INTER-BENCHMARK TO REVISE THE ADVICE FRAMEWORK FOR THE SPRAT STOCK IN 7.DE BASED ON THE MOST RECENT CHANGES TO DATA-LIMITED SHORT-LIVED SPECIES ASSESSMENTS (IBPSPRAT)

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i Executive summary

The workshop aimed to review conclusions of the Workshop for Data-Limited Stocks of Short-Lived species (WKDLSSLS) and determine the most appropriate advice framework for Sprat in divisions 7.d and 7.e. Previously, advice has been provided by applying a ratio of previous survey index year values to the preceding years catch advice, with application of a 20% uncertainty cap (UC) and precautionary buffer (PB).

Previous work recommended several assessment approaches, including "1 over 2" ratio-based advice with 80% UC; surplus production model (SPiCT); and Constant Harvest Rate (CHR), derived from Management Strategy Evaluation (MSE). These approaches were further evaluated, with SPiCT results being too uncertain currently to consider further.

The MSE was tuned to the stock's biological variables, from survey observations or borrowing from North Sea sprat.

Three MSEs scenarios, relating to survey "catchability" were run, assuming no, 50% and 100% overestimation in survey biomass. Under each scenario, the maximum precautionary CHR performed better in terms of associated risk and harvest than "1 over 2" ratio-based advice. Resulting CHRs were 19%, 12% and 10% (No, 50% and 100% overestimation respectively). Assuming that some overestimation may take place in the survey, the CHR assuming 50% overestimation was adopted.

Processing of growth within the MSE results in within-year age class growth being unaccounted for. This results in underestimation of stock weights at the time of the survey, and so over estimation of realised CHR. A correction factor to account for this was calculated at 0.714. Applied to the CHR (12%) this results in a corrected CHR of 8.57% to be applied against most recent survey biomass index to define catch advice for a management year running July to June. If applied from January to December, a review of the advice after completion of the October/ November survey is recommended in the interim year, as a safeguard to advice still being applicable. The CHR is more risk averse than the previously applied 1 over 2 ratio-based advice.

As the survey biomass index is available in November, it may be possible to move provision of advice to November, for the execution of the fishery from January to December.

The IBP concluded that:

1. CHR based advice is more appropriate than 1 over 2 ratio-based advice.
2. Advice should be applied to the fishery from July year y to June year y+1.
3. A CHR of 8.57% is risk averse and provides highest yield.
4. If application of advice from January to December is to be maintained, it should be reviewed when survey data become available following the October/ November survey.
5. The optimal approach would be to undertake the assessment at the end of the October/ November survey (year *y*) in time for application from January to December (year *y*+1).

ii Expert group information

Expert group name	Inter-benchmark to revise the advice framework for the Sprat stock in 7.de based on the most recent changes to data-limited short-lived species assessments (IBPSprat)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair	Jonathan White, Marine Institute, Ireland
Meeting venue and dates	2–4 February 2021, Online meeting (11 participants)

1 Introduction

ICES advice on Sprat (*Sprattus sprattus*) in divisions 7.d and 7.e (English Channel) has been provided since 2013. Advice up to 2015 was based on a landings per unit of effort (LPUE) abundance indicator of stock size. From 2016, advice has been based on an acoustic survey stock size indicator, through ICES framework for category 3 stocks (ICES, 2012).

IBPSprat was tasked to review and advise on the appropriate advice basis in time for 2021 advice. Meeting Terms of Reference (Annex 3) called for the meeting to review, and determine the most appropriate advice framework:

1. Review conclusions of Workshop on Data-Limited Stocks of Short-Lived Species (WKDLSSLS 2020).
2. Clarify application of the latest advice for category 3 short-lived species (WKDLSSLS 2020).
3. Review and calculate options for providing advice (WKDLSSLS 2020).
4. Remaining issues, in moving to the proposed 1 over 2, clarified (WKDLSSLS 2020).
5. Pressing need to implement the updated guidance for the stock in time for HAWG 2021 so sensible advice can be given for this stock in line with ICES guidelines.

1.1 Background

Management Advice historical review

Since 2016, acoustic biomass estimates have been used as the index of stock development, based on a comparison of the most recent index value(s) (index A) against preceding values (index B), multiplied by the last advised catch. In some years of the assessment, index A has been based on the most recent single index year, while in others on the average of the most recent two indices. Index B has been based on the average of the preceding two- or three-years of the survey, this gave rise to “1 over 2” and “2 over 3” ratio-based advice options.

The framework for category 3 stocks also incorporates a cap on the advice due to uncertainty of the index. This Uncertainty Cap (UC) has been set at ±20%, to be implemented if the ratio of index A to index B was greater or less than 20%, limiting the applied ratio to 120% or 80% respectively.

The category 3 framework also incorporates a Precautionary Buffer reduction of 20%, to be applied once every three years if stock size is not increasing or fishing pressure is not decreasing.

The time-series of the application of “1 over 2”; “2 over 3” options; implementation of the UC and PB (Table 1.1), with the UC applied 2016 through to 2020:

Table 1.1. History of applied advice.

Advice Production Year	1 over 2	2 over 3	Calculated ratio	Uncertainty Cap Applied*	Precautionary Buffer applied	Applied ratio
2015 ADVICE	LPUE trend assessment					
2016 ADVICE	X		0.84	-X		0.80
2017 ADVICE	X		0.13	-X	X	0.64**
2018 ADVICE		X	0.29	-X		0.80
2019 ADVICE		X	0.47	-X		0.80
2020 ADVICE	X		1.35	+X	X	0.96**

*** + and - indicate where the UC was applied to limit the ratios to the lower (-) or upper (+) range, to 0.80 and 1.20 respectively.**

**** Application of the Precautionary buffer reduces the ratio a further 20% before application.**

Several options for the advice basis were reviewed by the meeting. Including these, the meetings reviewed:

- Review of the survey (PELTIC) and indices.
- 1 over 2 and 2 over 3 ratios applied to the preceding years advice with 20% Uncertainty Cap.
- 1 over 2 ratio applied to the preceding years advice with 80% Uncertainty Cap.
- Surplus Production model – SpiCT.
- Constant Harvest Rate application (CHR).
- Management Strategy Evaluation (MSE) was used to determine the CHR, and test application of 1 over 2 options with 20% and 80% UC.

Main conclusions from WKDLSSLS2 of relevance to this workshop

The main conclusions coming from WKDLSSLS2 (ICES, 2020) were summarised as:

- The shorter the lag between observations, advice, and management, the bigger the catches and the smaller the risks. This means that in-year (or seasonal) advice should always be preferred over the normal calendar (with an interim) year advice.
- For short-lived stocks with sufficiently long input dataseries (and with enough contrast of biomasses and production in the series) surplus production models will be applicable, and the advice can be formulated on the basis of F_{MSY} (rather than on constant catch at MSY), or preferably less than F_{MSY} (accounting for the strong fluctuations of these short-lived species). Such an F_{MSY} rule would be most successful if applied to an assessment including an indicator of the biomass population just prior to the management calendar. In WKLIFE, the latter was shown to be compulsory for correct performance of advice based on SPiCT (Surplus Production Model in Continuous Time).
- For DLSSLS with a survey monitoring system, a CHR strategy could be a better management procedure than 1 over 2 or 2 over 3 ratio-based advice options, when conditioned to the distribution of potential catchability of the survey and its *CV*.

- When knowledge of survey catchability or associate uncertainties are so poor as to preclude the definition of CHR, then Trend-based Harvest Control rules (according to the recent indications of biomass) can be applied, coupled preferably to some Uncertainty Cap constraints and to Biomass Safeguards, following the 1 over 2 ratio-based advice coupled with a symmetric Uncertainty Cap of 80% and a $B_{safeguard}$ (Istat).

During WKDLSSLS2, it was shown that the outcome of the search of a precautionary CHR, using MSE, depends upon several assumptions of the Operating model (OM); among them the main ones for this stock were:

- Stock–Recruit relationship steepness and variability;
- Growth model; and
- Survey catchability (bias relative to the absolute level of the population) and survey CV.

Another main input for the OM is B_{lim}, as the reference against which to measure risk of impaired recruitment over the projected population in the MSE. During WKDLSSLS2 the work carried out on Sprat in 7.de was considered provisional, and the WK not considered the place to adopt the results. The general conclusion of the WK was that "Definition of such CHR is to be made by MSE during inter benchmarks covering a range of uncertainties on life history, catchabilities, *CV* of the survey and setting of associated MSE parameters.

Following the findings of WKDLSSLS2, the IBP reviewed:

a) a SPiCT assessment tuned to available sprat survey data;
b) a management strategy based on a CHR applicable to the survey index, with careful checking of the OM conditioning (inputs and uncertainty ranges of parameters covered;
c) the performance of 1 over 2 ratio-based advice, coupled with a symmetric Uncertainty Cap of 80% and with $B_{safeguard}$ (Istat). In addition, a careful checking of the management 1 over 2 cycle for an optimal management of the fishery according to the recommendations from WKDLSSLS2 is set in Section 4.

2 Survey and indices

Advice for sprat 27.7.de is provided by ICES on an annual basis and, in recent years, has been based on an acoustic survey (Pelagic ecosystem survey in the Western Channel and Celtic Sea "PELTIC". ICES, 2015). The survey has been carried out over the area, in October, since 2013. To assess the ability of the survey to capture the stock ("catchability") survey methods were presented and results on distribution and biology over the eight-year time-series. These were further supported by additional studies examining presence of sprat in inshore waters; a recent genetic study on sprat and; results from a recent self-sampling programme by the sprat fishery.

PELTIC is an autumn survey, timed to coincide with the start of the Lyme Bay fishery for sprat. Acoustic data acquisition, used to estimate biomass, is limited to daylight surveying owing to the diel vertical migration this species exhibits, dispersing at sunset and rising to the surface out of reach to the acoustic beam. To convert acoustic biomass to abundance, a Target Strength (TS) equation is used. No dedicated sprat specific TS equation is available for the area and the generic clupeid value of b20 = -71.2 dB is used. This is the most commonly used value, although more negative values, which would increase the biomass, are used by some surveys for clupeids, including sprat, in adjacent waters.

