

1.1.1 Advice on fishing opportunities

ICES approach to advice on fishing opportunities

ICES approach to advice on fishing opportunities integrates the precautionary approach with the objective of achieving maximum sustainable yield (MSY), unless otherwise requested. The aim is, in accordance with the aggregate of international guidelines, to inform policies for high, long-term yields while maintaining productive fish stocks in marine ecosystems that meet expected environmental standards (e.g. good environmental status [GES] in the EU).

Annex 2 of the UN Fish Stocks Agreement (UN, 1995) contains guidelines for applying a precautionary approach within an MSY framework. In accordance with a precautionary approach, populations need to be maintained within safe biological limits to make MSY possible. Within safe biological limits, however, an MSY approach is necessary to maximize long-term yields. All ICES advice is consistent with the precautionary approach, which is a necessary but not a sufficient condition for MSY.

MSY is a broad conceptual objective aimed at achieving the highest yield over the long term. It is non-specific with respect to: (a) the biological unit to which it is applied; (b) the models used to provide scientific advice; (c) the definition of yields; and (d) the management methods used to achieve MSY. ICES interpretation of MSY is maximizing the average long-term yield from a given fish stock while maintaining the stock as productive. ICES considers the yield to be maximized as the part of the catch that is landed, measured in weight. Depending on regulations for the individual stock, this may be calculated relative to the landed catch above a prescribed minimum size.

Many of the models (mathematical and conceptual) used to estimate MSY and associated parameters typically assume that factors not explicitly included in the models either remain constant or vary around a historical long-term mean. Marine ecosystems are dynamic, however, and fish stocks will change not only in response to fishing patterns and fishing pressures but also to changes in their prey or their predators as well as to changes in the climate. ICES therefore considers MSY reference points to be valid only in the short and medium term (generally up to 5–10 years). MSY reference points should be subject to regular reviews and modified according to new information or process understanding.

To support the stock-by-stock management system, ICES provides advice on fishing opportunities and stock status for individual stocks. For some stocks ICES is only requested to advise on its status and not on fishing opportunities. In addition to the single-stock advice, ICES also provides mixed-fisheries considerations, fisheries overviews, and ecosystem overviews. These encapsulate the technical and biological interactions between stocks at an ecoregion scale.

For the purposes of identifying the advice rule to be applied when giving advice on fishing opportunities, ICES classifies stocks into six main categories on the basis of available knowledge:

Category 1 – *Stocks with quantitative assessments.* Includes stocks with full analytical assessments and forecasts that are either age-/length-structured or based on production models.

Category 2 – *Stocks with analytical assessments and forecasts that are only treated qualitatively.* Includes stocks with quantitative assessments and forecasts which, for a variety of reasons, are considered indicative of trends in fishing mortality, recruitment, and biomass.

Category 3 – *Stocks for which survey-based assessments or exploratory assessments indicate trends.* Includes stocks for which survey, trends-based assessment, or other indices are available that provide reliable indications of trends in stock metrics such as total mortality, recruitment, and biomass.

Category 4 – *Nephrops stocks where information on possible abundance can be inferred* and stocks for which a reliable time-series of catch can be used to approximate MSY. This is where there are reasonable scientific grounds to use life-history and density information from functional units to provide advice.

Category 5 – *Stocks for which either only data on landings or a short time-series of catch are available.*

Category 6 –Stocks for which there are negligible landings and stocks caught in minor amounts as bycatch. Includes stocks where landings are negligible in comparison to discards as well as stocks that are primarily caught as bycatch species in other targeted fisheries.

For category 1 and 2 stocks, ICES provides advice when requested in accordance with agreed management plans or strategies evaluated to be consistent with the precautionary approach (Figure 1). If such plans or strategies are not agreed upon by the relevant management bodies or have been evaluated by ICES as not being precautionary, ICES will give advice on the basis of ICES MSY approach.

