1.2.1 General context of ICES advice

ICES advises competent authorities on marine policy and management issues related to the impacts of human activities on marine ecosystems and the sustainable use of living marine resources.

Impacts of human activities on marine ecosystems

Almost all ICES member countries have policies that address *the impacts of human activities on marine ecosystems*. These policies may explicitly be framed as an implementation of an ecosystem approach. An important example is the Marine Strategy Framework Directive (MSFD) of the European Union (EC, 2008), which is a comprehensive framework for achieving good environmental status (GES) for European marine ecosystems. The Directive calls for scientifically-based indicators and standards for eleven descriptors of GES such as Biodiversity, Non-indigenous Species, Commercially Exploited Fish and Shellfish Stocks, Foodwebs, and Sea-floor Integrity.

The Regional Seas conventions have a role ensuring the cohesion of assessments within their regions. Both OSPAR and HELCOM have established specific coordinating platforms for the regional implementation of the MSFD, striving for harmonized national marine strategies to achieve good environmental status and implementing their overall agreed commitment to an ecosystem approach. As regards HELCOM, the MSFD implementation runs in parallel to the implementation of the Baltic Sea Action Plan (BSAP).

The ICES scientific community and ICES advisory services have played a key role in providing scientific guidance to define GES indicators and standards. The process of developing these indicators and standards at the European level is ongoing and the process is now being continued by specification of GES at the regional and national levels, conducting initial assessments, and revising current monitoring activities.

Marine spatial planning is envisioned as a key mechanism in achieving GES. The idea is to integrate planning and management actions across human activities (e.g. fisheries, renewable and non-renewable energy development, mineral extraction, transportation, etc.) to take into account the cumulative impact of all of these activities on ecosystems. This will require more spatially resolved data on more types of activities, and a better understanding of how these activities impact ecosystems. It will also require integrated ecosystem monitoring systems. The MSFD is an important challenge for the scientific community, and ICES welcomes the MSFD as an opportunity to apply an ecosystem approach.

Management of the exploitation of living marine resources

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 and 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 (EC, 2002)
- Communication from the European Commission on Implementing Sustainability in EU Fisheries through Maximum Sustainable Yield (EC, 2006)
- The Marine Strategy Framework Directive (EC, 2008)
- Norwegian Marine Resources Act (Lovdata, 2008 (Lov om forvaltning av viltlevande marine ressursar)),
- Russian Federal Law on Fisheries and conservation of biological resources in the waters. N 166-P3 20/12/2004 (Anon., 2004)

- Icelandic Fisheries Management Act (No. 38, 15 May 1990) (Anon., 1990)
- Faroe Islands Fisheries Management Act (Løgtingslóg nr. 28 um vinnuligan fiskiskap frá 10. mars 1994) (Anon., 1994)

An ecosystem approach to marine environmental policy, a precautionary approach and an MSY approach regarding living marine resources are prominent themes of the agreements and policies that set the context for ICES advice. A compilation of acronyms and terminology used in the ICES advice is available at http://www.ices.dk/advice/icesadvice.asp as acronyms_and_terminology.pdf.

1.2.1.1 An ecosystem approach to management of the marine environment

An ecosystem approach is intended to contribute to sustainable development. Sustainable development is defined in the Brundtland Report (WCED, 1987) as development that

> "meets the needs of the present without compromising the ability of future generations to meet their own needs."

An ecosystem approach has been defined in various ways but mainly emphasizes a management regime that maintains the health of the ecosystem alongside appropriate human uses of the environment, for the benefit of current and future generations. For example, the 1992 UN Convention on Biological Diversity (UN, 1992b) defines an ecosystem approach as

> "ecosystem and natural habitats management" to "meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned."

The Reykjavik Declaration (FAO, 2001) forms the basis for using an ecosystem approach in the management of the marine environment:

> "… in an effort to reinforce responsible and sustainable fisheries in the marine ecosystem, we will individually and collectively work on incorporating ecosystem considerations into that management to that aim."

The World Summit on Sustainable Development (UN, 2002) indicated that States should:

> "(30.d) Encourage the application by 2010 of the ecosystem approach, noting the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem[1] and decision V/6 of the Conference of Parties to the Convention on Biological Diversity".

An ecosystem approach is expected to contribute to achieving long-term sustainability for the use of marine resources, including the fisheries sector. An ecosystem approach serves multiple objectives, involves strong stakeholder participation, and focuses on human behaviour as the central management dimension.

1.2.1.2 A precautionary approach in fisheries management

A precautionary approach (PA) is described in the UN Fish Stocks Agreement (UN, 1995) as follows:

> "States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures."

Annex 2 of the UNFSA contains guidelines for applying a precautionary approach within an MSY framework. To quote:

> "The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target."

[1] "While it is necessary to take immediate action to address particularly urgent problems on the basis of the precautionary approach, it is important to advance the scientific basis for incorporating ecosystem considerations, building on existing and future available scientific knowledge." Source: Reykjavik Declaration, appendix I, pg. 107 (FAO, 2001).

In addition, the guidelines indicate:

- Precautionary reference points should be used to guide management;
- Target reference points are intended to achieve management objectives;
- Precautionary reference points should take account of reproductive capacity, the resilience of each stock, and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty;
- Management strategies shall seek to maintain stocks at, or restore stocks to, levels consistent with previously agreed precautionary reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures which can be implemented when precautionary reference points are approached;
- Fishery management strategies shall (a) ensure that the risk of exceeding limit reference points is very low, (b) initiate actions to facilitate stock recovery for stocks below precautionary reference points, and (c) ensure that target reference points are not exceeded on average; and
- When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set.

Although some aspects of the guidelines are not entirely clear or consistent (e.g. the relationship between precautionary and limit reference points is unclear; the fishing mortality rate to achieve MSY is referenced as both a target reference point and a limit reference point), it is most useful to recognize that MSY and a precautionary approach are complementary, and this is the spirit in which ICES applies these concepts.

Populations need to be maintained within safe biological limits according to a precautionary approach to make MSY possible. However, within safe biological limits, an MSY approach is necessary to achieve MSY. Lack of scientific information should not be an excuse for postponing management to maintain populations within safe biological limits and/or to delay implementing a strategy to attain MSY. In a sense, a precautionary approach is a risk-averse concept intended to avoid unproductive situations while an MSY approach is intended to make the best use of the ecosystem productivity. A precautionary approach (PA) is a necessary, but not a sufficient condition for MSY. The ICES precautionary approach (including the methods for estimating PA reference points) is described in more detail in the introduction of previous volumes of ICES advice (e.g. ICES, 2009b).

1.2.1.3 The maximum sustainable yield concept

Maximum sustainable yield has been a widely accepted objective for fisheries management for many decades. The United Nations Convention on the Law of the Sea (UN, 1982) notes

> "…State(s) must set an allowable catch, based on scientific information, which is designed to maintain or restore species to levels supporting a maximum sustainable yield (MSY)."

This policy was reaffirmed by WSSD (UN, 2002) which called on States to

> "Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015".

Maximum sustainable yield is a broad conceptual objective aimed at achieving the highest possible yield over the long term (an infinitely long period of time). It is non-specific with respect to: (a) the biological unit to which it is applied; (b) the models used to provide scientific advice; and (c) the management methods used to achieve MSY. The MSY concept can be applied to an entire ecosystem, an entire fish community, or a single fish stock. The choice of the biological unit to which the MSY concept is applied influences both the sustainable yield that can be achieved and the associated management options. For reasons discussed later, implementation of the MSY concept by ICES will first be applied to individual fish stocks, but it is considered that even on a single-stock basis an MSY can only be reached in a healthy environment.

