

## 1.2 Advice basis

### General context of ICES advice

ICES mission is to advance and share scientific understanding of marine ecosystems and the services they provide, and to use this knowledge to generate state-of-the-art advice that meets conservation, management, and sustainability goals. This advice supports ecosystem-based decision-making for the management of human activities in the ICES area, and contributes to the effective application of an ecosystem approach. The approach seeks to maintain the health of marine ecosystems, alongside human use, for the benefit of current and future generations.

An important part of ICES advice regards *the management of the exploitation of living marine resources*. The context for this part of ICES advice is set by several international agreements and policies:

- United Nations Convention on the Law of the Sea (UN, 1982 [known as UNCLOS]), which includes a call for a maximum sustainable yield (MSY) approach to managing fisheries;
- United Nations Conference on Environment and Development (UN, 1992a [known as UNCED]), including Chapter 17 of Agenda 21 which highlights a precautionary approach;
- United Nations Straddling Fish Stocks Agreement of 1995 (UN, 1995 [known as the UN Fish Stocks Agreement or UNFSA]) and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), both of which call for a precautionary approach;
- Convention on Biological Diversity (UN, 1992b [known as CBD]), which calls for conservation of biological diversity through an ecosystem approach;
- Johannesburg Declaration of the World Summit on Sustainable Development (UN, 2002 [known as WSSD]), which calls for an ecosystem approach and rebuilding fisheries to maximum sustainable yield.

In addition, ICES advice responds to the policy and legal needs of ICES Member Countries as well as to multinational and intergovernmental organizations that use the advice as the scientific basis to manage human activities that affect, and are affected by, marine ecosystems. Some applicable policy and legal instruments are:

- The Common Fisheries Policy of the European Union (CFP; EU, 2013);
- The Marine Strategy Framework Directive (MSFD; EU, 2008);
- The Norwegian Marine Living Resources Act (Anon., 2008);
- The Russian Federal Law on Fisheries and conservation of aquatic biological resources (Anon., 2004);
- The Icelandic Fisheries Management Act (Anon., 1990);
- The Norwegian Act on the Management of Marine Resources (Anon., 2017).

### Advisory process

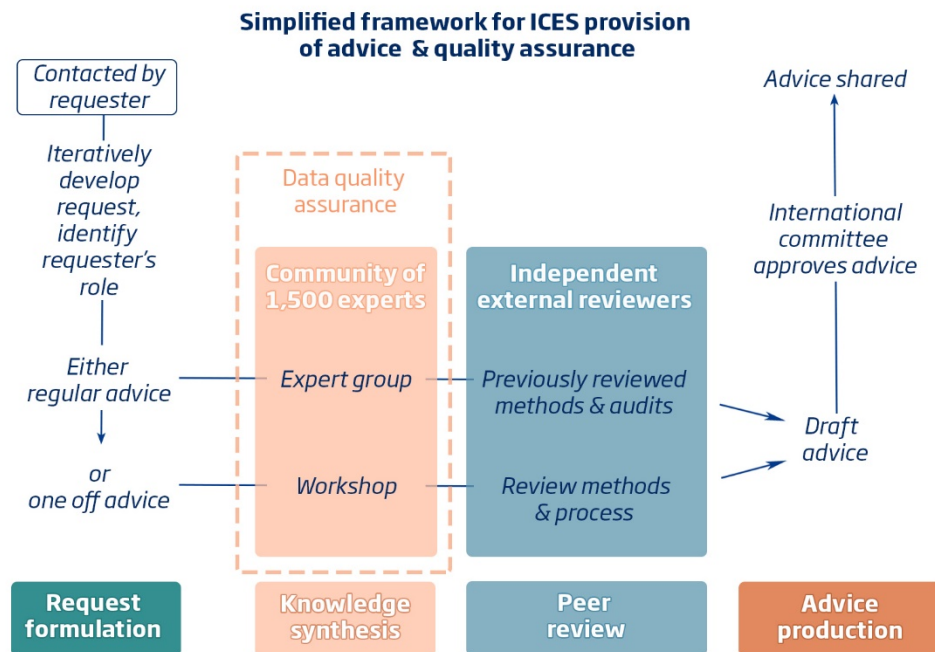
ICES aims at producing advice that (a) uses best practice data principles and best available quality-assured evidence, (b) is developed through a transparent, unbiased, impartial, and independent process, and (c) is recognized by all parties as being relevant to management.

The advisory process consists of four stages (Figure 1).

1. **Request formulation:** an iterative dialogue between the requesters of the advice and ICES takes place to clearly define the advice question(s), to ensure resources and expertise are available, and to confirm roles in the process. Different requesters have different expectations in the degree of consultation and engagement in the advice process, hence the need to clarify the role of the requester in the advice process. Many requests are covered by collaborative agreements with ICES.
2. **Knowledge synthesis:** generally groups of experts build the best available knowledge. The process is guided by the ICES Data Policy (ICES, 2016), the ICES advice framework, and the ICES Code of Conduct (ICES, 2018).
3. **Peer review:** independent review of data and methods, ensuring that the best available evidence and science has been used and that the advice adheres to ICES frameworks.

