Fisheries Research Services

Survey-based assessments with SURBA

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January 28, 2003

Working Document to the ICES Working Group on Methods of Fish Stock Assessment, Copenhagen, 29 January to 5 February 2003.

1 INTRODUCTION

Many of the fish stocks for which ICES provides fisheries management advice have declined rapidly in recent years, and several are now likely to be the subject of stringent management measures of one kind or another. The measures being proposed at the time of writing range from complete fishery closure to the familiar methods of quota restrictions and technical measures (partially closes areas, modified gear, and so on). The intention behind all this is to achieve stock recovery back to notionally sustainable levels, which would be to the long-term benefit of the fishing industry.

However, the proposed measures, while theoretically beneficial to the well-being of the stocks concerned, are likely to create severe difficulties for stock assessment scientists. Fishing vessels and quotas are expensive items, and we are told by industry representatives that many fishermen will be unable to withstand the economic impact of increased regulation. Some will doubtless seek decommissioning funding and leave the fleet, but some may continue to fish in defiance of any new restrictions. Of course, these skippers will not be able to land all their catch legally and will seek alternative markets. One obvious consequence of this will be a serious decline in the quality of reported landings data. Anecdotal evidence suggests that the ratio of illegal to legal landings could currently be as much as three-to-one in some areas. A recent development has been a threat by some skippers to refuse permission for scientists to sample their landings or discards, which will reduce the amount of data we can get on biological stock characteristics as well.

The standard assessment techniques that we use as members of ICES Working Groups are all based primarily on reported landings-at-age data. Data from research-vessel surveys are used, but only to "tune" estimates from the landings data which are considered to represent the "truth". Our current concern over the quality of reported landings-at-age data implies that these assessment methods might be generating misleading scientific advice to fisheries management, with serious implications for sustainability.

Therefore it is very important that we investigate thoroughly the potential of assessment methods based on data from research-vessel surveys. While such data are likely to have a greater variance than landings-at-age data, as they are collated from fewer samples, they are also under direct control and are unlikely to be affected by misreporting bias. Two Working Papers to recent ICES assessment Working Groups (Casey 2002, Needle 2002*a*) discussed the need for survey-based assessments, and presented relative-trend assessments for North Sea whiting using two simple methods (RCRV1A and RVS). A third WG paper (Needle 2002*b*) extended that work and applied a new model (SURBA 1.0) to the whiting stock in the West of Scotland (sub-area VIa). In this paper, I will extend further both the method and its description, and I will summarise the results of those SURBA applications reported thus far in Working Group reports.

2 SURBA 2.0

Cook (1997) described the results of applying a separable survey model called RCRV1A to survey data from six North Sea stocks, and showed (with some reservations) how survey data could be used to generate estimates of relative (not absolute) population trends. In this Section, I will describe briefly Cook's implementation, before summarising recent developments.

A separable model assumes that fishing mortality $\mathbf{F} = [F_{a,y}]$ is separable into an age effect $\mathbf{s} = [s_a]$ and a year effect $\mathbf{f} = [f_y]$, so that $\mathbf{F} = \mathbf{s} \times \mathbf{f}$. I use the term *temporal trend* in the rest of this paper to denote $\mathbf{f}$, as this avoids confusion with "year-effects" in residual plots. Suppose that the abundance of a particular cohort declines exponentially from one year to the next, so that

$$N_{a+1,y+1} = N_{a,y} \exp\left(-Z_y\right); \tag{1}$$

and that the rate of that decline is given by

$$Z_{a,y} = F_{a,y} + M_{a,y} = s_a f_y + M_{a,y},$$

where $M_{a,y}$ is the natural mortality rate on age a during year y. Then if a cohort recruits to the stock in year y with recruiting abundance r_y, we can calculate its abundance at age a as

$$\begin{aligned} N_{a,a-1+y} &= r_y \exp\left(-\sum_{i=1}^{a-1} Z_{i,i-1+y}\right) \\ &= r_y \exp\left(-\sum_{i=1}^{a-1} s_i f_{i-1+y} + M_{i,i-1+y}\right) \end{aligned} \tag{2}$$

That is, the abundance at age a is given by the abundance at the recruiting age multiplied by the exponential of the sum of the mortality rates in the intervening years. We will denote the vector of all recruiting abundances by $\mathbf{r} = [r_y]$.

In order to use relative abundance indices $I_{a,y}$ to estimate relative stock size, we assume a time-invariant proportional relationship between stock size and the abundance index. This is given by

$$I_{a,y} = q_a N_{a,y},$$

where q_a is the *catchability* of the survey at age a. Thus, a survey for which the abundance index was a reliable indicator of stock size at age a would have $q_a = 1.0$, while it could be that $q_a = 0.0$ for a survey which will never catch fish of the age in question (a gill-net survey will never take very large fish, for example). Then we can rewrite Equation 2 as

$$I_{a,a-1+y} = \frac{q_r}{q_a} I_{r,y} \exp\left(-\sum_{i=1}^{a-1} s_i f_{i-1+y} + M_{i,i-1+y}\right), \tag{3}$$

where q_r and $I_{r,y}$ are respectively the catchability and the abundance index values for the recruiting age of the cohort.

This expression gives us a model for how the abundance index evolves through time for any given cohort. However, we must still estimate mortality rates, and to do this we use a variation of the standard catch equation:

$$I_{a,y} = \frac{F_{a,y} N_{a,y} \left(1 - \exp\left(-s_a f_y - M_{a,y}\right)\right)}{s_a f_y + M_{a,y}}. \tag{4}$$

The RCRV1A model generates estimates for $\mathbf{s}$, $\mathbf{f}$ and $\mathbf{r}$ by minimising the sum-of-squares difference between observed and fitted survey-derived abundance,

$$\mathrm{SSQ} = \sum_{a=1}^{A} \sum_{y=1}^{Y} w_a \left(\ln I_{a,y} - \ln \hat{I}_{a,y} \right)^2,$$

where A is the number of ages, Y is the number of years, and $\mathbf{w} = [w_a]$ are age-weighting factors. The minimisation is carried out assuming a lognormal error distribution. The progressive decline in cohort size is modelled using Equation 3, and mortality is estimated from the abundance-index catch equation (Equation 4). However, the model as it stands is under-specified: since $\mathbf{s}$ and $\mathbf{f}$ are both estimated simultaneously, they can in theory take any number of nonsensical values. The RCRV1A solution to this is to fix the terminal value f_Y of the temporal trend in the terminal year, which is set so that the mean of all the temporal trends is 1.0: thus $f_Y = Y - \sum_{y=1}^{Y-1} f_y$. It is unfortunate that the terminal year is also the year of most interest to fisheries managers, and it may have been better to fix the first year instead. We must also provide a vector of catchabilities-at-age $\mathbf{q} = [q_a]$. There is currently no accepted method of determining empirically the catchability of a survey, so these values are arbitrary to a certain extent. Summary statistics (total stock biomass, spawning stock biomass, yield) are calculated in the usual manner.

In the original analyses, Cook (1997) found that the model fit could be extremely sensitive to noise in the data. He therefore introduced a *smoother* λ, which constrains the minimisation by a penalty function:

$$\mathrm{SSQ} = \sum_{a=1}^{A} \sum_{y=1}^{Y} w_a \left(\ln I_{a,y} - \ln \hat{I}_{a,y} \right)^2 + \lambda \sum_{y=1}^{Y} \left(\frac{f_y}{f_{y-1}} \right)^2.$$

Finally, we note that estimates of fishing mortality rates F are obtained from Equation 1, which can be rewritten as

$$F_{a,y} = \ln \left(\frac{N_{a,y}}{N_{a+1,y+1}} \right) - M_{a,y}.$$

So our mortality rate estimates are derived by looking at the ratios of abundances. Since the number of ratios will always be one less than the number of abundances, we can only estimate $A - 1$ age effects and $Y - 1$ temporal trends.

