General context of ICES advice

The context for 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 the 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), 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 Sustainable Fisheries 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)

The ecosystem approach, precautionary approach, and MSY are prominent themes of the agreements and policies that set the context for ICES advice. A general description of these themes is given in Sections 1.2.1–1.2.3 of this introduction to ICES advice. The final section (Section 1.2.4) describes their application to ICES advice on fisheries in more detail.

1.2.1 An Ecosystem Approach

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 variously defined, but principally puts emphasis on 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 the 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 the 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.

How does an "Ecosystem Approach" affect ICES advice?

The 13th Dialogue Meeting between ICES and the Clients (ICES, 2004) discussed the introduction of an ecosystem approach in ICES advice. It was agreed that implementation of the ecosystem approach should be incremental. It also pointed to opening up advisory processes to managers and stakeholders, which is occurring. ICES advice is also organized according to ecoregions to facilitate integration and an ecosystem perspective.

Incrementally implementing an ecosystem approach is necessary both because the understanding of ecosystems varies considerably between ecosystems, ecosystem components, and human activities that affect ecosystems. Also, policy and management instruments upon which an ecosystem approach can be based are incomplete. Ongoing research is advancing understanding and policy and management instruments are evolving. This development allows human activities that affect ecosystems to be addressed in a more integrated and comprehensive fashion. Increasingly, ICES is called on to take account of ecosystems in fisheries advice, and to give advice on other aspects of ecosystems.

Policies addressing the health of marine ecosystems

Almost all ICES member countries have policies that address ecosystem health.

An important example is the Marine Strategy Framework Directive 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 11 descriptors of GES such as Biodiversity, Commercial Fish Stocks, Food Webs, and Habitat.

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 agreeing on these indicators and standards at the European level is ongoing. This process will be followed by specification of GES at the regional and national levels, conducting initial assessments, and continuing current monitoring activities.

Maritime Spatial Planning is envisioned as a key mechanism to 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 account of 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 the ecosystem approach. In the coming years, ecosystem-based advice and management will certainly increase in importance.

1.2.2 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)."

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[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.

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.

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 between members of 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.

1.2.3 The Precautionary Approach

The Precautionary Approach 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 the precautionary approach, which are anchored by MSY. Specifically,

- Limit reference points set boundaries to constrain the harvest to safe biological limits within which the stock can produce MSY;
- Fishing mortality should not exceed the fishing mortality that generates MSY; and
- The biomass that generates MSY can serve as a rebuilding target for overfished stocks.

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 or restore stocks at 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 the precautionary approach are complementary, and this is the spirit in which ICES applies these concepts.

In a sense, the precautionary approach is a necessary, but not a sufficient condition for MSY. Populations need to be maintained within safe biological limits according to the 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.

1.2.4 The ICES approach to fisheries advice

ICES provides fisheries advice that is consistent with the broad international policy norms of MSY, the precautionary approach, and the ecosystem approach while at the same time responding to the specific needs of the management bodies requesting advice. ICES recognizes that the fisheries for which it provides advice have not in general 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 the MSY approach by 2015.

ICES is typically requested to provide catch advice on a stock-by-stock basis, as most of the stocks on which ICES advises are managed using stock-specific total allowable catches (TACs), although other fishery management measures are frequently used as well. Thus, the ICES framework for fisheries advice needs to be applicable to individual stocks. This does not obviate the option of modifying stock-specific advice to take account of technical interactions (e.g. by-catch in mixed species fisheries) or of biological interactions (e.g. predator–prey), 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 the 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 1.2.1 gives a hypothetical production function versus F and Figure 1.2.2 shows surplus production versus spawning-stock biomass.

