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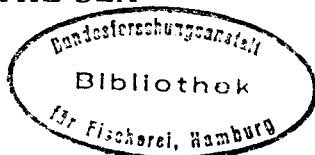


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**THE CHOICE OF TARGET FISHING MORTALITY IN HERRING
STOCKS**

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Abstract

In advising TACs for herring stocks, biologists have not been very consistent in the choice of a target fishing mortality. Over the years, several "biological reference points" have been used, but it has not been possible from a scientific point of view to express a clear preference for one of them. Also, the reference points used are not constant values, but they change from stock to stock, and from year to year.

Management advice would become more transparent and consistent if biologists admitted that optimum target F_s for each stock cannot be defined within sharp boundaries, but that an arbitrary choice has to be made within a range of reasonably safe values. In selecting such an arbitrary option, managers and biologists should not only consider yield/recruit or stock/recruitment relationships, but also recruitment variability, market demand for particular size categories, density dependant growth, and species interactions. Considering our limited knowledge about most of these aspects, there is no point in arguing about subtle differences in target F for each individual stock.

It is suggested that the choice of target F is restricted to a limited number of rounded F -values, say 0.20 and 0.30. If one of these options is selected, management should stick to it in future years, until empirical evidence shows the need for a revision of target F .

1. Introduction

Fisheries management has been rather successful in rebuilding most West-European herring stocks after the period of severe overfishing in the 1970s. Now that most of the stocks are out of the immediate danger zone, biologists have to decide what the next management objective should be. Should all stocks be allowed to grow as large as possible in order to create maximum buffer stocks, or should one aim for a more modest level of stock size? Should one try to maintain stock size at a fixed level, or should one aim at a fixed fishing mortality?

The last question is the easiest one to answer. Trying to maintain the stock at a specific level is not a very efficient way to run a fishery, at least not in fisheries where recruitment is fluctuating from year to year. In order to keep stock size constant, catch levels would have to fluctuate in the same way as recruitment. A better system is to take a certain fraction from the total stock each year. Total stock size will fluctuate less sharply than recruitment, so annual catches will be stabilized. The question then arises how large a fraction of the stock one could take each year.

The first definition of optimum fishing mortality, given by Beverton and Holt (1957) was the point of "maximum sustainable yield", i.e. the point where the yield/recruit curve reaches its maximum. The application of this management objective, usually called F-max, is problematic in herring fisheries. Some herring fisheries have a Y/R curve without maximum, which would suggest that the yield from those fisheries will continue to rise with increasing fishing mortality.

In the late 1970s, a new concept was introduced: the F-opt, also called F_{0.10}. This was the F value corresponding to the point of the Y/R curve where the slope was reduced to one tenth of its value at the origin. Total yield from the stock would be slightly lower than at F-max, but this loss was compensated by a higher catch/effort, a larger buffer stock, and less danger for recruitment failure. Although (or because) the arithmetics involved in calculating F-opt were not fully understood by most managers, F-opt was gradually adopted as the management objective for most herring stocks.

When herring stocks were recovering in the North Sea in the early 1980s, pressures from the industry increased to step up the exploitation level above F-opt. After all, F-opt was an arbitrary figure, and many people felt it was a bit overconservative. In 1986, ACFM changed the target fishing mortality for North Sea herring from F-opt back to F-max. This resulted in a sharp increase in TAC in 1987 (and reductions in TAC in later years).

Realizing that neither F-max nor F-opt were ideal target Fs under all circumstances, biologists in the mid 1980s increased the number of management options with some more "biological reference points" (Anon 1984a,b). The new concepts introduced were F-med, F-high and F-low. Again the arithmetics involved in calculating these points were fairly complicated, but the idea was simple: F-med is the average fishing mortality in some historic period when recruitment remained stable and things did not go wrong. F-low and F-high are by-products from the calculation of F-med, but these values are generally not considered to be realistic management objectives.

As the non-systematic use of too many reference points led to confusion and inconsistency in management advice, ACFM tried to set up guidelines for the use of them (Anon. 1989). Despite this attempt at standardization, ACFM itself in its most recent report (Anon. 1990) still advises different F-values for each of the herring stocks in the ICES area, and there is little consistency in the arguments used (table 1).

The discussion about the choice of target F has been hampered by the reluctance on the side of biologists to admit that the choice is basically an arbitrary one. There is a tendency to present only the very specific F-values corresponding to biological reference points as scientifically sound management options. The first step in getting a more open discussion on target F, therefore, is to show that biological reference points have no intrinsic, absolute value, and that a nearby rounded F-value may be just as good a management objective.

