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Surplus Production Analysis and Potential Precautionary Reference Points for Grand Bank Yellowtail Flounder (NAFO Div. 3LNO)

by

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Abstract

A non-equilibrium surplus production model (ASPIC) was applied to catch, effort, and survey biomass indices of Grand Bank yellowtail flounder (NAFO Div. 3LNO). The data generally fit the model well and parameter estimates may be useful for deriving biological reference points (e.g., maximum sustainable yield, MSY; biomass which can sustain MSY, B_{MSY}; and fishing mortality which produces MSY, F_{MSY}) and associated uncertainty. The model suggests that a MSY of 16,000 tons can be produced by a B_{msy} of 91,000 tons at a F_{msy} of 0.18. Estimated stock biomass was 70% of B_{msy} in 1998. A conditional nonparametric bootstrap indicates that parameters were relatively well estimated. Probability distributions were used to derive a harvest control rule in which the precautionary fishing mortality target (F_{buf} = 0.13) was based on a ten percent risk of exceeding the limit (F_{msy}) and a precautionary stock size threshold (B_{buf} = 35,000 tons) was based on a ten percent risk of falling below the lowest observed stock size (B_{loss} = 23,000 tons). Stochastic projections of the fishing mortalities prescribed by the control rule suggest that B_{msy} can be attained by the year 2002, after which stock biomass is expected to approach an equilibrium of approximately 114,000 tons and yield approximately 15,000 tons of harvest.

Introduction

An international fishery for yellowtail flounder, *Limanda ferruginea*, on the Grand Bank (NAFO Div. 3LNO) developed in the 1960s with a peak yield of 39,000 tons in 1972 (Table 1). The stock has been managed by total allowable catch (TAC) since 1973, with early TACs set at or above 35,000 tons (Walsh *et al*., 1998). During the early-1970s, commercial catch rates (CPUE) and survey biomass indices declined sharply, and total mortality rates were estimated to average 1.5 (ICNAF, 1975). Total allowable catches were reduced, and annual landings from 1976 to 1989 were restricted to an average of 16,000 tons. Sequential population analyses (SPA) confirmed that stock biomass decreased in the early-1970s, and indicated that biomass was stable in the mid to late 1970s, increased in the early-1980s, but began to decrease again in the mid-1980s, as catches exceeded 20,000 tons (Brodie and Pitt 1984, Brodie and Walsh 1989, see also Table 1). In 1989, the TAC was reduced to 5,000 tons, but annual landings actually averaged 13,000 tons from 1989-1993. Recruitment in the early-1990s was below average, stock biomass remained at low levels through 1993, and the stock was distributed in a small area of Div. 3NO relative to historic distributions across the Bank (Brodie *et al*., 1994, Murawski *et al*., 1997). In 1994, all directed fishing on Grand Bank yellowtail flounder was prohibited. During the moratorium on directed fishing, survey biomass indices generally increased, geographic distribution expanded, and a re-opening TAC of 4,000 tons was recommended for 1998 (Walsh *et al*., 1998a).

The early (1963-1975) fishery was conducted primarily by Canada and the USSR. Canada contributed nearly all landings from 1976 to 1981. In 1982, non-Canadian freezer trawlers began to fish the NAFO regulatory area on the Tail of the Bank, and landings from distant water fisheries increased to exceed Canadian landings in the late-1980s and early-1990s (Walsh *et al*., 1998a).

In May 1998, the NAFO Fisheries Commission requested that the Scientific Council calculate limit reference points and security margins which offer a high probability of not approaching limit reference points. A framework for applying a precautionary approach in providing scientific advice was proposed by Serchuk *et al*. (1997). The framework involves a harvest control rule (Figure 1) based on the following biomass and fishing mortality reference points.

B_{lim}: the level of stock biomass that the stock should not be allowed to fall below, which can be set as the lowest observed stock size (B_{loss}).
B_{buf}: a level of stock biomass, above B_{lim}, that acts as a buffer to ensure that there is a high probability that B_{lim} is not reached.
B_{target}: the target stock biomass or recovery level, which should correspond to the stock biomass that can produce maximum sustainable yield (B_{msy}).
F_{lim}: the rate of fishing mortality that should not be exceeded, which should correspond to the rate that produces maximum sustainable yield (F_{msy}).
F_{buf}: a fishing mortality rate, below F_{lim}, that acts as a buffer to ensure that there is a high probability that F_{lim} is not reached.
F_{target}: the target fishing mortality prescribed from the harvest control rule, which is set as less than F_{MSY}.

Maximum sustainable yield (MSY) and related reference points can be derived by age-structured production models (Sissenwine and Shepherd, 1987) and other methods. However, age-based analyses of Grand Bank yellowtail are suspect, because high levels of mortality estimated for older ages may be unrealistic. Therefore, absolute stock levels from SPA may be misleading (Walsh *et al*., 1998b).

Alternatively, surplus production models can provide guidance on stock status, MSY reference points, and associated uncertainties. Surplus production models can be useful in situations where information on age structure is unavailable or unreliable, and can provide an alternative perspective for stock assessment. Additionally, surplus production analysis may extend back to historical times when catch at age is not available for long-term perspectives of biomass and F.

Walsh *et al*. (1998b) explored surplus production of Grand Bank yellowtail using the Canadian spring survey as a tuning index, but concluded that results were sensitive to the assumption that catch was measured without error. The provisional model suggested that MSY=13,000 tons, B_{msy} = 73,000 tons, and F_{msy}=0.17. This investigation was performed to extend the analyses initiated by Walsh *et al*. (1998b), to derive MSY reference points and their associated uncertainty for Grand Bank yellowtail flounder, and to contribute to advice on an appropriate harvest control rule.

Methods

Input Data

Data for surplus production modeling are listed in Table 1. Landings are used as the nominal catch, which excludes discards and unreported landings. A substantial portion of total nominal catch from the mid-1980s and early-1990s is from prorated from unspecified flounder catches by South Korea and Canadian surveillance reports (almost two thirds in 1994, Walsh *et al*., 1998). 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 (Figure 2).

Eight biomass indices are plotted in Figure 3 (survey indices are plotted individually in Appendix A, and CPUE is plotted individually in Appendix B). Standardized CPUE of Canadian commercial vessels generally decreased in the 1960s and 1970s, increased slightly in the 1980s, and generally declined in the early-1990s (Brodie *et al*., 1994). However, Canadian CPUE may be a misleading index of biomass, because major shifts have occurred in the directivity of effort on yellowtail (e.g. during 1991-1993 a substantial amount of effort was targeting American plaice; Brodie *et al*., 1994), and the relative proportion of Canadian catch to total catch has varied.

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 in 1996 and 1997 (Walsh *et al*., 1997). Comparative tows of the Yankee and Engel trawls were used to derive a conversion factor of 1.4 for the Yankee catches in number (Walsh *et al*., 1998b). Comparative tows of the Engel and Campelen trawls were used to derive a size based conversion function (Warren *et al*., 1997). Methods to link the 1971-1982 Yankee series to the 1984-1997 Campelen series have not been developed (Walsh *et al*., 1998b). Therefore the 1971-1982 and 1984-1997 series were considered as separate biomass time series. The advantage of using the two separate series over using the 1971-1995 Engel series for production modeling (as in Walsh *et al*., 1998b) is to have a survey observation for the current year to determine current stock status. A biomass index from the Yankee trawl was derived from indices of abundance at age and fishery mean weights at age (Brodie and Pitt, 1984) as described by Walsh *et al*. (1998b). The Canadian Yankee biomass index decreased sharply in the early-1970s and increased slightly in the late-1970s. The 1984-1997 Campelen biomass index (Walsh *et al*., 1998a) decreased to low levels in the late-1980s and increased in the mid-1990s.

The biomass index from the Canadian autumn Campelen trawl survey increased from low levels in the early-1990s to a high index in 1997 (Walsh *et al*., 1998a). The biomass index from the Canadian juvenile groundfish survey increased from low levels in the late-1980s to a high index in 1994 (Walsh *et al*., 1995). The biomass index from the USSR/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 (Brodie and Walsh, 1992). The biomass index from the Spanish bottom trawl survey generally increased in the 1990s (Walsh *et al*., 1998a; Spanish survey observations were lagged to reflect biomass at the end of the previous year so that the 1998 index could be included in the analysis).

Results from SPA have not been used for annual catch projections, because high levels of mortality at older ages may also be unrealistic. Therefore, estimates of absolute biomass from SPA may be unreliable (Walsh *et al*., 1998b). However, SPA results may be useful as an index of relative stock biomass, as measured with error. In previous assessments, SPA results were only used for 'illustrative' purposes. SPA biomass estimates decreased from values greater than 100,000 tons in 1970 to less than 50,000 tons in the mid-1970s, increased to 90,000 tons in the early-1980s, then decreased to 20,000 tons in 1987 (Brodie and Walsh, 1988).

Correlations among biomass indices vary widely (Table 2). The Canadian juvenile index was negatively correlated will all other indices, except the Canadian autumn survey. Therefore, data from the Canadian juvenile survey were excluded from the present surplus production analyses. The Canadian CPUE series and the Canadian autumn survey were also negatively correlated. The CPUE index was initially excluded from the surplus production analysis because of the negative correlations and the potential problems using CPUE as an index of biomass (noted above), but the CPUE index was included in a sensitivity analysis. Of the eight pairwise correlations among the remaining six series of biomass indices included in the production analysis, six were strong ($r > 0.7$), and two were weak to moderate ($r = 0.2$ and 0.4; Appendix A). Four alternative configurations of biomass indices were examined as sensitivity analyses: 1) using the Canadian Yankee, Canadian Campelen, Canadian autumn, USSR/Russian, Spanish, and SPA series, 2) also including Canadian CPUE, 3) removing the USSR/Russian index, and 4) removing the SPA index.

Surplus Production Model

A nonequilibrium surplus production model incorporating covariates (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):

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

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):

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

Biological reference points are calculated from the production model parameters:

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

Initial biomass (expressed as a ratio to B_{msy}: *B1R*), *r*, MSY, and catchability coefficients for each biomass index (q_i) were estimated using nonlinear least squares of survey residuals. Two alternative model configurations were performed as sensitivity analyses: excluding a penalty term in the objective function for initial biomass estimates greater than the carrying capacity (i.e. $B1R > K$) and iteratively reweighting residuals based on mean square error of each biomass index series. Survey residuals were randomly resampled 500 times to derive bias-corrected probability distributions for parameter estimates and calculated variables.

Precautionary Reference Points and Harvest Control Rule

Precautionary fishing targets were derived from bootstrap probability distributions. An estimate of F_{buf} was derived from the tenth percentile of the F_{msy} estimate, which should have approximately a 10% risk of being greater than F_{msy} (Cadrin, 1999). This is consistent with a precautionary target developed by the ICES Study Group on the Precautionary Approach to Fisheries Management (ICES, 1998). Similarly B_{buf} was derived as the ninetieth percentile of the B_{loss} estimate, which should have a 10% risk of being less than B_{loss}.

A harvest control rule was formed based on the framework illustrated in Figure 1 (from Serchuk *et al*., 1997) using the MSY reference points, B_{loss}, and uncertainty estimates. A stochastic projection was used to assess the performance of the control rule using bootstrap estimates of starting biomass (1998), an assumed catch of 4,000 tons in 1998 (the TAC), and target Fs from the control rule. Performance of the control rule was assessed according to the probability of attaining the biomass target (B_{msy}) and projected yields. Expected mean biomass and yield under equilibrium conditions (B* and C*) can be derived from parameter estimates and any given level of F. For example expected biomass and catch at F_{buf} can be calculated:

$$B^* = K\,(1 - F_{buf} / r) \qquad (6)$$

$$C^* = F_{buf} \cdot B^* \qquad (7)$$

Results

The ASPIC model fit the Grand Bank yellowtail catch and biomass index data relatively well. The majority of variance in survey indices was explained by the model, but model fit varied among indices (R^2 ranged from 0.2 to 0.8; Appendix A). Residuals appeared to be randomly distributed for all survey indices, except the USSR/Russian series, which had a strong pattern of positive residuals during the 1970s and early-1980s and negative residuals for subsequent years (i.e. the USSR/Russian survey index decreased more rapidly than the Canadian spring survey index in the mid-1980s).