SURBA 2.0 (Survey-Based Assessment, version 2.0) is a recent development of RCRV1A. The basic method remains unchanged, but a user-friendly Windows interface with plotting capabilities has been added, and the following (more fundamental) modifications have been made:

1. Weights, proportion mature and natural mortality are read into the program as arrays, thus allowing variation through time as well as by age.

2. Estimation age weightings $\mathbf{w}$ may be entered manually. Alternatively, they can be calculated as the inverse of the variance of the survey index at that age, so that $w_a = \frac{n-1}{\sum_y \left(I_{a,y} - \bar{I} \right)^2}$ where n is the number of years in the survey time-series.

3. Problems arise if the model-fitting algorithm encounters zero index values. To avoid this, SURBA replaces such zero values with the lowest non-zero value at that age in the survey time-series, and reports that it has done so.

4. In RCRV1A, summary statistics (SSB, TSB, yield) were mean-standardised before output. This mean-standardisation did not include the last year, although the last-year value was printed. In SURBA, mean standardisation is done over the full time-series. Furthermore, mean F is now calculated from the $F_{a,y}$ array, rather than from scaled selectivity vectors.

5. The new model now includes a simple, deterministic forecasting capability. This is done by rolling the survey-estimated population forward through time, assuming fixed geometric mean recruitment and the fitted year and age effects.

SURBA 2.0 has been used so far to produce supporting assessments at the Working Group on the Assessment of Northern Shelf Demersal Stocks (ICES 2002*b*), and at the forecast subgroup of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (ICES 2002*a*).

3 EXAMPLES

3.1 North Sea cod: English Groundfish Survey

As an example of the results that SURBA provides, I have included here full input data and all SURBA plots for the North Sea autumn English Groundfish Survey (EngGFS) abundance indices on cod (1977–2002). I obtained these indices from the Appendix to the 2002 Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (ICES 2002*a*), from where I also obtained estimates of natural morality-at-age, proportion mature-at-age and stock weights-at-age. I used default age weightings, with age 0 observations given a weighting of 0.1 to reflect the likely scarcity of data at that age. I set default catchabilities ($q_0 = 0.04$, 1.0 otherwise) by experimenting with q_0 until I found a well-fitting value that didn't result in negative F estimates – the definition of catchability is a problem in SURBA that I will discuss further in § 4. Finally, I set the default selectivity vector to 1.0 for all ages (although this is not actually used in the current SURBA implementation). The input file is given in Table 1.

I have given all the output and plots (Figures 1 to 12) for a SURBA run with manual catchabilities and age-weightings (using the values in Table 1), and the F-smoother set to $\lambda = 1.0$. Figure 1 shows that the EngGFS survey tracks year-class strength through cohorts reasonably well, while Figure 2 shows that there are no substantial year-effects in the index. We see from Figure 3 that cohort abundance at older ages has been declining steadily throughout the time-series, although numbers at younger ages are more constant. Without further analysis, we cannot tell from this plot whether mortality (as indicated by the slope of the lines) has changed significantly. Similarly, we would find it difficult to support the popular hypothesis of reducing stock weights in North Sea cod from Figure 4. Figure 5 gives the fitted estimates of temporal trend, that is, the model proxy for the combination of fishing effort and mean natural mortality in the underlying population. The temporal trend has fluctuated around 1.0, and although it appears to have fallen in recent years, this may just be another fluctuation. Fitted age effects (Figure 6) show a flat-topped or even slightly domed selection pattern for stock mortality, while fitted cohort effects (Figure 7) are very low in recent years (supporting the VPA-derived assessment conclusion of weak recent year-classes). Following the summary plots of mean F_{2-4} (Figure 8) and relative SSB (Figure 9), SURBA gives a series of residual plots (Figure 10). We can see from these that age 0 is rather noisy, and that there are large residuals for ages 4 and 5, but that there is no overall pattern to residuals. This suggests that the assumption of a constant selection pattern might not be inappropriate. The final SURBA plots are given here as Figures 11 (observed and fitted index values) and 12 (catchability and age-weightings used in the assessment).

I have also given (Figure 13) a plot comparing the estimated relative SSB for this SURBA run with that from a series of alternative SURBA runs, and from the ICES WG assessment (ICES 2002*a*). In this comparison, and throughout the rest of the paper, I denote the alternative SURBA runs that I used as follows:

Run 1 Manual age-weightings (which will vary between stocks), F-smoother $\lambda = 1.0$ (the standard run).

Run 2 Inverse-variance age-weightings, F-smoother $\lambda = 1.0$.

Run 3 Manual age-weightings, F-smoother $\lambda = 0.5$.

Run 4 Inverse-variance age-weightings, F-smoother $\lambda = 0.5$.

Note that these settings do not necessarily result in very sensible models. Hence, the results I present here should be thought of as being exploratory. However, it is clear from Figure 13 that there is a close similarity between the information from the EngGFS survey (as modelled by SURBA) and that from the catch and survey data combined (as modelled by XSA). We can also see that the SURBA estimates are not particularly sensitive to the estimation settings used.

```
--- Title ---------------------------------------
Cod in IV EGFS Q3 (0-5 grp)
--- Number of ages ------------------------------
6
--- Number of years -----------------------------
26
--- First age -----------------------------------
0
--- First year ----------------------------------
1977
--- Plus-group flag (1 = plus-gp, 0 = not) ------
0
--- Index ---------------------------------------
1.389   6.270   0.447   0.324   0.057   0.011
1.256   2.284   1.250   0.099   0.099   0.013
1.855   2.423   0.580   0.200   0.027   0.036
1.023   5.084   0.670   0.153   0.073   0.011
7.424   1.136   1.386   0.128   0.038   0.040
0.255   3.237   0.290   0.329   0.053   0.037
9.510   1.540   1.096   0.120   0.110   0.029
0.038   6.122   0.475   0.178   0.041   0.021
0.828   0.430   1.189   0.107   0.056   0.020
0.121   3.438   0.115   0.202   0.029   0.011
0.038   1.422   1.065   0.028   0.061   0.015
1.678   0.836   0.407   0.198   0.001   0.042
0.598   2.285   0.248   0.118   0.061   0.006
0.383   0.608   0.504   0.061   0.014   0.012
4.840   0.752   0.155   0.073   0.013   0.004
1.684   2.440   0.159   0.046   0.036   0.008
0.377   0.742   0.650   0.082   0.016   0.016
2.134   2.637   0.295   0.154   0.019   0.005
0.026   1.028   1.277   0.119   0.056   0.002
4.133   0.673   0.725   0.171   0.019   0.020
0.005   4.044   0.284   0.054   0.025   0.001
0.389   0.118   1.396   0.082   0.008   0.007
0.095   0.367   0.055   0.236   0.013   0.006
0.040   0.953   0.197   0.015   0.032   0.000
0.026   0.174   0.528   0.032   0.002   0.005
0.019   0.789   0.146   0.127   0.017   0.000
--- Default age weightings ----------------------
0.10    1.00    1.00    1.00    1.00    1.00
--- Default catchabilities ----------------------
0.04    1.00    1.00    1.00    1.00    1.00
--- Catch-at-age selection pattern --------------
1.00    1.00    1.00    1.00    1.00    1.00
--- Mean F range --------------------------------
2       4
--- Num yrs for mean F, M, W, Mat, Rec, Forecasts
3       3       3       3       10      10
--- Natural mortality-at-age --------------------
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
2       0.8     0.35    0.25    0.2     0.2
--- Proportion mature-at-age --------------------
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
0       0.01    0.05    0.23    0.62    0.86
--- Stock weights-at-age ------------------------
0.009   0.307   0.837   2.299   3.7     7.086
0.009   0.237   1.028   2.585   4.519   6.718
0.005   0.248   0.826   2.456   4.881   6.695
0.011   0.225   0.901   2.578   4.282   6.643
0.012   0.27    0.746   2.62    4.992   8.6
0.006   0.247   0.895   2.223   5.015   7.75
0.006   0.252   0.954   2.097   4.201   6.585
0.005   0.203   0.815   2.312   3.839   7.163
0.008   0.219   0.632   2.634   4.95    7.309
0.006   0.202   0.835   1.88    3.97    8.518
0.008   0.232   0.724   2.458   3.919   5.982
0.008   0.328   0.813   2.248   2.534   6.586
0.011   0.245   0.878   1.874   4.309   4.652
0.011   0.302   0.805   2.215   3.521   6.17
0.01    0.273   1.021   2.28    4.595   6.355
0.01    0.231   1.18    3.067   5.683   7.424
0.011   0.183   0.871   2.591   6.657   7.898
0.008   0.157   0.59    2.054   5.31    8.816
0.005   0.201   0.712   2.101   4.644   8.231
0.006   0.209   0.673   1.817   3.443   6.718
0.002   0.15    0.687   2.038   4.548   4.3
0.027   0.297   0.47    1.211   4.025   5.08
0.011   0.245   0.655   1.155   3.2     7.837
0.008   0.201   0.848   2.231   3.533   0.000
0.006   0.19    0.511   1.773   3.801   5.551
0.009   0.258   0.783   1.595   4.119   0.000
```

