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The "one and only" Management Objective of fishery biologists

by

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Abstract

The provision of advice on fisheries management requires the formulation of appropriate management objectives. Although this is primarily a task for managers, biologists have a specific responsibility for ensuring that stocks remain at a sustainable level. In particular they can help in defining the limits in the levels of exploitation of a stock which reduces the probability of stock collapse to an acceptable risk.

This paper describes an approach how to determine such limits using one out of many possible long term models. Since it is desirable that advice is consistent from one year to another, robust parameters should be sought. An example is given for North Sea sole. Short term and long term considerations in the relation to the provision of advice are discussed.

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1. Introduction

Many of the exploited marine fish and shellfish stocks are managed in some way or another by applying restrictions to the fisheries. The responsibility for the management of these stocks is often at the level of governmental or inter-governmental bodies or may be delegated to the industry. The management objectives may take into account a variety of social, political, economic and conservation arguments; but because these lead to conflicting views, the objectives are often defined in rather broad terms. For instance the objectives of the Common Fisheries Policy (CFP) of the European Union (EU), laid down in Council Regulation (EEC) No.170/83 and 3760/92 are "to provide for rational and responsible exploitation of living aquatic resources and of aquaculture, while recognizing the interest of the fisheries in its long term development and its economic and social conditions and the interest of the consumers taking into account the biological constraints with due respect to the marine ecosystem."

Horwood and Griffith (1992) paraphrased the specific objectives of the CFP as to increase productivity, to produce efficiently, to stabilize markets, to ensure continuity of supply, to allow fair prices for consumers, and, in doing so, to give attention to the regional social structure within fisheries. It is obvious that all management objectives can not be met simultaneously and even may be conflicting. Therefore operational compromises have to be found.

In defining management objectives and associated measures, managers may wish to seek advice from experts, such as fishery biologists, economists and technicians. In the EU advice is given by the Scientific, Technical and Economic Committee for fisheries (STECF) of the Commission and by the Advisory Committee on Fishery Management (ACFM) of the International Council for the Exploration of the Sea (ICES). This paper will only concentrate on the biological advice.

It is clear that all fisheries management objectives depend on the availability of exploitable fish stocks. Thus the main task of fishery biologists is to give management advice which ensures that these stocks are maintained at sustainable levels in the short and the long term. This has lead to the concept of safe biological limits. In the past, ACFM has used various reference points on the equilibrium yield per recruit curve in defining its advice such as MSY, F_{max}, $F_{0.1}$, $F_{present}$, F_{high}, and F_{low}. A historical review on the use of these reference points in fishery management advice by ACFM is given by Serchuk and Grainger (1992). Although imbedded in the biology of a species, these reference points may not be interpreted as providing biological objectives since their selection may include non-biological arguments such as for example optimization of catches.

In 1991, ACFM introduced the concept of the "minimum biologically acceptable level" (MBAL) of spawning stock biomass (SSB) as a basis for classification of the state of the stocks into categories of the level of exploitation (ACFM, 1991). MBAL is defined on the basis of empirical information. In stocks for which there is ample information on historic stock sizes and recruitment, MBAL can be defined by the level of SSB below which the data indicate that the probability of poor recruitment increases. In stocks which have not shown a reduction in recruitment at low levels of SSB in the past and in stocks for which information is limited, it is considered safe to assume that MBAL is equal to the lowest level of SSB so far recorded. In that case MBAL should be considered as effectively a "safe historical limit" rather than a safe biological limit.

It must be emphasized that at present MBAL is defined on the basis of single stock assessments and does not take into account multi-species and ecosystem considerations. Since fish stocks serve as a food resource for many other marine organisms, including fish, birds and mammals, it may be desirable to develop other criteria for defining MBAL which take these requirements into account. Regardless of the way MBAL is defined, it is evident that the maintenance of a minimum spawning stock is a *conditio sine qua non* for the sustainability of the resources and is therefore the major or may be "one and only" "objective" in the area of responsibility of fishery biologists for providing advice.