The production model results estimate that MSY = 16,000 tons, B_{msy} = 91,000 tons, and F_{msy} = 0.18 (Appendix A, page A1). Biomass estimates were near the estimated carrying capacity in the 1960s when F was less than F_{msy} (Appendix A, page A2). Biomass declined to approximately 75% of B_{msy} in the late-1970s and early-1980s, as F exceeded F_{msy}. Fishing mortality increased in the late-1980s, and biomass decreased to 25% of B_{msy} in the early-1990s. Fishing mortality was much less than F_{msy} during the moratorium, and biomass increased to 70% of B_{msy} in 1998 (Appendix A, page A2). These results agree with the most recent descriptive stock assessment, which concluded that the stock is increasing and is at a level close to that of the mid-1980s (Walsh *et al*., 1998a). However, biomass estimates from ASPIC are generally greater than those from SPA. Performance of ASPIC on simulated data indicates that ratios to MSY reference points (B_t/B_{MSY} and F_t/F_{MSY}) are generally more reliable than absolute estimates of biomass or F (Prager *et al*., 1996; NRC, 1998; Prager, 1998).

Sensitivity analyses show that estimates of MSY, B_{msy}, F_{msy}, 1998 biomass, and 1997 F are relatively robust to excluding the SPA biomass series, including the CPUE series, iteratively reweighting, or removing the penalty term for $B1R>K$ (Table 3). The CPUE series produced a residual pattern which suggests increasing catchability over time (Appendix B). Estimates of MSY and F_{msy} appear to be sensitive to excluding the USSR/Russian survey (run 4 estimated MSY as 24,000 tons and F_{msy} as 0.28). An additional sensitivity run with provisional 1998 catch (4,000 tons) and Canadian spring and autumn 1998 survey indices (not reported in the 1998 assessment) also had very similar results to those in Appendix A (Table 3).

Conditional bootstrap results indicate that model parameters and derived estimates were relatively well estimated. Eighty percent confidence limits for F_{msy} = 0.13 to 0.23, B_{msy} = 76,000 tons to 111,000 tons (Appendix A, page A13), 1998 biomass = 52,000 tons to 82,000 tons (Appendix A, page A14), and F in 1997 = 0.01 to 0.02 (Appendix A, page A15).

A control rule based on results from the production model and the framework proposed by Serchuk *et al*. (1997) is illustrated in Figure 4. The lowest observed stock size (B_{loss}) was 23,000 tons in 1994, with an 80% confidence interval of 16,000 tons to 34,000 tons (Appendix A, page A14), suggesting that an appropriate level for B_{buf} is 34,000 tons. The tenth percentile of the F_{msy} estimate is 0.13 or 74% of F_{msy}. A default precautionary target of 75% F_{msy} was proposed by Restrepo *et al* (1998) for situations with moderate uncertainty. The control rule is consistent with reopening the directed fishery in 1998, because 1998 biomass was greater than B_{buf}. Long-term projections of the 1998 TAC and F from the control rule suggest that the stock will grow to B_{msy} by the year 2002 with approximately 60% probability, and will continue to approach the expected equilibrium of approximately 114,000 and yield 15,000 tons of annual catch (Appendix A, pages A14-15). However, projections assume average conditions (i.e. expected levels of recruitment and growth are implicitly assumed) and may not be accurate.

Discussion

Uncertainty in estimates of total catch continue to be a problem for modeling production of Grand Bank yellowtail flounder. The present results, conditional on the accuracy of nominal catch, suggest that the 1998 TAC is consistent with the control rule described herein and the precautionary approach proposed in Serchuk *et al*. (1997). However, uncertainty in catch is not included in the conditional bootstrap variance. Incorporating uncertainty from model misspecification would decrease F_{buf} and increase B_{buf}, implying that greater biomass levels should have been attained before the fishery could be reopened. Estimates of reference point values and their uncertainty will improve as future catch data improves. The present modeling approach allows comparison of expected changes in stock size with observed changes, and can modify reference point estimates to resolve the differences.

An implication of MSY theory and the framework proposed by Serchuk *et al*. (1997; illustrated in Figure 1) is maintenance of biomass levels greater than B_{msy}, because F_{buf} is less than F_{msy}. Therefore, implicit biomass targets will be greater than B_{msy}, despite the fact that $B_{target} = B_{msy}$.

Results from sensitivity analyses which excluded the USSR/Russian survey may not be reasonable. The comparative life history of Grand Bank yellowtail flounder suggests that an estimate of $r = 0.56$ is inconsistent with relatively late maturity and slow growth. The same model performs well in assessments of other stocks of yellowtail flounder, and the estimates of r are 0.62 for Georges Bank yellowtail and 0.46 for southern New England yellowtail (NEFSC, 1998). Grand Bank yellowtail grow much slower than southern stocks (Scott, 1954; Pitt, 1974) and mature at approximately age-6 (Pitt, 1970), whereas southern stocks of yellowtail mature at approximately age-2 (NEFSC, 1998). Therefore, the analyses that include the USSR/Russian survey data produce estimates of r for the Grand Bank stock that are much more parsimonious with its life history information ($r = 0.36$).

Estimates of absolute stock biomass and fishing mortality in a given year (t) are not generally as reliable as ratios to MSY reference points (e.g. B_t/B_{msy} and F_t/F_{msy}). If absolute estimates do not prove to be reliable, biomass reference points and current stock status can be expressed as survey biomass indices. However, the present model may be an appropriate method to combine and smooth survey indices for status determination.

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Table 1. Nominal catch, CPUE, survey biomass indices, and provisional SPA biomass estimates of Grand Bank yellowtail flounder.

Year	Landings (k t)	Canadian CPUE*	Canadian Yankee Survey	Canadian Campelen Survey	Canadian Autumn Survey	Canadian Juvenile Survey*	USSR/ Russian Survey	Spanish Survey	SPA Biomass (k t)
64	0.147	---	---	---	---	---	---	---	---
65	3.130	1.164	---	---	---	---	---	---	---
66	7.026	1.129	---	---	---	---	---	---	---
67	8.878	1.107	---	---	---	---	---	---	---
68	13.340	0.939	---	---	---	---	---	---	87.2
69	15.708	0.822	---	---	---	---	---	---	101.8
70	26.426	0.816	---	---	---	---	---	---	104.0
71	37.342	0.781	96.9	---	---	---	---	---	94.6
72	39.259	0.697	79.2	---	---	---	106	---	79.6
73	32.815	0.796	51.7	---	---	---	217	---	67.8
74	24.313	0.530	40.3	---	---	---	129	---	51.9
75	22.894	0.526	37.4	---	---	---	126	---	41.9
76	8.057	0.481	41.7	---	---	---	131	---	47.0
77	11.638	0.580	65.0	---	---	---	188	---	50.1
78	15.466	0.588	44.3	---	---	---	110	---	56.4
79	18.371	0.611	38.5	---	---	---	98	---	42.8
80	12.377	0.681	51.4	---	---	---	164	---	53.6
81	14.680	0.679	45.0	---	---	---	158	---	56.5
82	13.319	0.624	43.1	---	---	---	125	---	70.8
83	10.473	0.702	---	---	---	---	---	---	93.2
84	16.735	0.682	---	221.1	---	---	132	---	90.4
85	28.963	0.711	---	149.0	---	---	85	---	70.2
86	30.176	0.523	---	140.5	---	118.2	42	---	38.6
87	16.314	0.541	---	126.6	---	155.5	30	---	20.0
88	16.158	0.501	---	82.3	---	---	23	---	---
89	10.207	0.507	---	104.8	---	98.5	44	---	---
90	13.986	0.579	---	104.8	66.4	138.9	27	---	---
91	16.203	0.316	---	94.0	82.8	150.9	27	---	---
92	10.762	0.344	---	61.8	64.2	188.2	---	---	---
93	13.565	0.431	---	95.1	114.8	157.5	---	---	---
94	2.069	---	---	57.3	106.8	188.6	---	---	---
95	0.067	---	---	71.7	126.8	---	---	27.7	---
96	0.287	---	---	173.5	136.0	---	---	129.6	---
97	0.800	---	---	186.9	215.0	---	---	115.7	---
98	---	---	---	---	---	---	---	425.4	---
average	15.057	0.669	52.9	119.2	114.1	149.5	103	174.6	65.9

* not used in final model run.

Table 2. Correlation coefficients among biomass indices of Grand Bank yellowtail flounder (* indicates 95% significance).

	CPUE	Yankee	Campelen	autumn	juvenile	Russian	Spanish	SPA
CPUE	1.00							
Yankee	*0.62	1.00						
Campelen	0.77	---	1.00					
Autumn	-0.10	---	*0.73	1.00				
Juvenile	-0.63	---	-0.19	0.82	1.00			
Russian	*0.61	0.20	*0.93	---	-0.29	1.00		
Spanish	---	---	*0.97	0.47	---	---	1.00	
SPA	*0.80	*0.82	0.87	---	---	0.41	---	1.00

Table 3. Results from alternative production model configurations (MSY, K, B_{msy}, and B98 in thousand t units).

Model run	B1R	MSY	r	K	Bmsy	Fmsy	B98	F97	MSE	comment
4	0.37	23.85	0.562	169.90	84.95	0.281	63.53	0.015	0.062	excluding Russian survey
5	2.39	15.96	0.344	185.74	92.87	0.172	63.69	0.014	0.164	excluding SPA biomass
6	2.17	16.38	0.361	181.45	90.72	0.181	63.43	0.014	0.135	Appendix A
6i	1.03	18.41	0.396	186.10	93.05	0.198	71.38	0.013	0.058	iteratively reweighted
6p	6.32	15.66	0.364	171.90	85.95	0.182	63.49	0.014	0.134	no penalty function
7	1.06	17.77	0.347	205.08	102.54	0.173	67.88	0.013	0.115	including CPUE
98	2.20	16.07	0.344	187.10	93.54	0.172	65.57	0.056	0.140	including 1998 data

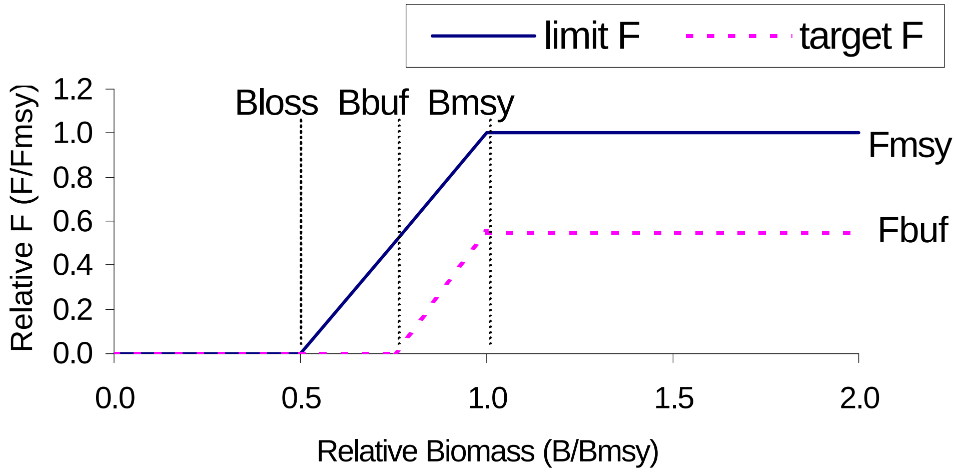

Fig. 1. Schematic harvest control rule based on framework proposed by Serchuk *et al*. (1997).

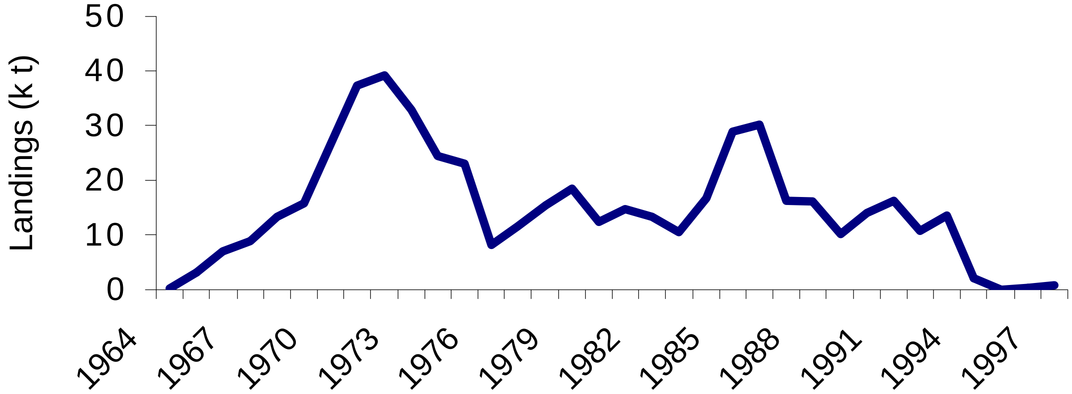

Fig 2. Landings of Grand Bank yellowtail flounder.

