NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N2988 NAFO SCR Doc. 98/12

SCIENTIFIC COUNCIL MEETING - MARCH 1998

In Search of Stability How to Halt the Decline of Fish Stocks

by

Ewen Bell and Gunnar Stefánsson

Marine Research Institute, P. O. Box 1390
Skulagata 4, 121-Reykjavik, Iceland

Introduction

Several meetings (COMFIE 1997, SGPAFM 1996, 1998) have addressed the issue of how fish stocks should be utilised in accordance with the precautionary approach, yet in such a fashion as to allow harvests to be taken from the fish stock. The obvious problem with most suggested procedures is their reliance on fishing mortality and stock biomass or removal estimates and such estimates are only available for a fraction of most fish stocks. The following presents a method which may alleviate this and at least attain stability and improved future catches from a continued over exploitation.

This paper focuses on two sections, firstly how to bring a collapsing fishery back to sustainable levels and secondly how to extend the scope of limit reference points to non age based analyses.

As a minimum we will assume that a series of catches (Y_t) and a commercial or survey CPUE relative abundance index (U_t) are available. Furthermore, we assume that the stock has been fished quite heavily, has been reduced to well below optimum levels and is on a continued decline. In this case any control rule would at least have to halt the decline. This is the intention of the following design.

A simple quote rule would set next year's quote as a function of this year's quota and recent biomass changes. Denote the current present relative change in biomass by $\bullet_t$, which could for example be estimated with $\bullet_t=((U_{t-1}-U_{t-2})/U_{t-2}$ but smoother estimates may be desirable.

The Magnússon-Stefánsson procedure is partially based on scaling the future quota (i.e. intended catch) according to the change in CPUE (although several modifications exist):

$Q_t=Y_{t-1}(1+g\bullet_t)$

$$Y_t = Y_{t-1}\left[1+g\frac{B_{t-1}-B_{t-2}}{B_{t-2}}\right]$$

where g is termed the feedback gain.

Limit reference points must be estimated from the time series used as the relative abundance index, in this case it is used as a proxy for BMSY. A target reference point (U_{pa}) was set as half of the 95th percentile, with the limit reference (U_{lim}) point set to half of the target.

This paper analyses projected stock size and yield for 33 *ICES* stocks, all of which undergo a full age based analysis. The advantage in using these stocks is that calculation of key stock attributes (MSY, BMSY, Fcrash etc.) *is* possible for assessment of the performance of the model. The simulation model used is mostly the same as that presented in NAFO SCR Doc. 98/7.

Method

Each time step consists of fishery management, implementation of advice, stock recruitment and an assessment. Advice in the form of quotas is derived using only assessment data and catch records. Implementation translates the quota into a required fishing mortality which is then used in conjunction with a selection pattern derived from the historical data.

Recruitment to the stock is governed by Ricker functions, the parameters being estimated outside the model from historical SSB and Recruit data. Realised recruitment is a normally distributed random function using the CV obtained from fitting the Ricker parameters.

The assessment is a normally distributed random function of the true SSB with a CV of 0.35. The relative abundance index (U) in this example is taken to be the observed SSB (real SSB*error), but could in practice be any fraction.

As previously suggested, the relative change in abundance may require smoothing, and preliminary analyses confirm this need. Failure to smooth means that although the overall trend may be for an increase in U (and therefore SSB), error in stock measurement for year t-1 may result in a lower estimate of U and thus a reduced quota being set. The net effect of this is that the fishery remains at an excessively low level and never approaches MSY. Greater smoothing reduces the chance of erroneous catch changes during sustained growth or decline, but reduces and delays change when the index reaches an inflexion point. This leads to an unsustainable fishery at the start of periods of stock decline, forcing the population down even more rapidly. Relative change is therefore taken as the difference between U_{t-1} and the mean of U_{t-2} and U_{t-3}.

Reopening of closed fisheries is a contentious issue but is an essential component of this model. Large reductions in U with low yields often result in the closure of a fishery. The threshold U for reopening is U_{lim} with a quota of $0.2*U_{lim}$. If U has increased beyond U_{pa}, the fishery is reopened with $0.2*U_{pa}$.

The pseudo-biological reference points are also used to make management action more drastic as the SSB index passes between them. When U falls below U_{lim}, the fishery is closed. When U is above U_{pa}, there is no restriction. As U drops from U_{pa} to U_{lim}, the advised quota is reduced to zero in a linear manner. This is formalised as follows.

$$Y_t = Y_{t-1}\left[1 + g\frac{B_{t-1} - B_{t-2}}{B_{t-2}}\right] \times q$$

when $U_{t-1} < U_{lim}$, q=0

When $U_{lim} < U_{t-1} < U_{pa}$, $q = \frac{U_{pa} - U_{t-1}}{U_{pa} - U_{lim}}$

When $U_{t-1} > U_{pa}$, q=1

If the stock is seen to decline whilst U_{t-1} is greater than U_{pa}, the quota is held constant. This prevents reacting to natural stock reduction due to density dependence until fishing mortality is likely to be a significant proportion of total mortality.

