27.7de)
    - Evaluate the validity of using (reconstructed) discards for **rjh.27.4c7d**
  - Discards survival
    - Evaluate survival studies by gear/length/seasonality
    - Define a survival rate (range) based on studies on long term survivability

- Working document on surveys
  - Overview of available surveys and potential use for each stock (taken into account WKSKATE 2020)
  - Details by survey:
    - Length distribution by survey/area
    - Spatial distribution
    - Temporal coverage
    - Spatial distribution (e.g. division 4.a for rjc) and frequency of zeros
  - Indices
    - Abundance, total biomass, exploitable biomass (including confidence bounds)
    - Explore other relevant grouping for indices
      - mature exploitable biomass, immature exploitable biomass
      - catch length distribution as cut-off (e.g. 30+, 30/50, 50+; quantify the ratio between length groups in commercial catches and surveys)
  - Explore methods to combine surveys and define best survey combination

    - Delta-GAM / Tweedie
        - Combine by quarter (e.g. Q3 surveys)
    - INLA
    - Design based

- Working document on assessment models
    - State Space Bayesian Model (**rjc.27.3a47d only**)
    - SPiCT
    - JABBA

Annex 4: Blonde ray stock ID

Blonde ray in Divisions 4.c,7.d (rjh.27.4c7d)

Arguments for considering Division 4.b to be included in the stock unit:

Tagging experiments show some exchange between 4.c and 4.b. Bird *et al*. (2020) reported that of blonde ray tagged and released in 4.c, of returns were from 4.c and 28.6% from 4.b, and considered that "*R. brachyura tagged in the southern North Sea also moved into the central North Sea (Division 4.b), suggesting that this stock may extend further north than currently assumed.*". Recent tagging studies from a Dutch study (unpublished) also indicate similar movement patterns.

Preliminary results from a genetic study do not provide evidence either way, and work is still ongoing.

The most convincing evidence is given by analyses of surveys data (INLA) which shows a clear spill-over from the north of 4.c to the south of 4.b in recent years (top figure below). If this continues, then not accounting for catches in 4.b in the future could lead to more uncertain assessments. The spatial distribution of blonde ray in the North Sea from trawl surveys indicates that blonde ray is distributed in the central North Sea and mostly in the south of that Division (Heessen *et al*., 2015; bottom figure below).

Furthermore :

Blonde ray in 4.b does not currently belong to any stock (the neighbouring stock being rjh.27.4a6), and both surveys and commercial catches show that there is limited occurrence of blonde ray in the northern part of 4.b. This indicates that blonde ray in 4.b would be associated primarily with the rjh.27.4c7d stock unit rather than the rjh.27.4a6a stock unit.

Reported catches of blonde ray in 4.b have been 1-38 t (cf. 133-252 t for 7.d and 4.c), and so the magnitude of landings should be considered in the assessment.