Table 1: English Groundfish Survey of North Sea cod: SURBA input file.

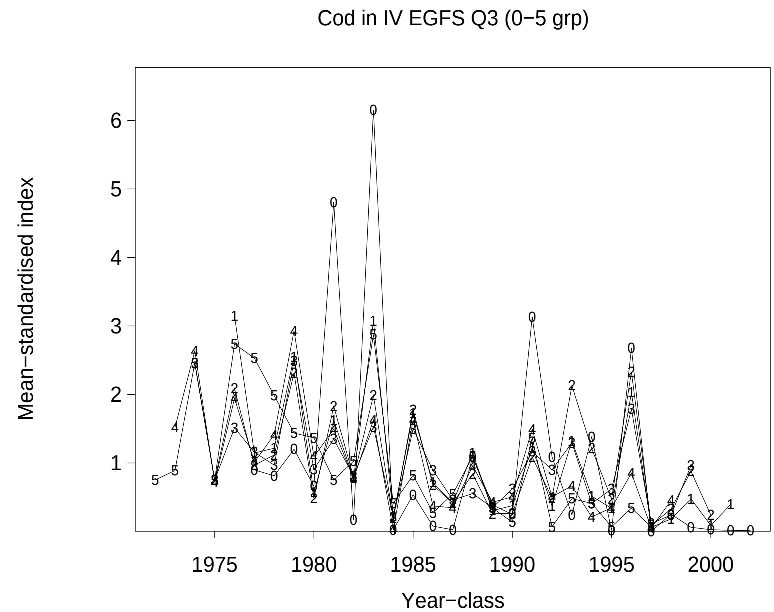


Figure 1: English Groundfish Survey of North Sea cod: mean-standardised survey abundance indices by age and year-class. Ages are indicated by line markers.

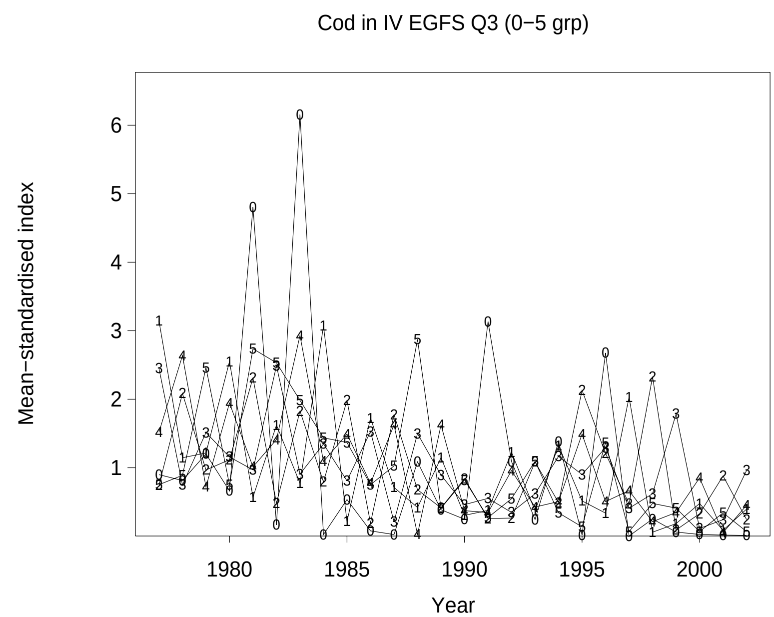


Figure 2: English Groundfish Survey of North Sea cod: mean-standardised survey abundance indices by age and year. Ages are indicated by line markers.

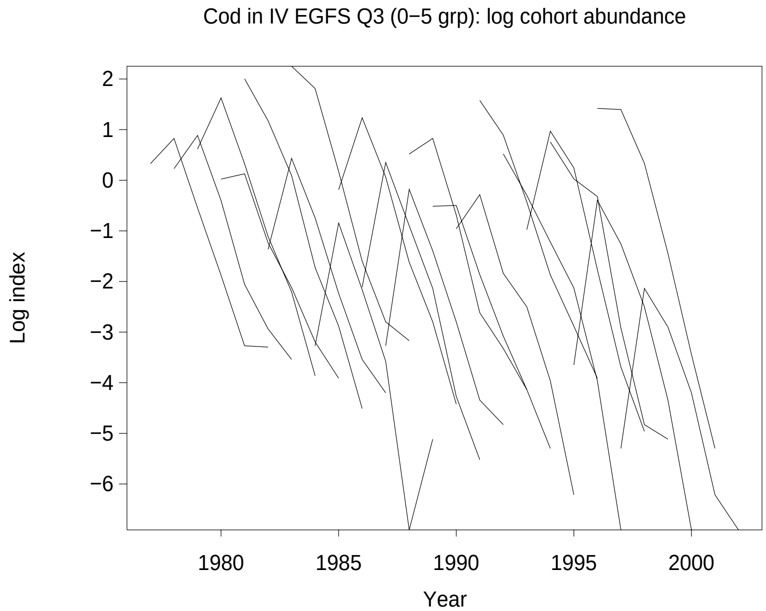


Figure 3: English Groundfish Survey of North Sea cod: log survey abundance indices by cohort. Each line represents the log index abundance of a particular cohort throughout its life.

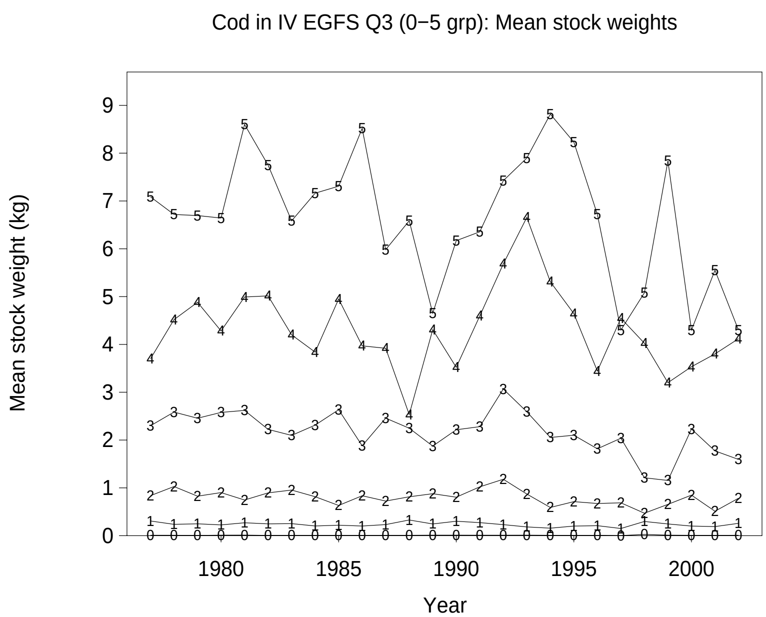


Figure 4: English Groundfish Survey of North Sea cod: mean stock weights-at-age. Ages are indicated by line markers.