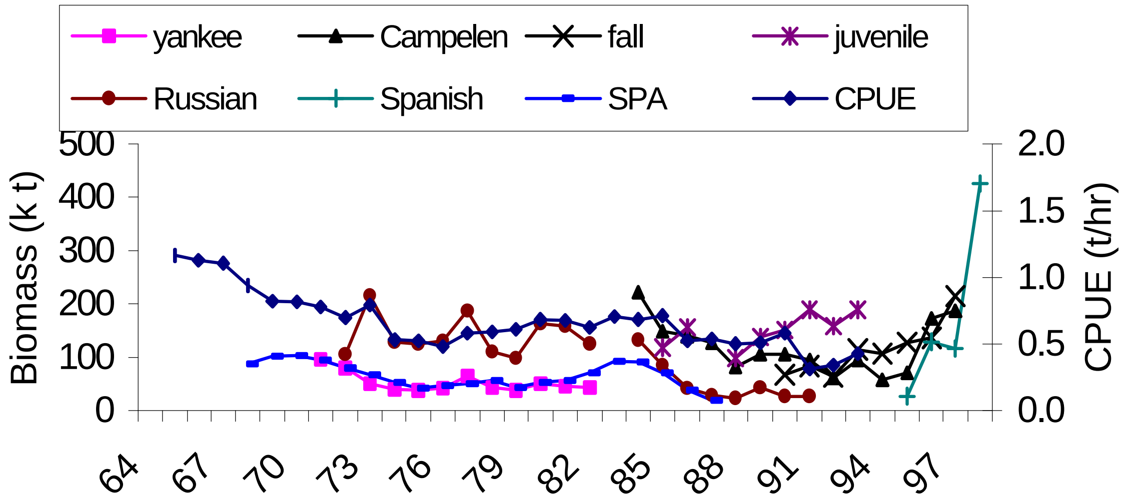

Figure 3. Indices of Grand Bank yellowtail flounder biomass (some indices are plotted individually in Appendix A).

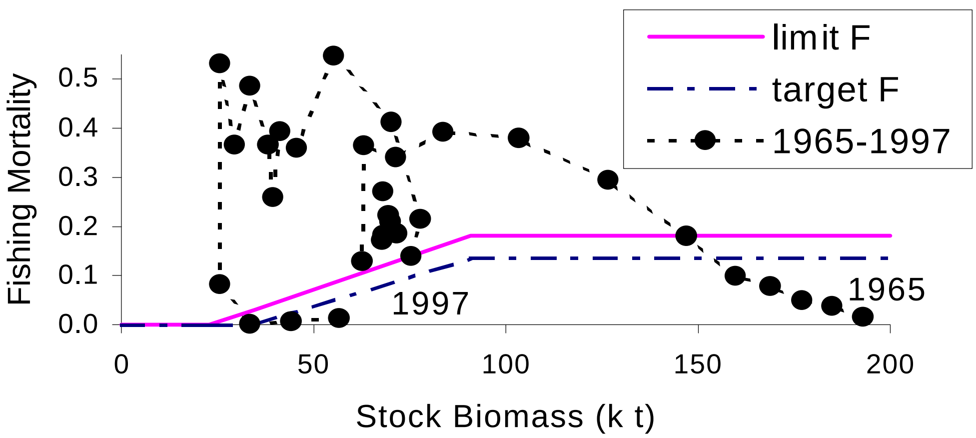

Fig. 4. Stock biomass and fishing mortality of Grand Bank yellowtail flounder in relation to a precautionary control rule.

```
                                                                                          05 Mar 1999 at 11:54
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.65)                                  FIT Mode

Author: Michael H. Prager
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CONTROL PARAMETERS USED (FROM INPUT FILE)
------------------------------------------------------------------------------------------------------------
Number of years analyzed:                     33          Number of bootstrap trials:                      0
Number of data series:                         6          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:                            911
Maximum F allowed in fitting:              5.000          Monte Carlo search trials:                   50000

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

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------
                                   |
 1  Canadian Campelen Survey       |  1.000
                                   |     14
                                   |
 2  Canadian Yankee Survey         |  0.000  1.000
                                   |      0     12
                                   |
 3  Canadian Autumn Survey         |  0.728  0.000  1.000
                                   |      8      0      8
                                   |
 4  USSR/Russian Survey Survey     |  0.932  0.198  1.000  1.000
                                   |      8     11      2     19
                                   |
 5  Spanish Survey (lagged)        |  0.716  0.000  0.994  0.000  1.000
                                   |      4      0      4      0      4
                                   |
 6  SPA biomass                    |  0.873  0.821  0.000  0.408  0.000  1.000
                                   |      4     12      0     15      0     20
                                    ---------------------------------------------
                                          1      2      3      4      5      6

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                   6.650E-03    1          N/A   1.000E+00         N/A
Loss( 1)  Canadian Campelen Survey              5.893E-01   14    4.911E-02   1.000E+00   1.320E+00       0.735
Loss( 2)  Canadian Yankee Survey                2.733E-01   12    2.733E-02   1.000E+00   2.372E+00       0.775
Loss( 3)  Canadian Autumn Survey                6.949E-01    8    1.158E-01   1.000E+00   5.598E-01       0.640
Loss( 4)  USSR/Russian Survey                   4.530E+00   19    2.665E-01   1.000E+00   2.433E-01       0.347
Loss( 5)  Spanish Survey (lagged)               1.958E+00    4    9.790E-01   1.000E+00   6.622E-02       0.231
Loss( 6)  SPA biomass                           1.128E+00   20    6.265E-02   1.000E+00   1.035E+00       0.499

TOTAL OBJECTIVE FUNCTION:                  9.17973526E+00

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

Number of restarts required for convergence:           28
Est. B-ratio coverage index (0 worst, 2 best):     1.7487
Est. B-ratio nearness index (0 worst, 1 best):     1.0000

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------
Parameter                                        Estimate     Starting guess   Estimated   User guess
B1R       Starting biomass ratio, year 1965     2.170E+00          2.000E+00           1            1
MSY       Maximum sustainable yield             1.638E+01          1.300E+01           1            1
r         Intrinsic rate of increase            3.611E-01          5.000E-01           1            1
........  Catchability coefficients by fishery:
q( 1)     Canadian Campelen Survey              2.654E+00          3.000E+00           1            1
q( 2)     Canadian Yankee Survey                6.708E-01          1.000E+00           1            1
q( 3)     Canadian Autumn Survey                2.987E+00          3.000E+00           1            1
q( 4)     USSR/Russian Survey                   1.381E+00          1.000E+00           1            1
q( 5)     Spanish Survey (lagged)               2.665E+00          3.000E+00           1            1
q( 6)     SPA biomass                           7.605E-01          1.000E+00           1            1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------------
Parameter                                        Estimate            Formula
MSY       Maximum sustainable yield             1.638E+01               Kr/4
K         Maximum stock biomass                 1.814E+02
Bmsy      Stock biomass at MSY                  9.072E+01                K/2
Fmsy      Fishing mortality at MSY              1.806E-01                r/2

F(0.1)    Management benchmark                  1.625E-01          0.9*Fmsy
Y(0.1)    Equilibrium yield at F(0.1)           1.622E+01          0.99*MSY

B-ratio   Ratio of B(1998) to Bmsy              6.992E-01
F-ratio   Ratio of F(1997) to Fmsy              7.818E-02
Y-ratio   Proportion of MSY avail in 1998       9.095E-01          2*Br-Br^2     Ye(1998) = 1.490E+01

........  Fishing effort at MSY in units of each fishery:
fmsy( 1)  Canadian Campelen Survey              6.804E-02          r/2q( 1)        f(0.1) = 6.124E-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	0.016	1.968E+02	1.928E+02	3.130E+00	3.130E+00	-4.383E+00	8.989E-02	2.170E+00
2	1966	0.038	1.893E+02	1.849E+02	7.026E+00	7.026E+00	-1.285E+00	2.104E-01	2.087E+00
3	1967	0.050	1.810E+02	1.771E+02	8.878E+00	8.878E+00	1.518E+00	2.776E-01	1.995E+00
4	1968	0.079	1.737E+02	1.688E+02	1.334E+01	1.334E+01	4.227E+00	4.376E-01	1.914E+00
5	1969	0.098	1.645E+02	1.598E+02	1.571E+01	1.571E+01	6.855E+00	5.442E-01	1.814E+00
6	1970	0.180	1.557E+02	1.470E+02	2.643E+01	2.643E+01	1.004E+01	9.959E-01	1.716E+00
7	1971	0.295	1.393E+02	1.266E+02	3.734E+01	3.734E+01	1.372E+01	1.633E+00	1.536E+00
8	1972	0.380	1.157E+02	1.032E+02	3.926E+01	3.926E+01	1.598E+01	2.106E+00	1.275E+00
9	1973	0.392	9.241E+01	8.362E+01	3.282E+01	3.282E+01	1.623E+01	2.173E+00	1.019E+00
10	1974	0.341	7.583E+01	7.129E+01	2.431E+01	2.431E+01	1.562E+01	1.889E+00	8.359E-01
11	1975	0.364	6.713E+01	6.293E+01	2.289E+01	2.289E+01	1.483E+01	2.015E+00	7.401E-01
12	1976	0.129	5.907E+01	6.245E+01	8.057E+00	8.057E+00	1.478E+01	7.145E-01	6.512E-01
13	1977	0.172	6.580E+01	6.767E+01	1.164E+01	1.164E+01	1.532E+01	9.525E-01	7.253E-01
14	1978	0.223	6.948E+01	6.949E+01	1.547E+01	1.547E+01	1.548E+01	1.232E+00	7.659E-01
15	1979	0.270	6.950E+01	6.794E+01	1.837E+01	1.837E+01	1.535E+01	1.497E+00	7.661E-01
16	1980	0.182	6.648E+01	6.799E+01	1.238E+01	1.238E+01	1.535E+01	1.008E+00	7.328E-01
17	1981	0.210	6.945E+01	6.988E+01	1.468E+01	1.468E+01	1.552E+01	1.163E+00	7.656E-01
18	1982	0.186	7.029E+01	7.147E+01	1.332E+01	1.332E+01	1.564E+01	1.032E+00	7.748E-01
19	1983	0.139	7.261E+01	7.536E+01	1.047E+01	1.047E+01	1.591E+01	7.696E-01	8.004E-01
20	1984	0.215	7.805E+01	7.769E+01	1.674E+01	1.674E+01	1.604E+01	1.193E+00	8.603E-01
21	1985	0.412	7.735E+01	7.026E+01	2.896E+01	2.896E+01	1.552E+01	2.283E+00	8.527E-01
22	1986	0.547	6.391E+01	5.518E+01	3.018E+01	3.018E+01	1.382E+01	3.028E+00	7.045E-01
23	1987	0.359	4.756E+01	4.549E+01	1.631E+01	1.631E+01	1.231E+01	1.986E+00	5.242E-01
24	1988	0.393	4.355E+01	4.114E+01	1.616E+01	1.616E+01	1.148E+01	2.175E+00	4.801E-01
25	1989	0.259	3.888E+01	3.934E+01	1.021E+01	1.021E+01	1.113E+01	1.437E+00	4.285E-01
26	1990	0.366	3.980E+01	3.821E+01	1.399E+01	1.399E+01	1.089E+01	2.027E+00	4.387E-01
27	1991	0.485	3.670E+01	3.338E+01	1.620E+01	1.620E+01	9.830E+00	2.688E+00	4.046E-01
28	1992	0.366	3.033E+01	2.937E+01	1.076E+01	1.076E+01	8.890E+00	2.029E+00	3.343E-01
29	1993	0.532	2.845E+01	2.550E+01	1.356E+01	1.356E+01	7.909E+00	2.946E+00	3.137E-01
30	1994	0.081	2.280E+01	2.565E+01	2.069E+00	2.069E+00	7.948E+00	4.467E-01	2.513E-01
31	1995	0.002	2.868E+01	3.337E+01	6.700E-02	6.700E-02	9.819E+00	1.112E-02	3.161E-01
32	1996	0.007	3.843E+01	4.413E+01	2.870E-01	2.870E-01	1.204E+01	3.601E-02	4.236E-01
33	1997	0.014	5.018E+01	5.667E+01	8.000E-01	8.000E-01	1.404E+01	7.818E-02	5.532E-01
34	1998		6.343E+01						6.992E-01

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Canadian Campelen Survey

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed yield	Model yield	Resid in log effort	Resid in yield
1	1965	*	6.116E-03	0.0162	3.130E+00	3.130E+00	0.00000	0.000E+00
2	1966	*	1.432E-02	0.0380	7.026E+00	7.026E+00	0.00000	0.000E+00
3	1967	*	1.889E-02	0.0501	8.878E+00	8.878E+00	0.00000	0.000E+00
4	1968	*	2.978E-02	0.0790	1.334E+01	1.334E+01	0.00000	0.000E+00
5	1969	*	3.703E-02	0.0983	1.571E+01	1.571E+01	0.00000	0.000E+00
6	1970	*	6.776E-02	0.1798	2.643E+01	2.643E+01	0.00000	0.000E+00
7	1971	*	1.111E-01	0.2949	3.734E+01	3.734E+01	0.00000	0.000E+00
8	1972	*	1.433E-01	0.3804	3.926E+01	3.926E+01	0.00000	0.000E+00
9	1973	*	1.479E-01	0.3924	3.282E+01	3.282E+01	0.00000	0.000E+00
10	1974	*	1.285E-01	0.3410	2.431E+01	2.431E+01	0.00000	0.000E+00
11	1975	*	1.371E-01	0.3638	2.289E+01	2.289E+01	0.00000	0.000E+00
12	1976	*	4.862E-02	0.1290	8.057E+00	8.057E+00	0.00000	0.000E+00
13	1977	*	6.481E-02	0.1720	1.164E+01	1.164E+01	0.00000	0.000E+00
14	1978	*	8.386E-02	0.2226	1.547E+01	1.547E+01	0.00000	0.000E+00
15	1979	*	1.019E-01	0.2704	1.837E+01	1.837E+01	0.00000	0.000E+00
16	1980	*	6.860E-02	0.1820	1.238E+01	1.238E+01	0.00000	0.000E+00
17	1981	*	7.916E-02	0.2101	1.468E+01	1.468E+01	0.00000	0.000E+00
18	1982	*	7.022E-02	0.1864	1.332E+01	1.332E+01	0.00000	0.000E+00
19	1983	*	5.236E-02	0.1390	1.047E+01	1.047E+01	0.00000	0.000E+00
20	1984	7.569E-02	8.117E-02	0.2154	1.674E+01	1.674E+01	-0.06986	0.000E+00
21	1985	1.944E-01	1.553E-01	0.4122	2.896E+01	2.896E+01	0.22429	0.000E+00
22	1986	2.148E-01	2.061E-01	0.5469	3.018E+01	3.018E+01	0.04142	0.000E+00
23	1987	1.289E-01	1.351E-01	0.3586	1.631E+01	1.631E+01	-0.04746	0.000E+00
24	1988	1.963E-01	1.480E-01	0.3928	1.616E+01	1.616E+01	0.28254	0.000E+00
25	1989	9.740E-02	9.777E-02	0.2595	1.021E+01	1.021E+01	-0.00380	0.000E+00
26	1990	1.335E-01	1.379E-01	0.3661	1.399E+01	1.399E+01	-0.03302	0.000E+00
27	1991	1.724E-01	1.829E-01	0.4855	1.620E+01	1.620E+01	-0.05941	0.000E+00
28	1992	1.741E-01	1.381E-01	0.3664	1.076E+01	1.076E+01	0.23214	0.000E+00
29	1993	1.426E-01	2.005E-01	0.5320	1.356E+01	1.356E+01	-0.34030	0.000E+00
30	1994	3.611E-02	3.039E-02	0.0807	2.069E+00	2.069E+00	0.17231	0.000E+00
31	1995	9.344E-04	7.565E-04	0.0020	6.700E-02	6.700E-02	0.21121	0.000E+00
32	1996	1.654E-03	2.451E-03	0.0065	2.870E-01	2.870E-01	-0.39299	0.000E+00
33	1997	4.280E-03	5.319E-03	0.0141	8.000E-01	8.000E-01	-0.21730	0.000E+00

* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

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    -0.0699                                          ===|
1985     0.2243                                             |=========
1986     0.0414                                             |==
1987    -0.0475                                           ==|
1988     0.2825                                             |===========
1989    -0.0038                                             |
1990    -0.0330                                            =|
1991    -0.0594                                           ==|
1992     0.2321                                             |=========
1993    -0.3403                               ==============|
1994     0.1723                                             |=======
1995     0.2112                                             |========
1996    -0.3930                             ================|
1997    -0.2173                                    =========|
                 ------------------------------------------------------------------------------------
```

