WORKSHOP ON THE DEVELOPMENT OF QUANTITATIVE ASSESSMENT METHODOLOGIES BASED ON LIFE-HISTORY TRAITS, EXPLOITATION CHARACTERISTICS, AND OTHER RELEVANT PARAMETERS FOR DATA-LIMITED STOCKS (WKLIFEXII)

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i Executive summary

The objective of the Twelfth Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII) was to further develop methods for stock assessment, stock status, and catch advice for stocks in ICES Categories 2–6, focusing on the provision of sound advice rules adhering to the ICES advisory framework and principles for fisheries management. This report addresses (i) questions from different ICES assessment working groups and stakeholders regarding the applicability of the data-limited technical guidelines, (ii) the prioritisation of future tasks regarding the ICES data-limited framework, (iii) further development and testing of data-limited methodologies with specific focus on the review of the current ICES advice framework for stock Categories 4-6, spatial indicators, and reference points for surplus production models, and (iv) other relevant data-limited topics. A survey of participants resulted in a high prioritisation score of four topics of the ICES data-limited roadmap: (1) risk equivalence, best available science, guidelines and communication of data-limited methods, (2) value of information of different data-types and data preparation, (3) better advice for slow-growing species, and (4) observation and parameter uncertainty in empirical harvest control rules and length-based approaches. The current ICES approach for Category 5 and 6 stocks, with an advice for constant annual catch and a periodic reduction with a precautionary buffer, is a form of non-adaptive management and an initial review revealed that it may not be precautionary if a stock is overfished but also overly precautionary in other situations. An exploration of spatial indicators showed that these have the potential to inform on stock status. A stochastic definition of MSY $B_{trigger}$ for surplus production models takes uncertainty into account and leads to higher reference values than the current definition for stocks with low and intermediate biomass variability.

ii Expert group information

Expert group name	Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII)
Expert group cycle	Annual
Year cycle started	2012
Reporting year in cycle	1/1
Chair(s)	Carl O'Brien, United Kingdom
	Tobias Mildenberger, Denmark
	Simon Fischer, United Kingdom
Meeting venue(s) and dates	16-20 October 2023, Lisbon, Portugal, with hybrid meeting access (41 participants)
Expert group name	Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII)

1 Introduction

1.1 Terms of reference

The Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII)

The Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII), chaired by Carl O'Brien (UK), Tobias Mildenberger (Denmark) and Simon Fischer (UK) will meet in Lisbon, Portugal, 16–20 October 2023 (with MS Teams hybrid meeting access). The workshop should address the following Terms of Reference:

1. Support the rollout of the WKLIFE X Category 2 and 3 methods in 2023 and beyond.
    a. Review recommendations (e.g. from WKMSYSPiCT1, WKMSYSPiCT2) and requests for clarification made by ICES groups (e.g. Elasmobranch, Celtic Seas and Deep Seas advisory processes) on the application of the methods presented in WKLIFE X Annex 3 and provide clear and concise feedback on issues raised and incorporate into suggested updates to the ICES Guidance, as appropriate.
    b. Conduct additional analyses if required.
    c. Revisit the multiplier of the rb rule (Method 2.1) and consider alternative multipliers for specific life-history groups.
    d. Consider situations needing zero-catch advice and how to leave zero-catch advice.
    e. Check if the technical guidelines require updating based on recent developments.
    f. Develop an R tool to facilitate and standardise the application of the rfb/rb/chr rule and link the tool to TAF.
2. WKLIFE XI drafted a 5-year roadmap of work required to improve the provision of ICES data-limited advice. Based on this roadmap, map topics to stocks in ICES categories 2-6, prioritise topics depending on ICES requirements and create a work plan for the next years.
3. Initiate a review of the ICES advice framework for categories 4, 5, and 6.
    a. Summarise the ICES stocks in these categories and their advice methods.
    b. Evaluate the current approaches in these categories with respect to risk equivalence and their ability to follow the ICES precautionary approach.
    c. Start exploring alternative approaches for these stocks.
4. Further explore the use of empirical indicators
    a. Explore spatial indicators to inform on stock abundance (e.g. bycatch species) to facilitate their use in harvest control rules.
    b. Consider alternative empirical indicators that could be useful as part of harvest control rules.
5. Evaluate and improve the application of and management advice based on surplus production models, such as SPiCT.
    a. Further develop guidelines for model fitting and validation and the use of priors.
    b. Evaluate alternative definitions of biomass limit and threshold reference points for harvest control rules based on surplus production models.

   c. Explore the implications of dynamic reference points.
   d. Evaluate the incorporation of additional information (e.g. length data) into surplus production models.

6. Explore data-limited stock assessments, harvest control rules (e.g. dynamic harvest rate rules), and simulations approaches for specific life-history strategies
   a. Short-lived species, e.g. Celtic Sea sprat.
   b. Elasmobranchs and other slow-growing species (e.g. thornback ray in Iberian waters, application of SPiCT, simulation of empirical harvest control rules).
   c. Other life-history strategies, e.g. Nephrops, crabs, cephalopods.
7. Further explore and develop assessment and advice methods with focus on data- and/or resource-limited fisheries, together with exploring approaches of moving towards an ecosystem perspective, from both within and outside the ICES' community.
8. Summarize recent work by the scientific community, including published papers and exploratory work on Empirical rules and production models; review and address these publications with respect to ICES advice.

WKLIFE XII will report to ACOM no later than **17 November** 2023.

1.2 Background

The Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE) is the premier venue for developing, evaluating and improving the stock assessment methods and indicators that are suitable for providing advice for data-limited fish stocks.

Around 60% of the more than 260 fish stocks for which ICES provides advice are data-limited but require advice on fishing opportunities. The recent changes to the methods for assessment of data-limited stocks are the result of WKLIFE's work, and the workshop aims to help continue and expand advice provision to ensure that ICES principles are followed.

ICES is working to provide catch advice for all stocks that is in line with the Precautionary approach and, where possible, also follows the maximum sustainable yield (MSY) approach. The methods developed and tested by WKLIFE and WKDLSSLS are key to ICES' advancements in this area.

The group's last meeting (WKLIFE XI in January 2023) was the first since 2020 and was mainly aimed at scoping the future directions of WKLIFE. This meeting (WKLIFE XII in October 2023) was more aligned with previous meetings where participants presented and discussed their work with the ambition of improving the science guiding the advice ICES provides for data-limited stocks.

WKLIFE XII followed the Terms of Reference (ToR) detailed in the previous section and the main aims were to

- support the rollout of the recently developed new methods for ICES stocks in categories 2 and 3,
- continue developing and prioritizing tasks of the 5-year WKLIFE roadmap,
- initiate the review of methods for stocks in data-limited categories 4-6,
- further evaluate and develop empirical harvest control rules and surplus production models,
- explore approaches for specific life-history types, and
- provide updates on methods for data and resource-limited fisheries.

1.3 Conduct of the meeting

The list of participants and agenda for the workshop are presented in Annex 1 and Annex 8, respectively. WKLIFE XII was held as a hybrid meeting at IMPA-Algés, Lisbon, Portugal, and remote access was provided over Microsoft Teams. The meeting was well attended, with 41 participants (14 in person, 27 online).

Intersessional work had taken place ahead of the WKLIFE XII meeting by its participants, and this was presented during the workshop in 23 plenary presentations. Unlike the previous WKLIFE XI meeting with several subgroups, WKLIFE XII was held only with plenary sessions. In addition to the pre-scheduled presentations, several more open plenary discussions were held, including on the prioritisation (through an online survey) of the WKLIFE roadmap drafted by WKLIFE XI and a discussion on more collaborations.

Given ICES' role as a knowledge provider, it is essential that experts contributing to ICES' science and advice maintain scientific independence, integrity and impartiality. It is also essential that their behaviours and actions minimise any risk of actual, potential or perceived Conflicts of Interest (CoI).

To ensure credibility, salience, legitimacy, transparency and accountability in ICES' work, to avoid CoI and to safeguard the reputation of ICES as an impartial knowledge provider, all contributors to ICES' work are required to abide by the ICES Code of Conduct. The ICES code of ethics and professional conduct from 2022 was brought to the attention of participants at the workshop and no CoI was reported.

1.4 Plenary presentations

Twenty-three presentations were given during the plenary sessions of WKLIFE XII. Presenter, title, and synopsis or relevant section of the report are indicated below.

- Anne Cooper – *ICES approach to advice for data-limited stocks* – This presentation gave an introduction to ICES and the ICES approach and categories for data-limited stocks.
- Simon Fischer – *Updates on the Category 3 empirical harvest control rules; revisiting the rb rule, zero-catch considerations, and R package* (ToRs 1bcdf) – see Section 2.2
- Tobias Mildenberger – *Zero catch advice with SPiCT* (ToRs 1bd) – see Section 2.3
- Elvar Hallfredsson – *rfb – rule WGDEEP* – The ICES assessment working group on deep-sea stocks provided feedback on the use of the WKLIFE methods. The questions are summarised in Section 2.4 and a preliminary response is provided in Annex 7.
- Sophy McCully Phillips and Jurgen Batsleer – *WGEF feedback to WKLIFE XII* – The ICES assessment working group on elasmobranch stocks provided feedback on the use of the WKLIFE methods. The questions are summarised in Section 2.4 and a preliminary response is provided in Annex 7.
- Elena Balestri – *The perspective of the fishing industry* – A perspective of the fishing industry on the WKLIFE X methods used for the ICES advice was given. The questions are summarised in Section 2.4 and a preliminary response is provided in Annex 7.
- Simon Fischer – *Initial review of the ICES advice framework for categories 4-6 and initial simulation testing* (ToR 3abc) – see Sections 4.1, 4.2, and 4.5
- Hector Andrade – *LBSPR assessment of tusk in the Northeast Arctic – initial results* (ToR 3c) – see Section 4.3
- Lionel Pawlowski – *Species vulnerability in the French tropical small-scale demersal fisheries using Productivity and Susceptibility analysis* (ToR 3c) – see Section 4.4

- Peter Kidd – *The ability of spatial indicators to classify stock status* (ToR 4a) – see Section 5.2
- Marta Cousido Rocha – *Challenges developing ad-hoc MSE for sole in divisions 8.c and 9.a* (ToR 4b) – see Section 5.3
- Tanja Miethe - *Length-based indicators and surveys* (ToR 4b, 1a) – see Section 5.4
- Momoko Ichinokawa – *Application of SPiCT for Japanese stock assessment and management with simple MSE* (ToR 5) – see Section 6.2
- Tobias Mildenberger - *Precautionary reference points for surplus production models* (ToR 5bc) – see Section 6.3
- Paul Bouch – *SPiCT and one-way trip analysis* (ToR 5) – see Section 6.4
- Bárbara Pereira – *Applying SPiCT to Nephrops in FU 28-29* (ToR 5 & 6) – see Section 6.5
- Andrés Uriarte - *Perturbation-Reaction Rule: A semi-quantitative data-limited approach to manage small pelagic fishes* (Tor 6a) – see Section 7.2
- Laurie Kell - *Adaptive management for Sardinian sea urchins and risk-equivalent frameworks* (ToR 6c) – see Section 7.3
- Laurie Kell – *Celtic Sea sprat and ecosystem reference points* (ToR 6a) – see Section 7.4
- Liese Carleton – *Plans for evaluating shellfish management strategies in Ireland* (ToR 6c) – see Section 7.5
- Romaric Jac – *The conservation potential of rabbitfish Chimaera monstrosa in the face of global changes* (ToR 6b) – see Section 7.6
- Wendell Medeiros Leal – *ICES data-limited assessment framework for blackspot seabream* (ToRs 7 & 8) – see Section 8.2
- Rehab Farouk Abdelfattah Soliman – *Choosing DLMs for artisanal Egyptian Red Sea* – see Section 8.3

The report sections corresponding to these presentations are listed above. Please note that the report sections are a summary of the work presented by the respective author(s) and whilst discussed during the workshop, the summaries merely convey the presenters' views and do not necessarily infer the agreement of all WKLIFE participants.

1.5 Structure of the report

The report structure follows the Terms of Reference (ToRs) of the meeting (see Section 1.1), with Sections 2-8 focussing on ToRs 1-8. Each section contains a summary of the work presented and the following discussion for the ToRs. Some presentations addressed several ToRs, and this is mentioned in the section title.

The structure of the report is as follows:

- Section 1 provides an introduction to the meeting and the report,
- Section 2 focuses on supporting the rollout of WKLIFE X Category 2 and 3 methods (ToR 1),
- Section 3 focuses on the WKLIFE data-limited roadmap (ToR 2),
- Section 4 focuses on approaches for ICES Category 4-6 stocks (ToR 3),
- Section 5 focuses on empirical (model-free) indicators (ToR 4),
- Section 6 focuses on further work on surplus production models (ToR 5),
- Section 7 focuses on approaches for specific life-history strategies (ToR 6),
- Section 8 focuses on any other data-limited work, and
- Section 9 summarises open discussions.

Instead of providing conclusions from the workshop at the end of the report as is customary with ICES' reports, each of the Sections 2–8 provides a synthesis of the material presented within each Section.

In addition to the report sections, several Annexes are attached to the report:

- Annex 1: List of participants
- Annex 2: Resolution
- Annex 3: Sardinian sea urchin (Annex to Section 7.4)
- Annex 4: Short-lived species (Annex to Section 7.4)
- Annex 5: Considerations (Annex to Section 7.3)
- Annex 6: Challenges developing ad-hoc MSE for Sole in divisions 8.c and 9.a
- Annex 7: Preliminary responses to questions on WKLIFE X methods (Annex to Section 2.4)
- Annex 8: Workshop agenda

1.6 Follow-up process within ICES

The participants at WKLIFE XII agreed to provide text for the draft workshop report by Friday, 3rd November 2023 (without tracked changes) and to then comment on the compiled draft report no later than 14th November 2023, when the report can be finalised by the Chairs and formatted by the ICES Secretariat. During the week beginning 6th November 2023, the Chairs will review the compiled draft report before participants comment (with tracked changes) before 14th November 2023.

2 Supporting the rollout of the WKLIFE X Category 2 and 3 methods (ToR1)

2.1 Introduction

One of the main aims of WKLIFE XII was to support the rollout of the WKLIFE X (ICES, 2021) Category 2 and 3 methods in ICES. ICES first used these methods to provide advice for data-limited stocks in 2021, and the rollout continued in 2022 and 2023. ICES technical guidelines were published in 2022 (ICES, 2022).

This section provides updates and responses to questions on the WKLIFE X methods. Section focuses on the Category 3 empirical harvest control rules (rb rule, zero-catch considerations, and an R package), Section 2.3 focuses on zero-catch considerations for the Category 2 harvest control rule with SPiCT, Section 2.4 summarises questions posed to WKLIFE this year, and Section 2.5 discusses whether there is a need for revising technical guidelines.

2.2 Updates on the Category 3 empirical harvest control rules; revisiting the rb rule, zero-catch considerations, and R package (ToRs 1bcdf)

2.2.1 Zero-catch considerations for the empirical Category 3 harvest control rules (ToR 1d/b)

ToR 1d of WKLIFE XII requested considerations for situations needing zero-catch advice and how to leave zero-catch advice.

The empirical Category 3 harvest control rules (rfb/rb/chr rules; ICES, 2022) include a biomass safeguard (b) that reduces the catch advice linearly down to zero when the biomass index (I) falls below a biomass index trigger value (I_{trigger}), essentially imposing a hockey-stick form on the harvest control rule ($b = \min\{1, I_{y-1}/I_{\text{trigger}}\}$). The methods were tested generically in simulations and were shown to be precautionary in the long term and can recover depleted stocks. This means there is no additional need for further reductions in the catch advice or advising zero catch. However, ICES precautionary considerations allow for advising zero catch based on expert opinion.

The rfb and rb rules calculate a new catch advice (A_{y+1}) by adjusting a reference catch, which is usually the previous catch advice (A_y), with some more harvest control rule elements (denoted by α here):

$$A_{y+1} = A_y \times \alpha$$

This means that, in the unlikely situation that the previous advice is zero, the new advice will also be zero and cannot leave zero. The chr rule is not affected because the new catch advice is calculated independently of the previous advice by setting the new catch advice based on a target harvest rate. WKLIFE XI (ICES, 2023) suggested alterations to the calculation of the reference catch for the rfb and rb rules could be considered, and this should ideally be tested with simulations.

This workshop (WKLIFE XII) conducted additional analyses for an alternative approach to calculate the reference catch. The alternative reference catch calculation followed the principle used to determine the target harvest rate for the chr rule and included:

(1) calculating the mean catch (L_{mean}) length for historical years,
(2) identifying those years (y_{ref}) in which the mean catch length was at or above the MSY proxy reference length ($L_{\mathrm{mean}} \geq L_{F=M}$), and
(3) averaging the catch values from these years and multiplying the final value by 0.5:

$$C_{\mathrm{ref}} = 0.5 \sum\nolimits_{i \in y_{\mathrm{ref}}} C_i / N$$

where N is the number of years in y_{ref}.

The original simulation framework used in WKLIFE X (ICES, 2021) was used, and the simulations for the rfb and rb rule were repeated for the new reference catch, including the 29 generic stocks and two fishing histories. Figure 2.2.1.1 shows the results for the B_{lim} risk (long-term, i.e. over a 100-year projection period) of the new approach in comparison with the default reference catch. The risk with the new approach is very similar to the standard approach and did not, on average, lead to a higher risk.

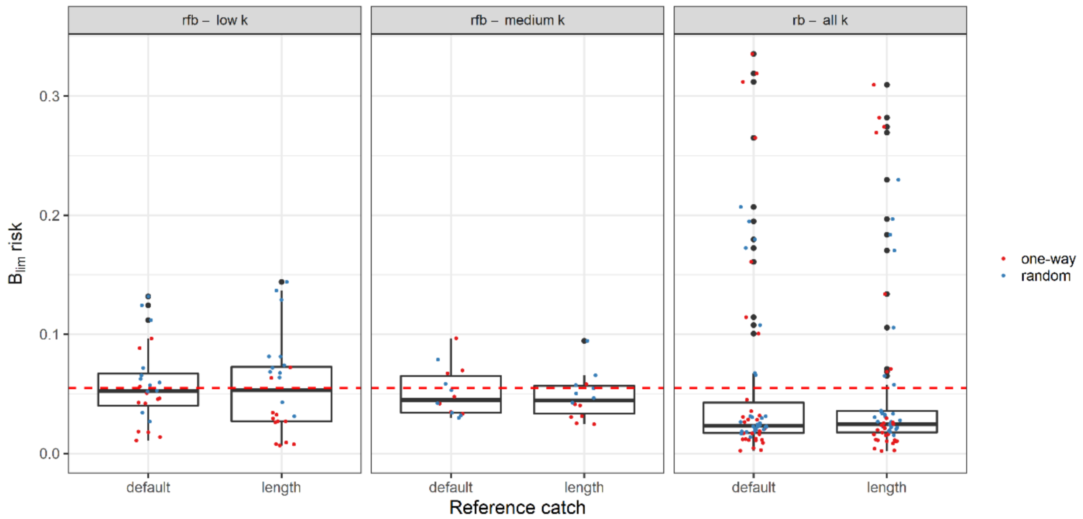

Figure 2.2.1.1. Comparison of the Blim risk for the default rfb and rb rules (labelled "default") to the approach where the reference catch is selected based on historical catch length data (labelled "length"). The risk is the long-term risk over a 100-year projection period. Please note that this change only affected the first year of the simulation. Each point corresponds to one generic stock, and the colours denote the fishing history (one-way and random). Results are grouped for the two multipliers of the rfb rule (low-k stocks with multiplier $m = 0.95$, i.e. stocks with von Bertalanffy $k < 0.2\ \mathrm{year}^{-1}$ and medium-k stocks with multiplier $m = 0.90$, i.e. stocks with $0.2\ \mathrm{year}^{-1} \leq k < 0.32\ \mathrm{year}^{-1}$) and the rb rule for stocks irrespective of k. See WKLIFE X (ICES, 2021) for details on the simulation and groupings.

Please note that this new approach for the reference catch was only used in the first year of the simulation and then defaulted to the standard approach, where the new advice is calculated by adjusting the previous advice. In reality, this approach should only be used sparingly, e.g. to leave a zero-catch advice, and only once.

The ICES technical guidelines (ICES, 2022) already offer an alternative to using the previous catch advice when realised catches are very different to the catch advice values and the rfb or rb rule is implemented for the first time. In such cases, the reference catch should be based on the last realised catch or an average over several years (e.g. recent three years). This is because the methods are meant to adjust the realised catches that affect the stock.

A situation where either approach would have been applicable is the 2023 ICES advice for starry ray (*Amblyraja radiata*) in subareas 2 and 4 and Division 3.a (Norwegian Sea, North Sea, Skagerrak, and Kattegat, https://doi.org/10.17895/ices.advice.21857001). For this stock, the rfb rule was applied in 2023 for the first time, and the advice in previous years was zero. This zero-catch advice was then used as the reference catch, and the new advice is also zero. Realised catches (mainly discards) in previous years were well above zero (several hundred tonnes). Consequently, following ICES technical guidelines would have led to a reference catch based on the last catch or an average catch, and the new catch advice would not be zero. However, this species is included in a list of prohibited species in the EU and UK, so the zero-catch advice is intentional. Nevertheless, the advice calculation does not strictly follow ICES technical guidelines, and ACOM should clarify such situations (WKLFIE XII made a recommendation to do this).

2.2.2 Revisiting the multiplier of the rb rule (ToR 1c)

For non-short-lived stocks of Category 3 for which no length data are available, ICES technical guidelines (ICES, 2022) recommend the "rb rule". This method does not include a target and only follows the ICES precautionary approach. To ensure the method is precautionary in the long term, it includes a low multiplier of $m = 0.5$, which leads to a reduction of the catch advice over time. The ICES technical guidelines describe the rb rule as a "method of last resort" that should only be used if neither the rfb or chr rule can be used, and the rb rule should be avoided if possible.

Figure 2.2.2.1 shows the data used by WKLIFE X (ICES, 2021) to select the multiplier of $m = 0.5$ for the rb rule. WKLIFE X chose the multiplier as a compromise because not all stocks met the 5% risk threshold specified by the ICES precautionary approach and because of the large spread of multipliers between the stocks.

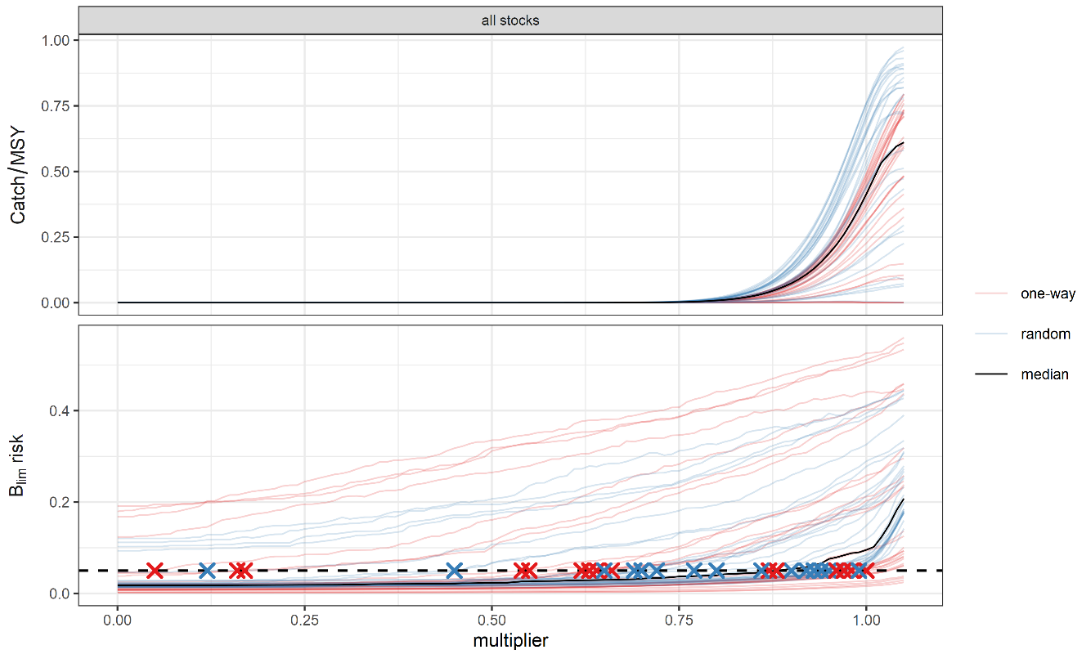

Figure 2.2.2.1. The data used by WKLIFE X (ICES, 2021) to select the multiplier of $m = 0.5$ for the rb rule. Each curve corresponds to one of the 29 generic stocks, and the colours correspond to the two fishing histories (one-way and random before applying the rb rule). The black solid curve is the median over all stocks and fishing histories. The points ("X") indicate where the risk curves for the individual stocks meet the 5% threshold (horizontal dashed line), but not all curves meet this threshold. Summary statistics (risk, catch) are long-term values over a 100-year projection period.

This workshop (WKLIFE XII) tried to re-evaluate the multiplier for the rb rule by looking again at the data from WKLIFE X (ICES, 2021) without conducting new simulations. Figure 2.2.2.2 illustrates the multipliers required for meeting the 5% risk threshold. There is a wide range of multipliers between stocks, and even the multiplier for the same stocks can differ substantially between fishing histories. The spread of multipliers is much wider than for the rfb rule.

The rb rule is based on fewer data than the rfb rule (no length data), and following the precautionary approach to fisheries, this would mean that the multipliers should be lower than for the rfb rule. Figure 2.2.2.3 shows a suggestion of multipliers discussed at WKLIFE XII. The suggestion was to keep the generic multiplier of $m = 0.5$ for all stocks unless there is compelling scientific evidence that the von Bertalanffy individual growth rate k is below 0.2year^{-1}, in which case a multiplier of $m = 0.75$ could be used. WKLIFE XII discussed this and other options for setting the multiplier, but the group concluded that the spread of multipliers is large, and no consensus was reached on how to address this. Further simulations were considered unlikely to help a decision, and the most desirable way forward is to avoid the rb rule and instead move to the rfb or chr rule, which may only require a single year of catch length data. Consequently, the group concluded that the multiplier for the rb rule and the technical guidelines do not need to be changed.

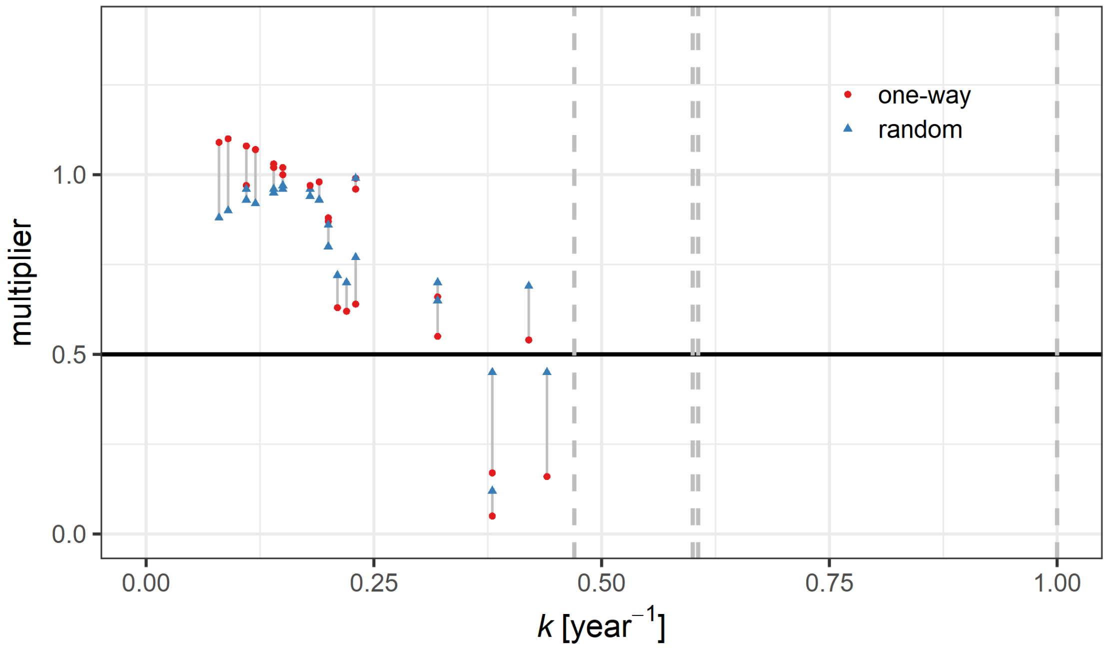

Figure 2.2.2.2. The multipliers of the rb that lead to a Blim risk of 5%, corresponding to the Xs in Figure 2.2.2.1, sorted by von Bertalanffy individual growth rate k (x-axis, slower-growing species on the left, faster-growing species on the right), based on the data from WKLIFE X (ICES, 2021). Each point corresponds to one of the 29 generic stocks, and points connected by a vertical line correspond to the two fishing histories of the same stock. Some stocks never reached the 5% risk threshold, and the vertical dashed lines indicate these.

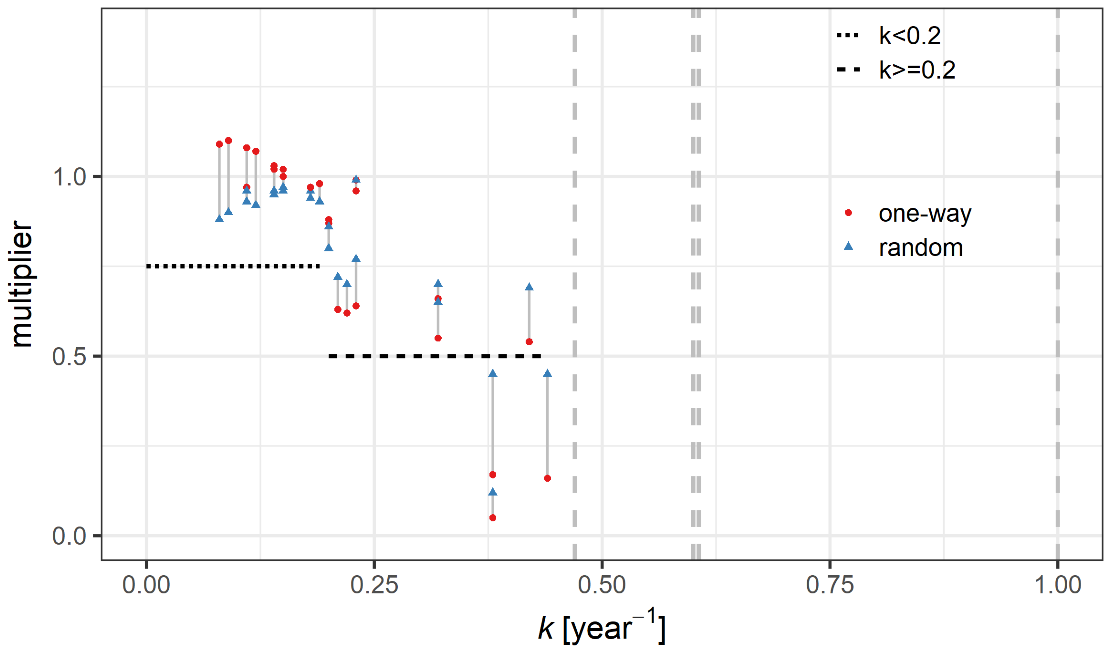

Figure 2.2.2.3. The same data as in Figure 2.2.2.2 (the multipliers of the rb that lead to a Blim risk of 5%) but with a suggestion of multipliers depending on the von Bertalanffy *k* individual growth rate of the stock (horizontal dashed/dotted lines).

2.2.3 cat3advice – an R package for applying the Category 3 empirical harvest control rules (ToR 1f)

Although the Category 3 empirical harvest control rules (rfb/rb/chr) are relatively simple, there can be confusion on their specific application. To address this, the R package "cat3advice" was developed. The aims of this package are to (1) facilitate the correct application of the Category 3 empirical harvest control rules, (2) ensure the ICES technical guidelines (ICES, 2022) are followed, (3) allow integration into ICES' transparent assessment framework (TAF, https://taf.ices.dk, https://github.com/ices-taf), (4) produce outputs required for ICES advice sheets and assessment working group reports, and (5) ensure reproducibility of the calculations.

The package is hosted on GitHub at https://github.com/shfischer/cat3advice, and the repository includes installation instructions. There is extensive documentation in the form of help files for all user functions, including example data and code. Furthermore, there is a package vignette that showcases the functionality of how the package can be used for the rfb, rb and chr rules. The vignette is part of the package and is also available online at https://github.com/shfischer/cat3advice/blob/main/vignettes/cat3advice.md.

The package includes functions for all the components of the harvest control rules, such as the reference catch (usually advice), the biomass index trend (component r), the length-based fishing pressure proxy (component f), the biomass safeguard (component b), the multiplier (component m), the target harvest rate, etc. For these components, there are functions to calculate the value and plot the results in a similar way to the ICES advice sheet.

For example, the biomass index trend (component r of the rfb rule) function expects a biomass index time series as an input and then calculates the 2 over 3 ratio (average of the last two index values divided by the average of the three preceding index values) (see an example in Table 2.2.3.1 and Figure 2.2.3.1).

The input for the length-based fishing pressure proxy (component f of the rfb rule) is a length frequency distribution such as the one provided by InterCatch. The package also allows calculating the length at first capture (L_c) as defined by ICES (see an example in Table 2.2.3.2 and Figure 2.2.3.2). If the length distribution is noisy, the length classes can be smoothed by increasing the size of the length classes.

Table 2.2.3.1. cat3advice package – example usage for the biomass index trend.

```
### load example plaice data
data("ple7e_idx")
tail(ple7e_idx)
#>     year     index
#> 14 2016 1.3579990
#> 15 2017 1.3323659
#> 16 2018 1.1327596
#> 17 2019 0.8407277
#> 18 2020 0.5996326
#> 19 2021 1.0284297
### calculate biomass trend
r <- r(ple7e_idx, units = "kg/hr")
r
#> An object of class "rfb_r".
#> Value: 0.738718062433358
### plot
plot(r)
```

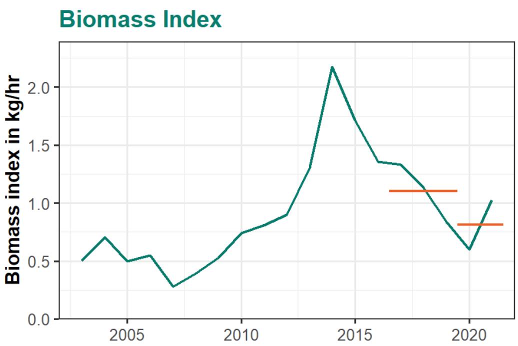

Figure 2.2.3.1. cat3advice package - example figure for the biomass index trend.

Table 2.2.3.2. cat3advice package - example calculation of the length at first capture (Lc) from a length frequency distribution.

```
### load example plaice data
data("ple7e_length")
tail(ple7e_length)
#>      year catch_category length numbers
#> 772 2015       Landings    660   21.30
#> 773 2017       Landings    660   15.06
#> 774 2016       Landings    670   15.41
#> 775 2019       Landings    670   79.40
#> 776 2017       Landings    690  364.22
#> 777 2018       Landings    690  131.96
### calculate length at first capture Lc
lc <- Lc(ple7e_length, pool = 2017:2021)
lc
#> [1] 260
plot(lc)
```

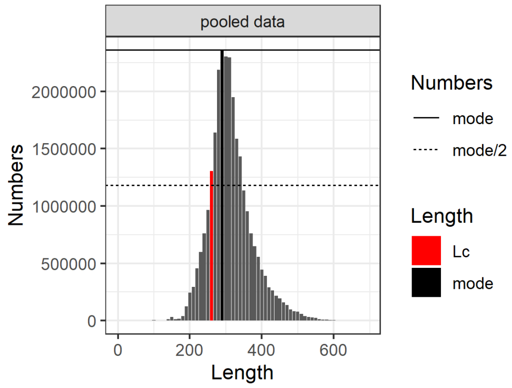

Figure 2.2.3.2. cat3advice package - example illustration of the length at first capture (Lc) calculated from a length frequency distribution.

