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Guide to Data-limited stock assessment

This guide describes how fish stocks are assessed when there are not sufficient data available to use conventional models.

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Summary

Fish stock assessment is the scientific approach used to advise fisheries' managers on measures to avoid stock depletion and to optimise catches (yields). A minority of the stocks from which the World's catch of fish is sourced are assessed using conventional methods, and there is a need to develop approaches to making assessments of the other stocks. Hence there have been advances in methods of assessment which fully utilise available data to give advice on those stocks where conventional assessment methods are not feasible; the data-limited stocks.

The main body of this document outlines the basis of the data-limited methods used by the International Council for Exploration of the Sea (ICES), the scientific body responsible for carrying out stock assessments in the Northeast Atlantic and Baltic Seas. In particular, this document details how data-limited fish stock assessments are carried out by ICES, and how the results are used to give catch advice. It therefore provides a generic guide to the ICES data-limited advice as published for each stock annually. There is also a brief guide to methods developed outside the ICES framework, with particular reference to shellfish assessments.

ICES has been engaged in the development and implementation of data-limited assessment methods for stocks with a wide range of data availability, and these methods have been implemented in ICES' scientific working groups to advise managers on catch limits. Central to this process has been the use of research vessel survey data, in some cases dating back more than 30 years, to examine trends in stocks. Advised catch limits are based on these trends; where the stocks have been found to be increasing catches can increase and *vice-versa*. Where survey data are not available, advice is given on the basis of previous catches.

To reduce the risk of overfishing, a 'precautionary buffer' may be included, which means that the advised catch is decreased by 20%. The implementation of this reduction is dependent on expert judgment of the status of the stocks. As a part of this process, simulations have been carried out to test this method's ability to provide information that will allow management to stabilise stocks and provide continuing sustainable yields. These simulations indicated that stocks might stabilise over a period of 3-5 years, but beyond that there may be a risk of overexploitation unless stocks were assessed against reference points for fishing pressure (fishing mortality or rate of harvest).

As a consequence, ICES has developed a suite of reference points based on relatively easily collectable data; catch, catch per unit effort, and length distributions of the catches. Together with biological characteristics of the stocks, these can be compared with designated 'proxy' or substitute reference points to assess a stock's status. These proxy reference points have been used to provide advice from 2017 and reduce the need for expert judgment in the implementation of the precautionary buffer.

More recently (2021) ICES has introduced methods for incorporating these proxy reference points within the data-limited assessment. These methods have been simulation tested and found to be precautionary, that is the stocks on average remain within safe biological limits with a 95% probability over an extended period, thereby avoiding the requirement to implement the precautionary buffer using expert judgment. These methods are currently being rolled out through the ICES advisory process.

The ICES data-limited methods have resulted in precautionary measures to protect certain stocks of vulnerable species such as elasmobranchs (skates and sharks) through prohibitions on landings. Data-limited assessments have also provided assurance that some stocks are relatively stable and have also been used for major stocks that are routinely fully

assessed when conventional methods are temporarily not feasible because of uncertainties in the data.

This document also provides a description and interpretation of the current version of the ICES data-limited advice as it can be downloaded on from the ICES website on a stock-by-stock basis.

Worldwide there have been considerable efforts to develop methods for assessing stocks with minimal data, with some methods showing good correspondence with conventional analytical techniques. Some of these methods, particularly for shellfish stocks are briefly described.

The two Appendices provide more details of how proxy reference points are calculated, and how the current ICES data limited advice is formulated.

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Glossary of terms

Term	Definition
Biomass at MSY: B_{MSY}	This is defined as the estimated level of biomass of a stock which produces MSY at long term equilibrium. B_{MSY} can also be defined as spawning stock biomass that results from fishing at F_{MSY} for a long time. In production models it corresponds to the level of biomass at which the surplus production of the stock is maximised
½ Biomass at MSY: ½ B_{MSY}	Level of Biomass corresponding to half of B_{MSY}. ICES uses this as proxy for MSY $B_{trigger}$ (see below) when stocks are assessed using a production model. Therefore, where production models are used in ICES Data-limited assessments this is the proxy used for MSY $B_{trigger}$
Biomass limit: B_{lim}	Biomass limit reference point; stocks with spawning stock biomass below this level are considered to suffer from impaired recruitment (recruit overfished) and hence may not be able to sustain a fishery. While this is the definition for fully assessed stocks, estimating this parameter for data-limited stocks is more difficult in the absence of a full assessment, so other approaches are used see Section 4.2
Fish Stock	"A relatively homogeneous and self-contained sub population of a species, whose loses by emigration and accession by immigration are, if any, minimal in relation to the rates of growth and mortality." See Guide to Fish Stock assessment and ICES reference points (Seafish, 2022b) for further information. In many data-limited assessments a stock may be assumed to be as defined above, but there may not be substantive evidence that this is so.
F_{MSY}	Rate of Fishing mortality consistent with achieving Maximum Sustainable Yield (MSY). In ICES data-limited assessments a proxy for F_{MSY} is used, based on a production (section 4.3) or size-based model (Appendix 1).
International Council for Exploration of the Sea: ICES	International scientific body responsible for carrying out fish stock assessments in the ICES Area: The Northeast Atlantic and Baltic Seas. Also advises governments on other scientific issues concerning the marine environment www.ices.dk
Maximum Sustainable Yield: MSY	Catching the maximum quantity that can safely be removed from the stock, while maintaining its capacity to produce sustainable yields in the long term.
MSY $B_{trigger}$	When the stock is above this level, the stock it is considered capable of being sustainably harvested at F_{MSY} to support a fishery. In some ICES data-limited assessments ½ B_{MSY} is used as a proxy for MSY $B_{trigger}$. If the stock falls below this level, ICES advice would include an element of catch reduction to encourage the stock to rebuild.
Safe biological limits	When a stock is inside safe biological limits it has sufficient reproductive capacity to support a fishery
Target reference point	Target reference points are levels of fishing mortality and/or Biomass of a stock which managers aim for in the long term
Total Allowable Catch: TAC	The Total Allowable Catch (TAC) is a catch limit (expressed in tonnes or numbers) set for a fishery generally for a year or a fishing season.
Trigger reference levels	Trigger reference levels, such as MSY $B_{trigger}$ are levels of biomass of a stock which should trigger management action to bring the stock back towards the target

1 Introduction

Stock assessments are used to advise fisheries' managers on management measures within an agreed framework. However, Costello et al, (2012) found that 80% of global fish catches are taken from stocks without full assessments. They also estimated that there is potential for improvements in stock abundance (+56% overall) and yields (8-40%) if those stocks which are not currently assessed were subject to assessment and appropriate management.

As discussed in two other Guides in this series (Seafish, 2022b,c) full analytical assessments require extensive data on age structures of fish catches, which is both time consuming and expensive to collect.

However, for many stocks there are data sources available from both surveys and commercial catches which, with the appropriate analysis, can be used to inform on stocks using data-limited assessment methods.

