BRIEFING NOTE

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Maximum Sustainable Yield

SHETLAND FISHERMEN'S ASSOCIATION

Maximum Sustainable Yield

Summary

- **Maximising the sustainable yield from fisheries may be a worthy general objective.**
- **In practice, we do not know what the maximum sustainable yields from fish stocks actually are.**
- **We probably <u>cannot</u> know what maximum sustainable yields are, as we do not have sufficient knowledge of all the factors that influence yield.**
- **The so-called 'MSY approach' to fisheries management is not based on knowledge of what maximum sustainable yields actually are, but rather on various proxies and estimates that are themselves largely based on past stock sizes. These reflect environmental conditions in the past, rather than the present.**
- **Attempts to meet unrealistic targets based on historic stock sizes are doing substantial damage to the fishing industry without delivering MSY.**

Introduction

The **Maximum Sustainable Yield (MSY)** is theoretically the largest catch (harvest) that can be taken from a fish stock over an indefinite period without reducing the size of the stock. Put another way, it is the largest possible long-term sustainable catch.

The MSY is associated with an intermediate stock size (neither too small nor too big) where the growth rate of the stock is at a maximum, due to high levels of reproduction and 'recruitment' and the rapid growth of individual fish. This maximises the amount that can be taken from the stock without reducing its size. In most modern fisheries models MSY occurs at about 30% of the unexploited stock size.

Background

Growth, Reproduction and Production

Fish, like other living things, reproduce and grow; they produce more fish.

The size of a fish stock is typically measured by its biomass, or the weight of fish. It increases through reproduction and recruitment (i.e. the addition of new young fish to the stock) and through increases in the size of individual fish. Essentially the fish stock produces its own new fish biomass.

The amount of new biomass production by a fish stock depends on the size of the stock. Production is limited when a fish stock is small because there are few fish to reproduce and grow. Recruitment is low, in other words.

Production is also limited when a fish stock is large because of density-dependent factors such as competition and the availability of food, which affect recruitment and the growth of individual fish.

An unexploited fish stock will tend to grow to a maximum size where production is just sufficient to balance losses from the stock through mortality. Unexploited stocks also tend to become dominated by older, larger and slower-growing individuals. It follows that the production of unexploited fish stocks is relatively low.

Harvesting a fish stock reduces the constraints of density-dependent factors such as competition and the availability of food. That enables the surviving fish to grow more rapidly and allows greater recruitment. Exploitation also tends to remove the larger and slower-growing fish; as they are replaced by younger, faster-growing fish, this tends to increase the aggregate growth rate of the stock.

For these reasons, the production of a fish stock – and hence the available surplus production – increases when it is exploited. This has two important consequences:

- **An exploited fish stock will always be smaller than the unexploited stock.**
- **An exploited fish stock is more productive than an unexploited stock.**

Sustainable Exploitation

The production of new biomass makes fish stocks and other living resources renewable and allows for sustainable exploitation. Because a fish stock reproduces and grows it is possible to take a harvest from the stock and yet for the stock to be the same size at the end of the year as it was at the beginning. Provided the harvest does not exceed the production of the stock, it is possible to continue taking the harvest indefinitely without reducing the size of the stock.

This contrasts with non-renewable resources such as oil, coal and minerals, which are not renewed (at least not on a human time-scale). These sorts of resources cannot be exploited sustainably.

Sustainable exploitation takes only the surplus production, which is the excess production over and above that needed to maintain the size of the stock. The amount of surplus production depends both on the size of the stock and the size of the individual fish within the stock. As we have seen, older and larger fish tend to grow more slowly than younger and smaller fish, and overall production is limited at both large and small stock sizes.

An important point to note is that any fish stock can be exploited sustainably, regardless of its size, although the sustainable harvest may be small if the size of the stock means that surplus production is low. Sustainability does not depend on the size of a fish stock, only on the balance between surplus production and the harvest taken.