4. **Advice production:** an answer to the request is drafted by an advice drafting group, approved with international consensus via ICES Advisory Committee (ACOM), and published publicly. The evidence and supporting rationale are explained in the advice.

In accordance with ICES quality policy, ICES operates an independent peer-review system. The scientific basis for responses to non-recurring requests for advice is subject to a peer-review process, before or in conjunction with the advice drafting group. For recurring advice on fishing opportunities, ICES has implemented a benchmark process in which the methods, including the data series to be used by the expert groups in addressing the requests, are developed. Benchmarks are subjected to a peer-review process similar to the process for non-recurring requests, and the results are published.



**Figure 1** Simplified schematic of the ICES advisory process.

Workshops, advice drafting groups, and the final ACOM approval of the advice are open to stakeholders who have observer status within ICES. Requesters of ICES advice may attend the entire advisory process as an observer for their respective requests.

## Advice products

The advice products provided by ICES can be classified into two categories:

- **Advice** which is adopted by ICES Advisory Committee (ACOM); and
- **Services** provided by the ACOM Leadership and/or by the Secretariat under the oversight and final endorsement of ACOM.

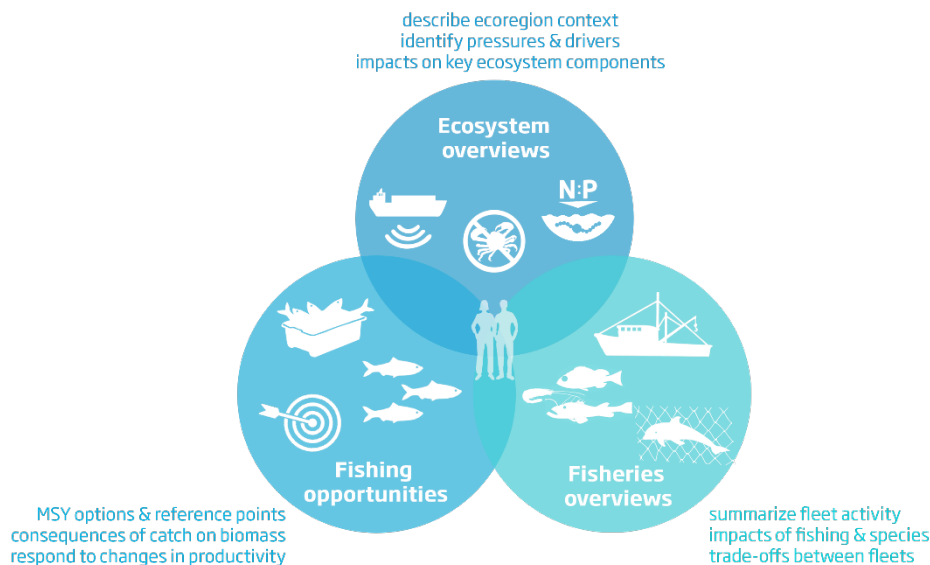
## Advice

The majority of the advice is provided in response to standing requests (recurrent advice) from the requesters of advice (the European Commission (DG MARE), the North Atlantic Salmon Conservation Organization (NASCO), the North East Atlantic Fisheries Commission (NEAFC), and Norway). In addition to the recurring advice ICES also provides advice in response to special requests from the Commissions mentioned above and from the Helsinki Commission (HELCOM), the OSPAR Commission (OSPAR), the European Commission (DG ENV), and ICES Member Countries.

ICES considers ecosystem-based management (EBM) as the primary way of managing human activities affecting marine ecosystems. Three main recurrent advice products are provided to support EBM (Figure 2):

1. Advice on fishing opportunities;
2. Fisheries overviews; and
3. Ecosystem overviews

These products are continually developing to address new information as well as changes in the ecosystem, legislation, and the drivers of fisheries and other anthropogenic marine activities.



**Figure 2** Three main products of recurrent ICES advice that provide the evidence base for ecosystem-based management.

## Services

A Service is the provision of scientific information or a process that produces scientific information asked for by policy-makers. The service may include recommendations made by individual- or groups of scientists, but it does not include a recommendation on behalf of ICES (except to reiterate a recommendation previously agreed by ACOM).

While Services are not ICES approved advice, they share the same characteristics of quality assurance and are developed in a transparent process that is unbiased and politically neutral.

