Benchmark Workshop for selected elasmobranch stocks (WKELASMO)

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Ole Thomas Albert
Institute of Marine Research in Norway

Thomas Barreau
Muséum National d'Histoire Naturelle

Jurgen Batsleer
Wageningen Marine Research

Loïc Baulier
Institut Français de Recherche pour l'Exploitation de la Mer

BENCHMARK WORKSHOP FOR SELECTED ELASMOBRANCH STOCKS (WKELASMO)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Manuela Azevedo • Alain Biseau

Authors

Ole Thomas Albert • Haritz Arrizabalaga • Manuela Azevedo • Thomas Barreau • Jurgen Batsleer • Lucie Baude • Loïc Baulier • Casper Berg • Gérard Biais • Alain Biseau • Cristina Rodríguez Cabello • Steven Cadrin • Rui Coelho • Paul Coleman • Enric Cortes • Andrés Domingo • Jim Ellis • Rodrigo Forselledo • Romaric Jac • Graham Johnston • Armelle Jung • Claudia Junge • Antonia Klöcker • Pascal Lorance • Carlos Mayor • Gary Melvin • David Murray • Mauricio Ortiz • Hege Overbø¸ • Amélia Viricel Pante • Jan Jaap Poos • Bárbara Serra-Pereira •Joana Silva • Christoph Stransky • Nathan Taylor • Caroline Aas Tranang • Verena Trenkel • Lies Vansteenbrugge • Jesús García Villar • Zachary Whitener

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Contents

i Executive summary

A Benchmark Workshop for selected elasmobranch stocks (WKELASMO) was convened to evaluate the appropriateness of data and methods to assess and provide short-term forecast of four stocks: Porbeagle in the Northeast Atlantic (por.27.nea), thornback ray in the Bay of Biscay (rjc.27.8), undulate ray in the Channel (rju.27.7de), and cuckoo ray in western waters (rjn.27.678abd).

For **porbeagle in the Northeast Atlantic**, the workshop (and the reviewers from the stock identity working group (SIMWG)) considered that there is not enough evidence to split the stock despite genetic analysis and mark-recapture data indicating a possibility of two components. A SPiCT assessment using reported landings since 1926, three commercial indices and one reconstructed survey, was accepted and the forecast settings agreed, leading the stock into **category 2**. The stock is estimated to be harvested largely below F_{MSY} (F/F_{MSY} = 0.02), and the biomass, while increasing, remains below MSY-$B_{trigger}$ (B/B_{MSY} = 0.43). The 35th percentile of the catches at F_{target} is 324 tonnes.
Members of WKELASMO from the International Commission for the Conservation of Atlantic Tunas (ICCAT) provided additional assessments using JABBA and SPicT, both using a Fox model. Results were very similar and gave the same perception as the final accepted SPiCT assessment.

For **thornback ray in the Bay of Biscay**, a synthesis of work on stock boundaries within Subarea 8 was presented, indicating that this species in this area may be considered to comprise of two stocks: 8.abd and 8.c. The workshop (and the review from SIMWG) agreed to follow this conclusion.

- **Thornback ray in divisions 8.abd**: a Bayesian state-space biomass production model including Close kin mark-recapture (CKMR) results was accepted as the basis of the assessment and forecast, leading the stock into **category 2**. The stock is estimated to be exploited close to F_{MSY}, and Biomass close to B_{MSY}. The forecast at F_{MSY} provides catches (35th percentile) 34% lower than the previous advice.

- **Thornback ray in Division 8.c**: sensitivity analyses using SPiCT do not allow to overcome the very high uncertainty around the F estimate. Therefore, the workshop recommends that this stock remains in **category 3** with empirical methods to be used as the basis of the advice.

For **undulate ray in the English Channe**l, a SPiCT assessment using removals since 2005 and two survey indices (FR-CGFS, since 1990, and Q1SWECOS, since 2006) was accepted. The workshop also agreed on the settings for the short-term forecast, leading the stock into **category 2**. This stock, formerly considered depleted, is now estimated to be harvested well below F_{MSY} with a biomass above B_{MSY}. Given the change of perception of the state of the stock and the use of a forecast and reference points, the workshop considered that the large increase of the forecasted removals (3.6 times higher than the previous advice) is sensible.

For **cuckoo ray in the western waters**, investigations on stock identity did not provide enough evidence to split the stock, which may be a metapopulation. A SPiCT assessment using a combined index of stock abundance (from six surveys) and the landings since 2005 was accepted. The workshop also agreed on the settings for the short-term forecast, leading the stock into **category 2**. The stock is estimated to be harvested below F_{MSY} with a biomass above B_{MSY}, which is considered to be the consequence of the cuckoo ray being a non-target species with a rather high intrinsic growth rate (r~0.5). The 35th percentile of the landings at F_{MSY} is largely higher (~3 times) than the previous advice.

ii Expert group information

Expert group name	Benchmark Workshop for selected elasmobranch stocks (WKELASMO 2022)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Alain Biseau, France
	Manuela Azevedo, Portugal
Meeting venue and dates	Data Evaluation Workshop: 29 November – 3 December 2021, online (28 participants)
	Intersessional meeting: 11 January 2022, online (15 participants)
	Intersessional meeting: 3 February 2022, online (28 participants)
	Intersessional meeting: 15 February 2022, online (16 participants)
	Benchmark Workshop: 26-29 April 2022, online (18 participants)

1 Introduction

1.1 Terms of reference

2021/2/FRSG25 A Benchmark Workshop for selected elasmobranch stocks (WKELASMO), chaired by External Chair Manuela Azevedo, Portugal, and ICES Chair Alain Biseau, France, and attended by two invited external experts Enric Cortés, USA, and Jan Jaap Poos, Netherlands, will be established and will meet online 29 November - 3 December 2021 for a data evaluation meeting and in Nantes, France and online, for a 5-day Benchmark meeting 7–11 March 2022 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;
    vii. Further considerations of environmental drivers, multi-species information, and ecosystem impacts for stock dynamics in the assessments and outlook;
    viii. Examine mixed fisheries interaction;
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. Knowledge about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology where possible. If no analytical assessment method can be agreed, then an alternative method for providing advice (ideally one of the WKLIFE X (https://doi.org/10.17895/ices.pub.5985) methods) 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.

WKELASMO will report by 7 April 2022 for the attention of ACOM.

The deadline for WKELASMO reporting for the attention of ACOM was revised to 19 May 2022 (see section 1.2).

1.2 Description of the Benchmark Process

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

A rather large participation by ICCAT members, for the porbeagle discussions, was very beneficial to the group.

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 29 November – 3 December 2021. 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, with the exception of undulate ray, was done during an online meeting held 03 February 2022 with some members of the stock identity working group (SIMWG).
4. The actual benchmark, planned 7–11 March was postponed due to the Bureau decision related to the Russia-Ukrainian war, and finally was held 26–29 April.
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:

Porbeagle Working Documents

Title	Description	Contributors
1. WD_DE_WKELASMO_Biais_Stz_Norw_CPUE_rev WD_DE_WKELASMO_Biais_Stz_Norw_CPUE_Supp	Norwegian CPUE	Gérard Biais
2. WD_DE_WKELASMO_Biais_Stz_French_CPUE_rev WD_DE_WKELASMO_Biais_Stz_French_CPUE_Supp	French CPUE	Gérard Biais
3. WKELASMO_WD_Righton *et al* Porbeagle movements	Spatial distribution	David Righton *et al.*
4. WGEF_2021_WD_02_Viricel *et al*_Porbeagle pop structure BoB	Population structure inferred using molecular markers	Amélia Viricel *et al.*
5. DE_WKELASMO_Biais_Porbeagle_survey_supp	Abundance in the French survey in the Bay of Biscay and Celtic Sea	Gérard Biais
6. WKELASMO_2022_WD_POR_Stock identification	Stock delineation of NE Atlantic porbeagle	Jim Ellis *et al*
7. WD_Haugen *et al*. stock identification of North Atlantic porbeagle	Interdisciplinary stock identification of North Atlantic porbeagle	Janne Haugen *et al.*
8. WKELASMO_WD_Biais *et al*_NEA porbeagle stock identity issues	Stock Identity issues	Gérard Biais *et al.*
9. WKELASMO_2021_WD_Junge *et al.*_Porbeagle SPICT	Exploratory SPiCT assessment	Claudia Junge *et al.*
10. WD_WKELASMO_Biais_Porbeagle_SPiCT runs	Exploratory SPiCT assessment	Gérard Biais

Some of the Working Documents presented to WKELASMO have also been given as contributions to ICCAT, and the reader is referred to the relevant ICCAT Collective Volume of Scientific Papers (https://www.iccat.int/en/pubs_CVSP.html)

Undulate ray (7.de) Working Documents

Title	Description	Contributors
1. WKELASMO_WD_Silva Q1SWECOS rjn and rju in 7.e WKELASMO_WD_Silva Q1SWECOS indices in 7.e using 'surveyIndex'	Q1SWECOS data	Joana Silva
2. WKELASMO_WD_Ribeiro Santos and Shaw E&W Discards estimates		
3. WKELASMO_WD_Ribeiro Santos and Shaw E&W Discards estimates	Discard estimates	Ana Ribeiro Santos, Stephen Shaw
4. WD_WKELASMO_Baulier_Reconstruction of time series of removals_rju7de	Catches/Removals time series	Loïc Baulier
5. WD_WKELASMO_Baulier_Specification of priors for rju7de	Priors for SPiCT	Loïc Baulier
6. WKELASMO_WD_Baude-Baulier_SPiCT_simulations_rju7de_previous WKELASMO_WD_Baude-Baulier_SPiCT_simulations_rju7de_V2	SPiCT assessment	Lucie Baude, Loïc Baulier

Thornback ray (8) Working Documents

Title	Description	Contributors
1. WKELASMO2_WD_Rdz-Cabello_Issues related with stock identity of *R. clavata*	Stock Identity issues	Christina Rodriguez-Cabello and Fransisco Sanchez
2. WKelasmo_WD_Lorance_stockIdentity_rjc.27.8	Stock distribution	Pascal Lorance
3. WKelasmo_WD_rjc.27.8abd_Assessment	Stock assessment	Verena Trenkel, Pascal Lorance
4. WKELASMO_WD_Spain_8c_Rclavata_SPICT	Exploratory SPiCT assessment – southern stock	Cristina Rodriguez-Cabello *et al.*

Cuckoo ray (78) Working Documents

Title	Description	Contributors
1. WKELASMO_WD_Silva Q1SWECOS rjn and rju in 7.e WKELASMO_WD_Silva Q1SWECOS indices in 7.e using 'surveyIndex'	Q1SWECOS data	Joana Silva
2. WKELASMO_WD_Ribeiro Santos and Shaw E&W Discards estimates	Discard estimates	Ana Ribeiro Santos, Stephen Shaw
3. Landings of *Leucoraja naevus*	Corrected landings	Graham Johnston
4. WKelasmo_WD_Lorance_stockIdentity_rjn.27.678abd	Stock distribution	Pascal Lorance *et al.*
5. WKelasmo_WD_Lorance_Silva_SurveyIndices_rjn.27.678abd	Surveys indices	Pascal Lorance and Joana Silva
6. WKELASMOWD_SPiCT runs for *Leucoraja naevus*	SPiCT runs	Paul Coleman and Graham Johnston

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 Conflict of Interest (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

Porbeagle: Further studies must be encouraged to better appreciate the implications of the complexity of the porbeagle stock structure in the NEA for stock assessment and fishery management. A biomass (or abundance) index should continue to be available in the future to monitor the stock (e.g. extension of the 2018–2019 survey, improved analyses of observer data from longline fleets…).

Thornback ray in Division 8.c: Due to the lack of contrast of the data and the uncertainty in the fishing mortality estimates, the model for rjc.27.8c was not accepted. It was suggested to conduct more trials with shorter time series and modified priors and revise it in the next benchmark.

Cuckoo ray in western waters: A future re-examination of stock structure is required (including relevant data relating to genetic structure, parasites, movements and life-history). A stock identification project for *L. naevus*, involving genetic and other approaches, would be beneficial. It is also recommended to re-examine discard data to allow its use in an assessment and to enhance the combined overall index used in the assessment.

Undulate ray in the Channel: It is suggested to re-examine FR-CGFS and Q1SWECOS to improve individual survey indices and explore whether a combined index would be deemed suitable for this stock, with such explorations to consider the potential gear, vessel and seasonality effects. Such work could be usefully undertaken during a dedicated workshop on surveys in the Celtic Seas ecoregion following similar process of WKSKATE in 2020 where surveys in the North Sea ecoregion were evaluated (ICES, 2021c).

2 Porbeagle (*Lamna nasus*) in the Northeast Atlantic and adjacent waters (por.27.nea)

2.1 Introduction

The 2009 ICCAT-ICES WG carried out an initial analytical assessment of the Northeast Atlantic (NEA) porbeagle stock (ICCAT, 2010). A Bayesian Surplus Production (BSP) model (Babcock and Cortes, 2010) was used, but the lack of CPUE data for the peak of the fishery was considered adding considerable uncertainty in identifying the status of the stock. In addition, an age-structured production model (Porch *et al.*, 2006) was used to provide contrast with the BSP model, but the fishing mortality estimated for the historic period was unrealistic. As a result, outputs of models were considered too uncertain for management advice to be based on them (ICES, 2009).

As a result, the ICES assessment of the state of the stock in 2010 was based primarily on the observation that the northern fisheries had ceased and not resumed, indicating that the stock was probably depleted (ICES, 2010). The subsequent 2012 assessment was unchanged (ICES, 2012). In 2015, the stock status was considered unknown because previous perceptions of the stock were based largely on the historic decline in landings and changes in fishing patterns, but that factors other than fish abundance can also influence landings (ICES, 2015). The stock size is still considered unknown in 2019 ICES advice for 2020–2023 (ICES, 2019).

2.2 Stock Identity

Two WDs (Biais *et al.*, 2022, Righton *et al.*, 2022) presented results from the large number of pop-up satellite archival tags (PSATs) deployed on porbeagle in the NE Atlantic from 2006 to 2019 (n=88 counting deployments > 8 days in length). Release areas were North Sea (n=1), Faroes Islands (n=1), North Ireland (n=20), Celtic Sea (n=12) and SW Celtic Sea and Bay of Biscay shelf edge (n=54). The plots of reconstructed tracks show limited number of daily positions in the northeast of Scotland, the North Sea and the Norwegian Sea (Figures 2.6.1 and 2.6.2).

The average percentage per month of daily positions in this area is estimated at 3% from March to July and at 26% from August to February for the porbeagle tagged in the Bay of Biscay and the South Celtic Sea in spring-summer. This low use of the northeastern portion of their habitat by these porbeagle is associated with a frequent return to or near the tagging area in spring of the following year, with 76% of 22 tag deployments lasting over 11 months.

This migration pattern suggest a change in porbeagle distribution to explain past large catches in the North Sea and in the Norwegian Sea, or that the exploited biomass may be composed of several fractions which are not fully mixed on the main fishing areas due to their different areas and times of site fidelity. This latter possibility is supported by a preliminary genetic analysis based of mitochondrial DNA that suggest genetic differences between behavioural groups (Viricel *et al.*, 2021 WD). However, this analysis was based on a limited sample and must be confirmed by complementary genetic analysis on nuclear DNA.

Consequently, further studies must be encouraged to better appreciate the implications of the complexity of the stock structure and population structure of porbeagle in the NEA for stock assessment and fishery management. However, there is not yet sufficient information to consider another option than a single stock for porbeagle in the NEA. Tagging and catch data support the western limit of the stock area at 42°W but with its southern limit could be extended southward from 36°N to 5°N, to align with ICCAT (Ellis *et al.*, 2022).

2.3 Input data for stock assessment

2.3.1 Catch data

Porbeagle landings are assumed to be close to catches until 2009, as the high value of this species must have limited discards (ICES, 2021). Since the EU zero TAC was introduced in 2010, reported landings are likely much less representative of catches, but there is no doubt that catches have been reduced by a very large proportion since 2010. Therefore, the use of landings to estimate catches may cause a limited underestimate of catches until 2009, as comprehensive landing data are available for the main fishing nations and discards limited. From 2010 onwards, discards are unquantified, and in the absence of such data, their level is assumed to be insufficiently large enough to distort the trend shown by the landings too much.

The 2021 WGEF landing data were revised using (Figure 2.3.1):

→ landings submitted in response to the WKELASMO data call (2005–2020 requested) by France, Germany, the Netherlands, Norway, the UK-England and the UK-Scotland. All these countries have previously reported landings to the annual WGEF data calls. Now submitted landings were therefore crossed-checked for eventual updates against the 2021 WGEF landings table.

→ ICCAT catch statistics provided to the WKELASMO. ICCAT Faroe Islands catches from 1953 to 1960 were included because it is assumed they were in the NEA before the porbeagle fishery began in the NWA. WGEF Spanish landing were replaced ICCAT catches, because WGEF landing were suspected of including landings of other shark species (no change from 1950 to 1987).

→ Data base of the French Fisheries Directorate for the revision of the French landings from 1973 to 1987 and Ifremer data base (Harmonie) for the revision of the French landings from 1988 to 1999.

→ Norwegian official statistic reports for the revision of the Norwegian catches for some limited differences (years 1971, 1973 and 1984) and conversion from gutted weight to live weight using the transformation coefficient (1.3) provided in Norwegian official statistic reports (years 1926 to 1972, except years 1958-1960, 1969, 1970 already in live weight)

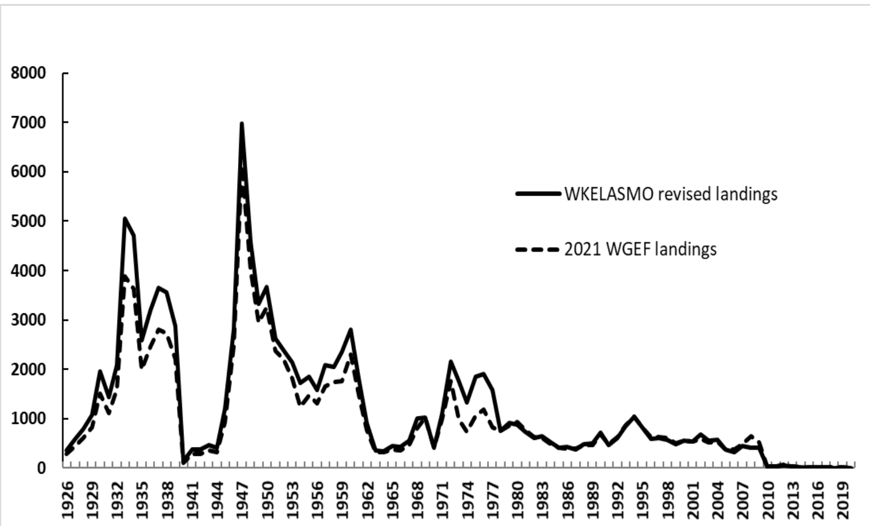


Figure 2.3.1: NEA Porbeagle total landings (tons).

2.3.2 CPUE series

Three longline CPUE series were made available for the NEA porbeagle stock benchmark, standardized by a GLM:

→ A Norwegian longline CPUE series from 1950 to 1972, in number of fish by day, from personal logbooks of five vessels of the Norwegian directed fishery, in number of fish by day (Biais, 2022a and b);

→ A French longline CPUE series from 1972 to 2009, in catch by trip, from logbooks of 19 vessels of the French directed fishery, a revision of the CPUE series already presented at the 2009 ICCAT-ICES assessment (Biais, 2022c and d);

→ A composite survey CPUE series constructed by combining CPUEs of a French commercial vessel, from 2000 to 2009, with CPUEs of a survey carried out in 2018–2019, in number of fish by day and by ICES rectangle (Biais, 2022e, f and g).

In addition, a Spanish longline CPUE series has been available since the 2009 ICCAT-ICES assessment (ICCAT, 2010; Mejuto *et al.*, 2010) that used it. This is a bycatch series of the surface longline targeting swordfish, in round weight per trip and per thousand hooks.

The Norwegian longline CPUE series

The Norwegian CPUE series was obtained from three handwritten logbooks for five longliners of the directed fishery (Biais 2022 a). Since this fishery ceased in the 1980s, these logbooks are now rare. Although limited in number, those obtained provided a sufficiently large database for further analysis, with 1683 daily catches in number per 1°x1° rectangle for the period 1950 to 1972 (years 1965-67 missing). First, considering that a vessel follows likely the porbeagle movement, the independence of pairs of catches in same or adjacent 1°x1° rectangles and taken at intervals varying from one to ten days was assessed using Kendall's rank correlations (p-value<0.05). Based on results, the CPUEs were selected if there are at least five days between successive catches when taken in same or contiguous rectangles. Otherwise, CPUEs were assumed to be independent observations, as it seems unlikely that a vessel may find again the same group of fish the next day by skipping a 1°x1° rectangle, given the variability in fish moves shown by SPAT deployments. This selection significantly reduced the number of daily catches that could be used from 1683 to 616, but it was considered necessary for obtaining unbiased abundance indices. Using this subsample, six subareas were defined based on mean CPUEs per rectangle and observed discontinuities. They extend along the Norwegian coast, south 69°N, to the North Scotland, also extending in the north and central part of the North Sea (Figure 2.3.2). This historic fishing area of the Norwegian fishery was supplemented by new areas to the west and south of Ireland in the 1960s. The CPUEs were standardized comparing three GLM approaches, all adapted to the presence of zero catch days in the CPUE series (negative binomial error distribution, Tweedie error distribution, delta-GLM approach combining a binominal error distribution with a Gamma error distribution) using CPUEs from the historic fishing area of the Norwegian fishery (Biais, 2022a). The year, the month, the subarea and the vessel were included in the GLM variables as well as the interactions between these effects. The selection of the model to retain was proposed on the basis on five folds cross validations, Akaike’s Information Criteria and quantile residual plots. Following the presentation of this GLM comparison, the WKELASMO requested to complement the analysis by examining the effects of using all six defined spatial units (not excluding spatial units in west and southwest of Ireland) and quarter instead month as temporal variable to standardize the Norwegian longliner CPUEs, with GLMs using the negative binomial error distribution with a log link, given its relevance when CPUEs are integers and varies largely and its performances in comparison with GLMs using other distributions. Following the presentation of this supplement to previous analysis (Biais, 2022b), the GLM model involving the effects of the year, the month and the subarea and using a negative binomial error structure was selected as final model. The series of relative annual indices obtained with this model shows a downward trend in the second half of the 1950s, but this trend seems to have stabilized in the early 1960s, followed by a slight increase in the late 1960s and early 1970s (Figure 2.3.3).

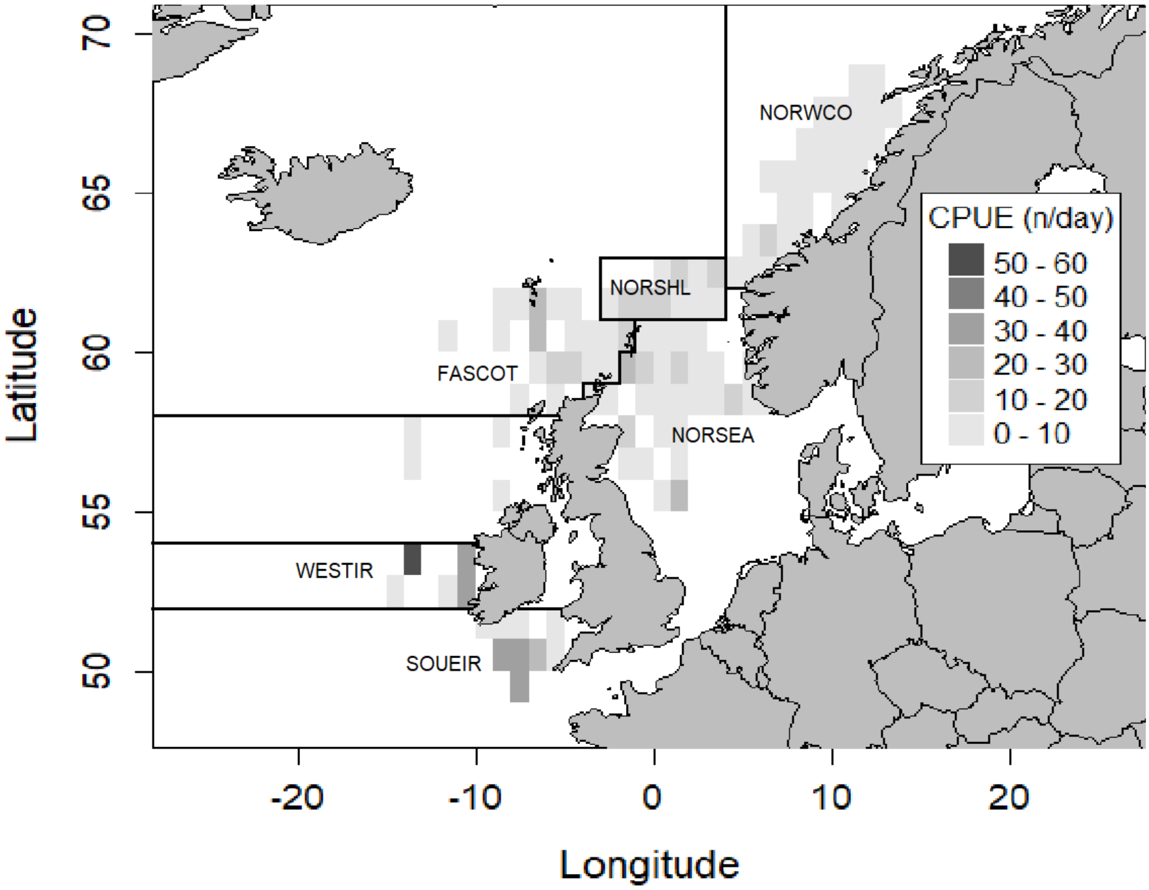


Figure 2.3.2: Mean number of fish per day and per 1°x1° rectangle caught by Norwegian longliners in the North East Atlantic from available logbooks (mean using only independent observations) for years 1950 to 1972, with delineations of the spatial units used in their analysis: WESTIR (west and southwest of Ireland), SOUEIR (southwest of Ireland), FASCOT (southwest to southeast Faroe and northwest Scotland), NORSHL (northern edge of the North Sea shelf), NORSEA (North Sea), NORWCO (Norwegian coast north 62°N).

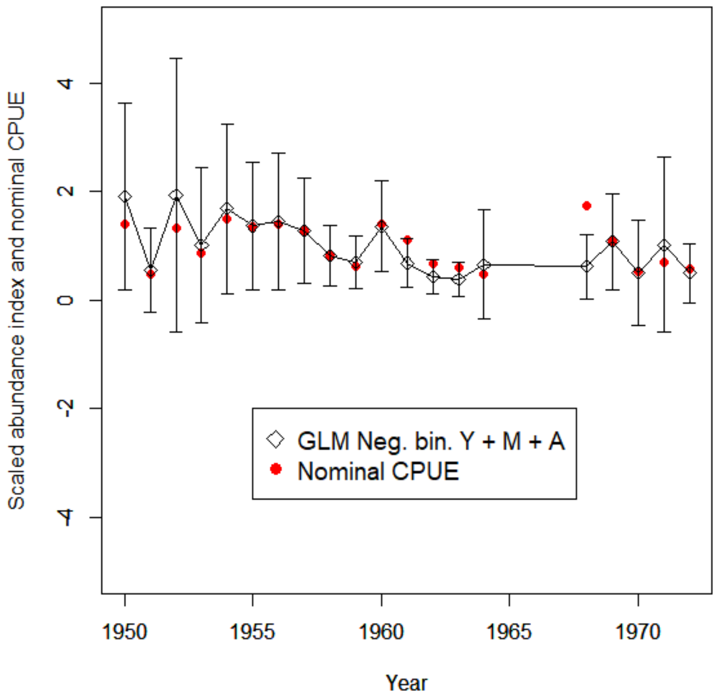


Figure 2.3.3: Relative annual indices (scaled by the mean) provided by the final GLM (negative binomial error distribution with a log link) selected by lowest five folds cross validation MSE (variables included: year, month and area) to standardize CPUEs of Norwegian long-liners in the North East Atlantic, with the nominal CPUEs also scaled by the mean.

To obtain a biomass index for doing a SPiCT assessment with indices and catch in weight, the Norwegian logbooks used to obtain the relative abundance index were also used. They provide catch by weight (gutted fish without head) for most landings. This allows the calculation of annual mean fish weights based on 92% of the daily CPUEs used in the GLM standardization for all years from 1950 onwards, except 1970 and 1972. For these two years, the mean weights were estimated by the average of the mean weights of the closest years (1969 and 1970, since the series ends in 1972). These mean weights were used to transform the abundance relative index in a biomass relative index series by multiplying each annual index by the corresponding annual mean weight (Figure 2.3.11).

The French longline CPUE series

CPUEs of long-liners in the French directed fishery are available since 1972, the second year of the fishery, until it was stopped by a zero TAC in 2010 (Biais 2022 c and d). Its fishing area extends mainly on the shelf edge of the Bay of Biscay, but also in the Celtic Sea (Figure 2.3.4). In order to get the longest possible time series, these CPUEs are in weight per trip. This series was first presented to the 2009 ICCAT-ICES WG which used it for an exploratory assessment. As in 2009, the choice to select boats was made in order to avoid short participations and thus a better interannual comparability of abundance indices (19 vessels selected, all based in Yeu Island). In addition to this previous processing, the CPUE series was cleaned to limit the effects of sailing time to the fishing areas as well as to exclude some trips targeting tunas or whose values suggested an error in the reporting process. CPUEs were standardized with a GLM, using a Gamma error distribution with a log link. The variables considered were the year, the month, the area (ICES divisions 7 a and f-g, 7 h-j-k and 8), the vessel and their interactions. The selection of the final model was performed as for the Norwegian CPUEs. This model involves the four variables considered but not their interactions. The relative abundance index obtained decreases in the 1970s, but thereafter varies without trend (Figure 2.3.5).

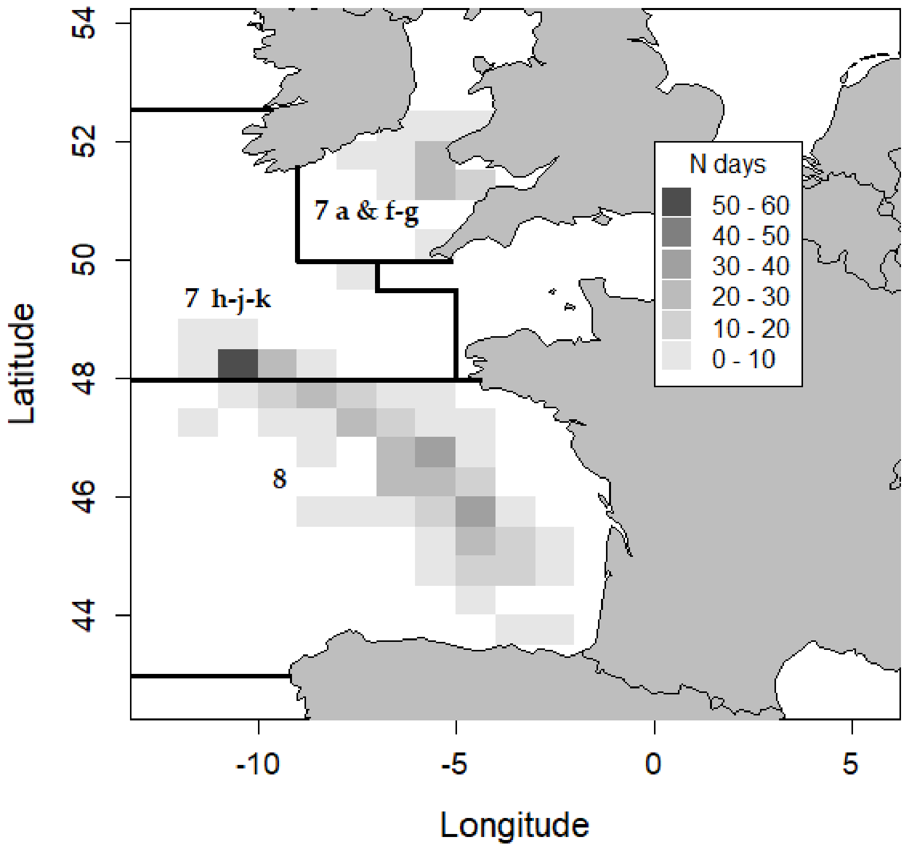


Figure 2.3.4: Fishing effort distribution by ICES rectangle of the French long-liners whose CPUEs contribute to the French CPUE series with limits of areas used to standardize the CPUEs for years 1999 to 2009 (data not available by ICES rectangle prior to 1999).

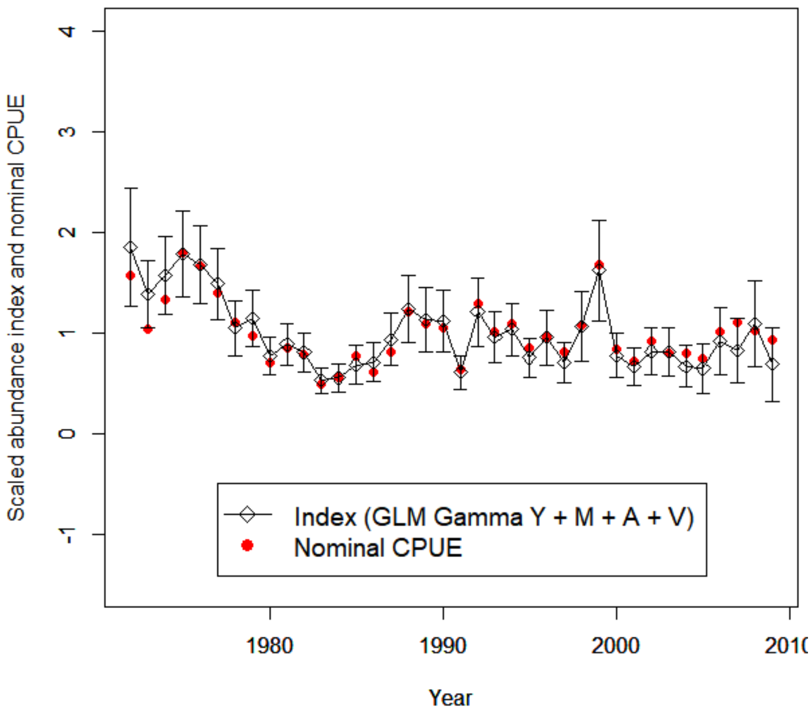


Figure 2.3.5: Relative annual indices (scaled by the mean) provided by the final GLM (Gamma error distribution with a log link) selected by five lowest folds cross validation MSE (variables included: year, month, area and vessel) to standardize CPUEs of the 19 long-liners of the French tuning fleet targeting porbeagle in Northeast Atlantic, with the nominal CPUEs also scaled by the mean.

The composite survey CPUE series

The composite survey CPUE series combines CPUEs of a French commercial vessel, from 2000 to 2009, with CPUEs of a survey carried out in 2018-2019. This was done to construct a series long enough to provide information on the trend in abundance since the cessation of the directed fishery in 2010, in the absence of any possibility of basing an assessment on commercial CPUE since the implementation of the regulations that stopped the French directed fishery and almost all porbeagle landings in European countries.

The survey was carried out in May-June 2018 and 2019, during about one month and a half in both years, with a chartered long-liner based in Yeu Island whose captain and crew were experienced in porbeagle longline fishing. The gear was a longline with 336 hooks, identical to gear used by the commercial directed fishery for the first set of the day. Two sets per day were planned, as usual in the commercial fishery, but with the same gear whereas a longline twice the length is generally used in commercial fishery for the second set of the day. The two daily sets were planned in the same ICES rectangle with one to three fishing days by statistical rectangle (but generally two) that must be at least 10 days apart. The survey area comprised 16 ICES rectangles extending along the shelf edge of the Bay of Biscay and the south Celtic Sea (Figure 2.3.6). Thus, the survey aimed to obtain systematic sampling of a core area of the former directed fishery in a time when this area is an important part of the porbeagle habitat as evidenced by PSAT deployments and commercial CPUEs. The positions of fishing stations were fixed and as far apart as possible. This sampling scheme and the daily change in ICES rectangle were intended to provide independent daily observations. This was verified by an analysis of the relationship between CPUEs on consecutive days when sets are made within 30 nautical miles of each other in contiguous statistical rectangles (Biais, 2022e).

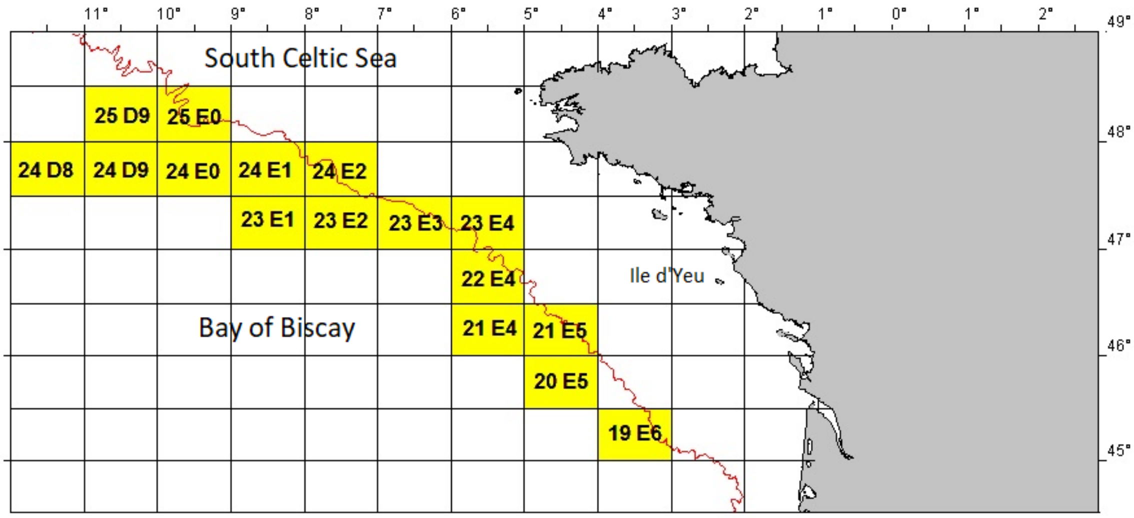


Figure 2.3.6: Statistical rectangles forming the French porbeagle survey area in the Bay of Biscay and the South Celtic Sea.

The combination of CPUEs of this survey with commercial CPUEs required that the latter be detailed, including specific positions, numbers of fish caught and hooks by set. Mandatory declarative logbooks do not provide these data, but it was possible to get them for a vessel of the directed fishery of which the captain provided his personal diaries for years 2000 to 2009. This vessel contributed to total French landing for about 10% each year from 2000 to 2008. In an initial attempt for combining commercial and survey CPUEs, the commercial CPUEs were scaled to 336 hooks and a selection of sets was made to mimic the survey sampling plan, using only CPUEs from May-June and within the survey area. In its presentation, WKELASMO suggested an analysis of the possible difference in catchability between longline sets with 3 or 4 lines (252-336 hooks), usually in the morning, and sets with 9 or 10 lines (756-840 hooks), usually in the afternoon. The results of this analysis showed that scaling to the same number of hooks was insufficient to properly incorporate the difference between the two types of longlines.

Consequently, a GLM was considered to be a better method to combine all CPUEs, including the type of longline in the variables (Biais, 2022f). Nevertheless, in order to limit the number of types of longline to two (252-336 hooks or 756-840 hooks), given the number of commercial CPUE available (n=740), a scaling to the same number of hooks was kept, assuming that the catchability is not affected by a small difference in number of hooks within each type. To select independent observations, as the survey CPUEs are, due to its sampling design, an analysis based on Kendall's rank correlations was performed as for the Norwegian longline CPUEs. It shows that CPUEs are independent observations after one day when 252-336 hooks are used and after two days when 756-840 hooks are used. According to this result, it appears more difficult to track porbeagle in the Bay of Biscay and in the southern Celtic Sea than in northern European waters, but the reason remain speculative (fishing technique, environment, prey density…).

When two consecutive CPUEs are 50 NM apart, they were considered independent observations because they are not in contiguous ICES rectangles, using the same rationale than for the Norwegian CPUEs. Consequently, two series of independent CPUEs were constructed based on the distance and number of days between sets, one for each type of long line. In addition, a final possibility of improvement of the consistency between survey and commercial CPUEs was investigated by examining the distribution per ICES rectangle of commercial CPUEs.

Because a systematic sampling plan is adopted for the survey, the number of statistical rectangles visited during the survey is independent of the porbeagle distribution. The fishing effort of a commercial vessel is naturally more limited on area of low porbeagle density. To investigate this possible relationship between CPUEs and set distribution (Biais 2022 g), the series of independent CPUEs resulting from 252 or 336 hook sets was used because they form a longer series (n= 252) than the 756 or 840 hook CPUE series (n= 224), due to the selection to get independent observations. The survey area was divided in two parts: a northwestern subarea (North 47°N and west 7° W), which includes about half of ICES rectangles of the survey area, and the rest outside this NW subarea. Using the mean by ICES rectangle in May-June (survey months), to limit the effect of set distribution by rectangle, the mean CPUE was calculated by subarea (of the survey area) for every year. The proportion of ICES rectangles with longline sets in these subareas was also calculated in May-June every year. Then, the relationship between the proportion of set in the NW subarea and the mean CPUE outside this area in May-June was examined. As expected, there is a negative correlation between these two quantities (Figure 2.3.7). The relationship is linear with a slope significantly different from zero at alpha level of 0.05 (p-value<0.01). Therefore, the CPUEs outside the NW area provide a basis to estimate the number of ICES rectangles of the NW area where the commercial vessel would have set longlines in 2018 and 2019 with its usual fishing behaviour.

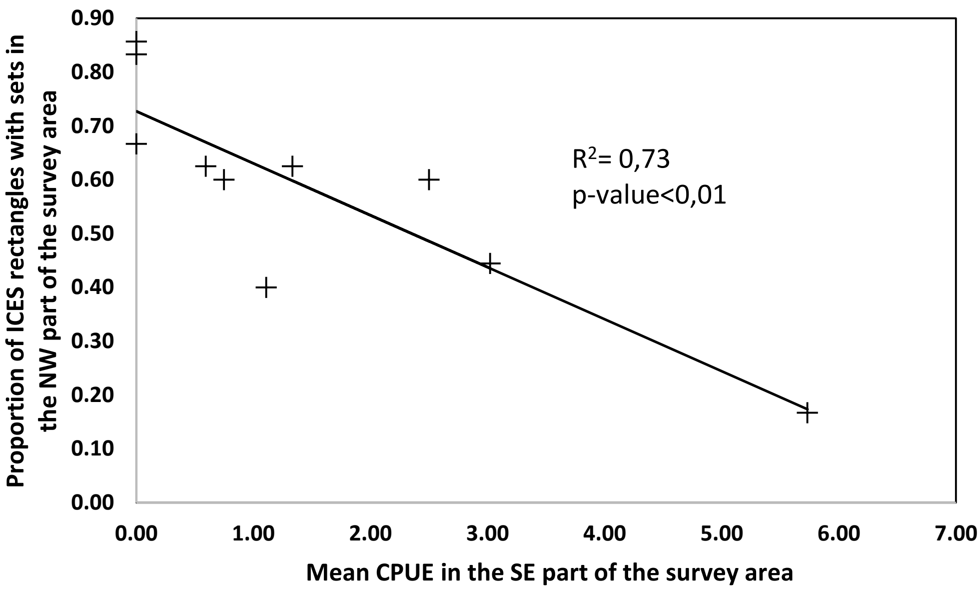


Figure 2.3.7: Porbeagle in the NEA – Relationship between the proportion of ICES rectangles with sets in the NW part of the survey area (North 47¨N and West 7°W) and the mean CPUE of ICES rectangles South 47¨N and East 7°W in the survey area in May-June.

In these two years, the CPUE outside the NW area (i.e. in the southeastern part of survey area) are 5.3 and 4.4 porbeagle per set respectively, thus within the range of values used for estimating the linear relationship. They can therefore be used to estimate the proportion of ICES rectangles with sets in the NW area in 2018 (21%) and in 2019 (30%). These proportions and the number of rectangles with sets in the SE part of the survey area (7 in 2018 as in 2019) allow us to estimate that the number of rectangles in the NW area should have been 2 in 2018 and 3 in 2019 to have a distribution of sets by area similar to than that observed for the commercial vessel whose CPUEs are used to extend the survey series.

To obtain a consistent CPUE series, some ICES rectangles must consequently be selected among the rectangles with sets in 2018 (n=9) or in 2019 (n=8) in the NW area. The mean CPUEs in May-June outside the NW area can easily be grouped in two categories, depending on whether theirs mean CPUEs are above the mean or not, with large gap between the means of the two groups, with one having a mean CPUE nearly seven times higher than the other. The 2018 and 2019 CPUEs are obviously in the group of high CPUEs as they are about three times the 2000-2009 mean CPUE. Three years make up this group from 2000 to 2009: 2000, 2002 and 2009. In these years, the three ICES rectangles more frequented (by number of years) are 25D9, 25E0 and 24D9, in descending order of frequentation and priority to the easternmost rectangle in case of equality (25E0 and 24D9), considering that the vessel should navigate from east to west when exploring the NW area along the shelf edge. Therefore, only the CPUEs in these three ICES rectangles 25D9, 25E0 and 24D9 (25D9 and 25E2 in 2018, all three in 2019) must be selected to obtain a survey series comparable to the commercial series that complement it.

With regard to the commercial CPUEs, when independent observations are made using 252 or 336 hooks, they are comparable to the survey CPUEs (after scaling to 336 hooks when 252 hooks are deployed), considering that the fishing technique is identical, that the vessel in based on Yeu Island in both cases, with the consequence that crew skill is similar and that the possible "skipper effect" is eliminated by the criteria set to obtain independent observations. A unique series can then be created to complement the survey CPUEs (including only those in selected ICES rectangles in the NW area) back to 2000 with comparable commercial CPUEs. The full CPUE series to standardize was formed by adding the CPUEs when 756 or 840 hooks are used, also scaled to the same number of hooks. This full CPUE series is referred as composite survey CPUE series later in the report.

