Northwest Atlantic Fisheries Organization

Serial No. N4880 **NAFO SCR Doc. 03/61**

SCIENTIFIC COUNCIL MEETING – JUNE 2003

Sensitivity Analysis of Survey Biomass Indices used to Tune ASPIC Production Model for Grand Bank Yellowtail Flounder

Stephen J. Walsh and W. B. Brodie

Northwest Atlantic Fisheries Centre,
Science, Oceans, and Environment Branch, Department of Fisheries and Oceans,
P. O. Box 5667, St. John's, Newfoundland Canada, AlC 5Xl.

Abstract

Several formulations of the ASPIC production model, using numerous survey and CPUE indices, showed that the Russian and Spanish surveys, along with the Canadian CPUE data, had strong residual patterns in the model fit. The model results were sensitive to excluding the Russian survey data. A good model fit, giving very similar results to the accepted formulation, was obtained by including only the Canadian survey time series and setting the initial biomass to B_{MSY} ratio at 2.0. Exploration of the convergence criteria in the ASPIC model showed that key results from the model were neither sensitive to varying the input criteria, nor to using 3 different versions of ASPIC which use different criteria for model convergence.

Introduction

In the 2002 review of the stock assessment of NAFO Divisions 3LNO yellowtail flounder, STACFIS **recommended** that *further exploration of the ASPIC model with yellowtail flounder data be conducted for 2003, including sensitivity of the model to various indices and to the convergence criteria.*

The authors note that some sensitivity analysis has been presented every year since the ASPIC production model was adopted in 2000. Since 2000, the formulation of the "**standard model**" has been a model with nominal catch and the Campelen spring survey series being calibrated, or tuned, by the Canadian Yankee spring survey, the Canadian Campelen fall survey, the Russian and Spanish spring surveys (Walsh *et al.*, 2002)

The purpose of this paper is to present in an unbiased manner the sensitivity analyses of all indices used in the model so that the final model will have only those time series which are agreed. A second objective is to examine the effects of changes in convergence criteria on model performance and parameter estimates.

Methods

<u>Input Data</u>

Potential input data for surplus production modelling are listed in Table 1. Estimated landings were used as nominal catch, but these do not include discards or unreported landings. A substantial portion of total nominal catch from the mid-1980s and early-1990s were from Canadian surveillance reports or prorated from unspecified flounder catches by South Korea. Nominal catch increased from negligible levels in the 1960s to a peak of 39 000 tons in 1972. Annual landings decreased to an annual average of 13 000 tons from 1976 to 1984, increased to approximately 30 000 tons in 1985 and 1986, decreased to an average of 14 000 tons from 1987 to 1993, and were less than 1 000 tons from 1995 to 1997, occurring as by-catch during the moratorium. Since the moratorium was lifted in 1998, the catches have increased to a 14 000 tons in 2001(Table 1; Fig. 1) and in each year from 1998-2001 the TAC has been exceeded by about 10% per year (Walsh *et al*., 2002)

Standardized Canadian CPUE and five time series of survey biomass indices are plotted in Fig. 1 and 2. Canadian CPUE generally decreased in the 1960s and 1970s, increased slightly in the 1980s, and again began declining from the mid-1980s to the early-1990s. Since the re-opening of the fishery in 1998, CPUE has reached levels comparable to mid to late-1960s (Walsh *et al*., 2002). However, Canadian CPUE may be a misleading index of biomass, because major shifts have occurred in the directivity of effort on yellowtail. During 1991-93 a substantial amount of 'directed' effort was targeting American plaice (Brodie *et al*., 1994) and during 1998-99 the fishery has been restricted because of the 5% by-catch restriction for cod and plaice (Walsh *et al*., 2002). As well, the relative proportion of Canadian catch to total catch has varied extensively.

The Canadian spring survey used a 'Yankee' otter trawl from 1971 to 1982, an 'Engel' otter trawl from 1984 to 1995, and a 'Campelen' shrimp trawl since 1995 (McCallum and Walsh, 1996). Comparative tows of the Yankee and Engel trawls were used to derive a conversion factor of 1.4 for the Yankee catches by number but not by weight. The unconverted Yankee survey biomass is 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 from 1984 to 2002. Methods to link the 1971-82 Yankee series to the 1984-2002 Campelen equivalent series have not been developed. Therefore the 1971-82 and 1984-2002 series were considered to be separate biomass indices. The Canadian Yankee biomass index decreased sharply in the early-1970s to 1975, and after a slight increase up to 1977, it fluctuated around an average level of 45 000 tons from 1978-82 (Table 1; Fig. 2). The 1984-2002 Campelen biomass index (Walsh *et al.,* 2002) decreased to low levels in the late-1980s and early-1990s and then began to increase in the mid-1990s to a present level that is twice the size of the mid-1980s (Fig. 2).

The biomass index from the Canadian fall Campelen trawl surveys has increased steadily from low levels in the early-1990s to a high index in 2002 (Fig. 2). The biomass index from the fall 1986-94 Canadian juvenile groundfish surveys (Walsh *et al*., 1995) and the catch rate series from the July DFO/industry grid surveys (Walsh *et al*., 2002) were not used because of a negative correlation with most indices (e.g. the juvenile index remained stable or showed an increase during the late-1980s and early-1990s when most other indices were decreasing, (Cadrin and Walsh. 1999), and the grid survey catch rate from 1996-2002 does not reflect the upward trend in the annual survey index (Walsh *et al*., 2002), possibly because it does not cover the whole stock area.

The biomass index from the 1972-1991 Russian bottom trawl survey sharply declined from relatively high levels in the 1970s and early-1980s to low levels in the late-1980s and early-1990s (Fig. 2) (Brodie and Walsh, 1992). The 1995-2002 biomass index from the Spanish survey has been converted to Spanish Campelen trawl units (Paz *et al.,* 2003) and are used here in this analysis. The Spanish time series has generally shown a strong upward trend (Fig. 2). Noteworthy is that the Russian surveys covered all of the Grand Bank while the Spanish survey only covers the regulatory Area of Div. 3NO.

Seven combinations of biomass indices were examined in the sensitivity analysis: 1) using the Canadian Yankee, Canadian Campelen fall, Russian, and Spanish survey time series 2) also including Canadian CPUE, 3) removing the Russian index, 4) removing the Spanish index, 5) removing both the Russian and Spanish, 6) removing the Canadian Yankee index and 7) removing the Campelen fall index.

There are two formulations of the model: 1) a series of observations on nominal catch and the Canadian fishery CPUE series and 2) a series of observations on nominal and catch corresponding Canadian Campelen survey which acts as a CPUE proxy. The various survey biomass estimates are incorporated into the analysis as model tuning indices, analogous to tuning an age structured model (Prager 1994). Model # 2 is the standard model used in the assessment of Grand Bank yellowtail flounder since 2000 (Walsh *et al*., 2002).

<u>Surplus Production Model</u>

A non-equilibrium surplus production model incorporating covariates - ASPIC (Prager, 1994, 2000) 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):

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

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 to B_{msy}: *B1R*), *r*, MSY are made, along with catchability coefficients (q) for each index. An objective function is minimized using nonlinear least squares of index residuals.

ASPIC versions

All analyses presented here use version 3.92 of ASPIC, with the exception of 4 comparison runs using version 3.81 and 3.91 to examine convergence criteria. Version 3.81 was the software used in the 2002 assessment (Walsh *et al.*, 2002), at which time a difference was noted in the bootstrap results from version 3.81 and version 3.91. Although parameter estimates were virtually identical, many more trials in the bootstrap analysis were rejected due to lack of convergence when using the latter version. Some of the difference was due to changes in input criteria, which are discussed in detail below. However, in discussions with the author of the software (Prager, pers. comm.), it was noted that version 3.91 required 6 re-convergences of the model to the same point in order for the software to accept a solution, whereas version 3.81 required only 3 re-convergences. However, the number of attempts allowed by ASPIC to reach the required number of convergences was equal in both versions. Thus the program failed to converge on more occasions when using version 3.91, where it was able to converge in version 3.81, especially in bootstrap runs. In other words, the convergence criterion was made stricter within the software of version 3.91, but the limit on tries to reach it was not increased. In version 3.92, this limit was increased.

Results and Discussions

A) Sensitivity Analysis

Model Formulation No. 1

Model # 1 incorporates a series of observations on nominal catch and corresponding Canadian CPUE series (Fishery CPUE - Catch) and uses the Canadian Yankee spring and Campelen spring and fall survey series, the Russian surveys and the Spanish surveys as tuners.

Table 2 shows that correlations among biomass indices varied widely. The CPUE index was initially excluded from the surplus production analysis because of the potential problems using CPUE as an index of biomass (noted above), but it is included in a sensitivity analysis. Of the six pairwise correlations among the remaining five series of biomass indices included in the production analysis, six were moderate to strong ($r>0.6$), and two were weak ($r<=0.2$).

Table 3 shows the model fit the data relatively well. The majority of variance in survey indices was explained by the model, but fit varied among indices (r^2 ranged from 0.3 to 0.9). The Russian and Spanish surveys' SSE contributed highly to the unexplained variability in the model.

Figure 3 shows the residual plot of the Canadian CPUE/catch time series which indicates a pattern of positive residuals in earlier years and more or less negative residuals in later years. This may be interpreted as whether or not the CPUE is tracking the major shifts which have occurred in this fishery. In the 1980s and early-1990s the proportion of Canadian catch to total catch varied extensively and there were major shifts in the directivity of Canadian effort in the early- and late-1990s. This residual pattern could also be consistent with increasing efficiency of the fleet over time. Nevertheless Fig. 1 and 2 do show that it is tracking the pattern of decline and increase seen in the survey series. Figure 4 shows the fit of the CPUE to the model and it shows good agreement especially from1970 to 1988. Is CPUE directly proportional to abundance or is it a misleading index of biomass?