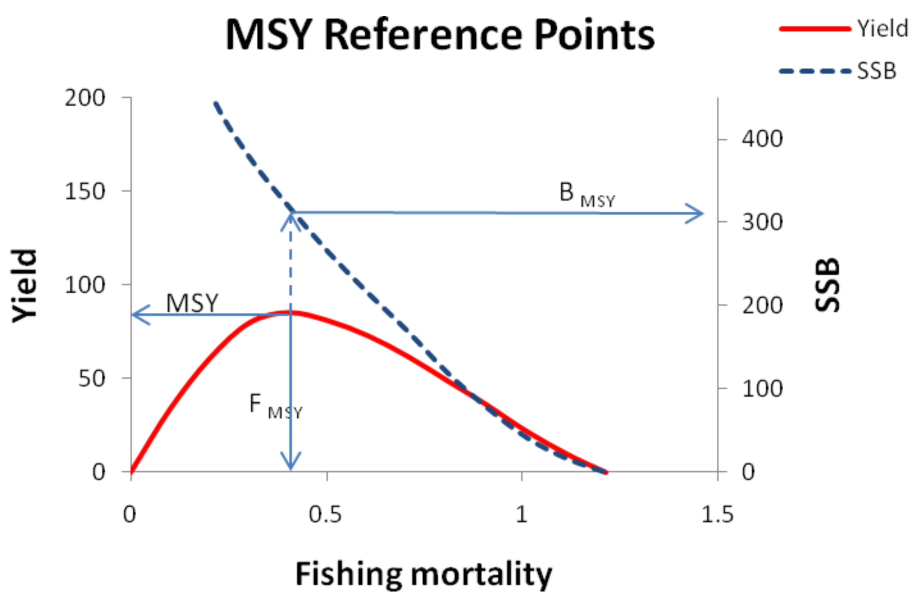

Figure 1.2.1 Example of a production versus fishing mortality (F) for a hypothetical fishery. SSB: Spawning-stock biomass.

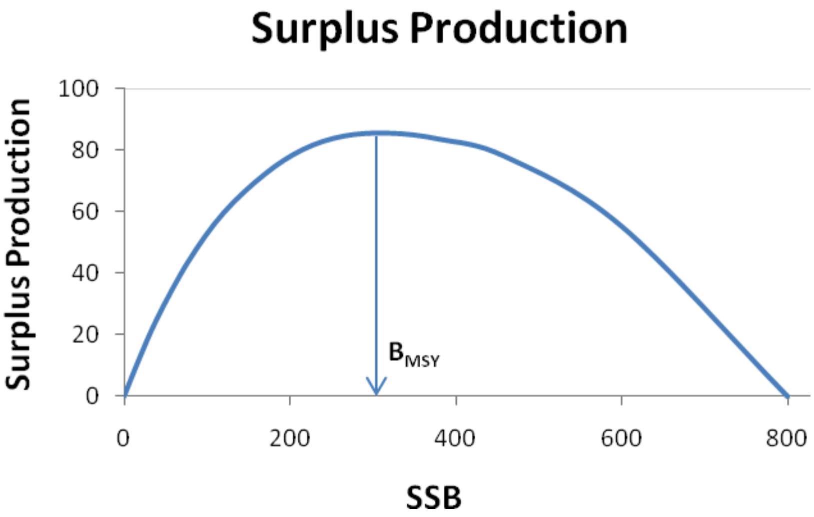

Figure 1.2.2 Example of surplus production versus spawning-stock biomass (SSB) for a hypothetical stock. The theory is that harvesting around 80 units when the stock is at B_{MSY} would leave the SSB unchanged. At the carrying capacity (800 units of SSB) there is no surplus production. If a fishery begins on a stock at carrying capacity, 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, which 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]

The ICES framework for fisheries management recognizes that the characteristics of fish stocks vary and the information available on individual stocks also varies. There are three main categories of stocks, and application of the ICES framework to each of these categories is discussed below.

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 since 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 MSY approach on attaining a fishing mortality rate at or below F_{MSY}. In this approach, both fishing mortality and biomass reference points are used; these reference points are F_{MSY} and $B_{MSY\text{-}trigger}$. The approach does not 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.