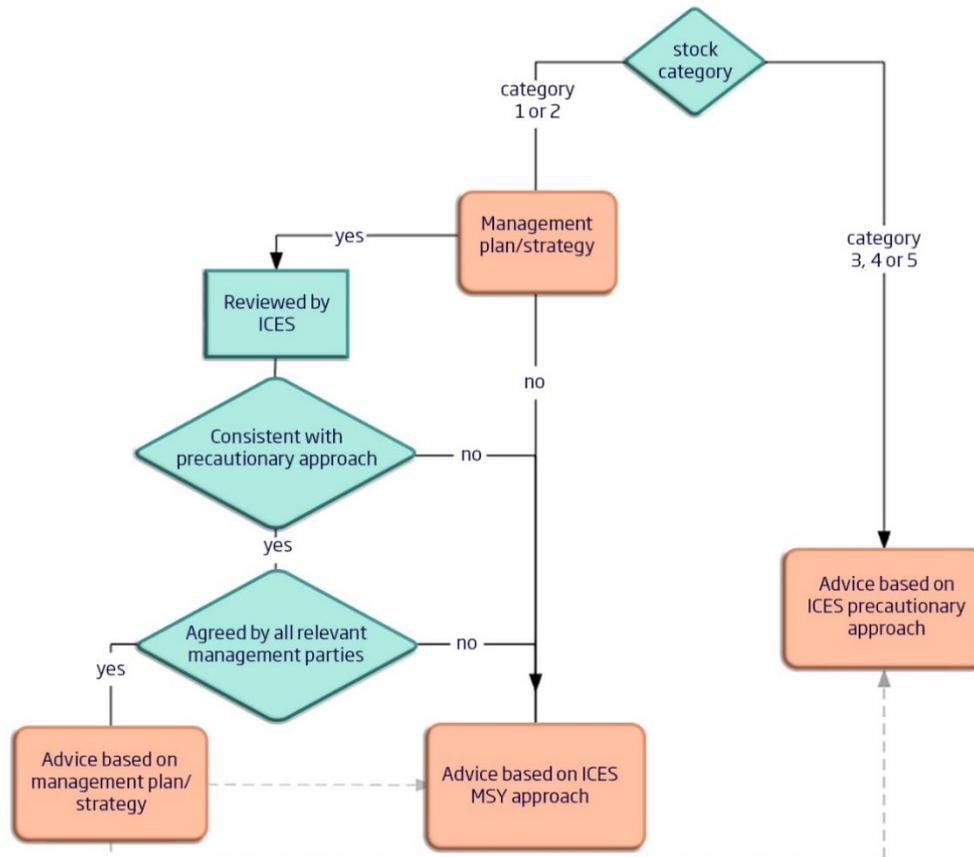


Figure 1 Flow diagram showing the basis of ICES advice. The broken grey lines indicate that sometimes the advice in management plans is consistent with ICES MSY approach or the precautionary approach.

As the knowledge available is insufficient to apply ICES MSY approach to category 3–6 stocks, the advice is based on the precautionary approach. ICES has, however, developed approaches to determine proxies for MSY reference points for some stocks in categories 3 and 4. Based on these proxies, ICES will assess both the state and exploitation of the stocks relative to MSY criteria.

Most of the fish and shellfish fisheries advised on by ICES are managed by total allowable catches (TACs) and are increasingly subject to discard bans or landing obligation (LO) regulations. Different regulations are in place within the ICES area, and different regulations may relate to different management areas. For EU waters, an LO was introduced in 2015 and was fully in place by 2020. Following the introduction of the LO, catches may be split into three categories: reported landings at or above minimum conservation reference size (MCRS), reported landings below MCRS, and discards. Discards may also be split into dead discards and live discards, based on information on survival rates. ICES discard estimates are normally based on data from observer schemes and may include discards which, in accordance with the landing obligations/discard bans, should be landed. Estimates of discarding not observed are often imputed based on observations from similar métiers, seasons, or areas.

Generally, ICES assumes that the current fishing pattern and discarding practices are likely to remain unchanged over the forecast period. ICES may split the advised catch and other catch scenarios into the three categories above (or four categories if a fraction of discards is assumed to survive).

If the fishing pattern or/and ratio between landings and discards change(s) in the forecast period, due to changes in compliance with the landing obligation or discard ban, ICES will not distinguish between landings below MCRS/catching size and discards in the catch scenarios. Those two components will instead be combined into one category: projected discards. Landings above MCRS/catching size may, in these cases, be termed 'projected landings' as illustrated in Figure 2.