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	*	1.293E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	1.240E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	1.188E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.132E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.072E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	9.857E+01	0.00000	0.0
7	1971	1.000E+00	1.000E+00	0.0	9.690E+01	8.495E+01	0.13165	1.195E+01
8	1972	1.000E+00	1.000E+00	0.0	7.920E+01	6.924E+01	0.13447	9.965E+00
9	1973	1.000E+00	1.000E+00	0.0	5.170E+01	5.609E+01	-0.08147	-4.388E+00
10	1974	1.000E+00	1.000E+00	0.0	4.030E+01	4.782E+01	-0.17111	-7.521E+00
11	1975	1.000E+00	1.000E+00	0.0	3.740E+01	4.221E+01	-0.12110	-4.815E+00
12	1976	1.000E+00	1.000E+00	0.0	4.170E+01	4.189E+01	-0.00449	-1.877E-01
13	1977	1.000E+00	1.000E+00	0.0	6.500E+01	4.539E+01	0.35912	1.961E+01
14	1978	1.000E+00	1.000E+00	0.0	4.430E+01	4.661E+01	-0.05092	-2.314E+00
15	1979	1.000E+00	1.000E+00	0.0	3.850E+01	4.558E+01	-0.16871	-7.075E+00
16	1980	1.000E+00	1.000E+00	0.0	5.140E+01	4.560E+01	0.11963	5.796E+00
17	1981	1.000E+00	1.000E+00	0.0	4.500E+01	4.687E+01	-0.04078	-1.873E+00
18	1982	1.000E+00	1.000E+00	0.0	4.310E+01	4.794E+01	-0.10646	-4.842E+00
19	1983	0.000E+00	0.000E+00	0.0	*	5.055E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	5.211E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	4.713E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	3.701E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	3.052E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	2.759E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	2.639E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	2.563E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	2.239E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	1.970E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	1.710E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	1.721E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	2.238E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	2.960E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	3.801E+01	0.00000	0.0

* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

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     0.1317                                         |=====
1972     0.1345                                         |=====
1973    -0.0815                                      ===|
1974    -0.1711                                  =======|
1975    -0.1211                                    =====|
1976    -0.0045                                         |
1977     0.3591                                         |==============
1978    -0.0509                                       ==|
1979    -0.1687                                  =======|
1980     0.1196                                         |=====
1981    -0.0408                                       ==|
1982    -0.1065                                     ====|
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                                         |
                   ----------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canadian Autumn 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	*	5.655E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	5.407E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	5.187E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	4.915E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	4.650E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	4.161E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	3.455E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	2.760E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	2.265E+02	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	2.005E+02	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	1.764E+02	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	1.965E+02	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	2.075E+02	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	2.076E+02	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	1.986E+02	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	2.074E+02	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	2.099E+02	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	2.169E+02	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	2.331E+02	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	2.310E+02	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	1.909E+02	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	1.420E+02	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	1.301E+02	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	1.161E+02	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	1.189E+02	0.00000	0.0
26	1990	1.000E+00	1.000E+00	0.0	6.640E+01	1.096E+02	-0.50131	-4.322E+01
27	1991	1.000E+00	1.000E+00	0.0	8.280E+01	9.058E+01	-0.08983	-7.782E+00
28	1992	1.000E+00	1.000E+00	0.0	6.420E+01	8.499E+01	-0.28053	-2.079E+01
29	1993	1.000E+00	1.000E+00	0.0	1.148E+02	6.810E+01	0.52226	4.670E+01
30	1994	1.000E+00	1.000E+00	0.0	1.068E+02	8.566E+01	0.22060	2.114E+01
31	1995	1.000E+00	1.000E+00	0.0	1.268E+02	1.148E+02	0.09953	1.201E+01
32	1996	1.000E+00	1.000E+00	0.0	1.360E+02	1.499E+02	-0.09722	-1.389E+01
33	1997	1.000E+00	1.000E+00	0.0	2.150E+02	1.894E+02	0.12653	2.555E+01

* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

```
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    -0.5013                         ====================|
1991    -0.0898                                         ====|
1992    -0.2805                                  ===========|
1993     0.5223                                             |=====================
1994     0.2206                                             |=========
1995     0.0995                                             |====
1996    -0.0972                                         ====|
1997     0.1265                                             |=====
                   -------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED) USSR/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	*	2.663E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.553E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.446E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	2.331E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	2.207E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	2.029E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.749E+02	0.00000	0.0
8	1972	1.000E+00	1.000E+00	0.0	1.060E+02	1.425E+02	-0.29610	-3.653E+01
9	1973	1.000E+00	1.000E+00	0.0	2.170E+02	1.155E+02	0.63094	1.015E+02
10	1974	1.000E+00	1.000E+00	0.0	1.290E+02	9.844E+01	0.27032	3.056E+01
11	1975	1.000E+00	1.000E+00	0.0	1.260E+02	8.690E+01	0.37148	3.910E+01
12	1976	1.000E+00	1.000E+00	0.0	1.310E+02	8.623E+01	0.41817	4.477E+01
13	1977	1.000E+00	1.000E+00	0.0	1.880E+02	9.344E+01	0.69915	9.456E+01
14	1978	1.000E+00	1.000E+00	0.0	1.100E+02	9.596E+01	0.13655	1.404E+01
15	1979	1.000E+00	1.000E+00	0.0	9.800E+01	9.382E+01	0.04357	4.178E+00
16	1980	1.000E+00	1.000E+00	0.0	1.640E+02	9.388E+01	0.55783	7.012E+01
17	1981	1.000E+00	1.000E+00	0.0	1.580E+02	9.649E+01	0.49312	6.151E+01
18	1982	1.000E+00	1.000E+00	0.0	1.250E+02	9.869E+01	0.23630	2.631E+01
19	1983	0.000E+00	0.000E+00	0.0	*	1.041E+02	0.00000	0.0
20	1984	1.000E+00	1.000E+00	0.0	1.320E+02	1.073E+02	0.20735	2.472E+01
21	1985	1.000E+00	1.000E+00	0.0	8.500E+01	9.702E+01	-0.13228	-1.202E+01
22	1986	1.000E+00	1.000E+00	0.0	4.200E+01	7.620E+01	-0.59565	-3.420E+01
23	1987	1.000E+00	1.000E+00	0.0	3.000E+01	6.282E+01	-0.73907	-3.282E+01
24	1988	1.000E+00	1.000E+00	0.0	2.300E+01	5.680E+01	-0.90411	-3.380E+01
25	1989	1.000E+00	1.000E+00	0.0	4.400E+01	5.432E+01	-0.21076	-1.032E+01
26	1990	1.000E+00	1.000E+00	0.0	2.700E+01	5.276E+01	-0.66989	-2.576E+01
27	1991	1.000E+00	1.000E+00	0.0	2.750E+01	4.609E+01	-0.51640	-1.859E+01
28	1992	0.000E+00	0.000E+00	0.0	*	4.056E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	3.521E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	3.542E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	4.608E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	6.094E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	7.825E+01	0.00000	0.0

* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

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    -0.2961                                 ============|
1973     0.6309                                             |=========================
1974     0.2703                                             |===========
1975     0.3715                                             |===============
1976     0.4182                                             |=================
1977     0.6991                                             |============================
1978     0.1365                                             |=====
1979     0.0436                                             |==
1980     0.5578                                             |======================
1981     0.4931                                             |====================
1982     0.2363                                             |=========
1983     0.0000                                             |
1984     0.2074                                             |========
1985    -0.1323                                        =====|
1986    -0.5956                     ========================|
1987    -0.7391               ==============================|
1988    -0.9041         ====================================|
1989    -0.2108                                     ========|
1990    -0.6699                  ===========================|
1991    -0.5164                        =====================|
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
                   ---------------------------------------------------------------------------------
```