$B_{MSY\text{-}trigger}$ is a biomass reference point that triggers a cautious response; the cautious response is to reduce fishing mortality to reinforce the tendency for 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 $B_{MSY\text{-}trigger}$ evolves from the PA reference point B_{pa} which ICES has used as a basis for fisheries advice since the late 1990s. B_{pa} is a biomass designed to avoid reaching B_{lim}, therefore if SSB is above B_{pa} the probability of impaired recruitment should be low (Figure 1.2.3). The evolution in the determination of $B_{MSY\text{-}trigger}$ requires contemporary data with fishing at F_{MSY} to experience the normal range of fluctuations in biomass.

[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.

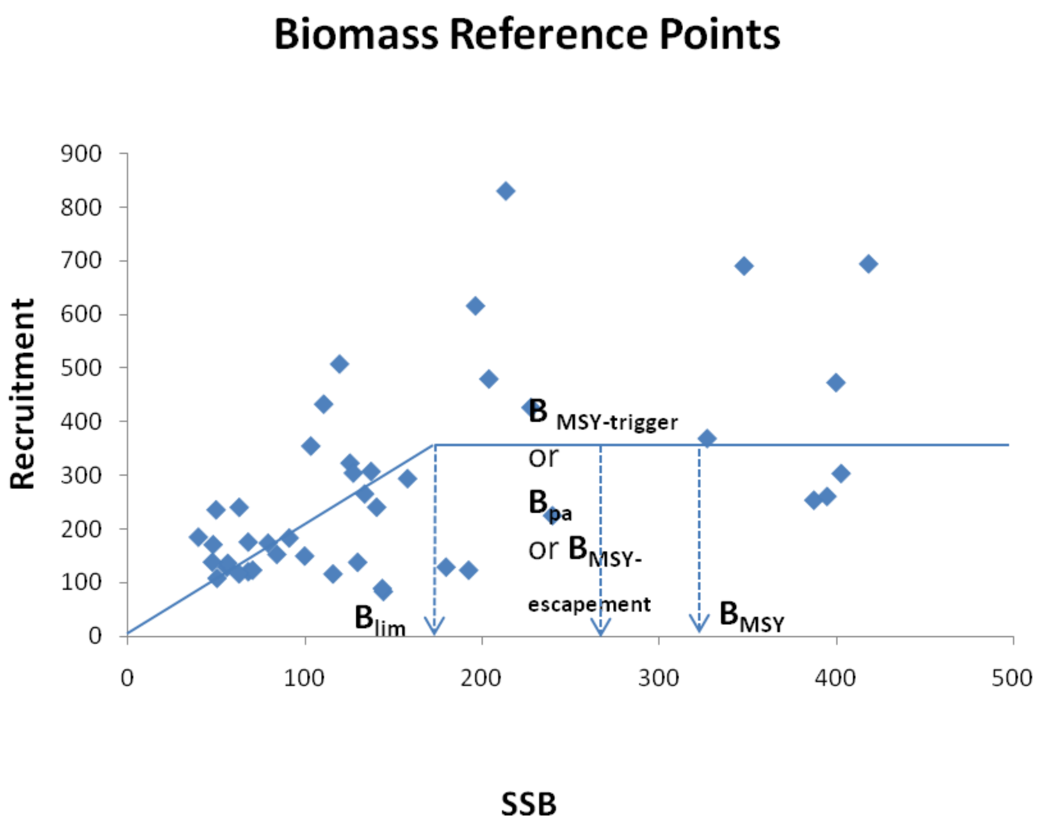

Figure 1.2.3 Illustration of biomass-based biological reference points. B_{lim} and B_{pa} are reference points used in the Precautionary Approach (PA) framework, while $B_{MSY\text{-}escapement}$ will be used in the MSY framework for short-lived species. They are all defined later in the text.

The ICES MSY approach as specified in the Harvest Control Rule (HCR) is depicted in Figure 1.2.4.