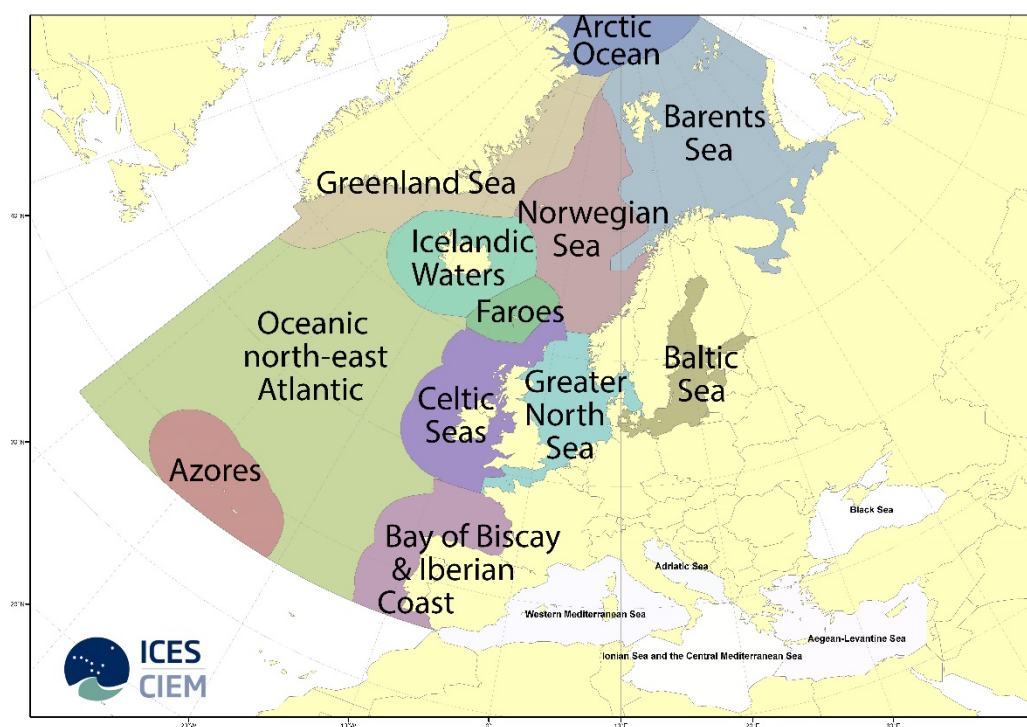
The services fall into four categories:

1. **Technical Services:** This service is the provision of factual information with no or minimal interpretation, e.g. the provision of data and research results.
2. **Clarification of Advice:** This service helps users understand advice previously provided by ICES.
3. **Process Services:** This service facilitates delivery of, e.g. a report of best scientific understanding of an issue, in cases where ICES is not requested to offer advice but is asked to provide scientific integrity to a process.
4. **Review Services:** This service covers peer review of scientific activities (including research proposals, survey or sampling designs, or research results conducted independent of ICES). In provision of the service ICES is responsible for selecting qualified experts, without a vested interest, to provide reviews. The reviews will be produced by the experts, and ICES does not comment on or interpret those reviews.

## Ecosystem and fisheries overviews, and viewpoints

Ecosystem-based management (EBM), if correctly applied, will contribute to the long-term sustainable use of marine resources, including the fisheries sector. EBM serves multiple objectives, involves effective stakeholder participation, and focuses on human behaviour as the central management dimension. A more detailed description of the ICES approach to ecosystem-based management can be found in the ICES advisory plan. The Ecosystem and Fisheries Overviews are a key mechanism by which ICES identifies and disseminates the best available knowledge for ecosystem-based management. Overviews are formally approved for publication by ACOM as an ICES advisory product.

These overviews complement ICES advice by providing information on ecosystems and allowing users to understand the implications of management decisions in an ecosystem context. They provide a concise and informative introduction to ecoregions (Figure 3), and to the human activities that take place within them. The overviews will therefore increase ICES capacity to provide the integrated ecosystem advice that is required to meet the needs of requesters of advice and society in general. The overviews are continuously evolving documents, addressing issues of interest and incorporating new knowledge.



**Figure 3** Map of ICES ecoregions. MSFD sub areas in the Mediterranean and Black Sea are also shown.

### Ecosystem overviews

The ecosystem overviews have been developed through workshops with requesters of advice, reviewed by the ICES integrated ecosystem assessment expert groups, and are adopted by ACOM. The ecosystem overviews focus on regional manageable pressures and describe their implications on the state and variability of the system.

The purpose of the ecosystem overviews is to describe:

1. the location, scale, and the management and assessment boundaries of the ecoregion;
2. the distribution of human activities and resultant pressures (in space and time) on the environment and ecosystem; and
3. the state of the ecosystem (in space and time) and the linking of key pressures, including climate change, to the changes of ecosystem components.

The ecosystem overviews are structured around five sections: (1) Ecoregion description; (2) Key signals within the environment and ecosystem; (3) Pressures; (4) Climate change impacts; and (5) State of the ecosystem.

The contents of the ecosystem overviews are based on information provided by expert groups that specialize in state descriptors, published data products, and GIS layers from reliable sources. The core of the ecosystem overviews are figures that relate the main pressures within an ecoregion to (a) the activities that most directly impose these pressures, and (b) the ecosystem components that are most impacted by these pressures. Generally, expert judgment is applied, as in many cases there is very little or no quantitative information available on a given activity–pressure–ecosystem component pathway. The following methodology is applied for selection of pressures:

1. Identify all pressures of the ecoregion.
2. Consider the risk each individual pressure poses in the region in terms of:
  - a) Probability of occurrence;
  - b) Magnitude (space and/or severity of impact).
3. Select the top (usually five) pressures from a management perspective based on an evaluation of the importance for the region.
4. For each selected top pressure:
  - a) Determine the main human activities contributing to these pressures;
  - b) Evaluate the main relationships between the ecosystem components and each of the five pressures.
5. Identify (where available) written sources to support these links.