The final output is an advice value that follows the ICES rounding rules. If a discard rate is provided, the advice can be divided into discards and landings. An advice table that produces the values required for an ICES advice sheet can also be produced; see Table 2.2.3.3 for an example.

Table 2.2.3.3. cat3advice package - example calculation of the advice for the rfb rule.

```
### example calculation of the advice with the rfb rule
advice <- rfb(A = A, r = r, f = f, b = b, m = m, discard_rate = 27)
advice
#> An object of class "rfb".
#> Value: 1219.4
### produce table for advice sheet
advice(advice)
#> --------------------------------------------------------------------------------
#> Previous catch advice Ay (advised catch for 2022) |                   1742 tonnes
#> --------------------------------------------------------------------------------
#> Stock biomass trend
#> --------------------------------------------------------------------------------
#> Index A (2020,2021)                              |                   0.81 kg/hr
#> Index B (2017,2018,2019)                         |                   1.10 kg/hr
#> r: stock biomass trend (index ratio A/B)         |                         0.74
#> --------------------------------------------------------------------------------
#> Fishing pressure proxy
#> --------------------------------------------------------------------------------
#> Mean catch length (Lmean = L2021)                |                       320 mm
#> MSY proxy length (LF=M)                          |                       340 mm
#> f: Fishing pressure proxy relative to MSY proxy  |
#>    (L2021/LF=M)                                  |                         0.93
#> --------------------------------------------------------------------------------
#> Biomass safeguard
#> --------------------------------------------------------------------------------
#> Last index value (I2021)                         |                   1.03 kg/hr
#> Index trigger value (Itrigger = Iloss x 1.4)     |                   0.39 kg/hr
#> b: index relative to trigger value,              |                         1.00
#>    min{I2021/Itrigger, 1}                        |
#> --------------------------------------------------------------------------------
#> Precautionary multiplier to maintain biomass above Blim with 95% probability
#> --------------------------------------------------------------------------------
#> m: multiplier                                    |                         0.95
#>    (generic multiplier based on life history)    |
#> RFB calculation (r*f*b*m)                        |                  1130 tonnes
#> Stability clause (+20%/-30% compared to Ay,      |
#>    only applied if b=1)                          |      Applied |           0.7
#> Catch advice for 2023 and 2024                   |
#>    (Ay * stability clause)                       |                  1219 tonnes
#> Discard rate                                     |                          27%
#> Projected landings corresponding to advice       |                   890 tonnes
#> % advice change                                  |                         -30%
```

The ICES TAF system contains an example repository for Category 3 stocks with the rfb rule and the cat3advice R package, available at https://github.com/ices-taf-dev/ices_cat_3_template. This repository can be used as a template for other stocks.

The first version of the cat3advice R package was released just before the 2023 ICES assessment working group season and has been used for several stocks, including stocks at WGCSE, WGNSSK, WGDEEP and WGEF. Initial feedback was positive, and the package seemed to facilitate the calculation of catch advice, particularly when requested for many stocks.

The package will be further developed and maintained based on feedback from users. The developers encourage feedback, bug reports, and feature requests. The easiest way to do this is through the issue page of the package's issue page on GitHub (https://github.com/shfischer/cat3advice/issues). Requests for collaborations are welcome. Changes can also be suggested using GitHub's workflow procedures (fork the repository, make change(s), submit a pull request).

2.3 Zero catch advice with SPiCT (ToRs 1bd)

The catch advice based on SPiCT (Pedersen and Berg, 2017) can be zero if the biomass is below biomass limit reference points (B_{lim}). For example, the accepted SPiCT assessment for Pollack in subareas 6-7 (pol.27.67) in 2023 recommends a total allowable catch (TAC) of zero as the estimated fishing mortality is above F_{MSY} and the estimated biomass is below the biomass limit reference point (Figure 2.3.1).

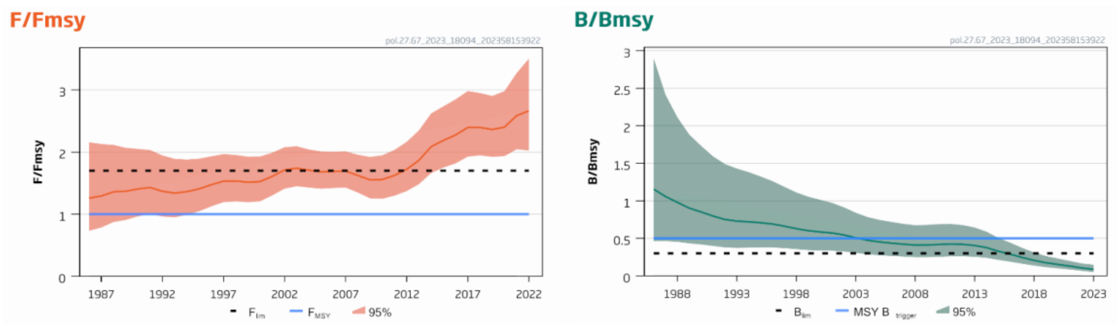

Figure 2.3.1: Fishing mortality relative to FMSY and biomass relative to MSY Btrigger and Blim for the pollack stock in subareas 6-7 according to the SPiCT assessment in 2023.

SPiCT can recover from a zero catch advice as the TAC recommended by the SPiCT harvest control rule (HCR) does not depend on last year's catch or advice and the SPiCT-based HCR includes a target reference point. However, SPiCT cannot handle zeros as the main state processes are modelled in log scale. This should not be a problem in many situations, as the actual catch is often larger than zero even if the TAC was zero for example due to unwanted catch. In the rare case where the actual catch (or landings) are actually zero a low number has to be used instead of zero. Such a number can be around 1 ton if catches used to be around hundreds of tons or higher.

A simulation example based on a haddock stock of Mildenberger *et al.* (2022), showed that the SPiCT-based HCR using a small number (around 1 ton) instead of zero leads to a quick stock recovery and catch close or above of MSY in subsequent years (yellow lines in Figure 2.3.2). However, this simulation example also showed that large jumps in the catches (as potentially caused by zero or close-zero catch advice) can lead to an increase of the assessment uncertainty and an increase in the noise parameters associated with the fishing mortality process (sdF) and the catch observations (sdC; yellow lines in Figure 2.3.3) These increases are caused by the violation of the random walk process used to model the fishing mortality process.

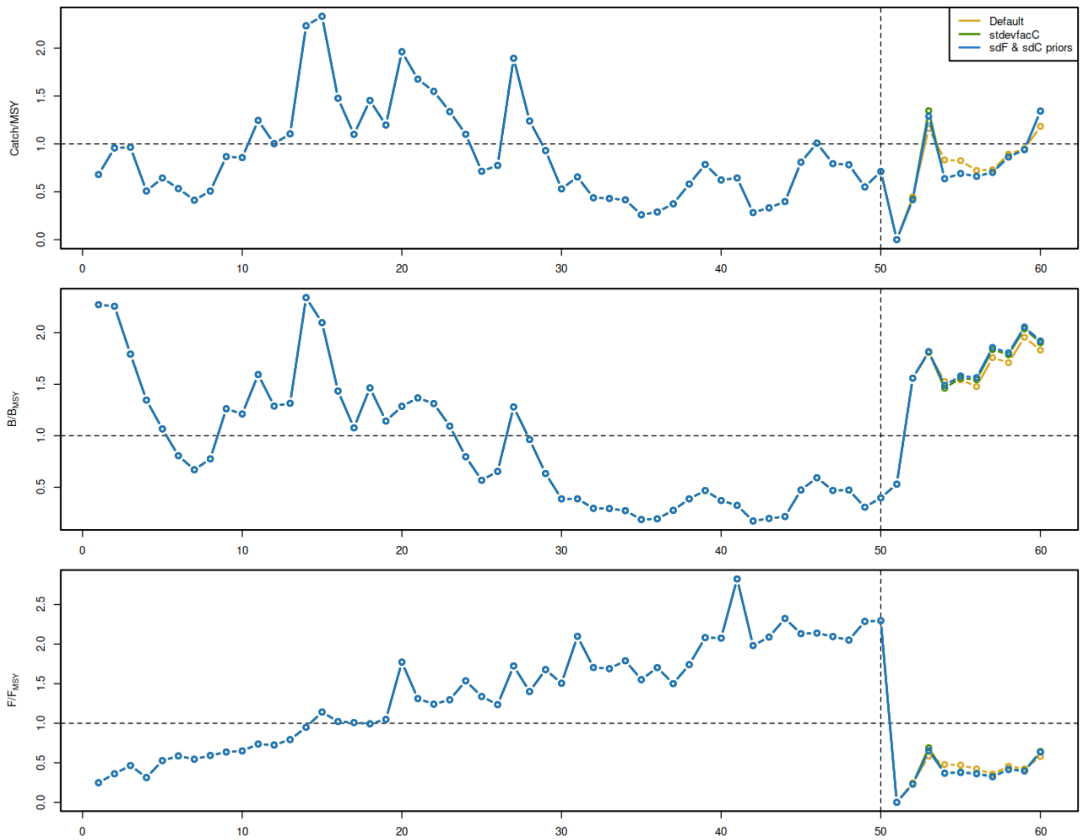

Figure 2.3.2: Stock trajectories for a haddock stock estimated by SPiCT.

Two modifications were tested that allow the random walk process in SPiCT to accommodate large jumps in the catches: (1) multiplying the catch uncertainty in the year with the zero catch advice with a small value, which can be achieved by assigning a small value to the vector stdevfacC for the year with the zero catch advice, (2) using a wide prior around a large value for sdF and small value for sdC. Both approaches reduce the variable patterns in the estimated noise parameters and lead to more stable assessments (Figure 2.3.3). As more subjective modifications are needed for option 2 with the modification of the priors, option 1 with a low number of stdefvacC is recommended for now. Specific values and modifications should be decided on a case-by-case basis and sensitivity scenarios should demonstrate that results are relatively insensitive to the value chosen. Alternative solutions for zero catch advice with SPiCT will be developed in the future. Ultimately, all options including the default option lead to stock recovery and similar stock trajectories (Figure 2.3.2).

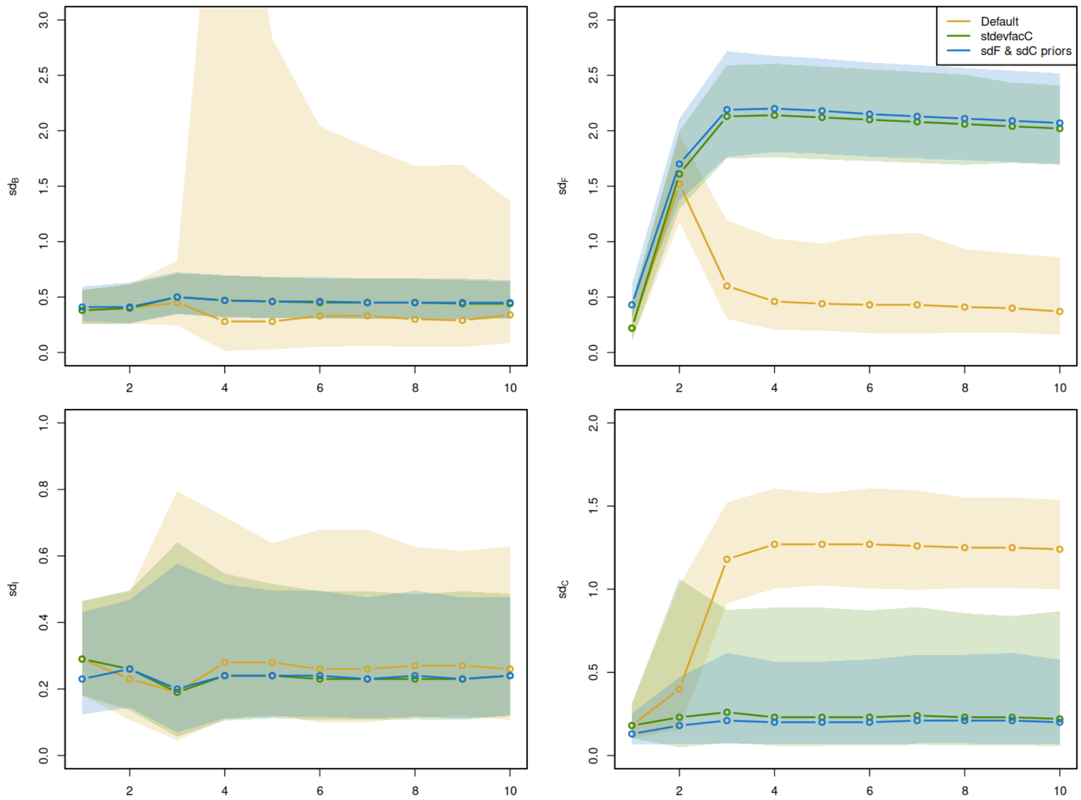

Figure 2.3.3: Point estimates and uncertainty of noise parameters estimated by SPiCT for a haddock stock for year 1 to 10, where year 2 corresponds to the assessment in the year after the zero catch advice.

2.4 Questions on the WKLIFE X Category 2 and 3 methods (ToR 1a)

2.4.1 Introduction

One of the aims of the WKLIFE XII meeting in October 2023 was to support the ICES community with the continued rollout of the WKLIFE X methods for categories 2 and 3. The main assessment working groups in ICES with the most stocks in these categories are WGDEEP and WGEF. The chairs of these groups were invited to WKLIFE to give feedback on using the new methods and ask questions. Furthermore, the Scottish Fishermen's Federation provided a perspective from the fishing industry on the data-limited methods. The following subsections summarise the questions. Some of the questions have already been answered previously, but still keep returning to WKLIFE. To improve communications of the WKLIFE methods, WKLIFE plans to create a frequently asked questions (FAQ) document for the next meeting of WKLIFE. This means that not all questions are fully addressed in this report, but a preliminary response is provided in Annex 7.

2.4.2 Comments from WGDEEP

In 2023, WGDEEP drafted advice for eight Category 3 stocks (all with the rfb rule) and one stock in categories 5 and 6. The following are comments (rephrased for clarity) from WGDEEP on the rfb rule:

- Does the multiplier m reduce the advice over time?
- Criticism that the new rule (rfb) leads to even lower advice than the 2 over 3 rule
- Why does the advice go down even if the index is going up?
- What to do if new life-history parameters such as L_∞ are found; is there a need to recalculate things back in time?
- Which life-history parameters (or strategies) matter when the von Bertalanffy growth model might not be appropriate?
- Can the advice interval for the rfb rule (default: biennial) be changed?
- cat3advice R package; match output as much as possible to advice sheets (e.g. provide inverse f)
- Allow changes to the assumption of M/k=1.5 for the length-based indicator
- What to do when there are missing index values, can values be interpolated?

There were additional comments on issues such as stock identity or spatial distribution on which WKLIFE cannot comment.

A preliminary response is provided in Annex 7.

2.4.3 Comments from WGEF

In 2023, WGEF drafted advice for 25 stocks, of which 3 were in Category 2, 11 in Category 3 (9 with the rfb rule, 1 with the rb rule, 1 without advice), 2 in Category 5, and 9 in Category 6. The following are comments (rephrased for clarity) from WGEF, mainly on the rfb rule:

- When calculating the mean catch length, should the length class corresponding to the length of first capture (L_c) be included?
- For some stocks, catch length data can be sparse (e.g. only landings, not discards or neither). Could survey length data be used instead?
- Some stocks have an I_{loss} near zero, which is at the start or end of the time series, so using $I_{trigger}$=1.4I_{loss} is not appropriate. In such cases, WGNSSK and WGEF used the 20th quantile of the time series. Is this approach appropriate?
- Should there be more tests of the multiplier "m" for elasmobranch species?
- Is the generic SPiCT harvest control rule appropriate for long-lived species such as porbeagle shark?

A preliminary response is provided in Annex 7.

2.4.4 Comments from the Scottish Fishermen's Federation

A representative of the Scottish Fishermen's Federation provided feedback on the new data-limited methods used by ICES to give the perspective of the fishing industry as the end user of the ICES advice. The comments are listed below and are rephrased for clarity:

- The “precautionary multiplier” of the ICES Category 3 advice rule reduces the advice over time
- Comments on the whiting (*Merlangius merlangus*) in Division 3.a (Skagerrak and Kattegat) advice sheet from 2022: https://doi.org/10.17895/ices.advice.19454252
    - The stock size is estimated to increase by 45%, but the catch advice is a reduction of 27%.
    - B_{lim} is not specified, but apparently 1/3 of the estimated biomass.
    - The multiplier is arbitrarily set at 0.5 – Unless the biomass doubles in a year, the TAC is reduced.
- Comments on the anglerfish (*Lophius budegassa, Lophius piscatorius*) in Subareas 4 and 6, and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) 2022 advice sheet: https://doi.org/10.17895/ices.advice.19772359
    - The MSY proxy length ($L_{F=M}$) is based on the modal catch lengths and growth parameters (L_{∞}). This growth parameter is not specified.
    - Even if the biomass remains the same and the stock is within safe levels, the advice will still continue to reduce.
- Comments on the ling (*Molva molva*) in subareas 3, 4, 6–9, 12, and 14 (Northeast Atlantic and Arctic Ocean) 2023 advice sheet: https://doi.org/10.17895/ices.advice.21828360
    - The index of ling abundance used for this advice has more than tripled since 2001. The TAC in 2023 is less than half the TAC of the mid-2000s and half what it was in the late 2010s.
    - In the example of ling, the use of the target mean length creates a paradox where bigger recruitment leads to more juveniles on the ground and a smaller “mean length”, which results in a cut in the catch advice.
    - In fisheries where market demand drives the size, the mean length might not be as significant (fishers might target smaller sizes through spatial knowledge or selectivity).
    - To get out of this loop, a shift in fishing patterns/behaviours is required, but this is unrealistic because there are market constraints and fishermen may not be aware.
    - A status quo in values (index, length data, etc.) will still lead to cuts because of the multiplier of 0.95.
    - The catch advice calculations are triggering ”loops of doom”; it is almost impossible to bounce back.
    - There is no way of getting out of these downward spirals unless the data-limited nature of the stock is addressed, which might take years and is not always possible.
    - It is difficult to justify the paradox of increasing stock indicators with decreasing catch advice.
    - In the absence of an empirical proof of decline, including a precautionary cut deviates from advice and risks to step into management.
    - No consideration is given to at-sea perception and observation, creating chokes when combined with the landing obligation and quota management.
- General comments
    - There are concerns over the appropriateness of this newer method (rfb rule) with the risk derived from simulations. It is a closed box, the simulation parameters will drive the outcome, and there is no space for a sense check.

- Are the simulations wide enough, or is this just a fulfilling prophecy as they drive the outcome?
- The WKLIFE X report mentioned that outputs were sensitive to a number of starting specifications ("Therefore, all optimisation ("tuning") towards achieving specific objectives are conditional on the simulation specifications.")
- There are various steps of precaution layered up (i.e. MSY proxy length - modal …why?)

A preliminary response is provided in Annex 7.

2.5 ICES technical guidelines (ToR 1c)

WKLIFE XII discussed the need to change the ICES technical guidelines for Category 2 and 3 stocks (ICES, 2022). While there has been further work and clarifications on the WKLIFE X methods, there is no immediate need to change the methods. However, there are repeated questions on the methods, particularly for the Category 3 empirical harvest control rules (rfb/rb/chr rules), some of which are detailed in Section 2.4 and draft responses in Annex 7). At WKLIFE XII, a suggestion was made to update the guidelines, but only to add more details and clarifications where needed (including a log of all the changes) and not to change the methods. A document with these changes is being prepared, and ACOM leadership can decide whether the current guidelines document needs to be re-published.

2.6 References

ICES. 2021. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. 2:98. 72 pp. http://doi.org/10.17895/ices.pub.5985.

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In *Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11*, 20 pp. International Council for the Exploration of the Sea (ICES). https://doi.org/10.17895/ices.advice.19801564.

ICES. 2023. Eleventh Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XI). ICES Scientific Reports. 5:21. 74 pp. https://doi.org/10.17895/ices.pub.22140260.

Mildenberger, T.K., Berg, C.W., Kokkalis, A., Hordyk, A.R., Wetzel, C., Jacobsen, N.S., Punt, A.E. and Nielsen, J.R. 2022. Implementing the precautionary approach into fisheries management: Biomass reference points and uncertainty buffers. Fish and Fisheries, 23(1): 73–92. https://doi.org/10.1111/faf.12599.

Pedersen, M.W. and Berg, C.W. 2017. A stochastic surplus production model in continuous time. Fish and Fisheries, 18(2): 226–243. https://doi.org/10.1111/faf.12174.

3 WKLIFE roadmap (ToR 2)

3.1 Background

The previous WKLIFE workshop (WKLIFE XI; ICES, 2023) was tasked with discussing work relevant to WKLIFE to advance ICES data-limited advice for categories 2-6 and scope future directions. This resulted in a draft roadmap of aims, goals, and perceived requirements for the coming 5 years. This roadmap identified a list of 60 issues, grouped loosely into 10 categories in no particular order:

1. General considerations
2. Data and data preparation
3. Stocks in ICES stock Category 4, 5, 6
4. Empirical indicators and empirical harvest control rules
5. Length-based methods (indicators & models)
6. Surplus production models
7. Data-limited reference points and harvest control rules
8. Simulation framework / MSE /operating models
9. Short-lived/fast-growing species
10. Long-lived/slow-growing species, elasmobranchs, and sensitive & rare species

This workshop (WKLIFE XII) was tasked with prioritising topics and creating a work plan. WKLIFE attempted to achieve this by creating an online survey (with Microsoft Forms) in which participants could assign a priority score between 1 (least important and not urgent) and 5 (most important and urgent) to each of the 60 issues in the roadmap (Figure 3.1). Additionally, participants had the opportunity to add one more point to the list. Participants were then asked to complete this survey individually.

Disclaimer

This approach was the easiest way to get an overview of the participants' views without allowing specific participants a higher weighting or the opportunity to influence others. It should be noted the outcome is not necessarily representative of the entire WKLIFE group because not all participants submitted a response. Experts attending WKLIFE and submitting the survey may have specific interests based on personal preferences or their work, so the outcome should not be regarded as representative of the ICES community. Lastly, the chairs of WKLIFE and the WKLIFE group do not necessarily endorse the outcome of the survey. This approach was rather an exercise to get some opinions and should not be regarded as the only source of information to shape the future of WKLIFE and data-limited research in ICES.

3.2 Roadmap survey and prioritisation

Of the 41 participants attending WKLIFE XII (in-person and remotely), 26 completed the survey. For each of the 60 issues, the average (arithmetic mean) score was calculated. The issues were sorted by score from highest (most important) to lowest (least important) without considering the sections, and the results are presented in Table 3.1. The time participants spent on the survey varied greatly between around four minutes and more than one hour, with an average time of 32 minutes.

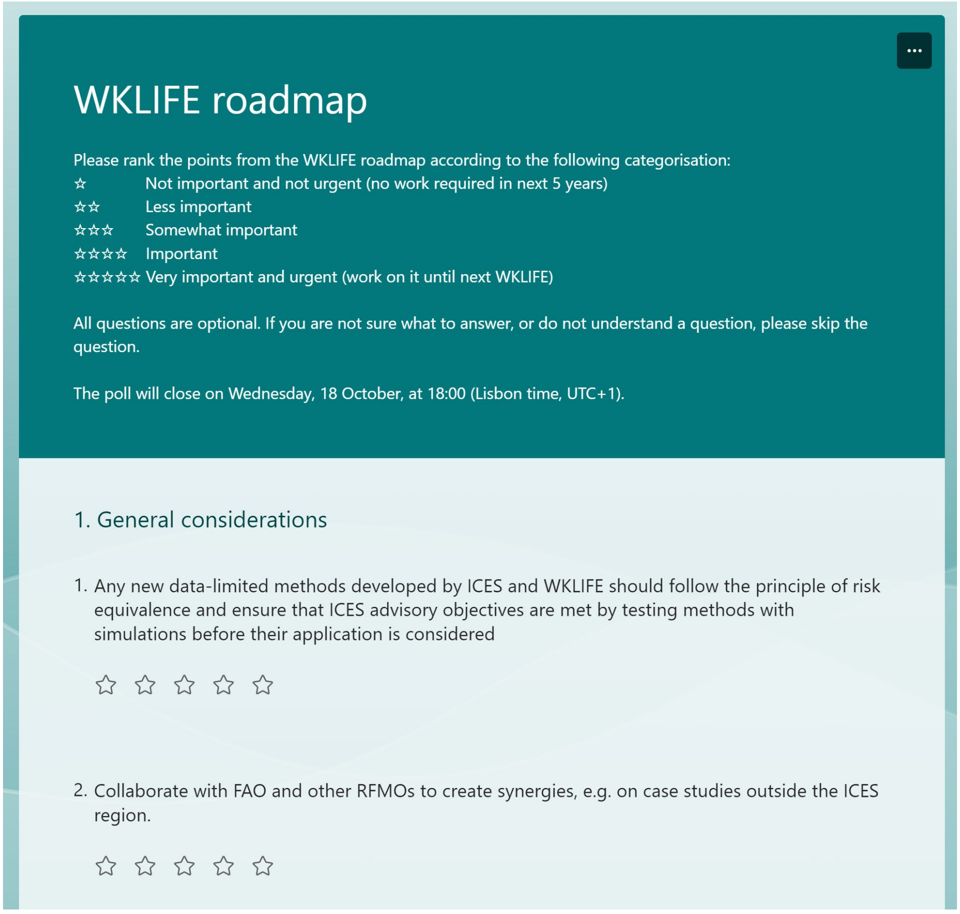

Figure 3.1. Screenshot of the first page of the roadmap survey.

Each of the 60 issues received the highest score (5) by at least one participant apart from "Consider revising the ICES stock categories.", which also received the lowest average score (2).

Seven participants added a suggestion for an additional topic to include in the roadmap. However, these topics were already largely covered in one of the other 60 issues (improved communication; communicate changes in the advice method; approaches for Category 5 and 6 stocks; collaboration outside EU) or are very specific (provide an alternative to FishBase or SeaLifeBase; approaches for other life histories such as shellfish or coastal species).

3.3 Commentary on the roadmap and the future of WKLIFE

The top two issues, and four of the top 10 issues, were general points not related to developing specific approaches. These were topics around (1) considering risk equivalence (fewer data should not lead to riskier management advice and may mean more precautionary advice), (2) using the best available science (in the broad sense of this term as used by ICES and as included in the ICES advisory framework and principles, i.e. using the best science available at the time, continuously improving it, and reviewing and documenting changes), and (3) communication (outreach and collaboration, explain changes). These are important considerations that should continue to guide the current and future work of WKLIFE.

Other issues ranked high were more specific considerations, such as (1) input data and preparation for assessments, (2) slow-growing species, and (3) uncertainty.

Some important topics in the roadmap did not reach the top 10 but are still considered very important for ICES, such as improving the advice for the more data-limited categories 4-6 (which was still in the top third in the roadmap scoring exercise). WKLIFE is aware of this, will continue putting effort into these categories, and included a draft Term of Reference for the next meeting.

Some other important issues were highlighted, e.g. on data collection and processing. However, these are considered outside the scope of WKLIFE and should be addressed by other ICES expert groups (e.g. WGBIOP or benchmarks). The issue of elasmobranchs, for which ICES provides advice but which can be on lists of prohibited or threatened species, was mentioned. WKLIFE may be caught in the crossfire of this issue when data-limited methods are used in such cases. This is an issue that should be resolved by ACOM and not WKLIFE, and a recommendation to ACOM is made by WKLIFE XII.

On the other hand, there are other important considerations on which no one is currently working on due to limited interests, resources, or capacity. This may be an opportunity to recruit new or returning participants to WKLIFE. However, the list of issues identified by WKLIFE is huge, and WKLIFE cannot work on everything. Within the discussions of WKLIFE XII, there was the notion that WKLIFE meetings may have had to focus too much on addressing requests from ACOM. WKLIFE may push back on some ACOM requests in the future to allow more focus on specific topics and scientific novelty. The scope and workload of recent WKLIFE meetings have increased substantially, possibly too much. Future WKLIFE meetings could focus on fewer topics (e.g. 1-2 larger issues per meeting). It should also be noted that WKLIFE is a workshop intended to develop, test, and review data-limited methods to assist ICES with the science behind providing advice for data-limited stocks. Ultimately, WKLIFE is not a benchmark workshop, and some of the work presented at WKLIFE could rather be part of a benchmark meeting.

The outcome of the roadmap scoring exercise was used to inform the drafting of the Terms of Reference for the next WKLIFE meeting as well as the meeting's recommendations to ICES. For example, to address the communication issue, WKLIFE plans to develop a Frequently Asked Questions (FAQ) document on the data-limited methods until the next meeting and adopt it there. This document aims at improving the communication to the users of the methods and also freeing up time from the method's developers because the same questions keep returning to WKLIFE.

Finally, the discussion turned to the future of WKLIFE. The group agreed that the workshop is still very important for ICES. The status of the expert group as a workshop and not a working group was noted. The ICES rules for working groups are stricter, particularly regarding participation at the workshop and for participants from non-ICES member countries. There was a general consensus that WKLIFE should continue as a workshop because this makes meetings more open to participants, requires less bureaucracy and allows more flexibility in setting and adapting the scope of the meeting from year to year.

3.4 References

ICES. 2023. Eleventh Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XI). ICES Scientific Reports. 5:21. 74 pp. https://doi.org/10.17895/ices.pub.22140260

Table 3.1. Outcome of the WKLIFE roadmap survey. The table shows the ranking of the individual points of the roadmap, sorted from highest to lowest score. The original ID corresponds to the ID from WKLIFE XI (ICES, 2023) and the group ID to those defined in Section 3.1 of this report.

Rank	Score	Issue	Original ID	Group ID
1	4.520	Any new data-limited methods developed by ICES and WKLIFE should follow the principle of risk equivalence and ensure that ICES advisory objectives are met by testing methods with simulations before their application is considered.	1	1
2	4.346	Make use of best available science to improve the provision of data-limited advice in ICES and review new developments from inside and outside ICES community.	4	1
3	4.160	The default priors of SPiCT might in some cases not be sufficient or adequate. Specific guidelines on model fitting and validation and priors are required. This includes generic priors reflecting likely doubling times or process noise levels for taxonomic groups as well as guidance on how to derive priors from case-specific data or analyses.	34	6
4	4.115	Make the broader community more aware of and collaborate on methods and guidelines for data-limited data-preparation and assessment.	3	1
	4.115	Consider the value of information of different data-limited data types (e.g., length-data, biological data for the estimation of life-history parameters) which can help inform recommendations to design additional surveys and sampling.	8	2
6	4.043	Training in data preparation, such as CPUE standardisation and abundance index estimation using spatio-temporal models for species with patchy distributions and zero-inflated data (e.g., elasmobranchs) could help stock assessors with the applications of the updated/developed data preparation guidelines.	13	2
7	4.042	Improve the provision of advice for slow-growing species so that their specific life-history characteristics are better considered.	53	10
8	4.038	Consider how observation and parameter uncertainty could be included into empirical harvest control rules, e.g., uncertainty in the abundance index time series or uncertainty in growth parameter K.	23	4
	4.038	Consider quantifying the uncertainty associated with the estimated exploitation (stock) status of length-based models.	31	5
10	3.962	Aim to explain changes in the advice/method better, particularly if there are large changes in the advice value or method. Improve the communication of advice uncertainty. If considering phasing in advice based on a new method, consider asymmetric caps.	6	1
11	3.957	Better model diagnostics for length-based models, performance testing of length-based models, sensitivity analyses (e.g. regarding life-history parameter input), uncertainty analyses, model validation.	30	5
12	3.917	Develop simulations that are more specific to slow-growing species (growth model, natural mortality, recruitment, sex-disaggregated models, etc), either by adapting generic simulations or basing case studies on stocks with more data (e.g., spurdog).	55	10
13	3.913	Explore the applicability and suitability of alternative harvest control rules, e.g., harvest-rate based rules.	59	10
14	3.885	Consider the use of length-based models in ICES and how they could be used to provide advice, e.g., in addition to Category 2-3 approaches or to inform the advice for Category 4-6 stocks.	28	5
15	3.870	The current definition of the biomass limit and threshold reference points for production models goes back to a suggestion made in the ICES assessment of the Greenland halibut stock in 2013, where Blim was defined as the biomass where the productivity corresponds to half of BMSY and MSYBtrigger was defined around 1.4 times that biomass (0.5 BMSY). This definition is only valid for a symmetrical Schaefer-like production curve and should be revisited. A more general definition of these reference points should be derived by e.g. a) Defining the reference points based on the relationship between target and threshold/limit reference points for data-rich stocks, b) Defining these reference points as a function of the estimated uncertainty around BMSY,	41	7

Rank	Score	Issue	Original ID	Group ID
		c) Defining these reference points based on the estimated lowest ever observed biomass, d) Accounting for the spawning potential ratio of the stock, e) Defining BMSY as the biomass threshold reference point.		
16	3.846	Explore the suitability of alternative indicators, e.g., spatial indicators to inform on stock abundance and how they could be used in harvest control rules.	20	4
17	3.826	Take into account ecosystem considerations for the management advice of short-lived species, and the definition of appropriate reference points (e.g. considering forage fish).	52	9
18	3.808	Collaborate with FAO and other RFMOs to create synergies, e.g. on case studies outside the ICES region.	2	1
19	3.800	Review the ICES advice framework for categories 4, 5, and 6. a) Summarise the ICES stocks in these categories and their advice methods. b) Involve other groups (including stakeholders) and experts or set up initiatives to explore the data currently being used, available data not being used, or data that could be collected to improve method application. c) Evaluate the current approaches with respect to risk equivalence and their ability to follow the ICES precautionary approach. d) Explore alternative approaches (e.g., length-based methods or catch-only methods supplemented by additional data such as length data). e) Explore, test, and tune alternative approaches.	17	3
20	3.792	Develop new length-based assessment models that relax the equilibrium assumption, e.g., implement a length-informed production model.	32	5
21	3.769	Specific guidelines (e.g. on how the required input data of the recommended empirical harvest control rules and assessment methods should be prepared) could help standardise data preparation and improve data quality (e.g., on length data).	12	2
	3.769	Length data for specific life-history types (e.g. elasmobranchs or other slow-growing species) might not be representative of a full stock because of spatially restricted sampling or dome shaped selectivity that catches a restricted window of lengths. Consider approaches for addressing this issue.	15	2
23	3.750	Explore alternative harvest control rules such as dynamic harvest rate rules or escapement strategies and aim to find generic parameterisations that could be an alternative to the x over y rules. Evaluate alternative recommendations on harvest control rules best suited for specific short-lived species types (e.g. anchovy-like vs. sardine-like stocks).	50	9
24	3.739	Evaluate the performance of surplus production models under the assumption of strong recruitment pulses or non-stationary processes (e.g. gradual environmental changes and shocks).	37	6
25	3.654	Explore and develop guidelines on how to derive case specific priors from available (limited) data.	14	2
26	3.640	Improve spatio-temporal modelling of distribution and estimation of abundance indices considering patchy distribution and ontogenetic migrations as well as zero-inflated data.	57	10
27	3.625	Explore the suitability of length indicators for specific species or life-history strategies, e.g., mean catch length might be replaced with Lmax5%, and alternative reference point definitions.	21	4
28	3.619	Develop SPiCT further by, for example a) Implementing the option for multiple fleets. b) Implementing a stage-based version that models the unexploitable stock biomass.	35	6
29	3.600	Productivity of fish stocks is likely not stationary, but changes over time. Assuming constant productivity and/or reference points is likely overestimating sustainable harvest rates assuming that the productivity for many stocks has likely decreased over the last decades due to e.g., environmental changes. Explore dynamic reference points that account for changes in productivity (e.g. the ecosystem-based fishing mortality value FECO developed during ICES WKIRISH).	42	7

Rank	Score	Issue	Original ID	Group ID
30	3.583	Effort data can be incorporated into many assessment methods and can provide crucial information for the estimation of fishing mortality rates.	10	2
31	3.577	Evaluate the implications of sporadic data (i.e. data not sampled regularly or continuously) on estimated stock status	48	8
32	3.545	Evaluate the methods for accepting, rejecting, weighting of individual models in an ensemble, e.g. SPiCT models with different prior assumptions.	38	6
	3.545	Further develop and refine the ICES advice framework for short-lived species. Further develop simulation frameworks for short-lived/fast-growing species to ensure these are appropriate for simulation testing, e.g., by including seasonal time steps in the operating model.	49	9
34	3.538	Consider approaches for combining multiple abundance indices or surveys for use in empirical harvest control rules.	16	2
	3.538	Explore options to move away from single-stock single-species models towards including mixed fisheries, multi-species, ecosystem, or integrated models and ecosystem considerations (e.g. climate change).	47	8
36	3.524	Consider alternative approaches before running full MSE, e.g., screen indicators with receiver-operating characteristic (ROC) curves to ensure only promising indicators are used.	54	10
37	3.500	Life-history parameters and biological information, such as natural mortality values or stock-recruitment relationship for elasmobranchs are highly uncertain and not studied well enough. Additional surveys or sampling, e.g., tagging studies or surveys focusing on data-limited/sensitive species can help inform length-based indicators and assessment methods as well as the definition of operating models for simulation testing of management procedures.	11	2
	3.500	Quantify uncertainty of estimates of length-based indicators, e.g., LBIs, by means of bootstrapping and/or Monte Carlo.	19	3
	3.500	Explore linking qualitative (stock status) indicators to quantitative harvest control rules.	25	4
	3.500	Simulation testing of length-based models, e.g., explore and quantify the lag effect in the length frequency distributions.	33	5
	3.500	Explore more precautionary management measures, e.g., lower fractiles in the probabilistic harvest control rule for highly sensitive species.	60	10
42	3.478	Consider adapting current indicator-based empirical harvest control rules for specific life-history strategies (e.g., elasmobranchs).	22	4
43	3.458	Aim to improve the quality of available data (better or more representative data to allow analyses, collaboration with industry, making better use of surveys, identify gaps, citizen science, catch reconstruction), e.g. through collaboration with other ICES data expert groups.	56	10
44	3.435	Develop alternative operating models suitable for data-limited stocks, e.g., production models as operating models (not as a replacement for more complex or age-based operating models, but still better than no MSE).	43	8
45	3.417	Diagnostics, in particular reflecting prediction skill, are essential for model validation. Additional prediction skill metrics, such as ROC (receiver operating characteristic) curves or leave-one-out method, should be included in the diagnostics toolbox of SPiCT.	36	6
46	3.381	Collaborate with other ICES MSE groups, such as WKMSEDEV.	46	8
47	3.375	Consider using receiver operating characteristics (ROC) curves to select and weight indicators when including them into harvest control rules and MSEs.	24	4
48	3.364	Further develop MSE (closed-loop) simulation frameworks for evaluating data-limited harvest control rules, e.g. adapting for specific life-history strategies or developing case studies conditioned on data-rich stocks.	45	8
49	3.304	Develop a data-poor harvest control rule management advice on production models that is not based on reference points, but rather on stabilising the biomass or a biomass level from a reference period.	39	6

Rank	Score	Issue	Original ID	Group ID
50	3.286	Further develop and evaluate the impact of time lags between observations, assessment and management cycle on harvest control rules and the impact of lags on indicators.	51	9
51	3.240	Improve natural mortality estimates (e.g. through collaboration with other ICES data expert groups), e.g., with mark-recapture studies.	58	10
52	3.217	Further exploration and testing of the rb rule.	26	4
53	3.192	Map ICES groups and their interactions with WKLIFE.	5	1
54	3.154	Evaluate the implications of continuous sampling vs. snapshot length frequency distributions (length data not representative of a whole year). Develop guidelines and methods that can accommodate or account for snapshot data.	27	5
55	3.043	Explore the use of model frameworks such as Stock Synthesis to test a suite of data-limited methods and indicators, e.g. using diagnostic test of prediction residuals, and, thus, calculate the value of information either with generated data or a data-rich case study.	44	8
56	3.040	Historical catch data is usually highly uncertain or only reflecting landings, i.e. no information about discard rates. Additional effort should be put into the reconstruction of historical catches and discard rates to allow defining the most probable catch time series and quantify the uncertainty associated with that time series.	9	2
57	3.000	Revisit the suitability of PSA (productivity and susceptibility analysis) and PSA-like approaches for use in ICES, including approaches such as CSIRO's SAFE or Cefas' SWAF.	18	3
	3.000	Consider including catch constraints to reduce inter-annual variability.	40	6
59	2.957	Consider borrowing information for life-history parameters.	29	5
60	2.000	Consider revising the ICES stock categories.	7	1

4 Initial review of the ICES advice framework for categories 4, 5, and 6 (ToR 3)

4.1 Background

The focus of WKLIFE over the past years has been on categories 2 (mainly stocks with accepted surplus production models) and 3 (mainly stocks with a biomass indicator but no accepted stock assessment), and advice methods for these stocks were revised and published in new ICES technical guidelines (ICES, 2022). Stocks in more data-limited categories 4-6 have received less attention so far. As of 2023 (ICES, 2023), Category 4 only includes *Nephrops* stocks where data can be borrowed, Category 5 is for stocks with landings or short time series of catch, and Category 6 is for stocks with negligible landings and bycatch species. The common feature of stocks in categories 4-6 is that there is no (reliable) stock index, but other data may be available.