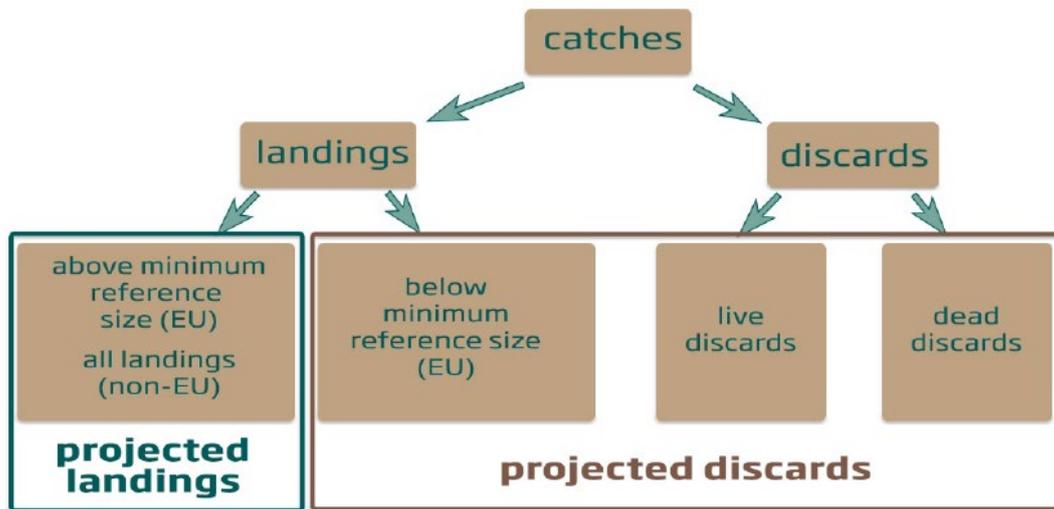


Figure 2 Catch categories used by ICES in stock assessments and forecasts. For an explanation of these categories, see the text above.

General approach

Fisheries directly affect fish stocks through catches. Fishing mortality (F) is a measure of fishing pressure; it is the rate derived from the proportion in numbers of fish in a year class taken by fisheries during one year. The fishing mortality referred to in ICES advice is estimated as the average F over those ages which dominate in the catches. For some stocks, such as Icelandic cod, saithe, and most *Nephrops* stocks, ICES uses harvest rates (HRs) instead of fishing mortality. The harvest rate is defined as the fraction of a reference biomass or abundance that is caught by the fishery during a year.

The production in a fish stock can be highly variable. It is related to recruitment, stock size (often expressed as spawning-stock biomass [SSB]), and the size structure in the stock; these in turn also depend on the fishing mortality and fishing patterns.

Surplus production of a stock is the catch that can be harvested without changing the average production in the long term. For a given fishing pattern there is a level of fishing mortality that, in the long term, will generate the highest surplus production. This peak of surplus production (above minimum conservation/reference size) is the MSY, and the fishing mortality generating this peak is F_{MSY} .

Fishing mortality is the only variable that can be directly controlled by fisheries management. Fisheries management cannot directly control the stock size only influence it through overall fishing mortality. Stock size is also subject to natural variability that on a year-to-year basis can exceed the influence of fishing. MSY refers to a long-term average. A management strategy that harvests variable yields in response to the natural variability in stock size will, on average, give yields closer to the long-term MSY than a strategy operating with the maximum constant yield that could be taken sustainably.

Due to the variability in stock size, there may be situations where the spawning stock is so low that reproduction is at significant risk of being impaired. A precautionary approach implies that fisheries management in such situations should be more cautious. For stocks where quantitative information is available, the reference point B_{lim} may be identified as the stock size below which there is a high risk of reduced recruitment (Figure 3). A precautionary safety margin incorporating the uncertainty in ICES stock estimates leads to the precautionary reference point B_{pa} , which is a biomass reference point designed to have a low probability of being below B_{lim} . When the spawning-stock size is estimated to be above B_{pa} , the probability of impaired recruitment is expected to be low.

For short-lived species, for which recruitment is highly variable, the biomass can fluctuate widely between years. A precautionary approach in this situation implies that a minimum stock size, $B_{escapement}$, should remain in the sea every year after fishing to ensure future recruitment.

F_{lim} is the fishing mortality which in the long term will result in an average stock size at B_{lim} . Fishing at levels above F_{lim} will result in a decline in the stock to levels below B_{lim} . ICES also defines F_{pa} , which is the fishing mortality that results in no more than 5% probability of bringing the spawning stock to below B_{lim} in the long term.

