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An Assessment of the Grand Bank Yellowtail Flounder Stock, NAFO Divisions 3LNO, in 2004

by

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Abstract

All available information on the biology, assessment, fishery and management of Grand Bank yellowtail flounder stock, Divisions 3LNO, is drawn together to assess the status of the stock in 2004. Recent surveys by Canada and Spain indicate that stock size increased after 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. The ASPIC model results were used to provide short and medium term yield projections under a range of fishing mortalities. Results are presented in a precautionary approach framework, and the probability that current and projected stock sizes are below B_{MSY} is estimated to be very low.

I. Fishery and Management

A. TAC regulation

The stock has been under TAC regulation since 1973, when an initial level of 50,000 tons was established. In 1976, the TAC was lowered to 9,000 tons, 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 tons and 23,000 tons and was unchanged at 15,000 tons for the last 4 years of that period. The TAC was set at 5,000 tons 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 tons 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 tons 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 SCs recommended TAC of 10,000 tons 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 tons in 2001-02, increasing to 14,500 tons for 2003 and 2004. Scientific Council provided 2-year TAC advice in 2002, when the stock was last assessed, and confirmed the 2004 advice in 2003, 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 tons in 1972 (Table 1; Fig. 1). With the exception of 1985 and 1986, when the nominal catch was around 30,000 tons, catches were in the range of 10,000 to 18,000 tons from 1976 to 1993, the year before the moratorium. Canada and the USSR were the major participants in the fishery up to 1975, with Canada taking virtually all the catch from 1976-81 (Table 1). Canadian catches were consistently around the TAC in the mid- to late-1970s, but were under the TACs in the early-1980s as much of the Canadian fishery for flounders was directed toward American plaice in Div. 3L. Canadian catches were stable around 6,700 tons from 1991-93, then declined to zero in 1994.

Catches by other nations began to increase in 1982 as freezer trawlers started to fish in the NAFO Regulatory Area on the Tail of the Bank, Div. 3NO (Tables 1 and 2) (see also Walsh *et al*., 1995). In 1985 and 1986, as well as for the period of 1989-1994, catches for all other nations combined exceeded those of Canada. USA catches declined steadily from 3,800 tons in 1985 to zero in 1991 and 1992 (Table 2), with about 700 tons per year estimated during 1993-94. Catches by Spain and Portugal also decreased to relatively low levels during the period of 1992-96. South Korea, which fished this stock beginning in 1982, and caught between 3,500 and 5,900 tons per year from 1989 to 1992, has had no vessels in this fishery since early-1993. It should be noted that the catches for S. Korea in many years include a substantial amount of yellowtail flounder determined from breakdowns of catches reported as unspecified flounder.

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.

Before the moratorium in 1994

Overall, the catches from this stock exceeded the TAC in each year from 1985-93, often by a factor of two (Table 1; Fig. 1). However, there is still considerable doubt about the precise catch levels from this stock in the years leading up to the moratorium. Up to one-third of the catch in some years (almost two-thirds in 1994) was determined from Canadian surveillance reports and estimates of the proportion of yellowtail flounder in catches of unspecified flounder by S. Korea (Table 2; see also Brodie *et al*., 1994). It is estimated that non-contracting parties of NAFO took about 35% of the total catches from the stock from 1989 to 1992.

During the moratorium 1994-1997

During the moratorium (1994-97), catches decreased from approximately 2,000 tons in 1994 to around 300-800 tons per year, which were taken as by-catch in other fisheries (Table 1). The predominant catches were those Spain reported as by-catches in the skate fishery.

After the moratorium 1998-2003

Since the fishery re-opened in 1998, catches have ranged from 4,400 tons (1998) to 14,100 tons (2001). In 1998, a total catch of about 4,400 tons was taken, 1) in a directed commercial fishery by Canada (3,700 tons), 2) as a by-catch (85 tons) in the Portuguese otter trawl fishery in the NAFO Regulatory Area of Div. 3N and 3) as a by-catch (562 tons) in the Spanish skate fishery in the NAFO Regulatory Area of Div. 3NO (Tables 1 and 2).

In 1999 four countries reported landings and a total catch of about 6,900 tons was taken, 1) in directed fishery by Canada (5,746 tons), 2) as a by-catch (300 tons) in the Portuguese Greenland halibut/redfish fishery, 3) as a by-catch (752 tons) in the Spanish skate fishery and 4) as by-catch (96 tons) in the Russian Greenland halibut fishery. The latter three fisheries took place in the NAFO Regulatory Area of Div. 3NO (Tables 1 and 2). In the 2000 fishery, Spain, Portugal, Russia, and Estonia reported a total catch of 1,696 tons in the NAFO Regulatory Area of Div. 3NO and Canada reported a catch of 9,959 tons from otter trawl fisheries inside the zone.

In 2001 the total catch was 14,145 tons, which is the highest level since 1991. Canada caught 12,238 tons, Spain 1,391 tons, with the remaining catch coming from Portugal, Russia, Estonia, and Lithuania (Tables 1 and 2). Catches by these five countries occurred in the NAFO Regulatory Area of Div. 3NO. As in previous years, some estimates of catch were used instead of officially reported statistics. In the 1998-2001 fisheries, catches exceeded the TACs by about 10% per year.

In 2002, the catch estimate of about 10,700 tons is below the TAC of 13,000 tons. Canada caught 9,959 tons, followed by Portugal at 461 tons. The reduction from 2001 was caused primarily by Canada not catching its allocation, due mainly to problems with by-catch, although the combined catch of all other nations declined from about 1,900 tons in 2001 to about 840 tons in 2002. The Spanish catch of 161 tons was about 1,200 tons lower than in 2001.

In 2003, the catch estimate agreed by STACFIS was 13,806 tons. This included averages of catch estimates from two or more sources from some contracting parties. The possible range of catches in 2003 was relatively narrow: 13,477 tons to 14,134 tons. Canadian catches were 2,749 tons higher than in 2002, and at 12,708 tons were the highest since 1987 (Table 1). Details on the Canadian fishery can be found in Brodie *et al.* (2004). Catches by Portugal in 2003 were similar to 2002 at just under 500 tons, while Spanish catches in 2003 were estimated to be higher in 2003 than 2002, but below the levels in 2000-2001 (Table 2).

C. <u>The Canadian fishery</u> (SCR Doc. 04/41)

The yellowtail fishery on the Grand Banks was prosecuted by Canada in 2003, for the sixth year following a 4-year moratorium on directed fishing. Data on spatial and temporal trends, length composition, and an analysis of Canadian CPUE data are presented in Brodie *et al.* (2004).

D. <u>The 2003 fishery by non-Canadian vessels</u> (SCS Docs 04/3, 5, 9)

Catches in 2003 were taken by Spain (mean estimate 381 tons, range 62-700 tons, Portugal (mean 491, range 481-500 tons), Russia (184 tons) and Estonia (42 tons). Length frequencies of yellowtail flounder were available from only Portugal, from Div. 3N, July to November. The length frequencies of the total Canadian catch and the Portuguese catch are plotted together in Fig. 2. The peak in the Canadian fishery was at 36-37 cm, compared to 34-35 cm in the Portuguese fishery.

II. Research survey data

A. <u>Canadian stratified-random surveys spring and fall surveys</u> (SCR Doc. 04/36)

Abundance and biomass trends

Figure 3 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*., (2004). 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 fall survey biomass estimates have increased every year since 1994, except in 2002. One interpretation of the recent data is that the fall 2001 estimate appears as a positive anomaly and spring 2002 as a negative anomaly in their respective time series.

