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The 2006 Assessment of the Grand Bank Yellowtail Flounder Stock, NAFO Divisions 3LNO

by

Stephen J. Walsh, W. B. Brodie and M. J. Morgan

Northwest Atlantic Fisheries Center, Science Branch, Department of Fisheries and Oceans, Canada.
P. O. Box 5667, St. John's, Newfoundland Canada, AlC 5Xl.
Email: walshs@dfo-mpo.gc.ca

Abstract

All available information on the biology, assessment, fishery and management of Grand Bank yellowtail flounder stock, Division 3LNO, was drawn together to assess the status of the stock in 2004. Recent surveys by Canada and Spain indicate that stock size increased since a moratorium on directed fishing was declared in 1994. A surplus production model (ASPIC), incorporating current and historical survey and catch indices, was used to assess relative biomass and fishing mortality rates. If accepted, these results will be used to provide short and medium term yield projections under a range of fishing mortalities. Results will also be presented in a precautionary approach framework.

Fishery and management

A. TAC Regulation

The stock has been under TAC regulation since 1973, when an initial level of 50 000 t was established. In 1976, the TAC was lowered to 9 000 t, following a series of high catches (Fig. 1; Table 1) and a reduction in stock size. From 1977 to 1988, the TAC varied between 12 000 t and 23 000 t and was unchanged at 15 000 t for the last 4 years of that period. The TAC was set at 5 000 t in 1989 and 1990, following sharp declines in stock size after the large catches in 1985 and 1986, then increased to 7 000 tons in 1991-94. However, NAFO Fisheries Commission decided that no directed fisheries would be permitted for this stock and some other groundfish fisheries (cod, American plaice and witch flounder) on the Grand Bank during 1994. From 1995 to 1997, the TAC was set at zero and a fishery moratorium was imposed. Following an increase in survey biomass, Scientific Council in 1997 recommended a re-opening of the yellowtail flounder fishery with a precautionary TAC of 4 000 t for the 1998 fishery. With the cessation of the moratorium, other management measures were imposed, such as delaying the re-opening until August of 1998 to allow the majority of yellowtail flounder spawning in that year to be completed, and restricting the fishery to Div. 3N and 3O. For the 1999 fishery, a TAC was set at 6 000 t and again restricted to Div. 3N and 3O, but there were no restrictions on the time period. A stock production model was used as the basis for Scientific Council's recommended TAC of 10 000 t for the 2000 fishery. Since then, the stock production model has continued to be the basis of TAC advice, which was set at 13 000 t in 2001-2002, increasing to 14 500 tons for 2003 and 2004 and 15, 000 tons for 2005-2006 period. Scientific Council provided 2-year TAC advice in 2004, when the stock was last assessed, and confirmed the 2004 advice in 2005, following an interim monitoring update.

B. Catch Trends

The nominal catch increased from negligible amounts in the early 1960s to a peak of 39 000 t in 1972 (Table 1; Fig. 1). With the exception of 1985 and 1986, when the nominal catch was around 30 000 t, catches were in the range of 10 000 to 18 000 t from 1976 to 1993, the year before the moratorium.

During the moratorium (1994-97), catches decreased from approximately 2 000 tons in 1994 to around 300 - 800 tons per year, as by-catch in other fisheries (Table 1). Since the fishery re-opened in 1998, catches have increased from 4 400 tons to a high of 14 100 tons in 2001. Overall, catches exceeded the TACs during 1985 to 1993 and again from 1998-2001, by about 10% in the latter period (Table 1; Fig. 1). Since 2002 the catches have been below the TAC. Both the 2004 and 2005 nominal catch estimates of 13 354 tons and 13 933 tons, respectively are below their respective TAC of 14 500 tons and 15 000 tons. In 2004, Canada caught 12 575 tons and in 2005 caught 13 137 tons.

In some years, small catches of yellowtail have been reported from the Flemish Cap, NAFO Div. 3M. STACFIS previously noted that these catches were probably errors in reporting or identification, as the reported distribution of yellowtail flounder does not extend to the Flemish Cap.

Table 2 shows a breakdown of the Canadian catches by year, division and gear. With the exception of the 1991-1993 period, when Canadian vessels pursued a mixed fishery for plaice and yellowtail flounder in Div. 3O, the majority of catches have been taken in Div. 3N. The most important gear is otter trawl. Details on the Canadian fishery can be found in Brodie *et al.* (2006). The Canadian otter trawl catch in Div. 3L of 2 760 t[1] in 2004 was the highest in this Division since 1986 but the catches declined by about 1 000 t in Div. 3N and 1 800 t in Div. 3O from 2003 to 2004. Although the Div. 3L and 3O catches were lower in 2005 when compared to 2004, Canada's highest catch of 10 572 t came from Div. 3N and represents the highest level from this division since 1981.

C. **The Canadian Fishery** (SCR Doc. 06/26, 40)

The yellowtail fishery on the Grand Banks was prosecuted by Canada in 2004 and 2005. Data on spatial and temporal trends, length composition, and an analysis of Canadian CPUE data are presented in Brodie *et al.* (2006). Spatial and temporal patterns in the catches of the fleet in 2004 are presented in Walsh and Brodie (2006).

The catch of yellowtail flounder by Canadian vessels in NAFO Div. 3LNO in 2005 was approximately 13 140 tons, the highest by this fleet since 1987, and similar to levels in 2003 and 2004. The catch increased from just under 10 000 tons in 2002, when effort was lower because of problems with by-catch of American plaice. Length compositions of yellowtail were similar in 2004 and 2005, with about 40% of the catch numbers coming from lengths in the range 36-39 cm. Much of the Canadian catch in 2004-2005 came from Div. 3N, mostly in areas just north and west of the Southeast Shoal. Otter trawl continues to be the dominant gear in this fishery. CPUE increased in 2004 and remained high in 2005, although it remains difficult to compare CPUE with periods prior to 1998, due to the changes in the fishery and in the fleet behaviour. Avoidance of by-catch of species under moratorium, such as American plaice and cod, continues to be a major influence on the Canadian fishery for yellowtail flounder.

In the 2004 fishery there was seasonal pattern in depths fished, being shallower in the winter time when compared to other seasons and in the distribution of effort. Analysis of temperature data and CPUE suggests a catchability relationship with yellowtail catches being taken in warmer waters.

D. The 2004-2005 Fisheries by Non-Canadian Vessels (SCS Doc. 05/5, 6, 8; SCS Doc. 06/7, 9)

Sampling of size composition from commercial catches of yellowtail flounder in 2004 and 2005 was available from the Canadian directed fishery for yellowtail, and from the fisheries for Greenland halibut and skate in the NRA of Div. 3NO. The length frequencies of the Canadian and Spanish catches for 2004 and 2005 are plotted together in Figure 2. The minimum codend mesh size in the Canadian fleet is 145 mm while Spain uses a minimum of 130 mm mesh size when fishing for Greenland halibut. In 2004, the mode in the Spanish yellowtail by-catch was 38-39 cm. However, in the Spanish fishery in 2005 the mode of 36-37 cm was similar to that seen in the 2004-2005 Canadian fishery. In 2004 and 2005 skate fisheries of Portugal and Russia, where a minimum codend mesh size of 280 mm is used, the mode in the 2004 Portuguese and Russian catches was 38-39 cm, while the mode (32-33 cm) in the 2005

[1] Erroneously reported as 42 760 tons in Walsh *et al*., 2005

Russian catches showed a shift to smaller fish (Fig 3). This shift in 2005 size composition in the 280 mm mesh codend Russian fishery was not evident in the 145 mm mesh codend Canadian fishery. No explanation was given as to why more smaller yellowtail were being taken in this large mesh fishery in 2005 when compared to 2004.

II. Research Survey Data

A. Canadian Stratified-random Surveys Spring and Fall Surveys (SCR Doc. 06/41)

Abundance and biomass trends

Figure 4 and Tables 3 and 4 compare the population abundance and biomass estimates of yellowtail flounder in the Canadian spring and fall surveys. Detailed descriptions of survey trends in both series are contained in Walsh *et al*. (2006). Survey indices show similar trends in both series, although the fall estimates have generally been higher since 1992, with the exception of 1996 and 1999. The fall survey indicates that the upward trend in stock size started in 1993 while the spring survey showed the trend starting in 1995. The spring survey shows an annual variation in stock size while the fall survey biomass estimates have increased every year from 1994 to 2004, except in 2002. In 2005 the fall survey showed a 9% decrease in biomass while the spring survey showed a 14% increase.

Figure 5 shows the result of a regression of the biomass estimates from the spring and fall time series. A linear relationship is evident with 77% of the variation being explained by the model. Two time regimes are present: 1990-1995, when the stock was at its lowest and estimates were more in agreement, and 1996-2005, when the stock was on the increase and the estimates were more variable. Coincidentally, the switch in survey gears took place in the fall of 1995 and probably what is seen here is a seasonal difference in catchability with increasing stock size, which would account for the widening confidence intervals seen in Fig. 4. Catchability estimates from the stock production model indicate *q's* from the Campelen surveys are around 3, and therefore swept-area stock-size is likely being overestimated in the spring and fall surveys (see Appendix 1).

Size composition and growth

Figures 6 and 7 show the length composition of survey catches from spring and fall surveys by year for Div. 3LNO (combined sexes). Size composition in most recent years generally showed one main peak in the length frequencies in the spring surveys and multi-modal peaks in the fall surveys. More small fish were present in the survey catches beginning in the fall of 1995 onward due to the increased efficiency of the new Campelen survey gear over the old gear. Annual shifts in modes could be evidence of year classes moving through the time series.

In the spring surveys in 1996, 1997, 1999 and 2000 there were bimodal distributions seen in the data which can be tracked from year to year. For example following the first mode, in 1998 its peak is at 27.5 cm; by 1999, the peak has moved to 31.5 cm where it stays for 2000; and by 2001 it has moved to 32.5 cm. Over the next two years, the peak remained strong but doesn't appear to move because growth was probably reduced considerably (see Dwyer *et al*., 2003). At this point, it is probably made up of a number of different age classes. However since 2000 there were no bimodal peaks evident in the data (Fig. 6).

In the fall surveys, multi-modal peaks are more common and unlike the spring surveys, were evident in surveys from 2001-2005 (Fig. 7). After 30-32 cm, growth slows and becomes almost negligible between years. This is consistent with the growth curves constructed using ages from thin-sectioned otoliths (Dwyer *et al*., 2003).

Figure 8 attempts to look further at the modal length differences seen in the spring and fall surveys. Using survey data from Canada and Spain for the period 1995-2005, a cut off of 21 cm was chosen as a proxy for recruitment. At that size yellowtail are not recruited to any of the regulated fisheries. Population numbers at length for yellowtail flounder less than 22 cm (age 0-3 years) are plotted from the spring and fall Canadian surveys and total numbers caught from the spring Spanish surveys (Fig. 10).

With the exception of the spring and fall of 1995, (Canada switched to the Campelen trawl in the fall of 1995) the overall trend in the Canadian and the Spanish spring surveys is similar to the Canadian fall surveys from 1996-2003. In 2004 and 2005 surveys, the Canadian fall index is much higher (Fig. 8A). Walsh *et al.* (2006a) reported several large catches (numbers >1 000 fish) in the Southeast Shoal (nursery) area in the fall of 2004 and 2005 surveys, that were not evident in the spring surveys and these large catches also contained a large number of "juveniles".

Figure 8B shows that there was no linear relationship between 1996-2005 Canadian spring and fall estimates. However, if you remove the 2004 and 2005 estimates then a statistical significant relationship was evident (Fig. 8B and 8C).

Age (SCR 06/21)

Age validation studies undertaken for yellowtail flounder indicate that the thin-sectioned otolith technique is the best method for ageing this species (Dwyer *et al*., 2003). It was concluded that thin sections may possibly underestimate the ages of the oldest fish in the population but this method is the most accurate. Yellowtail flounder have been aged up to 30 years using this method. Given the inaccuracies in the old whole-otolith ageing method, a significant part of the historical otolith archive will have to be re-aged.

Therefore, a first step is to determine how many otoliths actually need to be re-aged in order to produce age-length keys from sub-samples of the complete collection with a minimum loss of information. A preliminary analysis carried out using otolith samples from the 1998 spring and fall surveys indicated that sub-sampling sizes around 60% of the total sample size can produce adequate age-length matrices (Dwyer *et al.*, 2004). However, this result relied on data from a single year, and hence, potential differences between years could not be evaluated. To address this issue, we repeated these analyses for a different survey year. The year 1991 was selected because it provides good contrast with 1998, mainly due to the differences between years in the survey trawls employed (Engels trawl in 1991 and Campelen trawl in 1998), and the trends of the yellowtail flounder stock (decreasing in 1991and increasing in 1998). Despite these differences, the results for 1991 were highly consistent with the findings already obtained for 1998 (see Koen-Alonso *et al*., 2006 for details). The spring and fall age-length matrices differed significantly (2D Kolmogorov-Smirnov test *p*-value = 0.0017) and should not be combined. Sub-sampling sizes of 60% allow building sub-sampled age-length matrices (SSALMs) that are similar enough to the full data age-length matrices (FDALMs) to be considered adequate for building age-length keys from survey otoliths with a minimum loss of information.

Numbers at age are not available at this time, so the cohort strength model (Walsh *et al.*, 2002) was not updated.