2 Evolution of ICES data-limited assessment

Stock assessment methods evolved over the course of the 20th century, particularly following the publication of 'On the Dynamics of Exploited Fish Populations' by Beverton & Holt, in 1957, which set out the basis for many of the methods developed since. As modeling knowledge and computing power increased, assessment methods improved over the years for stocks with adequate data, but there is a clear need to build capacity to assess those stocks which are data-limited.

In 2011, the European Commission and the International Council for the Exploration of the Sea (ICES), the scientific body responsible for carrying out stock assessments in the Northeast Atlantic and Baltic Seas, recognised that there was a need to standardise and refine data-limited methods to assess the many stocks within the Northeast Atlantic for which science-based management advice was not available.

Since then, ICES has been working on improving a set of methods for assessment through annual workshops; 'Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks', short title 'WKLIFE'; where researchers and assessment scientists develop and test data limited methods. These methods have been used for routine assessments and are subject to continuing refinement. There have been 10 of these WKLIFE workshops since 2011, the most recent workshop was held in October 2020 short title WKLIFE X (ICES, 2021).

The results of this work have been used to provide guidance to the ICES expert Working Groups which assess stocks on a regional basis. The first data-limited assessments under this framework (ICES, 2012) were carried out in 2012, and their use has grown rapidly ever since. By 2014, 64% of the 256 stocks for which management advice is provided by ICES were assessed using data-limited methods. These include stocks of commercially important species such as Eastern Baltic cod, anglerfish, North Sea lemon sole, and skates and rays.

The WKLIFE X approach is an advance on earlier methods and is detailed in Annex 3 of the WKLIFE X report (ICES, 2021). The assessment methods are summarised below and in the Appendices 1 and 2 of this Guide.

2.1 ICES Stock categories

All ICES stocks (ICES, 2012) are divided into six categories, depending on the amount and type of information available to scientists for assessing a stock's status and level of exploitation:

• Category 1; stocks with full analytical assessments and forecasts are possible.

• Category 2; stocks with analytical assessments and forecasts that are only treated qualitatively (where for example forecasts are available as trends only).

Categories one and two denote stocks such as cod, herring or haddock, for which the available data and information allow an analytical assessment and provision of stock size information.

Categories three to six, which we are concerned with for this document, are graded as data-limited, where only various pieces of the jigsaw are available:

• Category 3; advice is given on these stocks using time series of indices of abundance usually from research vessel surveys. Assessment methods in this category have advanced substantially over the past decade (see below).

• Category 4; advice is given on the bases of specialised modelling methods that use time series of catch data.

• Category 5; only commercial landings data are available.

• Category 6; only by-catch data are available.

Assessments of stocks in categories five and six are advised on the basis of previous years' catches, risk assessment and a precautionary buffer (see below) where appropriate, see ICES, (2012).

2.2 Making stock advice precautionary

The precautionary approach dictates that uncertainty should be taken into account in the advice. This was incorporated into the original ICES data-limited method (ICES, 2012) by an additional reduction of 20%, known as 'the precautionary approach (PA) buffer', which is introduced in the Total Allowable Catch (TAC) advice when there is significant uncertainty. If the information is poor and the stock is considered at risk, a zero or lowest possible unavoidable level of catch can be advised on the basis of a data-limited assessment.

This PA buffer reduction is not intended to be applied every year, since it would result in year on year decreases in advised catches that may not be justified by the evidence. It is also not applied where *"expert (that is the scientists') judgment determines that the stock is not reproductively impaired (that is, inside safe biological limits) and where there is evidence that the stock size is increasing significantly, or exploitation has reduced".*

2.3 New Approaches

The implementation of the PA buffer could result in large reductions in advised catch based on expert judgment. Therefore, ICES WKLIFE (ICES, 2021) has worked towards an approach for Category 3 assessments which reduces reliance on expert judgment whilst remaining precautionary.

This has resulted in a number of different advice rules (that is a set of rules which govern the advice on catch see Appendix 2) which are chosen dependent on the information available and the growth rate of the stock. These advice rules were tested by simulation modelling. In this, models were run many times simulating a number of years, with different elements being changed randomly in each run to build randomness or ‘stochasticity’ into the modelling to simulate real world conditions.

In order to make the advice precautionary, only advice rules were included where the stock had only an average annual 5% probability of being outside safe biological limits (below B_{lim}) in long term projections. This is an equivalent to remaining inside safe biological limits with an average annual 95% probability, and consistent with ICES’ interpretation of the precautionary approach.

This eliminates the reliance on expert judgment to decide whether to implement the PA buffer in the catch advice. This new approach can be used for Category 3 stocks, where the appropriate data and reference points are available, and is currently being rolled out through the ICES advice.

This is being carried out through the ICES benchmarking process, where scientists and stakeholders review all information on the stock; ecosystem and fisheries data, stock distribution, candidate assessment models and reference points. They agree on the assessment model to be used by the ICES Working Groups, which meet annually and provide catch advice on stocks. For data-limited stocks the catch advice is most often given biennially for two years’ catches, although the Working Group may revisit the assessment in the intervening year.

These innovations by ICES WKLIFE have moved Category 3 data limited assessments closer to the full assessment counterparts, and therefore may improve some fisheries on data-limited stocks prospects of gaining MSC (Marine Stewardship Council[1]) certification, although it seems likely that there would be further actions required to improve the assessment to retain certification.

3 Category three assessments

Category three stock assessments account for around 53% of ICES’ data-limited assessments (ICES, 2014). This approach is used when an index of abundance or biomass is available. This is usually derived from research vessel surveys or in some cases, from commercial data. that provide time series of standardised catch per unit effort. The trends in this index are used as a basis for advice. An example from ICES advice (ICES, 2018a) is given in Figure 1, which shows catch per unit of effort (Biomass index kg/hour) of eastern Baltic Sea cod taken in research vessel surveys from 2003-18, and for which there was no analytical assessment for that year; 2018.

[1] Sustainable Fishing | MSC | Marine Stewardship Council

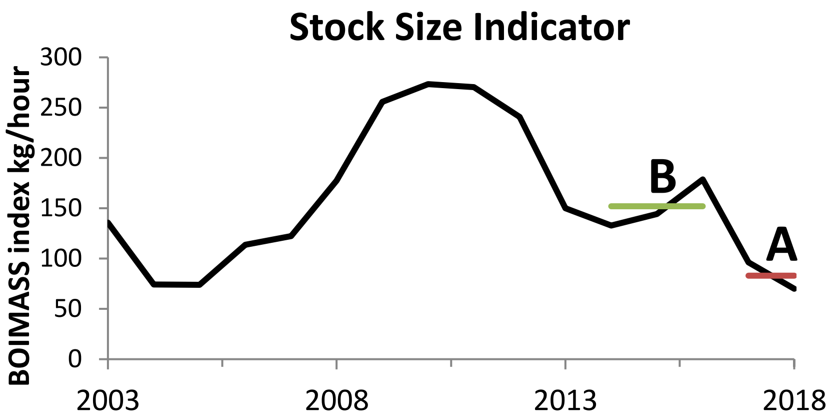

Figure 1 Stock size indicator for Cod (*Gadus morhua*) in subdivisions 24–32, eastern Baltic stock (eastern Baltic Sea) 2018 assessment; standardised catch per unit of effort (kg/hour of cod 30 cm or larger) from research vessel surveys (ICES 2018a).