Figure 4.1.1 shows an overview of the number of stocks in the ICES categories by year. The number of advice sheets published by ICES is lower because, for many stocks, advice is given less frequently than annually. According to the ICES library (https://ices-library.figshare.com), in 2022, ICES published 179 advice sheets, of which 4 were in Category 4, 14 in Category 5, and 8 in Category 6. By the time of WKLIFE XII in mid-October 2023, ICES published advice sheets for 143 stocks, of which none were in Category 4, 11 in Category 5, and 13 in Category 6. In 2022, of the four advice sheets for Category 4 stocks, 3 were for *Nephrops* stocks, and only one was for a finfish stock. This was pollack in subareas 6-7 and used the depletion-corrected average catch (DCAC; MacCall, 2009) model to calculate the advice value. This stock was subsequently benchmarked and moved to Category 2 in 2023. This means there is currently no non-*Nephrops* stock in Category 4. *Nephrops* stocks use a methodology that is different compared toother ICES data-limited stocks. Consequently, the review in Section 4.2 focuses exclusively on categories 5 and 6.

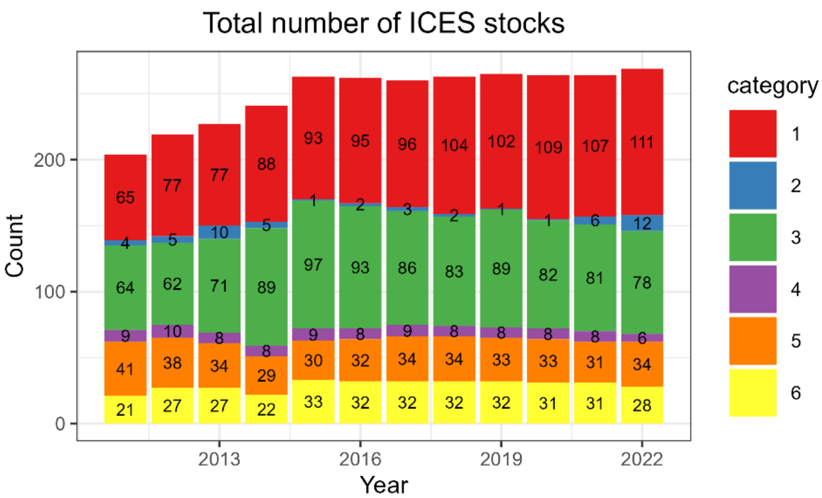

Figure 4.1.1. Number of stocks in the ICES categories by year. The number of stocks does not necessarily correspond to the number of advice sheets released by year. Data source: Anne Cooper, ICES.

4.2 Initial review of the ICES advice framework for categories 5 and 6 (ToR 3abc)

The ICES data-limited stocks guidance report from 2012 sets out the methods to give advice for stocks in categories 5 and 6 and suggests three methods. The first option is to conduct a productivity and susceptibility analysis (PSA), although this has never been used, and no details are given on how this would lead to a catch advice. The second and most frequently used option is to give the same catch advice as before (i.e. advise constant catch) but periodically reduce the advice by 20% with a precautionary (PA) buffer, usually every three years. The third option is to provide zero-catch advice.

Table 4.2.1 shows an overview of the ICES advice sheets for stocks in categories 5 and 6 released in 2022 and 2023. Most stocks in these categories are deep-sea species assessed by WGDEEP and elasmobranchs assessed by WGEF. The number of years for which advice is given ranges from one year (one stock) to four years. The PA buffer was usually applied when it was not used within the last three years, except for two cases in 2022 based on expert opinion or when the advice was for zero catch.

Table 4.2.1. ICES stocks in categories 5 and 6, for which an advice sheet was published in 2022 and 2023. Please note that the data for 2023 is incomplete and only includes advice sheets released until mid-October 2023.

Year	Category	Expert group	Stock	# advice years	PA buffer	Justification for not applying PA buffer
2022	5	WGDEEP	alf.27.nea	2	yes	
2022	5	WGDEEP	rng.27.5b6712b	2	no	<3 years
2022	5	WGDEEP	usk.27.6b	2	yes	
2022	5	WGBIE	ldb.27.7b-k8abd	3	no	<3 years
2022	5	WGCSE	sol.27.7h-k	2	no	<3 years
2022	5	WGEF	raj.27.89a	-	-	
2022	5	WGEF	rjc.27.7e	2	no	<3 years
2022	5	WGEF	rje.27.7de	2	yes	
2022	5	WGEF	rjf.27.67	2	yes	
2022	5	WGEF	rjh.27.7afg	2	yes	
2022	5	WGEF	rjh.27.7e	2	yes	
2022	5	WGEF	rji.27.67	2	yes	
2022	5	WGNSSK	nep.fu.5	2	yes	
2022	5	WGHANSA	jaa.27.10a2	2	yes	
2022	6	WGDEEP	sbr.27.6-8	2	no	zero catch advice
2022	6	WGEF	raj.27.67a-ce-k	-	-	
2022	6	WGEF	rjb.27.67a-ce-k	2	no	zero catch advice
2022	6	WGEF	rjb.27.89a	-	-	
2022	6	WGEF	rju.27.7bj	2	no	zero catch advice

Year	Category	Expert group	Stock	# advice years	PA buffer	Justification for not applying PA buffer
2022	6	WGEF	rju.27.8ab	2	no	decreased effort & increased catches
2022	6	WGEF	rju.27.8c	-	-	
2022	6	WGEF	rju.27.9a	2	no	low harvest rate
2023	5	WGDEEP	bli.27.nea	4	no	zero catch advice
2023	5	NWWG	cod.2127.1.14.osc	1	yes	
2023	5	WGCSE	sol.27.7h-k	3	yes	
2023	5	WGBIE	ple.27.89a	2	yes	
2023	5	WGWIDE	mur.27.67a-ce-k89a	3	yes	
2023	5	WGEF	gag.27.nea	4	yes	
2023	5	WGEF	rjh.27.4a6	4	no	<3 years
2023	6	WGDEEP	rng.27.1245a8914ab	4	yes	
2023	6	WGCSE	bss.27.6a7bj	3	yes	
2023	6	WGCSE	ple.27.7bc	3	yes	
2023	6	WGCSE	cod.27.6b	3	yes	
2023	6	WGEF	cyo.27.nea	4	no	zero catch advice
2023	6	WGEF	bsk.27.nea	4	no	zero catch advice
2023	6	WGEF	agn.27.nea	4	no	zero catch advice
2023	6	WGEF	rja.27.nea	4	no	zero catch advice
2023	6	WGEF	raj.27.3a47d	-	-	
2023	6	WGEF	guq.27.nea	4	no	zero catch advice
2023	6	WGEF	rjb.27.3a4	4	no	zero catch advice
2023	6	WGEF	sck.27.nea	4	no	zero catch advice
2023	6	WGEF	thr.27.nea	4	no	zero catch advice

The current approach for stocks in categories 5 and 6 is described by ICES as following the ICES precautionary approach. Generally, ICES defines that a management strategy is precautionary when the long-term risk of the stock biomass falling below a biomass limit reference point below which the stock's productivity is thought to be impaired (i.e. $SSB<B_{lim}$) should not exceed 5%. However, the question of whether this approach does indeed follow the ICES precautionary approach arises because this has never been shown or tested. Consequently, WKLIFE XII conducted MSE simulations (management strategy evaluation, in the sense of a closed-loop simulation) to explore the performance of the current approach. The simulations were performed with the same generic simulation framework that was also used to develop the Category 3 empirical harvest control rules (rfb/rb/chr rules). For details on the simulation framework and stocks, see WKLIFE X (ICES, 2021) and Fischer *et al*. (2020, 2021a,b, 2022). The simulations were based on 29 generic stocks created from life-history considerations and two fishing histories ("one-way"

where the fishing mortality was increased exponentially and "random" with random fishing mortality trajectories) to account for different starting conditions prior to the implementation of the management strategy. Uncertainty was included through recruitment variability (σ_R=0.6) and with 500 iterations (simulation replicates) per scenario and stock or 10,000 for sensitivity runs. The management strategy was defined as a constant catch that was reduced every three years by 20% with the PA buffer. The code for the simulations is available on GitHub at https://github.com/shfischer/GA_MSE_cat456.

Figure 4.2.1 presents an exploration of the default ICES Category 5 & 6 management strategy for one example stock (a generic pollack stock). The catch was reduced over time until it reached zero while the stock recovered. Figure 4.2.2 shows the approach's sensitivity to the stock's starting condition and how long the management strategy was implemented. A less depleted starting condition resulted in a lower long-term risk (risk of the stock falling below B_{lim}), and a longer implementation period led to a lower risk. The results of all 29 stocks are plotted in Figure 4.2.3. The outcome depended on the individual stock, with the risk for some stocks staying high (well above 5%, for some stocks above 50%) because the initial catch reduction was not fast enough and caused the stocks to collapse.

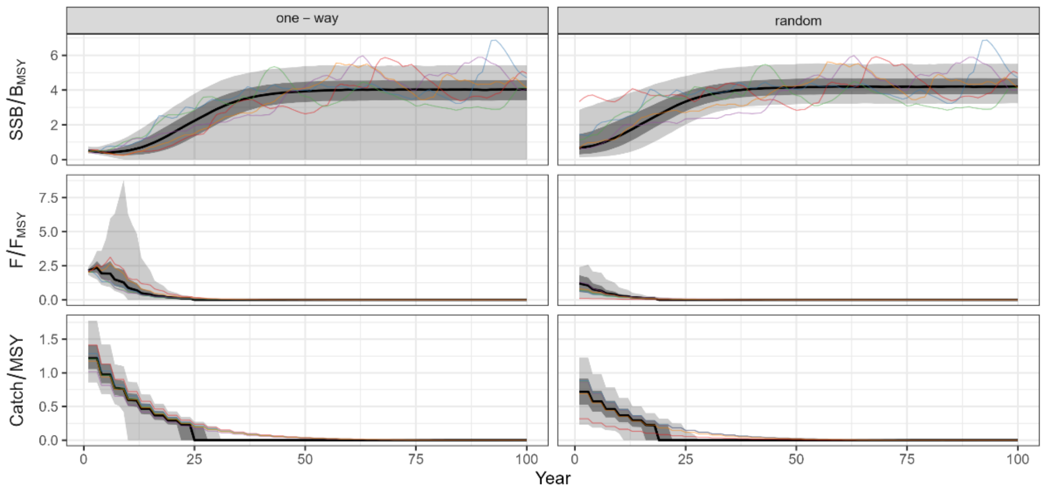

Figure 4.2.1. Exploration of the default Category 5 & 6 management strategy (constant catch, reduced every three years by 20%) for one generic example stock (pollack) for two fishing histories (one-way and random). Solid black curves indicate the median, surrounded by 50% and 90% confidence intervals. Coloured curves are individual iterations (simulation replicates).

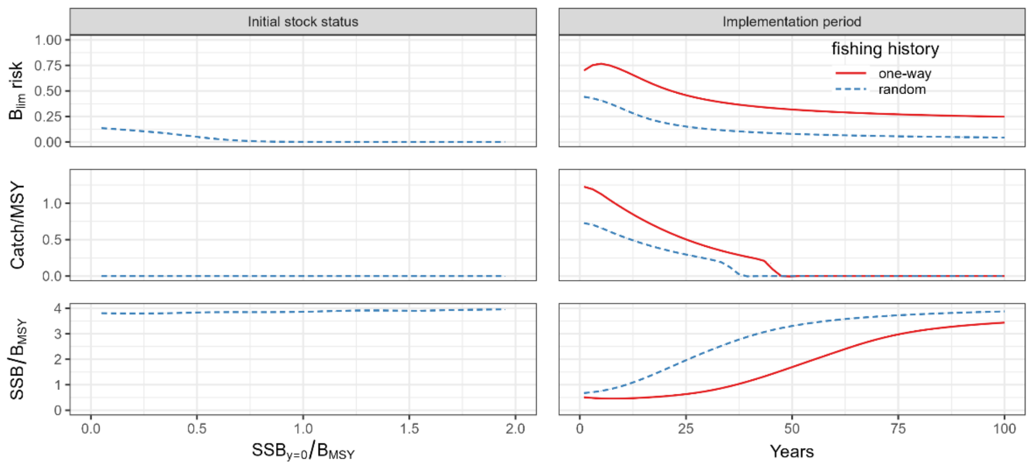

Figure 4.2.2. Sensitivity of initial depletion (SSB relative to BMSY, left) and the duration of the implementation (right) on the performance of the default Category 5 & 6 management strategy (constant catch, reduced every three years by 20%) for one generic example stock (pollack) and two fishing histories (one-way and random).

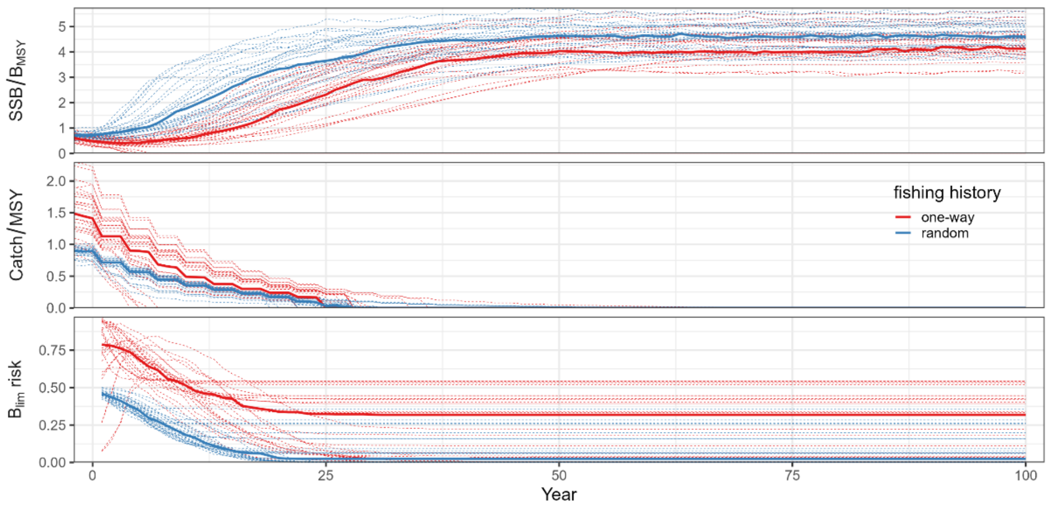

Figure 4.2.3. Results of all 29 stocks for the default Category 5 & 6 management strategy (constant catch, reduced every three years by 20%). The two colours highlight the two fishing histories, the dashed curves correspond to the medians of the individual stocks, and the solid curves are the median over all stocks by fishing history.

In conclusion, it is difficult to answer the question of whether the current approach for ICES Category 5 and 6 stocks follows the ICES precautionary approach. Under the current approach, the catch can only stay constant or be reduced but can never increase. Like other constant catch approaches, the performance depends crucially on the condition of the stock and the catch level relative to the stock size, as well as the characteristics of the specific stock. Because the stock condition of stocks in categories 5 and 6 is generally entirely unknown (and stocks could be depleted), the approach is potentially less precautionary than those for categories 1-3 because it is not adaptive to changes in the stock. However, the approach could also be overly precautionary in other situations. On the other hand, the option to provide zero catch advice is already the most precautionary catch advice possible.

When ICES guidelines for categories 5 and 6 are strictly followed, the PA buffer reduces the catch advice irrespective of stock status. A first option to change the approach is to make the PA buffer conditional on the stock status and only apply it when needed. For stocks in categories 5 and 6, no biomass index is available, but catch length data might exist. Similar to component f of the rfb rule for Category 3 stocks, an approach was explored where the PA buffer was only applied when the mean catch length (above the length of first capture) was at or below the MSY proxy reference length $L_{F=M}$ (but this was still only checked once every three years). The outcome is shown in Figure 4.2.4 for one example stock (pollack). In this scenario, the PA buffer was applied less frequently, which in turn meant that the catch was reduced more slowly. This had the result that, on average, the stock collapsed after around 15 years.

Subsequently, the conditional PA buffer was adapted to allow flexibility in (1) the size of the buffer (default: 20%), (2) the frequency of the application (default: every three years), and (3) an additional multiplier to the reference length $L_{F=M}$. This flexible PA buffer was optimised towards generic management objectives (aim at MSY for SSB and catch, reduce inter-annual catch variability, and add a penalty if B_{lim} risk exceeds 5%) with a genetic algorithm, following the procedure developed by Fischer *et al.* (2021a,b). The results are shown in Figure 4.2.5, and the "optimal" parameterisation was where the PA buffer essentially halved the catch (PA buffer size 51%) but was only applied every five years. Furthermore, the reference length multiplier was 1.9, i.e. the buffer was always applied unless the mean catch length was above $1.9L_{F=M}$. This moved the reference length to a very high length close to the asymptotic length L_∞ and meant that the PA buffer was almost always applied. It should be noted that this was only an *exploration* and is the outcome of only one scenario for one stock, and the *results should not be generalised* or applied this way.

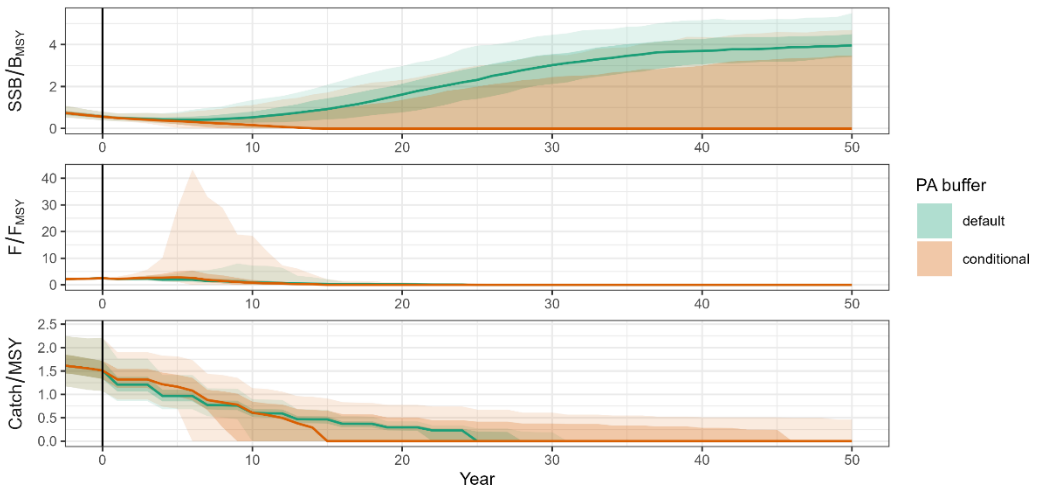

Figure 4.2.4. Comparison of the default Category 5 & 6 management strategy (constant catch, reduced every three years by 20%, "default") to an alternative where the PA buffer was only applied when the mean catch length was below the MSY proxy reference length LF=M ("conditional"). Results are shown for one example stock (pollack) and the one-way fishing history.

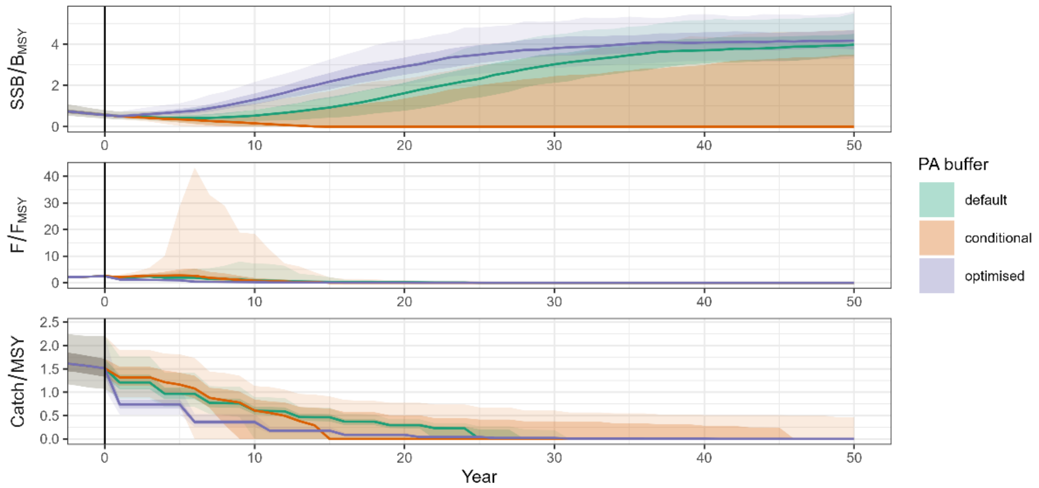

Figure 4.2.5. Comparison of the results from Figure 4.2.4 ("default" and "conditional") with another option ("optimised") where the PA buffer (size, frequency, and multiplier to the reference length) was optimised to meet generic MSY and risk objectives.

4.3 LBSPR assessment of tusk in the Northeast Arctic – initial results (ToR 3c)

Tusk *Brosme brosme* is a deep-water, long-lived species fished across the Atlantic Ocean. Despite its commercial importance, little is known about the species biology in much of its distribution hampering fishery assessment efforts. We are estimating tusk life history parameters in the Northeast Arctic stock (age, growth, and reproduction parameters) from data recorded by the Institute of Marine Research and then using these parameters as input in a Length Based Spawning Potential Ratio (LBSPR) model to assess the stock. Results are then compared to the current CPUE index used in the Northeast Arctic to provide fishing advice. Initial results support the notion of a stock in healthy levels. Moreover, SPR and CPUE index showed a comparable trend. These results indicate the LBSPR model has potential as an assessment method for tusk stocks where data is limited. A manuscript is under preparation for a future publication.

4.4 Species vulnerability in the French tropical small-scale demersal fisheries using Productivity and Susceptibility Analysis (ToR 3c)

Fish stocks in the French tropical overseas territories are considered to be data-limited due to complex local context preventing easy routine data collection. A PSA has been set across 4 territories (French Guiana, French Antilles - Martinique/ Guadeloupe, La Réunion and Mayotte) to assess the vulnerability of 243 species and groups of species and compare the overall vulnerability of the species involved in the local fisheries across territories. The analysis was built upon past project datasets, exploratory assessments, literature, database (Fishlife, Fishbase) and also fishers's knowledge. Weight of each attribute was set identically between territories to allow easier comparisons. Mayotte and French Guiana were found to be the region with most vulnerable species as local fisheries tend to target big and slow growing species and local contexts that prevent effective sustainable management.

Filling the attributes scores for each species highlighted the level of scarcity of available local information and was found helpful to set priorities to improve data collection locally. One inherent risk of using information from other areas is that those parameters might not be relevant locally due to other local dynamics in the fish population and/or the fishery. Local data collection of biological parameters is being implemented gradually in order to overcome this kind of issue and develop stock assessment using surplus production model and length-based approach.

One aspect of this exercise was to set vulnerability thresholds. This traffic light approach might be helpful for managers to classify local species. This was tested for 3 approaches to define those limits.

The first one considers the existence of local regulations in place. It was found for the French Antilles that the most vulnerable species were those where regulation had to be set. Therefore using the vulnerability score for each of those species could help to set limits. This work needs to be extended to the other territories.

The second one was to compare F/F_{MSY}, B/B_{MSY} estimates from exploratory assessments using surplus production models. Results were considered unconclusive possibly because of too short time-series (9 years) to run the models. That step can be considered of interest to show where data collection should be prioritized or increased in regard to species vulnerabilities and performances of existing models using the available information.

The third one was to classify species according to the IUCN Red list. The lower limit was estimated as the median of the « Least concern » and « near threatened » species. The upper limit was estimated as the median of the « vulnerable » group. This group was statistically different than the « least concern/near threatened » group but not from the « endangered » and « critically endangered » groups. Those two groups had few individuals and the resulting median was considered too high. This method was considered as the final choice to set the vulnerability thresholds.

The tropical demersal fisheries can be considered as mostly mixed fisheries. The PSA is useful to identify which species might need prioritized attention. However, setting regulation for the most vulnerable species may trigger some technical/spatial management measure impacting the catch of other species (e.g. management of a target species or adaptation of gear to reduce vulnerable bycatch species).

One might also wonder how to set up annual catches as the PSA is not a truly quantitative assessment and projection tool. PSA may however provide enough information to derive a precautionary buffer based on guidelines that still need to be defined. The literature does not seem to have any standards on this. This buffer is expected to incorporate the accounted uncertainties and risk associated with vulnerability levels within the local fishery (at the level of the considered species but also, for mixed fisheries, with respect to those of the other species in the catches). As a transitory period towards full analytical assessments and forecasts when data are sufficient, an advice on catch level could then be built upon a combination of a precautionary buffer and some reference points/limits derived from previous knowledge of historical period of low productivity/higher susceptibility (e.g. lowest catches + subsequent recovery periods).

A publication about this work is in preparation.

4.5 Discussion

The current approach for stocks in categories 5 and 6 is not adaptive because the catch advice is not changed based on the stock status. The initial review of the approach for categories 5 and 6 revealed deficiencies, and WKLIFE should work on improving the science for providing catch advice for these stocks.

For stocks in these categories, no (reliable) stock index is available. Other data, such as lengths or life-history information, may be available but is currently not used. The currently used PA buffer may be improved by making it conditional based on stock status or exploitation and possibly also allowing an increase in the catch advice. The available data could allow the use of indicators (e.g. length-based indicators, spatial indicators, or indicator ensembles), the application of length-based models (e.g. LB-SPR; Hordyk *et al.*, 2015) or catch-only models in combination with auxiliary information (e.g. versions of stock synthesis such as SS-DL).

Productivity and susceptibility analysis (PSA) may be useful in determining where the focus of research should be or even informing the need or size of a precautionary buffer. WKLIFE III (ICES, 2013, Section 4) previously looked at PSAs, and the results from this exercise should be revisited. Many stocks in categories 5 and 6 are elasmobranchs caught as bycatch, and if these have a high discard survival, the total catch is possibly less important. Alternative, more qualitative approaches, such as flowcharts or hierarchical approaches (e.g., considering whether to increase or decrease the catch), could be considered, and lessons might be learned from areas outside ICES where such approaches are used or considered. During discussions at WKLIFE XII, there was also the notion expressed that we may have done everything we could do based on the available data but efforts to improve the current system should continue.

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5 Further work on empirical indicators (ToR 4)

5.1 Background

This section summarises further work on empirical indicators for use in data-limited situations, and includes work on spatial indicators (Section 5.2), a preliminary MSE for a sole stock (Section 5.3) and considerations for using survey length data (Section 5.4).

5.2 The ability of spatial indicators to classify stock status (ToR 4a)

The Terms of Reference (ToRs) and 5-year roadmap in the WKLIFE XI report identified the need to explore the ability of spatial indicators to inform on stock abundance (ICES, 2023; WKLIFE XI roadmap, Section 7.1.4, point 20, and Section 7.2, ToR 4.a). This presentation summarised results from an initial investigation into the relationship between 12 spatial indicators and spawning stock biomass (SSB) of 9 data-rich stocks. Spatial indicators were calculated from survey data and measured various spatial features, including location (N=2), range (N=3), occupancy (N=2), and aggregation (N=5) for each stock. Analysis was refined to surveys with adequate spatial coverage of the stock area they informed on in assessment, resulting in 13 time series for 7 stocks. Location indicators were also removed as they are not able to highlight if expansion and contraction is related to SSB.

Receiver operating characteristic (ROC) curves were used to assess the relationship between SSB and the 10 remaining spatial indicators and determine their ability to classify stock status as positive and negative (i.e. greater or less than MSY $B_{trigger}$). ROC curves were formed by: (a) plotting annual spatial indicator values (y-axis) against annual SSB/MSY $B_{trigger}$ estimates (x-axis); (b) placing a discriminatory threshold on the spatial indicator (y-axis) where instances below were classified as negative and instances above were classified as positive; (c) calculating the proportion of positive years correctly classified as positive (true positive rate; TPR); (d) calculating the proportion of negative years incorrectly classified as positive (false positive rate; FPR); (e) plotting FPR (x-axis) against TPR (y-axis); (f) repeating steps b-e for varying levels of the spatial indicator threshold. The area under the ROC curve (AUC) and true skill score (TSS = TPR - FPR) are useful summary statistics that quantify classification skill. High AUC values indicate a positive relationship between the spatial indicator and SSB, and that the indicator is able to correctly classify years where SSB < MSY $B_{trigger}$ and where SSB >= MSY $B_{trigger}$ (i.e. years when the stock was overfished or within safe biological limits). High TSS indicates that the spatial indicator and specific threshold level show good classification performance. Good performance was inferred if AUC > 0.75 or TSS > 0.5.

Of the four types of spatial indicators investigated, occupancy indicators performed best with high AUC and TSS for the greatest number of stocks (5 to 6 stocks) and surveys (7 to 9 surveys). The performance of aggregation indicators varied, performing well for 2 to 6 stocks and 2 to 6 surveys. Range indicators showed the least consistent performance, with good classification skill for only for 2 to 3 stocks and 2 to 4 surveys. Taken together, all indicators showed good classification skill of stock status for at least two stocks, but the occupancy indicators were the most promising due to highest degree of consistency across surveys and stocks. Three main limitations were outlined: (1) time series of spatial indicators are only informative if the survey data they are calculated from have good spatiotemporal coverage, (2) ROC curves require contrast in

SSB/MSY $B_{trigger}$ which is not always available, (3) SSB/MSY $B_{trigger}$ may not accurately represent true stock status. Suggestions for future research from WKLIFE attendees included testing spatial indicators for juveniles and adults separately, testing spatial indicators for stocks outside of the North Sea where survey data is less 'well-behaved', and using alternative reference points, e.g. B_{lim} instead of MSY $B_{trigger}$.

General Text on ROC Curves

ROC curves are a graphical method used to visualise the ability of an indicator to correctly classify the true state of an observed system. Binary predictions from the combination of an indicator and varying threshold levels are compared to the known binary state of the system that the indicator is trying to inform on. Thus, ROC curves validate predictions against observations. Classification performance can then be compared between indicators, facilitating screening of uninformative indicators that do not approximate the observed system well, see Section 7.4 where ROC curves were used to choose between alternative empirical indicators for use in a harvest control rule. The discriminatory threshold that classifies the greatest number of instances correctly can also be derived, resulting in an indicator time series with an optimised threshold that has been validated. ROC curves therefore lend themselves to tasks that require exploration of indicators (e.g. ToR 4). Knowledge gained from these explorations can then inform whether specific indicators should be tested in harvest control rules (e.g. ToR 6) or assessment and advice methods (e.g. ToR 7). More demanding testing (e.g. simulation, MSE) is therefore refined to informative indicators.

5.3 Challenges developing ad-hoc MSE for sole in divisions 8.c and 9.a (ToR 4b)

The common sole (*Solea solea*) is a valuable fish species in the Iberian Atlantic waters (ICES divisions 8.c and 9.a) but concerns have arisen regarding the performance of the current harvest control rule, the *rfb* rule (Method 2.1 in ICES, 2022), as it resulted in substantial advised catch reductions of 36% in 2021 and 35% in 2023. These results are in contrast with the data-poor assessment methods (e.g. Length-Based Indicators-LBI, Length-Based Spawning Potential Ratio-LBSPR, and mean length-based mortality estimators-MLZ) results which suggested compatibility with sustainable stock exploitation. Consequently, we have decided to explore a proposal for a new catch rule that may work better for the common sole. Hence, we are currently in the process of developing an ad-hoc Management Strategy Evaluation (MSE). For that we use the Fisheries Library in R (FLR project) and also the knowledge and code available at Fischer *et al*. (2020) and Fischer *et al*. (2021) where a MSE procedure has been developed for analyzing the performance of the *rfb* rule.