Figure 4 shows the result of a regression of the biomass estimates from the spring and fall time series. A linear relationship is evident with 75% 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 1996-2003, 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. Catchability estimates from the stock production model indicate *q's* from the surveys are around 3, and therefore swept-area stock-size is likely being overestimated in the surveys (Walsh *et al.,* 2002).

Size composition and growth

Figures 5 and 6 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. 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 should be evidence of year-casses moving through the time series.

In the spring surveys in 1996 and 1997, there were bimodal distributions: the first mode at about 20.5 cm and 24.5 cm respectively and the second (in both surveys) at 36.5 cm. The first mode can be seen to progress but the second has dissipated. 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 remains strong but doesn't appear to move because growth is probably reduced considerably. At this point, it is probably made up of a number of different age classes.

Similarly, in the fall surveys, beginning in 1991 there are one or more peaks visible. 1995 appears multi-modal. In 1996, the peak is at 22.5 cm; in 1997 it is at 26.5 cm; in 1998 it is at 28.5 cm; in 1999 it is at 30.5 cm; in 2000 it is at 32.5 cm; and from 2001-2003 it remains at 32.5 cm. In 2001 there is also second peak at 20.5 cm which is seen at about 23.5 cm in 2002.

In both spring and fall, length modes, thought to represent age classes, can be seen moving along the x-axis up until about 30-32 cm after which growth slows and becomes almost negligible between years. This is consistent with the growth curves constructed using ages from thin-sections (Dwyer *et al*., 2003).

Age (SCR 04/5, 49)

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. It is fairly certain that age estimation of yellowtail using the traditional method of ageing the surface of whole otoliths is accurate up to a fish length of about 25 cm.

Numbers at age from the 2002 and 2003 surveys are not available at this time, so the cohort strength model (Walsh *et al*., 2002) was not updated. However, considerable progress is being made with respect to the ageing of yellowtail (Dwyer *et al*., 2003; Dwyer, 2004; Dwyer *at al*., 2004). All yellowtail otoliths from spring and fall surveys in 1998 have been re-aged. An analysis has suggested that the age-length keys from the spring and fall research surveys should not be combined and that a sub-sampling could be used to substantially reduce the number of otoliths which need to be re-read (Dwyer *et al*., 2004).

B. <u>Co-operative DFO/fishing industry seasonal surveys</u> (SCR Doc. 04/13)

Co-operative trawl surveys between Canadian Department of Fisheries and Oceans (DFO) and a Canadian fishing company in Div. 3NO have been carried out since 1996, using a commercial fishing gear without a codend liner. These surveys are done using a grid design, which was expanded in 2000. The CPUE for the indexed grid blocks for July surveys from 1996-2003 has shown a steady increase from 1999 to 2003 (Maddock Parsons and Brodie, 2004). CPUE from the expanded grid area has increased by approximately 5-10% each year since the initial coverage in 2000. The length composition of catches consists of fish mainly in the size range of 26-46 cm (less than 5% under 30 cm in the 2003 surveys). The percentage of fish greater than 40 cm has been at a lower level in recent surveys, about 17% in 2003. On average, about 80% of the female yellowtail caught in the original grid area, were sexually mature, and there has been an increasing trend in recent years.

C. <u>Spanish stratified-random spring surveys in the Regulatory Area, Div. 3NO</u> (SCR Doc. 04/10)

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 1300 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)

The biomass of yellowtail increased sharply up to 1999, and has declined from 2001 to 2003 (Fig. 7). The 1995-2002 results are in general agreement with the Canadian spring series for all of Div. 3LNO. However, in 2003 the Spanish survey shows a further decline while the Canadian series shows an increase. Length frequencies in the 2003 Spanish survey showed a peak around 32-34 cm. (Paz *et al*., 2004). As in the Canadian surveys (Fig. 5 and 6), this survey shows the same progression of the peak in the length frequencies from the mid-1990s to 2003.

D. Stock distribution

Stock: (SCR Doc. 04/36)

In all Canadian surveys, yellowtail flounder were most abundant in strata on the Southeast Shoal and immediately to the west in Div. 3N, most of which straddle the Canadian 200 mile limit. Yellowtail flounder appear to be more abundant in the NAFO Regulatory Area of Div. 3N in the 1999 – 2003 surveys than in previous years, and the northward distribution of the stock has again extended in Div. 3L, similar to mid-1980s when overall stock size was also relatively large. Tag returns from the fishery since 1998 have also confirmed the northward extension of the stock in recent years (Walsh *et al*., 2001b). The proportion of biomass north of 45^0 N confirms that the range of the stock has been extending northward since 1995, with one obvious exception in the spring of 2002 when the proportion of biomass in the northern area is close to that of the early-1990s. The preliminary analysis of the amount of fish found in deepwater showed that small catches of yellowtail are more prevalent in waters deeper than 92 m during the spring surveys 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 indicate seasonal movements but there is no annual pattern to the data.

Spatial analyses of length composition of the stock

In recent surveys, the biomass of yellowtail on the Grand Bank has reached levels higher than anything seen in historical surveys. In the absence of age data to follow cohorts, there have been questions about the timing and magnitude of the recruitment. To consider this, Simpson and Walsh (2004) examined the distribution of size-classes from the spring survey data. They split the length composition into three groups: 19 cm and under; 20-35 cm, and greater than 35 cm. Their results showed that when the stock was at its lowest abundance and the geographic range had contracted to the south, as in 1992 and 1993, most of the stock was located in and around the nursery area[1] where a higher proportion of medium size fish were found (Fig. 8). A higher proportion of larger fish were found to the west of that area. When the abundance of the stock was high in the 1985-86 period there were more large fish than seen in the other period of high biomass, 2000-01. There was also an absence of fish under 20 cm during the early period, because of the inefficiency of the old (Engel) survey trawl. In 1985-86, larger fish were distributed in higher proportions to the area west of the nursery and in approximately 50:50 proportions with medium sized fish to the north and northwest areas. In the 2000-01 period, the stock was made up of a higher proportion of medium size fish from good year-classes in the mid 1990s. Larger fish were mainly to the west of the nursery area and catches to the north and northwest had a higher proportion of medium size fish (Fig. 8). In conclusion, when the stock was at its lowest levels in the early 1990s, there were several good year-classes produced and others continued to be produced during the moratorium. These good year-classes were responsible for the sudden increase in biomass during and after the moratorium (Walsh *et al*., 2004). They were not detected in significant numbers at smaller sizes due to the inefficiency of the Engel survey trawl used in Canadian surveys prior to fall 1995.

E. Biological studies

Maturity

Maturity at size was estimated using Canadian spring research vessel data from 1984-2003. 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. The last 4 years have seen an increase with the L_{50} for males averaging 25 cm. Female L_{50} has been fairly stable with at most a 1 cm decline from 34 to 33 cm (Fig. 9). The estimate for 2003 is the only one in the time series that is less than 32 cm. There was significant inter-annual variation in the proportion mature at length for both males and females (generalized linear models: males $\chi^2 = 351.4$, df = 19, p <0.0001, females $\chi^2 = 107.6$, df = 19, p <0.0001). In general for males, years prior to 1992 were significantly different from 2003. After this there are also years that are significantly different from the final year but there is no pattern. For females, all years except 1994 are significantly different from 2003.

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[1] The juvenile nursery area is mainly bounded by 43.30° to 44.30°N and 51° W (Walsh *et al.*, 2001). A line at 44.30°N in Figure 7 denotes the northern limit in Div 3N.