C. Spanish Stratified-random Spring Surveys in the Regulatory Area, Div. 3NO (SCR Doc. 06/13)

Beginning in 1995, Spain has conducted stratified-random surveys for groundfish in the NAFO Regulatory Area (NRA) of Div. 3NO. These surveys cover a depth range of approximately 45 to 1 300 m. In 2003, after extensive comparative fishing between the old vessel, C/V *Playa de Menduiňa* and old Pedreira trawl with the new vessel, C/V *Vizconde de Eza*, using a Campelen 1800 shrimp trawl as the new survey trawl, all data have been converted to Campelen units (Paz *et al.*, 2003, 2004). In 2006, an error in the estimation method was corrected and all survey estimates were re-calculated (González-Troncoso *et al*., 2006).

The biomass of yellowtail in the Div. 3NO of the NRA increased sharply up to 1999, and since then has shown a similar annual fluctuation pattern seen in the Canadian spring surveys of Div. 3LNO (Fig. 4 and 9). Most (89%) of the biomass comes from strata 360 and 376 similar to other years. Length frequencies in the 2004 and 2005 Spanish survey showed a mode around 32-34 cm. As in the Canadian spring surveys (Fig. 6), this survey showed a similar progression of the peak in the length frequencies from 1998 to 2005. There was no evidence of recruitment pulse in recent years similar to the Canadian spring survey results.

D. Stock Distribution

Stock: (SCR Doc. 06/23, 29, 41)

In all Canadian surveys, yellowtail flounder were most abundant in strata on the Southeast Shoal and immediately to the west of the shoal in Div. 3N (MacCall's Basin-see Simpson and Walsh, 2003), most of which straddle the Canadian 360 km (200 mile) limit. Yellowtail flounder appeared to be more abundant in the NAFO Regulatory Area of Div. 3N in the 1999-2005 surveys than in previous years, and the northward distribution of the stock has again extended in Div. 3L in recent surveys, similar to that seen in the mid-1980s when overall stock size was also relatively large. From 1996-2001, and in 2003 and 2005, the proportion of biomass north 45° latitude was higher in the spring than in the fall. Tag returns from the fishery since 1998 has also confirmed the northward extension of the stock in recent years (Walsh *et al*.. 2001). The proportion of biomass north of 45° confirms that the range of the stock has been extending northward since 1995, with one obvious exception, the spring survey in 2002 when the proportion of biomass was lower in the northern area and in aligned with surveys in the early 1990s when stock size was low..

The analysis of yellowtail flounder movements on the Grand Bank using traditional Peterson disc tags and electronic archival data storage tags (DSTs) showed yellowtail movements are generally southward from their release site. The DST measurement data for depth and temperature for yellowtail flounder during their period at liberty showed substantial vertical activity. Most of the vertical movements occurred at night and during all months. Night-time movements often lasted for several hours with occasional descents back to the bottom. The data suggests that July, August and September were the most active months These results were similar to that reported in the Walsh and Morgan (2004) analysis on Grand Bank yellowtail behaviour from 29 DSTs and to Cadrin and Westwood (2004) analysis of Georges Bank yellowtail flounder.

The preliminary analysis of the amount of fish found in deepwater showed that small catches of yellowtail were more prevalent in waters deeper than 92 m (mostly in the depth range of 93-183 m) during the spring surveys in particular along the southern slope, than during the fall surveys. However, the vast majority of the stock was still found to be shallower than 93 m in both seasons. This reduction in the frequency of small catches in deep water from spring to fall could imply seasonal movements but there is no annual pattern to the data to support this hypothesis.

Colbourne and Walsh (2006) noted that in 1990-2005 surveys the centroid of the biomass of yellowtail flounder located within Div. 3NO was found over the Southeast Shoal of the Grand Bank. This area corresponds to some of the warmest bottom temperatures found anywhere on the Grand Banks. The authors reported that spring bottom temperatures in this region range from a minimum of 1-2°C during cold years (1990) to 3-4°C during warm years (1998 and 1999). Fall bottom temperatures were, in general, warmer than spring values ranging from 2-3°C in most years to maximum values of between 7-8°C during extreme years (1999). Since 1999, with the exception of 2002, survey catch rates of yellowtail have remained significantly higher that those before 1995. With the exception of 2003 survey, spring bottom temperatures have also been higher than they were in the early 1990s. The cold temperature values observed in the spring of 2003 were anomalous and lasted from April to June and were above average during the remainder of the year (Colbourne *et al*., 2004). However there is no indication that cold temperatures had a limiting factor on the northward distribution of yellowtail flounder in the 2002 spring survey and in the 2004 fall survey.

In summary, there was a steady increase in the abundance of yellowtail flounder coinciding with a northward expansion of the stock from 1995 up to 2005 that also coincided with increasing bottom temperatures. Small amounts of yellowtail were sometimes found in deepwater.

E. Biological Studies

Maturity at size was estimated using Canadian spring research vessel data from 1984-2005. Estimates were produced using a probit model with a logit link function and a binomial error structure (SAS, 1989). L_{50} declined in males, by about 7 cm from around 30 cm in the mid-1980s to 23 cm in 1999 (Fig. 11). Although there have been short term fluctuations there has been a downward trend since 2001-2004, with L_{50} averaging just under 25 cm. Female L_{50} has been fairly stable until the last 3 years which have all been estimated at less than 32 cm almost 1.5 cm below the long term average (Fig. 11). There was significant inter-annual variation in the proportion mature at length for both males and females (generalized linear models: males χ^2 = 404.0, df = 21, p <0.0001, females

χ^2=185.4, df=21, p <0.0001). In general for males, years prior to 1992 were significantly different from 2005. After this there were also years that are significantly different from the final year but there was no pattern. For females, all years were significantly different from 2005.

F. Assessment Results

Estimates of female proportion mature at length, population numbers at length, and annual length weight relationships were used to produce an index of female SSB from the spring survey. Annual length weight relationships were unavailable prior to 1990 so for those years a relationship produced using data from 1990-1993 was used. The specific length weight relationships are given in Table 5. Female SSB declined from 1984 to 1992 (Fig. 12). Since 1995 it has increased substantially. The average index over the 1996-1998 period was 66 000 t, similar to levels in the mid-1980s. There was a large increase in the index in 1999 consistent with the large increase in the overall survey abundance index for that year. Estimates for 1999-2001 were fairly similar and much higher than any previous estimate. There was a large decline in the index in 2002, similar to the overall survey abundance and biomass indices for that year. The SSB index increased again in 2003 and overall has been increasing since 1995. The 2000 to 2005 average biomass was 137 000 t, substantially higher than that of the mid-1980s. In general the female SSB index mirrored the trend seen in the total survey biomass index.

Stock-recruitment relationship

Since there were no available age data for 2002-2003, the recruitment index (cohort strength model, Walsh *et al.*, 2002) was not updated.

Surplus production model (ASPIC)

Surplus Production Model

A non-equilibrium surplus production model incorporating covariates (ASPIC; Prager, 1994, 1995) was applied to nominal catch and survey biomass indices, as was done in the 2002 and 2004 assessment of this stock (Walsh *et al*., 2002; 2004). The Schaefer production model used assumes logistic population growth, in which the change in stock biomass over time (dB_t/dt) is a quadratic function of biomass (B):

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

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):

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

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

$$MSY = K\,r / 4; \quad B_{msy} = K / 2; \quad F_{msy} = r / 2$$

Initial biomass (expressed as a ratio to B_{msy}: $B1R$), r, MSY, and catchability coefficients for each biomass index (q_i) were estimated using non-linear least squares of survey residuals. Once a model formulation is accepted, a bootstrapped run can be made, in which survey residuals are randomly re-sampled 500 times to derive bias-corrected probability distributions for parameter estimates. This bootstrap analyses will be the basis for catch projections. In the model runs presented, and for all subsequent projections, it was assumed that the catch in 2006 would equal the TAC of 15 000 t, although catches in 2002-2005 were estimated to be less than the TACs.

Because of differences in catchability among the various indices, relative (to *MSY* values) indices of biomass and fishing mortality rate were used instead of absolute values. Fishing mortality refers to yield (catch) /biomass ratio.

Input data/model formulation

The production model formulation included: 1) the nominal catch data (1965-2005); 2) Russian spring surveys (1972-1991); 3) Canadian Yankee spring surveys (1971-1982); 4) Canadian Campelen spring surveys (1984-2005); 5) Canadian Campelen fall surveys (1990-2005); and 6) the Spanish spring (1995-2005) survey (now in Campelen equivalents). These indices were the same (updated) indices accepted by STACFIS in the 2001, 2002 and 2004 assessments of this stock.

The input data for surplus production model are listed in Table 6, and the ASPIC input file is shown in Table 7. Estimated landings were used as nominal catch, but do not include discards. The Canadian spring surveys have used a variety of survey gears since this series began in 1971. A 'Yankee' otter trawl was used from 1971 to 1982, an 'Engel' otter trawl was used from 1984 to 1995 (spring), and since the fall of 1995 a 'Campelen' shrimp trawl has been used (McCallum and Walsh, 1997). Comparative tows between 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 (biomass). Therefore the unconverted Yankee survey biomass estimates were used here. Comparative tows between the Engel and Campelen trawls were used to derive a size-based conversion factor for the Engel survey results prior to fall 1995 (Warren *et al*., 1997; Walsh *et al*., 1998). Methods to link the 1971-1982 Yankee series to the 1984-2003 Campelen (or equivalent) series have not been developed, therefore, these two series were considered to be separate indices of biomass in the production model.

Other survey indices were tested in the 2004 assessment (Brodie *et al*., 2004) and included the unconverted 1986-94 Canadian fall juvenile groundfish surveys (Walsh *et al*., 1995); the average catch rate from the DFO/FPI grid surveys from July 1996-2001 which both gave negative correlations with most indices and were excluded from the model. The Canadian trawler CPUE series was not used as an index in the model, due to previous results which showed a strong residual pattern (Walsh and Cadrin, 2000). As well, there are concerns that CPUE in various time periods may not be comparable, due to various restrictions which affected fleet behaviour and influenced CPUE, e.g. by-catch restrictions from 1998 onward. Formulations using these indices were not tested in this assessment.

Walsh and Brodie (2003) looked at sensitivity of the ASPIC model to various indices of abundance for this stock, as well as to number of model assumptions. Some different model formulations in 2004 were explored to test the sensitivity of results to various indices and model assumptions. As in previous years, results with this version and formulation of ASPIC were not sensitive to starting estimates of various parameters (survey *q's*, random number seed, *B1/K*, etc.). As seen in the sensitivity analysis presented by Walsh and Brodie (2003), the model formulation was very sensitive to excluding the Russian series: *MSY* increases to 21 000 t, K increases, and B_{MSY} increases from 80 000 t to 94 000 t. The model estimates B_1R to be 0.56 which would indicate that *B* at the start of the time series is far below B_{MSY}, increasing to about B_{MSY} by 1968-69. Although possible, this seems unlikely, given the trajectory of the only index available at that time (Canadian CPUE; see Brodie *et al*., 2006). That index shows a rapid decline in CPUE during the late 1960s, which would appear to be unlikely if biomass was doubling, as the ASPIC model indicates. Similar results were obtained when both the Russian and Spanish time series were excluded. As noted in Prager (1994), the starting biomass in the first year, even in relative terms, is usually quite imprecise, and he recommends against drawing inferences about the biomass in the first 2-4 years unless auxiliary information is available.

Following review by STACFIS in 2003 and again in 2004, there were no recommendations to change the standard formulation, which has been accepted in the assessments of this stock since 2000. To ensure comparability of results with the versions of ASPIC used in 2001, 2002 and 2004, the same version of the ASPIC software (v 3.81) was used in the current assessment.

Results

Standard model formulation: The input file for the bootstrap ASPIC run is in Table 6. Correlations among biomass indices varied (Appendix 1). Of the five pair-wise correlations among the five biomass indices included in the production analysis, four were high (r >0.7), and one was low (r = 0.2, Russian *vs*. Candian Yankee). This excludes a sixth possible comparison involving only 2 data points (Russian *vs*. Canadian fall).

The model fit the data relatively well (for detailed output, see Appendix 1). The majority of variance in survey indices was explained by the model, but fit varied among indices (r^2 ranged from 0.30 to 0.88). Residuals appeared to be randomly distributed for the Canadian survey indices. The Russian series had a strong pattern of positive residuals during the 1970s and early 1980s and negative residuals for subsequent years. This index showed a more rapid decline in stock size than that detected by the Canadian spring survey index in the mid-1980s. The Spanish survey series, which covers only a portion of the stock area, showed negative residuals in the first 3 years followed by positive residuals, indicating that this series increased faster than the model estimates in the latter period.

ASPIC model estimates of relative biomass (B_t /B_{msy}) and fishing mortality rates (F_t /F_{msy}) are more precisely estimated than absolute values (Prager, 1995). Therefore the estimates of annual biomass (as of Jan 1) and fishing mortality rates were presented in relative terms.