Actually, we are in the initial stages of developing our ad-hoc MSE addressing several challenges that have emerged during the different steps of this process. The first challenge involves dealing with the different sources of uncertainty when defining our Operating Models (OMs). Initially, we have focused our efforts on offering alternatives for defining the recruitment variability, the steepness of the stock-recruitment relationship, the growth parameters, and the natural mortality. Although we are confident in the adequacy of the options that we have proposed for addressing the uncertainty related to steepness and recruitment variability, the decisions concerning the natural mortality and growth parameters are still open for further discussion and consideration.

Then, we focus on formulating an alternative catch rule. In these initial stages, we have decided to start with a simple rule, with the option of incorporating additional components if they are required. Our new proposal focuses on using the spawning potential rates (SPR) estimates derived from the LBSPR method (Hordyk *et al*., 2015) since our simulations have confirmed the correct performance of this data poor assessment method. Several questions have been raised regarding the definition of the new catch rule. The crucial one focuses on the selection of an appropriate value for the SPR MSY proxy used in the new catch rule formulation. To address this issue, simulations have conducted, however, it remains an open question on which we are actively working on.

Finally, challenges have arisen in relation to the definition of the metrics or indicators required to evaluate the performance of different management strategies. Specifically, the key question focuses on how to define B_{lim} and the associated risk of biomass falling below this threshold. This is an open question that requires careful consideration, as it plays a key role in evaluating the effectiveness of the new catch rule.

For further details about this work, please refer to the working document in Annex 7 which provides a comprehensive overview of the initial stages and critical discussion points involved in the development of an ad-hoc MSE for common sole.

5.4 Length-based indicators and surveys (ToR 4b, 1a)

The empirical r × f × b rule contains the multiplier f relating to length-based indicator mean length and its MSY proxy reference point $L_{F=M}$, which are calculated based on commercial catch length distributions. This reference point depends on assumptions such as knife-edged and asymptotic selectivity, von Bertalanffy growth, equilibrium dynamics including constant recruitment and constant life history traits (M/k, L_∞). Length distributions should be representative of catches (and the underlying population), where L_c is a property of the catch (Jardim *et al*. 2015). The dependence of $L_{F=M}$ on L_c is illustrated for an example stock in Figure 5.4.1. When looking at the mean length in the catch of a virtually unexploited stock, we can see that the correct value of L_c is important for calculating the mean length as it relates not just to the impact of fishing pressure on the population but also to the sampling effect (Figure 5.4.1, Miethe *et al*. 2019).

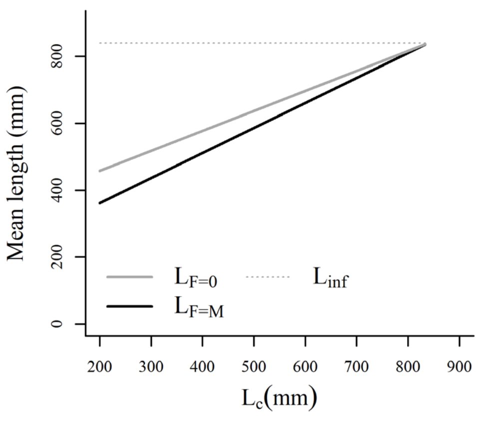

Figure 5.4.1. $L_{F=M}$ depending on L_c, and $L_{F=0}$ for comparison for cuckoo ray (L_∞ =839 mm, M/k=1.48, see Miethe *et al*. 2019)

A question from WGEF was submitted on whether fisheries-independent survey data can be used to derive LBIs for empirical rules if catch length data is sparse or not available. Fisheries-independent survey length distributions can give important information on population length distributions. Karnauskas *et al.* (2011) showed that length distributions from fisheries-independent survey data from a tropical reef can be used to infer stock trends from size spectra and L_{max} for data-limited species. Kell *et al*. 2022 tested the robustness of the use of LBI in advice rules and found that when using LBIs from fisheries-independent surveys the rules performed not as well as those based on catch data. Particularly, indicators based on the left side of the length distribution (smaller fish) performed worse than others based on larger lengths. This result reflects the fact that often the length at first capture from the fisheries-independent survey does not match the L_c from the catches. Using an incorrect L_c can bias mean length and the MSY proxy reference point $L_{F=M}$.

Basic per recruit equations (Equation 5.4.1) can be used to illustrate the impact of exploitation on the population length distributions, and thereby catches and survey data, for the example stock of cuckoo ray (Miethe *et al*. 2019):

$$\tilde{N}_t = \begin{cases} e^{-Mt} & t < t_c \\ e^{Ft_c} e^{-(F+M)t} & t \geq t_c \end{cases} \qquad t = \frac{-\ln(1-\tilde{L}_t)}{k}$$

Equation 5.4.1

where $\tilde{N}_t$ is the numbers at age t, t_c is the age at standardized length at first capture $\tilde{L}_c$ (all lengths standardized by L_∞) assuming knife-edged selectivity and von Bertalanffy growth (k). When exploited at F=M, lower values of $\tilde{L}_c$ lead to more truncated steeper length distributions, in the population as well as in survey or catch length distributions (Figure 5.4.2, left panel). So, if the commercial fisheries actually operates at $\tilde{L}_c = 0.4$, a wrong assumption on selectivity can bias the reference points. Therefore calculating a reference point $L_{F=M}$ with a lower $\tilde{L}_c$ (in orange) from fisheries-independent surveys will lead to a lower and unprecautionary reference point if the population is actually exploited at higher values $\tilde{L}_c$ (blue).

With some knowledge of fisheries selectivity, fisheries-independent survey length distributions could be used to calculate indicators and reference points by selecting the appropriate length range to make survey data is representative not just of the population but also of catches. In the example Figure 5.4.2 (right panel), if the population is exploited at $\tilde{L}_c = 0.4$ (blue) but the survey selects smaller lengths ($\tilde{L}_c$=0.3 in orange), using only length classes above $\tilde{L}_c = 0.4$ would allow the calculation of unbiased reference points and indicators.

With some knowledge on the L_c from the commercial catches available then the fisheries-independent survey data could be used. Without knowledge of L_c from the commercial fishery, fisheries-independent length data should not be used to estimate mean length for the $r \times f \times b$ rule.

In general, LBI screening of survey length data and available catch length data can be a useful tool to better understand data and selectivity patterns, compare data sources and if possible evaluate underlying population dynamics.

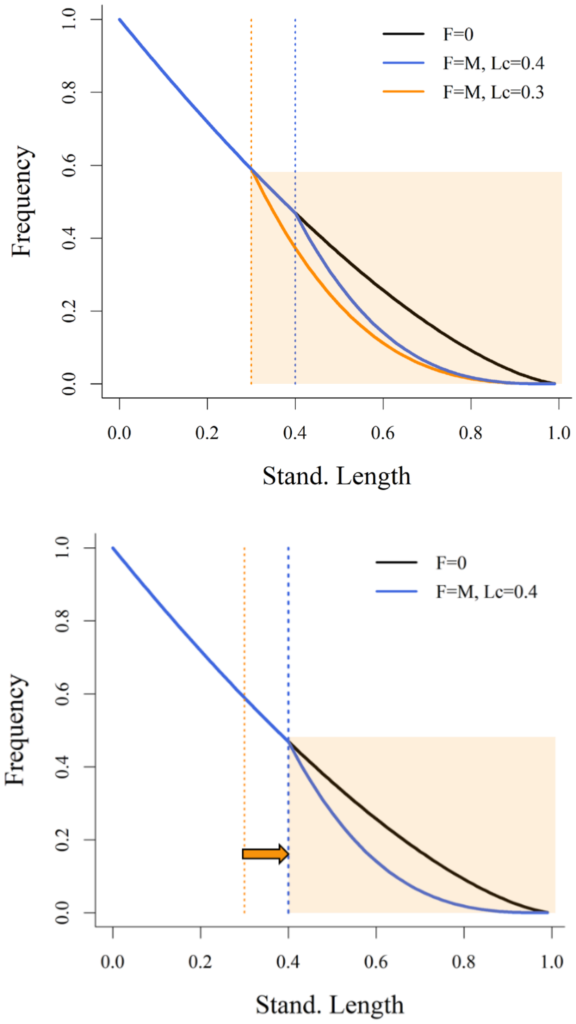

Figure 5.4.2. Length frequency in the population (Equations 1), for example cuckoo ray (L∞=839mm, M/k=1.48). (Left) For different values of commercial catch $\tilde{L}_c$, in orange box represents catch length distributions above $\tilde{L}_c$=0.3 from the respective population. (Right) Length distribution in the orange box represents catch length distributions above $\tilde{L}_c$=0.4.

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6 Further work on surplus production models (ToR 5)

6.1 Background

This section summarises further work on surplus production models such as SPiCT, including the use of SPiCT as an operating model for management strategy evaluation (MSE; Section 6.2), an exploration of precautionary reference points for surplus production models (Section 6.3), the performance of SPiCT with one-way trips (Section 6.4), and the application of SPiCT to *Nephrops* (Section 6.5).

6.2 Application of SPiCT for Japanese stock assessment and management with simple MSE (ToR 5)

As a result of the revised Fisheries Act in force in 2020, the expansion of fishery stocks assessed and managed by Total Allowable Catch (TAC) is a pressing issue in Japan. Japan's fishery stocks have been divided into two types: Type 1, which is assessed using an age-structured model, and Type 2, which is assessed using only historical abundance indices and total catch data. While the harvest control rule adopted by the Japan Fisheries Research and Education Agency (FRA) for the Type-2 stocks is empirical and generic without stock abundance estimation, some stakeholders and fisheries managers sometimes need an abundance estimation and a more explicit management rule towards maximum sustainable yield (MSY) for these Type-2 stocks. Against this background, Japanese stock assessment scientists have been struggling to introduce a new stock assessment method, the state-space surplus production model (SSPM), into the Japanese stock assessment and management system since 2021. The procedure for introducing the SSPM is as follows: 1) review existing software (SPiCT, JABBA, self-developed) to perform PMs and compare performance with simulated data, 2) decide to use SPiCT (fast, peer-reviewed, stable estimation of stock biomass), 3) develop guidelines for the application of SPiCT in Japanese assessment, and 4) develop MSE procedures based on production model results.

In this presentation, the 4th step of developing MSE procedures based on the results of the SSPM was briefly introduced. While details of the procedure will be published in the near future and are not explained here (but are available in Japanese at https://www.fra.go.jp/shigen/fisheries_resources/meeting/stok_assesment_meeting/2023/2023-03.html#), the concept, advantages and disadvantages of MSE are summarised as follows:

- Any available uncertainty can be taken into account in determining future management strategy, even using a production model.
- The degree of precaution depends on the degree of uncertainty estimated for each species as the standard error of estimated parameters and the magnitude of process and observation errors.
- Management advice is expected to be more precautionary than for Type 1 stocks (VPA, no consideration of parameter uncertainty).
- This MSE requires less data and effort than age-structured MSE, although structural uncertainty cannot be considered.

Although the MSE procedure we have developed is relatively simple compared to the MSE where structural uncertainty can be considered, it would be a reasonable way to reflect the characteristics of the target fishery stock in the management measures and to incorporate a degree of uncertainty, even in situations where data and human capacity to construct MSE are scarce.

6.3 Precautionary reference points for surplus production models (ToR 5bc)

While the target reference points F_{MSY} and B_{MSY} are clearly defined for surplus production models, threshold and limit reference points such as F_{lim}, MSY $B_{trigger}$, and B_{lim} are more difficult to define in the context of surplus production models. These reference points are supposed to reduce or terminate fishing mortality when the reproductive capacity of the stock is reduced or compromised and are preferably defined based on a change-point in the stock-recruitment relationship (ICES, 2021d). The change-point indicates the stock size under which the reproductive potential decreases rapidly. However, for surplus production models the stock-recruitment relationship is part of the production curve, which is a smooth function without any change-points. Therefore, arbitrary levels of surplus production were used as indicators of low or compromised reproductive capacity in the past. For example, the workshop on Greenland halibut in 2013 used the biomass corresponding to the surplus production of half of the maximum (MSY) as an indicator of reduced recruitment potential and, thus, proxy for B_{lim} (ICES, 2013). For a Schaefer-type surplus production model with a symmetric production curve, the suggested B_{lim} was equal to 0.3 B_{MSY}. The authors derived F_{lim} and MSY $B_{trigger}$ based on the defined B_{lim} as Flim = 1.7 F_{MSY} and MSY $B_{trigger}$ = 0.5 B_{MSY}. These definitions are still used within ICES today even if the surplus production curve is not symmetric (ICES, 2021d). The reference points MSY $B_{trigger}$ and B_{lim} play a crucial role within the harvest control rule (HCR) for Category 2 stocks as they imply reduced or no fishing mortality, respectively, and various levels have substantial implications on the potential yield, risk, and interannual variability in yield (Mildenberger *et al*., 2022).

In this study, we explored the effect of various alternative definitions for threshold and limit reference points for surplus production models. We fitted SPiCT with a fixed symmetric production curve (Schaefer-type surplus production model) to the catches and exploitable biomass of 64 data-rich stocks (Figure 6.3.1). For 8 stocks the models did not converge or estimated trajectories were not meaningful (large uncertainty bounds) and were excluded from further analysis (red lines and polygons in Figure 6.3.1).

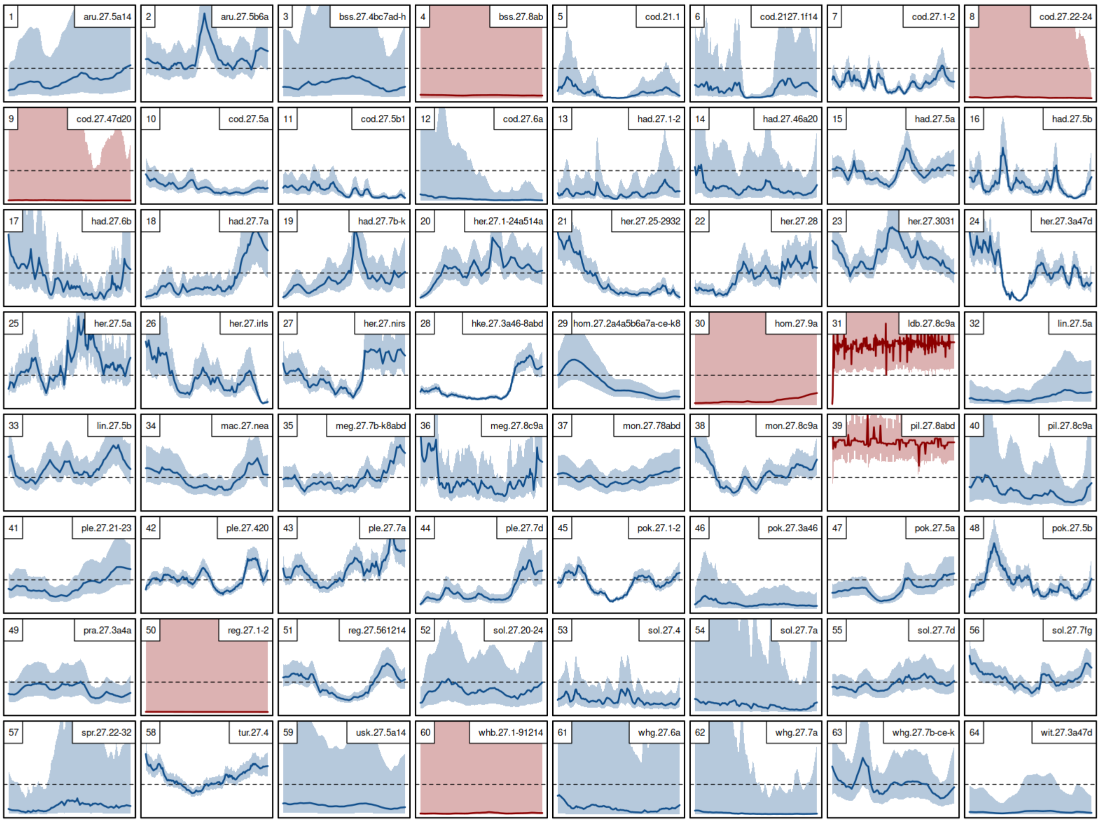

Figure 6.3.1. Biomass relative to BMSY for 64 data-rich stocks estimated by SPiCT fitted to assessment output data. For 8 stocks the estimated trajectories were not meaningful and were excluded from further analysis (red color).

Regarding MSY $B_{trigger}$, we explored the definition that is used for data-rich stocks, that is MSY $B_{trigger}$ is equal to the 5th percentile of the biomass distribution when fished at F_{MSY} (ICES, 2021d). This definition resulted in larger values than the current definition for 91% of the 56 stocks (Figure 6.3.2). The new threshold reference points were on average 42% larger than the current levels for these stocks implying reduced fishing mortality at higher biomass than current threshold levels.

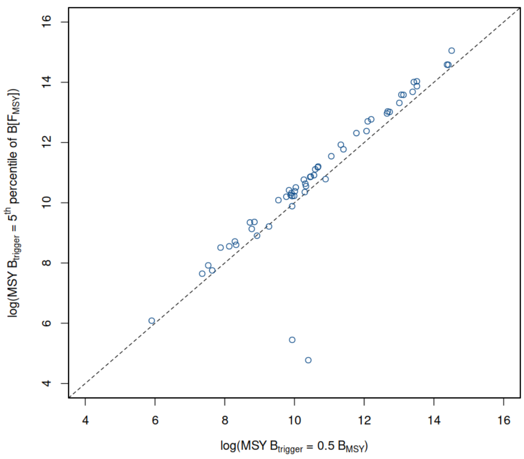

Figure 6.3.3. Current vs. new definition of MSY Btrigger on log scale for 56 stocks. For the majority of stocks the new definition of MSY Btrigger is larger than the current definition.

The advantage of the new definition is that it is an accepted definition within ICES in line with ICES guidelines for Category 1 stocks and that it accounts for aleatory uncertainty. This means that the threshold reference point is equal to B_{MSY} if there is no aleatory uncertainty and declines with increasing natural variability of the stock (i.e., higher process error, σ_B in SPiCT; Figure 6.3.3).

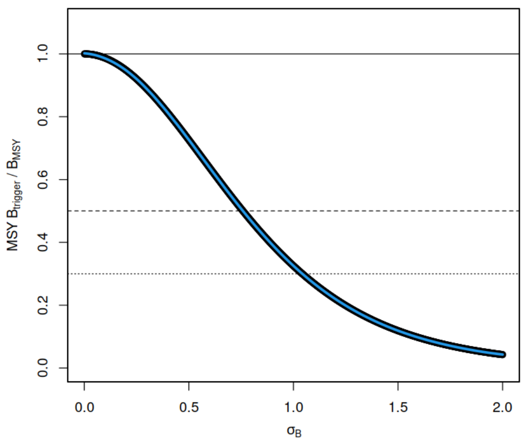

Figure 6.3.3. New definition of MSY Btrigger relative to BMSY as a function of the noise parameter of the biomass process (σ_B).

Even for data-rich stocks in Category 1, there are a range of different definitions of the limit reference point (B_{lim}), such as the lowest observed biomass or the lowest observed biomass with high recruitment (ICES, 2021d). The preferred definition is based on the change-point of the segmented regression fitted to the stock-recruitment data. We explored six different definitions for B_{lim} that were also used by previous studies (e.g., Myers et al. 1994; van Deurs et al. 2021): Biomass that corresponds to (1) 50% of MSY (0.5 MSY), (2) 20% of virgin biomass (0.2 K), (3) 20% of maximum observed biomass (0.2 B_{max}), the lowest observed biomass with large surplus production, where large surplus production is defined to be above the (4) 50th percentile (0.5 SP) and (5) 80th percentile (0.8 SP), and (6) the biomass from which the stock recovers to B_{MSY} within 4 years (4 rt). The corresponding values for these six definitions relative to the current definition for the 56 stocks are shown in Figure 6.3.4. For a Schaefer-type surplus production model the alternative reference points are around previous ones (close to 1-1 line). As expected, the three definitions that depend on the observed biomass show more variability. The definition based on rebuilding time suggests lower values than current levels, but this can be attributed to the chosen rebuilding time of 4 years, which might be adequate for short-lived species, but is likely too low for longer-lived species. Ideally, the rebuilding time depends on the generation cycle of the stock under study.

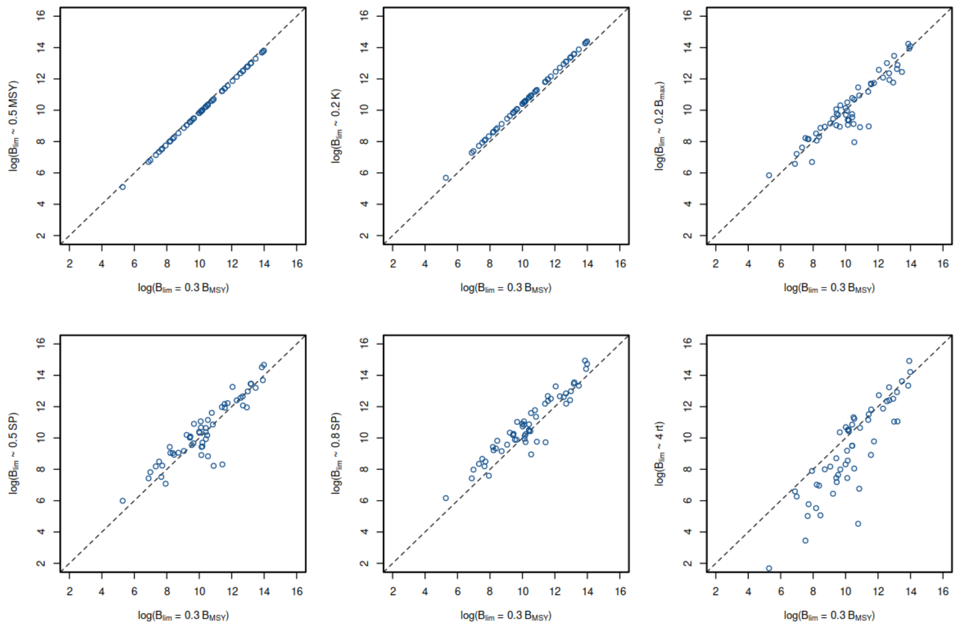

Figure 6.3.4. Current definition of Blim (x axis) vs 6 different definitions of Blim (y axis of 6 panels) on log scale for 56 stocks.

We estimated F_{lim} as the fishing mortality that leads to the median biomass around B_{lim} corresponding to the definition currently used for Category 1 stocks within ICES in addition to the current definition as $F_{lim} = 1.7\ F_{MSY}$ (ICES, 2021d). Corresponding F_{lim} values are similar to current levels (Figure 6.3.5).

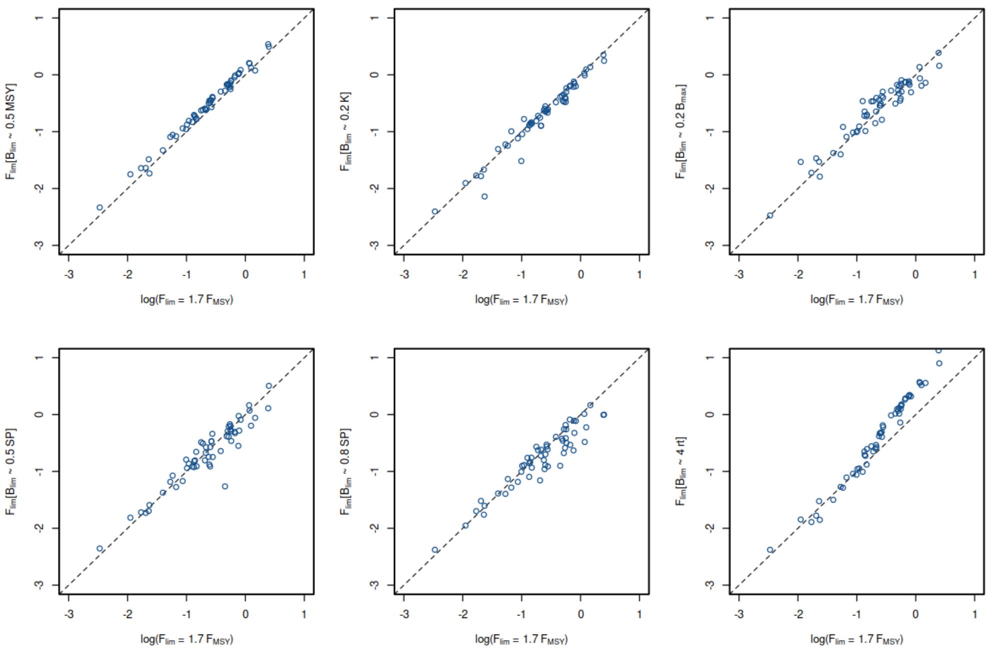

Figure 6.3.5. Current definition of Flim (x axis) vs 6 different definitions of Flim (y axis of 6 panels) on log scale for 56 stocks.

Reference points play an important role and current levels can be improved so that they are valid for models with symmetric and asymmetric production curves and take aleatory uncertainty into account. While this analysis demonstrated that current Category 1 definitions can be applied for MSY $B_{trigger}$ and F_{lim}, the definition of B_{lim} for surplus production models is more challenging and more research is needed. The definition based on rebuilding time is promising as it accounts for the growth rate of the species (Cadrin, 1999) and provides a universal currency that can be compared between models, however, raises the need to define the acceptable time for rebuilding. Further work should explore the yield-risk trade-off of various rebuilding times and the possibility of generalising rebuilding times based on generation cycles.

6.4 SPiCT and one-way trip analysis (ToR 5)

SPiCT assessments have generally appeared to perform well with a wide range of data sets, including one-way trip type data. These time series show a consistent trend in fishing mortality and lack contrast that is typically believed to be important to allow surplus production models to accurately estimate the parameters. To evaluate the actual performance of SPiCT whilst using time series that do not fully track the evolution of the fishery, simulated time series were generated with known parameters and trends. One hundred iterations of 40-year time series were created with a 10% noise around the catch, biomass growth and index. The time series trends were:

- Full time series – fishing mortality increases from zero on a virgin biomass up to a peak of 2 times F/F_{MSY}, and then decreasing to a F/F_{MSY} of 1
- Increasing Fishing from Zero - fishing mortality increases from zero on a virgin biomass up to a peak of 2 times F/F_{MSY}
- Increasing Fishing from 0.5 F/F_{MSY} - fishing mortality increases from 0.5 times F/F_{MSY} up to a peak of 2 times F/F_{MSY}
- Decreasing fishing from B_{MSY} – fishing mortality decreases from 2 times F/F_{MSY} to F/F_{MSY} starting from a biomass at B_{MSY}

- Decreasing fishing from a depleted state – fishing mortality decreases from 2 times F/F_{MSY} to F/F_{MSY} starting from a biomass of 0.15 virgin biomass

The outputs and retrospectives of the SPiCT assessments from the simulated data sets were consistently good for all the fishing pattern trends. Retrospectives were within Mohn's rho guidelines and confidence levels were reasonable. In the vast majority of cases the assessments would meet the SPiCT guidelines.

When compared to the actual F/F_{MSY} values the SPiCT models were reasonably accurate at estimating the F/F_{MSY} both throughout the timeseries and at the endpoint for all the different fishing mortality trends. There was a lot more uncertainty and variability in the F/F_{MSY} assessment around the timeseries that exhibited increasing fishing mortality. When comparing the B/B_{MSY} trends however, it was the timeseries with decreasing mortality trends that struggled to provide consistent estimates. As expected different parts of a fishing trend evolution are required to correctly estimate the different parameters. A timeseries of increasing fishing will be less able to estimate that fishing mortality whereas a stock recovering time series is less capable of estimating the biomass reference points. This is a worrying situation in both of those scenarios, and is exacerbated with potential overconfidence in the assessment due to the SPiCT outputs and strong diagnostics. An awareness of this issue, and identification of additional guidelines and post hoc indicators is an important ongoing issue.

Priors on the intrinsic growth rate parameter (r) and the initial depletion (bkfrac) were shown to help counteract the uncertainty in the F/F_{MSY} and B/B_{MSY} reference points respectively. It was however difficult to determine the effectiveness of the priors in a post hoc manner. A stronger prior that dramatically reduced uncertainty produces outputs similar to a weaker prior that had no impact on the assessment, and still had considerable uncertainty. Developing an understanding of suitable priors and prior certainty could significantly improve assessments when the full fishery time series is not available.

6.5 Applying SPiCT to Nephrops in FU 28-29 (ToR 5 & 6)

This section focuses on ToR 5 of WKLIFE XII which requested advances on further work on SPiCT, applied to other life-strategies like Norway lobster (*Nephrops norvegicus*) (ToR 6c), with the case-study of the *Nephrops* functional units 28–29 (Atlantic Iberian waters East and southwestern and southern Portugal), in Division 9.a (nep.fu.2829).

In 2021, this stock was selected for the 'Benchmark Workshop on the application of SPiCT to produce MSY advice for selected stocks' (WKMSYSPiCT; ICES, 2021a). Yet, "*due to the wide confidence limits and contradictory results obtained in the most relevant runs*" presented to WKMSYSPiCT (ICES, 2021a), "*the state of the stock in relation to reference points is unknown and SPiCT was not accepted to provide assessment and advice for the Nephrops FU 28-29 stock*" during that benchmark. Also to note that SPiCT was accepted during the same benchmark (ICES, 2021a) as the basis for the assessment of three other *Nephrops* functional units in Division 9.a (González Herraiz *et al.*, 2023). Currently, *Nephrops* functional units 28–29 remain as a Category 3 stock for which the latest advice was given in 2023 by the Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE) (ICES, 2023a). Given the most recent ICES guidelines to provide advice for data limited stocks (ICES, 2023b), this stock should have been assessed using the ICES rfb rule (Method 2.1, ICES, 2021b). However, since the fishing pressure indicator from the MLZ, accepted in 2015 by WKProxy (ICES, 2016), is based on more complete information than the one in the Method 2.1, the new rule was not applied, following the ACOM recommendation.

So, for WKLIFE XII the main goals on this case-study were: i) to discuss the issues raised in WKMSYSPiCT; and ii) to run new SPiCT trials with an updated data series and new model configurations.

One recommendation made by the WKMSYSPiCT for future approaches with nep.fu.2829 was: "*a longer biomass index could allow to understand what was the biomass level when the fishing pressure was high and therefore could provide extra information and help the model to stabilize and produce more coherent results*" (ICES, 2021a). Apart from the biomass indices already included in the SPiCT runs during that benchmark (i.e., the standardized commercial CPUE 2002-2022, and the Portuguese Crustacean Survey (NepS)), other sources of information were compiled (Figure 6.5.1):

i. the Portuguese autumn-IBTS survey (PtGFS-WIBTS-Q4) considering the *strata* between 200 and 750 m depth (1990-2002),
ii. the PtGFS-WIBTS-Q4 considering the *strata* between 200 and 500 m depth (1990-2022), and
iii. the older Portuguese Crustacean Surveys (1981-1994).

To note that all these three indices have issues in terms of providing a reliable biomass index for *Nephrops* FU 28-29, as the PtGFS-WIBTS-Q4 was not designed for *Nephrops* and the older Portuguese Crustacean Surveys conducted opportunistic sampling, they were not stratified, and did not always cover the same area. Nevertheless, it is important to highlight that the catch data for these FUs is available since 1975. Yet, there is an abrupt drop in catches reported from 1982 to 1983, from around 1392 tonnes to 244 tonnes (Figure 6.5.1), that cannot be explained solely based on the species biology (i.e., dynamic or abundance), but due to the fact that Spain stopped reporting their catches from these FUs. This was probably a consequence of the 1978 agreement, between Portugal and Spain, according to which the Spanish trawl fleet was only allowed to operate outside the 12-mile zone (Cadima *et al*., 1995). Although outside the 12-mile zone is where most of *Nephrops* grounds are located, that fleet also targets deepwater rose shrimp (*Parapenaeus longirostris*), which is a more valuable and coastal species, being the focus of that fleet in years when it is more abundant. Also, it was referred during the WKLIFE XII discussion that by near that time Spain and Portugal entered the EU (in 1986) which may also had an impact on the areas where the Spanish fleet operated.

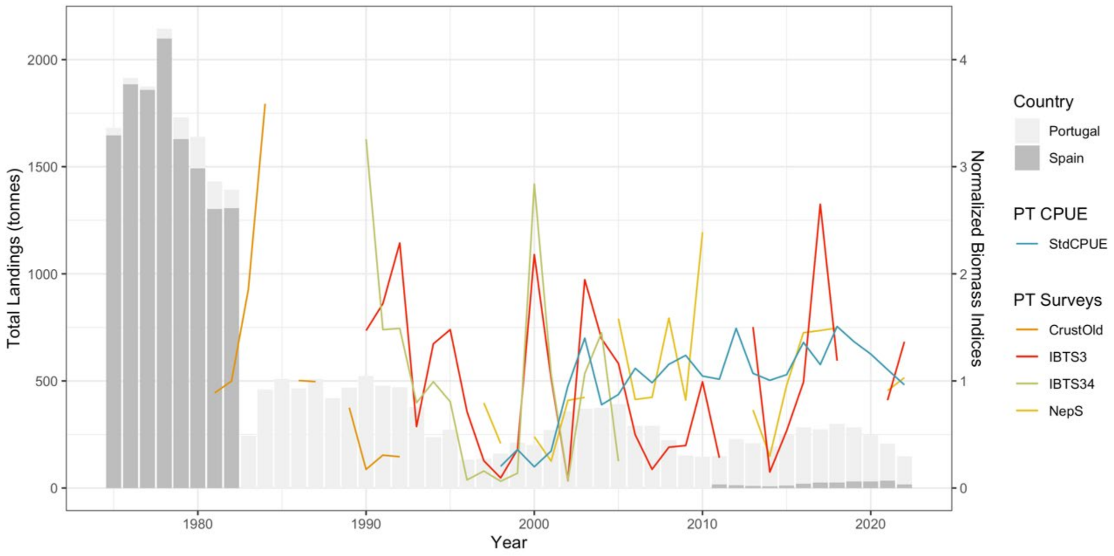

Figure 6.5.1. Total landings of Nephrops functional units 28–29 (nep.fu.2829) by country (in tonnes) and available normalized biomass indices: standardized commercial CPUE (StdCPUE), Portuguese Crustacean Survey (NepS), Portuguese autumn-IBTS survey (200-750 m) (IBTS34), Portuguese autumn-IBTS survey (200-500 m) (IBTS3) and the older Portuguese Crustacean Surveys (CrustOld).

During WKMSYSPiCT (ICES, 2021a) the high fishing pressure during 1975-1982 and the possible unreported catches by Spain from 1983 to 1992 were dealt with in two ways in the SPiCT trials:

i. adding uncertainty to the catches in two different periods: *stdevfacC*=3 in 1975-1983 and *stdevfacC*=2 in 1984-1992;
ii. setting a prior for log standard deviation of fishing mortality process (*logsdf*=0.4).

When preparing the WKLIFE XII meeting and the new SPiCT runs for the present case-study, the period to which the uncertainty in the catches had been applied was questioned. The same uncertainty (*stdevfacC*=3) was added for both the year with the lowest catches (1983), as well as to the period with the highest catches (1972-1982). Therefore, new runs were conducted changing the period to which the uncertainty was added (i.e., *stdevfacC*=3 in 1975-1982 and *stdevfacC*=2 in 1983-1992; runs 3 to 5 in Table 6.5.1).

A total of five new SPiCT runs for *Nephrops* FU 28-29 were presented to WKLIFE XII. The input data for those runs was the same:

i. catch series (three more years than in WKMSYSPiCT): 1975-2022;
ii. standardized commercial CPUE series (new model and three more years): 2002-2022;
iii. NepS survey series (two more years than in WKMSYSPiCT): 1997-2022 (no index in 1999 and 2004 as other vessel was used; no survey in 2011, 2012, 2019 and 2020).