The model suggests that a maximum sustainable yield (MSY) of 19 000 tons can be produced by a total stock biomass of 102 000 tons (B_{msy}) at a fishing mortality rate on total biomass of 0.19 (F_{msy}) (Table 8).

Model Formulation # 2 – the Standard Model

Model #2 use the Canadian Campelen spring survey CPUE with nominal catch and the 4 other survey indices as tuners.

Table 4 shows correlations among biomass indices varied widely. Of the five pair-wise correlations among the remaining four series of biomass indices, four were moderate to strong ($r>0.6$), and one was weak ($r<=0.2$).

Table 5 shows the model fit the data relatively well. The majority of variance in survey indices was explained by the model, but fit varied among indices (r^2 ranged from 0.3 to 0.9). The Russian and Spanish surveys' SSE again contributed highly to the unexplained variability in the model.

Figures 5 to 9 show the residual patterns for each to the data series in the model. Residuals appeared to be randomly distributed for all Canadian survey indices, but not for the Russian, which had a strong pattern of positive residuals during the 1970s and early-1980s and negative residuals for subsequent years. The Spanish series showed a pattern of negative residuals in the first three years and positive residuals in the last three years.

Figures 10 to 14 show the observed and expected fits of each series to the model. The Russian series does not fit well in the period of 1971-1984 but tracks the model better since 1985 (Fig. 13). This could indicate a change in catchability. Is a poor fit and a strong residual pattern indicative of a misleading index of biomass? The Spanish time series does not fit the model well, mainly because of the large increase in this series from 1997 to 1998 (Fig. 14). We know that there is a huge difference in catchability between the old and new survey gears and the Canadian survey gears. If the Spanish survey does not cover the entire stock area and has a residual pattern, is it a misleading index of biomass?

The model suggests that a maximum sustainable yield (MSY) of 18 000 tons can be produced by a total stock biomass of 79 000 tons (B_{msy}) at a fishing mortality rate on total biomass of 0.22 (F_{msy}) (Table 8 run # 2).

Sensitivity

The summary of sensitivity analyses in Table 8 shows that estimates of MSY, B_{msy}, F_{msy}, B_{2003}/B_{msy} and F_{2002}/F_{msy} are relatively robust to excluding every index except the Russian series, including the CPUE series. For the CPUE run (#1 in Table 8) the pattern of positive residuals in earlier years and the mainly negative residuals in later years (Fig. 3) may be reflective of whether the Canadian CPUE is tracking major shifts in the fishery for yellowtail or the efficiency of the fleet. In addition, there was some difficulty in getting the model to converge and the trajectory of relative biomass indices never exceeded the level at which MSY could be obtained for most of the period (1973-1999) (Fig. 4). The apparent reason for this is that the model calculates the population biomass at the start of the time series as being below MSY (B_1R or $B_1/B_{MSY} = 0.77$; run#1 in Table 8; see Fig. 15). This would not appear likely, given that the fishery began in the 1960s and stock would have been close to an unexploited state. Is the Canadian CPUE a misleading index of biomass?

In the standard model, the B_1R (B_1/B_{MSY}) = 2.20,when a penalty term for large estimate of B_1 is used (Table 8: run 2; see Fig. 16). When the penalty term is removed the estimate of B_1R = 43.8 (Table 8, run#3) which is unrealistic, even though large estimates of starting biomass are not unusual in ASPIC analyses. The resulting parameter estimates change little, and so a penalty term appears justified in the standard model (Prager, 1994). Iteratively re-weighting the indices (run#4) also did not produce much change in the parameter estimates.

The standard model is sensitive to excluding the Spanish survey index. This results in a reduction in r (0.45 to 0.39) and increase in K (158 000 to 173 000 tons) which affect B_{MSY} (79 000 tons to 86 000 tons) and F_{MSY} (0.22 to 0.19), and a minor change in MSY (17 000 tons) (Table 8; run 7; see Fig. 18). Excluding the Spanish series produces an r = 0.39 , which may be more in agreement with recent revision to the life history information that this species is a slow growing and long lived species (Dwyer *et al*., 2003).

The Russian time series agrees well with the Canadian spring survey and has a moderately strong Rsq when included, but has a residual pattern as discussed above. The standard model is very sensitive to excluding the Russian series. MSY doubles to 34 000 tons, r drops from 0.45 to 0.40, K doubles to 344 000 tons, F_{MSY} drops from 0.22 to 0.20 and B_{MSY} increases from 79 000 tons to 172 000 tons (Table 8; run 6). The model estimates B_1R to be 0.22 which would indicate that B at the start of the time series is far below B_{MSY} which as mentioned above is not according to theory. Figure 17 shows that the trajectory of relative biomass indices never exceeded the level at which MSY could be obtained from 1965 to 2001. Similar results are obtainable when both the Russian and Spanish time series are excluded (Table 8, run 8; Fig. 19).

With only the Canadian time series in the model the results are drastically different, and realistic only if we believe that B_1 is less than MSY at the start of the time series, i.e. in 1960s when the biomass should be about K. Production theory would argue against accepting that conclusion since one would expect that the stock would be close to an unexploited state and that when the fishery begins the stock would show a decline over time, as the standard model shows. The Russian time series is the only other survey time series that covers most of the earlier years, 1972-91, besides the Canadian Yankee series from 1971-82, but it has a poor fit to the model and a residual pattern in the data. A strong residual pattern in the Canadian CPUE model resulted in it being dropped in the 2000 assessment (Walsh and Cadrin, 2000; Walsh *et al.,* 2000). However, it is possible to introduce a fixed constraint in the model software where by B1R is set to 2.0 (which we think it should be, given the several runs in Table 8) and it is kept constant at the starting guess throughout the run of the model (Prager, 2000). Table 9 shows the estimates of parameters when B1R is kept constant.

In Table 9 run # 1 is the standard model repeated from Table 8 (run # 2). Run[1] # 3 is the standard model with B1R fixed at 2.0. Estimates of model parameters, MSY, B_{msy}, F_{msy}, B_{2003}/B_{msy} and F_{2000}/F_{msy} were not sensitive to fixing B1R but r showed an increase from 0.40 to 0.48, a value more in line with the faster growing Georges Bank yellowtail flounder stock (Walsh and Cadrin, 2000). The model is sensitive to excluding the Russian time series and r is estimated at 0.52 with a corresponding effect on K, B_{msy}, F_{msy}, B_{2003}/B_{msy} and F_{2002}/F_{msy} but little effect on MSY (Table 9: run #4). However, when the Russian and Spanish series (Table 9 run # 5) are excluded there are only minor differences in r, K, MSY B_{msy},and F_{msy} when compared with the standard model (Table 9, run # 1; see Fig. 20). Table 10 shows the standard model output minus the Spanish and Russian series and with a fixed B1R. When you B1R is fixed at 2.0 in the Canadian CPUE/catch (Model 1 formulation) it also performs well when compared to the standard model, with close agreement in MSY, B_{msy}, and F_{msy} but with lower r (0.45 to 0.40) and higher K (158 000 tons to 174 000 tons) (Table 9; run # 6: Fig. 21)

Summary of the sensitivity analysis

1) If the diagnostics for a poor model fit include a low Rsq (<0.4) and a strong residual pattern, then the Russian and Spanish series should be excluded as they are likely to be misleading indices of biomass.
2) If the diagnostics for a poor model include a strong residual pattern, then the Canadian CPUE and the Russian and Spanish series should be excluded.
3) A good model fit of data with no residual patterns and high goodness of fit values can be obtained by including only the Canadian survey time series and setting the BIR estimate as a constant.
4) If the Russian and Spanish indices are left in the standard model, then by the same reasoning the CPUE series should also be included and this could then become the 'new standard model'.

A) <u>Comparison of convergence criteria.</u>

To look at the effect of using different ASPIC versions (3.81, 3.91, 3.92) and the effect of 2 different convergence criteria in each model, 5 bootstrap runs were made. Each run used 50 bootstraps only, to conserve time, compared to the 500 trials used in the assessment. The same input file was used in all 5 runs, with the exception of the convergence criteria entries, as follows:

	First Set	Second Set
Relative convergence criterion (simplex):	1.000E-06	1.000E-08
Relative convergence criterion (restart):	3.000E-06	3.000E-08

The first criterion applies to the simplex optimization routine. The second criterion applies to randomized restarts of the model to avoid local minima in the solution, and is recommended to be higher than the simplex criterion. More details on these can be found in the current ASPIC User's Guide (Prager, 2000).

Run 1 = Ver 3.81 with first set of convergence criteria.
Run 2 = Ver 3.91 with first set of convergence criteria.
Run 3 = Ver 3.81 with second set of convergence criteria.

[1] Run # 2 in Table 9 is the standard model with the Russian series excluded (as in run # 6 of Table 8) but with a new seed to start the model. It is cited as a way of dealing with difficult data - however the same results were obtained.

Run 4 = Ver 3.91 with second set of convergence criteria.
Run 5 = Ver 3.92 with second set of convergence criteria.

The second set (used in runs 3-5) are the values recommended as defaults by Prager's users guide for ASPIC, and he recommends that these values not be changed. For yellowtail assessments in 2000 and 2001 however, the first set of values was used.

Run 1 – 0 trials rejected for lack of convergence.
Run 2 – 9 trials rejected for lack of convergence.
Run 3 – 34 trials rejected for lack of convergence.
Run 4 – 37 trials rejected for lack of convergence.
Run 5 – 0 trials rejected for lack of convergence.

The input convergence criteria, appears to be the main factor in the number of rejected trials. However, in comparing version 3.81 to 3.91 (Run 1 *vs* 2, and Run 3 *vs* 4), more trials were rejected in version 3.91. As noted above, there were internal differences in the 3 versions of ASPIC which affected model convergence, and the results of the 5 comparison runs are completely consistent with the model differences.