2. Interpretation of MBAL

Although the concept of MBAL was introduced as a reference point for classification of exploited fish stocks, it may also be used in relation to management objectives, since management must be aimed ay maintaining or bringing stocks above this level. There is, however, a risk of misinterpretation of MBAL. Corten (1993) gives some examples and a discussion of recent problems which are arisen by the fishery managers interpretation of MBAL .

It may be tempting for managers to interpret MBAL directly as a short term target and to loose existing restrictions on the exploitation of a stock in order to approach the MBAL level. In many cases this may ease problems of enforcement for a while and accommodate requests from the industry for more fish. In that case, however, the stocks would have to be steered close to the rim of the abyss. In principle, there are no biological objections in doing so as long the minimum level is appropriately defined and the stock can be accurately estimated. However, this procedure requires management measures which can be strictly enforced. Exploiting a stock near the minimum level increases the probability that it will decrease below this level in any particular year. Thus, in order to prevent the stock from falling below MBAL, managers should be prepared to take effective immediate measures from one year to another to control fishing mortality which might be very drastic indeed. Apart from the experience in the past that such measures are very difficult to achieve, they will almost certainly be in conflict with other "non-biological" objectives, such as continuity of supply, survival of the industry and social stability.

Therefore a better approach would be to consider MBAL as a boundary condition for formulating a long term objective. Following this interpretation, management should be aimed at creating a situation in the fisheries which minimizes the probability that SSB drops below the minimum level. In practice this would mean of course that stocks are maintained at higher levels of biomass so that the need for taking severe management measures in any particular year would be avoided. This would obviously improve the compatibility with "non-biological" management objectives, because severe measures are bound to be disruptive for the industry.

This paper provides a model which can help in defining a long term management objective and providing appropriate biological advice to meet this objective.

3. A long term model

A number of models have been developed for long term catch and stock prognoses. The most widely used models are the traditional Yield per Recruit and Biomass per Recruit which describe the average equilibrium yield and biomass for varying levels of fishing mortality, irrespective of variations in recruitment. The underlying assumptions are constant weight at age, constant natural mortality and a constant maturity-ogive. More sophisticated models exist (Anon., 1993), which can take account of observed or assumed stock-recruitment relationships and density dependent growth.

The input parameters used in such analyses are average values and therefore the results represent the average situation. In practice yields and biomasses will fluctuate around that average. In fact, each point on the curve is the average of a distribution of possible yields and biomasses. We are interested in these distributions, because they provide information on the probability of the stock to be above or below a certain level for a given level of exploitation. These probability distributions may be used to define a level of exploitation which minimizes the probability that the biomass of the stock drops below MBAL to any acceptable degree.

The most important parameter responsible for variations in yield and biomass is recruitment variability. For many heavily exploited fish stocks this variability is reasonably well known and on the basis of certain assumptions this information can be used to define the distribution of each point on the yield and biomass curves due to this variation.

A model has been developed to estimate the variability in long term yield and SSB due to recruitment by implementing the observed variability in the traditional model. The model is actually a catch prediction program which runs over a large number of years with recruitment as the only variable input parameter. Random recruitment is taken in each year from the observed distribution described by a spline function (Burden et all. 1981). The reason of using the spline function is that it can describe any type of distribution. Extremely poor and extremely good year classes appear in the same frequency as has been observed historically. The other input parameters for the model are the same as for the traditional Yield per Recruit : exploitation pattern, natural mortality by age, maturity-ogive and weight at age in the catch and in the stock. An application of the model has been programmed in PASCAL and has been used in the 1993 Working Group on the Assessment of Demersal Stocks in the North Sea under the name "SPLIR" (Anon., 1994).

For defined levels of average fishing mortality the output gives the average yield, biomass and SSB, as well as the arithmetic and geometric mean from the recruitments generated from the spline function. The distribution of the the Yields and SSB's are presented as cumulative probability distributions.