While the survey covers a wide area and expanded from 2017, the biomass used in the stock assessment of sprat in 7.de is limited to English waters of the western English Channel (northern part of ICES Division 7.e, stratum "WC", Figure 2.1). Results of a recent genetic study on sprat in the NE Atlantic (McKeown *et al.*, 2020) showed no significant differences between sprat from this stock and those in the wider area (including the North Sea), which confirms that some connectivity remains, e.g. through the advection of eggs or larvae. The time-scales at which this happens however, are unknown and consistency in spatial distribution of the acoustically derived sprat biomass suggested that the Lyme Bay area should be treated as a single subpopulation unit: sprat was consistently aggregated in the Lyme Bay area throughout the time-series, with occasional presence further west along the south coast of England, particularly at the start of the time-series. A similar distribution was found during a one-off summer survey in May–June, 2011.

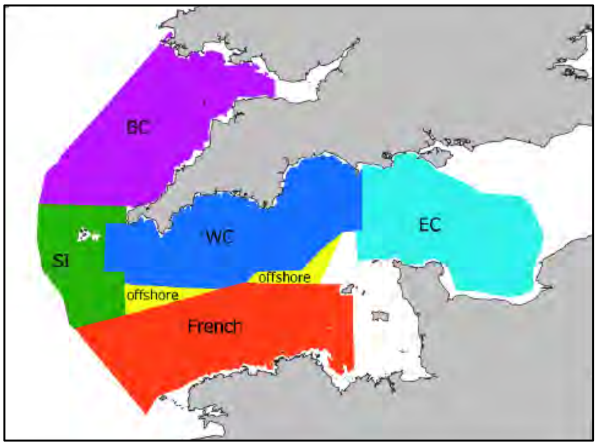

Figure 2.1. Map of PELTIC survey area with strata. Strata WC, BC and SI were covered from 2013 with French and offshore added since 2017. EC was covered once in 2018. Please note that only sprat biomass from WC is used in the English Channel sprat 7.de stock assessment.

The stratum covered by the survey that provides the biomass index for the assessment (Figure 2.1), covers a subsection (less than a quarter) of the 7.de management unit. Based on survey observations of variable amounts of sprat outside the stratum as well as sprat landings particularly from 7.d (the eastern part of the English Channel), the survey biomass should be considered an underestimate of the biomass in 7.de.

While the length frequency information from the survey was broad and included fish from ages 0 to 6, few consistent patterns were found over the time-series. This is likely owing to sensitivity of the estimates to the location and number of trawl samples conducted. A dedicated fieldwork study in collaboration with the industry confirmed that very low numbers of sprat (of any size or age) reside in the shallow inshore waters, not covered by the PELTIC survey. The interannual variation in catchability of the different ages should be accounted for in any MSE modelling. The overall biomass was not however, significantly affected by the length (and age) structure of the catches in the fishing hauls.

The age structure in the survey estimates varied notably between years and not in a consistent manner (hindering year classes to be tracked across the time-series). The occurrence of age 0 was quite varying over the time-series, not appearing much in the first years of the survey series.

Length frequency data available for the last three fishing seasons, collected by a self-sampling programme, confirmed that the English spat fishing industry target the larger sprat for human consumption. Spatial information on main fishing activity confirms that the fishery is restricted to the western part of Lyme Bay.

The panel was content that based on the evidence presented during the session and the fact that the survey has been evaluated by two ICES Working Groups on an annual basis (WGACEGG, WGIPS), the catchability of PELTIC was robust. The biomass estimates are suitable to be used in the stock assessment and biomass values used in the assessment are likely to be underestimates.

3 Growth parameters

Age–length data obtained from the PELTIC surveys were used to estimate the von Bertalanffy growth parameters for sprat in 7.de. Age is estimated by counting the annual growth increments in the otoliths, being therefore an integer variable. Assuming sprat spawn in March however, and the PELTIC takes place in October, sampled animals are 0.58 years (7/12 months) older than in March. In order to account for this, age was transformed into a numeric variable by adding 0.58 to the integer values. Sprat age ranged from 0.58 to 6.58, although only one undersized individual was aged as 6.58. This specimen was considered an outlier and removed from the growth analysis.

The von Bertalanffy curve was fitted to data collected between 2013 and 2020 using a non-linear least squares model (function *nls* in R statistical package). The IBP considered fixing the parameter *t0* of the von Bertalanffy equation (the time at which individuals have length equal to 0) at a specific moment of the reproductive cycle (hatching or metamorphosis) in order to add more biological realism to the equation. Justification for this was not apparent however, and given the uncertainty associated with the timeline for these natural events in the stock, the best model fit was selected, with no constraints in *t0*:

$$L_\infty = 148.72$$

$$k = 0.454$$

$$t_0 = -1.452$$

The von Bertalanffy growth equation estimated for sprat in 7.de was as follows (Figure 3.1):

$$Length\ (mm) = L_\infty \cdot (1 - e^{(-k(Age - t_0))}) \qquad \text{Equation 1}$$

It is worth noting that the PELTIC takes place every year between October and November and therefore the growth parameters estimated are specific for this time of the year. Additional age–length data from different months would allow estimation of average annual growth rates.

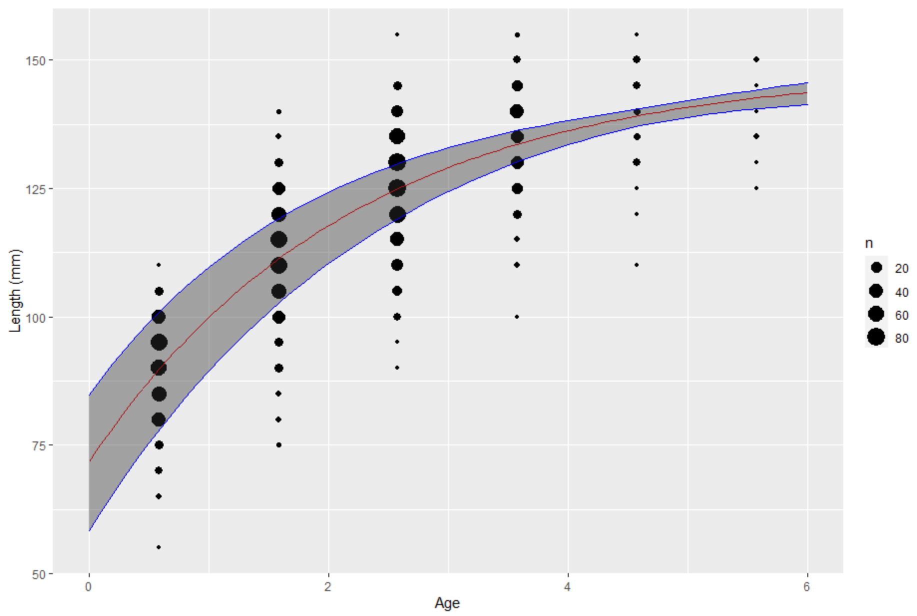

Figure 3.1. Age–length data for sprat in 7.de and the estimated von Bertalanffy curve. Size of circles represents the number of samples (*n*); grey area represents 95% confidence intervals of the mean von Bertalanffy curve, in red.

4 Annual and Season advice timings

Advice for the stock has to date been on an annual, calendar year basis, with the PELTIC survey taking place in October/ November (year y-1), the assessment in February/ March of the next year (y) and issuing of advice in June for setting of Total Allowable Catches (TAC) and fishing the following year January to December (y+1) ("Annual Calendar" in Figure 4.1). The main bulk of the fishery takes place from July/August to December (91% of catch between 2014 and 2019). This means that by the time of the start of the fishery in July of year+1, the youngest sprats (age 0 group) assessed by the survey (in y-1) will be 2 years old. In this time, the next survey will have taken place and a new biomass estimate will be available for the following assessment, however this information is not used in management of the current year's fishery. Given the short-lived nature of sprat, a large proportion of the fish observed in the PELTIC survey in year y-1 will have already disappeared from the exploitable biomass in year y+1.

It is advisable to change the management calendar to a seasonal calendar, running from July (year y) to June y+1, "Annual Seasonal" (Figure 4.1).

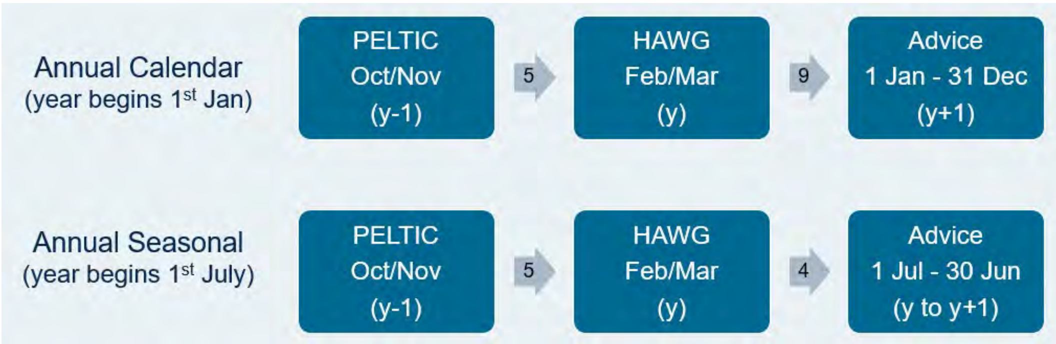

Figure 4.1. Timing of survey, assessment and advice application under "Annual calendar" year and "Annual seasonal" year scenarios (numbers in arrows represent months in time steps between activities).

Recommendations to change the management calendar aligned with WKDLSSLS conclusions which indicated that: "All simulations showed that the shorter the lag between observations, advice and management, the bigger the catches and the smaller the risk" (ICES, 2019a). This conclusion was unanimous across species with "short-lived life-history trait" parameterisations, MSE frameworks and software.

5 SPiCT

A Surplus Production Model in Continuous Time (SPiCT, Pedersen and Berg, 2017) was applied to estimate MSY proxy reference points and the stock status of sprat in division 7.de. Input data of the model were the biomass index provided by the PELTIC survey (2013–2020) and the landing time-series reported to ICES. As official landings in 2020 were still unknown at the moment of the IBP, it was assumed countries contributed with the same proportion to the total landings as in previous years, i.e. total landings in 2020 were 10% higher than English landings (provisional English landings in 2020 were provided by Cefas for this IBP). Annual landings were available since 1985, whereas quarter landings were only available since 2010. The IBP panel also considered using a landing per unit effort (LPUE) time-series as an indicator of biomass, but this option was finally rejected given the nature of the fishery. The fleet catching sprat consists of relatively small vessels and the majority of the catches are in the close vicinity to their homeport. In addition, the landings are primarily governed by the capacity and demand from the processors and the TAC available, rather than by the stock biomass. Although the LPUE was used as an indicator of biomass for this stock in the past, the index provided by the PELTIC survey is considered a better indicator of biomass.