F. Assessment Results

Female Spawning Stock Biomass (SSB)

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. 10a). Since 1995 it has increased substantially. The average index over the 1996-1998 period was 66,000 tons, 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. The SSB index increased again in 2003. The 2000 to 2003 average is 122,000 tons, with a peak value in 2003 around 170,000 tons, which is substantially higher than that of the mid-1980s. In general, the female SSB index mirrors the trend in the total biomass index from the surveys.

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. Fig 10b shows the relationship from the last assessment of this stock. Cohort strength increased in the early- to mid-1990s, and has remained high through the late-1990s. It is interesting to note that cohorts produced in the first half of the 1990s were from low SSB estimates (Fig. 10a).

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 assessment of this stock (Walsh *et al*., 2002). 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 will be made, in which survey residuals are randomly re-sampled 500 times to derive bias-corrected probability distributions for parameter estimates. This will be the basis for catch projections. In the model runs presented, and for all subsequent projections, it was assumed that the 2004 catch would equal the TAC of 14,500 tons, although catches in 2002 and 2003 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/biomass ratio.

Input data/model formulation

The production model formulation includes: 1) the nominal catch data (1965-2003); 2) Russian spring surveys

(1972-1991); 3) Canadian spring (Yankee) surveys (1971-1982); 4) Canadian Campelen spring surveys (1984-2003); 5) Canadian Campelen fall surveys (1990-2003); and 6) the Spanish spring (1995-2003) survey (now in Campelen equivalents). These are the same (updated) indices accepted by STACFIS in the 2001 and 2002 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 of the Yankee and Engel trawls were used to derive a conversion factor of 1.4 for the Yankee catches by number but not by weight (biomass). Therefore the unconverted Yankee survey biomass estimates were used here. Comparative tows of 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.

The biomass index from the 1986-94 Canadian fall juvenile groundfish surveys (Walsh *et al.*, 1995) was not used because of a negative correlation with most indices (i.e. this index increased during the early 1990s when most other indices were decreasing (Walsh and Cadrin, 2000). Similarly, the average catch rate from the DFO/FPI grid surveys from July 1996-2001 also 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.

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. Their summary was as follows:

1) If the diagnostics for a poor model fit include a low R-squared (<0.4) and a strong residual pattern, then the Russian and Spanish series should be excluded as they are likely to be misleading indices of biomass.
2) If the diagnostics for a poor model include a strong residual pattern, then the Canadian CPUE and the Russian and Spanish series should be excluded.
3) A good model fit of data with no residual patterns and high goodness of fit values can be obtained by including only the Canadian survey time series and setting the B1R (initial B/B_{msy} ratio) estimate as a constant .
4) If the Russian and Spanish indices are left in the standard model, then by the same reasoning the CPUE series should also be included and this could then become the 'new standard model'.

Following review by STACFIS in 2003, 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 2002, the same version of the ASPIC software (v 3.81) was used in the current assessment.

Results

Standard model formulation: 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 >0.77), 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 0.86). 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 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.

The results are very similar to the 2002 assessment, and suggest that a maximum sustainable yield (MSY) of 17,600 tons can be produced when the total stock biomass (B_{msy}) is 80,000 tons and the fishing mortality rate (F_{msy}) is 0.22 (Appendix 1). The MSY estimate is slightly below that estimated (17,800 tons) in the 2002 assessment (Walsh *et al*., 2002). Estimates of relative biomass and fishing mortality rates are shown in Fig. 11. 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 (Fig. 11). The analysis showed that relative biomass (B_t / B_{msy}) was below the level at which MSY can be produced from 1973 to 1999, and at its minimum in 1994 the ratio was about 0.21, which is below the suggested B_{lim} reference point of 30% B_{msy} 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 2005, assuming a catch of 14,500 tons in 2004, the relative biomass B_t / B_{msy} is estimated to be 1.28. The stock is considered to be within the safe zone as defined in the Scientific Council Precautionary Approach Framework (NAFO, 2004), with low probability of exceeding the limit reference points (Fig. 12).

The relative fishing mortality rate (F_t / F_{msy}) was high during most of the historical fishery (Fig 11), 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 F-ratio estimated in 2004 (65%), if the TAC is 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.

Alternative formulations: Some different model formulations 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 in the sensitivity analysis presented in Walsh and Brodie (2003), the model formulation is very sensitive to excluding the Russian series. MSY increases to 21,000 tons, K increases, and B_{MSY} increases from 80,000 tons to 94,000 tons. 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 (Fig. 13). Although possible, this seems unlikely, given the trajectory of the only index available at that time (Canadian CPUE). That index shows a rapid decline in CPUE during the late-1960s (Brodie *et al*., 2004), 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 are 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.

Catch Projections: Medium-term projections were carried out by extending the ASPIC bootstrap projections forward to the year 2014, assuming constant fishing mortality at 2/3 F_{msy}, 0.75 F_{msy} and 0.85 F_{msy}. The projections are conditional on the estimated values of r, the intrinsic rate of population growth and K, the carrying capacity. All analyses assumed that the catch in 2004 would equal the TAC of 14,500 tons, even though the TACs have not been taken in 2002 and 2003. At 2/3 F_{msy}, catch and stock size continue to increase slightly (Table 8), and probability that biomass in 2005 is below B_{msy} is about 6%, declining to less than 3% after 2008. Catch and biomass both decrease slightly in the projections at 0.75 and 0.85 F_{msy}. At 0.75 F_{msy}, the probability of biomass being below B_{msy} is stable around 5-6% throughout the projection years. At 0.85 F_{msy}, the probability that biomass is below B_{msy} increases from 6% in 2005 to around 13 % from after 2011 (Fig. 14). Also, at 0.85 F_{msy}, the 95th percentile of the bootstrapped F is above $F_{msy.}$ Scientific Council advised that the TAC in each of 2005 and 2006 be set at 15,000 tons, corresponding to the projected yield in these years at 2/3 $F_{msy.}$

Summary

Yellowtail flounder on the Grand Bank declined in the late-1980s and early-1990s to its lowest observed level (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 14,000 tons in recent years, and stock size estimates remain high, above B_{msy}, 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 2/3 F_{msy}, and well below the limit reference point ($F_{LIM} = F_{MSY}$). Scientific Council advised that the TAC in 2005 and 2006 be set at 15,000 tons in each year.

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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							14,500

[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. Breakdown of 1984-2003 catches from Table 1 listed as "other."

Year	Spain	Portugal	Panama	USA	Cayman Is.	Estonia	Misc.	**Total**
1984	25	-	1,800 [a]	-	-	-	11	**1,836**
1985	2,425	-	4,208 [a]	3,797	803 [a]	-	12	**11,245**
1986	366	5,521	4,044 [a]	2,221	1,728 [a]	-	2	**13,882**
1987	1,183	-	-	1,535	-	-	-	**2,718**
1988	3,205	-	-	863	-	-	100 [b]	**4,163**
1989	1,126	5	-	319	-	-	101 [b]	**1,551**
1990	119	11	-	6	-	-	2,981 [b]	**3,117**
1991	246	-	-	-	-	-	5,212 [b]	**5,458**
1992	122	1	-	-	-	-	-	**123**
1993	-	-	-	68	-	-	6,800 [a]	**6,868**
1994	719	-	-	700 [a]	-	-	650 [a]	**2,069**
1995	65	-	-	-	-	-	-	**65**
1996	232	-	-	-	-	-	-	**232**
1997	657	-	-	-	-	-	-	**657**
1998	562	85	-	-	-	-	-	**647**
1999	752	300 [a]	-	-	-	-	-	**1,052**
2000	1,114 [b]	247	-	-	-	53	-	**1,486**
2001	1,391 [b]	320 [b]	-	-	-	47	1	**1,759**
2002	161 [b]	461 [b]	-	-	-	14	-	**636**
2003	381 [c]	491 [c]	-	-	-	42	-	**914**

[a] Not reported to NAFO.Catches estimated from surveillance reports.