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

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	*	5.045E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	4.824E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	4.628E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	4.385E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	4.149E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	3.712E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	3.083E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	2.462E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	2.021E+02	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	1.789E+02	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	1.574E+02	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	1.753E+02	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	1.852E+02	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	1.852E+02	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	1.771E+02	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	1.851E+02	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	1.873E+02	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	1.935E+02	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	2.080E+02	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	2.061E+02	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	1.703E+02	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	1.267E+02	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	1.160E+02	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	1.036E+02	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	1.060E+02	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	9.780E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	8.081E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	7.582E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	6.075E+01	0.00000	0.0
30	1994	1.000E+00	1.000E+00	0.0	2.770E+01	7.642E+01	-1.01467	-4.872E+01
31	1995	1.000E+00	1.000E+00	0.0	1.296E+02	1.024E+02	0.23582	2.723E+01
32	1996	1.000E+00	1.000E+00	0.0	1.157E+02	1.337E+02	-0.14452	-1.799E+01
33	1997	1.000E+00	1.000E+00	0.0	4.254E+02	1.690E+02	0.92298	2.564E+02

* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

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    -1.0147                         ====================|
1995     0.2358                                             |=====
1996    -0.1445                                          ===|
1997     0.9230                                             |==================
                   -----------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 6 (NON-BOOTSTRAPPED) SPA biomass

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	*	1.466E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	1.406E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	1.347E+02	0.00000	0.0
4	1968	1.000E+00	1.000E+00	0.0	8.720E+01	1.284E+02	-0.38670	-4.117E+01
5	1969	1.000E+00	1.000E+00	0.0	1.018E+02	1.216E+02	-0.17764	-1.978E+01
6	1970	1.000E+00	1.000E+00	0.0	1.040E+02	1.118E+02	-0.07152	-7.713E+00
7	1971	1.000E+00	1.000E+00	0.0	9.459E+01	9.631E+01	-0.01802	-1.720E+00
8	1972	1.000E+00	1.000E+00	0.0	7.964E+01	7.849E+01	0.01456	1.151E+00
9	1973	1.000E+00	1.000E+00	0.0	6.781E+01	6.359E+01	0.06429	4.222E+00
10	1974	1.000E+00	1.000E+00	0.0	5.186E+01	5.422E+01	-0.04433	-2.351E+00
11	1975	1.000E+00	1.000E+00	0.0	4.192E+01	4.786E+01	-0.13263	-5.945E+00
12	1976	1.000E+00	1.000E+00	0.0	4.699E+01	4.749E+01	-0.01050	-4.958E-01
13	1977	1.000E+00	1.000E+00	0.0	5.007E+01	5.146E+01	-0.02726	-1.384E+00
14	1978	1.000E+00	1.000E+00	0.0	5.643E+01	5.285E+01	0.06553	3.579E+00
15	1979	1.000E+00	1.000E+00	0.0	4.283E+01	5.167E+01	-0.18756	-8.836E+00
16	1980	1.000E+00	1.000E+00	0.0	5.363E+01	5.170E+01	0.03658	1.926E+00
17	1981	1.000E+00	1.000E+00	0.0	5.654E+01	5.314E+01	0.06196	3.397E+00
18	1982	1.000E+00	1.000E+00	0.0	7.081E+01	5.435E+01	0.26453	1.646E+01
19	1983	1.000E+00	1.000E+00	0.0	9.319E+01	5.731E+01	0.48613	3.588E+01
20	1984	1.000E+00	1.000E+00	0.0	9.041E+01	5.908E+01	0.42548	3.133E+01
21	1985	1.000E+00	1.000E+00	0.0	7.017E+01	5.343E+01	0.27256	1.674E+01
22	1986	1.000E+00	1.000E+00	0.0	3.856E+01	4.196E+01	-0.08460	-3.404E+00
23	1987	1.000E+00	1.000E+00	0.0	1.995E+01	3.460E+01	-0.55041	-1.464E+01
24	1988	0.000E+00	0.000E+00	0.0	*	3.128E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	2.992E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	2.906E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	2.538E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	2.234E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	1.939E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	1.951E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	2.538E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	3.356E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	4.310E+01	0.00000	0.0

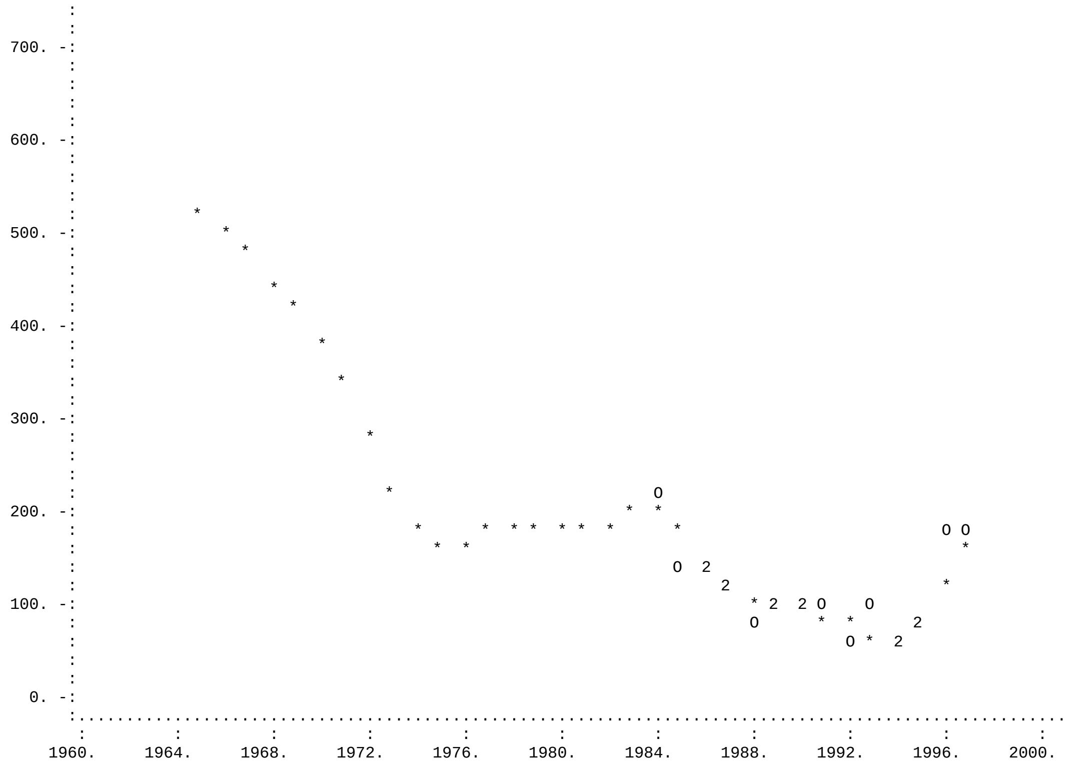
* Asterisk indicates missing value(s).

3LNO yellowtail flounder (biomass in kt)

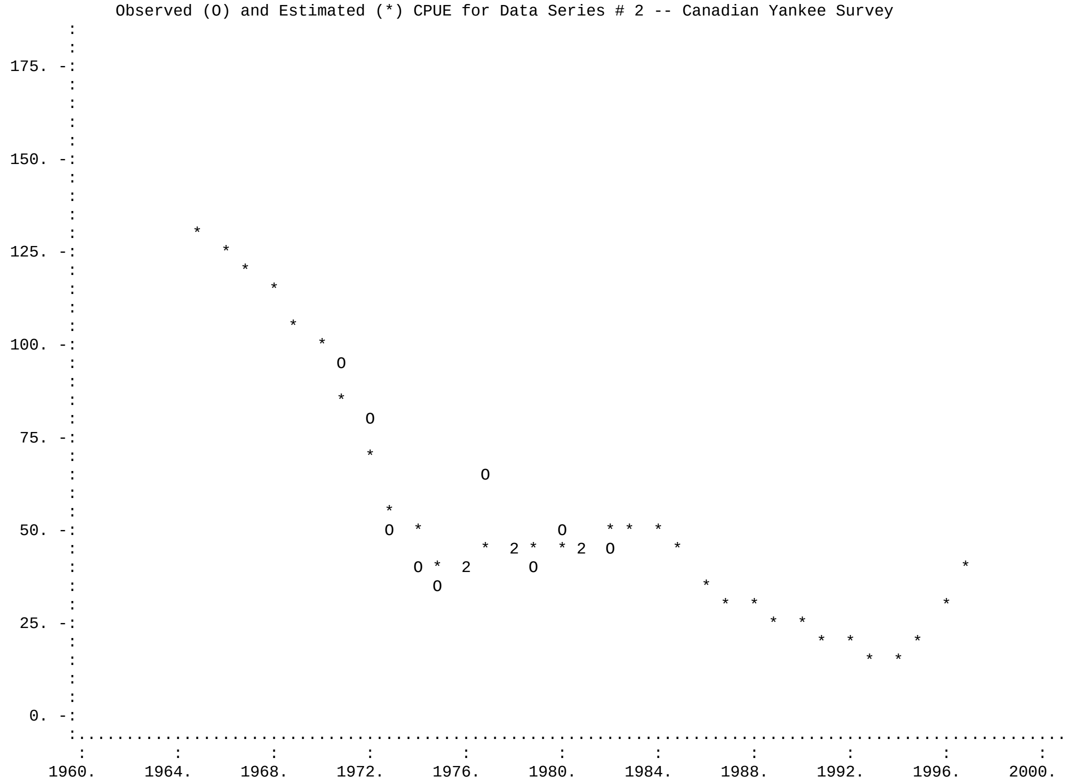
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 6

```
                   -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    -0.3867                              ===============|
1969    -0.1776                                      =======|
1970    -0.0715                                          ===|
1971    -0.0180                                            =|
1972     0.0146                                             |=
1973     0.0643                                             |===
1974    -0.0443                                           ==|
1975    -0.1326                                        =====|
1976    -0.0105                                             |
1977    -0.0273                                            =|
1978     0.0655                                             |===
1979    -0.1876                                     ========|
1980     0.0366                                             |=
1981     0.0620                                             |==
1982     0.2645                                             |===========
1983     0.4861                                             |===================
1984     0.4255                                             |=================
1985     0.2726                                             |===========
1986    -0.0846                                          ===|
1987    -0.5504                       ======================|
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                                             |
                   ------------------------------------------------------------------------------------
```

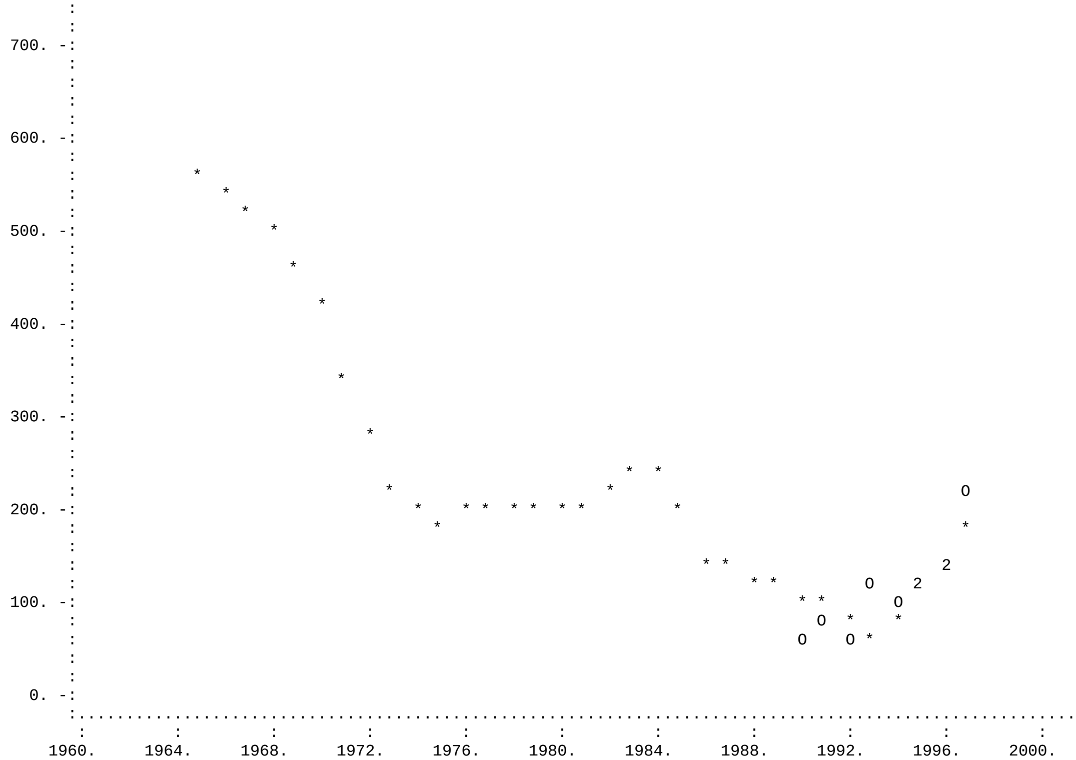
Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Canadian Campelen Survey