The standardisation process was conducted with GLM using a Tweedie error distribution because data are continuous and include null values, with the usual choice of a log link. The model selection was done with the full series of survey CPUEs, because it was done before noticing the need to compare the spatial distribution of commercial and survey CPUEs. It was assumed that the removal of few CPUEs in two years (n=21 out of 535) has no consequence on the analysis previously performed to select the final model.

Four variables were considered for inclusion in the models tested: the year, type of longline (252-336 hooks or 756-840 hooks), month or period (February-April, May-June, July-September), to have periods before, during and after the survey, as an alternative to the month that limits the risk of over parametrisation, area (Celtic Sea north 48°30N, North Bay of Biscay from 45°N to 48°30N, South Bay of Biscay south 45°N) to catch the effect of the survey area (North Bay of Biscay), as the number of observations forces the ICES rectangle to be merged into larger spatial units. The selection of the final model was based on five folds cross validations, Akaike's Information Criteria and quantile residual plots, like for the other GLM. This model involves the year, the type of longline and the area. The relative abundance index obtained shows a moderate increase of abundance of porbeagle in the Bay of Biscay and the southern Celtic Sea area from 2009 to 2019 (Figure 2.3.8).

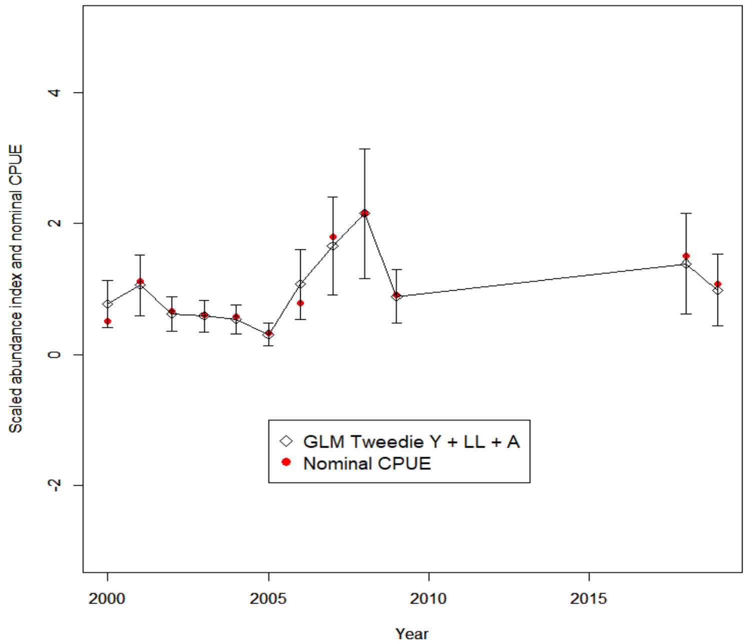


Figure 2.3.8: Relative annual indices (scaled by the mean) provided by the final GLM (Tweedie error distribution with a log link) selected to standardize the composite survey CPUEs (variables included: year, type of longline and area), with the nominal CPUEs scaled by the mean.

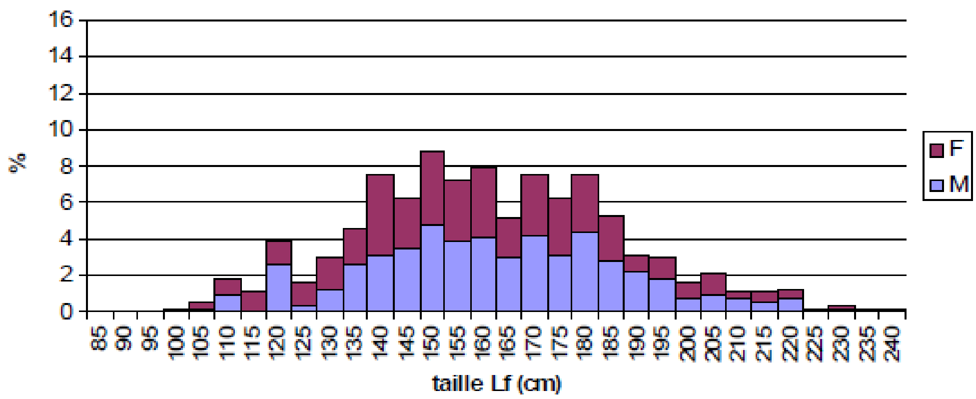
To obtain a biomass index for doing a SPiCT assessment with indices and catch in weight, a mean weight series must be made available. A weight-length relationship based on landing data collected in 2008-2009 (Hennache and Jung, 2010) was used with length distributions from April to June of these two years (not available for each year separately) to calculate a mean weight for 2008-2009. Since the survey was carried out in May-June and that 80% of the commercial CPUEs selected to complement the survey are from April-June, the use of landing length distribution in these last three months (in Hennache and Jung, 2010) appeared relevant to provide biomass indices comparable to those of the survey and representative of the catch used to complement the survey CPUEs. The mean weight thus calculated is 59 kg.

This mean weight is above the values reported for May-June from 1980 to 1989 which are comprised between 42 and 53 kg (Lallemand-Lemoine, 1991), but the mean weight reported for July (61 kg) is greater than in 2008-2009 (44 kg). The higher July value in the 1980s likely indicates a sampling from the shelf edge when in July 2008-2009, the length distribution may have included samples from the Celtic Sea where the French fishery used to move in summer and where the fish are smaller. However, this shows that the mean weights do not appear to have changed much between the 1980s and 2000s. Given this observation, but also the low dynamic of porbeagle populations and the likely stability of the exploitation pattern in the absence of changes in fishing gears and practices in the French fishery in the 2000s, a stability of the length distribution of the exploitable population of porbeagle from 2000 to 2008 appear an acceptable assumption. That supports using the 2008-2009 mean weight from 2000 to 2009 to convert the composite survey abundance index into a biomass index.

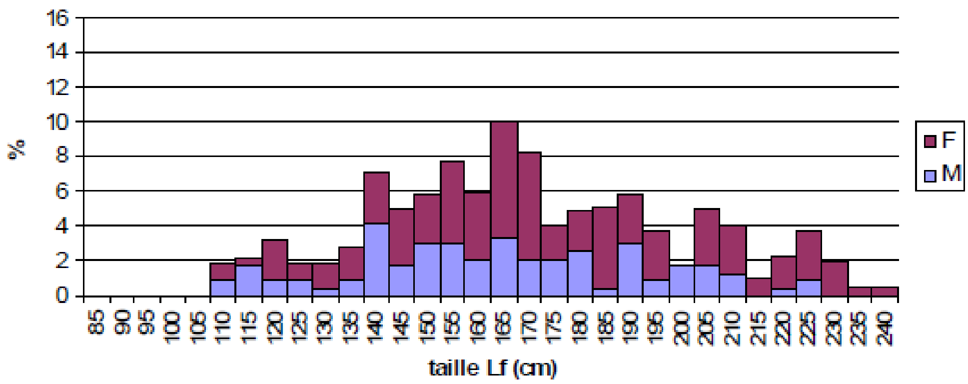
The 2018 and 2019 mean weights were obtained using the available weight-length relationship and the length distributions of survey catches. They are respectively 78 and 72 kg, values in agreement with the observed shift to the right of the length distribution between 2008-2009 and

2018-2019 (Figure 2.3.9). The mean weights obtained were used to transform the composite survey abundance index in a biomass index by multiplying each annual abundance index by the corresponding annual mean weight (Figure 2.3.11).

May 2008-2009 (n=570)



June 2008-2009 (n=237)



May-June 2018-19 (n=299)

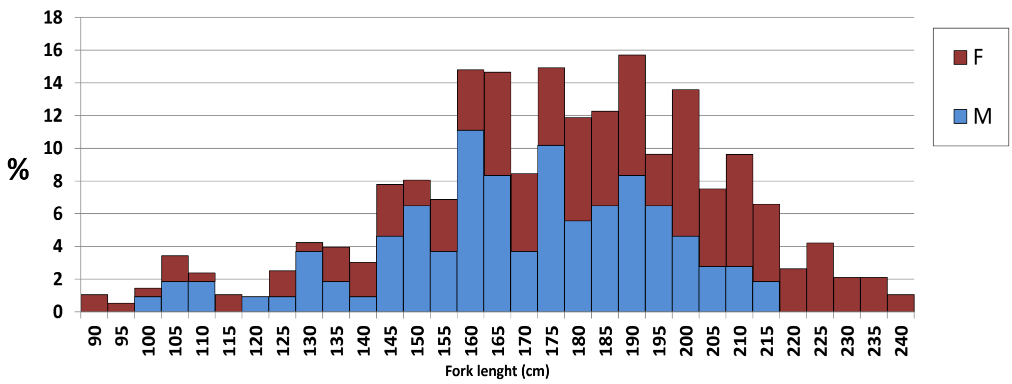


Figure 2.3.9: Comparison of the length distributions of the survey in 2018-2019 and in landings in the same months in 2008-2009 (source Hennache and Jung, 2010).

The Spanish longline CPUE series

The Spanish longline CPUE series was presented at the 2009 ICCAT-ICES porbeagle stock assessments meeting (ICCAT 2010; Mejuto *et al*., 2010). CPUEs were provided by trips (in kg round weight per thousand hooks) of the surface longline targeting swordfish in the whole North Atlantic, from 1986 to 2007. For 88% of the trips (n=15458) no porbeable was found. At the request of the 2009 ICCAT-ICES working group, an analysis restricted to two zones (#4 and 5) in the eastern Atlantic (East 20°W from 35°N to 55°N) was carried out to be used in the assessment. 5844 trips were reported in this area from 1986 to 2007 for 5699 porbeagle caught. The portion of this area north of 45°N comprises about half of these catches, although it is reported that traditional longline appears in this zone only sporadically during certain years and quarters. Some of the trips carried out during 1980s in this area are also indicated to may have taken advantage of sporadic local concentrations of porbeagle. CPUEs were standardized using GLM procedures assuming a delta-lognormal distribution error. The final model was selected using Akaike's Information Criteria, Bayesian Information Criteria and the likelihood ratio test (variables included: year, zone, quarter, bait, year*zone, year*quarter). The relative abundance index obtained (Figure 2.3.10) includes higher values in the 2000s, with large interannual variations.

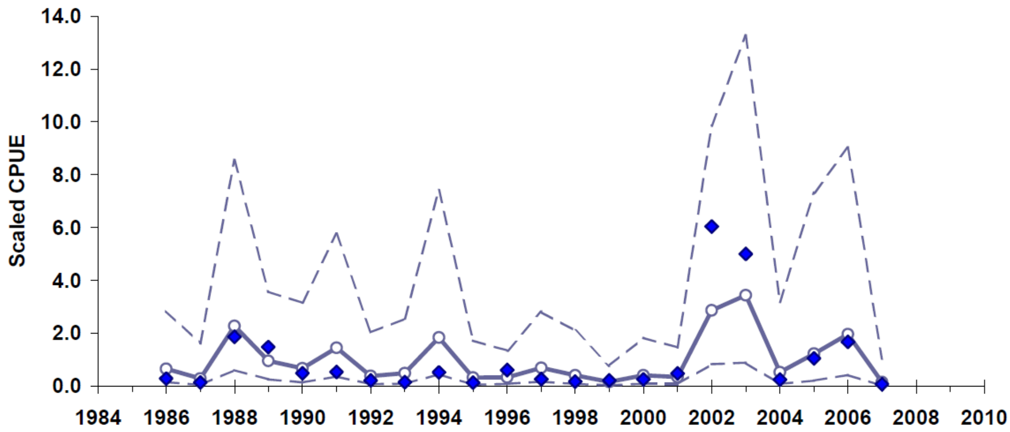


Figure 2.3.10: Standardized CPUE of porbeagle caught as by-catch of the Spanish surface longline fishery targeting swordfish, provided by the GLM selected (delta-lognormal distribution error; variables included: year, zone, quarter, bait, year*zone, year*quarter) with confidence limits and mean nominal CPUEs (blue rhombuses).

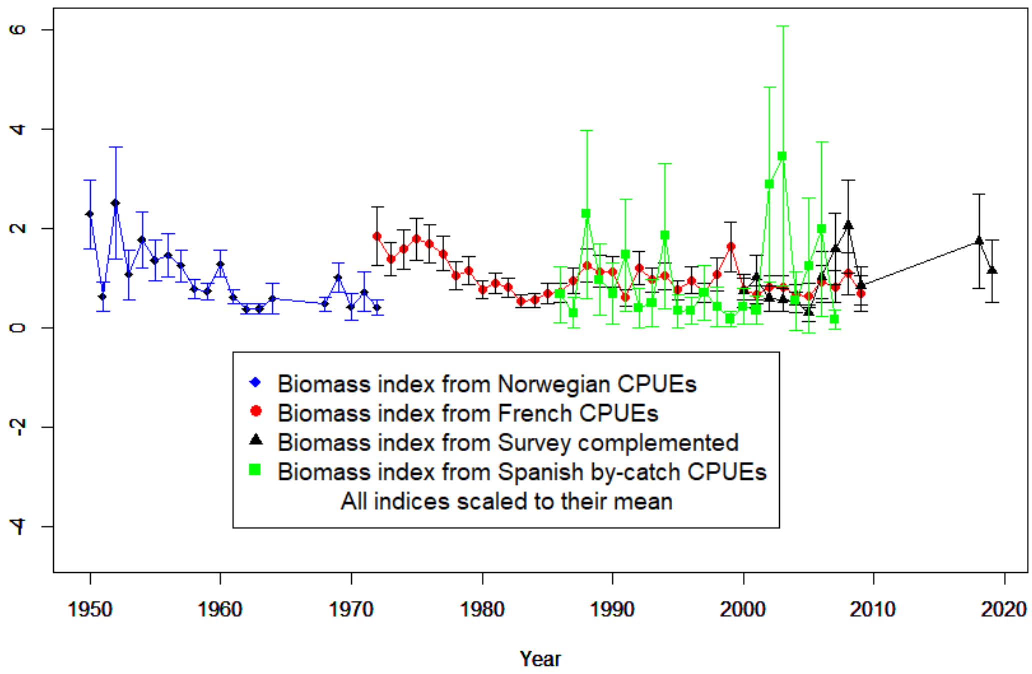


Figure 2.3.11: Biomass indices used in the porbeagle SPiCT runs provided by the standardization of the four available CPUEs series.

2.3.3 Life-history parameters

SPiCT model runs were carried out using 0.059 yr^{-1} as a prior for the intrinsic growth-rate (r). This value was computed for the western Atlantic porbeagle population (Cortes and Semba, 2020).

2.4 Stock assessment

For all SPiCT (Pedersen and Berg, 2017) runs presented at the WKELASMO, the acceptance was examined with the list of criteria recommended by Mildenberger *et al.* (2020). Analyses were conducted in 3.6.3 (R Core Team, 2020) using the ellipse (Murdoch and Chow, 2020), SPiCT (Pedersen and Berg, 2017) and TMB (Thygesen *et al*., 2017) packages.

Exploratory assessments with JABBA (Winker *et al*., 2018) were also presented. This Bayesian state-space surplus production model framework provides a comprehensive toolbox to conduct model diagnostics to objectively evaluate the four model plausible criteria recommended in Carvalho *et al.* (2021): (1) model convergence (2) fit to the data, (3) model consistency (retrospective pattern) and (4) prediction skill through hindcast cross-validation. More information on use of the 'JABBA' R package can be found in Ortiz *et al.* (2022) and in Winker *et al*. (2018).

Prior to the development of a Norwegian directed fishery with first landing reported in 1926, all available information seems to show that porbeagle was only caught incidentally in limited quantities by Norwegian fisheries in the absence of a local market. No other fishery appears to have existed before 1946. There is therefore every reason to believe that the stock was very little exploited before 1926 and its biomass was close to the virgin state. The prior for the biomass ratio to the carrying capacity was consequently fix to 0.99 in all exploratory assessments carried with SPiCT, considering this prior informative (sd log (B/K)=0.2).

2.4.1 Exploratory assessments

Four sets of SPiCT exploratory runs were presented at the WKELASMO.

The first one (Biais, 2022h) did not include the Spanish longline index because the benefit of using it was discussed later. It included five runs (see below), starting with a Schaefer model as a reference run (informative prior for n set to 2). In subsequent runs, the prior for n remains set at 2, but with a different sd of log(n) in R3 to R5, and with no change in priors for B/K (or same basis of unfished biomass in 1926 when the starting year of the run is changed) and r:

- → R1 Reference run with a Schaefer model (prior for n=2, sd of log(n)=0.2);
- → R2 Robust estimation flag on catches to verify if this option could improve the diagnostics of the reference run in which the Shapiro test for normality of catch residuals fails to pass;
- → R3 Semi-informative prior for n (sd of log(n)=0.5), because the posterior value below 2 seemed to indicate that a lower n could provide a less flat production curve;
- → R4 Same as R3 but starting in 1950 to test whether the fit is improved when the run is restricted to years for which biomass indices are available;
- → R5 Relative sd of catches five times that of 2010, due to the uncertainty in discards size since 2010, with a semi-informative prior for n.

This initial exploration of using the SPiCT model with new data presented to the WKELASMO suggested a better fit when using a semi informative prior for n, implying a Fox model (posterior n close to 1), and a higher relative sd of catches from 2010 onwards (run R5), with no benefit from other options.

The parameter of the run R5 were selected for an exploratory assessment with JABBA that compared this run with an alternative scenario including the Spanish longline index (Ortiz *et al*., 2022). Both scenarios are consistent with SPiCT run R5, with respect to B/B_{MSY} and F/F_{MSY} trends. The JABBA criteria for plausible model acceptance are met for both scenarios, but the incorporation of the Spanish index degrades the precision of the fit. Considering that both runs are plausible, Ortiz *et al*. (2022 a) suggest to select the scenario that incorporates all available indices.

A second set of SPiCT exploratory runs was also provided by Ortiz *et al*. (2022 b). Like the JABBA exploratory assessment, it allows to compare run R5 of the set #1 with a run having the same priors but incorporating the Spanish index (Run Ref). Four additional sensitivity runs were added, all incorporating the Spanish index:

- → S1 Terminal year 2010 = same as Run Ref, but end catch and index series in 2010.
- → S2 Terminal year 2015 = same as Run Ref, but end catch and index series in 2015.
- → S3 Higher r prior assumptions = increase the mean r prior by a factor of three (3*0.059) same standard error of 0.2 as Run Ref.
- → S4 Low standard error for the Survey index = assuming a higher precision of the composite survey index (0.5 * se Index) compared to the fisheries dependent CPUE series.

Based on the results from these sensitivity runs, the Run Ref was proposed to be the final model. Comparison with the JABBA assessment incorporating the Spanish index again shows good consistency between the trends of two models, with JABBA B_{2020}/B_{MSY} being slightly above the SPiCT estimate (0.51 vs 0.47).

However, the choice of a prior for n leading to a posterior n close to 1 was pointed out as being in contradiction with a low prior for r. Indeed, this later implies a low productivity, as expected for a porbeagle stock, whereas n close to one implies a productive stock. Therefore, a third set of 8 exploratory SPiCT runs was presented, all with an informative prior for n set to 2 (sd log(n)=0.2), but with a comparison of runs when the prior for r (still set to 0.059) is informative (sd log(r)=0.2) or semi-informative (sd log(r)=0.5), whether the Spanish index is incorporated or not.

This set of runs incorporated the composite survey index whether the spatial distribution of survey observations in 2018 and 2019 is adjusted to that of the commercial vessel observations during 2000-2009 or not. It shows that B/B_{MSY} Mohn's rho are reduced with the adjusted series. The benefit of a more consistent series was thus confirmed. On other hand, the incorporating the Spanish index has larger consequences on acceptance criteria. Without this index, the runs with a semi-informative prior on r (sd log(r)=0.5) meet the all the acceptance criteria with a posterior r low enough to be considered realistic for the species; but, when the Spanish index is inserted, the runs with a semi-informative prior on r are not acceptable because a significant F/F_{MSY} retrospective pattern with peels in years 3 and 4 largely above the others in their terminal years. The solution of adding a prior on the sd of the Spanish index with a high value was tried, without changing the results much. Since the majority of WKELASMO members were in favour incorporating the Spanish index, the run with an informative prior on r was selected, although the F/F_{MSY} Mohn's rho was high (> 0.4). The presentation of results of these runs is available on the WKELASMO sharepoint (presentation folder). However, it was noted after the presentation that the index sd's should have been scaled to their means rather to their minima to allow the prior on the sd of the Spanish index to have the intended effect.

Therefore, a fourth set of 10 exploratory runs was provided to compare runs (Tables 2.4.1 and 2.4.2; Figures available on the WKELASMO sharepoint in presentation folder):

→ when the Spanish index is not inserted (runs #1 and #2) or if it is (runs #3 to #10)

→ when the sd's of the priors for log(r) is 0.2 (run #1 and runs #3 to #5) or if it is 0.5 (run #6 to run #10)

→ when different priors are adopted for sd of the Spanish index. Three values were initially selected: 0.9, 1.2 and 1.8, considering that posterior sd of the composite survey index is about 0.6 in results of runs #1 and #2. Therefore, sensitivity runs with a prior for the sd of the Spanish index 1.5, 2 or 3 times higher seemed relevant. In addition, because the fit fails for more than 3 years in the retrospective analysis when sd of the priors for log(r) is 0.5 and prior for sd of the Spanish index is 0.9 (run #6), but not when this sd is 1.2 (run #9), the runs #7 and #8 were added to explore the effect of sd's of the Spanish index when it increase from 0.9 to 1.2.

As with set #3, the only runs that meet all the acceptance criteria without restriction are those with a semi-informative prior on r (sd for log(r) = 0.5). Theirs posterior r is again low enough to be considered realistic for the species (=0.09). However, the retrospective pattern is no longer an issue with sd for log(r) of 0.5 when inserting the Spanish index, considering higher uncertainty for this index (sd > 1).

As with set #3, the only runs that meet all the acceptance criteria without restriction are those with a semi-informative prior for r (sd for log(r) = 0.5). The retrospective pattern is no longer an issue when inserting the Spanish index, considering higher uncertainty for this index (sd > 1). As a result, there is now an advantage to use this index to meet the acceptance criteria. However, results are very similar whether the Spanish index is inserted or not when a semi-informative prior is used for r. The posterior r of these runs is again low enough to be considered realistic for the species (=0.09).

Table 2.4.1: Results of NEA Porbeagle stock exploratory SPiCT runs (set #4)
Indices: NO = Norwegian longline index; FR = French longline index; SUR = composite survey index; SP = Spanish longline index
Acceptance: see table 2.4.2 for criteria; Retrospective: Mohn's rho in red when rho > 0.2 or < -0.15

Scenario (changes between runs high-lighted in yellow)	Catch (years)	Indices		Priors: value and sd of log(value) between brackets			Acceptance	Estimates				Retropective : Mohn's rho		B2020.94/ B_{MSY}	F2020.94/ F_{MSY}	Stochastic reference points	
		List*	sd	n	B/K	r		n	K	r	B1950 /K	B/ B_{MSY}	F/ F_{MSY}			B_{MSY}	F_{MSY}
# 1 - Reference	1926-2020	NO + FR + SUR	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.2)	Yes but	1.76 [1.15-2.68]	75398 [32588-174450]	0.063 [0.043-0.094]	38223/75398 = 0.51	0.09	0.46	0.41 [0.12-1.48]	0.02 [0-0.11]	28998 [12614-66667]	0.03 [0.01-0.07]
# 2 - identical to run #1 with with priors on sd r= 0.5	1926-2020	NO + FR + SUR	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.5)	Yes but	1.75 [1.17-2.61]	61580 [26298-144197]	0.087 [0.038-0.202]	29647/61580 = 0.48	0.08	0.32	0.44 [0.14-1.42]	0.02 [0-0.09]	25404 [11413-56547]	0.05 [0.02-0.13]
# 3 - identical to run #1 with SPA index and prior on its sd c(log(0.9),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.2)	Yes but	1.75 [1.14-2.66]	73175 [34621-154664]	0.064 [0.043-0.094]	36191/73175 = 0.49	0.11	0.36	0.38 [0.12-1.21]	0.02 [0-0.11]	29526 [13919-62632]	0.03 [0.01-0.07]
# 4 - identical to run #3 with prior on sd of SP index c(log(1.2),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.2)	Yes but	1.74 [1.14-2.66]	73293 [34485-155774]	0.064 [0.043-0.094]	36311/73293 = 0.5	0.07	0.37	0.39 [0.12-1.25]	0.02 [0-0.11]	29485 [13833-62849]	0.03 [0.01-0.07]
# 5 - identical to run #3 with prior on sd of SP index c(log(1.8),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.2)	Yes but	1.75 [1.15-2.67]	74126 [33748-162812]	0.063 [0.043-0.094]	37072/74126 = 0.5	0.05	0.40	0.4 [0.12-1.33]	0.02 [0-0.11]	29328 [13366-64352]	0.03 [0.01-0.07]
# 6 - identical to run #2 with SPA index and prior on its sd c(log(0.9),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.5)	No	1.74 [1.17-2.58]	59894 [27919-128489]	0.089 [0.039-0.2]	28065/59894 = 0.47	0.27 (3 yrs)	-0.13 (3 yrs)	0.42 [0.14-1.27]	0.02 [0-0.09]	25534 [12271-53132]	0.05 [0.02-0.13]
# 7 - identical to run #4 with prior on sd of SP in-dexc(log(1.0),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.5)	Yes	1.74 [1.17-2.58]	59822 [27922-128169]	0.089 [0.04-0.199]	28025/59822 = 0.47	0.20 (4 yrs)	0.02 (4 yrs)	0.43 [0.14-1.28]	0.02 [0-0.08]	25508 [12270-53028]	0.05 [0.02-0.13]
# 8 - identical to run #4 with prior on sd of SP index c(log(1.1),0.1,1)	**1926-2020**	**NO + FR + SUR +SP**	**Yes**	**2 (0.2)**	**0.99 (0.2)**	**0.059 (0.5)**	**Yes**	**1.74 [1.17-2.58]**	**59837 [27875-128450]**	**0.089 [0.04-0.199]**	**28054/59837 = 0.47**	**0.16**	**0.11**	**0.43 [0.15-1.29]**	**0.02 [0-0.08]**	**25495 [12245-53084]**	**0.05 [0.02-0.13]**
# 9 - identical to run #4 with prior on sd of SP index c(log1.2),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.5)	Yes	1.74 [1.17-2.58]	59903 [27798-129087]	0.089 [0.04-0.199]	28123/59903 = 0.47	0.16	0.11	0.43 [0.15-1.29]	0.02 [0-0.08]	25488 [12204-53232]	0.05 [0.02-0.13]
# 10- identical to run #4 with prior on sd of SP index c(log(1.8),0.1,1)	1926-2020	NO + FR + SUR +SP	Yes	2 (0.2)	0.99 (0.2)	0.059 (0.5)	Yes	1.74 [1.17-2.59]	60594 [27201-134985]	0.088 [0.039-0.2]	28754/60594 = 0.47	0.11	0.18	0.44 [0.14-1.34]	0.02 [0-0.08]	25481 [11887-54623]	0.05 [0.02-0.13]

Table 2.4.2: Acceptance of NEA Porbeagle stock SPiCT runs presented at the WKELASMO online meeting
Conclusion (bottom line) is Y (Yes) when all the acceptance criteria are met, "Y but" when criteria are not met for the order of magnitude of F/FMSY (≤1) and its Mohn's rho (should –be comprised between -0.15 and 0.2), but the acceptance can be discussed considering that the very low catches since 2010 limit the quality of this criteria. Conclusion is No when B/BMSY Mohn's rho is not comprised between -0.15 and 0.2.
The results of the tests for normality of the capture residuals and bias or normality of the residuals of indices 3 and 4 are not considered as criteria that can prohibit acceptance of the series because the observed hypothesis violations are due to a small number of annual values.

# run	1	2	3	4	5
Convergence	Y	Y	Y	Y	Y
All variance parameters of the model parameters are finite	Y	Y	Y	Y	Y
No violation of model assumptions based on one-step-ahead residuals (bias, auto-correlation, normality)	No for normality of catch residuals	No for normality of catch residuals	No for normality of catch residuals and bias/normality residuals index 3 and 4	No for normality of catch residuals and bias/normality residuals index 3 and 4	No for normality of catch residuals and bias/normality residuals index 3 and 4
Consistent patterns in the retrospective analysis	Y for B/ B_{MSY} but Mohn's rho F/F_{MSY} =0.46	Y for B/ B_{MSY} but Mohn's rho F/F_{MSY} =0.32	Y for B/ B_{MSY} but Mohn's rho F/F_{MSY} =0.36	Y for B/ B_{MSY} but Mohn's rho F/F_{MSY} =0.37	Y for B/ B_{MSY} but Mohn's rho F/F_{MSY} =0.40
Realistic production curve	Y	Y	Y	Y	Y
Assessment uncertainty	N OM B/B_{MSY} =1 OM F/F_{MSY} =2	Y	N OM B/B_{MSY} =1 OM F/F_{MSY} =2	N OM B/B_{MSY} =1 OM F/F_{MSY} =2	N OM B/B_{MSY} =1 OM F/F_{MSY} =2
No influence of initial values on the parameter estimates	Y	Y for 28/30 fits (1 fits failed)	Y for 28/30 fits (2 fits failed)	Y for 26/30 fits (4 fits failed)	Y for 27/30 fits (2 fits failed 1 large distance)
Conclusion	Yes but	Yes but	Yes but	Yes but	Yes but

Table 2 (continued): Acceptance of NEA Porbeagle stock SPiCT runs presented at the WKELASMO on line meeting.
Conclusion (bottom line) is Y (Yes) when all the acceptance criteria are met, "Y but" when criteria are not met for the order of magnitude of F/FMSY (≤1) and its Mohn's rho (should –be comprised between -0.15 and 0.2), but the acceptance can be discussed considering that the very low catches since 2010 limit the quality of this criteria. Conclusion is No when B/BMSY Mohn's rho is not comprised between -0.15 and 0.2.
The results of the tests for normality of the capture residuals and bias or normality of the residuals of indices 3 and 4 are not considered as criteria that can prohibit acceptance of the series because the observed hypothesis violations are due to a small number of annual values.

# run	6	7	**8**	9	10
Convergence	Y	Y	**Y**	Y	Y
All variance parameters of the model parameters are finite	Y	Y	**Y**	Y	Y
No violation of model assumptions based on one-step-ahead residuals (bias, auto-correlation, normality)	No for normality of catch residuals and bias/normality residuals index 3 and 4	No for normality of catch residuals and bias/normality residuals index 3 and 4	**No for normality of catch residuals and bias/normality residuals index 3 and 4**	No for normality of catch residuals and bias/normality residuals index 3 and 4	No for normality of catch residuals and bias/normality residuals index 4
Consistent patterns in the retrospective analysis	Y for F/F_{MSY} (3 years) but Mohn's rho B/B_{MSY} =0.27	Y (4 years)	**Y**	Y	Y
Realistic production curve	Y	Y	**Y**	Y	Y
Assessment uncertainty	Y	Y	**Y**	Y	Y
No influence of initial values on the parameter estimates	Y for 25/30 fits (4 fits failed and 1 large distance)	Y for 23/30 fits (7 fits failed)	**Y for 29/30 fits (1 fit failed)**	Y for 23/30 fits (7 fits failed)	Y for 25/30 fits (4 fits failed and 1 large distance)
Conclusion	No	Yes	**Yes**	Yes	Yes

2.4.1 Final assessment

In the final set of exploratory runs, runs #8, #9 and #10 are very similar in terms of diagnostics, parameter point estimates and uncertainty. The Shapiro´s p-values of the composite survey index differ slightly among these runs, with runs #8 and #9 showing values slightly below the 5% significance level (0.0426 for run #8 and 0.0458 for run #9); the p-value for run #10 is 0.0635. However, run #8 resulted in a lower number of failures when testing the influence of initial values on the parameter estimates (1 fit failed) compared to run #9 (7 fits failed) and run #10 (4 fits failed and 1 large distance), supporting accepting run #8 as the final assessment.

In the diagnostics of this run (Figure 2.4.1), the Shapiro test for the normality of catch residuals fails, as with other exploratory runs, because the decline in catches due to the second Word War and fishing regulations implemented since 2010. In addition to the Shapiro's p-value of the composite survey index (#3) just below 0.05, this test as well as the test for bias fail to pass for the Spanish longline index (#4). As for the catch residuals, this is due to one or two residuals and, therefore, these results are not considered to show a violation of assumptions that could invalidate the model run.

The production curve appears rather flat because substantial process error, but this is not unusual (Figure 2.4.2). The exploited biomass decreases below B_{MSY} in the early 1950s. Despite an increase in the 2010s due to the fishing restriction in place since 2010, B/B_{MSY} is well below B_{MSY} in 2020. The retrospective patterns are consistent (Figure 2.4.3).

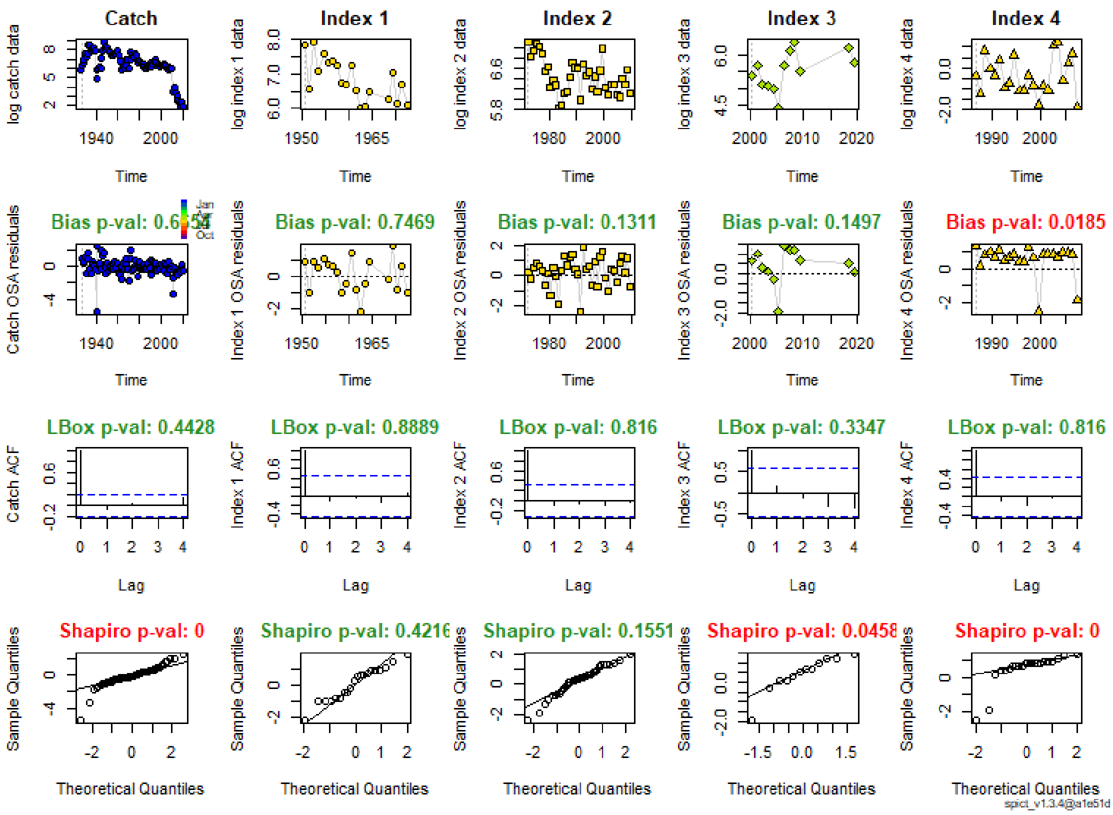


Figure 2.4.1: Diagnostics plots of the final assessment of NEA porbeagle stock (por.27.nea).
Index 1: Norwegian longline biomass index
Index 2: French longline biomass index
Index3: Composite survey biomass index
Index4: Spanish longline biomass index

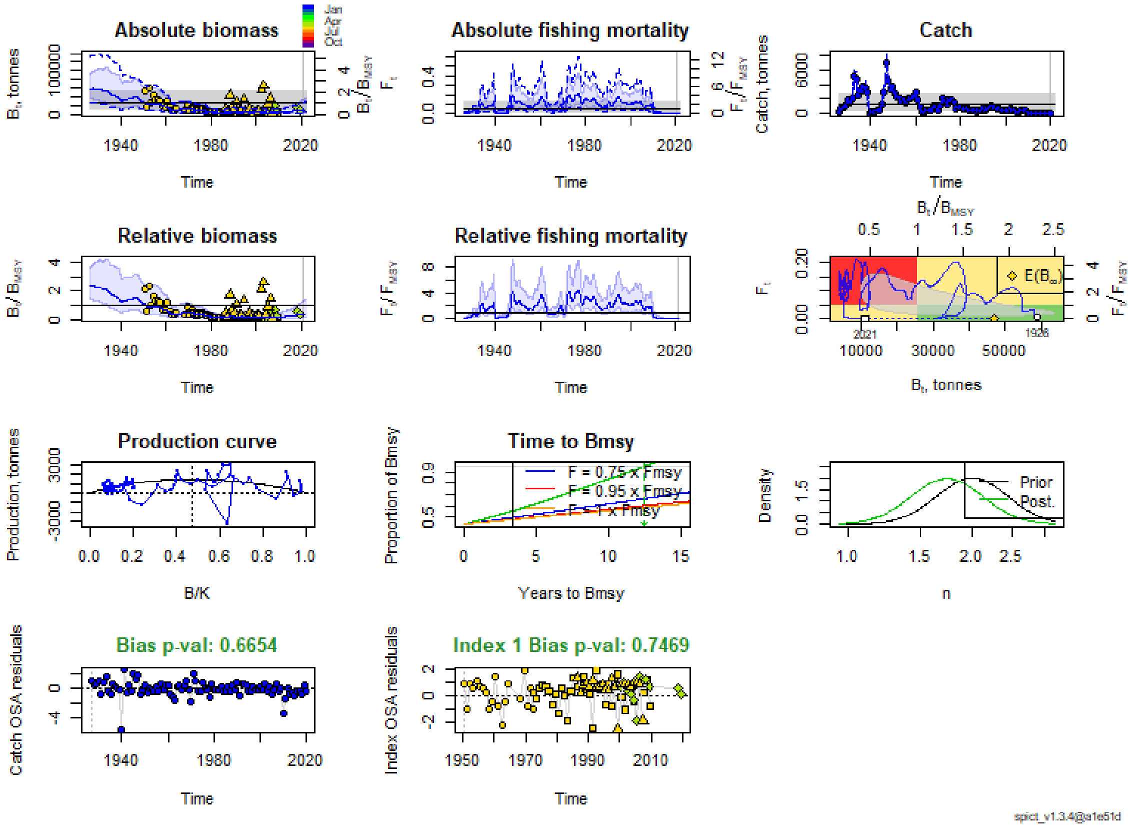


Figure 2.4.2: Result plots of the final assessment of NEA porbeagle stock (por.27.nea).

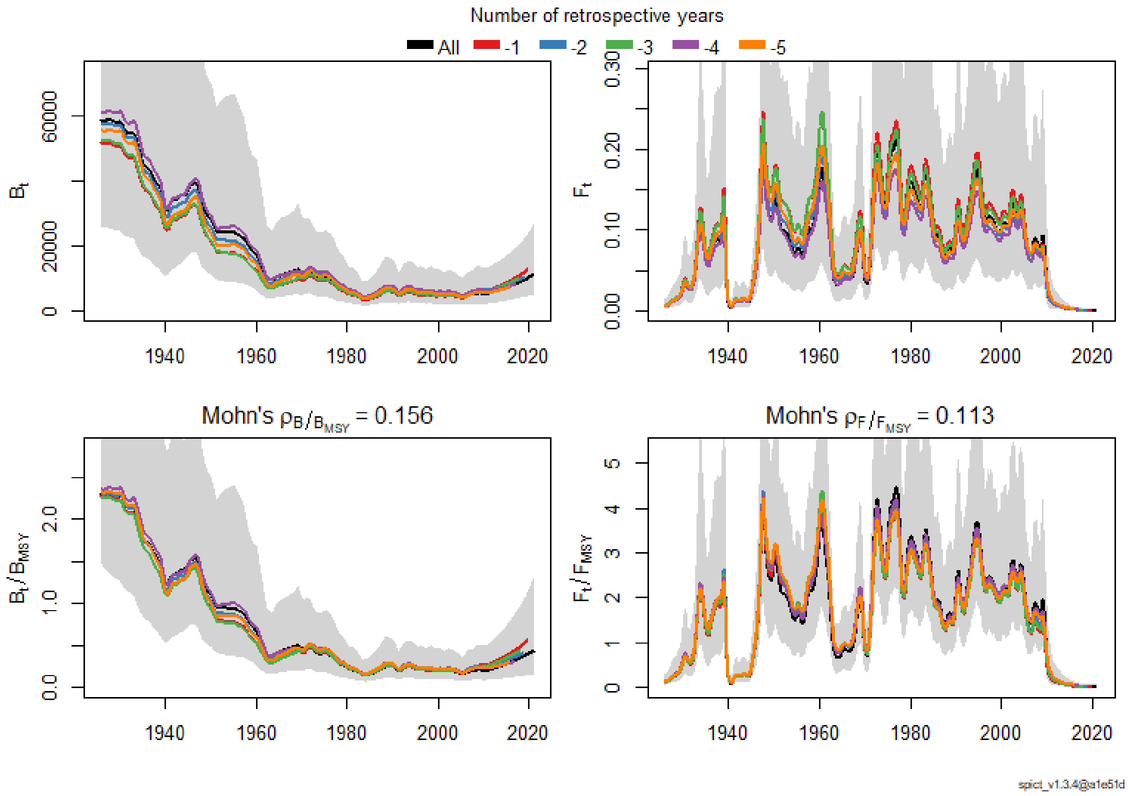


Figure 2.4.3: Retrospective plots of the final assessment of NEA porbeagle stock (por.27.nea).

2.4.2 Forecast

A forecast was made for information. The "manage()" function in the spict R package was used with the scenario 8. The forecast was carried out using a target fishing mortality (F=0.03) which is the Fmsy reduced (since the estimated biomass is below MSY Btrigger) and followed the fractile rule proposed by WKMSYCat34 (ICES 2017). The corresponding catch are 324t, B/B_{MSY} is 0.49 [0.15,1.6] and F/F_{MSY} is 0.56 [0.05,6.28].

2.5 Future considerations/recommendations

Genetic studies for individuals from different regions (at least Bay of Biscay –Celtic Sea and North Sea - Norwegian Sea) should be continued or initiated, in order to confirm possible genetic differences between behavioural groups that may return to different spring-summer feeding areas each year. The need for appropriate sampling should be emphasized (small individuals, fish tagged with PSATS).

The PSAT deployments should be continued with attempts to obtain tracks in consecutive years. The planned PSAT deployments in northern European waters (by Norway) are welcomed to contribute to the knowledge of the stock structure by showing whether porbeagle in the Norwegian sea in summer have the same migration pattern than those tagged in the Bay of Biscay and the South Celtic Sea.

The difficulty of estimating discards should necessitate a specific at sea observer program if porbeagle landings continues to be banned in most European countries.

The continuation of the spring-summer survey in the Bay of Biscay and the southern Celtic Sea would be beneficial to follow the evolution of the exploited biomass with a fishery-independent index. This extension would allow the value of the investment made to carry out the survey in 2018 and 2019, but also to extend the two-year series obtained with commercial data in order to constitute a coherent series to evaluate the effect of the fishing limitation measures adopted since 2010. The extension of this survey to other regions and/or additional surveys in other regions should be considered.

The wide variations in the Spanish longline CPUE series should require an examination of the spatial distribution of trips that may be the cause. The possibility of obtaining an area and over-wintering season index with this series should be investigated as well as its extension beyond 2007.

2.6 Reviewers' report

2.6.1 Stock ID

Steve Cadrin, Christoph Stransky, David Murray and Zachary Whitener

New information on genetics (Viricel *et al.,* 2021 WD) and tagging (Biais *et al*. 2022 WD, Righton *et al*., 2022 WD) was considered in the context of previously available information (reviewed by Ellis *et al*., 2022 WD and Haugen *et al*., 2022 WD). Porbeagle have anti-tropical distributions throughout the North Atlantic and southern hemisphere, and analyses of mitochondrial DNA (mtDNA) indicate genetically distinct populations in each hemisphere (Kitamura and Matsunaga 2010, n=53) but no apparent genetic structure within the North Atlantic (n=40 from the northwest Atlantic, n=35 from northeast Atlantic; Testerman 2014). A recent analysis of mtDNA confirms two separate populations in the North Atlantic and southern hemisphere and no genetic structure within the North Atlantic (n=70 northwest Atlantic, n=99 northeast Atlantic, n=2 Mediterranean markets; González *et al*. 2021). Life history information also suggests a relatively homogeneous population in the North Atlantic with only minor regional differences (Ellis *et al*., 2022 WD, Haugen *et al*., 2022 WD). Genetic and life history patterns suggest that there is sufficient reproductive connectivity to maintain a single genetic population in the North Atlantic, apparently including the Mediterranean. Information from tagging suggests a low rate of movement between the northeast and northwest Atlantic, with one porbeagle tagged in Irish waters and recaptured on the Grand Banks ten years later (Cameron *et al*., 2018) from a total of 346 conventional tag recaptures (Ellis *et al*., 2022 WD), and location estimates from several archival tag deployments that indicate movement across the ICES-NAFO boundary(42°W) from porbeagle tagged in the Bay of Biscay (Figure 1, Biais *et al*., 2022 WD) and off the British Isles (Figure 2, Righton *et al*., 2022 WD). Thermal preferences and temperature distributions also suggest that movement between the northeast Atlantic and the Mediterranean is limited (Ellis *et al*., 2022 WD). Biais *et al.* (2022 WD) reported two general movement patterns to the north and to the west from porbeagle tagged in the Bay of Biscay (Figure 1), and preliminary genetic analysis of one mtDNA character from a few individuals in each behavioural group (n=10 north, n=9 west) suggest genetic differences (Viricel *et al*., 2021 WD).