Three exploratory SPiCT assessments were performed:

- an annual model using calendar year (January–December)
- an annual model using fishing year (July–June);
- a model using quarterly data.

As suggested in the SPiCT guidelines (Mildenberger *et al.,* 2020), several attempts were made to fit the models to the available data, which included increasing interactions of optimisation, shortening the catch time-series to cover the period with biomass index, and adjusting the shape of the production curve. Despite efforts to this end, the annual model with a calendar year did not converge and confidence intervals of the parameter estimates with the other two models were too high to provide conclusive results (Figure 5.1). The IBP concluded SPiCT should be tested again in the future when the time-series of biomass index is long enough to provide reliable outputs.

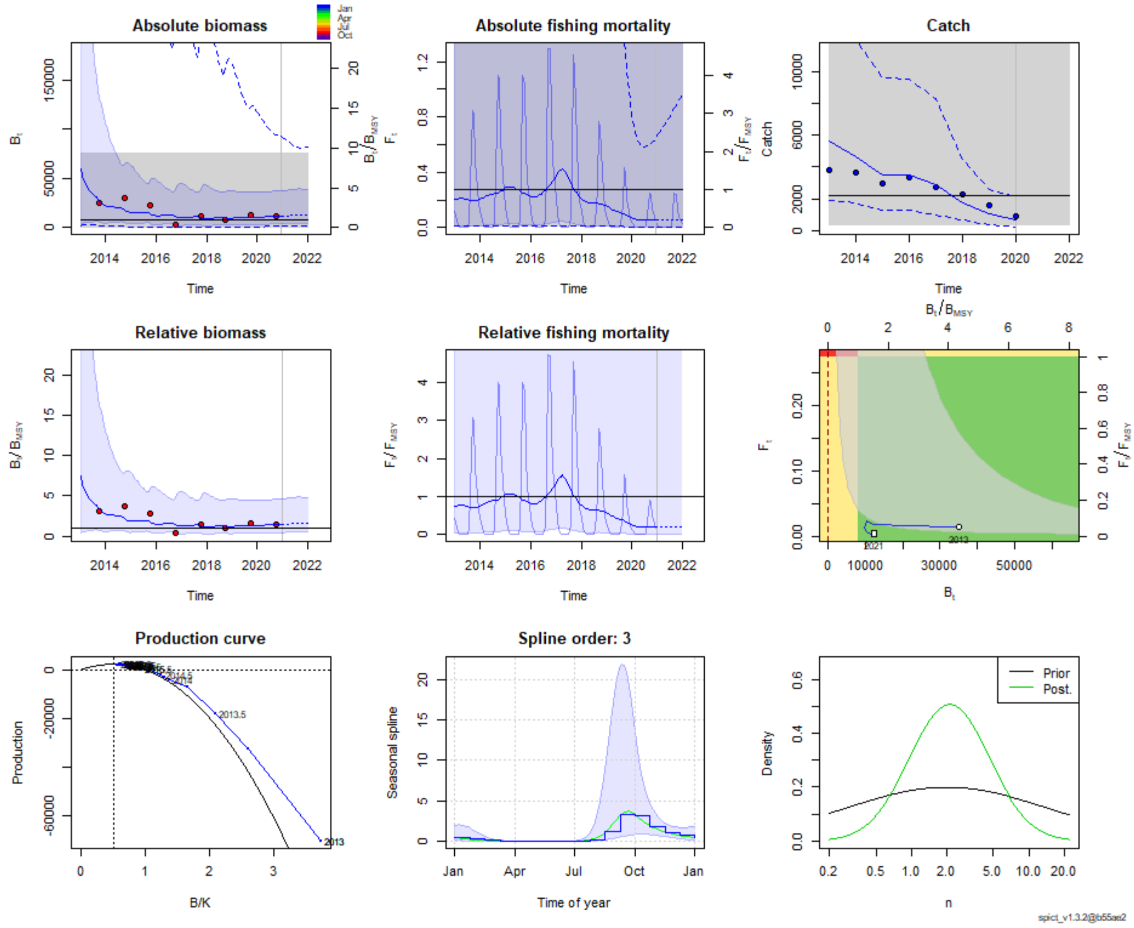

Figure 5.1. Outputs of the SPiCT model using quarterly data.

6 Category 3, Survey trend-based advice

Advice for the stock has followed the ICES Precautionary approach, *Category 3 – Stocks for which survey-based assessments or exploratory assessments indicate trends*. This has been applied in recent years: the applied advice approach for the fishery in 2020 was based on "2 over 3" with 20% symmetric Uncertainty Cap, while the approach applied for 2021 was based on "1 over 2" with the same 20% symmetric Uncertainty Cap (Table 1.1). As such in the latter case, advice was based on the most recent advised catch, adjusted relative to the change in stock-size of the most recent index value relative to the two preceding values. This framework incorporates an uncertainty cap of ±20%, and application of a further 20% precautionary buffer every three years where indicated as necessary relative to stock size and fishing pressure. This was consistent with the approach tested previously for a range of stocks and in general found to be appropriate (ICES, 2017c).

The "1 over 2" (1o2) approach was proposed for short-lived Category 3 stocks by WKDLSSLS to replace the previous generic index-based "2 over 3" for category 3 (data-limited stocks) stocks. This came from recognition by the assessment Working Group (HAWG; ICES, 2020) that the previous index based "2 over 3" (2o3) approach, when applied to short lived species, gave advice based on biomass no longer present in the population at the time of fishing.

The 2o3 approach was demonstrated to be slow in responding to rapid changes in the size of stocks with a short lifespan and expressing rapid changes in biomass (*r* selection species). In a situation of rapidly decreasing or increasing biomass, the index is unable to respond in an appropriate timeframe or to an appropriate extent.

WKDLSSLS 2019 (ICES, 2019a) examined and tested *via* MSE the application of 1 over 2 ratio-based advice with a range of different uncertainty caps and safeguards applied to data-limited, short-lived species. The emergent recommendations from the WKDLSSLS (ICES, 2019) reinforced the need to move short lived species away from a 2o3 assessment, as in all scenarios it proved to be less precautionary than 1o2 ratio based or Constant Harvest Rate (CHR) based advice (ICES, 2019a).

A secondary consideration for any index trend-based advice basis is the uncertainty cap, which limits the degree of interannual change in advice arising from the approach, by "capping" any change in the advice (ICES, 2017a) to ±20% of the current advice. The purpose of this is intended to prevent extreme swings in the advised catch, and while suitable in providing stability to the advice for longer lived species, it has been shown to be counterproductive for species that exhibit high variability in biomass and limits the ability of the advice to respond to a dynamic population (WKDLSSLS2; ICES, 2020).

WKDLSSLS tested a range of uncertainty caps and concluded that for short lived species an 80% uncertainty cap proved the most precautionary for 1o2 based advice (ICES, 2019). WKDLSSLS2 (ICES, 2020) noted that a 1o2 with 80% uncertainty cap does not necessarily lead to long-term MSY and will primarily limit the risk of the stock falling below 20% B_{lim} in a ten-year time frame, and should be considered provisional while aiming to achieve a better management approach.

The 1o2 with 80% UC contains an inherent risk of inducing a positive feedback effect in the advice (where a limit to the advice implies a limit to the TAC, which in turn limits the following year's advice). It was noted by the HAWG (ICES, 2020), WKDLSSLS2 (ICES, 2020), and by the IBP that an 80% decrease in advice requires a 500% increase in the following advice to return to the previous level, taking a minimum of three years to achieve when an 80% uncertainty cap is applied (Figure 6.1). This would lead to depressed catch advice, which may run contrary to an observed high biomass index value.

In addition to the uncertainty cap associated with the index-based assessment, ICES also mandates an additional precaution to safeguard overexploitation of a stock where the stock status or stock exploitation is unknown. The Precautionary Buffer (a 20% reduction of advice on a 3-year basis if stock size is not increasing or fishing pressure is not decreasing; Section 1.1), acts in addition to provided advice. WKDLSSLS2 (ICES, 2020) tested the 1o2 with 80% without applying the Precautionary Buffer and found it to be precautionary.

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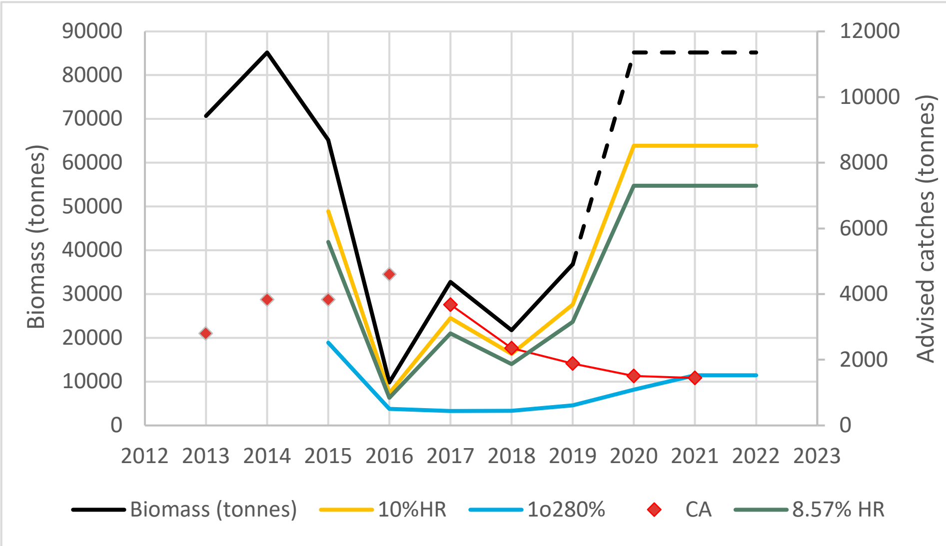

Figure 6.1. Simulation of advice resulting from 1 over 2 survey method with 80% uncertainty cap, 20% and 8.57% Harvest Rate based advice and the provided advice (CA). (Dashed black line indicates simulated survey biomass, survey index and advice are temporally off set to year of advice to aid visualisation).

