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Sensitivity Analysis and Alternate Model Formulation of Survey Biomass Indices used to Tuned ASPIC Surplus Production Model for Grand Bank Yellowtail Flounder

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Abstract

The last detail sensitivity analysis and alternate model formulation for the ASPIC surplus production model was presented at NAFO in 2003. This paper updates much of that analysis here. Unlike the 2003 analysis, with an additional 4 years of index data, the NAFO accepted formulation of the standard model is now robust enough to exclude the poorly fitted USSR-Russian spring time series. Results of the sensitivity analyses would suggest that the accepted standard model should be constrained by fixing the B1 ratio at 2.0 so that the starting biomass in the first year is not greater than K. An alternate formulation of the standard model which excluded the 1971-1991 Russian spring survey series and the 1990-94 Canadian fall converted series (Campelen units) and used the Canadian 1985-1994 converted juvenile groundfish surveys (Campelen units) appended to the 1995-2005 regular Campelen time series showed promise as an alternate standard model. Several STACFIS recommendations were made to further explore sensitivity and alternate model formulations. At this point in time, there is no reason to suggest the alternate formulation of the standard model with the juvenile series is a better model to replace the existing one until further exploration of the model is undertaken. The sensitivity analysis methods described here should be an integral part of the full assessment of the yellowtail flounder stock.

Introduction

In the 2006 review of the stock assessment of NAFO Division 3LNO yellowtail flounder, STACFIS **recommended** that *further exploration of the ASPIC surplus production model including sensitivity analysis on various input indices be presented in 2007.*

The author notes that sensitivity analyses has been presented every year since the ASPIC production model was adopted in 2000, and a major review was carried out in 2003 (Walsh and Brodie 2003). Since the acceptance of surplus production model (ASPIC) by Scientific Council in 2000 as a standard analytical model for assessing the state of the stock and projecting yield, the formulation of the "**standard model**" has been a model with Campelen spring survey (CPUE:weight) and nominal catch (weight) with the series being tuned by the Canadian Yankee spring survey, the Canadian Campelen fall survey, and the Russian and Spanish spring surveys (Walsh and Brodie 2003)

The purpose of this paper is to present in an unbiased manner the sensitivity analysis of the standard model formulation indices so that the final model will have only those time series which fit the model best. A second objective is to examine alternate model formulation performance and parameter estimates.

Methods

<u>Prologue</u>
Quality of data inputs

In preparing for the numerous trail runs of ASPIC model for the 2007 STACFIS and STACFEN presentations, I discovered errors in the 1990-1997 Canadian fall estimates. When the input (aspic.inp) file was created for the 1998 NAFO workshop on survey analytical methods the biomass-at-age indices were used because these indices were mainly being tested in several different analytical models on estimation survey data (Walsh et al. 1999). Unfortunately they have remained in the ASPIC input file since then. Differences between this incorrect version and the corrected version were relatively minor with the exception of the 1997 estimate which was close to 8000t[1] in difference. I re-ran the NAFO 2006 ASPIC accepted formulation of the model with the corrected indices followed by 500 bootstraps to get bias corrected estimates for the comparison. The following results show the closeness in results as uncorrected and corrected estimates: r = 0.44, 0.44; MSY = 17.5, 17.4 mt; Bmsy = 78.9, 79.1 mt; Fmsy =0.22, 0.22; and 2/3 Fmsy = 0.649, 0.649. To be sure the medium term projections were carried out and the projected yield for 2007 an 2008 on which TAC advice was given were identical. All of the analysis used in this paper used the corrected version.

Input Data

Sensitivity Analysis

The standard model input indices for surplus production modelling as used for all assessment of stock status since 2000 are listed in Table 1. Detail descriptions are found in Walsh and Cadrin (2000); Walsh and Brodie (2003) and Walsh et al. (2006). The analysis presented here is using the data series from ***1965-2005*** from the 2006 assessment.

The trends in catch and the five time series of survey biomass indices are plotted in Figures 1 and 2. From 1971 to 1982 the Canadian spring survey used a 'Yankee' 41.5 otter trawl; from 1984 to the spring of 1995 an 'Engel' 145 High Lift otter trawl was used; and from the fall of 1995 to the present a 'Campelen' 1800 shrimp trawl was used (see McCallum and Walsh 1996 for details). Comparative tows of the Yankee and Engel trawls were used to derive a conversion factor of 1.4 for the Yankee spring catches by number but not by weight. The unconverted Yankee spring survey biomass index was used here. Comparative tows of the Engel and Campelen trawls were used to derive a size based conversion function (Warren et al. 1997). The converted Engel to Campelen survey biomass is used here for the period 1984 to 1995. Methods to link the 1971-1982 Yankee series to the 1984-2005 Campelen equivalent series have not been developed. Therefore the 1971-1982 and 1984-2005 Canadian spring series were considered to be separate biomass indices in the model specification.

The 1972-1991 Russian spring surveys of Divisions 3LNO used a variety of 'unknown design type' bottom trawl. The 1995-2005 Spanish spring surveys cover only the NRA in Divisions 3NO using a Pedreria otter trawl from 1995-2001 and a Campelen 1800 shrimp trawl from 2002 to the present. After comparative fishing trials in early 2000 (Pax et al. 2002), the Pedreria biomass index was converted to Campelen trawl units (Paz et al. 2003, 2004). In 2006 an error was discovered in the conversions for the biomass estimation and the biomass was recalculated (González-Troncoso et al. 2006) and used here in this analysis.

The various 1971-94[2] spring surveys, in general, showed a declining trend with time, and all of the 1990-1994 fall surveys showed an increasing trend with time. With the exception of the 1984-2005 Canadian Campelen spring series which forms the model with nominal catch, the other various survey biomass indices are incorporated into the analysis as model tuning indices. This is analogous to tuning an age structured model (Prager 1994).

The accepted **Standard Model** formulation used in the yellowtail flounder assessment since 2000 used a penalty term added to the objective function to constrain the estimate of the starting biomass B_1 to be less than the maximum stock biomass, 'K', i.e. the carrying capacity, according to that expected from the tenets of the logistic theory. Prager (1994) notes that the ASPIC model's logarithmic objective function is relatively insensitive to the estimate of the starting biomass B_1 when the penalty term is not used. Prager (1994) suggests in the ASPIC v3.81 Users Manual an alternate constraint method to the use of the penalty term which fixes the ratio of the starting biomass B_1 to Bmsy (B1 ratio) at a value between 1.5 too 2.0 if it is suspected that the stock was at or near virgin biomass at the start of the fishery. Based on the limited knowledge of biomass and catches of yellowtail flounder prior to the 1965 fishery, this assumption is inherent in the semi-annual assessment of stock status.

The addition of new annual survey and catch data can change some of the parameter estimations in the model, and in the diagnostics output for the correlation matrix, model mean square error and goodness of fit, number of convergence trials, and Prager's (1996) two reliability statistics known as the converge index and the nearness index (see Prager 1996 for discussion). All are located on page 1 of the model output (see Appendix A). Also on the same

[1] In the abundance-at-age file there are many otoliths that could not be read and are classified as unknowns. When the biomass-at-age were calculated using a length-weight relationship these unknown's would not be included in the results.

[2] There were no Grank Bank spring surveys by USSR/Russia and Canada in 1983

page look for any goodness of fit warning messages: “B1 ratio constraint term contributing to loss. Sensitivity analysis advised”. This has been found on the output of all standard model runs in the assessments carried out since 2000.

The sensitivity analysis used here compared the estimated parameters from the standard model with the 1) penalty included in the model (ASPIC FIT mode), 2) the penalty term removed (ASPIC FIT mode), 3) the model runned with the iteratively reweighted fit (ASPIC IRF mode) and 4) with the penalty term removed and the alternate constraint of fixing B1 ratio to 2.0 (ASPIC FIT mode).

Alternate model formulations

In the 2003 sensitivity analysis using ASPIC version 3.81, Walsh and Brodie (2003) considered and analyzed other available indices to be used with the standard model. The Canadian CPUE index showed a strong residual pattern which indicated a pattern of positive residuals in earlier years and more or less negative residuals in later years. This residual pattern questions whether or not the CPUE is tracking the major shifts which have occurred in this fishery. It was not accepted in the 2000 assessment (Walsh and Cadrin 2000; Walsh et al. 2000) nor in the alternate model formulation in 2003 (Walsh and Brodie 2003); the latter for reasons not entirely explained by STACFIS, i.e. the Russian spring survey also had a stronger residual pattern but was left in the model. Other time series indices tested included the 1) biomass index from the fall 1985-94 Canadian juvenile groundfish surveys (see Walsh and Power 1995 for details) and 2) the catch rate series from the July DFO/industry grid surveys (Walsh et al. 2002) were not used in the final model formulation because of a negative correlation with other indices (see Walsh and Brodie 2003 for discussions). A negative correlation will not allow the model to converge.

The alternate model formulations used here and compared with the standard model formulation output estimates of parameters consisted of 1) the standard model with the Russian spring series removed, 2) the standard model with the converted 1985-1994 juvenile groundfish survey index in Campelen units included, and 3) variants of this converted 1985-1994 juvenile groundfish survey index. Because of shortness of the grid study time series and the unresolved debate over the validity of using the Canadian CPUE series they were not included in the analysis presented here.

Table 2 reproduces Table 1 ASPIC input indices along with those from the other formulations. Figure 2a and 2b compares trends in the various indices of biomass.

<u>Surplus Production Model</u>

A non-equilibrium surplus production model incorporating co-variates (ASPIC; Prager 1994, 1995) was applied to nominal catch and biomass indices. The production model assumes logistic population growth, in which the change in stock biomass over time (dB_t/dt) is a quadratic function of biomass (B):

$$dB_t/dt = rB_t - (r/K)B^2_t \quad (1)$$

where r is the intrinsic rate of population growth, and K is carrying capacity. For a fished stock, the rate of change is also a function of catch biomass (C):

$$dB_t/dt = rB_t - (r/K)B_t^2 - C_t \quad (2)$$

Biological reference points can be calculated from the production model parameters:

$$MSY = K\,r / 4 \quad (3)$$
$$B_{msy} = K / 2 \quad (4)$$
$$F_{msy} = r / 2 \quad (5)$$

ASPIC can fit data from several CPUE or survey abundance series. When more than one series is used, common estimates of initial biomass (expressed as a ratio of B_1 to B_{msy}:), r, MSY are made, along with catchability coefficients (q) for each index. An objective function is minimized using nonlinear least squares of the indices residuals.

Model tuning is similar to tuning an age structure analysis. The tuning index enters the model and is compared to the production model estimates of the stock size and residuals are incorporated into computation of the objective function (see Prager 1994, 1996 for details).

ASPIC versions

All analyses presented here use version 3.81 of ASPIC, which is the accepted software used since the 2000 assessment. Walsh and Brodie (2003) present a detail discussion of comparative results of parameters estimates using different versions of the software.

Results and Discussions

Sensitivity Analyses

Table 3-6 show the correlation matrices, goodness of fit, convergence trials and reliability statistics for the each run of the model. For the sensitivity analysis the comparisons include: 1) the standard model with the penalty tern included, 2) the standard model with the penalty term removed 3) the standard model with iteratively reweighted fits (IRF mode) and 4) model 2 with B1 ratio fixed at 2. A summary of the biological and fishing parameter estimates derived from each of the model runs are located in Table 7 together with the model mean square errors. Analysis #s 1, 2 and 4 were runned in the ASPIC 'FIT" mode and analysis # 3 were runned in the ASPIC 'IRF" mode, where an inverse variance weighting was used. In the 'FIT" mode all series indices were assigned equal weightings..

Model # 1, the accepted **Standard Model** formulation incorporates a series of observations on Campelen spring biomass index (CPUE) along with nominal catch as the model and uses the Canadian Yankee spring and Canadian Campelen fall survey series, the Russian spring surveys and the Spanish spring surveys as tuners (runned in the ASPIC FIT mode) (Table 7).

Tables 3-6 shows the correlations among biomass indices varied widely with some losses and gains in relationships depending on configuration used. In the standard model output in Table 3 the 5 pairwise correlations show that 4 were moderate to strong (r>0.7), and one, the Russian spring survey index was weak. The Russian spring series was a poorly correlated with the Yankee spring survey time series (r<=0.2) for the overlapping 1971-1982 time series. The model fits, in terms the coefficient of determination 'r^2 ', showed that use of the Russian series fitted the model poorly ($r^2 = 0.3$) while the model fits for the other series had $r^2 > 0.6$.

Table 7 shows the summary results from model manipulations: Model #2 used the standard model with penalty term removed (ASPIC FIT mode); Model # 3 used the standard model with an iteratively reweighted fit (ASPIC IRF mode), and Model # 4 used the standard model with B1 ratio constrained at 2.0 (ASPIC FIT mode). The reliability statistics for the model fits are almost identical (Tables 3-6) and Table 7 shows that running the model in the IRF mode has a significant, 50%, reduction in error (MSE) when compared to the FIT mode outputs.

The full ASPIC output from Model #1, the standard model, including the 500 bootstrap trials to estimate the bias corrected estimates are shown Appendix A. It shows the residual patterns for each of the data series in the standard model. Residuals appeared to be more or less randomly distributed for all Canadian survey indices, but not for the Russian spring survey, which had a strong pattern of positive residuals during the 1970s and early 1980s and negative residuals for subsequent years. Figures 2 shows the Russian spring series in comparison to the two Canadian spring indices that overlap. There is no correlation between both 1971-1982 Russian spring and Canadian Yankee indices (r = .20; p= 0.5594, n = 11) however, both 1984-1991 Russian and Canadian Campelen series track each other well (r = .93; p= 0.0007, n = 8). The 1971-1983 Russian series may be a misleading index of biomass. The Spanish series showed a pattern of negative residuals in the first three years and positive residuals in the next 8 years. Although the Spanish time series did not fit the model well, in the Walsh and Brodie (2003) sensitivity analysis of the standard model formulation from the 2002 stock assessment the addition of 4 more years of survey data has improved that fit (r>0.5).

Sensitivity

The summary of sensitivity analyses in Table 7 shows the B1 ratio of the standard model (Model #1) with the penalty term included still exceeds 2.0. This has been consistent in all assessment runs with this model formulation (see also Walsh and Brodie 2003). The trend in the relative and bias corrected estimates (500 bootstrap trials from ASPIC 'BOT' mode) of biomass and fishing mortality are presented in Figures 3 a and 3b and showed that there is almost no difference in these indices. With the exception of the B1 ratio, the amount of bias (%) estimated in the bootstrap for MSY, r, K, Bmsy, Fmsy, B/Bmsy and F/Fmsy was less than 1% (see last page of Appendix A). Removal of the penalty term (Model #2) shows that without the term the B1 ratio is a lot higher (Table 7). Although the removal of the penalty term changes the estimates of other parameters they do not appear to be dramatic (most notable was a decrease in r from 0.45 to 0.42 and an increase in F_{2006}/F_{msy}). In the 2003 sensitivity analysis, the B1 ratio was estimated to be 43.8 when the penalty term was removed, however, most parameter estimates were similar to those estimated with the penalty term in the model. Having the B1 ratios>2 conflicts with the perception that the yellowtail flounder stock in the mid-1960s was near virgin state according population theory.

Running the model in the IRF mode (Model # 3) resulted in the amount of model error decreasing by 43% and the B1 ratio being close to 2.0. i.e. 1.99. With the exception of B/Bmsy and F/Fmsy, the estimates of key parameters were close to that derived with the standard model (equal weights given to all indices) in which the penalty term is used to constrain B1 (Table 7). Similar IRF mode results were seen in the 2003 analysis by Walsh and Brodie (2003). In Model # 4 formulation the alternate constraint method of fixing the B1 ratio at 2.0 was used and, with the exception of 'r' dropping from 0.45 to 0.43, and changes in B/Bmsy and F/Fmsy most estimates of key parameters were similar to the standard model with the penalty included.

Figures 4a and 4b compares the trends in the estimated relative biomass and fishing mortality from the standard model formulation with that derived using 1) an iterative reweighting fit (IRF mode) of the standard model and 2) the standard model with the penalty term excluded and the B1 ratio fixed at 2. With the exception of the 1965-1968 biomass trends, there is no difference in the time series trends of relative biomass and fishing mortality between the standard model (penalty term in) and the model constrained so B is fixed at 2 (penalty term removed) and the standard model runned in the IRF mode.