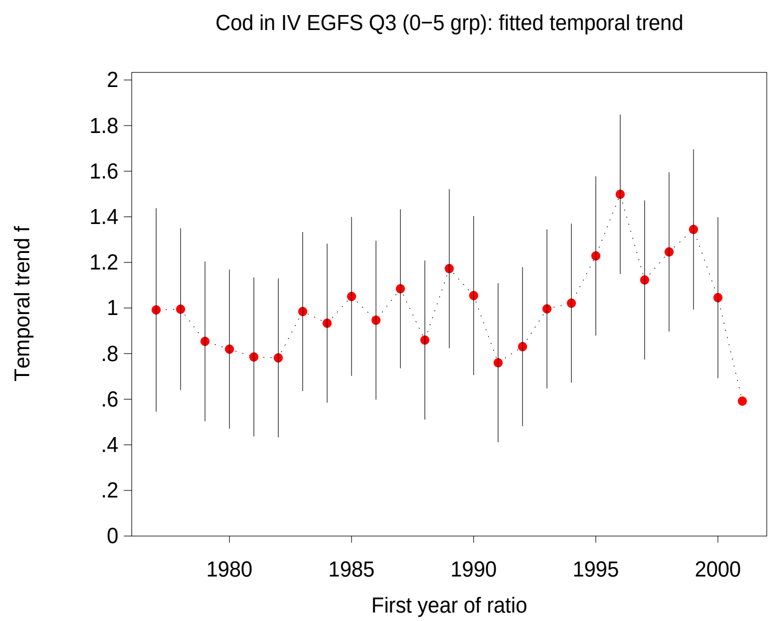


Figure 5: English Groundfish Survey of North Sea cod: fitted temporal trend. Dots are point estimates, which are also joined together by the dotted line. Solid lines give ± 2 standard errors about the point estimates.

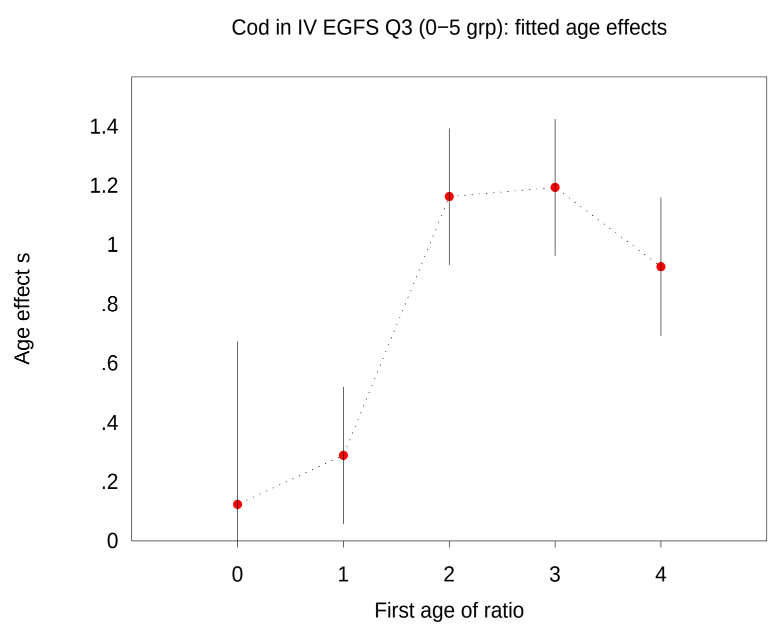


Figure 6: English Groundfish Survey of North Sea cod: fitted age effect. Dots are point estimates, which are also joined together by the dotted line. Solid lines give ± 2 standard errors about the point estimates.

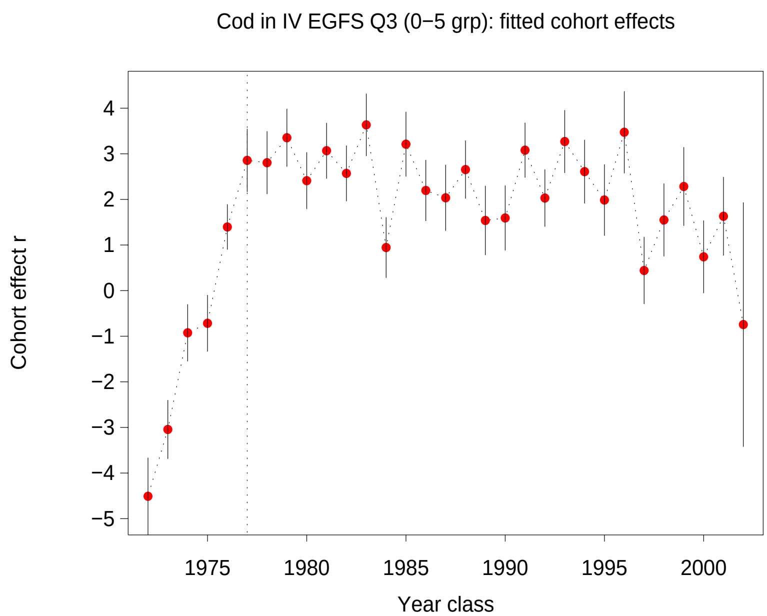


Figure 7: English Groundfish Survey of North Sea cod: fitted cohort effects. Dots are point estimates, which are also joined together by the dotted line. Solid lines give ± 2 standard errors about the point estimates. The vertical dotted line divides cohorts recruiting at age 0 (to the right of the line) and cohorts recruiting at older ages in the first year of the separable model (to the left). The latter are much lower because they have experienced several years of mortality before entering the model matrix.

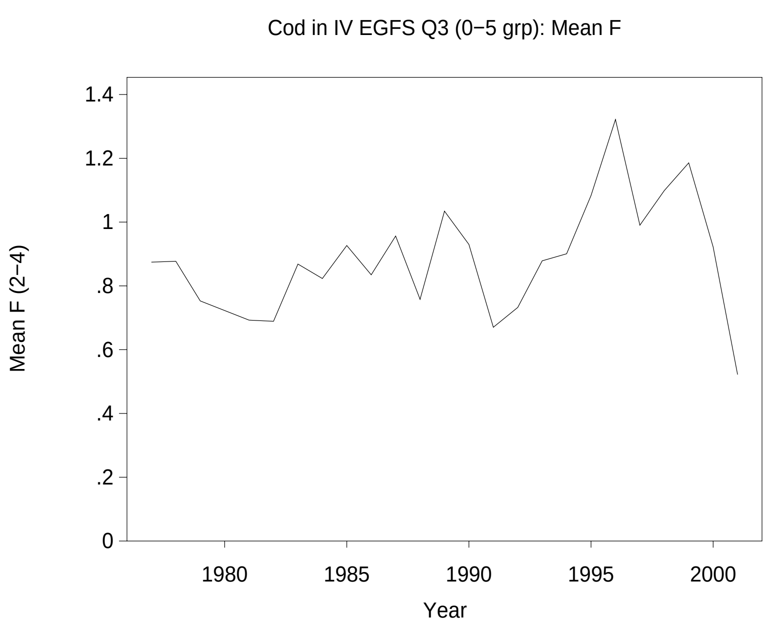


Figure 8: English Groundfish Survey of North Sea cod: estimated $\bar{F}_{2-4}$.