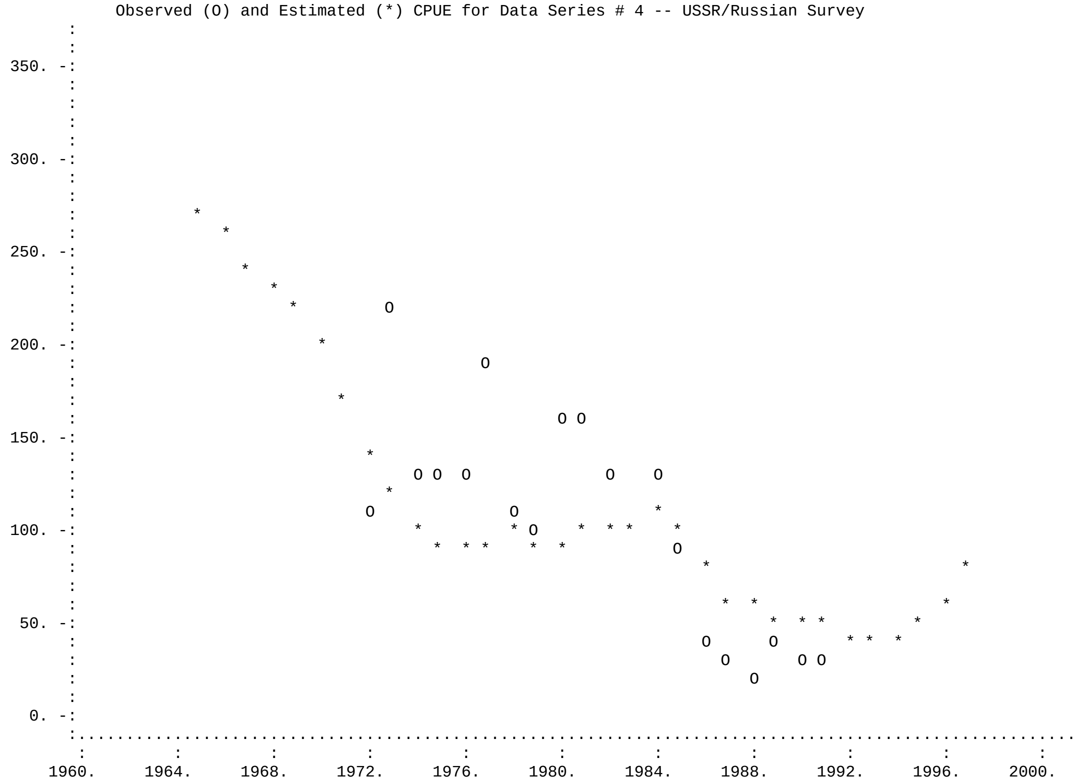
Observed (O) and Estimated (*) CPUE for Data Series # 2 -- Canadian Yankee Survey



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

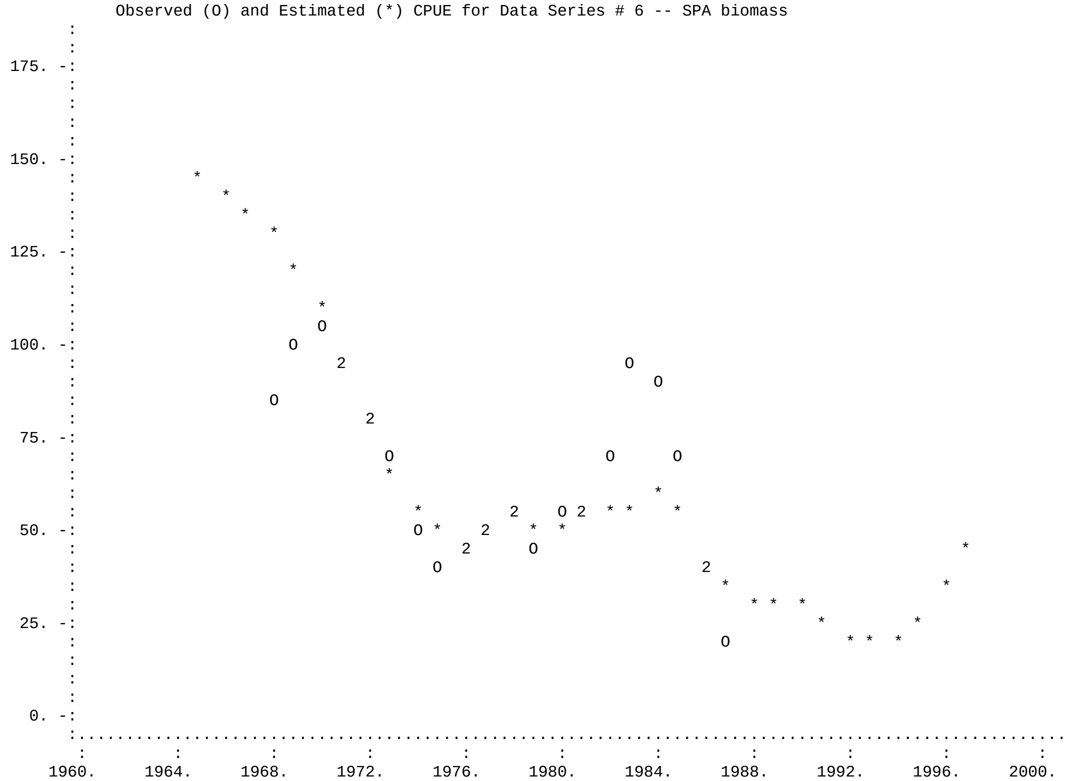


Observed (O) and Estimated (*) CPUE for Data Series # 4 -- USSR/Russian Survey



Observed (O) and Estimated (*) CPUE for Data Series # 5 -- Spanish Survey (lagged)

Observed (O) and Estimated (*) CPUE for Data Series # 6 -- SPA biomass



```
                                  Time Plot of Estimated F-Ratio and B-Ratio
           :
           :
     3.5 -:
           :
           :
           :
           :
     3.0 -:                                                             F
           :                                                                             F
           :
           :                                                                        F
           :
     2.5 -:
           :
           :                                                          F
           :            B                   F                                F
           :               B              F
     2.0 -:                 B                   F                      F       F    F
           :                    B               F
           :                      B
           :                         B
           :                           F
     1.5 -:                           B                   F
           :                                                                   F
           :                              B
           :                                             F      F       F
           :
     1.0 -:- -  - -  - -  - -  - -  2 -  - 2  - -  - 2  - -  2 -  2 -  - -  - -  - -  - -  - -  - -  - -  - -  -
           :                                                            B B
           :                                   B         B B      B  B 2
           :                                     B  2 B        B              B                             B
           :                                                                                              B
     0.5 -:                      F                                              B  B
           :                    F                                                   B  B B      F    B
           :                 F                                                            B B  B B
           :               F
           :            F                                                                               F
     0.0 -:                                                                                        F  F
           :.........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1960.     1964.     1968.     1972.     1976.     1980.     1984.     1988.     1992.     1996.     2000.
```

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	2.270E+00	2.170E+00	-4.42%	2.082E+00	2.593E+00	2.170E+00	2.449E+00	2.794E-01	0.123
K	1.784E+02	1.814E+02	1.68%	1.515E+02	2.219E+02	1.629E+02	1.973E+02	3.432E+01	0.192
r	3.629E-01	3.611E-01	-0.47%	2.685E-01	4.545E-01	3.085E-01	4.134E-01	1.049E-01	0.289
q(1)	2.646E+00	2.654E+00	0.31%	1.899E+00	3.376E+00	2.278E+00	3.024E+00	7.458E-01	0.282
q(2)	6.753E-01	6.708E-01	-0.66%	4.876E-01	9.228E-01	5.685E-01	8.006E-01	2.321E-01	0.344
q(3)	2.993E+00	2.987E+00	-0.21%	2.127E+00	4.036E+00	2.509E+00	3.510E+00	1.000E+00	0.334
q(4)	1.375E+00	1.381E+00	0.42%	1.003E+00	1.773E+00	1.164E+00	1.576E+00	4.113E-01	0.299
q(5)	2.657E+00	2.665E+00	0.29%	1.804E+00	3.795E+00	2.171E+00	3.205E+00	1.034E+00	0.389
q(6)	7.477E-01	7.605E-01	1.71%	5.579E-01	9.692E-01	6.365E-01	8.420E-01	2.055E-01	0.275
MSY	1.605E+01	1.638E+01	2.09%	1.363E+01	1.762E+01	1.501E+01	1.683E+01	1.814E+00	0.113
Ye(1998)	1.496E+01	1.490E+01	-0.41%	1.191E+01	1.739E+01	1.349E+01	1.645E+01	2.960E+00	0.198
Bmsy	8.922E+01	9.072E+01	1.68%	7.573E+01	1.109E+02	8.147E+01	9.863E+01	1.716E+01	0.192
Fmsy	1.814E-01	1.806E-01	-0.47%	1.343E-01	2.273E-01	1.543E-01	2.067E-01	5.243E-02	0.289
fmsy(1)	6.970E-02	6.804E-02	-2.37%	5.871E-02	8.475E-02	6.356E-02	7.737E-02	1.381E-02	0.198
fmsy(2)	2.759E-01	2.692E-01	-2.44%	2.399E-01	3.175E-01	2.569E-01	2.977E-01	4.080E-02	0.148
fmsy(3)	6.127E-02	6.046E-02	-1.34%	4.552E-02	8.174E-02	5.254E-02	7.010E-02	1.756E-02	0.287
fmsy(4)	1.337E-01	1.308E-01	-2.18%	1.171E-01	1.509E-01	1.245E-01	1.416E-01	1.709E-02	0.128
fmsy(5)	6.946E-02	6.776E-02	-2.44%	4.607E-02	1.007E-01	5.554E-02	8.169E-02	2.616E-02	0.377
fmsy(6)	2.445E-01	2.375E-01	-2.88%	2.183E-01	2.773E-01	2.322E-01	2.651E-01	3.296E-02	0.135
F(0.1)	1.633E-01	1.625E-01	-0.42%	1.208E-01	2.045E-01	1.388E-01	1.860E-01	4.719E-02	0.289
Y(0.1)	1.589E+01	1.622E+01	2.07%	1.350E+01	1.745E+01	1.486E+01	1.666E+01	1.796E+00	0.113
B-ratio	7.199E-01	6.992E-01	-2.88%	5.529E-01	9.439E-01	6.281E-01	8.283E-01	2.002E-01	0.278
F-ratio	7.671E-02	7.818E-02	1.91%	5.547E-02	1.046E-01	6.557E-02	8.950E-02	2.393E-02	0.312
Y-ratio	9.224E-01	9.095E-01	-1.40%	8.001E-01	9.943E-01	8.617E-01	9.700E-01	1.083E-01	0.117
f0.1(1)	6.273E-02	6.124E-02	-2.14%	5.284E-02	7.628E-02	5.720E-02	6.963E-02	1.243E-02	0.198
f0.1(2)	2.484E-01	2.423E-01	-2.20%	2.159E-01	2.857E-01	2.312E-01	2.679E-01	3.672E-02	0.148
f0.1(3)	5.515E-02	5.441E-02	-1.20%	4.097E-02	7.356E-02	4.729E-02	6.309E-02	1.580E-02	0.287
f0.1(4)	1.203E-01	1.177E-01	-1.96%	1.054E-01	1.358E-01	1.120E-01	1.274E-01	1.538E-02	0.128
f0.1(5)	6.251E-02	6.099E-02	-2.19%	4.146E-02	9.064E-02	4.998E-02	7.352E-02	2.354E-02	0.377
f0.1(6)	2.200E-01	2.137E-01	-2.59%	1.964E-01	2.496E-01	2.089E-01	2.386E-01	2.967E-02	0.135
q2/q1	2.513E-01	2.528E-01	0.59%	2.042E-01	3.129E-01	2.245E-01	2.820E-01	5.750E-02	0.229
q3/q1	1.132E+00	1.125E+00	-0.54%	8.988E-01	1.418E+00	1.007E+00	1.292E+00	2.848E-01	0.252
q4/q1	5.192E-01	5.203E-01	0.22%	4.261E-01	6.318E-01	4.701E-01	5.735E-01	1.034E-01	0.199
q5/q1	9.942E-01	1.004E+00	0.99%	7.119E-01	1.361E+00	8.470E-01	1.189E+00	3.424E-01	0.344
q6/q1	2.825E-01	2.866E-01	1.43%	2.298E-01	3.421E-01	2.546E-01	3.120E-01	5.735E-02	0.203