The stock size indicator for this cod stock has been decreasing since around 2010. For the purposes of giving management advice, the recent trend in biomass is assessed by calculating the mean biomass index in the last two survey years (index A) compared with the previous three (index B) years. In this case line A is 45% lower than line B.

Given the uncertainty that the stock index actually represented the true state of the stock, there is a requirement to avoid large changes in catch opportunities due to variability in the index. If the PA buffer (see page 7) is not applied the change in the advised catch is capped at $\pm$20%, referred to as an uncertainty cap or change limit. If the PA buffer is applied (see page 12) then larger catch reductions can be advised. Note that this approach is in the process of being superseded, where data are available, by a new set of advice rules as discussed in Sections 2.3 and 5.

4 Proxy reference points

Fully assessed (Category 1) stocks are assessed against reference points for the precautionary approach and maximum sustainable yield (MSY) see Seafish (2022b,c). Initially, there were no reference points for assessments conducted under the data-limited framework (ICES, 2012). Simulations carried out in WKLIFE (ICES, 2013) demonstrated that the Category 3 method illustrated in Figure 1 could stabilise stocks in the short term; three to five years. In the longer term the absence of reference points risked overexploitation of stocks.

Subsequently, WKLIFE has made it a priority to develop and test methods to derive so-called ‘proxy’ or substitute reference points.

4.1 Length based indicators (LBIs)

These indicators are based on the size distributions (numbers of fish in each length category) of samples taken from catches, which are combined with information on life history characteristics such as growth rates, maximum size, length at maturity and length at first capture by the gear. The methods have been available for some time, but their development has been accelerated recently with the emphasis on developing data-limited methods. ICES has developed a suite of length-based indicators for stock health for use in data-limited assessments. Length based indicators have been developed for conservation of larger individuals (that is the breeding potential of the stock) and the conservation of immature fish.

However, the main length-based proxy reference point used in the guidelines is for F_{MSY}. This relates to the mean length of the catch (above length of recruitment), L_{mean}, to a target reference length $L_{(F=M)}$ where fishing mortality rate (F) is considered to be equal to natural (M) mortality rate. This is taken as a proxy for F_{MSY}. If the mean length of the catch is estimated to be at $L_{(F=M)}$, it can be said that the stock is being fished at a fishing mortality corresponding to the F_{MSY} proxy. However, if L_{mean} is less than $L_{(F=M)}$ the stock is exploited at a rate above the F_{MSY} proxy, and if L_{mean} is greater than $L_{(F=M)}$ it is exploited at a rate below the F_{MSY} proxy. For full details of how this reference point is derived are given in Appendix 1.

An example of the use of this reference point is from the 2020 ICES advice for North Sea lemon sole is shown in Figure 2. The mean length of the recruited catch (L_{mean}) is calculated and compared with the $L_{(F=M)}$ using the indicator ratio L_{mean} / $L_{(F = M)}$. Because the L_{mean} is above $L_{(F=M)}$ for most of the timeseries this indicates that the stock has been exploited at below F_{MSY}.

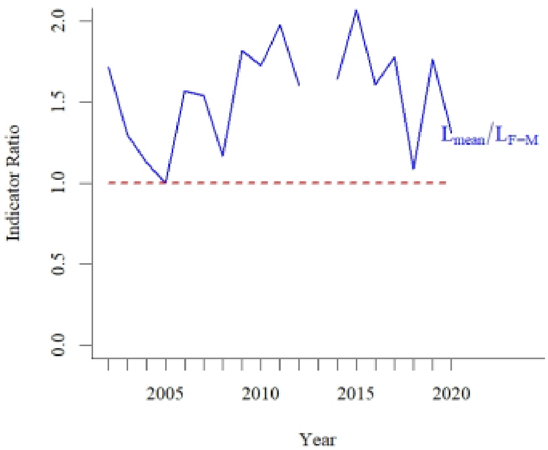

Figure 2 Lemon sole in Subarea 4 and divisions 3.a and 7.d. The indicator ratio L_{mean} / $L_{(F = M)}$ from the length-based indicator (LBI) method is used for the evaluation of the exploitation status. The exploitation status is below the F_{MSY} proxy when the indicator ratio value is higher than 1 (shown by a dotted red line)

4.2 Biomass reference points

In ICES fisheries assessments, biomass reference points are used to designate levels of spawning stock above which stocks should be maintained to ensure sufficient stock for reproduction. Therefore, to define biomass reference levels there is a need to obtain information on the relationship between spawning stock biomass levels and recruitment. For data-limited stock assessment this information is not usually available.

Therefore, other approaches are used to define biomass reference points. In this context two reference points are defined:

- Biomass trigger (or $B_{trigger}$) reference level, if the stock is below this level management action should be taken to conserve the stock

- Biomass limit (or B_{lim}) reference limit, below which stock is depleted and considered to have reduced reproductive capacity.

Where a production model (Section 4.3) is fitted, half the biomass at MSY ($0.5B_{MSY}$) is often used as a $B_{trigger}$ level and up until the introduction of the WKLIFE X advice rules, this was the only biomass trigger level used in the ICES data-limited stock methods.

Under the advice rules for Category 3 stocks introduced by WKLIFE X, biomass reference points have been introduced as levels of the stock size indicator (see Figure 1). The index trigger level ($I_{trigger}$) which is effectively the $B_{trigger}$ level, is set at 1.4 times to the lowest observed level of the biomass index (I_{loss}). Therefore, effectively setting B_{lim} at I_{loss} (see Table 1 Appendix 2). However, this approach is caveated because in cases where the stock has been lightly exploited or the index period does not cover a time of low biomass, it may result in the advice being too precautionary.

4.3 Production models

These models assume that the surplus production is related to the biomass of the stock. Lightly exploited stocks close to the carrying capacity of the environment and heavily exploited stocks with a low biomass are situations where stocks are likely to be less productive. Production models assume that if a population is reduced by fishing there will be compensatory growth and/or reproduction. That is, the fish will grow faster and/or breed more successfully, creating 'surplus production'. By modelling the surplus production response at different levels of biomass, the biomass (B_{MSY}) and fishing mortality (F_{MSY}) which produces MSY is estimated.