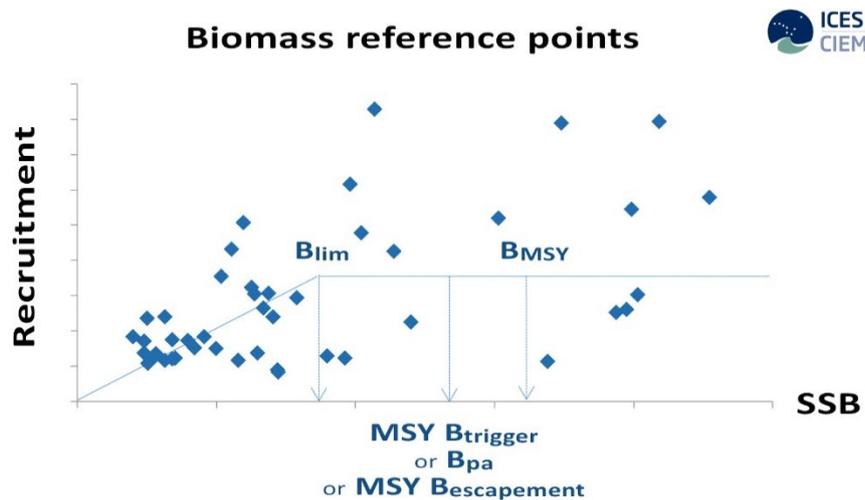


Figure 3 Illustration of biomass-based biological reference points. B_{lim} and B_{pa} are precautionary reference points related to the risk of impaired reproductive capacity, while $MSY B_{escapement}$ (often equal to B_{pa}) is used in the advice framework for short-lived species. $MSY B_{trigger}$ is the parameter in ICES MSY framework which triggers advice on reduced fishing mortality relative to F_{MSY} . B_{MSY} is the expected average biomass if the stock is exploited at F_{MSY} . The diamond shapes in the plot show the variable values of recruitment versus SSB that have been observed over the years. Recruitment can be seen to be generally lower when SSB is below B_{lim} .

Some fish eat other fish, which means growth in numbers for the predator and mortality for the prey; fish populations also compete for food or habitat. Thus the size and productivity of a fish stock may depend on the state of other stocks, as well as on its own abundance. It also means that as a population of fish increases, growth and mortality for that species cannot be expected to remain constant, as there will be increasing competition for food and habitat within that population.

ICES incorporates such multispecies interaction considerations into the single-species framework in the Baltic Sea, the Barents Sea, and the North Sea. This is done by applying natural mortality and growth rates derived from models of species interactions, using size, age, and stomach data for several species. ICES routinely incorporates short-term changes in growth and maturation into short-term projections to account for competition and food supply. ICES also expects to periodically update MSY reference points (typically as part of the benchmark process) to ensure they reflect current biological parameters and dynamics.

Long-lived category 1 and 2 stocks

For long-lived category 1 and 2 stocks, ICES bases its MSY approach on attaining a fishing mortality rate of no more than F_{MSY} while maintaining the stock above B_{lim} with at least 95% probability.

Under this approach, ICES uses the fishing mortality and biomass reference points F_{MSY} and $MSY B_{trigger}$. F_{MSY} is estimated as the fishing mortality with a given fishing pattern and current environmental conditions that gives the long-term maximum yield. To ensure that fishing at F_{MSY} is sustainable, F_{MSY} must not be above F_{pa} . The best estimate of F_{pa} is considered to be the fishing mortality that results in a less than 5% probability of $SSB < B_{lim}$ in the long term. This is appropriate, since a precautionary approach is a necessary boundary to ensure sustainability, even though it is in itself not a sufficient condition for achieving the MSY implied by the MSY framework.

$MSY B_{trigger}$ is considered the lower bound of SSB fluctuation (fifth percentile of B_{MSY}) when fished at F_{MSY} and is used in ICES advice rule to trigger a cautious response. The cautious response, in cases where the spawning stock falls below $MSY B_{trigger}$, is to reduce fishing mortality in order to allow a stock to rebuild to levels capable of producing MSY. The reduction in fishing mortality is proportional to the ratio between the size of the spawning stock and $MSY B_{trigger}$ (SSB is estimated at spawning time [in the first year of the forecast]).