7 Management Strategy Evaluation and Constant Harvest Rate estimate

The MSE framework used here was originally developed to test WKMSYCat34 catch advice approaches (ICES, 2017a) under WKLIFE 6–9 (ICES, 2017b; ICES, 2017c; ICES, 2018; ICES, 2019b) and Fischer *et al.* (2020) and built in the "R" statistical coding environment using FLR libraries (FLCore and FLash). Runs are based on 500 replicates, with stock status established over a 25-year spin-up period, and advice measures implemented for a further 25-year projection period, following the schematic in Figure 7.2.

The time-step structure of the MSE was established following an "Annual Seasonal" cycle (Figure 7.1), based upon the PELTIC survey taking place in October/November (of year *y*), assessment in the HAWG (February to March; year *y*) and application to the fishery in July to June (year *y*+1). A "Lagged" version of the MSE was also established, to simulate the time-lag of 14 months between survey and fishery seen in the current management "Annual Calendar" cycle. Results however, did not follow expectations owing to the MSE handling of integer year growth steps, and lack of clarity of MSE process steps. This approach was not fully evaluated and results were no further pursued. Once the MSE frameworks allows for monthly or quarterly growth steps, this should be re-visited.

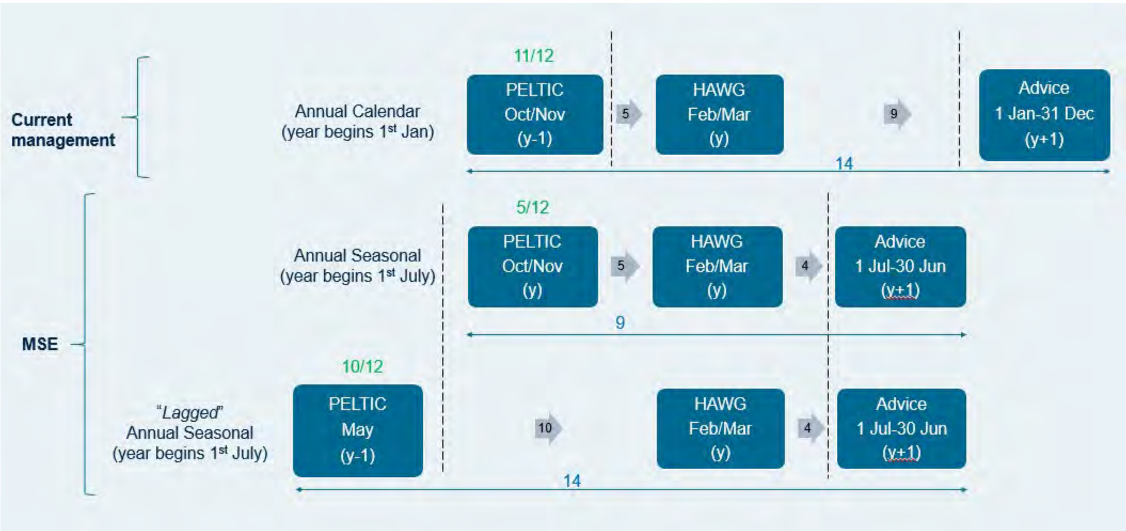

Figure 7.1. Timing of the "Current management" regime "Annual Calendar" and MSE year set-up "Annual Seasonal". A "Lagged" "Annual Seasonal" MSE set up was established to simulate the 14-month time-lag in comparison with the "Current management" regime "Annual Calendar", however results were found to be inconsistent with expectations and therefore not followed.

The Operating model was initially established under a set of three von Bertalanffy structures, four recruitment scenarios and two length–weight relationship estimates based on preceding work (ICES, 2019a).

These were further tuned during IBPSprat to the Sprat 7.d–e stock through Von Bertalanffy equation variables L_∞, k and t_0 fitted to the observations of length-at-age during the PELTIC survey (Section 3). In addition, recruitment was modelled with a hockey-stick model with steepness taken at the median value reported for sprat by Myers *et al.* (1999) for the Beverton and Holt S–R relationship, and with a variability around the expected recruitment taken from the closely related North Sea stock.

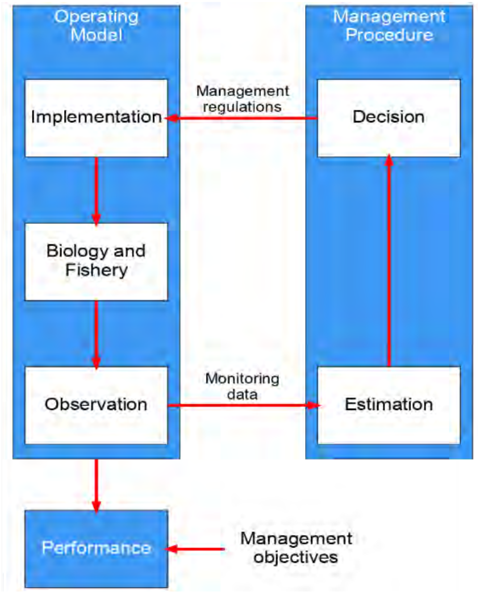

Figure 7.2. MSE structure schematic.

These were considered representative of sprat species. In comparison with the default values taken for other stocks (Fischer *et al.*, 2020) these can be considered conservative and risk averse.

Final values were:

- VB4: $L_\infty = 14.9; k = 0.454; t_0 = -1.452$;
- LW1: a = 0.0000048; b = 3.19;
- Steepness: s = 0.65 (Myers *et al.*, 1999);
- Recruitment variability: 0.78 (from N. Sea sprat stock HAWG (ICES, 2020).

Natural mortalities-at-age were estimated from the von Bertalanffy growth input parameters according to life-history theory (FLife R package), following Gislason *et al.* (2010). B_{lim} was defined as the breakpoint in a segmented stock–recruitment function, conditional to the assumed steepness and virgin biomass (FLife R package, breakpoint b = B_{lim} = 308, where default for virgin biomass = 1000).

Maturity was modelled with a sigmoidal function in the MSE, centred on the age of 50% maturity (a50). The a50 was estimated to the 0-age class (maturity-at-age 0=50%) by the R package FLife. Given spawning biomass is calculated at 75% (nine months) into the MSE year (with the MSE year beginning in July and spawning occurring in March/April), the resulting maturities are rather similar to those for the North Sea sprat stock.

Fleet selectivity was modelled with a double normal distribution (Hilborn *et al.*, 2003) with the mode equal to the age of 50% maturity, (a50) as detailed above.

Catchability at age from the survey was modelled as a logistic curve (Figure 7.4). Three variants of overestimation of survey catchability were simulated: "None", where, without error, the survey catchability was assumed to detect up to exact numbers of sprat; "50%", where up to an assumed 50% overestimation is added to the catchability of the survey index and; "100%", where up to 100% overestimation is added to the catchability. Percentages refer to the over estimation of catches when ages have reached full selectivity within the survey, at age 2+. These were simulated in the MSE with settings in Table 7.1, each with estimation error. Settings for the final agreed MSE are presented in Table 7.2.

Table 7.1. MSE catchability settings for none, 50% 100% over estimation.

Settings\ over estimation simulation	None	50%	100%
Max	1.0	1.5	2.0
Steepness	1.1	1.1	1.1
A_{50}	0.5	0.1	0.1

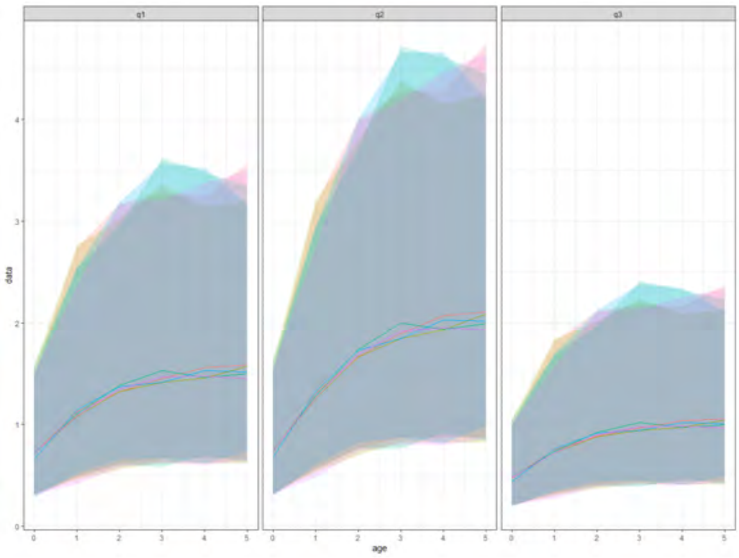

Figure 7.3. MSE survey catchability profiles of 50% (left) 100% (middle) and No (right) overestimation.

Survey observations by age (Equation 2) were multiplied by stock weights-at-age to emulate the process of obtaining a survey biomass index for provision of advice:

$$B_y^s = \sum_a w_w \ I_{a,y} \quad \text{Equation 2}$$

Where w_a are stock weights-at-age, taken at the beginning of the annual time-step in the MSE.

The applied *CV* (coefficient of variation) of the survey series in the MSE was set to a relatively high value (*CV*=0.5) in comparison with many other MSEs (e.g. Fischer *et al.*, 2020 who set it at 0.20) owing to the large inter-annual variability of age composition. This is a conservative and risk averse decision for the evaluation of HCRs.

Two types of assessment basis were tested:

Catch ratio-based advice: Advised catch (*A*) is based on the most recent advised catch multiplied by the ratio (*r*) of the most recent biomass index value and the average of the two preceding values (1o2), (ICES, WKMSYCat34 2017).

$$A_{y+1} = rA_{y1}; r = \frac{\sum_{i=y-x+1}^{y} B_i^s / x}{\sum_{i=y-z+1}^{y-x} B_i^s / z} \quad \text{Equation 3}$$

Where x is the numerator of the catch rule and z the denominator (e.g. x=1 and z=2 corresponds to the 1o2 ratio-based advice option).

***Constant Harvest Rate (CHR)*:** Advised catch corresponds to a fixed proportion, CHR (h) of the biomass index.

$$A_{y+1} = hB_y^s \qquad \text{Equation 4}$$

Three scenarios of fishing pressure, prior to implementation of the catch advice options, were simulated for 25 years to establish starting points for the stock, and were defined as:

1. FH1 “Patterson”: Fishing mortality increased exponentially from 0 to F_P corresponding to Patterson’s exploitation rate (E=0.4=F/Z).
2. FH2 “One-way trip”: Fishing mortality increased exponentially from 0 to 1.5F_P.
3. FH3 “Roller-coaster”: Fishing mortality increased exponentially from 0 to 1.5F_P, in 12 years, stayed at this level for seven years and then decreased exponentially to F_P by the end of the 25-year historic period.