Due to the limited time available to work on WKLIFE XII, runs with the new input series (i.e., those based in the PtGFS-WIBTS-Q4 and the older Portuguese Crustacean Surveys) were not tested.

The most meaningful differences between the input series used in WKMSYSPiCT and those used in WKLIFE XII are in the standardized commercial CPUE series (Figure 6.5.2), as the final standardization model configuration was updated and accepted in the WGBIE meeting in 2021 (ICES, 2021c). The results and outputs of all the five runs are presented in detail in a working document prepared for this workshop (WD Serra-Pereira *et al.*, 2023). The SPiCT model configurations, including the variables/periods to which uncertainty was added and the priors' settings are summarized in Table 6.5.1. In general:

i. **run 1** used the same model configurations as the WKMSYSPiCT run 4;
ii. **run 2** used the same model configuration as run 1 but removing the priors for *logalpha* and *logbeta*;
iii. **run 3** changed the period to which the uncertainty was added to the catch in relation to WKMSYSPiCT;
iv. **run 4** used the same model configuration as run 3 but only applying uncertainty to the catch in 1983-1992;
v. **run 5** used the same model configuration as run 3 but changed the standard deviation for priors *logn* and *logr* from 0.3 and 0.2 respectively, to 0.5.

Table 6.5.1 also shows the tested diagnostics from the checklist for acceptance of a SPiCT assessment. In general, no major issues were found. Overall, the model outputs of the SPiCT runs show that the removal of the priors for *logalpha* and *logbeta* (runs 2 to 5) gave significant improvements in the model outputs. As well as when changing the period to which the uncertainty was added (runs 3 to 5), contributing both to large developments comparing to the runs discussed in WKMSYSPiCT. Runs 3 and 5 provided the best results so far, but future trials should still be performed.

Therefore, as future work, it is proposed to:

i. fine-tune model configuration following WKLIFE XII suggestions (e.g., run model without priors, add a prior for *logsdb* to avoid overfitting of the production curve, run sensitivity runs for each prior);
ii. run SPiCT with the new input series (i.e., those based in the PtGFS-WIBTS-Q4 and the older Portuguese Crustacean Surveys);
iii. if a candidate run is reached, propose this stock for the 2024/2025 benchmark cycle using SPiCT assessment.

Table 6.5.1. Summary of the SPiCT exploratory runs tested for Nephrops FU 28-29 during WKLIFE XII.

	SPiCT runs				
Input series	**1**	**2**	**3**	**4**	**5**
C	1975-2022	1975-2022	1975-2022	1975-2022	1975-2022
I1 (std CPUE)	2002-2022	2002-2022	2002-2022	2002-2022	2002-2022
I2 (survey NepS)	1997-2022	1997-2022	1997-2022	1997-2022	1997-2022
Increased uncertainty (stdev)					
C					
1975-1983 (same as in WKMSYPiCT)	3	3			
1984-1992 (same as in WKMSYPiCT)	2	2			
1975-1982			3		3
1983-1992			2	3	2
I2 (surveyNepS) (2010 and 2014)	2	2	2	2	2
Priors					
logn	log(2),.3,1	log(2),.3,1	(log(2), 0.3, 1)	(log(2), 0.3, 1)	(log(2), 0.5, 1)
logalpha	log(1),.3,1				
logbeta	log(1),.3,1				
logbkfrac	log(0.5), 0.2, 1	log(0.5), 0.2, 1	(log(0.5), 0.5, 1)	(log(0.5), 0.5, 1)	(log(0.5), 0.5, 1)
logr	log(0.2),0.2,1	log(0.2),0.2,1	(log(0.2), 0.2, 1)	(log(0.2), 0.2, 1)	(log(0.2), 0.5, 1)
Diagnostics					
1. Convergence	✓	✓	✓	✓	✓
2. Finite parameters	TRUE	TRUE	TRUE	TRUE	TRUE
3. Violation of model assumptions					
shapiro	C**	C**	C**	C***	C*
bias	✓	✓	✓	✓	✓
acf	C*, I2*	✓	✓	✓	✓
LBox	C*	✓	✓	✓	✓
4.Retrospective pattern					
Mohn's Rho					
FFmsy	3.724	0.051	0.070	0.073	0.085
BBmsy	-0.530	-0.011	-0.014	-0.014	-0.018
5.Realistic production curve	✓	✓	✓	✓	✓
6. Assessment uncertainty	✓	✓	✓	✓	✓
7. Initial values sensitivity	☒	☒	✓	☒	✓

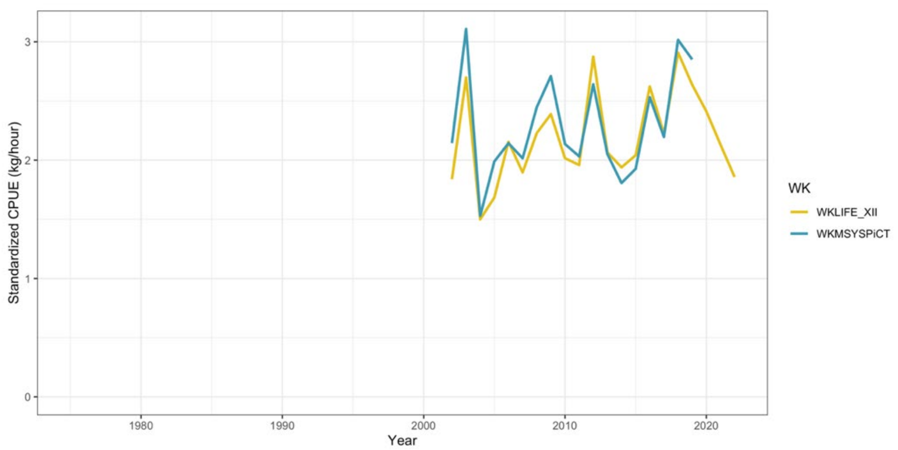

Figure 6.5.2. Comparison of the standardized commercial CPUE series used in the SPiCT runs during WKMSYSPiCT and WKLIFE XII.

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7 Approaches for specific life-history strategies (ToR 6)

7.1 Background

This section summarises work presented at WKLIFE XII on approaches for specific life-history strategies, and includes work on a perturbation-reaction rule for small pelagics (Section 7.2), sea urchins (Section 7.3), sprat (Section 7.4), shellfish (Section 7.5), and rabbitfish (Section 7.6).

7.2 Perturbation-Reaction Rule: A semi-quantitative data-limited approach to manage small pelagic fishes (Tor 6a)

Further work on the so-called Perturbation Reaction rule (Pert rule), was presented to WKLIFE XII (Uriarte *et al.*, in preparation). A preliminary version of the rule had been originally presented in ICES 2021 WKDLSSLS meeting by Sánchez-Maroño *et al.*, comparing its performance with other rules adapted from literature (Dyn-F, Fadapt_hr and G-control – Carruthers *et al*. 2016). The Pert-rule is a rule designed for Category 3 stocks being monitored with a biomass index, aiming at setting sustainable harvest rates around or below harvest rates consistent with MSY (HRmsy.proxy), so that advised catches are yearly set as the product of the biomass indicator (available at the beginning of the management period) and the HRmsy proxy.

$$TAC_{y+1} = I_{current} \cdot HR_{msy.proxy}$$

The Pert-Rule uses the relative changes in biomasses (from the available index) and catches resulting from a perturbation of the original harvest rates to move the exploitation towards harvest rates consistent with MSY (preferably below HRmsy). The rule assumes that for small pelagics the shape (parameter P) of a Pella-Thomlinson production model is generally below 1. With this assumption the Pert-rule is a semiquantitative harvest control rule consisting of three steps: a) reduction of the original harvest rate by -25% (Perturbation) (or other pre-agreed percentage), b) an assessment of the effect of such a reduction through a diagnostic algorithm (after some years left for the stock to reach equilibrium) and c) a final reaction to move the initial harvest around HRmsy (but preferably below HRmsy). The diagnostic algorithm (in b) can be complemented with 1 or 2 additional statistical tests to assure the stock has arrived to a new equilibrium status, so that the changes in biomass are valid enough as to trigger the reaction step (c) of the rule.

The Pert-Rule shows a reasonable performance in terms of setting final HRf/Hrmsy around 1, in particular for stocks heavily exploited in the past. The best performance of the rule was that of assuming different shapes of the production curve function for stocks assessed as over-exploited (by the rule) from those under-exploited (the Dual Pert_Rule), applied with two tests coupled to the Logic algorithm (for stability and for significant changes of biomass after perturbation. Simulations carried out on sardine or anchovy like stocks show that a single application of the Pert-rule waiting for a maximum of 8 years after a perturbation of -25% is capable of setting a new (final) harvest rate on average below HRmsy, with long terms risks of falling below B_{lim} lower than 0.2 ($p(B_{lim}) \leq 0.2$) (Figure 7.2.1 below). However application of the Pert-rule to underexploited stocks needs some tunning to assure it places final HR closer to HRmsy than where it was originally before the perturbation.

The Pert-Rule can be applied repeatedly, after the initial perturbation, by considering every new harvest rates induced by the rule as a new perturbation for which the resulting changes of the population biomass and catches are to be assessed again to trigger new advice for a new HRmsy.proxy hoping every time the new HR would be closer to HRmsy. The preliminary simulations show that multiple applications of the rule (with two Tests) overcome the performance of the single application of the rule, because it reduces further the risks of falling below B_{lim} for the highly overexploited stocks towards sustainable levels, while still allowing substantial harvest rates over HRmsy (between 0.44 to 0.8). As an example, the Figure 7.2.1 below shows the long term average catches over MSY and risks of falling below B_{lim}, resulting after application of the Pert-rules 1, 2, 3 or 4 repeated times (Changes 2-5) (with a maximum waiting time of 8 years each), for a sardine or anchovy like populations (both together) monitored with a survey having an observation error of 0.3 and following a Pella Thomlison with process error of 0.7.

The results of the MSE of the Pert-Rule are being prepared for publication, therefore just a brief summary was presented here.

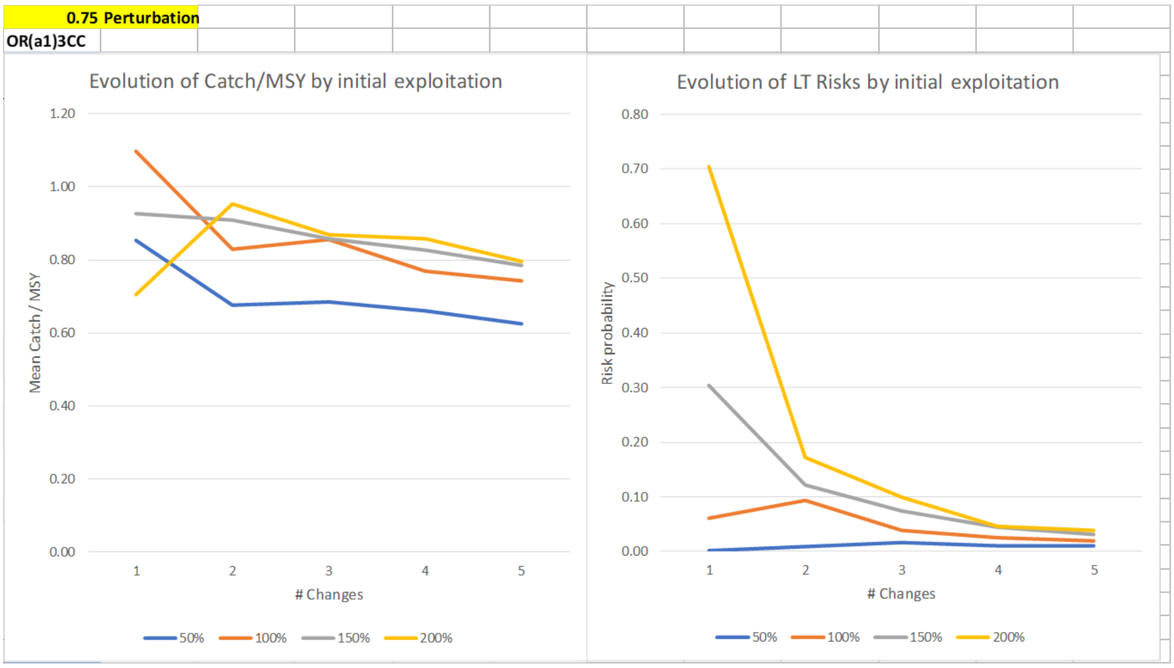

Figure 7.2.1: Long term average Catch over deterministic MSY (left panel) and long term risks of falling below Blim (right panel) for final harvest rates resulting from the repeated applications of the Perturbation rule (Dual-shaped Pert_Rule with a perturbation = -25% and with a maximum waiting number of years equal 8), as a function (X axes) of the number of times the rule is successively applied (as defined by the number of changes of the harvest rates, whereby the initial perturbation by -25% refers to change #1, the first reaction and setting of a new harvest rate is change #2 and every new application of the rules adds one to the former number of changes, i.e., the second application of the rules is change #3, and so on), until a maximum of 4 repeated applications of the rule (5 changes). Results are reported by lines according to initial harvest rate before application of the rule (50%, 100%, 150% or 200% times HRmsy). The rule is applied with 2 complementary tests for the two species together (anchovy and sardine like stocks), both with medium productivity (i.e., Steepness of 0.75), using the assessment indicator of OR (DeltaCrat/DeltaBrat) with a noisy filtering 3CC. The monitoring system has an observation error of 0.3 & the population surplus production has a process error of 0.7 (large but presumed to be applicable for short lived stocks). The maximum number of years waiting for a diagnosis of the logic algorithm (Tmax) is set as 8 years (before a reaction of the rule is forced to happen). Therefore the maximum number of total waiting years can be inferred roughly by multiplying the number of changes by 8. Blim is defined as the Minimum between 1/Bmsy and 20%K.

7.3 Adaptive management for Sardinian sea urchins and risk-equivalent frameworks (ToR 6c)

Fisheries management has to deal with a range of uncertainties, the available data and knowledge therefore determines the probability of achieving management objectives, i.e. the level of risk. Uncertainty, therefore, forms a key part of fishery decision-making processes. We therefore propose a tiered management framework for fisheries exploited in areas beyond national juristdiction (ABNJs) and coastal waters not managed under existing frameworks, e.g. under the Common Fisheries Policy (CFP) of the EU or by regional fisheries management organizations (RFMOs). The framework reflects the available information, and helps to ensure risk equivalence, i.e. that a lack of knowledge should not permit higher risk. The tiers are Level 1 – Risk assessment using PSA, Level 2 Assessment based on indicators or an assessment model, without clearly defined reference points and decision rules, where historical trends but not absolute estimates are available; and Level 3 – Quantitative assessment with reference points and clear decision rules in place. The advice framework requires estimates of population growth rate (r) to derive fishing mortality targets (F_{MSY}) and limits (F_{lim}) for use in the PSA at Level 1, indicator reference levels at Level 2; and to derive priors for quantitative assessments at Level 3. These can be derived from life history parameters, e.g. $L_{infinity}$ and k from the von Bertalannfy growth equation, and length at maturity (L_{mat}). Depending on the available knowledge parameters may be available from the stock of concern, comparable stocks, species, and taxa. Once data and key parameters have been obtained and priors estimated, a quantitative assessment (i.e. a Bayesian State-Space Surplus Production Model framework) can be conducted to estimate stock status relative to reference points. As other sources of data become available, such as length, effort or indices of fishing or total mortality, these can be included in and the improvement in prediction skill of the model evaluated. Guidelines on how to improve fisheries data collection (type, amount and verification of data) and the assessment process will be developed, based on an analysis of the value-of-information.

As a prototype of the framework, a management plan is being developed for the sea urchin stock in Sardinia. Data for a formal stock assessment are limited, although information on catch and, effort, individual size, and habitat are available. A diver survey is currently being conducted, providing a fishery-independent index of abundance and size data for use in an empirical harvest control rule. The study aims to develop a management strategy based on currently available data, and then evaluate the benefits of alternative data sets and knowledge for use in stock assessment. The benefits of tagging and lab-based studies will be evaluated, as well as current fishery sampling schemes. We will use MSE to develop a Management Procedure. Once implemented, a Management Procedure requires less effort than conducting a stock assessment each time advice is required. This should allow time to gain a better understanding of resource dynamics and evaluate the benefits of collecting improved information. To do this, we are using a biomass dynamic assessment (JABBA), that can use indices based on length to provide priors for and time series of fishing mortality. Once the Management Procedure has been implemented and run for several years, we will perform an implementation review to check whether the Operating Model dynamics were plausible, the management procedure worked as expected, whether objectives were achieved, and how the advice framework can be improved.

More information is available from Annex 3 of this report.

7.4 Celtic Sea sprat (ToR 6a & 7)

Sprat is a commercially valuable species and an important component of the Northeast Atlantic ecosystem. Despite this, insufficient information exists for Celtic Seas sprat to estimate stock status and reference points. We have therefore conducted a Management Strategy Evaluation using a seasonal Operating Model conditioned on life history parameters to evaluate empirical control rules. Strategic information from an ecosystem model (Ecopath with Ecosim) was used to split natural mortality into background (M1) and predation (M2) mortality and to model environmental drivers. Potential indicators for use in the empirical control rule included an acoustic survey targeting herring, total catch and length data. Receiver Operator Characteristics (ROC) curves were used to screen the indicators, allowing the number of alternative control rules to be reduced, since there is no need to simulation test indicators with poor classification skill. This allowed the focus to be on conditioning alternative Operating Models to test the robustness of the rules to uncertainty about resource dynamics. We showed that i) a relative harvest rate control rule based on catch and the acoustic survey can meet MSY and PA objectives, and ii) setting catch immediately after the survey (i.e., in-year rather than in the following year) provides higher yields and less chance of stock collapse.

Ecosystem Reference Points

Pragmatic steps which account for the needs of predators and the influence of environmental variation on stock production are needed to operationalise an ecosystem-based approach to fisheries management (EAFM). To make progress towards EAFM, the development of approaches which incorporate ecosystem complexity with practical assessment and management options will become increasingly important. One emerging opportunity to advance an ecosystem approach in the short term is to integrate ecosystem information into traditional single-species stock assessment and management frameworks. The sprat case study provides an example, where an Operating Model was conditioned on predation mortality to evaluate ecosystem reference points. ICES mainly provides advice on a single-species basis, where the objectives are to achieve maximum sustainable yield (MSY) while ensuring that productivity is not impaired, using target and limit reference points such as F_{MSY} and B_{lim}. Pelagic species such as sprat, however, like other Northeast Atlantic forage fish stocks with internationally managed fisheries, support the health and resilience of marine ecosystems. Therefore, sustainable ecosystem-based fisheries management also requires the development of ecosystem reference points (ERPs) to ensure that prey stocks are sustainable for the consumptive needs of predators and to minimise risks due to a changing environment. Such information is needed to inform decision-makers of the trade-offs between MSY and ecosystem objectives, such as Good Environmental Status. We therefore use the MSE framework, developed initially for sprat, to stress test the current ICES advice framework. To do this we conduct Management Strategy Evaluation to evaluate whether the current advice framework can maintain pelagic stocks at levels that satisfy the needs of predators. The framework will provide i) a pragmatic route for the integration of ecosystem information into fisheries management advice and ii) a new flexible ecosystem reference point which can be used to assess the performance of management strategies relative to the needs of other ecosystem components.

More information is available from Annex 4 and Annex 5 of this report.

7.5 Plans for evaluating shellfish management strategies in Ireland (ToR 6c)

Current approaches in providing advice for data-limited stocks within the ICES framework (e.g., 'rfb', 'rb', and 'chr' rules) have not explicitly been tested for shellfish and may be inappropriate given their unique biology, distribution, and management systems. Many shellfish species in Irish waters inhabit inshore areas (< 12 nm) and do not fall under EU TAC regulation, with a few exceptions.

One major challenge in developing suitable harvest control rules for shellfish is the uncertainty surrounding growth parameters. Age determination methods cannot rely on hard part analysis and often require resource-intensive techniques like tagging or direct monitoring through lab or in situ experiments. While FishBase and FishLife can estimate life history parameters for data-limited finfish based on meta-analysis of related species, SeaLifeBase has limited capabilities in comparison. Estimating L_∞ is usually more manageable than the growth parameter 'k'.

Razor clams present an interesting case study. Scientific surveys of the North and South Irish Sea have been conducted annually since 2017, enabling the estimation of total biomass by size class through spatiotemporal modelling. Additionally, vessels engaged in razor clam fishing are obliged to report iVMS data, which provides distributions of effort at a fine scale. These data are currently under exploration using Empirical Orthogonal Factors (EOFs), with a focus on identifying high-risk areas susceptible to local depletion. Certain spatial indicators may be useful in this regard, and will be investigated further.

Prioritizing the shellfish issue list in Irish waters is currently underway, in collaboration with stakeholders to establish explicit management objectives. Subsequently, exploration will focus on creating generic and case-specific operating models, followed by testing various harvest control rules. These rules could involve spatial and habitat indicators, index-based indicators, length-based indicators (possibly independent of von Bertalanffy 'k'), or seasonal indicators related to depletion and/or change in ratio of exploited subclasses.

7.6 The conservation potential of rabbitfish *Chimaera monstrosa* in the face of global changes (ToR 6b)

Deep-sea chondrichthyans have received less scientific attention compared to their inshore and pelagic counterparts. This disparity primarily results from the misconception that they are less susceptible to global environmental changes and fishing pressures (Dulvy *et al.*, 2014). Despite their growing recognition for their crucial role in maintaining biodiversity and sustaining the health of deep-sea ecosystems (Hammerschlag *et al.*, 2019), these species remain relatively understudied. This lack of research is primarily due to their limited commercial importance and lack of public appeal. A notable species among the chondrichthyans is *Chimaera monstrosa* Linnaeus, 1758, commonly referred to as rabbitfish. While *C. monstrosa* once had a broader distribution, it is now predominantly found in the northeastern Atlantic and the Mediterranean Sea (Sion *et al.*, 2004; Ebert and Stehmann, 2013; ICES, 2020; Jakobsdóttir *et al.*, 2020; Jac *et al.*, 2022). Recent research indicates that global warming has expanded their habitat to Arctic waters (Gordó-Vilaseca *et al.*, 2023; Jac *et al.* in review). *Chimaera monstrosa* is classified as 'Near Threatened' by the IUCN Red List for European waters (Dagit and Hareide, 2015) due to its relatively slow maturation, long lifespan, small litters, infrequent reproduction, and tendency to aggregate (Moura *et al.*, 2004; Calis *et al.*, 2005; Holt *et al.*, 2013; Rigby and Simpfendorfer, 2015). Despite measures put in place by the North-East Atlantic Fishery Commission, according to ICES Official Nominal

Catches (http://ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx) *C. monstrosa* continues to be a common bycatch among chondrichthyans in northern waters, with European landings tripled from 2006 to 2021. Thus, it is imperative to assess the population dynamics and resilience of *C. monstrosa* populations.

In this study, we conducted an analysis of *C. monstrosa* using Norwegian survey data from the Institute of Marine Research (IMR) across key ecoregions, including ICES Norwegian Sea Ecoregion (NSE), Barents Sea Ecoregion (BSE), the northern part of the Greater North Sea Ecoregion (GNSE), and the Celtic Seas Ecoregion. We compiled three datasets, one covering data from the most recent five survey years (2018–2022), during which we systematically expanded our sampling efforts for *C. monstrosa* and gathered valuable life-history information. The second dataset spanned from 1984 to 2022, including historical catches from two survey time series and detailed length data. We used Generalized Linear Mixed Effects Models with the 'sdmTMB' package (Anderson *et al.*, 2022; ICES, 2023) to model the spatial aspects of precaudal length (PCL), maturity, and sex. Spatial meshes were constructed using R-INLA. Akaike's information criterion (Akaike, 1974) guided variable determined the crucial factors influencing PCL and maturity, with 'gear,' 'month,' and 'year' treated as random effects for robust models. Regarding the temporal analysis, we assessed *C. monstrosa* abundance and length distribution in the GNSE region using spatio-temporal Generalized Additive Mixed Models. Spatial meshes were generated using R-INLA, providing insights into *C. monstrosa* dynamics in this region over time. The R package used to implement the models is described in detail in Breivik *et al*. (2021).

Our study offers valuable insights into the spatial distribution of rabbitfish length and maturity in the NEA, providing an understanding of their ecology and biology. The initial examination of the data revealed compelling trends and patterns. The data underscores the importance of regulating bottom gears, especially in areas with female rabbitfish aggregations, to reduce bycatch and ensure sustainable fishing practices. Initial analyses also suggest that *Chimaera monstrosa* demonstrates adaptability and resilience as it thrives amid warming NEA waters, showing a notable increase in large individuals in the NSE and BSE regions, indicating hypothetically a success in warming waters. However, potential challenges and uncertainties loom, particularly in the GNSE area, where warming waters (Mackenzie and Schiedek, 2007) may disrupt critical breeding habitats, affect population dynamics, and alter the food web (Kortsch *et al.*, 2015). Regional variations in rabbitfish life history traits call for tailored management strategies. Consequently, our data suggest that conservation efforts should target critical areas and strong aggregations of mature individuals, considering their aggregation behaviour to address vulnerability in specific locations and times. Establishing a conservation baseline for rabbitfish in the NEA is crucial for their long-term sustainability amid climate change and human activities. Our data strongly advocate for the implementation of targeted management strategies to minimize bycatch and protect this valuable marine resource.

This study was carried out by Romaric Jac, Fabian Zimmermann and Claudia Junge as part of the Arctic Sea Rabbit project.

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8 Other work on data-limited approaches (ToR 7 & 8)

8.1 Background

This section summarises work presented at WKLIFE XII on any other data-limited approaches.

8.2 ICES data-limited assessment framework for blackspot seabream (ToRs 7 & 8)

The stock structure of blackspot seabream (*Pagellus bogaraveo*) in the ICES area is still unknown. Thus, for stock assessment and scientific advice on management purposes, ICES considers three different components: a) Subareas 6, 7, and 8; b) Subarea 9, and c) Subarea 10 (Azores region). Based on genetic and tagging studies, blackspot seabream in subarea 10 is considered a stock unit. In the Azores, blackspot seabream has been exploited at least since the 16th century as part of the Azorean demersal fishery, mainly by two fleet components: the handlines and longliners (Pinho *et al.*, 2014). According to ICES, this stock is classified as Category 3, and the rfb rule (ICES, 2022) was applied in 2023. However, the current stock status is still unknown, even though in the Azores, different data sources, such as fishery-dependent and independent, are available. In this sense, the main goal of this academic exercise was to explore the ICES data-limited assessment framework for blackspot seabream in the Azores.

Length-frequency data from the EU Data Collection Framework (DCF) for 1993-2022 was used to explore length-based assessment models, such as LBI (Froese, 2004) and LBSPR (Hordyk *et al.*, 2015), and detailed information about the framework adopted for those models and results is described in Medeiros-Leal *et al.* (2023). The overall findings for LBI (Figure 8.2.1) and LBPSR (Figure 8.2.2) indicate that the fishing pressure for this stock in the Azores exceeded the MSY levels throughout the analyzed time series. However, there has been a slight recovery observed in the most recent years because of several management measures implemented (TAC, minimum landing and hook size, fishing area restrictions) in the Azores (Santos *et al.*, 2019; Medeiros-Leal *et al.*, 2023).

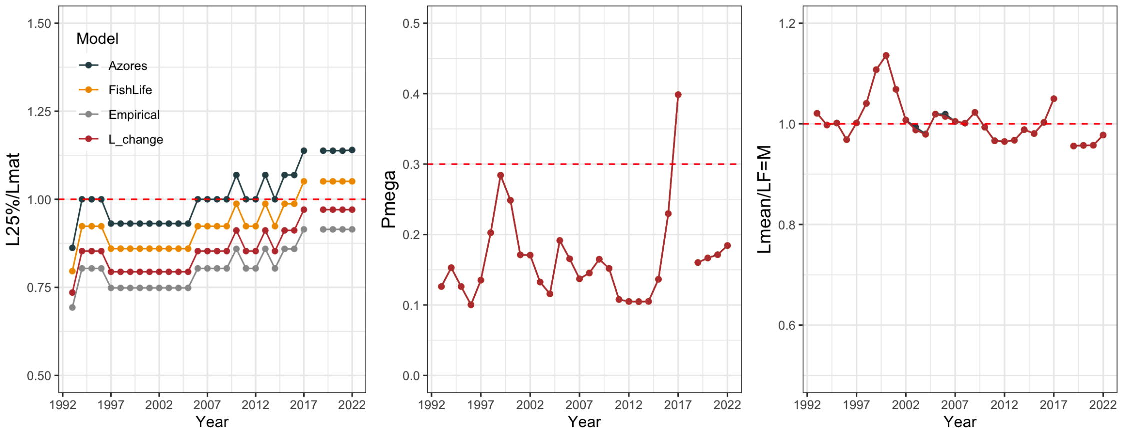

Figure 8.2.1. Indicator ratios and reference points for blackspot seabream Pagellus bogaraveo from the Azorean commercial fishery, derived from the Length-Based Indicators (1993-2022). The colours represent a sensitivity analysis for different inputs values of L_{mat} parameter.

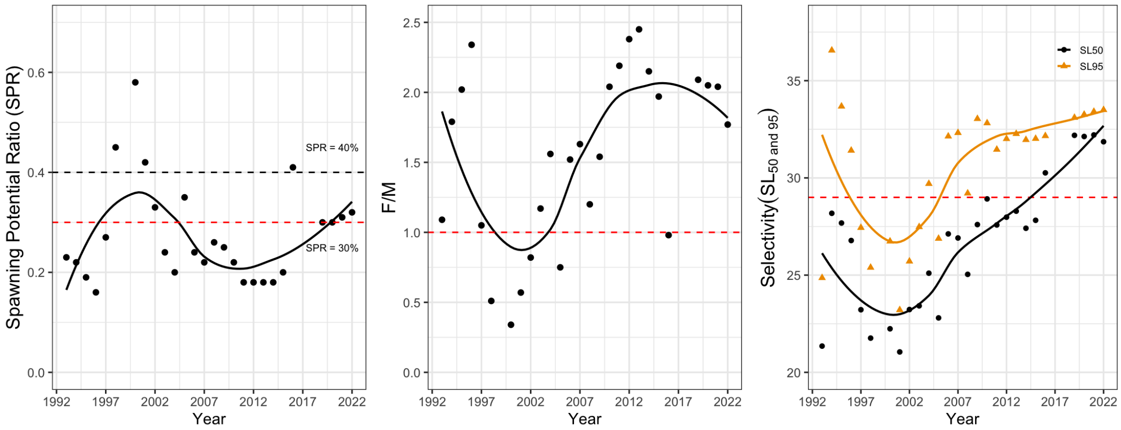

Figure 8.2.2. Plots of spawning potential ratio (SPR), ratio of fishing mortality to natural mortality (F/M), and selectivity parameters (SL50 and SL95) derived from the Length-Based spawning potential ratio method were applied for blackspot seabream Pagellus bogaraveo using the Azorean commercial fishery length-composition (1993-2022). Red dashed lines indicate the threshold values for SPR (= 30%), F/M (= 1), and selectivity (= length at maturity—Lmat). Black dashed lines indicate the threshold values for SPR (= 40%).

The second step in the present academic exercise was to reconstruct and improve the current standardized abundance indices, fishery-dependent (CPUE and LPUE) and independent (Azorean spring bottom longline survey), removing potential biases related to métiers attribution, fleet components, target effect, number of inquiries, and depth distribution. Therefore, the first trials of the SPiCT production model (Pedersen and Berg, 2017) were explored, comparing the old CPUE and LPUE standardization processes (GLM: zero inflated) with two new approaches (GAM + reconstructed indices), using all reconstructed data for CPUE (2003-2022), LPUE (1985-2016), survey (1996-2019), and landings (1985-2022).

The outputs suggested a very significant improvement in the model parameters results (Table 8.2.1), indicating that the new CPUE, LPUE, and survey indices standardization performed better than the previous procedure. On the other hand, the SPiCT model presented a continuous decrease in biomass from 1999 to 2010, with a stable period between 2011 and 2015 and a very slight increase since thereafter (Figure 8.2.3). The management reference points presented similar results, where the relative biomass (B_{2022}/B_{MSY}) and exploitation level (F_{2022}/F_{MSY}) in 2022 ranged from 0.45-0.59 and 0.94-1.20 respectively, indicating that the blackspot seabream fishery in the Azores is in an overfished status (Figure 8.1.3).

This is the first application of an extensive assessment based on the ICES data-limited assessment framework for blackspot seabream in Azorean waters, and all methodologies applied here seem to agree. These results can easily illustrate how regulations and adaptive fishery management could ensure sustainability and help the stock recover from a previous overfishing scenario.

Table 8.2.1. Model parameters and reference points of SPICT model for the blackspot seabream Pagellus bogaraveo from the Azores (Subarea 10) using the old standardization process for CPUE, LPUE and Survey, and the two new approaches.

	CPUE modelling		
	Old_CPUE	**Offset_Effort**	**s_Effort**
	Model parameters		
Sdb	0.006	0.15	0.09
Sdf	0.11	0.16	0.07
Sdc	0.08	0.03	0.08
Sd1	0.09	0.27	0.23

	CPUE modelling		
Sd2	0.58	0.11	0.13
Sd3	0.80	0.67	0.75
	Reference points		
B/B_{MSY}	0.45	0.59	0.54
F/F_{MSY}	1.20	0.94	1.14
F_{MSY}	0.22	0.22	0.16
MSY	926	857	821

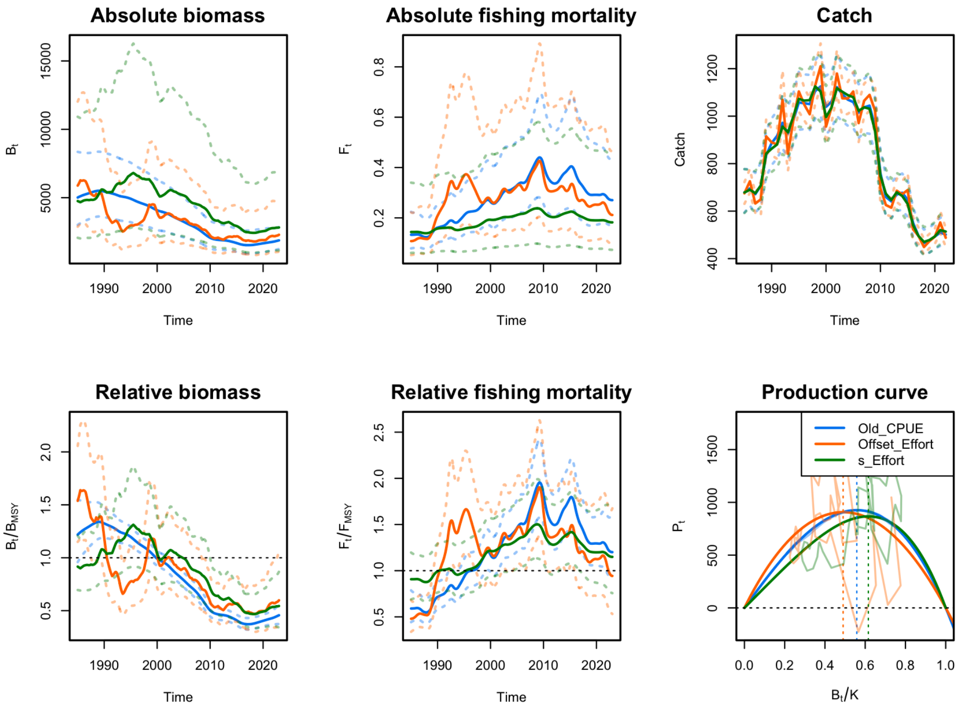

Figure 8.2.3. Basic results of SPICT model for the blackspot seabream *Pagellus bogaraveo* from the Azores (Subarea 10) using the old standardization process for CPUE, LPUE and Survey, and the two new approaches.

8.3 Data-limited methods for Egyptian artisanal Red Sea fisheries (ToRs 7 & 8)

Rehab Farouk Abdelfattah Soliman, PhD student of Queen's University Belfast presented a meta-review of data limited methods (DLMs) to guide choices for evaluating the most common fish stocks in the artisanal fisheries of the Egyptian Red Sea (ERS). The review was further informed by a stakeholder survey covering the artisanal fishery of the ERS, for which the primary regulation is a four-month closed season. A disconnect exists between fishers and managers regarding the purpose and effectiveness of current regulations (paper under review). Previous stock assessments in the ERS revealed over-exploitation of multiple species, prompting a need for additional limitations on the fishing effort.