[b] Includes some estimated catches.

[c] Average of a range of estimates

Table 3. A comparison of the biomass and abundance estimates from Canadian spring and fall surveys of Div. 3LNO, 1984-2003.

	BIOMASS (000t)		ABUNDANCE (MILLIONS)	
	SPRING	FALL	SPRING	FALL
1984	217.7	.	544.2	
1985	146.8	.	374.1	
1986	138.2	.	326.5	
1987	124.6	.	394.2	
1988	81.0	.	203.1	
1989	103.8	.	532.9	
1990	103.1	65.8	367.4	192.5
1991	93.4	82.4	320.3	297.1
1992	61.4	64.5	217.4	215.9
1993	93.3	112.8	246.3	371.9
1994	55.6	106.4	148.4	287.9
1995	70.6	129.8	187.4	592.2
1996	175.6	134.3	639.4	579.1
1997	174.9	222.9	695.5	781.5
1998	202.2	231.6	733.6	828.2
1999	365.7	249.9	1,289.9	937.1
2000	287.5	335.0	922.5	1,152.3
2001	366.0	475.8	1,328.5	1,651.9
2002	199.5	339.7	690.9	1,174.8
2003	386.5	368.3	1,250.1	1,262.6

BIOMASS ESTIMATES (000 t) FOR SPRING AND FALL SURVEYS, BY DIVISION

	SPRING			FALL		
	3L	3N	3O	3L	3N	3O
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

Table 4. A comparison of average weights per tow of catches of yellowtail flounder from the Canadian surveys of Div. 3LNO. Upper and lower refer to approx. 95% confidence intervals.

	SPRING			FALL		
YEAR	MEAN	UPPER	LOWER	MEAN	UPPER	LOWER
1984	32.0	40.6	23.4			
1985	14.6	17.4	11.7			
1986	14.1	18.3	9.8			
1987	12.7	16.3	9.2			
1988	8.2	10.5	6.0			
1989	10.6	14.4	6.7			
1990	10.6	14.1	7.0	6.6	10.0	3.2
1991	9.5	12.4	6.6	8.1	11.6	4.7
1992	6.0	9.0	3.1	6.7	10.8	2.6
1993	9.1	14.0	4.2	11.3	16.9	5.8
1994	5.3	8.8	1.8	10.4	16.7	4.1
1995	6.9	9.8	3.9	12.6	16.0	9.3
1996	17.1	20.5	13.6	12.0	15.9	8.0
1997	17.0	22.5	11.6	19.7	24.1	15.3
1998	25.7	32.4	19.0	19.9	24.5	15.3
1999	35.3	42.5	28.1	23.4	28.3	18.6
2000	27.9	33.3	22.5	28.7	39.7	17.7
2001	34.9	49.2	20.5	40.3	49.8	30.7
2002	19.2	24.3	14.1	28.7	36.7	20.7
2003	37.2	42.8	31.5	32.6	40.0	25.2

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

Table 6. Inputs to ASPIC model (Standard formulation, Appendix 1)

		Canadian survey biomass indices				
		Campelen units		unconverted	Survey Biomass indices	
Year	Catch (000t)	Spring	Fall	Yankee	Russia	Spain (Campelen)
1965	3.130					
1966	7.026					
1967	8.878					
1968	13.340					
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	14.680			45.0	158.0	
1982	13.319			43.1	125.0	
1983	10.473					
1984	16.735	217.7			132.0	
1985	28.963	146.8			85.0	
1986	30.176	138.2			42.0	
1987	16.314	124.6			30.0	
1988	16.158	81.0			23.0	
1989	10.207	103.8			44.0	
1990	13.986	103.1	66.4		27.0	
1991	16.203	93.4	82.8		27.5	
1992	10.762	61.4	64.2			
1993	13.615	93.3	114.8			
1994	2.069	55.6	106.8			
1995	0.067	70.6	126.8			9.3
1996	0.232	175.6	136.0			43.3
1997	0.658	174.9	215.0			38.7
1998	4.386	202.2	231.6			122.6
1999	6.894	365.7	249.9			197.0
2000	11.161	287.5	335.0			144.7
2001	14.145	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	14.500					

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

```
  'BOT'                  ## Mode (FIT, IRF, BOT)
'3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=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. set to same as 2001 and 2002
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
40                       ## Number of years of data.
```

Table 8. Medium term projections for Yellowtail flounder. The 5,25,50,75 & 95th percentiles of fishing mortality, biomass, . yield,B/Bmsy (Br) are shown for a fishing mortality of 2/3Fmsy.
The results are derived from an ASPIC bootstrap run (500 iterations) with a catch constraint of 14,500 tonnes in 2004.

F	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
5	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127
25	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139
50	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
75	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
95	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
Fmsy	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
2/3Fmsy	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145

B	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
5	83.64	85.87	87.40	88.85	90.07	91.06	91.71	92.24	92.68	93.04
25	97.64	99.19	100.26	101.11	101.88	102.46	102.80	103.11	103.38	103.48
50	102.62	103.59	104.43	104.98	105.34	105.65	105.88	106.12	106.30	106.40
75	107.20	107.44	107.93	108.34	108.69	109.06	109.27	109.48	109.60	109.70
95	113.98	115.62	116.38	118.07	118.55	120.03	121.62	122.34	122.93	123.37

Y	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
5	14.79	14.77	14.76	14.76	14.75	14.75	14.75	14.74	14.74	14.74
25	14.93	15.02	15.08	15.13	15.16	15.19	15.21	15.22	15.23	15.24
50	15.02	15.18	15.30	15.39	15.46	15.52	15.56	15.59	15.62	15.64
75	15.11	15.34	15.53	15.67	15.78	15.86	15.94	15.99	16.03	16.06
95	15.27	15.64	15.93	16.18	16.37	16.52	16.65	16.74	16.81	16.86

Br	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
5	0.99	1.02	1.04	1.05	1.06	1.07	1.08	1.09	1.09	1.10
25	1.16	1.19	1.20	1.22	1.23	1.24	1.24	1.25	1.25	1.26
50	1.26	1.28	1.29	1.30	1.31	1.32	1.32	1.32	1.33	1.33
75	1.35	1.37	1.37	1.38	1.38	1.39	1.39	1.39	1.39	1.39
95	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46

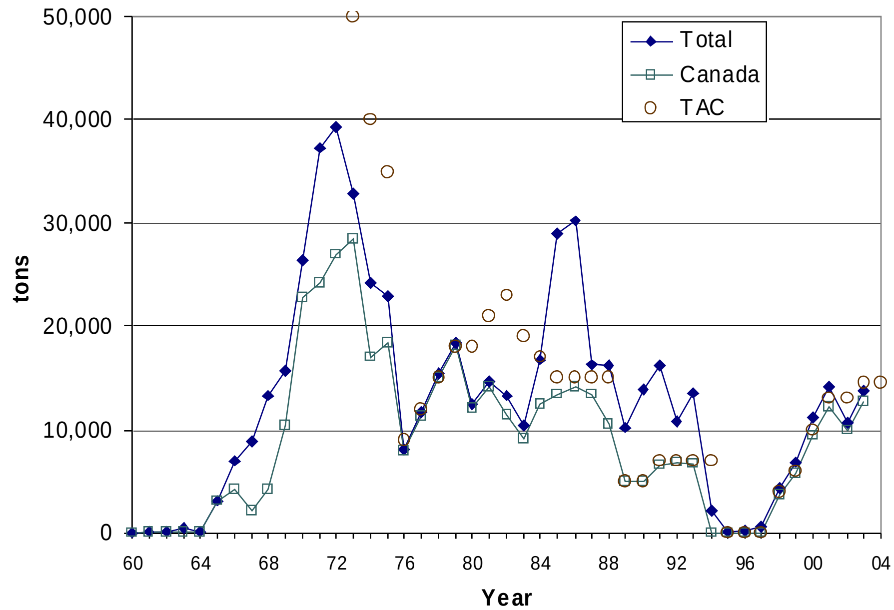

Fig. 1. Catches (Canadian and total) and TACs, Div. 3LNO yellowtail flounder.