## Fisheries overviews

These overviews have been established by ICES after feedback from requesters of advice. The fisheries overviews provide management advice on the trade-offs linked to mixed-fisheries scenarios, summarize activities of different fishing fleets, provide information on the composition of catches and bycatches, introduce fisheries management frameworks/agreements/measures, and evaluate ecosystem effects of fishing activities. The fisheries overviews also deal with technical interactions occurring in different fisheries by areas and species.

The purpose of fisheries overviews is to describe:

1. national fishing fleets in the ecoregion, including their fishing gears and spatio-temporal fishing patterns;
2. status of the fisheries resources and the level of exploitation relative to the agreed objectives and reference points;
3. mixed-fisheries considerations of relevance to the management of the fisheries; and
4. impacts of fishing gear on the ecosystem in terms of the seabed and the bycatch of endangered, protected and/or threatened species.

The fisheries overviews are structured around the following eight sections: (1) Who is fishing; (2) Catches over time; (3) Description of the fisheries; (4) Fisheries management; (5) Status of the fishery resources; (6) Mixed fisheries; (7) Species interactions; and (8) Effects of fisheries on the ecosystem.

The contents of the fisheries overviews utilize information provided by expert groups, ICES databases (SAG, SID, official catch statistics, and VMS/logbook database), and the STECF database of catches and effort. Production of the figures and tables is standardized across ecoregions, and all data used to produce the figures are provided as CSV files. The figures and tables are produced dynamically using the ICES Fisheries Overview package (<https://github.com/ices-tools-prod/icesFO>), linking directly to ICES databases and a copy of the STECF database of catches and effort. The development of each fisheries overview is available on TAF, ([https://github.com/ices-taf/2019\\_BtS\\_FisheriesOverview](https://github.com/ices-taf/2019_BtS_FisheriesOverview)), ensuring transparency and reproducibility.

## Viewpoints

In addition to the recurrent advice and special requests, ICES publishes viewpoints. Viewpoints highlight our capacity to provide impartial evidence-based analyses of emerging topics related to the state and sustainable use of the marine resources. As unsolicited advice, viewpoints allow expert groups to draw managers' attention to the implications of new knowledge for society and the management of human activities.

## Advice on fishing opportunities

The ICES approach to advice on fishing opportunities integrates ecosystem-based management 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 achieve MSY. All ICES advice is consistent with the precautionary approach, which is a necessary but not a sufficient condition for MSY.

Maximum sustainable yield 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. The MSY concept can be applied to an entire ecosystem, a fish community, or a single stock. ICES applies the MSY concept to single stocks as well as to groups of stocks in the context of mixed fisheries, where stocks are caught together in a fishery. ICES interpretation of MSY is maximizing the average long-term yield from a given stock while maintaining productive fish stocks.

In relation to MSY, ICES defines yield to be maximized as the wanted part of the catch measured in weight, i.e. the part of the catch that is landed and above any agreed minimum conservation/reference 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 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 the fisheries but also to changes in fishing patterns and fishing pressures on their prey or their predators as well as to climate changes. ICES therefore considers MSY reference points to be valid only in the medium term and to be subject to regular reviews.

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 the status in relation to MSY, precautionary and, if applicable, management reference points 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.

The advice rule applied by ICES in developing the advice on fishing possibilities depends on management strategies agreed by relevant management parties, and the information and knowledge available for the concerned stocks.

If the relevant management parties have agreed on a management plan or strategy, and the plan/strategy has been evaluated by ICES to be consistent with the precautionary approach, ICES will provide advice in accordance with the plan/strategy when requested.

If no management plan/strategy has been agreed by all relevant management parties, or the agreed plan/strategy has been evaluated by ICES not to be consistent with the precautionary approach, ICES will provide advice applying the ICES MSY advice rule if possible or the precautionary approach.

The ICES MSY advice rule requires a relatively high level of data and knowledge on the dynamics of the stocks concerned. If the data and knowledge requirements are not fulfilled ICES cannot provide advice consistent with MSY; instead ICES applies an advice rule that is based only on precautionary considerations.

For the purposes of identifying the advice rule to be applied when giving advice on fishing possibilities, ICES classifies the 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 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.