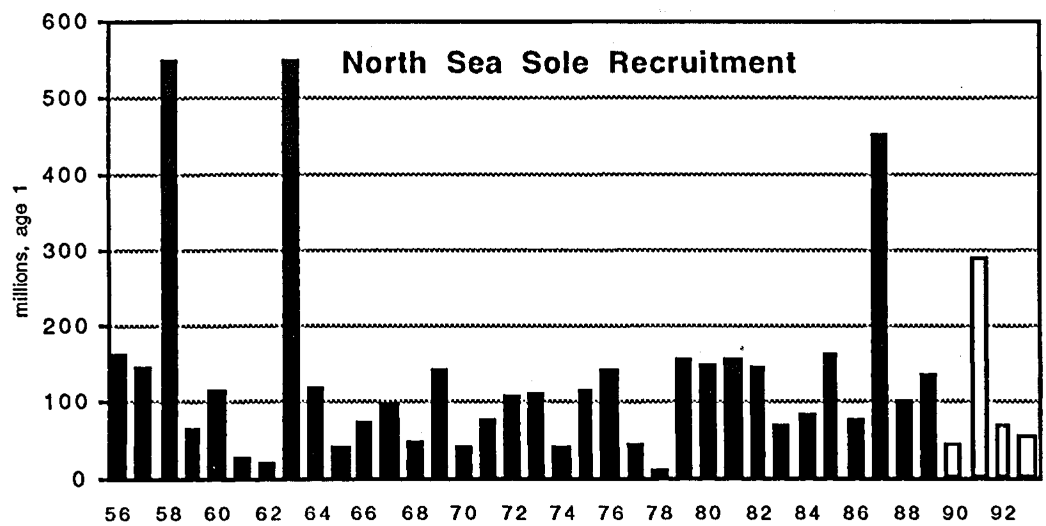
An example of the application of the model to data for North Sea sole is given below. Table 1 gives the input data used in the analyses (Anon., 1994), which are averages over the years 1990-1992. The average exploitation pattern is scaled to the fishing mortality in 1992.

Table 1 Input parameters for the model

age,	exploitation pattern,	M,	maturity, ogive,	weight, catch,	weight stock
1,	0.004,	0.100,	0.000,	0.133,	0.050
2,	0.180,	0.100,	0.000,	0.182,	0.147
3,	0.556,	0.100,	1.000,	0.216,	0.194
4,	0.599,	0.100,	1.000,	0.270,	0.268
5,	0.612,	0.100,	1.000,	0.327,	0.321
6,	0.506,	0.100,	1.000,	0.400,	0.414
7,	0.548,	0.100,	1.000,	0.416,	0.410
8,	0.515,	0.100,	1.000,	0.472,	0.486
9,	0.520,	0.100,	1.000,	0.482,	0.501
10,	0.425,	0.100,	1.000,	0.547,	0.526
11,	0.436,	0.100,	1.000,	0.578,	0.560
12,	0.878,	0.100,	1.000,	0.500,	0.514
13,	0.713,	0.100,	1.000,	0.677,	0.602
14,	0.677,	0.100,	1.000,	0.669,	0.746
15+,	0.677,	0.100,	1.000,	0.676,	0.676

Recruitment estimates are available for a period of 37 years from VPA and recruitment surveys for the year classes 1956-1992. These are shown in Figure 1. For the calculation of the spline, describing the year class distribution the values were arranged in ascending order.

Figure 1 Recruitment distribution used in the analyses



Average recruitment in this series is 133 million 1-year-olds (arithmetic mean) or 97 million (geometric mean).