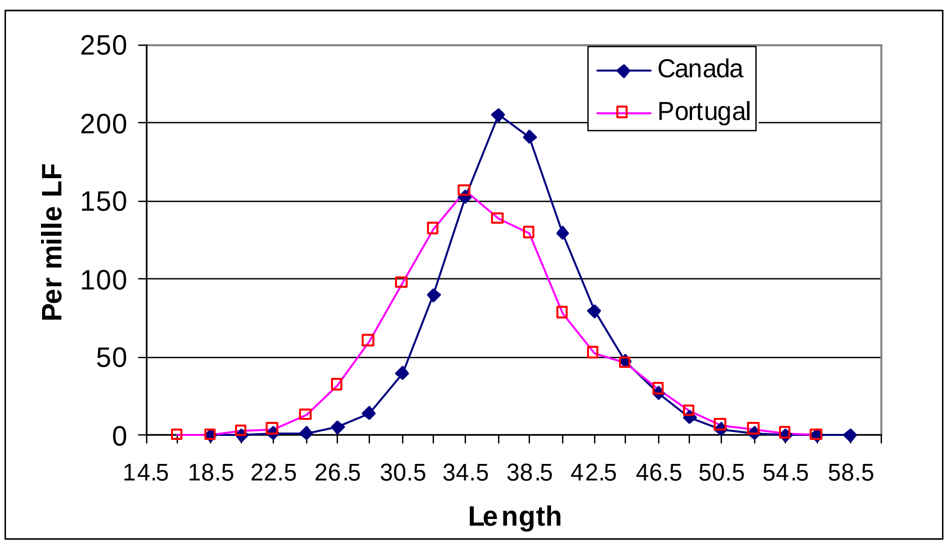

Fig. 2. Comparison of length frequencies of yellowtail from Portuguese and Canadian fisheries in 2003.

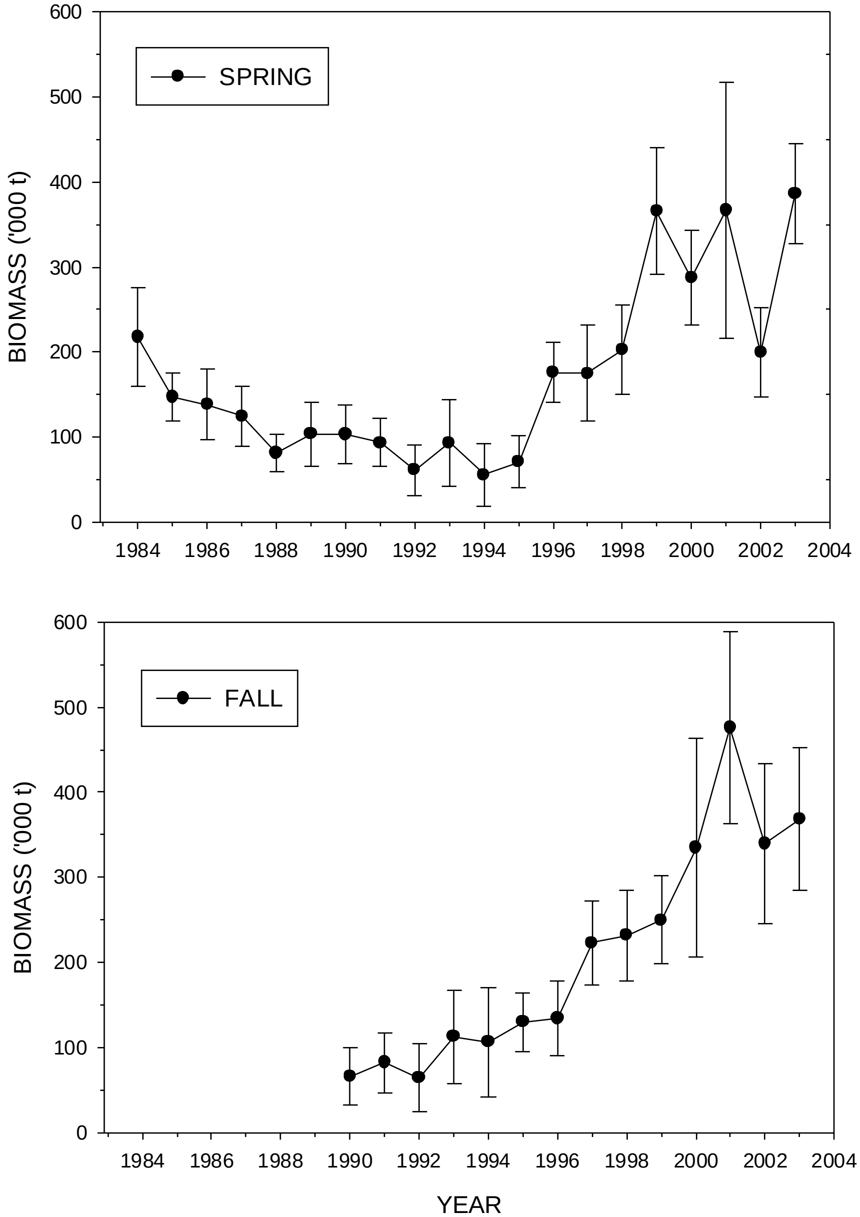

Fig. 3. Canadian spring and fall estimates of biomass of yellowtail flounder in Div. 3LNO with 95% confidence intervals.

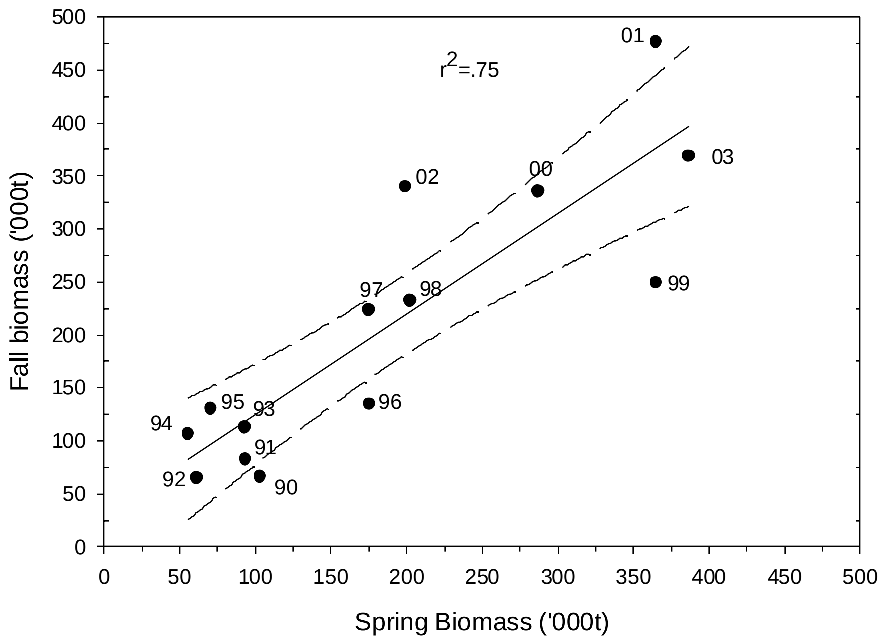

Fig. 4. Regression of Canadian spring and fall estimates of yellowtail flounder biomass in Div. 3LNO, 1990-2003.