The PhD studies are exploring alternative management options, such as total allowable catches and alternative controls of fishing effort, based on available data. A review of data-limited methods was conducted, assessing the types of data required, and the reference points generated for management plans. Our survey among fishers found that some fishers are willing to participate in measuring their catch. There is time series data of catches for a few species, and life history traits obtained from surveying the literature.

Our review of appropriate DLMs used a scoring system with four criteria: data availability in the Egyptian Red Sea, track record of previous results, ease of use, and suitability for over-exploited stocks. Each DLM reviewed was assigned a score from 1 to 5 for each of these criteria, with DLMs ranked by their total weighted score. Weightings were based on subjective criteria, but sensitivity tested with Monte-Carlo bootstrapping statistics. The three consistently highest scoring DLMs were LBB, LBSPR, and CMSY. Incorporating fisher-derived data and training for stock assessment personnel were considered important aspects for improved stock management. The next steps involve designing an effective data collection strategy for fisher-derived length frequency data.

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9 Open discussions

9.1 Collaborations and papers

Over the past years, much of the WKLIFE work was done by individual experts or in small groups, mainly from the same institutes. However, participants expressed great interest in collaborating on scientific work and papers together and several ideas for collaborative papers were brought forward and discussed. Ideas for collaborations included:

- The history and future of data-limited advice in ICES
- Advice approach for ICES Category 4-6 stocks

Work on these papers will be conducted intersessionally and progress presented during the next WKLIFE meeting. A full list of collaboration ideas, including the main person to contact, is kept on the WKLIFE SharePoint.

Annex 1: List of participants

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Annex 2: Resolution

The Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII)

The Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XII), chaired by Carl O'Brien (UK), Tobias Mildenberger (Denmark) and Simon Fischer (UK) will meet in Lisbon, Portugal, 16–20 October 2023 (with MS Teams hybrid meeting access). The workshop should address the following Terms of Reference:

9. Support the rollout of the WKLIFE X Category 2 and 3 methods in 2023 and beyond.
    a. Review recommendations (e.g. from WKMSYSPiCT1, WKMSYSPiCT2) and requests for clarification made by ICES groups (e.g. Elasmobranch, Celtic Seas and Deep Seas advisory processes) on the application of the methods presented in WKLIFE X Annex 3 and provide clear and concise feedback on issues raised and incorporate into suggested updates to the ICES Guidance, as appropriate.
    b. Conduct additional analyses if required.
    c. Revisit the multiplier of the rb rule (Method 2.1) and consider alternative multipliers for specific life-history groups.
    d. Consider situations needing zero-catch advice and how to leave zero-catch advice.
    e. Check if the technical guidelines require updating based on recent developments.
    f. Develop an R tool to facilitate and standardise the application of the rfb/rb/chr rule and link the tool to TAF.
10. WKLIFE XI drafted a 5-year roadmap of work required to improve the provision of ICES data-limited advice. Based on this roadmap, map topics to stocks in ICES categories 2-6, prioritise topics depending on ICES requirements and create a work plan for the next years.
11. Initiate a review of the ICES advice framework for categories 4, 5, and 6.
    a. Summarise the ICES stocks in these categories and their advice methods.
    b. Evaluate the current approaches in these categories with respect to risk equivalence and their ability to follow the ICES precautionary approach.
    c. Start exploring alternative approaches for these stocks.
12. Further explore the use of empirical indicators
    a. Explore spatial indicators to inform on stock abundance (e.g. bycatch species) to facilitate their use in harvest control rules.
    b. Consider alternative empirical indicators that could be useful as part of harvest control rules.
13. Evaluate and improve the application of and management advice based on surplus production models, such as SPiCT.
    a. Further develop guidelines for model fitting and validation and the use of priors.
    b. Evaluate alternative definitions of biomass limit and threshold reference points for harvest control rules based on surplus production models.
    c. Explore the implications of dynamic reference points.

  d. Evaluate the incorporation of additional information (e.g. length data) into surplus production models.

14. Explore data-limited stock assessments, harvest control rules (e.g. dynamic harvest rate rules), and simulations approaches for specific life-history strategies
    a. Short-lived species, e.g. Celtic Sea sprat.
    b. Elasmobranchs and other slow-growing species (e.g. thornback ray in Iberian waters, application of SPiCT, simulation of empirical harvest control rules).
    c. Other life-history strategies, e.g. Nephrops, crabs, cephalopods.
15. Further explore and develop assessment and advice methods with focus on data- and/or resource-limited fisheries, together with exploring approaches of moving towards an ecosystem perspective, from both within and outside the ICES' community.
16. Summarize recent work by the scientific community, including published papers and exploratory work on Empirical rules and production models; review and address these publications with respect to ICES advice.

WKLIFE XII will report to ACOM no later than **17 November** 2023.

Annex 3: Sardinian sea urchin

A management plan is being developed for the sea urchin stock in Sardinia. However, data for a formal stock assessment are limited, although information on catch and, effort, individual size, and habitat are available. A diver survey is currently being conducted, which will provide a fishery-independent index of abundance and size data for use in an empirical harvest control rule. The aims of the study are to develop a management strategy based on currently available data and to evaluate the benefits of alternative data sets and knowledge for use in stock assessment. As well as field and fishery sampling schemes, the benefits of tagging, and lab-based studies will be evaluated.

Therefore, we conduct a Management Strategy Evaluation using an Operating Model, that represents the main uncertainties about stock and fleet dynamics, to develop a management strategy that best meets objectives and to evaluate potential assessment methods.

The aim of fisheries management is to ensure that resources are exploited sustainably and that the risk of depletion is at an acceptable level. This requires considering biological but also economic and social objectives. For example, if the status of a stock is poorly known then there is a risk of overfishing and as a consequence, the fishery will be closed, while, precautionary advice to prevent overfishing will set catches low. In both cases, yield will be forgone. Ideally, tiered fisheries management frameworks should ensure risk-equivalence across categories, so that in a situation with poor or limited data and consequently higher uncertainty, management should not permit higher risks (Fischer *et al*., 2023). Risk equivalence permits a formal treatment of uncertainty and allows decisions to be made to maintain a resource within acceptable risk levels (Roux *et al*. 2022), and allows prioritisation of data collection, scientific study and monitoring, control and surveillance.

Adaptive Management

In natural resource management, the importance of adaptive management to reduce the risk of failing to achieve management objectives due to uncertainty has long been recognised (Walters and Hilborn, 1978). Adaptive management learns by doing, so that policies evolve as new observations and information become available (Walters and Holling, 1990). Adaptive management and MSE both consider feedback. Adaptive Management has six steps

1) Problem Assessment
2) Design
3) Implementation
4) Monitoring
5) Evaluation, and
6) Adjustment

In this initial work, we are mainly concerned with the first two steps, problem assessment and design, to develop an advice framework that meets objectives using Management Strategy Evaluation. After implementation, a review should be conducted to evaluate whether the scenarios tested were plausible, the impact of new knowledge, have objectives have been achieved, has the MP performed as designed, and how can improvements be made. This also requires the evaluation of potential assessment methods.

Management Strategy Evaluation

Management Strategy Evaluation helps in the design of robust strategies by testing alternative assessment methods and feedback control rules. This is done by simulation testing Management

Procedures, to ensure that they are able to meet ecological, social and economic objectives despite uncertainty (Sharma *et al*., 2020).

The steps when conducting a Management Strategy are

i) Identify and prioritise objectives, and trade-offs
ii) Selection of hypotheses for the Operating Models (OMs);
iii) Conditioning the OMs based on data and knowledge
iv) Identifying candidate management strategies
v) Running the Management Procedure as a feedback controller to simulate the long-term impact of management; and then
vi) Identifying the Management Procedures that robustly meet management objectives

The components of a Management Procedure represent the collection and analysis of data, assessment methods or empirical rules, and the feedback harvest control rules (HCRs) used to set catch limits. Once implemented, a Management Procedure requires less effort than conducting a stock assessment each time advice is required. This should allow time to gain a better understanding of resource dynamics.

The Operating Model describe the resource dynamics in simulation trials to provide a pragmatic basis for the comparison of assessment methods and management strategies. The Operating Model includes the Observation Error Model, which generates simulated fishery data.

A single reference case Operating Model was developed, using life history theory, parameters are modelled as random variables, including their correlations. This allows the benefits of reducing uncertainty about parameters (epistemic uncertainty) to be evaluated and the benefits of improving priors for use in Bayesian stock assessments (Berger, 1994, Chen *et al*., 2000). A problem with such an approach is a lack of consideration of uncertainty about the processes modelled (ontological uncertainty). Therefore, a robustness set of Operating Models is also conditioned. These are a limited set of scenarios which include the most important uncertainties in the model structure, fixed parameters, and data. These scenarios should have high plausibility and be likely to have major impacts on the performance of the management strategies and assessment methods. A highly plausible scenario is one that fits prior knowledge, with many sources of corroboration, without the complexity of explanation, and with minimal conjecture (Connell *et al*., 2006).

Empirical Indicators

The Operating Model is first used to run simulations without feedback to generate empirical indicators using the Observation Error Model. ROC curves were then used to identify the best indicator using the area under the Receiver Operator Characteristics (ROC) curves

Simulations were run for three scenarios, constant F, a stepwise change and a trend in F. The OM and the simulated data sets are shown in Figure A2.1. Three potential indicators were then generated using the OEM, an index of abundance, a size i.e. a length-based indicator, and relative harvest rate (Catch/Index). The indicators are then compared to the corresponding "known" OM values in Figure A2.2. The corresponding ROC curves are shown in Figure A2.2; the line colour represents the lag between an indicator and the Operating Model quantity.

The area under the curve (AUC) provides a measure of classification skill, i.e. the curve for an index with no skill, a coin toss, would fall along the y=x line and have an AUC of 0.5. A curve with perfect classification would have all true positives and no false positives, and so will pass through the (0,1) point and have an AUC of 1. A ROC curve shows that the harvest rate indicator performs best and that there is a lag in the length-based indicator and abundance index, as it takes several years for the size distribution to respond to a change in fishing mortality. This can be seen in Figure A2.3, which plots the AUC by year after the perturbation in F.

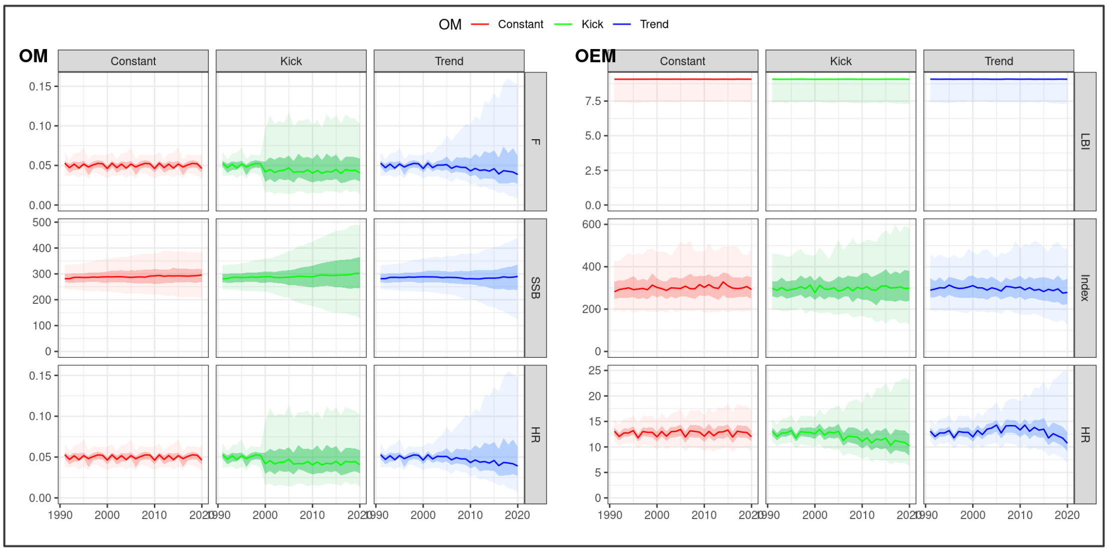

Figure A3.1 A comparison of the Operating (OM) and Observation Error Models (OEM) for indicators for the projections of fishing with stepwise change and trend in fishing mortality. The length-based indicator (LBI) is comparable to F, the index to spawning stock biomass (SSB), and harvest rate (HR) to F. Ribbons show the 33rd to 66th and 10th to 90th percentiles.

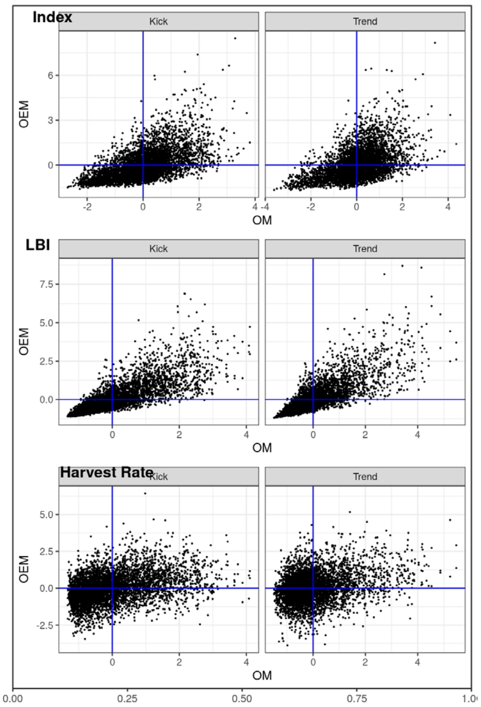

Figure A3.2. Plots of Observation Error Model versus Operating Model for a) survey index, b) L_{mean} length based indicator and c) harvest rate.

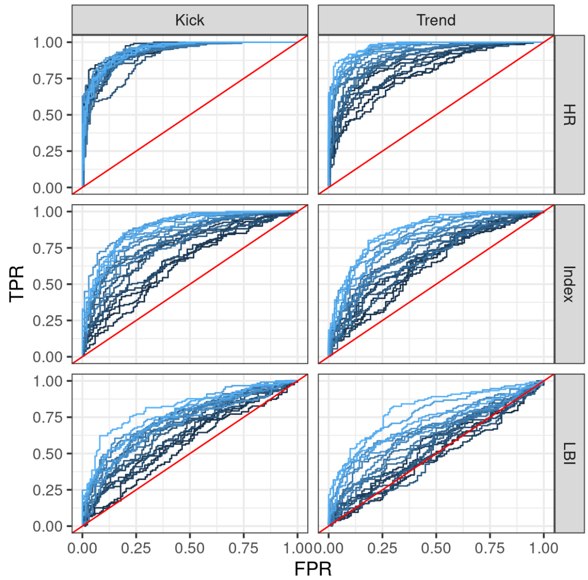

Figure A3.3. Receiver Operator Characteristics curves for a) survey, b) L_{mean} length-based indicator and c) harvest rate. The line colour represents the lag between an indicator and the Operating Model quantity it is an index of.

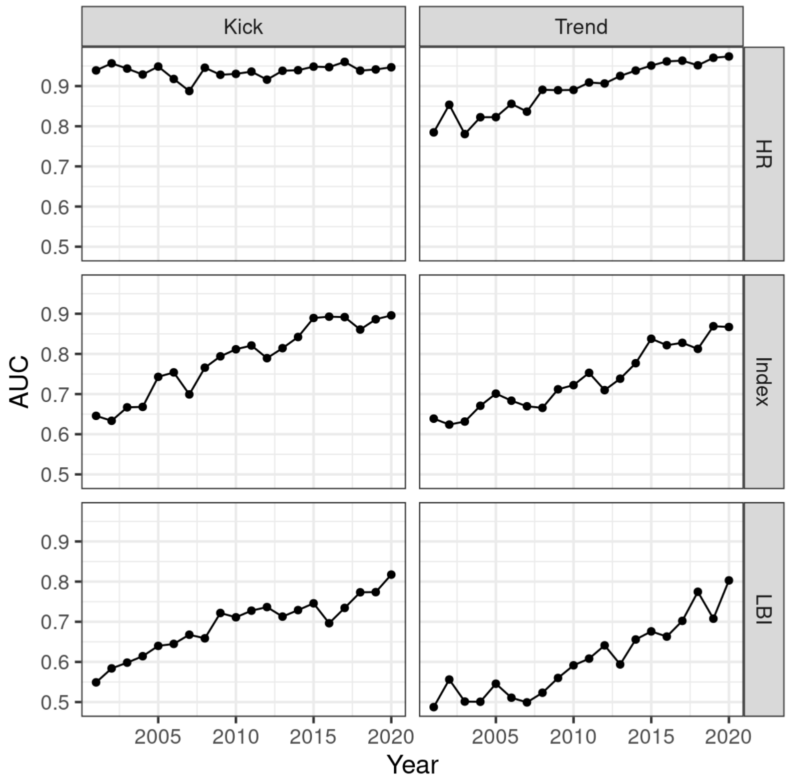

Figure A3.4. Area under the Receiver Operator Characteristics curves for a) survey, b) L_{mean} length based indicator and c) harvest rate. The line colour represents the lag between an indicator and the corresponding Operating Model quantity.

Assessment Methods

After implementation, it is necessary to check whether the Operating Model dynamics were plausible, did the management procedure work as expected, whether were objectives achieved and how can the advice framework be improved. Under Adaptive Management, this corresponds to monitoring, evaluation, and adjustment.

To do this requires conducting a stock assessment, reviewing the historical and current status relative to reference points, and providing advice on the response of the stock to management. Therefore, we use the Operating Model to evaluate potential assessment methods.

The appropriate assessment method depends on the type, length of the time series and the quality of the data. We therefore propose to use a Bayesian biomass dynamic model (JABBA) that can use catch, indices of abundance and effort and harvest rate data. To fit JABBA, priors are required for the production function, initial and subsequent state relative to reference points, catchability, and measure and process error. We therefore used the Operating Model to evaluate the potential data sets and knowledge.

First, we run a single Bayesian assessment and compare priors and posteriors for different prior CVs for population growth rate (r) and data sets (Figures A2.5 and A2.6). Next, the estimates of F_{MSY} (based on harvest rate) and MSY are compared (Figure A2.7 and A2.8).

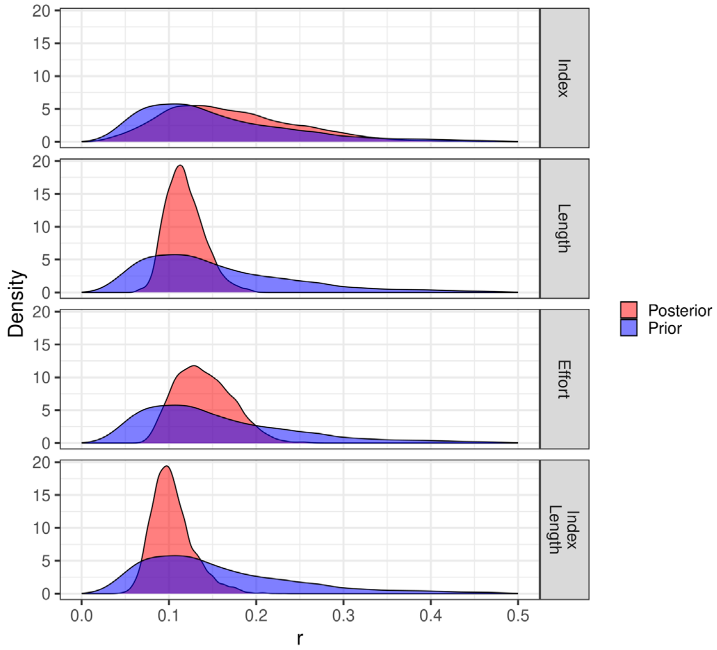

Figure A3.5. r priors with a CV of 60%, compared to posteriors from the biomass dynamic model run with different data sets, i.e. Index of abundance, size as an index of fishing mortality, effort, and the index and size data.

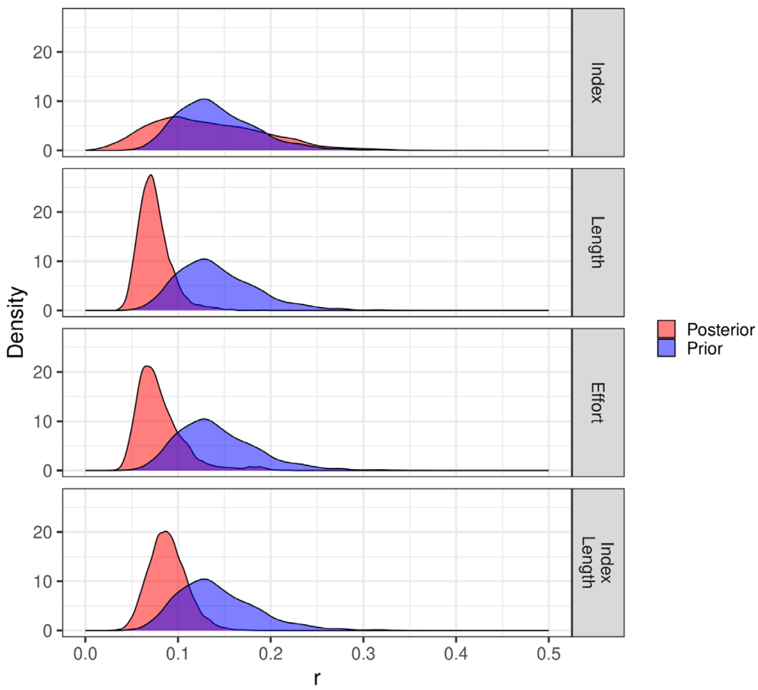

Figure A3.6. r priors with a CV of 30%, compared to posteriors from the biomass dynamic model run with different data sets, i.e. Index of abundance, size as an index of fishing mortality, effort, and the index and size data.

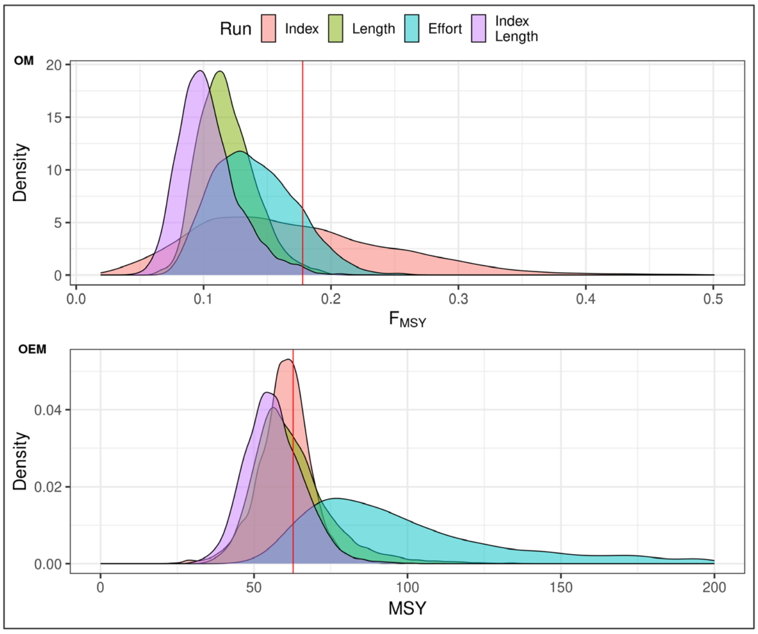

Figure A3.7. Estimates of F_{MSY} and MSY for the biomass dynamic assessment for priors with a CV of 60%.

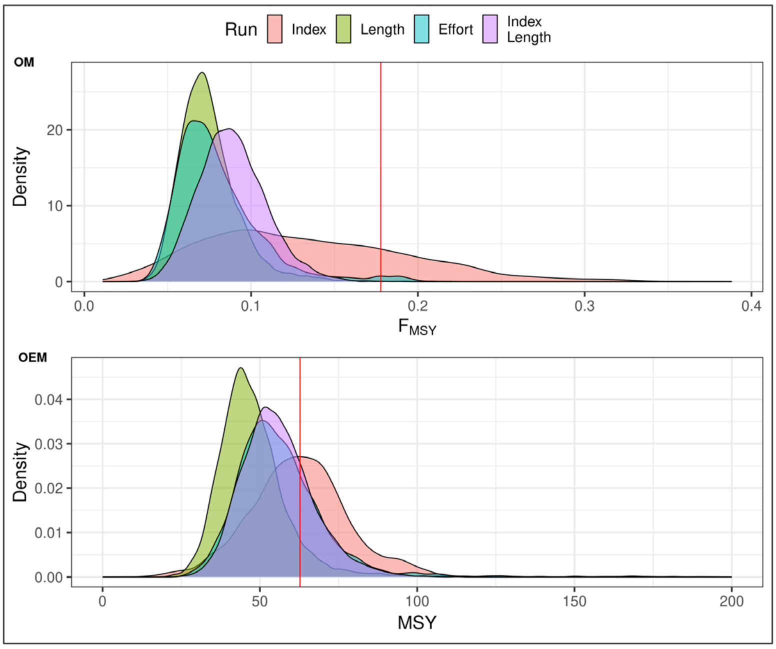

Figure A3.8. Estimates of F_{MSY} and MSY for the biomass dynamic assessment for priors with a CV of 30%.

Following the single assessment runs, JABBA was run for multiple trials for different types and lengths of data.

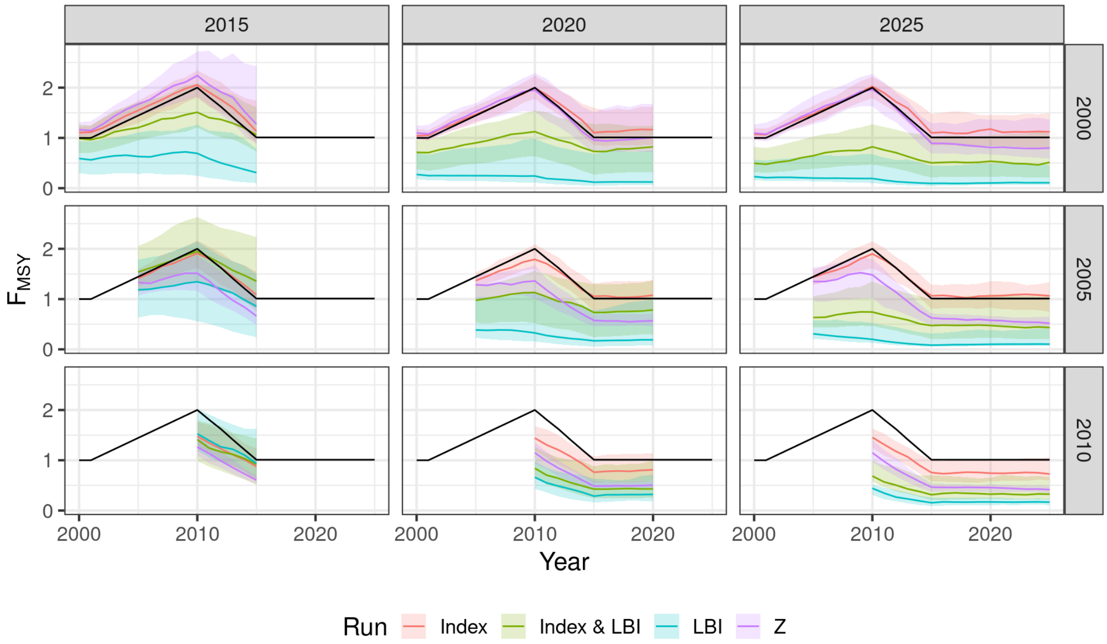

Figure A3.8. Comparison of estimates of fishing mortality.

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Annex 4: Short-lived species: Celtic Sea sprat

Contributor: Laurie Kell

The Celtic Sea sprat case study is an attempt to explore harvest control rules and simulation approaches for short-lived species with key roles in the ecosystem. Sprat is a key forage fish in the Celtic Sea ecosystem, forming an important part of the food chain for key predatory species, including mackerel (*Scomber scombrus*), whiting (*Merlangius merlangus*), Atlantic cod (*Gadus morhua*), horse mackerel (*Trachurus trachurus*), marine mammals and birds. However, there is insufficient understanding, information and data on the sprat populations in the Celtic Seas region to be able to provide robust advice on current status or on potential changes in productivity in the short to medium timeframes. Therefore, ICES held a Workshop to develop a research roadmap for Channel and Celtic seas sprat (WKRRCCSS, ICES, 2023). The aims were to identify and prioritise potential and existing data sets, assessment methods, and advice needs of fisheries managers and stakeholders that take their role in ecosystem functioning into account. The roadmap will help deliver future research to underpin the scientific advice on the management of the fisheries. Components of the roadmap include considering **Wider Ecosystem Questions and Improving Advice for Management**.

ICES Advice for Category 3 stocks is based on the "rfb" harvest control rule, where indices are available for biomass (r) and fishing mortality (f, e.g. derived from length data), along with "b" a biomass cut-off where the catch is reduced if the biomass index falls below a threshold (Fischer *et al*., 2020). The ICES Workshop on Data-limited Stocks of Short-lived Species (WKDLSSLS, ICES, 2019), however, concluded that the rfb-rule did not work well for faster-growing species such as sprat, as in these cases the rule resulted in poor management performance, i.e. high risks of stock collapse and low yields. Instead, it was recommended to use harvest rate-based rules and escapement strategies. Sánchez-Maroño *et al*. (2021) found that the shorter the lag between observations, advice and management, the smaller the biological risks and the higher the catches.

Therefore, as part of the roadmap, a Management Strategy Evaluation framework has been developed to evaluate alternative HCRs, including in-year advice based on an acoustic survey, catch and relative harvest rate. The Operating Model is seasonal allows the incorporation of environmental drivers, and was conditioned on life-history theory and strategic information from an ecosystem model. The objective is to show how ecosystem understanding can be incorporated within existing precautionary and maximum sustainable yield frameworks to provide a robust management framework that can meet multiple objectives despite uncertainty.

Three potential indicators were evaluated, an acoustic survey, L_{mean}, a length-based indicator, and relative harvest rate (H). If a survey (I) is considered an absolute index of abundance, catch divided by the index will also be an absolute estimate of harvest rate (C/I). The relative harvest rate (H) is defined as the ratio of the catch (C) divided by a stock size indicator (I), e.g. a biomass index:

$$H_{y+1} = C_y/I_y$$

The three indicators were compared using Receiver Operator Characteristics curves in Figure A3.1. The lines are for different lags between the indicator and the quantity it is a proxy for. The area under the curve (AUC) provides a measure of classification skill, i.e. the curve for an index with no skill, a coin toss, would fall along the y=x line and have an AUC of 0.5. A curve with perfect classification would have all true positives and no false positives, and so will pass through the (0,1) point and have an AUC of 1. A comparison of the curves shows that the harvest rate indicator performs best. There is a lag for the length-based indicator, as in 2021, the year when the fishing mortality is perturbed has no classification skill, however. Skill improves over time, as it takes a few years for the increase in fishing mortality to have an effect on the size distribution of older ages.

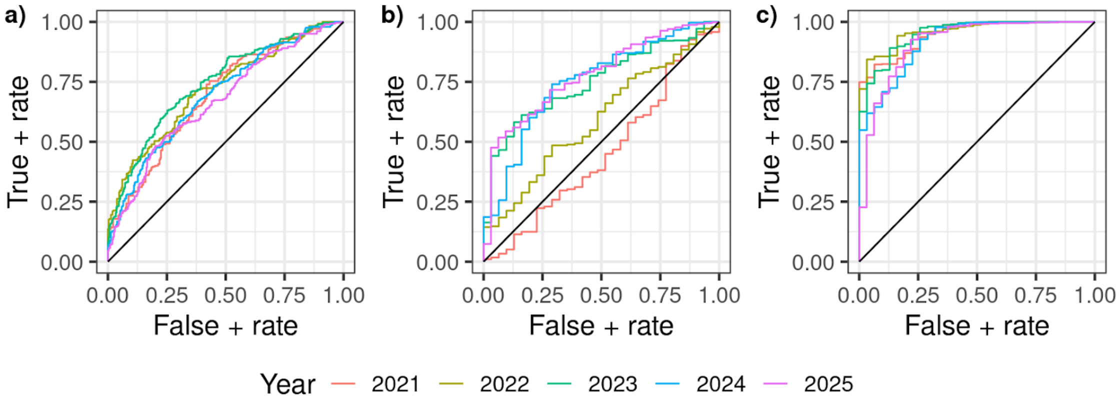

Figure A4.1 Receiver Operator Characteristics curves for a) survey, b) Lmean length based indicator and c) harvest rate, line colour represents the lag between an indicator and the Operating Model quantity it is an index of.

ROC curves allow the screening of potential indicators so that it is not necessary to run a large suite of candidate management procedures. Based on this analysis, a relative harvest rate control rule was chosen for evaluation (Figure A3.2)

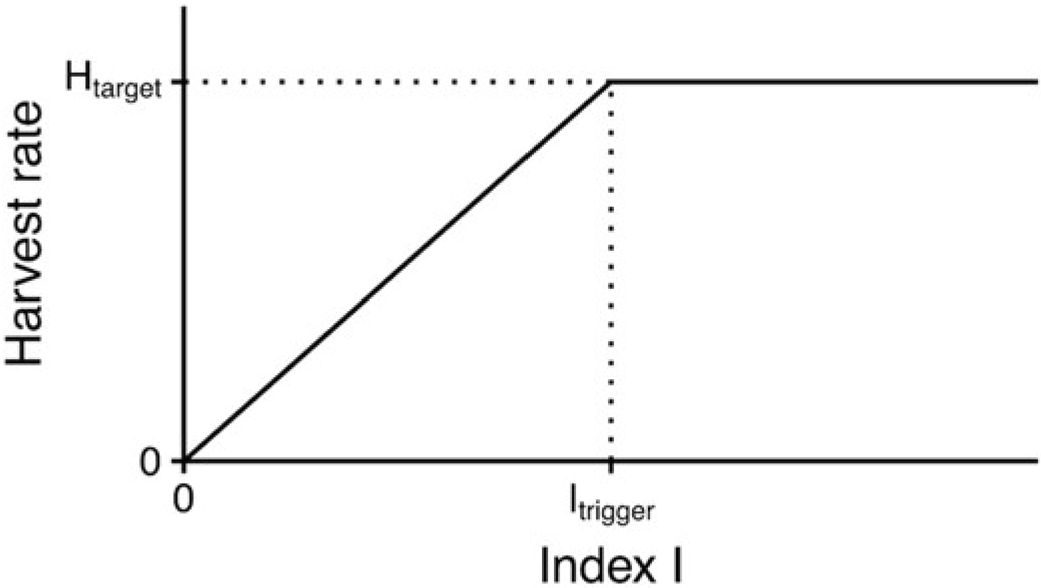

Figure A3.2. Harvest control rule, sets the harvest rate (H) based on an index (I), below the trigger value ($I_{trigger}$) the harvest rate is reduced linearly to 0.

Four different target harvest rates, i.e. 25, 50, 100 and 150% of F_{MSY} were evaluated, for Operating Model scenarios that evaluated the impact of changes in recruitment due to external drivers, or a shock manifested as a one-off increase in natural mortality (e.g. Bastardie *et al.*, 2021).

The results for SSB relative to Blim are presented in Figure 6.a.3, boxes correspond to the 33rd to 66th percentiles with the median and the whisker extends to the 5th percentile. For a strategy to meet the precautionary objective, the whisker should not cross the reference line, set as the biomass at which recruitment is 30% of virgin recruitment. The red box is for the simple projection (intended as a benchmark)., and the four rules, BR is the HCR that uses a biomass rule and HR is the relative harvest rate rule, the number represents the lag either 0, i.e. in-year, or 1 advice is provided for the following year.