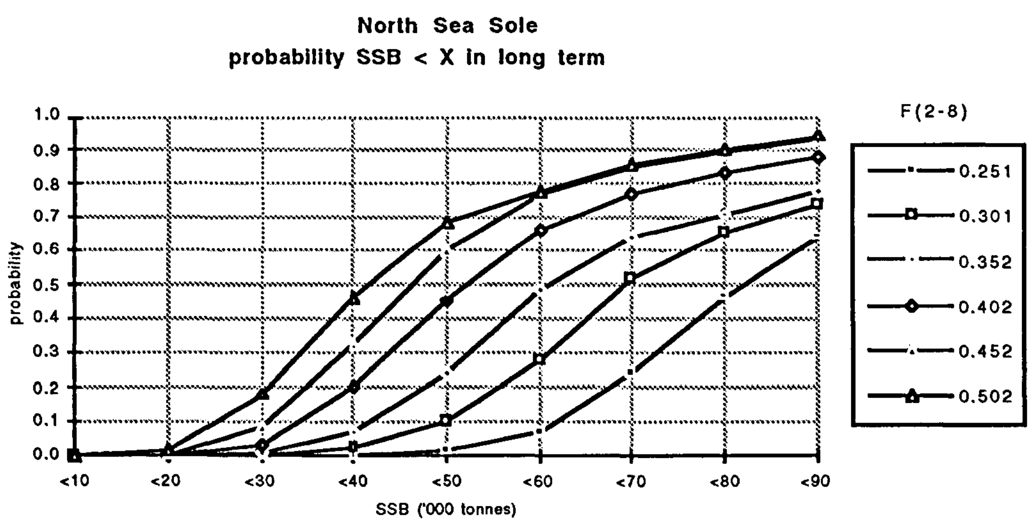
The fishery was simulated over a period of 1000 years with F-factors ranging between 0.5 and 1.0 with steps of 0.1, applied to the exploitation pattern in 1992. The average yields, biomasses and recruitment, estimated by the model are given in Table 2. The cumulative probability distribution for SSB is given in 10 intervals with an interval size of 10 thousand tonnes (Figure 2).

table 2 Results of the model

F-factor,	F(2-8),	AM recruits,	GM recruits,	Yield,	SB,	SSB,
0.5,	0.251,	121,	93,	23,	112	90
0.6,	0.301,	123,	93,	23,	99	75
0.7,	0.352,	134,	98,	25,	95	71
0.8,	0.402,	127,	93,	24,	81	58
0.9,	0.452,	125,	95,	23,	74	51
1.0,	0.502,	130,	95,	24,	71	47

The simulated average recruitment over the years in the runs is close to that in the observed recruitment distribution. The simulated recruitment , however, is not exactly the same and differs also between runs, because a different random set of recruitment is generated for each run. The average yield is constant, which reflects the flat-topped yield curve, characteristic for this stock.

Figure 2 Probability curves of SSB for different levels of F



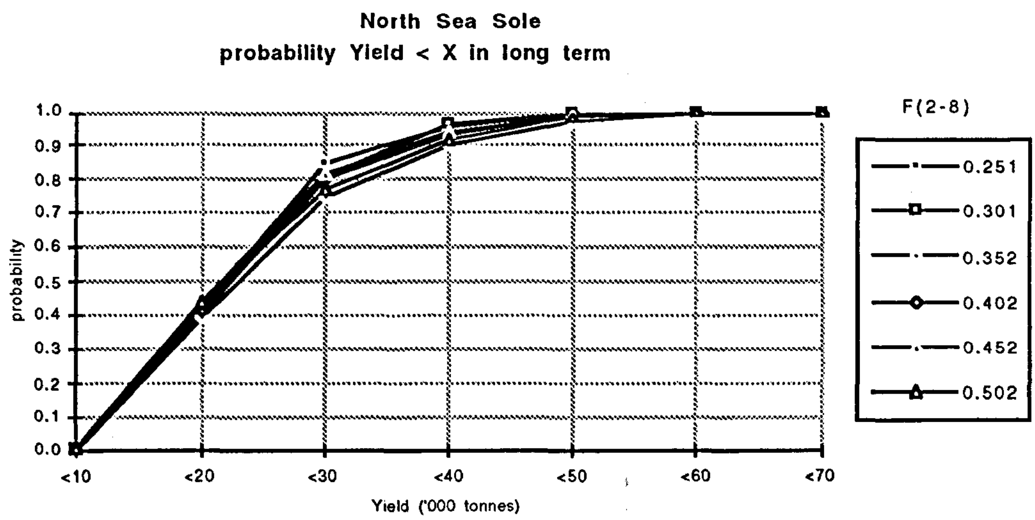
In principle, the SSB values in the figure corresponding to the cumulative 50% probability of SSB represent the median of the distributions of expected SSB's. These values should be close to the average, if the distribution is a normal one. The curve for an average fishing mortality of 0.502 corresponds with an F-factor of 1.0 in 1992. The average long term SSB for this level of F is 47 thousand tonnes. According to the figure, SSB will be below that level in about 60% of the years.