AN ANALOGY

The surplus production from a fish stock might be compared to the interest on a bank account. If you have £1,000 in a bank account that pays 5% interest per year then at the end of the year you will have £1,050. If you withdraw £50 and spend it and you will still have £1,000 in the bank, which will earn another £50 next year. Thus, you can go on withdrawing and spending £50 each year indefinitely without affecting the amount of money you have saved. The £50 per year can be thought of as the ‘surplus production’ from the account or as its ‘sustainable yield’.

Overfishing

Overfishing occurs when the harvest taken from a fish stock (of whatever size) exceeds the stock's ability to regenerate itself; when the catch is greater than the surplus production.

That reduces the size of the stock because its production is insufficient to replace the fish removed. The smaller stock will have a smaller surplus production, so the sustainable yield will be less than it was. If fishing continues at the same level the sustainable yield will again be exceeded, causing a further reduction in the stock size and its surplus production.

If unchecked, overfishing can create downward pressure on the size of the stock and substantially reduce its size.

'Recruitment overfishing' occurs when the size of a fish stock is reduced to a level where lack of recruitment (due to limited production of eggs) becomes a limiting factor on the stock's production.

AN ANALOGY (2)

To extend the analogy above, if you withdraw £100 from your bank account and spend it then at the end of the year you will only have £950 remaining in the bank. You will have 'over-exploited' the account; exceeded its surplus production. If you continue to withdraw £100 each year then the amount of money in the account will continue to diminish.

Stock Collapse

The term 'collapse' is widely used and abused, particularly in non-scientific contexts. It is often claimed that fish stocks have already collapsed or that they may collapse. There is, however, no agreed definition of what constitutes the collapse of a fish stock – a recent review identified 20 different definitions in the scientific literature.

A fish stock can be said to have collapsed if it has experienced an abrupt decline to a relatively small size and has remained depleted for an extended period of time.

The limited production (and therefore growth potential) of a small stock means that it may be difficult for a collapsed fish stock to recover. That may be exacerbated by other changes in the wider environment, such as increases in the abundance of competing or predatory species.

Despite wide usage of the term, there are few examples of true stock collapses as defined above triggered by overfishing. They include Newfoundland cod (1990s) and North Sea herring (1960s and 1970s). In both cases, collapse stemmed from persistently high fishing pressure amid falling stock sizes.

Significantly, herring is the only example of a stock collapse in the North Sea; **no demersal North Sea stock has ever collapsed**, despite extended periods of very high fishing pressure in the past.

Defining Maximum Sustainable Yield

As noted above, the production of a fish stock is limited both when it is small and when it is large. The surplus production, and thus the sustainable harvest or yield that can be taken from a stock is greater at intermediate stock sizes where there are sufficient fish to ensure high levels of reproduction (and recruitment) but not so many fish that growth is limited by density-dependent factors.

Theoretically there is a **Maximum Sustainable Yield (MSY)** at the stock size where the surplus production is greatest. This represents the maximum sustainable harvest that can be taken from the stock in the long term. Most modern fisheries models suggest that MSY occurs when a fish stock is just under one-third (30%) of its unexploited size.

If the stock size is larger or smaller than the MSY level then the sustainable harvest that can be taken will be less than this maximum.

Maximum Sustainable Yield may also be defined in terms of the level of fishing mortality (F), which is a measure of the fishing pressure on a stock. For a given set of conditions, F_{msy} is the level of fishing mortality that generates the greatest surplus production (and thus the greatest sustainable yield). B_{msy} is the expected average biomass of the stock if it is exploited at F_{msy}.

Commitment to MSY

Maximum Sustainable Yield has long been recognised as a theoretical concept by fisheries scientists, rooted in mathematical models of the production of fish stocks. Maximising the sustainable yield also has a long history as a general objective of fisheries management.

The modern commitment to MSY-based fisheries management originated in the 2002 'Earth Summit' (formally, the World Summit on Sustainable Development) in Johannesburg. Participants, including the UK through its then membership of the European Union, committed themselves to maintain populations of harvested fish stocks above levels that can produce the maximum sustainable yield.

This commitment was enshrined in the reformed Common Fisheries Policy in 2013:

"The CFP shall apply the precautionary approach to fisheries management, and shall aim to ensure that exploitation of living marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield." [1]

It should be noted that the commitment is to maintain stock sizes above the levels that can produce the maximum sustainable yield rather than at the MSY level. **That implies accepting a smaller yield than the maximum possible**, because surplus production declines at stock sizes above the MSY level.