The model results are very similar to the 2002 and 2004 assessments, and suggest that a maximum sustainable yield (*MSY*) of 17 460 tons (80% CL = 165 600, 183 500) can be produced when the total stock biomass (B_{msy}) is 78 930 (80% CL=73 090, 88 280) tons and the fishing mortality rate (F_{msy}) is 0.22 (80% CL = 0.19, 0.25) (Appendix 1) similar to the bias corrected estimates for 2004 assessment (17 350 t, 78 990 t, 0.21, respectively). Estimates of relative biomass and fishing mortality rates are shown in Fig. 13. Biomass showed a continuous decline from the late 1960s to the mid-1970s, stabilized through the mid-1980s, before declining further until about 1994, when the moratorium was imposed. The analysis showed that relative biomass (B_t/B_{msy}) was below the level at which *MSY* can be produced from 1973 to 1998, and at its minimum in 1994 the ratio was about 0.20, which is below the suggested Blim reference point of 30% Bmsy proposed by the SC Study Group on Limit Reference Points (NAFO 2004, SCS Doc. 04/12). Since 1994, the stock increased rapidly to a point where $B_t/B_{msy} > 1.0$, and at the beginning of 2007, assuming a catch of 15 000 t in 2006, the relative bias corrected biomass B_t/B_{msy} is estimated to be 1.32 (80% CL = 1.11, 1.45). The stock is considered to be within the safe zone as defined in the Scientific Council Precautionary Approach Framework (NAFO, 2004).

The relative fishing mortality rate (F_t/F_{msy}) was high during most of the historical fishery (Fig 13), in particular during the mid to late 1980s to the early 1990s when landings were often double the TAC (Fig.1). Since the fishery re-opened in 1998, the fishing mortality rate has been gradually increased to the advised level of $2/3F_{msy}$ which was close to the bias corrected *F*-ratio of 0.65 (80% CL = 0.56, 0.82) estimated in 2006, if the TAC was taken (Appendix 1). Since the moratorium in 1994, the estimated yield from the stock has been below surplus production levels, allowing the stock to grow.

Summary

Yellowtail flounder on the Grand Bank declined in the late 1980s and early 1990s to its lowest observed level in 1994 (about 20% B_{msy}) following several years of excessive catch. The stock was under a directed-fishery moratorium from January 1, 1994 until Aug 1, 1998. The stock increased rapidly during and following the closure, as strong year classes produced in the early to mid-1990s (albeit at low SSB levels), benefited from 4+ years of reduced fishing mortality. Catches have increased from about 4 400 tons in 1998 to around 15 000 tons in recent years, and stock size estimates remain high, above Bmsy, likely with a very low probability of being below B_{LIM} (=30% B_{MSY}). Fishing mortality is estimated to be around the recommended level of $2/3F_{msy}$, and well below the limit reference point ($F_{LIM} = F_{MSY}$).

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Table 1. Nominal catches by country and TACs (tons) of yellowtail in NAFO Divisions 3LNO

Year	Canada	France	USSR/Rus.	S.Korea[a]	Other[b]	Total	TAC
1960	7	-	-	-	-	7	
1961	100	-	-	-	-	100	
1962	67	-	-	-	-	67	
1963	138	-	380	-	-	518	
1964	126	-	21	-	-	147	
1965	3,075	-	55	-	-	3,130	
1966	4,185	-	2,834	-	7	7,026	
1967	2,122	-	6,736	-	20	8,878	
1968	4,180	14	9,146	-	-	13,340	
1969	10,494	1	5,207	-	6	15,708	
1970	22,814	17	3,426	-	169	26,426	
1971	24,206	49	13,087	-	-	37,342	
1972	26,939	358	11,929	-	33	39,259	
1973	28,492	368	3,545	-	410	32,815	50,000
1974	17,053	60	6,952	-	248	24,313	40,000
1975	18,458	15	4,076	-	345	22,894	35,000
1976	7,910	31	57	-	59	8,057	9,000
1977	11,295	245	97	-	1	11,638	12,000
1978	15,091	375	-	-	-	15,466	15,000
1979	18,116	202	-	-	33	18,351	18,000
1980	12,011	366	-	-	-	12,377	18,000
1981	14,122	558	-	-	-	14,680	21,000
1982	11,479	110	-	1,073	657	13,319	23,000
1983	9,085	165	-	1,223	-	10,473	19,000
1984	12,437	89	-	2,373	1,836 [b]	16,735	17,000
1985	13,440	-	-	4,278	11,245 [b]	28,963	15,000
1986	14,168	77	-	2,049	13,882 [b]	30,176	15,000
1987	13,420	51	-	125	2,718	16,314	15,000
1988	10,607	-	-	1,383	4,166 [b]	16,158	15,000
1989	5,009	139	-	3,508	1,551	10,207	5,000
1990	4,966	-	-	5,903	3,117	13,986	5,000
1991	6,589	-	-	4,156	5,458	16,203	7,000
1992	6,814	-	-	3,825	123	10,762	7,000
1993	6,747	-	-	-	6,868	13,615	7,000
1994	-	-	-	-	2,069	2,069	7,000 [d]
1995	2	-	-	-	65	67	0 [d]
1996	-	-	-	-	232	232	0 [d]
1997	1	-	-	-	657	658	0 [d]
1998	3,739	-	-	-	647	4,386	4,000
1999	5,746	-	96	-	1,052 [b]	6,894	6,000
2000 [c]	9,463	-	212	-	1,486	11,161	10,000
2001 [c]	12,238	-	148	-	1,759	14,145	13,000
2002 [c]	9,959	-	103	-	636	10,698	13,000
2003 [c]	12,708	-	184	-	914 [e]	13,806	14,500
2004	12,575		158	-	621	13,354	14,500
2005	13,140	299	8	-	486	13,933	15,000
2006							15,000

[a] South Korean catches ceased after 1992
[b] includes catches estimated from Canadian surveillance reports
[c] provisional
[d] no directed fishery permitted
[e] Includes catches averaged from a range of estimates

Table 2. Canadian catches of yellowtail flounder by division, from 1973 to 2005. Data from 2003-05 are from preliminary Canadian ZIF statistics and maybe slightly different from STATLANT data.

	OTTER TRAWL				
YEAR	**3L**	**3N**	**3O**	**3LNO**	**OTHER GEARS**
1973	4,188	21,470	2,827	28,475	17
1974	1,107	14,757	1,119	16,983	70
1975	2,315	13,289	2,852	18,456	2
1976	448	4,978	2,478	7,904	6
1977	2,546	7,166	1,583	11,295	0
1978	2,537	10,705	1,793	15,035	56
1979	2,575	14,359	1,100	18,034	82
1980	1,892	9,501	578	11,971	40
1981	2,345	11,245	515	14,105	17
1982	2,305	7,554	1,607	11,466	13
1983	2,552	5,737	770	9,059	26
1984	5,264	6,847	318	12,429	8
1985	3,404	9,098	829	13,331	9
1986	2,933	10,196	1,004	14,133	35
1987	1,584	10,248	1,529	13,361	59
1988	1,813	7,146	1,475	10,434	173
1989	844	2,407	1,506	4,757	252
1990	1,263	2,725	668	4,656	310
1991	798	2,943	2,284	6,025	564
1992	95	1,266	4,633	5,994	820
1993	-	2,062	3,903	5,965	782
1994	-	-	-	-	0
1995	-	-	-	-	2
1996	-	-	-	-	0
1997	-	1	-	1	0
1998	-	2,968	742	3,710	29
1999	-	5,636	107	5,743	3
2000	1,409	7,733	278	9,420	43
2001	183	8,709	3,216	12,108	130
2002	22	7,707	2,035	9,764	195
2003	28	8,186	4,482	12,696	1
2004	2,760	7,205	2,609	12,574	3
2005	284	10,572	2,283	13,139	1

Table 3 A comparison of spring and fall abundance and biomassestimates from annual bottom trawl surveys in Div. 3LNO, 1984-2005

BIOMASS (000t)				Abundance (million)	
	SPRING	FALL		Spring	Fall
1984	217.7	.	1984	544.2	
1985	146.8	.	1985	374.1	
1986	138.2	.	1986	326.5	
1987	124.6	.	1987	394.2	
1988	81	.	1988	203.1	
1989	103.8	.	1989	532.9	
1990	103.1	65.8	1990	367.4	192.5
1991	93.4	82.4	1991	320.3	297.1
1992	61.4	64.5	1992	217.4	215.9
1993	93.3	112.8	1993	246.3	371.9
1994	55.6	106.4	1994	148.4	287.9
1995	70.6	129.8	1995	187.4	592.2
1996	175.6	134.3	1996	639.4	579.1
1997	174.9	222.9	1997	695.5	781.5
1998	202.2	231.6	1998	733.6	828.2
1999	365.7	249.9	1999	1289.9	937.1
2000	287.5	335	2000	922.5	1152.3
2001	366	475.8	2001	1328.5	1651.9
2002	199.5	339.7	2002	690.9	1174.8
2003	386.5	368.3	2003	1250.1	1262.6
2004	307.9	374.7	2004	966.7	1,431.0
2005	388.8	342.7	2005	1,164.8	1,376.3

BIOMASS ESTIMATION FOR SPRING AND FALL SURVEYS

	3L	3N	30	3L	3N	30
1984	21.9	167.7	28.2			
1985	21.1	88.2	37.5			
1986	12.6	95.1	30.5			
1987	5.8	77.5	41.2			
1988	3.7	51.4	25.8			
1989	4.0	78.3	21.5			
1990	2.2	75.7	25.1	2.1	46.5	17.3
1991	1.1	69.1	23.3	1.0	50.9	30.5
1992	0.2	49.6	11.6	0.9	44.1	19.4
1993	0.1	50.8	42.4	1.1	94.2	17.5
1994	0.0	46.3	9.2	0.0	95.5	10.9
1995	0.0	57.9	12.7	1.2	102.8	25.7
1996	1.1	103.9	70.6	2.2	113.2	18.9
1997	0.5	121.3	53.2	1.3	164.2	57.5
1998	0.5	143.7	58.0	5.2	173.6	52.8
1999	28.5	238.5	98.7	9.6	191.9	48.4
2000	17.5	197.3	72.1	12.5	252.8	69.7
2001	4.4	297.9	63.6	25.5	368.9	81.4
2002	0.6	147.3	51.6	13.6	272.7	53.5
2003	34.3	280.2	72.0	18.6	252.0	97.7
2004	15.3	216.7	75.8	22.2	291.6	60.9
2005	43.6	263.7	81.5	14.1	261.5	67.1

Table 4 A comparison of spring and fall mean weight per tow, with approximate 95% confidence limits, for Div 3LNO combined.

SPRING				FALL			
YEAR	MEAN	UPPER	LOWER	YEAR	MEAN	UPPER	LOWER
1984	31.97	40.56	23.39	1984			
1985	14.56	17.38	11.73	1985			
1986	14.08	18.30	9.85	1986			
1987	12.72	16.29	9.15	1987			
1988	8.25	10.49	6.01	1988			
1989	10.57	14.41	6.73	1989			
1990	10.57	14.09	7.05	1990	6.59	9.99	3.19
1991	9.49	12.37	6.60	1991	8.14	11.60	4.67
1992	6.05	9.02	3.08	1992	6.70	10.79	2.62
1993	9.08	14.00	4.17	1993	11.33	16.88	5.78
1994	5.29	8.78	1.81	1994	10.37	16.66	4.08
1995	6.86	9.81	3.92	1995	12.61	15.97	9.25
1996	17.06	20.48	13.64	1996	11.97	15.89	8.04
1997	17.03	22.52	11.55	1997	19.71	24.09	15.32
1998	25.70	32.39	19.01	1998	19.89	24.48	15.29
1999	35.27	42.49	28.05	1999	23.43	28.28	18.58
2000	27.89	33.25	22.52	2000	28.72	39.74	17.70
2001	34.87	49.22	20.52	2001	40.26	49.80	30.73
2002	19.20	24.27	14.12	2002	28.70	36.69	20.72
2003	37.16	42.80	31.52	2003	34.17	41.94	26.40
2004	29.29	35.43	25.15	2004	38.77	46.79	30.75
2005	37.77	45.07	30.48	2005	30.51	36.80	24.21

Table 5. Length weight relationships used to produce an index of female SSB from the spring survey. The relationships are of the form log(weight)=(*a**log(length))+*b*).