As in our previous evaluation of harvest control rules (NAFO SCR Doc. 98/7) a limit can be placed on the degree of acceptable interannual change in the quota (delta). Highly variable quotas are undesirable as they create instability in the whole fishing industry, thus it seems sensible to limit the amount of change from one year to the next. The range of deltas examined here are 0.25, 0.33, 0.50 and 1 (unlimited change). A delta of 0.25 implies that quotas will change by up to 25% from one year to the next.

100 simulations were run for each combination of g and delta. with each simulation projecting stock size and harvest for 30 years.

Results

The most important criterion under this type of management is the probability of failing to halt the stock's decline and thus driving the stock to extinction. Determining suitable levels of G and delta must take this probability into account, and there should be an extremely low probability of extinction occurring. Table 1 shows the percentage of stocks which become extinct on more than 1% of simulations.

Table 1. Percentage of 33 ICES stocks which became extinct in more than 1% of simulations (100).

	G			
Delta	0.5	1	1.5	2
0.25	76	73	76	67
0.33	70	67	73	67
0.5	64	67	67	67
1	0	0	3	12

Varying G appears to have little effect on the probability of stock extinction, although there is a decrease in the range of probabilities at G=2. Delta, on the other hand, has a large influence on the probability of stock extinction. Using delta=4 (restricting interannual quota change to 25%) will drive 76% of stocks to extinction with a 1% probability.

Increasing the extinction tolerance from 1% to 10% of occasions makes relatively little impact on the percentage of stocks becoming extinct, emphasising the extreme vulnerability of some stocks to insensitive management.

Table 2. Percentage of 33 ICES stocks which became extinct in more that 10% of simulations (100).

	G			
Delta	0.5	1	1.5	2
0.25	67	67	67	67
0.33	64	67	67	64
0.5	36	48	55	55
1	0	0	0	0

Long term yield is the most important criterion for the fisherman. The following table (table 3) shows the mean yield (over all projections of all species) as a % of MSY.

Table 3. Long term average yield as a % of MSY over 33 ICES stocks.

	G			
Delta	0.5	1	1.5	2
0.25	47.2	48.4	47.6	48.1
0.33	53.2	54.4	53.3	53.7
0.5	56.1	59.3	58.3	58.1
1	52.6	60.1	65.9	68.6

Again, low deltas have the weakest performance. Long term yield is lower because the quotas do not increase quickly when the stock size rises, and are forced to fall again when the population crashes again. Allowing unlimited change provides the highest long term yield although quotas may fluctuate drastically. Varying G has no effect whilst interannual quotas variation is limited. Once there is unlimited change in the quota, however, increasing G is beneficial to long term yield. A high G means that during years of rapidly increasing stock size the quota can also be rapidly increased.

Figure 1 shows a forecast time series for Icelandic Cod using G=2 and delta=1. Initial yields are unsustainable and are rapidly reduced, although not before the stock collapses to dangerously low levels. There is then a period of stock rebuilding which the yield follows with a one year time lag. The stock then peaks and falls, but while U is above U_{pa} the yield is held constant. Once U drops below U_{pa} the yield is correspondingly reduced.

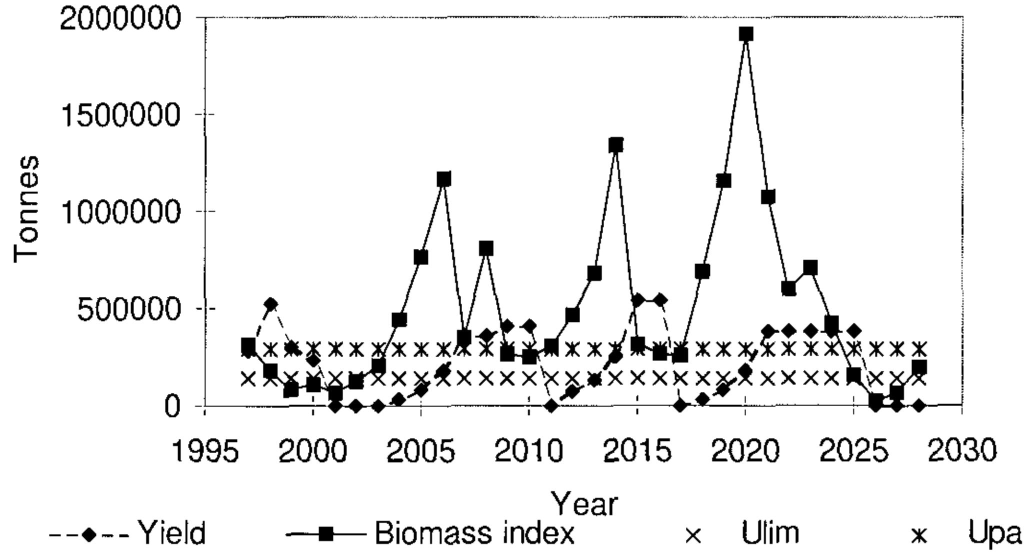

Figure 1. Forecast time series for Icelandic Cod using G=2 and delta=1.