UK legislators may therefore wish to reconsider the language used to capture our MSY commitment in the future.

MSY in Practice

Maximum Sustainable Yield is a theoretical concept rooted in mathematical models of fish stocks. These models suggest that there is an optimum stock size at which the surplus production is at a maximum. However, these are relatively simplistic models that do not reflect the complexity, variability and uncertainty of the real world.

The point is that we cannot identify the actual maximum sustainable yield of a fish stock, as we lack a sufficiently detailed understanding of the relationships between the size of fish stocks and their recruitment and growth, as well as the density-dependent factors such competition and predation that affect their production.

The best we can do in the real world is to view the maximum sustainable yield as the maximum yield that can be taken on average in the long-term. This is reflected in the CFP's definition of MSY as *"the highest **theoretical** equilibrium yield that can be continuously taken **on average** from a stock under **existing average environmental conditions** without significantly affecting the reproduction process"* [2] (emphasis added).

This approximation of a maximum sustainable yield is rather different to the theoretical mathematical concept of MSY as the maximum surplus production at a specific identifiable stock size.

It is worth stressing also the reference in the CFP definition to 'existing environmental conditions'. Today's MSY is likely to be different to the MSY that prevailed under different environmental conditions in the past.

1 Regulation EU 1380/2013 on the Common Fisheries Policy: Article 2.2.
2 Regulation EU 1380/2013 on the Common Fisheries Policy: Article 4.1.7.

Uncertainties and environmental variations in the real world mean that to maximise the sustainable yield in the long term we might want a buffer to accommodate fluctuations in stock sizes or production. In effect, to avoid taking too much in 'bad' years it may be necessary to leave substantial potential yield unharvested in 'good' years.

The ICES MSY Approach[3]

Established in 1902, the International Council for the Exploration of the Sea (ICES) is an internationally recognised marine science organisation. Among other things, it assesses the state of commercial fish stocks and offers advice on their management.

For what are defined as long-lived Category 1 and 2 fish stocks (i.e. those with quantitative analytical assessments and forecasts), ICES aims to:

- **Maintain the level of fishing pressure at the level that will generate the maximum sustainable yield (F_{msy}).**
- **Maintain the stock size above B_{lim}.**

Given that a fish stock will naturally vary in size even when it is fished at F_{msy}, ICES defines MSY $B_{trigger}$ as the lower limit of this range of normal fluctuations in stock size. Determining MSY $B_{trigger}$ requires knowledge of the normal range of fluctuations in the size of a stock when it is fished at F_{msy} under current conditions. If these data are not available then MSY $B_{trigger}$ is normally set at B_{pa}.

MSY $B_{trigger}$ is used to trigger advice for a more cautious management approach. If a stock size falls below MSY $B_{trigger}$ ICES will advise a reduction in fishing pressure (F) to allow the stock to increase in size to the levels capable of producing the maximum sustainable yield. The size of the advised reduction in fishing mortality depends on how far below MSY $B_{trigger}$ the stock size has fallen.

If the stock size has fallen below B_{lim} then ICES advice will aim to bring it above B_{lim} as soon as possible, even if that results in advice of zero catch.

Mixed Fisheries

ICES acknowledges that for fish stocks exploited by mixed species fisheries **it may not be possible to achieve the single stock MSY catch advice for all stocks simultaneously**.

3 This section is largely based on ICES's "Introduction to Advice" (pp. 6 - 8): Available online at: https://www.ices.dk/sites/pub/Advice/Introduction_to_advice_2018.pdf

Discussion of MSY

Maximising the sustainable yield from fisheries in the long term is a worthy objective in general terms.

That said, the requirement to achieve Maximum Sustainable Yield is a political commitment rather than a biological or management necessity. A fish stock can be exploited sustainably regardless of its size (although the yield may be small if the surplus production is low) and is not necessarily being overfished or at risk of collapse if it is nor at the MSY level. **The maximum sustainable yield is not the only sustainable yield that can be taken from a fish stock**.