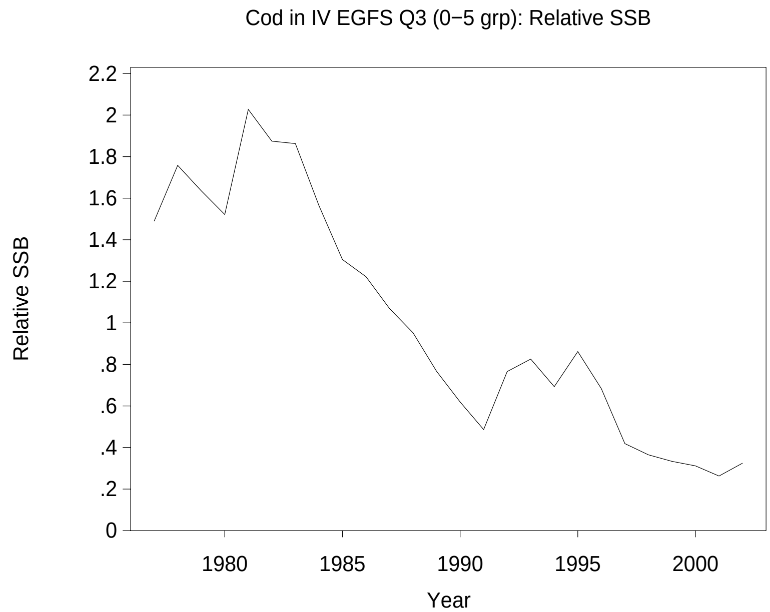
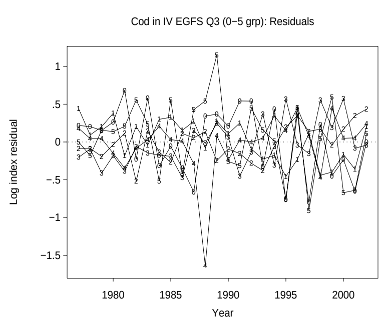
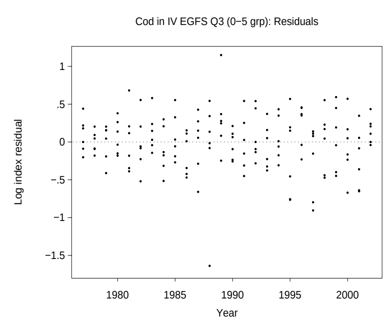


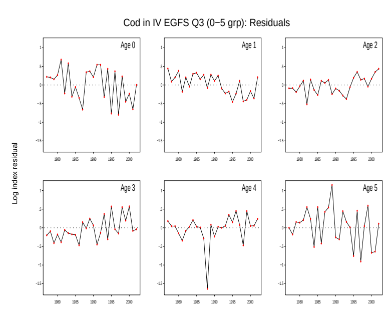
Figure 9: English Groundfish Survey of North Sea cod: estimated relative (mean-standardised) spawning stock biomass.



(a) Overlaid lines



(b) Overlaid points



(c) Separate ages

Figure 10: English Groundfish Survey of North Sea cod: log index residual plots.

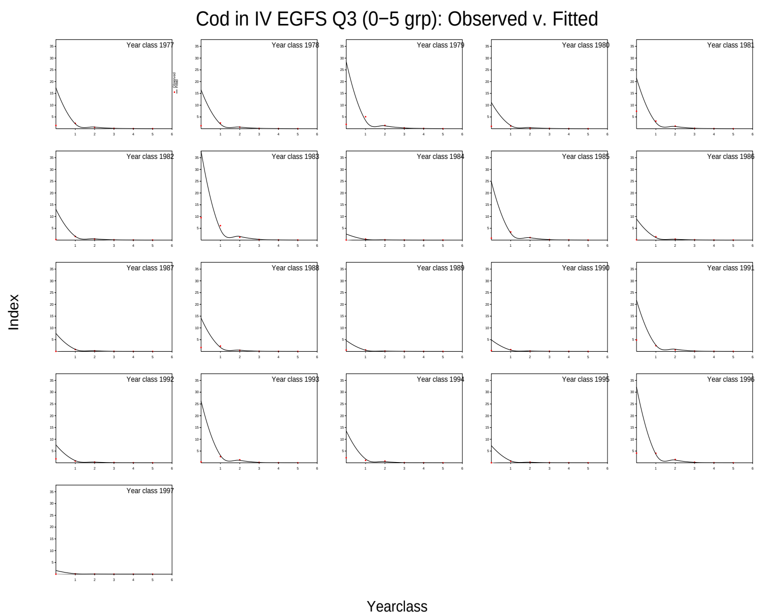


Figure 11: English Groundfish Survey of North Sea cod: comparison between observed (points) and fitted (lines) survey abundance indices, for each year.

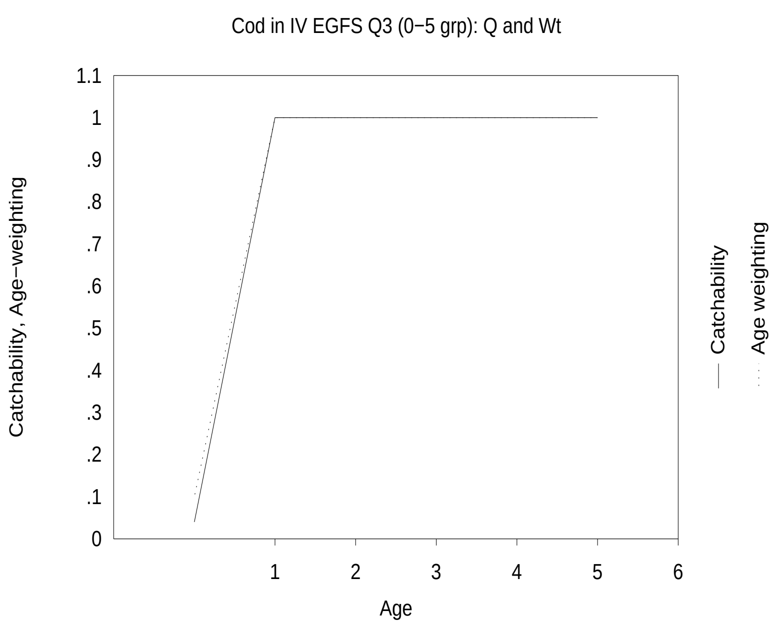


Figure 12: English Groundfish Survey of North Sea cod: values at age of catchability **q** and age-weightings **w** used in assessment.

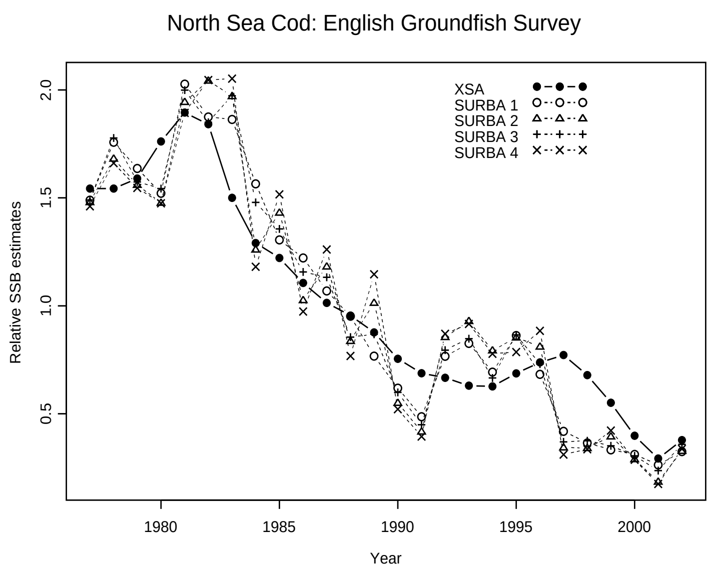


Figure 13: English Groundfish Survey of North Sea cod: comparison of estimated mean-standardised relative SSB from the ICES WG assessment and four SURBA runs.