In summary, most information available supports the conclusion that porbeagle consist of a single genetic population in the North Atlantic, which is relevant for determining species conservation status (Curtis *et al*., 2016). Preliminary results on genetic differences among behavioural groups in the northeast Atlantic (Viricel *et al*., 2021 WD) will need confirmation with more samples and genetic characters (ideally nuclear characters), and investigation of spatial overlap of the two behavioural groups (e.g., in the Bay of Biscay) will need to be considered for stock identification. The observed movement rates between the Northwest, Northeast Atlantic, and

Mediterranean appear to be low enough to consider separate spatial units for stock assessment and fishery management. Therefore, the information available supports the current ICES advisory unit (subareas 1-10, 12 and 14, the Northeast Atlantic and adjacent waters) extended southward to 5°N, the extent of the ICCAT North Atlantic fishing area (ICCAT, 2010).

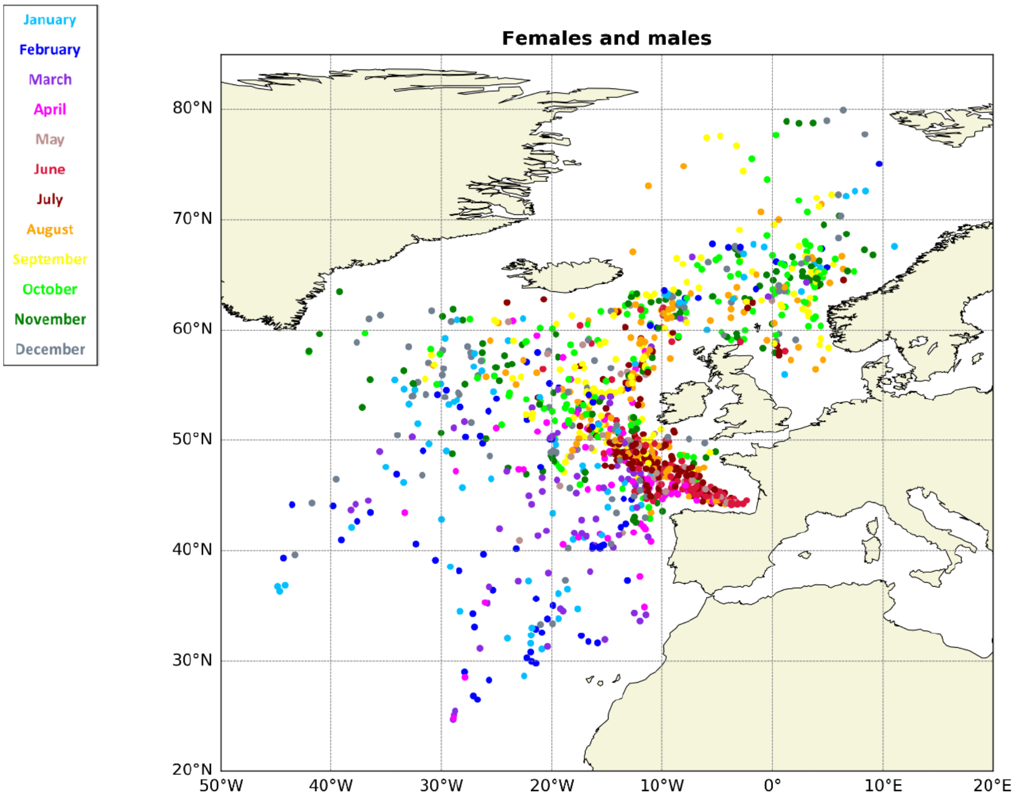


Figure 2.6.1. Estimated daily positions (coloured dots are 10 days apart) of 43 porbeagle tagged in the Bay of Biscay between May and July in 2011-2019 (from Biais *et al.*, 2022 WD).

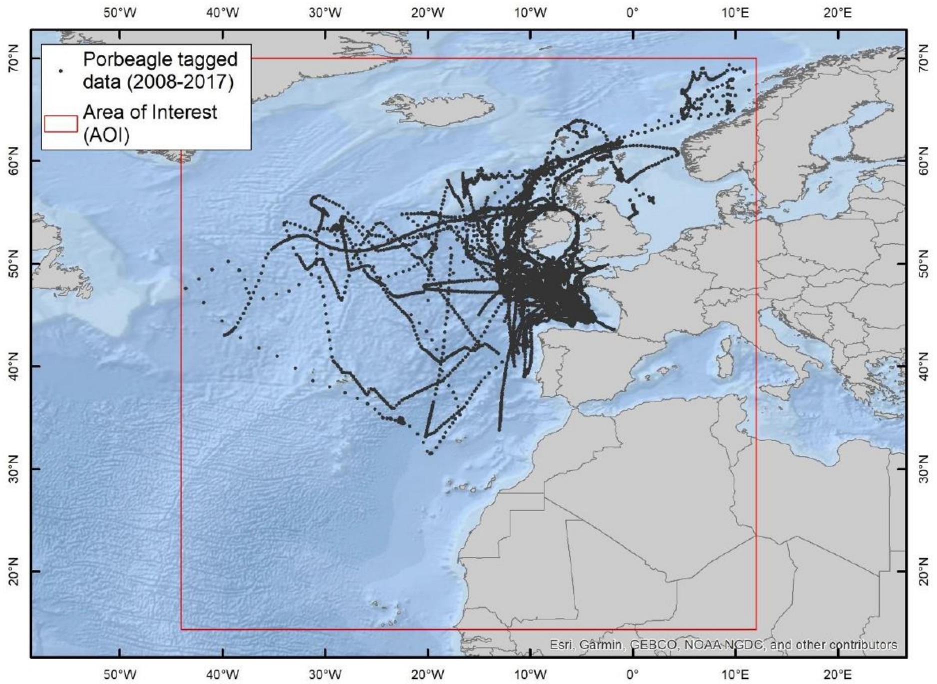


Figure 2.6.2. Positional estimates from all PSAT datasets > 8 days in length. Each symbol shows a daily estimate. Positional estimates were derived from bespoke algorithms suited to the transmitted or archived data received from Microwave Telemetry or Wildlife Computers PSAT tags.

2.6.2 Stock assessment

Enric Cortés and Jan Jaap

The stock identity of porbeagle was extensively discussed. While there seemed to be strong indication of site fidelity and repeated migration routes, the genetic differentiation among different regions in the North-east Atlantic was not strong, and based on a limited number of samples. Ultimately, it was decided to keep the current management units.

There were several potential relative abundance index series that could be used to inform a surplus production model. One of the issues with all abundance indices was that the sample size and spatial coverage of the indices were small compared to the size of the management unit.

SPiCT, a Bayesian surplus production model, was used to assess the status of the Northeast stock of porbeagle. Data inputs to the model included total catches (1926-2020) and three biomass indices: a Norwegian CPUE based on logbooks of longline vessels targeting porbeagle (1950-1972), a French CPUE also based on longline vessels targeting porbeagle (1972-2009), and a French CPUE based on the personal logbook of a commercial longliner targeting porbeagle (200-2009) complemented with a survey biomass index conducted in the Bay of Biscay and the Celtic Sea in 2018-2019 (this index will be referred to as composite index). Additionally, a bycatch CPUE index from the Spanish pelagic longline fleet (1986-2007) was also available.

The assessment used the intrinsic rate of increase (r_{max}=0.059) used in the ICCAT (2020) stock assessment and set the prior for the shape parameter n to 2, which implies a Schaefer production model with an inflection point of the production curve of Bmsy/K=0.5. It was pointed out that the n corresponding to the value of r=0.059 is 3.4 (which corresponds to Bmsy/K=0.60 obtained from a relationship between the inflection point and the rate of increase per generation, rT) and thus that the priors of r and n were internally inconsistent. This was investigated by setting the prior of n to 1) 3.4 with sd=0.5 (uninformative) and 2) 3.4 with sd=0.2 (more informative). With sd=0.5, the posterior was still estimated at 1.3 and with sd=0.2, the assessment did not pass the acceptance criteria. Values of Bmsy/K <0.5 imply a more productive stock than predicted by life history characteristics, based on which the expectation would be a value >0.5Bmsy/K. This result may be due to the large interannual increases in the three biomass indices considered initially (especially the Norwegian index and some years for the composite index), which would conflict with the low productivity implied by the life history.

There was a question about the apparent concurrent trend in the indices and catches: a positive correlation between the decrease in catches and the Norwegian index from 1950 to 1972 and a positive correlation between the decrease in catches and the French index from 1972 to 2009. Further examination of the "plotspict.ci" plots from SPiCT showed that there were no positive increases in index at large catches that could indicate model violations.

There was also further discussion on the survey biomass index for 2018-2019. Rationale was presented as to why the index should be based on an analysis considering 10 statistical rectangles (reduced sampling area) with higher mean CPUE, including that there was an increase in R-squared of the index-effort relationship.

Several model configurations were trialed with 3 or 4 biomass indices, the composite index with or without a reduced area considered, and several assumptions about the sd of the priors of r and n. In general, there were retrospective patterns in F and F/Fmsy, which improved when the sd for r was set to 0.2. When using 4 indices, the Spanish index was not fit well owing to its very large interannual variability and the retrospective patterns improved when using sd=0.2 for r and a prior for the sd of variance was used ("logsdi" in SPiCT). It was recommended to run a sensitivity trial using very high or low values in the Spanish index to ensure that results would not be unduly affected by these changes. Another assessment using an alternative Bayesian production model (JABBA) was presented by the ICCAT Secretariat. Data inputs were the same as for the SPiCT assessment, with a few differences: the inflection point of the population growth curve/production curve was fixed at 0.37 (a Fox production model) implying a shape parameter n=1.01; initial depletion at the beginning of the model was 0.90 (vs 0.99 in SPiCT); and the standard error of the observation error variance for the indices was fixed at 0.25 (vs. using the actual observed values in SPiCT). An additional assessment using SPiCT was also presented by the ICCAT Secretariat with results similar to those run by the ICES WGEF.

There was extended discussion about the validity of the inclusion of the Spanish longline biomass index in the assessment. On one hand it was pointed out that the index was discussed during the 2009 ICCAT stock assessment and deemed appropriate for inclusion at the time, that it provides additional information on the relative abundance of the NE Atlantic stock of porbeagle east of 45° W, and that it is not based on a directed fishery that could lead to a hyperstable CPUE. On the other hand, there was concern that this this index provides information on porbeagle density further south than where the directed fisheries operated, in an area where PSAT deployments have shown that only a part of the exploited biomass migrates to and therefore raises questions about whether it provides better information on the abundance of the exploited biomass than the directed fisheries. Additionally, the validity of including this index in the base run was questioned because it shows interannual increases in abundance of 1 order of magnitude that are biologically impossible. It was recommended that at least, several of the peaks displayed by this index be down-weighted (i.e., increase the uncertainty of those data points) possibly by using robust estimation for those data points.

In all, despite some differences in model (JABBA and SPiCT ICES/ICCAT) configuration, both modelling approaches provided very similar outlooks of the status of the NE Atlantic porbeagle stock, pointing to a still overfished stock, but with overfishing no longer occurring, with the low values of current F consistent with the landing prohibition in effect since 2010. Despite the caveats about the Spanish index, the runs with 4 indices, prior for n=2 (sd=0.2), prior for r=0.059 (sd=0.2 or sd=0.5), and a prior for "logsdi" were deemed the most appropriate to assess the status of this stock. After further exploration a run that included a prior for n=2 (sd=0.2), prior for r=0.059 (sd=0.5), initial depletion=0.99 (sd=0.2), the four indices, but placing higher uncertainty in the Spanish index by setting a prior for logsdi=1.0, and scaling the se of each index to have a mean of 1 (vs. scaling it to the minimum value as initially done) was deemed to be the best run to determine stock status and provide catch advice. In conclusion, the data utilized in the assessment were the best available to the analysts and the assessment methods to determine stock status were adequate given the data available.

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3 Thornback ray (*Raja Clavata*) in the Bay of Biscay (rjc.27.8)

3.1 Introduction

Thornback ray is the second most important skate species landed from Subarea 8, after cuckoo ray, with landings of 400 to 500 tonnes per year in the 2010s. ICES has considered one assessment unit for thornback ray (rjc.27.8) in the Bay of Biscay since the early time of advice delivery for elasmobranchs where the status of skate species were generally assessed at the level of eco-region. A recent close-kin mark-recapture (CKMR) study allowed to analyse the genetic and demographic population structure and to estimate the adult biomass in divisions 8.abd. Although involving a much smaller sample size, an on-going classical tagging study in the Cantabrian Sea (Division 8.c) provided complementary information on the stock identity. This chapter presents the results of recent studies of population identity and describes their use to split the former ICES stock unit rjc.27.8 into two smaller units, namely rjc.27.8abd and rjc.27.8c. Stock assessment for each of the new units using a Bayesian state-space biomass production model and SPiCT respectively the rjc.27.8abd and rjc.27.8c are presented. For both models, landings, discards and biomass indices derived from surveys are available.

3.2 Stock Identity

In order to conduct a close-kin mark-recapture (CKMR) study, 7451 individuals from the Bay of Biscay were genotypes on 3668 SNPs (Trenkel *et al.*, 2022). Most of the genotyped rays form this large sample came from commercial landings (N=7039) and a further 412 came from scientific surveys, including EVHOE (G7212), four dedicated coastal surveys in the bays of Douarnenez and Brest, the Nurse survey in coastal waters and estuaries of the Bay of Biscay and the Sturat survey in the Gironde estuary conducted by INRAe to monitor the only remaining population of sturgeon (*Acipenser sturio*). Lastly, some individuals came from other source including genetic sampling carried out by APECS (www.apecs.fr) and individuals collected by fishers. The sampling locations of genotyped individuals covered the main catching areas of thornback ray in divisions 8.abd (Figure 3.1).

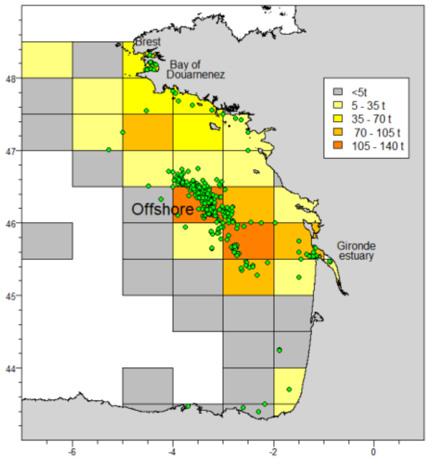


Figure 3.1. Map of CKMR sampling locations for thornback ray in the Bay of Biscay (green spots) and cumulated French landings by ICES rectangle in years 2015-2019.

Related individuals identified from the genotyping of this large sampled included 99 parent-offspring pairs (POPs, so including 198 individuals) and 3400 full siblings (FSPs) and half siblings pairs (HSPs), including 3323 unique individuals, 389 from the Gironde and 2921 from the off-shore shelf (Trenkel *et al*., 2022). The numbers of unique individuals included in HSPs and FSPs was smaller than two times the number of pairs because many individuals related to several others, forming families.

Larger number of samples from the Gironde estuary and the central Shelf of the Bay of Biscay, referred to as Offshore area (Figure 3.1) on the offshore shelf with no pair (POP, FSP or HSP) comprising one individual from the Gironde and the other from the offshore shelf suggested the two area are independent in terms of demography. These two areas appeared to be well below the 10 % threshold in dispersal, which has been postulated to consider that populations are demographically correlated (Waples and Gaggiotti, 2006; Palsbøll *et al*., 2007; Marandel *et al*., 2018). "Dispersal" in this context was defined according to the definition from Palsbøll *et al*., (2007): "*the movement of individuals from one genetic population (or birth place) into another*". Here, it would be the proportion of adults, born in one area (Gironde or Offshore), which contributed to the next generation in the other. With a 10 % dispersal between Offshore and Gironde, there should be, at least for the smaller Gironde population, 10 % of parents coming from offshore and a possibly higher proportion of individuals would have sibs and halfsibs offshore. Instead, 389 and 2921 individuals from Gironde and Offshore respectively were found to be part of one or several FSPs and HSPs and no pair comprised individuals from both areas, so that the dispersal might be very low.

From a population genetic point of view, the two local populations were significantly differentiated (G-statistic, p-value<0.001). The comparison of minor allele frequencies (MAF, the proportion of the less frequent allele at every SNP) between the two areas, showed large differences for some SNPs and an overall spread for all SNPs (Figure 3.2).

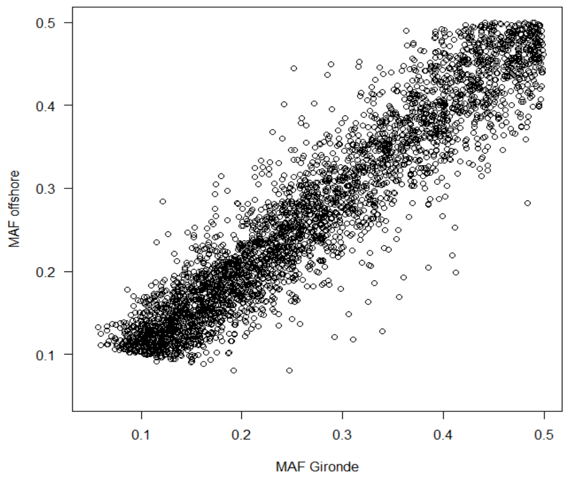


Figure 3.2. Comparison of minor allele frequencies of SNPs between local populations of thornback ray in the Bay of Biscay.

3.3 Stock assessment Division 8.abd

Both a monospecies production model for thornback ray and a multispecies production model for skates and ray in the Bay of Biscay were developed (Marandel *et al*., 2016, 2019). For stock assessment the monospecies production model was further developed to include absolute abundance estimates for thornback ray obtained by applying the genetic close-kin mark-recapture approach (CKMR).

3.3.1 Catch data

International landings data are provided to ICES through Intercatch. Landings quantities are considered reliable since 2009. Prior to 2009, landings were not reported by species and most landings of thornback ray were reported as 'skates and rays'. The bulk of landings of thornback ray in 8.abd are from French fleets, other contributing countries are Spain, UK and Belgium.

The abundance of thornback ray is moderate. Based on the ranking of benthic and demersal fish species from 8.abd, it was only the 20th species in landings from this area. Therefore, most fishing operations recorded during on-board observations had no catch of thornback ray and estimated discards were uncertain or not available for fleets and years where there were not enough observations with catches of the species. Discards were therefore estimated for ranges of years, 2009-2014 and 2015-2020, based on the average levels of discards for the three broad gear categories bottom trawls, nets and lines. These ranges of years were chosen because the TAC is thought to have become restrictive from about 2015. As discard survival is high for nets and lines gears, only trawl discards were estimated in several steps. In the first step, onboard observations provided mean discard rates between 2 and 10 %. Trawls represent 57% to 75 % of the landings across years. Assuming discard survival of 75% for trawlers and 98% for other gears (Van Bogaert *et al*., 2020), estimated dead discard rate were 0.3-2%. This might seem small, but can be explained by the fact that thornback ray is a bycatch species. Biomass indices from the EVHOE survey which are used for this assessment also suggest that the bulk of thornback ray catches in a trawl in this area are individuals larger than 50 cm which are of marketable size. On average, the exploited biomass index from the survey is 88% of the total biomass index. As commercial trawlers use larger mesh size and often larger ground gears, a large proportion of small rays are likely to escape. Given the low level of dead discards (<5%) only landings were used for assessment.

3.3.2 CKMR-derived absolute biomass estimates

Application of the close-kin mark-recapture (CKMR) approach provided absolute abundance estimates for thornback ray in two local populations in the Bay of Biscay, in the Gironde estuary and for the offshore central shelf area (Trenkel *et al*., 2022). Estimates for the years 2012 to 2015 were considered sufficiently reliable to be used for model fitting (Figure 3.3a). This time series does not need to be updated in the future. Its main purpose is to anchor the absolute level of the biomass model estimates.

The number of mature individuals in the two local populations was transformed into total biomass in the Bay of Biscay (8.abd) using the following steps:

1. Raise mature abundance to mature biomass using mean estimated individual weights for mature individuals from the samples used in Trenkel *et al*. (2022): 3.77 kg for females; 2.79 kg for males;
2. Raise mature biomass to total biomass for the two local populations based on aged-structured equilibrium simulations: 1.75 conversion factor;
3. Raise total biomass in the two local populations to the whole Bay of Biscay (8.abd) based on the proportion of landings from the two local populations: 1.64 – 2 conversion factors.

Combining the results from all steps, the resulting total absolute biomass estimates propagating uncertainty in CKMR abundance estimates are shown in Figure 3.3b.

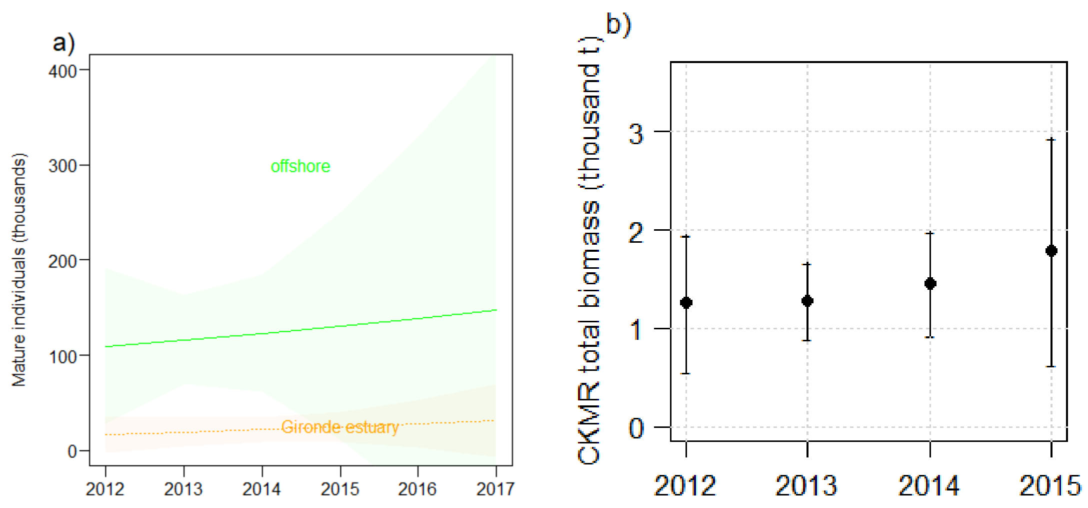


Figure 3.3. a) CKMR estimated number of absolute mature thornback rays in two subpopulations in the Bay of Biscay (from Trenkel *et al*., 2022); b) Derived absolute total biomass estimates for thornback ray in the Bay of Biscay (8.abd). 95% confidence bands in a), 90% confidence intervals in b).

For step 2 a Leslie projection model was used to estimate equilibrium total and spawning stock biomass. Survival rates were as in Marandel *et al*. (2019), see Figure 3.4a. Egg survival was assumed as 0.22. Probabilities of maturity-at-age were as in Trenkel *et al*. (2022), see Figure 3.4b. The mean length-at-age was calculated using the sex-specific growth curve from Serra-Pereira *et al*, 2008). For transforming numbers to weight, the mean weight-at-age was calculated using the length-weight relationship with coefficients used: a=0.00535; b=3.0465. Projecting the Leslie matrix, the equilibrium spawning stock and total biomass at age were obtained (Figure 3.4c). The conversion factor corresponds to the total/spawning biomass.

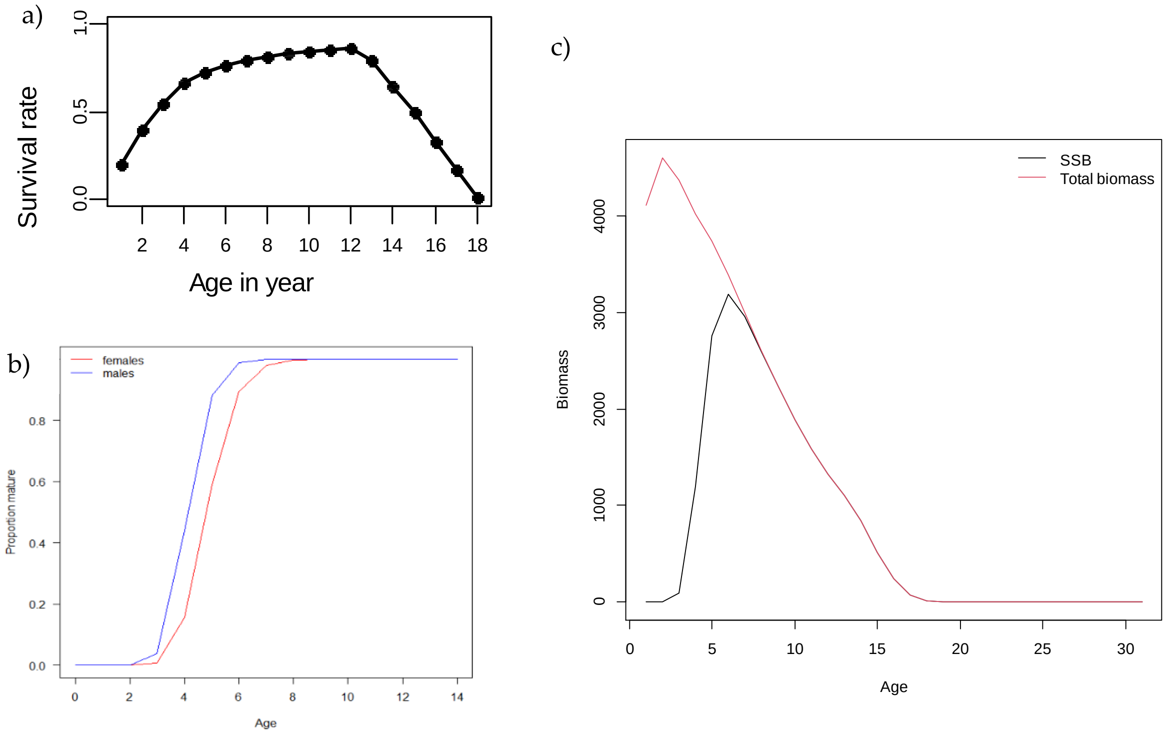
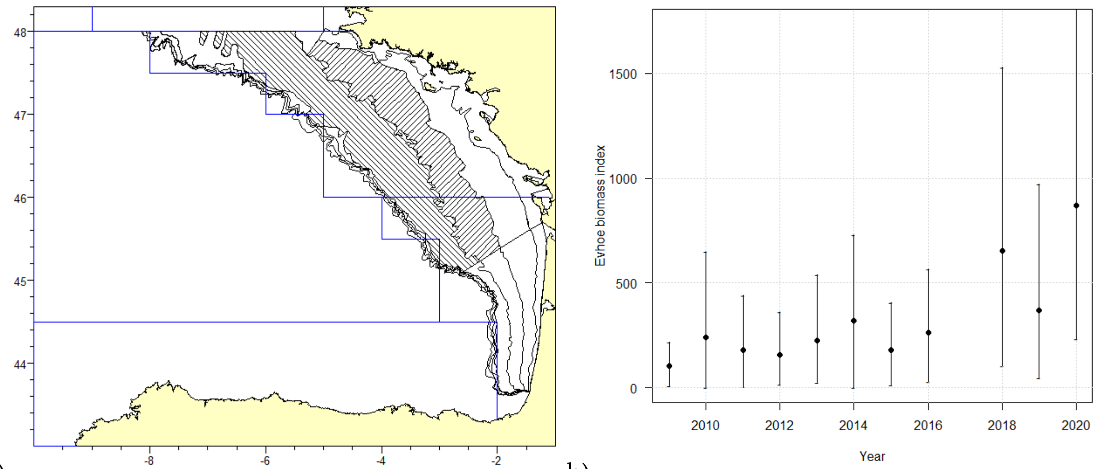


Figure 3.4. Leslie model parameters and results used for obtaining conversion factor to transform CKMR spawning stock biomass to total biomass. a) Survival rate at age;. b) Maturity at age; c) Equilibrium biomass at age.

3.3.3 Survey biomass index

The biomass index was derived from the EVHOE survey using DATRAS data for the period 2009 to 2021 (no data were available for 2017 due to vessel breakdown). Sampling strata were used to delineate the area where the bulk of catch was made in the commercial fisheries and in the survey. Sampling strata where the species was not caught in the survey or with only occasional catches were excluded. Hence only the two largest survey strata (GN4 and GN3) were retained for index calculation (Figure 3.5).



a) b)

Figure 3.5. a) Sampling strata of EVHOE bottom trawl used for biomass index calculation and b) time series of total biomass index with 95% bootstrap confidence intervals. Since 2016, this survey has sampled a fixed station design.

The biomass index was then calculated using a swept area approach where the biomass caught in the area swept by the sampling trawl was raised to the survey area for the two selected strata (Figure 3.5b). Confidence intervals and the variance of the biomass index were obtained using a non-parametric data bootstrap conditioning on the total number of hauls in a given year and assigning resamples to the appropriate strata. Note that confidence intervals were rather symmetrical, justifying the use of a normal distribution for the observation error in the production model.

3.3.4 Bayesian Production model

The Bayesian state-space biomass production model is an extension of the model in Marandel *et al*. (2016). It includes absolute abundance estimates for thornback ray obtained by applying the genetic close-kin mark-recapture approach (CKMR) as explained in Trenkel *et al*. (2022).

The population dynamics is modelled as:

$$Y_{t+1} \sim N\left((r+1)Y_t - rY_t^2 - \frac{C_t}{K},\ \ \sigma^2\right) \qquad (1)$$

$$Y_t = \frac{B_t}{K}$$

where Y_t is the relative biomass in year t, σ^2 the process variance for relative biomass, B_t the absolute biomass, r the intrinsic growth rate, K the carrying capacity and C_t landings.

Two data sets were used for model fitting. Survey derived biomass indices I_t were modelled by a normal distribution

$$I_t \sim N(qB_t, \tau_t^2) \qquad (2)$$

where q is survey catchability τ_t^2 the variance of the biomass index in year t.

The CKRM abundance estimate for thornback ray was transformed into biomass CKMR*t* as explained above which was then modelled as

$$CKMR_t \sim N(q_{ckmr}\, B_t, \varepsilon_t^2) \tag{3}$$

where ε_t^2 is the estimation variance for the CKMR biomass estimates in year t. The catchability coefficient q_{ckmr} was set to 1 as the CKMR index is assumed to be absolute. However, a test run was carried for which q_{ckmr} was estimated.

The model was fitted using a Bayesian approach. Information on prior distributions is summarised in Table 3.1. An informative prior was created for intrinsic growth rate r using life history parameters (McAllister *et al.*, 2001) while an uninformative prior was used for carrying capacities K (see description in Marandel *et al.*, 2016). The prior for the process variance σ^2 was chosen to be moderately informative while the observation variances (τ_t^2 for biomass indices and ε^2 for CKMR estimates) were assumed known (Table 3.2). For the EVHOE index, the survey CV was fixed for all years at 0.3. This was the largest value that would allow satisfactory convergence of the model. In the future with more data, it might become possible to use larger CV values. For survey catchabilities q the prior had most mass <0.5, for this Beta(1,3) was used. In the test run estimating q_{ckmr}, an informative prior centred on 1 was used: $q_{ckmr} \sim N(1, 0.1^2)$.

Table 3.1: Prior distributions for process model (eq. 1 and 3). K is in tonnes.

r~Beta mode, sd	Y_1~Beta mode, sd	K~Uniform min,max	$1/\sigma^2$~Gamma mode, sd
0.105, 0.05	0.4, 0.10	20, 250 000	400,1

Table 3.2. Variance parameters in observation model.

Parameter	Equation	Value
τ_t^2	2	Constant survey biomass index CV of 0.3
ε_t^2	3	Estimated variances for CKMR-based biomass estimates

All computations were performed with the R platform (R Core Team, 2014). JAGS (Plummer, 2003) was used for Bayesian inference and was run within R using the *rjags* package (Plummer, 2016). Results were calculated for three parallel MCMC chains, composed of 500,000 iterations with different initialization points. The burn-in for each MCMC chain was 500,000 iterations and autocorrelation among samples was limited by saving every 500th parameter value, leading to 1000 samples from posterior distributions. Global convergence was checked with the Potential Scale Reduction Factor, PSRF, and the Multivariate Potential Scale Reduction Factor diagnostic, MPSRF, which summarizes individual PSRF (Brooks and Gelman, 1998).

3.3.5 Forecast

The ICES advice for this stock is provided bi-annually. Short term forecasts were carried out assuming a status quo (Fsq as F is the last year of the assessment) harvest rate (median posterior) for the interim year and status quo as well as Fmsy harvest rates for the two years of forecasts.

In accordance with ICES rules for this type of stock assessment, the 35% percentile of the projected catch distribution was applied as catch for the two years of forecast for both scenarios.

3.3.6 Assessment results

Convergence was achieved for all parameters and state variables. All posterior parameter distributions differed markedly from their prior distributions, indicating the important contribution made by the data (Figure 3.6).

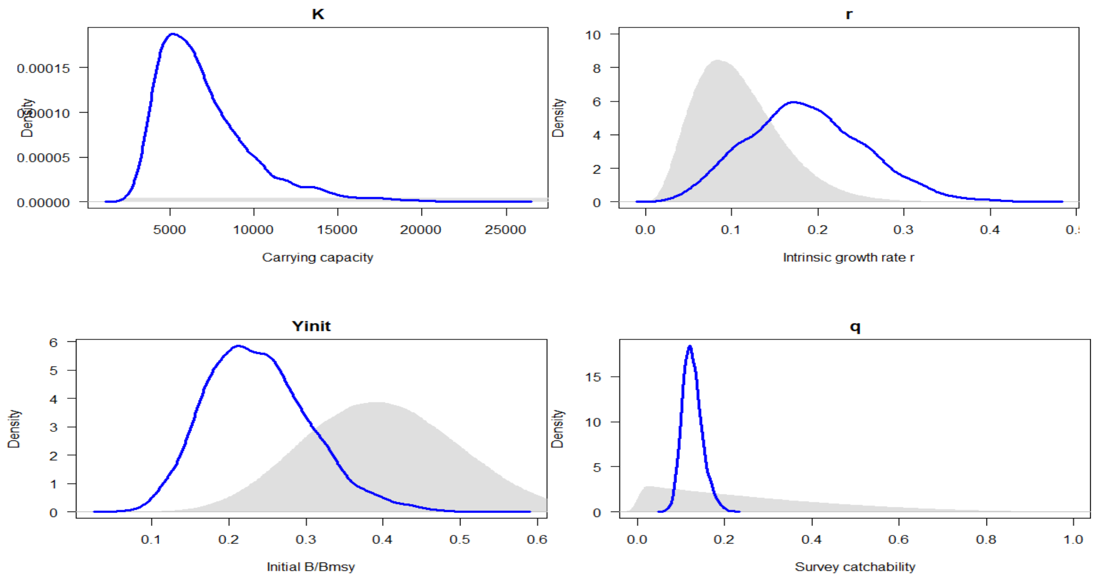


Figure 3.6. Prior (grey surfaces) and posterior (blue lines) distributions for parameter estimates for production model.

Model parameter estimates are given in Table 3.3. Reference points were directly derived from two estimated model parameters, intrinsic population growth rate *r* and carrying capacity *K*, using the median of the posterior distribution (Table 3.4). The test run which estimated a catchability coefficient for the CKMR abundance estimates led to similar parameter estimates, except for *K* which was somewhat higher (Table 3.4). Further, q_{ckmr} was not different from 1, supporting the use of the simpler model with q_{ckmr}=1.

Table 3.3. Bayesian production model posterior parameter estimates and credible interval bounds

Parameter	Description	Posterior median	Lower 2.5 percentile	Upper 97.5 percentile
R	intrinsic population growth rate	0.18	0.07	0.33
K	carrying capacity (tonnes)	6331	3505	14531
Q	EVHOE survey catchability	0.12	0.09	0.18
Yinit	depletion rate in 2009 (B_{2009}/K)	0.23	0.12	0.39

Test run with catchability coefficient for CKMR

Parameter	Description	Posterior median	Lower 2.5 percentile	Upper 97.5 percentile
R	intrinsic population growth rate	0.19	0.07	0.33
K	carrying capacity (tonnes)	8086	4006	16448
Q	EVHOE survey catchability	0.12	0.08	0.18
Yinit	depletion rate in 2009 (B2009/K)	0.22	0.12	0.36
q_{ckmr}	CKMR catchability	0.95	0.75	1.15

Table 3.4. Thornback ray (*Raja clavata*) in divisions 8.abd. Reference points, values and their technical basis.

Framework	Reference points	Value	Technical basis
MSY approach	MSY Btrigger	0.5 Bmsy = 0.25 K	Relative value. Bmsy is estimated directly from the assessment model and changes when the assessment is updated.
	Fmsy	r/2	Relative value. Fmsy is estimated directly from the assessment model and changes when the assessment is updated
Precautionary approach	Blim	0.3 x Bmsy	Relative value. (equilibrium yield at this biomass is 50% of MSY)
	Flim	1.7 Fmsy	Relative value (the F that drives the stock to Blim)

Harvest rate estimates as well as total biomass estimates are presented relative to their maximums sustainable yield values, i.e. F/Fmsy and B/Bmsy respectively. The estimated biomass increased over time, while the harvest rate decreased, though neither were above respectively below the MSY value by 2020 (Figure 3.7 top). Note that the uncertainty of both biomass and harvest rate estimates is rather large but still possibly somewhat underestimated. As the length of the data time series increases, precision of estimates can be expected to improve.

The retrospective analysis which consisted of sequentially removing data corresponding to the three final years showed that estimates were sensitive to this, though median posterior estimates remained within the 80% credible of the full data time series (2009-2020) (Figure 3.7 bottom). This result is not surprising given the time trend in survey CPUE that appeared at the end of the time series. Mohn's rho was 0.19 for biomass B and 0.09 for harvest rate F.

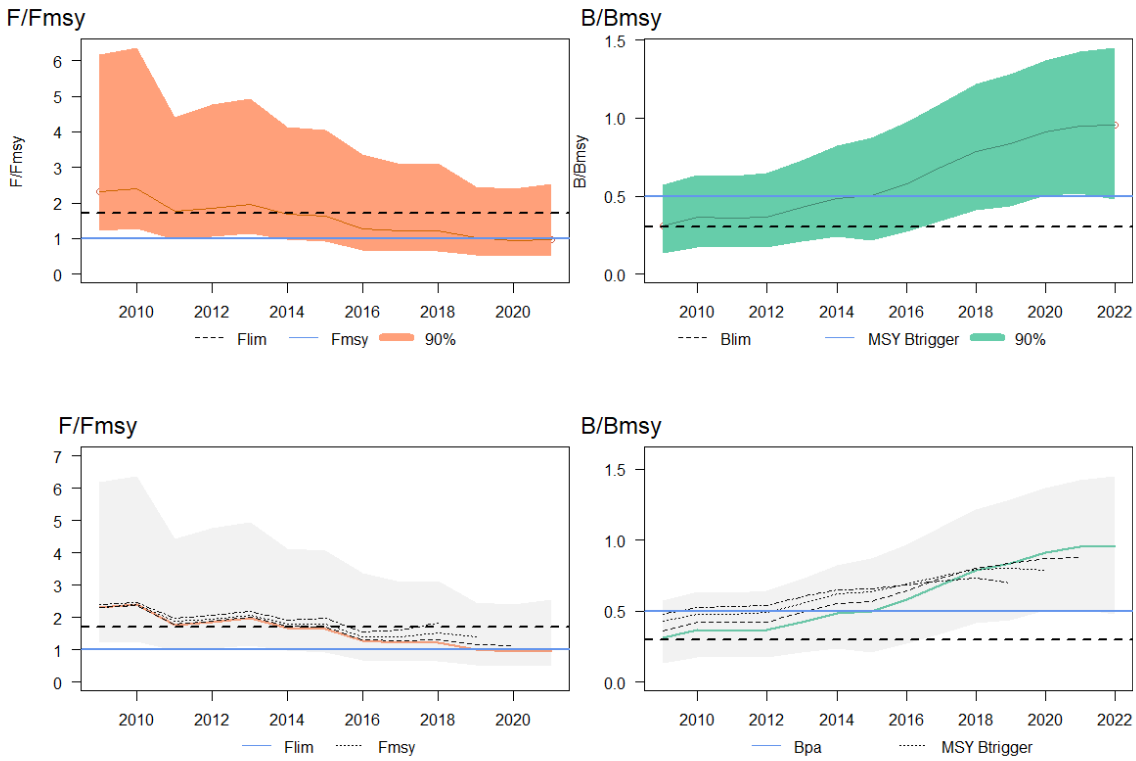


Figure 3.7. Top row: Relative estimates for harvest rate as a proxy for fishing mortality (left) and total biomass (right) as well as precautionary (pa) and MSY reference points. Median estimates (solid lines) and 80% credible intervals. Bottom row: Retrospective analysis of harvest rate (left) and total biomass (right) removing final years in model fitting. Grey surface and coloured continuous line correspond to full assessment results in top row.

Residual plots for both biomass tuning time series showed no strong patterns, thus providing no evidence of any systematic model misfit (Figure 3.8).

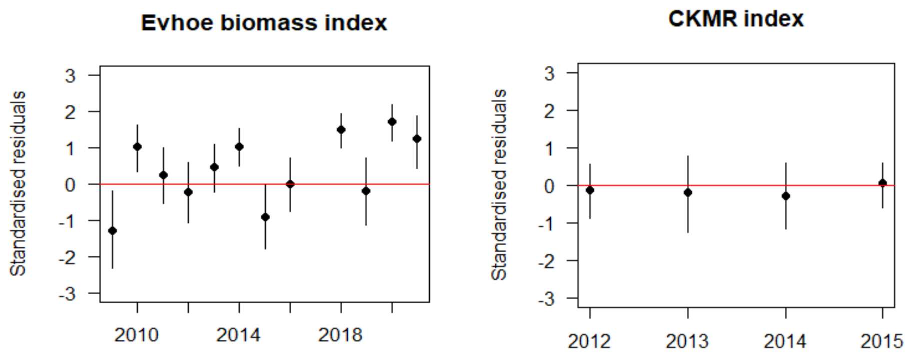


Figure 3.8. Residuals for EVHOE biomass index (left) and CKMR abundance estimates (right). Median posterior estimates (solid lines) and 80% credible intervals.

The results for the test run estimating catchability for the CKMR index (q_{CKMR}) were similar to the base run (Figure 3.9 top). The residuals also indicated satisfactory model fit (Figure 3.8 right). Further, the posterior of q_{CKMR} was only marginally different from the prior and included 0. Thus, the base run provides a satisfactory and parsimonious stock assessment for thornback ray in the Bay of Biscay (divisions 8.abd).

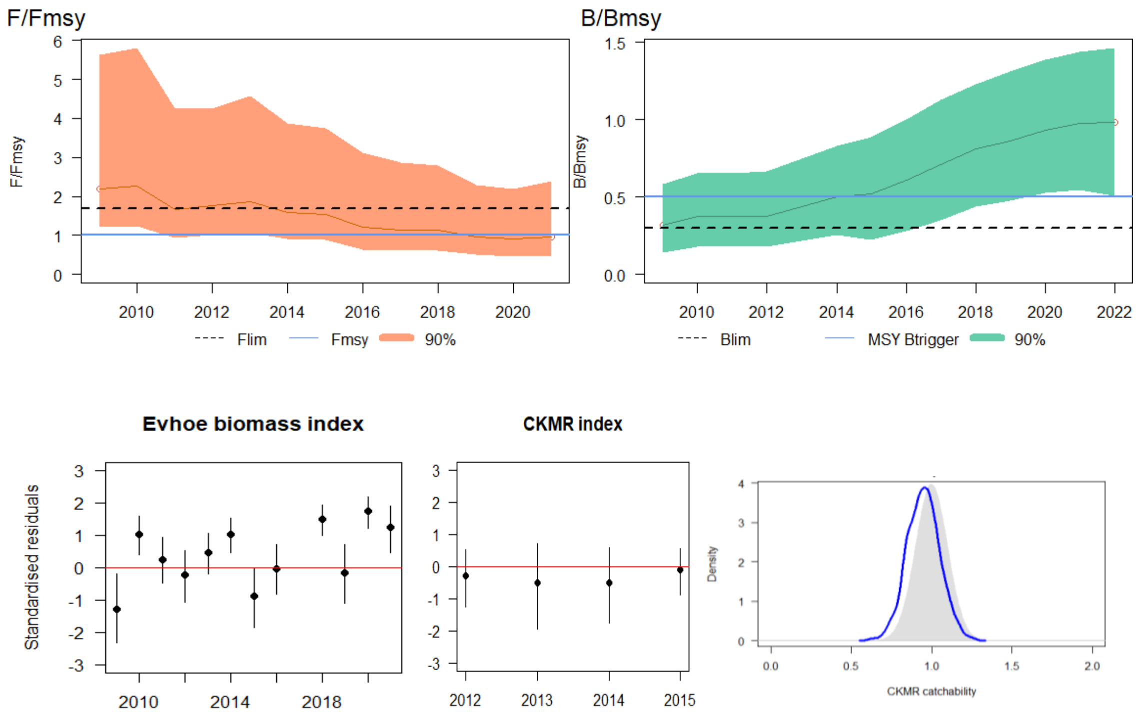


Figure 3.9. Results for test run estimating catchability for CKMR index. Top row: Relative estimates for harvest rate as a proxy for fishing mortality (left) and total biomass (right) as well as precautionary (pa) and MSY reference points. Median estimates (solid lines) and 80% credible intervals. Bottom row: Residuals and comparison between prior and posterior for q_{CKMR}.

3.3.7 Forecast

The results for the interim year projection under status quo harvest rate are given in Table 3.5 and two-year ahead forecasts for status quo and Fmsy exploitation in Table 3.6. Applying the precautionary approach, the 35th percentile of projected catches was used for the two years of forecasts. The uncertainty impacting projected catch distributions differs between the two presented catch scenarios. For the *status quo* harvest rate scenario, the uncertainty comes solely from uncertainty in projected biomass (harvest rate=catch/biomass). In contrast, the distribution of catches in the Fmsy scenario is impacted both by the uncertainty in projected biomass as well as the uncertainty in growth rate r (Fmsy= r/2). Hence the uncertainty is wider in the second scenario leading to a substantial lower 35% catch percentile value despite the fact that the median harvest rate for this stock was close to Fmsy in recent years.