These are graphically represented in Figure 7.4.

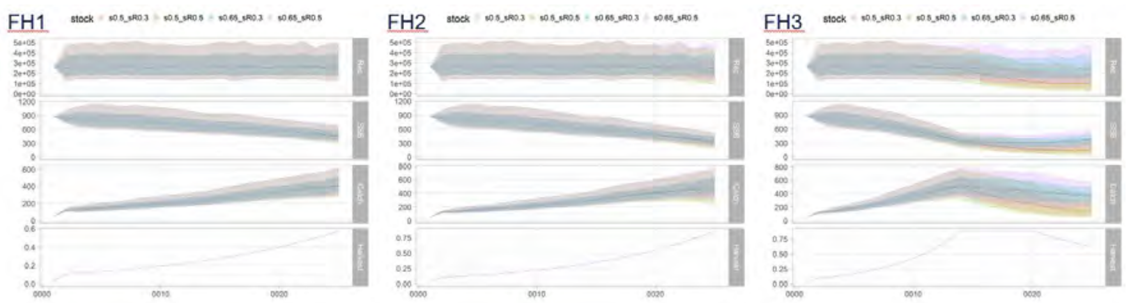

Figure 7.4. Examples of the simulated fishing pressures FH1 “Patterson”, FH2 “One-way trip and FH3 “Roller-coaster” prior to the implementation of catch advice options.

The operating model is dependent upon the survey observation, its associated error and assumed catchability. Survey observations were generated from the operating model (with catchability modelled as a logistic curve) following Equation 5.

$$I_{a,y} = q_a N_{a,y} e^{-t_s(F_a+M_a)} e^{\varepsilon_{a,y}} \qquad \text{Equation 5}$$

Where:

q_a = survey catchability-at-age;

N = stock numbers-at-age and year from the operating model;

y = year;

t_s = timing of the survey in relation to the model year;

F_a = fishing mortalities-at-age;

M_a = natural mortalities-at-age;

e = assumed error (CV = 0.5, detailed above).

Performance of the advice options were monitored in the MSE through two performance statistics (WKDLSSLS2; ICES, 2020):

- *Risk*: The average probability of SSB being below B_{lim} where the average is taken across iterations and time. Values < 0.05 are considered precautionary. This is Risk type 1, which equals Risk type 3 in the long term.
- *Mean yield*: Median of the mean catch over time and across iterations.

The performance indicators were evaluated over short (first five years), medium (next ten years, 6–15) and long (last ten years, 16–25) term periods after the start of management implementation.

To calculate the maximum sustainable CHR, the MSE was iteratively run to find the highest harvest rate with a risk of less than 5% (short, medium or long-term). The MSE was spun up with the three fishing scenarios and the CHR applied for the 25-year projection period (50 years total).

To find the maximum sustainable CHR, for each fishing scenario operating model (OM):

1. Harvest rates (*h*) began at 1%.
2. OMs were run applying harvest rate *h* during the projection period.
3. Performance statistics were calculated at the end of each simulation.
4. If any risk statistics (short, medium or long-term) were <5% set *h*=*h*+1% and repeat from step 2.

Table 7.2. Agreed settings for MSE.

Parameter	Value	Rationale
VBL (L_{inf}, k, t_0)	L_{inf}: 14.9 K: 0.454 t_0: -1.452	This is derived from actual data and hence constitutes the best approximation to the stock (Section 3)
Weight-at-age	a=0.0000048, b=3.19	From PELTIC survey (see Section 7).
M	Following Gislason	Estimated within the MSE.
Maturity	Age 0= 0.5 / Age 1=0.950 Age 2= 0.997 / Age 3+=1	Rather similar to North Sea sprat with a shift of one year to accomodate to the seasonal year in the MSE.
Recruitment function	Segmented regression with steepness s = 0.65	From Meyers *et al.* (1999).
Recruitment variability	0.78	Conservative measure assumed for sprat (similar to North Sea sprat stock).
B_{lim}	308 tonnes	As estimated by FLife (R) and representing 30% of virgin biomass. Note values are relative.
Survey catchability	1.5	The survey is considered to be a good estimate of the stock, indeed it might underestimate rather than overestimate stock size (Section 2). The panel decided to set survey catchability parameter in the MSE to 1.5, accounting for an overestimation of the survey biomass by 50% on ages 2+, thereby being conservative (a risk averse decision).
Survey CV	0.5	To account for variable age class availability (mainly age 0). This is conservative (risk averse) assumtion
Timing of survey in MSE	3.5/12	This accounts for the survey time lag in the MSE. The MSE starts on July 1st, the survey is conducted in October/November.
Fishing Histories	All three FHs simulated in a 25 year run-up period	FH1 “Patterson”; FH2 “One-way trip and; FH3 “Roller-coaster”.
Time frame for projections	Short: first five years (26–30) Medium: next ten years (31–40) Long: Last ten years (41–50)	

Thereby increasing the harvest rate until all risk levels become unacceptable. This enabled the maximum constant HR the theoretical stock can sustain to be determined while remaining within safe biological limits.

Of the performance statistics the risk performance statistic was used to indicate appropriate CHR, ensuring SSB remains above B_{lim} (the breakpoint of the intrinsically determined segmented Stock–Recruitment relationship) with a probability of 95% (Annex 4).

Comparisons of advice basis options (CHRs and the 1o2 option, alone and with 20% and 80% UC, and an Istat biomass safeguard) *via* their associated risk levels and yields under each survey overestimation option were made with each of the three fishing histories (example Figure 7.5). Note that under FH2 and FH3, in the short term (five years), no options fell below the 5% risk threshold. This is a result of these simulated fishing histories reducing the stock below a level from which it is able to recover adequately within the first five years of applying the tested management measures.

To investigate MSE derived CHR associated risk and yield values, a 20% CHR was evaluated alongside a CHR of 12% and the 1o2 option, alone and with 20% and 80% UC, and an Istat biomass safeguard (Figure 7.6). This again shows the CHR to be the most risk averse approach, at 12%. As may be expected risk levels are higher with a 20% CHR. In the short term, it is still more risk averse than 1 over 2 ratio-based options, and additionally, in all instances a 20% CHR is still more risk averse than the recently applied 1 over 2 ratio-based option with 20% UC, and gives higher yields. In the medium and long term however, the WKDLSSLS2 suggested rule, 1o2 with 80% UC and Istat, would be more precautionary than a 20% CHR, for the three fishing trajectories tested here.

Final results, with survey over estimation at 50% are shown in Section 9.5.

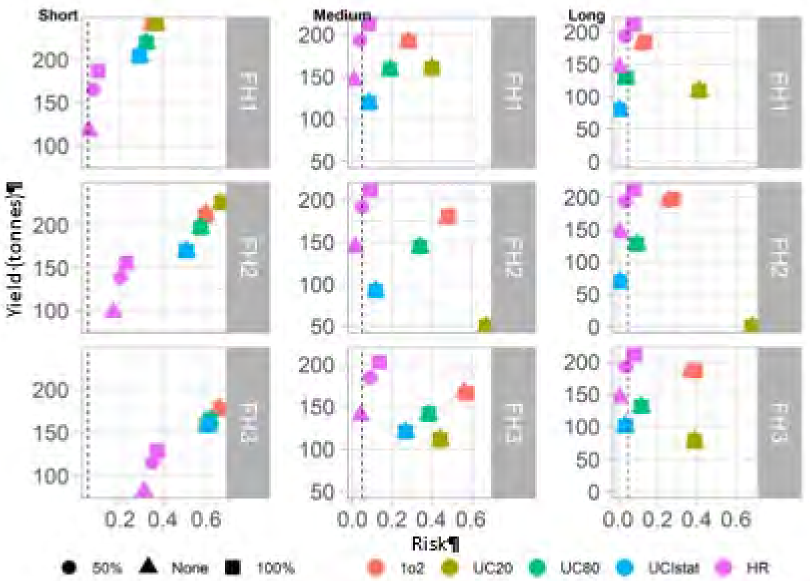

Figure 7.5. An example of results of an assessment of advice bases options. (Note this is not the final CHR results). A 14% constant harvest rate (maximum CHR assuming 50% survey over estimation) and 1o2, with 20%, 80% UCs and 80% UC with Istat Biomass safeguard. The figure displays short-, medium- and long-term effects for fishing histories FH1, FH2 and FH3 ("Patterson", "One-way trip" and "Roller-coaster" respectively) and different realised survey catchabilities (no, 50% and 100% overestimation). Results for the final MSE are given in in Section 9.1.

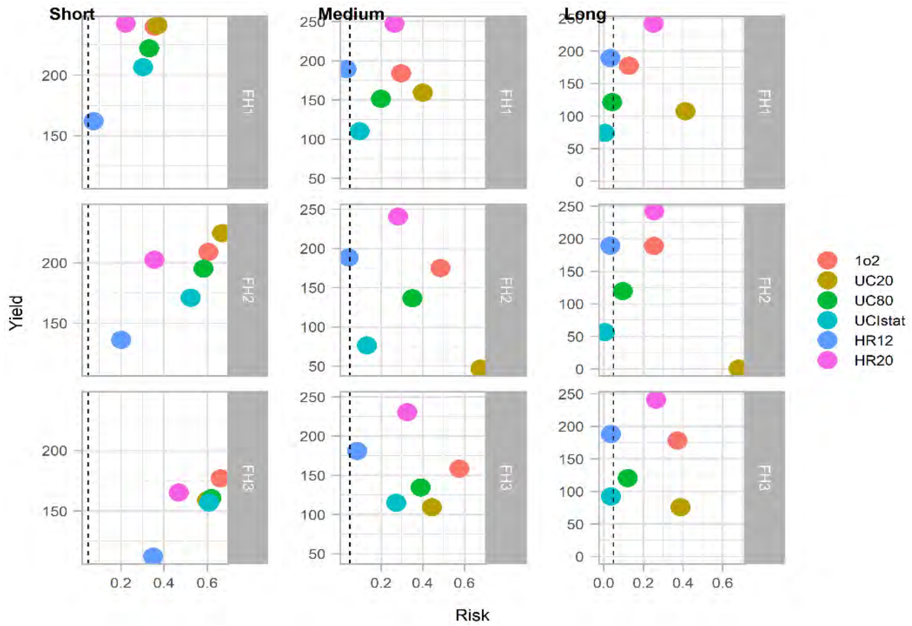

Figure 7.6. 12% and 20% constant harvest rates (maximum CHR assuming 50% survey over estimation) relative to 1o2, with 20%, 80% UCs and 80% UC with Istat Biomass safeguard. The figure displays short-, medium- and long-term effects for fishing histories FH1, FH2 and FH3 ("Patterson", "One-way trip" and "Roller-coaster" respectively). Results for the final MSE are given in in Section 9.1.