3.2 Other surveys

I repeated the sets of four SURBA runs listed above for all the survey abundance indices which have been analysed using SURBA in ICES assessment WGs. The list of indices which I include here was defined by the need for speed rather than completeness, as the SURBA input files were already available in these cases. However, it represents a reasonable cross-section of the stocks on which we have to give advice, and indicates the kind of information we can expect to obtain by using a survey-based model.

I have listed the indices below, along with the relevant figure number and a comment or two on what we can conclude from the plots. I should repeat that the SURBA run settings that I used did not necessarily result in very sensible model fits in all cases, and we would need to do more in-depth analyses before we could comment authoritatively on these results.

ScoGFS VIa haddock (Figure 14) This plot shows some differences in the magnitude of change in relative SSB between TSA and SURBA, but as these are relative values, the absolute level is not very important. What we should note is that the direction of change in all series is the same at all times, which means that TSA and SURBA are quite consistent. We see as well that there is no great difference between the four SURBA runs.

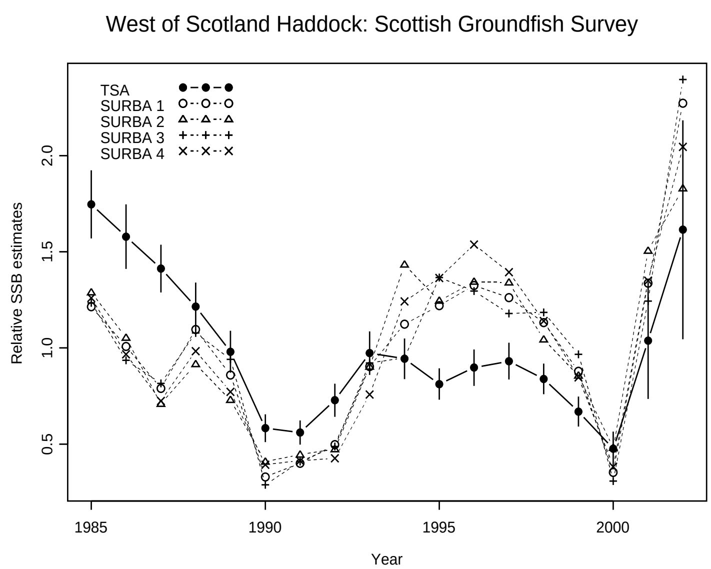


Figure 14: Scottish Groundfish Survey of West of Scotland haddock: comparison of estimated mean-standardised relative SSB from the ICES WG assessment (with error bars) and four SURBA runs.

BTS IV plaice (Figure 15) In this plot, we see considerable differences between the catch-at-age-driven XSA estimate and the survey-driven SURBA estimates. In particular, large fluctuations and the highest (relative) SSB estimates in the whole series are apparent from SURBA runs, but are completely missed by XSA. Without knowing more about the fishery, it is hard to comment on this feature. We can also see that the SURBA runs using inverse-variance age-weighting (2 and 4) give consistently higher estimates than those with manual age-weighting (1 and 3). This is a case where we would need further exploration to determine the most suitable age-weighting.

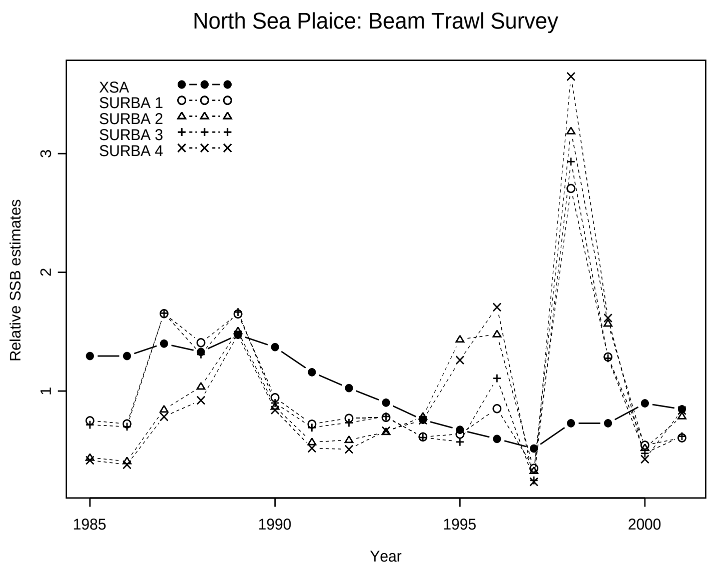


Figure 15: Beam Trawl Survey of North Sea plaice: comparison of estimated mean-standardised relative SSB from the ICES WG assessment and four SURBA runs.

BTS (Tridens) IV plaice (Figure 16) The Tridens subset of the plaice BTS series is short, and we might consider that the length of the time-series would be mitigating against a good model fit. Bearing this in mind, we can see from the plot that the overall trend of SURBA estimates, over the 6 years for which we do have data, is very similar to that from XSA. This suggests that the Tridens survey is covering much the same ground as the main fishing fleets.

IV whiting: three surveys (Figures 17–19) In a recent Working Paper to the North Sea Demersal WG (Needle 2002*a*), I examined the hypothesis that one reason for the difficulty in assessing whiting was differing population signals from different sources. That is, the combination of low market value and restrictive quotas might be leading to a divergence between landings data and survey indices. In that paper I concluded that there were two distinct clusters of information, with the EngGFS and ScoGFS survey series saying one thing, the IBTS series and the landings-at-age data saying another. However, those analyses were done using RCRV1A, and

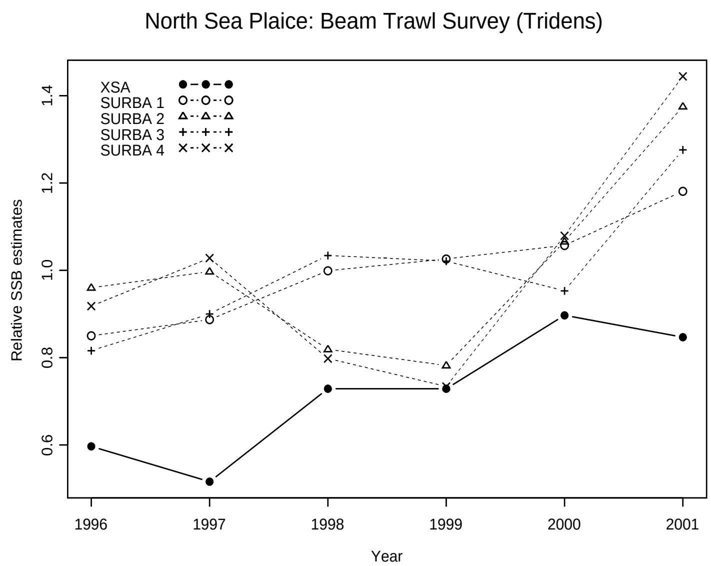


Figure 16: Beam Trawl Survey (Tridens) of North Sea plaice: comparison of estimated mean-standardised relative SSB from the ICES WG assessment and four SURBA runs.

the conclusion when using SURBA is rather different. Although there are some discrepancies, we can see that the trends in relative SSB estimates over the last 10 or so years have been reasonably consistent. The EngGFS and IBTS series do show a drop in the last year, but the uncertainty in the TSA estimates for that year is so large that an equivalent drop is perfectly plausible. The more obvious difference in earlier years could be due to the breaking-down of the assumption of constant selection.