Table 3.5. Thornback ray (*Raja clavata*) in division 8.abd. The basis for the catch scenarios.

Basis	Value	Notes
Median F2022/Fmsy	0.98	Harvest rate in 2022
Median B2023/MSY Btrigger	1.91	B2023 is at the beginning of the year 2023
Catch (2022)	314	Assumed catch data for 2022 $HR_{status\ quo}$

Table 3.6a. Thornback ray (*Raja clavata*) in division 8.abd. Annual catch scenarios for 2023.

Basis	Status quo harvest rate	Fmsy Harvest rate
Catch (t)	309	254
Stock size (B2024/MSY Btrigger), median	1.92	1.96
Fishing mortality (F2023/Fmsy), median	0.97	0.79
Probability of B2024 falling below Blim	0	0
Probability of B2024 falling below Btrigger	0	0
Probability of F2023 exceeding Flim	0.17	0.11
Probability of F2023 exceeding Fmsy	0.48	0.35
% Advice change*	3	-16

***Advice value relative to catch in 2021.**

Table 3.6b. Thornback ray (*Raja clavata*) in divisions 8.abd. Annual catch scenarios for 2024.

Basis	Status quo harvest rate	Fmsy Harvest rate
Catch (t)	304	257
Stock size (B2025/MSY Btrigger), median	1.93	1.99
Fishing mortality (F2024/Fmsy), median	0.94	0.79
Probability of B2025 falling below Blim	0	0
Probability of B2025 falling below Btrigger	0	0
Probability of F2024 exceeding Flim	0.18	0.12
Probability of F2024 exceeding Fmsy	0.46	0.35
% Advice change*	1	-15

***Advice value relative to catch in 2021.**

3.4 Stock assessment Division 8.c

Up to now, the assessment of this stock (rjc.27.8c) was included with stock rjc.27.8abd (northern Bay of Biscay) as rjc.27.8 stock (see introduction). Both stocks (northern and southern Bay of Biscay) were assessed since 2014 under category 3 of ICES DLS using biomass indicator trends estimated from the two main surveys conducted in the area. The north Spanish bottom trawl survey (SpNGFS-WIBTS-Q4) and the French trawl survey EVHOE. During the benchmark the two stocks were split. In the case of southern stock (rjc.27.8c) a SPiCT model has been developed.

3.4.1 Catch data

Data used correspond to landings (t) of *Raja clavata* by the Spanish fleet (the main fleet) operating in this area (ICES Division 8.c; Cantabrian Sea) which represents around the 85 % of Spanish landings in ICES Subarea 8. Species-specific landings are available only from 2009. Prior to 2009, landings were not reported by species and most landings of thornback ray were reported as 'skates and rays'. Therefore, data corresponding to previous years has been estimated. Based on specific landings from 2010-2020 and on board sampling a ratio of 40% of Rajidae landings are attributed to thornback ray in Division 8.c. Retrospective landings prior 2009 have been calculated using this ratio (Figure 3.10).

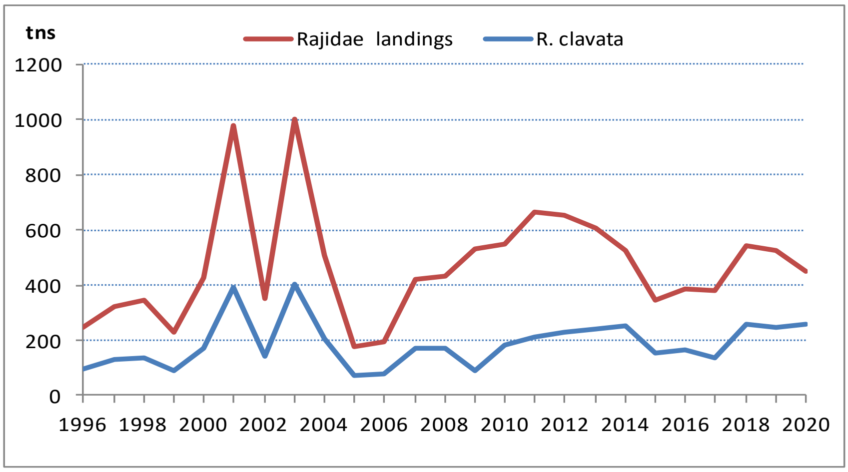


Figure 3.10. Total landings of *Rajidae* species in ICES Division 8.c since 1996 and *Raja clavata* landings (from 1996 to 2008 estimated).

Discard estimates are available, but not for the whole time series (Figure 3.11) so this information has not been included in the assessment and only landings data have been considered. Therefore, data used correspond to landings (t) of the Spanish fleet operating in this area (Cantabrian Sea) from 2000 to 2020.

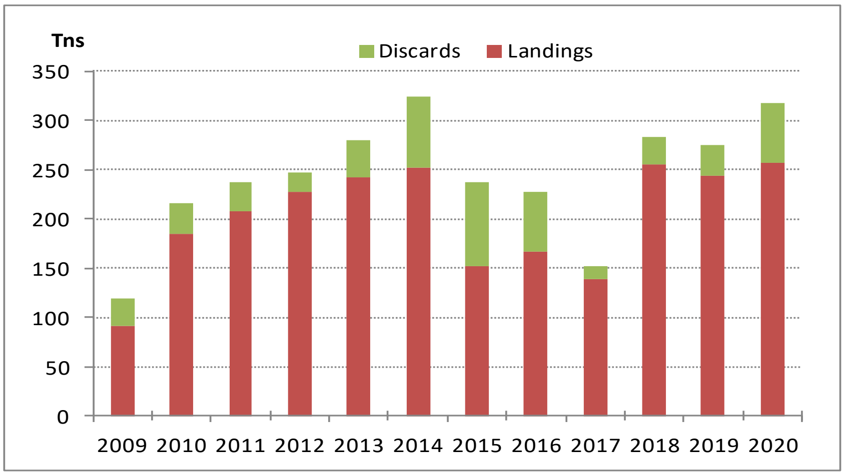


Figure 3.11. Landings and discards of *Raja clavata* by the Spanish fleet in Division 8.c years 2009-2020.

3.4.2 Survey biomass index

The biomass index used in this analysis corresponds to the standardized biomass index obtained from the bottom trawl survey carried out annually in the study area (SpNGFS-WIBTS-Q4). The sampling design is random stratified sampling based on 30 minutes bottom trawl hauls with five geographical sectors and three depth strata (>70-120 m, 121-200 m and 201-500 m). The survey covers the geographical distribution of the species within the Cantabrian Sea and Galician shelf, especially the bathymetrical range. In spite of inter-annual differences, the spatial distribution of *R. clavata* remains similar among years (Fernández-Zapico *et al.*, 2020; 2021). The species is widely distributed along the continental shelf (Figure 3.12).

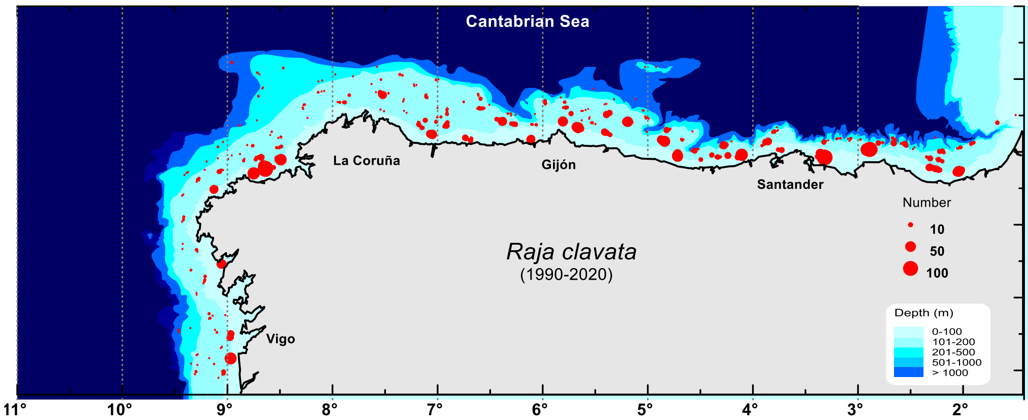


Figure 3.12. Geographic distribution of *R. clavata* catches (number/haul) during North Spanish bottom trawl surveys for the period 1990-2020.

The survey index time series started in 1983 and is standardized from 1990 (Figure 3.13). In the last years the biomass of *R. clavata*, expressed as kilogram per haul (30 minutes trawl), has been fluctuating with a slight decrease but it remains between the medium-high values of the time series (Figure 3.13).

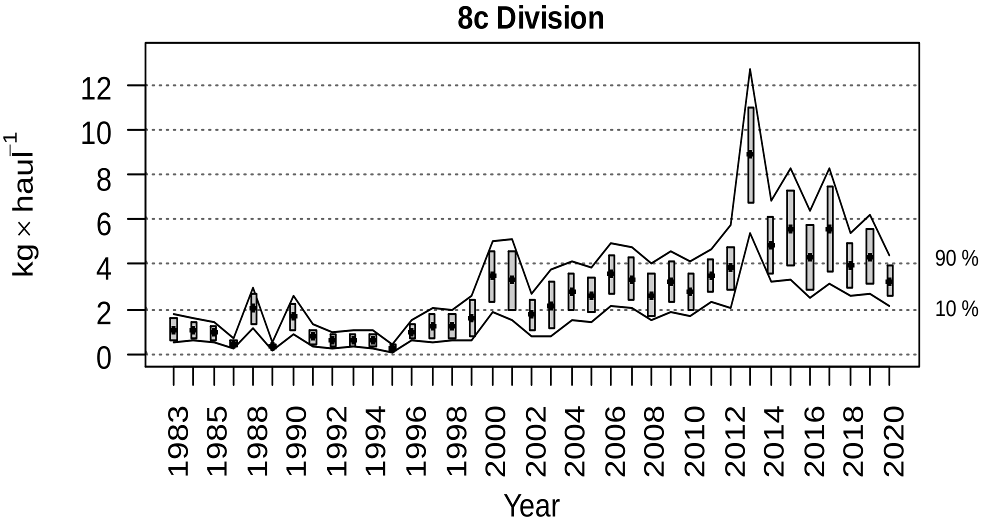


Figure 3.13. Evolution of *R. clavata* biomass index during the North Spanish shelf bottom trawl survey time series in ICES Division 8.c. Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α = 0.80, bootstrap iterations = 1000).

3.4.3 Exploratory assessments

SPiCT analyses were conducted based on landings and biomass survey index. Several SPiCT trials were performed. Landings prior to 2009 were recalculated as commented in the above section (Rodríguez-Cabello *et al.*, 2022 WD). Time interval considered was year.

First (scenario 1) the period from 2000 to 2020 was selected and the default priors were used. Some of the criteria used for the acceptance of the model were met such as; the model converged, the variance parameters were finite and no violation of model assumptions. However, the confidence intervals (CI) for absolute biomass and absolute fishing mortality were wide (Figure 3.14). Thus, the model was not accepted. The summary of the model parameters with their respective 95% confidence intervals are shown in Table 3.7. The outputs of SPiCT model are shown in Figure 3.14.

Table 3.7. Model parameter estimates and their 95% confidence intervals (CI). Scenario 1.

	Estimate	CI low	CI upp	log.est
alpha	1.390	0.130	14.863	0.329
beta	2.812	0.804	9.840	1.034
r	0.676	0.040	11.472	-0.392
rc	1.547	0.075	31.769	0.436
rold	5.332	0.000	2.855E+10	1.674
m	199.622	151.329	263.327	5.296
K	751.831	56.943	9926.57	6.623
q	0.013	0.001	0.308	-4.337
n	0.873	0.042	18.175	-0.135
sdb	0.161	0.024	1.075	-1.829
sdf	0.142	0.044	0.455	-1.954
sdi	0.223	0.119	0.418	-1.500
sdc	0.398	0.278	0.571	-0.920

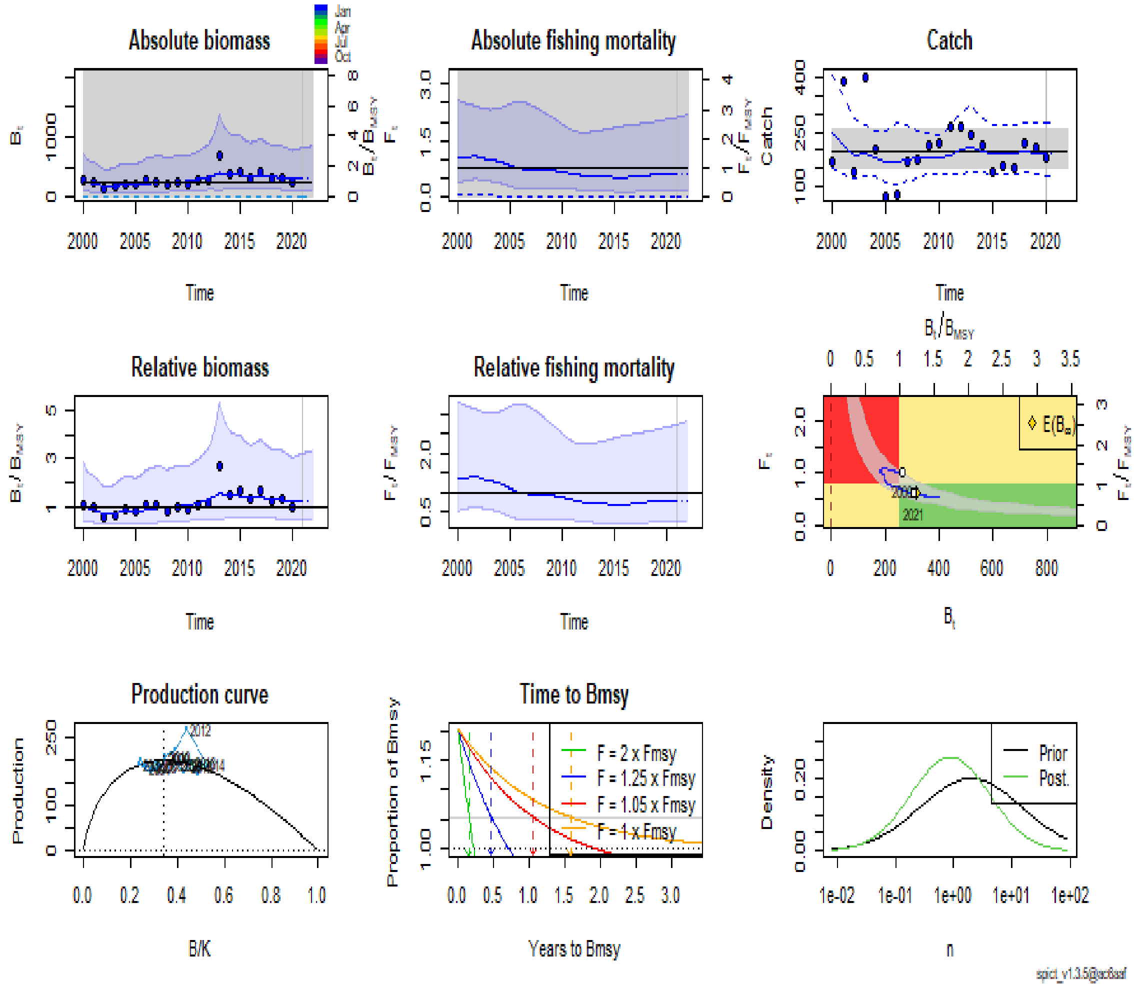


Figure 3.14. Plot of the results obtained with SPiCT model (scenario 1).

A new trial (scenario 2) was performed changing the default parameters as suggested by the group during the Benchmark meeting (26-29 April 2022). The time series was enlarged considering all the landings period (1996-2020). Due to uncertainty in the years prior 2009 this was incorporated in the model by scale the uncertainty. The new parameters are summarized in Table 3.8.

Table 3.8. Constrains of default parameters. Scenario 2

Time series	**1996–2020**
Model Parameters	
Shape parameter	(inpinilogn <- log(2))
Scale the uncertainty	inp$stdevfacC[1:13]<-5
Prior r	inp$priors$logr<- c(log(0.2), 0.2,1)
Modify sd of biomass index	inp$stdevfacI (vector years)

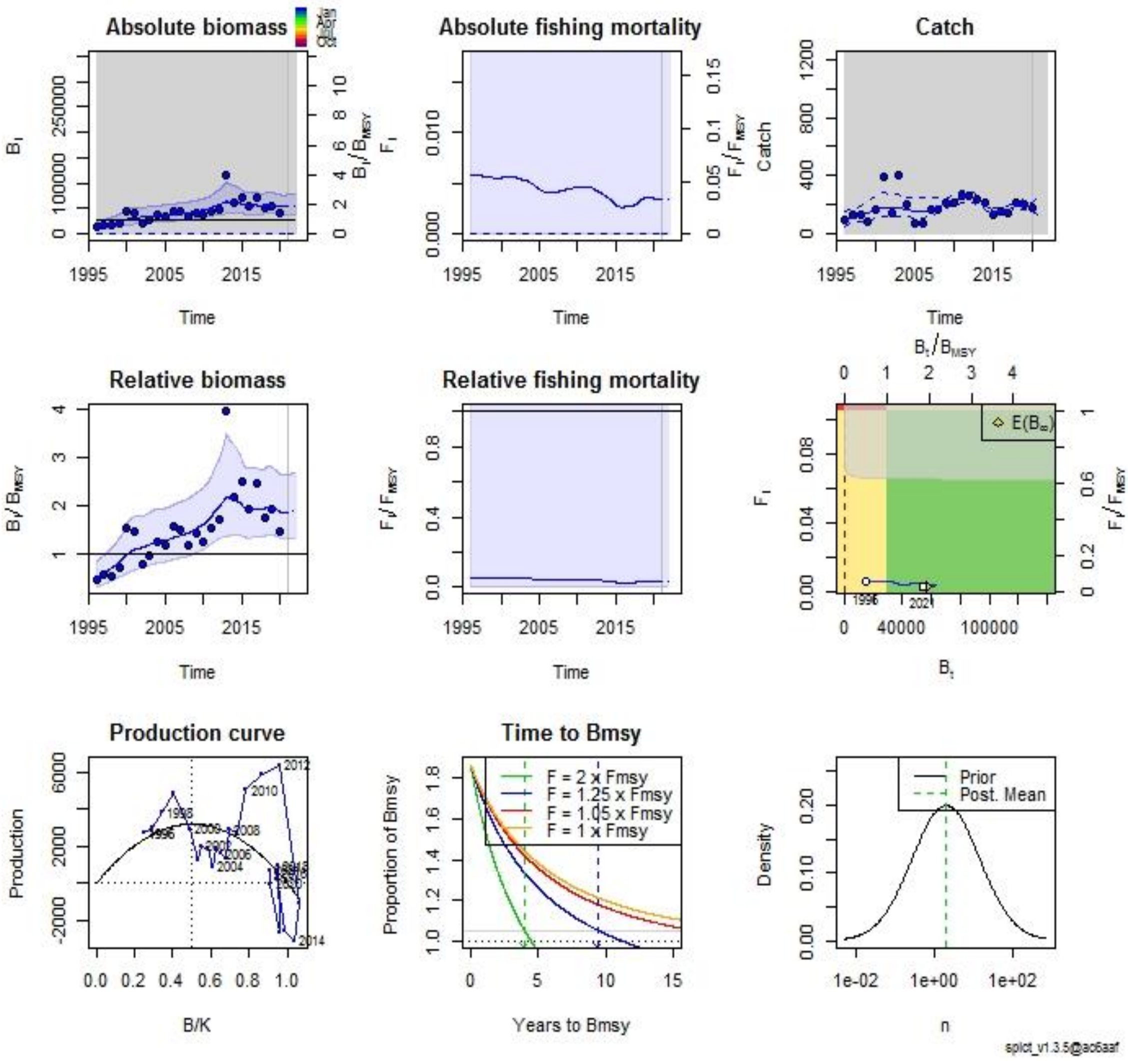


Figure 3.15. Plot of the results obtained with SPiCT model for data and constrains of Table 3.8 (scenario 2).

Table 3.9. Model parameter estimates for the second scenario (see Table 3.8).

	estimate	CI low	CI upp	log.est
alpha	7.509	2.155	26.168	2.016
beta	0.613	0.231	1.626	-0.489
r	0.214	0.148	0.309	-1.543
rc	0.214	0.148	0.309	-1.543
rold	0.214	0.148	0.309	-1.543
m	3205.4	1.840	5582761.0	8.073
K	59964.6	32.883	109350500.0	11.002
q	0.000	0.000	0.166	-9.472
sdb	0.103	0.036	0.296	-2.276
sdf	0.159	0.074	0.343	-1.836
sdi	0.771	0.535	1.111	-0.260
sdc	0.098	0.065	0.148	-2.325

3.5 Future considerations/recommendations

The assessment for rjc.27.8abd was accepted. Due to the lack of contrast of the data and the uncertainty in the fishing mortality estimates the model for rjc.27.8c was not accepted. It was suggested to conduct more trials with shorter time series and modified priors and revise it in the next benchmark.

3.6 Reviewers report

3.6.1 Stock ID

Steve Cadrin, Christoph Stransky, David Murray and Zachary Whitener

New information on fine-scale population structure from genetics and spatial distribution (Lorance 2022 WD) as well as recent tagging data (Rodríguez-Cabello and Sánchez 2022 WD) were considered in the context of previous information available on population structure. The species range extends from Norway and Iceland to Northwest Africa, including the Mediterranean and Black Seas (Chevolot *et al*. 2006). Recent survey and fishery catches are discontinuously distributed, with discrete patches in the Bay of Biscay (Divisions 8.ab) and the Cantabrian Shelf (Division 8.c; Lorance 2022 WD, *here:* Figure 3.16), and these discrete areas of concentration have persisted over decades (e.g., Bay of Biscay survey in the 1970s, Quéro *et al*. 1989). Close-kin analysis of 3668 Single Nucleotide Polymorphisms (SNPs) from 7451 individuals sampled from 2011 to 2020 in the Bay of Biscay found no parent-offspring pairs in multiple discrete areas (e.g., 8.bc 'offshore' patch vs. the Gironde estuary, *here:* Figure 3.16), suggesting that thornback ray in these patches within the Bay of Biscay are demographically separate populations (Trenkel *et al*. 2022). This new perception of fine-scale population structure results from the new analysis of more sensitive genetic characters sampled from a larger number of specimens, as compared to previous genetic analyses (e.g., Chevolot *et al*. 2006). The close-kin analysis did not sample the Cantabrian Shelf (8.c), but tagging information and divergent survey trends among areas also support the perspective of fine-scale population structure. During 2012-2017, within Spanish surveys of the Cantabrian Shelf (8.c), 410 thornback rays were tagged, and six were recaptured with time at liberty from two weeks to over three years and all movements were within42 miles (68 km, Rodríguez-Cabello and Sánchez 2022 WD, *here:* Figure 3.17). Although there were few recaptures from tagging on the Cantabrian Shelf, the results are consistent with larger tagging studies of thornback ray off the British Isles that suggest residence within an average of 10-50 nautical miles (19–93 km; Walker *et al*. 1997, Bird *et al*. 2020). Different trends in survey biomass indices for the Bay of Biscay (8.abd) and the Cantabrian Shelf (8.c) also suggest local stocks with limited mixing (Lorance 2022 WD).

In summary, thornback ray appear to have local populations with discrete spatial distributions. Based on the review of new and previous information on stock identity of thornback ray, WKELASMO supported the proposal by Lorance (2022 WD) to revise ICES advisory units from a single stock in subarea 8 (Bay of Biscay) to two separate stocks in 1) Divisions 8.abd (Bay of Biscay) and 2) 8.c (Cantabrian Shelf). WKELASMO participants concluded that data are insufficient to support finer-scale advisory units. Expanded analysis of SNPs from samples in other ICES areas beyond the Bay of Biscay could confirm the conclusion of separate populations in 8.abd vs. 8.c and provide valuable information on stock identity of thornback ray throughout its range.

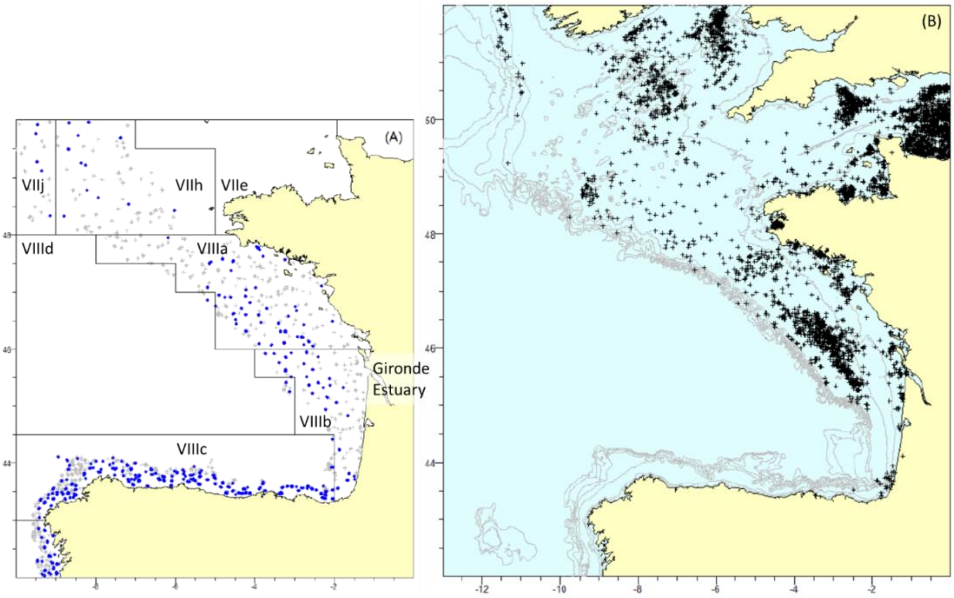


Figure 3.16. Geographic distribution of occurrences of thornback ray in the Bay of Biscay from surveys EVHOE and SP-North (A) and catches of thornback ray from French on-board observations of fishing fleets (from Lorance, 2022 WD).

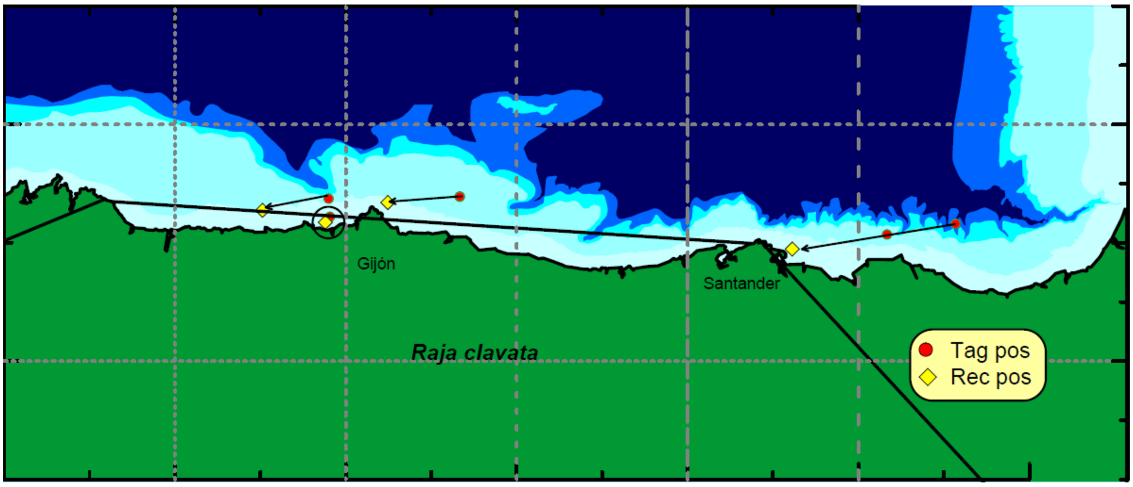


Figure 3.17. Release and recapture locations of thornback rays tagged on the Cantabrian Shelf (Division 8.c; from Rodríguez-Cabello and Sánchez, 2022 WD).

3.6.2 Stock assessment

Enric Cortés and Jan Jaap

In the benchmark process, the stock identity for the Thornback rays was extensively discussed. SNP data from the Bay of Biscay suggested that thornback ray in patches of high abundance are demographically separate populations: whereas close-kin relationships were found within these patches, no such relationships were found between patches, separated by distances substantially smaller than the overall distance between the Bay of Biscay and the Cantabrian Sea. The SNP data did not cover the Cantabrian Sea, but tagging information and divergent survey trends among the two areas support the hypothesis of population structure that merits a separation between two stock units.

For the Bay of Biscay, a recent Close-Kin Mark-Recapture study informs about the absolute adult biomass of the thornback ray stock over the period 2012-2015. This information can be used in a stock assessment for a longer period of time by combining it with trend information from catches and biomass indices. Before the estimates of adult abundance from CKMR could be used as information for biomass in the stock assessment, three steps were needed to convert abundance to biomass. First the mature abundance needed to be transformed to mature biomass using mean estimated individual weights for mature individuals. Then, the mature biomass needed to be raised to total biomass using a 1.75 conversion factor. This conversion factor was derived from the ratio between total and spawning stock biomass in a Leslie projection model at equilibrium. Finally, the biomass in the two local populations needed to be raised to the total biomass for the whole Bay of Biscay. Conversion factors for this raising were based on the proportion of landings from the two local populations.

To incorporate the CKMR information about the absolute biomass in a surplus production model, a Bayesian surplus production model implemented in JAGS was used to assess the status of the thornback ray (*Raja clavata*) stock in the Bay of Biscay (ICES divisions 8.abd). Inputs to the model included total catches, a biomass index derived from a bottom-trawl survey, and absolute biomass estimates obtained from a Close-Kin Mark-Recapture (CKMR) study. There was general consensus that the incorporation of the CKMR biomass estimates into the stock assessment model was an improvement with respect to previous assessments.

There were a number of questions about the data inputs used, in particular the treatment of uncertainty for the EVHOE biomass index. The assessment fixed the observation error variance to a constant CV of 0.3. It was noted that by fixing the annual CV to this arbitrary value instead of using the actual observed uncertainty in the form of an annual CVs/SEs the uncertainty in the index would be underestimated, in particular for the three most recent years of data, which showed large uncertainty. The assessment authors clarified that when using the actual CVs the model did not converge and that a CV of 0.3 was the largest value that could be used for the model to converge. There was some discussion about the priors used in the model, the choice of which seemed justifiable.

Results showed that the posteriors were substantially different from the priors and thus that the data were informative. It was noted that the labels for the F_{MSY}/ F_{LIM} and B_{MSY}/B_{PA} shown in the plots of relative fishing mortality and relative biomass were inverted and that there was large uncertainty in the estimated trajectories. The model converged and there was no clear pattern in the residuals of the EVHOE index or the CKMR index suggesting a satisfactory fit to the data. It was noted that short-term projections using the 35th percentile of the predicted catch distribution when fishing at F_{MSY} should be undertaken.

In all, the data utilized in the assessment were the best available to the analysts, and the assessment method of the status of this stock was adequate given the data available. The inclusion of the CKMR estimates of absolute abundance into the model was an innovative and welcome addition to the modelling approach.

Another stock assessment using SPiCT for the thornback ray stock in the Cantabrian Sea (ICES Division 8.c) was presented for the first time at the meeting. The initial model configuration used all the default SPiCT settings and showed very high uncertainty in estimated parameters and reference points. It was noted that there was no contrast in the catch and biomass index data used. After discussion, the consensus was that the model should be further developed using the longest catch series (i.e., starting in 1996) but giving higher uncertainty to the initial catches from 1996 to 2008; use the SEs available for the biomass index; and use a prior of r with a mean of 0.2 and a log(sd) of 0.2 (based on the posterior results from the assessment for the Bay of Biscay stock) and fixing the shape parameter n=2 (i.e. to a Schaefer model). As a sensitivity, a prior could be given to the initial depletion. Inspection of the updated model configuration revealed that the confidence intervals of absolute and relative F were extremely large and therefore nothing could be concluded about stock status. Based on this, the recommendation was to reject the assessment at this time and to continue model development into the future. It was also suggested that this stock may be a good candidate to apply length-based methods since length compositions are available.

3.7 References

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4 Cuckoo ray (*Leucoraja naevus*) in the West of Scotland, southern Celtic Seas, western English Channel and Bay of Biscay (rjn.27.678abd)

4.1 Introduction

Leucoraja naevus or cuckoo ray, is a medium-bodied, soft ray, widely distributed in the NE Atlantic (Ellis *et al* 2015). While not generally considered a coastal species, they can be found from shallow to medium depths. They are taken in reasonable numbers in a variety of surveys in the ecoregion, especially on offshore grounds. Since 2014, assessment for this stock unit has been based on a combined survey index, using the ICES 2/5 rule for Category 3 stocks. For most of its distribution, it is caught mainly as a bycatch in mixed demersal fisheries. Unlike other ray species, it is not usually specifically targeted, although local, seasonal fisheries are known to exist in the Irish Sea and to the west of Ireland. Differing fisheries in the same waters may have different discarding patterns. French and Irish vessels in the Irish Sea are known to have differing retention patterns, with French boats normally discarding them, while Irish vessels may retain them for local markets (Lynch, *pers comm*). Fisheries are therefore difficult to define accurately.

4.2 Stock Identity

ICES originally considered that there were separate stocks of *L. naevus* in the NE Atlantic; specifically that there was a stock in subareas 6 and 7, with a separate stock in divisions 8.a, b, d. In 2014 (ICES, 2015). ICES revised its stock units and combined these two stocks into one unit. Additional stock units in 8.c and 4 have remained separate. Two possible changes to this stock identity are now considered:

a) That there is a natural 'break' in the distribution to the SW of Ireland, closely coinciding with the latitude separating ICES divisions 7.b and j.

b) That there is no natural division between ICES subareas 4 and 6, and that the stock continues into the North Sea.

A comprehensive discussion of the stock identity is available in Lorance *et al.*, 2022 WD.

Splitting the stock at SW Ireland and connection with the North Sea

Figure 4.1a shows the distribution of catches of *L. naevus* from four surveys. On these plots a 'break' in distribution appears visible in 7.j, which could suggest the split in the stock at SW Ireland. This break however is less visible in Figure 4.1b and 4.2, which shows catches of cuckoo ray observed on board commercial fishing vessels.

Meanwhile, Figure 4.1b clearly shows that catches of cuckoo ray are continuous from ICES subarea 6 into subarea 4, with no change in distribution.

However, it is not clear from a management point of view how best to address the whole stock-identity issue, where the population extends through a large area (from Norway to Spain), but where individuals may not be highly mobile. It is therefore considered that there should be no change to the current stock units without further investigation into the population structure, particularly by further use of genetic methods (and other approaches).

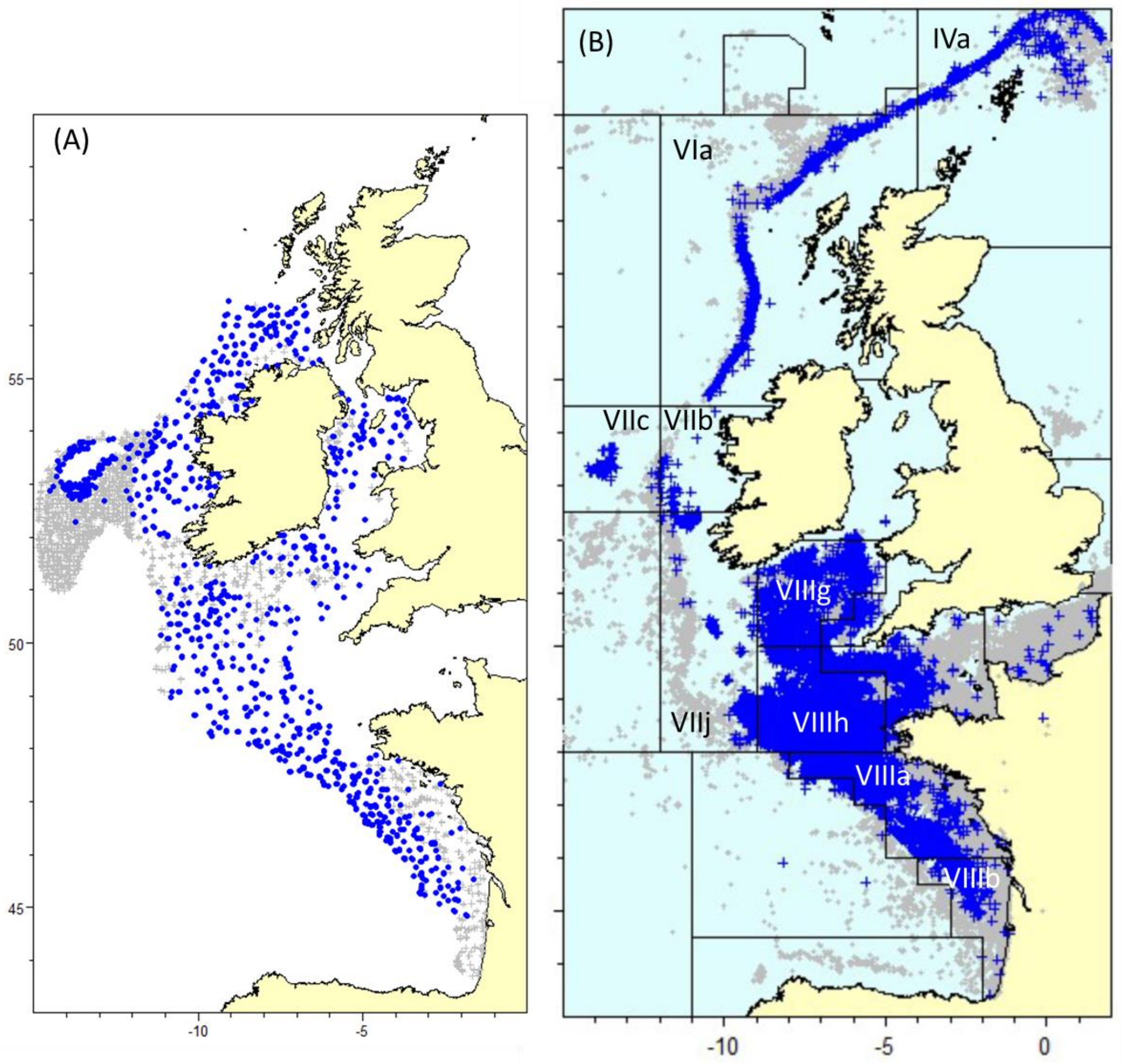

Figure 4.1. Distribution of cuckoo ray occurrence in four surveys (A; FR-EVHOE, IE-IGFS, NIGFS and SP-PORC; grey crosses: sampled hauls; blue dots: hauls with cuckoo ray catch) and French on-board observations (B; grey crosses: location of observed fishing operations in 2003–2020 from all gears; blue crosses: location of cuckoo ray catch; from Lorance *et al.* 2022 WD). Additional survey and on-board fishery observations are in Lorance *et al.* 2022 WD and Silva 2021 WD).

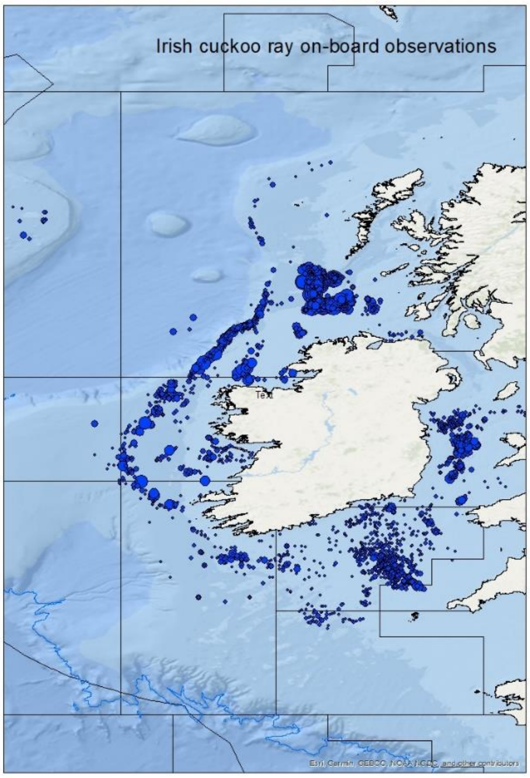

Figure 4.2. Irish observations of *L. naevus* on commercial fishing vessels from Lorance *et al*. 2022 WD.

4.3 Input data for stock assessment

There has been no previous quantitative assessment for this stock, or indeed species. Following ICES guidelines, a SPiCT model was explored and chosen for assessment of this stock (ICES 2021b). Landings and survey data were available. Discard information for this stock are not considered reliable and are therefore not quantified. There is no individual TAC available, this species is part of a mixed TAC for demersal skates and rays. Furthermore, given the large spatial coverage of this stock unit, it also extents to two mixed TACs depending on the fishing area in question. Projections are therefore based on Fsq.

4.3.1 Catch data

Landings of *Leucoraja naevus* from ICES stock area in 6, 7, 8.abd, were extracted from the estimated landings table used within WGEF (ICES, 2021a). Another extraction of all ray and skate species within the same stock area was also made (Figure 4.3, Johnston 2022 WD). An initial comparison was made of the proportion of landings of *L. naevus* with the total (Figures 4.3 and 4.4).

Discards are not considered reliable for this stock. Declared discards in logbooks are very infrequent, and observer rates from some countries are too low to be reliably raised. Therefore, only landings are used in this assessment.

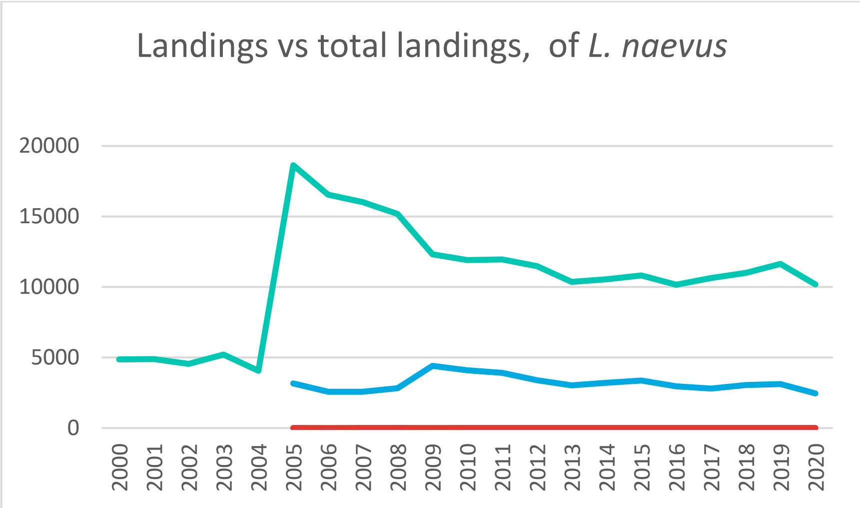

Figure 4.3. Landings of *L. naevus* and total landings of skates and rays in ICES stock area 6, 7, 8.abd.

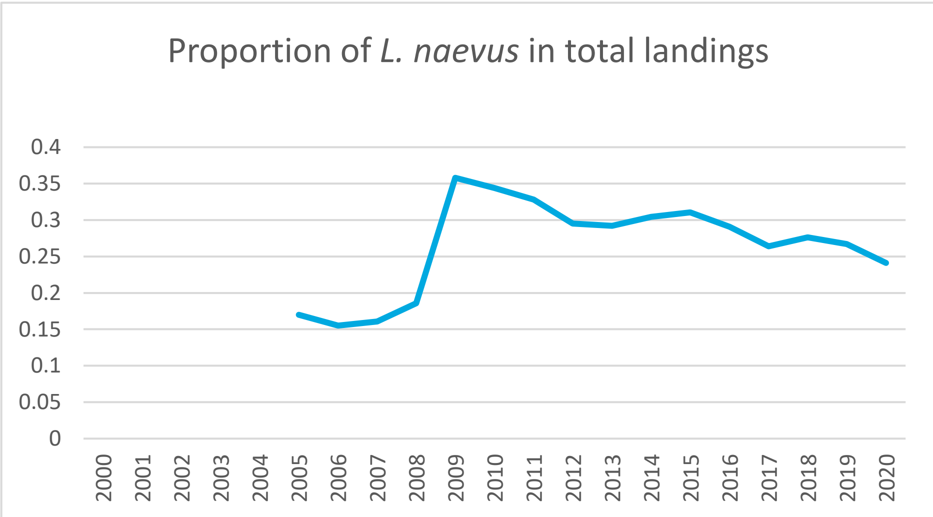

Figure 4.4. Proportion of *L. naevus* in total landings of skates and rays in ICES stock area 6, 7, 8.abd.

Two issues arise from these landings figures:

1. The large change in proportion of *L. naevus* in the total catch between 2008 and 2009 and
2. The absence of species-specific *L. naevus* landings prior to 2005.

It was agreed that landings figures from 2009-2020 should be accepted without change. It was further agreed that landings from 2000-2004 could not be reliably rebuilt and so should not be included in any proposed model runs. However, the declared landings between 2005-2009 were to be further explored in order to rebuilt/reinterpreted to provide a longer time-series for the assessment model.

The simplest method to rebuild these landings is to look at the proportion of landings in the immediate following years where landings are believed to be reliable. The mean proportion of *L. naevus* in the catch from 2009–2011 is 0.34, although the proportion does decline slightly from year to year. Being slightly precautionary, multiplying the total landings by 0.33 gives an estimate of what the landings should have been in those years (Table 4.1). This was accepted and are therefore used in the SPiCT assessment below.

Table 4.1. Landings of *L. naevus* from ICES stock area 6, 7, 8.abd.