In summary, the best fitted standard model was derived using the iterative reweighting fit (IRF mode). However, when ASPIC is run in the IRF mode, the bootstrapping utility that would derive the bias corrected estimates, and hence medium and long term yield projections are not available in the ASPIC software package. Dropping the penalty term in the standard model and fixing the B1 ratio at 2.0 also gave lower estimates of 'r' than the standard model and the number of convergence trials dropped from 33 to 7. There could be an argument for a model that gives a lower 'r', which should reflect a population intrinsic rate of growth being closer to the current perception that the Grand Bank yellowtail flounder is a slow growing and long-lived species (Dwyer et al. 2003), however, 'r' may be measured imprecisely by the model. Variability around the bias corrected estimates from a model with B1 ratio fixed at 2.0 was also much lower than that estimated by the standard model as seen in Table 15. The conclusion is that the standard model with the penalty term in place is insensitive to the estimate of the starting biomass in the first year (Prager 1996) and dropping the penalty term constraint and using the fixed B1 ratio constraint results in a less variable estimates of biological and fishing parameters and a better estimate of 'r' that fits closer our perception of the rate of growth for this stock.

<u>Alternate Model formulation</u>

The alternate model formulations used here, and compared with the standard model formulation output estimates of parameters, consisted of 1) the standard model with the Russian spring series removed, 2) the standard model with the converted 1985-1994 juvenile groundfish survey index in Campelen units included, and 3) variants of this converted 1985-1994 juvenile groundfish survey index in Campelen units.

Excluding Russian series

The correlation matrices, goodness of fit, convergence trials and reliability statistics of various alternate model formulations of the standard model are shown in Tables 8-9 and parameter estimates are compared in Table 14 with those derived from the standard model. Model fits are modestly improved with the removal of the Russian series. Fixing B1 ratio at 2.0 does not improve the fit. There was no improvement in the model fit reliability statistics when compare to the standard model in Table 3, however the model converged at a faster rate (33 vs 17 trials) when the Russian series was removed.

Model # 1, (repeated from Table 7), is the accepted **Standard Model** formulation that incorporates a series of observations on Campelen spring biomass index along with nominal catch in the model and uses the Canadian

Yankee spring and Canadian Campelen spring and fall survey series, the Russian spring surveys and the Spanish spring surveys as tuners (runned in the ASPIC FIT mode). Because of the poor fit of the Russian spring surveys to the other indices of biomass and the strong residual pattern in residuals (Table 3, Appendix 1), Models # 2 and #3 are the standard model with the Russian time series removed.

Walsh and Brodie (2003) reported that the standard model was very sensitive to removing the Russian time series from the model. Large changes in estimates of B1 ratio, MSY, B_{msy}, F_{msy}, B_{2003}/B_{msy} and F_{2002}/F_{msy} were noted at that time when compared to the standard model. Here with the Russian index removed, the Model (# 2) estimates of MSY, B_{msy}, F_{msy}, B_{2007}/B_{msy} and F_{2006}/F_{msy} were relatively robust to excluding the Russian series, however, there was a 37% decrease in model error (MSE) when the time series was excluded. With the Russian series excluded, the B1 ratio (B_{1965}/B_{MSY}) showed a small increase from 2.15 to 2.19, a small increase in 'r' from 0.45 to 0.49 and a decrease in 'K' (159, 000 to 149, 000 t) which would affect B_{MSY} (decrease from 79,400 t to 75,000 t) (Table 14; Models # 1 and 2). F_{MSY} increased from 0.22 to 0.25 and MSY showed a minor change and the medium term projected yields at 2/3 F_{msy} would be expected to have a slightly higher estimate should this model formulation be used. Excluding the series resulted in an increase in 'r' from 0.45 to 0.49 , which is in disagreement with recent revision to the life history information that this species is a slow growing and long lived species (Dwyer et al 2003) i.e. higher 'r' is a sign of a fast growing species. Nevertheless 'r' may be measured less precisely in the ASPIC model (Prager 1994). Here Model # 2 (Table 14) shows that with the Russian series removed from the standard model, and using the alternate constraining method whereby the penalty term was dropped and B1 fixed at 2.0 there were minor changes in estimates of parameters when compared to leaving the penalty term in. Model error was still 37% lower than that estimated in the Standard Model.

Canadian juvenile series

The second alternate formulation used was the 1985-94 juvenile groundfish surveys which covered all of the major yellowtail habitat in the Divisions 3LNO and employed a Yankee 41 shrimp trawl. Based on the results of comparative fishing experiments between the Yankee 41 shrimp trawl and the Campelen 1800 shrimp trawl aboard *CCG Wilfred Templeman* this time series was converted to Campelen trawl units (Walsh and Veitch 2005). These surveys started in August in the earlier years and the moved to September in later years (see Walsh and Power 1995), one month earlier than the start of most of the annual fall surveys which began in 1990. Figure 5 shows the index of the 1985-94 converted Yankee time series in Campelen units (from here on referred to as the "juvenile surveys") and the 1990-1994 converted Engel time series in Campelen units and the 1995-2006 Campelen time series.

Table 14, Models # 4 and 5, show that inclusion of the juvenile time series into the standard model (Model # 4) and the standard model with the Russian series excluded (Model # 5) would not result in model convergence because of negative correlations with the model (Campelen spring/nominal catch) and the Russian time series. Both the Campelen (Engel converted) spring and the Russian spring surveys both showed a decline in stock size during the 1985-1993 period while the fall 1985-94 juvenile series and the regular 1990-1994 fall series showed an increasing trend (Fig 6).

In the currently accepted standard model formulation, the Canadian fall index was derived from a converted (in Campelen units) large mesh/large footgear Engel otter trawl and a small mesh/small footgear Campelen shrimp trawl. The juvenile surveys used a small mesh/small footgear Yankee shrimp trawl with similar length selection pattern as the Campelen survey trawl (Walsh and Veitch 2005). I dropped the short 1990-1994 fall Engel converted time series and replaced it with the 1985-1994 juvenile surveys to create a "new" shrimp trawl fall survey index (Figs. 5 and 6). This now allowed the fall surveys to be extended back to 1985 similar to the Canadian Campelen spring index which began in 1984 thus providing another the index to cover the time period leading up to the collapse of the stock.

In Table 14, Model # 6 is the alternate formulation for the standard model with the Russian time series excluded and the "new fall shrimp trawl survey" index included. Since the Campelen spring index is in the model with catch then this new series is the only tuning index to cover the time period leading up to the collapse of the stock. The correlation matrices, goodness of fit, convergence trials and the reliability statistics are presented in Tables 8. Of the 4 pairwise correlations among the biomass indices included in the production analysis, all were strong (r>0.8) and the model fits in terms of r^2 were very moderate to high (r^2 >0.5) and compared well with the accepted standard model formulation diagnostics in Table 3. However, the key biological parameter estimates, MSY, K and Bmsy, in the alternate model show much larger estimates when compared to the standard model (Model # 1; Table 14). A decrease in 'r' from 0.45 to 0.42 is contributing to this inflation. As well the B1 ratio of 0.70 is low in the alternate model compared when with 2.15 in the standard model. Model errors was similar in both formulations. There are minor changes in fishing parameters between the two models. Figures 7 and 7b shows the alternate model fits of the relative and the bias corrected (from the 500 bootstrap trials) estimates of biomass and fishing mortality. There were minor differences in the precision of indices.

Tables 11-13 show Models #7-9 sensitivity analysis of the alternate standard model, similar to that seen with the standard model in Table 7, with output correlation matrices, goodness of fit, convergence trials and the reliability statistics. There were minor changes in the correlations, fits and reliability statistics, however, it took only 3 trials for the model to converge in the IRF mode as compared to 35 in the FIT mode and 7 trials with B1 ratio fixed at 2. Table 14 summaries the changes in parameter estimates. Minor difference are seen when the penalty term is dropped and when the IRF mode is used (noticeable drop in model error), however, constraining the model by fixing B1 gave unrealistic estimates similar to Model #s 2 and 3 when the Russian index was removed. Realistically there is no need to use a penalty term or a fixed constraint method since B1 ratio is well below 2.0.

The biological and fishing parameter estimates and errors from the accepted standard model and the alternate standard model are presented in Table 15. The trajectory of relative biomass and fishing mortality in the new alternate model (# 6) formulation was compared with the accepted standard model formulation (Model #1) used in the current NAFO assessment in Figure 8a and 8b. Only the trajectories of the relative biomass from 1965-1971 showed a major difference in trend due to the standard model's starting biomass being greater than the maximum stock biomass (K) while the alternate standard model shows it was well below K. After 1971 the trends were similar and have close agreement from 1987-2006. The alternate standard model calculates the relative population biomass at the start of the time series as being below Bmsy (B_1 ratio or B_{1965}/ B_{MSY} = 0.70; Table 14; Fig. 7a). This condition of B1< Bmsy in the earlier years would indicate that a stock that was in already in an exploited state. The perception from the Standard Model was, given that the fishery began in the 1965, the stock should have been close to an unexploited state. According to logistic theory the biomass in the first year B_1 should be less than the maximum stock biomass (carrying capacity) which occurs for the alternate standard model but is not with the accepted standard model, even with the penalty term used.

To investigate this large difference in the perception of stock size at the start of the fishery from both model runs, both the catch and the Canadian CPUE index (from Brodie et al. 2006) were overlaid on the biomass trajectories for the standard model and the alternate standard model and shown in Fig. 9. The catches during 1965-1969 period showed an increasing trend matching the biomass trend for the alternate standard model while the CPUE index showed a decreasing trend similar to that seen in the biomass trajectory from the accepted standard model. If the CPUE index for the 1965-70 time period is proportional to stock biomass then the biomass would have to be high to sustain the high catch rates. However, Brodie et al. (2006) and Walsh and Brodie 2003 caution the use of this index. In addition Prager (1996) cautions about making inferences about the first 2– 5 years without auxiliary information because of imprecision in the estimate of B1 in the starting year. If we dropped the 1965-1969 then the trend in the biomass trajectories for both models are similar. Other information on the fishery and stock size is not currently available for the period leading up to the 1965 reported landings.

Table 15 compares the bias corrected estimates of biological and fishing parameters based on 500 bootstrap trials for the Standard Model, the Standard Model with B1 fixed at 2.0 and the Alternate Standard Model. The relative interquartile range from the bootstrap table is a measure of statistical dispersion and expressed here as a percentage. The model parameter estimates of MSY, B_{msy}, F_{msy}, B_{2007}/ B_{msy} and F_{2006}/ F_{msy} are relatively robust to the three formulations with most changes in estimates seen in the alternate standard model. The variance around the estimates is lower for the standard model when B1 is fixed at 2 and highest for the alternate standard model formulation.

Summary and conclusions

With an additional 4 years of index data, the NAFO accepted formulation of the standard model is now robust enough to exclude the Russian time series. This reversal in the conclusion from the 2003 sensitivity analysis is due to the increase in the length of the yellowtail flounder time series of catch and survey indices. As the time series is lengthen, the model fit and resiliency should improve along with the precision of the estimates. Results of the sensitivity analyses would suggest that the accepted standard model should be constrained so that the starting biomass in the first year is not greater than K. Dropping the penalty term and fixing B1 ratio at 2.0 will give a more realistic biological model (lower 'r'), and minor changes in the estimate of fishing mortality will have little effect on the projected yield for the 2007 fishery (Table 15). At this point in time there is no reason to suggest the alternate formulation of the standard model with the juvenile series is a better model to replace the existing one. The sensitivity analysis methods described here should be part of the full assessment of the yellowtail flounder stock.

Epilogue

When this analysis was presented at the 2007 meeting it generated a lot of discussion and suggestions for future work that formed the basis of several STACFIS recommendations that are repeated here: Based on the results of the sensitivity analysis and the alternate model formulation in the input data used in the ASPIC surplus production model, **STACFIS** recommends the following: 1) *that a sensitivity analysis of parameter estimates for the surplus production model (ASPIC) be routinely completed at the semi-annual assessments; 2) that further investigations of the effect of excluding the Russian spring time series, 1971-1991 from the standard formation of the surplus production model used in all stock assessments since 2000 be conducted; and, 3)that a comparative evaluation of the parameter estimates, levels of precision, model fits and diagnostics derived from ASPIC versions 3.81, used in the semi-annual stock assessments, with that derived from the latest version 5.1 be conducted.* Based on the promising results from an alternate formulation of the ASPIC surplus production model **STACFIS** recommends *that other sources of yellowtail flounder survey and fishery data for the time period before 1971 be explored to gather information on the state of the stock which could affect the choice of model formulation that best describes the time period 1965-1970.*

A suggestion for the accepted standard model to improve the fit would be to drop the 1971-82 USSR – Russian series because of poor correlation with the Canadian Yankee spring surveys for the same time period. The 1984-1991 USSR-Russian series is well correlated with the Canadian spring survey times series for the same period. It was noted that in a 1997 paper by Bulatova et al. (Thanks Antonio!) that the 1971-82 series estimates were based on fixed stations while the 1984-1991 followed a random stratified sampling design. This could explain a lack of a relationship with the Canadian survey data which is based on a stratified random design for the same time period.

In the alternate standard model formulation, a question was raised as to the validity of dropping the 1990-1994 fall converted (Engel) Canadian Campelen time series and replacing it with the Canadian juvenile series for the period 1985-1994 and then appended it to the 1995-2005 Campelen fall series. In response, this would extend the fall converted time series back to 1985 and overlap the Canadian 1984-2005 spring survey time series, thereby providing another view of what happen to the stock leading up to the 1994 moratorium. However, one could have also entered the Canadian Engel unconverted data for the fall 1990-1994 as a separate index into the model and this should be investigated

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Table 1 Input data indices used in the standard 2006 ASPIC Surplus Production model from 1965-2005 (see Walsh et al. 2006 for details)

Year	Nominal catch (000 t)	Canadian Yankee survey (000 t)	Russian survey (000 t)	Canadian Campelen spring survey (000 t)	Canadian Campelen fall survey (000 t)	Spanish survey in NRA (000 t)
1965	3.13					
1966	7.026					
1967	8.878					
1968	13.34					
1969	15.708					
1970	26.426					
1971	37.342	96.9				
1972	39.259	79.2	106.0			
1973	32.815	51.7	217.0			
1974	24.313	40.3	129.0			
1975	22.894	37.4	126.0			
1976	8.057	41.7	131.0			
1977	11.638	65.0	188.0			
1978	15.466	44.3	110.0			
1979	18.351	38.5	98.0			
1980	12.377	51.4	164.0			
1981	14.68	45.0	158.0			
1982	13.319	43.1	125.0			
1983	10.473					
1984	16.735		132.0	217.7		
1985	28.963		85.0	146.8		
1986	30.176		42.0	138.2		
1987	16.314		30.0	124.6		
1988	16.158		23.0	81.0		
1989	10.207		44.0	103.8		
1990	13.986		27.0	103.1	65.8	
1991	16.203		27.5	93.4	82.4	
1992	10.762			61.4	64.5	
1993	13.565			63.3	112.8	
1994	2.069			55.6	106.4	
1995	0.067			70.6	129.8	9.3
1996	0.287			175.6	134.3	43.3
1997	0.8			174.9	222.9	38.7
1998	4.348			202.2	231.6	122.6
1999	6.561			365.7	249.9	197
2000	11.121			287.5	335.0	144.7
2001	14.147			366.0	475.8	182.7
2002	10.698			199.5	339.7	148.5
2003	13.806			386.5	368.3	136.8
2004	13.354			307.9	374.7	170.0
2005	13.933			388.8	342.7	156.5

**Note a correction made to Canadian fall survey estimates from 1990 to 1997 which incorrectly used Biomass at age data series in the assesment since 2000-2006. A correction was also made to the 1999 point due to a keypunch error.*

Table 2 Input indices used in the alternate surplus production model trials in Tables 7 & 13