Appendix 1 below shows parameters from the 5 runs. The number of rejected trials (or the version of ASPIC used), makes little difference in the parameter estimates from the bootstrapped output. One note is that bootstrap runs with ver 3.92 take about 3 times as long to run as ver 3.81 with the same input file. This requires about 3 days to run the standard model for yellowtail, with 500 bootstrap trials, on a reasonably fast PC.

In reviewing previous SC assessments of the Div. 3LNO yellowtail stock using ASPIC, it appears as if the convergence criteria recommended by Prager (second set above) have been changed at some point. This was likely done to speed-up the running of bootstrap models with 500 trials, which would take almost twice as long to run using the stricter convergence criteria, given the number of trials rejected. Based on the results in Appendix 1, it is unlikely that this change had a major effect on model results.

Acknowledgements

This paper benefited greatly from the input of Steven Cadrin and Mike Prager.

References

Brodie, W. B., and S.J. Walsh. 1992. An assessment of the yellowtail flounder stock in Division 3LNO. NAFO SCR Doc. 92/61, Ser. No. N2115, 28p.

Brodie, W. B., S.J. Walsh, D. Power and M.J. Morgan. 1994. An assessment of the yellowtail flounder stock in Divisions 3LNO. NAFO SCR Doc. 94/44, Ser. No. N2414, 40p.

Cadrin S.X and S.J. Walsh. 1999. Surplus production analysis and potential precautionary reference points for Grand Bank yellowtail flounder (NAFO Divisions 3LNO) NAFO SCR Doc. 99/3, Ser. No. N4046, 48p.

McCallum B.R. and S.J Walsh. 1996. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971-present. NAFO SCR Doc. 96/50, Ser. No. N2726, 18p.

Paz, X., D. Gonźalez Troncoso and E. Román. 2003. New time series for yellowtail flounder from the comparative experience between the C/V Playa de Menduiña and the R/V Vizconde de Eza in the NAFO Regulatory Area of Divisions 3NO, 1995-2002. NAFO SCR Doc. 03/6, Ser. No. N4812, 15p.

Prager, M.H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fish. Bull. 92: 374-389.

Prager, M.H. 2000. Users manual for ASPIC: a stock-production model incorporating covariates. Program Version 3.82 SEFSC Miami Lab Doc. MIA-92/93-55.

Walsh, S.J., W.B. Brodie, D.B. Atkinson, and D.Power. 1995. An assessment of the yellowtail flounder stock in Divisions 3LNO. NAFO SCR Doc. 95/74, Ser. No. N2591, 44 p.

Walsh, S.J. and S.X. Cadrin. 2000. Evaluating total allowable catch projections for yellowtail flounder (Limanda ferruginea) on the Grand Bank using multiple indices and surplus production analysis. NAFO SCR Doc. 00/44, Ser. No. N4275, 40p.

Walsh, S.J., M.J. Morgan, D. Power, C. Darby, D. Stansbury, M.J. Veitch and W.B. Brodie. 2000. The millennium assessment of Grand Bank yellowtail flounder stock in NAFO Divisions 3LNO. NAFO SCR Doc. 00/45, Ser. No. N4276, 46p.

Walsh, S.J., W.B. Brodie, M.J. Morgan, D. Power, K.S. Dwyer and C. Darby. 2002. Stock assessment and management of the Grand Bank yellowtail flounder stock. NAFO SCR Doc. 02/71, Ser. No. N4684, 54p.

Warren, W., W. Brodie, D. Stansbury, S. Walsh, J. Morgan, and D. Orr. 1997. Analysis of the 1996 comparative fishing trial between the Alfred Needler with the Engel 145 trawl and the Wilfred Templeman with the Campelen 1800 trawl. NAFO SCR Doc. 97/68, Ser. No. N2902, 12 p.

Appendix 1. Table of ASPIC results, from the 5 runs described in the section on convergence criteria.

	Vers 3.81 (Run 1)	**Vers 3.91 (Run 2)**	**Vers 3.81 (Run 3)**	**Vers 3.91 (Run 4)**	**Vers 3.92 (Run 5)**
Parameter			**Bias-corr. estimates**		
B1ratio	2.45	2.14	2.25	2.14	2.14
K	155.30	157.30	156.40	157.10	157.10
r	0.46	0.45	0.45	0.45	0.45
q(1)	3.2	3.32	3.26	3.33	3.33
q(2)	0.85	0.86	0.86	0.86	0.86
q(3)	3.51	3.71	3.71	3.73	3.73
q(4)	1.71	1.73	1.79	1.74	1.74
q(5)	3.90	3.90	3.87	3.92	3.92
MSY	17.45	17.80	17.71	17.79	17.79
Ye(2003)	17.10	17.01	17.23	17.02	17.01
Bmsy	77.65	78.66	78.20	78.56	78.56
Fmsy	0.23	0.23	0.23	0.23	0.23
B/Bmsy	1.25	1.21	1.24	1.21	1.21
F/Fmsy	0.65	0.67	0.66	0.67	0.67

Table 1 Nominal catch, CPUE, and survey biomass indices of Grand Bank Yellowtail flounder

Year	Landings (kt)	Canadian CPUE*	Canadian Yankee Spring Survey Biomass (kt)	Canadian Campelen Spring Survey Biomass (kt)	Canadian Campelen Fall Survey Biomass (kt)	USSR/Russia Spring Survey Biomass (kt)	Spanish Spring Survey Biomass (kt)
1965	3.13	1.16					
1966	7.03	1.09					
1967	8.88	1.08					
1968	13.34	0.91					
1969	15.71	0.78					
1970	26.43	0.79					
1971	37.34	0.76	96.90				
1972	39.26	0.67	79.20			106.00	
1973	32.82	0.76	51.70			217.00	
1974	24.31	0.50	40.30			129.00	
1975	22.89	0.50	37.40			126.00	
1976	8.06	0.46	41.70			131.00	
1977	11.64	0.54	65.00			188.00	
1978	15.47	0.56	44.30			110.00	
1979	18.35	0.58	38.50			98.00	
1980	12.38	0.65	51.40			164.00	
1981	14.68	0.65	45.00			158.00	
1982	13.32	0.59	43.10			125.00	
1983	10.47	0.67					
1984	16.74	0.65		217.73		132.00	
1985	28.96	0.67		146.78		85.00	
1986	30.18	0.49		138.17		42.00	
1987	16.31	0.52		124.57		30.00	
1988	16.16	0.48		80.98		23.00	
1989	10.21	0.48		103.77		44.00	
1990	13.99	0.55		103.11	65.80	27.00	
1991	16.20	0.29		93.43	82.40	26.50	
1992	10.76	0.33		61.37	64.50		
1993	13.57			93.27	112.80		
1994	2.07			55.63	106.40		
1995	0.07			70.62	129.80		11.83
1996	0.29			175.62	134.30		55.36
1997	0.80			174.95	222.90		49.42
1998	4.35	0.89		202.25	231.60		181.63
1999	6.56	0.97		365.70	249.90		251.58
2000	11.12	1.07		287.50	335.00		184.76
2001	14.15	0.85		366.00	475.80		182.70
2002	14.3**						
Average	14.81	0.68	52.88	158.97	184.27	103.24	131.04

* not used in the standard model
** assumes the TAC is taken in 2002 fishery with a 10% overrun

Table 2. Correlation matrix for Nominal catch/Canadian CPUE series model with survey biomass indices, using 1965-2002 data. From Model 1 in Table 8.

Normal convergence.

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

Series	1	2	3	4	5	6
1 FisheryCPUE-catch/	1.000					
	33					
2 Canadian Campelen Spring Survey	0.866	1.000				
	14	18				
3 Canadian Spring Yankee Survey	0.646	0.000	1.000			
	12	0	12			
4 Canadian Fall Survey	0.781	0.884	0.000	1.000		
	8	12	0	12		
5 Russian Spring Survey	0.606	0.933	0.198	1.000	1.000	
	19	8	11	2	19	
6 Spanish Survey	0.221	0.883	0.000	0.630	0.000	1.000
	4	7	0	7	0	7

Table 3. Goodness of fit for Nominal catch/Canadian CPUE model with survey biomass indices using 1965-2002 data (Model 1 in Table 8)

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) FisheryCPUE-catch/	1.869E+00	33	6.029E-02	1.000E+00	1.047E+00	0.397
Loss(2) Canadian Campelen Spring Survey	7.159E-01	18	4.474E-02	1.000E+00	1.410E+00	0.861
Loss(3) Canadian Spring Yankee Survey	2.811E-01	12	2.811E-02	1.000E+00	2.245E+00	0.774
Loss(4) Canadian Fall Survey	7.851E-01	12	7.851E-02	1.000E+00	8.039E-01	0.832
Loss(5) Russian Spring Survey	5.370E+00	19	3.159E-01	1.000E+00	1.998E-01	0.262
Loss(6) Spanish Survey	3.223E+00	7	6.447E-01	1.000E+00	9.789E-02	0.359
TOTAL OBJECTIVE FUNCTION:	1.22445461E+01					

Number of restarts required for convergence: 151
Est. B/Bmsy coverage index (0 worst, 2 best): 1.0052 < These two measures are defined in Prager
Est. B/Bmsy nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

Table 4. Correlation matrix for Nominal catch/Canadian Campelen spring survey model and survey biomass indices using 1965-2002 data. This is the 2002 accepted standard model formulation (Model 2 in Tbl 8).