In practice, MSY depends on:

- The production of the unit, which describes the relation between productivity and the size of the unit (e.g., population biomass), which in turn depends on the growth rates, natural mortality rates, and reproductive rates of the members of the production unit;
- Interactions of members within the production unit and interactions with other production units (intra- and inter-specific interactions);
- Environmental conditions (e.g., climate, environmental quality), which affect production, and intra- and inter-specific interactions; and

- Fishing practices and fishery selectivity that determine the size and age composition of the catch (both the landings and the discards).

The models (mathematical and conceptual) used to estimate MSY and associated parameters typically assume that all of the factors not explicitly included in the models remain constant. Thus, MSY estimates are generally conditional on current conditions and assumptions. This assumption is reasonable as long as the analysis does not attempt to project changes which are very different from the prevailing conditions or from conditions which have been observed historically. Marine ecosystems are, however, dynamic and fish stocks will not only change in response to the fisheries directly targeting them but also to changes in fishing patterns and fishing pressures on their prey or their predators. This has implications for the further development of the MSY approach as discussed in the context of incorporation of ecosystem considerations in ICES advice below (Section 1.2.2.5).

1.2.2 ICES approach to fisheries advice: Maximum sustainable yield within a precautionary approach

The ICES approach to fisheries advice integrates a precautionary approach, maximum sustainable yield, and an ecosystem approach into one advisory framework. The aim is, in accordance with the aggregate of international guidelines, to inform policies for high long-term yields while maintaining productive fish stocks within healthy marine ecosystems.

ICES provides fisheries advice that is consistent with the broad international policy norms of the precautionary approach, MSY, and an ecosystem approach while also responding to the specific needs of the management bodies requesting advice. A precautionary approach has been recognised as an important basis for fisheries management in all the jurisdictions advised by ICES. ICES notes that the fisheries for which it provides advice have generally not been managed with MSY as an objective. The current European Commission policy (EC, 2006) does not call for EC fisheries to be managed according to MSY until 2015. Therefore, the nature of ICES fisheries advice is evolving. The evolution includes options for a transition process to attain full implementation of an MSY approach by 2015. Ecosystem limitations on fisheries have typically not yet been identified in management policies in the ICES area. However, as the EU MSFD is implemented, such limits will be recognized to achieve environmental objectives, especially regarding biodiversity, sea floor integrity, and foodwebs. Therefore, harvests may be further limited in consideration of potential fishery impacts on marine ecosystems beyond the impact on target fish stocks, such as on biodiversity, sea floor integrity, and foodwebs.

One can consider a precautionary approach, maximum sustainable yield, and an ecosystem approach as nested boundaries to harvesting living marine resources, where the outer boundary is defined by a precautionary approach to maintain fish stock productivity (Figure 1.2.1). Not all fishing strategies within such precautionary limits will lead to large long-term yields and considerations of wider ecosystem impacts may further limit options. A precautionary approach, maximum sustainable yield, and an ecosystem approach are therefore not seen as alternative strategies, but as an integrated framework of nested boundaries to harvesting living marine resources:

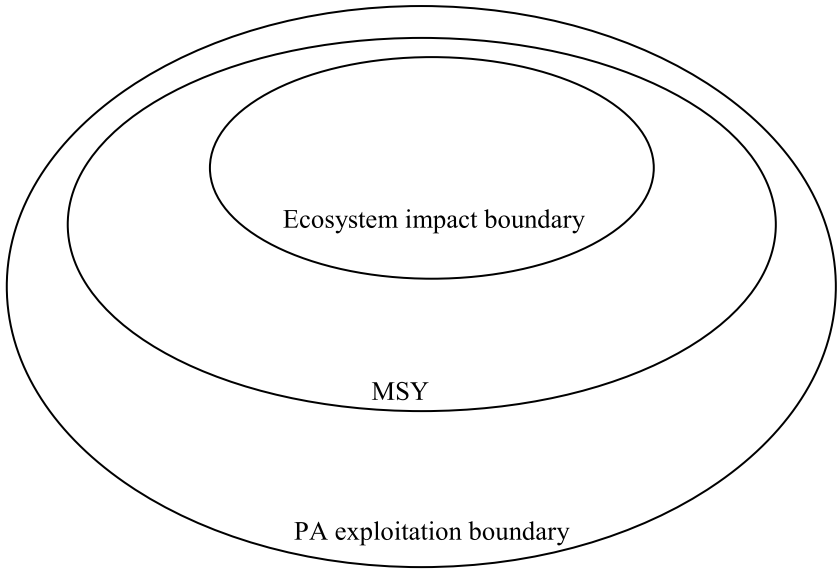

Figure 1.2.1 Limits to the exploitation of living marine resources that arise from a precautionary approach regarding single-stock exploitation, an MSY approach, and an ecosystem approach as an integrated framework of nested boundaries.

This nested approach is implemented on the basis of some concepts regarding the dynamics of fish populations and a framework of reference points:

ICES is typically requested to provide catch advice on a stock-by-stock basis, as fisheries on most of the stocks for which ICES provides advice are managed using stock-specific total allowable catches (TACs). In many cases, other fishery management measures are used as well, such as technical regulations (e.g. closed areas, mesh sizes, and days-at-sea limitations). Thus, the ICES framework for fisheries advice needs to be applicable to individual stocks. This does not obviate the need to modify stock-specific advice to take account of technical interactions (e.g. bycatch in mixed-species fisheries) or of biological interactions (e.g. predator–prey relationship), but the starting point for ICES fisheries advice is the individual fish stock.

Fisheries affect fish stocks through the fishing mortality rate (F) applied to these stocks. Production of a fish stock is the sum of the population weight (biomass) augmented by recruitment and growth minus the loss from natural mortality. Production can be highly variable but, on average, it is related to stock size (often expressed as spawning-stock biomass or SSB), which in turn depends on F. That is, for each F, there is a long-term average production and an average stock size. The relationship between F, production, and stock size is called the production function. Surplus production is the catch that can be harvested without changing the stock size. The peak of the production function is MSY, and the fishing mortality generating this peak is F_{MSY}. Figure 1.2.2 gives a hypothetical production function versus F and Figure 1.2.3 shows surplus production versus spawning-stock biomass.

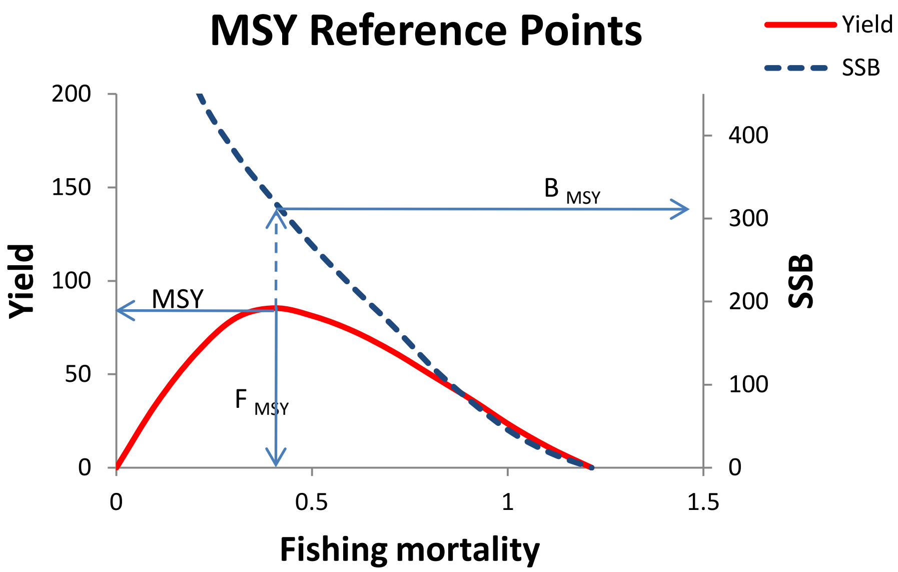

Figure 1.2.2 Example of a yield (production) versus fishing mortality (F) for a hypothetical fishery. SSB: spawning-stock biomass.