Year	Nominal catch (000 t)	Canadian Yankee survey (000 t)	Russian survey (000 t)	Canadian Campelen spring survey (000 t)	Canadian Campelen fall (000 t)	Spanish survey (000 t)	Candian Juvenile in Campelen Units (000 t)	Combine Can. Juvenile & Can. Campelen Fall (000t)
1965	3.13							
1966	7.026							
1967	8.878							
1968	13.34							
1969	15.708							
1970	26.426							
1971	37.342	96.9						
1972	39.259	79.2	106					
1973	32.815	51.7	217					
1974	24.313	40.3	129					
1975	22.894	37.4	126					
1976	8.057	41.7	131					
1977	11.638	65	188					
1978	15.466	44.3	110					
1979	18.351	38.5	98					
1980	12.377	51.4	164					
1981	14.68	45	158					
1982	13.319	43.1	125					
1983	10.473							
1984	16.735		132	217.7				
1985	28.963		85	146.8			94.1	**94.1**
1986	30.176		42	138.2			128.0	**128.0**
1987	16.314		30	124.6			47.4	**47.4**
1988	16.158		23	81			73.7	**73.7**
1989	10.207		44	103.8			110.7	**110.7**
1990	13.986		27	103.1	65.8		120.2	**120.2**
1991	16.203		27.5	93.4	82.4		149.8	**149.8**
1992	10.762			61.4	64.5		113.7	**113.7**
1993	13.565			63.3	112.8		150.3	**150.3**
1994	2.069			55.6	106.4		247.3	**247.3**
1995	0.067			70.6	129.8	9.3		129.8
1996	0.287			175.6	134.3	43.3		134.3
1997	0.8			174.9	222.9	38.7		222.9
1998	4.348			202.2	231.6	122.6		231.6
1999	6.561			365.7	249.9	197		249.9
2000	11.121			287.5	335.0	144.7		335
2001	14.147			366.0	475.8	182.7		475.8
2002	10.698			199.5	339.7	148.5		339.7
2003	13.806			386.5	368.3	136.8		368.3
2004	13.354			307.9	374.7	170.0		374.7
2005	13.933			388.8	342.7	156.5		342.7

Table 3a. Correlation matrix for Standard model: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model 1, Table7). A penalty term is used in calculating the total objective function when B1>2.

```
CONTROL PARAMETERS USED (FROM INPUT FILE)
------------------------------------------------------------------------------------------------------------------------
Number of years analyzed:                      42            Number of bootstrap trials:                             0
Number of data series:                          5            Lower bound on MSY:                             1.000E+00
Objective function computed:            in effort            Upper bound on MSY:                             5.000E+01
Relative conv. criterion (simplex):     1.000E-06            Lower bound on r:                               1.000E-01
Relative conv. criterion (restart):     3.000E-06            Upper bound on r:                               5.000E+00
Relative conv. criterion (effort):      1.000E-02            Random number seed:                               9114895
Maximum F allowed in fitting:               5.000            Monte Carlo search mode, trials:           2        50000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                          code  0
------------------------------------------------------------------------------------------------------------------------
Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Fishery-catch/Spring biomass       |   1.000
                                       |      22
                                       |
 2  Canadian Yankee Survey             |   0.000   1.000
                                       |       0      12
                                       |
 3  Canadian Fall Survey               |   0.877   0.000   1.000
                                       |      16       0      16
                                       |
 4  Russian Survey                     |   0.933   0.198   1.000   1.000
                                       |       8      11       2      19
                                       |
 5  Spanish Survey Converted biomass   |   0.840   0.000   0.790   0.000   1.000
                                       |      11       0      11       0      11
                                       --------------------------------------------------
                                               1       2       3       4       5
```

3b. Goodness of fit for Standard Model using the 1965-2005 (Model 2, Table 7). A penalty term is used in calculating the total objective function when B1>2.

```
GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS
------------------------------------------------------------------------------------------------------------------------
                                                     Weighted            Weighted       Current     Suggested    R-squared
Loss component number and title                           SSE     N           MSE        weight        weight      in CPUE

Loss(-1)  SSE in yield                              0.000E+00
Loss( 0)  Penalty for B1R > 2                       5.353E-03     1           N/A     1.000E+00           N/A
Loss( 1)  Fishery-catch/Spring biomass              1.050E+00    22     5.250E-02     1.000E+00     1.297E+00        0.827
Loss( 2)  Canadian Yankee Survey                    2.659E-01    12     2.659E-02     1.000E+00     2.561E+00        0.804
Loss( 3)  Canadian Fall Survey                      1.088E+00    16     7.772E-02     1.000E+00     8.761E-01        0.875
Loss( 4)  Russian Survey                            4.963E+00    19     2.920E-01     1.000E+00     2.332E-01        0.294
Loss( 5)  Spanish Survey Converted biomass_2006     2.951E+00    11     3.279E-01     1.000E+00     2.077E-01        0.559
TOTAL OBJECTIVE FUNCTION:                      1.03239738E+01

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

Number of restarts required for convergence:               33
Est. B-ratio coverage index (0 worst, 2 best):         1.7969                < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):         1.0000                <     et al. (1996), Trans. A.F.S. 125:729
```

Table 4a. Correlation matrix for Standard model with penalty term removed : Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model #2, Table # 7).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

	1	2	3	4	5
1 Fishery-catch/Spring biomass	1.000 22				
2 Canadian Yankee Survey	0.000 0	1.000 12			
3 Canadian Fall Survey	0.877 16	0.000 0	1.000 16		
4 Russian Survey	0.933 8	0.198 11	1.000 2	1.000 19	
5 Spanish Survey Converted biomass	0.840 11	0.000 0	0.790 11	0.000 0	1.000 11

Table 4b. Goodness of fit for Standard Model with penalty term removed using the 1965-2005 (Model # 2, Table # 7).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	0.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	1.167E+00	22	5.833E-02	1.000E+00	1.197E+00	0.798
Loss(2) Canadian Yankee Survey	2.623E-01	12	2.623E-02	1.000E+00	2.661E+00	0.795
Loss(3) Canadian Fall Survey	1.060E+00	16	7.574E-02	1.000E+00	9.216E-01	0.865
Loss(4) Russian Survey	4.646E+00	19	2.733E-01	1.000E+00	2.554E-01	0.316
Loss(5) Spanish Survey Converted biomass_2006	3.232E+00	11	3.591E-01	1.000E+00	1.944E-01	0.528
TOTAL OBJECTIVE FUNCTION:	1.03672406E+01					

```
Number of restarts required for convergence:             6
Est. B-ratio coverage index (0 worst, 2 best):      1.7819           < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):      1.0000           <     et al. (1996), Trans. A.F.S. 125:729
```

Table 5a. Correlation matrix for Standard model with an iteratively reweighted fit (IRF mode) : Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model #3, Table # 7).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

	1	2	3	4	5
1 Fishery-catch/Spring biomass	1.000 22				
2 Canadian Yankee Survey	0.000 0	1.000 12			
3 Canadian Fall Survey	0.877 16	0.000 0	1.000 16		
4 Russian Survey	0.933 8	0.198 11	1.000 2	1.000 19	
5 Spanish Survey Converted biomass	0.840 11	0.000 0	0.790 11	0.000 0	1.000 11

Table 5b. Goodness of fit for Standard Model with an iteratively reweighted fit (IRF mode) using the 1965-2005 (Model # 3, Table # 7).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	1.259E+00	22	6.295E-02	1.354E+00	1.351E+00	0.844
Loss(2) Canadian Yankee Survey	6.300E-01	12	6.300E-02	2.352E+00	2.345E+00	0.803
Loss(3) Canadian Fall Survey	8.692E-01	16	6.209E-02	1.012E+00	1.024E+00	0.875
Loss(4) Russian Survey	1.075E+00	19	6.323E-02	2.056E-01	2.042E-01	0.267
Loss(5) Spanish Survey Converted biomass_2006	5.723E-01	11	6.359E-02	1.715E-01	1.694E-01	0.521
TOTAL OBJECTIVE FUNCTION:	4.40540738E+00					

Number of restarts required for convergence:	10	
Est. B-ratio coverage index (0 worst, 2 best):	1.7367	< These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):	1.0000	< et al. (1996), Trans. A.F.S. 125:729

Table 6a. Correlation matrix for Standard model with B1 fixed at 2: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model # 4, Table #7).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4	5
1	Fishery-catch/Spring biomass	1.000				
		22				
2	Canadian Yankee Survey	0.000	1.000			
		0	12			
3	Canadian Fall Survey	0.877	0.000	1.000		
		16	0	16		
4	Russian Survey	0.933	0.198	1.000	1.000	
		8	11	2	19	
5	Spanish Survey Converted biomass	0.840	0.000	0.790	0.000	1.000
		11	0	11	0	11

Table 6b. Goodness of fit for Standard Model with B1 fixed at 2 using the 1965-2005 (Model #4, Table #7).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	1.084E+00	22	5.422E-02	1.000E+00	1.263E+00	0.818
Loss(2) Canadian Yankee Survey	2.655E-01	12	2.655E-02	1.000E+00	2.579E+00	0.798
Loss(3) Canadian Fall Survey	1.057E+00	16	7.549E-02	1.000E+00	9.072E-01	0.872
Loss(4) Russian Survey	4.875E+00	19	2.868E-01	1.000E+00	2.388E-01	0.298
Loss(5) Spanish Survey Converted biomass_2006	3.067E+00	11	3.408E-01	1.000E+00	2.009E-01	0.545
TOTAL OBJECTIVE FUNCTION:	1.03491867E+01					

Number of restarts required for convergence: 7

Est. B-ratio coverage index (0 worst, 2 best): 1.7922 < These two measures are defined in Prager

Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 7. Sensitivity Analysis of STANDARD PRODUCTIONMODEL used in the 2006 assessment (MSY, K, B_{msy}, and B_{2007} in thousand t units) using the 1965-2005 data series, and version 3.81 of the software. **Runs** 2-4 is the same setup as run 1 for the standard model, but with iterative re-weighting, with the penalty term removed and with B1 ratio fixed . ***All runs use ratio values of B_{2007} and F_{2006}.*** All runs except # 3 (IRF mode) are with the "FIT" mode of ASPIC.

Model	**B_1R**	**MSY**	**r**	**K**	**Bmsy**	**Fmsy**	**B_{2007} B/ B_{msy}**	**F_{2006} F/ F_{msy}**	**MSE**	**Comment**
1	**2.15**	**17.69**	**0.45**	**158.9**	**79.43**	**0.22**	**1.33**	**0.64**	**0.14**	**Standard Model (SM)**
2	3.40	16.87	0.42	162.2	81.10	0.21	1.25	0.71	0.14	Penalty removed
3	1.99	17.84	0.45	158.7	79.33	0.23	1.40	0.60	0.06	Iteratively reweighted IRF Mode
4	2.00	17.52	0.43	163.8	81.91	0.21	1.30	0.61	0.14	Fixed B1R at 2.0

MSE = SSE/N-p where SSE is the total objective function, N= number of residual, i.e. sum of N in goodness of fit test table and p= number of parameters (B1R, MSY, r + number of 'q's) form the Model parameter estimate table.

Table 8a. Correlation matrix for Standard model with the Russia index removed: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model # 2, Table #14)

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS) code 0

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4
1	Fishery-catch/Spring biomass	1.000 22			
2	Canadian Yankee Survey	0.000 0	1.000 12		
3	Canadian Fall Survey	0.877 16	0.000 0	1.000 16	
4	Spanish Survey Converted biomass	0.840 11	0.000 0	0.790 11	1.000 11

Table 8b. Goodness of fit for Standard Model using the 1965-2005 with the Russia index removed. (Model # 2, Table #14)

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	8.110E-03	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	9.415E-01	22	4.708E-02	1.000E+00	1.136E+00	0.848
Loss(2) Canadian Yankee Survey	2.766E-01	12	2.766E-02	1.000E+00	1.933E+00	0.805
Loss(3) Canadian Fall Survey	1.094E+00	16	7.817E-02	1.000E+00	6.840E-01	0.878
Loss(4) Spanish Survey Converted biomass_2006	2.824E+00	11	3.138E-01	1.000E+00	1.704E-01	0.567
TOTAL OBJECTIVE FUNCTION:	5.14502118E+00					

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

Number of restarts required for convergence: 17
Est. B-ratio coverage index (0 worst, 2 best): 1.7932 < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 9a. Correlation matrix for Standard model with Russian index removed and B1 fixed at 2: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model # 3, Table #14)

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

	1	2	3	4
1 Fishery-catch/Spring biomass	1.000 22			
2 Canadian Yankee Survey	0.000 0	1.000 12		
3 Canadian Fall Survey	0.877 16	0.000 0	1.000 16	
4 Spanish Survey Converted biomass	0.840 11	0.000 0	0.790 11	1.000 11

Table 9b. Goodness of fit for Standard Model with Russian index removed and B1 fixed at 2 using the 1965-2005 (Model #3, Table #14).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	9.449E-01	22	4.724E-02	1.000E+00	1.136E+00	0.847
Loss(2) Canadian Yankee Survey	2.778E-01	12	2.778E-02	1.000E+00	1.932E+00	0.803
Loss(3) Canadian Fall Survey	1.098E+00	16	7.845E-02	1.000E+00	6.840E-01	0.877
Loss(4) Spanish Survey Converted biomass_2006	2.811E+00	11	3.123E-01	1.000E+00	1.718E-01	0.577
TOTAL OBJECTIVE FUNCTION:	5.13200744E+00					

Number of restarts required for convergence: 15
Est. B-ratio coverage index (0 worst, 2 best): 1.7947 < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 10a. Correlation matrix for Standard model with Canadian juvenile-fall index in the model and Russian index removed: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model #6, Table # 14).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4
1	Fishery-catch/Spring biomass	1.000 22			
2	Canadian Yankee Survey	0.000 0	1.000 12		
3	Canadian Fall with converted Juv	0.812 21	0.000 0	1.000 21	
4	Spanish Survey Converted biomass	0.840 11	0.000 0	0.797 11	1.000 11

Table 10b. Goodness of fit for Standard Model with Canadian juvenile-fall index in the model and Russian index removed using the 1965-2005 (Model #6, Table #14).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	1.014E+00	22	5.071E-02	1.000E+00	1.284E+00	0.846
Loss(2) Canadian Yankee Survey	2.803E-01	12	2.803E-02	1.000E+00	2.323E+00	0.787
Loss(3) Canadian Fall with converted Juvenile S	3.251E+00	21	1.711E-01	1.000E+00	3.805E-01	0.744
Loss(4) Spanish Survey Converted biomass_2006	3.425E+00	11	3.806E-01	1.000E+00	1.711E-01	0.503
TOTAL OBJECTIVE FUNCTION:	7.97071059E+00					

Number of restarts required for convergence:	35	
Est. B-ratio coverage index (0 worst, 2 best):	1.1810	< These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):	1.0000	< et al. (1996), Trans. A.F.S. 125:729

Table 11a. Correlation matrix for Standard model with Canadian juvenile-fall index in the model and Russian index removed –Penalty term removed: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model #7, Table # 14).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4
1	Fishery-catch/Spring biomass	1.000			
		22			
2	Canadian Yankee Survey	0.000	1.000		
		0	12		
3	Canadian Fall with converted Juv	0.812	0.000	1.000	
		21	0	21	
4	Spanish Survey Converted biomass	0.840	0.000	0.797	1.000
		11	0	11	11

Table 11b. Goodness of fit for Standard Model with Canadian juvenile-fall index in the model and Russian index removed –Penalty term removed using the 1965-2005 (Model #7, Table # 14).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	0.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	9.755E-01	22	4.878E-02	1.000E+00	1.316E+00	0.848
Loss(2) Canadian Yankee Survey	2.785E-01	12	2.785E-02	1.000E+00	2.306E+00	0.791
Loss(3) Canadian Fall with converted Juvenile S	3.421E+00	21	1.801E-01	1.000E+00	3.566E-01	0.738
Loss(4) Spanish Survey Converted biomass_2006	3.385E+00	11	3.761E-01	1.000E+00	1.707E-01	0.522
TOTAL OBJECTIVE FUNCTION:	8.05980332E+00					

Number of restarts required for convergence: 39
Est. B-ratio coverage index (0 worst, 2 best): 1.1933 < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 12a. Correlation matrix for Standard model with Canadian juvenile-fall index in the model and Russian index removed – using an iteratively reweighted fit (IRF mode): Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model 8, Table #14).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4
1	Fishery-catch/Spring biomass	1.000			
		22			
2	Canadian Yankee Survey	0.000	1.000		
		0	12		
3	Canadian Fall with converted Juv	0.812	0.000	1.000	
		21	0	21	
4	Spanish Survey Converted biomass	0.840	0.000	0.797	1.000
		11	0	11	11

Table 12b. Goodness of fit for Standard Model with Canadian juvenile-fall index in the model and Russian index removed – using an iteratively reweighted fit (IRF mode): using the 1965-2005 (Model #8, Table #14).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	1.280E+00	22	6.398E-02	1.284E+00	1.300E+00	0.846
Loss(2) Canadian Yankee Survey	6.519E-01	12	6.519E-02	2.323E+00	2.309E+00	0.789
Loss(3) Canadian Fall with converted Juvenile S	1.263E+00	21	6.649E-02	3.805E-01	3.708E-01	0.744
Loss(4) Spanish Survey Converted biomass_2006	5.777E-01	11	6.419E-02	1.711E-01	1.727E-01	0.496
TOTAL OBJECTIVE FUNCTION:	3.77232993E+00					

Number of restarts required for convergence: 3
Est. B-ratio coverage index (0 worst, 2 best): 1.1769 < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 13a. Correlation matrix for Standard model with Canadian juvenile-fall index in the model and Russian index removed – using B1 ratio fixed at 2.0: Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2005 data as used in NAFO 2006 stock assessment. (Model 9, Table #14).