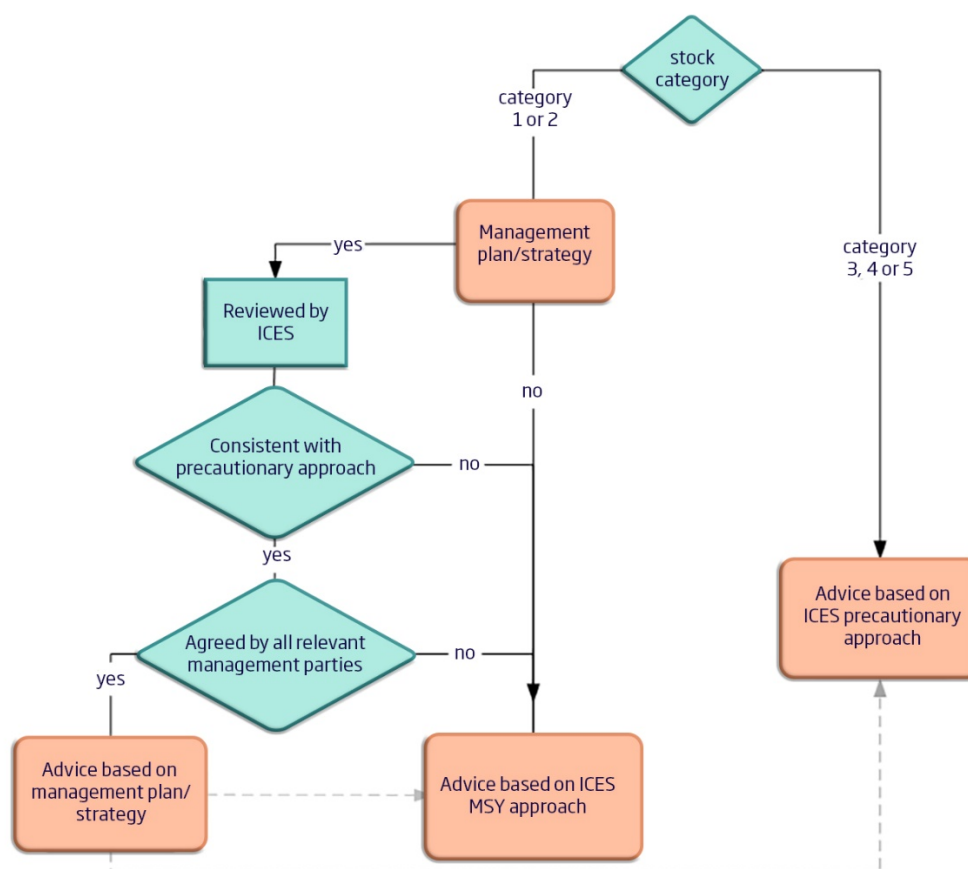
**Category 3** – *Stocks for which survey-based assessments or exploratory assessments indicate trends.* Includes stocks for which survey, trends-based assessments, or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass.

**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 information and density information from neighbouring areas to provide advice.

**Category 5** – *Stocks for which only landings or a short series of catches are available.*

**Category 6** – *Negligible landings stocks 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 in accordance with agreed management plans/strategies evaluated to be consistent with the precautionary approach when requested. If such plans/strategies are not agreed or have been evaluated by ICES as not being precautionary, ICES will give advice on the basis of the ICES MSY approach.



**Figure 4** Flow diagram showing the basis of the ICES advice. The grey broken lines indicate that sometimes the advice in management plans is consistent with the ICES MSY approach or with the precautionary approach.

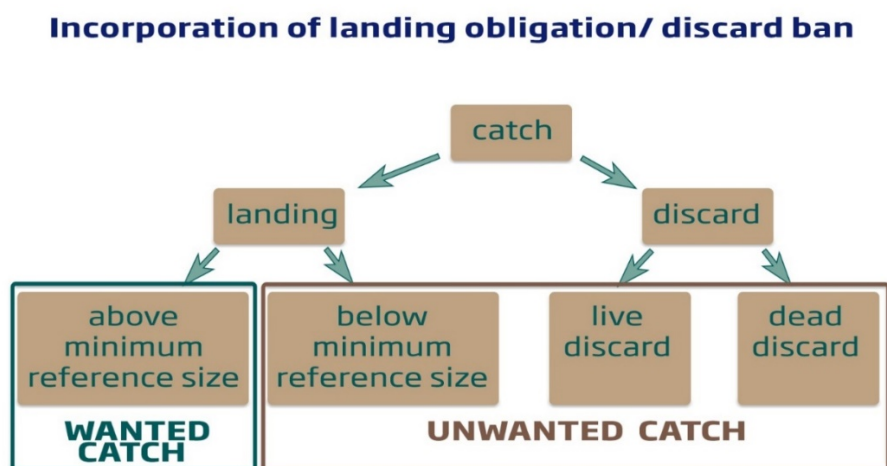
As the knowledge available is insufficient to apply the ICES MSY approach to category 3–6 stocks, the advice rule is based on the precautionary approach. ICES has, however, developed an approach to determine proxies for MSY reference points for some stocks in categories 3 and 4. Based on these proxies,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

Limitations on fisheries may be required in order to achieve environmental objectives, especially regarding biodiversity, habitat integrity, and foodwebs. This will not affect the catch that can be taken from a stock in accordance with the objectives of MSY and the precautionary approach, and will therefore not affect ICES advice on fishing possibilities. The limitations may, however, affect the fisheries' opportunities to fully utilize the advised fishing possibilities. ICES may, if requested, advise on the likely impact of such limitations on the catch but will, as explained, not include such considerations in the advice on fishing opportunities.

Most of the fish and shellfish fisheries managed by total allowable catches (TACs) in ICES statistical areas are increasingly subject to discard bans or landing obligation regulations. Different regulations are in place within the ICES area, and different regulations may pertain to shared stocks. For EU waters, a landing obligation has been phased in since 2016. Since then catches may be split into three categories; reported landings at or above minimum conservation/catching size, reported landings below minimum size (BMS), and discards. The 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 to the landing obligations/discard bans should be landed. The estimates of discarding not observed are assumed based on observations from similar métiers, seasons or areas.