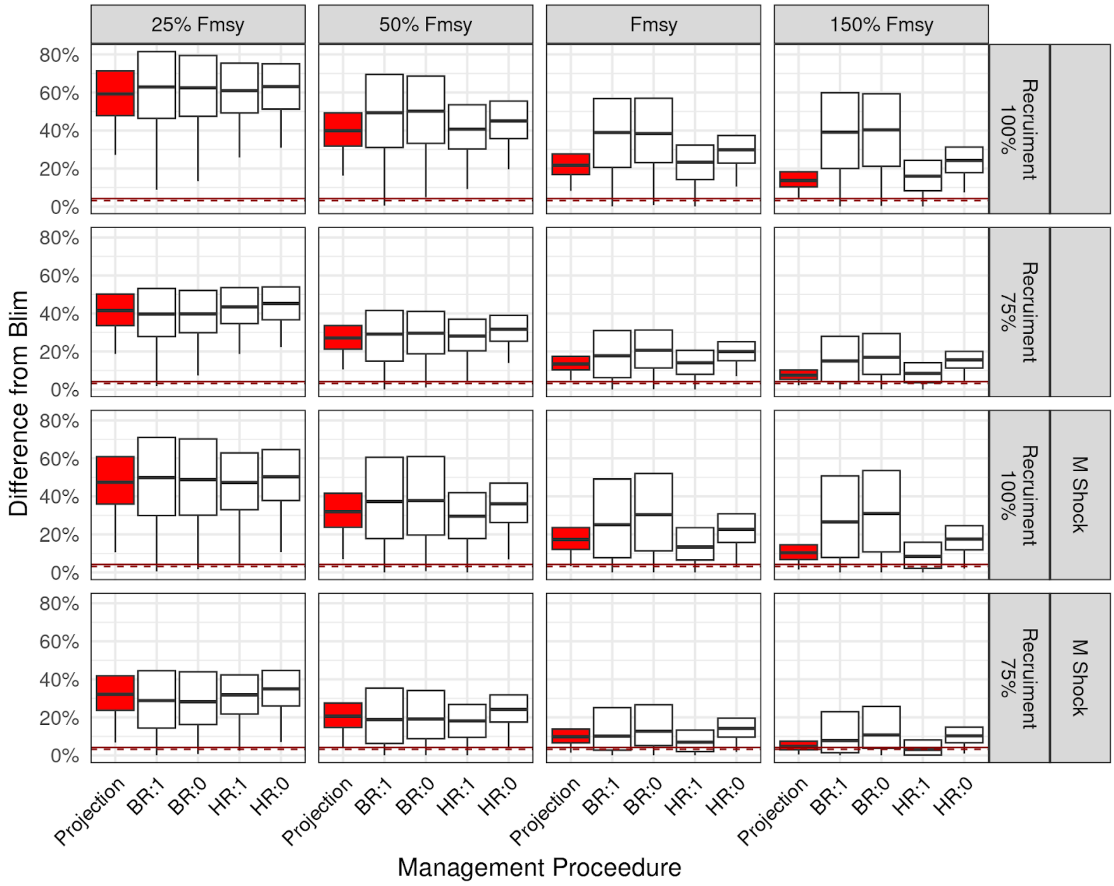

Figure A4.3. Summaries of SSB relative to the reference case virgin level, for the four Operating Models (1st row is the reference case) and the different target F levels for the projection and control rules; boxes correspond to the 33rd to 66th percentiles with the median and the whisker extends to the 5th percentile.

If recruitment does not change and there is no M shock, (row 1) then if the target F is 25%F_{MSY} all rules achieve the objective, However, if F is 50%F_{MSY} then the BR rules fail, while for F_{MSY} and 150%F_{MSY} only the in-year harvest rate rule (HR:0) achieves the objective. The only rule that is robust for the recruitment and M scenarios is the HR:0 rule. These results confirm the ROC analysis.

The simulations showed

- How ROC curves can be used to screen potential indicators for use in empirical control rules, meaning that the number of simulations of alternative control rules can be reduced, and more resources are devoted to evaluating robustness by conditioning reference sets of Operating Models.
- That a harvest rate control rule can meet MSY and PA objectives
- That an in-year advice rule is more robust than using the survey to set advice for the following year.

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Annex 5: Considerations towards an ecosystem perspective

Contributor: Laurie Kell

A potential first step to help move towards an ecosystem perspective is to implement an Ecosystem Approach to Fisheries Management, where ecosystem factors are considered as part of single-species advice. A way to do this in the short term is to integrate ecosystem information into traditional single-species stock assessment and management frameworks (e.g., Howell et al., 2021). For example, by extending the ICES single species assessment advice framework, based on Maximum Sustainable Yield (MSY) and the Precautionary Approach (PA), to include ecosystem objectives and communicate trade-offs.

To explore data-limited harvest control rules and simulation approaches for short-lived species with key ecosystem roles, a stress test was performed by conducting a Management Strategy Evaluation (MSE) for Celtic Seas Sprat. Where ecosystem reference points (ERPs) were defined, then the risk of not achieving them under the ICES advice rule due to uncertainty was assessed. The approach is being further developed for North Atlantic Mackerel to test the generality of the approach.

Sprat are commercially valuable and a key component of the North East Atlantic ecosystem as major predators of zooplankton, competitors amongst others for herring, and prey for piscivorous fish, marine mammals, and seabirds. Despite this, insufficient information exists for Celtic Seas sprat, one of five North East Atlantic stocks, to estimate stock status and reference points.

There are several ways in which ecosystem objectives can be explicitly considered in MSE (Figure A4.1). The choice depends on the level of knowledge, data and models available (de Moor, 2023).

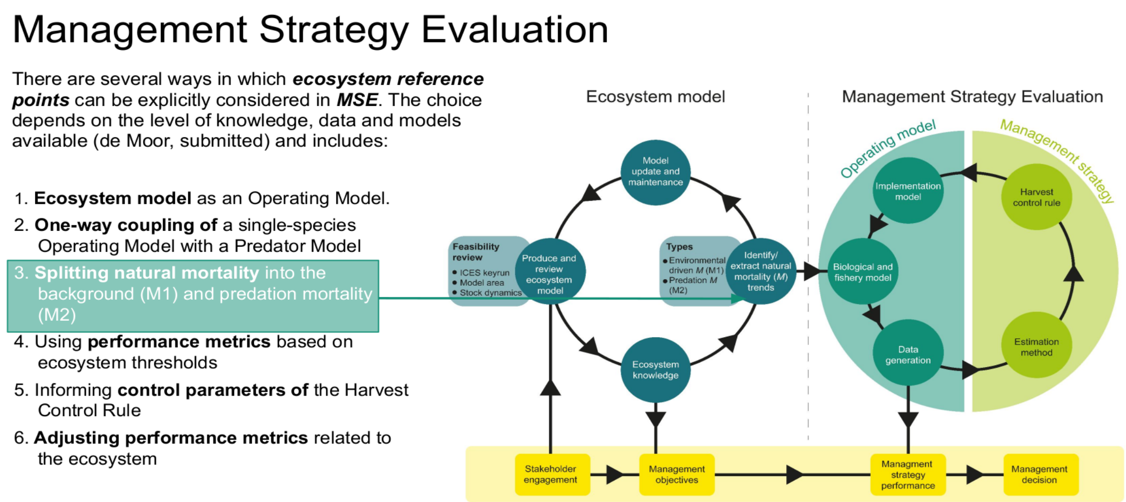

Figure A5.1 Summary of how ecosystem reference points can be considered as part of single species advice.

We chose option 3, and developed a single-species Operating Model by splitting natural mortality into background (M1) and predation (M2) mortalities. Both M1 and M2 are informed by strategic information from the Irish Sea Ecopath with Ecosim (EwE) model. We then compare the performance of alternative advice rules for performance metrics based on PA, MSY and ecosystem objectives (i.e., forage: the biomass of prey left in the system for consumption by predators). This allows an evaluation of whether ecosystem objectives are still achieved under the current MSY and PA advice rules, and the incorporation of indirect and direct drivers of change, e.g. environmental impacts and changes in predator populations. Alternative empirical harvest control rules were then evaluated. There were two forms of the rule, a biomass rule (BR), and a relative harvest rate rule (HR), run either immediately after the survey (a lag of 0) or the following year (lag 1).

As an example of an ecosystem reference point, we used "predator ration" based on the biomass lost to the stock due to M2. This is equivalent to how yield to the fishery is calculated, i.e. as

$$R = \sum_{i=0}^{n} W_i N_i M2_i / Z_i (1 - \exp(-Z_i))$$

Where W is the mass-at-age, N is the numbers-at-age, M2 is predation mortality, and Z is the total mortality.

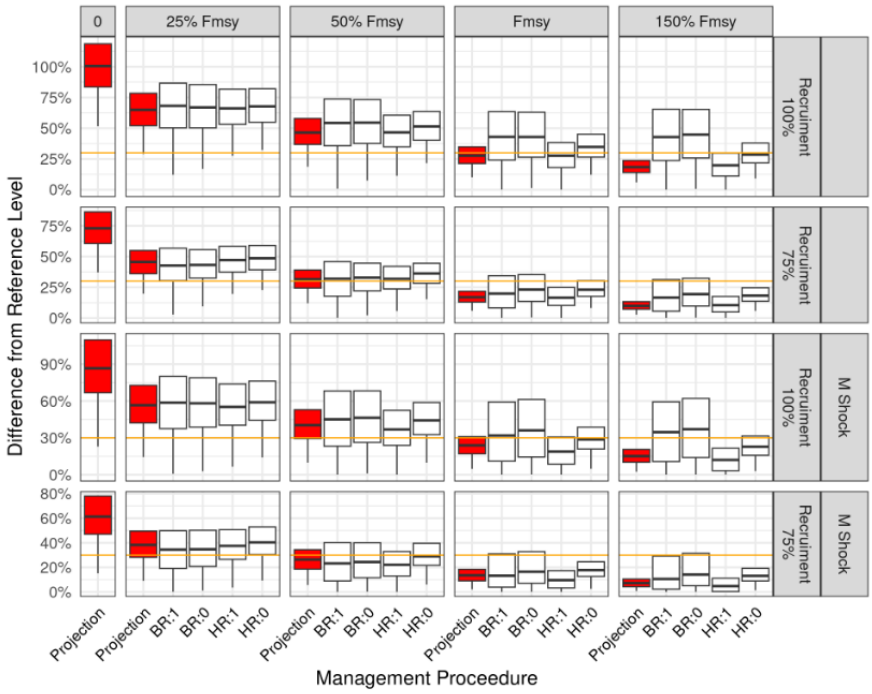

Figure A5.2. Summaries of forage relative to forage available in the unfished reference case, for the four Operating LBI Models (1st row is the reference case) and the different target F levels for the projection and control rules; boxes correspond to the 33rd to 66th percentiles with the median and the whisker extends to the 5th percentile.

The results for predator needs are summarised in Figure A4.2, by Operating Model Scenario (rows) and target F level (columns). As a benchmark, the control rules are compared to a projection (red boxplot). Operating Model scenarios evaluated the impact of changes in recruitment due to external drivers, or a shock manifested as a one-off increase in natural mortality (e.g. Bastardie, *et al.*, 2021). Four different target harvest rates, i.e. 25, 50, 100 and 150% of FMSY were evaluated. The boxes correspond to the 33rd to 66th percentiles, with the median, and the whisker extending to the 5th percentile. The horizontal reference line is 30% of the predator ration at F=0 from the simple projection. Although this is arbitrarily set, so is the level of recruitment impairment used to set B_{lim} in the trials conducted to develop the ICES rfb rule (Fischer *et al.*, 2022), it provides a framework and starting point for discussion between stakeholders which is flexible relative to alternate policy commitments (e.g., Good Environmental Status) and specific predator needs for resilience and/or recovery.

In this example, we assume that for a strategy to meet an ecosystem precautionary objective, there should be a greater than 95% chance of the stock remaining above 30% of the forage available from an unfished stock, i.e. the whisker should not cross the reference line. Although somewhat arbitrary provides a basis for discussion, and is not unlike how the sustainability performance metric was set based on B_{lim} by Fischer *et al*., (2021), where Blim was set to be the level of SSB where recruitment was 30% of virgin. One-way coupling of an ecosystem model could be used to assess the potential impact on predator populations.

If the recruitment level does not change (1st row) then only HR:0 achieves the ecosystem objective; as the target fishing level increases, the level of forage available declines. The biomass rules (BR) produce more variability. If recruitment is impaired then the level of forage available for predators is reduced, while if there is a shock in M then the variability for the biomass rule (BR) increases. The in-year harvest rate rule (HR:0) achieves a higher level of forage with less variability. Therefore, the most robust rule is the HR:0 rule.

Northeast Atlantic forage fish stocks, with internationally managed fisheries, deliver important social and economic benefits while supporting marine ecosystems' health and resilience. Pragmatic steps that account for predators' needs and the influence of environmental variation on stock production are needed to operationalise an ecosystem-based approach to fisheries management for such shared stocks. Therefore, the development of approaches that incorporate ecosystem complexity with practical assessment and management options is becoming increasingly important. Implementing an ecosystem approach requires working with stakeholders to agree on Operating Model scenarios, and ecosystem modellers to condition these Operating Models, and then to achieve overall agreement on the performance metrics for predator needs. Once completed, the framework can then be developed to provide ecosystem reference points and strategic information to support decision-makers with knowledge of the trade-offs between objectives for MSY and ecosystem recovery.

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Annex 6: Challenges developing ad-hoc MSE for Sole in division 8.c and 9.a

Working document to the Workshop 12 on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFEXII) 16–20 October 2023

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Abstract:

The common sole (Solea solea) is a valuable fish species in the Iberian Atlantic waters (ICES Subdivisions 8.c and 9.a) but concerns have arisen regarding the performance of the current harvest control rule, the rfb rule (method 2.1 in ICES, 2022), as it resulted in substantial advised catch reductions of 36% in 2021 and 35% in 2023. These results are in contrast with the datapoor assessment methods results which suggested compatibility with sustainable stock exploitation. Consequently, we have decided to explore a proposal for a new catch rule that may work better for the common sole. Hence, we are currently in the process of developing an ad-hoc Management Strategy Evaluation (MSE). For that we use the Fisheries Library in R (FLR project) and also the knowledge and code available at Fisher et al. (2020) and Fisher et al. (2021) where a MSE procedure has been developed for analyzing the performance of the rfb rule. This working document outlines the initial stages of our ad-hoc MSE for common sole in Iberian Atlantic waters, highlighting the challenges faced.

Introduction

The common sole (*Solea solea*, Linnaeus, 1758) is a species of flatfish which is widely distributed in Northeast Atlantic shelf waters, from the northwest of Africa to southern Norway, including the North Sea, the western Baltic and the Mediterranean Sea. Inhabiting sandy and muddy bottoms (Quero et al., 1986), this species is generally targeted by multi-species fleets (gillnetters and trawlers) and has traditionally been considered of great relevance due to its high commercial value (Teixeira and Cabral, 2010).

The unit management of the common sole stock in the Iberian Atlantic waters includes the ICES Subdivisions 8.c and 9.a. Actually, this sole stock is considered in category 3 since 2021 and its advice is derived using the *rfb* rule (method 2.1 in ICES, 2022; catch rule simulation-test at Fischer et al., 2020). This harvest control rule (HCR) provides advice based on the stock trend from a biomass index, the mean length in the catch relative to an MSY length proxy and a biomass safeguard to ensure compliance with ICES precautionary approach. More precisely, the *rfb* catch rule is defined as

$$A_{y+1} = C_{y-1} \times r \times f \times b \times m,$$

where the advised catch for next year A_{y+1} is based on the most recent year's observed catch C_{y-1} adjusted by the following components:

$$r = \frac{\sum_{i=y-2}^{y-1} (I_i/2)}{\sum_{i=y-5}^{y-3} (I_i/3)},\ f = \frac{L_{y-1}}{L_{F=M}},\ b = min\left\{1, \frac{I_{y-1}}{I_{trigger}}\right\}$$

being I_i the biomass index, $\underline{L}_{y-1}$ the mean catch length above the length of first capture and $L_{F=M}$ a theoretical MSY reference length, proposed by Beverton and Holt (1957), and $I_{trigger} = 1.4\, I_{loss}$, where I_{loss} is the lowest observed biomass index value. The m component is set at 0.9 since this is the recommended value for medium-lived stocks with k in $[0.2, 0.32]$ as the common sole. Finally, it is important to mention that, when $b \geq 1$ a stability clause limiting the catch advised change to +20% and -30% of the previous catch advice is applied.

As previously stated, the *rfb* rule was first applied to advise common sole 8c.9a catches in 2021 by the Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE 2021) after the benchmark workshop on selected stocks in the western waters in 2021 (WKWEST; ICES, 2021). The group's decision established that catches should not exceed 320 tonnes for each of the years 2022 and 2023, leading to a 36% reduction from the 2021 catch advice of 502 tonnes, derived from the precautionary approach for stocks in category 5.

Similarly, the WGBIE decision on 2023 established that catches should not exceed 209 tonnes for each of the years 2024 and 2025, leading to a 35% reduction from the 2023 catch advice of 320 tonnes. In Table 1, you can observe the values of each of the *rfb* components for its 2021 and 2023 applications. Notably, the two components based on the index remain below 1 in both years, while the component based on the length in the catches exceeds 1.

The fact that the length-based component (f) exceeds one is consistent with the findings derived from data poor length-based methods. Particularly, the following methods were applied for common sole: Length-Based Indicators (LBI; Froese, 2004; ICES, 2015), the Length-Based Spawning Potential Ratio (LBSPR; Hordyk et al., 2015) and the mean length-based mortality estimators (MLZ; Then et al., 2018). All three methods yielded results that are in accordance with a sustainable exploitation of the stock.

On the other hand, two biomass indices are available for this stock: a standardized commercial LPUE (Landings per Unit of Effort) from Portugal and a standardized biomass index from the Spanish IBTS-Q4 bottom-trawl survey (G2784). This last index is provided by applying a spatio-temporal Bayesian model to the raw data of the survey. Among these two options considered for use in the *rfb* rule, the decision, made in the WKWEST 2021 benchmark, was to use a weighted sum of the Portuguese LPUE and the Spanish Bayesian survey index. The weights vary by year in accordance with the percentage of catches from each of the countries. Figure 1 displays the combined index, which is utilized to derive the index-based component (r, b) of the catch rule. We can observe a decreasing trend in the combined index from 2013, which aligns with the r and b values. However, while the index has decreased by 31% (percentage of difference between the 2013 and 2021 values), the advised catch has been reduced from 502 to 209 tonnes which corresponds to a 58% decrease.

As a result, it appears that the *rfb* rule could be overly conservative in managing the catch of common sole. This is further supported by the data-poor methods LBI and LBSPR, which indicate that the length compositions align with a MSY (Maximum Sustainable Yield) exploitation scenario. Consequently, the objective is to propose a new catch rule that may better suit the common sole. To achieve this, we are in the process of developing an ad-hoc Management Strategy Evaluation (MSE) procedure and this document aims to outline the initial stages of this process, with a specific focus on challenges encountered along the way.

The rest of this document is organized as follows. First, provide an overview of the general materials and methods utilized during the early stages of MSE development. Then, the preliminary operating models are defined while open questions and related doubts are highlighted. Following that, the sampling process is described, emphasizing the decisions made in this regard. Subsequently, our attention turns to an analysis of the implementation of the *rfb* rule in the R code, along with the presentation of initial concepts for new catch rule definitions, including opportunities to address open issues. Finally, we discuss which metrics to evaluate the proposed catch rules may be more suitable in our study.

Component	2021	2023

r	0.90	0.85
m	0.90	0.90
f	1.03	1.04
b	0.91	0.82

Table 1: Values of the *rfb* rule components for common sole in 2021 and 2023 applications

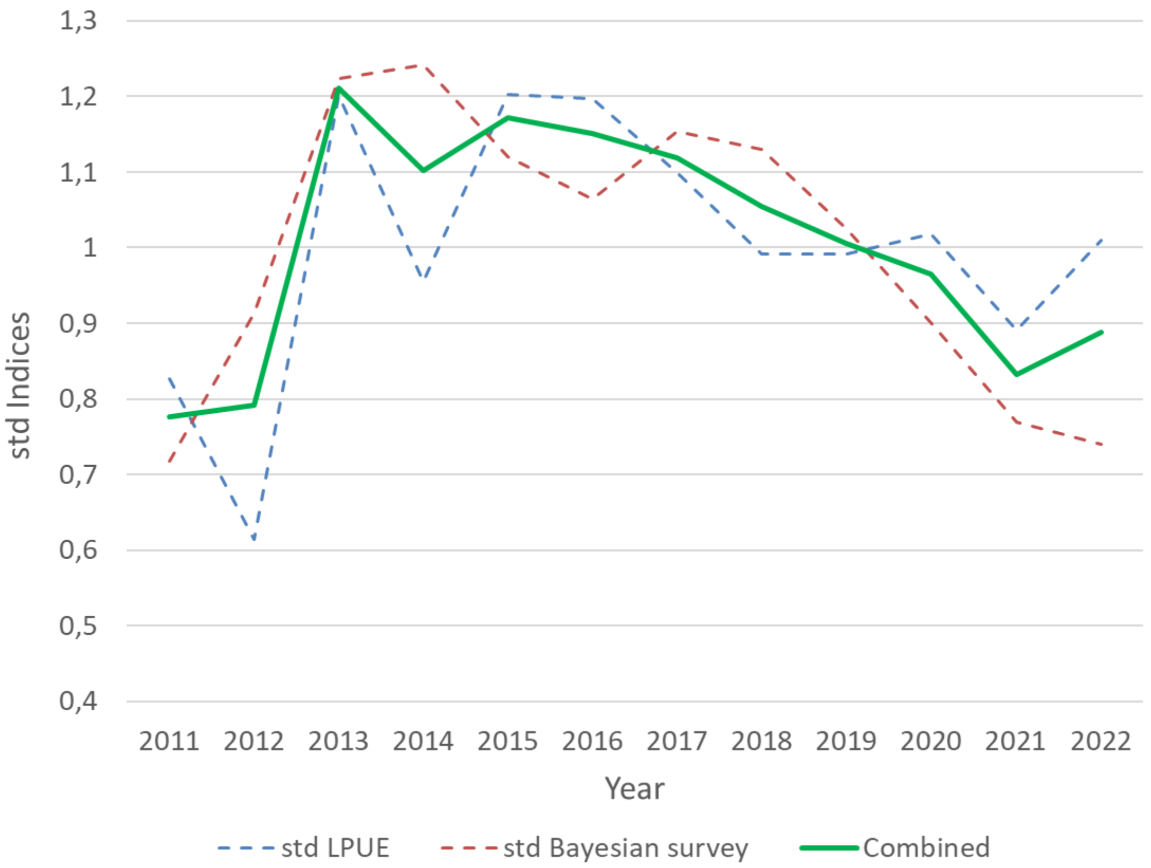

Figure 1: Portuguese LPUE (std LPUE), Spanish Bayesian survey index (std Bayesian survey) and their combined version through a weighted sum where the weights vary by year in accordance with the percentage of catches from each of the countries.

Material and methods

The initial phase of the MSE procedure involves the creation of the Operational Models (OMs). For that, we use the Fisheries Library in R (FLR, Kell et al., 2007) software and the FLR package FLife to simulate stocks based on life-history parameters. More specifically, in the initial stage of the common sole MSE, we create age-structured OMs using the FLife package and the following life-history parameters: allometric parameters for length–weight, a and b

relationship, von Bertalanffy growth model parameters L_∞, k, and t_0, and length at 50% maturity L_{50}. The code used for this purpose is based on the code developed by Fisher et al. (2020), which can be found at https://github.com/shfischer/wklifeVII, and was created to assess the performance of the *rfb* rule through simulations across twenty-nine fish stocks covering a wide range of life histories.
In the considered OMs, growth was modelled with the von Bertalanffy growth equation, recruitment by a Beverton–Holt stock recruit function, virgin SSB set to 1000 (units) for all stocks, the maximum age a_{max} and plus-group set as the age (rounded up) where the stock reached 95% of L_∞, maturity modelled with a sigmoid function centered on a_{50}, and fisheries selectivity modelled as a logistic function. The age range for computing *fbar* has been set to 2-9, based on the overall length frequency distribution (LFD) computed from common sole commercial catches from 2011–2021. Further details regarding key aspects of the OMs are discussed in the following section.

Once OMs have been established, the sampling process should be carried out. At this stage, we integrate the approaches and codes presented by Fisher et al. (2020) and Fisher et al. (2021) to develop a unified and adapted code that provides an index of relative biomass and length frequency distributions for simulated common sole stocks. The code derived from Fisher et al. (2021) can be found at https://github.com/shfischer/GA_MSE_PA/tree/PA and includes an updated version of Fisher et al. (2020)'s code, designed to assess the performance of an optimized *rfb* rule using a genetic algorithm. Specific details about the LFDs and index definitions are provided in the sampling section below.

Finally, the calculation of the original *rfb* rule and also of our proposal (detailed in section “Catch rule definitions”) is carried out based on Fisher et al. (2021) code, also the stock projection based on the catch rule value is runned based on such code using the mse FLR package.

Operating Models

While there are numerous processes to consider when defining the OMs, we have prioritized the following processes and parameters as the initial focal points: recruitment variability, steepness of the Beverton-Holt model, growth through von Bertalanffy parameters and natural mortality.

In our MSE framework, the source of stochasticity in the OM comes from the recruitment variability. Therefore, the selection of suitable values for the coefficient of variability (CV) in recruitment emerges as a crucial consideration in the OMs definition. Consequently, an analysis of the variability within the recruitment estimates of ICES data-rich sole stocks has been conducted. More precisely, we computed the CV associated to the recruitment time series estimates of each one of the following sole stocks: sol.27.20-24, sol.27.4, sol.27.7a, sol.27.7d, sol.27.7e, sol.27.7fg and sol.27.8ab. Finally, the CV’s are summarized by calculating their median, along with the 20th and 80th percentiles, thereby offering both extreme values, one on the lower end and another on the upper, with the median representing a plausible value for recruitment variability. The values obtained, and consequently, those taken into consideration in the definition of the set of OMs, are as follows: 0.36 for the 20th percentile, 0.43 for the median, and 0.78 for the 80th percentile.

The steepness of the stock-recruitment relationship plays a key role in assessing the risks associated with different management strategies. A steeper curve indicates the ability of the population to recover quickly from low stock sizes, thus reducing the risk of population collapse. Hence, the incorporation of OMs that consider a range of steepness values is essential. Then, we have adopted three values, according to the median, 20th percentile and 80th percentile extracted from the steepness values obtained by Myers (2011) for different stocks of *Solea solea*. These values are as follows: 0.72 for the 20th percentile, 0.84 representing the median, and 0.91 for the 80th percentile. We expect this approach to ensure a comprehensive representation of steepness variability, improving the robustness of our management strategy framework.

Von Bertalanffy growth parameters provide essential information about age and length stock structure. In particular, in our simulation framework, they also defined the maximum age, set as the age corresponding to a length equal to $0.95 \times L_\infty$, i.e., $a_{max} = -ln(0.05)/k + t_0$. Hence, their values in the OMs should be selected with caution. As a first option, we have taken into account the study conducted by Teixeira and Cabral (2010). In their research, von Bertalanffy growth parameters L_∞, k, and t_0 were derived for common sole using data collected between January 2003 and June 2005 from commercial fishing vessels operating along the Portuguese coast (division 8c). The study provides sex-specific estimates that we summarized through their mean: $L_\infty = (L_{\infty,female} + L_{\infty,male})/2 = (52.15 + 46.69)/2 = 49.4$

$$k = (k_{female} + k_{male})/2 = (0.23 + 0.21)/2 = 0.22$$

$$t_0 = (t_{0,female} + t_{0,male})/2 = (-0.11 + -1.57)/2 = -0.84$$

While these values may be suitable for describing the growth of our common sole stock in divisions 8c and 9a, it is also imperative to create operational models that consider alternative values. Then, we have looked for alternative information regarding growth, for instance, from other *Solea solea* stocks like common sole in divisions 8a-b, but unfortunately, we have not been able to find relevant information. Consequently, we welcome proposals and suggestions to address this issue.

Natural mortality (M) is one of the more challenging parameters to estimate accurately in fish stocks, therefore, it is critical to include diverse M values in our set of OMs. Actually, in the application of the data-poor assessment methods, LBI, LBSPR and MLZ, to assess common sole in divisions 8c and 9a, a value of $M = 0.31$ is used. However, this selection lacks a reasoned justification. On the contrary, in the remaining ICES sole stocks, a constant age-specific mortality vector set at 0.1, is used, but, as in the previous case, this choice also lacks a well-founded justification.

Consequently, as a first option, we decided to estimate a global natural mortality value using a set of empirical methods implemented in the metaM function of the R package FSA (Ogle et al. 2023). These methods calculate M based on von Bertalanffy parameters, maximum age, or the age at which half the fish in the population become mature (a_{50}). The chosen methods, among the options available in the metaM function, and their estimates are presented in Figure 2. The M vector at age in the OM is set as a constant value equal to the median of these M estimates, which is 0.3743, as indicated by the horizontal line in Figure 2.

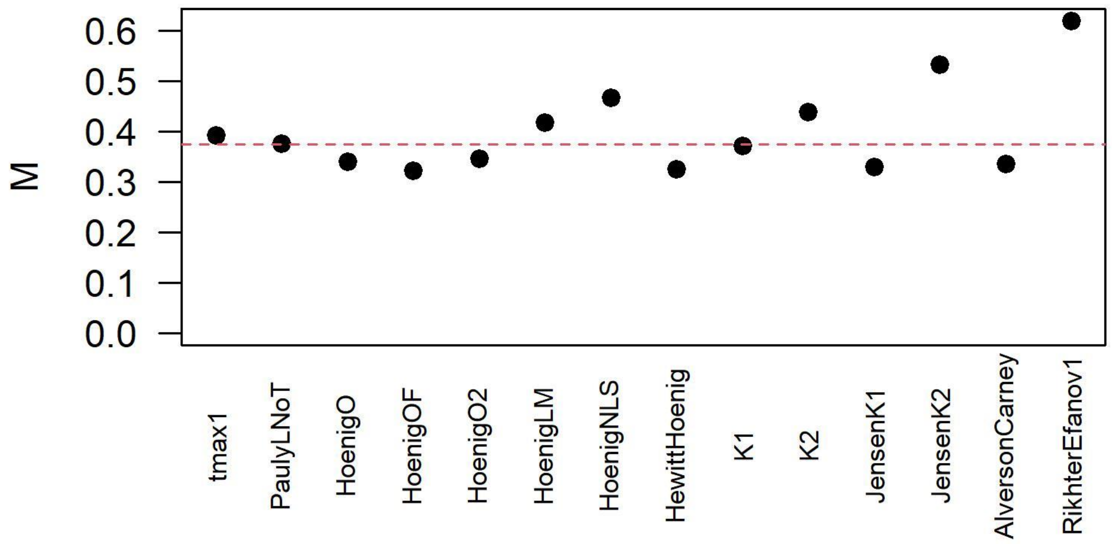

Figure 2: M estimates derived from the empirical methods implemented in the FSA package. Horizontal red line represented the median of the different M estimates.

On the other hand, given that a constant age-specific mortality rate of 0.1 is used for all ICES sole stocks except for sole stock in divisions 8c and 9a, we have decided to include this as an alternative OM. However, it's crucial to note that if we use, for example, the empirical M estimator termed “HoenigO2” in the metaM function of FSA package, defined as $M = 5.52 \times a_{max}^{-1.08}$, and solve for a_{max} when $M = 0.1$, the resulting value of a_{max} is 41 years, which appears unrealistic.

Given the notable vulnerability of young ages to predation and environmental risks, we also consider an alternative not constant M at age vector to address this issue. The M at age vector is obtained by calculating the median of the M at age vectors derived from the empirical estimators of Gislason (2010), Charnov et al. (2013), Lorenzen (1996) and Cook (2013). The estimates obtained using these M estimators and the their median (final M estimator) are presented in Figure 3.

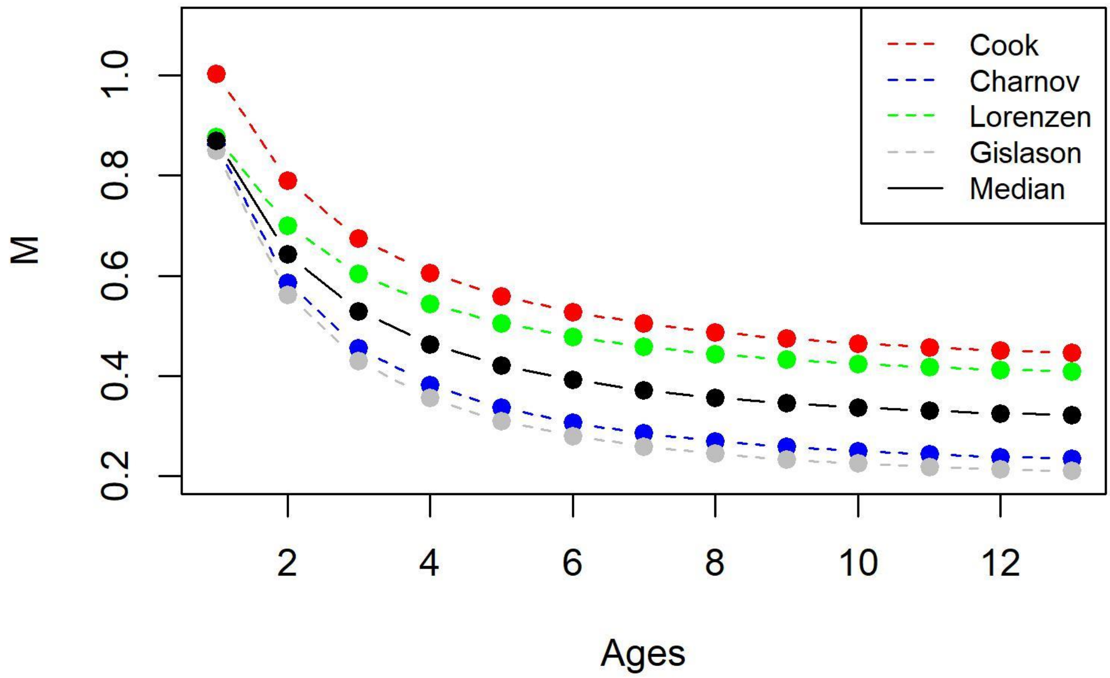

Figure 3: M estimates derived from the empirical methods of Gislason (2010), Charnov et al. (2013), Lorenzen (1996) and Cook (2013), and their median (final M at age estimates).

Sampling process

The sampling process conducted on our OMs focuses on obtaining an index of relative biomass and a length frequency distribution. This distribution is particularly essential for proposing new catch rules based on alternative indicators derived from the LFDs information.

The index of relative biomass is computed as follows:

$I_y = \left(\sum_{t=1}^{a_{max}} s_t N_{t,y} W_{t,y}\right) \times e_y,$

being $N_{t,y}$ the population number at age t and year y, $W_{t,y}$ the population weight at age t and year y, e_y is the log-normal error term derived from a log-normal distribution centered in one with $\sigma_I = 0.2$, and finally s_t is the selectivity defined as $s_t = \frac{1}{1+e^{-3\times(t-1-(a_{max}/8)}}$. Figure 2 shows the selectivity index values previously to multiply by e_y. Please note that our selectivity formulation has been adapted from the approach used in Fisher et al. (2020) for replicating the selectivity patterns observed in the polyvalent fleet and in the Spanish IBTS-Q4 bottom-trawl whose data is used to derive the indices of relative biomass in Figure 1. Specifically, we noticed that the mean of the historical minimum length in the data used to calculate the Portuguese LPUE is 19.32 cm, whereas in the Spanish IBTS-Q4 bottom-trawl data it is 22.21 cm. As a result, we adjusted the denominator in the selectivity formulation to reduce the selectivity associated with ages before maturity, as can be seen in Figure 3.