The advice rule leads to catch advice corresponding to a fishing mortality of:

- 1) $F = F_{MSY}$ when SSB is at or above $MSY B_{trigger}$
- 2) $F = F_{MSY} \times SSB / MSY B_{trigger}$ when the stock is below $MSY B_{trigger}$ and above B_{lim}
- 3) If the F following from applying rule 2 is insufficient to bring the stock above B_{lim} in the short term, ICES advice will be based on bringing the stock above B_{lim} at the end of the projection year. If there is no F that will bring the stock above B_{lim} at the end of the projection year or when the forecast is highly sensitive to assumptions (e.g. incoming recruitment), ICES will advise zero catch based on precautionary considerations until the SSB is above B_{lim} with high probability.

Conceptually, SSB in the advice rule is the estimated spawning-stock size at the beginning of the year to which the advice applies (advice year), or at spawning time in the year before the advice year. For example, for an assessment performed in 2020 using data through 2019, the reference spawning-stock size for most stocks will be the projected size at the beginning of 2021.

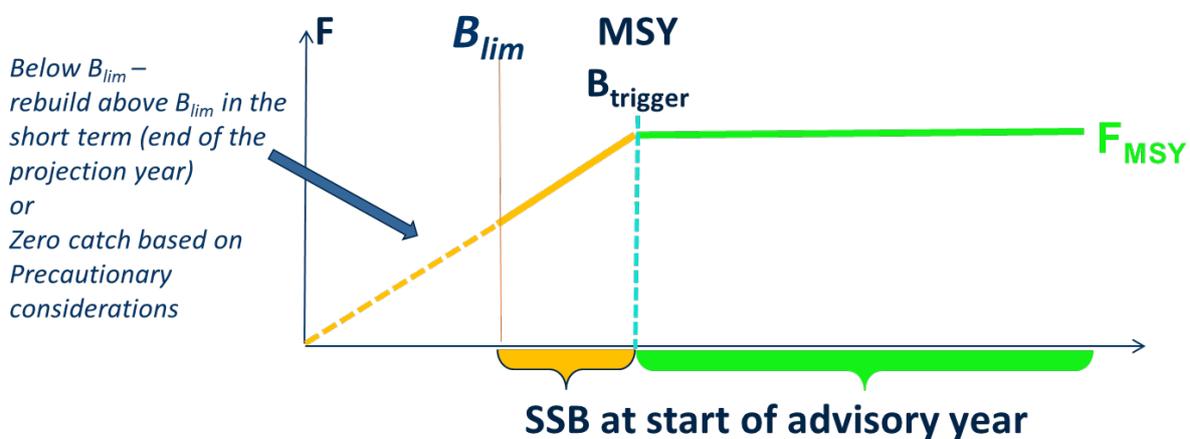


Figure 4 ICES advice rule for category 1–2 stocks.

The MSY approach does not use a B_{MSY} estimate. B_{MSY} is a notional value around which stock size fluctuates when fishing at F_{MSY} . B_{MSY} strongly depends on the interactions between the fish stock and the environment it lives in, including biological interactions between different species. Historical stock size trends may not be informative about B_{MSY} (e.g. when F has exceeded F_{MSY} for many years or when current ecosystem conditions and spatial stock structure are, or could be, substantially different from those in the past). Estimates of B_{MSY} are very sensitive to the assumption that all future factors that influence fisheries productivity remain unchanged in the future.

Determination of $MSY B_{trigger}$ requires contemporary data that identify the normal range of fluctuations in biomass when stocks are fished at F_{MSY} . If the observation on fluctuation in biomass is insufficient to estimate $MSY B_{trigger}$, the reference point is normally set at B_{pa} (if this reference point is available). If sufficient observations of SSB fluctuations associated with fishing around F_{MSY} are available, the $MSY B_{trigger}$ should be re-estimated to correspond to the fifth percentile of B_{MSY} when fishing at F_{MSY} .

ICES has provided advice on plausible values around F_{MSY} (F_{MSY} range) for a number of stocks in response to a request by the EU. The F_{MSY} ranges [$F_{MSY lower}$, $F_{MSY upper}$] are derived to deliver no more than a 5% reduction in long-term yield, compared with the MSY obtained by fishing at F_{MSY} in the long term. To be consistent with ICES precautionary approach, F_{MSY} or $F_{MSY upper}$ is capped so that the probability of $SSB < B_{lim}$ is no more than 5% in any single year.