Figure 2 shows another projection of Icelandic Cod, this time using G=1, delta=1. The rate of quota increase is slower resulting in a lower yield before the stock declines again. The advantage, however, lies in less overfishing at the start of stock decline. this is unavoidable due to the time lag involved in calculating changes in biomass index (U). The decreased overfishing results in a more rapid stock rebuilding.

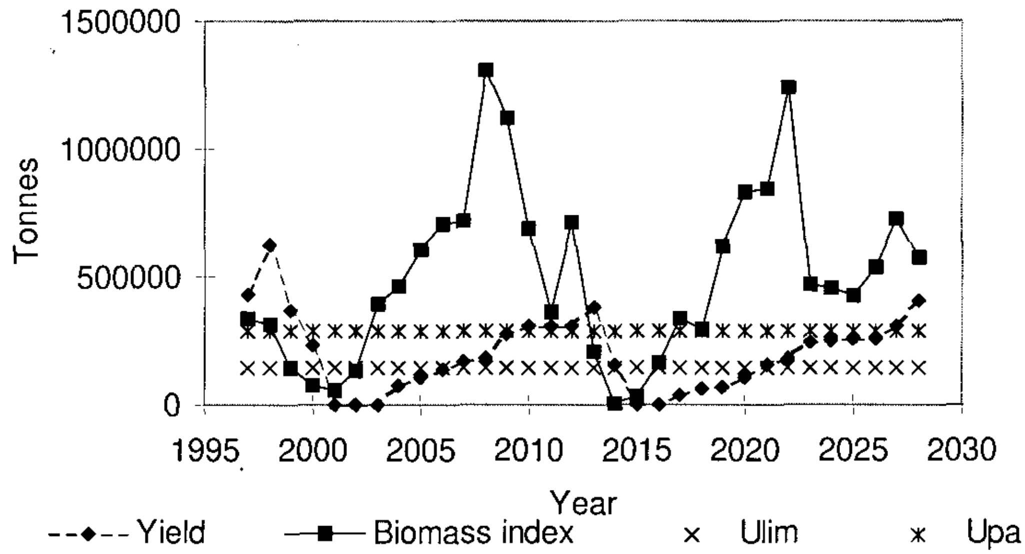

Figure 2. Forecast time series for Icelandic Cod using G=1 and delta=1.

Discussion

Contrary to the results of the HCR using age based data (NAFO SCR Doc. 98/7.) limiting the interannual catch change (Delta) is not advisable for the feedback gain method. The probability of stock extinction remains high for all but the most adaptable of HCRs, the flexibility required to act on rapid changes in stock status. The long term yield is also highest when using a delta of 1, thus there would appear to be no conflict of interests.

The level of feedback-gain (G) must be chosen sensitively. The figures for yield indicate that long term yields can be maximised through increasing G, however the probability of stock extinction also rises due to gross overfishing at the start of a stock decline. G=1 would appear to be a more sensible level.

The choice of U_{lim} and U_{pa} should be explored more carefully. In this investigation Upa was a proxy for BMSY and half of the 95^{th} percentile was not a good estimate of this, being between -40% and 120% out. In situations where the feedback-gain method is likely to be employed there are going to be very few measures of biomass on which to base Ulim and Upa. 20-25% of virgin biomass is currently the favoured approach.

The simple feedback procedure described and tested here has been extended and tested for marine mammals (Magnusson and Stefansson 1988). Some of the extensions include such smoothing, but the incorporation of catch "jumps" and some simple population estimation models in order to ensure convergence to specific targets has also been described.

Most importantly, however, it is quite clear that a progressive decline in "reasonable" stock indices can not be sustained for many decades: For a fishery to be sustainable the abundance must go up as much as it goes down. It is equally clear that not providing any advice in the light of decades of stock decline is contrary to operating within the PA.

One method to counteract this to some extent has been indicated in the present paper: A simple feedback method which proposes catch reductions by the same percentage as the observed reduction in the abundance index will do much better than no measure at all.

References

COMFIE (1997). Report of the Comprehensive Fishery Evaluation Working Group. ICES CM1997/Assess:15

SGPAFM (1997). Study Group on the Precautionary Approach to Fisheries Management. ICES CM 1997/Assess:7

SGPAFM (1998). Study Group on the Precautionary Approach to Fisheries Management. ICES CM 1998/Assess

Magnusson K.G. and Stefansson G. (1988). A feedback strategy to regulate catches from a whale stock. Report of the International Whaling Comission (Special issue II). pp 171-189).