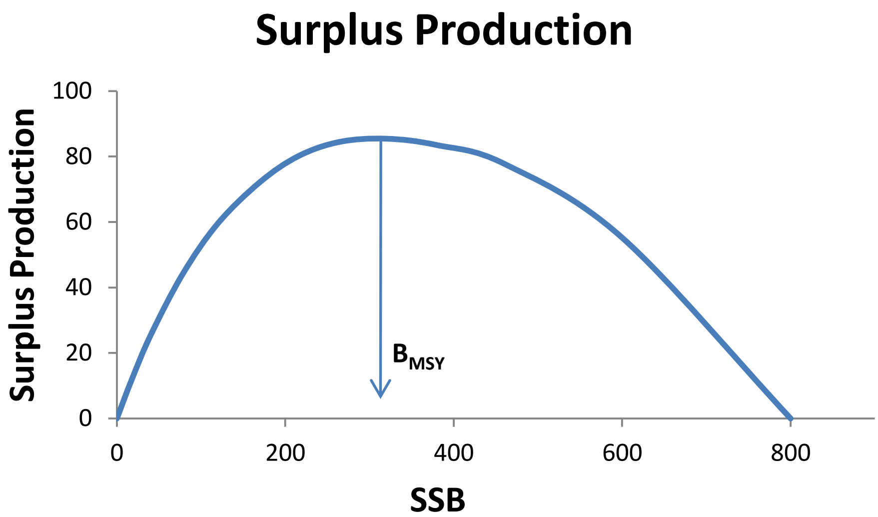

Figure 1.2.3 Example of surplus production versus spawning-stock biomass (SSB) for a hypothetical stock. The theory is that harvesting around 80 units when the stock is at B_{MSY} would leave the SSB unchanged. On a stock at the carrying capacity (800 units of SSB) there is no surplus production. If a fishery begins on a stock at carrying capacity (i.e. the virgin state), the SSB is reduced and surplus production is generated.

Fishing mortality is the only variable in the production function that can be directly controlled by fisheries management. Fisheries management cannot control SSB, it can only influence it through F. SSB is also subject to natural variability that on a year-to-year basis can overwhelm the influence of F. MSY is a long-term average, and the maximum constant yield that can be taken sustainably is lower than MSY.[2]

Due to the natural variability in SSB, beyond the influence of F, there may be situations where the spawning stock is so low that a significant risk exists that reproduction is 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 may be reduced recruitment. A precautionary safety margin incorporating the uncertainty in actual stock estimates leads to a precautionary reference point B_{pa}, which is a biomass designed to avoid reaching B_{lim}. Therefore, when SSB is above B_{pa} the probability of impaired recruitment

[2] There are technical reasons that the maximum long-term average yield or MSY is greater than the maximum constant yield. See Beddington and May (1977) and Sissenwine (1978) for the implications for fisheries management.

is expected to be low. For short-lived species, a precautionary approach implies that a minimum stock size, $B_{escapement}$, should remain in the sea after fishing (Figure 1.2.4).

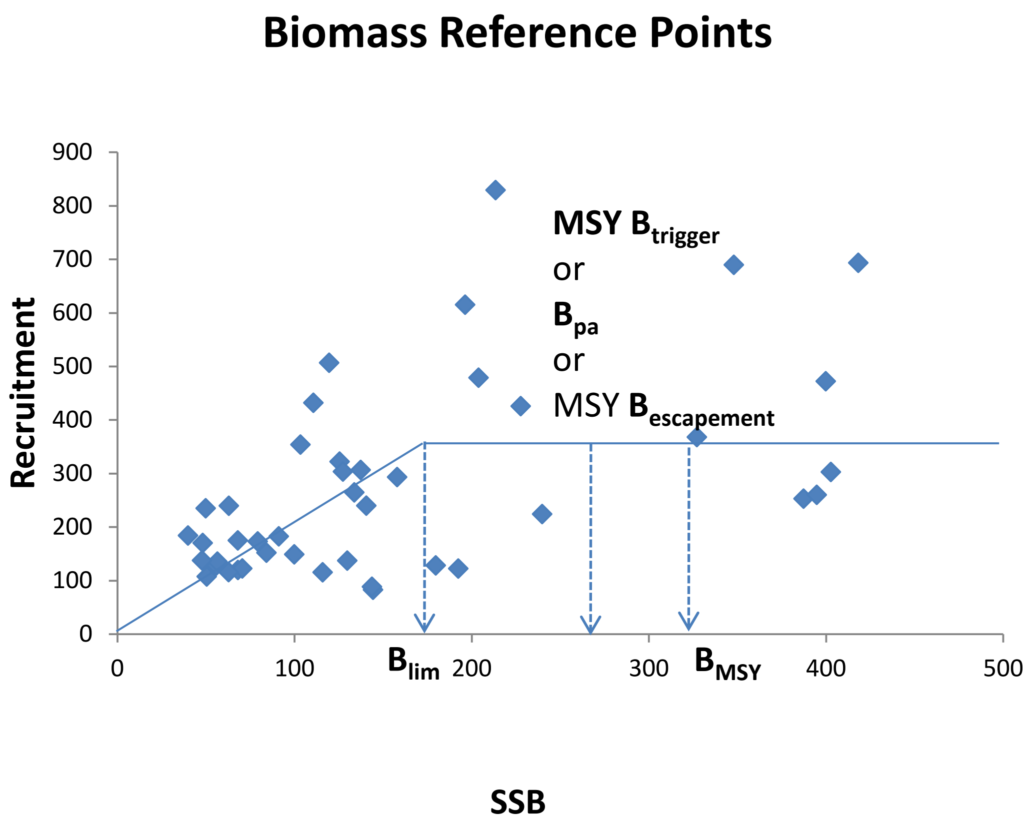

Figure 1.2.4 Illustration of biomass-based biological reference points. B_{lim} and B_{pa} are precautionary reference points related to the risk of impaired reproductive capacity, while MSY $B_{escapement}$ is used in the advice framework for short-lived species. MSY $B_{trigger}$ is the parameter in the ICES MSY framework which triggers advice on a reduced fishing mortality relative to F_{MSY}. B_{MSY} is the average biomass expected if the stock is exploited at F_{MSY}.

The ICES framework for fisheries management recognizes that the characteristics of fish stocks are different, and the information available on individual stocks also varies.

The ICES framework uses both fishing mortality rates and biomass reference points. In general, F_{MSY} should be lower than F_{pa}, (a precautionary buffer to avoid that *true* fishing mortality is at rates associated with severely reduced productivity when the *perceived* fishing mortality is at F_{pa}) and MSY $B_{trigger}$ should be equal to or higher than B_{pa}. This is appropriate since a precautionary approach is a necessary, but not sufficient, condition for MSY.

There are three main categories of stocks, and application of the ICES framework to each of these categories is discussed below.