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:	24
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	1
Residual-adjustment factor:	1.0641

USER CONTROL INFORMATION (FROM INPUT FILE)

Name of biomass (BIO) file	3LNOyt6.bio
Name of output file (this file)	3LNOyt.prj
Number of years of projections	14

Year	Input data	User data type
1998	4.000E+00	TAC
1999	6.900E+00	F:F(1997)
2000	8.290E+00	F:F(1997)
2001	9.350E+00	F:F(1997)
2002	9.550E+00	F:F(1997)
2003	9.550E+00	F:F(1997)
2004	9.550E+00	F:F(1997)
2005	9.550E+00	F:F(1997)
2006	9.550E+00	F:F(1997)
2007	9.550E+00	F:F(1997)
2008	9.550E+00	F:F(1997)
2009	9.550E+00	F:F(1997)
2010	9.550E+00	F:F(1997)
2011	9.550E+00	F:F(1997)

TRAJECTORY OF ABSOLUTE BIOMASS (BOOTSTRAPPED)

Year	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
1965	2.132E+02	1.968E+02	-7.67%	1.665E+02	2.818E+02	1.872E+02	2.445E+02	5.732E+01	0.269
1966	2.023E+02	1.893E+02	-6.42%	1.610E+02	2.760E+02	1.795E+02	2.308E+02	5.124E+01	0.253
1967	1.918E+02	1.810E+02	-5.62%	1.564E+02	2.610E+02	1.725E+02	2.178E+02	4.536E+01	0.237
1968	1.818E+02	1.737E+02	-4.46%	1.505E+02	2.397E+02	1.643E+02	2.066E+02	4.234E+01	0.233
1969	1.697E+02	1.645E+02	-3.06%	1.427E+02	2.224E+02	1.555E+02	1.939E+02	3.834E+01	0.226
1970	1.589E+02	1.557E+02	-2.04%	1.333E+02	1.980E+02	1.438E+02	1.774E+02	3.356E+01	0.211
1971	1.413E+02	1.393E+02	-1.40%	1.186E+02	1.757E+02	1.277E+02	1.576E+02	2.987E+01	0.211
1972	1.174E+02	1.157E+02	-1.46%	9.667E+01	1.482E+02	1.047E+02	1.314E+02	2.671E+01	0.228
1973	9.344E+01	9.241E+01	-1.10%	7.440E+01	1.227E+02	8.222E+01	1.074E+02	2.522E+01	0.270
1974	7.667E+01	7.583E+01	-1.10%	5.892E+01	1.047E+02	6.601E+01	8.992E+01	2.391E+01	0.312
1975	6.783E+01	6.713E+01	-1.03%	5.073E+01	9.503E+01	5.767E+01	8.095E+01	2.328E+01	0.343
1976	5.974E+01	5.907E+01	-1.12%	4.261E+01	8.638E+01	4.964E+01	7.263E+01	2.299E+01	0.385
1977	6.653E+01	6.580E+01	-1.10%	4.924E+01	9.250E+01	5.638E+01	7.909E+01	2.271E+01	0.341
1978	7.009E+01	6.948E+01	-0.87%	5.322E+01	9.509E+01	6.032E+01	8.238E+01	2.206E+01	0.315
1979	6.994E+01	6.950E+01	-0.63%	5.374E+01	9.389E+01	6.031E+01	8.189E+01	2.159E+01	0.309
1980	6.683E+01	6.648E+01	-0.53%	5.150E+01	9.057E+01	5.853E+01	7.876E+01	2.024E+01	0.303
1981	6.975E+01	6.945E+01	-0.43%	5.493E+01	9.212E+01	6.175E+01	8.101E+01	1.927E+01	0.276
1982	7.055E+01	7.029E+01	-0.38%	5.637E+01	9.176E+01	6.274E+01	8.124E+01	1.849E+01	0.262
1983	7.299E+01	7.261E+01	-0.51%	5.954E+01	9.278E+01	6.522E+01	8.274E+01	1.751E+01	0.240
1984	7.836E+01	7.805E+01	-0.41%	6.614E+01	9.675E+01	7.124E+01	8.740E+01	1.616E+01	0.206
1985	7.751E+01	7.735E+01	-0.20%	6.678E+01	9.441E+01	7.141E+01	8.578E+01	1.437E+01	0.185
1986	6.394E+01	6.391E+01	-0.05%	5.457E+01	7.955E+01	5.872E+01	7.133E+01	1.261E+01	0.197
1987	4.762E+01	4.756E+01	-0.13%	3.918E+01	6.206E+01	4.297E+01	5.458E+01	1.161E+01	0.244
1988	4.368E+01	4.355E+01	-0.29%	3.583E+01	5.728E+01	3.947E+01	5.014E+01	1.066E+01	0.244
1989	3.901E+01	3.888E+01	-0.34%	3.171E+01	5.219E+01	3.515E+01	4.534E+01	1.019E+01	0.261
1990	4.001E+01	3.980E+01	-0.53%	3.300E+01	5.276E+01	3.632E+01	4.588E+01	9.556E+00	0.239
1991	3.685E+01	3.670E+01	-0.42%	3.050E+01	4.883E+01	3.335E+01	4.227E+01	8.923E+00	0.242
1992	3.045E+01	3.033E+01	-0.40%	2.440E+01	4.268E+01	2.726E+01	3.577E+01	8.512E+00	0.280
1993	2.846E+01	2.845E+01	0.00%	2.219E+01	3.981E+01	2.476E+01	3.341E+01	8.658E+00	0.304
1994	2.261E+01	2.280E+01	0.82%	1.574E+01	3.459E+01	1.858E+01	2.782E+01	9.239E+00	0.409
1995	2.874E+01	2.868E+01	-0.20%	2.070E+01	4.294E+01	2.400E+01	3.485E+01	1.085E+01	0.377
1996	3.881E+01	3.843E+01	-0.97%	2.936E+01	5.607E+01	3.361E+01	4.612E+01	1.250E+01	0.322
1997	5.031E+01	5.018E+01	-0.26%	3.933E+01	6.620E+01	4.438E+01	5.772E+01	1.335E+01	0.265
1998	6.378E+01	6.343E+01	-0.55%	5.224E+01	8.210E+01	5.753E+01	7.247E+01	1.494E+01	0.234
1999	7.512E+01	7.486E+01	-0.35%	6.179E+01	9.235E+01	6.781E+01	8.454E+01	1.673E+01	0.223
2000	8.331E+01	8.325E+01	-0.06%	6.831E+01	1.004E+02	7.526E+01	9.255E+01	1.729E+01	0.208
2001	8.952E+01	8.948E+01	-0.05%	7.331E+01	1.067E+02	8.097E+01	9.902E+01	1.805E+01	0.202
2002	9.379E+01	9.376E+01	-0.03%	7.660E+01	1.110E+02	8.467E+01	1.030E+02	1.837E+01	0.196
2003	9.749E+01	9.721E+01	-0.28%	7.946E+01	1.149E+02	8.852E+01	1.065E+02	1.803E+01	0.185
2004	1.005E+02	1.002E+02	-0.32%	8.213E+01	1.194E+02	9.189E+01	1.096E+02	1.767E+01	0.176
2005	1.031E+02	1.026E+02	-0.45%	8.431E+01	1.224E+02	9.428E+01	1.123E+02	1.798E+01	0.174
2006	1.055E+02	1.047E+02	-0.72%	8.652E+01	1.262E+02	9.689E+01	1.151E+02	1.821E+01	0.173
2007	1.072E+02	1.064E+02	-0.75%	8.937E+01	1.285E+02	9.931E+01	1.169E+02	1.759E+01	0.164
2008	1.086E+02	1.078E+02	-0.73%	9.062E+01	1.297E+02	1.007E+02	1.185E+02	1.778E+01	0.164
2009	1.098E+02	1.089E+02	-0.81%	9.190E+01	1.314E+02	1.017E+02	1.194E+02	1.768E+01	0.161
2010	1.109E+02	1.099E+02	-0.89%	9.242E+01	1.322E+02	1.021E+02	1.200E+02	1.795E+01	0.162
2011	1.119E+02	1.106E+02	-1.09%	9.381E+01	1.332E+02	1.030E+02	1.213E+02	1.825E+01	0.163
2012	1.125E+02	1.112E+02	-1.08%	9.507E+01	1.345E+02	1.043E+02	1.223E+02	1.804E+01	0.160

NOTE: Printed BC confidence intervals are always approximate.
At least 500 trials are recommended when estimating confidence intervals.

TRAJECTORY OF ABSOLUTE FISHING MORTALITY RATE (BOOTSTRAPPED)

Year	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
1965	1.494E-02	1.623E-02	8.62%	1.121E-02	1.924E-02	1.318E-02	1.710E-02	3.920E-03	0.262
1966	3.537E-02	3.800E-02	7.42%	2.586E-02	4.437E-02	3.148E-02	4.006E-02	8.576E-03	0.242
1967	4.719E-02	5.013E-02	6.23%	3.526E-02	5.783E-02	4.212E-02	5.289E-02	1.078E-02	0.228
1968	7.552E-02	7.902E-02	4.64%	5.738E-02	9.138E-02	6.674E-02	8.335E-02	1.661E-02	0.220
1969	9.564E-02	9.827E-02	2.75%	7.464E-02	1.139E-01	8.502E-02	1.053E-01	2.026E-02	0.212
1970	1.765E-01	1.798E-01	1.87%	1.417E-01	2.101E-01	1.578E-01	1.949E-01	3.713E-02	0.210
1971	2.904E-01	2.949E-01	1.55%	2.308E-01	3.506E-01	2.604E-01	3.247E-01	6.438E-02	0.222
1972	3.756E-01	3.804E-01	1.27%	2.919E-01	4.639E-01	3.312E-01	4.256E-01	9.441E-02	0.251
1973	3.880E-01	3.924E-01	1.14%	2.895E-01	4.963E-01	3.347E-01	4.451E-01	1.104E-01	0.285
1974	3.375E-01	3.410E-01	1.05%	2.438E-01	4.451E-01	2.848E-01	3.958E-01	1.110E-01	0.329
1975	3.599E-01	3.638E-01	1.07%	2.528E-01	4.927E-01	2.987E-01	4.302E-01	1.315E-01	0.365
1976	1.276E-01	1.290E-01	1.14%	9.006E-02	1.755E-01	1.062E-01	1.528E-01	4.660E-02	0.365
1977	1.702E-01	1.720E-01	1.02%	1.241E-01	2.271E-01	1.441E-01	2.004E-01	5.631E-02	0.331
1978	2.209E-01	2.226E-01	0.76%	1.634E-01	2.891E-01	1.882E-01	2.569E-01	6.866E-02	0.311
1979	2.689E-01	2.704E-01	0.54%	2.003E-01	3.504E-01	2.296E-01	3.117E-01	8.216E-02	0.306
1980	1.811E-01	1.820E-01	0.54%	1.350E-01	2.328E-01	1.552E-01	2.071E-01	5.198E-02	0.287
1981	2.093E-01	2.101E-01	0.38%	1.597E-01	2.641E-01	1.810E-01	2.373E-01	5.628E-02	0.269
1982	1.855E-01	1.864E-01	0.45%	1.438E-01	2.295E-01	1.621E-01	2.080E-01	4.585E-02	0.247
1983	1.383E-01	1.390E-01	0.45%	1.105E-01	1.664E-01	1.230E-01	1.534E-01	3.040E-02	0.220
1984	2.147E-01	2.154E-01	0.33%	1.751E-01	2.517E-01	1.932E-01	2.349E-01	4.177E-02	0.195
1985	4.117E-01	4.122E-01	0.12%	3.342E-01	4.801E-01	3.705E-01	4.489E-01	7.846E-02	0.191
1986	5.464E-01	5.469E-01	0.08%	4.288E-01	6.517E-01	4.835E-01	5.997E-01	1.162E-01	0.213
1987	3.583E-01	3.586E-01	0.09%	2.737E-01	4.358E-01	3.119E-01	3.959E-01	8.399E-02	0.234
1988	3.926E-01	3.928E-01	0.06%	2.960E-01	4.794E-01	3.395E-01	4.332E-01	9.372E-02	0.239
1989	2.582E-01	2.595E-01	0.49%	1.909E-01	3.140E-01	2.228E-01	2.853E-01	6.245E-02	0.242
1990	3.642E-01	3.661E-01	0.50%	2.739E-01	4.396E-01	3.172E-01	4.018E-01	8.453E-02	0.232
1991	4.812E-01	4.855E-01	0.89%	3.495E-01	5.927E-01	4.162E-01	5.350E-01	1.188E-01	0.247
1992	3.657E-01	3.664E-01	0.19%	2.590E-01	4.622E-01	3.106E-01	4.142E-01	1.037E-01	0.283
1993	5.355E-01	5.320E-01	-0.66%	3.676E-01	7.225E-01	4.460E-01	6.358E-01	1.898E-01	0.354
1994	8.100E-02	8.066E-02	-0.43%	5.473E-02	1.167E-01	6.765E-02	9.915E-02	3.150E-02	0.389
1995	1.991E-03	2.008E-03	0.86%	1.372E-03	2.697E-03	1.657E-03	2.347E-03	6.895E-04	0.346
1996	6.430E-03	6.503E-03	1.15%	4.733E-03	8.420E-03	5.592E-03	7.416E-03	1.824E-03	0.284
1997	1.406E-02	1.412E-02	0.39%	1.092E-02	1.766E-02	1.238E-02	1.584E-02	3.460E-03	0.246
1998	5.760E-02	5.787E-02	0.47%	4.596E-02	6.995E-02	5.133E-02	6.394E-02	1.261E-02	0.219
1999	9.703E-02	9.741E-02	0.39%	7.532E-02	1.219E-01	8.542E-02	1.093E-01	2.387E-02	0.246
2000	1.166E-01	1.170E-01	0.39%	9.049E-02	1.464E-01	1.026E-01	1.313E-01	2.868E-02	0.246
2001	1.315E-01	1.320E-01	0.39%	1.021E-01	1.652E-01	1.158E-01	1.481E-01	3.235E-02	0.246
2002	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2003	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2004	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2005	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2006	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2007	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2008	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2009	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2010	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246
2011	1.343E-01	1.348E-01	0.39%	1.042E-01	1.687E-01	1.182E-01	1.513E-01	3.304E-02	0.246