Year	*a*	*b*
prior to 1990	3.10	-5.19
1990	3.19	-5.33
1991	3.05	-5.12
1992	3.02	-5.06
1993	3.11	-5.20
1994	3.09	-5.19
1995	3.10	-5.20
1996	3.09	-5.15
1997	3.09	-5.17
1998	3.05	-5.11
1999	3.15	-5.27
2000	3.17	-5.32
2001	3.09	-5.20
2002	3.08	-5.20
2003	3.09	-5.22
2004	3.12	-5.24
2005	3.17	-5.32

Table 6. Input indices used in the ASPIC production model

Year	Nominal catch (000 t)	Yankee survey (000 t)	Russian survey (000 t)	Campelen spring (000 t)	Campelen fall (000 t)	Spain survey (000 t)
1965	3.13					
1966	7.026					
1967	8.878					
1968	13.34					
1969	15.708					
1970	26.426					
1971	37.342	96.9				
1972	39.259	79.2	106.0			
1973	32.815	51.7	217.0			
1974	24.313	40.3	129.0			
1975	22.894	37.4	126.0			
1976	8.057	41.7	131.0			
1977	11.638	65.0	188.0			
1978	15.466	44.3	110.0			
1979	18.351	38.5	98.0			
1980	12.377	51.4	164.0			
1981	14.68	45.0	158.0			
1982	13.319	43.1	125.0			
1983	10.473					
1984	16.735		132.0	217.7		
1985	28.963		85.0	146.8		
1986	30.176		42.0	138.2		
1987	16.314		30.0	124.6		
1988	16.158		23.0	81.0		
1989	10.207		44.0	103.8		
1990	13.986		27.0	103.1	66.4	
1991	16.203		27.5	93.4	82.8	
1992	10.762			61.4	64.2	
1993	13.565			63.3	114.8	
1994	2.069			55.6	106.8	
1995	0.067			70.6	126.8	9.3
1996	0.287			175.6	136.0	43.3
1997	0.8			174.9	215.0	38.7
1998	4.348			202.2	231.6	122.6
1999	6.561			365.7	246.9	197
2000	11.121			287.5	335.0	144.7
2001	14.147			366.0	475.8	182.7
2002	10.698			199.5	339.7	148.5
2003	13.806			386.5	368.3	136.8
2004	13.354			307.9	374.7	170.0
2005	13.933			388.8	342.7	156.5

Table 7. Input file for bootstrapped ASPIC run shown in Appendix 1

```
'BOT'                          ## Mode (FIT, IRF, BOT)
'3LNO ytail (v3.81, 2002 formulation with 2005 data) 2006=TAC'## Title
  'EFF'                        ## Error type ('EFF' = condition on yield)
  1                            ## Verbosity (0 to 4)
  500                          ## Number of bootstrap trials, <= 1000
  2 50000                      ## Monte Carlo search enable (0,1,2),N trials
  1d-6                         ## Convergence crit. for simplex set to same
                                  as 2002 and 2004
  3d-6                         ## Convergence crit. for restarts
  1d-2                         ## Convergence crit. for estimating effort
  5.0                          ## Maximum F when estimating effort
  1                            ## Statistical weight for B1 > K as residual
  5                            ## Number of data series (fisheries)
  1 1 1 1 1                    ## Statistical weights for fisheries
  2                            ## B1-ratio (starting guess)
  13                           ## MSY (starting guess)
  0.5                          ## r (starting guess)
  3 1 3 1 3                    ## q (starting guess)
  1 1 1 1 1 1 1 1              ## Flags to estimate parameters
  1 50                         ## Min and max allowable MSY
  0.1 5                        ## Min and max allowable r
  9114895                      ## Random number seed change by plus 1
 42                             ## Number of years of data
```

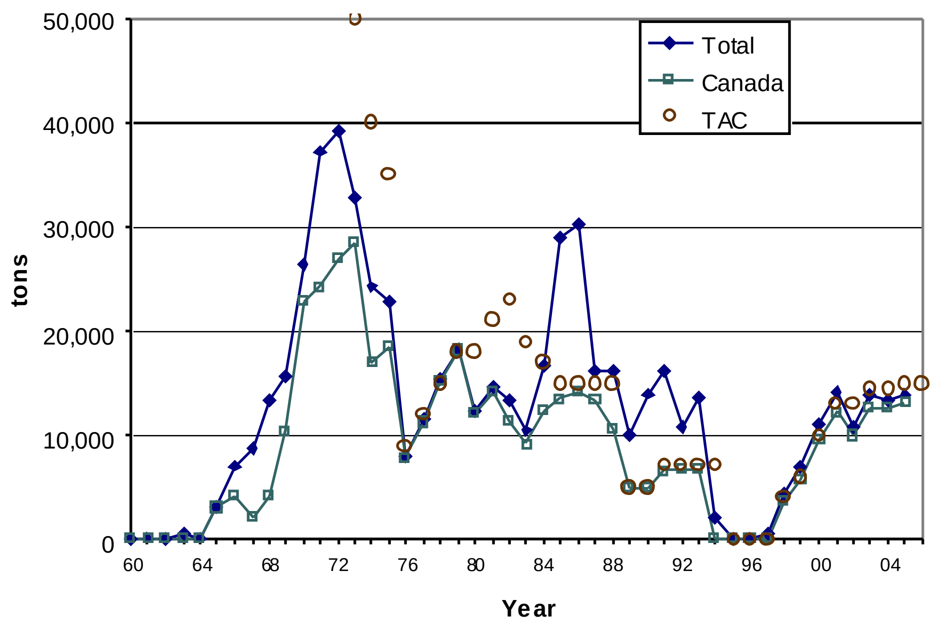

Fig. 1. Catches (Canadian and total) and TACs, Div. 3LNO yellowtail flounder.

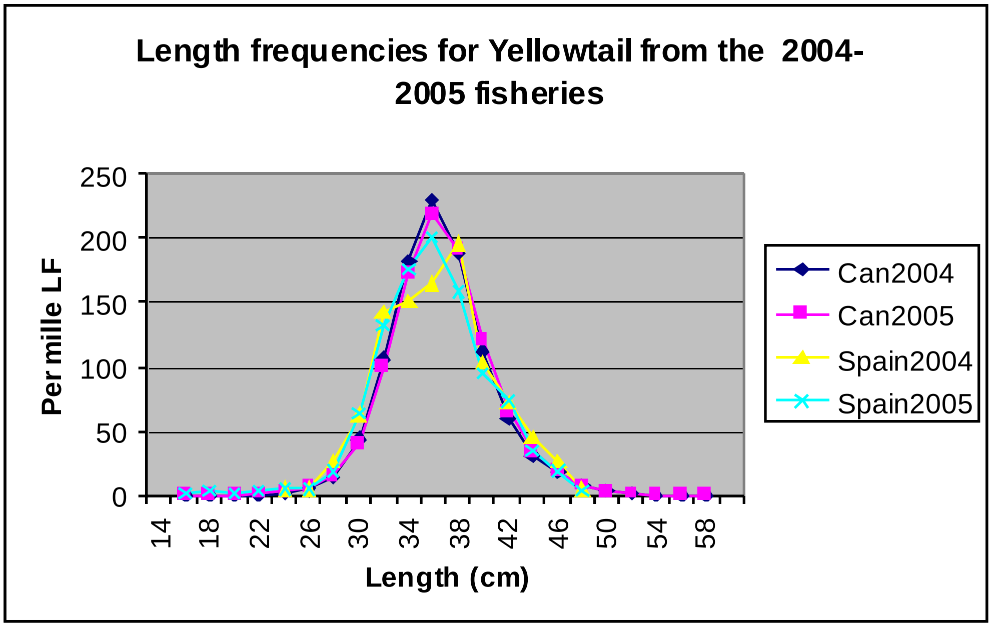

Fig. 2. Comparison of length frequencies of yellowtail flounder from the Canadian (145 mm mesh codends) and Spanish fisheries (130 mm mesh codends) in 2003 and 2004. Note that Spanish 2004 data is only from one sample .

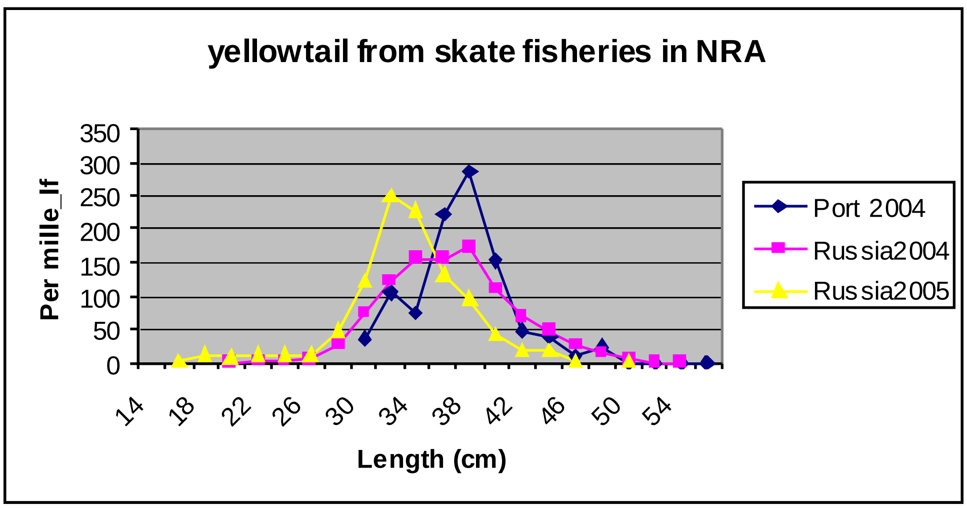

Fig. 3. Length frequency of yellowtail flounder from the 2004 Portuguese and 2004-2005 skate fisheries in the NRA with minimum mesh size of 280 mm.

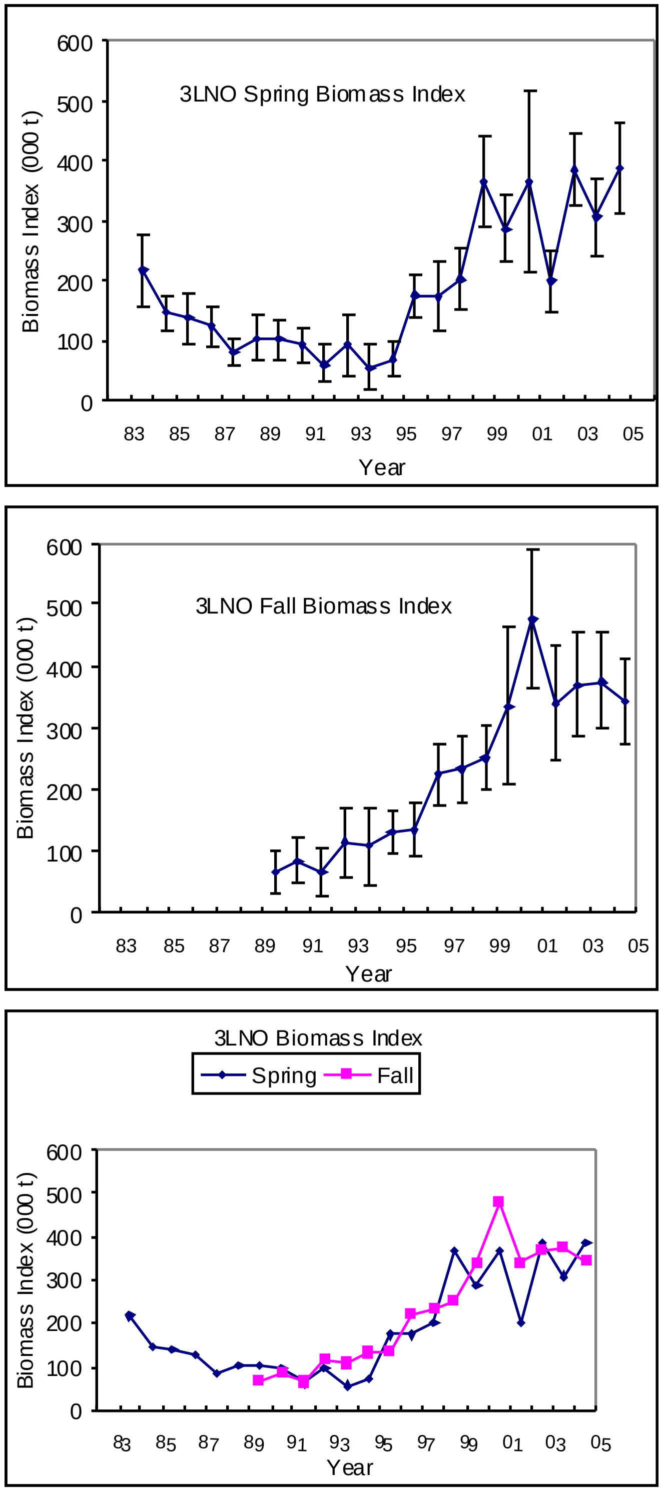

Fig. 4. Canadian spring and fall estimates of biomass of yellowtail flounder in Div. 3LNO with approximate 95% confidence intervals.

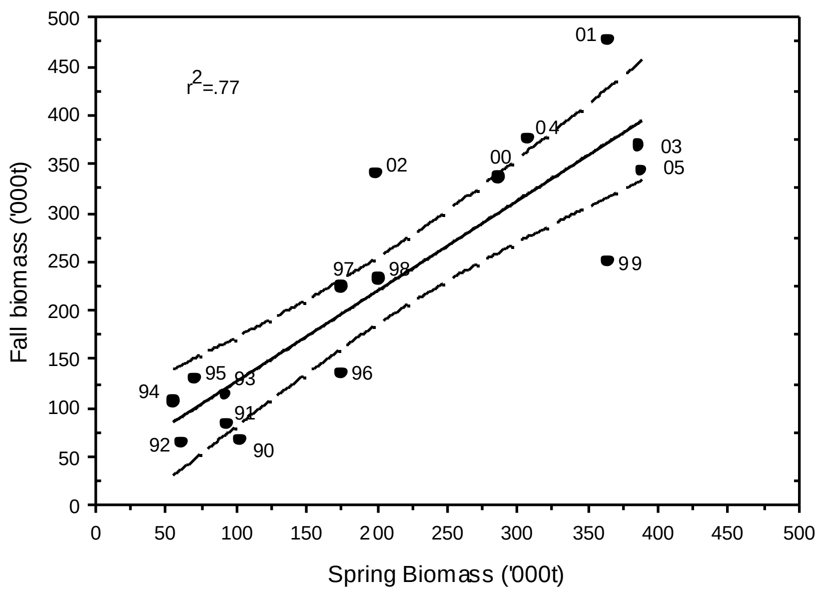

Fig. 5. Regression of Canadian spring and fall estimates of yellowtail flounder biomass in Div. 3LNO, 1990-2005.