8 Adjustment for timing differential: Correction factor

The established MSE uses a single set of weights-at-age, attributing to each age class the expected mean weight corresponding to the integer value of the age. These are applied to the MSE estimations of the spawning biomass and to the survey biomass index observation in each yearly time-step. Since there is a notable monthly step however, between the beginning of the year, the survey and assessment, it is necessary to account for in-year growth of each of the age classes in the stock as growth, especially in younger age classes in this short-lived species, will contribute a notable addition to the stock weight throughout the year. This will impact the MSE estimated CHR.

Weights-at-age in the biomass reported by the PELTIC in reality will be higher than those simulated by the MSE ("mseINDEX"), as mean weights at the beginning of the year are applied in the MSE. Therefore, the MSE is using an underestimate of the stock weight-at-age-structure at survey time. The MSE estimate of a Constant Harvest Rate ("CHRmse") if applied directly to the actual PELTIC survey index will allow higher catches than the ones presumed to be taken in the MSE modelling (as the PELTIC index is expected to be higher than the mseINDEX). This increase in stock weights-at-age would implicitly increase the experienced harvest rate exerted by the fishery if the CHRmse is applied to the PELTIC index. A correction factor to the CHRmse is therefore required, which should be set equal to the ratio of mseINDEX/"PelticIndex", where PelticIndex equates to the weight-at-age structure present at the time of the survey. This time-step accounts for a seven-month growth period, comprising the months between spawning in March and the survey in October.

Settings for the calculation of the correction are detailed in (Annex 5). A stock size at the time of the survey ($^{3.5}/_{12}$ months) estimated using weights-at-age corresponding to the integer age (as estimated at the time of spawning) derived from the MSE estimate and based on 100 000 individuals would incur a stock biomass weight of 608 tonnes. When calculated with the correct weight-at-age at survey time relative to spawning (at $^{7}/_{12}$ months), results in a stock biomass weight of 852 tonnes. The discrepancy in the two, 243 tonnes, represents a reduction of the MSE estimate by 28.6%. This equates to application of a correction factor of 0.714 to the MSE estimated CHR.

(NOTE: The spreadsheet with associated calculations are available the IBPSprat SharePoint, file: "HR_Correction_Factor_Calc_MASTER_Do_Not_Edit_18-2-2021")

9 Results and Conclusions

9.1 Management calendar

The IBP endorsed the conclusions of ICES WKDLSSLS (ICES, 2019; ICES, 2020) to shorten as much as possible time between survey, advice and implementation of management, to achieve more reactive management to changes in the stock size of this short-lived data-limited stock. For this reason, the IBP recommends moving the management from the “calendar year” to a “seasonal year” (running from July (y) to June (y+1)), based on the survey inputs from autumn of year y-1. The final recommendation of an HCR based on a Constant Harvest Rate is based on the assumption that such a change in the management year is adopted. The recommended advice rule has not been fully tested on the current annual schedule of management (which provides advice for calendar year y+1 from a survey index of year y-1, resulting in a 14-month lag between survey observation and implementation of advice).

While this has not been fully tested, sensitivity analyses to a 14-month time-lag (implemented by shifting the timing of the survey) have shown that advice based on the MSE CHR is more sensitive to the size of the biomass index than to the lag in timing between the survey and implementation of advice. Further to this, the CHR relies on only the most recent biomass survey index, and therefore is more responsive than the 1 over 2 advice rule.

If using the CHR under the current management timelines (January to December), then a review of the advice after completion of the October/ November survey (in year y) is highly recommended, as a safeguard to the biomass not being below the previously estimated level.

In this case, application of the CHR to the new biomass index is advisable to conform to the safe harvest level. This is feasible as the survey biomass index result is available every year before the end of November, so such checking would correct any deviations from intended CHR before the start of the management year in January. Furthermore, this availability makes feasible a move the advice based on the CHR to November.

9.2 Potential for SPiCT assessment and management

Exploratory SPiCT model fits to the available data either with changing years (calendar or July–June y+1) or with quarterly data were made but proved to be unsuccessful. The annual model with a calendar year did not converge and the confidence intervals of the parameters estimated with the other two models were too high to provide conclusive results. The IBP panel concluded SPiCT should be tested again in the future when the time-series of biomass index is long enough to provide reliable outputs.

9.3 MSE for harvest control rule options

The group compared the performance of CHR to index-trend harvest control rules through MSE.

The CHR of 12% was the maximum value estimated under the 50% survey catchability overestimation level that remained a risk <5% in the long term under all fishing histories, giving the highest yield. Results of performance of simulations of the HCRs 1o2 and the final run CHR of 12%, are displayed in Figure 9.1. In all instances, advice based upon the CHR, is more precautionary in the short, medium and long term, and allows greater catches than survey based 1 over 2 advice with 20% or 80% UC, with the exception in the long term of 1 over 2 with 80%

UC coupled with an Istat safeguard. While this has a slightly smaller risk than the CHR, both are below 0.05. Further, investigations to examine the potential impact of a higher harvest ratio being experienced by the stock, owing for example to the lag between survey and implemented CHR, showed that even a CHR of 20% produced more risk averse advice than the previously applied 1 over 2 advice with 20% UC (Figure 7.6).

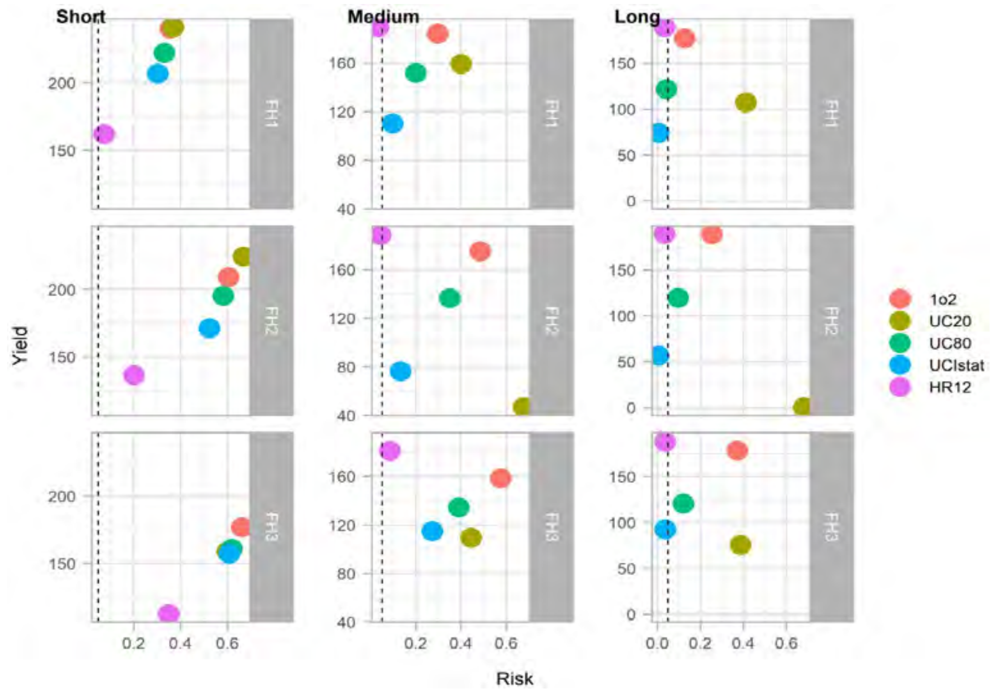

Figure 9.1. Comparison of final results of estimated maximum constant harvest rate 12% (HR12) and 1o2 without UC, and with 20%, 80% UC, and 80% UC with Istat Biomass safeguard. The figure displays short, medium and long-term effects, for fishing histories FH1, FH2 and FH3 ("Patterson", "One-way trip" and "Roller-coaster" respectively). These are the results for the final MSE run as in Section 9.1.

9.4 Category 3, Survey trend-based advice

The 1 over 2 rule was tested with 20% and 80% symmetric uncertainty caps, while asymmetric uncertainty caps were disregarded. A biomass safeguard was also tested with the 80% UC (UCIstat). The 20% uncertainty cap was deemed least precautionary for this short-lived species (Figure 9.1) and not considered as a possible management option. The 1o2 with an 80%UC was more precautionary than that without any UC. The 1o2 rule was not sensitive to the timing of the survey nor the survey catchability as it is a modifier of previous catch advice according to relative trends in the stock index.

9.5 Constant Harvest Rate

The highest possible CHR, while keeping the risk <5% was 12%.

To account for the offset in the growth of age classes in the stock, relative to the time of the survey a correction factor was applied to 12% CHR (Section 8). The correction factor was calculated within a spreadsheet (IBPSprat SharePoint, file: "HR_Correction_Factor_Calc_MASTER_Do_Not_Edit_18-2-2021"). **The correction factor was estimated at 0.714 of the CHR estimated by the MSE, this results in an advised constant harvest rate of 8.57%.**

The application of this corrected CHR is shown to be precautionary for the seasonal management of this fishery, without further interannual restriction, therefore an Uncertainty Cap or periodic Precautionary Buffer are not required.

10 Comments from Reviewers

Andrés Uriarte (AZTI, Basque Country, Spain) and Pia Schubert (Agri-food and Biosciences Institute, Northern Ireland, UK).

General

The Expert panel considers that the work carried out by the group was comprehensive and sound, and allowed to address sufficiently the ToRs appointed to the group. However, the review and calculation of the options for providing advice using the conclusions from WKDLSSLS 2020 for sprat 27.7de, was not an easy straightforward task for the IBP.

The Work addressed the potential for applying SPiCT, the trend-based Harvest Control Rules (HCRs) (1-over-2 with 80% UC and Istat) and a Constant Harvest rate (CHR); each of them suggested by WKDLSSLS2 for this stock.

As a successful fitting of SPiCT was not achieved, the group correctly focussed on verifying the relative performance of the trend-based HCRs (1o2) versus the maximum precautionary CHR.