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

		1	2	3	4
1	Fishery-catch/Spring biomass	1.000			
		22			
2	Canadian Yankee Survey	0.000	1.000		
		0	12		
3	Canadian Fall with converted Juv	0.812	0.000	1.000	
		21	0	21	
4	Spanish Survey Converted biomass	0.840	0.000	0.797	1.000
		11	0	11	11

Table 13b. Goodness of fit for Standard Model with Canadian juvenile-fall index in the model and Russian index removed – using B1 ratio fixed at 2.0: using the 1965-2005 (Model #9, Table #14).

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	9.422E-01	22	4.711E-02	1.000E+00	1.339E+00	0.848
Loss(2) Canadian Yankee Survey	2.721E-01	12	2.721E-02	1.000E+00	2.318E+00	0.806
Loss(3) Canadian Fall with converted Juvenile S	3.641E+00	21	1.916E-01	1.000E+00	3.291E-01	0.729
Loss(4) Spanish Survey Converted biomass_2006	3.450E+00	11	3.833E-01	1.000E+00	1.646E-01	0.500
TOTAL OBJECTIVE FUNCTION:	8.30515304E+00					

Number of restarts required for convergence:	7	
Est. B-ratio coverage index (0 worst, 2 best):	1.7292	< These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):	1.0000	< et al. (1996), Trans. A.F.S. 125:729

Table 14 Results from ALTERNATE PRODUCTION MODEL configurations of the standard model used in the 2006 assessment using the 1965-2005 data series, and version 3.81 of the software. Alternate models include 1985-1994 converted juvenile survey index in Campelen units and a combined 1985-1994 juvenile survey index with the 1995-2005 Canadian Campelen fall survey in Campelen units. Model 1 is the standard model from Table 7. Models 2 and 3 did not converge because of negative correlations with the converted juvenile series with Russian spring survey and Canadian spring survey, respectively. Model 9 would not run. ***All runs use ratio values of B_{2007} and F_{2006}.*** All runs except # 3 (IRF mode) are with the "FIT" mode of ASPIC.

Model	**B_1R**	**MSY**	**r**	**K**	**Bmsy**	**Fmsy**	**B_{2007} B/ B_{msy}**	**F_{2006} F/ F_{msy}**	**MSE**	**Comment**
1	**2.15**	**17.69**	**0.45**	**158.9**	**79.43**	**0.22**	**1.33**	**0.64**	**0.14**	**Standard Model (SM)**
2	2.19	18.35	0.49	148.9	74.44	0.25	1.43	0.57	0.09	Exclude Russian from SM
3	2.00	18.41	0.49	149.9	74.95	0.25	1.43	0.57	0.09	Exclude Russia Fixed B1Ratio
4										SM with Converted Juvenile-**no convergence**
5										SM Include Juvenile Exclude Russia- **no convergence**
6	0.70	20.10	0.42	193.1	96.55	0.21	1.46	0.52	0.13	SM Exclude Russia include New Juvenile/Fall
7	0.85	19.43	0.44	177.1	88.55	0.22	1.46	0.53	0.13	SM Exclude Russia include New Juvenile/Fall . Penalty term removed
8	0.70	20.12	0.41	194.7	97.34	0.21	1.45	0.52	0.06	SM Exclude Russia include New Juvenile/Fall . Iteratively reweighted
9	2.0	18.2	0.47	153.7	76.8	0.24	1.45	0.57	0.14	SM Exclude Russia include New Juvenile/Fall . FIXED B1 ratio=2

Table 15. Bias corrected estimates (BC) of biological and fishing parameters based on 500 bootstrap trials for the Standard Model, Standard Model with B1 fixed at and the Alternate Standard Model. A penalty term is used in calculating the total objective function when B1>2 for the Standard Model used in the 2000-2006 ASPIC surplus production runs; The penalty term is removed and B1 is fixed at 2 in the Standard Model; and an alternate to the Standard Model is used. ***All runs use ratio values of B_{2007} and F_{2006}***
The relative interquartile range from the bootstrap table is a measure of statistical dispersion and expressed here as a percentage.

Parameter Name	Standard Model		Standard Model B1=2		Alternate Standard Model	
	BC	IRQ%	BC	IRQ%	BC	IRQ%
B1 ratio	2.29	17.8	2.00	0.0	0.71	42.9
q	3.25	17.5	3.22	15.9	2.56	18.3
r	0.44	14.3	0.42	12.3	0.41	20.3
K (mt)	158.2	9.6	165.2	8.3	195.2	22.2
MSY (mt)	17.4	5.1	17.4	4.6	19.9	7.4
Yield 2007	15.6	8.4	16.1	6.2	16.0	15.6
Bmsy	79.1	9.6	82.6	8.3	97.6	22.2
Fmsy	0.22	14.3	0.21	12.9	0.20	20.3
B2007/Bmsy	1.33	11.6	1.29	11.5	1.46	8.1
F2006/Fmsy	0.64	17.8	0.67	11.5	0.52	13.2

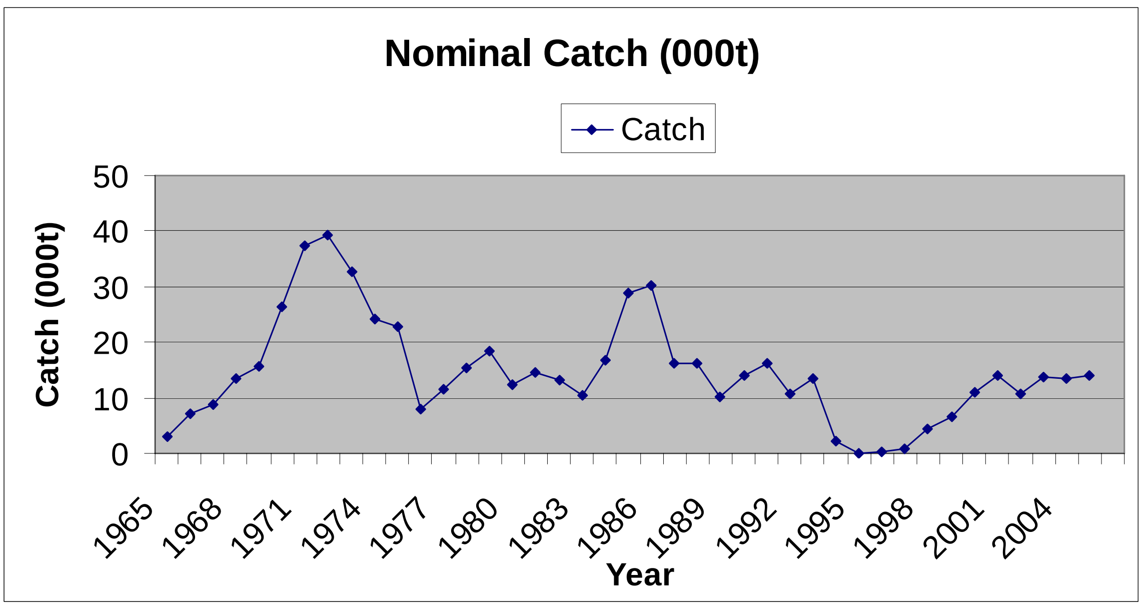

Fig. 1 Trends in the nominal catch index used in the standard formulation of the ASPIC surplus production model for the 2006 NAFO assessment.

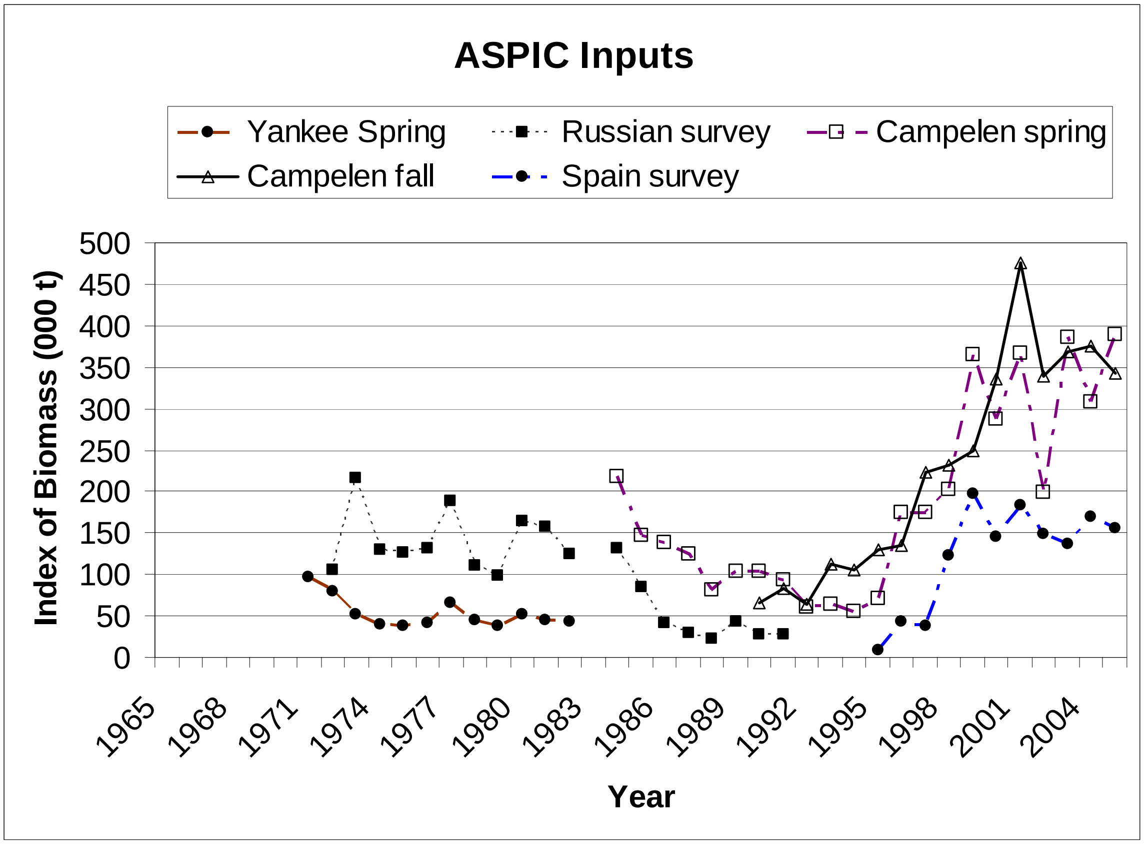

Fig. 2a . Trends in biomass from various surveys used in the standard formulation of the ASPIC surplus production model used in the 2006 NAFO assessment.

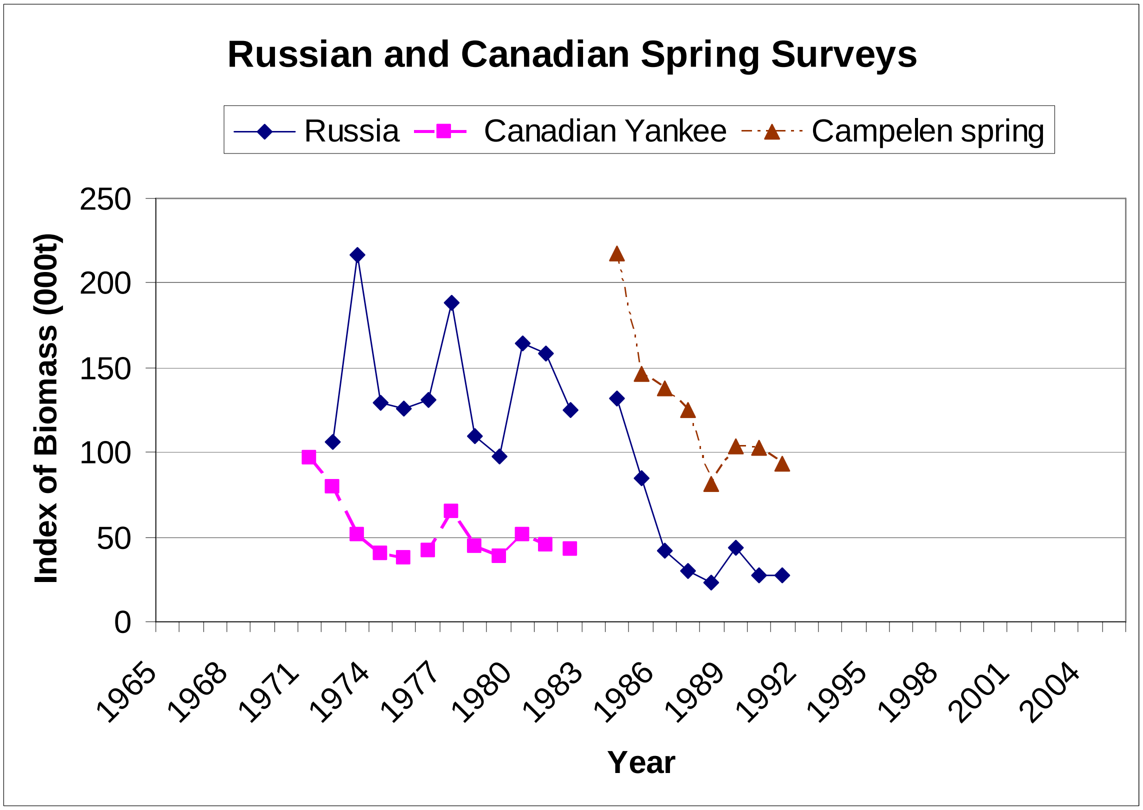

Fig. 2b . Comparison of the trends in biomass from the 1971-91 Russian and spring surveys used in the standard formulation of the ASPIC surplus production model used in the 2006 NAFO assessment.