1.2.2.1 Long-lived stocks with population size estimates

For stocks with a population size estimate, ICES can calculate the catch that will achieve a desired fishing mortality rate. For most stocks with population size estimates, ICES can also forecast future stock size as a function of catch (i.e. for a range of catch options). In stocks naturally having many age groups, future stock size is not overly dependent on recruitment because many older animals exist in the population (unless the stock age composition has been truncated by overfishing). When population projections are too dependent on recruitment, projections are less reliable because recruitment can be variable and difficult to predict.

For long-lived stocks with population size estimates, ICES bases its approach on attaining a fishing mortality rate at, or below, F_{MSY}.

Annex 2 of the UN Fish Stocks Agreement (UNFSA; UN, 1995) states that "The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold." The World Summit for Sustainable Development (WSSD, Johannesburg; UN, 2002) states that "To achieve sustainable fisheries, the following actions are required at all levels: (a) Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015." The first statement refers to F_{MSY} as an upper limit to fishing mortality. From a starting point of excessive exploitation (until recently this was the case for many stocks in the ICES area), the latter statement can be considered as an intermediate step towards fulfilling the UNFSA requirements as it establishes an intermediate target for fishing mortality at F_{MSY}, so that stocks are restored by 2015. Competent authorities advised by ICES have based their implementation on the WSSD and the interpretation that fishing mortality should be reduced to F_{MSY} by 2015 where possible (e.g. EC, 2006). The ICES MSY framework is thus based on this approach.

In this approach, both fishing mortality and biomass reference points are used; these reference points are F_{MSY} and MSY $B_{trigger}$. The approach does not currently use a B_{MSY} estimate. B_{MSY} is a notional value around which stock size fluctuates when $F = F_{MSY}$. Recent 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). B_{MSY} strongly depends on the interactions between the fish stock and the environment it lives in, including biological interactions between different species.

MSY $B_{trigger}$ is considered the lower bound of fluctuation around B_{MSY}. It is a biomass reference point that triggers a cautious response. The cautious response is to reduce fishing mortality to allow a stock to rebuild and fluctuate around a notional value of B_{MSY} (even though the notional value is not specified in the framework). The concept of MSY $B_{trigger}$ evolves from the PA reference point B_{pa} that ICES has used as a basis for fisheries advice since the late 1990s (see Figure 1.2.4). The evolution in the determination of MSY $B_{trigger}$ requires contemporary data with fishing at F_{MSY} to identify the normal range of fluctuations in biomass when stocks are fished at this fishing mortality rate.

The ICES approach as specified in the ICES harvest control rule (HCR) is illustrated in Figure 1.2.5.

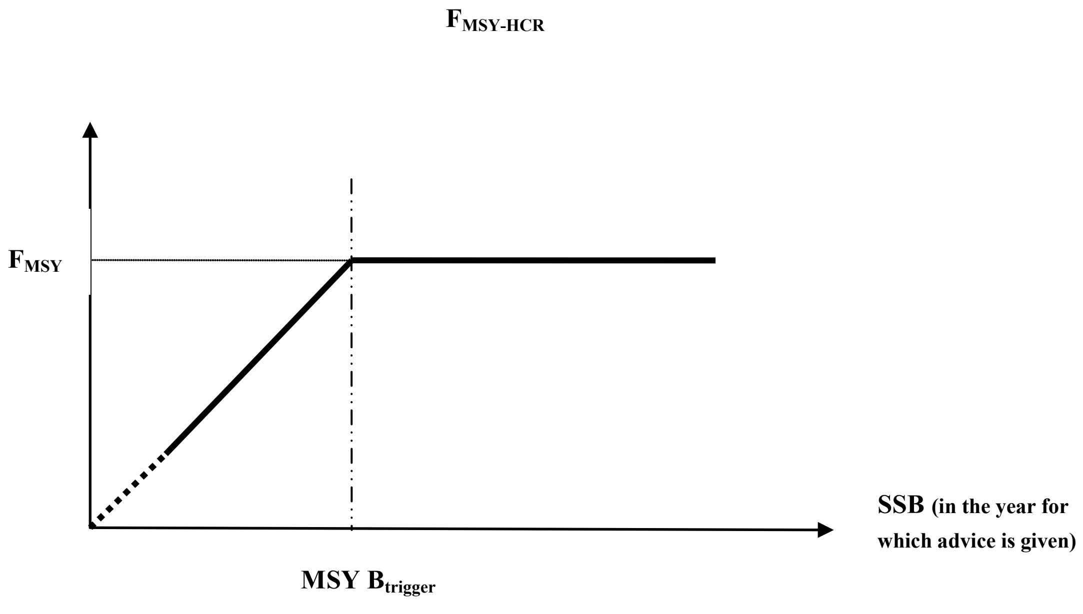

Figure 1.2.5 Approach shown in the ICES harvest control rule. Vertical axis is fishing mortality (F). Horizontal axis is spawning-stock biomass (SSB).

Conceptually, SSB in the HCR is the estimated SSB at the beginning (or at spawning time) of the year to which the advice applies (advice year). For example, for an assessment performed in 2012 using data through 2011, the reference SSB will be the projected SSB at the beginning of 2013. $F_{MSY\text{-}HCR}$ is the fishing mortality rate used to calculate a catch option for the advice year. However, it may not be possible to project SSB to the beginning of the advice year, or the projections themselves may introduce so much additional uncertainty that it would be better to use a current SSB estimate. In such cases, the SSB used in the HCR will be the most recent reliable estimate.

Since MSY $B_{trigger}$ is intended to safeguard against an undesirable or unexpected low SSB when fishing at F_{MSY}, the trigger reference point should be based on the natural variation in SSB (including the assessment uncertainty) once F_{MSY} has been reached. Ideally, F_{MSY} should take account of recruitment, growth, and natural mortality under current or recent ecosystem conditions, and be derived through stochastic simulations of target F in the context of a harvest control rule. However, recruitment functions are typically very noisy and poorly defined. It is therefore common to use proxies for F_{MSY}, such as F_{max}, $F_{0.1}$, M, and $F_{20\text{-}40\%SPR}$[3] (Figure 1.2.6). Thus F_{MSY} is used as a generic term for a robust estimate of a fishing mortality rate associated with high long-term yield.