Year	*L. naevus* landings	Total ray landings	Proportion	Proposed landings figure
2000		4863.018		
2001		4888.633		
2002		4547.936		
2003		5195.2609		
2004		4058.41656		
2005	3164.092	18633.12696	0.169810057	6148.932
2006	2564.888	16529.02042	0.155174851	5454.577
2007	2575.244	16009.44791	0.160857749	5283.118
2008	2818.909	15181.06455	0.185685873	5009.751
2009	4407.937	12312.83202	0.357995367	4407.937
2010	4096.064	11907.15651	0.344000151	4096.064
2011	3915.97	11942.12206	0.327912392	3915.97
2012	3388.014	11485.73683	0.294975759	3388.014
2013	3028.151	10364.17694	0.292174766	3028.151
2014	3208.921	10541.01501	0.304422378	3208.921
2015	3359.961	10814.00369	0.310704636	3359.961
2016	2954.71	10165.06528	0.29067295	2954.71
2017	2804.136	10625.14628	0.263915092	2804.136
2018	3037.411	10992.3379	0.276320746	3037.411
2019	3110.633	11640.4648	0.267225804	3110.633
2020	2452.831	10170.16591	0.241179022	2452.831

Accepted figures
Recalculated
Unacceptable/unreliable

4.3.2 CPUE

Several survey indices are available for this stock. SPiCT can use either use surveys indices as individual inputs or as a single input if combining surveys into an overall index. This has previously been calculated by WGEF for advice (See ICES (2020a) as an example). For the benchmark, indices were recalculated from the survey data available in DATRAS, to provide a combined survey index. Indices were calculated by raising swept area fished to the total sampled area, so that these are provided in absolute values in tonnes (Lorance and Silva, 2022 WD).

Until 2020, the previous stock assessments used only two fisheries-independent surveys: IE-IGFS (= IGFS) and EVHOE.

Additional survey data from EVHOE (Q4), IE-IGFS (Q4), NIGFS (Q1 and Q4), SP-PORC (Q3) and SCOWCGFS (Q1 and Q4) are now examined. The UK(E&W)-BTS-Q3 in 7.afg was not considered at this stage with the main focus on GOV surveys, with only the additional beam trawl survey in 7.e considered. It was not considered that there were any other suitable surveys in the area.

The addition of further three surveys, expands the area covered to other parts of the stock distribution including the Porcupine Bank (Division 7.c), Irish Sea (7.a) and the West of Scotland (6.a), thus likely to better represent the actual biomass trajectory. The survey SCOROC (Scottish Rockall Survey), covering the Rockall Bank in 6.b, was not used as only two cuckoo rays were caught from 2011 to 2020. The low abundance of cuckoo ray in this survey suggests that the species biomass in Division 6.b is minor comparatively to other areas. Lastly, an index from the

Q1SWECOS (Cefas Q1 Southwest Ecosystem Survey) was estimated separately (Silva, 2021WD and Silva, 2022WD) though it is integrated to the overall biomass index.

The biomass indices combined to provide an overall index for the stock assessment are based on the exploited biomass (individuals ≥ 50 cm total length). In addition, indices are also presented for each survey in terms of the total biomass (all length ranges) and the abundance of juveniles (defined here as individuals < 50 cm total length).

The final exploitable biomass as calculated and used in the assessments is presented in Table 4.2, with further detailed methodology described in Lorance and Silva (2022 WD).

Table 4.2. Exploited biomass index for the total stock (in tonnes), with confidence intervals (From Lorance and Silva 2022 WD).

Year	Biomass	LowCI	HighCI
2005	5483	4358	6608
2006	3717	2826	4609
2007	6866	5219	8513
2008	7550	6092	9008
2009	7154	5711	8597
2010	6293	4606	7979
2011	8511	6530	10492
2012	6912	5300	8524
2013	8351	6367	10335
2014	13090	9437	16742
2015	14050	10802	17297
2016	8946	7149	10743
2017	12340	7106	17575
2018	10787	7634	13941
2019	13606	10076	17135
2020	11489	8975	14003

4.3.3 Life-history parameters

For the SPiCT model runs, two sources of information were available to set priors. SPiCT primarily uses r, intrinsic growth-rate, as a variable prior. For these runs, r as published in Fishlife (Thorsen *et al.,* 2017) was used. This had a value of 0.41. It was considered that this was potentially higher than believable in real-life conditions, so variations of r were also used in additional runs.

4.4 Stock assessment

Details of all assessments, inputs, runs and r-scripts are available on the WKELASMO Sharepoint (*password required*).

4.4.1 Exploratory assessments

Initial runs compared the use of individual surveys with the use of a combined survey index as outlined in Section 4.3.2. It was clear that the use of the combined survey lead to a better model fit and so runs outlined from here on use the combined survey index. Further details on the use of the individual surveys can be found in Coleman and Johnston 2022 WD.

The initial assessment during the benchmark had 5 runs. These had the settings outlined below in Table 4.3.

Table 4.3. SPiCT runs 1–5. Scenarios and variable settings

Prior	Scen1 (default)	Scen2	Scen3	Scen4	Scen5
Intrinsic Growth		FishLife	FishLife	FishLife	FishLife
production curve			Schaefer n=2	Schaefer n=2	Schaefer n=2
initial depletion				log(0.5),0.5,1	log(0.3),0.5,1

Outputs

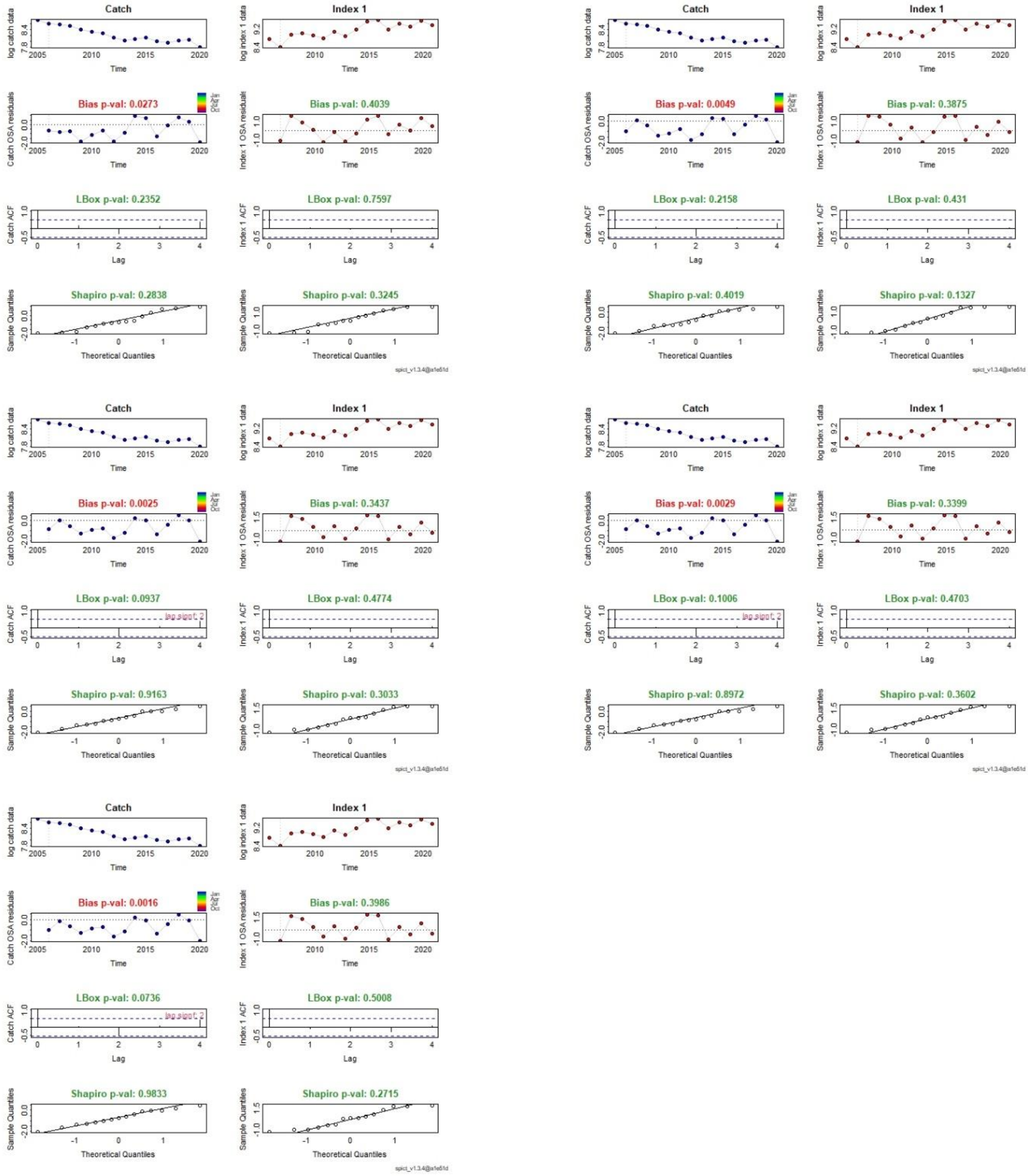

Figure 4.5. Diagnostics, Scenarios 1–5

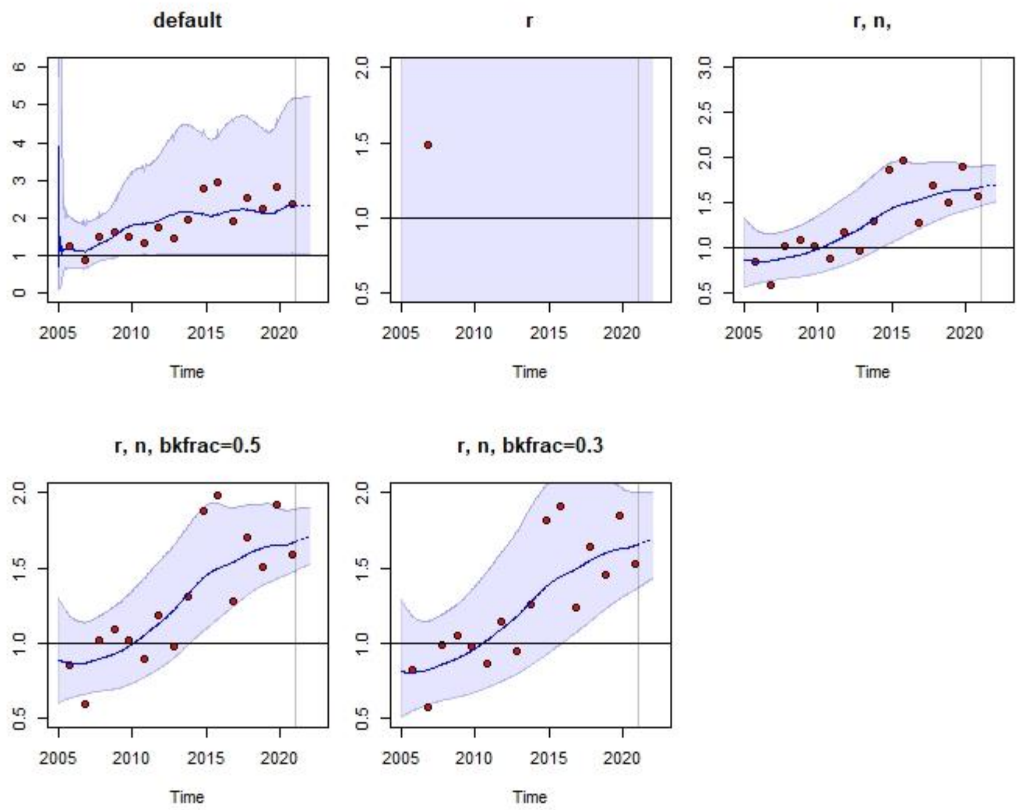

Figure 4.6. B/Bmsy, Scenarios 1–5.

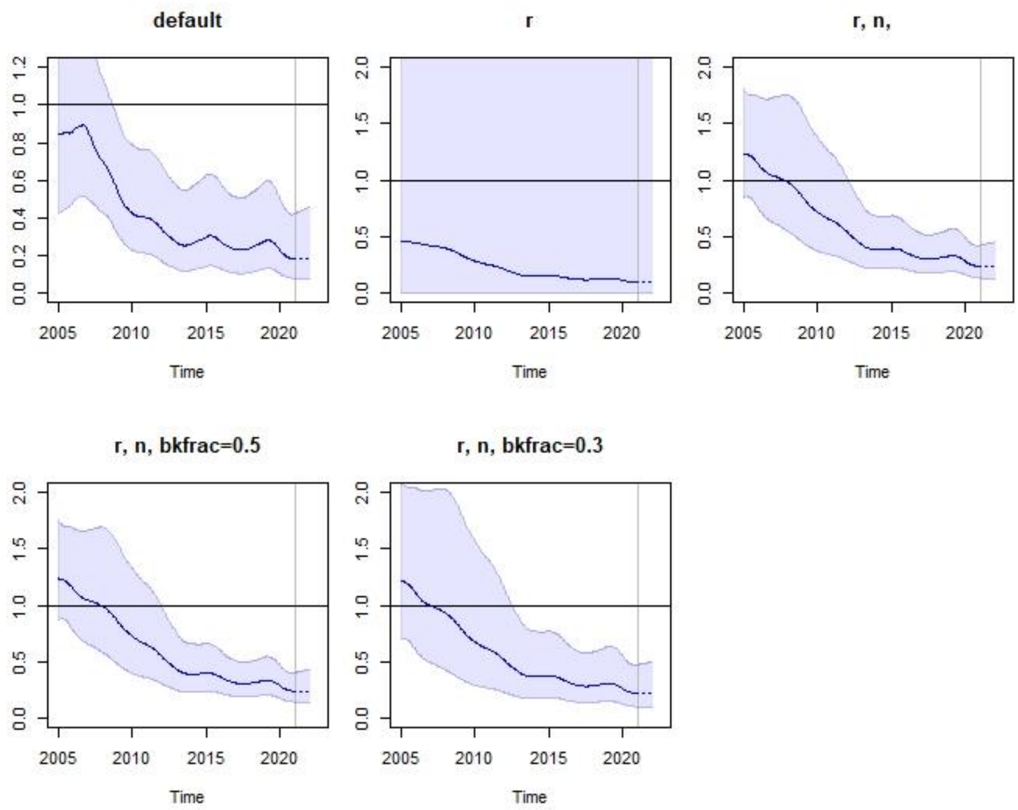

Figure 4.7. F/Fmsy, Scenarios 1–5.

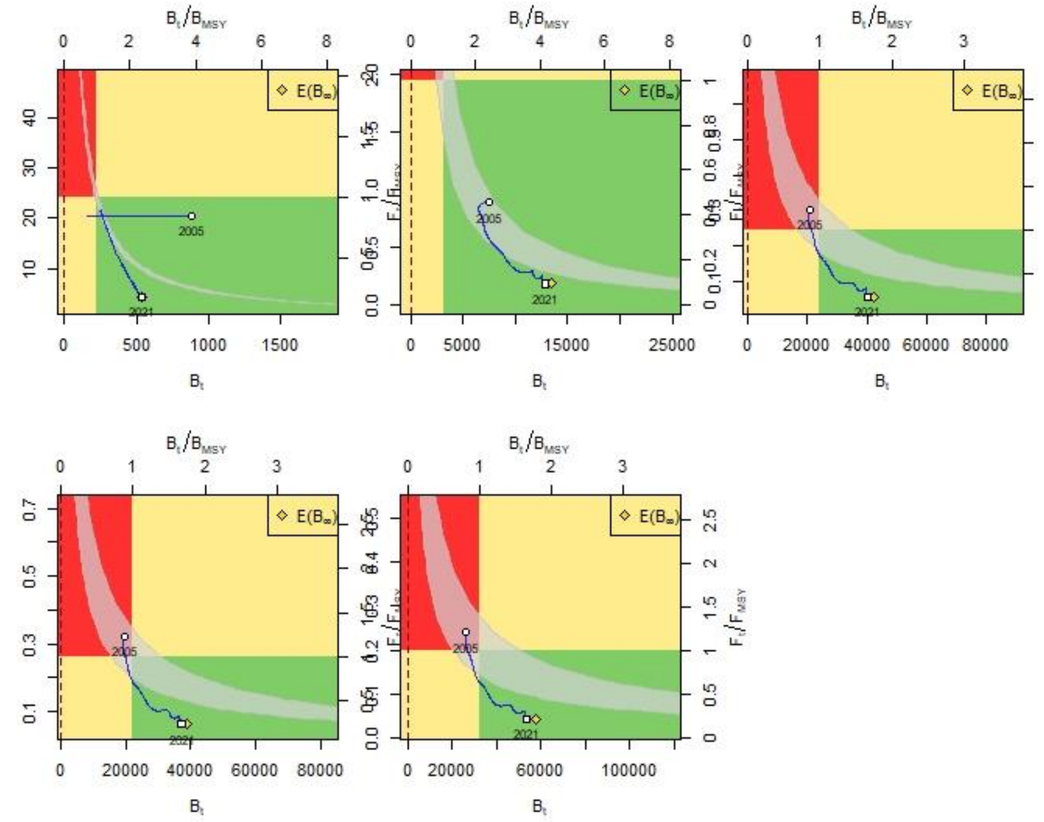

Figure 4.8. Kobe plot showing Fishing mortality vs Biomass, Scenarios 1–5.

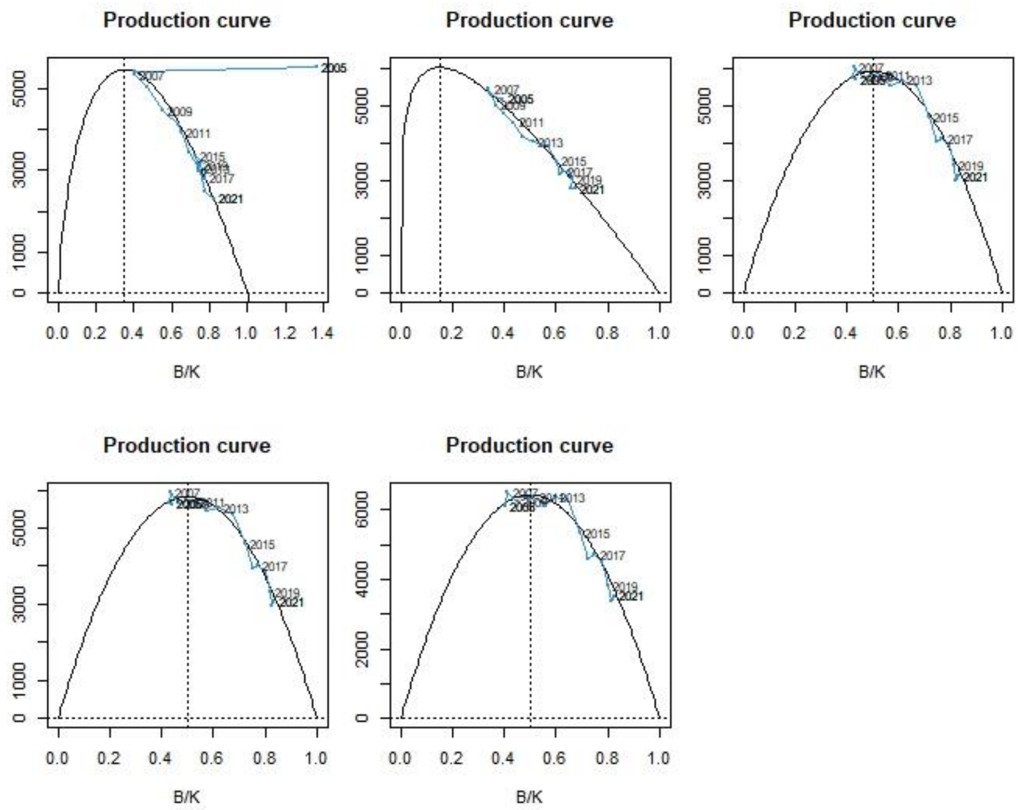

Figure 4.9. Production curve, Scenarios 1–5.

Table 4.4. Order of magnitude check (values ≥1=FAIL), Scenarios 1-5.

		Orders of magnitude difference
Scenario 1	B/Bmsy	0
	F/Fmsy	1
Scenario 2	B/Bmsy	8
	F/Fmsy	9
Scenario 3	B/Bmsy	0
	F/Fmsy	0
Scenario 4	B/Bmsy	0
	F/Fmsy	0
Scenario 5	B/Bmsy	0
	F/Fmsy	0

All scenarios converged. Of the above scenarios, Scenario 1 and 2 were immediately rejected due to the very large confidence intervals in the F/Fmsy and B/Bmsy plots, the lack of fit with the production curves, and the very high order-of-magnitude differences (Table 4.4). Further sensitivity runs were requested during the benchmark meeting, with Scenario 4 considered as the base case run and Scenario 3 another potential viable run.

4.4.2 Final assessment

Two additional runs were considered for sensitivity analysis, for a total of 7 runs altogether. These had the settings outlined below in Table 4.5. Scenarios 3 and 4 (considered the base case run) were maintained. Scenario 5 was also maintained for comparative purposes. Scenario 6 is identical to Scenario 5, but with an initial depletion of 0.2 instead of 0.3. Scenario 7 is identical to scenario 3, but with an initial depletion of 0.3 instead of 0.5.

Table 4.5. Additional sensitivity runs and settings.

Prior	Scen3	Scen4	Scen5	Scen6	Scen7
Intrinsic Growth	Fishlife	log(0.2), 0.3, 1	log(0.2), 0.3, 1	log(0.2), 0.3, 1	Fishlife
production curve	Schaefer n=2	Schaefer n=2	Schaefer n=2	Schaefer n=2	Schaefer n=2
initial depletion	log(0.5),0.5,1	log(0.5),0.5,1	log(0.3),0.5,1	log(0.2),0.5,1	log(0.3),0.5,1

Outputs

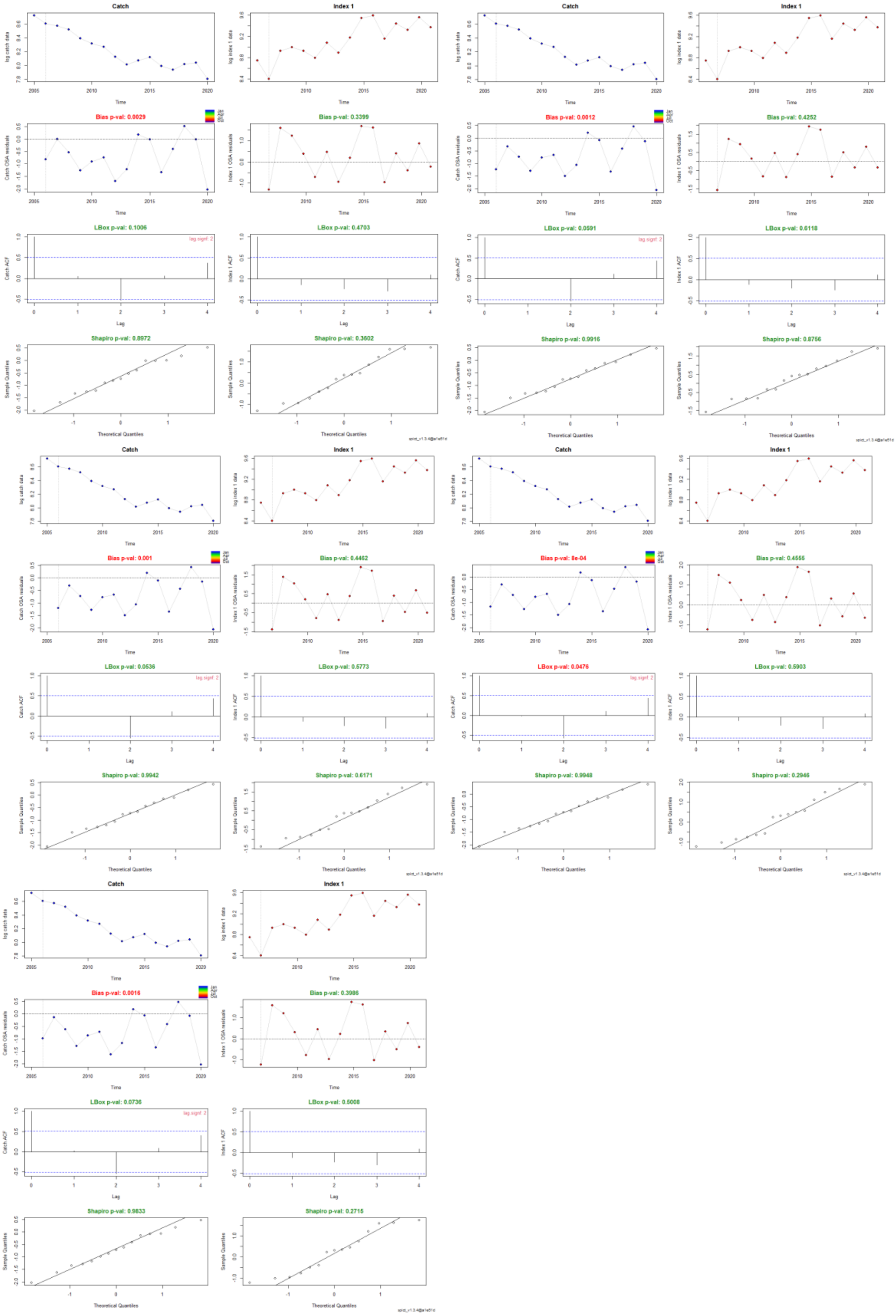

Figure 4.10. Diagnostics, Scenarios 3-7.

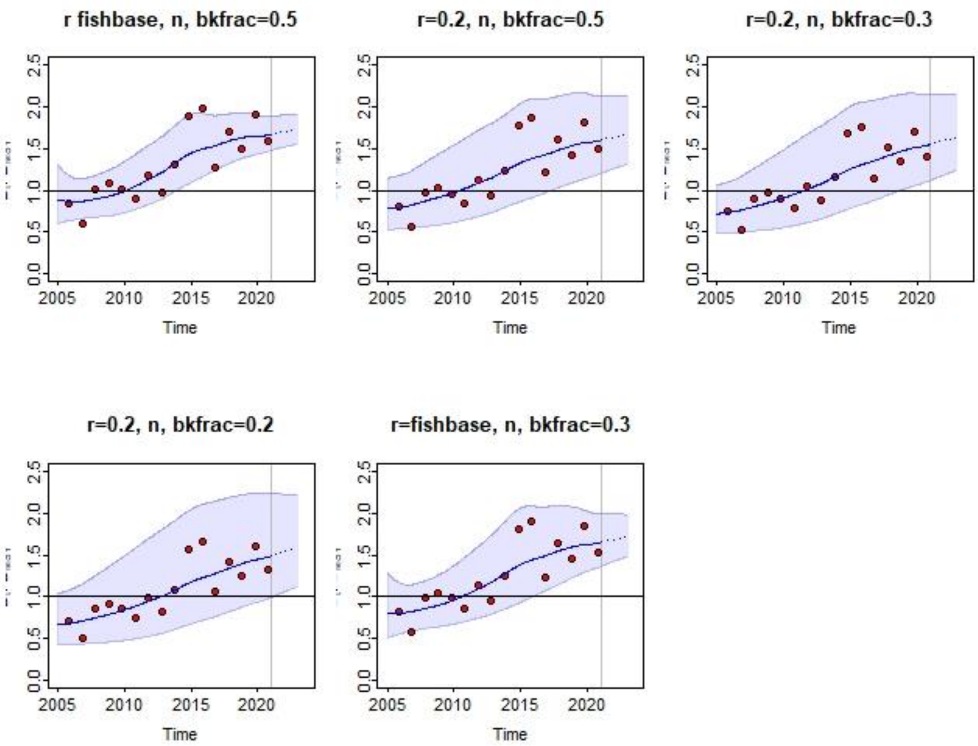

Figure 4.11. B/Bmsy, Scenarios 3–7.

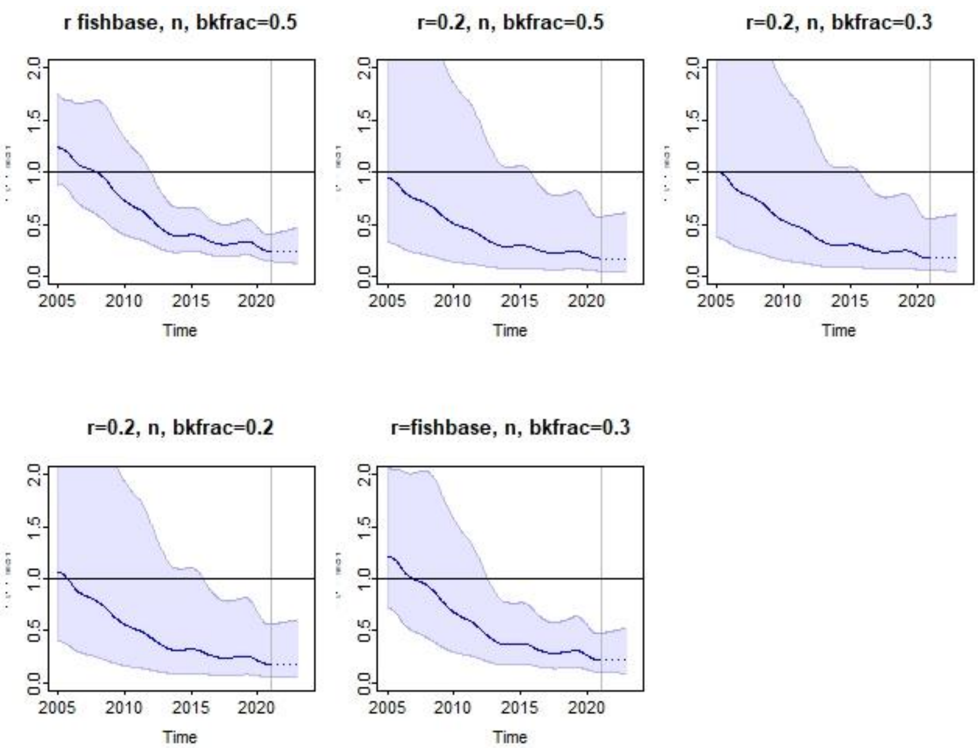

Figure 4.12 F/Fmsy, Scenarios 3 (top left)- 7 (bottom right),

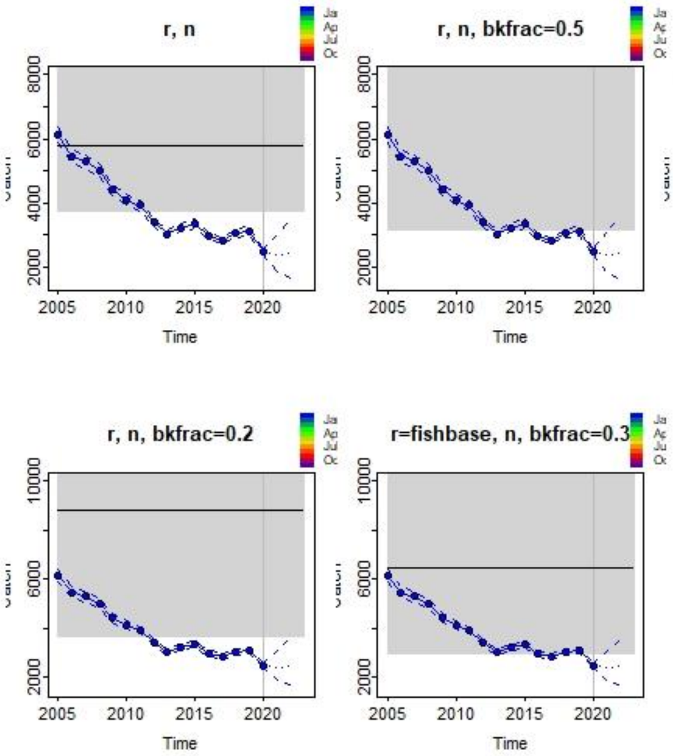

Figure 4.13. Catch, Scenarios 3–7. The horizontal line shows MSY.

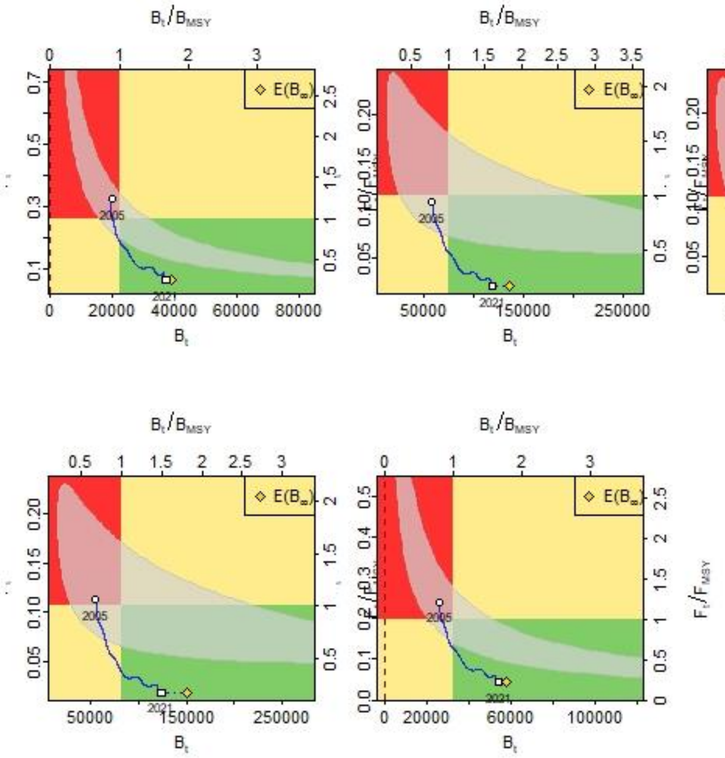

Figure 4.14. Kobe plot showing Fishing mortality vs Biomass, Scenarios 3–7.

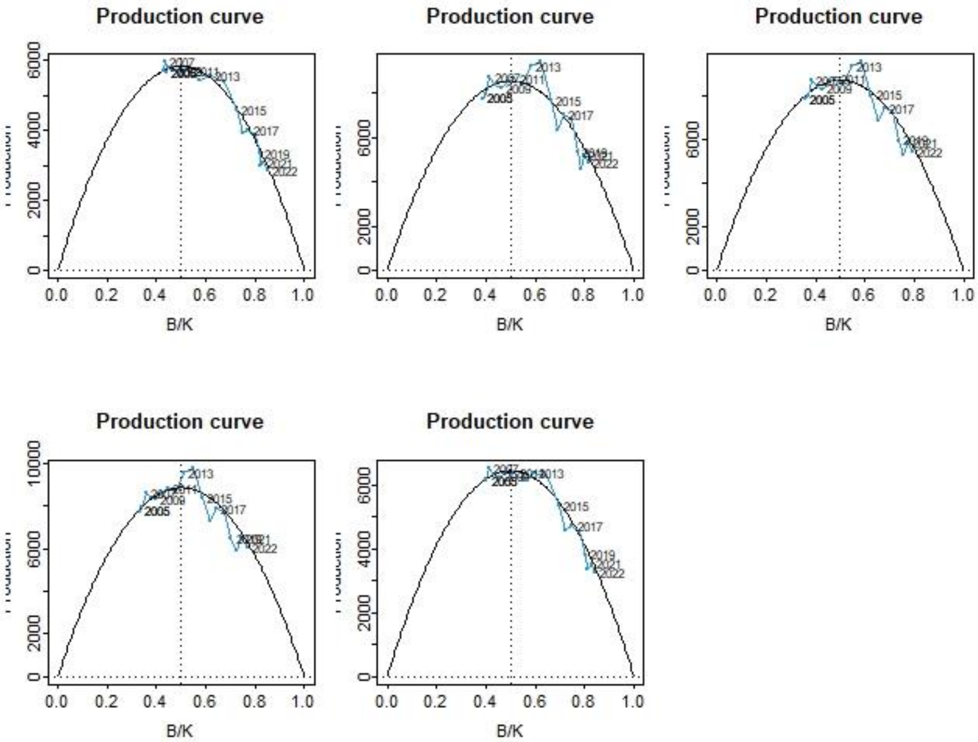

Figure 4.15. Production curves, Scenarios 3–7.

Table 4.6. Parameter estimates of Scenarios 3-7.

	alpha (95% CI)	beta (95% CI)	r (95% CI)	rc (95% CI)	rold (95% CI)	m (95% CI)	K (95% CI)	q (95% CI)
Scenario 3	5.2308	0.1335	0.5225	0.5225	0.5225	5823.3783	44582.2771	0.333
	(0.6546-41.7966)	(0.0213-0.8374)	(0.1278-2.1362)	(0.1278-2.1362)	(0.1278-2.1362)	(3749.4129-9044.5453)	(7570.4228-262545.3656)	(0.0602-1.8415)
Scenario 4	5.6756	0.1338	0.2304	0.2304	0.2304	8550.1527	148432.4431	0.1057
	(0.7004-45.9904)	(0.0213-0.8421)	(0.1262-0.4208)	(0.1262-0.4208)	(0.1262-0.4208)	(3190.4229-22913.925)	(36751.3423-599493.4819)	(0.0219-0.5092)
Scenario 5	6.0293	0.1329	0.2226	0.2226	0.2226	8712.5326	156569.7476	0.1065
	(0.7767-46.8027)	(0.0212-0.8336)	(0.1219-0.4064)	(0.1219-0.4064)	(0.1219-0.4064)	(3457.8872-21952.198)	(41570.1277-589704.3677)	(0.0244-0.4655)
Scenario 6	6.1074	0.1324	0.2129	0.2129	0.2129	8873.0109	166717.1689	0.1066
	(0.7857-47.4712)	(0.0211-0.8288)	(0.1152-0.3935)	(0.1152-0.3935)	(0.1152-0.3935)	(3664.9277-21482.0945)	(46119.4952-602665.191)	(0.0259-0.4393)
Scenario 7	5.6329	0.1325	0.3967	0.3967	0.3967	6446.255	65006.2241	0.2365
	(0.7153-44.3561)	(0.0212-0.828)	(0.0584-2.693)	(0.0584-2.693)	(0.0584-2.693)	(2985.066-13920.6985)	(4741.3268-891271.4465)	(0.0203-2.7587)

Table 4.6 continued. Parameter estimates of Scenarios 3-7.

	sdb (95% CI)	sdf (95% CI)	sdi (95% CI)	sdc (95% CI)
Scenario 3	0.0346	0.1489	0.1807	0.0199
	(0.0046-0.2616)	(0.1009-0.2197)	(0.1236-0.2644)	(0.0032-0.1219)
Scenario 4	0.0324	0.1511	0.1838	0.0202
	(0.0042-0.2504)	(0.1021-0.2236)	(0.1252-0.2699)	(0.0033-0.1243)
Scenario 5	0.0301	0.1534	0.1815	0.0204
	(0.004-0.2247)	(0.104-0.2261)	(0.125-0.2636)	(0.0033-0.1251)
Scenario 6	0.0296	0.1549	0.181	0.0205
	(0.004-0.2221)	(0.1052-0.228)	(0.125-0.2619)	(0.0033-0.1257)
Scenario 7	0.0317	0.1518	0.1788	0.0201
	(0.0042-0.2379)	(0.103-0.2237)	(0.1233-0.2593)	(0.0033-0.1232)

Table 4.7 Order of magnitude check (values ≥1=FAIL), Scenarios 3-7.

		order of magnitude				order of magnitude
scen3	B/Bmsy	0		scen6	B/Bmsy	1
	F/Fmsy	0			F/Fmsy	1
scen4	B/Bmsy	0		scen7	B/Bmsy	0
	F/Fmsy	1			F/Fmsy	0
scen5	B/Bmsy	0				
	F/Fmsy	1				

Again, all runs converged. Examination of the diagnostics showed excessive order of magnitude differences between B/Bmsy and F/Fmsy in Scenarios 4,5 and 6. These runs were therefore excluded. Scenario 7 was considered very similar to Scenario 3. However, of the two, only Scenario 3 had a Mohn's rho value that was within the acceptable ICES range (ICES 2020b). This states that for long-lived stocks, Mohn's rho should be no more than 0,2 or no less than -0.15. Scenario 3 had values of 0.0691358 for F/Fmsy and -0.05525389 for B/Bmsy. Therefore Scenario 3 is considered the accepted assessment for this stock.

4.4.3 Forecast

With Scenario 3 chosen as the final assessment, a forecast was carried out using four management default options with the preferred option in bold

- No Fishing (F = 0)
- Fishing at Status Quo
- Hockey stick
- **35th Catch quantile**

This resulted in the following outputs:

Table 4.8 Management options (est.C in tonnes).

Management options			
	est.C	est.B.Bmsy	est.F.Fmsy
1. F=0	0	1.79	0
2. F=Fsq	4228.2	1.63	0.44
3. F=Fmsy	9014.3	1.44	1
4. F=Fmsy_C_fractile	8603.6	1.46	0.95

Table 4.9. Predicted Catch and States (exploitable biomass, B, and Catch in tonnes).

Predicted Catch and States				
	prediction	cilow	ciupp	log.est
B_2023.00	38360.18	6530.52	225327.02	10.55
F_2023.00	0.06	0.01	0.39	-2.76
B_2023.00/Bmsy	1.72	1.55	1.91	0.54
F_2023.00/Fmsy	0.24	0.13	0.47	-1.42
Catch_2022.00	2405.13	1665.65	3472.91	7.79
E(B_inf)	39092.89	NA	NA	10.57

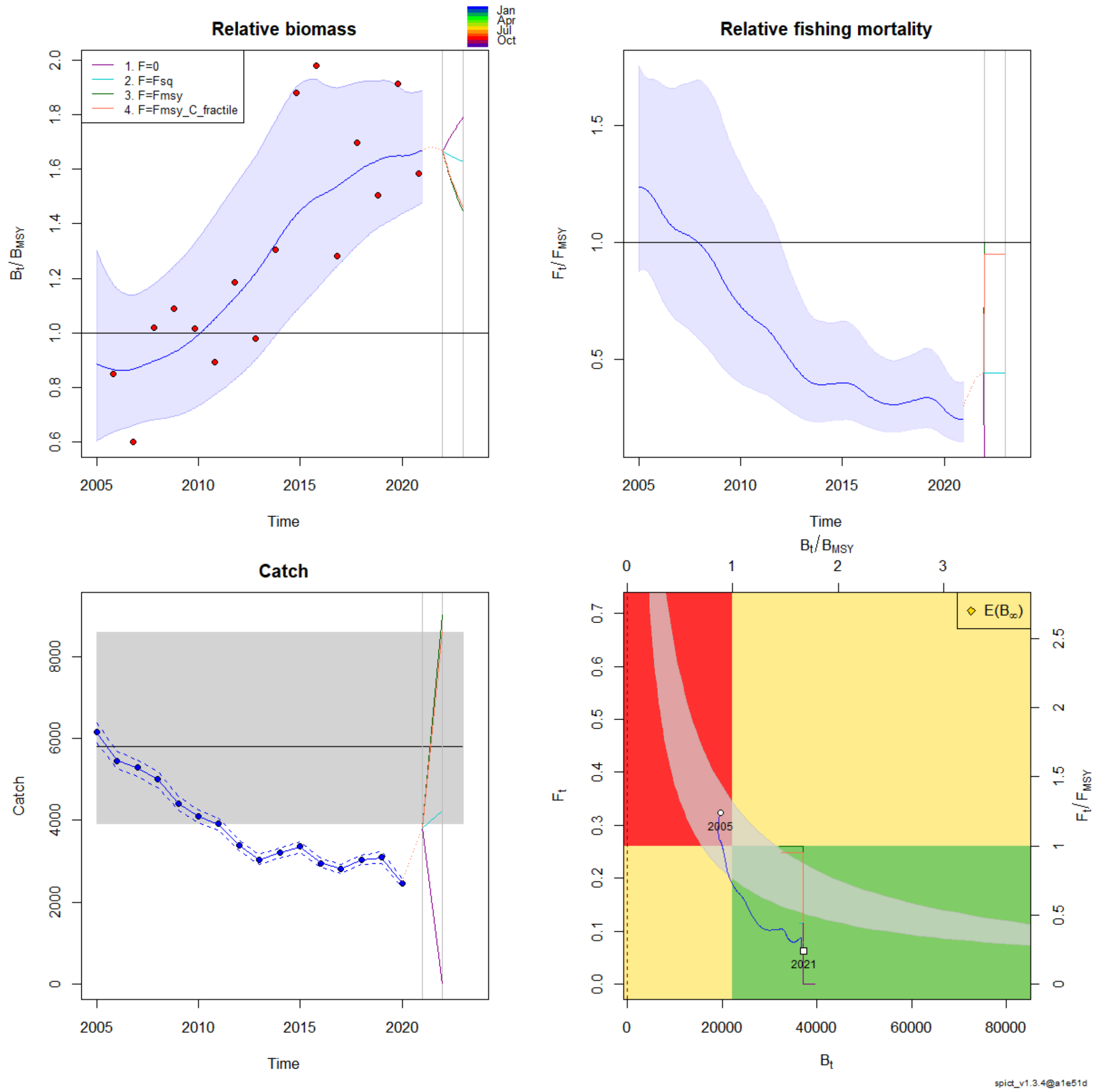

Figure 4.16 Forecast results (Catch in tonnes).

Fishing at the forecast level for the 35th catch quantile would lead to a catch of 8,603 t in 2023. This is considerably higher than current levels, with landings of 2,450t in 2020.

4.5 Future considerations/recommendations

A future re-examination of stock structure is required (including relevant data relating to genetic structure, parasites, movements and life-history). A stock identification project for *L. naevus*, involving genetic and other approaches, would be beneficial.

Re-examine discard data to allow its use in an assessment. However, current reporting and sampling structures may not allow this.

Further recommendation to enhance the combined overall index used in the assessment as to explore potential gear, vessel, and seasonality effects not currently account for. Most surveys used a type of 'GOV' gear, with subtle differences in ground gear etc., except for the Q1SWECOS where fishing occurs using two 4 m beam trawls. Surveys are also conducted at different times of the year, from Q1, Q3 and Q4 (Lorance and Silva, 2022 WD). Thus, future quantitative evaluations may be needed as to better evaluate potential effects of catchability and selectivity on the current output metrics and its implications to the overall assessment. Such work could be usefully undertaken during a dedicated workshop on surveys in the Celtic Seas ecoregion following similar process of WKSKATE in 2020 where surveys in the North Sea ecoregion were evaluated (ICES, 2021c).