Therefore, surplus production corresponding to MSY is maximised at some point between these extremes, usually at around half the unfished biomass. This is illustrated in Figure 3

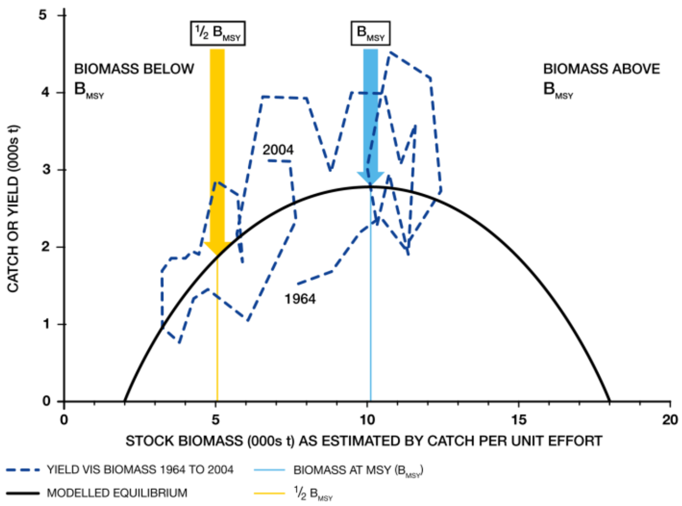

Figure 3 Illustrates a simple surplus production model. The stock yield (catch in 1000s of metric tonnes per annum) is plotted against the corresponding estimates of stock biomass over the period 1964 until 2004 in blue. The curved line shows the model at equilibrium, fitted by an iterative method. When the stock biomass is at 10,000 metric tonnes this corresponds to Biomass at maximum sustainable yield (B_{MSY}) with a maximum sustainable yield (MSY) of 2,900 tonnes per annum. The reference point ½B_{MSY} can be used as a trigger level; that is, when the stock falls below this level management action should be taken to reduce fishing and boost the stock.

The version used in ICES data-limited advice is the Stochastic Surplus Production Model in Continuous Time or SPiCT (Pedersen & Berg, 2017). It enables models using several time series of catch and effort data, from research vessel surveys such as in Figure 1 to be employed and estimates changes over time in the population and fishery dynamics, taking into account the variation in data sets due to observation errors. Effectively, this means that the variations are smoothed over time and the outputs show the level of confidence attached to the estimates. This SPiCT model is discussed at greater length in the ICES technical guidelines (ICES, 2018b) and in WKLIFE X (ICES, 2021). Normally ICES uses ½ B_{MSY} as the proxy MSY $B_{trigger}$ level.

An example of SPiCT model output is shown in Figure 4. These results show trends in the Eastern Baltic Sea cod stock (the same stock and the same advice (ICES 2018a) as discussed in Section 3 page 8) since the 1990s. Current biomass is estimated to be below MSY $B_{trigger}$ proxy and fishing mortality well above that associated with MSY (F_{MSY}), indicating that the stock is reproductively impaired. This justified the application of the PA buffer in the ICES advice, making the advised reduction in catch 36%.

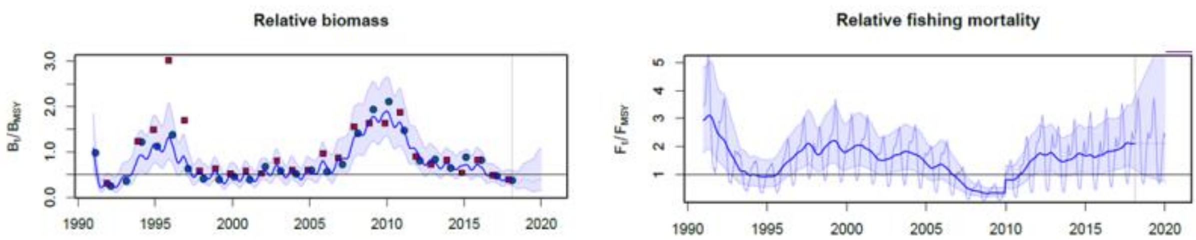

Figure 4 Cod in subdivisions 24–32, eastern Baltic stock (ICES 2018a). SPiCT analysis showing relative biomass B relative to B_{MSY} and fishing mortality F relative to F_{MSY} plotted against time. The symbols in the relative biomass plot indicate observed biomass indices derived from the annual first and fourth quarter Baltic Sea international bottom trawl research vessel surveys, while the shaded areas in both plots indicate 95% confidence intervals. The horizontal lines indicate levels relative to the F_{MSY} and MSY $B_{trigger}$ proxies derived from the production model.

5 ICES advice based on SPiCT models and on life-history traits

These methods rely heavily on underlying assumptions, which may not always be valid or which the SPiCT model may fail to fit with sufficient confidence. For this reason, results from these indicators are only included in the advice when there is confidence in the results.

The length-based indicators and SPiCT models have been used to inform expert judgment to advise on whether the PA buffer should be applied. The approach outlined in Sections 3 and 4 is being superseded by the precautionary advice framework developed for Category 3 stocks and detailed in Annex 3 of the WKLIFE X report (ICES, 2021). These are outlined below and in detail in Appendix 2.

5.2 SPiCT models

ICES WKLIFE X (ICES, 2021) gives a series of criteria which must be fulfilled if a SPiCT model is to be used. The advice is made precautionary by taking into consideration the location of the stock in relation to the proxy MSY $B_{trigger}$ reference point, usually ½ B_{MSY} and advising a catch which corresponds to less than the modelled target fishing mortality (see Appendix 2 for details).

5.3 Advice rules for empirical approaches based on life-history traits

As discussed above (Section 2.2) the WKLIFEX (ICES, 2021) workshop in 2021 developed and simulation tested a set of precautionary advice rules which incorporate information from:

- Indexed biomass (stock size indicator) trends as in Section 3
- Life history traits of the stock, specifically growth rates; see Appendix 1

- The proxy for F_{MSY} length-based indicator fishing mortality $L_{(F=M)}$ as described in Section 4.1 and in Appendix 1
- Biomass reference points based on the stock size indicator (I) as described in Section 4.2
- There is also a 'Stability clause' which limits changes in advised catch from +20% to -30% unless the stock size indicator (I) is below the Biomass trigger level ($I_{trigger}$) in which case the advised catch can be reduced by more than 30%.

The appropriate advice rule to use is based on the growth rate of the stock and the data available, Figure 9 in Appendix 2 outlines the decision framework. The precautionary element is included in a multiplier (m) which is a pre-set value dependent on the growth rate of the stock and/or the advice rule used. It varies from 0 to 1 and is applied in every assessment. Its value is based on the simulation testing carried out by WKLIFE X on a sample of stocks (ICES, 2021). Based on these simulations, values of m are chosen which maintain the average annual probability of the biomass declining outside safe biological limits (below B_{lim}) to an average of less than 5% in long term projections. It is therefore consistent with the ICES interpretation of the precautionary approach (see Section 2.2)

This makes it different from the application of the PA buffer, which is a 20% reduction applied intermittently, with application based on expert opinion advised by the location of the stock in relation to proxy reference points where they are available.

5.4 Caveats

As is expected with any modelling, performance of these catch rules in terms of how precautionary they are and whether they lead to MSY exploitation is dependent on how well the biomass index represents trends, and to what extent the proxies represent 'true' values. Short lived species are a particular problem for giving catch advice because of their rapid growth and death rates, and a number of approaches to advice for these stocks have been included see Appendix 2.