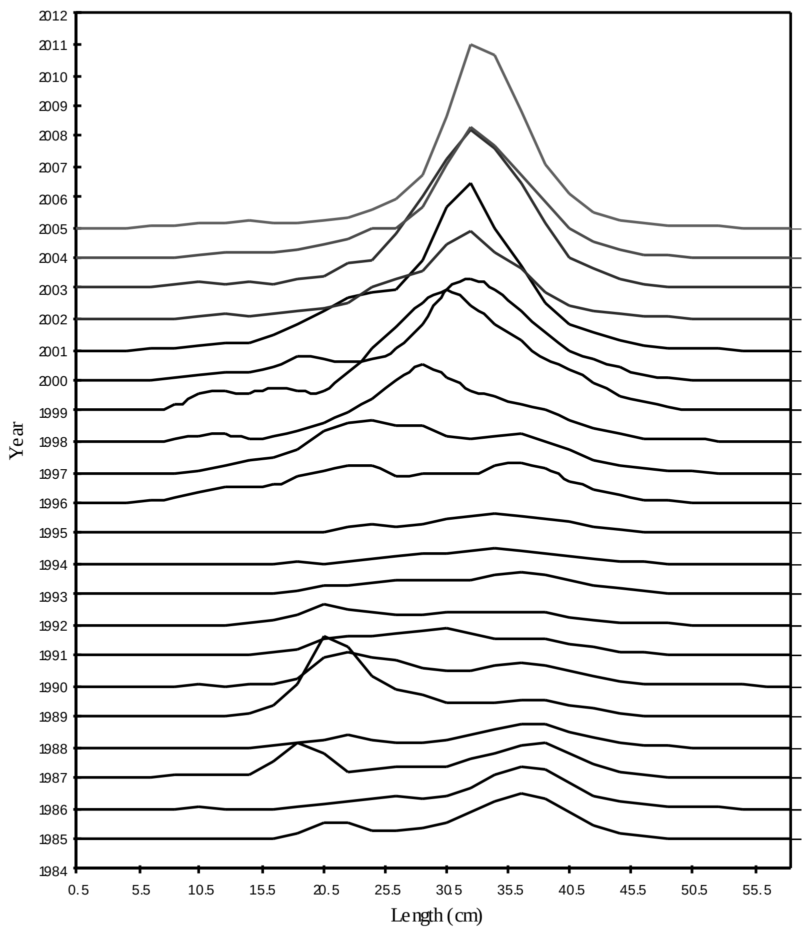

Fig. 6. Length frequency of yellowtail flounder in the spring surveys of Div. 3LNO, 1984-2005 (combined sexes).

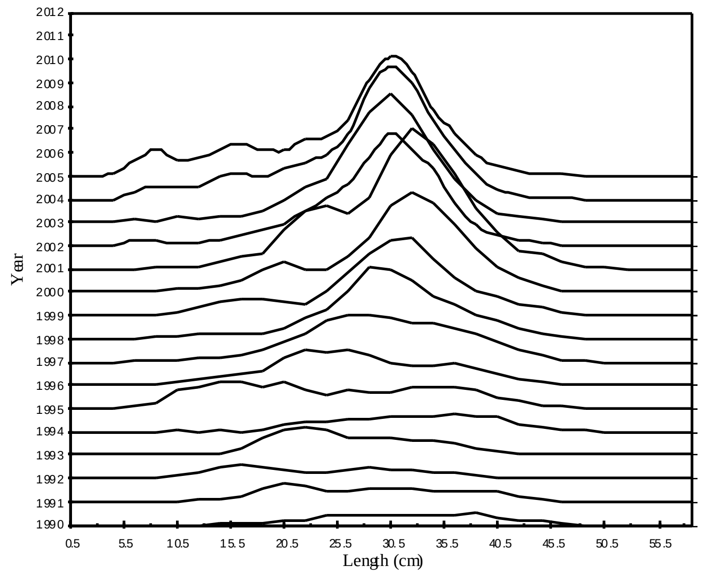

Fig. 7. Length frequency of yellowtail flounder in the fall surveys of Div. 3LNO, 1984-2005 (combined sexes).

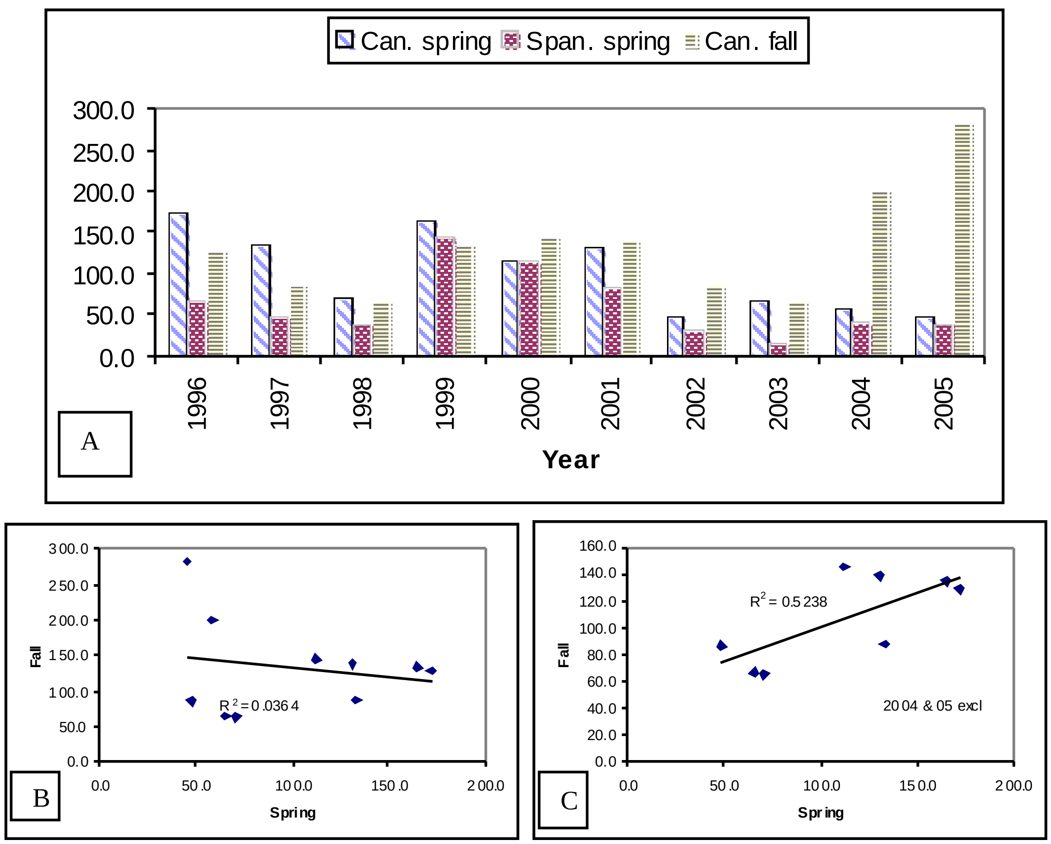

Fig. 8. **A**. Population numbers of yellowtail flounder less than 22 cm in the Canadian and total numbers from Spanish surveys; **B**. regression of Canadian spring and fall estimates from 1996-2005; and **C**. regression of Canadian spring and fall estimates from 1996-2003.

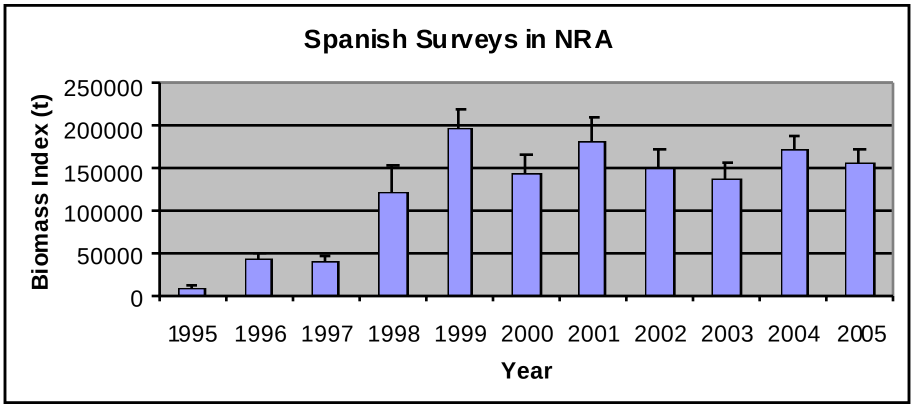

Fig. 9. Converted biomass estimates from Spanish surveys in the NRA of Div. 3NO. Error bars are 1 standard deviation.

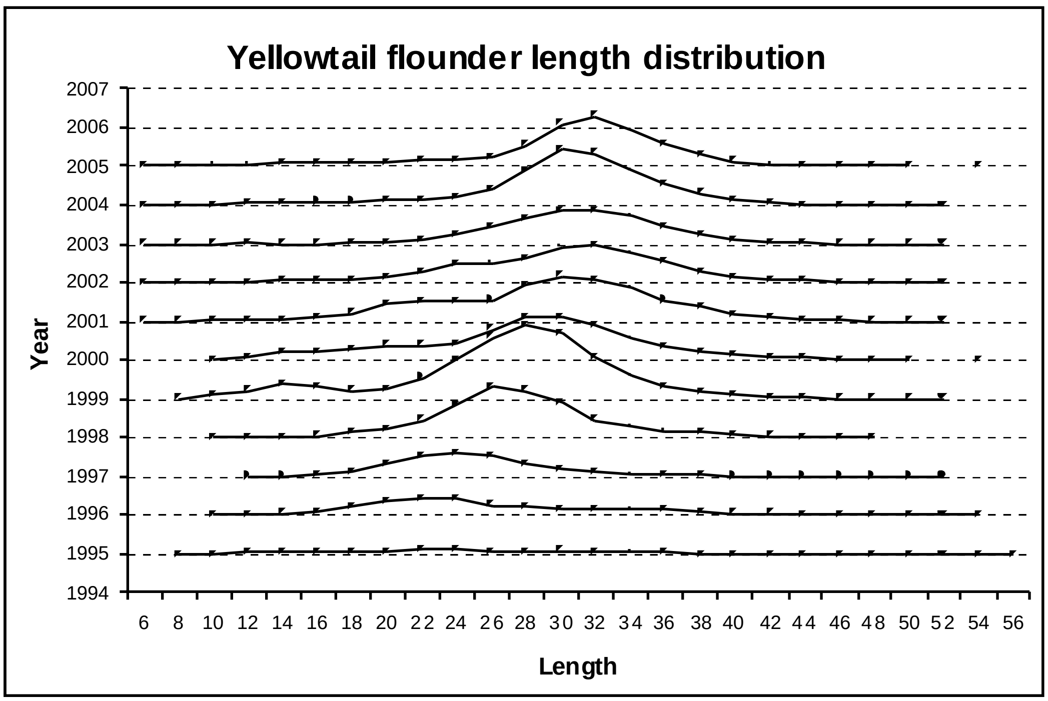

Fig. 10. Length frequency of yellowtail flounder in the Spanish spring surveys of Div. 3LNO, 1995-2005 (combined sexes).

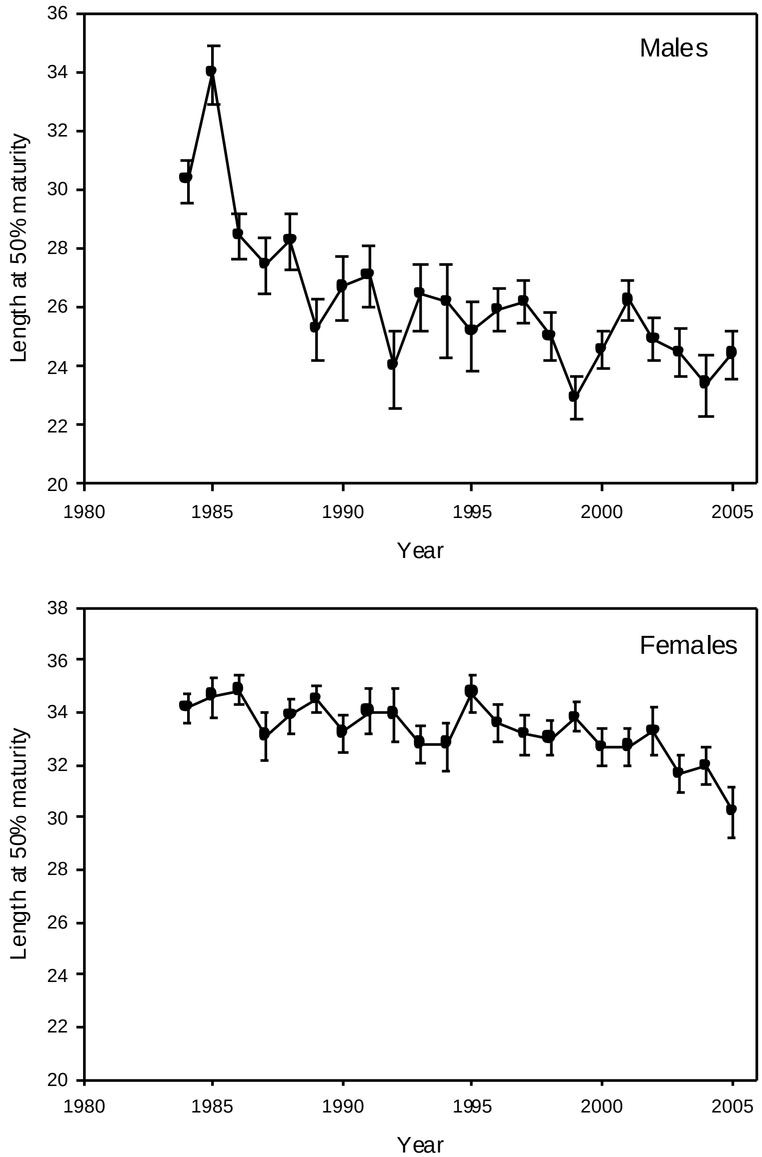

Fig. 11. Length at 50% maturity of male and female yellowtail flounder from annual Canadian research vessel surveys of Div. 3LNO from 1984 to 2005.