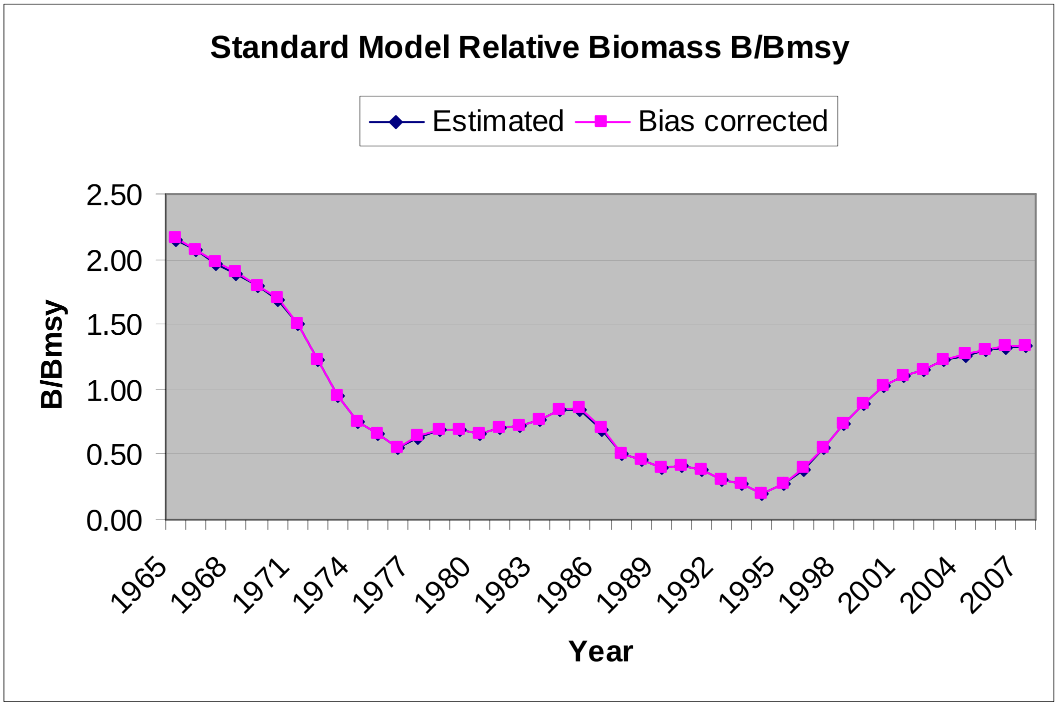

Fig. 3a. Comparison of the trends in the estimated relative biomass and bias corrected (500 bootstrap trials) relative biomass from standard formulation of ASPIC surplus production model used in the 2006 NAFO assessment. Standard formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

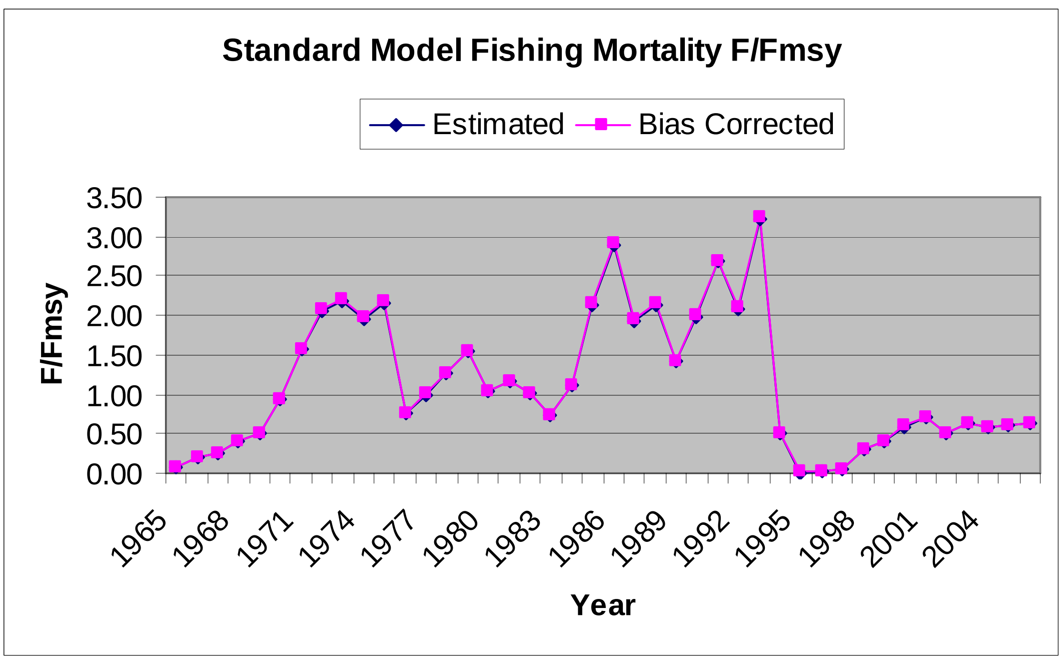

Fig. 3b. Comparison of the trends in the estimated relative fishing mortality and bias corrected (500 bootstrap trials) relative fishing mortality from standard model formulation of ASPIC surplus production model used in the 2006 NAFO assessment. Standard model formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

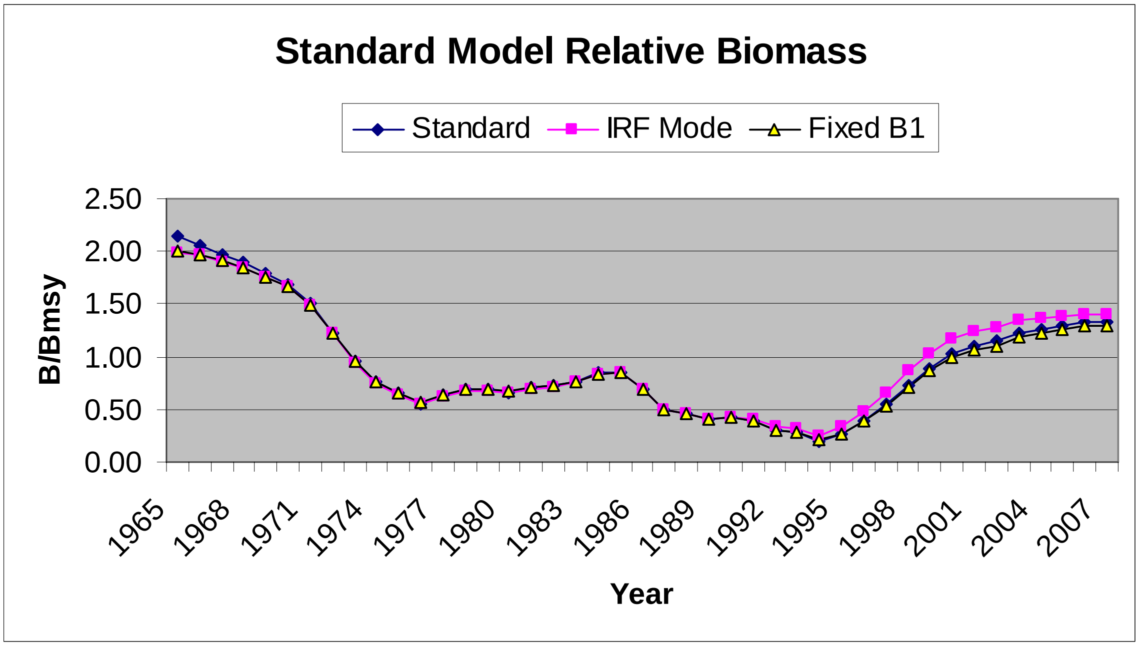

Fig. 4a. Comparison of the trends in the estimated relative biomass from the standard formulation of ASPIC surplus production model with that derived using 1) an iterative reweighting fit (IRF mode) of the same time series and 2) a fit that constrains B1 = 2 for the same time series. Standard model formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

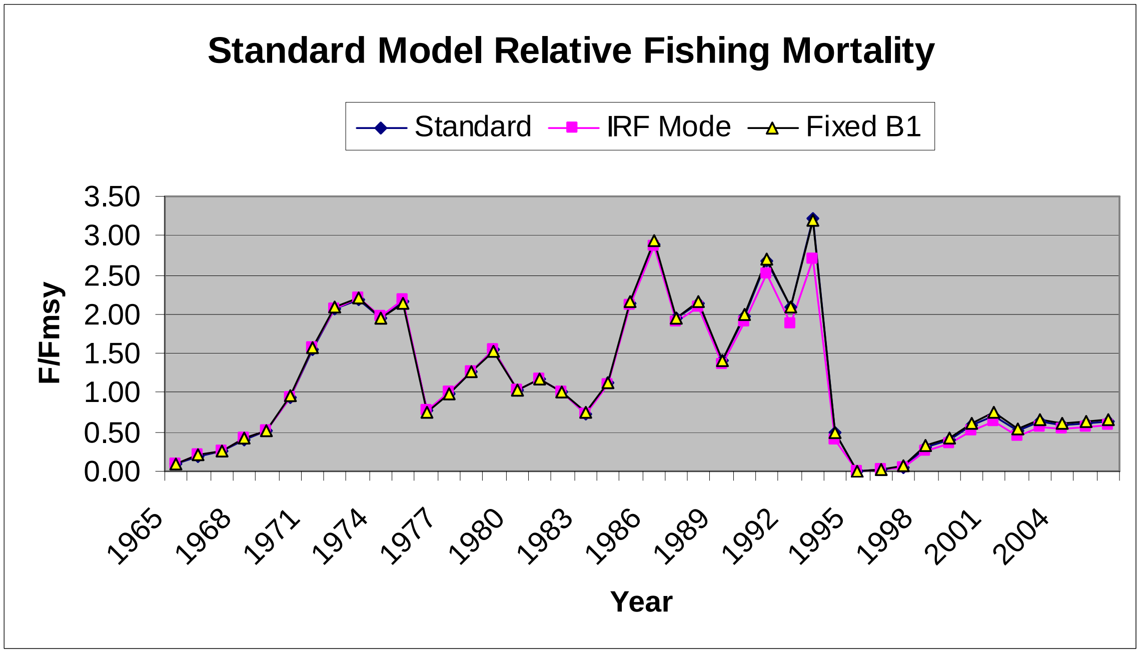

Fig. 4b. Comparison of the trends in the estimated relative fishing mortality from the standard formulation of ASPIC surplus production model with that derived using 1) an iterative reweighting fit (IRF mode) of the same time series and 2) a fit that constrains B1 = 2 for the same time series. Standard model formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

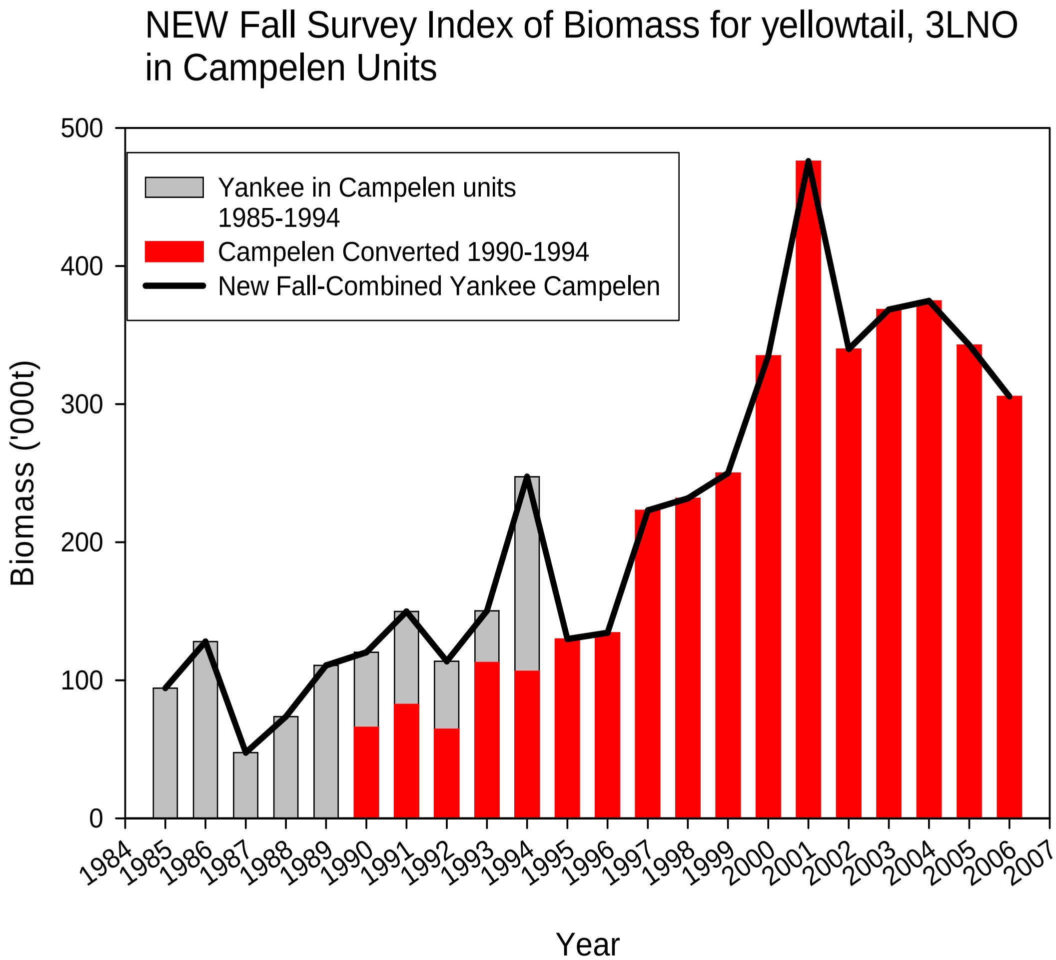

Fig. 5 Time series of fall biomass estimates of yellowtail flounder on the Grand Bank, 1985-2006. The 1985-94 Yankee shrimp trawl estimates were converted to Campelen trawl units (Walsh 2005;NAFO SCR Doc. 05/48.The new fall index combines converted 1985-1994 Yankee and 1995-2005 Campelen (unconverted)

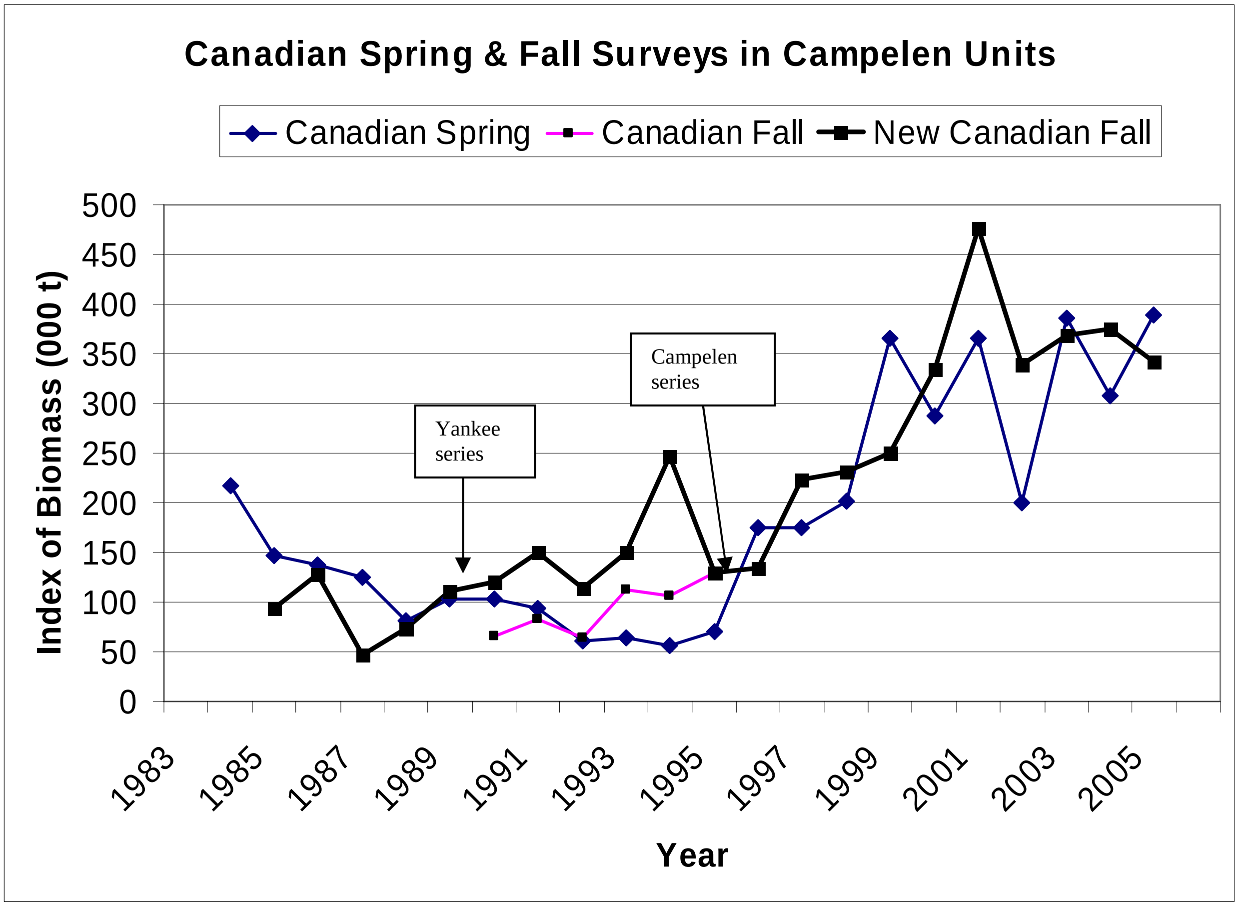

Fig. 6 Comparison of trends in biomass derived from Canadian bottom trawl surveys used in an alternate formulations of the standard ASPIC surplus production model. New Canadian fall series is explained in Figure 5. The old Canadian fall (Engel converted data) covers the period 1990-1994