To compare the relative performance of these two management options within an MSE, the key element was to set up a justified Sprat Operating Model (OM). During WKDLSSLS it was shown that the outcome of the search of a precautionary constant harvest rate depends upon several assumptions of the OM. Key among them are the S–R relationship steepness, growth model, survey catchability (bias relative to the absolute level of the population) and survey CV. Another important assumption for the OM is B_{lim}, as the reference upon which to measure risk of impaired recruitment over projected population in the MSE. The IBP should be the place to adopt those settings or to adjust them.

Using a MSE as a simulation tool to estimate a constant harvest rate has been a ground-breaking inter-benchmark.

On the definition of the Operating Model to test the performance of the advisory rules

For the definition of the OM, parameter values were selected and justified (see Table 9.1), in general choosing the most risk averse values:

The growth parameters were achieved by fitting a von Bertalanffy growth curve to observations from the PELTIC survey, which justified the parameters. The doubts about forcing T0 to equal 0 were disregarded after discussion as they would worsen the fitting to the data.

50% maturity at age 0 was justified to best accommodate an intermediate maturity for the age group when reaching age 1. Fishery selectivity was centred around the age 50% maturity, so around age 0, which was considered appropriate. In case the actual selectivity would be more centred on age 1 than on age 0 (as presumed in the MSE) then the adopted option would be risk averse compared to selectivity centred on age 1.

Natural mortality was adopted following currently accepted models of Gislason *et al.* (2010), based on growth parameters.

The survey was considered to potentially incur an overestimation of the sprat population by setting Catchability at age 3+ at 1.5 (which implied an overestimation of age group 1 of about 10).

Such a decision was considered precautionary and risk averse, as the survey is likely to underestimate the biomass of Sprat for the following reasons:

a) The survey index does cover only a fraction of the entire 7.de divisions. Though most of the biomass seems to be located in that region around Lyme Bay, where the fishery takes place. It is known that a part of the population is out of the surveyed region of reference.

b) The TS values is the generic clupeid value of b20 = -71.2 dB, which seems appropriate for this species and is a precautionary in comparison to other values used in neighbouring areas for Sprat.

c) The catchability at age 0 could be smaller than that presumed of about 0.7 (for the overall catchability at age 3+ of 1.5), because the actual abundance of ages 0 relative to older ages in the PELTIC age compositions is smaller than the ones presumed to be seen within the MSE model (as resulted from some Excel sheet simulations carried out during the IBP) (Not shown in the report).

Despite all these indications of survey underestimation, the group decided to take the catchability pattern corresponding to overestimation of 50% at ages 3+, to be risk averse when searching for the maximum and precautionary Constant Harvest rate (pCHR).

Another key parameter of the survey was the Coefficient of Variation (CV), this was set at 0.5, above that actually reported in recent years for this survey (around 0.25) and above values usually taken into account, when testing the performance of trend-based HCR for data-limited stocks (Fischer *et al.*, 2020). This is again a conservative, risk averse decision, as the larger the CV the smaller the resulting pCHR.

While revising the S–R relationship, the IB decided to choose the steepness of 0.65 (from Meyers *et al.*, 1999), which was below the median steepness for all cupleidae in that paper (of 0.71) and below the typical one being used for many DLS stock of about 0.75 (Fischer *et al.*, 2020) and lower than the one applied to North Sea sprat. As the greater the steepness the greater the resilience to exploitation of fish stocks, the selected value can be considered precautionary and risk averse.

The CV around expected median recruitment over B_{lim} was set at 0.78, a value consistent with North Sea sprat, and higher than the ones originally devised in WKSpratMSE (ICES 2019) and by Walker (WKDLSSLS; ICES, 2019), of σR=0.3 and 0.5. Again, this decision was defensible and moving from the original setting to a more precautionary value (and hence more suitable and risk averse compared to initial values).

B_{lim} was estimated at around 30% of virgin biomass (B0) by FLife based on life-history parameters. This might be considered a suitable conservative value in comparison with the typical default option in many MSE of 20% B0 (Meyers *et al.*, 1994; Punt *et al.*, 2016), but it is more aligned with presumed relatively low resilience to fishing of pelagic fish stocks (Mace and Sinsenwine, 1993).

The IBP noted that the CHR calculation in the MSE using an annual seasonal calendar needed re-shuffling of the data, and it was not possible to directly compare the performance of a CHR under the current management (calendar year with 15 months between survey and start of fishery) and annual seasonal (nine months between survey and start of fishery). The IBP recognised that the construction of a quarterly or monthly MSE package would be beneficial to properly address such comparisons. The results of the analysis carried out by the IBP group refer to the annual seasonal calendar, while other management time cycles could not be explicitly analysed during the meeting, results in all instances indicated that the identified CHR options were more risk averse than the current 1 over 2 ratio-based advice.

On the results

While the results clearly show that the constant harvest rate outperforms the 1o2 rule (Figure 7.5), it is essential to take all the factors into consideration. Calculating the maximal constant harvest rate requires very careful estimation of all the necessary parameters, including life history and recruitment. The IBP found that MSE constant harvest rate is sensitive to these parameters, and miss-parameterization might lead to a CHR too high for the stock. More work than included in the report was made available to the group, and in previous WKDLSSLS reports (ICES, 2020), which proved these statements even though they were not repeated in this report.

It is also important to consider the timing of the survey within the simulated year, spawning time and time of the fishery. After careful selection of survey timing in the MSE, estimation of growth parameters from the stock and setting the survey catchability to overestimate by up to 50%, the MSE estimated a CHR of 12% to for the annual seasonal calendar management. However, there was evidence, and the group and reviewers agreed, for the need to include a correction factor to the simulated CHR, to account for an offset in the growth of age classes at survey time relative to that at the start of the year (Section 8). Such a correction of 0.715 reduced the precautionary CHR to 8.57%.

Based on the decisions taken on biological parameters, most of them risk averse, and application of the final correction factor, the reviewers panel consider that the approach followed by the IBP group to define the pCHR is robust, risk averse, and applicable to the stock managed on the seasonal management scheme. The expert panel endorses the results and conclusions of the IBPSprat report and the recommendations listed in Section 11 below.

Some comments on the process and on the message to pass to managers

- The MSE had a too rigid configuration, which did not allow proper checking of different management years, detailed growth during the year, etc. This hampered the amount of sensitivity analysis carried out and testing of the current calendar year management strategy. Hence the recommendation was only explicitly tested for a seasonal management year running from July to June based on the survey in the previous October. The current management calendar (January–December year y+1 based on survey input of year y-1) could not be explicitly tested.
- It should be noted that as the CHR has been explicitly derived based on a seasonal management year (July to June), if the current management year (January–December year y+1) is to remain unchanged, the proposed Constant Harvest Rate value would not be explicitly appropriate. In such a case, the maximum CHR should be re-evaluated with a further developed MSE and in-depth testing of different advice/ management scenarios. Nevertheless, if the current management year (January–December year y+1) is desired to be kept, then a way to overcome this limitation would be to check the advice given on such basis, with the application of the CHR to the most recent Biomass index available during the interim year (y). Such review should be conducted annually (Section 11.1, Basis and application of assessment and advice for 2021).
- The documentation on the basis to select the range of values for the parameters defining the sprat population dynamics of the Operating Model of the MSE was scarce and diffuse, not easy to follow. Much of the work writing the report has been done by the Chair and the reviewers.

11 Recommendations

11.1 Basis and application of assessment and advice for 2021

Following the IBP work and review, it is recommended that advice for Sprat (*Sprattus sprattus*) in divisions 7.d and 7.e (English Channel) should be based on a constant harvest ratio (CHR) derived from the MSE and incorporating a correction factor for within year stock growth, of 8.57%, applied to the most recent survey-based biomass index derived by the PELTIC survey. Advice should be applied to a seasonal management July to June. There is no need of application of an uncertainty cap or periodic applications of a precautionary buffer.

Justification for this is based upon the following:

- The CHR relies on the survey biomass from only one year, and therefore is more responsive to stock status than 1 over 2 ratio-based advice, and is not linked to the preceding catch advice.
- Advice based upon the final CHR is more precautionary than survey 1 over 2 ratio-based advice with a 20% UC, as recently applied to this fishery.
- The CHR has been established on the basis of it being applied from July to June, and would be best suited to this management regime with the most recent survey results applied to advice and fishery.
- If using the CHR under the current management timelines (January to December), then a review of the advice after completion of the October/ November survey (in year *y*) is recommended, as a safeguard to ensure that the provided advice is still appropriate.
- This is feasible as new survey biomass estimates are available each year before the end of November.
- Application of the proposed CHR based advice to the current management timelines (January to December) may be justified, owing to its risk averse nature, noting:
  - selection of parameters in the MSE/ CHR calculations
  - selection of the 50% overestimation of catchability in the survey
  - that even a 20% CHR is shown to provide more risk averse advice than 1 over 2 ratio-based advice with 20% or with 80% UC and Istat in the short term.
  - The CHR of 8.57% should be tested in an MSE with appropriate time steps as soon as possible, as it could not be explicitly tested in this manner.

The MSE based CHR of 12.0% (Section 7), corrected for within year stock growth (Section 8) by a factor of 0.714 gives a CHR of 8.57%. The most recent survey, undertaken in October 2020, gave a biomass index of 33 798 tonnes. Applying the CHR to this gives catch advice of 2897 tonnes, a 100.3% increase on the last advised catch (Table 11.1). Following points listed above, this is appropriate for July 2021 to June 2022, or, if applied January 2022 to December 2022, it should be accompanied by a review/revision when survey data become available in November 2021.

Table 11.1. Sprat in divisions 7.d and 7.e. The basis for the catch scenarios.*

Biomass index (2020)	**33,798 tonnes**
Constant Harvest Rate	8.57%
Advised catch for 2021 (issued in 2020)	1446 tonnes
Discard rate	Negligible
Catch advice**	2897 tonnes
% advice change ***	100.3%

*** The figures in the table are rounded. Calculations were made with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.**

**** Advice for July 2021 to June 2022 (or, January 2022 to December 2022 when accompanied by review/revision in November 2021); is calculated as [Biomass index (2020)] × [Constant Harvest Rate].**

***** Current advice relative to the preceding advice.**

The availability of the survey Index by the end of November, after examination by WGACEGG, makes feasible a move the advice based on the CHR to November (y) to be implemented on calendar year (January–December of y+1). As the bulk of the fishery takes places during the second half of every year (about 95%) (and the lag time between survey and managed fishery would be shorter than for the management system July–June) then the current CHR value would be as well sustainable and applicable to such management timeline system.