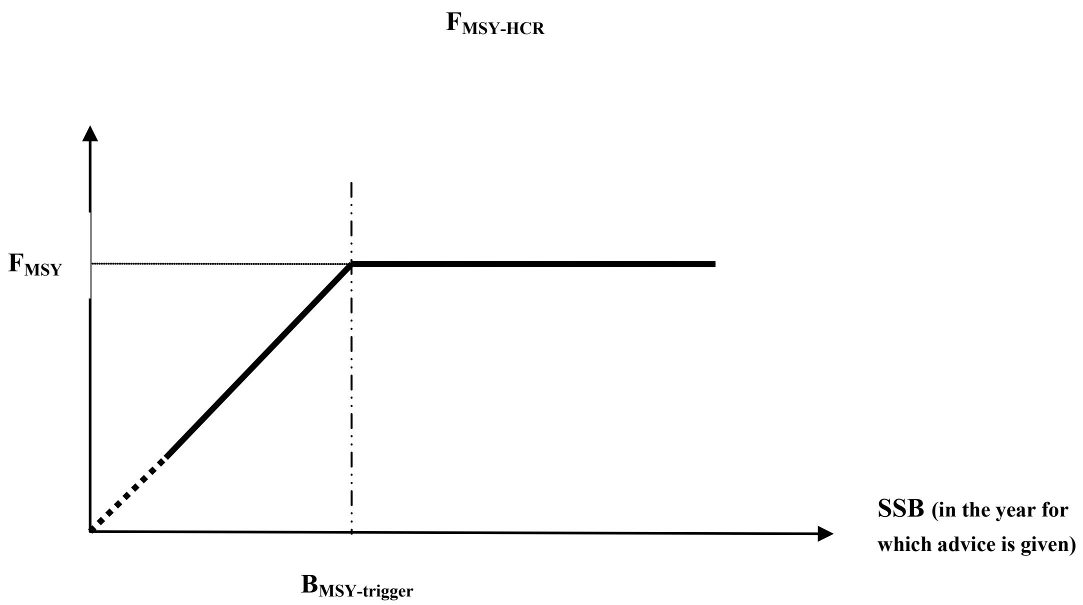

Figure 1.2.4 MSY approach shown in Harvest Control Rule.

Conceptually, SSB in the HCR is the estimated SSB at the beginning of the year to which the advice applies (advice year). For example, for an assessment performed in 2011 using data through 2010, the reference SSB will be the projected SSB at the beginning of 2012. $F_{MSY\text{-}HCR}$ is the fishing mortality rate that is 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 projections 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 $B_{MSY\text{-}trigger}$ 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 1.2.5). Thus F_{MSY} is used as a generic term for a robust estimate of a fishing mortality rate associated with high long-term yield.