VIIa whiting: two surveys (Figures 20–21) The results for Irish Sea whiting show yet more consistency between survey-based and landings-based assessments. This is a little counter-intuitive, as the Irish Sea whiting assessment is plagued by problems of regional fisheries which are unrepresentative of the stock as a whole. Nevertheless, the relative SSB trends shown here are the most consistent of all those that I have collated in this paper. Whether this is the result of the particular SURBA model settings that I used remains to be seen.

4 Future work and other approaches

SURBA is very much in the early stages of development, and we would need to improve it considerably before we could consider using it in fisheries-management advice. Here is a partial wish-list of desired SURBA developments.

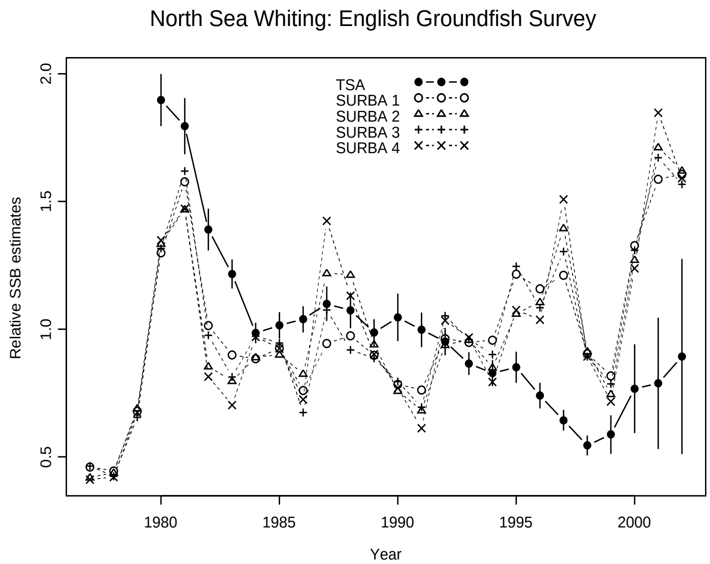


Figure 17: English Groundfish Survey of North Sea whiting: comparison of estimated mean-standardised relative SSB from the ICES WG assessment (with error bars) and four SURBA runs.

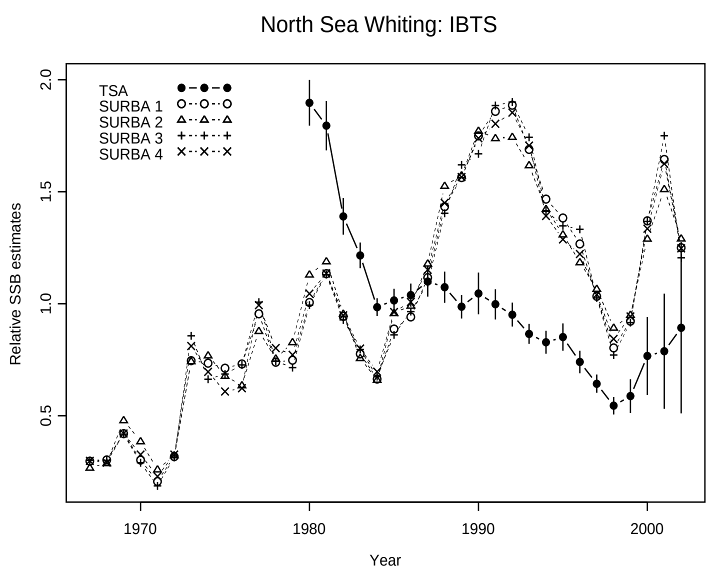


Figure 18: IBTS for North Sea whiting: comparison of estimated mean-standardised relative SSB from the ICES WG assessment (with error bars) and four SURBA runs.

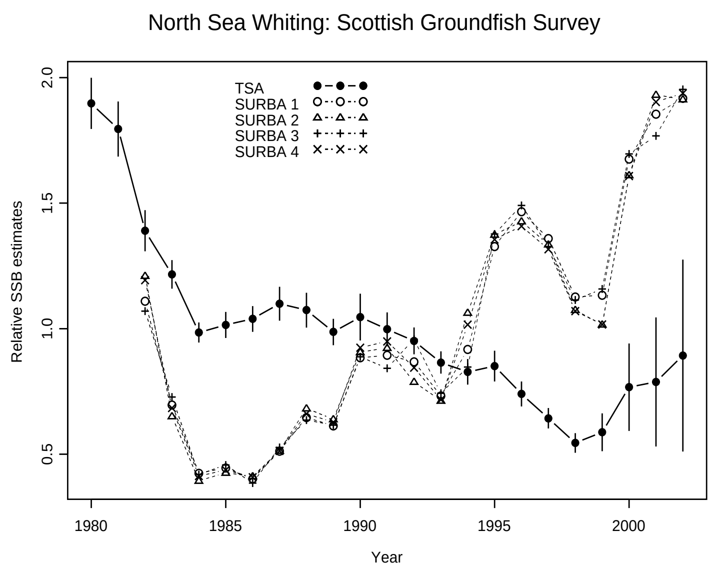


Figure 19: Scottish Groundfish Survey of North Sea whiting: comparison of estimated mean-standardised relative SSB from the ICES WG assessment (with error bars) and four SURBA runs.

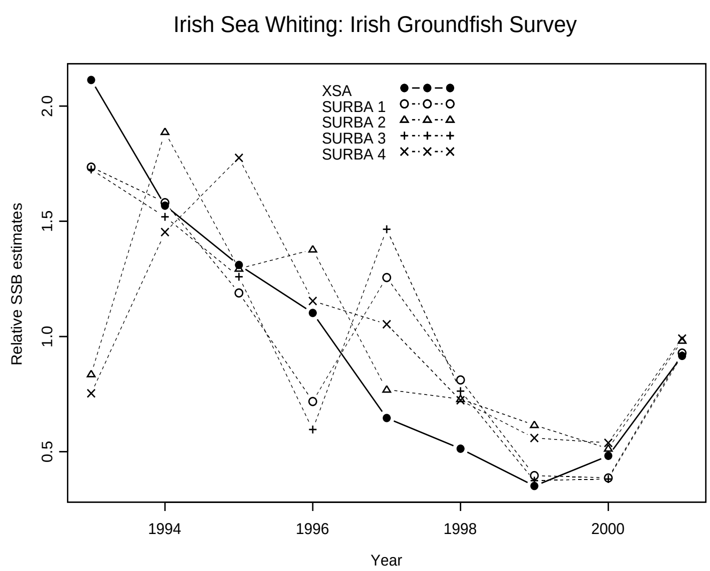


Figure 20: Irish Groundfish Survey of Irish Sea whiting: comparison of estimated mean-standardised relative SSB from the ICES WG assessment and four SURBA runs.

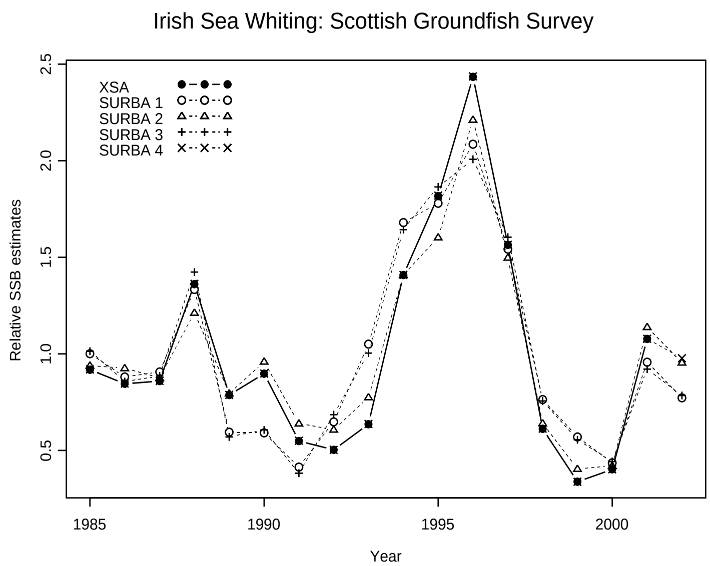


Figure 21: Scottish Groundfish Survey of Irish Sea whiting: comparison of estimated mean-standardised relative SSB from the ICES WG assessment and four SURBA runs.