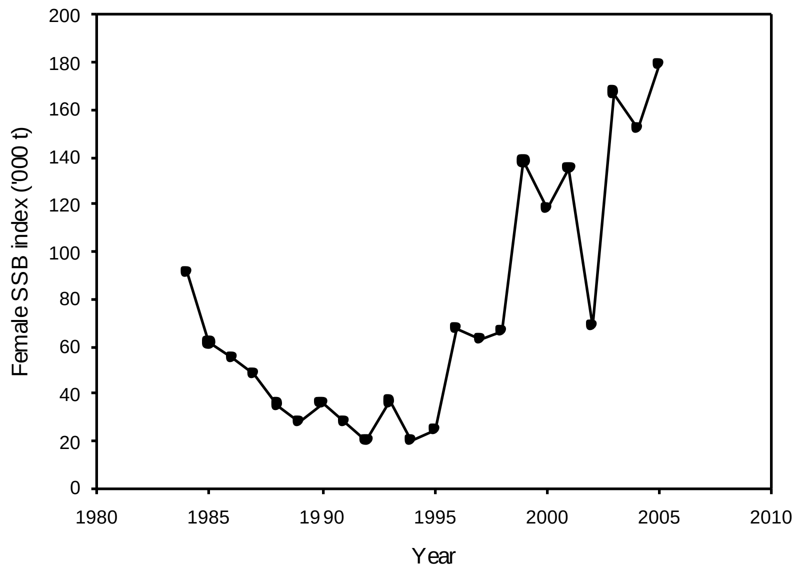

Fig. 12. Index of female spawning stock biomass ('000t) for Div. 3LNO yellowtail flounder as calculated from Canadian spring research vessel surveys from 1984-2005.

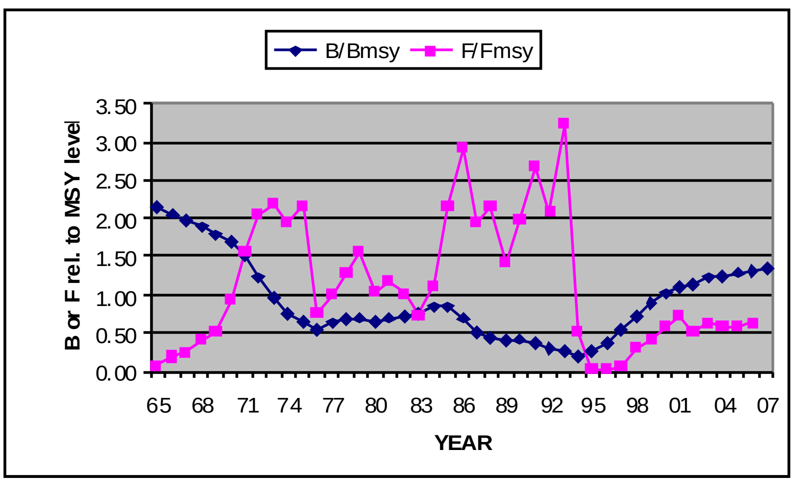

Fig 13. Results of ASPIC model (Appendix 1-estimated population trajectory table) for yellowtail flounder in Div. 3LNO. Biomass is shown relative to B_{msy} and Fishing Mortality relative to F_{msy}.

APPENDIX 1.

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3LNO ytail (v3.81, 2002 AND 2004 formulation with 2005 data) 2006=TAC                                                           Page 1
                                                                                                       07 Jun 2006 at 18:10.51
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.81)                                                  BOT Mode

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


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


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


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
----------------------------------------------------------------------------------------------------------------------
                                   |
 1  Fishery-catch/Spring biomass   |   1.000
                                   |     22
                                   |
 2  Canadian Yankee Survey         |   0.000   1.000
                                   |      0     12
                                   |
 3  Canadian Fall Survey           |   0.879   0.000   1.000
                                   |     16      0     16
                                   |
 4  Russian Survey                 |   0.933   0.198   1.000   1.000
                                   |      8     11      2     19
                                   |
 5  Spanish Survey Converted biomass |   0.840   0.000   0.797   0.000   1.000
                                   |     11      0     11      0     11
                                   ------------------------------------------------
                                          1       2       3       4       5


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

Loss(-1)  SSE in yield                                0.000E+00
Loss( 0)  Penalty for B1R > 2                         5.228E-03    1          N/A     1.000E+00          N/A
Loss( 1)  Fishery-catch/Spring biomass                1.052E+00   22    5.259E-02     1.000E+00    1.297E+00        0.827
Loss( 2)  Canadian Yankee Survey                      2.658E-01   12    2.658E-02     1.000E+00    2.565E+00        0.804
Loss( 3)  Canadian Fall Survey                        1.093E+00   16    7.811E-02     1.000E+00    8.731E-01        0.875
Loss( 4)  Russian Survey                              4.959E+00   19    2.917E-01     1.000E+00    2.337E-01        0.294
Loss( 5)  Spanish Survey Converted biomass_2006       2.954E+00   11    3.282E-01     1.000E+00    2.078E-01        0.558
TOTAL OBJECTIVE FUNCTION:                         1.03293968E+01

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

Number of restarts required for convergence:             43
Est. B-ratio coverage index (0 worst, 2 best):        1.7969               < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):        1.0000               <     et al. (1996), Trans. A.F.S. 125:729


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

B1R       Starting biomass ratio, year 1965           2.150E+00          2.000E+00            1            1
MSY       Maximum sustainable yield                   1.768E+01          1.300E+01            1            1
r         Intrinsic rate of increase                  4.448E-01          5.000E-01            1            1
........  Catchability coefficients by fishery:
q( 1)     Fishery-catch/Spring biomass                3.279E+00          3.000E+00            1            1
q( 2)     Canadian Yankee Survey                      8.429E-01          1.000E+00            1            1
q( 3)     Canadian Fall Survey                        3.675E+00          3.000E+00            1            1
q( 4)     Russian Survey                              1.704E+00          1.000E+00            1            1
q( 5)     Spanish Survey Converted biomass_2006       1.365E+00          3.000E+00            1            1


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

MSY       Maximum sustainable yield                   1.768E+01               Kr/4
K         Maximum stock biomass                       1.590E+02
Bmsy      Stock biomass at MSY                        7.950E+01                K/2
Fmsy      Fishing mortality at MSY                    2.224E-01                r/2

F(0.1)    Management benchmark                        2.002E-01           0.9*Fmsy
Y(0.1)    Equilibrium yield at F(0.1)                 1.750E+01           0.99*MSY