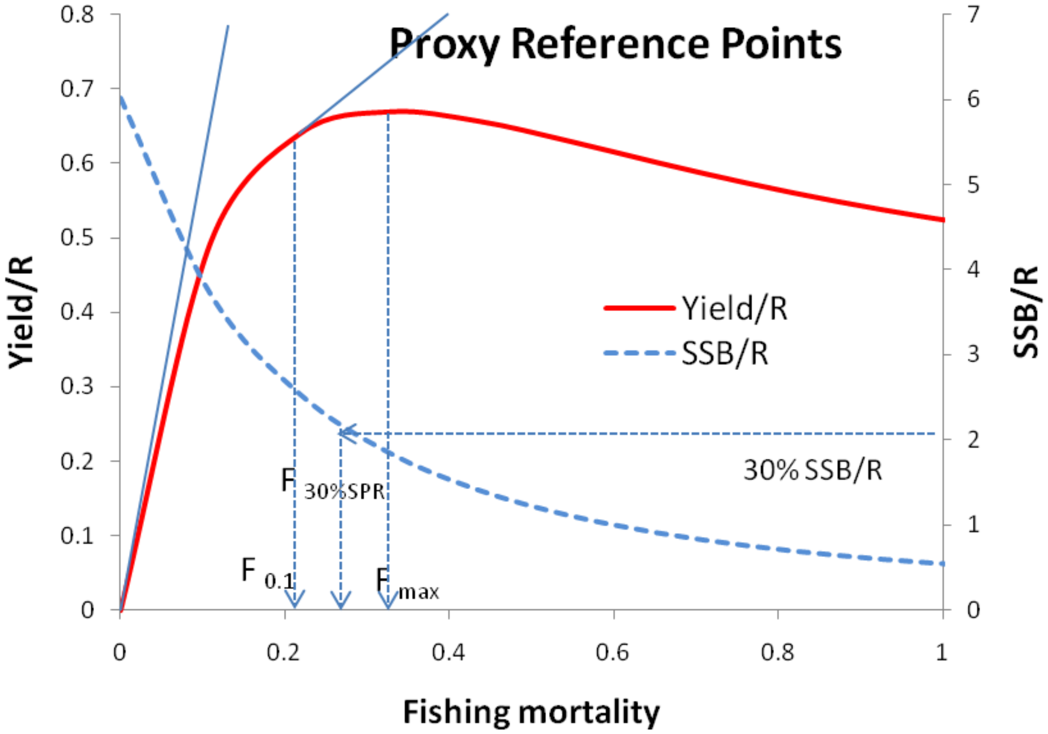

Figure 1.2.5 Illustrations of various proxies for F_{MSY}.

As an initial option, $B_{MSY\text{-}trigger}$ 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 $B_{MSY\text{-}trigger}$ should be re-estimated to correspond to the lower bound of the range of stock sizes associated with MSY. It is expected that re-estimated values will generally be higher than B_{pa}.

The ICES MSY Harvest Control Rule (Figure 1.2.4) 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 $B_{MSY\text{-}trigger}$). 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 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 the precautionary approach discussed below), the causes for the low stock size should be examined, and additional

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[3] $F_{20\text{-}40\%SPR}$ are fishing mortalities that reduce the life time reproductive output of a year class to 20–40% 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.

conservation measures may be recommended for the stock to prevent a further decline. The special consideration given at low stock sizes is depicted by a broken line in Figure 1.2.4.

Short-lived stocks with population size estimates

The future size of a short-lived fish stock is sensitive to recruitment because there are only a few age groups in the natural population. Incoming recruitment is often therefore 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 very imprecise, as are any catch forecasts.

For short-lived stocks, the ICES MSY approach is aimed at achieving a target escapement ($B_{MSY\text{-}escapement}$, the amount of biomass left to spawn, see Figure 1.2.3), which is more robust against low SSB and recruitment failure than a fishing mortality approach. 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 available 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 $B_{MSY\text{-}escapement}$ should be set so there is a low risk of future recruitment being impaired, similar to the basis for estimating B_{pa} in the precautionary approach. For short-lived species, where most of the annual surplus production is from recruitment (not growth), B_{MSY} and B_{pa} might be expected to be similar. Therefore B_{pa} is a reasonable initial estimate of $B_{MSY\text{-}escapement.}$

Stocks without population size estimates

For many fish stocks, the data available are inadequate to estimate the current population size and the catch resulting from fishing at a desired F. However, other data may be available to allow ICES to assess the desirable intensity of fishing.

For stocks without population estimates, ICES practice has been to base advice on recent average catches when there is no quantitative or qualitative evidence of declining abundance. The ICES MSY approach calls for a determination of the status of exploitation relative to F_{MSY} (overfishing or no overfishing) and consideration of the stock trend. The following table is the framework for advice for stocks without population size estimates.

	No overfishing	**Overfishing or unknown exploitation status**
Decreasing stock trend	Reduce catch	Reduce catch
Stable stock trend or no trend information	Do not allow catches to increase.	Reduce catch [5]
Increasing stock trend	Do not allow catches to increase	Do not allow catches to increase.