The slope of the cumulative probability curves depends on the rate of exploitation and the variability of the recruitment. Higher levels of fishing mortality lead to steeper slopes. Also stocks with less variability in recruitment will show steeper slopes. In the ultimate case of constant recruitment the curves will be knife-edged. The dependency of the variability of the SSB distribution on recruitment variability is important, since with the same risk - a probability of SSB falling below a certain level - stocks with less variable recruitment can be exploited at a higher level of fishing mortality than stocks with more variable recruitment.

Different values of SSB have been suggested in the past as a minimum acceptable level for North Sea sole, but it is beyond the scope of this paper to discuss these in detail. However, the stock-recruitment plot shows no indications of reduced recruitment at low levels of spawning biomass in the historical series. Since recruitment is uncertain at SSB levels below 35 thousand tonnes, it has recently been suggested that MBAL should not be set below 35 thousand tonnes (Anon.,1994). If it would be considered desirable that the stock never decreases below that level in the long term, the probability curves indicate that a reduction of fishing mortality by 40-50% compared to the present level is required. However, if a probability of 10% of the stock being below 35 thousand tonnes would be acceptable, a reduction by 20%, corresponding to an average F of 0.400, would be sufficient.

Such a model would seem useful to translate the MBAL concept into a long term management objective of an appropriate level of fishing mortality, because the latter can be defined with an associated intended risk.

Figure 2 Probability curves of Yield for different levels of F



Similar probability curves are derived for the long term yield (Figure 3). The average annual yield is about 23 thousand tonnes and the distribution of yields is virtually the same for all considered levels of fishing mortality, because of the flat-topped yield/recruit curve characteristic for this stock. In fact, Figure 3 suggests that there is nothing to gain or loose by a reduction of fishing mortality in the long term. This may, however, not be true if recruitment decreases at levels of biomass below 35 thousand tonnes. In this example, stock biomasses below this level represent unknown territory but "normal" recruitment has been assumed. However, the number of occasions when the stock is below this arbitrary chosen value is significant at high levels of fishing mortality. Therefore, this implementation of the model may overestimate the yields and biomasses at the higher levels of F and the probabilities in Figures 2 and 3 on the left side of the curves at the higher levels of F may be underestimated.

This problem may not be as serious as it looks, since we are mainly interested in those options which keep the stock outside unknown territory. It would, however, be more conservative and therefore preferable to include a stock/recruitment relationship in the model, as used by Skagen (1991) in a comparable model for medium-term stock projections also using stochastic recruitment. A comparison and discussion of both models is given in the Report of the Working Group on Long-Term Management Measures (Anon., 1993).

The results of the model presented here are robust from one year to another, because the input parameters represent average values over a number of years and the distribution of observed recruitments. These will change little from year to year. The results will, however, be less robust to changes in weight or maturation at age. Such changes have been observed in many species. The causes for these are often unclear but for flatfish they may include for instance density, eutrophication, temperature and beam trawl effort (Rijnsdorp. 1994). It may be possible to take account of the effect of some of these factors to some extent in a long term model. However, other long term projection models, presently in use, have the same disability. Therefore the results of these models should be considered with care, especially when they are extrapolated outside observed historical limits.