B-ratio   Ratio of B(2007) to Bmsy                    1.332E+00
```

F-ratio	Ratio of F(2006) to Fmsy	6.390E-01		
F01-mult	Ratio of F(0.1) to F(2006)	1.408E+00		
Y-ratio	Proportion of MSY avail in 2007	8.896E-01	2*Br-Br^2	Ye(2007) = 1.573E+01
....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	Fishery-catch/Spring biomass	6.783E-02	r/2q(1)	f(0.1) = 6.105E-02

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1965	0.019	1.709E+02	1.671E+02	3.130E+00	3.130E+00	-3.823E+00	8.420E-02	2.150E+00
2	1966	0.044	1.640E+02	1.599E+02	7.026E+00	7.026E+00	-4.310E-01	1.975E-01	2.063E+00
3	1967	0.058	1.565E+02	1.531E+02	8.878E+00	8.878E+00	2.523E+00	2.608E-01	1.969E+00
4	1968	0.091	1.502E+02	1.459E+02	1.334E+01	1.334E+01	5.349E+00	4.112E-01	1.889E+00
5	1969	0.114	1.422E+02	1.381E+02	1.571E+01	1.571E+01	8.072E+00	5.115E-01	1.788E+00
6	1970	0.209	1.345E+02	1.265E+02	2.643E+01	2.643E+01	1.146E+01	9.394E-01	1.692E+00
7	1971	0.347	1.196E+02	1.075E+02	3.734E+01	3.734E+01	1.531E+01	1.562E+00	1.504E+00
8	1972	0.458	9.753E+01	8.569E+01	3.926E+01	3.926E+01	1.744E+01	2.060E+00	1.227E+00
9	1973	0.488	7.572E+01	6.731E+01	3.281E+01	3.281E+01	1.719E+01	2.192E+00	9.524E-01
10	1974	0.436	6.009E+01	5.574E+01	2.431E+01	2.431E+01	1.608E+01	1.961E+00	7.559E-01
11	1975	0.481	5.185E+01	4.757E+01	2.289E+01	2.289E+01	1.480E+01	2.164E+00	6.523E-01
12	1976	0.171	4.376E+01	4.709E+01	8.057E+00	8.057E+00	1.473E+01	7.693E-01	5.505E-01
13	1977	0.222	5.044E+01	5.244E+01	1.164E+01	1.164E+01	1.563E+01	9.978E-01	6.344E-01
14	1978	0.283	5.443E+01	5.465E+01	1.547E+01	1.547E+01	1.595E+01	1.273E+00	6.846E-01
15	1979	0.343	5.491E+01	5.353E+01	1.835E+01	1.835E+01	1.578E+01	1.541E+00	6.907E-01
16	1980	0.229	5.234E+01	5.410E+01	1.238E+01	1.238E+01	1.587E+01	1.029E+00	6.584E-01
17	1981	0.259	5.584E+01	5.660E+01	1.468E+01	1.468E+01	1.621E+01	1.166E+00	7.024E-01
18	1982	0.226	5.737E+01	5.897E+01	1.332E+01	1.332E+01	1.650E+01	1.015E+00	7.216E-01
19	1983	0.164	6.055E+01	6.386E+01	1.047E+01	1.047E+01	1.699E+01	7.374E-01	7.616E-01
20	1984	0.249	6.706E+01	6.732E+01	1.673E+01	1.673E+01	1.726E+01	1.118E+00	8.436E-01
21	1985	0.475	6.759E+01	6.092E+01	2.896E+01	2.896E+01	1.663E+01	2.138E+00	8.502E-01
22	1986	0.645	5.526E+01	4.679E+01	3.018E+01	3.018E+01	1.460E+01	2.899E+00	6.951E-01
23	1987	0.431	3.968E+01	3.781E+01	1.631E+01	1.631E+01	1.281E+01	1.940E+00	4.991E-01
24	1988	0.476	3.617E+01	3.393E+01	1.616E+01	1.616E+01	1.186E+01	2.141E+00	4.550E-01
25	1989	0.314	3.188E+01	3.252E+01	1.021E+01	1.021E+01	1.150E+01	1.411E+00	4.010E-01
26	1990	0.441	3.317E+01	3.174E+01	1.399E+01	1.399E+01	1.129E+01	1.981E+00	4.173E-01
27	1991	0.596	3.048E+01	2.719E+01	1.620E+01	1.620E+01	1.000E+01	2.680E+00	3.834E-01
28	1992	0.463	2.428E+01	2.326E+01	1.076E+01	1.076E+01	8.826E+00	2.081E+00	3.054E-01
29	1993	0.717	2.235E+01	1.900E+01	1.362E+01	1.362E+01	7.412E+00	3.222E+00	2.811E-01
30	1994	0.111	1.614E+01	1.866E+01	2.069E+00	2.069E+00	7.322E+00	4.986E-01	2.031E-01
31	1995	0.003	2.140E+01	2.594E+01	6.700E-02	6.700E-02	9.636E+00	1.161E-02	2.691E-01
32	1996	0.006	3.096E+01	3.689E+01	2.320E-01	2.320E-01	1.257E+01	2.827E-02	3.895E-01
33	1997	0.013	4.330E+01	5.042E+01	6.580E-01	6.580E-01	1.527E+01	5.867E-02	5.447E-01
34	1998	0.068	5.791E+01	6.418E+01	4.386E+00	4.386E+00	1.699E+01	3.073E-01	7.284E-01
35	1999	0.091	7.051E+01	7.591E+01	6.894E+00	6.894E+00	1.762E+01	4.083E-01	8.869E-01
36	2000	0.132	8.123E+01	8.453E+01	1.116E+01	1.116E+01	1.760E+01	5.936E-01	1.022E+00
37	2001	0.158	8.767E+01	8.935E+01	1.414E+01	1.414E+01	1.740E+01	7.118E-01	1.103E+00
38	2002	0.114	9.093E+01	9.421E+01	1.070E+01	1.070E+01	1.706E+01	5.105E-01	1.144E+00
39	2003	0.140	9.730E+01	9.877E+01	1.381E+01	1.381E+01	1.664E+01	6.285E-01	1.224E+00
40	2004	0.131	1.001E+02	1.017E+02	1.335E+01	1.335E+01	1.630E+01	5.906E-01	1.260E+00
41	2005	0.134	1.031E+02	1.041E+02	1.393E+01	1.393E+01	1.598E+01	6.015E-01	1.297E+00
42	2006	0.142	1.051E+02	1.055E+02	1.500E+01	1.500E+01	1.578E+01	6.390E-01	1.322E+00
43	2007		1.059E+02						1.332E+00

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

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

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in yield
1	1965	*	5.481E+02	0.0187	3.130E+00	3.130E+00	0.00000	0.000E+00
2	1966	*	5.244E+02	0.0439	7.026E+00	7.026E+00	0.00000	0.000E+00
3	1967	*	5.020E+02	0.0580	8.878E+00	8.878E+00	0.00000	0.000E+00
4	1968	*	4.783E+02	0.0915	1.334E+01	1.334E+01	0.00000	0.000E+00
5	1969	*	4.527E+02	0.1138	1.571E+01	1.571E+01	0.00000	0.000E+00
6	1970	*	4.147E+02	0.2089	2.643E+01	2.643E+01	0.00000	0.000E+00
7	1971	*	3.525E+02	0.3474	3.734E+01	3.734E+01	0.00000	0.000E+00
8	1972	*	2.810E+02	0.4582	3.926E+01	3.926E+01	0.00000	0.000E+00
9	1973	*	2.207E+02	0.4875	3.281E+01	3.281E+01	0.00000	0.000E+00
10	1974	*	1.828E+02	0.4362	2.431E+01	2.431E+01	0.00000	0.000E+00
11	1975	*	1.560E+02	0.4813	2.289E+01	2.289E+01	0.00000	0.000E+00
12	1976	*	1.544E+02	0.1711	8.057E+00	8.057E+00	0.00000	0.000E+00
13	1977	*	1.720E+02	0.2219	1.164E+01	1.164E+01	0.00000	0.000E+00
14	1978	*	1.792E+02	0.2830	1.547E+01	1.547E+01	0.00000	0.000E+00
15	1979	*	1.755E+02	0.3428	1.835E+01	1.835E+01	0.00000	0.000E+00
16	1980	*	1.774E+02	0.2288	1.238E+01	1.238E+01	0.00000	0.000E+00
17	1981	*	1.856E+02	0.2594	1.468E+01	1.468E+01	0.00000	0.000E+00
18	1982	*	1.934E+02	0.2258	1.332E+01	1.332E+01	0.00000	0.000E+00
19	1983	*	2.094E+02	0.1640	1.047E+01	1.047E+01	0.00000	0.000E+00
20	1984	2.177E+02	2.208E+02	0.2486	1.673E+01	1.673E+01	0.01396	0.000E+00
21	1985	1.468E+02	1.998E+02	0.4754	2.896E+01	2.896E+01	0.30803	0.000E+00
22	1986	1.382E+02	1.534E+02	0.6449	3.018E+01	3.018E+01	0.10464	0.000E+00
23	1987	1.246E+02	1.240E+02	0.4314	1.631E+01	1.631E+01	-0.00488	0.000E+00
24	1988	8.100E+01	1.113E+02	0.4763	1.616E+01	1.616E+01	0.31735	0.000E+00
25	1989	1.038E+02	1.066E+02	0.3139	1.021E+01	1.021E+01	0.02683	0.000E+00
26	1990	1.031E+02	1.041E+02	0.4406	1.399E+01	1.399E+01	0.00960	0.000E+00
27	1991	9.340E+01	8.915E+01	0.5960	1.620E+01	1.620E+01	-0.04663	0.000E+00
28	1992	6.140E+01	7.626E+01	0.4628	1.076E+01	1.076E+01	0.21673	0.000E+00
29	1993	9.330E+01	6.229E+01	0.7167	1.362E+01	1.362E+01	-0.40394	0.000E+00
30	1994	5.560E+01	6.119E+01	0.1109	2.069E+00	2.069E+00	0.09572	0.000E+00
31	1995	7.060E+01	8.507E+01	0.0026	6.700E-02	6.700E-02	0.18646	0.000E+00
32	1996	1.756E+02	1.210E+02	0.0063	2.320E-01	2.320E-01	-0.37258	0.000E+00
33	1997	1.749E+02	1.653E+02	0.0130	6.580E-01	6.580E-01	-0.05621	0.000E+00
34	1998	2.022E+02	2.105E+02	0.0683	4.386E+00	4.386E+00	0.04004	0.000E+00
35	1999	3.657E+02	2.489E+02	0.0908	6.894E+00	6.894E+00	-0.38468	0.000E+00
36	2000	2.875E+02	2.772E+02	0.1320	1.116E+01	1.116E+01	-0.03650	0.000E+00
37	2001	3.660E+02	2.930E+02	0.1583	1.414E+01	1.414E+01	-0.22250	0.000E+00
38	2002	1.995E+02	3.089E+02	0.1135	1.070E+01	1.070E+01	0.43735	0.000E+00
39	2003	3.865E+02	3.239E+02	0.1398	1.381E+01	1.381E+01	-0.17679	0.000E+00
40	2004	3.079E+02	3.334E+02	0.1314	1.335E+01	1.335E+01	0.07947	0.000E+00
41	2005	3.888E+02	3.415E+02	0.1338	1.393E+01	1.393E+01	-0.12971	0.000E+00
42	2006	*	3.461E+02	0.1421	1.500E+01	1.500E+01	0.00000	0.000E+00

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0       0.25       0.5      0.75        1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year  Residual      ---------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0140                                             |=
1985     0.3080                                             |============
1986     0.1046                                             |====
1987    -0.0049                                             |
1988     0.3173                                             |=============
1989     0.0268                                             |=
1990     0.0096                                             |
1991    -0.0466                                           ==|
1992     0.2167                                             |=========
1993    -0.4039                             ================|

1994     0.0957                                             |====
1995     0.1865                                             |=======
1996    -0.3726                              ===============|
1997    -0.0562                                           ==|
1998     0.0400                                             |==
1999    -0.3847                              ===============|
2000    -0.0365                                            =|
2001    -0.2225                                    =========|
2002     0.4374                                             |=================
2003    -0.1768                                      =======|
2004     0.0795                                             |===
2005    -0.1297                                        =====|
2006     0.0000                                             |
                    ---------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 and 2004 formulation with 2005 data) 2006=TAC Page 5
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	*	1.409E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	1.348E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	1.291E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.230E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.164E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.066E+02	0.00000	0.0
7	1971	1.000E+00	1.000E+00	0.0	9.690E+01	9.063E+01	0.06694	6.274E+00
8	1972	1.000E+00	1.000E+00	0.0	7.920E+01	7.224E+01	0.09195	6.958E+00
9	1973	1.000E+00	1.000E+00	0.0	5.170E+01	5.675E+01	-0.09314	-5.046E+00
10	1974	1.000E+00	1.000E+00	0.0	4.030E+01	4.699E+01	-0.15358	-6.690E+00
11	1975	1.000E+00	1.000E+00	0.0	3.740E+01	4.010E+01	-0.06974	-2.701E+00
12	1976	1.000E+00	1.000E+00	0.0	4.170E+01	3.970E+01	0.04915	2.000E+00
13	1977	1.000E+00	1.000E+00	0.0	6.500E+01	4.421E+01	0.38533	2.079E+01
14	1978	1.000E+00	1.000E+00	0.0	4.430E+01	4.607E+01	-0.03920	-1.771E+00
15	1979	1.000E+00	1.000E+00	0.0	3.850E+01	4.513E+01	-0.15883	-6.627E+00
16	1980	1.000E+00	1.000E+00	0.0	5.140E+01	4.561E+01	0.11948	5.789E+00
17	1981	1.000E+00	1.000E+00	0.0	4.500E+01	4.772E+01	-0.05860	-2.716E+00
18	1982	1.000E+00	1.000E+00	0.0	4.310E+01	4.972E+01	-0.14287	-6.619E+00
19	1983	0.000E+00	0.000E+00	0.0	*	5.384E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	5.676E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	5.136E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	3.945E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	3.188E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	2.860E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	2.741E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	2.676E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	2.292E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	1.961E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	1.602E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	1.573E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	2.187E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	3.110E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	4.251E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	5.411E+01	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	6.400E+01	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	7.127E+01	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	7.533E+01	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	7.943E+01	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	8.327E+01	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	8.571E+01	0.00000	0.0
41	2005	0.000E+00	0.000E+00	0.0	*	8.780E+01	0.00000	0.0
42	2006	0.000E+00	0.000E+00	0.0	*	8.898E+01	0.00000	0.0

* Asterisk indicates missing value(s).

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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    0.0669                                         |===
1972    0.0920                                         |====
1973   -0.0931                                     ====|
1974   -0.1536                                   ======|
1975   -0.0697                                      ===|
1976    0.0491                                         |==
1977    0.3853                                         |===============
1978   -0.0392                                       ==|
1979   -0.1588                                   ======|
1980    0.1195                                         |=====
1981   -0.0586                                       ==|
1982   -0.1429                                   ======|
1983    0.0000                                         |
1984    0.0000                                         |
1985    0.0000                                         |
1986    0.0000                                         |
1987    0.0000                                         |
1988    0.0000                                         |
1989    0.0000                                         |
1990    0.0000                                         |
1991    0.0000                                         |
1992    0.0000                                         |
1993    0.0000                                         |
1994    0.0000                                         |
1995    0.0000                                         |
1996    0.0000                                         |
1997    0.0000                                         |
1998    0.0000                                         |
1999    0.0000                                         |
2000    0.0000                                         |
2001    0.0000                                         |
2002    0.0000                                         |
2003    0.0000                                         |
2004    0.0000                                         |
2005    0.0000                                         |
2006    0.0000                                         |
                ---------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 and 2004 formulation with 2005 data) 2006=TAC

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canadian Fall Survey

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	6.026E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	5.752E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	5.518E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	5.224E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	4.944E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	4.394E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	3.584E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	2.783E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	2.208E+02	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	1.906E+02	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	1.608E+02	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	1.854E+02	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	2.000E+02	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	2.018E+02	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	1.924E+02	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	2.052E+02	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	2.108E+02	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	2.225E+02	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	2.465E+02	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	2.484E+02	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	2.031E+02	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	1.458E+02	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	1.329E+02	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	1.171E+02	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	1.219E+02	0.00000	0.0
26	1990	1.000E+00	1.000E+00	0.0	6.640E+01	1.120E+02	-0.52295	-4.562E+01
27	1991	1.000E+00	1.000E+00	0.0	8.280E+01	8.924E+01	-0.07486	-6.436E+00
28	1992	1.000E+00	1.000E+00	0.0	6.420E+01	8.212E+01	-0.24618	-1.792E+01
29	1993	1.000E+00	1.000E+00	0.0	1.148E+02	5.932E+01	0.66017	5.548E+01
30	1994	1.000E+00	1.000E+00	0.0	1.068E+02	7.863E+01	0.30623	2.817E+01
31	1995	1.000E+00	1.000E+00	0.0	1.268E+02	1.138E+02	0.10822	1.301E+01
32	1996	1.000E+00	1.000E+00	0.0	1.360E+02	1.591E+02	-0.15705	-2.313E+01
33	1997	1.000E+00	1.000E+00	0.0	2.150E+02	2.128E+02	0.01023	2.188E+00
34	1998	1.000E+00	1.000E+00	0.0	2.316E+02	2.591E+02	-0.11229	-2.752E+01
35	1999	1.000E+00	1.000E+00	0.0	2.499E+02	2.985E+02	-0.17781	-4.863E+01
36	2000	1.000E+00	1.000E+00	0.0	3.350E+02	3.222E+02	0.03899	1.281E+01
37	2001	1.000E+00	1.000E+00	0.0	4.758E+02	3.342E+02	0.35334	1.416E+02
38	2002	1.000E+00	1.000E+00	0.0	3.397E+02	3.576E+02	-0.05127	-1.787E+01
39	2003	1.000E+00	1.000E+00	0.0	3.683E+02	3.680E+02	0.00087	3.187E-01
40	2004	1.000E+00	1.000E+00	0.0	3.747E+02	3.788E+02	-0.01093	-4.120E+00
41	2005	1.000E+00	1.000E+00	0.0	3.427E+02	3.863E+02	-0.11986	-4.364E+01
42	2006	0.000E+00	0.000E+00	0.0	*	3.892E+02	0.00000	0.0

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3