What the simulation testing has shown is that they consistently perform better than the original '2 over 3' rule coupled with the PA buffer and uncertainty cap (ICES, 2021).

As previously mentioned, in Section 4.2, it should also be noted that there is an issue with data limited stocks for which the level of exploitation is considered to be relatively light. The lowest observed level of the biomass index (I_{loss}) may not be representative of safe biological limits (B_{lim}), therefore $I_{trigger}$, which is set at 1.4 × I_{loss} may be set too high and hence the advice may be too precautionary.

7 Understanding the ICES Advice

ICES provides scientific advice to fisheries and environmental managers in the Northeast Atlantic. This includes national governments and international organisations such as the European Union.

The link to the latest ICES advice can be found here; ICES Advice. Once this page is opened, the latest advice can be found by year and stock. Opening the species links will then show links to the various stocks of this species, as defined by location. For example, Figure 5 shows how to find the advice for the stock of plaice in divisions 7h-k (Celtic Sea, southwest of Ireland) in 2021.

NEAFC - Defenition of the fisheries that use collection bags in the NEAFC Regulatory Area (ICES subareas 1 and 2) and to assess their impact on species caught and bycaught

Advice 2021

- Guide to ICES Advisory framework and principles
- Advice on Ecosystem Services and Effects
- Advice on fishing opportunities
- Aquaculture Overview - Norwegian Sea ecoregion
- Ecosystem Overviews
- Fisheries Overviews and mixed fisheries advice
- Technical Guidelines

Advice by ecoregion

Arctic Ocean, Azores, Baltic Sea, Barents Sea, Bay of Biscay and Iberian coast; Celtic Seas, Faroes, Greater North Sea, Greenland Sea, Icelandic waters, Norwegian Sea, Oceanic Northeast Atlantic

Advice by species

Anchovy, Anglerfish, Blackspot seabream, Blue ling, Blue whiting; Boarfish, Brill, Capelin, Cod, Deep-sea species, Eel, Elasmobranchs, Flounder, Greater silver smelt, Greenland halibut, Haddock, Hake, Herring, Horse mackerel, Lemon Sole, Ling, Mackerel, Megrim, Plaice, Norway lobster, Norway pout, Orange roughy, Pollack, Red gurnard, Redfish, Saithe, Salmon, Sandeel, Sardine, Sea bass, Sea trout, Shrimp, Sole, Sprat, Striped red mullet, Turbot, Tusk, Whiting, Witch

Plaice (Pleuronectes platessa) in Division 7.a (Irish Sea)

Plaice (Pleuronectes platessa) in Division 7.d (eastern English Channel)

Plaice (Pleuronectes platessa) in Division 7.e (western English Channel)

Plaice (Pleuronectes platessa) in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak)

Plaice (Pleuronectes platessa) in Subarea 8 and Division 9.a (Bay of Biscay and Atlantic Iberian waters)

Plaice (Pleuronectes platessa) in divisions 7.b–c (West of Ireland)

Plaice (Pleuronectes platessa) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)

Plaice (Pleuronectes platessa) in divisions 7.h–k (Celtic Sea South, southwest of Ireland)

Figure 5 Screen shots of the page on the ICES website relating to the latest stock advice. Above; latest advice by species: click on the species required, in this case plaice and links to all the advice relevant to that species are selected (right). To access advice relevant to the stock, open the appropriate link, in this case the Plaice in divisions 7h-k (Celtic Sea, southwest of Ireland).

Once the appropriate stock advice has been located, the advice can be downloaded as a pdf document. These documents have a number of standardised headings. The information given under these headings **in bold** is discussed below, referring to the concepts described in this Guide. 'ICES Advice Table' numbers refer to the Tables in the ICES Advice.

Under the heading **ICES advice on fishing opportunities** the precautionary advised catch in tonnes is given for the next period. The next heading is **Stock development over time,** which has a few sentences describing recent trends and graphs of stock abundance, fishing pressure (where available) and/or catches, which form the basis of the advice.

The next section is headed **Catch scenarios**, where the basis for predictions for next year's catch advice is given. Unlike analytical assessments, for data-limited assessments only one catch scenario is given and is presented in ICES Advice Table 2. The ICES assessment category is given; (Categories 3-6; see page 7) and the basis for the calculation of the advised catch next year are given.

Also given is the rationale for application or otherwise of the precautionary buffer where relevant. Expert judgement and the status of the stock in relation to the proxy reference points can be used to assess whether the stock is likely to be outside safe biological limits (see page 7) and the precautionary buffer applied if appropriate. However, for Category 3 stocks, the use of the precautionary buffer is becoming superseded by the new approach outlined in Section 5.

Under the next heading **Basis for the advice**, the ICES precautionary approach is taken for data-limited assessments and any agreed management plan on the stock is described briefly and referenced. The information under **Quality of the assessment** is important for information on uncertainties and recent developments in the assessment and how consistent the current assessment is with those for previous years.

In the **Issues relevant for the advice** section, the assessment scientists have a free hand to add further text, graphics and tabulations explaining other issues relevant to the assessment. These can include uncertainties over catch data, further biological information, or management issues relating to the implementation of the advice.

The next section **Reference points** tabulates (ICES Advice Table 3) the reference points used, if relevant, and briefly describes how they were derived including a reference to the appropriate workshop or working group. **Basis of the assessment** details technical details of the assessment in ICES Advice Table 4, and which ICES Working Group carried out the assessment.

Under the heading **History of the advice, catch, and management** in ICES Advice Table 5, a time series of previous advised and agreed TACs are given, along with official landings and estimates of catches carried out by ICES either from discard surveys or other sources. Under **History of the catch and landings** ICES Advice Table 6 breaks down the most recent catch information by gear type for this stock. ICES Advice Table 7 is a time series of landed catches by nation.

The next heading contains a **Summary of the assessment** (ICES Advice Table 8) which tabulates the data behind the graphical outputs presented in the section **Stock development over time**. Finally, under the heading **Sources and references** the documents referred to in the text are listed.

8 Data-limited assessments worldwide

Worldwide, there have been a number of developments in data-limited stock assessment. In a report to FAO, Rosenberg et al, (2014) compare four methods that provide preliminary estimates of the relative stock biomass using catch data, information on the fisheries and the life history of the target species. In America, a set of methods has been packaged in a ‘Data-Limited Methods Tool Kit[2]’ which has been designed to enable wider uptake and use of data-limited methods. Examples of data-limited methods, particularly related to shellfish stocks are discussed below.

8.1 Assessments without seasonal growth rings

Obtaining information on growth and age structures of stocks is a basis for many stock assessment methods. For crustacean species, it is difficult to age individual specimens; because hard structures are shed each moult (Becker et al, 2018) and therefore growth rings are not available. Similar problems occur in fish species where there are no clear seasonal growth rings on hard structures such as otoliths.

Methods used to determine growth rates include mark and recapture, where captured individuals are measured, tagged and released into the wild, and re-measured upon recapture after a known time interval.