As stated before, the model uses random recruitment from a function describing a given recruitment distribution. It does not take account of any time trends in the data. When there are indications for trends such as observed in North Sea cod (Daan and Heessen, 1993) and North Sea herring (Corten 1986), a different approach would be required. Also in situations where poor and good recruitments alternate or appear random it may well be that the SSB never or only occasionally decreases below a specified threshold. However, when within the same recruitment distribution periods of good and poor recruitment can be distinguished, this has an effect on the probability distribution of SSB's. In such situations the present model may give a too optimistic view by underestimating these events.

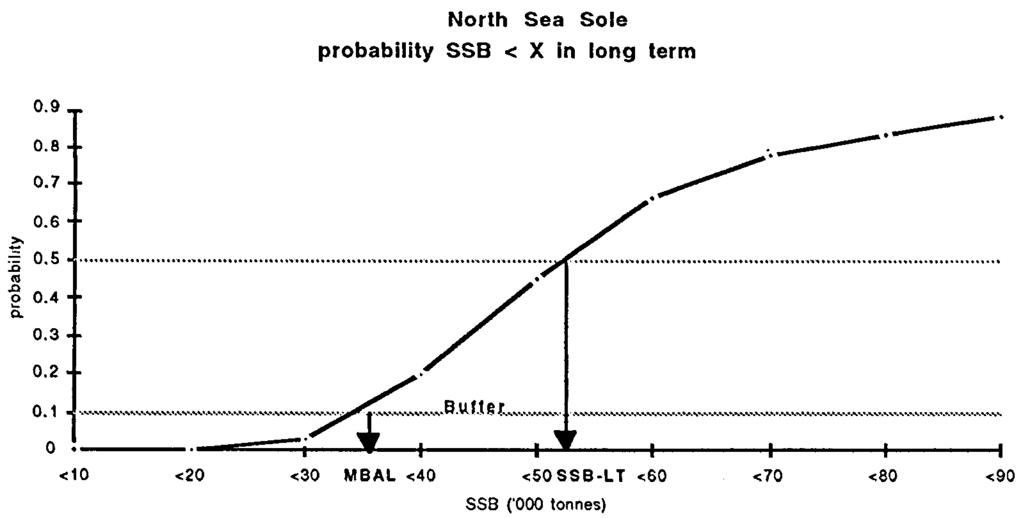
It should be noted that the model does not help to define a minimum acceptable level of SSB. It helps only to identify the level of fishing mortality which minimizes the risk that SSB drops below a preferred level of SSB to any definable degree. Managing the fishery at this level of mortality is one out of many possible strategies to achieve this. Also the choice of which probability is acceptable to managers is not a biological issue.

4. A short term application of a long term model

This type of model is developed particularly to evaluate long term strategies. However, the present model, and associated long term models, can also be used for giving advice on mid and short term management. In the presently accepted procedures, ACFM gives specific management advice only when the stock is already below or is expected to drop below MBAL. In fact this advice may be coming too late because the damage may already have been done. The following procedure might help to prevent this situation.

The long term equilibrium SSB (SSB_{LT}) associated with a preferred level of long term fishing mortality is larger than MBAL. The difference between SSB_{LT} and MBAL depends on the slope of the cumulative probability curve of the expected biomass (Figure 3). More generally the difference will be associated with the variability of recruitment. The difference will be smaller in stocks with less variable recruitment.

Figure 3 Probability curves with reference points and management buffer



In order to minimize the risk that SSB drops below MBAL, short term TAC advice might be given whenever the stock decreases below SSB_{LT}. The difference between SSB_{LT} and MBAL could be interpreted as a buffer and SSB_{LT} could be interpreted as an appropriate management target. The advantage of this procedure is that it is rather simple compared to other methods used for short term risk analyses. It is also a straightforward and objective procedure, which takes recruitment variability into account as a basis for defining the required buffer.

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