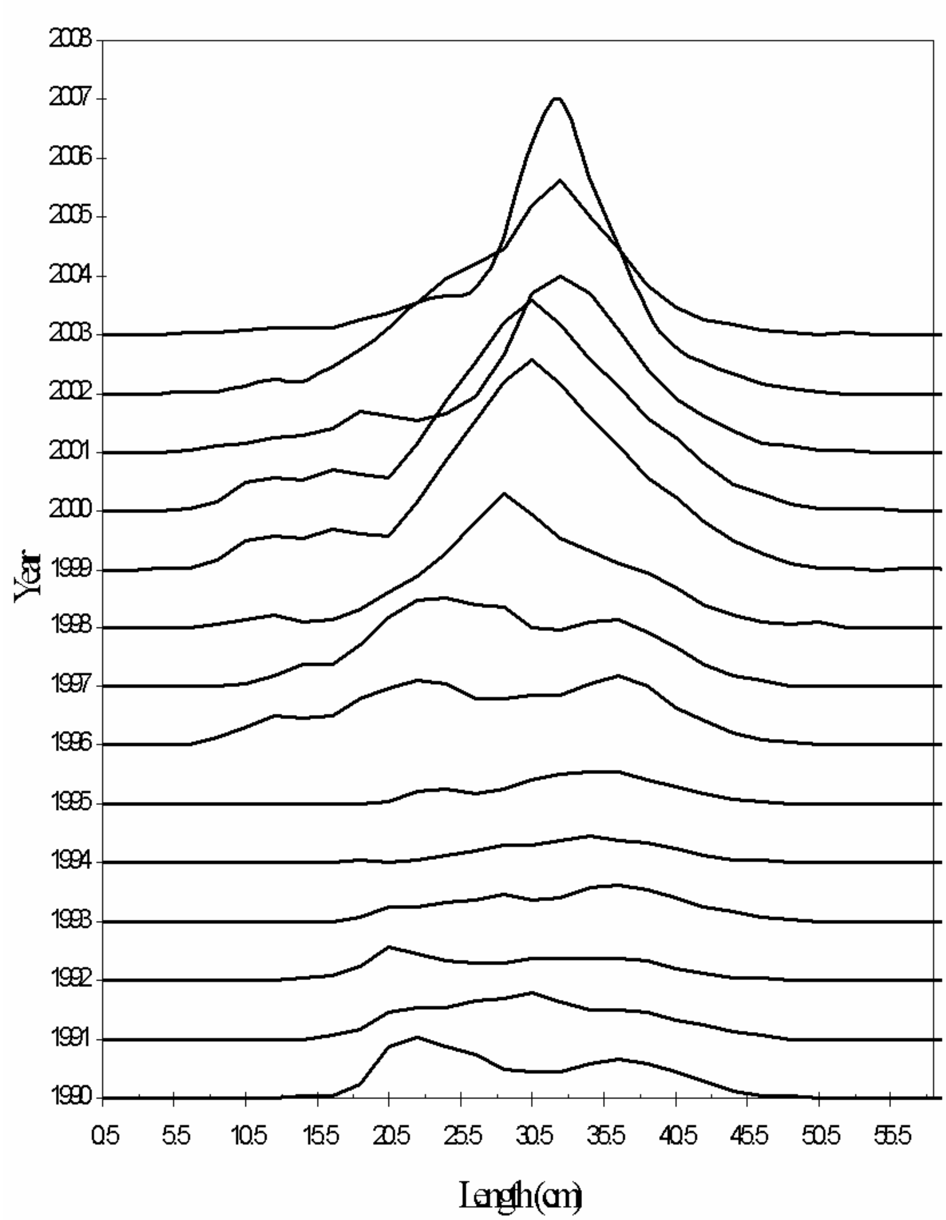

Fig. 5. Length frequency of yellowtail flounder in the spring surveys of Div. 3LNO, 1990-2003 (combined sexes).

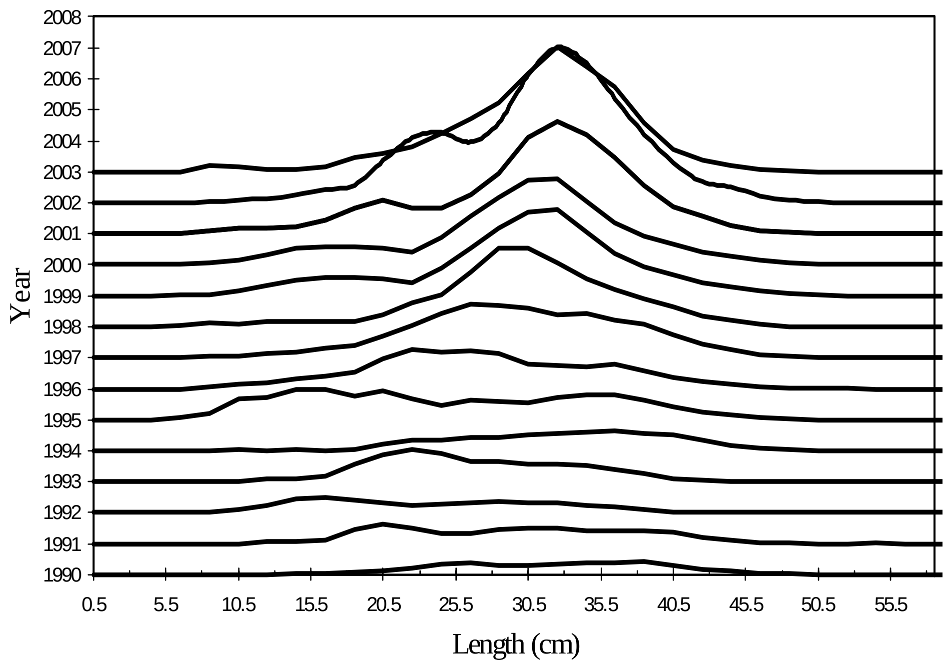

Fig. 6. Length frequency of yellowtail flounder in the fall surveys of Div. 3LNO, 1990-2003 (combined sexes).