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

If the fishing pattern and ratio between landings and discards may change in the forecast period, due to changes in compliance with the landing obligation/discard ban, ICES will not distinguish between landings below minimum conservation/catching size and discards in the catch scenarios. Those two components will instead be combined into one category: unwanted catch. The landing above minimum conservation/catching size may, in these cases, be termed wanted catch as illustrated in Figure 5.



**Figure 5** Catch categories used by ICES in stock assessments and forecasts. For an explanation of these categories, see text above.



## ICES MSY advice rule

Fisheries directly affect fish stocks through catches. The fishing mortality ( $F$ ) is a measure for 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 over ages that dominate in the catches. For some stocks, such as Icelandic cod, saithe, and most *Nephrops* stocks, ICES uses harvest rates (HR) 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 or SSB), and the size structure in the stock; these in turn also depend on the fishing mortality and fishing pattern.

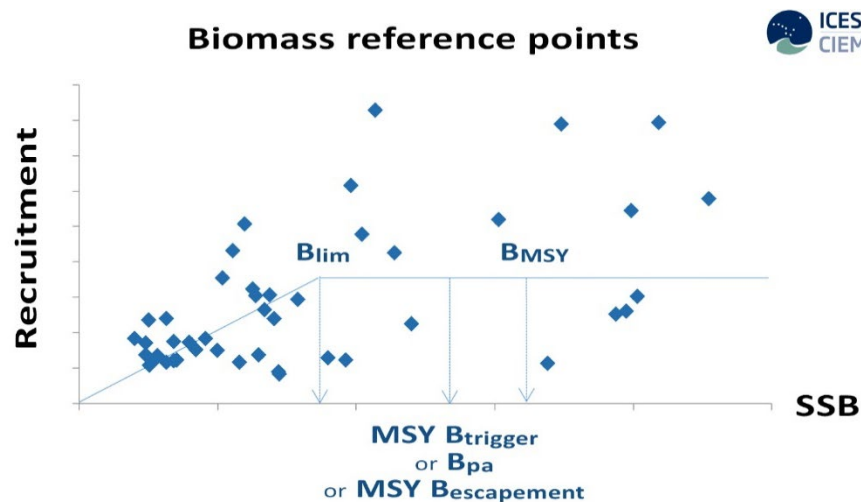
Surplus production of a stock is the catch that can be harvested without changing the average production in the long term. For a given fishing pattern there is a level of fishing mortality that, in the long term, will generate the highest surplus production. This peak of the surplus production (above 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; it can only influence it through the 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, a reference point  $B_{lim}$  may be identified as the stock size below which there is a high risk of reduced recruitment. A precautionary safety margin incorporating the uncertainty in ICES stock estimates leads to a 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 the recruitment is highly variable, the biomass can fluctuate wildly 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  $B_{lim}$ . Again, to account for the uncertainty in the assessment, ICES applies a precautionary buffer  $F_{pa}$  to avoid that *true* fishing mortality is above  $F_{lim}$ . ICES also defines  $F_{p,0.5}$  as the fishing mortality that results in no more than 5% probability of bringing the spawning stock to below  $B_{lim}$  (ICES, 2015).



**Figure 6** 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 the ICES MSY framework which triggers advice on a reduced fishing mortality relative to  $F_{MSY}$ .  $B_{MSY}$  is the expected average biomass if the stock is exploited at  $F_{MSY}$ . Diamonds show the variable 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 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, one cannot expect growth and mortality for that species to remain constant, as there will be increasing competition for food and habitat within that population.

ICES incorporates such species interaction considerations into the single-species framework in the Baltic, 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 update MSY reference points (typically as part of the benchmark process) to ensure they reflect current 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.

In 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,  $F_{MSY}$  is not allowed to be above  $F_{pa}$  or  $F_{p.05}$ . 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 maximum sustainable yield implied by the MSY framework.

$MSY B_{trigger}$  is considered the lower bound of spawning-stock biomass fluctuation (5th percentile of  $B_{MSY}$ ) when fished at  $F_{MSY}$ , and is used in the 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]  $F$ ).

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

1.  $F = F_{MSY}$  when the spawning-stock biomass is at or above  $MSY B_{trigger}$ ; and
2.  $F = F_{MSY} \times \text{spawning-stock biomass} / MSY B_{trigger}$  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  $B_{lim}$  in the short term. This may result in advice of zero catch. ICES interprets short term as the end of the projection year.

Conceptually, spawning-stock biomass 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 2019 using data through 2018, the reference spawning-stock size for most stocks will be the projected size at the beginning of 2020.

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 5th percentile of  $B_{MSY}$  when fishing at  $F_{MSY}$ .