[2] www.datalimitedtoolkit.org

8.2.1 Crustacean assessments

One method which has been used to assess crustacean fisheries is known as Length Cohort Analysis (LCA). Currently, the Cefas (Cefas, 2020a,b) model-based assessments used this method for brown crab and lobsters in English waters. Average growth rates are obtained from mark and recapture studies. The size distributions of the catches are obtained by sampling from the seasonal landings at the main landing places and raising these to the estimated aggregate total landings from a wider designated stock area.

The average growth rate is applied to the estimated size distributions of the catch to estimate the numbers at age of the catch. Based on a rational assumption about the likely natural death rate of the species these waters it is possible to back calculate to the likely age structure of the stock in the sea.

8.2.2 Cephalopod mollusc assessments

Cuttlefish, squid and octopus populations are characterized by rapid growth, a relatively short life-span and adults that die after spawning. Here the approach can be similar to the ICES method for short-lived stocks, where mangers aim at a target escapement of adult fish to reproduce and replenish the stock (see Guide to fishing at MSY (Seafish, 2022c)).

Abundance is estimated using catch per unit effort of the stock as it passes through the fishery. As the target escapement abundance is approached, managers would expect to take action, such as fishery closure, to ensure that sufficient adults survive to spawn. See Beddington et al, (1990) for an example and Pierce and Guerra (1994) for discussion.

8.2 Bivalve mollusc assessments

For some sedentary molluscan stocks such as cockles and mussels it is possible to survey the entire area of the stock, either intertidally in all-terrain vehicles or by grab sampling from a survey vessel. Samples are taken using quadrats (square frames placed on the sediment within which all the shellfish are sampled) at low tide, or grabs (which are lowered from a vessel over the seabed and grab a sample of shellfish within a set area) sampling a fixed area of the seabed at each station regularly along transects (Dyer & Bailey, 2017). See Figure 6

The mean density of the stock (by year class if the animals can be aged, using growth rings on their shells) is estimated from the samples, and the total area surveyed is used to estimate the total tonnage of the stock in each management area. This can then form the basis of the assessment of the quantity which can be harvested next year by the fishery. Where conservation of bird populations (for example) is an imperative, allowance in harvesting rates can be made to ensure sufficient food is available for them.

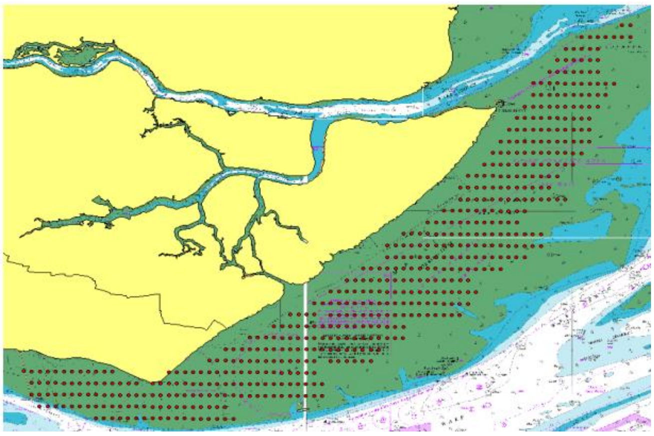

Figure 6 Cockle survey sampling positions in the main cockle harvesting areas in the Thames Estuary carried out by the Kent and Essex IFCA in 2017 (Dyer & Bailey, 2017)

Appendix 1 Length based indicators

Growth of fish

These indicators rely on there being information on the growth rate of the fish in the stock. This is obtained by age determination of sufficient samples of fish, using otoliths or other methods, to estimate the average growth rate of the fish in the stock. The general shape of a fish's growth in length with time is as shown in Figure 7.

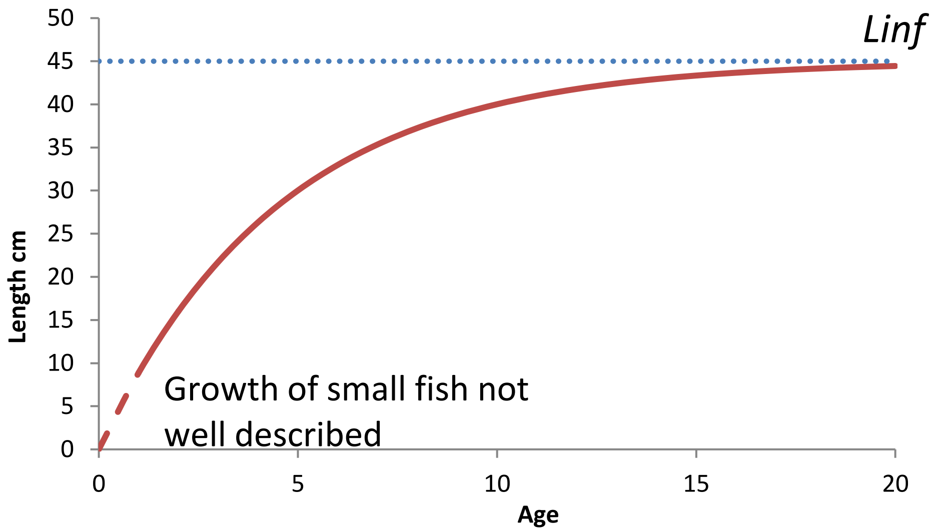

Figure 7 Generalised shape of the growth curve of fish according to the von Bertalanffy growth curve. The rate at which the growth of the fish approaches Linf is related the von Bertalanffy growth constant by equation 1.

The theory behind this curve (attributed to von Bertalanffy, in 1938) is that fish grow quickly when they are young because the surface area of their stomachs and intestines is large relative to their body size, so they have a relatively large surface area to absorb food. The growth slows down as the area to absorb food decreases relative to the size of the fish reaching an 'L infinity' or Linf on the graph. Linf is not the absolute maximum size that the species grows to, since some specimens grow larger, but is considered the average maximum size of the majority of the stock.

The rate at which the fish grow is described by the von Bertalanffy constant (*k*), and their maximum size (or L_{inf}) is related to genetic and environmental factors, and it varies between stocks. The equation describing this curve is;

$$\mathbf{L_t = L_{inf}(1 - exp^{-k(t-to)})} \qquad 1$$

Where L_t = Length of fish at time t (years (yr), L_{inf} = Length infinity (see above), k = the von Bertalanffy constant (unit: yr^{-1}), exp is the exponential constant, and to (years) is a constant which accounts for the fact that growth of small fish is not well described; see Figure 7

Fishing mortality F_{MSY} proxy

As discussed in the Guide to fishing at MSY (Seafish, 2022c), a stock which is unexploited would be expected to have a range of ages in the stock, hence also a wide distribution of lengths and a high mean length. As the stock becomes exploited the older fish are removed from the stock and it is composed mostly of smaller faster growing individuals so the mean length decreases. Therefore, for as an indication of the level of exploitation the mean length of the catch has potential, but there is a need for reference points.