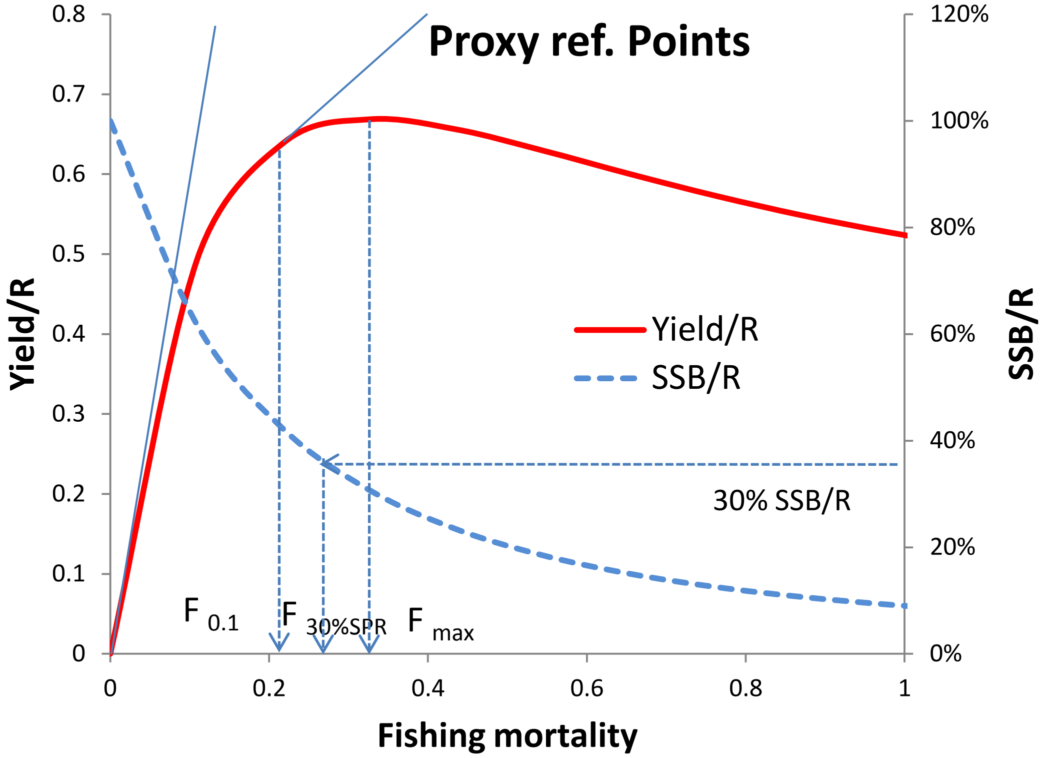

Figure 1.2.6 Illustrations of various proxies for F_{MSY}. For SSB/R 100% is at F = 0. Other numerical values are illustrative only and will vary from stock to stock.

As an initial option, MSY $B_{trigger}$ is set at B_{pa} when this reference point is available, unless there is a sound basis for using a different value. In the future when there are sufficient observations of SSB fluctuations associated with fishing around F_{MSY}, the MSY $B_{trigger}$ should be re-estimated to correspond to the lower bound of the range of stock sizes associated with MSY. In general, it is anticipated that re-estimated values will be higher than B_{pa}.

The ICES harvest control rule (Figure 1.2.5) is designed to promote recovery of the stock to the normal range of stock sizes associated with MSY when the stock is below this range (i.e. when it is below the MSY $B_{trigger}$). For most fisheries, recovery should theoretically occur at a fishing mortality of F_{MSY}[4]. The likelihood and speed of recovery is increased by reducing F whenever the stock is below the stock size range associated with fishing at F_{MSY}. However, at very low stock sizes, the normal tendency for stock recovery at F less than or equal to F_{MSY} may not hold. In these

[3] $F_{30\text{-}40\%SPR}$ are fishing mortalities that reduce the life time reproductive output of a year class to 30–40% of the reproductive output without fishing.

[4] The theory is that fish populations compensate for fishing by increasing their production per unit stock size as stock size decreases. This type of response is known as compensatory. Production functions typically exhibit compensation. However, it is possible that at low stock sizes, production per unit stock size decreases as stock size decreases. This type of response is known as depensatory. It is difficult to observe (in part because there are few observations of stocks at very low stock sizes), but there are mechanisms that potentially result in depensation. Depensation has the potential to lead to extinction of a population.

cases, the fishing mortality rate derived from the HCR is likely to be so low that fishing may cease anyway. Nevertheless, when the stock size is so low that recruitment failure is a concern (e.g. at or below B_{lim} as estimated for a precautionary approach), additional conservation measures may be recommended to prevent a further decline. The special consideration given at low stock sizes is depicted by a broken line in Figure 1.2.5.

Competent authorities receiving ICES advice have adopted several management plans in the spirit of the harvest control rule described above. When these plans are considered consistent with a precautionary approach and if no competent authority with a legitimate interest rejects a plan as the basis for the advice, the advice on the first page of the ICES advisory document will be based on the management plan. Other options will be included in the body of the advisory report.

The transition to advice based on reaching F_{MSY} in 2015

Based on policy documents of management authorities and discussions with managers, there is general agreement that fisheries on the stocks for which ICES is requested to provide advice should be managed according to an MSY approach by 2015, but the transition should be gradual. Significant progress has been made in recent years developing and implementing precautionary management plans. These plans should not be jeopardized until they can be revised to be consistent with an MSY approach (as well as being precautionary). Over the next few years, ICES will advise on options that take account of this evolving situation.

Although the World Summit on Sustainable Development (UN, 2002) called for stocks to be restored to levels that can produce MSY by 2015 where possible (which requires that overfishing relative to MSY be ended well in advance of 2015, but for many stocks it is already too late), this is not the policy of the European Commission (see EC, 2006). The EC and other management bodies that request advice from ICES have indicated they favour a gradual transition to implementing an MSY approach.

Direct application of the ICES MSY framework

In 2010 ICES introduced an MSY framework for fisheries advice. ICES provides a catch option by direct application of the ICES HCR. During the transition period (for advice in 2011–2015) where F is above F_{MSY} and/or current biomass is below MSY $B_{trigger}$, ICES applies a stepwise transition to reach F_{MSY} by 2015. The transition is in equal steps beginning with the year in which the transition was initiated.

Transition scheme

If an estimate or a proxy of F_{MSY} was available, the transition began in 2011 and F is reduced in five equal steps. Consequently, the catch option for 2013 will be:

$$F_{MSY\text{-}HCR\text{-}transition}(2013) = \text{Min}\{0.4 \bullet F(2010) + 0.6 \bullet F_{MSY\text{-}HCR}(2013); F_{pa}\}$$

whereas for the following years:

$$F_{MSY\text{-}HCR\text{-}transition}(2014) = \text{Min}\{0.2 \bullet F(2010) + 0.8 \bullet F_{MSY\text{-}HCR}(2014); F_{pa}\}$$
$$F_{MSY\text{-}HCR\text{-}transition}(2015) = \text{Min}\{0.0 \bullet F(2010) + 1.0 \bullet F_{MSY\text{-}HCR}(2015); F_{pa}\}$$

where F (2010) is the current year estimate of the fishing mortality in 2010 and $F_{MSY\text{-}HCR}$ (2013) is according to the ICES HCR in Figure 1.2.5, being equal to F_{MSY} if SSB in 2013 is at or above MSY $B_{trigger}$ and reduced linearly if SSB is below. The $F_{MSY\text{-}HCR\text{-}transition}$ values are capped at F_{pa} to maintain consistency with a precautionary approach. The plan for transition to MSY recognizes that managers want a gradual transition, although they have not formally agreed to such a plan.

However, there may be situations where a gradual transition is not appropriate because stock size is low (e.g. below B_{lim}) and the outlook is for a further decline (e.g. as a result of low recruitment) unless fishing mortality is reduced more rapidly. In such cases, ICES may advise on a more rapid transition or application of $F_{MSY\text{-}HCR}$ as soon as possible.

1.2.2.2 Short-lived stocks with population size estimates

The future size of a short-lived fish stock is very sensitive to recruitment because there are only a few age groups in the natural population. Incoming recruitment is often the main component of the fishable stock. In addition, care must be given to ensure a sufficient spawning-stock size as the future of the stock is highly dependent on annual recruitment. For short-lived species, estimates or predictions of incoming recruitment are typically imprecise, as are the accompanying catch forecasts.

For most short-lived stocks, the ICES MSY framework is aimed at achieving a target escapement (MSY $B_{escapement}$, the amount of biomass left to spawn, see Figure 1.2.4), which is robust against low SSB and recruitment failure if recruitment is uncertain. The catch corresponds to the stock biomass in excess of the target escapement. No catch should be allowed unless this escapement can be achieved.