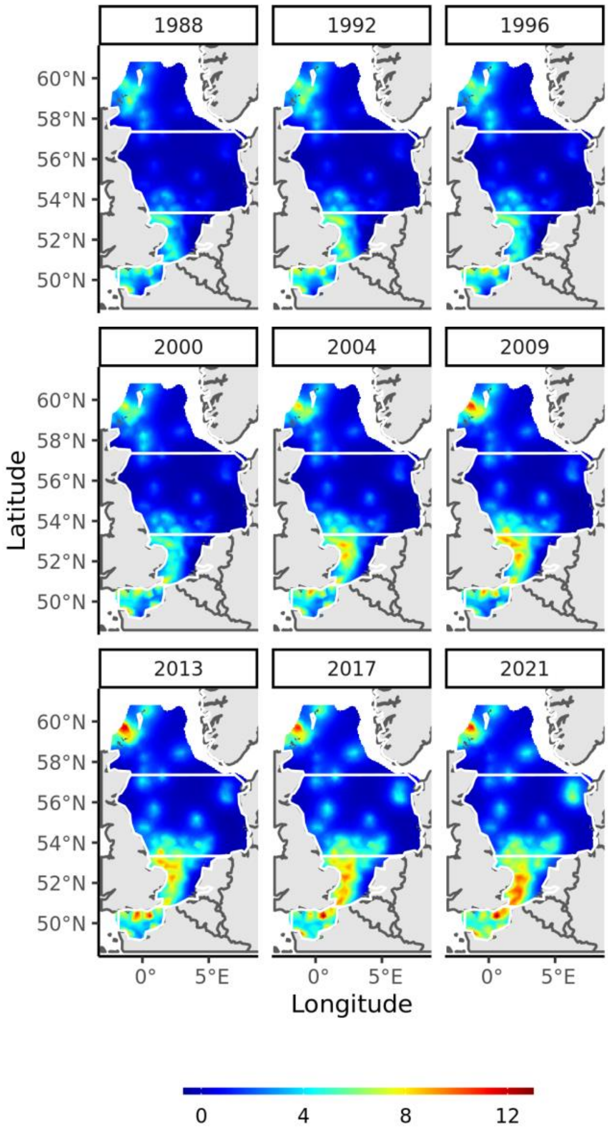
Therefore, WKBELASMO recommends extending the stock unit for blonde ray to cover 4.b for the assessment and, providing robust results using the proposed new stock unit (rjh.27.4bc7d), to use the refined stock unit in the advisory process.

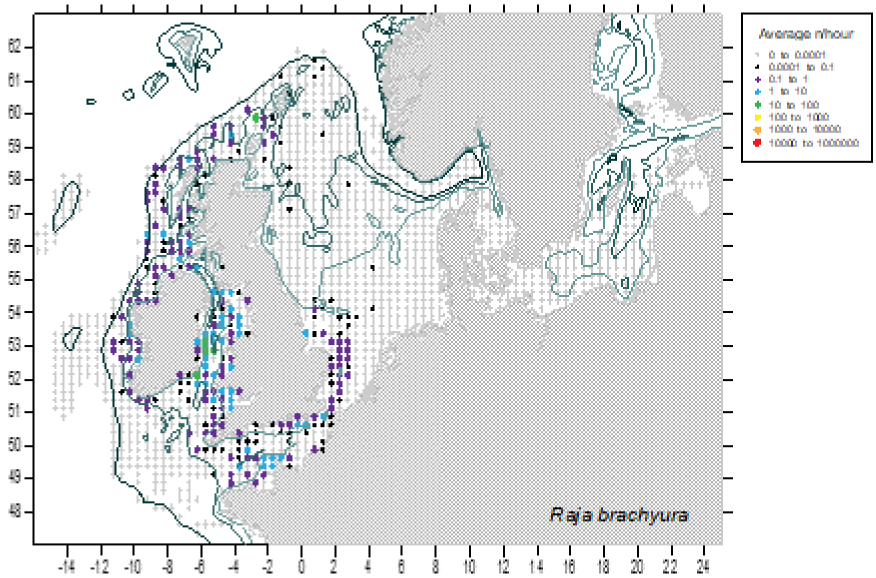
Note that the decision should be made by ACOM-LS as soon as possible, in order to get 4b data to be processed well in advance of the March meeting.

References

Bird, C., Burt, G. J., Hampton, N., McCully Phillips, S. R. and Ellis, J. R. (2020). Fifty years of tagging skates (Rajidae): Using mark-recapture data to evaluate stock units. *Journal of the Marine Biological Association of the United Kingdom*, 100: 121–131.

Heessen, H. J. L., Daan, N. and Ellis, J. R. (Eds.) (2015). Fish atlas of the Celtic Sea, North Sea, and Baltic Sea. Wageningen Academic Publishers / KNNV Publishing, 572 pp.


1988
1992
1996
2000
2004
2009
2013
2017
2021
60°N
58°N
56°N
54°N
52°N
50°N
Latitude
0°
5°E
Longitude
0
4
8
12


Average n/hour
0 to 0.0001
0.0001 to 0.1
0.1 to 1
1 to 10
10 to 100
100 to 1000
1000 to 10000
10000 to 1000000
Raja brachyura