Failing to achieve MSY simply means that the sustainable yield from the fishery is less than it might be; it **does not necessarily mean that the stock is being over-fished or is going to collapse**.

The political commitment to MSY takes no account of the difficulties of achieving MSY in practice. Instead, it has resulted in unrealistic targets and unrealistic timescales.

At the time of writing, one of the best examples of this phenomenon is advice on North Sea cod catches, with a political requirement to meet a target based on what the stock size was in 1996. The consequent recommendation of a substantial cut in the North Sea cod quota is not required to ensure sustainability; indeed, ICES itself points out that unchanged catches would result in a larger stock size next year.

Knowing What We Do Not Know

While maximising the sustainable yield from fisheries makes sense, in most cases we do not know what the maximum sustainable yield actually is. We don't have the necessary information about how the size of fish stocks and other factors affect their recruitment and growth.

Worse, the maximum sustainable yield probably **cannot** be known due to the impracticality of collecting and understanding the necessary data.

The so-called 'MSY approach' to fisheries management is not based on knowledge of the maximum sustainable yields from fish stocks, but rather on various proxies. Most of these are based in turn on historic levels of abundance.

This breaks one of the tenets of maximum sustainable yield; that it is the maximum sustainable yield that can be taken under **current environmental conditions**. Yet, in most cases the reference points that are used in the MSY approach to management are based on environmental conditions in the past (up to 20 to 30 years in the past in some cases) when environmental conditions were different.

Unrealistic Targets

The danger of the current approach to MSY is that imposes unrealistic targets and timescales on fisheries. Fisheries managers are forced to grapple with political objectives rather than biological issues. Attempting to meet arbitrary targets causes significant damage to the fishing industry without contributing positively to the sustainability of fish stocks.

It is highly likely that the damage caused by efforts to achieve MSY will outweigh the benefits of doing so.

Glossary

B The **Spawning Stock Biomass (SSB) –** The size (weight) of the stock of mature fish.

Blim The **Biomass Limit reference point –** The minimum acceptable spawning stock biomass.

- Below Blim there is a high risk that recruitment will be 'impaired' (seriously decline) and that the stock could 'collapse' (suffer severely reduced mortality).
- Blim is set on the basis of historical data.
- If the spawning stock biomass is below Blim the stock is classed as "suffering reduced reproductive capacity".

Bpa The **Biomass Precautionary Approach reference point –** The minimum spawning stock biomass consistent with the 'Precautionary Approach'.

- Since the spawning stock biomass can only be estimated with uncertainty, and to reduce the risk of the actual biomass falling below the minimum acceptable level, Bpa is set at a higher level than Blim.
- The difference between Blim and Bpa creates a 'buffer zone'. So long as the estimated biomass remains above Bpa the chances of the actual biomass falling below Blim should be small.
- The distance between Blim and Bpa depends on the uncertainty in the stock assessment and the level of risk that is acceptable in managing the stock.
- If the spawning stock biomass is below Bpa but above Blim the stock is classed as "being at risk of suffering reduced reproductive capacity".
- If the spawning stock biomass is above Bpa the stock is classed as "having full reproductive capacity".

F The **Fishing Mortality Rate –** The proportion of the stock that is removed (killed) each year by fishing activity.

- This includes landed and discarded fish, and any other fish that die as a result of fishing activities (such as fish that escape from the net but later die of injuries they received).

Flim The proportion of the stock that is removed (killed) each year by fishing activity.

- The fishing mortality rate that, if maintained, will drive the stock to the biomass limit (Blim).
- If the fishing mortality rate is above Flim the stock is classed as being "harvested unsustainably".

Fpa The maximum fishing mortality rate consistent with the 'Precautionary Approach'.

- Due to the uncertainties in estimating Flim, Fpa is set at a lower level to reduce the risk of the actual fishing mortality rate exceeding Flim.
- Fishing mortality rates above Fpa are not sustainable.
- If the fishing mortality rate is above Fpa but below Flim the stock is classed as being "at risk of being harvested unsustainably".
- If the fishing mortality rate is above Fpa the stock is classed as being "harvested sustainably".


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