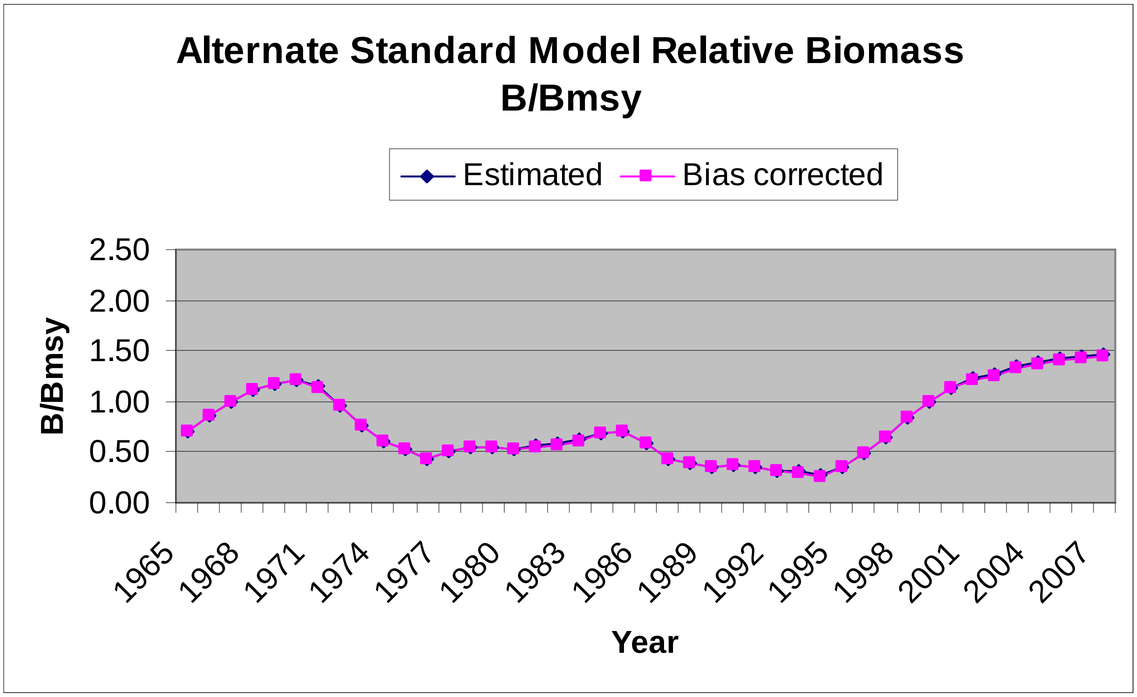

Fig. 7a. Comparison of the trends in the estimated relative biomass and bias corrected (500 bootstrap trials) relative fishing mortality from an alternate standard formulation of ASPIC surplus production model used in the 2006 NAFO assessment (see Model 6 in Table 13). The alternate standard model, like the standard accepted model formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

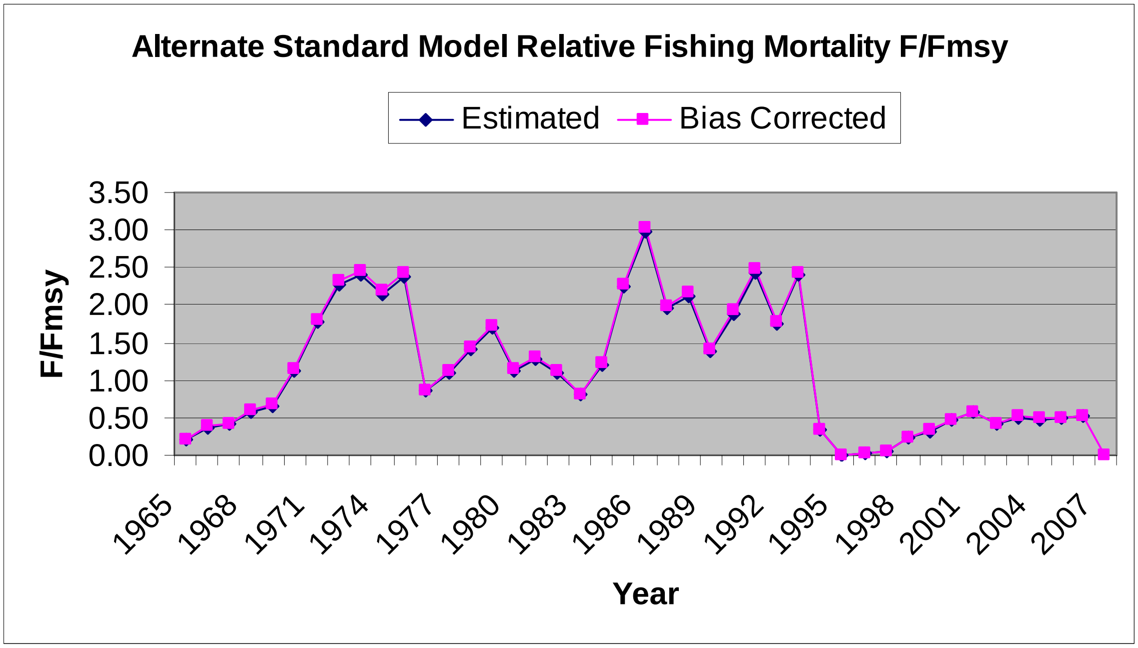

Fig. 7b. Comparison of the trends in the estimated relative fishing mortality and bias corrected (500 bootstrap trials) relative fishing mortality from an alternate standard formulation of ASPIC surplus production model used in the 2006 NAFO assessment (see Model 6 in Table 13). The alternate standard model, like the accepted standard model formulation uses a penalty term in the calculation of the total objective function to constrain B1<2.

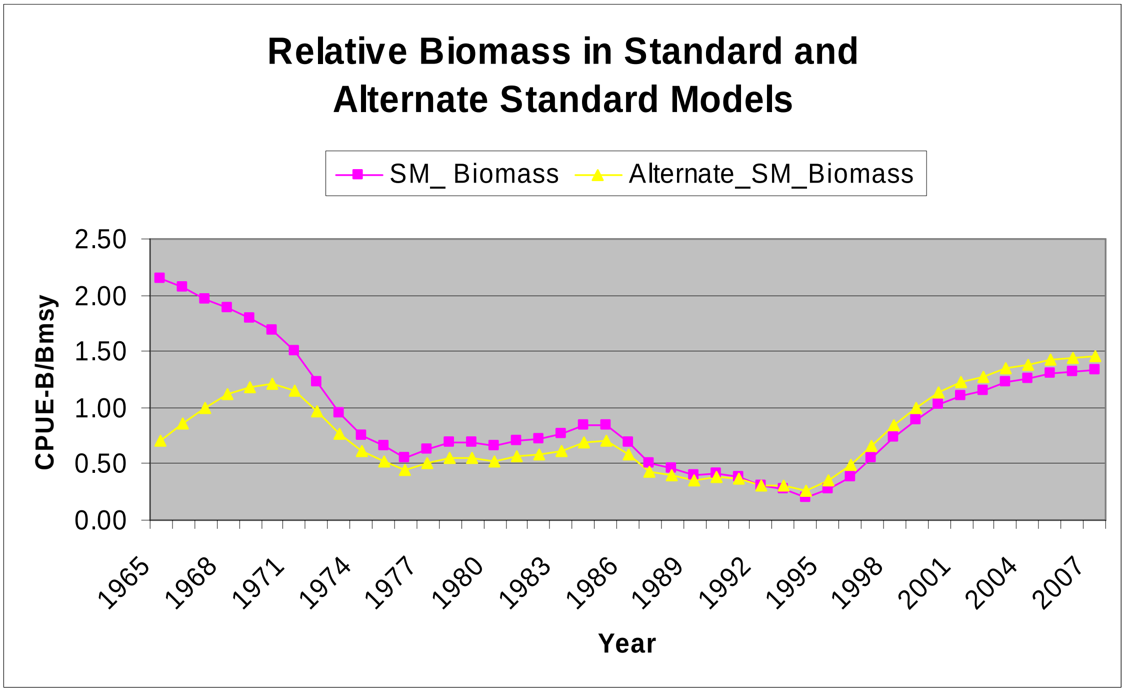

Fig. 8a Comparison of trends in relative biomass from the standard model and the alternate standard model

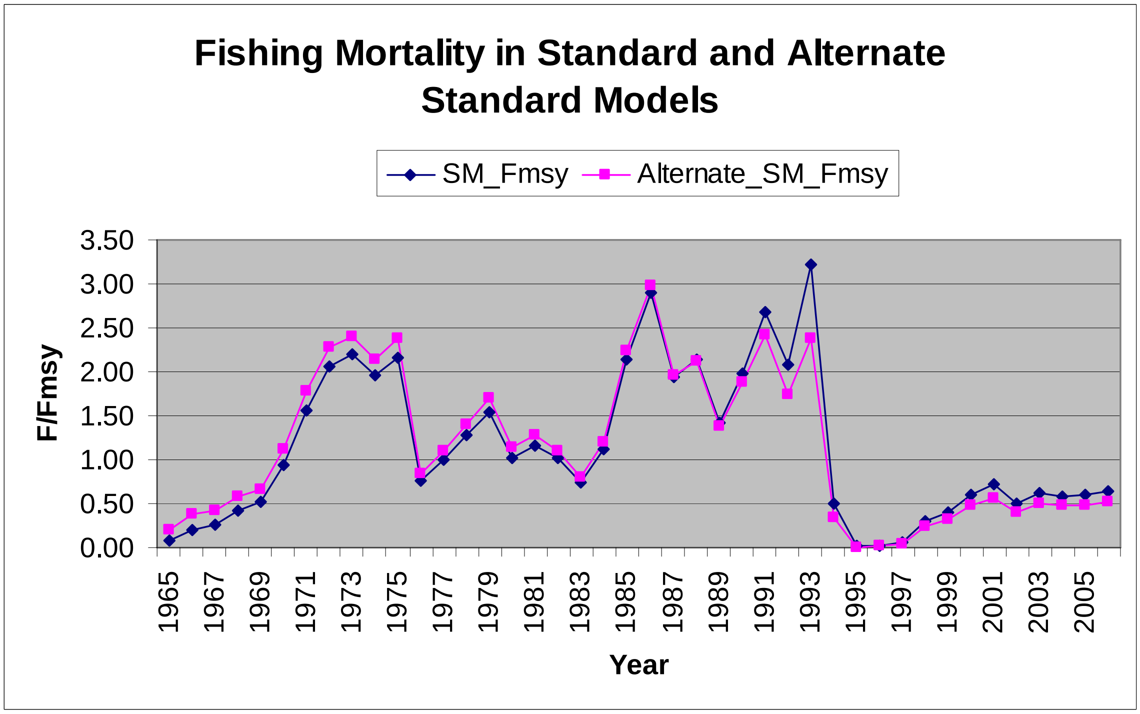

Fig. 8b Comparison of trends in fishing mortality from the standard model and alternate standard model.

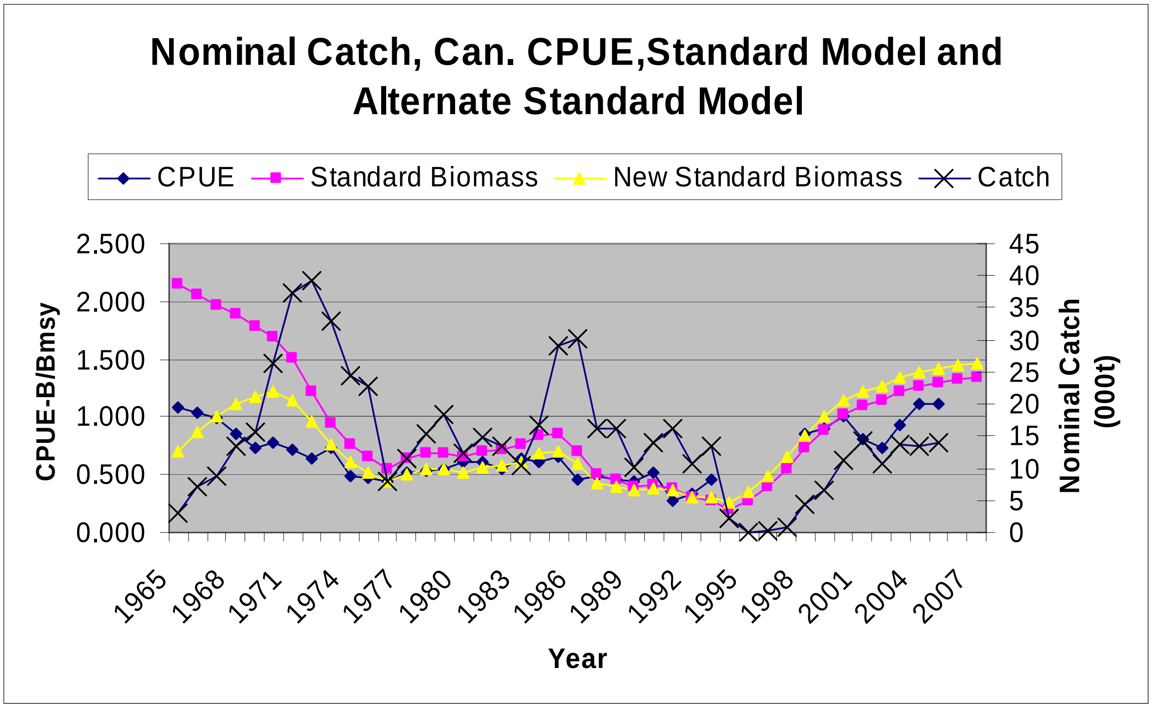

Fig. 9. Comparison of trends in catch, Canadian CPUE index, and standard model and alternate standard model relative biomass

APPENDIX A

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3LNO ytail (v3.81, 2002 standard model formulation used with 2005 data) 2006=TAC
Page 1
                                                                                    14 Jun 2007 at 23:58.41
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.81)                               BOT Mode

Author: Michael H. Prager; NOAA/NMFS/S.E. Fisheries Science Center                      ASPIC User's Manual
        101 Pivers Island Road; Beaufort, North Carolina  28516  USA                     is available gratis
                                                                                             from the author.
Ref:    Prager, M. H.  1994.  A suite of extensions to a nonequilibrium
        surplus-production model.  Fishery Bulletin 92: 374-389.


CONTROL PARAMETERS USED (FROM INPUT FILE)
------------------------------------------------------------------------------------------------------------------------
Number of years analyzed:                        42            Number of bootstrap trials:                      500
Number of data series:                            5            Lower bound on MSY:                        1.000E+00
Objective function computed:              in effort            Upper bound on MSY:                        5.000E+01
Relative conv. criterion (simplex):       1.000E-06            Lower bound on r:                          1.000E-01
Relative conv. criterion (restart):       3.000E-06            Upper bound on r:                          5.000E+00
Relative conv. criterion (effort):        1.000E-02            Random number seed:                          9114895
Maximum F allowed in fitting:                 5.000            Monte Carlo search mode, trials:           2     50000


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                       code  0
------------------------------------------------------------------------------------------------------------------------
Normal convergence.