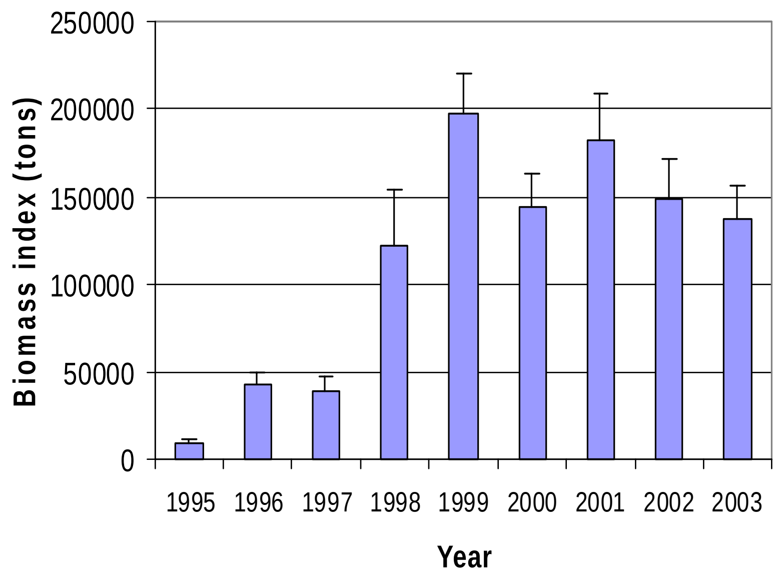

Fig. 7. Converted biomass estimates from Spanish surveys in the NRA of Div. 3NO. Error bars are 1 standard deviation.

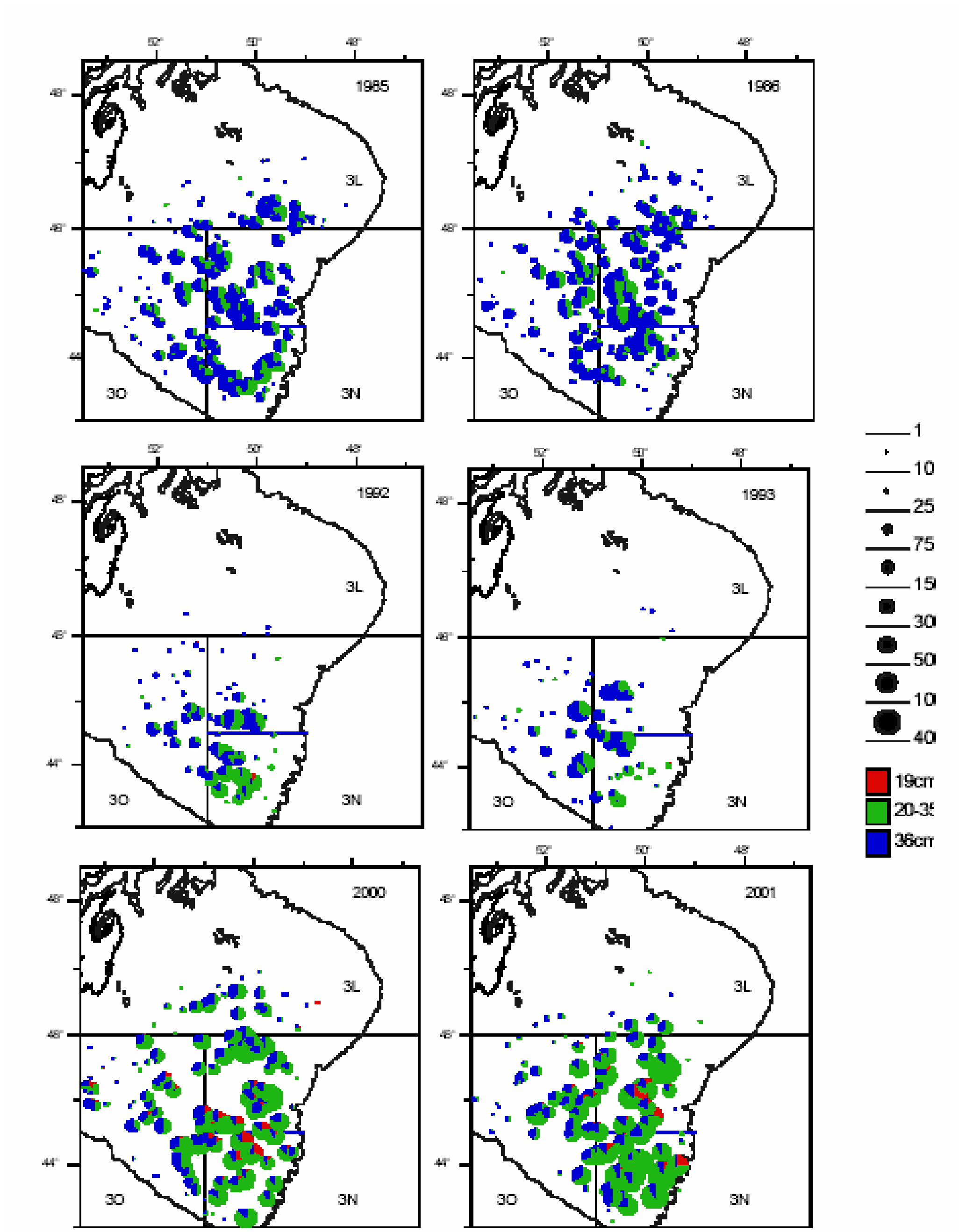

Fig 8. Size distribution of yellowtail flounder in select years on the Grand Banks, NAFO Divisions 3LNO. The contour line is the 200 m depth. The blue line at 44^0.30N in Div. 3N is the approximate northern limit of the nursery area bounded by 51^0W and 43^0.30N.