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

Series	1	2	3	4	5
1 Fishery-catch/Spring biomass	1.000				
	18				
2 Canadian Spring Yankee Survey	0.000	1.000			
	0	12			
3 Canadian Fall Survey	0.884	0.000	1.000		
	12	0	12		
4 Russian Spring Survey	0.933	0.198	1.000	1.000	
	8	11	2	19	
5 Spanish Survey	0.883	0.000	0.630	0.000	1.000
	7	0	7	0	7

Table 5. Goodness of fit test for the Standard Model using 1965-2002 data (Model 2, Tbl 8)

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	5.795E-03	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	7.598E-01	18	4.749E-02	1.000E+00	1.401E+00	0.843
Loss(2) Canadian Spring Yankee Survey	2.665E-01	12	2.665E-02	1.000E+00	2.496E+00	0.805
Loss(3) Canadian Fall Survey	1.034E+00	12	1.034E-01	1.000E+00	6.432E-01	0.827
Loss(4) Russian Spring Survey	5.009E+00	19	2.947E-01	1.000E+00	2.258E-01	0.289
Loss(5) Spanish Survey	2.852E+00	7	5.704E-01	1.000E+00	1.166E-01	0.415
TOTAL OBJECTIVE FUNCTION:	9.92810854E+00					

NOTE: B1/Bmsy constraint term contributing to loss. Sensitivity analysis advised.

```
Number of restarts required for convergence:          63
Est. B/Bmsy coverage index (0 worst, 2 best):     1.7909            < These two measures are defined in Prager
Est. B/Bmsy nearness index (0 worst, 1 best):     1.0000            <     et al. (1996), Trans. A.F.S. 125:729
```

Table 6. Goodness of fit test for the Standard Model with the Russian time series excluded (Model 6, Tbl 8)

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	6.368E-01	18	3.980E-02	1.000E+00	1.225E+00	0.874
Loss(2) Canadian Spring Yankee Survey	2.976E-01	12	2.976E-02	1.000E+00	1.638E+00	0.776
Loss(3) Canadian Fall Survey	8.857E-01	12	8.857E-02	1.000E+00	5.503E-01	0.888
Loss(4) Spanish Survey	2.457E+00	7	4.914E-01	1.000E+00	9.920E-02	0.481
TOTAL OBJECTIVE FUNCTION:	4.27713832E+00					

```
Number of restarts required for convergence:        2090
Est. B/Bmsy coverage index (0 worst, 2 best):     0.7775            < These two measures are defined in Prager
Est. B/Bmsy nearness index (0 worst, 1 best):     0.8931            <     et al. (1996), Trans. A.F.S. 125:729
```

Table 7. Goodness of fit test for the Standard Model with the Spanish time series excluded (Model 7, Tbl 8)

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	1.460E-02	1	N/A	1.000E+00	N/A	
Loss(1) Fishery-catch/Spring biomass	8.761E-01	18	5.476E-02	1.000E+00	1.138E+00	0.789
Loss(2) Canadian Spring Yankee Survey	2.680E-01	12	2.680E-02	1.000E+00	2.326E+00	0.786
Loss(3) Canadian Fall Survey	8.946E-01	12	8.946E-02	1.000E+00	6.968E-01	0.777
Loss(4) Russian Spring Survey	4.760E+00	19	2.800E-01	1.000E+00	2.226E-01	0.322
TOTAL OBJECTIVE FUNCTION:	6.81333560E+00					

NOTE: B1/Bmsy constraint term contributing to loss. Sensitivity analysis advised.

```
Number of restarts required for convergence:          23
Est. B/Bmsy coverage index (0 worst, 2 best):     1.7377            < These two measures are defined in Prager
Est. B/Bmsy nearness index (0 worst, 1 best):     1.0000            <     et al. (1996), Trans. A.F.S. 125:729
```

Table 8. Results from alternative production model configurations from 2002 assessment (MSY, K, B_{msy}, and B_{2003} in thousand t units) using the 1965-2002 data series, a converted Spanish index and version 3.92 of the software. *Run 5 is using version 3.81 from the 2002 assessment with old Spanish index and run 5a is with new Spanish index.*

Run 4 is the same setup as run 3, but with iterative re-weighting and run 5 is the same setup as run 3 but with the penalty term removed . ***All runs use ratio values of B_{2003} and F_{2002}.*** All runs except # 4 (IRF mode) are with the "FIT" mode of ASPIC.

Model	**B_1R**	**MSY**	**r**	**K**	**Bmsy**	**Fmsy**	**B_{2003} B/ B_{msy}**	**F_{2002} F/ F_{msy}**	**MSE**	**Comment**
1	0.77	19.4	0.38	205.2	102.6	0.19	1.15	0.64	0.12	Include CPUE
2	**2.20**	**17.7**	**0.45**	**158.1**	**79.1**	**0.22**	**1.21**	**0.68**	**0.15**	**Standard Model**
3	43.8	17.0	0.45	150.2	75.1	0.23	1.21	0.71	0.15	Penalty removed
4	2.00	18.0	0.46	156.2	78.1	0.23	1.33	0.61	0.05	Iteratively reweighted
5	***2.16***	***17.8***	***0.45***	***157.3***	***78.6***	***0.23***	***1.21***	***0.68***	***0.15***	***Version 3.81, 2002 accepted formulation***
5a	*2.15*	*17.7*	*0.45*	*158.1*	*79.1*	*0.22*	*1.21*	*0.68*	*0.15*	*Version 3.81 with Converted Spanish indices*
6	0.22	34.1	0.40	344.2	172.2	0.20	1.00	0.44	0.09	Exclude Russian
7	2.26	16.8	0.39	172.8	86.4	0.19	1.15	0.75	0.11	Exclude Spanish
8	0.23	34.9	0.33	424.4	212.2	0.17	0.85	0.51	0.04	Exclude Rus+Spain
9	2.15	17.7	0.45	157.9	79.0	0.23	1.21	0.68	0.18	Exclude Yankee
10	2.16	18.2	0.49	150.4	75.2	0.24	1.20	0.66	0.16	Exclude Camp. fall

Table 9. Results from trial production model configurations from 2002 assessment using the 1965-2002 data series, a converted Spanish index and version 3.92 of the software. Models included fixing B1R, and excluding the Russian and Spanish survey indices. Run # 1 is the standard model (run 2) from Table 8.

Model	**B_1R**	**MSY**	**r**	**K**	**Bmsy**	**Fmsy**	**B_{2003} B/ B_{msy}**	**F_{2002} F/ F_{msy}**	**MSE**	**Comment**
1	**2.20**	**17.7**	**0.45**	**158.1**	**79.1**	**0.22**	**1.21**	**0.68**	**0.15**	**Standard Model**
2	0.22	33.91	0.40	342.1	171.0	0.20	1.01	0.44	0.09	Exclude Russia Use New seed
3	2.00	17.8	0.48	158.9	79.4	0.22	1.20	0.68	0.15	Fixed B1R at 2.0
4	2.00	18.9	0.52	143.2	71.6	0.26	1.39	0.55	0.10	Fixed B1R Exclude Russia
5	***2.00***	***17.9***	***0.46***	***156.8***	***78.4***	***0.23***	***1.36***	***0.59***	***0.05***	***Fixed B1R Exclude Russia and Spain***
6	2.00	17.1	0.40	170.3	85.2	0.20	1.27	0.66	0.12	CPUE model with fixed B1R

Table 10 . Model output with Canadian Yankee spring survey, and Canadian Campelen fall survey indices in the model. B1R has been fixed at 2.0 (Model 5, Tbl 9).

3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

05 Jun 2003 at 12:07.45

CONTROL PARAMETERS USED (FROM INPUT FILE)

Number of years analyzed:	38	Number of bootstrap trials:	0
Number of data series:	3	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-08	Lower bound on r:	1.000E-01
Relative conv. criterion (restart):	3.000E-08	Upper bound on r:	5.000E+00
Relative conv. criterion (effort):	1.000E-04	Random number seed:	9114894
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	2	3
1 Fishery-catch/Spring biomass	1.000 18		
2 Canadian Spring Yankee Survey	0.000 0	1.000 12	
3 Canadian Fall Survey	0.884 12	0.000 0	1.000 12

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	6.913E-01	18	4.321E-02	1.000E+00	9.595E-01	0.873
Loss(2) Canadian Spring Yankee Survey	2.696E-01	12	2.696E-02	1.000E+00	1.538E+00	0.804
Loss(3) Canadian Fall Survey	7.929E-01	12	7.929E-02	1.000E+00	5.229E-01	0.801
TOTAL OBJECTIVE FUNCTION:	1.75379363E+00					

Number of restarts required for convergence:	6	
Est. B/Bmsy coverage index (0 worst, 2 best):	1.7190	< These two measures are defined in Prager
Est. B/Bmsy 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 B/Bmsy, year 1965	2.000E+00	2.000E+00	0	1
MSY	Maximum sustainable yield	1.793E+01	1.300E+01	1	1
r	Intrinsic rate of increase	4.574E-01	5.000E-01	1	1
....	Catchability coefficients by fishery:				
q(1)	Fishery-catch/Spring biomass	2.889E+00	3.000E+00	1	1
q(2)	Canadian Spring Yankee Survey	8.696E-01	1.000E+00	1	1
q(3)	Canadian Fall Survey	3.022E+00	3.000E+00	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	Related quantity
MSY	Maximum sustainable yield	1.793E+01	Kr/4	
K	Maximum stock biomass	1.568E+02		
Bmsy	Stock biomass at MSY	7.842E+01	K/2	
Fmsy	Fishing mortality at MSY	2.287E-01	r/2	
F(0.1)	Management benchmark	2.058E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.775E+01	0.99*MSY	
B./Bmsy	Ratio of B(2003) to Bmsy	1.362E+00		
F./Fmsy	Ratio of F(2002) to Fmsy	5.890E-01		
F01-mult	Ratio of F(0.1) to F(2002)	1.528E+00		
Ye./MSY	Proportion of MSY avail in 2003	8.687E-01	2*Br-Br^2	Ye(2003) = 1.558E+01
....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	Fishery-catch/Spring biomass	7.915E-02	r/2q(1)	f(0.1) = 7.124E-02