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Fishery-catch/Spring biomass       |   1.000
                                       |      22
                                       |
 2  Canadian Yankee Survey             |   0.000   1.000
                                       |       0      12
                                       |
 3  Canadian Fall Survey               |   0.877   0.000   1.000
                                       |      16       0      16
                                       |
 4  Russian Survey                     |   0.933   0.198   1.000   1.000
                                       |       8      11       2      19
                                       |
 5  Spanish Survey Converted biomass   |   0.840   0.000   0.790   0.000   1.000
                                       |      11       0      11       0      11
                                       --------------------------------------------------
                                               1       2       3       4       5


GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS
------------------------------------------------------------------------------------------------------------------------
                                                     Weighted            Weighted      Current    Suggested    R-squared
Loss component number and title                           SSE     N           MSE       weight       weight      in CPUE

Loss(-1)  SSE in yield                              0.000E+00
Loss( 0)  Penalty for B1R > 2                       5.353E-03    1            N/A    1.000E+00          N/A
Loss( 1)  Fishery-catch/Spring biomass              1.050E+00   22      5.250E-02    1.000E+00    1.297E+00        0.827
Loss( 2)  Canadian Yankee Survey                    2.659E-01   12      2.659E-02    1.000E+00    2.561E+00        0.804
Loss( 3)  Canadian Fall Survey                      1.088E+00   16      7.772E-02    1.000E+00    8.761E-01        0.875
Loss( 4)  Russian Survey                            4.963E+00   19      2.920E-01    1.000E+00    2.332E-01        0.294
Loss( 5)  Spanish Survey Converted biomass_2006     2.951E+00   11      3.279E-01    1.000E+00    2.077E-01        0.559
TOTAL OBJECTIVE FUNCTION:                      1.03239738E+01

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

Number of restarts required for convergence:           33
Est. B-ratio coverage index (0 worst, 2 best):     1.7969              < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):     1.0000              <     et al. (1996), Trans. A.F.S. 125:729


MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate     Starting guess    Estimated   User guess

B1R       Starting biomass ratio, year 1965         2.153E+00          2.000E+00            1            1
MSY       Maximum sustainable yield                 1.769E+01          1.300E+01            1            1
r         Intrinsic rate of increase                4.454E-01          5.000E-01            1            1
........  Catchability coefficients by fishery:
q( 1)     Fishery-catch/Spring biomass              3.279E+00          3.000E+00            1            1
q( 2)     Canadian Yankee Survey                    8.438E-01          1.000E+00            1            1
q( 3)     Canadian Fall Survey                      3.678E+00          3.000E+00            1            1
q( 4)     Russian Survey                            1.706E+00          1.000E+00            1            1
q( 5)     Spanish Survey Converted biomass_2006     1.365E+00          3.000E+00            1            1


MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate            Formula        Related quantity

MSY       Maximum sustainable yield                 1.769E+01               Kr/4
K         Maximum stock biomass                     1.589E+02
Bmsy      Stock biomass at MSY                      7.943E+01                K/2
Fmsy      Fishing mortality at MSY                  2.227E-01                r/2

F(0.1)    Management benchmark                      2.004E-01          0.9*Fmsy
Y(0.1)    Equilibrium yield at F(0.1)               1.751E+01           0.99*MSY
```

```
B-ratio   Ratio of B(2007) to Bmsy                 1.334E+00
F-ratio   Ratio of F(2006) to Fmsy                 6.380E-01
F01-mult  Ratio of F(0.1) to F(2006)               1.411E+00
Y-ratio   Proportion of MSY avail in 2007          8.887E-01          2*Br-Br^2     Ye(2007) = 1.572E+01

........  Fishing effort at MSY in units of each fishery:
fmsy( 1)  Fishery-catch/Spring biomass             6.791E-02           r/2q( 1)       f(0.1) = 6.112E-02
```

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1965	0.019	1.709E+02	1.671E+02	3.130E+00	3.130E+00	-3.880E+00	8.410E-02	2.152E+00
2	1966	0.044	1.639E+02	1.599E+02	7.026E+00	7.026E+00	-4.605E-01	1.973E-01	2.064E+00
3	1967	0.058	1.564E+02	1.530E+02	8.878E+00	8.878E+00	2.509E+00	2.606E-01	1.969E+00
4	1968	0.092	1.501E+02	1.458E+02	1.334E+01	1.334E+01	5.343E+00	4.110E-01	1.889E+00
5	1969	0.114	1.421E+02	1.380E+02	1.571E+01	1.571E+01	8.071E+00	5.112E-01	1.789E+00
6	1970	0.209	1.344E+02	1.264E+02	2.643E+01	2.643E+01	1.147E+01	9.390E-01	1.692E+00
7	1971	0.348	1.195E+02	1.074E+02	3.734E+01	3.734E+01	1.532E+01	1.561E+00	1.504E+00
8	1972	0.459	9.744E+01	8.560E+01	3.926E+01	3.926E+01	1.745E+01	2.059E+00	1.227E+00
9	1973	0.488	7.563E+01	6.723E+01	3.281E+01	3.281E+01	1.719E+01	2.192E+00	9.523E-01
10	1974	0.437	6.001E+01	5.566E+01	2.431E+01	2.431E+01	1.608E+01	1.961E+00	7.556E-01
11	1975	0.482	5.178E+01	4.749E+01	2.289E+01	2.289E+01	1.480E+01	2.165E+00	6.519E-01
12	1976	0.171	4.369E+01	4.701E+01	8.057E+00	8.057E+00	1.473E+01	7.695E-01	5.500E-01
13	1977	0.222	5.036E+01	5.237E+01	1.164E+01	1.164E+01	1.563E+01	9.979E-01	6.340E-01
14	1978	0.283	5.435E+01	5.457E+01	1.547E+01	1.547E+01	1.595E+01	1.273E+00	6.843E-01
15	1979	0.343	5.484E+01	5.345E+01	1.835E+01	1.835E+01	1.578E+01	1.542E+00	6.904E-01
16	1980	0.229	5.227E+01	5.403E+01	1.238E+01	1.238E+01	1.587E+01	1.029E+00	6.581E-01
17	1981	0.260	5.577E+01	5.653E+01	1.468E+01	1.468E+01	1.621E+01	1.166E+00	7.021E-01
18	1982	0.226	5.730E+01	5.891E+01	1.332E+01	1.332E+01	1.650E+01	1.015E+00	7.214E-01
19	1983	0.164	6.048E+01	6.380E+01	1.047E+01	1.047E+01	1.699E+01	7.372E-01	7.615E-01
20	1984	0.249	6.700E+01	6.727E+01	1.673E+01	1.673E+01	1.727E+01	1.117E+00	8.436E-01
21	1985	0.476	6.754E+01	6.087E+01	2.896E+01	2.896E+01	1.664E+01	2.137E+00	8.504E-01
22	1986	0.645	5.522E+01	4.675E+01	3.018E+01	3.018E+01	1.460E+01	2.898E+00	6.952E-01
23	1987	0.432	3.964E+01	3.778E+01	1.631E+01	1.631E+01	1.281E+01	1.939E+00	4.991E-01
24	1988	0.477	3.614E+01	3.389E+01	1.616E+01	1.616E+01	1.187E+01	2.141E+00	4.550E-01
25	1989	0.314	3.185E+01	3.249E+01	1.021E+01	1.021E+01	1.151E+01	1.411E+00	4.010E-01
26	1990	0.441	3.315E+01	3.172E+01	1.399E+01	1.399E+01	1.130E+01	1.980E+00	4.173E-01
27	1991	0.596	3.046E+01	2.716E+01	1.620E+01	1.620E+01	1.001E+01	2.678E+00	3.835E-01
28	1992	0.463	2.426E+01	2.324E+01	1.076E+01	1.076E+01	8.829E+00	2.080E+00	3.055E-01
29	1993	0.717	2.233E+01	1.898E+01	1.362E+01	1.362E+01	7.415E+00	3.221E+00	2.811E-01
30	1994	0.111	1.613E+01	1.865E+01	2.069E+00	2.069E+00	7.326E+00	4.982E-01	2.031E-01
31	1995	0.003	2.139E+01	2.594E+01	6.700E-02	6.700E-02	9.644E+00	1.160E-02	2.693E-01
32	1996	0.006	3.096E+01	3.690E+01	2.320E-01	2.320E-01	1.258E+01	2.823E-02	3.899E-01
33	1997	0.013	4.331E+01	5.044E+01	6.580E-01	6.580E-01	1.528E+01	5.857E-02	5.453E-01
34	1998	0.068	5.794E+01	6.422E+01	4.386E+00	4.386E+00	1.700E+01	3.067E-01	7.294E-01
35	1999	0.091	7.055E+01	7.596E+01	6.894E+00	6.894E+00	1.763E+01	4.075E-01	8.883E-01
36	2000	0.132	8.128E+01	8.459E+01	1.116E+01	1.116E+01	1.760E+01	5.925E-01	1.023E+00
37	2001	0.158	8.773E+01	8.940E+01	1.414E+01	1.414E+01	1.740E+01	7.104E-01	1.105E+00
38	2002	0.113	9.099E+01	9.427E+01	1.070E+01	1.070E+01	1.706E+01	5.096E-01	1.146E+00
39	2003	0.140	9.735E+01	9.881E+01	1.381E+01	1.381E+01	1.663E+01	6.274E-01	1.226E+00
40	2004	0.131	1.002E+02	1.017E+02	1.335E+01	1.335E+01	1.629E+01	5.896E-01	1.261E+00
41	2005	0.134	1.031E+02	1.042E+02	1.393E+01	1.393E+01	1.597E+01	6.006E-01	1.298E+00
42	2006	0.142	1.052E+02	1.056E+02	1.500E+01	1.500E+01	1.578E+01	6.380E-01	1.324E+00
43	2007		1.059E+02						1.334E+00

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Fishery-catch/Spring biomass

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in yield
1	1965	*	5.485E+02	0.0187	3.130E+00	3.130E+00	0.00000	0.000E+00
2	1966	*	5.247E+02	0.0439	7.026E+00	7.026E+00	0.00000	0.000E+00
3	1967	*	5.021E+02	0.0580	8.878E+00	8.878E+00	0.00000	0.000E+00
4	1968	*	4.784E+02	0.0915	1.334E+01	1.334E+01	0.00000	0.000E+00
5	1969	*	4.528E+02	0.1139	1.571E+01	1.571E+01	0.00000	0.000E+00
6	1970	*	4.148E+02	0.2091	2.643E+01	2.643E+01	0.00000	0.000E+00
7	1971	*	3.525E+02	0.3477	3.734E+01	3.734E+01	0.00000	0.000E+00
8	1972	*	2.809E+02	0.4586	3.926E+01	3.926E+01	0.00000	0.000E+00
9	1973	*	2.206E+02	0.4881	3.281E+01	3.281E+01	0.00000	0.000E+00
10	1974	*	1.827E+02	0.4368	2.431E+01	2.431E+01	0.00000	0.000E+00
11	1975	*	1.559E+02	0.4821	2.289E+01	2.289E+01	0.00000	0.000E+00
12	1976	*	1.543E+02	0.1714	8.057E+00	8.057E+00	0.00000	0.000E+00
13	1977	*	1.719E+02	0.2222	1.164E+01	1.164E+01	0.00000	0.000E+00
14	1978	*	1.791E+02	0.2834	1.547E+01	1.547E+01	0.00000	0.000E+00
15	1979	*	1.754E+02	0.3433	1.835E+01	1.835E+01	0.00000	0.000E+00
16	1980	*	1.773E+02	0.2291	1.238E+01	1.238E+01	0.00000	0.000E+00
17	1981	*	1.855E+02	0.2597	1.468E+01	1.468E+01	0.00000	0.000E+00
18	1982	*	1.933E+02	0.2261	1.332E+01	1.332E+01	0.00000	0.000E+00
19	1983	*	2.094E+02	0.1642	1.047E+01	1.047E+01	0.00000	0.000E+00
20	1984	2.177E+02	2.208E+02	0.2488	1.673E+01	1.673E+01	0.01400	0.000E+00
21	1985	1.468E+02	1.998E+02	0.4758	2.896E+01	2.896E+01	0.30810	0.000E+00
22	1986	1.382E+02	1.534E+02	0.6454	3.018E+01	3.018E+01	0.10459	0.000E+00
23	1987	1.246E+02	1.240E+02	0.4319	1.631E+01	1.631E+01	-0.00502	0.000E+00
24	1988	8.100E+01	1.112E+02	0.4767	1.616E+01	1.616E+01	0.31720	0.000E+00
25	1989	1.038E+02	1.066E+02	0.3142	1.021E+01	1.021E+01	0.02675	0.000E+00
26	1990	1.031E+02	1.041E+02	0.4409	1.399E+01	1.399E+01	0.00962	0.000E+00
27	1991	9.340E+01	8.915E+01	0.5965	1.620E+01	1.620E+01	-0.04659	0.000E+00
28	1992	6.140E+01	7.626E+01	0.4631	1.076E+01	1.076E+01	0.21680	0.000E+00
29	1993	9.330E+01	6.230E+01	0.7172	1.362E+01	1.362E+01	-0.40387	0.000E+00
30	1994	5.560E+01	6.120E+01	0.1110	2.069E+00	2.069E+00	0.09598	0.000E+00
31	1995	7.060E+01	8.513E+01	0.0026	6.700E-02	6.700E-02	0.18712	0.000E+00
32	1996	1.756E+02	1.211E+02	0.0063	2.320E-01	2.320E-01	-0.37157	0.000E+00
33	1997	1.749E+02	1.655E+02	0.0130	6.580E-01	6.580E-01	-0.05494	0.000E+00
34	1998	2.022E+02	2.108E+02	0.0683	4.386E+00	4.386E+00	0.04145	0.000E+00
35	1999	3.657E+02	2.493E+02	0.0908	6.894E+00	6.894E+00	-0.38320	0.000E+00
36	2000	2.875E+02	2.776E+02	0.1319	1.116E+01	1.116E+01	-0.03502	0.000E+00
37	2001	3.660E+02	2.934E+02	0.1582	1.414E+01	1.414E+01	-0.22104	0.000E+00
38	2002	1.995E+02	3.094E+02	0.1135	1.070E+01	1.070E+01	0.43876	0.000E+00
39	2003	3.865E+02	3.243E+02	0.1397	1.381E+01	1.381E+01	-0.17547	0.000E+00
40	2004	3.079E+02	3.338E+02	0.1313	1.335E+01	1.335E+01	0.08070	0.000E+00
41	2005	3.888E+02	3.419E+02	0.1337	1.393E+01	1.393E+01	-0.12858	0.000E+00
42	2006	*	3.465E+02	0.1421	1.500E+01	1.500E+01	0.00000	0.000E+00

* Asterisk indicates missing value(s).

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3LNO ytail (v3.81, 2002 formulation with 2005 data) 2006=TAC                                                   Page 4

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0140                                             |=
1985     0.3081                                             |============
1986     0.1046                                             |====
1987    -0.0050                                             |
1988     0.3172                                             |=============
1989     0.0267                                             |=
1990     0.0096                                             |
1991    -0.0466                                           ==|
1992     0.2168                                             |=========
1993    -0.4039                             ================|

1994     0.0960                                             |====
1995     0.1871                                             |=======
1996    -0.3716                              ===============|
1997    -0.0549                                           ==|
1998     0.0414                                             |==
1999    -0.3832                              ===============|
2000    -0.0350                                            =|
2001    -0.2210                                    =========|
2002     0.4388                                             |==================
2003    -0.1755                                      =======|
2004     0.0807                                             |===
2005    -0.1286                                        =====|
2006     0.0000                                             |
                   ------------------------------------------------------------------------------------
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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Canadian Yankee Survey

Data type I1: Year-average biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	1.411E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	1.350E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	1.292E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.231E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.165E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.067E+02	0.00000	0.0
7	1971	1.000E+00	1.000E+00	0.0	9.690E+01	9.068E+01	0.06633	6.219E+00
8	1972	1.000E+00	1.000E+00	0.0	7.920E+01	7.228E+01	0.09147	6.923E+00
9	1973	1.000E+00	1.000E+00	0.0	5.170E+01	5.676E+01	-0.09343	-5.063E+00
10	1974	1.000E+00	1.000E+00	0.0	4.030E+01	4.700E+01	-0.15370	-6.695E+00
11	1975	1.000E+00	1.000E+00	0.0	3.740E+01	4.010E+01	-0.06963	-2.697E+00
12	1976	1.000E+00	1.000E+00	0.0	4.170E+01	3.969E+01	0.04929	2.006E+00
13	1977	1.000E+00	1.000E+00	0.0	6.500E+01	4.422E+01	0.38531	2.078E+01
14	1978	1.000E+00	1.000E+00	0.0	4.430E+01	4.608E+01	-0.03930	-1.776E+00
15	1979	1.000E+00	1.000E+00	0.0	3.850E+01	4.513E+01	-0.15894	-6.632E+00
16	1980	1.000E+00	1.000E+00	0.0	5.140E+01	4.562E+01	0.11932	5.781E+00
17	1981	1.000E+00	1.000E+00	0.0	4.500E+01	4.773E+01	-0.05887	-2.729E+00
18	1982	1.000E+00	1.000E+00	0.0	4.310E+01	4.974E+01	-0.14325	-6.638E+00
19	1983	0.000E+00	0.000E+00	0.0	*	5.386E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	5.680E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	5.139E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	3.947E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	3.190E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	2.862E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	2.743E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	2.678E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	2.294E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	1.962E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	1.603E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	1.575E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	2.190E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	3.116E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	4.259E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	5.422E+01	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	6.413E+01	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	7.142E+01	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	7.549E+01	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	7.959E+01	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	8.343E+01	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	8.587E+01	0.00000	0.0
41	2005	0.000E+00	0.000E+00	0.0	*	8.796E+01	0.00000	0.0
42	2006	0.000E+00	0.000E+00	0.0	*	8.913E+01	0.00000	0.0

* Asterisk indicates missing value(s).

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3LNO ytail (v3.81, 2002 formulation with 2005 data) 2006=TAC                                                          Page 6

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0663                                             |===
1972     0.0915                                             |====
1973    -0.0934                                         ====|
1974    -0.1537                                       ======|
1975    -0.0696                                          ===|
1976     0.0493                                             |==
1977     0.3853                                             |===============
1978    -0.0393                                           ==|
1979    -0.1589                                       ======|
1980     0.1193                                             |=====
1981    -0.0589                                           ==|
1982    -0.1433                                       ======|
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
                   ------------------------------------------------------------------------------------
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RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canadian Fall Survey

Data type I2: End-of-year biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	6.026E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	5.751E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	5.517E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	5.223E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	4.942E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	4.392E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	3.582E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	2.781E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	2.206E+02	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	1.904E+02	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	1.606E+02	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	1.851E+02	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	1.998E+02	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	2.016E+02	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	1.922E+02	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	2.050E+02	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	2.107E+02	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	2.224E+02	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	2.463E+02	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	2.483E+02	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	2.030E+02	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	1.457E+02	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	1.329E+02	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	1.171E+02	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	1.219E+02	0.00000	0.0
26	1990	1.000E+00	1.000E+00	0.0	6.580E+01	1.120E+02	-0.53166	-4.617E+01
27	1991	1.000E+00	1.000E+00	0.0	8.240E+01	8.920E+01	-0.07929	-6.800E+00
28	1992	1.000E+00	1.000E+00	0.0	6.450E+01	8.209E+01	-0.24120	-1.759E+01
29	1993	1.000E+00	1.000E+00	0.0	1.128E+02	5.930E+01	0.64298	5.350E+01
30	1994	1.000E+00	1.000E+00	0.0	1.064E+02	7.863E+01	0.30247	2.777E+01
31	1995	1.000E+00	1.000E+00	0.0	1.298E+02	1.138E+02	0.13120	1.596E+01
32	1996	1.000E+00	1.000E+00	0.0	1.343E+02	1.592E+02	-0.17034	-2.494E+01
33	1997	1.000E+00	1.000E+00	0.0	2.229E+02	2.130E+02	0.04541	9.895E+00
34	1998	1.000E+00	1.000E+00	0.0	2.316E+02	2.594E+02	-0.11331	-2.779E+01
35	1999	1.000E+00	1.000E+00	0.0	2.499E+02	2.988E+02	-0.17885	-4.894E+01
36	2000	1.000E+00	1.000E+00	0.0	3.350E+02	3.225E+02	0.03795	1.247E+01
37	2001	1.000E+00	1.000E+00	0.0	4.758E+02	3.345E+02	0.35233	1.413E+02
38	2002	1.000E+00	1.000E+00	0.0	3.397E+02	3.579E+02	-0.05220	-1.820E+01
39	2003	1.000E+00	1.000E+00	0.0	3.683E+02	3.683E+02	0.00002	9.201E-03
40	2004	1.000E+00	1.000E+00	0.0	3.747E+02	3.791E+02	-0.01168	-4.401E+00
41	2005	1.000E+00	1.000E+00	0.0	3.427E+02	3.866E+02	-0.12051	-4.389E+01
42	2006	0.000E+00	0.000E+00	0.0	*	3.894E+02	0.00000	0.0

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3