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 obtained just prior to the fishery (or during the fishing year) have been analyzed. Therefore, an adaptive framework may be applied as follows:

1. Set a preliminary TAC that ensures a high likelihood of the target escapement being achieved or exceeded. This preliminary TAC is likely to be considerably below the final TAC (step 3).
2. Assess the stock just before or during the fishing year, typically based on a survey or an experimental fishery.
3. Adjust the TAC based on the assessment in step 2, ensuring that escapement is at, or above, the target.

The MSY $B_{escapement}$ should be set so there is a low risk of future recruitment being impaired, similar to the basis for estimating B_{pa} in a precautionary approach. For short-lived species, where most of the annual surplus production is from recruitment (not growth), MSY $B_{trigger}$ and B_{pa} might be expected to be similar. Therefore B_{pa} is a reasonable initial estimate of MSY $B_{escapement}$.

1.2.2.3 Stocks without population size estimates – the data-limited stocks

Of the more than 200 stocks for which ICES provides advice, ICES (2012a) determined that 122 do not have population estimates from which catch options can be derived using the existing MSY framework. These cases have been labelled as "data-limited". Up to and including 2011, ICES provided qualitative advice regarding the future exploitation of such stocks for which there is either limited knowledge about their biology or lack of data about their exploitation. Advice recipients have, however, expressed a strong interest in ICES developing quantitative advice based on the information available. In 2012, ICES has therefore developed a framework for quantitative advice regarding such stocks. This framework will, as other advice approaches, be refined in the future.

The principles underlying this framework is that the available information should be used, that the advice to the extent possible should be based on the same principles as applied for stocks with analytical assessments and catch forecasts, and that 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 the stock status is poorly known. The margin of risk tolerance is a management prerogative, but in the absence of any proposal by managers ICES has applied values which are given below.

Unlike the classic fishery management problem of estimating maximum sustainable yield (MSY), data-limited fishery analysis must often be content simply to estimate a yield that is likely to be sustainable.

The ICES approach to data-limited fishery analysis calls for a determination of the status of exploitation relative to F_{MSY} (overfishing or no overfishing) and consideration of the stock trend. In cases where data allow an assessment of current exploitation (e.g. trends-based assessment, catch curve analysis), proxies for F_{MSY} based on, for example, yield-per-recruit (YPR) analysis such as F_{max}, $F_{0.1}$, M, and $F_{20\text{-}40\%SPR}$, can be used to give advice in relation to sustainable exploitation. Recent understanding of life-history relationships have demonstrated that the required parameters for a YPR analysis can be calculated on the basis of very limited life-history information on a case-by-case stock basis (ICES, 2012b).

Such information is not available for stocks where only landings are available or for stocks caught in minor amounts as bycatch. In such cases the history of landings is the only reference and quantitative advice on that basis then needs to be applied on a precautionary basis.

The majority of the data-limited stocks have more information available than merely either catch or landings. The starting point for this analysis is therefore a categorization of the stocks according to the data and analyses that are available. The categorization of stocks is intended to reflect the decreasing availability of data, and thus the conclusions on the fishing pressure and state of the stock are likely to be less certain as one goes down the categories.

ICES has used the following categorizations:

Category 1 – data-rich stocks (quantitative assessments)
These are the stocks that are not considered data-limited and this category includes stocks with full analytical assessments and forecasts as well as stocks with quantitative assessments based on production models.

Category 2 – stocks with analytical assessments and forecasts that are only treated qualitatively
This category includes stocks with quantitative assessments and forecasts which for a variety of reasons are merely indicative of trends in fishing mortality, recruitment, and biomass.

Category 3 – stocks for which survey-based assessments indicate trends
This category includes stocks for which survey indices (or other indicators of stock size such as reliable fishery-dependant indices; e.g. lpue, cpue, and mean length in the catch) are available that provide reliable indications of trends in stock metrics such as mortality, recruitment, and biomass.

Category 4 – stocks for which reliable catch data are available
This category includes stocks for which a time-series of catch can be used to approximate MSY.

Category 5 – data-poor stocks
This category includes stocks for which only landings data are available.

Category 6 – negligible landings stocks and stocks caught in minor amounts as bycatch
This category includes stocks where landings are negligible in comparison to discards. It also includes stocks that are part of stock complexes and are primarily caught as bycatch species in other targeted fisheries. The development of indicators may be most appropriate for such stocks.

As a consequence, a precautionary approach implies that exploitation rates advised for stocks below the data rich stocks (Category 1) will be more conservative than F_{MSY}.

For each of these categories, methods have been employed to provide quantitative advice. These methods are generally based on approaches published in the scientific literature and most of the specific, quantitative forecast methods which have been applied have also been subjecedt to formal testing in simulations. The methods and the associated simulations are presented in ICES (2012b). ICES recognizes that there are alternative approaches to many of the methods proposed and it has in some cases been possible for the experts involved to provide methods which are more adequate for a specific stock while maintaining the same principle of precaution as the general framework.

The framework for data-limited stocks includes the following considerations regarding uncertainty and precaution to be applied in sequence:

- As the methodologies used to estimate stock status, trends, and forecasts, due to the limited data available, are expected to be more susceptible to noise than methods used to produce forecasts for data-rich stocks, a change limit of ±20% has been applied in the advice. This change limit is relative to the reference on which it is based and may be, e.g. recent average catches or a projection of a trend.
- A principle of an increasing precautionary margin with decreasing knowledge about the stock status has been applied:
    - The reference points for exploitation used have, when proxies could be identified, been selected on the lower margins of F_{MSY} – either at the lower range of an interval, as $F_{0.1}$ or similar.
    - A precautionary margin of −20% has been applied for those cases when the stock status relative to candidate reference points for stock size or exploitation is unknown. Exceptions to this rule have been made in cases where expert judgement determines that the stock is not reproductively impaired, and where there is evidence that the stock size is increasing or that exploitation has reduced significantly – for instance, on basis of survey indices or a reduction in fishing effort in the main fishery if the stock is taken as a bycatch species.

This approach is intended to move in the direction of sustainable exploitation, having due regard for the species' biological characteristics and uncertainty in the information. This implies that advice is applicable to a time-frame which is compatible with a measurable response in the metrics used as the basis for the advice; i.e. in the simplest case, and where the least information is available, this would imply a multi-annual constant catch advice. Where least information is available, including cases where the 20% precautionary margin has been applied, ICES therefore considers that the advice is not expected to be changed for a fixed and determined period such as, for example, three years, unless important new knowledge emerges regarding a stock which may justify a revision of the advice.

1.2.2.4 Ecosystem considerations in fisheries advice

The move toward an ecosystem approach to management (UN, 1992b, 2002; FAO, 1995) implies that human activities should be managed such that the overall health of the marine ecosystem is not placed at risk. This means that fisheries management must consider not only the direct effects on fishery targets, but also the impacts on biodiversity, marine ecosystem structure, functioning, and marine habitats. The advice must also be based on the best available knowledge about the interactions between the fish populations and their environment, be it other fish populations, other organisms, or the physico-chemical environment.

A first step is to incorporate knowledge about the interactions between the various fish populations, for which advice is given. Two types of interactions should be considered in fisheries management, as described below.

One type of interactions (referred to as “technical interactions”) results from the non-selective nature of many fishing operations. That is, the fishery captures a mixture of species and it is not entirely possible to control which species and how much of each is caught. For a mixed-species fishery, it may not be possible to achieve the single-stock MSYs (translated into TACs) of all the stocks simultaneously. Either the TACs 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 TACs for other stocks from being exceeded. ICES has developed a mixed-species fisheries model (ICES, 2009a, 2010). The full value of this model (and future models of this type) will be realized with input from managers and stakeholders on trade-offs between species in the catch.