Fishery catch per unit effort data or resource survey abundance information may be used to assess population trends, taking uncertainty into account. Age or size composition data are often useful for assessing the status of the fishery relative to F_{MSY}. However, there are situations where even this type of information is not available. In such cases, it might still be possible to give advice but the basis for this advice cannot be prescribed in advance. This approach is intended to move in the direction of MSY, but this is unlikely to be achieved without additional or more complete information.

[5] In cases where catches are already very low, instead of a reduction, ICES advises that no increase of the catch should take place unless there is evidence that this will be sustainable. For other stocks, 2011 is the first year ICES collated and analysed data. For new stocks where there is insufficient information to evaluate the status and exploitation, ICES advises that catches should not be allowed to increase in 2012

Multispecies considerations

As discussed above, ICES advice is provided on an individual stock basis. However, the multispecies nature of fisheries and ecosystems is important. Two types of interactions should be considered in fisheries management.

One type of interactions (referred to as "technical interactions") results from the non-selective nature of many types of 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 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.

Another type of interactions results from "biological interactions" (predator–prey; competition for food or habitat) between species. Such interactions mean that as one species increases, another species is likely to decrease. 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. 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. Although biological interactions can be important in terms of the response of stocks to an 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}.

Precautionary approach

The ICES MSY approach for fisheries advice is also designed to be consistent with the precautionary approach. F_{MSY} is the highest fishing mortality rate permissible in the ICES MSY harvest control rule, in accord with Annex 2 of the UNFSA. Also, as called for in the UNFSA, F_{MSY} is a fishing mortality reference point needed to achieve MSY. $B_{MSY\text{-}trigger}$ is regarded as a precautionary reference point to establish the boundaries within which the stock can produce MSY. When a stock falls below $B_{MSY\text{-}trigger}$, a pre-agreed conservation and management action is triggered to rebuild the stock to a biomass that can produce MSY.

ICES advice has been based on the precautionary approach since the late 1990s. The precautionary approach suggested by ICES consists of reference points expressed in terms of fishing mortality and biomass:

	Spawning-stock biomass (SSB)	Fishing mortality (F)
Limit reference point	B_{lim}: minimum biomass. Below this value, recruitment is expected to be 'impaired' or the stock dynamics are unknown.	F_{lim}: fishing mortality rate expected to be associated with stock 'collapse'[6] if maintained over a longer time.
Precautionary reference point	B_{pa}: precautionary buffer to avoid that *true* SSB is at B_{lim} when the *perceived* SSB is at B_{pa}.	F_{pa}: precautionary buffer to avoid that *true* fishing mortality is at F_{lim} when the *perceived* fishing mortality is at F_{pa}.
	The buffers safeguard against natural variability and uncertainty in the assessment. The size of the buffer depends upon the accuracy of the projections (of SSB and F), and the risk society accepts that the true SSB is below B_{lim} and the true F is above F_{lim}. The accuracy of the projections depends on the magnitude of the variability in the natural system and on the accuracy of the population estimates.	

[6] "Collapse" means the stock suffers from severely reduced productivity. "Collapse" does not mean that a stock is at high risk of biological extinction. However, recovery of the stock to an improved status is likely to be slow and will depend on effective conservation measures.

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).

Like the precautionary approach, the ICES MSY approach uses both a fishing mortality rate and a biomass reference point. In general, F_{MSY} should be lower than F_{pa}, and $B_{MSY\text{-}trigger}$ should be equal to or higher than B_{pa}. In most situations, the ICES MSY approach will be more cautious with respect to future stock status than the ICES precautionary approach. This is appropriate since PA is a necessary, but not sufficient, condition for MSY.

For some stocks at low sizes, ICES has previously recommended a zero catch to promote recovery above B_{pa} in the next management year, or as soon as possible. However, such recommendations are often sensitive to the estimate of recent recruitment. That is, the recommended catch is likely to be low or zero when the stock is below B_{pa} if estimated recruitment is poor, whereas no decrease of even an increase in catch might be indicated if recruitment is estimated to be good. This makes sense if estimates of recruitment are reliable, but such estimates are usually among the most imprecise elements of an assessment. Thus, this approach can create instability in advice (changes from year to year that are more a reflection of noisy data rather than a signal). As an alternative, when stock size is low such that the risk of impaired recruitment is high (e.g. at or below B_{lim}), the ICES MSY harvest control rule (depicted by a broken line) calls for careful examination of the causes for the low stock size and the future outlook, and for the implementation of additional conservation measures if appropriate.