ICES has, as requested by the EU, provided advice on plausible values around  $F_{MSY}$  (range for  $F_{MSY}$ ) for a number of stocks. 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 maximum sustainable yield (MSY) obtained by fishing at  $F_{MSY}$  in the long term. To be consistent with the 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 model to address this; for the main demersal stocks in the North Sea, Bay of Biscay, and the Celtic Sea, ICES provides information on catch composition of different fisheries strategies to illustrate the trade-offs between the strategies.

### 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 be taken, therefore, 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 2) and  $F_{cap}$ . Each year, 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 an MSY  $B_{escapement}$  is not needed; this is because the escapement strategy uses the 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 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, therefore, may 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) all the 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 with decreasing knowledge about the stock status may then be applied, subject to the following:
  - or those cases when it is likely that  $F > F_{MSY}$ , or when the stock status relative to candidate reference points for stock size or exploitation is unknown, a precautionary margin of  $-20\%$  (precautionary [PA] buffer) is then applied to derive the advised catch. Exceptions to this rule have been made in cases where expert judgement determines that the stock is not reproductively impaired, or where there is evidence that the stock size is increasing significantly or that exploitation has been reduced. This would be based, for instance, on survey indices or on a reduction in fishing effort in the main fishery if the stock is taken as a bycatch species. The decision whether or not to apply the PA buffer has to be re-considered every three years.

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% precautionary (PA buffer) has been applied, ICES considers the advice valid for a fixed and determined period. That period could be two years, for example, 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 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 large longevity), or the quality of the data.

*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. Landings only stocks or negligible landings stocks and stocks caught in minor amounts as bycatch.* In situations where only landings/catch data are available, and no relevant 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 precautionary 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 maximum sustainable yield (MSY) proxies for stocks in categories 3 and 4.

A stock is classified on the basis of two MSY proxy indicators: one for exploitation and a second for biomass. Whenever possible, the indicators are designated either green (exploitation is at or below the  $F_{MSY}$  proxy, and biomass is at or above the  $MSY B_{trigger}$  proxy) or red (exploitation is above the  $F_{MSY}$  proxy, and biomass is below the  $MSY B_{trigger}$  proxy). 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  $MSY B_{trigger}$ . Whereas 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 developed and validated further.

### ICES approach to classify exploitation and stock status

ICES uses pictograms to represent the status of the stocks and their exploitation, relative to management objectives as defined by ICES MSY and precautionary approach reference points, as well as to agreed management strategies where they exist.

When reference points are missing, and if the available information is sufficient to conduct one, ICES presents a qualitative evaluation. The structure and the associated symbols and text are given below in Tables 1 to 3, for MSY and precautionary approaches.

**Table 1** Pictograms used by ICES to represent the evaluation of the stock status.

Status relative to reference points	Qualitative evaluation	Description
		Desirable situation, e.g. fishing pressure is below or stock size is above the relevant reference point.
		Status lies between the precautionary (PA) and limit (lim) reference points.
		Undesirable situation, e.g. fishing pressure is above or stock size is below the relevant reference point.
		Status of the stock is either (1) <b>Unknown</b> when neither quantitative assessment nor proxy calculation exist, or (2) <b>Undefined</b> when there is an analytical assessment but reference points are undefined.
		Absolute level unknown, but increasing.
		Absolute level unknown, but unchanged.
		Absolute level unknown, but decreasing.

**Table 2** Fishing pressure ( $F$ ,  $F_{\text{proxy}}$ ,  $F/F_{\text{MSY}}$ , or harvest rate).

Fishing pressure	Explanation	Sign	Text
MSY reference ( $F_{\text{MSY}}$ , $F_{\text{MSY proxy}}^1$ )	$F \leq F_{\text{MSY}}$		At (if $F = F_{\text{MSY}}$ ) Below (if $F < F_{\text{MSY}}$ )
	$F \ll F_{\text{MSY}}$ ( $F \sim 0$ ), $F \ll F_{\text{MSY proxy}}^1$		Below / Below proxy
	$F > F_{\text{MSY}}$ , $F > F_{\text{MSY proxy}}^1$		Above / Above proxy
	No reference point		Undefined
	Stock status unknown		Unknown
Precautionary approach ( $F_{\text{PA}}$ , $F_{\text{lim}}$ )	$F \leq F_{\text{PA}}$		Harvested sustainably
	$F_{\text{lim}} > F > F_{\text{PA}}$		Increased risk
	$F \geq F_{\text{lim}}$		Harvested unsustainably
	No reference point <sup>2</sup>		Undefined
	Stock status unknown (even if reference point is defined)		Unknown

<sup>1</sup> The evaluation of the proxies should only concern the year of the evaluation, i.e. when the estimation of MSY proxies uses data up to year Y the tick marks (/ ) are only included in the year Y. In the remaining years a is used, except when information is conclusive that the stock status will remain the same for the other years.

<sup>2</sup> For stocks with defined MSY reference point(s) or MSY proxies, but NO defined PA reference point(s):

- if a is used for the MSY reference point, a should also be used for the PA reference point.
- if a is used for the MSY reference point, a should be used for the PA reference point.

However, the text should be adapted to specify that PA reference point values are not defined (i.e. “above/below candidate reference points”). In such cases, the terms “Harvested sustainably” and “Full reproductive capacity”, provided for cases when PA reference points are defined, should not be used.