Estimates of MSY reference points depend on the size and age selectivity of the fishery. In many cases, both a higher yield and a larger stock size can be obtained by changing fishing practices (e.g. mesh size) to achieve more favourable size and age selectivity. However, changing fishing practices to favour one species may put other species at a disadvantage in a mixed-species fishery. In the future, mixed-species fisheries advice should consider trade-offs between species in terms of changes in fishing practices that influence selectivity.

In 2012, ICES provides catch options that incorporate technical interactions regarding demersal fisheries in the North Sea. The options are given as scenarios and not as the basis for the advice as single-stock management plans are currently in force, and mixed-fisheries advice would require an agreed policy for mixed-fisheries management by the relevant authorities.

Another type of interactions results from ’biological interactions‘. Some fish eat other fish, in which means growth for the predator and mortality for the prey. Fish populations also compete for food or habitat. Such interactions mean that as populations of one species increase by higher numbers and increased growth, populations of other species are likely to decrease because their mortality increases due to predation. It also means that as a population of fish increases one cannot expect that growth and mortality for that species remains constant as there will be increasing competition for food and habitat within that population. This is what is referred to in ecology as ‘density-dependence’ and the reason that it is not realistic to make simple projections of the growth of biomasses from low population sizes as the fishing pressure is reduced, for instance towards F_{MSY}. This is also the basic reason for ICES to refrain from defining rebuilding targets based on a B_{MSY} concept and the reason B_{MSY} is not a part of the ICES approach to MSY.

The implication is that all of the expected increases in stock size based on applying an MSY approach on an individual stock basis are unlikely to occur simultaneously. Some stocks will increase substantially, but biological interactions may prevent other stocks from increasing as much as anticipated, and there may even be stocks that decrease in abundance as they are predated on by larger predator populations or are exposed to increased competition for food or habitat.

ICES has for a number of years incorporated such multispecies considerations in the single-species framework by applying natural mortality or growth rates that are derived from models of species interactions using size, age, and stomach data. In 2012 dynamic natural mortality rates, reflecting the past history of predator populations, were used for the first time in the North Sea herring assessment and thus formed the basis for advice.

This is a first step toward incorporating species interactions in fish stock assessments and advice and helps in making short-term predictions, where the surrounding ecosystem can be considered constant relative to the stock in question, more accurate. The utility of this approach is, however, very limited when it comes to medium-term forecasts or the exploration of reference points in an ecosystem context because the populations of all the various fish species are expected to change with changing fishing regimes and the interactions can therefore not be considered to be constant.

This means that a full-fledged MSY approach cannot be implemented on a stock-by-stock basis. Basic MSY reference points such as F_{MSY}, B_{MSY}, and MSY $B_{trigger}$ are conditional on a variable surrounding ecosystem and the other predator or prey fish populations living in it because growth and natural mortality, both of which are influenced by other fish populations, are determinants of these reference points.

This means that the references to MSY reference points in UNFSA (UN, 1995) and other international agreements ultimately must be interpreted as features of the fish community or even the ecosystem rather than as constant parameters of a fish stock.

Although biological interactions thus are important in terms of the response of stocks to a change in fishing pressure within a MSY approach, there are relatively few situations where the response of a multispecies community of fish to changes in fishing mortality can be reliably predicted. In cases where such predictions are possible, multispecies fishing mortality strategies can be developed to achieve MSY on a multispecies basis, and to evaluate trade-offs between species based on preferences from managers and stakeholders. In situations where predictive models accounting for biological interactions are not reliable, it will be necessary to adopt a stock-by-stock MSY approach based on the observed response of these stocks once they have been fished at F_{MSY}.

In 2012 ICES provides considerations on options to incorporate biological interactions between herring, sprat, and cod in the Baltic in advice and fisheries management. The options are not presented as the basis for the advice as there are single-stock management plans in force, and multispecies fisheries advice would require an agreed policy for relevant authorities to consider biological interactions in fisheries management.

Achieving single- or multi-species MSY is not necessarily sufficient to assure all aspects of a healthy ecosystem and may need to be supplemented with measures to mitigate undesirable impacts on ecosystems. This need for supplementary measures is also considered in ICES advice. Reducing fishing mortality or changing selectivity should also reduce: (a) bycatch of non-target and sensitive species; (b) impacts on habitat and biodiversity; (c) the risk of truncated age structure; and (d) alterations that could possibly affect ecosystem functionality.

In some cases, advice has included considerations of the impacts of fisheries on other components of the ecosystems. An example is the advice regarding sandeel, which is based on an escapement strategy to ensure that there is sufficient sandeel biomass to support populations of other biota that feed on sandeel.

Where specific marine environmental management policies exist that require the regulation of fisheries to achieve their objectives, the fisheries advice will be restricted within the limitations required to achieve these objectives. In the EU context, this may be the case regarding fishing impacts on habitats relative to the Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora), and fisheries impacts on biodiversity, sea floor integrity, and foodwebs relative to the Marine Strategy Framework Directive (Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy). In the NEAFC context, advice has already been provided on fishing practices and fishing limitations to protect habitats of cold-water corals.

1.2.2.5 Management plan evaluations

Recovery, or long-term, management plans have already been agreed for a number of fish stocks or fisheries within the ICES area, and new plans are being proposed. ICES has evaluated such management plans according to their compliance with a precautionary approach regarding risks to maintenance of reproductive capacity, and now also evaluates them according to the likelihood that high yields will be produced in the longer term. Stakeholders and authorities may raise other issues that may also be addressed in a specific management plan evaluation, such as stability of yield and risks under specific recruitment regimes.

The management plans in place by 2012 were generally agreed prior to the introduction of MSY in the ICES advice, and on the basis of plan compliance with a precautionary approach. Some plans have since been evaluated with regard to generating high long-term yields, and these plans are considered also to be in accordance with an MSY approach.

It is generally anticipated that in the future competent authorities will aim at management plans (or replacement of management plans) being consistent with MSY. Management plan evaluations will be conducted to determine how plans perform in terms of long-term average catch, average stock size, average fishing mortality rate, and the statistical distributions of these variables. The ICES HCR will be used as a reference in comparing plan performance, although ICES does not claim that this HCR is inherently superior to other HCRs. Unless managers agree on specific performance criteria, the management plan evaluation can only be comparative; that is, there is no basis for rejecting a management plan if it is consistent with an MSY approach and it does not violate the precautionary approach.

1.2.3 ICES processes to provide stock status and single-stock advice

ICES uses specific terminology and symbols to describe the status of stocks. The wording aims at using a nomenclature which is less prone to misinterpretation, but at the same time allows for a match to the legal description, which still uses “safe biological limits“. ICES discontinued the use of this wording in 2008 as “safe biological limits” has in some cases misled the recipients of ICES advice and other stakeholders to consider stocks described as being “outside safe biological limits” to be biologically threatened (i.e. close to extinction).

The terminology now uses different wording for the description of the stock status for biomass and fishing mortality and for the comparison to reference points based on an MSY approach, a precautionary approach, and existing and implemented management plans.

In the case of management plans, the terminology changes depending on the characteristics of a specific reference point; namely, if the reference point is considered a target or a limit. If considered a target, this reference point would usually come with a target range, which means that a green symbol can be used when the stock is within the estimated or defined range (e.g. NEA mackerel), although for most of the stocks a range has not been defined. It is necessary to identify whether the reference points are defined as targets or as limits for each individual plan.