11.2 Recommendations

The IBP has built on previous work of WKDLSSLS and WKLIFE, applied and developed the recommendations and advice provision options. There remain items requiring further development to improve advice on the stock. The issues list below (Table 11.2) describes areas for future work, with suggestions to appropriate focus groups.

Table 11.2. Recommendation list.

Ref	Issue	Attention of
1	Build MSE with quarterly time-steps to: To enable growth in the stock between survey, assessment and execution of the fishery to be modelled and hence better estimate the experienced HR and CHR. Presently in the MSE the stock weights are set in for the calendar year (as an integer), while in the stock will experience growth between the survey, assessment and fishery, giving a larger stock size at fishery, while the survey estimate will be lower. This has currently been offset by estimating the stock growth over the intervening time period, to correct the MSE estimated CHR down, to account for the larger CHR which would be experienced. Currently the MSE has a rigid temporal configuration, which did not allow proper investigation of different management periods (years and months), and lagged times between survey, advice and management, detailing growth during the year, etc. Advice based upon the final CHR, and applied to a lagged fishing cycle is believed to be more precautionary than survey based 1 over 2 advice. The MSE results indicates that the CHRs are more sensitive to the timing and values of the survey, than the lag between the survey and implementation of advice. This appears contrary to conclusions of WKDLSSLS, that time-lags between surveys and advice should be as short as possible. This should be explored in more detail with development of a seasonal MSE. Refer to Figure 7.1 and Section 7 to follow issues and development associated with timing and "Lagged" MSE.	WKLIFE / WKDLSSLS3/ Future benchmark
2	Shorten time period between survey, assessment and application of advised catch. Presently survey happens in October of year "*y*", while assessment takes place in March of year *y*+1 and fishery according to advice on year *y*+2 (January to December). This time frame should be shortened, in the first instance, to applying the survey results (year *y*), and advice from July (*y*+1) to June (*y*+2).	ACOM
3	Incorporate a biomass safeguard, a minimum biomass cut-off point for advising a >0 catch, this may develop from previous work of WKDLSSLS on Istat biomass safeguards.	WKLIFE / WKDLSSLS3/ Future benchmark
4	The IBP supports the industry self-sampling programme and recommends that length frequency samples across the year should be collected and aged. This would enable the fishery selectivity to be better studied, and the lengt–-weight relationship, specific to the stock to be derived. Addition of age information will allow the von Bertalanffy life history parameters to be updated.	HAWG Future benchmark
5	Genetic samples should be collected to enable work on defining stock identity.	HAWG/ WGBIOP/

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Annex 1: List of participants

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Annex 2: Terms of Reference

IBPSprat Inter-benchmark to revise the advice framework for the Sprat stock in 7.de based on the most recent changes to data-limited short-lived species assessments

2020/2/FRSG56. The IBP to implement changes to data limited short-lived species assessments (IBP-Sprat), chaired by (Jonathan White, Ireland), and reviewed by Andrés Uriarte, Spain and Pia Schuchert, UK, will meet online from the 2–4th February.

The inter-benchmark will clarify the application of the latest advice for category 3 short-lived species following the conclusion of WKDLSSLS 2020 (working group for data-limited stocks of short-lived species) to the Sprat 27.7de stock.

a) Review the conclusions of WKDLSSLS for implementation in ICES advice for short-lived category 3 stocks.
b) Review and calculate the options for providing advice, using the conclusions from WKDLSSLS 2020 for sprat 27.7de.

Supporting information

Priority	Advice for category 3 stocks was updated in 2019 by WKDLSSLS 2019 and WKLIFE 2019, as it was determined that the previous 2 over 3 rule was not satisfactory for short-lived species. While accepting that a move to the proposed 1 over 2 was needed, issues regarding the implantation to annual advice as given for Sprat 27.7.de remained. These will be clarified at WKDLSSLS 2020. There is a pressing need to implement the updated guidance for this stock in time for HAWG 2021 so sensible advice can be given for this stock in line with ICES guidelines.
Scientific justification	WKDLSSL 2019 has determined that the 1 over 2 rule for advice better reflects the life history of short-lived species and avoids the disconnect in advice given using fish no longer present in the population when utilising a 2 over 3 rule.
Resource requirements	The inter-benchmark will be carried out online, due to the ongoing COVID-19 pandemic
Participants	Scientists with expertise in data-limited assessment and short-lived species will be required.
Secretariat facilities	None
Financial No financial implications	No financial implications
Linkages to advisory committees	The results of this work will feed in directly in the ICES advisory process.
Linkages to other committees or groups	This workshop is relevant to: WGHANSA that assesses a number of data-limited short-lived species.
Linkages to other organizations	

Defer for further discussion and post revision on Resolutions Forum for approval (to be addressed by SG Chair, EG Chair, ACOM or SCICOM chair and Secretariat).

Annex 3: HCR Performance Statistics

HCR Performance statistics under fishing pressures FH1, FH2 and FH3, before application of the correction factor.

FH1 "Patterson": Fishing mortality increased exponentially from 0 to F_P corresponding to Patterson's exploitation rate (E=0.4=F/Z).

Survey catchability	HR	Time Frame	Risk	depl20	depl40	mean_yield	mean_SSB	mean_F	meanICV
100% overestimation	0.06	S	0.049	0.011	0.119	101.075	687.281	0.116	0.477
100% overestimation	0.10	M	0.034	0.004	0.128	186.663	667.227	0.217	0.376
100% overestimation	0.10	L	0.033	0.003	0.120	186.664	661.409	0.216	0.364
50% overestimation	0.07	S	0.049	0.011	0.120	101.042	686.878	0.115	0.477
50% overestimation	0.12	M	0.034	0.004	0.130	189.335	662.134	0.220	0.394
50% overestimation	0.12	L	0.034	0.003	0.121	189.198	654.029	0.220	0.378
No overestimation	0.11	S	0.050	0.012	0.123	105.354	680.632	0.121	0.473
No overestimation	0.19	M	0.045	0.005	0.146	196.419	645.815	0.233	0.397
No overestimation	0.19	L	0.045	0.005	0.139	195.977	637.974	0.233	0.381

FH2 "One-way trip": Fishing mortality increased exponentially from 0 to 1.5F_P.

Survey catchability	HR	Time Frame	Risk	depl20	depl40	mean_yield	mean_SSB	mean_F	meanICV
100% overestimation	–	S	–	–	–	–	–	–	–
100% overestimation	0.10	M	0.044	0.008	0.133	185.511	663.902	0.215	0.385
100% overestimation	0.10	L	0.034	0.003	0.120	186.664	661.378	0.216	0.364
50% overestimation	–	S	–	–	–	–	–	–	–
50% overestimation	0.12	M	0.044	0.009	0.136	188.211	657.925	0.219	0.403
50% overestimation	0.12	L	0.035	0.003	0.122	189.197	653.609	0.220	0.378
No overestimation	–	S	–	–	–	–	–	–	–
No overestimation	0.18	M	0.044	0.009	0.136	188.211	657.925	0.219	0.403
No overestimation	0.19	L	0.045	0.006	0.139	195.977	637.133	0.233	0.381

FH3 "Roller-coaster": Fishing mortality increased exponentially from 0 to 1.5FP, in 12 years, stayed at this level for seven years and then decreased exponentially to FP by the end of the 25-year historic period.

Survey catchability	HR	Time Frame	Risk	depl20	depl40	mean_yield	mean_SSB	mean_F	meanICV
100% overestimation	–	S	–	–	–	–	–	–	–
100% overestimation	0.07	M	0.040	0.022	0.089	139.487	740.885	0.147	0.381
100% overestimation	0.10	L	0.035	0.004	0.123	186.323	661.409	0.216	0.367
50% overestimation	–	S	–	–	–	–	–	–	–
50% overestimation	0.09	M	0.047	0.024	0.104	148.324	719.790	0.160	0.397
50% overestimation	0.12	L	0.037	0.005	0.124	188.023	653.609	0.219	0.378
No overestimation	–	S	–	–	–	–	–	–	–
No overestimation	0.13	M	0.044	0.023	0.096	144.008	728.871	0.154	0.395
No overestimation	0.19	L	0.048	0.008	0.141	195.472	637.133	0.232	0.382

Annex 4: Settings in correction factor Calculation

Parameter	Setting details
Natural mortality	M, VB4 (fitted)
Survey / assessment timing	There is a time-lag between the realised MSE time-step, assumed as July, and the assessment, undertaken in October/ November, of three and a half months; $^{3.5}/_{12}$. This time-step is incorporated into the realised growth
Natural Mortality	Age — VBG (fitted) 0 — 1.170 1 — 0.810 2 — 0.666 3 — 0.595 4 — 0.556 5 — 0.533 6 — 0.520
Catchability	50% overestimation: Age — Catchability/age 0 — 0.709 1 — 1.094 2 — 1.335 3 — 1.441 4 — 1.480 5 — 1.493 6 — 1.498
Weight at spawning	Von Bertalanffy growth at time of spawning (using the age as integer so as if it were at the beginning of the year): VB4: $L_\infty = 14.9; k = 0.454; t_0 = -1.452$ LW1: a = 0.0000048; b = 3.19 Steepness: s = 0.65 Age — weight/age 0 — 2.58E-03 1 — 7.40E-03 2 — 1.25E-02 3 — 1.67E-02 4 — 1.99E-02 5 — 2.21E-02 6 — 2.36E-02

Parameter	Setting details	
Weight at survey	Von Bertalanffy growth lagged to time of survey by seven months:	
	7 months = 7/12 = 0.583 decimal years	
	VB4: $L_{\infty} = 14.9; k = 0.454; t_0 = -1.452$	
	LW1: a = 0.0000048; b = 3.19	
	Steepness: s = 0.65	
	Age	weight/age
	0	5.25E-03
	1	1.04E-02
	2	1.51E-02
	3	1.87E-02
	4	2.13E-02
	5	2.31E-02
	6	2.42E-02
Fishing pattern	Age	F/age
	0	0.470
	1	0.999
	2	1.000
	3	1.000
	4	1.000
	5	1.000
	6	1.000
Fishing pattern multiplier	0.2 As defined in MSE (the multiplier which leads to the F value at equilibrium in the long term).	

Annex 5: Correction Factor calculation

Screen grab of the correction factor calculation excel file "HR_Correction_Factor_Calc_MAS-TER_Do_Not_Edit_18-2-2021.xlsx" (IBPSprat SharePoint).