Most fisheries catch a mixture of species; it is not entirely possible to control either which species those are or how much of each species is caught. For stocks exploited by mixed-species fisheries, it may not be possible to achieve the single-stock MSY catch advice for all the stocks simultaneously. Either the advised catches for some stocks will be exceeded in trying to catch the TACs of other stocks, or the TACs for some stocks will not be caught in order to prevent overshooting the TACs of other stocks. ICES has developed a mixed-species fisheries forecast to address this; for the main demersal stocks in the

North Sea, Bay of Biscay, Iberian waters and Celtic Sea, ICES provides a range of mixed fisheries scenarios to the trade-offs between the different scenarios.

Short-lived category 1 and 2 stocks

The future size of a stock of short-lived species is very sensitive to recruitment because of the small number of age groups present in the natural population. Incoming recruitment is often the main, or only, component of the fishable stock. Care must therefore be taken to ensure that the spawning-stock size is above levels where recruitment is impaired, as the future of the stock is highly dependent on annual recruitment.

For most stocks of short-lived species, similarly to the long-lived species, the ICES MSY approach is aimed at providing MSY while ensuring that the probability of the stock being below B_{lim} in any single year is no more than 5%. For some stocks, advice is given based on agreed management plans that have been shown to be precautionary. For some other stocks, ICES uses two reference points: $MSY_{B_{escapement}}$ (see Figure 3) and F_{cap} . $MSY_{B_{escapement}}$ is estimated to be robust against low SSB and includes a biomass buffer to account for uncertainty in both the assessment and catch advice. In some cases, however, defining $MSY_{B_{escapement}}$ is not necessary; this is because the escapement strategy uses a 95% probability of being above B_{lim} directly.

For many of these stocks of short-lived species, F_{cap} is defined to limit exploitation rates when biomass is high. A large stock is usually estimated with greater uncertainty; when the catch is taken, for example, the uncertainty in the escapement biomass is greater. By capping the F , the escapement biomass is increased in proportion to stock size, maintaining a high probability of achieving the minimum amount of biomass left to spawn. In some cases (such as following high recruitment), this will result in a median SSB above $MSY_{B_{escapement}}$ in the long term.

The advised yearly catches correspond to the estimated stock biomass in excess of the $MSY_{B_{escapement}}$ but are constrained to allow a fishing mortality no higher than F_{cap} . In the absence of agreed management plans or a defined F_{cap} , the advice is based on the MSY or precautionary approaches.

For some short-lived species, assessments are so sensitive to incoming recruitment that the amount of biomass in excess of the target escapement cannot be reliably estimated until data on the incoming year class are available. For most of the stocks concerned, such data are obtained just before the fishery starts (or during the fishing year). The advice on fishing opportunities may therefore only be given either directly prior to the start of the fishing season or after the fisheries has started.

Category 3–6 stocks

A substantial number of the stocks for which ICES provides advice have no population estimates from which catch options can be derived using the MSY framework. ICES has therefore developed a precautionary framework for quantitative advice regarding such stocks.

The overall aim of the approach for these stocks is to ensure that the advised catch is sustainable. The underlying principles of the approach are that (a) the best available information should be used and (b) a precautionary approach should be followed. The latter implies that as information becomes increasingly limited, more conservative reference points should be used, and a further margin of precaution should be adopted when there is limited knowledge of the stock status. The margin of risk tolerance is a management prerogative, but in the absence of any proposal by managers, ICES applies the values given below.

A precautionary approach for category 3–6 stocks involves a framework with the following considerations regarding uncertainty and precaution being applied in sequence:

1. The methodologies used to estimate trends in these stocks may be more susceptible to noise due to limited data or knowledge. Consequently, any change in the perception of stock trends (based on available information such as trends in biomass index or assessments considered representative of trends only) is capped by a change limit of $\pm 20\%$ (uncertainty cap). This cap is generally applied to the previous catch advice or, if it is the first year of application, to the average of recent catches.

2. An additional precautionary margin (a precautionary buffer [PA buffer]) with decreasing knowledge about the stock status may then be applied, subject to the following:
 - a. In cases where exploitation and stock status have been identified through MSY reference points or qualitative evaluation the diagram below (boxes 1 to 5) is used to determine whether or not the precautionary buffer should be applied.
 - b. In cases where exploitation and/or stock status are unknown (boxes 6 to 9 in diagram below) the PA buffer should be applied unless the exceptions in the diagram below for **both** exploitation **and** stock status are met and documented.
 - c. The decision on whether or not to apply the PA buffer has to be re-considered every three years.