2. How precise are biological Reference points

In this paragraph, some limitations of biological reference points will be listed. In particular the question will be addressed whether these points have a unique value, or whether they change depending on changes in the fishery.

F-max.

F-max corresponds to the maximum of the Y/R curve. The shape of this curve, however, depends largely on the exploitation pattern in the fishery. If younger age groups are exploited, the maximum will shift towards lower F-values. The yield curve also depends on assumptions about natural mortality: an increase in M will shift the maximum towards higher F-values.

The Y/R curve assumes constant growth parameters at different stock sizes. Density dependant growth will shift the maximum towards higher F-values.

The Y/R curve does not take into account possible stock/recruitment relationships. Herring fisheries with no exploitation of juveniles sometimes have Y/R curves with no defined maximum. This would imply that F could be increased indefinitely. Of course, this would bring the stock below the minimum spawning stock size.

F-opt (=F0.10).

Also calculated from the Y/R curve, and therefore subject to the same limitations as F-max. The choice of a point at the yield curve where the slope is 10% of the value at the origin, is entirely arbitrary. One could just as well choose a slope of 5% or 15%.

F-med

The following definition of F-med is taken from the 1989 ACFM report (Anon 1989). "The value of F-med may be calculated very simply from a stock/recruitment plot. The procedure is simply to draw a line through the origin, which leaves an equal number of points on either side of the line. The slope of this line corresponds to recruitment per unit biomass, and the reciprocal of this value is an estimate of the spawning biomass per recruit (an estimate of survival) which must be maintained for the stock to be sustainable. The fishing mortality (conditional on the assumed exploitation pattern) to which this biomass-per-recruit value corresponds may be determined from the plot of the relationship between these quantities and yield the estimate of F-med".

Despite ACFM's assurance that the procedure is very simple, some biologists (and managers) still have some problems in understanding what is actually being done, and as a consequence, few people are questioning the validity of F-med as a management objective. Yet, the value of F-med is only a kind of average for some historic period when the fishery was sustainable. If the fishery has traditionally exploited the stock at a low level, F-med will be automatically be low. This is the case for instance in Div VIa South, VIIb,c, where F-med is 0.24. In the North Sea, where exploitation has always been more intensive, the calculated F-med is 0.35. So, F-med is nothing more than the average F in periods when the fishery did not collapse. The fact that catches at that level were sustainable does not necessarily mean that the fishery was managed in an optimum way. Stocks may either have been underexploited, or exploited at an uneconomically high level. In fact, one does not need much fisheries research to manage a fishery at a level that has empirically been shown to be sustainable.

F-low and F-high

These values are calculated in the same way as F-med; only in this case the line in the stock/recruitment plot is drawn in such a way that either 90% or 10% of the points are left above the line. As these reference points usually are extreme values, they are seldom recommended as target F.

F-status quo (F-sq)

The fishing mortality which corresponds to the present situation. This value has no biological meaning at all, as it will change each year.

3. Towards a restricted choice of target fishing mortalities

The above review shows that all biological reference points are subject to variation if the nature of the fisheries changes. Moreover, nearly all of them contain an arbitrary element. The conclusion must be that none of them has unique characteristics from a scientific point of view, and that there are no scientific arguments to restrict the choice of target-F to the specific reference points of a particular fishery.

Biological reference points can only be used to indicate an approximate range of safe management options. The size of this range may be estimated from an inspection of the various reference points in a number of stocks (table 2).

The lower limit of realistic management options may be set at about $F=0.15$. This value corresponds with the average F -opt in most stocks. Below this value, the fishery only takes a fraction of the potential harvest, and the stock is underexploited.

The upper limit could be set at the level of F -med values found in some fully exploited herring stocks. This value is around 0.35 for the North Sea and Div VIa North. An increase in F above 0.35 does not result in an appreciable increase in yield, but it reduces stock size and thereby leads to stronger catch fluctuations.

The range of safe management options would thus extend from about $F=0.15$ to $F=0.35$. Within this range, there is no point in arguing about subtle differences, such as whether to choose 0.29 instead of 0.30. Such differences are within the margins of error on the assessment (and within the variations of reference points for one stock).