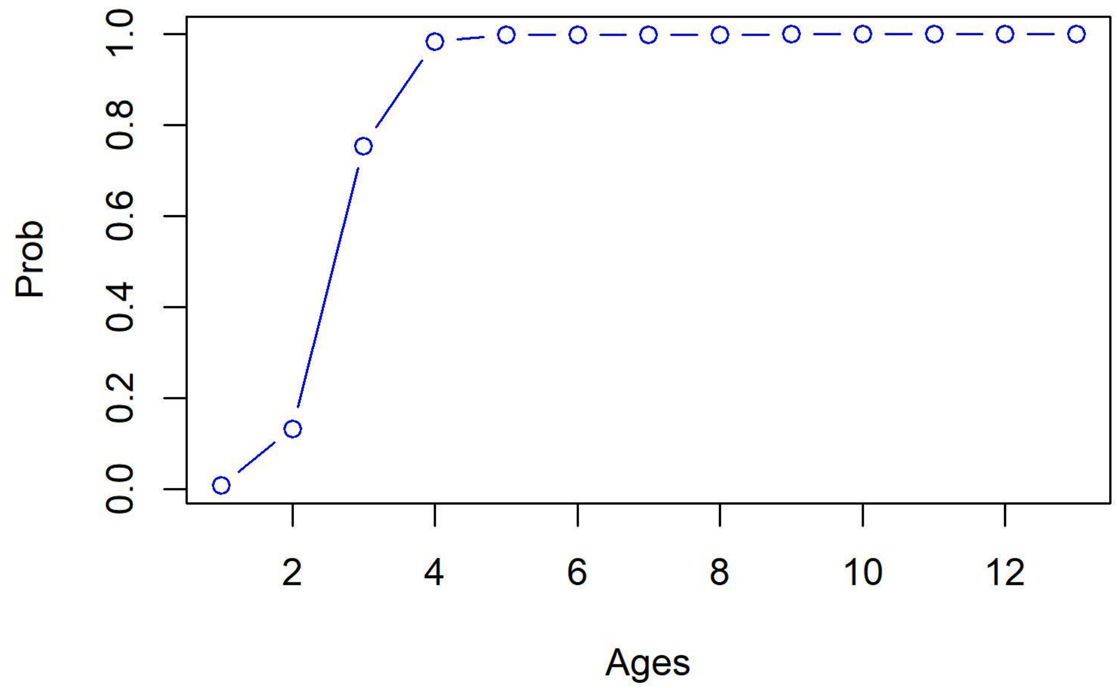

Figure 3: The selectivity of the index of relative biomass derived in the sampling process over our OMs.

Catch length frequencies were generated by applying a simulated inverse age-length key to the catch at age distribution according to Simon et al. (2020), see their supplementary material for more details. Essentially, the key steps are as described in Figure 4. One notable difference compared to Simon et al. (2020) is that the standard deviation associated with the normal distribution is determined from a coefficient of variation (CV), acknowledging that the level of variability may vary among different age groups. Specifically, $\sigma_{L_t} = CV \times L_t$, with a CV value of 0.1. Finally, to introduce variability into the resulting distribution obtained from the steps in Figure 4, noise is incorporated. This noise is derived from a log-normal error term derived from a log-normal distribution with a mean of one and a standard deviation of 0.1.

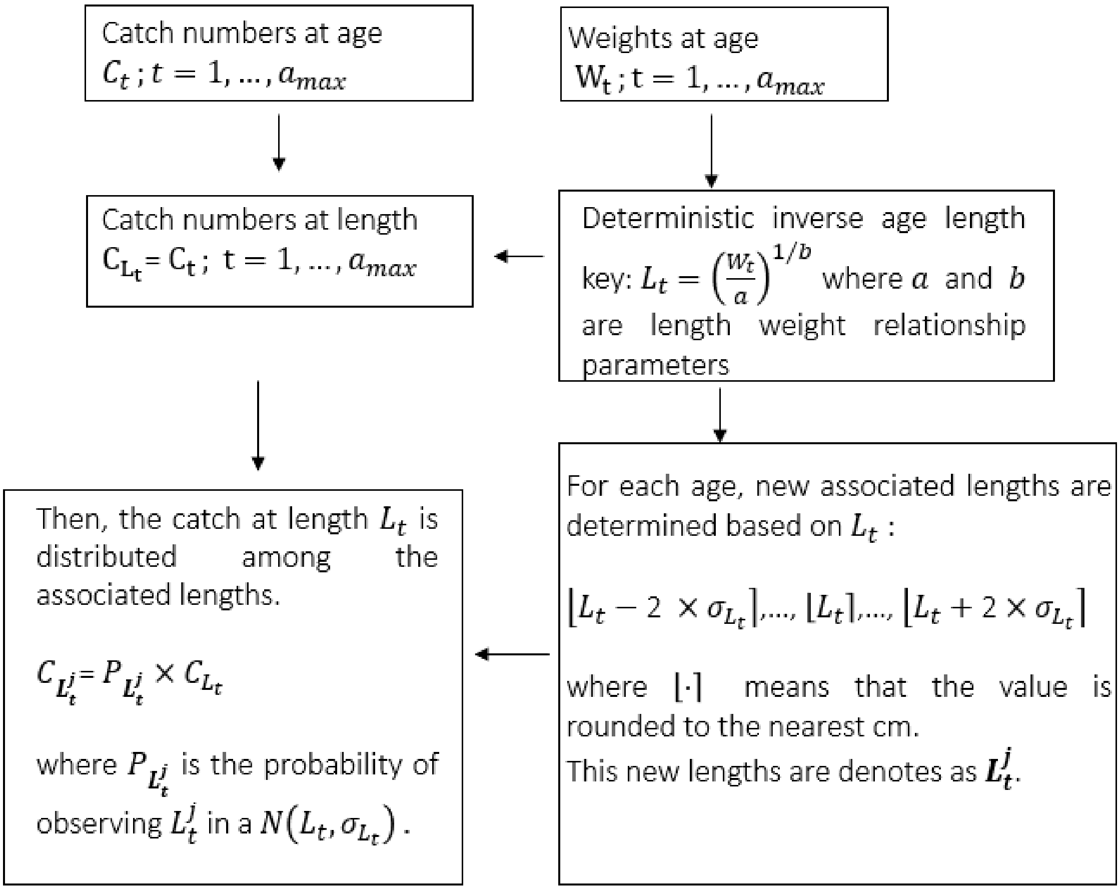

Figure 4: The key steps in the simulation of catch length frequencies.

Catch rule definitions

The initial step involved comprehending the implementation of the *rfb* catch rule in the Fisher et al. (2021) code. As the code had incorporated an optimized *rfb* rule based on a genetic algorithm, we proceeded to simplify and adjust the code to calculate the *rfb* catch rule based on the formulation currently used by ICES. Our objective is to compute both the *rfb* rule and our new proposals within each OM scenario for comparing their performance.

The code review has enabled us to identify several interesting aspects for discussing the implementation of the *rfb* rule. Firstly, we observed that the MSY reference length, $L_{F=M}$, used in the f component, is computed as $L_{F=M} = L_\infty + 2 \times (M/k) \times L_c / (1 + 2 \times (M/k))$ with M/k fixed at 1.5. However, in practice, even for data-poor stocks, it is often possible to use more specific M/k ratios. This leads us to question whether OM information should be incorporated into this calculation.

Another interesting aspect concerns component b, specifically the calculation of I_{loss}. It has been observed that in the code, the I_{loss} value is computed using the historical values of the index of relative biomass, specifically the 50 years before initiating the catch rule application in the projection. However, as new values of the relative biomass index are generated during the projection, the I_{loss} remains static and is not recalculated. We believe that its recalculation each time a new year is incorporated into the index should be done.

Finally, we also realized that $\underline{L}_{y-1}$, in Simon et al. (2021) code, is computed as the mean length in the catch above the length of first capture (L_c), weighted by the catch numbers at length. However, in practice, it is common to compute it by using the mean of the midpoints of the class lengths in the length frequency distribution, weighted for the corresponding frequencies. Nonetheless, upon investigation, we have determined that the $\underline{L}_{y-1}$ value remains relatively stable regardless of the two different calculation methods, indicating that this decision has a low impact.

Next, we initiated a brainstorming to propose a new catch rule with the aim of improving the performance of the existing *rfb* rule. We opted to begin with a simpler rule than the *rfb* one. Given that we use the LBSPR method to assess the status of common sole, we consider that a component based on the estimated SPR value should be incorporated in our proposed rule. To be more specific, our initial proposal is as follows:

$$A_{y+1} = C_{y-1} \times r \times f,$$

where A_{y+1} is the advised catch for next year, C_{y-1} is previous observed catch, r is the "2 over 3" component following the definition in the *rfb* rule, and f is defined as the ratio of spawning potential ratio estimate (SPR_{y-1}) to a MSY SPR proxy.

At this point, the first challenge is to determine an appropriate value for the MSY SPR proxy. According to Legault and Brooks (2013), SPR estimates ranging between 0.35 and 0.4 are generally associated with a stock at the *MSY* level. Taking into account that the accuracy of the catch rule will largely depend on the *MSY SPR* proxy, we decided to conduct a simulation study to determine the equilibrium SPR at F_{msy} under the OM scenarios described in previous sections. The results are presented in Figure 5. As we can see, the equilibrium value of SPR in relation to a F_{msy} exploitation varies significantly depending on M and steepness values, while the coefficients of variation associated with recruitment have a minimal impact. The question then arises as to how we can derive a *MSY SPR* proxy taking into account these results. Maybe the median of these values could be a viable option, leading to a value of 0.358. Another option is to compute the SPR median avoiding the extreme values of h, recruitment CV and M, that is, considering the scenarios using the constant $M = 0.3743$ or the M at age in Figure 3, combined with $M = 0.1$, $h = 0.84$, and recruitment $CV = 0.43$, in that case, the obtained value is 0.30.

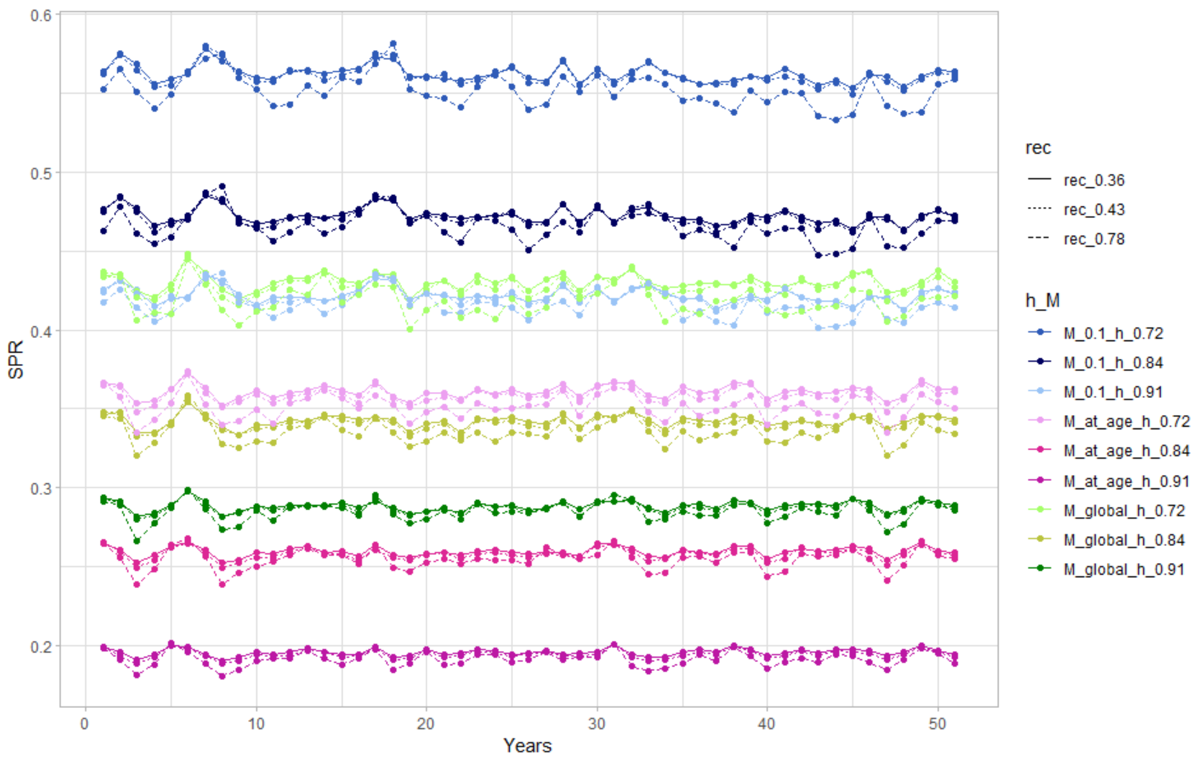

Figure 5. Equilibrium SPR estimates at F_{msy} under the different OM scenarios.

Another open question that we also need to address is how to summarize the M at age vector into a single global value to be used as an input in the LBSPR method for obtaining the SPR estimates. Currently, we are using the mean of the mortality values for ages ranging from 3 (the nearest integer to $a_{50} = 2.55$, which represents the age at 50% maturity) to 10 (the age from which there are already few individuals in the stock). This approach excludes both the immature ages and the older ones, nevertheless, the appropriateness of the chosen method may still be a subject of discussion.

In addition, regarding the implementation of the catch rule, while this is a more technical detail rather than a conceptual one, it's worth noting that after deriving the advised catch using the catch rule, we should project the stock based on this value. However, in the initial code version, we encountered an issue when using the Flash package. In some cases, Flash implements a catch of 0 in the projection instead of the advised catch derived from the rule. This issue comes from a problem within the Flash package. To address this challenge, we decided to move our code to Flasher, a more recent package that resolved this problem.

After addressing the mentioned open issues, the following tasks will focus on testing the new catch rule across various equilibrium levels (overexploited, optimal exploitation, and underexploited).

Performance Metrics

A set of metrics or indicators that reflect the performance of different management strategies in achieving the desired objectives for fisheries management has been included in Simon et. al (2021) code. Specifically, these derived metrics and indicators are as follows:

- the medians of SSB, F, $Catch$, SSB/SSB_{msy}, F/F_{msy} and $Catch/MSY$ time series,
- the median of the ICV (inter-annual catch variability) defined as $|(C_y - C_{y-v})|/C_{y-v}$, where C_y is the catch for the year y and v the frequency of advice ($v = 2$ in our case).
- B_{lim} risk (defined as the number of times that the SSB is below B_{lim} over all years and replicates, expressed as a proportion). In the same way, the SSB_{msy} and $SSB_{msy}/2$ risks are also computed. Finally, risk of collapse is computed as the of the number of times that the SSB is below 1.

Our first challenge lies in defining B_{lim}, a decision of crucial importance in the MSE procedures since B_{lim}establishes the reference point for evaluating the risk of overfishing and the sustainability of the population. Consequently, its definition requires careful and meticulous consideration. Simon et al. (2021) define it as the SSB where recruitment is reduced by 30% compared to its virgin state. However alternative definitions can be proposed, for example, in Walker et al. (2023), where an ad-hoc MSE for English Channel sprat is conducted, B_{lim} is defined as the value of SSB at the breakpoint of the segmented regression. Hence, an open question is which B_{lim} definition is adequate for use in common sole ad-hoc MSE.

Furthermore, there is a related question regarding how to define the risk below B_{lim}. As mentioned earlier, in Simon et al. (2021), it is defined as the number of times that SSB falls below B_{lim} across all years and replicates expressed as a proportion. Nevertheless, this straightforward definition may not be suitable for assessing risk in all scenarios, especially when the SSB of the stock is already below B_{lim} in the year preceding the first year of projection. Expecting a risk below 5% by considering all projection years for its calculation becomes unrealistic in such cases. In line with this, ICES (2013) suggests that "If a stock's SSB is currently below B_{lim}, it is not logical to expect that the probability of $SSB < B_{lim}$ is ≤ 5% in all years. It seems more logical to judge a recovery plan (or an initial recovery phase within a long-term management plan) by its ability to deliver SSB recovery within an appropriate time frame." According to this, defining the risk below B_{lim} is also an open question that requires further discussion to be suitable for all scenarios, including those simulating a recovery plan.

Conclusions

In summary, this document provides a comprehensive overview of the initial stages and critical discussion points involved in the development of an ad-hoc MSE for common sole (*Solea solea*). More precisely, the OMs construction and the sampling procedure, for biomass indices and LFDs, are described, the implementation of the *rfb* rule is reviewed, and a preliminary new catch rule definition is presented.

Throughout the document, we have highlighted open questions that can be brought up for group discussion. In the OMs definition, one of the most crucial concerns involves addressing uncertainty in natural mortality. We have proposed three potential approaches to address this uncertainty, and welcome additional group discussion regarding their appropriateness. Another open question in the OMs definition relates to the need for additional information to define an alternative growth model. This is a crucial aspect that requires further investigation.

Concerning the definition of the new catch rule, a key point is the selection of an appropriate value for the MSY SPR proxy. While this document presents one approach, we advocate a discussion of its suitability and the proposal of alternative solutions.

Lastly, we emphasize the relevance of adequate definitions of B_{lim} and the associated risk of biomass falling below this threshold. This is an open question that requires careful consideration, as it plays a key role in evaluating the effectiveness of the catch rule.

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Annex 7: Preliminary responses to questions on WKLIFE X methods

Questions from WGDEEP presented to WKLIFE XII on the rfb rule on 16 October 2023 (rephrased for clarity)

1. Does the multiplier m reduce the advice over time?
    - Response copied from WKLIFE XI report (ICES, 2023, Section 2.2.8, page 28):
    - "There is sometimes the incorrect perception that the multiplier of the rfb and chr rules continuously decreases the catch advice over time. The multiplier of the empirical harvest control rules is a tuning parameter that ensures that the advice follows the ICES precautionary approach. The components of the harvest control rules are multiplicative, this means that the multiplier can be thought of as adjusting the target of the harvest control rules, i.e. the reference length in component f of the rfb rule and the target harvest rate of the chr rule. This principle is illustrated in the following equation for the rfb rule:
    $$A_{y+1} = A_y\, r\, f\, b\, \mathbf{x} = A_y\, r \frac{L_{y-1}}{L_{F=M}}\, b\, \mathbf{x} = A_y\, r \frac{L_{y-1}}{L'_{F=M}/\mathbf{x}}\, b = A_y\, r \frac{L_{y-1}}{L'_{F=M}}\, b$$
    where A_{y+1} is the new catch advice, A_y the previous catch advice, r, f, and b the components of the rfb rule, x the multiplier, L_{y-1} the mean catch length, and $L_{F=M}$ the MSY proxy reference length."
2. Criticism that the new rule (rfb) leads to even lower advice than the 2 over 3 rule
    - The 2 over 3 rule was implemented in 2012 as an interim measure based on the best available science at that time. Re-evaluation of this method through simulation has shown that the 2 over 3 rule does not follow the ICES precautionary approach and can increase the risk of stock depletion over time. This means that the catch advice from the 2 over 3 rule in many cases was higher than it should have been. The new rfb rule was implemented after extensive simulation testing and review and was designed to explicitly follow the ICES precautionary approach and the MSY approach. This means that the catch advice from the rfb rule may be lower than from the 2 over 3 rule but this is required to follow ICES management objectives.
3. Why does the advice go down even if the index is going up?
    - The previous 2 over 3 rule calculated catch advice based on the trend from a biomass index. In addition to this, the rfb rule also considers (1) the exploitation of the stock based on catch-length data and (2) includes a biomass safeguard that reduces the catch advice if the biomass index falls below a trigger value. The catch advice calculated with the rfb rule is a result of all these considerations combined. Furthermore, the trend in the biomass index is calculated by using data from the most recent five years, i.e. an increase in the index in a single year does not necessarily result in a positive biomass trend.
4. What to do if new life-history parameters such as L_∞ are found; is there a need to recalculate things back in time?
    - There is no need to annually update life-history parameters. If new growth parameters are available and these are substantially different from previous estimates, these should be used. To ensure consistency in the calculation, derived values such as the reference length $L_{F=M}$ should also be updated and the historical mean catch

length compared to this new reference length. Growth parameters and derived metrics such as the reference length should be periodically reevaluated, e.g. every 3-5 years, following a similar schedule to benchmarks for Category 1 data-rich stocks, but kept constant in-between unless there is compelling new evidence for a change.
- See also the following question

5. Which life-history parameters (or strategies) matter when the von Bertalanffy growth model might not be appropriate
    - The individual growth rate (von Bertalanffy k) is only used to decide which method or multiplier is used and a rough estimate is enough, e.g. is k below 0.2/year or not. The only other growth parameter used for the rfb rule is the asymptotic length L_∞, which is used in the calculation of the reference length $L_{F=M}$ but the actual shape of the growth curve is less important.
6. Can the advice interval for the rfb rule (default: biennial) be changed?
    - The ICES technical guidelines recommend the implementation of the rfb rule with a biennial advice interval (ICES, 2022). WKLIFE XI (ICES, 2023) was asked if the rfb rule could be applied on an annual basis and concluded that this is unlikely to increase the risk of stock depletion but has the undesirable feature of reducing the long-term catch and should only be used in exceptional cases when asked for by ICES advice requesters (ICES, 2023, 2.2.4.1, page 21). Other advice intervals (from one to five years) were included in the generic testing of the rfb rule (Fischer et al., 2021a,b) but the biennial advice interval appeared to work best. Longer advice intervals can reduce the reactivity of the rfb rule and may increase the risk of stock depletion because the catch cannot be reduced fast enough.
7. cat3advice R package; match output as much as possible to advice sheets (e.g. provide inverse f)
    - TO DO
8. Allow changes to the assumption of M/k=1.5 for the length-based indicator
    - The assumption of M/k=1.5 is solely used for a simple calculation of the reference length $L_{F=M}$. This simplification of reality was shown to be appropriate in simulation testing even if the reality (operating model) was different and the parameterisation of the rfb rule with its multipliers accounts for potential deviations. Deviations from M/k=1.5 are possible following Jardim et al. (2015; Appendix A):
    - $L_{F=\gamma M,k=\theta M} = \frac{\theta L_\infty + L_c(\gamma+1)}{\theta+\gamma+1}$
    - where γ links the natural mortality M to fishing mortality F as the proxy for MSY, θ links the von Bertlanffy k to M, L_∞ is the asymptotic length and L_c is the length at first capture.
    - The function for the calculation of the reference length in the cat3advice R package (Lref()) includes an argument (Mk) to change the M/k ratio to any user-defined value.
9. What to do when there are missing index values, can values be interpolated?
    - In general, interpolating missing index values is not recommended because this would imply information is available when it does not exist. This is an area that needs further consideration.

Questions from WGEF presented to WKLIFE XII on 16 October 2023 (rephrased for clarity)

10. When calculating the mean catch length, should the length class corresponding to the length of first capture (L_c) be included?
    - The ICES technical guidelines specify that only length classes above L_c should be considered. Whether L_c is included or not does not really matter as long as it is done consistently between years. The cat3advice R package function for calculating mean catch length (Lmean) includes L_c by default, but this can be turned off by setting the argument include_Lc=FALSE.
11. For some stocks, catch length data can be sparse (e.g. only landings, not discards or neither). Could survey length data be used instead?
    - Some work on this issue was presented at WKLIFE XII. The conclusion was that it might be possible to use survey length data if no or insufficient (commercial) length data are available. The length at first capture L_c should still be estimated from catch data because the L_c from survey data might be too low and bias the reference length $L_{F=M}$.
12. Some stocks have an I_{loss} near zero, which is at the start or end of the time series, so using $I_{trigger}=1.4I_{loss}$ is not appropriate. In such cases, WGNSSK and WGEF used the 20th quantile of the time series. Is this approach appropriate?
    - ICES technical guidelines specify that $I_{trigger}$ is a value below which a stock's productivity is thought to be impaired and offer a calculation based on the lowest observed index value, I_{loss}, if no other information is available. If index values are very low or questionable at the beginning, these values could be removed. Using the 20th percentile of the index time seems appropriate and will lead to a larger $I_{trigger}$. This means the biomass safeguard will already be applied at higher index values and is more precautionary than the default approach.
13. Should there be more tests of the multiplier "m" for elasmobranch species?
    - The Category 3 empirical harvest control rules (rfb/rb/chr) were tested for a wide range of scenarios and stocks, including slow-growing and long-lived species and elasmobranchs. These methods were tuned to be precautionary in the long term, so there is no immediate need for additional testing. Stock-specific simulations for specific stocks are encouraged, and the ICES technical guidelines encourage such work. The WKLIFE roadmap and proposed ToRs for the next WKLIFE meeting also include work on specific life histories, including considerations for elasmobranchs.
14. Is the generic SPiCT harvest control rule appropriate for long-lived species such as porbeagle shark?
    - TO DO?

Comments from the Scottish Fishermen's Federation presented to WKLIFE XII on 16 October 2023 (rephrased for clarity)

15. The "precautionary multiplier" of the ICES Category 3 advice rule reduces the advice over time
    - ICES uses three methods to calculate the advice for Category 3 data-limited stocks (excluding short-lived species). These are the "rfb rule" for species with slower individual growth, the "chr rule" for stocks with medium individual growth, and the "rb rule" for stocks for which no reliable length data from the catch is available. These three methods include a multiplier in the calculation of the catch advice, which ensures that the catch advice leads to long-term precautionary management advice. Precautionary in this context means that the risk of the stock being depleted is reduced to a low level.
    - For the rfb rule and the chr rule, this multiplier does not lead to a continuous reduction of the catch advice every time the rules are applied. Instead, the multiplier acts as a correction factor and changes the management targets of these advice rules. If a stock is estimated to be below this corrected management target, the advice value will be reduced. However, if a stock is estimated to be at or above this management target, the multiplier does not reduce the advice further.
    - The third advice rule, the "rb rule", was only proposed as a method of last resort and should be avoided if possible. This rule is used when no reliable length data are available. Contrary to the rfb and chr rules, the rb rule does not include a management target and simply adjusts the catch advice based on the stock trend, as observed with the stock index. The rb rule likely reduces the catch advice over time with the multiplier. This is needed to ensure that (1) the management advice is precautionary in the long term, (2) the depletion risk is not greater than for the other methods, and (3) the depletion risk does not increase over time. This situation can be avoided when length data are available that are representative of the catch of the stock. These length data allow the application of the rfb or chr rules, which do not lead to a continuous reduction in the catch advice. A single year of length data can be enough to move away from the rb rule to either the rfb or chr rule.

- Comments on the whiting (*Merlangius merlangus*) in Division 3.a (Skagerrak and Kattegat) advice sheet from 2022: https://doi.org/10.17895/ices.advice.19454252

16. The stock size is estimated to increase by 45%, but the catch advice is a reduction of 27%.
    - This is because the advice for this stock is calculated with the "rb rule". For details, see the previous question on the precautionary multiplier.
17. B_{lim} is not specified, but apparently 1/3 of the estimated biomass.
    - This whiting stock is an ICES Category 3 data-limited stock. This means there is no analytical stock assessment available, and the biomass of the stock is unknown. Consequently, the biomass limit reference B_{lim} is unknown.
18. The multiplier is arbitrarily set at 0.5 – Unless the biomass doubles in a year, the TAC is reduced.
    - This is a feature of the "rb rule". For details, see the previous question on the precautionary multiplier. The multiplier is not arbitrary but based on extensive simulations to ensure the catch advice follows ICES management objectives.

- Comments on the anglerfish (*Lophius budegassa, Lophius piscatorius*) in Subareas 4 and 6, and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) 2022 advice sheet: https://doi.org/10.17895/ices.advice.19772359

19. The MSY proxy length ($L_{F=M}$) is based on the modal catch lengths and growth parameters (L_∞). This growth parameter is not specified.
    - In the absence of more detailed stock-specific information, the MSY proxy catch length is estimated from two parameters, both derived from the length data. The value for L_∞, used by the ICES assessment working group (WGCSE) is 140cm.
20. Even if the biomass remains the same and the stock is within safe levels, the advice will still continue to reduce.
    - No. The catch advice for this stock is calculated with the rfb rule, which does not decrease the catch advice over time. For details, see the question 15 on the precautionary multiplier.

- Comments on the ling (*Molva molva*) in subareas 3, 4, 6–9, 12, and 14 (Northeast Atlantic and Arctic Ocean) 2023 advice sheet: https://doi.org/10.17895/ices.advice.21828360

21. The index of ling abundance used for this advice has more than tripled since 2001.
    The TAC in 2023 is less than half the TAC of the mid-2000s and half what it was in the late 2010s.
    - WKLIFE cannot comment on the TACs because they are a political decision.
    - There have been changes in the way ICES provided advice for this stock. The advice for 2007 to 2012 was based on qualitative considerations. In 2012, the advice method was changed to the "2 over 3 rule". This method adjusted the catch advice based on the trend from a stock index. This method was implemented by ICES in 2012 as an interim measure and was based on the best available science at this time. Continued research on data-limited methods has shown that this method does not actually provide management advice compliant with the precautionary approach. Consequently, ICES changed the framework for such stocks in 2022 and replaced the "2 over 3 rule" with an improved "rfb rule". This means that the catch advice values before 2022 may have been too high and any comparison of more recent catch advice values to these historical values should be considered with caution. Since 2008, the TAC and catch have been higher than the ICES catch advice in most years. This means that a comparison of current ICES catch advice values to historical TACs may not be appropriate.
22. In the example of ling, the use of the target mean length creates a paradox where bigger recruitment leads to more juveniles on the ground and a smaller "mean length", which results in a cut in the catch advice.
23. In fisheries where market demand drives the size, the mean length might not be as significant (fishers might target smaller sizes through spatial knowledge or selectivity).
24. To get out of this loop, a shift in fishing patterns/behaviours is required, but this is unrealistic because there are market constraints and fishermen may not be aware.
    - The mean length of fish in the catch is used as a measure of fishing pressure. This mean catch length is calculated over the total catch of a stock and all fleets/gears. The final mean catch length is only calculated from fish above the length of first capture. This removes younger and smaller individuals that are not fully selected by the fishery and also means that distortions in the length distribution caused by

    stronger recruitment events are less influential on the outcome. Ling is a slow-growing and long-lived species. This means that the population mainly consists of many older (larger) fish, and younger (smaller) fish have less influence on the population structure and the mean length.
  - Selectively fishing for specific sizes due to market demand can cause other issues, such as high discards, and if discard mortality is high, increase total mortality on the stock, although WKLIFE cannot comment on the specific ling stock.

25. A status quo in values (index, length data, etc.) will still lead to cuts because of the multiplier of 0.95.
26. The catch advice calculations are triggering ”loops of doom”; it is almost impossible to bounce back.
27. There is no way of getting out of these downward spirals unless the data-limited nature of the stock is addressed, which might take years and is not always possible.
    - No. The catch advice calculated with the rfb rule does not reduce the catch advice over time unless the stock is declining or being overfished. For details, see the previous question on the precautionary multiplier.
28. It is difficult to justify the paradox of increasing stock indicators with decreasing catch advice.
29. In the absence of an empirical proof of decline, including a precautionary cut deviates from advice and risks to step into management.
30. No consideration is given to at-sea perception and observation, creating chokes when combined with the landing obligation and quota management.
    - The rfb rule uses several data sources, including a stock index and length data, as a proxy for the fishing pressure. An increase in the stock size, as observed in the stock index, does not necessarily mean that the stock is in a good condition. For ling, the length-based fishing pressure proxy indicates that the stock is being fished above the sustainable MSY level, and so the catches need to be reduced. ICES gives catch advice for an entire stock unit, and observations of specific areas within the stock area may not be representative of the stock.

- General comments

31. There are concerns over the appropriateness of this newer method (rfb rule) with the risk derived from simulations. It is a closed box, the simulation parameters will drive the outcome, and there is no space for a sense check.
32. Are the simulations wide enough, or is this just a fulfilling prophecy as they drive the outcome?
33. The WKLIFE X report mentioned that outputs were sensitive to a number of starting specifications (“Therefore, all optimisation (“tuning”) towards achieving specific objectives are conditional on the simulation specifications.”)
    - The implementation of the new WKLIFE X methods for Category 3 stocks (rfb/rb/chr rules) is the culmination of more than five years of scientific work. The work has been developed under the supervision of the WKLIFE workshops, where it has also been reviewed. Furthermore, the scientific work has been published in five scientific articles in internationally renowned scientific journals, where the work was peer-reviewed by several independent reviewers. The simulations accounted for many scenarios, including different life histories, depletion scenarios,

and sensitivity analyses. The methods were developed generically so that they are applicable to any ICES stock without requiring extensive stock-specific information. The catch advice might appear fairly low, but this is required to ensure management objectives are met in the long term. Additional more stock-specific data can be collected and used in case-specific analyses. However, this is a data and labour-intensive and expensive process but may lead to a higher catch advice.

34. There are various steps of precaution layered up (i.e. MSY proxy length - modal …why?)
    - The methods were developed generically to be applicable to a wide range of stocks and meet the required management objectives (maximum sustainable yield, MSY, and precautionary approach). See also the previous question.

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Annex 8: Workshop agenda

16 October (Monday)

09:**30** – 10:00 Introductions & meeting ToRs

10:00 – 13:00 Presentations and plenary discussions (ToR 1)

- *ToR 1: Support the rollout of the WKLIFE X Category 2 and 3 methods in 2023 and beyond*
- **Anne Cooper** – Data-limited stocks and management in ICES
- **Simon Fischer** – Updates on empirical harvest control rules – Revisit rb rule, zero-catch considerations, R package (ToR 1)
- **Tobias Mildenberger** – Zero-catch considerations for SPiCT

13:00 – 14:15 <u>Lunch break</u>

14:15 – 18:00 Presentations and plenary discussions (ToR 1, continued)

- **Elena Balestri** – View from fishing industry bodies/end users on data-limited advice
- *15:00* – **Elvar Hallfredsson/Juan Gil Herrera** – feedback from WGDEEP on new methods
- *15:30* – **Sophy Philips/Jurgen Batsleer** – feedback from WGEF on new methods
- Discussion on technical guidelines – updates required?

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17 October (Tuesday)

09:**00** – 13:00 Presentations and plenary discussions (ToR 3)

- *ToR 3: categories 4-6*
- **Hector Antonio Andrade Rodriguez – Tusk and LBSPR (ToR 3 & 6)**
- **Simon Fischer** – Review of categories 4-6 and initial simulation testing
- Plenary discussion about categories 4-6 advice
- *Tor 4: empirical indicators*
- **Peter Kidd** – Spatial indicators and ability to classify stock status

13:00 – 14:15 <u>Lunch break</u>

14:15 – 18:00 Presentations and plenary discussions (ToR 4)

- **Marta Cousido Rocha** – MSE work on sole and expanding indicators (ToRs 4 & 6)
- *Tor 6: Approaches for specific life histories*
- **Andrés Uriarte** – Perturbation-reaction rule for short-lived species
- Time for data-limited work and discussions

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18 October (Wednesday)

09:00 – 13:00 Presentations and plenary discussions (ToR 5 & 6)

- *Tor 4: empirical indicators*
- **Tanja Miethe** – Using survey length data for length-based indicators
- *ToR 5: Surplus production models*

- **Momoko Ichinokawa** – Surplus production model s and management strategy evaluation
- **Tobias Mildenberger** – Precautionary reference points for surplus production models
- *ToR 6: Approaches for specific life histories*
- **Laurie Kell** – Sea urchin management plan and ecosystem reference points for pelagic species (ToRs 4-7)
- **Liese Carleton** – Plans for shellfish work

13:00 – 14:15 Lunch break

14:15 – 18:00 Presentations and plenary discussions

- *ToR 6: Approaches for specific life histories (continued)*
- **Romaric Jac** – The conservation potential of rabbitfish *Chimaera monstrosa* in the face of global changes
- **Laurie Kell** – Short-lived species
- *Roadmap afternoon* (link)

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19 October (Thursday)

09:00 – 13:00 Presentations and plenary discussions

- *ToR 5: Surplus production models*
- **Wendell Medeiros Leal** – ICES data-limited assessment framework for Blackspot seabream
- **Paul Bouch** – SPiCT and contrast in data
- *ToR 7 & 8 (other data-limited work)*
- **Lionel Pawlowski** – PSA
- *Roadmap discussion*

13:00 – 14:15 Lunch break

14:15 – 18:00 Presentations and plenary discussions

- *ToR 5: Surplus production models*
- **Bárbara Pereira** – SPiCT for Nephrops
- *ToR 7 & 8 (other data-limited work)*
- **Rehab Farouk Abdelfattah Soliman** – Data-limited methods for Egyptian Red Sea fish stocks
- *Collaboration & paper session*
- *Other discussions*

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20 October (Friday)

09:00 – 13:00 Presentations and plenary discussions

- Update roadmap (ToR 2)
- Adopt updates of technical guidelines (if needed)
- Adopt executive summary
- Plan for WKLIFE XIII
- Any other business

13:00: Finish

- Optional: open plenary session