Furthermore, although assumed to be of negligible impact to the overall index, the current combined index does not account for the degree of overlap between the index of EHVOE and Q1SWECOS in divisions 7.f and 7.h. Additionally, the current methodology for Q1SWECOS used in the assessment follows the random stratified survey design with no associated CIs provided, as the results are estimates of absolute biomass on swept area weighting (Silva, 2021 WD). A second methodology was developed to understand the uncertainty of using Q1SWECOS in its current form, which could be also further explored so as to provide an alternative index (Silva, 2022 WD).

4.6 Reviewers report

4.6.1 Stock ID

Steve Cadrin, Christoph Stransky, David Murray and Zachary Whitener

Information on spatial distribution, genetics, geographic variation in size distribution, and tagging was reviewed (Lorance *et al.* 2022 WD, Silva 2021 WD). Cuckoo ray are distributed in the eastern Atlantic, from southern Norway to the Mediterranean Sea, and survey and fishery catches from ICES areas suggest a relatively continuous spatial distribution from the Shetland Islands (ICES Division 4a) along the continental shelf to the Bay of Biscay (8b; Lorance *et al.* 2022 WD, Figure 1). Nykänen *et al.* (2020) analyzed mitochondrial DNA from 188 specimens sampled from west of Scotland (6a), west of Ireland (7bc), and the Celtic Sea (7gj) and found no evidence of population structure. Size distributions of survey catches had similar size ranges among areas, with slightly different length modes, suggesting a well-mixed stock among areas (Lorance *et al.* 2022 WD). However, Bird *et al.* (2019) reported results from 43 tagged cuckoo ray with two months to six years at large that were mostly recaptured in the same ICES Division as the release location and exhibited a maximum distance of 425 km.

In summary, cuckoo ray appear to have local home ranges but are continuously distributed among ICES areas, with no evidence of genetic or phenotypic population structure. Therefore, WKELASMO concluded that information on stock identity is insufficient to revise the current advisory unit (Subareas 6 and 7, Divisions 8ab and 8d: west of Scotland, southern Celtic Seas, western English Channel, and Bay of Biscay). Uncertainty in stock identity can be addressed with further investigation of geographic variation in genetics (ideally using more sensitive nuclear markers) and life history (e.g., size at maturity from surveys).

4.6.2 Stock Assessment

Enric Cortés and Jan Jaap

The stock identity was discussed in detail during the benchmarking process. Two observations started the discussion on a change in the division of the species over different stocks: (i) there is a natural 'break' in the distribution to the SW of Ireland, closely coinciding with the latitude separating ICES divisions 7.b and j and (ii) there is no natural division between ICES subareas 4 and 6, and that the stock continues into the North Sea. A comprehensive discussion of the stock identity was made available in Working Document xxxx. Finally, the benchmark decided not to change the current stock units. Further investigation into the population structure was recommended, particularly by further use of genetic methods.

As inputs to a possible surplus production model, Landings and survey data were available. Discard information for this stock are not considered reliable and are therefore not quantified. Catches were thus assumed equal to landings. Estimates of landings prior to 2005 were deemed too unreliable based to be used as proxies for removals. This decision was based on a sudden increase in landings between 2004 and 2005 that could not be explained by changes in the fisheries, or the stock biology.

Landing in the period 2005-2009 were estimated by the benchmark. This was done by estimating the proportion of landings in the immediate following years where landings are believed to be reliable. This proportion was applied to the total landings of rays in the period 2005-2009.

Seven survey indices (EVHOE (Q4), IE-IGFS (Q4), NIGFS (Q1 and Q4), SP-PORC (Q3) and SCOWCGFS (Q1 and Q4)) were available for this stock. For the benchmark, indices were recalculated from the survey data available in DATRAS, to be able to provide a combined survey index, to be tested in the assessment. Indices were calculated by raising swept area fished to the total sampled area, so that these are provided in absolute values in tonnes (Lorance and Silva, WD5). These combined biomass indices provided an overall index for the stock assessment, based on the exploited biomass (individuals ≥ 50 cm total length).

SPIcT was used to assess the status of the cuckoo ray (*Leucoraja naevus*) stock in ICES subareas 6 and 7, and divisions 8.a, b and d (ICES stock code rjn.27.6abd). Inputs to the model included total catches, and two configurations for biomass indices: runs including 7 separate indices (disaggregated runs) and runs including the single index that was obtained independently by combining the 7 indices (aggregated runs). For both index configurations (disaggregated and aggregated) 5 runs were developed by sequentially adding a prior for r, fixing the shape parameter n to 2 (i.e., forcing it to a Schaefer model), and setting initial depletion to 0.5 or 0.3.

There was concern that the estimated values of r obtained by setting a prior derived from FishLife were unrealistically high (r~1 for the disaggregated runs) and still high but more credible for the aggregated runs (r~0.5, but with very large CIs). It was noted that the extreme r values were likely a result of the steeply declining catch series and increasing trends of the biomass indices, which the model interpreted as the stock having an unusually large productivity.

After discussion, the recommendation from the panel and reviewers was to develop a base model based on the aggregated index, which was deemed to be more representative of real stock trends than the individual indices. The base run should also include a prior of r more consistent with that of other skate stocks (a value of r=0.2 was recommended) and an initial depletion of 0.5. Since there did not seem to be any information on historic catches, a sensitivity run using a very high initial depletion (0.1-0.2) was also proposed to explore how the model would respond to an assumption of a heavily exploited stock at the beginning of the model. There was also a question about the very low magnitude of recent catches and it was explained that it was likely a result of introduced regulations.

Concern was expressed that because the catches were declining and the indices were increasing, the result is a large increase in biomass according to the surplus production model, resulting in very low F values and some biomass estimates being close to the carrying capacity. Therefore, the validity of using these results to provide catch advice was questioned since if stock status indicates with great certainty that $F \ll F_{MSY}$ and that $B \gg B_{MSY}$ this could result in a very large increase in allowable catches. To that point it was noted that catch forecasts are needed, but considering the caveats mentioned.

The final model accepted was run 3, which used the prior of r obtained from FishLife, the shape parameter from the Schaefer model (n=2), and an initial depletion of 0.5 with sd=0.5. Although the posterior estimate of r from this model was high (r=0.52) the retrospective patterns were the best.

4.7 References

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5 Undulate ray (*Raja undulata*) in the English Channel (rju.27.7de)

5.1 Introduction

Undulate ray in the English Channel (rju.27.7de) is currently assessed as a Category-3 stock and its management follows the precautionary approach. Since 2020, the advice is formulated in terms of catch and based upon the evolution of the total biomass index provided by the FR-CGFS survey carried out in autumn in Division 7.d. Undulate ray in the English Channel was listed as a prohibited species between 2009 and 2013 and a null TAC was set in 2014 so the data series of substantial landings begins in 2015. When landings were authorised again in 2015, the original precautionary TAC (expressed in terms of landings) was set at 111 tonnes (100 t for Division 7.e and 11 t for Division 7.d, Council Regulation (EU) 2015/104). The following advice for this stock (2016) was based on landings recorded in 2015. Due to limited landing opportunities for the rju.27.7de stock following the resumption of the setting of a TAC, most of the catch is currently discarded. Targeting of undulate ray is not allowed in the English Channel.

During the benchmark workshop WKELASMO, 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.

5.2 Stock Identity

No catches of undulate ray have been reported in the North Sea during the IBTS and BTS scientific surveys over the period 2018-2020. The only observations of this species during the NS-IBTS survey in 2019-2020 were made in Division 7.d. Even though landings of undulate ray can be reported in Division 4.c, the stock is perceived as only marginally extending into southern North Sea (Ellis *et al.*, 2012).

Regarding the western side of the distribution area in the English Channel, the species was not caught during the IBTS surveys covering the Celtic Sea in 2018-2020. In addition, Silva (2021 WD) showed that undulate ray caught in the western English Channel during the Q1SWECOS (Cefas Q1 Southwest Ecosystem Survey) beam trawl survey was essentially concentrated in the eastern part of Division 7.e. The author also reported the absence of this species from hauls carried out in the Celtic Sea (Figure 5.2.1).

As for the BTS survey covering the North Sea, English Channel, Irish Sea and northern Celtic Sea, the only reported catches of undulate ray were associated with stations within the English Channel in 2018-2020. The distribution of recent observations of the species in international trawl surveys coincide with its historical distribution as described by Ellis *et al.* (2012).

These observations suggest that the exchanges between the stock of undulate ray inhabiting the English Channel and other populations are very limited.

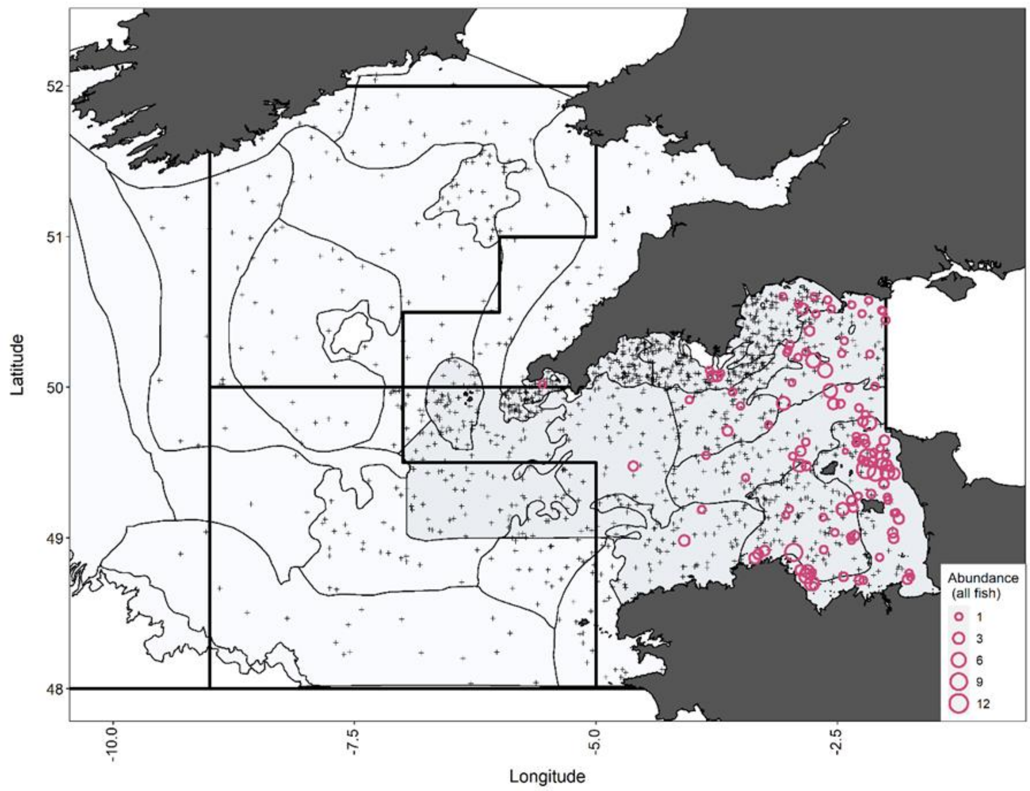

Figure 5.2.1. Spatial distribution of undulate ray caught during Q1SWECOS survey (2006–2020). Source: Silva (2021 WD).

Undulate ray has been shown to usually perform movements within a small spatial range in the English Channel, and individuals residing in an estuary of the Norman-Breton Gulf in spring have been observed migrating out of it in the course of the summer (Trancart *et al.*, 2020). Periodical seaward and coastward movements have been reported in other areas within the English Channel (Hook, 2019), similar to also observed in Galician waters (Leeb *et al.*, 2021). These seasonal movements are associated with a site residency in coastal areas. It is hence expected that this stock shows a limited degree of mixing. However, a cluster analysis performed on sequences of nuclear DNA did not detect any genetic structure between the individuals from the different sampled locations based on deviation from Hardy-Weinberg equilibrium (Stephan *et al.*, 2015). The same study however reveals some level of genetic differentiation at small spatial scale, as shown by significant values of the fixation index F_{ST} (Stephan *et al.*, 2015). Nevertheless, undulate ray in Divisions 7.d and 7.e are considered to comprise a single stock.

5.3 Input data for stock assessment

Data series of dead catch (designated as "removals" here) and total biomass indices from scientific surveys FR-CGFS (for Division 7.d) and Q1SWECOS (for Division 7.e) were used as inputs for the SPiCT runs. Detailed information on the input data can be found in Baulier (2022a, b WD).

5.3.1 Catch data

Removals consist of the combination of two types of data: landings and dead discards. For this stock discards can represent a large part of the catch (the main part since 2009) thus, ignoring dead discards in the assessment would produce a biased diagnosis. Data were provided by the three main countries contributing to catches of this stock: Belgium, France and the United Kingdom. When considering the stock of undulate ray in the English Channel (rju.27.7de), three periods can be differentiated:

1. Before 2009. Although the reporting of some species-specific landings of skates and rays did occur before that year in the English Channel, it only became mandatory in 2009 following Council Regulation (EU) 43/2009. In earlier years, species-specific landings were generally associated with the main commercial skate species in the area, a group not including undulate ray. Thus, undulate ray landings were usually included in a broad category of "skates & rays", a generic denomination encompassing less common species or of lesser commercial importance, and unsorted landings of the main species.
2. From 2009 to 2014. The obligation of reporting landings of skates by species coincided with the inclusion of undulate ray into the list of prohibited species for vessels of the European Union. As a consequence, with the exception of minor and sparse reports, no landings of undulate ray occurred between 2009 and 2015. During this period, fishing mortality is assumed to be almost exclusively associated with the discarding of dead or dying individuals.
3. From 2015 onwards. With the setting of a separate precautionary TAC for the stock, data series of substantial landings of undulate ray started in 2015. The data call for WKELASMO having been issued in 2021, the last available year of data is 2020.

The three countries (Belgium, France and the UK) associated with the recent exploitation of the stock provided time series of landings and estimated discards by ICES division and fleet for periods 2 and 3. Landing data by country are expected to be exhaustive for 2009-2020.

Discard estimates rely on national sampling programmes involving onboard scientific observers. Because undulate ray is mostly a coastal species (Ellis *et al.*, 2012), it is often caught by the smaller fishing vessels. This fleet segment tends to be under-represented in the national sampling programmes. This is partly because these vessels provide limited boarding opportunities for observers due to constraints on space onboard and/or because they represent a relatively small contribution to the landings of the main stocks for which sampling is essentially designed. It entails that sample sizes (numbers of vessels and undulate ray samples) are regularly too small to allow the estimation of discarded quantities for all possible combinations of fleet and ICES division. Ignoring combinations of fleet and area for which estimates of discards are unavailable leads to underestimating the discards of undulate ray in the English Channel.

A method is here presented to fill gaps in the data series of discards between 2009 and 2020 in ICES divisions 7.d and 7.e using estimates from other years and sometimes the other division, as well as a method to estimates landings in 2005-2008. In the years preceding the inscription to the list of prohibited species, undulate ray was not sorted and was landed within a generic "Skates & rays" category. Furthermore, national onboard sampling programmes used to estimate discards in the English Channel had been not initiated or were in their infancy.

Owing to the particularities of the times series of discard estimates from Belgium, France and the United Kingdom, ad-hoc approaches were suggested for each of the series. The resulting estimates of discarded quantities were then multiplied by the estimated mortality rates of discarded fish to yield time series of dead discarded biomass.

Due to the high uncertainty associated with the estimation of certain quantities, it was decided to adopt a precautionary and conservative approach when compensating the absence of data. Indeed, the underestimation of removals to which this choice leads is expected to generate an underestimation of the intrinsic rate of increase of the population (r) and an overestimation of the biological capacity K, two quantities influencing management reference points.

5.3.1.1 Landings

Reporting landings by species became mandatory in 2009 for skates in the English Channel. Before that year, a generally low and fluctuating proportion of landings of skates and rays was reported by species, primarily for the main commercial species (e.g. *Raja clavata, Raja brachyura, Leucoraja naevus*). The obligation of reporting by species coincided with the inscription of undulate ray on the list of prohibited species where it remained until 2014. As a consequence, landing data for undulate ray in the English Channel are scarce prior to 2015, when a precautionary TAC was introduced. Landing data were provided on an annual basis by Belgium and on a quarterly basis for France and the UK for WKELASMO. For simulation scenarios using quarterly data, Belgian landings were divided by a factor 4, to evenly distribute annual landings between the quarters. The same procedure was applied to discard estimates, which were all provided on an annual basis.

Landing data for the 2005-2008 period were reconstructed to extend the data series and improve parameter adjustment. The reconstruction of landings was limited to 2005-2008 because it was based on temporal trends in French landings reported by statistical rectangle, mostly labelled as "Skates & Rays" and coded "RAJ" in data reported to ICES. To estimate Belgian and British landings before 2009, the ratio of Belgian or British to French catches of undulate ray in recent years was used.

a) French reconstructed landings 2005–2008

Leblanc *et al*. (2013), based on the hypothesis that the decrease in French landings of skates and rays in Division 7.e between 2007–2008 and 2009–2010 was imputable to the simultaneous prohibition of undulate ray, estimated the annual French landings of undulate ray at 300 tonnes in Division 7.e prior to the ban.

This approach could not be applied to French landings of skates and ray in Division 7.d. While French landings of skates and rays decreased between 2008 and 2009 in Division 7.e, the opposite pattern was observed in Division 7.d (Figure 5.3.1).Therefore, a higher degree of detail was considered and the estimation of discards of undulate ray was based on records of landings of skates and rays by species (sorted and unsorted). Prior to 2009, species-specific landings for the main commercial skate species can also be found in logbooks and sale records. However, the proportion of species-specific records for one given species varies in time and variations in recorded landings of one particular species cannot be directly interpreted as variations in actual landings of this species. Similarly, quantities reported in the generic category “Skates & rays” to which landings of undulate ray were included, vary in composition with time and fleet. Because no specific landings of undulate ray by French vessels were reported before 2009, the landings of this species were a component of the generic category.

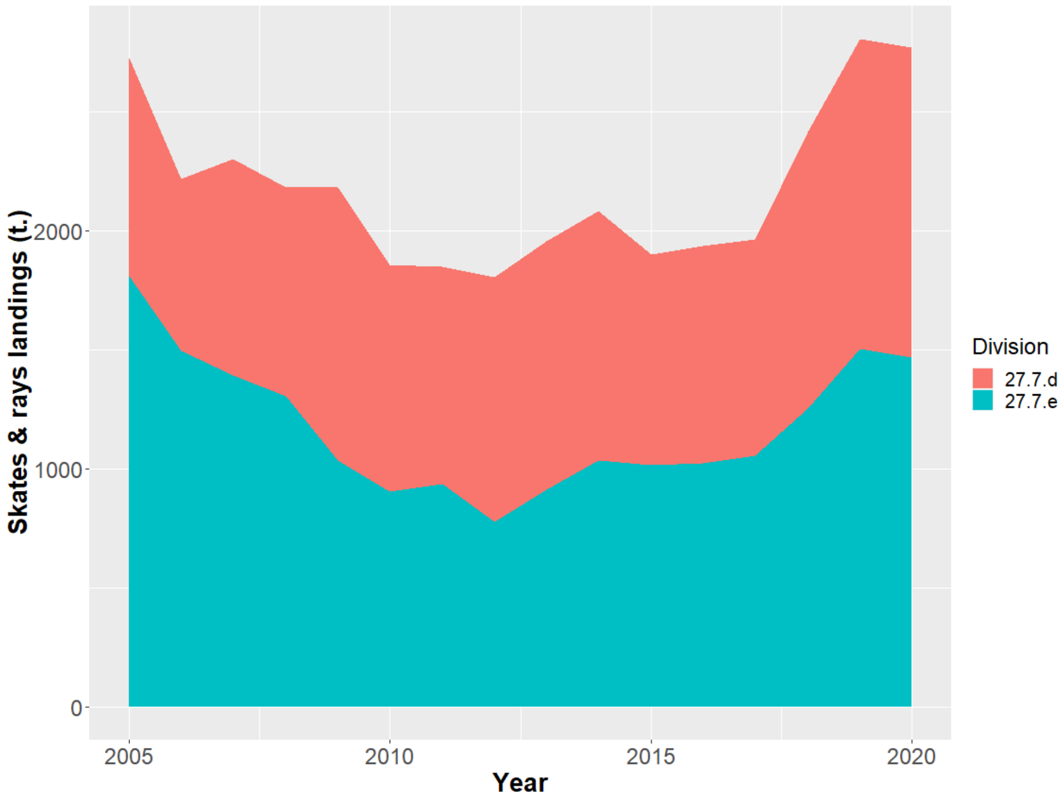

Figure 5.3.1. Time series of estimated landings of skates and rays in the English Channel by French vessels since 2005.

In order to limit the influence of variations in contributions of other species to the "Skates & rays" category, only landings originating from the more coastal areas were considered. Indeed, undulate ray being mostly encountered in shallower waters (Ellis *et al.*, 2012), its relative weight within the generic category is expected to be larger for coastal areas and hence variations in quantities ascribed to the generic category are supposed to be more affected by changes in landings of undulate ray. Small-sized vessels are usually not equipped with VMS transmitters hence, a coarser approach was undertaken to separate landings from inshore and offshore fishing grounds in the English Channel. This was done by distinguishing ICES statistical rectangles whose limits intersect the coastline or encompassing any of the Channel Islands ("coastal" rectangles) and those whose limits do not intersect the coastline ("offshore" rectangles). The focus on coastal rectangles reduces errors associated with the reconstruction of landings of undulate ray, but this introduces an underestimation of landed quantities, as undulate ray also contribute to landings from the so-called offshore rectangles.

French landings of skates and rays by species, including a "Skates & rays" category incorporating various species are presented in Figure 5.3.2 for coastal rectangles. Despite the obligation to have separated records by species, the "Skates & rays" category was still present in data after 2009, although showing a decline in proportion over time.

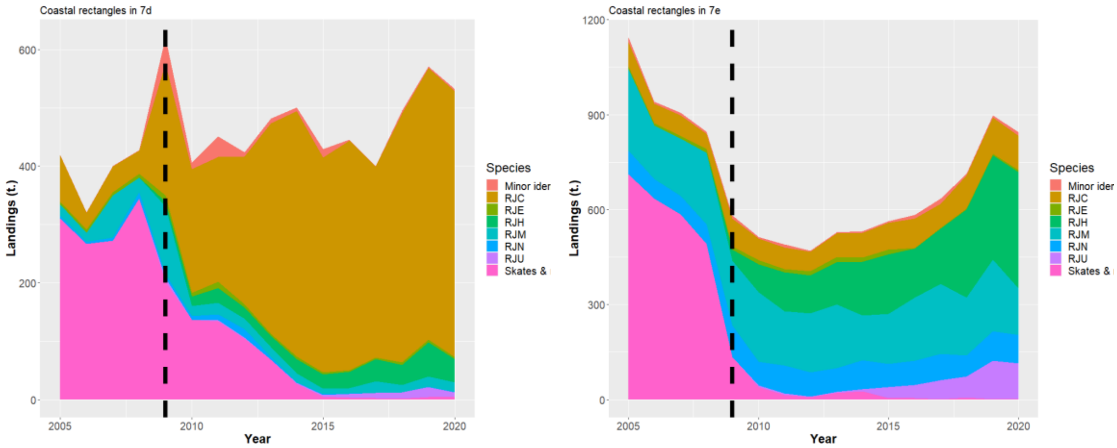

Figure 5.3.2. Initial French landings of skate and ray species from the coastal rectangles of the English Channel since 2005 by division. Year 2009, marking the transition to mandatory reporting of species names, is represented as a vertical dashed line.

Raw differences in landings of "Skates & rays" between 2008 and 2009 are not considered here, because, as mentioned earlier, quantities reported in this category are not only affected by changes in landings of skate and ray species of secondary importance, but are also influenced by the proportion of main commercial skates sorted by species. In order to correct for this bias, an attempt was made here to reconstruct 2005-2008 time series of landings of species for which specific records are available in the early 2010s. Extending the series backwards past 2005 was considered too doubtful here, given the short time span on which trends were derived.

This reconstruction was based on the backward projection of time trends in specific landings, or their average if the linear trend in landings was not statistically significant. 2010–2013 was selected as the reference period to derive these trends or averages, based on the assumption that relative changes in landed quantities observed within this period reflected changes that had occurred during 2005-2008. 2009 was excluded from this reference period, being a year of transition to the full sorting by species. Consistent with the conservative approach adopted so far, when the reconstruction process yielded a lower quantity that the reported landings for a particular species, the later was used. New series of "Skates & rays" landings were then recalculated as the difference between these reconstructed series and total landings of skates and rays. The reconstructed series are presented in Figure 5.3.3.

The differences in the reconstructed landings of "Skates & rays" between 2008 and 2009 are 88.7 tonnes and 207.9 tonnes for divisions 7.d and 7.e, respectively. Following the same reasoning as Leblanc *et al*. (2013), the decrease in landings is attributed to the absence of undulate ray in 2009 landings. Hence, the difference in landings of "Skates & rays" between 2008 and 2009 is assumed to correspond to landings of undulate ray in 2008.

An additional assumption is required to extend the series of landings of undulate ray before 2008. Here we supposed that landings of undulate ray followed the same trend as landings of the generic category "Skates & rays" between 2005 and 2008 in each of the divisions.

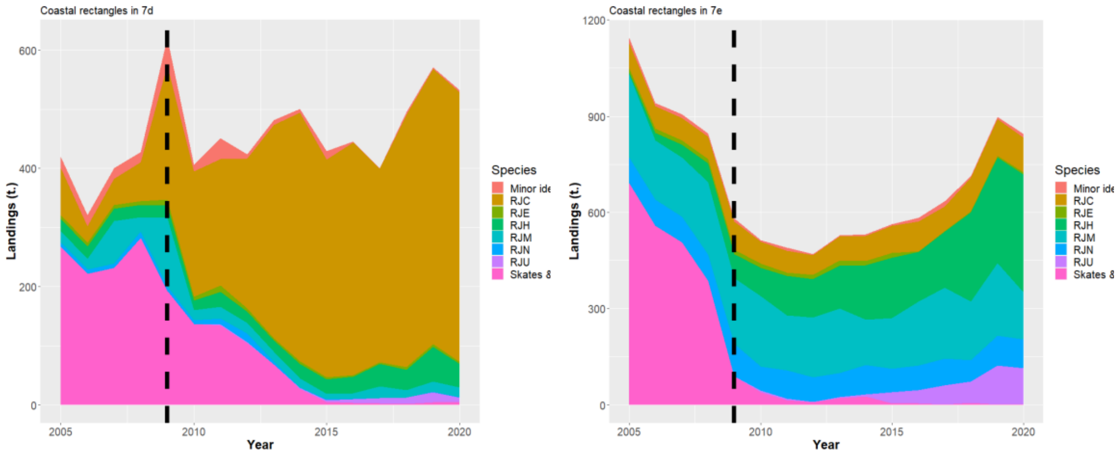

Figure 5.3.3. French landings of skate and ray species from the coastal rectangles of the English Channel since 2005, with reconstructed quantities between 2005 and 2009 by division. Year 2009, marking the transition to mandatory reporting of species names, is represented as a vertical dashed line.

In order to reproduce the 2005–2007 French landings of undulate ray, the estimated proportion of undulate ray landings relative to landings of "Skates & rays" calculated for 2008 (31.5% and 76.8% in Division 7.d and 7.e respectively) is multiplied by the reconstructed landings of "Skates & rays" in 2005–2007 (Table 5.3.1).

Table 5.3.1. Reconstructed French landings of undulate ray by ICES division for the period 2005–2008, in tonnes.

	2005	2006	2007	2008
27.7.d	84.3	69.8	72.9	88.7
27.7.e	369.9	311.0	290.7	207.9
Total	454.2	380.9	363.5	296.6

b) British reconstructed landings 2005–2008

The calculation relies on the assumption that the ratios of undulate ray catches between British and French fleets have remained constant over time in each ICES division. The average ratio derived over the period 2016–2020 is then applied to the 2005–2008 period to obtain the reconstructed British landings of undulate ray for 2005–2008 (Table 5.3.2).

Table 5.3.2. Reconstructed British landings of undulate ray by ICES division for the period 2005–2008, in tonnes.

	2005	2006	2007	2008
27.7.d	150.8	124.9	130.4	158.7
27.7.e	302.0	253.9	237.3	169.7
Total	452.8	378.9	367.7	328.4

c) Belgian reconstructed landings 2005–2008

The same method as for British landings is applied to estimate Belgian landings of undulate ray in 2005–2008. In this case, the mean ratios of Belgian to French catches of undulate ray by division were calculated for 2016–2018, the last two years being excluded due to the recent prohibition on landing this species in Belgium. The outcome is summarised in Table 5.3.3.

Table 5.3.3. Reconstructed Belgian landings of undulate ray by ICES division for the period 2005–2008, in tonnes.

	2005	2006	2007	2008
27.7.d	4.4	3.6	3.8	4.6
27.7.e	7.7	6.4	6.0	4.3
Total	12.0	10.1	9.8	8.9

Some scenarios for the SPiCT model were based on the short time series (2009–2020) while others were based on the extended series (2005–2020).

5.3.1.2 Dead discards

Discarded quantities of undulate ray are estimated using different approaches depending on the specificities of the national onboard sampling programmes. Belgian data are raised using the landings of the species of interest, French data are raised based on the landings of all species, and British data (E&W) are raised using fishing effort. Discard estimates were provided to WKELASMO on an annual basis and at the level of the fleet and the ICES division.

Due to the unavailability of discard estimates for some combinations of year-fleet-division caused by insufficient sample sizes, a reconstruction of missing data was carried out (Baulier, 2022a WD). The approach applied differed between countries.

a) Belgium

The raising factor applied for the estimation of discarded quantities is the landing of the considered species. Since a national legislation promoted in 2019 prohibits landing undulate ray, the most recent estimates correspond to year 2018 (Table 5.3.4). Discard estimates were provided for beam trawl only, as the dominant gear used by Belgian fishing vessels in the English Channel.

Table 5.3.4. Initial estimates of annual discards of undulate ray by Belgian beam trawlers as reported to ICES (for WKELASMO), in tonnes.

	2016	2017	2018
27.7.d	0.5	19.5	14.8
27.7.e	0.9	52.6	138.0
Total	1.4	72.1	152.8

Due to the suspiciously low values estimated for 2016, it was decided during an intermediate meeting on 11 January 2022 not to use these estimates in the reconstruction of the data series. Hence, the arithmetic mean of the 2017–2018 estimates for each of the ICES divisions were extended over the period 2009–2020. For divisions 7.d and 7.e, the means are 17.2 tonnes and 95.3 tonnes respectively.

b) France

The raising factor applied for the derivation of French discard estimates is the landings of all species combined and estimation was originally made at the level of EU-DCF-level-5 fleet corresponding to the combination of a fishing gear and a target species (e.g. OTB-DEF, for otter trawl targeting demersal fish). Because small sample sizes frequently prevented the estimation of discards for some fleets, these fleets were pooled into broader categories of gear families: gillnets (GNS) and trammel nets (GTR) were pooled into the category "Nets", bottom otter trawls (OTB) and multi-rig otter trawls (OTT) were pooled into the category "Bottom trawls". The available discard estimates by ICES division and gear family are presented in Table 5.3.5. A distinct peak is noticeable in the series of discards in 2012 for bottom trawls in Division 7.e. A detailed examination of the onboard sampling data associated with this estimate revealed that observed fishing operations were carried out on average 9.3 m shallower than in 2011 (34.4 m versus 43.7 m), with both catch weights (28.5 kg versus 12.0 kg) and frequencies of occurrence (11.2% versus 6.6%) of undulate ray being approximately twice as high in 2012 as in the previous year. Because no obvious erroneous data could be pointed out, this estimate was kept within the time series. However, a smoothed data series (loess function in R with span=0.9) was used to moderate the influence of this outlier. (Figure 5.3.4).

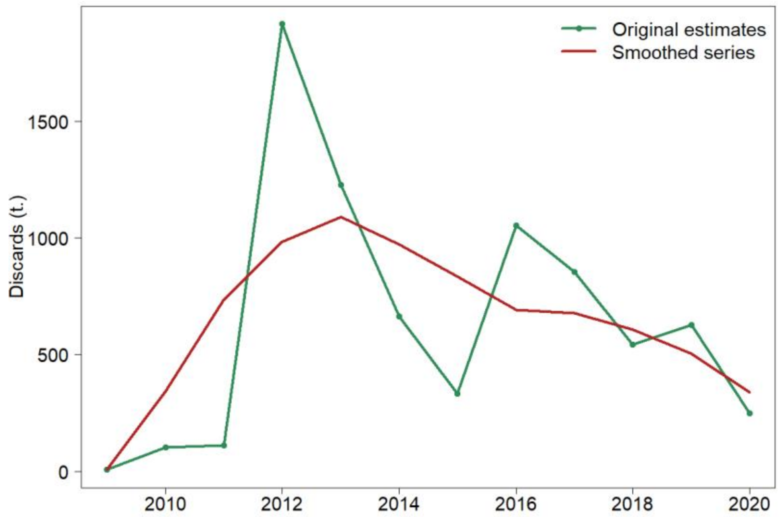

Figure 5.3.4. Initial as reported to ICES (for WKELASMO) and smoothed data series of discard estimates of undulate ray by French bottom trawlers in Division 7.e.

While discards are estimated for all years for bottom trawls, missing estimates can be very frequent for other fleets (e.g. seines) (Table 5.3.5).

Table 5.3.5. Initial estimates of annual discards of undulate ray by French fleets, as reported to ICES, in tonnes.

27.7.d	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beam trawl	0.6	NA	NA	NA	2.2	6.0	6.1	25.2	25.7	115.0	5.1	NA
Bottom trawls	6.7	8.2	19.6	29.7	30.5	113.7	161.8	246.0	285.1	383.2	317.5	233.1
Nets	2.0	NA	9.7	4.7	6.1	16.5	21.7	11.8	10.9	9.3	3.2	5.3
Pelagic trawls	NA	NA	NA	NA	NA	0.4	2.1	NA	31.5	8.6	6.3	NA
Seines	NA	NA	NA	NA	NA	0.2	0.3	12.3	1.3	0.9	7.1	NA
Total	9.4	8.2	29.3	34.3	38.8	136.7	192.0	295.2	345.5	517.0	339.2	238.3

27.7.e	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beam trawl	NA	NA	5.4	19.0	21.5	21.7	17.1	17.8	NA	NA	NA	NA
Bottom trawls	7.0	101.8	110.4	1916.8	1226.4	663.2	333.8	1052.9	853.0	544.5	626.4	250.1
Dredges	NA	NA	419.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hooks and lines	0.8	NA	NA	NA	NA	NA	13.5	NA	NA	NA	NA	NA
Nets	1.3	62.2	13.9	18.3	39.6	39.4	40.4	65.0	65.0	95.6	88.2	92.9
Other gears	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	14.3	NA
Pelagic trawls	NA	NA	NA	NA	NA	0.9	NA	NA	NA	NA	NA	NA
Seines	NA	NA	4.1	NA	NA	NA	0.6	NA	NA	NA	NA	NA
Total	9.1	164.0	553.2	1954.1	1287.6	725.3	405.3	1135.7	918.0	640.1	729.0	343.0

The proposed approach was to simulate the missing values based on available estimates for the same fleet and division. The reconstruction algorithm applied the following rules:

- → When one missing value or one set or consecutive values was surrounded by two estimates, the mean of the two values was used.
- → When the value of the first or last year of the series was missing, the mean of the closest two values was used.
- → When only one estimate was available in the whole series, this estimate was extended to the whole series.
- → When a series does not contain any estimate, the missing values are not simulated. Therefore, assuming zero discards for this fleet and division.

The resulting series of estimated discards of undulate ray by French fleets are presented in Table 5.3.6.

To be noted that an alternative approach, based on the average ratio of estimates from one fleet over the estimates from the fleet of bottom trawlers (for which full series are available), was also applied and presented during an intermediate meeting on 11 January 2022. Based on the serrated pattern of the reconstructed time series, though the group considered it an inadequate approach.

Table 5.3.6. Reconstructed series of discards of undulate ray by French fleets, in tonnes. In grey: estimates from the reconstruction algorithm; in white: initial estimates as provided to ICES.

27.7.d	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beam trawl	0.6	1.4	1.4	1.4	2.2	6.0	6.1	25.2	25.7	115.0	5.1	60.1
Bottom trawls	6.7	8.2	19.6	29.7	30.5	113.7	161.8	246.0	285.1	383.2	317.5	233.1
Nets	2.0	5.9	9.7	4.7	6.1	16.5	21.7	11.8	10.9	9.3	3.2	5.3
Pelagic trawls	1.2	1.2	1.2	1.2	1.2	0.4	2.1	16.8	31.5	8.6	6.3	7.4
Seines	0.2	0.2	0.2	0.2	0.2	0.2	0.3	12.3	1.3	0.9	7.1	4.0
Total	10.8	16.9	32.2	37.2	40.2	136.7	192.0	312.0	354.5	517.0	339.2	309.9

27.7.e	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beam trawl	12.2	12.2	5.4	19.0	21.5	21.7	17.1	17.8	17.4	17.4	17.4	17.4
Bottom trawls	7.0	101.8	110.4	1916.8	1226.4	663.2	333.8	1052.9	853.0	544.5	626.4	250.1
Dredges	419.3	419.3	419.3	419.3	419.3	419.3	419.3	419.3	419.3	419.3	419.3	419.3
Hooks and lines	0.8	7.1	7.1	7.1	7.1	7.1	13.5	13.5	13.5	13.5	13.5	13.5
Nets	1.3	62.2	13.9	18.3	39.6	39.4	40.4	65.0	65.0	95.6	88.2	92.9
Other gears	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
Pelagic trawls	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Seines	4.1	4.1	4.1	2.3	2.3	2.3	0.6	0.6	0.6	0.6	0.6	0.6
Total	459.9	622.0	575.6	2398.1	1731.6	1168.4	839.9	1584.4	1384.1	1106.2	1180.8	809.1

c) United Kingdom

Fishing effort is used as a raising factor for the estimation of discarded quantities of undulate ray by UK (E&W) fleets operating in the English Channel (Ribeiro Santos and Shaw, 2021 WD). The initial time series of estimates are presented in Table 5.3.7.

Table 5.3.7. Initial estimates of annual discards of undulate ray by British fleets, as reported to ICES, in tonnes.

27.7.d	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GNS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200.9	11.5	NA
GTR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	132.0	144.7	66.7	18.5	NA
OTB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	500.2	696.2	178.9	NA
TBB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total											1320.	644.9	963.9	208.9	

27.7.e	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GNS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	195.1	NA	NA	NA	NA
GTR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OTB	21.4	1.3	NA	NA	NA	NA	NA	181.3	153.1	900.5	225.7	296.1	628.3	313.0	NA
TBB	20.4	NA	NA	NA	NA	NA	63.1	177.2	NA	234.0	95.4	493.1	530.1	299.4	NA
Total	41.8	1.3					63.1	358.5	153.1	1134.5	516.2	789.2	1158.4	612.3	

Following a recommendation ensuing the presentation of reconstructed series based on the same approach as for French data on 11th January 2022, it was decided to ignore estimates concerning years 2006-2008 and to focus on the more recent time period. It was also mentioned that the 2009–2020 time series ought to be divided into two periods, the first one (2009–2014) corresponding to the landing ban while the second (2015–2020) is associated with the resumption of the landings of undulate ray.

Consequently, each reconstructed series is constituted of an average value for the 2009–2014 period and a second average value for 2015–2020. For combinations of division and fleet associated with discards estimates in both periods, arithmetic means were applied. This concerns Division 7.e exclusively, as no estimates are available for the earlier period in Division 7.d. To remedy this lack of data, the fleet-specific ratios between the two average values by period for each fleet in Division 7.e were transposed to Division 7.d. If $R1/2_{7e,f}$ is the ratio of the mean of the first period over the second one for fleet *f* in Division 7.e and $Disc2_{7d,f}$ is the mean of available discards estimated for fleet *f* in Division 7.d, then $Disc1_{7d,f} = R1/2_{7e,f} \times Disc2_{7d,f}$ is the reconstructed mean of discards for the first period in Division 7.d for fleet *f*. In the case of nets (GTR and GNS), the average ratio derived for OTB and TBB in Division 7.e was used. This was also applied to GNS in Division 7.e. In two instances (TBB in 7.d and GTR in 7.e), no discard data could be reconstructed, for lack of estimates in both periods. This leads to a general underestimation of the cumulated series of discards. The mean discards by periods are synthesised in Table 5.3.8.

Table 5.3.8. Reconstructed averages of discards of undulate ray by period for British fleets, in tonnes.

27.7.d	2009–2014	2015–2020
GNS	38.1	106.2
GTR	32.5	90.5
OTB	162.2	458.4
TBB	NA	NA
Total	232.7	655.1
27.7.e	**2009–2014**	**2015–2020**
GNS	70	195.1
GTR	NA	NA
OTB	167.2	472.7
TBB	120.1	330.4
Total	357.3	998.2

In the same way as for landing data, a procedure has been suggested to extend the time series backwards to 2005-2008. Based on the reconstructed landings, the corresponding discards were reconstructed, assuming that all individuals below 50 cm TL were discarded and that the current length distribution in the catch reflects the distribution that would have been observed in 2005-2008. For Belgium, as the estimates of discards of undulate ray have only been considered reliable for two years: 2017 and 2018, the uncertainty associated with the reconstruction of pre-2009 discards was considered too high to be used, with only pre-2009 landings simulated for this country.

The reconstruction of discards was based upon the ratio of biomass of undulate ray below 50 cm TL over the biomass of undulate ray above and including 50 cm TL in the catch of the recent years. It is here hypothesized that all individuals below 50 cm TL (and only those) were discarded before 2009, and that the length distribution of individuals in 2005–2008 can be approximated by the length distribution established for the 2016–2020 period.

The length distribution is considered at the level of the ICES division for each country and fleet (excluding Belgium). The contributions of these fleets to recent (2006–2020) landings are used to break down the reconstructed 2005–2008 landings into landings by fleet. The reconstructed discards in year y for fleet j are estimated as:

$$Discards_{y,j} = Land_y \times \frac{\overline{Land}_{2016-2020,j}}{\overline{Land}_{2016-2020}} \times \frac{\overline{Catch{<}50}_{2016-2020,j}}{\overline{Catch{\geq}50}_{2016-2020,j}},$$

with $\overline{X}_{2016-2020}$ representing the mean annual value of a quantity X derived over the period 2016–2020.

The conversion from discards to dead discards was made using survival rates by gear for undulate or thornback ray found in the literature (Table 5.3.9 and Baulier, 2022a WD). Estimates of biomasses of dead discards are presented in Tables 5.3.10 and 5.3.11.

Table 5.3.9. Mortality rates of discards (source: van Bogaert *et al*. 2020) applied to produce time series of dead discards for undulate ray in the English Channel

Gear	Species	Mortality rate (%)	Used also for
GTR	*R. clavata*	1.1	GNS, hooks and lines
OTB	*R. clavata*	23.5	OTT, pelagic trawls, seines
TBB	*R. undulata*	42.1	Dredges

Table 5.3.10. Reconstructed French dead discards of undulate ray by ICES division for the period 2005–2008, in tonnes.

	2005	2006	2007	2008
27.7.d	5.2	4.3	4.5	5.4
27.7.e	15.7	13.2	12.3	8.8
Total	20.9	17.5	16.8	14.3

Table 5.3.11. Reconstructed UK (E&W) dead discards of undulate ray by ICES division for the period 2005–2008, in tonnes.

	2005	2006	2007	2008
27.7.d	0.2	0.2	0.2	0.3
27.7.e	3.0	2.5	2.4	1.7
Total	3.2	2.7	2.6	1.9

The difference between estimates of dead discards for France and the UK (E&W) stems from the high proportion of individuals below 50 cm TL in the catch of French bottom trawlers. With a value of around 0.3, it is almost one order of magnitude above what is observed for netters from both countries or E&W OTB. Overall, estimated dead discards are low compared to reconstructed landings for the period 2005–2008 (Figure 5.3.6). The resulting time series of removals (landings and dead discards) of undulate ray in the English Channel from 2005 to 2020 are presented in Figure 5.3.5.

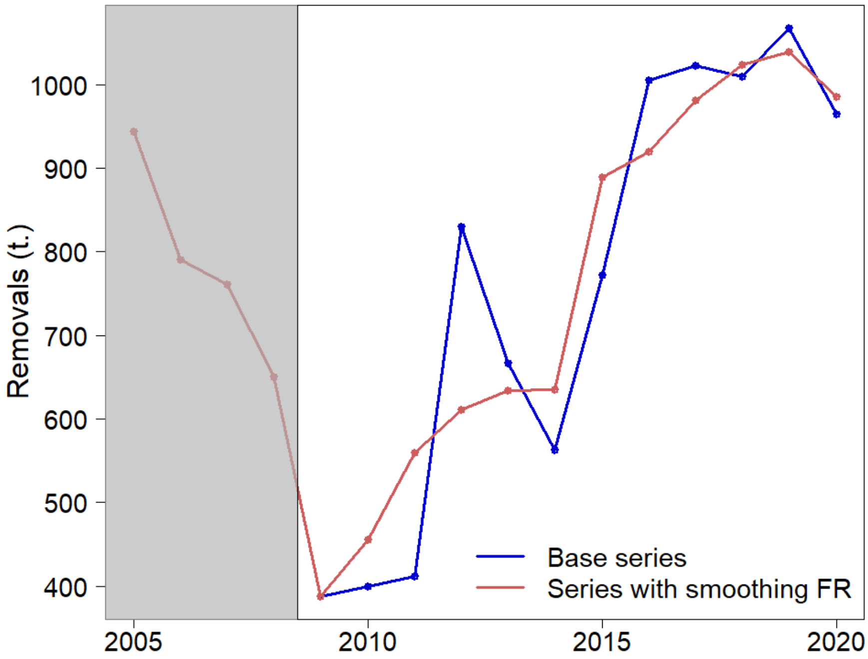

Figure 5.3.5. Time series of estimated removals (landings + dead discards) of undulate ray in the English Channel, with and without smoothing of the series of estimated discards for French bottom trawlers in Division 7.e. The shaded area represents the pre-2009 period.

Because the assumptions made to reconstruct the 2005–2008 data are stronger than for the reconstruction of the missing discard estimates between 2009 and 2020, a higher observation uncertainty is expected to be associated to the former values.