For comparison with **precautionary reference points**, ICES uses

for *fishing mortality*: "harvested sustainably" and a green symbol if $F <= F_{pa}$, "increased risk"and a yellow symbol if $F_{lim} > F > F_{pa}$, and "harvested unsustainably" and a red symbol if $F > F_{lim}$;

for *spawning stock biomass*: "full reproductive capacity" if $SSB \geq B_{pa}$, "increased risk" if $B_{lim} < B < B_{pa}$, and "reduced reproductive capacity" if $SSB < B_{lim}$.

For comparison with **MSY reference points**, ICES uses

for *fishing mortality*: "appropriate" and a green symbol if:

1) $F < F_{MSY}$ and SSB > MSY $B_{trigger}$, or
2) if $F < F_{MSYHCR}$ and SSB < MSY $B_{trigger}$,

and "below target" if F much less than F_{MSY} (approximately zero) while SSB is above $MSYB_{trigger}$

and "above target" and a red symbol if $F > F_{MSY}$ or $F > F_{MSYHCR}$ and SSB < MSY $B_{trigger}$;

for *spawning stock biomass*: "at trigger" or "above trigger" and a green symbol if SSB = MSY $B_{trigger}$ or SSB > MSY $B_{trigger}$, and "below trigger" and a red symbol if SSB < MSY $B_{trigger}$.

For comparison with **management reference points**, ICES uses

for *fishing mortality*: "below target" and a green symbol if F< F mgt target, or "below limit" and a green symbol if F< F mgt limit, at target" or "within target range" and a green symbol if F within a defined range, "above target" and a red symbol if F>F mgt target, and above limit" and a red symbol if F> F mgt limit;

for *spawnin- stock biomass*: "above target (or limit or trigger)" if SSB > B mgt target, limit or trigger biomass, "at target" and a green symbol if SSB within a defined range, and "below target (or limit or trigger)" if SSB < B mgmt plan target, limit or trigger biomass.

If reference points are not defined, ICES uses "undefined" and a grey question mark symbol, while the same symbol and "unknown" is used in cases where there is no analytical assessment available and thus no assessment results to compare with reference points. If input data (e.g. catch statistics or survey indices) is unavailable in a specific year and assessments can therefore not be performed, ICES uses "not available" and a grey questionmark.

In situations where very limited information is available and the stock status table is filled with grey question mark symbols, ICES provides additional, qualitative information where available. For example, this information could be based on survey information and give an indication of stock status or trend. Symbols used to provide this information are either grey arrows ("increasing" and arrow up for an increase of the parameter, "stable" and a horizontal arrow for a stable situation and "decreasing" and arrow down for a decreasing parameter – all of this gives no information an the absolute level of SSB or F) or inverted symbols (red or green on white) if there are indications on absolute stock status. In the latter case, a red symbol and a short explanatory description is used if F is very high, higher than expected to be safe for the stock, i.e. F > any safe limit, or SSB is very low, lower than expected to be safe for the stock, i.e. SSB < any safe limit, and a green symbol and a short explanatory description is used if F is very low, i.e. F < possible reference points or if SSB is very low, i.e. SSB > possible reference points.

Table 1.2.1 Symbols used to inform on stock status

Status relative to reference points	Qualitative evaluation	
		Desirable situation e.g. F is below the relevant reference point or SSB is above the relevant reference point
		Status lies between the precautionary (pa) and limit (lim) reference points
		Undesirable situation e.g. F is above the relevant reference point or SSB is below the relevant reference point
		Status of the stock is either unknown because there is no quantitative assessment, or undefined when there is an analytical assessment but reference points are not defined, or not available when input data (e.g. catch statistics or survey indices) is unavailable in a specific year and assessments can therefore not be performed
		Absolute level unknown, but increasing
		Absolute level unknown, but unchanged
		Absolute level unknown, but decreasing

The production of ICES advice can be separated into three distinct temporal phases (Figure 1.2.7):

- The first phase is the assessment, which uses data until Dec 31st of the last year. This phase is looking at the past only and dealing with the stock status.
- The second phase between the assessment and the forecast is the assessment (interim) year. As incomplete data are available for this year (the year is not over yet), ICES has to make a number of assumptions on the fishery and biology. These so-called interim year assumptions significantly influence the catch forecast for the next year, but these assumptions are the most uncertain. If in the following year these assumptions prove markedly different from reality, stock status would be much different than that forecasted .
- The third phase is the prognosis (forecast) on catch to be taken next year (the year for which advice is given).

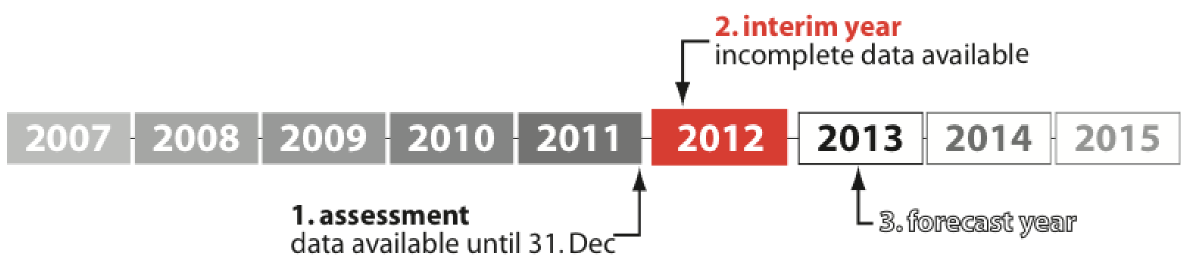

Figure 1.2.7 Timeline of the production of ICES advice. In this example ICES working groups are meeting in 2012 to prepare advice for 2013.

The framework for the statement regarding future fisheries (third phase) has been developed in consultation with the relevant competent authorities and is based on the following principles:

1. If competent authorities with an interest in the stock have agreed that a management plan can be the basis for advice and this management plan has been found to be precautionary, this management plan will be the basis for the ICES advice.
2. If this does not apply, the advice will be based on the ICES MSY framework.
3. If there is no basis for giving MSY-based advice, advice will be based on precautionary considerations (see introductory section to the 2009 advice report).

1.2.4 Advice to inform an ecosystem approach to marine management

At the 13th Dialogue Meeting between ICES and the Clients (ICES 2004), the ICES plans for the introduction of an ecosystem approach into the advice were discussed.

In 2008 ICES provided ecosystem overviews for the different sea regions (ICES, 2008). In 2012, these reviews will be updated starting with the Baltic Sea region. A new approach will be included in which an ecosystem description is combined with long-term trends in specific species or groups of species, and with long-term trends in drivers of ecosystem change such as climate and fishing pressure. Depending on the availability of long-term data, these overviews will be made available for the different ecoregions during 2012 and 2013.

The organisation of the advisory report in ecoregions facilitates an ecosystem approach to marine management which is currently narrowly focussed on fisheries management. In future, non-fisheries parts of the trophic chains will be considered and integrated into advice going beyond fisheries management; e.g. aspects of eutrophication in the Baltic Sea linked with the abundance of the top predator cod.

Our understanding of the functioning of the ecosystems is confined to certain ecosystem components. Work is underway to expand the number of ecosystem components beyond fisheries that are included in the ICES advice. However, this understanding is not uniform among ecosystems; some ecosystems have more data and the critical processes are understood better than in other ecosystems.

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