Table 1 Framework for application of precautionary approach for ICES category 3–6 stocks

		Stock size status or qualitative evaluation [^]		
		✗ or ✗	✓ or ✓	?
Fishing pressure status or qualitative evaluation [^]	✗ Or ✗	1 Apply PA buffer	4 Apply PA buffer	7 Apply PA buffer
	✓ or ✓	2 Apply PA buffer	5 Do not apply PA buffer	8 Consider applying PA buffer Apply Do not apply if: a) consistent* increase in stock size index or b) significant increase in stock size index ratio** (> 1.5)
	?	3 Apply PA buffer	6 Consider applying PA buffer: Apply Do not apply if: effort consistently* decreases or has remained stable	9 Consider applying PA buffer: Apply Do not apply if: a) consistent increase in stock size index or b) significant increase in stock size index ratio** (> 1.5) AND effort consistently* decreases or has remained stable

[^] The qualitative evaluation (e.g. ✗ or ✓) refers to the stock status.

* Consistent increase/decrease should be determined on the basis of a significant [Mann-Kendall test](#) using the last ten years of the stock index or effort data; the term ‘consistent’ replaces the term ‘continuous’, which allows for some year-to-year declines.

** “Index ratio” means the *x* latest index values compared with the *y* preceding values. Most often this will be the “2 over 3” stock size indicator ratio.

This framework with an uncertainty cap and application of the PA buffer was simulation tested for a range of stocks and in general was found to be appropriate (ICES, 2017). When stock trends are taken into account and combined with the considerations above, the resulting advice when using the same index of stock change may show a maximum decrease of 36% and a maximum increase of 20% over the previous advice. The advice is applicable to a time-frame that is compatible with a measurable response in the metrics used as the basis for the advice. In cases where the least amount of information is available, including cases where the 20% PA buffer has been applied, ICES considers the advice valid for a fixed and determined period. As an example, that period could be two years, unless important new knowledge emerges regarding a stock that justifies an interim revision of the advice.

The advice rule used to provide quantitative advice on fishing possibilities depends on the information available, and ICES has developed separate advice rules for each of the stock categories listed in this section and the sections above.

Category 3. Stocks for which survey-based assessments indicate trends. The most common approach for providing advice on fishing opportunities for the coming year(s) is based on the recent advised catch (or landings), adjusted for the change in stock-size index for the two most recent values relative to the three preceding values. Other reference years may be used, based on the level of stock biology knowledge (e.g. species with a relatively high longevity) or the quality of the data. Other approaches for providing precautionary advice are also available (ICES, 2012); these include providing zero catch or recovery plan advice for stocks with extremely low biomass relative to previous estimates.

Category 4. Stocks for which reliable catch data are available. The approach is to use catch information to evaluate whether the stock is fished sustainably, or whether a reduction in catch is required to achieve sustainability. Decreases or increases in catch advice are incremental and slow.

Categories 5 and 6. Stocks for which there are landings only or negligible landings and stocks caught in minor amounts as bycatch. In situations where only landings/catch data are available and no life-history or fishery information can be gleaned from similar stocks or species in the ecoregion or beyond, ICES will normally provide advice on the basis of previous catches/landings, applying the PA buffer. If catches have declined significantly over a period of time and this could represent a reduction in stock size, ICES may advise zero catch or the implementation of a management strategy.

ICES provides a framework for stock status classification relative to MSY proxies for stocks in categories 3 and 4.

A stock is classified on the basis of two MSY indicators: one for exploitation and a second for biomass. Whenever possible, the indicators are designated either green (exploitation is at or below F_{MSY} , and biomass is at or above $MSY B_{trigger}$) or red (exploitation is above the F_{MSY} , and biomass is below the $MSY B_{trigger}$). When no determination can be made, the indicators are designated as unknown.

Given the uncertainties in data and knowledge for stocks in these categories, ICES is not currently using these methods to provide quantitative estimates of the distance of F from F_{MSY} or of B from $MSY B_{trigger}$. While the classification of stocks is considered the best possible at the time of evaluation, revisions may occur as more information becomes available for these stocks and the methods and knowledge are further developed. The framework is expected to evolve over time, as the methods are further developed and validated.

Sources and references

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM:68. 42 pp. <https://doi.org/10.17895/ices.pub.5322>.

ICES. 2017. Report of the ICES Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for stocks in categories 3–6 (WKLIFEVI), 3–7 October 2016, Lisbon, Portugal. ICES CM 2016/ACOM:59. 106 pp.

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