Fishery managers should not be faced with too many options for target F . If the choice is too large, they will be inclined to change target F from one year to another, in order to meet short-term demands from the industry. The stock situation reached after say 10 years will depend more on chance than strategy.

A more rational approach would be to define 2 or 3 clearly distinct options, resulting either in a situation of relatively large stock size, or in relatively low stock size. Which of these options is selected for a particular fishery depends on a number of considerations, some of which are mentioned below. Once a particular option is chosen, actual fishing mortality should be stepwise adjusted until it reaches the desired target level, and then kept at this level for at least the next ten years. It is only this type of consistent management that will allow scientists to collect sufficient empirical data on the effects of different levels of stock size, both on the herring themselves and on the other species in the ecosystem.

Considering the above range of safe biological values (0.15-0.35), it is suggested to use only $F=0.20$ and $F=0.30$ as standard options for most herring stocks. Both options are sufficiently different to result in clearly distinct stock situations, the first one giving a stabilised spawning stock about 50% higher than the second one. Yet both options are well within the safe biological range; they will provide about the same average annual yield, and keep the stock out of the stock/recruitment danger zone.

4. Factors involved in the selection of a long-term target F.

A number of aspects should be considered when making a deliberate choice between a relatively low (0.20) or high (0.30) target F. Some of these aspects are well known; others are seldom mentioned in assessment reports.

Yield/recruit

Both the F=0.20 and F=0.30 option result in Y/R values that are close to the maximum of the yield curve. Therefore, this aspect is not very important in making the choice.

Recruitment variability

Stocks, with irregular occurrence of strong year classes should be exploited at a low value, in order to maintain a large buffer stock. In such cases, the F=0.20 option should be taken.

Effects on other fish stocks

Although little or no scientific evidence is yet available concerning the effects of a large herring stock on other fish species, the possibility of species interactions cannot be ruled out at this stage. In the North Sea, periods of herring scarcity have coincided with strong recruitment in cod, and periods of herring abundance with poor recruitment in cod. A large herring stock in the North Sea might also have a negative effect on species like sprat, plaice, sandeel and Norway pout. In such a situation, it would be prudent not to increase the herring stock too dramatically until more information on species interactions has become available. The F=0.30 option would therefore be preferable.

Density dependant growth

Again, for most herring stocks no evidence exists for the occurrence of density dependant growth among adult fish. Yet the possibility of reduced growth at extreme stock sizes cannot be ruled out, and if this risk is suspected, F=0.30 would be preferable.

Market preferences for certain size categories

The choice of target F for a certain stock will determine the long-term age composition of the stock, and thereby the average length composition of the catches. In fisheries where large herring are preferred, the F=0.20 option would be advisable.

5. Changing F towards the long-term target value

After a review of all aspects mentioned above, biologists and managers should not have too much problems in selecting one of the two options as target F for a particular herring fishery. The next step is to bring the current F in line with the long-term target.

Adjusting F towards the target F should preferably be done without drastic short-term changes in recommended TAC. The change in North Sea herring TAC from 235 000 t in 1986 to 600 000 t in 1987 is an example of how it should not be done. A reasonable criterion is to change recommended TACs by not more than 10% from one year to another. This will enable the industry to adjust to the change in catch level. As stock assessments generally fluctuate more strongly than the fish stocks themselves (Brander 1987), the 10% rule will also buffer the advice against errors in assessment.

In case F has to be reduced below the present level, advantage should be taken of the occurrence of strong year classes. These will allow F to be reduced, without strongly reducing the TAC.

7. References

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Table 1. Most recent advice on herring stocks provided by ACFM
(Anon 1989, 1990)

stock	recom.F	arguments
Div IVa,b	0.30	will allow some increase in SSB
Subdiv 22-24 and Div IIIa	0.61	reduction by 20% from F88 in order to stabilise SSB
Div VIa North	0.16	F-opt; will maintain buffer stock
Clyde	0.21	F-status quo
Div VIa South	0.24	F-med
Icelandic summer spawners	0.22	F-opt
Norwegian spring spawners	0.05	lowest practicable level

Table 2. Biological reference points for various herring stocks

stock	F-opt	Fmed	Fmax
North Sea	0.14	0.35	0.65
Subdiv 22-24, Div IIIa	0.22		0.53
Div VIa North	0.16	0.35	> 1.00
Clyde	0.13		
Div VIa South, VIIb,c	0.16	0.24	> 1.00
Icelandic summer spawners	0.22		0.51
Norwegian spring spawners	0.17		> 1.00