```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990    -0.5317                         =====================|
1991    -0.0793                                          ===|
1992    -0.2412                                   ==========|
1993     0.6430                                             |==========================
1994     0.3025                                             |============
1995     0.1312                                             |=====
1996    -0.1703                                      =======|
1997     0.0454                                             |==
1998    -0.1133                                        =====|
1999    -0.1789                                      =======|
2000     0.0379                                             |==
2001     0.3523                                             |==============
2002    -0.0522                                           ==|
2003     0.0000                                             |
2004    -0.0117                                             |
2005    -0.1205                                        =====|
2006     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED) Russian Survey

Data type I1: Year-average biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	2.850E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.727E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.609E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	2.486E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	2.353E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	2.155E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.832E+02	0.00000	0.0
8	1972	1.000E+00	1.000E+00	0.0	1.060E+02	1.460E+02	-0.32018	-4.000E+01
9	1973	1.000E+00	1.000E+00	0.0	2.170E+02	1.147E+02	0.63789	1.023E+02
10	1974	1.000E+00	1.000E+00	0.0	1.290E+02	9.493E+01	0.30665	3.407E+01
11	1975	1.000E+00	1.000E+00	0.0	1.260E+02	8.100E+01	0.44187	4.500E+01
12	1976	1.000E+00	1.000E+00	0.0	1.310E+02	8.018E+01	0.49088	5.082E+01
13	1977	1.000E+00	1.000E+00	0.0	1.880E+02	8.932E+01	0.74425	9.868E+01
14	1978	1.000E+00	1.000E+00	0.0	1.100E+02	9.307E+01	0.16708	1.693E+01
15	1979	1.000E+00	1.000E+00	0.0	9.800E+01	9.117E+01	0.07226	6.832E+00
16	1980	1.000E+00	1.000E+00	0.0	1.640E+02	9.215E+01	0.57644	7.185E+01
17	1981	1.000E+00	1.000E+00	0.0	1.580E+02	9.641E+01	0.49395	6.159E+01
18	1982	1.000E+00	1.000E+00	0.0	1.250E+02	1.005E+02	0.21843	2.453E+01
19	1983	0.000E+00	0.000E+00	0.0	*	1.088E+02	0.00000	0.0
20	1984	1.000E+00	1.000E+00	0.0	1.320E+02	1.147E+02	0.14020	1.727E+01
21	1985	1.000E+00	1.000E+00	0.0	8.500E+01	1.038E+02	-0.20000	-1.882E+01
22	1986	1.000E+00	1.000E+00	0.0	4.200E+01	7.974E+01	-0.64110	-3.774E+01
23	1987	1.000E+00	1.000E+00	0.0	3.000E+01	6.443E+01	-0.76438	-3.443E+01
24	1988	1.000E+00	1.000E+00	0.0	2.300E+01	5.781E+01	-0.92164	-3.481E+01
25	1989	1.000E+00	1.000E+00	0.0	4.400E+01	5.541E+01	-0.23051	-1.141E+01
26	1990	1.000E+00	1.000E+00	0.0	2.700E+01	5.410E+01	-0.69496	-2.710E+01
27	1991	1.000E+00	1.000E+00	0.0	2.750E+01	4.633E+01	-0.52159	-1.883E+01
28	1992	0.000E+00	0.000E+00	0.0	*	3.963E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	3.238E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	3.181E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	4.424E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	6.294E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	8.603E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	1.095E+02	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	1.296E+02	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	1.443E+02	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	1.525E+02	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	1.608E+02	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	1.685E+02	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	1.735E+02	0.00000	0.0
41	2005	0.000E+00	0.000E+00	0.0	*	1.777E+02	0.00000	0.0
42	2006	0.000E+00	0.000E+00	0.0	*	1.800E+02	0.00000	0.0

* Asterisk indicates missing value(s).

```
3LNO ytail (v3.81, 2002 formulation with 2005 data) 2006=TAC                                                         Page10

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 4
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972    -0.3202                                =============|
1973     0.6379                                             |==========================
1974     0.3067                                             |============
1975     0.4419                                             |==================
1976     0.4909                                             |====================
1977     0.7443                                             |==============================
1978     0.1671                                             |=======
1979     0.0723                                             |===
1980     0.5764                                             |=======================
1981     0.4939                                             |====================
1982     0.2184                                             |=========
1983     0.0000                                             |
1984     0.1402                                             |======
1985    -0.2000                                     ========|
1986    -0.6411                   ==========================|
1987    -0.7644              ===============================|
1988    -0.9216        =====================================|
1989    -0.2305                                    =========|
1990    -0.6950                 ============================|
1991    -0.5216                        =====================|
1992     0.0000                                             |

1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 5 (NON-BOOTSTRAPPED) Spanish Survey Converted biomass_2006

Data type I1: Year-average biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	2.282E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.183E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.089E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.990E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.884E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.726E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.467E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	1.169E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	9.180E+01	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	7.600E+01	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	6.485E+01	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	6.420E+01	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	7.151E+01	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	7.452E+01	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	7.299E+01	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	7.378E+01	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	7.719E+01	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	8.044E+01	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	8.711E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	9.186E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	8.312E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	6.384E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	5.158E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	4.628E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	4.436E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	4.331E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	3.709E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	3.173E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	2.592E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	2.546E+01	0.00000	0.0
31	1995	1.000E+00	1.000E+00	0.0	9.300E+00	3.542E+01	-1.33725	-2.612E+01
32	1996	1.000E+00	1.000E+00	0.0	4.330E+01	5.039E+01	-0.15160	-7.088E+00
33	1997	1.000E+00	1.000E+00	0.0	3.870E+01	6.888E+01	-0.57654	-3.018E+01
34	1998	1.000E+00	1.000E+00	0.0	1.226E+02	8.769E+01	0.33512	3.491E+01
35	1999	1.000E+00	1.000E+00	0.0	1.970E+02	1.037E+02	0.64149	9.328E+01
36	2000	1.000E+00	1.000E+00	0.0	1.447E+02	1.155E+02	0.22535	2.920E+01
37	2001	1.000E+00	1.000E+00	0.0	1.827E+02	1.221E+02	0.40314	6.062E+01
38	2002	1.000E+00	1.000E+00	0.0	1.485E+02	1.287E+02	0.14290	1.977E+01
39	2003	1.000E+00	1.000E+00	0.0	1.368E+02	1.349E+02	0.01375	1.868E+00
40	2004	1.000E+00	1.000E+00	0.0	1.700E+02	1.389E+02	0.20222	3.112E+01
41	2005	1.000E+00	1.000E+00	0.0	1.565E+02	1.423E+02	0.09534	1.423E+01
42	2006	0.000E+00	0.000E+00	0.0	*	1.441E+02	0.00000	0.0

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 5

```
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ----------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995    -1.3372               ===========================|
1996    -0.1516                                          ===|
1997    -0.5765                              ============|
1998     0.3351                                             |=======
1999     0.6415                                             |=============
2000     0.2254                                             |=====
2001     0.4031                                             |========
2002     0.1429                                             |===
2003     0.0138                                             |
2004     0.2022                                             |====
2005     0.0953                                             |==
2006     0.0000                                             |
                   ----------------------------------------------------------------------------------
```

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.293E+00	2.153E+00	-6.11%	2.147E+00	2.626E+00	2.218E+00	2.626E+00	4.079E-01	0.178
K	1.582E+02	1.589E+02	0.40%	1.466E+02	1.773E+02	1.514E+02	1.666E+02	1.521E+01	0.096
r	4.423E-01	4.454E-01	0.71%	3.823E-01	4.977E-01	4.105E-01	4.737E-01	6.321E-02	0.143
q(1)	3.249E+00	3.279E+00	0.94%	2.755E+00	3.812E+00	2.968E+00	3.537E+00	5.693E-01	0.175
q(2)	8.378E-01	8.438E-01	0.71%	6.763E-01	1.019E+00	7.594E-01	9.254E-01	1.660E-01	0.198
q(3)	3.649E+00	3.678E+00	0.79%	2.938E+00	4.423E+00	3.283E+00	4.036E+00	7.527E-01	0.206
q(4)	1.689E+00	1.706E+00	1.00%	1.420E+00	1.983E+00	1.531E+00	1.837E+00	3.060E-01	0.181
q(5)	1.366E+00	1.365E+00	-0.03%	1.127E+00	1.665E+00	1.238E+00	1.512E+00	2.741E-01	0.201
MSY	1.743E+01	1.769E+01	1.46%	1.652E+01	1.830E+01	1.700E+01	1.789E+01	8.871E-01	0.051
Ye(2007)	1.562E+01	1.572E+01	0.60%	1.458E+01	1.685E+01	1.503E+01	1.635E+01	1.311E+00	0.084
Bmsy	7.911E+01	7.943E+01	0.40%	7.332E+01	8.863E+01	7.570E+01	8.331E+01	7.605E+00	0.096
Fmsy	2.211E-01	2.227E-01	0.71%	1.912E-01	2.489E-01	2.052E-01	2.368E-01	3.160E-02	0.143
fmsy(1)	6.806E-02	6.791E-02	-0.21%	5.652E-02	8.077E-02	6.217E-02	7.433E-02	1.216E-02	0.179
fmsy(2)	2.655E-01	2.639E-01	-0.58%	2.289E-01	3.105E-01	2.476E-01	2.861E-01	3.854E-02	0.145
fmsy(3)	6.011E-02	6.055E-02	0.74%	4.752E-02	7.371E-02	5.272E-02	6.622E-02	1.350E-02	0.225
fmsy(4)	1.310E-01	1.306E-01	-0.29%	1.162E-01	1.477E-01	1.227E-01	1.393E-01	1.660E-02	0.127
fmsy(5)	1.626E-01	1.631E-01	0.33%	1.273E-01	2.049E-01	1.437E-01	1.825E-01	3.879E-02	0.239
F(0.1)	1.990E-01	2.004E-01	0.64%	1.721E-01	2.240E-01	1.847E-01	2.132E-01	2.844E-02	0.143
Y(0.1)	1.726E+01	1.751E+01	1.44%	1.636E+01	1.812E+01	1.683E+01	1.771E+01	8.783E-01	0.051
B-ratio	1.332E+00	1.334E+00	0.11%	1.144E+00	1.452E+00	1.252E+00	1.406E+00	1.539E-01	0.116
F-ratio	6.444E-01	6.380E-01	-0.98%	5.655E-01	7.946E-01	5.964E-01	7.108E-01	1.144E-01	0.178
Y-ratio	8.896E-01	8.887E-01	-0.11%	7.959E-01	9.794E-01	8.356E-01	9.367E-01	1.011E-01	0.114
f0.1(1)	6.125E-02	6.112E-02	-0.19%	5.087E-02	7.269E-02	5.595E-02	6.689E-02	1.094E-02	0.179
f0.1(2)	2.389E-01	2.375E-01	-0.52%	2.060E-01	2.795E-01	2.228E-01	2.575E-01	3.468E-02	0.145
f0.1(3)	5.410E-02	5.449E-02	0.66%	4.276E-02	6.634E-02	4.745E-02	5.960E-02	1.215E-02	0.225
f0.1(4)	1.179E-01	1.175E-01	-0.26%	1.045E-01	1.329E-01	1.104E-01	1.254E-01	1.494E-02	0.127
f0.1(5)	1.463E-01	1.468E-01	0.30%	1.146E-01	1.845E-01	1.293E-01	1.642E-01	3.491E-02	0.239
q2/q1	2.532E-01	2.573E-01	1.60%	1.976E-01	3.108E-01	2.217E-01	2.842E-01	6.251E-02	0.247
q3/q1	1.118E+00	1.122E+00	0.31%	9.357E-01	1.305E+00	1.015E+00	1.212E+00	1.976E-01	0.177
q4/q1	5.197E-01	5.201E-01	0.08%	4.236E-01	6.300E-01	4.749E-01	5.779E-01	1.029E-01	0.198
q5/q1	4.155E-01	4.164E-01	0.20%	3.413E-01	4.988E-01	3.744E-01	4.555E-01	8.111E-02	0.195

NOTES ON BOOTSTRAPPED ESTIMATES

- The bootstrapped results shown were computed from 500 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence:	23
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	0
Residual-adjustment factor:	1.0541