Beverton and Holt (1957) page 41 give an equation which can be modified (see Ehrhardt and Ault, 1992) to relate the mean length of the recruited[3] catch (L_{mean}) to the length at maximum size (L_{inf}, see above) to fishing (F) and natural (M) mortality rates, the von Bertalanffy growth constant k :

$$\mathbf{L_{mean}} = \mathbf{L}_{\boldsymbol{inf}}.\left[\mathbf{1} - \left(\frac{\mathbf{(F+M)}}{\mathbf{(F+M+k)}}\right).\left[\left(\mathbf{L_{inf}} - \mathbf{L_c}\right)/\mathbf{L_{inf}}\right]\right] \qquad 2$$

This can be re-arranged to arrive at the reference point $L_{(F=M)}$, which is calculated from length at infinity (L_{inf}) and length at recruitment (L_c) as shown in;

$$\mathbf{L_{(F=M)}} = \mathbf{0.75L_c} + \mathbf{0.25L_{inf}} \qquad 3$$

This is the point where the equilibrium mean length of the catch (above length at first capture L_c) would be if fishing mortality were equal to natural mortality. There is no requirement to know fishing or natural mortality, just that the theory indicates they would be equal at this point. This is the length based F_{MSY} proxy reference point used by ICES. An example of a length-frequency distribution is shown in Figure 8. In this the mean length of the catch L_{mean} red point is close to coincident with to $L_{(F=M)}$, so the stock is being exploited at a level close to the F_{MSY} proxy.

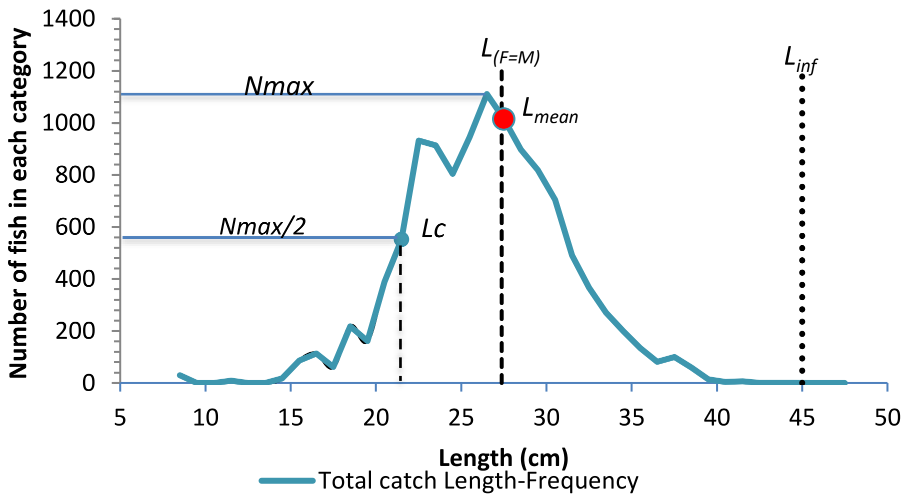

Figure 8 Example length-frequency distribution of catch (as estimated from observer and dockside sampling). The $L_{(F=M)}$ reference point defined in equation 3 above. Lc length at first capture is defined as the length corresponding to half (*Nmax/2*) the height of the ascending limb of the length frequency distribution, Linf as defined in from the von Bertalanffy growth equation (see equation 1) above. The mean length of the catch (L_{mean}*)* corresponds to the red point, which is close to coincident with $L_{(F=M)}$.

[3] Fish larger than L_c, the length at first capture, which is determined by a combination of the presence of small fish in the area of the fishery and selectivity of the gear and is estimated from the length-frequency distribution see Figure 8 for calculation

Appendix 2; Details of WKLIFE X Annex 3 methods

The new approach considers an inventory of the data and information available on the stock The flow chart shown in Figure 9 could be used to decide which type of assessment should be used.

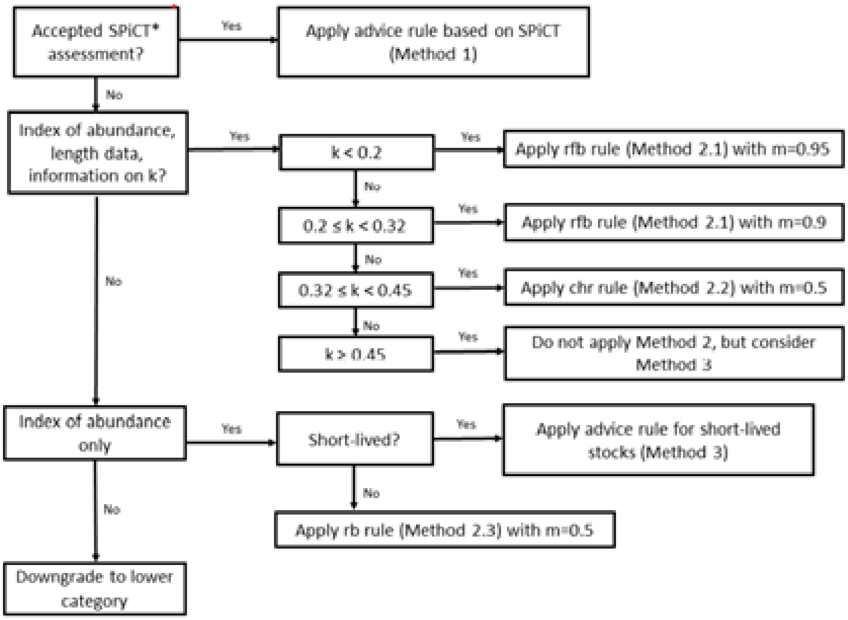

Figure 9 Flowchart of how the rules could be applied (ICES, 2021). The left-hand boxes refer to the reliable data and information to be used in the provision of advice; k refers to the von Bertalanffy growth parameter k (unit: yr^{-1}); see Appendix 1 for definitions

Method 1 Advice based on SPiCT production model assessments

The results of the models are expressed as probability distributions (from which the confidence intervals shown in Figure 4 are derived). This enables the catch advice to be based on the distribution of predicted values of catch at given levels of fishing mortality and biomass.

The catch is advised as the 35th percentile the catch corresponding to the target fishing mortality during the prediction period, one year for annual and two years for biennial assessments. Assuming a normal distribution, the 50th percentile (the median) would correspond to the mean targeted fishing mortality for MSY, so the 35th percentile would correspond to around 70% of catch at MSY.

Method 2.1; Advice based on the rfb rule

This is an improvement on the '3 over 2' rule described in Figure 1 which defines the rate of change of biomass index (r) by comparing the average index of abundance in the past two years with the previous three years. The advised catch for the year ahead (C_{y+1}) is derived from the previous year's catch (C_y) by the following equation:

$$C_{y+1} = C_y \times r \times f \times b \times m \quad (4)$$

In this method the multipliers required (see Table 1 for details) are;

- The value of m is based on the stock's growth rate from an estimate of the von Bertallanfy growth constant (k). In simulations, to reduce the risk of stocks being outside safe biological limits (below B_{lim}) to an average of less than 5% in long term projections, that is to make it precautionary, low growth rate stocks (k<0.2) required *m* = 0.95, whereas higher growth rate stocks ($0.2 \leq k \leq 0.32$) required m = 0.90.