- The need for the user to specify catchability-at-age for each survey is a serious problem with the method. It is difficult to see how these characteristics could be measured in the field, but there may well be a way to do so, or it might be possible to estimate catchabilities sensibly within the model itself. Mesnil (2003) suggests that we may be able to use auxiliary information, such as length compositions from the survey, to specify more directly these catchabilities. If SURBA or models like it are to be used seriously, then this problem will have to be addressed.

- The assumption of a constant age-effect is also difficult to defend. Remember that it is not the selectivity of the survey which is being measured by the age-effect, but that of the underlying fishery, and this can be expected to change through time. It may be possible to allow the age-effect to vary empirically through time, using an iterative residual-fitting process or a Kalman filter.

- The model does not currently allow for enough uncertainty in specification. A bootstrapped sensitivity analysis (with perturbations on, say, catchability and the F-smoother) would give a greater understanding into the effect of these settings, and whether much effort should be devoted to improving them.

- We have found that the model does not work particularly well with certain datasets, particularly when there are missing data in the last year. An example of this is Rockall haddock (ICES 2002*b*), which is surveyed only once every two years and which has a lot of missing data as a result. The reason for this problem is not clear.

- There are many small, primarily book-keeping problems which I would like to clear up, such as plotting with missing values, direct input of Lowestoft-type data files, a couple more diagnostic plots, and so on.

However, the main problem with SURBA is that it has not yet been used widely enough for all the likely bugs to come to light. The Northern Shelf WG (ICES 2002*b*) made the following recommendation:

> "New software (SURBA, appendix 1) was available to the WG to facilitate survey-based analyses of the fishery. The method proved to be a useful technique for investigating the dynamics of the fishery independently of the commercial catch and CPUE data. However, the additional workload put greater strains on the WG and the extent of the analyses undertaken was restricted due to time limitations. It is proposed that a study group should be initiated to investigate survey-based assessment methods (SGSURBA) and their application to existing data sets."

I think a dedicated forum of this kind is the only place where such problems will be properly ironed out, and I heartily concur with the WG's recommendation.

At the same time, we must remember that SURBA is only one implementation of a possible survey-based method and, being relatively simple, is probably not the best one to use in every situation. Other models currently being developed include:

STA (Beare et al. 2002) The Spatio-Temporal Assessment (STA) model generates an absolute estimate of stock abundance by considering the swept area and volume of the survey gear used, with observations smoothed by a combinations of generalised additive models.

CSA (Mesnil 2003) Catch-Survey Analysis (CSA) is a two-stage model, which looks to be particularly useful in the assessment of stocks for which few data are available. While not exclusively survey-based, it bears comparison with SURBA because it too places little reliance on age-structured catch data. The use of auxiliary information to specify survey catchabilities may also prove to be extremely useful.

KSA (Patterson 2002) Again, Kernel Survivors Analysis (KSA) is also not a survey-based method as such, but the methods it uses for estimating survey catchability may well find a home in SURBA.

TSA (Fryer 2001) Time Series Analysis (TSA) is a relatively new assessment method, using Kalman filter methodology on catch-at-age data and being used increasingly widely in ICES stock assessments. At FRS in Aberdeen, we intend to begin work soon on a new version using survey data only. This would avoid the problem in SURBA of assuming a fixed selectivity pattern, and would handle missing data and forecasts more sensibly.

All of these approaches would benefit from the attention of a Group along the lines of an ICES Study Group. Quite properly, the remit of the Methods WG itself is currently too wide to allow for much detailed work in this field.

5 Conclusions

Survey-based assessment methods are unlikely to produce historic population estimates that are directly comparable with those from catch-based methods. There are two main reasons for this: survey data are inherently noisy; and they are generally not collated in such a way as to derive absolute estimates of stock numbers. These factors go some way towards explaining the differences between survey and landings-based assessments highlighted in §3 above, although these differences do appear to be quite small. However, it remains the case that landings data will become increasingly biased and unreliable as stocks decline further and fisheries management measures become increasingly punitive.

Throughout this paper, I have assumed that that survey indices are unbiased (though variable) representations of stock trends. With good survey design, this will be true to a first approximation. The validity of a particular survey in the assessment of a given stock has to be evaluated separately from the assessment process, and I have not attempted this here. However, given this assumption, and accepting the current problems listed in § 4, I would claim that survey-based assessments are perfectly feasible and, indeed, are the methods we are likely to have to use in the future. Furthermore, we have seen that, for some stocks at least, the consistency between landings-based and survey-based assessments is close enough that a switch to the latter would give us more believable estimates (removing potential misreporting bias) without paying the cost of large changes in management advice.

While development work is still needed, the methodology implemented in SURBA 2.0 is beginning to approach that which would be required for a genuinely unbiased fisheries management scheme. One clear advantage of this model is that it is easy for assessment Working Groups to use – it has a straightforward user interface and produces appropriate plots automatically, although it remains to be seen whether it is doing what we think it is doing. In any case, we should encourage work on a variety of such methods, so that when fisheries management finally acknowledge that commercial fisheries data are unusable in the management context, we will be able to provide valid alternatives.

References

Beare, D., C. L. Needle, F. Burns, D. Reid & J. Simmonds (2002), 'Making the most of research vessel data in stock assessments: examples from ICES Division VIa'. ICES CM 2002/J:01.

Casey, J. (2002), 'Restrictive TACs: How do they affect ICES assessments and what do we do about it?'. Working Document WD5 to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak, Copenhagen, June 2002.

Cook, R. M. (1997), 'Stock trends in six North Sea stocks as revealed by an analysis of research vessel surveys', *ICES Journal of Marine Science* **54**, 924–933.

Darby, C. D. & S. Flatman (1994), 'Lowestoft VPA Suite Version 3.1 User Guide'. MAFF: Lowestoft.

Fryer, R. F. (2001), 'TSA: Is it the way?'. Working Document to the ICES Working Group on Methods of Fish Stock Assessments, Copenhagen, December 2001.

Fryer, R. F., C. L. Needle & S. A. Reeves (1998), 'Kalman filter assessments of cod, haddock and whiting in VIa'. Working Document WD1 to the ICES Working Group on the Assessment of Northern Shelf Demersal Stocks, Copenhagen, June 1998.

ICES (2002*a*), 'Appendix to the Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak'. ICES CM 2003/ACFM:02 Appendix.

ICES (2002*b*), 'Report of the Working Group on the Asessment of Northern Shelf Demersal Stocks'. ICES CM 2003/ACFM:04.

Mesnil, B. (2003), 'Catch-Survey Analysis (CSA): A very promising method for stock assessment, particularly when age data are missing or uncertain'. Working Document to the ICES Working Group on Methods of Fish Stock Assessment, Copenhagen, January 2003.

Needle, C. L. (2002*a*), 'Preliminary analyses of survey indices for whiting in IV and VIId'. Working Document WD2 to the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak, Copenhagen, June 2002.

Needle, C. L. (2002*b*), 'Survey-based assessments of whiting in VIa'. Working Document WD1 to the ICES Working Group on the Assessment of Northern Shelf Demersal Stocks, Copenhagen, August–September 2002.

Patterson, K. R. (2002), 'Exploring and quantifying structural uncertainty in age–structured fish stock assessments: An approach based on "kernel" survivors analysis'. ICES CM 2002/V:10.

Patterson, K. R. & G. D. Melvin (1996), 'Integrated Catch At Age Analysis Version 1.2', *Scottish Fisheries Research Report* **56**. FRS: Aberdeen.