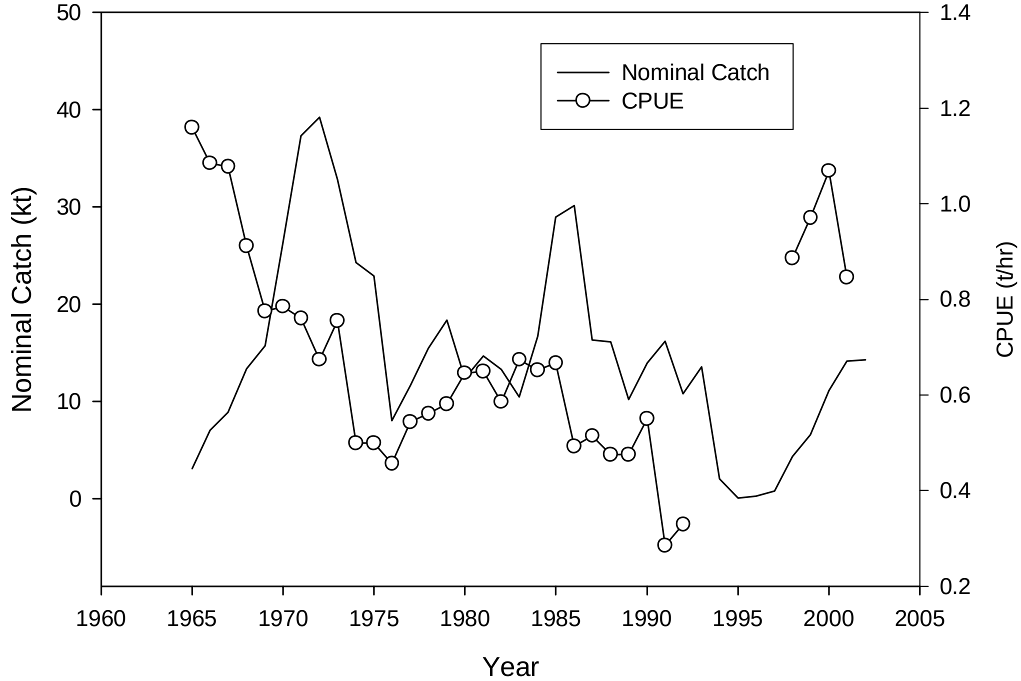

Fig. 1 Nominal catch and the Canadian CPUE series for Grand Bank yellowtail flounder

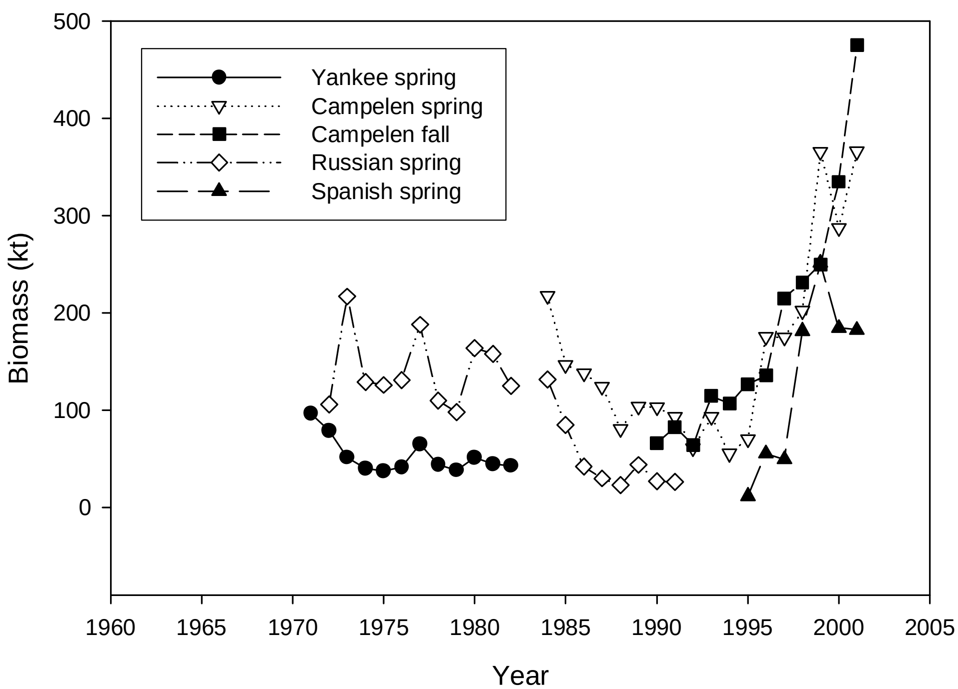

Fig. 2. Biomass indices of Grand Bank yellowtail flounder

```
3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

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    -0.2623                                   ==========|
1966    -0.0796                                          ===|
1967     0.0337                                             |=
1968     0.2688                                             |===========
1969     0.4653                                             |===================
1970     0.4308                                             |=================
1971     0.3480                                             |==============
1972     0.2729                                             |===========
1973    -0.0586                                           ==|
1974     0.1820                                             |=======
1975     0.0361                                             |=
1976     0.1110                                             |====
1977     0.0336                                             |=
1978     0.0400                                             |==
1979    -0.0148                                            =|
1980    -0.1138                                        =====|
1981    -0.0775                                          ===|
1982     0.0624                                             |==
1983    -0.0019                                             |
1984     0.0858                                             |===
1985    -0.0230                                            =|
1986     0.0390                                             |==
1987    -0.1984                                     ========|
1988    -0.2166                                    =========|
1989    -0.2539                                   ==========|
1990    -0.4169                            =================|
1991     0.1130                                             |=====
1992    -0.1488                                       ======|
1993    -0.7705             ===============================|
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998    -0.0976                                         ====|
1999    -0.0349                                            =|
2000    -0.0255                                            =|
2001     0.2700                                             |===========
2002     0.0000                                             |
                   ----------------------------------------------------------------------------------
```

Fig. 3. Residual pattern when Canadian CPUE is in the model with catch data (Model 1, Table 8).

3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

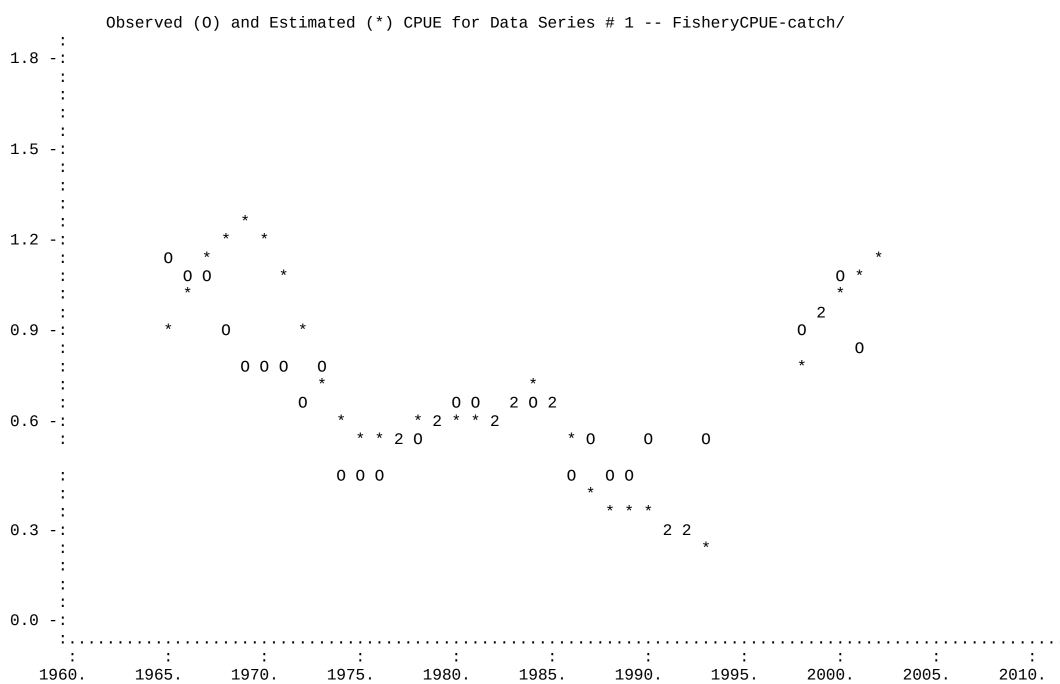

Fig. 4. Model fit of CPUE Fishery data (Model 1, Table 8).

```
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     0.0090                                             |
1985     0.3053                                             |============
1986     0.1015                                             |====
1987    -0.0079                                             |
1988     0.3140                                             |=============
1989     0.0244                                             |=
1990     0.0097                                             |
1991    -0.0439                                           ==|
1992     0.2236                                             |=========
1993    -0.3853                              ===============|
1994     0.1233                                             |=====
1995     0.2157                                             |=========
1996    -0.3443                               ==============|
1997    -0.0313                                            =|
1998     0.0625                                             |===
1999    -0.3614                               ==============|
2000    -0.0134                                            =|
2001    -0.2013                                     ========|
2002     0.0000                                             |
                   -----------------------------------------------------------------------------------
```

Fig. 5. Residual pattern when Campelen Spring survey (CPUE proxy) is used in the model with catch data as the standard model. (Figs 5-14, and Fig. 16 refer to Model 2 in Table 8)

```
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     0.0639                                             |===
1972     0.0904                                             |====
1973    -0.0938                                         ====|
1974    -0.1529                                       ======|
1975    -0.0680                                          ===|
1976     0.0519                                             |==
1977     0.3870                                             |===============
1978    -0.0383                                           ==|
1979    -0.1585                                       ======|
1980     0.1203                                             |=====
1981    -0.0585                                           ==|
1982    -0.1432                                       ======|
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                                             |
                   -----------------------------------------------------------------------------------
```

Fig. 6. Residual pattern for the Yankee Spring data in the standard model.

```
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    -0.5189                        =====================|
1991    -0.0741                                          ===|
1992    -0.2503                                   ==========|
1993     0.6391                                             |==========================
1994     0.2810                                             |===========
1995     0.0827                                             |===
1996    -0.1804                                      =======|
1997    -0.0087                                             |
1998    -0.1303                                        =====|
1999    -0.1979                                     ========|
2000     0.0206                                             |=
2001     0.3369                                             |=============
2002     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

Fig. 7. Residual pattern in the Campelen fall data in the standard model.