```
                   -1        -0.75     -0.5      -0.25     0         0.25      0.5       0.75      1
                   |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year  Residual     ---------------------------------------------------------------------------------
1965   0.0000                                              |
1966   0.0000                                              |
1967   0.0000                                              |
1968   0.0000                                              |
1969   0.0000                                              |
1970   0.0000                                              |
1971   0.0000                                              |
1972   0.0000                                              |
1973   0.0000                                              |
1974   0.0000                                              |
1975   0.0000                                              |
1976   0.0000                                              |
1977   0.0000                                              |
1978   0.0000                                              |
1979   0.0000                                              |
1980   0.0000                                              |
1981   0.0000                                              |
1982   0.0000                                              |
1983   0.0000                                              |
1984   0.0000                                              |
1985   0.0000                                              |
1986   0.0000                                              |
1987   0.0000                                              |
1988   0.0000                                              |
1989   0.0000                                              |
1990  -0.5230                          =====================|
1991  -0.0749                                           ===|
1992  -0.2462                                    ==========|
1993   0.6602                                              |==========================
1994   0.3062                                              |============
1995   0.1082                                              |====
1996  -0.1570                                        ======|
1997   0.0102                                              |
1998  -0.1123                                          ====|
1999  -0.1778                                       =======|
2000   0.0390                                              |==
2001   0.3533                                              |==============
2002  -0.0513                                            ==|
2003   0.0009                                              |
2004  -0.0109                                              |
2005  -0.1199                                         =====|
2006   0.0000                                              |
                   ---------------------------------------------------------------------------------
```

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

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	2.849E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.726E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.609E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	2.486E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	2.353E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	2.155E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.832E+02	0.00000	0.0
8	1972	1.000E+00	1.000E+00	0.0	1.060E+02	1.460E+02	-0.32039	-4.003E+01
9	1973	1.000E+00	1.000E+00	0.0	2.170E+02	1.147E+02	0.63749	1.023E+02
10	1974	1.000E+00	1.000E+00	0.0	1.290E+02	9.499E+01	0.30607	3.401E+01
11	1975	1.000E+00	1.000E+00	0.0	1.260E+02	8.106E+01	0.44106	4.494E+01
12	1976	1.000E+00	1.000E+00	0.0	1.310E+02	8.025E+01	0.49003	5.075E+01
13	1977	1.000E+00	1.000E+00	0.0	1.880E+02	8.938E+01	0.74358	9.862E+01
14	1978	1.000E+00	1.000E+00	0.0	1.100E+02	9.313E+01	0.16648	1.687E+01
15	1979	1.000E+00	1.000E+00	0.0	9.800E+01	9.122E+01	0.07167	6.778E+00
16	1980	1.000E+00	1.000E+00	0.0	1.640E+02	9.220E+01	0.57590	7.180E+01
17	1981	1.000E+00	1.000E+00	0.0	1.580E+02	9.645E+01	0.49352	6.155E+01
18	1982	1.000E+00	1.000E+00	0.0	1.250E+02	1.005E+02	0.21811	2.450E+01
19	1983	0.000E+00	0.000E+00	0.0	*	1.088E+02	0.00000	0.0
20	1984	1.000E+00	1.000E+00	0.0	1.320E+02	1.147E+02	0.14020	1.727E+01
21	1985	1.000E+00	1.000E+00	0.0	8.500E+01	1.038E+02	-0.19998	-1.882E+01
22	1986	1.000E+00	1.000E+00	0.0	4.200E+01	7.975E+01	-0.64120	-3.775E+01
23	1987	1.000E+00	1.000E+00	0.0	3.000E+01	6.444E+01	-0.76456	-3.444E+01
24	1988	1.000E+00	1.000E+00	0.0	2.300E+01	5.782E+01	-0.92183	-3.482E+01
25	1989	1.000E+00	1.000E+00	0.0	4.400E+01	5.541E+01	-0.23064	-1.141E+01
26	1990	1.000E+00	1.000E+00	0.0	2.700E+01	5.410E+01	-0.69499	-2.710E+01
27	1991	1.000E+00	1.000E+00	0.0	2.750E+01	4.633E+01	-0.52161	-1.883E+01
28	1992	0.000E+00	0.000E+00	0.0	*	3.963E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	3.238E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	3.180E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	4.421E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	6.288E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	8.593E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	1.094E+02	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	1.294E+02	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	1.441E+02	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	1.523E+02	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	1.606E+02	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	1.683E+02	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	1.733E+02	0.00000	0.0
41	2005	0.000E+00	0.000E+00	0.0	*	1.775E+02	0.00000	0.0
42	2006	0.000E+00	0.000E+00	0.0	*	1.799E+02	0.00000	0.0

* Asterisk indicates missing value(s).

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    -0.3204                              =============|
1973     0.6375                                           |=========================
1974     0.3061                                           |============
1975     0.4411                                           |==================
1976     0.4900                                           |====================
1977     0.7436                                           |==============================
1978     0.1665                                           |=======
1979     0.0717                                           |===
1980     0.5759                                           |=======================
1981     0.4935                                           |====================
1982     0.2181                                           |=========
1983     0.0000                                           |
1984     0.1402                                           |======
1985    -0.2000                                   ========|
1986    -0.6412                     ==========================|
1987    -0.7646                ===============================|
1988    -0.9218          =====================================|
1989    -0.2306                                  =========|
1990    -0.6950                   ============================|
1991    -0.5216                          =====================|
1992     0.0000                                           |
1993     0.0000                                           |
1994     0.0000                                           |
1995     0.0000                                           |
1996     0.0000                                           |
1997     0.0000                                           |
1998     0.0000                                           |
1999     0.0000                                           |
2000     0.0000                                           |
2001     0.0000                                           |
2002     0.0000                                           |
2003     0.0000                                           |
2004     0.0000                                           |
2005     0.0000                                           |
2006     0.0000                                           |
                  ---------------------------------------------------------------------------------
```

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

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	2.281E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.183E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.089E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.991E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.884E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.726E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.467E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	1.169E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	9.186E+01	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	7.607E+01	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	6.492E+01	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	6.427E+01	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	7.157E+01	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	7.458E+01	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	7.305E+01	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	7.384E+01	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	7.724E+01	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	8.049E+01	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	8.715E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	9.188E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	8.314E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	6.386E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	5.161E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	4.630E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	4.438E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	4.332E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	3.710E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	3.174E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	2.593E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	2.547E+01	0.00000	0.0
31	1995	1.000E+00	1.000E+00	0.0	9.300E+00	3.541E+01	-1.33688	-2.611E+01
32	1996	1.000E+00	1.000E+00	0.0	4.330E+01	5.035E+01	-0.15088	-7.052E+00
33	1997	1.000E+00	1.000E+00	0.0	3.870E+01	6.881E+01	-0.57557	-3.011E+01
34	1998	1.000E+00	1.000E+00	0.0	1.226E+02	8.759E+01	0.33623	3.501E+01
35	1999	1.000E+00	1.000E+00	0.0	1.970E+02	1.036E+02	0.64267	9.340E+01
36	2000	1.000E+00	1.000E+00	0.0	1.447E+02	1.154E+02	0.22654	2.933E+01
37	2001	1.000E+00	1.000E+00	0.0	1.827E+02	1.219E+02	0.40431	6.076E+01
38	2002	1.000E+00	1.000E+00	0.0	1.485E+02	1.286E+02	0.14402	1.992E+01
39	2003	1.000E+00	1.000E+00	0.0	1.368E+02	1.348E+02	0.01478	2.007E+00
40	2004	1.000E+00	1.000E+00	0.0	1.700E+02	1.387E+02	0.20315	3.125E+01
41	2005	1.000E+00	1.000E+00	0.0	1.565E+02	1.421E+02	0.09617	1.435E+01
42	2006	0.000E+00	0.000E+00	0.0	*	1.440E+02	0.00000	0.0

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 5

```
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual     ---------------------------------------------------------------------------------
1965    0.0000                                              |
1966    0.0000                                              |
1967    0.0000                                              |
1968    0.0000                                              |
1969    0.0000                                              |
1970    0.0000                                              |
1971    0.0000                                              |
1972    0.0000                                              |
1973    0.0000                                              |
1974    0.0000                                              |
1975    0.0000                                              |
1976    0.0000                                              |
1977    0.0000                                              |
1978    0.0000                                              |
1979    0.0000                                              |
1980    0.0000                                              |
1981    0.0000                                              |
1982    0.0000                                              |
1983    0.0000                                              |
1984    0.0000                                              |
1985    0.0000                                              |
1986    0.0000                                              |
1987    0.0000                                              |
1988    0.0000                                              |
1989    0.0000                                              |
1990    0.0000                                              |
1991    0.0000                                              |
1992    0.0000                                              |
1993    0.0000                                              |
1994    0.0000                                              |
1995   -1.3369                    ==========================|
1996   -0.1509                                           ===|
1997   -0.5756                                  ============|
1998    0.3362                                              |=======
1999    0.6427                                              |=============
2000    0.2265                                              |=====
2001    0.4043                                              |========
2002    0.1440                                              |===
2003    0.0148                                              |
2004    0.2031                                              |====
2005    0.0962                                              |==
2006    0.0000                                              |
                    ---------------------------------------------------------------------------------
```

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.285E+00	2.150E+00	-5.90%	2.150E+00	2.347E+00	2.225E+00	2.347E+00	1.213E-01	0.053
K	1.579E+02	1.590E+02	0.72%	1.462E+02	1.764E+02	1.510E+02	1.660E+02	1.499E+01	0.095
r	4.440E-01	4.448E-01	0.19%	3.843E-01	5.042E-01	4.133E-01	4.773E-01	6.400E-02	0.144
q(1)	3.248E+00	3.279E+00	0.95%	2.754E+00	3.742E+00	2.967E+00	3.542E+00	5.754E-01	0.177
q(2)	8.270E-01	8.429E-01	1.93%	6.654E-01	9.842E-01	7.488E-01	9.168E-01	1.680E-01	0.203
q(3)	3.670E+00	3.675E+00	0.13%	2.973E+00	4.458E+00	3.288E+00	4.055E+00	7.677E-01	0.209
q(4)	1.684E+00	1.704E+00	1.22%	1.409E+00	1.960E+00	1.530E+00	1.831E+00	3.009E-01	0.179
q(5)	1.355E+00	1.365E+00	0.73%	1.083E+00	1.674E+00	1.201E+00	1.519E+00	3.180E-01	0.235
MSY	1.746E+01	1.768E+01	1.29%	1.656E+01	1.835E+01	1.706E+01	1.791E+01	8.499E-01	0.049
Ye(2007)	1.569E+01	1.573E+01	0.28%	1.467E+01	1.686E+01	1.507E+01	1.634E+01	1.268E+00	0.081
Bmsy	7.893E+01	7.950E+01	0.72%	7.309E+01	8.818E+01	7.551E+01	8.301E+01	7.495E+00	0.095
Fmsy	2.220E-01	2.224E-01	0.19%	1.922E-01	2.521E-01	2.066E-01	2.386E-01	3.200E-02	0.144
fmsy(1)	6.783E-02	6.783E-02	0.01%	5.662E-02	7.996E-02	6.212E-02	7.362E-02	1.151E-02	0.170
fmsy(2)	2.688E-01	2.639E-01	-1.83%	2.325E-01	3.134E-01	2.500E-01	2.900E-01	4.005E-02	0.149
fmsy(3)	6.049E-02	6.053E-02	0.06%	4.811E-02	7.534E-02	5.373E-02	6.769E-02	1.395E-02	0.231
fmsy(4)	1.313E-01	1.305E-01	-0.60%	1.163E-01	1.436E-01	1.237E-01	1.375E-01	1.383E-02	0.105
fmsy(5)	1.628E-01	1.630E-01	0.10%	1.252E-01	2.087E-01	1.396E-01	1.873E-01	4.765E-02	0.293
F(0.1)	1.998E-01	2.002E-01	0.17%	1.729E-01	2.269E-01	1.860E-01	2.148E-01	2.880E-02	0.144
Y(0.1)	1.728E+01	1.750E+01	1.28%	1.640E+01	1.817E+01	1.689E+01	1.773E+01	8.414E-01	0.049
B-ratio	1.324E+00	1.332E+00	0.60%	1.108E+00	1.447E+00	1.223E+00	1.400E+00	1.770E-01	0.134
F-ratio	6.494E-01	6.390E-01	-1.60%	5.642E-01	8.170E-01	5.962E-01	7.215E-01	1.253E-01	0.193
Y-ratio	8.950E-01	8.896E-01	-0.60%	8.006E-01	9.871E-01	8.397E-01	9.501E-01	1.104E-01	0.123
f0.1(1)	6.104E-02	6.105E-02	0.01%	5.095E-02	7.197E-02	5.591E-02	6.626E-02	1.035E-02	0.170
f0.1(2)	2.419E-01	2.375E-01	-1.65%	2.092E-01	2.821E-01	2.250E-01	2.610E-01	3.605E-02	0.149
f0.1(3)	5.444E-02	5.448E-02	0.05%	4.330E-02	6.780E-02	4.836E-02	6.092E-02	1.256E-02	0.231
f0.1(4)	1.182E-01	1.175E-01	-0.54%	1.047E-01	1.293E-01	1.113E-01	1.238E-01	1.245E-02	0.105
f0.1(5)	1.465E-01	1.467E-01	0.09%	1.127E-01	1.879E-01	1.256E-01	1.685E-01	4.289E-02	0.293
q2/q1	2.574E-01	2.571E-01	-0.11%	2.086E-01	3.286E-01	2.322E-01	2.961E-01	6.394E-02	0.248
q3/q1	1.125E+00	1.121E+00	-0.35%	9.574E-01	1.321E+00	1.034E+00	1.237E+00	2.031E-01	0.181
q4/q1	5.137E-01	5.198E-01	1.18%	4.165E-01	6.144E-01	4.546E-01	5.651E-01	1.106E-01	0.215
q5/q1	4.168E-01	4.162E-01	-0.14%	3.463E-01	5.048E-01	3.784E-01	4.711E-01	9.262E-02	0.222

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:	29
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	0
Residual-adjustment factor:	1.0541