The sum of landings and dead discards provided the time series of removals, used as an input for the surplus production model (Figure 5.3.6).

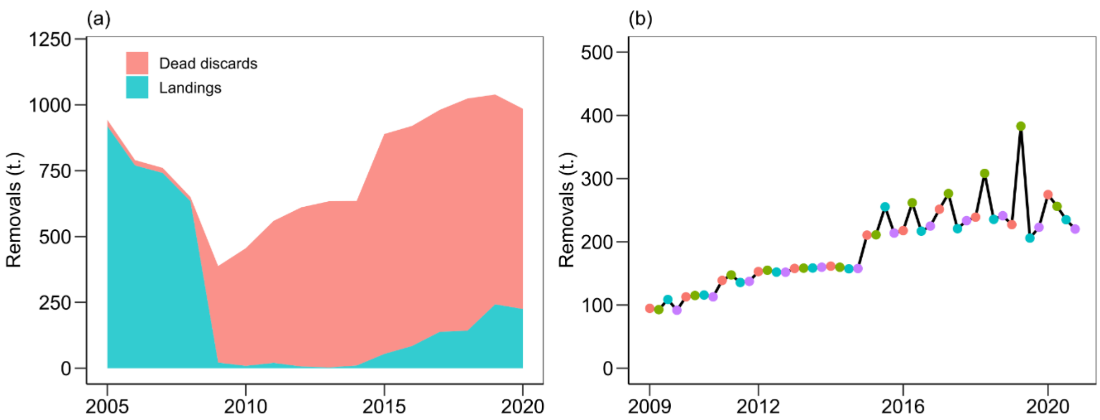

Figure 5.3.6. Time series of removals and its components, on an annual and quarterly basis (Baulier, 2022a WD)

5.3.2 Biomass indices

Two fishery-independent indices of total biomass are available for this stock (Figure 5.3.7). FR-CGFS (Channel GroundFish Survey) is the survey used historically to assess this category-3 stock (ICES, 2020a). It follows a stratified sampling design (strata are ICES statistical rectangles) with fixed stations and has been carried out in quarter 4 in ICES Division 7.d since 1990 using a GOV (Grande Ouverture Verticale) otter trawl. In 2015, the vessel originally used for the survey (RV Gwen Drez) was replaced by RV Thalassa. This vessel change was associated with a modification of the fishing gear, from a 19.7/25.9 GOV to a larger 36/47 GOV. An intercalibration experiment between the two vessels and gears was carried out in 2014 (Auber *et al.* 2015) but the numbers of undulate ray caught during this experiment were too low to compare catch rates for this species. Here we assume that this modification of the survey did not affect the value of the biomass index, expressed in terms of biomass per swept area.

In addition to this survey, the total biomass index from Q1SWECOS (Cefas Q1 Southwest Ecosystem Survey) was used as input for some scenarios. This survey sampling follows a stochastic stratified design and has been carried out during the first quarter since 2006. The sampling gear is a pair of 4-m beam trawls. Detailed information about this survey can be found in Silva (2021 WD). The high interannual variability of the survey index is likely not reflective of changes in biomass of undulate ray but at least partly induced by the random nature of the sampling within each stratum. Therefore, it generates an inter-annual fluctuation in the proportion of stations to be fished in shallower waters where the species is known to be more abundant. It was suggested during an intermediate preparatory meeting of WKELASMO to explore the use of a smoothed index series for Q1SWECOS, beside the original series. This was done by applying a smoothing coefficient of 0.9 using the loess function in R (Figure 5.3.7). Although in the accepted assessment it was considered the original time series for Q1SWECOS as the lack of contrast may not be suitable to use in SPiCT. Note that due to a different timing of the survey in 2020 (Q1SWECOS was conducted in June), 2020 data were excluded from the index series as the steep decline in numbers of undulate ray caught in areas where they are usually abundant may suggest a potential seasonal effect (Silva 2021 WD).

Similarly, the abruptness of the increase in the FR-CGFS index between 2018 and 2019 (+151%) is expected not to be compatible with a corresponding increase in the biomass of the population based on the knowledge of the biology of the species, populations of elasmobranchs tending to have a lower potential growth than most teleosts (e.g. Holden, 1973). To account for the doubtful nature of this biomass increase and reduce its influence on parameter estimation, a greater relative observation error (factor 3) was associated to FR-CGFS index values for 2019 and 2020 in some scenarios. Besides, the more uncertain biomass estimate for 2020 stemming from the lack of coverage of British waters by FR-CGFS during this particular year argues for a greater observation error for 2020. Still, the observed increase of the FR-CGFS biomass index may be due (in totality or partially) to the underestimation of the survey index in the years preceding 2019. Because the number of years during which biomass would have been underestimated is unknown, we did not simulate any scenarios with increased observation errors for these years.

As an alternative to the arbitrarily set factor 3 for the specification of a greater observation error, an alternative value of 5 was tested following a question from an external reviewer. It turned out that this factor change had only a marginal influence on the output.

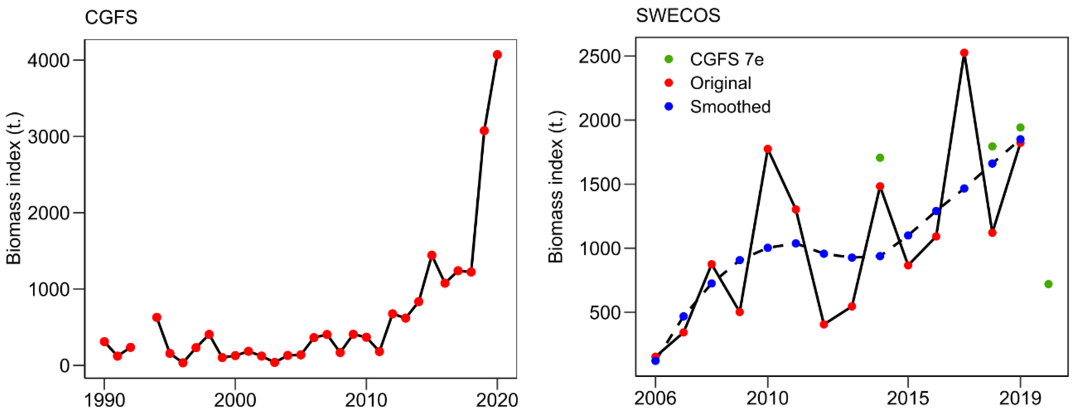

Figure 5.3.7. Total biomass index series used. Left panel: FR-CGFS series; right panel: Q1SWECOS original and smoothed series. The biomass index from FR-CGFS for 7.e is shown on right panel with the Q1SWECOS (Source: Baulier, 2022b WD).

In addition to these two series of biomass indices, a few data points exist for the FR-CGFS survey in Division 7.e, where this survey has recently been expanded to. However, with only four years in the series, these data are not used for the stock assessment (Figure 5.3.7).

5.3.3 Life-history parameters

To produce the population model a Leslie matrix (Baulier, 2022b WD) was used to generate prior distributions of the intrinsic rate of increase r and the shape parameter of the Pella-Tomlinson surplus production model used by SPiCT, where various life-history parameters were required. As using single values for these parameters would have led to point estimates of r and n, probability density function accounting for uncertainty were provided instead to generate probability distributions for r and n.

Parameters k and L_{inf} of the von Bertalanffy growth model were used to generate an estimate of the rate of natural mortality M, following a relationship obtained by Pauly (1980). Several relationships were presented in Pauly (1980) and the one not incorporating the influence of temperature was selected, as recommended by Then *et al.* (2015). M is linked to k and L_{inf} by:

$$M = 4.118 \times k^{0.73} \times L_{inf}{}^{-0.33}$$

Growth parameters used here were obtained from Portuguese populations of undulate ray. The mean estimates of the von Bertalanffy growth models were found in Moura *et al.* (2007): L_{inf} = 114.6 cm TL and k = 0.146 for the northernmost of the two areas considered, for females only. For parameter L_{inf}, a normal distribution with mean = 114 cm TL and standard deviance= 1 cm was selected. For parameter k, three values are available for Portuguese populations: 0.147 for the region of Peniche, 0.12 and 0.11 for individuals collected off Algarve (Moura *et al.*, 2007). Because no single value appears more credible than the others, a uniform distribution between 0.09 (Moura *et al.*, 2007) and 0.20 (Coelho and Erzini, 2002) was adopted for this parameter.

Because estimates of k and L_{inf} are usually negatively correlated, drawing parameter values independently from each parameter distribution is likely to generate a bias. To solve this issue, pairs of k and L_{inf} were drawn from a joint distribution of the two parameters. A correlation coefficient of -0.6 was used to generate this joint distribution. This value corresponds approximately to the mean of values found for fishes in the literature (Pilling *et al.*, 2002; He and Bence 2007; Midway *et al.*, 2015). The resulting distribution of natural mortality M resembles a uniform distribution and is presented in Figure 5.3.8.

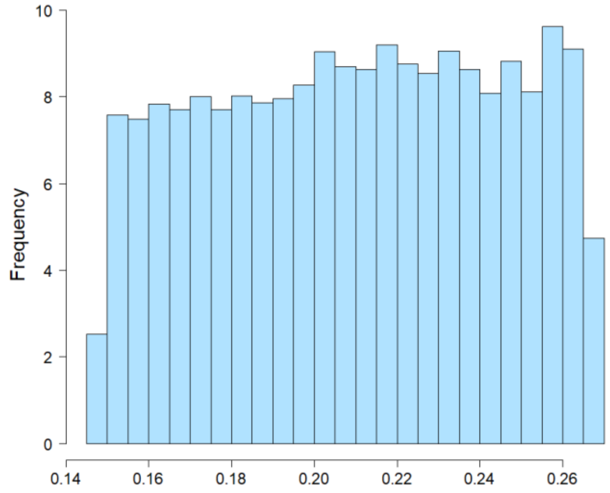

Figure 5.3.8. Distribution of simulated natural mortality M, based on Pauly's (1980) estimation.

A mortality rate of 2M was applied during the period spanning from hatching to the end of the year (four months if a spawning peak is assumed in May, as suggested by Stéphan *et al.*, 2015). The next year (between age 1 and age 2), a mortality rate of 1.5M was imposed. This was intended to account for the higher vulnerability in the first months of life. Natural mortality in the plus-group was simulated as following a truncated normal distribution centred on 0.4 with a standard deviation of 0.1 and lower and upper limits at 0.05 and 0.5, respectively (Figure 5.3.9).

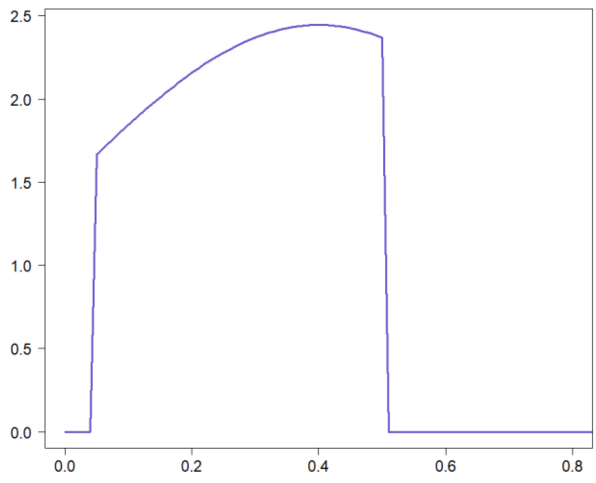

Figure 5.3.9. Prior distribution on natural mortality within the plus-group.

The parameters of the von Bertalanffy growth model were also used to derive the age at 50% maturity of females, for which only length was available (83.1 cm TL for the eastern English Channel, Stéphan *et al.*, 2015). The age at 50% maturity for females was calculated as 8.8 years. Based on the maturity ogive as a function of body length for female undulate rays in the eastern English Channel (Stéphan *et al.*, 2015), a maturity ogive was defined as a function of age. In a Leslie matrix model, individuals reproduce on the data of their birthday, defined here as January 1st. Individuals maturing at age 8 will reproduce for the first time at age 9. So, a maturation probability of 50% was ascribed to age 8 and maturation probabilities of 10% and 90% were ascribed to age 7 and 9 respectively. To account for variability in the maturation schedule, the maturation ogive was randomly added a lag of -1, 0, or +1 year.

The fertility function was defined here as the product of the survival probability to the next opportunity for reproduction, fecundity (number of eggs produced by female), and hatching probability. With a spawning peak set on the 1st of May, survival of future spawning females was calculated for four months. Individual fecundity was assumed distributed around a central value of 69.8 eggs, based on an observation by Serra-Pereira *et al*. (2015) of maximum ovarian fecundity in Portuguese waters. As the same author found no influence of body size on ovarian fecundity, the number of eggs was considered constant for all mature females. To account for uncertainty around this discrete estimate, a truncated normal distribution of mean 70 and standard deviation 20 was used. The distribution was bounded between 20 and 200 eggs. A coefficient of 0.5 was added to simulate a balanced sex-ratio at birth.

As no direct estimate of hatching rate was available for undulate ray was available, an estimate for *Amblyraja radiata* off the Danish coast was used. In their sample of egg capsules collected by trawl, Cox *et al.* (1999) observed that 52% had open hatching seams suggestive of successful hatching. This value was used as the central parameter of a truncated normal distribution of hatching rate, with a standard deviation of 0.3 (Figure 5.3.10). The lower and upper limits of the distribution were 0.2 and 1.0, respectively.

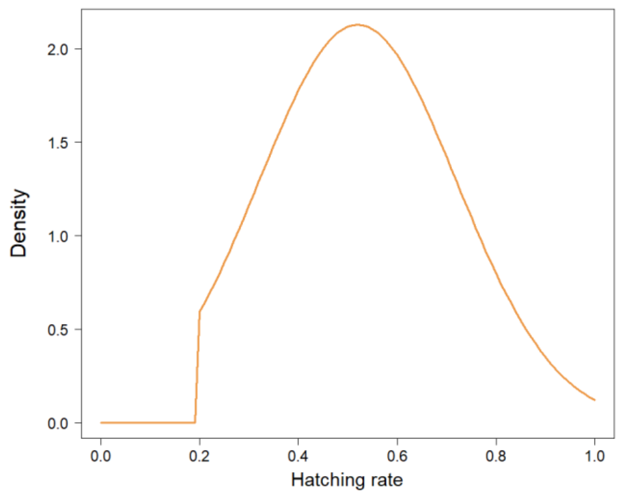

Figure 5.3.10. Prior distribution for the hatching rate

5.4 Stock assessment

5.4.1 Specification of priors for SPiCT parameters

Following the approach presented in McAllister *et al*. (2001), a demographic model was used to define priors for parameters *r* and *n* in the SPiCT model. Here, these distributions are the output of a Leslie-matrix model accounting for uncertainty in input parameters. The priors presented here are the informative alternatives to the SPiCT (Surplus Production model in Continuous Time; Pedersen and Berg, 2017) default priors generating low constraints on model adjustment.

A Leslie matrix with 11 age classes was built, with a birth-pulse formulation based on a post-breeding census simulating the dynamics of the female component of the population, considered an isolated entity (i.e. no emigration or immigration). The last age class was a plus-group in which individuals aged 10 and older accumulated. Incubation time was accounted for. It was estimated around 115 days at the public aquarium of Trégastel, France (APECS, 2012). In order to derive an estimate of the intrinsic rate of increase, the only considered source of mortality was natural mortality.

Probability distributions for parameters mentioned in Section 5.3.3 were used to produce different Leslie matrices to generate multiple values of *r* and *n* instead of a single pair of estimates. Log-normal probability density functions were then fitted to the distribution of estimates for *r* and *n* to generate informative priors. A total of 10 000 values were drawn for each input parameter of the Leslie matrix to generate as many projection matrices of the population model. For each projection matrix, an intrinsic rate of increase was derived. It corresponds to the logarithm of the first eigenvalue of the matrix. A density function was then fitted to the probability distribution of *r* and will be used as a prior for this parameter in the surplus production models. Additionally, the generation time *G* corresponding to the average age of parents of the offspring of a cohort was derived for each projection matrix. When using the statistical software R (R Core Team 2021), this variable is provided by the function 'gen.time' of the 'popbio' library. The generation time influences the value of the shape parameter *n* of the general Pella-Tomlinson formulation of the surplus production model.

Estimates of growth parameters and fecundity are associated with samples collected between 1999 and 2012. At this time, stocks of undulate ray from Portuguese coastal waters or from the English Channel had been exposed to fishing for several decades and their biomasses are assumed to have been far from their unexploited levels. It is therefore expected that the parameter estimates used here are only moderately if at all influenced by density-dependence, and hence the derived conditional *r* (sensu Gedamke *et al.*, 2007) should not be very different from the true intrinsic rate of increase.

The probability density distribution of the intrinsic rate of increase *r* resulting from the 10 000 simulations of the projection matrix of the population model (Leslie matrix) has a shape that could be assimilated to the one of a normal distribution (Figure 5.4.1). This normal distribution would have a mean of 0.184 and a standard deviation of 0.063.

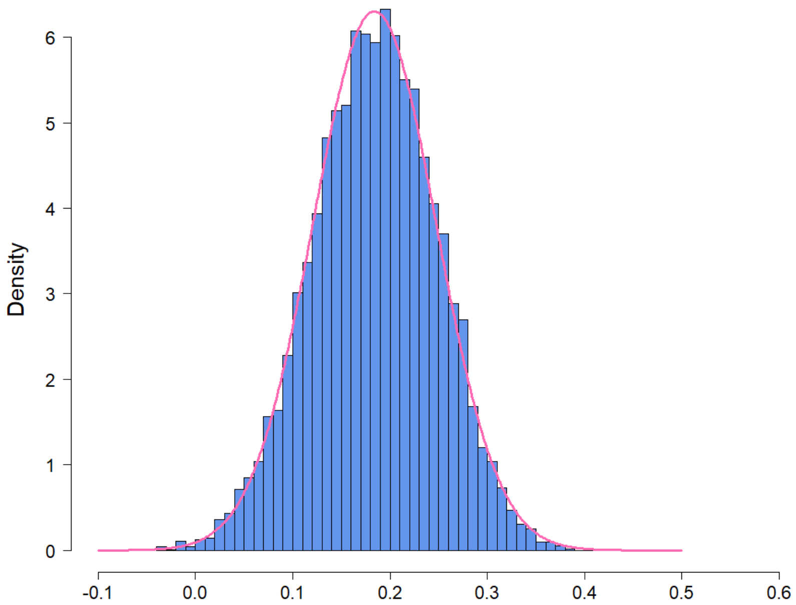

Figure 5.4.1. Distribution of the simulated intrinsic rate of increase *r* produced by the Leslie matrix simulations, and density function of the corresponding normal distribution (Baulier, 2022b WD).

Due to a constraint on the shape of prior used by SPiCT (only the lognormal shape is allowed), a log-normal prior with a looser fit to the original distribution of *r* was specified for this model (central parameter=log(0.184) and dispersion parameter=0.428).

The mean of the *r* simulated from the Leslie matrices (0.184) is lower than the value found by Liu *et al.* (2021) based on the Euler-Lotka equation (0.22) but the selected prior still shows a high probability density for this value. In addition, the value of *r* obtained here fall within the (very wide) range of credible values simulated using the R package 'FishLife' (Figure 5.4.2). This package produces simulations of life-history traits based on parameters data stored in Fishbase and correlation between related taxa. However, the prior derived using multivariate normal simulations and these same data (R package 'SPMpriors') has its higher densities at lower values of *r* (Figure 5.4.3), with a mean at 0.064. Such a low value is however unlikely to explain the fast observed increase in the exploitable biomass index.

On the opposite, the values of *r* simulated here using Leslie matrices are quite low compared to the estimate of 0.49 provided by Serra-Pereira *et al*. (2015) who used Jennings *et al.* (1998) approximation $r' = \log(Fec)\ /GenTime$.

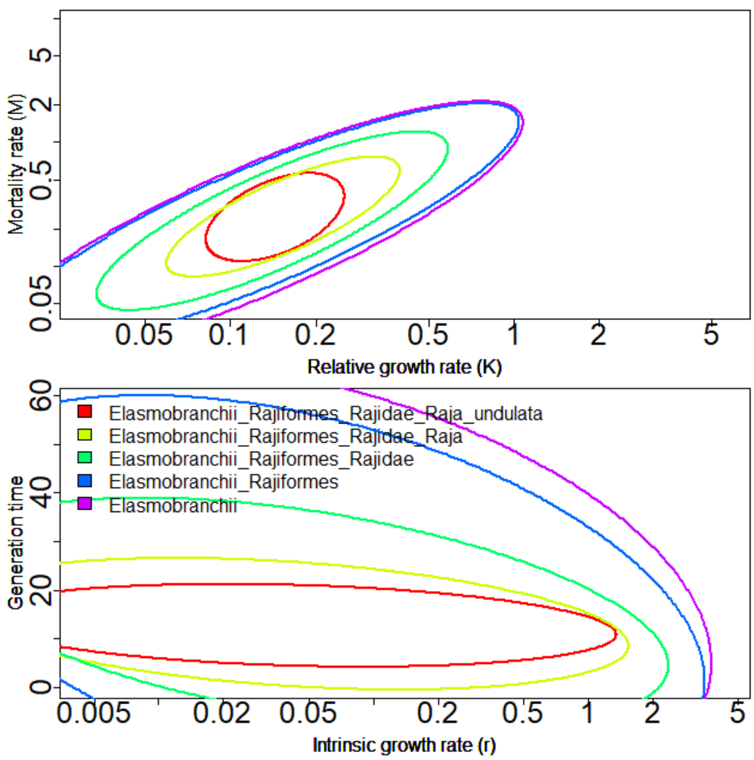

Figure 5.4.2. Bi-variate plots of predicted value intervals for *M*, *k*, Generation time, and *r* for *R. undulata* and its parent taxa, obtained using the R package 'FishLife'.

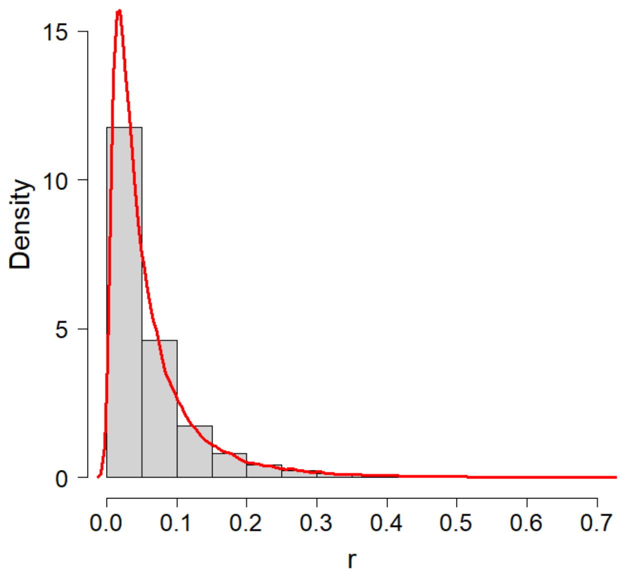

Figure 5.4.3. Prior on the intrinsic rate of increase *r* produced using the R package 'SPMpriors'.

An estimation of the shape parameter n of the Pella-Tomlinson production model is provided by a relationship with the relative position of the inflection point of the surplus production curve (i.e. C=*f*(B/K)). This inflection point R corresponds to the value of B/K associated with MSY. The relationship established by Fowler (1988, as cited by Cortés 2008) is $R = 0.633 - 0.187 \times \log(r \times T)$, where T is the generation time. This equation needs to be combined with another equation, derived by Winker *et al*. (2018): $R = n^{-\frac{1}{n-1}}$. The combination of the 10 000 simulations of the population dynamics generates 10000 values for R, which in turn produces as many estimates of n by solving the second equation numerically. A log-normal density function can easily be fitted to the resulting distribution of the shape parameter (Figure 5.4.4). It is defined by a central parameter of 0.626 and a dispersion parameter equal to 0.336. This prior can be directly used for SPiCT. Its mean value (1.98) is very close to the value corresponding to a Schaefer formulation (n=2) of the surplus production model.

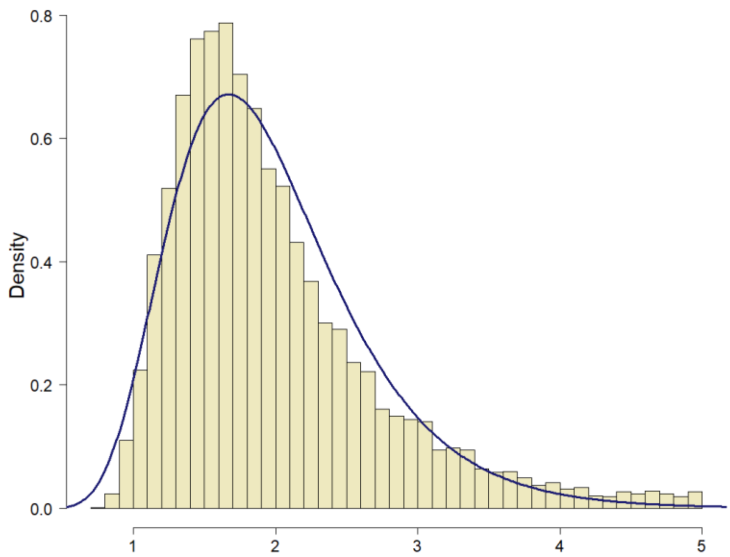

Figure 5.4.4. Distribution of the simulated shape parameter *n* produced by the Leslie matrix simulations, and density function of the corresponding lognormal distribution.

To set a relatively informative prior on the initial depletion ratio *bkfrac*, it was assumed that the stock was highly exploited independently of the year the data series started in (1990, 2005 or 2006), but the extent of the depletion was rather uncertain. It resulted in a prior for *bkfrac* defined as $log(bkfrac) \sim Norm(log(0.2), 0.5)$.

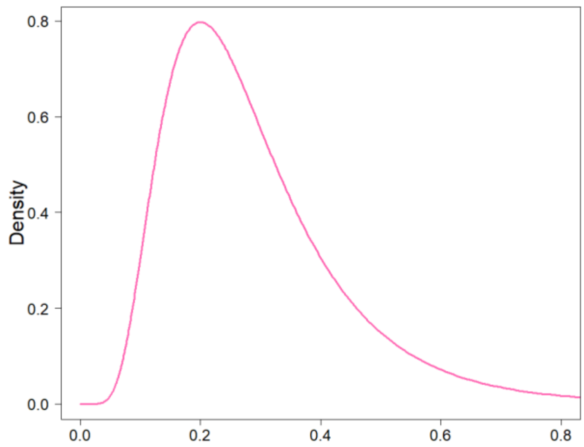

Figure 5.4.5. Probability density function of the informative prior on *bkfrac.*

5.4.2 Exploratory assessments

Various simulation scenarios were tested, differing in terms of the time series considered for removals, biomass index, the introduction of informative priors on parameter *r*, *n*, and *bkfrac*, and the optional setting of a greater observation error associated with the last two years of the FR-CGFS index series. In addition, for scenarios based on a time series of removals starting in 2009, a quarterly resolution of removals was tested beside the default annual resolution of data.

Altogether, 105 scenarios were explored. Most of them are presented in a working document (Baude and Baulier, 2022 WD). The remaining scenarios with one informative prior on *n* or *bkfrac* and scenarios with two informative priors on *r* and *bkfrac* or *n* and *bkfrac*, were explored following a recommendation from the external reviewers.

For each scenario, the validity of the simulation was first assessed using various criteria, and the results of the retained simulation scenarios were compared as a form of sensitivity analysis.

The available options were the following:

For removals:

- → Annual series of removals 2009–2020
- → Quarterly series of removals 2009–2020 to test whether integration of observations at a higher frequency improves the model
- → Annual series of removals 2005–2020, with specification of a greater observation error (x3) associated with years 2005–2008

For total biomass index:

- → FR-CGFS
- → FR-CGFS with higher observation errors for 2019–2020
- → Q1SWECOS smoothed series
- → FR-CGFS + Q1SWECOS smoothed series
- → FR-CGFS + Q1SWECOS smoothed series, with greater observation errors for CGFS 2019-2020

The non-smoothed time series of total biomass from the Q1SWECOS survey was not used in these exploratory assessments but was later incorporated for the definition of the best-case scenario as decided during the benchmark discussions.

Sensitivity to prior parameters integration was tested for each data combination with five runs:

→ Defaults priors of SPiCT: $log(n) \sim Norm(log(2),2)$; $log(\alpha) \sim Norm(0,2)$; $log(\beta) \sim Norm(0,2)$, n being the shape parameter of the surplus production model, α and β the ratios of observation over process errors for removals and biomass, respectively.

→ Informative prior for r, the intrinsic rate of increase of the population (+ defaults for other parameters)

→ Prior for r and n (+ defaults for other parameters)

→ Informative priors for r and n set to 2, assuming a Schaefer model (+ defaults for other parameters)

→ Informative priors for r, n and initial depletion level *bkfrac* relative to the biological capacity (+ defaults for other parameters)

For each scenario, the conformity of SPiCT simulations to criteria for acceptance listed by WKLIFE X (ICES, 2020c) was checked. They consist of seven points which are:

1. Model convergence (*Convergence*)
2. Variance parameters have to be finite (*Sd finite*)
3. No violation of model assumptions, based on one-step-ahead residuals (*Residuals*)
4. Consistent patterns in the retrospective analysis (*Retro*). For this item, we did the analysis with five retro-years and checked if the Mohn's rho of $F_{current}/F_{MSY}$ and $B_{current}/B_{MSY}$ were between -0.15 and 0.20 (thresholds used by WKFORBIAS ICES, 2020b)
5. Realistic production curve (*Produc curve*)
6. Absence of high assessment uncertainty (*Uncertainty*)
7. Initial values do not influence the parameter estimates (*Proportion inits*). For this item we set an arbitrary criterion based on the variation of parameter *logm* (logarithm of the deterministic estimate of MSY) over 30 trials compared to the first (base) run. The criterion was ticked when a lower threshold of 90% of runs with differences smaller than 1.0 tonne was reached. In addition, the proportion of trials that converged was indicated (*Proportion converg*).

As slight violations of the third rule do not necessarily invalidate the model (ICES, 2020c), when all other criteria were validated, the simulation was still considered valid. Similarly, since the threshold of a minimum fraction of convergence of 90% of the runs was arbitrarily set for criterion 7, scenarios that failed only due to this condition were still considered valid. In addition to these criteria, a final criterion of consistency of model estimates with the knowledge of the exploitation of the stock and the biology of the species was last considered.

5.4.2.1 SPiCT defaut priors

None of the tested simulations was validated when no informative prior on intrinsic rate of increase r was specified. All retrospective analyses failed, in particular when the time series was shortened by more than three years. When a higher observation error was associated to the last two years of the FR-CGFS index, convergence was never attained. The specification of removals on a quarterly basis did not make any significant difference compared to data aggregated at the annual level.

5.4.2.2 One informative prior used (*r, n,* or *bkfrac*)

a) Informative prior on *r*

No SPiCT simulations based on default priors and a single informative prior on *r* were validated based on the criteria defined by WKLIFE X (ICES, 2020c), except the scenario with the time series of removals starting in 2005 and the two survey indices with the setting of a greater observation error for the last two years of FR-CGFS. In all other cases, the criterion of limited uncertainty around estimates of $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ was not met. The very low value of the estimate of *n* (mean=0.227) for this validated scenario undermines the credibility of estimates obtained for the other parameters that are influenced by the value of the shape parameter. The strong density dependence suggested by such a low *n* does not appear compatible with what is known about undulate ray. Fowler (1988) described populations with the inflection point in the production curve situated at 0.2K (the inflection point is at 0.15K for this scenario) as corresponding to "productive commercial fish species and insect pests". Therefore, the output of this scenario was not considered a relevant candidate for the assessment of undulate ray in the English Channel.

b) Informative prior on *n*

When setting a unique informative prior on parameter *n,* three scenarios were validated. These were two scenarios using the two survey indices and the time series of removals starting in 2009 (on an annual basis with uniform observation error for the whole FR-CGFS series and on a quarterly basis with a greater observation error associated with the last two values of the FR-CGFS biomass index), as well as the scenario based on the FR-CGFS index, the time series of removals starting in 2005 and a greater observation error for the last two years of the FR-CGFS index. The first two scenarios mentioned above were disregarded on account of the unrealistic estimates of *r* (medians of 1.18 and 1.16).

c) Informative prior on *bkfrac*

When only an informative prior on *bkfrac* was set, one scenario passed the diagnosis criteria: the scenario using the FR-CGFS biomass index (without a greater observation error for the two most recent years) with the annual series of removals starting in 2009. However, this scenario produced an unrealistic estimate of *r* (median value = 1.513) and was not further considered.

5.4.2.3 Two informative priors used (combinations of *r, n,* and *bkfrac*)

a) Informative priors on *r* and *n*

When, in addition to an informative prior on *r*, an informative prior on *n* was specified, the simulation using the 2005-2020 removal series and the Q1SWECOS index along with the FR-CGFS biomass index with increased observation error for 2019 and 2020 was again validated. The other validated scenario was the one associating the 2005-2020 removal series and the FR-CGFS biomass index with increased observation error for 2019 and 2020.

b) Informative priors on *n* and *bkfrac*

When informative priors were specified for *n* and *bkfrac*, five scenarios were considered valid. Four of these scenarios were based on the 2009-2020 time series of removals and were then excluded based on the corresponding unrealistically high estimated values for parameter *r* (from 0.98 to 1.32).

The remaining validated scenario was based on the 2005-2020 time series of removals and the FR-CGFS biomass index with greater observation errors for 2019-2020. It yielded an estimate of 0.30 for *r*. This is considered a high value but not unrealistic.

c) Informative priors on *r* and *bkfrac*

Only one scenario with this combination of informative priors passed the validation criteria. It is defined by the FR-CGFS biomass index with a greater observation error for 2019-2020 and a time series of removals on an annual basis starting in 2009. It led to an estimate of the F_{2021}/F_{MSY} ratio very close to 1.0 and a B_{2021}/B_{MSY} below one, both ratios being associated with rather large confidence intervals.

5.4.2.4 Three informative priors used (*r, n,* and *bkfrac*)

Once an additional constraint was imposed upon the initial depletion ratio *bkfrac* (ratio of the biomass on the first year of the series by the biological capacity *K*) on the first year of the whole time series (1990 for FR-CGFS and combined biomass indices, 2005 or 2006 for Q1SWECOS), three simulations were validated with the 2009-2020 series of removals and another three with the 2005-2020 series of removals For the 2009-2020 series of removals, these simulations were associated with the biomass index from FR-CGFS alone, with and without specification of a greater observation error, and in combination with the Q1SWECOS index (with identical observation errors for FR-CGFS). The scenario combining the two index series but with a greater observation error for the last two values of the FR-CGFS index was rejected based on the criteria of the non-normal distribution of one-step-ahead (osa) residuals associated with removals (not shown) and the proportion of runs for which modifications of initial values led to substantial changes in the estimate of MSY.

When the time series of removals incorporated estimates for the period 2005-2008, the scenario including the FR-CGFS index with identical observation errors was not validated (failing of the retrospective analysis). Instead, the scenario combining the two biomass indices and the increased observation error for the last two years of FR-CGFS was retained. The scenario including the combination of the two biomass indices and identical observation error for the FR-CGFS index was also selected.

When the removals starting in 2009 were specified on a quarterly basis, the two simulations for which a greater observation error was set for the last two values of the FR-CGFS index were rejected on the basis of an insufficient proportion of runs with estimates of MSY unaffected by initial values as well as the non-normality of osa residuals for removals (with both biomass indices) or for removals and biomass index (with FR-CGFS index).

The quarterly resolution of removals did not improve the fit of the models. It actually had an opposite effect, potentially due to the fact that only landings were originally aggregated by quarter, while dead discards, which constitute the majority of removals for most of the time series, were estimated on an annual basis and were evenly broken down by quarter.

Note that the simulations considered valid here did not meet the criterion of the normal distribution of all one-step-ahead residuals.

5.4.2.5 Synthesis of validated scenarios

A total of 12 scenarios passed the SPiCT validation criteria. All validated scenarios were based on an annual resolution of the time series of removals. The features of these scenarios are presented in Table 5.4.1.

Table 5.4.1. Description of the 12 validated scenarios tested during the exploratory assessment. * signals when a greater observation error is associated with years 2019-2020 of the FR-CGFS biomass index.

Scenario	Informative priors	Biomass index	Start of removals
1	*r*	CGFS*+SWECOS	2005
2	*n*	CGFS*	2005
3	*r, n*	CGFS*	2005
4	*r, n*	CGFS*+SWECOS	2005
5	*n, bkfrac*	CGFS*	2005
6	*r, bkfrac*	CGFS*	2005
7	*r, n, bkfrac*	CGFS	2009
8	*r, n, bkfrac*	CGFS*	2009
9	*r, n, bkfrac*	CGFS+SWECOS	2009
10	*r, n, bkfrac*	CGFS*	2005
11	*r, n, bkfrac*	CGFS+SWECOS	2005
12	r, n, bkfrac	CGFS*+SWECOS	2005

All scenarios include the FR-CGFS total biomass index, either as the only biomass index (scenarios 2, 3, 5, 6, 7, 8 and 10) or in combination with the smoothed biomass index provided by the Q1SWECOS survey (scenarios 1, 4, 9, 11 and 12), as well as removals with an annual resolution. Three scenarios (7 to 9) are based on the shorter series (2009-2020) of removals, while the majority are associated with the extended (2005-2020) series. There is a clear trend in number of selected scenarios as more and more information is included through priors, with no validated scenarios when no informative priors were used, two scenarios when only an informative prior was introduced, four scenarios in the case of informative priors on two parameters, while six scenarios were selected when the three possible informative priors were used.

The parameter estimates corresponding to the various scenarios are synthetized in Table 5.4.2.

The parameter estimates from the selected scenarios share a common feature regarding the current status of the exploitation of the stock of undulate ray in the English Channel: the average value of the ratio $F_{current}/F_{MSY}$ is lower than 1.0, suggesting an under-exploitation relative to F_{MSY}. Yet, this ratio shows a relatively high variability between scenarios, from a value as low as 0.222 (Scenario 4) to a value indicating an exploitation close to F_{MSY} (0.942; for Scenario 8). The estimate from this later scenario is associated with the greatest uncertainty encountered here, with a 90% confidence interval covering the range 0.378 – 2.346. In addition, the various selected scenarios deliver concurring reconstructions of the history of the stock, with an evolution from a situation of depleted biomass and overfishing in the 1990s, to a stock currently exploited at a fishing mortality rate close to or below F_{MSY} (with the exceptions of scenarios 8 and 9 which yield estimates of $B_{current}/B_{MSY}$ of 0.836 and 0.882 respectively) and at a much-improved biomass level compared to the first year of the period considered (Baude and Baulier, 2022 WD).

However, parameter estimates differ between scenarios, sometimes to a large extent. The characteristics of the selected scenarios make the assessment of the respective influences of the introduction of the various informative priors, the use of the 2005–2008 removal data, the use of the different biomass indices and the setting of a greater observation error associated with the last two years of the FR-CGFS series possible.

Influence of the gradual specification of informative priors

Additions of informative priors resulted in an increase in estimates of parameters *r* and *bkfrac* in all cases but one: the addition of an informative prior on *r* between Scenario 2 and Scenario 3. This indicates that the models predict a poorer initial state of the stock when no information about *bkfrac* is provided. The informative priors on *n* and *bkfrac* defined here seem to have opposite influences upon the estimates of the other parameters. Indeed, the addition of an informative prior on *n* is accompanied with decreases in estimates of *q*, F_{MSY}, $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$, and increases in estimates of *K*, *n*, *MSY*, and B_{MSY}. On the contrary, the additional specification of a prior on *bkfrac* led to lower estimates for *K* and B_{MSY}, and higher estimates for parameters *bkfrac*, F_{MSY} and the ratio $B_{current}/B_{MSY}$.

Influence of the Q1SWECOS biomass index

The Q1SWECOS total biomass index presents an earlier and slower increase compared to the index derived from FR-CGFS. The addition of this biomass index had hardly any effect on the estimate of *r* but had a substantial influence on the estimation of B_{MSY} and F_{MSY}. B_{MSY} estimates were consistently lower after the addition of the Q1SWECOS index, while estimates of F_{MSY} were always larger. However, the effects upon the corresponding ratios $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ differed between scenarios, with an increase in $B_{current}/B_{MSY}$ for scenarios 4 and 12 while it decrease for scenario 9, and a decrease in $F_{current}/F_{MSY}$ for scenarios 4 and 12 and an increase for Scenario 9.

Influence of the inclusion of 2005–2008 removal estimates

This inclusion led to a decrease in the estimates of *r* and F_{MSY}, whereas increases were observed for parameters *K*, *n*, *bkfrac*, *MSY* and B_{MSY}. Unlike for the addition of the Q1SWECOS biomass index, consistent effects upon ratios $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ were observed, with an increase of the former and a decrease of the later. In addition, the uncertainty associated with the estimation of $B_{current}/B_{MSY}$ increased while it decrease for the ratio $F_{current}/F_{MSY}$.

Influence of the setting of a greater observation error for the last two years of the FR-CGFS index

This modification did not affect the estimation of *r*. In both cases, this led to decreases in estimates of *K*, *n*, *MSY* and B_{MSY}, while estimates of *bkfrac* and $F_{current}/F_{MSY}$ decreased compared to scenarios with a uniform specification of the observation error for the biomass index from FR-CGFS. There is a notable difference with the two pairs of comparable scenarios (7-8 and 11-12), with a decrease in $B_{current}/B_{MSY}$ in Scenario 8 and a small increase in Scenario 12.

Table 5.4.2. Parameter estimates for the 12 validated SPiCT scenarios listed in Table 5.4.1.

Scenario	*r* (95% CI)	*K* (95% CI)	*q1* (95% CI)	*q2* (95% CI)	*n* (95% CI)	*bkfrac* (95% CI)	*MSY* (95% CI)	B_{MSY} (95% CI)	F_{MSY} (95% CI)	$B_{current}/B_{MSY}$ (95% CI)	$F_{current}/F_{MSY}$ (95% CI)
1	0.177 (0.078;0.401)	10006.9 (2952.9;33911.2)	0.184 (0.038;0.900)	0.315 (0.069;1.428)	0.227 (0.033,1.576)	0.143 (0.039;0.529)	1148.3 (751.8;1753.8)	1464.9 (135.2;15872.8)	0.782 (-0.822;2.386)	3.154 (1.131;8.792)	0.267 (0.099;0.718)
2	0.252 (0.070;0.909)	52390.9 (3776.2;726868.6)	0.041 (0.010;0.170)		1.834 (0.918;3.665)	0.112 (0.016;0.786)	3411.6 (535.0;21754.2)	25040.1 (1800.4;348262.1)	0.136 (0.052;0.354)	1.279 (0.422;3.880)	0.229 (0.063;0.826)
3	0.200 (0.096;0.417)	75345.5 (6019.5;943099.8)	0.036 (0.010;0.136)		1.694 (0.979;2.933)	0.087 (0.011;0.684)	4164.6 (528.4;32825.8)	34840.2 (2519.4;481789.1)	0.117 (0.034;0.201)	1.061 (0.276;4.079)	0.231 (0.065;0.820))
4	0.209 (0.103;0.423)	50245.4 (8763.1;288094.1)	0.032 (0.010;0.109)	0.060 (0.017;0.208)	1.558 (0.849;2.860)	0.151 (0.038;0.590)	3038.7 (888.7;10390.0)	22478.8 (3435.4;147087.2)	0.133 (0.030;0.236)	1.488 (0.732;3.025)	0.222 (0.080;0.617)
5	0.296 (0108;0.811)	34984.8 (6649.3;184070.4)	0.044 (0.011;0.173)		1.890 (0.946;3.776)	0.172 (0.077;0.384)	2630.8 (786.1;8804.7)	16917.6 (2999.8;95408.1)	0.156 (0.074;0.325)	1.493 (0.937;2.380)	0.252 (0.077;0.819)
6	0.178 (0.081;0.392)	22393.6 (1942.6;258143.3)	0.076 (0.007;0.829)		0.918 (0.117;7.215)	0.170 (0.075;0.384)	1512.5 (276.7;8265.8)	7776.9 (253.1;238937.7)	0.194 (0.033;1.149)	1.612 (0.688;3.777)	0.403 (0.107;1.510)
7	0.332 (0.167:0.660)	15539.1 (5250.1;45992.0)	0.205 (0.062;0.680)		1.548 (0.978;2.451)	0.119 (0.054;0.259)	1489.8 (809.1;2743.4)	6970.8 (2251.5;21582.2)	0.214 (0.114;0.402)	0.995 (0.528;1.875)	0.681 (0.263;1.759)
8	0.329 (0.160;0.674)	13273.0 (5094.9;34578.5)	0.204 (0.065;0.641)		1.523 (0.966;2.399)	0.127 (0.058;0.279)	1281.5 (798.8;2056.1)	5906.9 (2208.6;15798.0)	0.215 (0.111;0.418)	0.836 (0.378;1.849)	0.942 (0.378;2.346)
9	0.331 (0.166;0.661)	13100.3 (5188.7;33075.1)	0.246 (0.079;0.760)	0.394 (0.131;1.187)	1.497 (0.974;2.301)	0.120 (0.054;0.269)	1286.1 (810.1;2041.7)	5782.4 (2265.2;14761.1)	0.220 (0.090;0.351)	0.882 (0.422;1.847)	0.889 (0.388;2.038)
10	0.223 (0.116;0.429)	44692.2 (10111.7;197532.5)	0.038 (0.011;0.136)		1.661 (0.942;2.929)	0.163 (0.072;0.366)	2784.4 (867.3;8939.7)	20485.0 (4135.9;101462.4)	0.133 (0.072;0.248)	1.394 (0.798;2.433)	0.260 (0.084;0.803)
11	0.215 (0.117;0.396)	59192.3 (13955.1;251071.0)	0.032 (0.010;0.104)	0.053 (0.016;0.179)	1.624 (0.913;2.886)	0.157 (0.071;0.349)	3598.9 (1152.7;11236.7)	26923.4 (5640.7;128506.5)	0.131 (0.058;0.205)	1.521 (0.871;2.657)	0.184 (0.064;0.524)
12	0.220 (0.117;0.414)	44294.1 (10809.2;181508.6)	0.033 (0.010;0.107)	0.061 (0.018;0.204)	1.548 (0.841;2.815)	0.181 (0.084;0.390)	2832.2 (1020.3;7861.7)	19767.3 (4239.4;92171.1)	0.141 (0.047;0.235)	1.581 (0.963;2.596)	0.223 (0.083;0.601)

A principal component analysis (PCA) was performed on these twelve scenarios in order to identify groups based on their outputs. The median of the parameters listed in Table 5.4.2 as well as the width of confidence intervals for $B_{current}/B_{MSY}$ and $F_{current}/F_{MSY}$ were considered as active variables. The biplot (plot of scenarios as individuals and projection of variables) on the first factorial plane is presented in Figure 5.4.6.