```
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    -0.3197                                =============|
1973     0.6391                                             |==========================
1974     0.3091                                             |============
1975     0.4452                                             |==================
1976     0.4951                                             |====================
1977     0.7476                                               |==============================
1978     0.1697                                             |=======
1979     0.0743                                             |===
1980     0.5790                                             |=======================
1981     0.4959                                             |====================
1982     0.2201                                             |=========
1983     0.0000                                             |
1984     0.1405                                             |======
1985    -0.2020                                     ========|
1986    -0.6428                   ==========================|
1987    -0.7662              ===============================|
1988    -0.9232        =====================================|
1989    -0.2329                                    =========|
1990    -0.6998                 ============================|
1991    -0.5291                        =====================|
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                                             |
                   ------------------------------------------------------------------------------------
```

Fig. 8. Residual pattern in Russian Spring survey data in the standard model.

```
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    -1.2665                    =========================|
1996    -0.0745                                            =|
1997    -0.4970                                   ==========|
1998     0.5658                                             |===========
1999     0.7229                                             |==============
2000     0.3069                                             |======
2001     0.2421                                             |=====
2002     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

Fig. 9. Residual pattern in Spanish spring survey data in the standard model.

```
3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

                Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Fishery-catch/Spring biomass
           :
     600. -:
           :
           :
           :          *
           :            *
     500. -:              *
           :                *
           :                  *
           :
           :                    *
     400. -:
           :
           :                      *                                                       O   O
           :
           :
     300. -:                                                                                  * *
           :                        *                                                       2
           :                                                                              *
           :
           :                          *                     2                           *
     200. -:                                            * *   *                         O
           :                            *     * * * * *                             O O
           :                              * *                 *                       *
           :                                                O O
           :                                                    2 *               *
     100. -:                                                          2 2 O   O
           :                                                        O     * *     2
           :                                                                O * 2
           :
           :
       0. -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1960.     1965.     1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.


                Observed (O) and Estimated (*) CPUE for Data Series # 2 -- Canadian Spring Yankee Survey

           :
```

Fig 10. Model fit of the Campelen spring survey index for the standard model

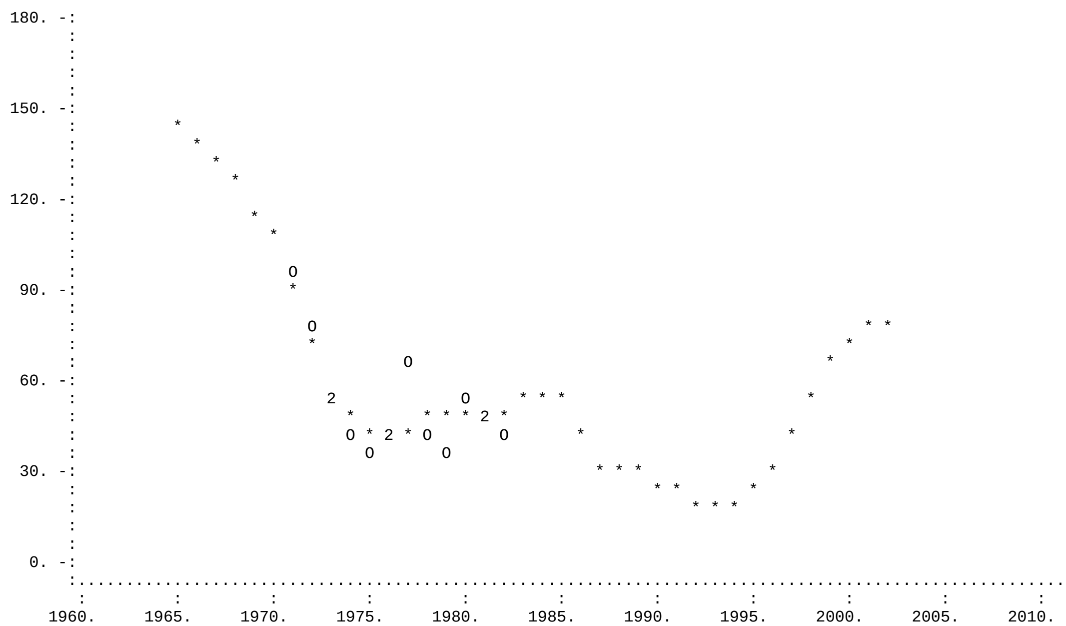

Fig 11 Model fit of the Yankee spring survey index for the standard model.

3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

Observed (O) and Estimated (*) CPUE for Data Series # 3 -- Canadian Fall Survey

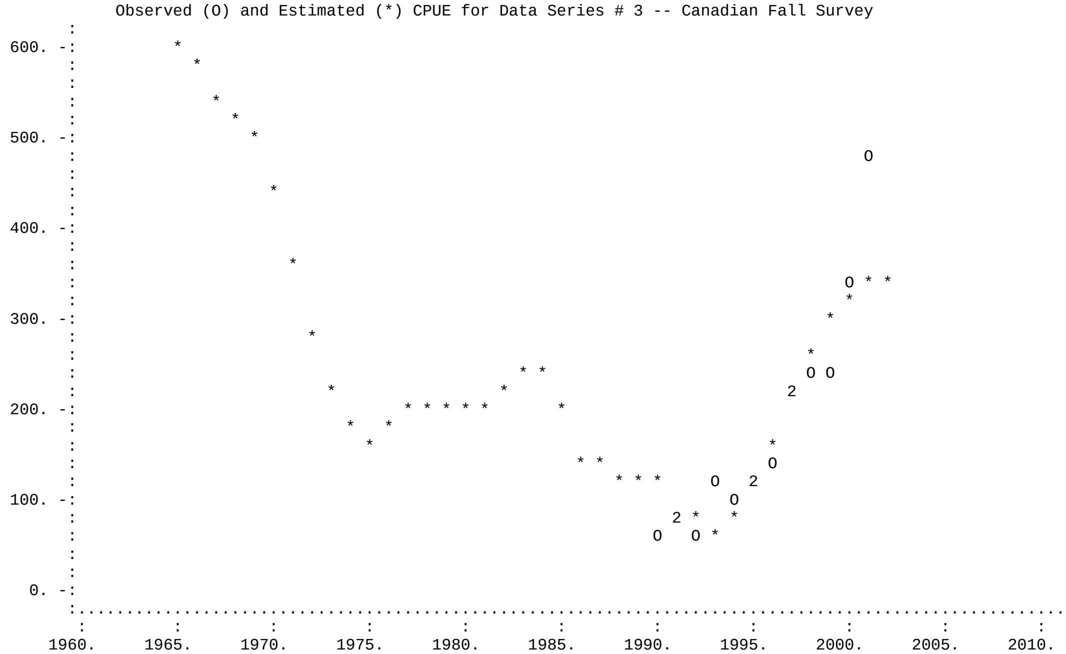

Fig 12. Model fit of the Campelen fall survey index for the standard model.

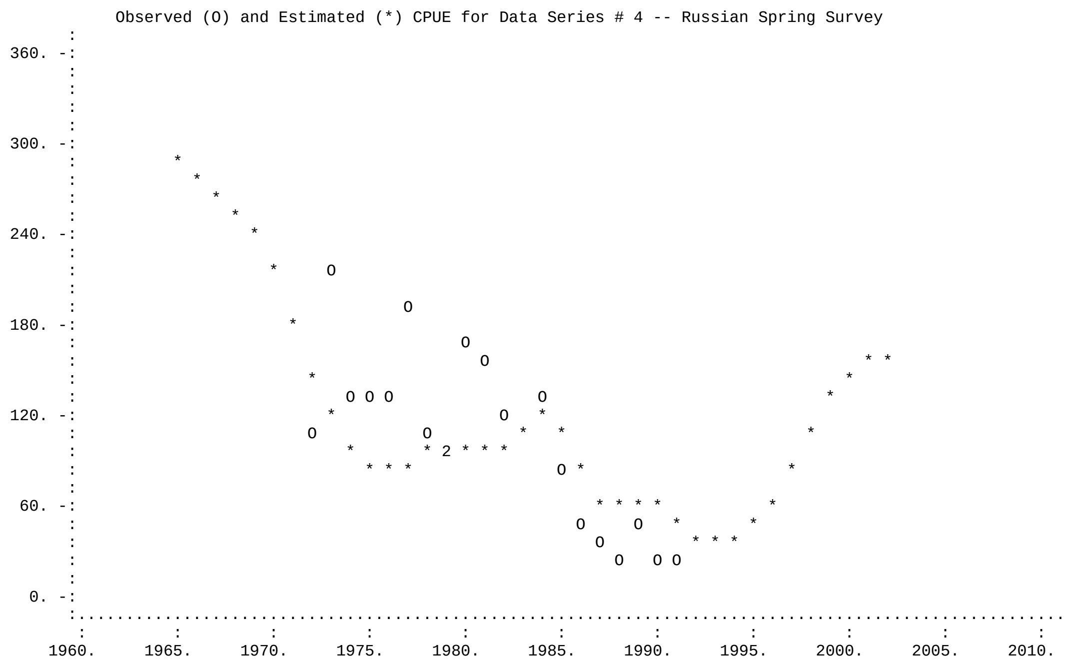

Fig 13. Model fit of the Russian spring survey index for the standard model.