Ecosystem considerations

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 functioning, and marine habitats.

MSY is not necessarily sufficient to assure some aspects of a healthy ecosystem. Therefore, MSY may need to be supplemented with measures to mitigate undesirable impacts on ecosystems. This need for supplementary measures is also considered in the ICES advice. Reducing fishing mortality 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.

1.2.5 Evolution in ICES fisheries advice

As noted earlier, ICES has applied a precautionary approach framework to fisheries advice since the late 1990s. Based on policy documents of management authorities and discussions with managers, there is general agreement that the stocks and fisheries 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). As such, 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; 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 the MSY approach.

In 2010 ICES introduced the ICES MSY approach for fisheries advice in 2011. In the transition period (advice for 2011–2015), three catch options will be provided by ICES if the requisite information is available. The first option reflects a stepwise transition to the ICES MSY Harvest Control Rule by 2015. This transition was implemented with advice for 2011 if an estimate or a proxy of F_{MSY} was available. Otherwise, it will begin with advice for 2012. The transition will be in equal steps from the year in which it begins. If the transition began in 2011, F was to be reduced in 5 equal steps and the catch option for 2012 will be:

$$F_{MSY\text{-}HCR\text{-}transition}(2012) = \text{Min}\{0.6 \bullet F(2010) + 0.4 \bullet F_{MSY\text{-}HCR}(2012); F_{pa}\}$$

whereas for the following years:

$$F_{MSY\text{-}HCR\text{-}transition}(2013) = \text{Min}\{0.4 \bullet F(2010) + 0.6 \bullet F_{MSY\text{-}HCR}(2013); F_{pa}\}$$
$$F_{MSY\text{-}HCR\text{-}transition}(2014) = \text{Min}\{0.2 \bullet F(2010) + 0.8 \bullet F_{MSY\text{-}HCR}(2014); F_{pa}\}$$
$$F_{MSY\text{-}HCR\text{-}transition}(2015) = \text{Min}\{0.0 \bullet F(2010) + 1.0 \bullet F_{MSY\text{-}HCR}(2015); F_{pa}\}$$

where F(2010) is the current year estimate of the fishing mortality in 2010 and $F_{MSY-HCR}$ (2012) is according to the HCR in Figure 1.2.4, being equal to F_{MSY} if SSB in 2012 is at or above $B_{MSY-trigger}$ and reduced linearly if SSB is below. The $F_{MSY-HCR-transition}$ (2012) values are capped at F_{pa} to maintain consistency with the precautionary approach. The plan for transition to MSY takes cognizance of the general understanding 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 the stock 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 $F_{MSY-HCR}$ as soon as possible.

In its advice, ICES will also provide a catch option by applying the ICES MSY approach without a transition (that is, by direct application of the ICES MSY HCR).

In 2010 the ICES advice for 2011 highlighted (if available) three catch options based on a transition to the ICES MSY approach, on the ICES precautionary approach and on management plans if they were considered consistent with the ICES precautionary or MSY approaches. From 2011 onwards ICES will highlight only one catch option according to the following hierarchy: (1) existing management plans if they are considered consistent with the precautionary approach, and if all competent legitimate interested parties recognise them as a potential basis for the advice; (2) ICES MSY approach (transition when appropriate); (3) ICES precautionary approach.

1.2.6 Management plan evaluations

A key element of the evolution of ICES fisheries advice is the revision of management plans (or replacement of management plans) with plans that are consistent with the MSY approach. Management plan evaluations should 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 MSY HCR should 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 will be no basis for rejecting a management plan if it is consistent with the MSY approach and it does not violate the precautionary approach.

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