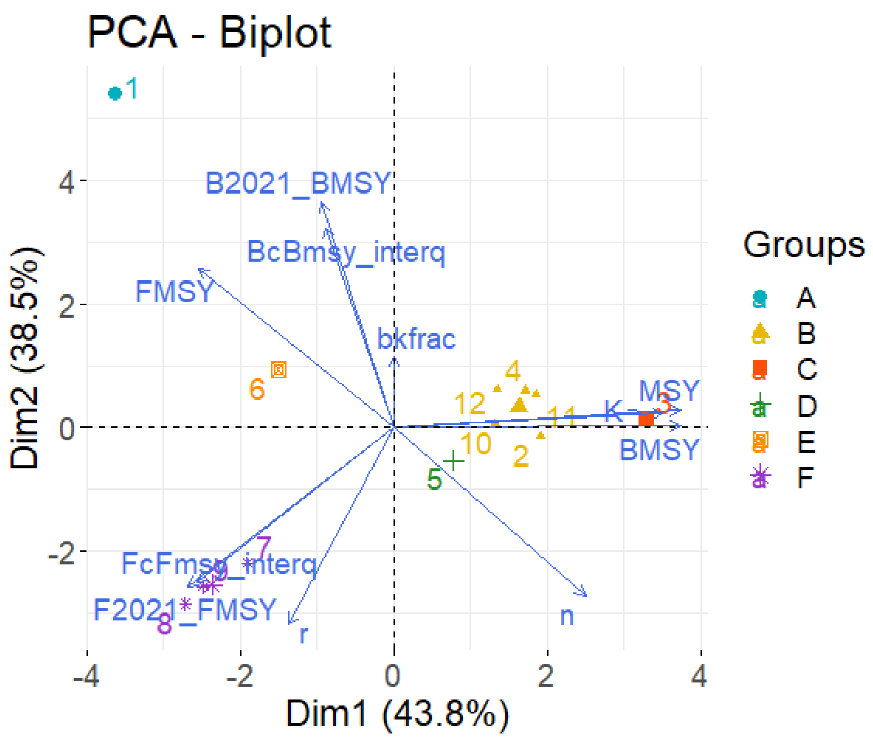

Figure 5.4.6. Bivariate plot of the PCA performed on parameter estimates. Scenarios (individuals) are identified with their number given in Table 5.4.1. Parameter estimates (variables) are represented as blue arrows; the suffix "interq" corresponds to the width of the 95% confidence interval.

Scenario 1 appears isolated in the first factorial plane and so is (but to a minor extent) Scenario 6. The remaining of the scenarios forms two main groups. The first group is constituted of scenarios 7, 8 and 9, while the second is composed of scenarios 2 to 5 and 10 to 12. These two main groups differ by the length of the data series of removals that has been used for the simulations, with scenarios based on the 2009-2020 series constituting the first main group whereas scenarios of the second main group ae associated with the 2005-2020 series.

5.4.3 Final assessment

The scenario deemed the most relevant was the one combining the series of removals starting in 2005, the two indices of total biomass (with specification of a greater observation error for the last two values of the FR-CGFS index) and the three informative priors on *r*, *n* and *bkfrac* (Scenario 12). Like in all other tested scenarios, a factor 3 is apply to increase the observation error associated with reconstructed 2005–2008 catches to account for the additional uncertainty inherent in the reconstruction process. It was concluded that the information brought by the three informative priors was relevant and not too constraining, that including the removal data before 2009 was bringing contrast to the time series of fishing mortality and that the Q1SWECOS biomass index, by providing information on changes in biomass in Division 7.e, was a complementary time series worth including into the assessment. Until the source of the fast increase of the FR-CGFS index between 2018 and 2019 is identified and the underlying process accounted for to adjust the relationship between the index and relative biomass, a greater observation error associated with 2019 and 2020 values is applied. The smoothing of the Q1SWECOS biomass index as done for the exploratory assessments was found unjustified. Therefore, a new run was made including the "raw" series of Q1SWECOS index.

5.4.3.1 Acceptance diagnosis

The results of the diagnosis acceptance test based on the seven criteria presented in Section 5.4.2 are summarised in Table 5.4.3.

Table 5.4.3. Acceptance diagnosis results for the accepted assessment scenario with informative priors for *r*, *n* and *bkfrac*, removals 2005–2020, and the total biomass indices from FR-CGFS (with greater observation error for 2009-2020, with factor 3) and Q1SWECOS (non-smoothed series). 1 indicates that the corresponding criterion was met while 0 indicates that the scenario did not meet the requirement for the criterion considered.

Convergence	Sd finite	Residuals	Retro	Produc curve	Uncertainty	Proportion inits
1	1	0	1	1	1	1.000

The plots corresponding to the acceptance diagnosis are presented in Figures 5.4.7 and 5.4.8.

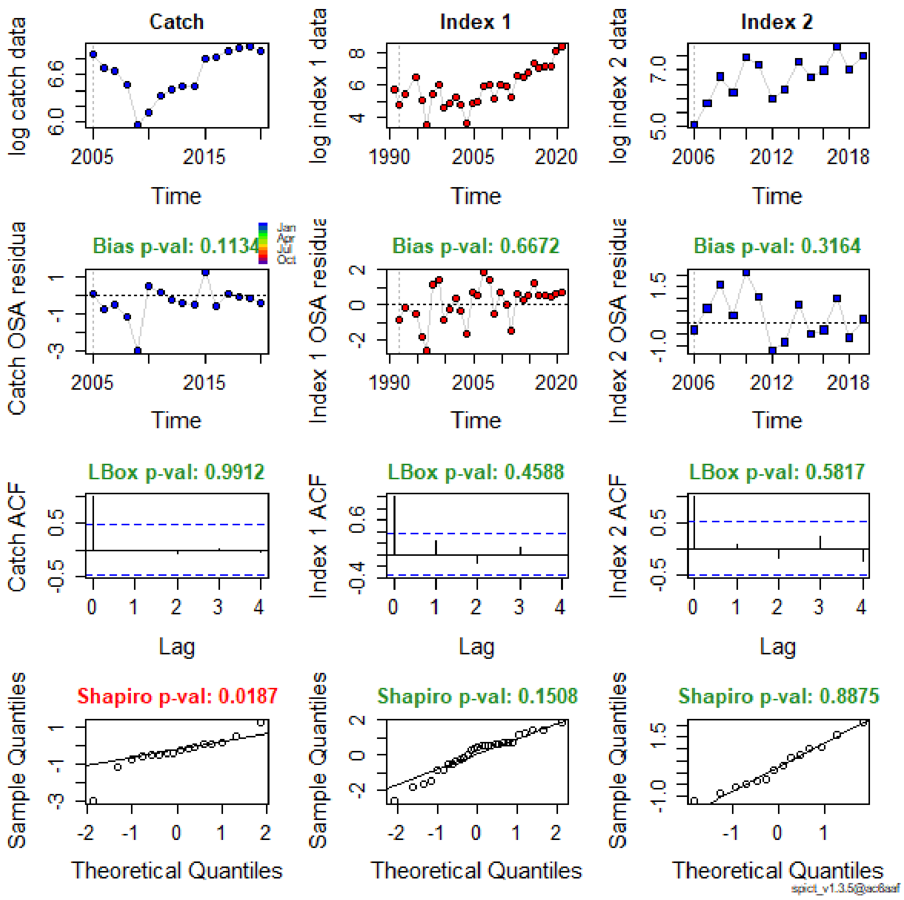

Figure 5.4.7. Diagnostic plots corresponding to the accepted assessment. Scenario with informative priors for *r*, *n* and *bkfrac*, removals 2005–2020, and the total biomass indices from FR-CGFS (with greater observation error for 2009-2020, with factor 3) and Q1SWECOS (non-smoothed series).

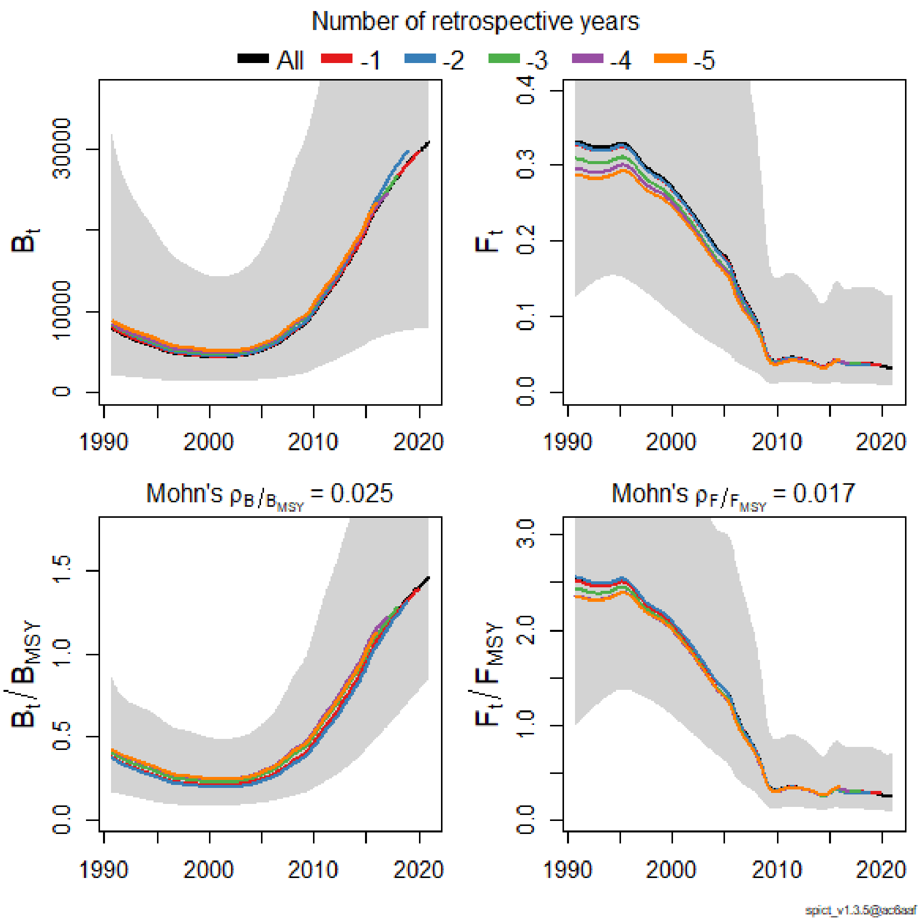

Figure 5.4.8. Plots of the retrospective analysis corresponding to the accepted assessment. Scenario with informative priors for *r*, *n* and *bkfrac*, removals 2005–2020, and the total biomass indices from FR-CGFS (with greater observation error for 2009–2020, with factor 3) and Q1SWECOS (non-smoothed series).

5.4.3.2 Parameter estimates

The output of the model indicates an overexploited stock with a biomass well below B_{MSY} in 1990 (17% of B_{MSY}, Table 5.4.4) with a slowly decreasing fishing mortality until 2009 when undulate ray was listed as a prohibited species (Figure 5.4.9). Fishing mortality has stabilised at a low level since then, allowing the biomass to increase beyond B_{MSY} in recent years. The introduction of precautionary TAC since 2015 does not seem to have resulted in an increase in F, which has remained between 0.03 and 0.05, below F_{MSY} (0.13) (Table 5.4.4).

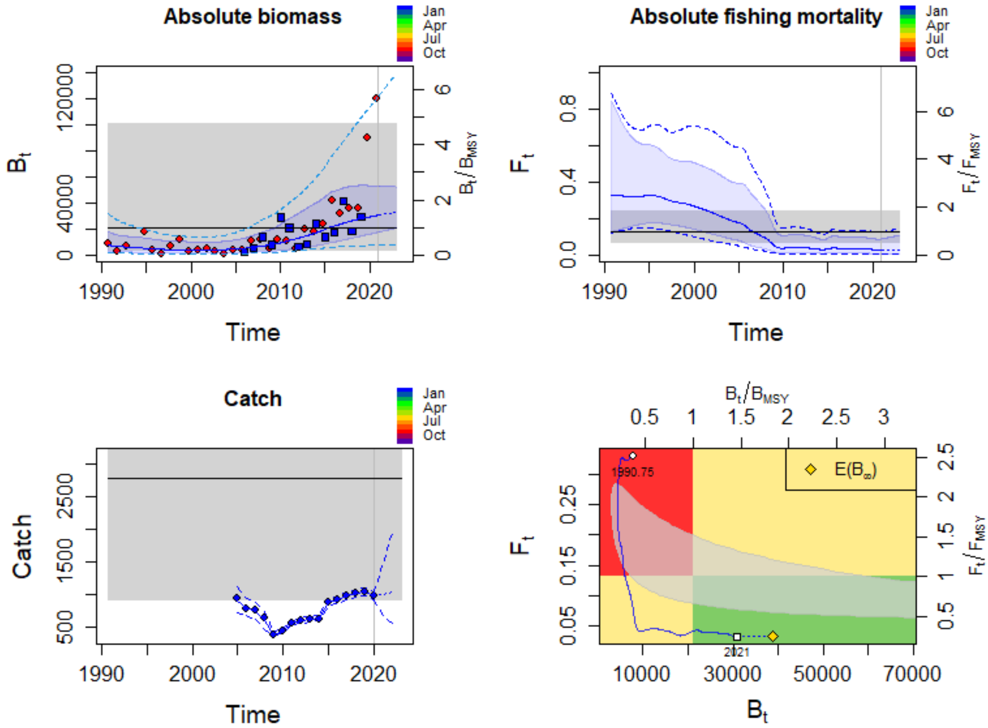

Figure 5.4.9. Result plots for the final assessment scenario: informative priors for *r*, *n* and *bkfrac*, removals 2005–2020, and the total biomass indices from FR-CGFS (with greater observation error for 2009-2020, with factor 3) and Q1SWECOS (non-smoothed series). On the top-left panel, red symbols represent data from FR-CGFS whereas blue symbols represent data from Q1SWECOS.

Table 5.4.4. Parameter estimates for the final assessment scenario: informative priors for *r*, *n* and *bkfrac*, removals 2005–2020, and the total biomass indices from FR-CGFS (with greater observation error for 2009-2020, with factor 3) and Q1SWECOS (non-smoothed series).

	Estimate (median)	Inf. 95% CI	Sup. 95% CI	s.d.	CV
r	0.217	0.115	0.410	0.325	0.334
K	46416.4	10897.6	197702.0	0.739	0.853
***q* (FR-CGFS)**	0.034	0.01	0.115	0.623	0.688
***q2* (Q1SWECOS)**	0.061	0.017	0.219	0.651	0.726
n	1.642	0.922	2.925	0.295	0.301
bkfrac	0.171	0.078	0.377	0.403	0.420
MSY	2780.4	929.6	8316.0	0.559	0.606
B_{MSY}	21175.2	4432.6	101158.6	0.798	0.943
F_{MSY}	0.131	0.071	0.244	0.315	0.323
B_{2021}/B_{MSY}	1.458	0.849	2.502	0.276	0.281
F_{2021}/F_{MSY}	0.244	0.085	0.701	0.538	0.580

5.4.3.3 Short-term forecast

The last observation used for model adjustment during the benchmark was made at the end of year 2020. A two-year projection (2021-2022) was then made, including an intermediate year (2021) with fishing mortality F considered constant and equal to the most recent estimate of F, and a year (2022) with management enforced as predicted by the $f_{0.35}^{c}$ rule (TAC on removals-based on the 35th percentile of the predicted catch distribution given the target fishing mortality F_{pred}^{T} during the prediction year) defined by WKLIFE X (ICES, 2020c). The timeline of the scenario is:

- 1990.75–2021.0: Observations
- 2021.0–2022.0: Intermediate period
- 2022.0-2023.0: Management period (at the end of which management is evaluated)

The advised removals for 2022.0–2023.0 corresponding to the $f_{0.35}^{c}$ rule are 3648 tonnes. This advice corresponds to a 3.6-fold increase compared to the average annual removals derived for the period 2018-2020 (1016 tonnes). 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 1.45 and F/F_{MSY} would be expected to be 0.88 at the beginning of 2023. The predicted trajectories are represented Figure 5.4.10.

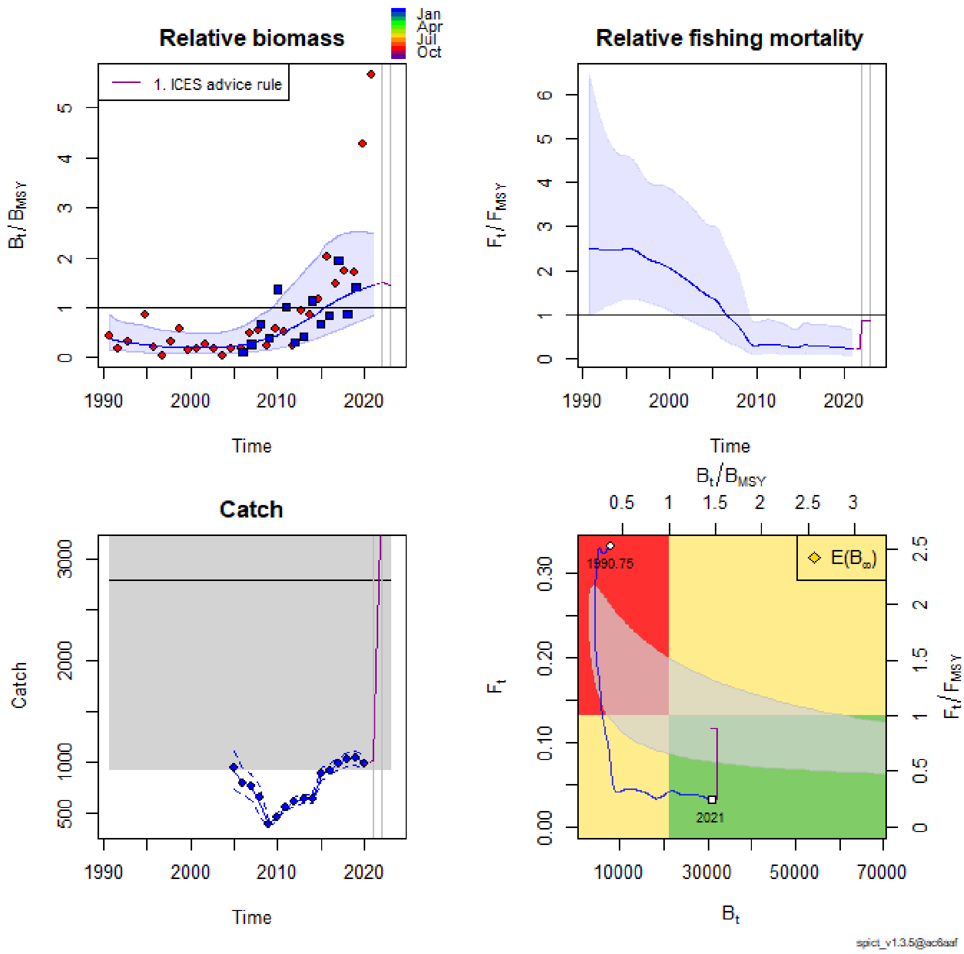

Figure 5.4.10. Projections corresponding to an intermediate year with status-quo fishing mortality (F=0.032) and a management year with an advice on removals of 3648 tonnes.

5.5 Future considerations/recommendations

The forecasted value of the advice on removals when applying the $f_{0.35}^{c}$ rule (3648 tonnes) is greater than the recent annual catch (2018–2020 average: 3390 tonnes) or recent removals (2018-2020 average: 1016 tonnes). It is also much greater than the current advice on total catch (2552 tonnes).

Once a new limit has been set on removals, the next step is to convert these advised removals into a catch advice. Using the usual procedure (i.e., applying the recently observed discard rate under the assumption that it would reflect the future discard rate) would not be considered since the recently observed discard rate corresponds to a situation wherein landings represent a minor part of removals (given the TAC constraint) and it is very unlikely that this discard rate would remain as high if more landings were to be allowed. Using this discard rate to derive the recommended landings would not be suitable because it would imply a considerable increase in the total catch to generate a great quantity of dead discards (over 12 000 tonnes if removals increase by the same factor 3.6).

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). Due to the patchy distribution of this species (Ellis *et al.*, 2012), the allowed landings may be quickly attained if targeting occurs, and discarding would take place as undulate ray is the object of an exemption to the landing obligation based on high survivability of discarded individuals. This situation could potentially generate a F greater than F_{MSY} in the short term because not all discarded undulate rays would survive (estimated survival rate for 2018-2020 across all fleets: 75.3%). In order to prevent overexploitation of the stock, complementary management measures may need to be considered (e.g. extension of the prohibition on targeting undulate in the English Channel, revocation of the current exemption to the landing obligation for this stock).

As the FR-CGFS biomass index series will extend and knowledge about the stock will increase, the application of a greater observation error associated with years 2019 and 2020 will have to be reconsidered in the future.

It is recommended that the survey indices related to the exploitable biomass (individuals ≥ 50 cm TL) are used in subsequent assessments, instead of total biomass, due to the direct link with stock productivity and fishing mortality. This modification is not expected to affect the selection of the best SPiCT scenario, as the time series of exploitable and total biomass appear very similar for undulate ray in the English Channel.

It is suggested to re-examine FR-CGFS and Q1SWECOS to improve individual survey indices and explore whether a combined index would be deemed suitable for this stock, with such explorations to consider the potential gear, vessel and seasonality effects. Such work could be usefully undertaken during a dedicated workshop on surveys in the Celtic Seas ecoregion following similar process of WKSKATE in 2020 where surveys in the North Sea ecoregion were evaluated (ICES, 2021).

Furthermore, the current methodology for Q1SWECOS used in this benchmark follows the random stratified survey design with no associated CIs provided, as the results are estimates of absolute biomass on swept area weighting (Silva, 2021 WD). A second methodology was developed to understand the uncertainty of using Q1SWECOS in its current form, which could be also further explored as to provide an alternative index (Silva, 2022 WD).

5.6 Reviewers report

Enric Cortés and Jan Jaap

No Stock ID issues were found for the undulate ray (*Raja undulata*) stock in the English Channel (ICES Divisions 7.d and 7.e). Discards for this stock can represent a large part of the catch. Ignoring dead discards in the assessment would thus produce a biased stock status. Data were provided by the three main countries contributing to catches of this stock: Belgium, France and the United Kingdom. Owing to gaps in the data, discard information had to be inferred for several years, the procedures for which are described in the report. A conversion from total discards to dead discards was then made using survival rates by gear for undulate or thornback ray found in the literature. Landings by species were only available since 2009, and landing data for the 2005-2008 period were reconstructed to extend the data series.

SPiCT was used to assess the status of the undulate ray (*Raja undulata*) stock in the English Channel (ICES Divisions 7.d and 7.e). Inputs to the model included two alternative total catch series: 2009-2020 and 2005-2020, the latter incorporating a reconstruction of catches from 2005 to 2008.

Three configurations for biomass indices: the CGFS index (1990-2020), the SWECOS index (2006-2019) smoothed, and the two indices used together. Given the concurrent increase in catches and indices, informative priors were used in all scenarios considered to meet acceptability criteria (all scenarios incorporating the default SPiCT priors failed the retrospective analysis acceptance criteria). The scenarios considered included several configurations of priors for r, the shape parameter n, and initial depletion, as well as considering a higher observation error in 2019 and 2020 for the CGFS index.

Two main groups of runs were identified as producing credible/reliable outputs: 1) with informative priors on r, n, and initial depletion, and catches starting in 2009; and 2) with informative priors on r, n, and initial depletion, but catches starting in 2005. Results showed high variability in absolute values of parameter estimates (K, MSY, BMSY…) and lower variability in relative quantities (Bcurrent/BMSY and Fcurrent/FMSY). All runs pointed to past overexploitation of a depleted stock and reference ratios pointing towards under- (or close to full) exploitation of a recovered (or close to recovered) stock. While the runs with catches reconstructed to 2005 highly influenced parameter estimates, the status relative to current relative fishing mortality was not modified but had larger influence on current relative stock biomass.

It was noted that by using a smoothed index each data point in the index is not independent of each other, which leads to high autocorrelation, and that SPIcT tends to focus on such indices leading to potential overfitting of that index. It was therefore recommended to use the SWECOS index in raw form (not smoothed). It was also noted that the runs with catches starting in 2005 were preferable to those with catches starting in 2009 because they provided better contrast. Additional runs using the raw SWECOS index revealed that results were little affected by this change. There was also a comment as to why the 2019 and 2020 data points in the CGFS index should be given higher uncertainty just based on the fact that they had high values. This led to a discussion about the credibility of the very large increase in the CGFS index, particularly from 2018 to 2019, which could be attributed to a very large recruitment or higher productivity than reflected by r, but it was also pointed out that such an increase (almost a tripling of the population in one year) was not biologically possible for an elasmobranch.

There was some additional discussion on short-term catch projections and it was decided that the status quo should be used for the interim year and that the TAC will be calculated following the 35th percentile of the predicted catch distribution. In all, the assessment and projection methods were accepted.

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Annex 1: List of participants

DE – Data Evaluation (29 November – 03 December 2021);
LH – Life history parameters (11 January 2022);
ID – Stock ID (03 February 2022);
PC – Porbeagle CPUE (15 February 2022);
AB – Assessment Benchmark (26 – 29 April 2022)

Name	Institute	Country	Email	DE	LH	ID	PC	AB
Manuela Azevedo *ICES external Chair*	IPMA	Portugal	mazevedo@ipma.pt	X	X	X	X	X
Ole Thomas Albert	IMR	Norway	ole.thomas.albert@hi.no				X	
Haritz Arrizabalaga	AZTI / ICCAT		harri@azti.es	X		X	X	
Thomas Barreau	National Museum of Natural History	France	thomas.barreau@mnhn.fr	X	X	X	X	X
Jurgen Batsleer	WUR	Netherlands	Jurgen.Batsleer@wur.nl	X		X		
Loïc Baulier	IFREMER	France	Loic.Baulier@ifremer.fr	X	X	X	X	X
Gérard Biais	IFREMER	France	gerard.biais@ifremer.fr	X	X	X	X	X
Alain Biseau *ICES Chair*	IFREMER	France	abiseau@ifremer.fr	X	X	X	X	X
Cristina Rodríguez Cabello	IEO	Spain	cristina.cabello@ieo.es	X	X	X		X
Steven Cadrin	University of Massa-chusetts Dartmouth	United States	scadrin@umassd.edu			X		
Rui Coelho	IPMA / ICCAT		rpcoelho@ipma.pt	X		X	X	
Paul Coleman	Marine Institute	Ireland	paul.coleman@marine.ie	X	X			X
Enric Cortes *External reviewer*	NOAA	United States	enric.cortes@noaa.gov	X	X	X	X	X
Jim Ellis	CEFAS	United Kingdom	jim.ellis@cefas.co.uk	X	X	X		X
Rodrigo Forselledo	National Directorate for Aquatic Re-sources	Uruguay	rforselledo@gmail.com	X		X	X	
Jette Fredslund	ICES		jette.fredslund@ices.dk	X		X		
Graham Johnston	Marine Institute	Ireland	graham.johnston@marine.ie	X	X	X	X	X
Armelle Jung	University of Brest	France	armelle.jung1@univ-brest.fr	X				

Name	Institute	Country	Email	DE	LH	ID	PC	AB
Claudia Junge	IMR	Norway	claudia.junge@hi.no	X		X	X	
Pascal Lorance	Ifremer	France	pascal.lorance@ifremer.fr	X	X	X		X
Iñigo Martinez	ICES		inigo@ices.dk	X	X	X	X	X
Carlos Mayor	ICCAT		carlos.mayor@iccat.int	X				
Gary Melvin	ICCAT					X		
David Murray	CEFAS	United Kingdom	david.murray@cefas.co.uk			X		
Mauricio Ortiz	ICCAT		mauricio.ortiz@iccat.int	X		X	X	X
Amélia Viricel Pante	University of La Rochelle	France	amelia.viricel-pante@univ-lr.fr			X		
Jan Jaap Poos *External reviewer*	WUR	Netherlands	janjaap.poos@wur.nl	X	X	X		X
Bárbara Serra-Pereira	IPMA	Portugal	bpereira@ipma.pt	X	X			
Joana Silva	CEFAS	United Kingdom	joana.silva@cefas.co.uk	X	X	X	X	
Christoph Stransky	Thünen-Institute of Sea Fisheries	Germany	christoph.stransky@thuenen.de			X		
Nathan Taylor	ICCAT		nathan.taylor@iccat.int	X		X	X	X
Caroline Aas Tranang	IMR	Norway	caroline.aas.tranang@hi.no	X				
Verena Trenkel	IFREMER	France	verena.trenkel@ifremer.fr			X		X
Lies Vansteenbrugge	ILVO	Belgium	lies.vansteenbrugge@ilvo.vlaanderen.be	X				
Jesús García Villar	ICCAT		jesus.garcia@iccat.int	X				
Zachary Whitener	Gulf of Maine Research Institute	United States	zwhitener@gmri.org			X		
Antonia Klöcker	IMR	Norway	antonia.klocker@hi.no					
Casper Berg *Invited expert*	DTU Aqua	Denmark	cbe@aqua.dtu.dk					X
Lucie Baude	Ifremer	France						X
Hege Overbø	IMR	Norway	hege.oeverboe.hansen@hi.no					
Romaric Jac	IMR	Norway	romaric.jac@hi.no					
Andrés Domingo	ICCAT		dimanchester@gmail.com					

Annex 2: Workshop agenda

WKELASMO, 29 November – 03 December 2021 (online meeting)
Data Evaluation

Agenda

29 Nov (Monday)

14:00-14:15 (CPH TIME))

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

14:15-15:30

Porbeagle (*Lamna nasus*) in the Northeast Atlantic and adjacent waters (por.27.nea) – Category 6 stock
Presentations and plenary discussions:

- **Gérard Biais**: Issues to be addressed during the benchmark workshop.

15:30-15:45 health break

15:45-18:00

- **Carlos Mayor**: Statistical data sources and information available from ICCAT;
- **Gérard Biais**: Sandardized catch rates of porbeagle in the Northeast Atlantic Ocean from Norwegian logbooks;
- **Gérard Biais**: Sandardized cath rates of porbeagle in the Northeast Atlantic Ocean from French longliner data by trip.

30 Nov (Tuesday)
14:00-15:30 (CPH TIME))

Cuckoo ray (*Leucoraja naevus*) (rjn.27.678abd) – Category 3 stock
Presentations, plenary discussion and proposed workplan:

- **Pascal Lorance**: Issues to be addressed during the benchmark workshop.

14:45-15:00 health break

15:30-16:00

- Issues to be addressed during the benchmark workshop (continued);
- **Loïc Baulier**: survivability of discarded cuckoo rays (*Leucoraja naevus*) in French bottom trawl fisheries.

01 Dec (Wednesday)

14:00-15:30 (CPH TIME))

Undulate ray (*Raja undulata*) in the English Channel (rju.27.7de) – Category 3 stock

Presentations, plenary discussion and proposed workplan.

- **Loïc Baulier**: Issues to be addressed during the benchmark workshop.

15:30-15:45 health break

15:45-17:30

- Issues to be addressed during the benchmark workshop (continued);
- Draft Workplan

02 Dec (Thursday)

14:00-15:30 (CPH TIME))

Thornback ray (*Raja Clavata*) in the Bay of Biscay (rjc.27.8) – Category 3 stock

Presentations, plenary discussion and proposed workplan.

Pascal Lourance: Issues to be addressed during the benchmark workshop.

15:30-15:45 health break

15:45-17:00

- Issues to be addressed during the benchmark workshop (continued)
- Draft Workplan

03 Dec (Friday)

14:00-16:20 (CPH TIME))

- **Porbeagle**:

  Survey abundance index 2018-2019 & commercial CPUE processed to provide abundance indices 2000-2019;

  Plenary discussion, conclusions and proposed workplan for the March 2022 benchmark assessment meeting

16:30-18:00

- **Undulata ray**:

  Plenary adoption of the workplan.
- **Cuckoo ray**:

  Plenary adoption of the workplan.
- **Thornback ray**:

Plenary adoption of the workplan.

WKELASMO, 11 January 2022 (online meeting)
Subject: Life-history parameters and discard survival rates

Agenda

Presentation and plenary discussions & recommendations:

17:00-19:00

Loïc Baulier – Compiled life-history parameters and discard survival rates for *Leucoraja naevus, Raja undulata* and *Raja clavata* (WKELASMO_LifeHistorySurvival.xlsx)

WKELASMO, 3 February 2022 (online meeting)
Subject: Stock ID

Agenda

Opening of the meeting; Welcome to the experts from the ICES Stock Identification Methods Working Group (SIMWG)

Presentations and plenary discussions & recommendations:

17:00-18:30

Thornback ray (*Raja Clavata*) **& Cuckoo ray** (*Leucoraja naevus*)

Pascal Lorance – Stock ID of thornback ray in the Bay of Biscay (rjc.27.8)

Pascal Lorance – Stock ID of cuckoo ray in Division 678abd (West of Scotland, southern Celtic Seas, western English Channel and Bay of Biscay) (rjn.27.678abd)

Graham Johnston - Landings of *Leucoraja naevus* – Proposal for corrected landings figures to be used by WKElasmo.

18:35-20:45

Porbeagle (*Lamna nasus*)

- **Steve Cadrin** - Interdisciplinary stock identification of North Atlantic porbeagle (*Lamna nasus*)
- **Jim Ellis** - Stock delineation of North-east Atlantic porbeagle *Lamna nasus*
- **Gérard Biais** – Stock ID of Porbeagle (*Lamna nasus*) in the Northeast Atlantic and adjacent waters (por.27.nea)
- **Mauricio Ortiz** – Review of the catch series for Northeast porbeagle shark stock (*Lamna nasus*) as input for the stock assessment

WKELASMO, 15 February 2022 (online meeting)
Subject: Porbeagle CPUE standardization

Agenda

Presentation and plenary discussions & recommendations:

15:00-17:30

Gerard Biais – Standardized catch rates of porbeagle in the Northeast Atlantic Ocean from French longliner data by trip (revised);

- Standardized catch rates of porbeagle in the Northeast Atlantic Ocean from Norwegian longliner logbooks (revised)

WKELASMO, 26–29 April 2022 (online meeting)
Assessment benchmark

Agenda

26 April (Tuesday)

13:00-16:00 (CPH TIME)

Presentations and plenary discussions:

Thornback ray (*Raja Clavata*) in Div.8abd (rjc.27.8abd)

<u>WD from Verena Trenkel & Pascal Lorance</u>

- **CKMR-derived absolute biomass estimates**
- **Catch and Survey biomass index**
- **Stock assessment with Bayesian production model - priors for process model**
- **Further trial runs/Final assessment**

Thornback ray (*Raja Clavata*) in Div.8c (rjc.27.8c)

- **Input data for stock assessment (SPICT?, Cat3 methods?)**
- **Exploratory stock assessment**

16:00-18:00

Report writing and collation

27 April (Wednesday)

13:00-16:00 (CPH TIME)

Presentations and plenary discussions:

Cuckoo ray (*Leucoraja naevus*) in the West of Scotland, southern Celtic Seas, western English Channel and Bay of Biscay (rjn.27.678abd)

<u>WD from Paul Coleman & Graham Johnston</u>

- **Input data (catch, CPUE) for stock assessment**
- **Priors for SPiCT parameters**
- **Exploratory assessments with SPiCT/Final assessment**

16:00-18:00

Report writing and collation

28 April (Thursday)

13:00-16:00 (CPH TIME)

Presentations and plenary discussions:

Undulate ray (*Raja undulata*) in the English Channel (rju.27.7de)

<u>WD from Lucie Baude & Loic Baulier</u>

- **Input data (catch, CPUE) for stock assessment**
- **Priors for SPiCT parameters**
- **Exploratory assessments with SPiCT/Final assessment**

16:00-18:00

Report writing and collation

29 April (Friday)

13:00-16:00(CPH TIME)

Presentations and plenary discussions:

Porbeagle (*Lamna nasus*) in the Northeast Atlantic and adjacent waters (por.27.nea)

WD from Gérard Biais, WD from Mauricio Ortiz *et al*

- **Input data (catch, CPUE) for stock assessment**
- **Priors for SPiCT/JABBA parameters**
- **Exploratory assessments with SPiCT and JABBA**
- **Further trial runs/Final assessment**

16:00-18:00

Report writing and collation

Annex 3: List of tasks by stock

Workplan Porbeagle in NEA (por.27.nea)

WD on stock ID

- Tagging data
- Genetic analyzes
- Fishery data (seasonal landings)
- Biological data
  Deadline: end January

CPUE data:

- deviation table to add to WD
- Plot all series together

Survey index series extended

- Analysis of spatiotemporal variations of commercial CPUEs
- Analysis of effect of number of hooks on CPUEs
- Discards to delete in survey CPUEs
  Deadline: end January

Catches

- Analysis of differences between ICES and ICCAT database
  Deadline: mid January

Discards

- Results of data call to summarise (length distributions, done by Claudia)
  Deadline: mid January

LH data

- Review to be made to see if there is other choice than using prior for r from NW stock.

SPiCT inputs

- Deadline: February 7th

SPiCT preliminary runs

- Catches from 1926, all abundance series together,
- Catches from 1972, FR abundance series + survey extended together.
  Final WD
  Deadline: February 21 st

Workplan Cuckoo ray (*Leucoraja naevus*) in the West of Scotland, southern Celtic Seas, western English Channel and Bay of Biscay (rjn.27.678abd)

- Working document for stock ID
    - Synthesis of information from tagging (mostly Bird *et al* 2020) and other studies (eg parasites)
    - Species distribution from survey data
    - Species distributions from any other source
        - French on-board observation
        - Archive data (former surveys, ...)
    - Length distribution from surveys and sampling (Port and on-board)
        - By survey/area/sex
        - Check for effect of sex ratio
        - Effect of area limit e.g. two possible stocks (67bc; 7a ek8abd vs latitudinal gradient (<48°=27.8; 48-50; 50--52.5; >52.5, i.e. is the change gradual of is there a break point?)
    - Size at maturity and maximum observed size by area (growth studies not informative, small samples and concerns with age estimations)
    - Trends in survey indices
        - Indices of total biomass
        - Compile survey indices by broad size groups (exploited, >= 50cm, vs juveniles , <50 cm) and explore other relevant grouping
        - Indices by sex

Deadline 31.01.2022 /Leader P. Lorance, contributors (G Johnston, J Ellis, J Silva,...)

- Estimation of landings back in time to 2001 (landings before 2009 reported as rajidae), i.e. split landings of Rajidae according to a species composition (deadline : 7 February)
    - Based on the method from Marandel *et al* (2018)
    - Based on species composition from on-board observations and surveys
- Survey indices
    - Considered how to incorporate CGFS western Channel, WECOS and BTS in biomass indices (indices for exploited biomass (>50 cm) estimated for 4 surveys: EVHOE, IGFS, NIGFS, SP-Porcupine from DATRAS + CGFS west from French national data and WECOS from DATRAS (Joana))
        - Includes considering how to account for 7.e (where there are survey catches)
- Estimation of discards
    - Data missing/insufficient in earlier years of the 2000s: estimate a pre-TAC discard rate for some years e.g. 2006-2008 or using all pre-TAC data (eg for France some data from 2003 to 2008 with variable coverage and sampling plans over time) and apply it back in time
- Discards survival

  - Define a survival rate (High discards low survival, accounting for discards necessary)
  - Does not need to be by fleet or gear (91 % of landings from otter trawl, 4% from beam trawls, 5% other)
- Decision meeting to decide on input data for the model / parameters : 10 January

- Assessment: SPiCT deadline WD: 21 February

Explore some sets of surveys or a combination (pre-combined index)

Workplan Undulate ray (*Raja undulata*) in the English Channel (rju.27.7de)

- Preliminary work:
  - Compilation of data on LH parameters (origin of data, derivation mode, reference)- deadline: end of December
    → Suggestion for parameter choice
  - Compilation of data on discard survival (origin of data, derivation mode, reference), including other species when large samples are available - deadline: end of December
    → Suggestion for parameter choice
- Building a time series of removals (landings+dead discards)
  - Filling gaps in discard series (i.e. when no estimate available for a combination of fleet-year) from 2009 on
  - Consideration of the backward extension of the landing series before 2009 (+dead discards), for France only? possible issue related to VMS for other countries than France according to the WD explaining the general methodology (mid-January)
- Surveys: investigate to use an index form the Q1SouthWest survey?
- Decision meeting to decide on input data for the model / parameters: 10 January
- SPiCT runs -> deadline WD: 21 February
  - Definition of priors for LH parameters
  - Preliminary runs (data series starting in 2008 or 2009)
  - Assessment of the need for further backward extension of the time series of removals
- Runs of the Bayesian multispecies state-space model and comparison of the outputs from the 2 types of models

Workplan Thornback ray (*Raja Clavata*) in Div.8abd (rjc.27.8abd)

- Working document for stock ID - comparison of 8.abd vs 8.c (P. Lorance with contributions from C. Cabello and G Diez)
    - Synthesis of information from former study (tagging, migration distance,...)
    - Species distribution from EVHOE and DEMERSALES (PL from DATRAS)
    - Synthesis of outcome of CKMR for metapopulation structure
    - Species distributions from any other source.
        - French on-board observation
        - Archive data (eg French survey in 1973 and 1976 supporting distributions from Quéro *et al*. 1989, study of Bay of Arcachon)
        - Data/knowledge from AZTI for the southeast of the Bay of Biscay
    - Length distribution from surveys and sampling (Port and on-board)
        - Length distribution in EVHOE vs DEMERSALES (total and by sex)
    - Size at maturity and maximum observed size in 8.abd and 8.c
    - Trends in survey indices in 8.abd vs 8.c: total and exploited biomass, juvenile number (<50 cm)

Deadline 31.01.2022 (for review the reviewer, external and SIMWG)

- Estimation of landings back in time to 2001 (landings before 2009 reported as rajidae), i.e. spilt landings of rajidae according to a species composition [in 8.abd, this will be more uncertain than for rnj.27.678abd because the species represents a smaller proportion of total catches of rajidae; in 8.c, where the species is the main rajidae caught, it should work fine]
    - 8.abd: based on the method from Marandel *et al* (2018)
    - 8.abd and 8.c: based on species composition from on-board observations and surveys
    - Action: P Lorance (8.abd) and C Cabello (8.c)
- Estimate the proportion of directed catch and bycatch (P Lorance (8.abd) and C Cabello (8.c))
- 8.abd: Comparison of CKMR biomass estimate to swept area biomass
- Survey indices
    - Describe the method for EVHOE indices (not all the survey area used, restricted to the main strata for the species)
- Discards (moderate but increased during the 2010s -TAC limit and size regulations)
    - Data missing/insufficient in earlier years of the 2000s: estimate a pre-TAC discard rate for some years e.g. 2006-2008 or using all pre-TAC data and apply it back in time
- Discards survival (moderate to good, accounting for survival necessary)

  - Define a survival rate
  - If possible by fleet (80% trawls 20% static and static operate inshore)
- Look at data for LBI

  Decision meeting to decide on input data for the model / parameters: 10 January

- Assessment: BBPM / SPiCT deadline WD: 21 February
  - If the stock is split assessment based on the Bayesian Biomass Production Model (incorporating CKMR estimate) in 8.abd and SPiCT in 8.c
  - If the stock area is kept as current (rjc.27.8) ?? unclear if CKMR could be incorporated in the model in that case… -> SPiCT

Remark: CKMR results expected in press at the time of the benchmark, so not included in this workplan.

Quéro, J. C., J. Dardignac, and J.-J. Vayne. 1989. Les poissons du golfe de Gascogne. Ifremer, Plouzané, 229pp.

Annex 4: Resolutions

WKELASMO - Benchmark Workshop for selected elasmobranch stocks

2021/2/FRSG25 A **Benchmark Workshop for selected elasmobranch stocks** (WKELASMO), chaired by External Chair Manuela Azevedo, Portugal, and ICES Chair Alain Biseau, France, and attended by two invited external experts Enric Cortés USA, and Jan Jaap Poos, Netherlands, will be established and will meet online 29 November - 3 December 2021 for a data evaluation meeting and in Nantes, France and online, for a 5-day Benchmark meeting 7–11 March 2022 to:

c) 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:
   ix. Stock identity and migration issues;
   x. Life-history data.
   xi. Review current sampling levels and adjust stratification levels for landings and discards accordingly;
   xii. Inclusion of recent scientific fishing surveys not yet considered in the assessment;
   xiii. Examine alternative assessment models to the current model;
   xiv. Explore impact of all tuning fleets on assessment estimates;
   xv. Further considerations of environmental drivers, multi-species information, and ecosystem impacts for stock dynamics in the assessments and outlook;
   xvi. Examine mixed fisheries interaction;
d) Agree and document the most appropriate method for evaluating stock status and (where applicable) short term forecast and update the stock annex as appropriate. Knowledge about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology where possible. If no analytical assessment method can be agreed, then an alternative method for providing advice (ideally one of the WKLIFE X (https://doi.org/10.17895/ices.pub.5985) methods) should be put forward;
f) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);
g) Develop recommendations for future improvements of the assessment methodology and data collection;
h) 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.

WKELASMO will report by 7 April 2022 for the attention of ACOM.

Stocks	Stock leader
por.27.nea	Gérard Biais
rjc.27.8	Pascal Lorance
rju.27.7de	Loïc Baulier
rjn.27.678abd	Pascal Lorance