3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

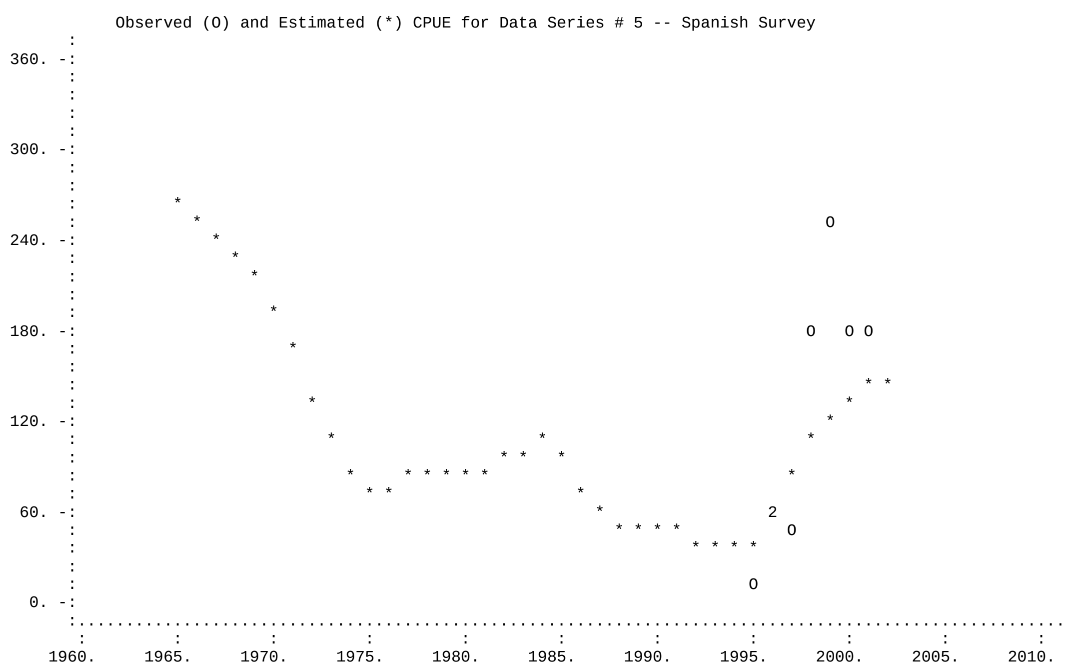

Fig 14. Model fit of the Spanish spring survey index for the standard model.

3LNO yellowtail flounder (biomass in kt) 10% overrun in 2002 fishery

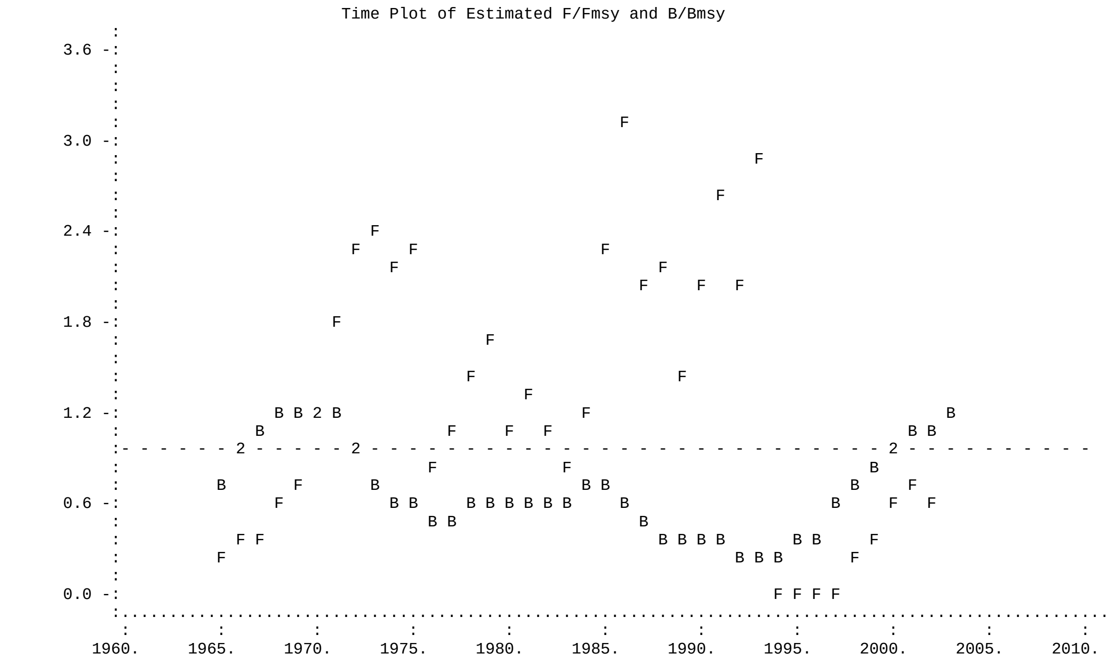

Fig. 15. Plot of estimated F/F_{msy} and B/B_{msy} from the catch/Canadian CPUE Model (Model 1, Table 8).

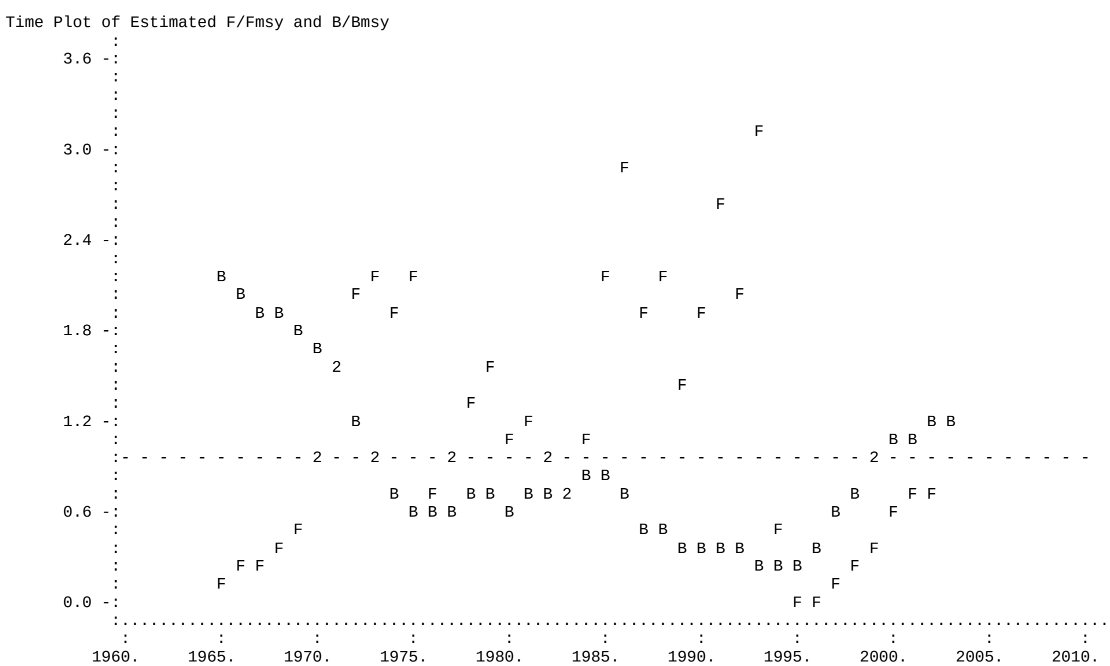

Fig. 16. Plot of estimated F/F_{msy} and B/B_{msy} from the Standard Model (Model 2, Table 8).

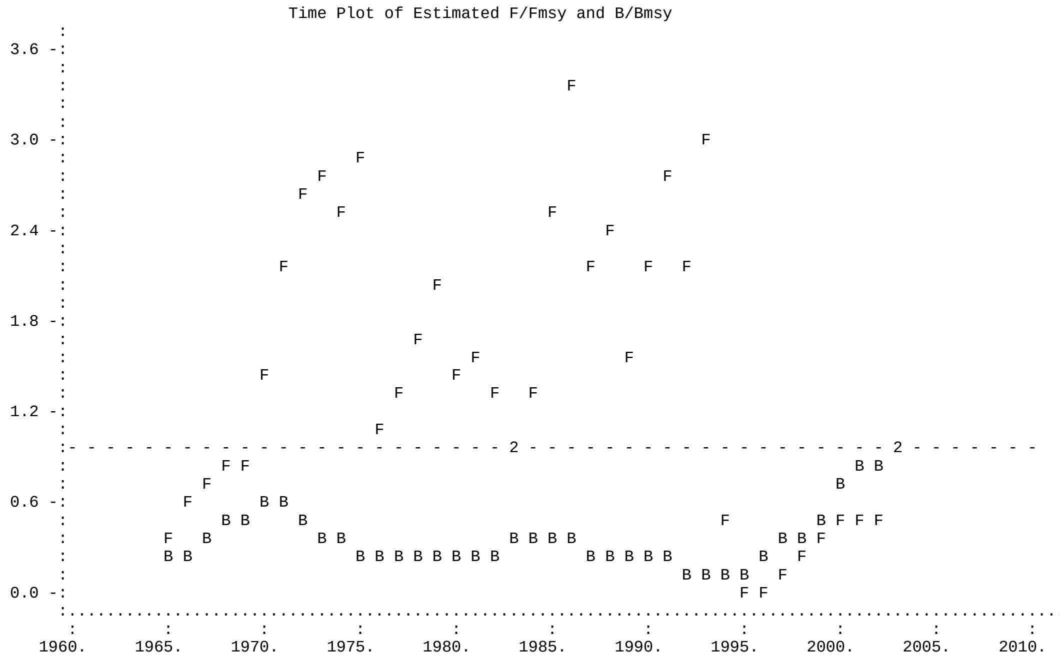

Fig. 17. Plot of estimated F/F_{msy} and B/B_{msy} Standard Model with the Russian time series excluded (Model 6, Table 8).