- The stock's status in terms of relative biomass (b); the catch is adjusted downwards if the biomass index (I) is below reference level $I_{trigger}$.

- The catch is adjusted by a multiplier (f) based on the indicator ratio $L_{mean}/L_{(F=M)}$ (see Figure 2) indicating the status of the stock in relation to the F_{MSY} proxy

Method 2.2; the constant harvest rate rule

For stocks with higher growth rates ($0.32 < k \leq 0.45$) a method has been derived which defines a proxy for F_{MSY} which is based on the mean catches when the stock is above the $L_{(F=M)}$ reference level. The data time series of length data are examined to find years where the mean length of the catch was above the $L_{(F=M)}$ reference level. The mean ratio of catch to the biomass index during those years is taken as the $F_{proxy\ MSY}$ (see Table 1 for formula).

The advised catch for the year ahead (C_{y+1}) is based on applying this $F_{proxy\ MSY}$ to the index of abundance from the previous year (I_{y-1}) and is derived from the following equation:

$$\mathbf{C_{y+1}} = \mathbf{I_{y-1}} \times \mathbf{F_{proxyMSY}} \times \mathbf{b} \times \mathbf{m} \qquad 5$$

Where I_{y-1}, $F_{proxy\ MSY}$, b and m are defined in Table 1.

Simulations were carried out using several stocks with growth rates in the range 0.32 < k < 0.45 and it was found that the value of m = 0.5 reduced the risk of stocks being outside safe biological limits (below B_{lim}) to an average of less than 5% in long term projections. Hence the advice rule was considered precautionary.

Method 2.3 the rb rule

For stocks where no length data are available so a length-based reference point for $L_{(F=M)}$ is not available. Information on growth is not used in this method and the equation used for advised catch for the year ahead is;

$$\mathbf{C_{y+1}} = \mathbf{C_y} \times \mathbf{r} \times \mathbf{b} \times \mathbf{m} \qquad 6$$

Simulations were carried out using several stocks with a broad range of growth rates and it was found that the value of m = 0.5 reduced the risk of stocks being outside safe biological limits (below B_{lim}) to an average of less than 5% in long term projections, hence the advice rule was considered precautionary This rule replaces the 2 over 3 rule described in Figure 1.

Stability clause

All the Method 2 assessments are subject to a stability clause. The catch advice is constrained to +20 or -30%, of previous year's catch, to avoid large changes in catch from year to year. However, catch advice may be decreased by more than this amount if the biomass index (I) is below ($I_{trigger}$).

Method 3; Short lived species

Short lived species such as sprat and sardines which live for periods of 2 to 3 years present particular problems for assessment advice. Their rapid growth and death rates mean that information goes out of date very rapidly. ICES has developed a number of approaches which may be used in these circumstances.

These include;

- Shortening the period of time between the assessment and implementation of the advice

- Using a '1 over 2' rule rather than a '2 over 3' rule (see Figure 1 and Table 1) for describing biomass index trends (r)

- Increasing the rage of the stability clause cap (or uncertainty cap) to $\underline{+}$80% allowing a greater change in catch from one year to the next.

- Harvesting a constant fraction of the stock expressed as a percentage of the estimated stock biomass (*Harvest Rate msy.proxy)* each year. This is possible when there is an acoustic survey of the biomass of the stock as is available for some pelagic species, such as sardines and sprats. This approach should be tested by evaluations of the strategy using a simulation to test the risk of falling below B_{lim}.

- Including an $I_{trigger}$ where the catch is reduced if the biomass index (I) is below $I_{trigger}$ in the calculation as in parameter b in Table 1.

The above is only a summary of the main features of the WKLIFE X methods. For full details the reader is referred to Annex 3 of the WKLIFE X report (ICES, 2021). The details of how these methods were derived are in the main body of the WKLIFE X report,or referred to in other ICES workshops on data limited assessments cited in the WKLIFE X report.

Table 1 Summary components in catch advice equations from ICES WKLFE X (ICES, 2021)

Term	Definition	Description and use
r	$\dfrac{\sum_{i=y-2}^{y-1}(I_i/2)}{\sum_{i=y-5}^{y-3}(I_i/3)}$	The rate of change in the biomass index (I), based on the average of the two most recent years of data (y−2 to y−1) relative to the average of the three years prior to the most recent two (y−3 to y−5), and termed the "2 over 3" rule; See Figure 1
f	$\dfrac{L_{mean\ y-1}}{L_{(F=M)}}$	The ratio of the most recent mean length ($L_{mean\ y-1}$) of the observed catch that is above the length of first capture (L_c) relative to the target reference length. This is the indicator ratio shown in Figure 2
I_{y-1}		The most recent biomass index I; usually for the year before the assessment y-1 where y is the year of the assessment
$F_{proxy\ MSY}$	$\dfrac{1}{u}\sum_{y \epsilon U} C_y/I_y$	The mean of the ratio catch/biomass index (C_y/I_y) for the set of historical years U where *f*, the indicator ratio in Figure 2 > 1; that is when the mean length of the recruited catch (above Lc) is > $L_{(F=M)}$ and u is the number of years in the set U.
b	$\min, \left\{1, \dfrac{I_{y-1}}{I_{trigger}}\right\}$	Biomass safeguard. Adjustment to reduce catch when the most recent index data (I_{y-1}) is less than $I_{trigger}$. When the most recent index data (I_{y-1}) is greater than $I_{trigger}$, b is set equal to 1. When it is below $I_{trigger}$, b is proportionality lower and hence the advised catch more precautionary. $I_{trigger}$ is set to 1.4× I_{loss}. I_{loss} is generally defined as the lowest observed index value for that stock; see page 10 section 4.2.
m	$[0,1]$	Multiplier applied to the harvest control rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. May range from 0 to 1.0.
Stability clause	$\min\{max(0.7C_y, C_{y+1}), 1.2C_y, C_{y+1})\ \}$	Limits the amount the advised catch can change upwards or downwards between years. The recommended values are +20% and −30%; that is the catch would be limited to a 20% increase or a 30% decrease relative to the previous year's advised catch. The stability clause does not apply when b < 1, that is when the biomass index is below the $I_{trigger}$ level so advised catch could be decreased by more than 30% under these circumstances.

9 Other guides in this series

These Guides are designed to enable understanding without the need for previous training or expertise in fisheries science. Concepts are presented graphically and in words and the key elements are explained in the summaries.

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• Principles of marine finfish product knowledge – Ref F-602-0617
http://seafoodacademy.org/pdfs/f-602-0617.pdf

• Principles of shellfish, non-marine finfish and marine food products, product knowledge – Ref A-602-0616
http://seafoodacademy.org/pdfs/a-602-0616.pdf

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