NOTE: Printed BC confidence intervals are always approximate.
At least 500 trials are recommended when estimating confidence intervals.

TABLE OF PROJECTED YIELDS

1998	4.000E+00	4.000E+00	0.00%	4.000E+00	4.000E+00	4.000E+00	4.000E+00	0.000E+00	0.000
1999	7.730E+00	7.704E+00	-0.34%	7.098E+00	8.285E+00	7.395E+00	8.042E+00	6.477E-01	0.084
2000	1.018E+01	1.011E+01	-0.63%	9.260E+00	1.108E+01	9.691E+00	1.069E+01	1.001E+00	0.098
2001	1.222E+01	1.210E+01	-0.96%	1.093E+01	1.333E+01	1.154E+01	1.286E+01	1.324E+00	0.108
2002	1.302E+01	1.288E+01	-1.09%	1.154E+01	1.422E+01	1.221E+01	1.370E+01	1.485E+00	0.114
2003	1.349E+01	1.331E+01	-1.32%	1.199E+01	1.476E+01	1.267E+01	1.419E+01	1.525E+00	0.113
2004	1.392E+01	1.367E+01	-1.74%	1.228E+01	1.523E+01	1.299E+01	1.457E+01	1.584E+00	0.114
2005	1.425E+01	1.398E+01	-1.88%	1.260E+01	1.555E+01	1.323E+01	1.492E+01	1.684E+00	0.118
2006	1.454E+01	1.423E+01	-2.09%	1.286E+01	1.589E+01	1.357E+01	1.523E+01	1.660E+00	0.114
2007	1.471E+01	1.444E+01	-1.81%	1.313E+01	1.620E+01	1.388E+01	1.554E+01	1.657E+00	0.113
2008	1.485E+01	1.461E+01	-1.61%	1.324E+01	1.631E+01	1.400E+01	1.569E+01	1.687E+00	0.114
2009	1.496E+01	1.475E+01	-1.39%	1.340E+01	1.639E+01	1.413E+01	1.582E+01	1.686E+00	0.113
2010	1.505E+01	1.487E+01	-1.22%	1.345E+01	1.654E+01	1.421E+01	1.594E+01	1.721E+00	0.114
2011	1.512E+01	1.496E+01	-1.05%	1.349E+01	1.661E+01	1.423E+01	1.597E+01	1.738E+00	0.115

NOTE: Printed BC confidence intervals are always approximate.
At least 500 trials are recommended when estimating confidence intervals.

Bias-Corrected Time Plot of B-Ratio (#) with Approximate 80% Confidence Interval (^,)
(Dashed reference line is 1.0)

```
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      3.3 -:
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           :
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      3.0 -:
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      2.7 -:
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      2.4 -:            ,
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      2.1 -:          ^
           :            ^#   ,
           :             ^ #
           :
           :               ^ #,
      1.8 -:                 ^
           :                  #
           :                  ^ ,
           :
           :                    #
      1.5 -:                    ^
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      1.2 -:                      ^,                                            ,         # # ##
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      0.9 -:                              ,  , , ,, , 2,                                    ^ ^^ ^ ^
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           :                         ^ #  # ## # ## ^    ,                 ,         ^ ^
           :                                ^^   ^^      #                   #    ^ ^
           :                           ^# ^    ^         ^                      ^
      0.6 -:                                               ,              ,#   ^
           :                            ^                  #, , ,            ^
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           :                                                  2 2# , ,,   #^
           :                                                     ^ #    # ^
      0.3 -:                                                       ^ 2
           :                                                          # ^
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      0.0 -:
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            :         :         :         :         :         :         :         :         :         :         :
         1959.     1965.     1971.     1977.     1983.     1989.     1995.     2001.     2007.     2013.     2019.
```
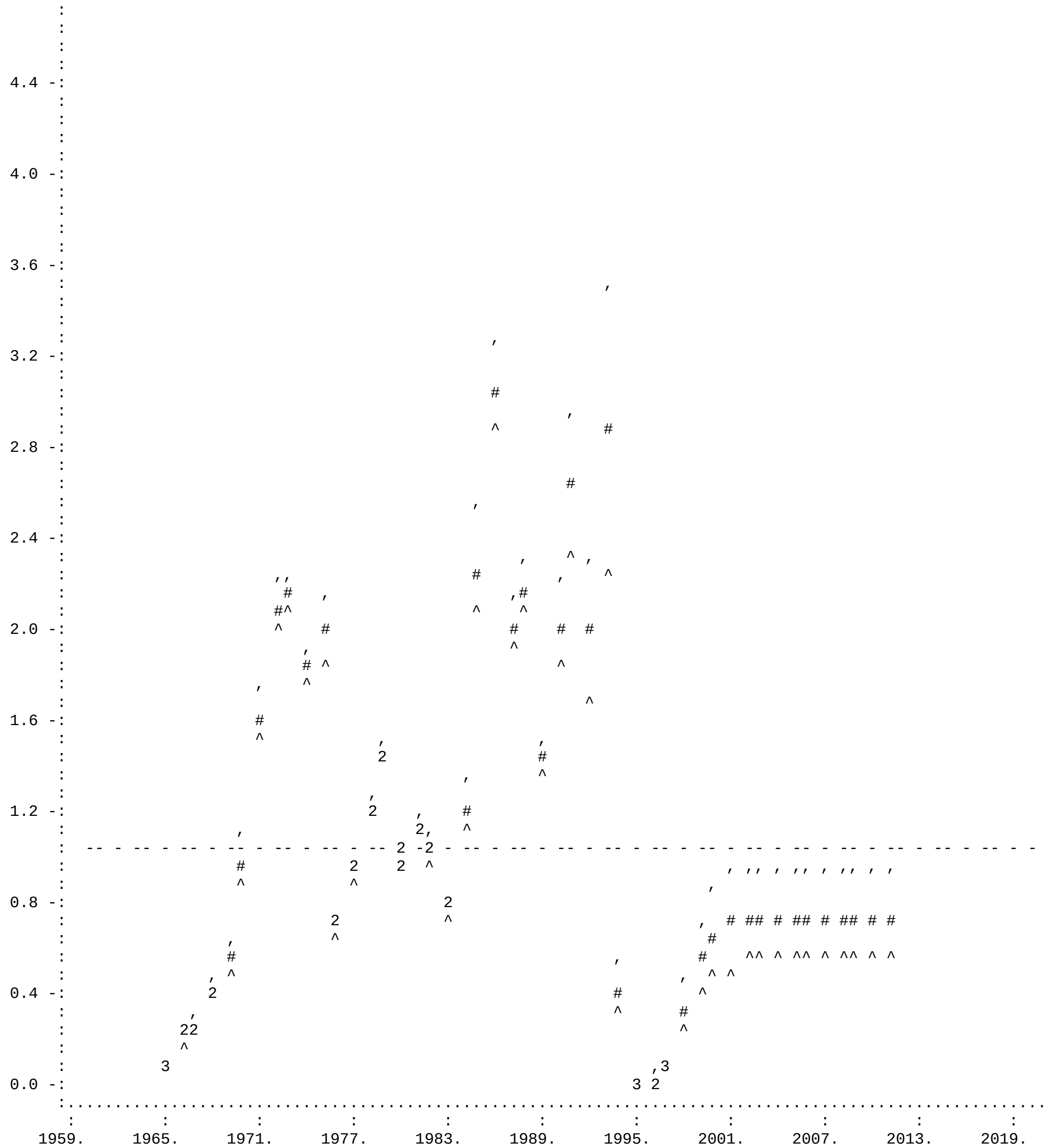

NOTE: Estimates beginning in 1999 depend on the user projection data listed on page 1.

Bias-Corrected Time Plot of F-Ratio (#) with Approximate 80% Confidence Interval (^,)
(Dashed reference line is 1.0)



NOTE: Estimates beginning in 1998 depend on the user projection data listed on page 1.

Appendix B. Sensitivity analysis of 3LNO yellowtail flounder surplus production including Canadian CPUE.

3LNO yellowtail flounder (biomass in kt)

05 Mar 1999 at 15:34

ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.65) FIT Mode

RESULTS FOR DATA SERIES # 7 (NON-BOOTSTRAPPED) Canadian CPUE

```
------------------------------------------------------------------------------------------------------------------------
Data type I1: Year-average biomass index                              Series weight:  1.000
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 7
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.1171                                             |=====
1966    -0.0116                                             |
1967    -0.0940                                         ====|
1968    -0.2905                                 ============|
1969    -0.4287                            =================|
1970    -0.3948                             ================|
1971    -0.3165                                =============|
1972    -0.2397                                   ==========|
1973     0.0982                                             |====
1974    -0.1499                                       ======|
1975    -0.0302                                            =|
1976    -0.1103                                         ====|
1977    -0.0063                                             |
1978    -0.0223                                            =|
1979     0.0366                                             |=
1980     0.1422                                             |======
1981     0.1080                                             |====
1982    -0.0037                                             |
1983     0.0547                                             |==
1984    -0.0126                                            =|
1985     0.1210                                             |=====
1986     0.0469                                             |==
1987     0.2672                                             |===========
1988     0.2858                                             |===========
1989     0.3384                                             |==============
1990     0.4958                                             |====================
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

```
                Observed (O) and Estimated (*) CPUE for Data Series # 7 -- Canadian CPUE
           :
           :
     1.75 -:
           :
           :
           :
           :
     1.50 -:
           :
           :
           :
           :
     1.25 -:                    * *
           :                 *       *
           :            O  2
           :                 O
           :            *              *
     1.00 -:
           :                    O
           :                              *
           :
           :                      O  O O    O
     0.75 -:
           :                              O *                 O O    O  2 O
           :                                                       * *    *
           :                                   *      2  2 2  * *  O                   O
           :                                   O 2  *                          O                        *
     0.50 -:                                        O                        2    O O
           :
           :                                                                   *  *                   *
           :                                                                        *  *
           :                                                                             *  *      *
     0.25 -:                                                                                  *  *
           :
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           :
           :
     0.00 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1960.     1964.     1968.     1972.     1976.     1980.     1984.     1988.     1992.     1996.     2000.
```