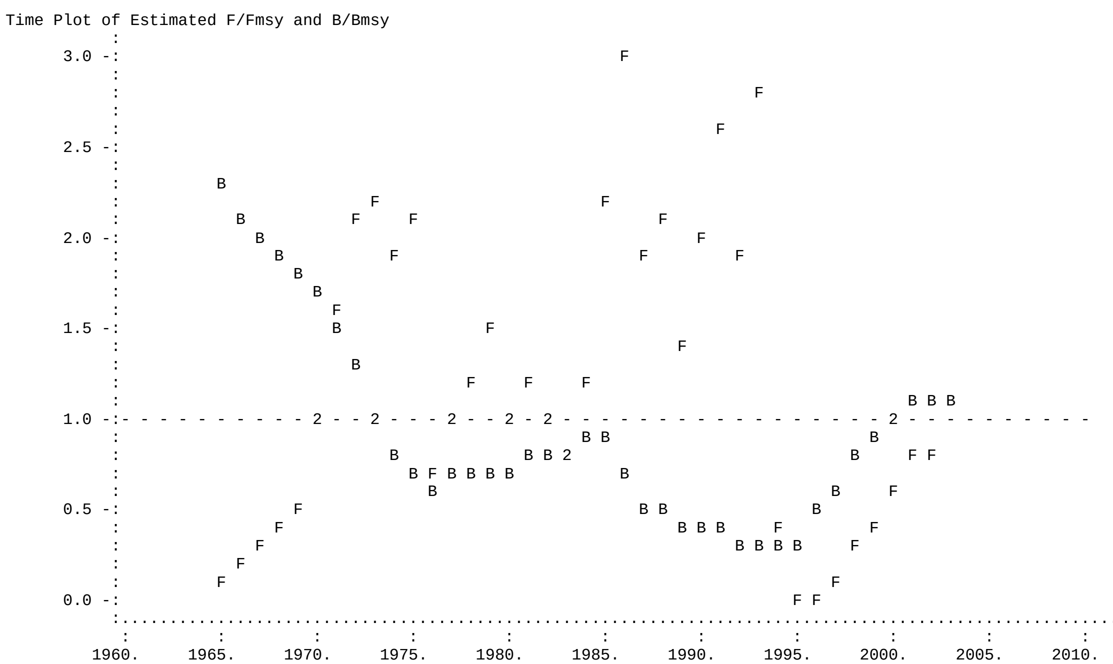

Fig. 18. Plot of estimated F/F_{msy} and B/B_{msy} Standard Model with the Spanish time series excluded (Model 7, Table 8).

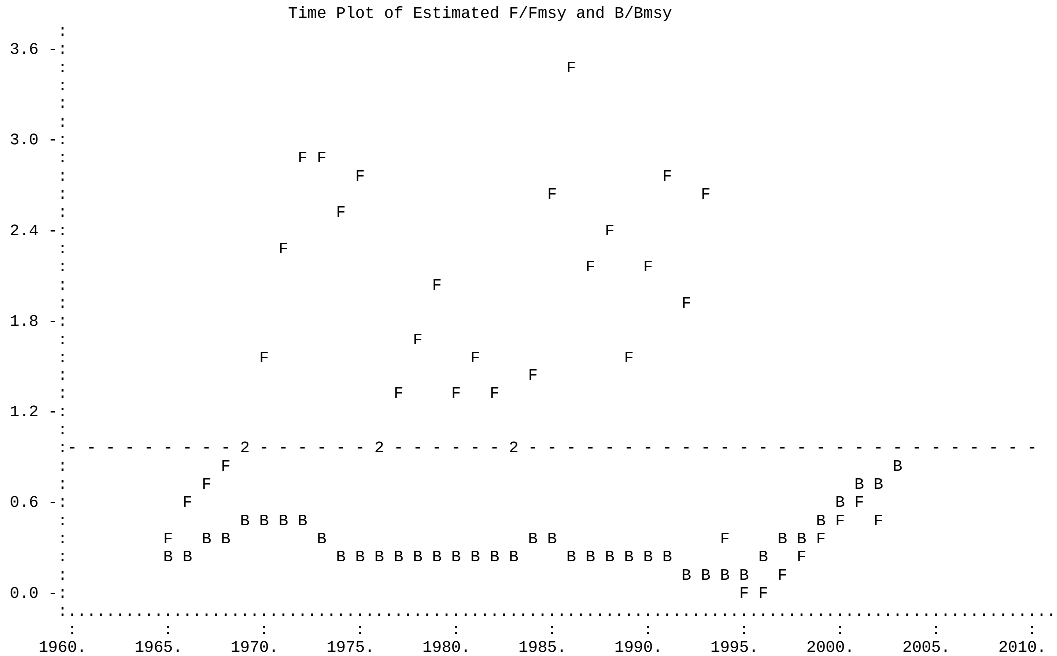

Fig. 19. Plot of estimated F/F_{msy} and B/B_{msy} Standard Model with both the Russian and Spanish time series excluded (Model 8, Table 8).

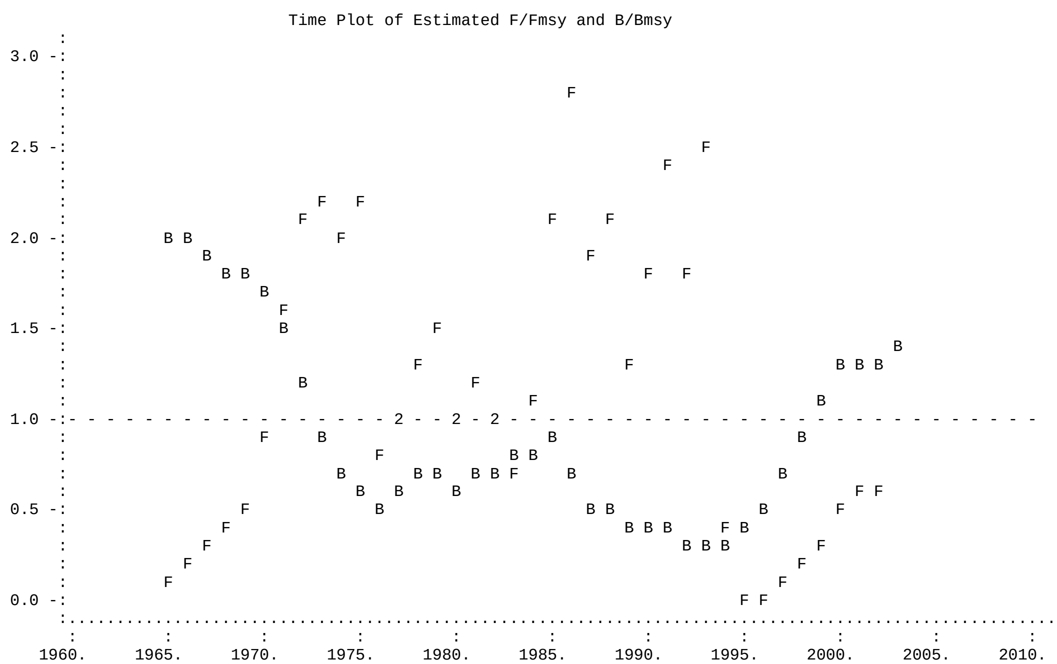

Fig. 20. Plot of estimated F/F_{msy} and B/B_{msy} Standard Model with the Russian and Spanish time series excluded and B1R is fixed at 2.0 (Model 5, Table 9).

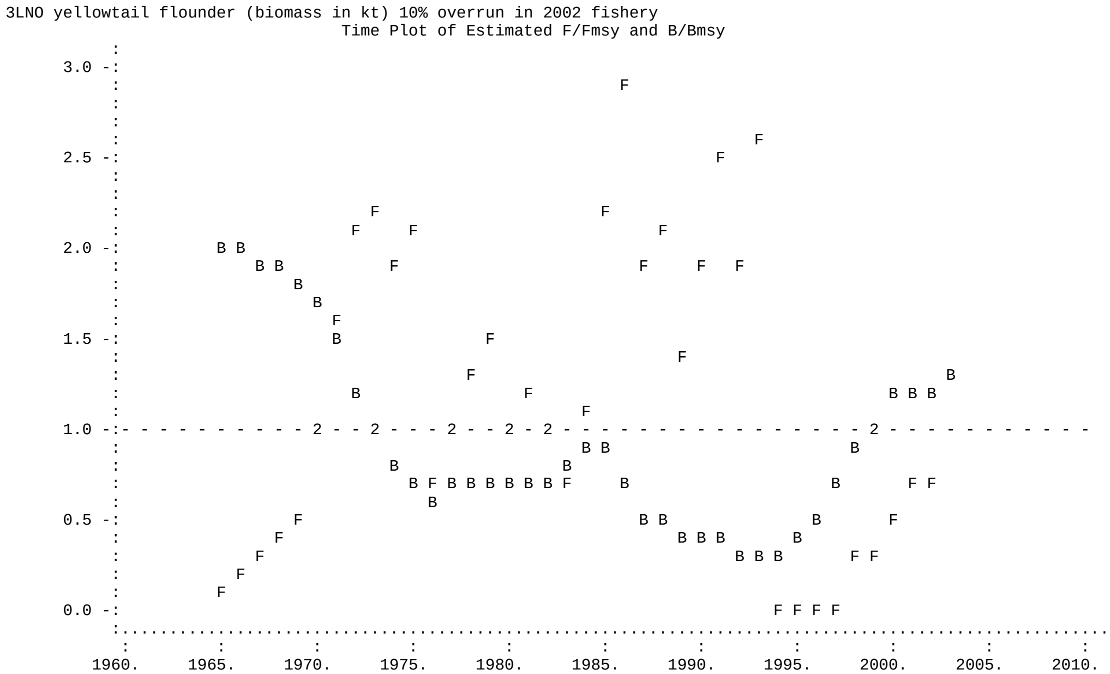

Fig. 21. Plot of estimated F/F_{msy} and B/B_{msy} from Canadian fishery CPUE/catch model with B1R fixed at 2.0 (Model 6, Table 9).