Fishing pressure	Explanation	Sign	Text
Management plan ( $F_{MGT}$ )	$F < F_{MGT}$ target or $F < F_{MGT}$ limit <sup>3</sup>	✓	Below
	$F$ within X% of target or within defined range	✓	At target or within the range
	$F > F_{MGT}$ target $F > F_{MGT}$ limit	✗	Above
	No (agreed) management plan	-	Not applicable
Qualitative evaluation [Not applicable for category 1 and 2 stocks]	If the exploitation of the stock can be conceptualized in relation to any possible reference points, a qualification is given:		
	When the fishing pressure indicator is very high (higher than expected to be safe for the stock), e.g. $F >$ any safe limit	✗	[Short qualification]
	When the fishing pressure indicator is very low, e.g. $F <$ possible ref. points	✓	[Short qualification]
	If the stock exploitation cannot be conceptualized in relation to any possible reference points, trends are shown by arrows only:		
	When the fishing pressure indicator increases	↗	Increasing
	When the fishing pressure indicator decreases	↘	Decreasing
	When the fishing pressure indicator is stable	→	Stable

**Table 3** Stock size (SSB, total biomass,  $B/B_{MSY}$ , or abundance/biomass indices).

Stock size	Explanation	Sign	Text
MSY ( $B_{trigger}$ , $B_{trigger proxy}$ )	$SSB \geq MSY B_{trigger}$ $SSB \geq MSY B_{trigger proxy}^1$	✓	At trigger / Above trigger / At proxy / Above proxy
	$SSB \geq MSY B_{escapement}$ [applicable for short-lived stocks with an MSY $B_{escapement}$ ]	✓	Above escapement
	$SSB < MSY B_{trigger}$ $SSB < MSY B_{trigger proxy}^1$	✗	Below trigger / Below proxy
	$SSB < MSY B_{escapement}$	✗	Below escapement
	No reference point	?	Undefined
	Stock status unknown	?	Unknown
Precautionary approach ( $B_{PA}$ , $B_{lim}$ )	$SSB \geq B_{PA}$	✓	Full reproductive capacity
	$B_{lim} < SSB < B_{PA}$	⦿	Increased risk
	$SSB \leq B_{lim}$	✗	Reduced reproductive capacity
	No reference point <sup>2</sup>	?	Undefined
	Stock status unknown (even if no reference point is defined)	?	Unknown

<sup>3</sup> If  $F_{MGT}$  target depends on  $SSB > MSY B_{trigger}$ , e.g. if the management HCR has two biomass triggers, then the value for  $F_{MGT}$  target as a function of SSB in the year in question is used in the comparison of the  $F$ .

Stock size	Explanation	Sign	Text
Management plan ( $SSB_{MGT}$ )	$SSB \geq B_{MGT}$ plan target, limit or trigger biomass	✓	Above or At target
	$SSB$ within X% of target or within defined range	✓	within the range
	$SSB < B_{MGT}$ plan target, limit or trigger biomass	✗	Below
	No (agreed) management plan	-	Not applicable
Qualitative evaluation	If the state of the stock can be conceptualized in relation to any possible reference points, a qualification is given:		
	When the stock size indicator is very low (lower than expected to be safe for the stock), e.g. $SSB < \text{any safe limit}$	✗	[Short qualification]
	When the stock size indicator is very high, e.g. $SSB > \text{possible reference points}$	✓	[Short qualification]
	If the state of the stock cannot be conceptualized in relation to any possible reference points, trends are shown by arrows only:		
	When the stock size indicator increases	↗	Increasing
	When the stock size indicator decreases	↘	Decreasing
	When the stock size indicator is stable	→	Stable

### Fisheries management strategy evaluations

Multiannual management plans and strategies have been agreed for a number of fish stocks or fisheries within the ICES area, and new plans are being proposed. Before using a plan/strategy as basis for the advice, ICES evaluates them relative to their compliance with a precautionary approach regarding risks to maintenance of reproductive capacity, and according to the likelihood that high yields will be produced in the long term. The evaluations also address issues raised by stakeholders and authorities that are contained in a specific management plan, such as stability of yield and risks under specific recruitment regimes.

ICES has adopted a precautionary criterion for long-lived stocks and a second, similar, criterion for short-lived stocks.

- **Long-lived stocks**

- a) The management plan/strategy is precautionary if, over the simulated period, the *maximum* probability that  $SSB$  is below  $B_{lim}$  is  $\leq 5\%$ , where the maximum (of the annual probabilities) is taken over all years in the plan/strategy (i.e. short and long term).

- **Short-lived stocks**

- a) If, under natural conditions of no fishing, the long-term annual probability of  $SSB$  being below  $B_{lim} \leq 5\%$ , then the same criteria as for long-lived stocks is used.
- b) If, under natural conditions of no fishing, the long-term annual probability of  $SSB$  being below  $B_{lim} > 5\%$ , then the management plan/strategy is precautionary if the maximum probability that  $SSB$  is below  $B_{lim}$  is  $\leq 5\%$  (after the fishery) in any year when a fishery takes place. In all other years the fishery should be closed.

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