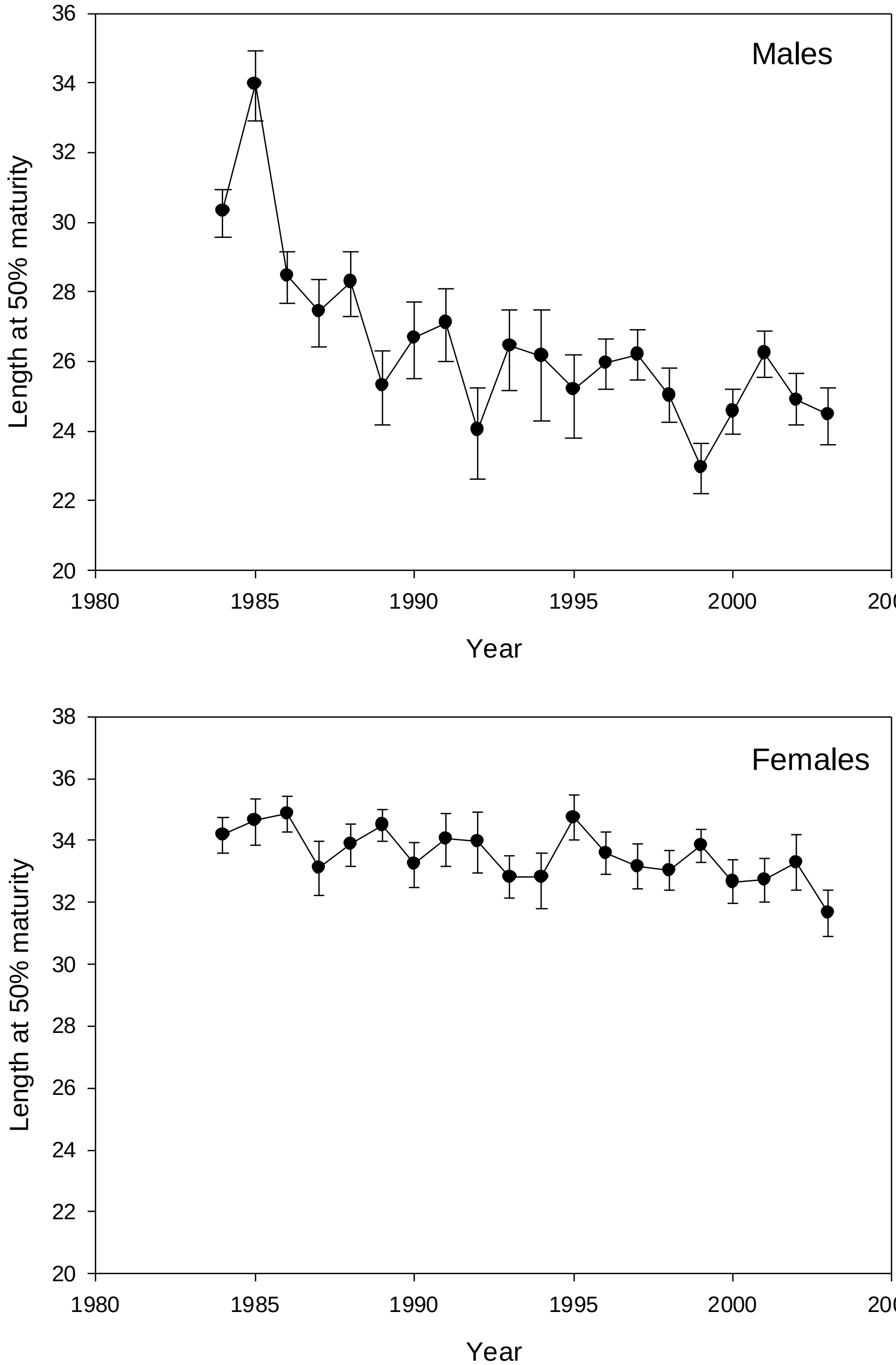

Fig. 9. Length at 50% maturity of male and female yellowtail flounder from annual Canadian research vessel surveys of Div. 3LNO from 1984 to 2003.

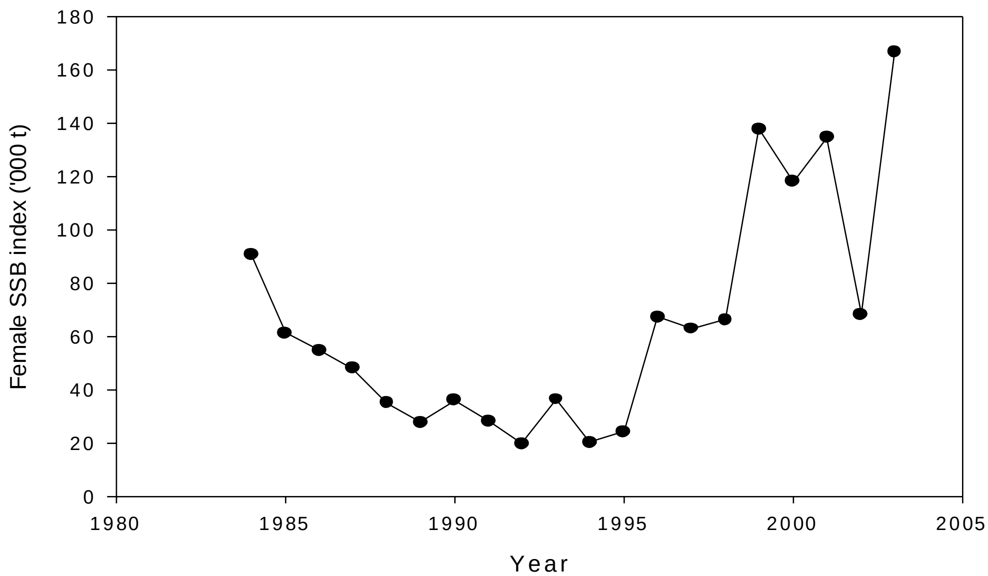

Fig 10a. Index of female spawning stock biomass (‘000t) for Div. 3LNO yellowtail flounder as calculated from Canadian spring research vessel surveys from 1984-2003.

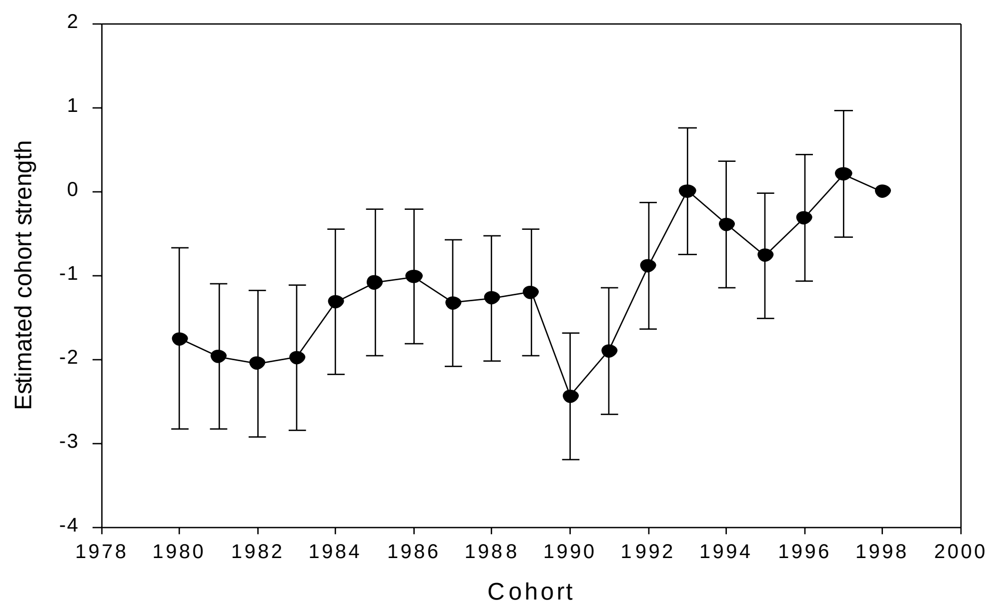

Fig 10b. Cohort strength model, 3LNO yellowtail, from Canadian survey data (from 2002 assessment, Walsh et al 2002).

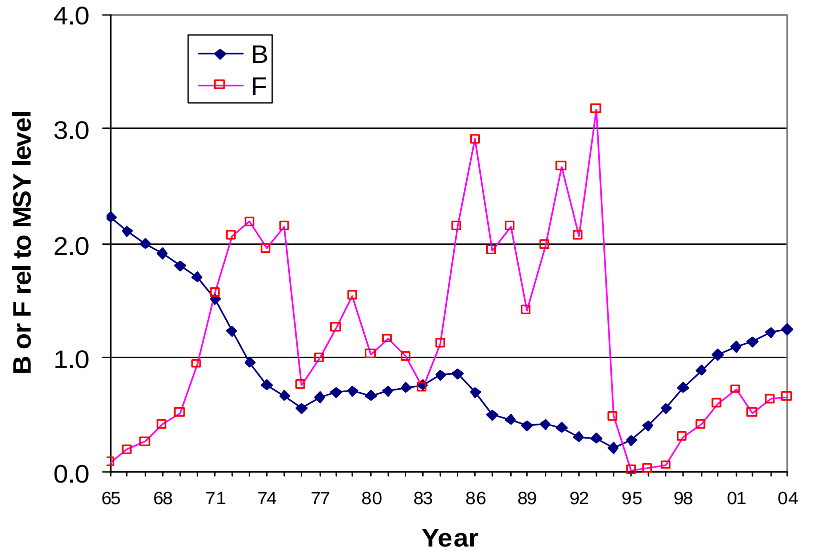

Fig. 11. Results of ASPIC model (Appendix 1), for yellowtail flounder in Div. 3LNO. Biomass is shown relative to B_{msy}, and Fishing mortality relative to F_{msy}.

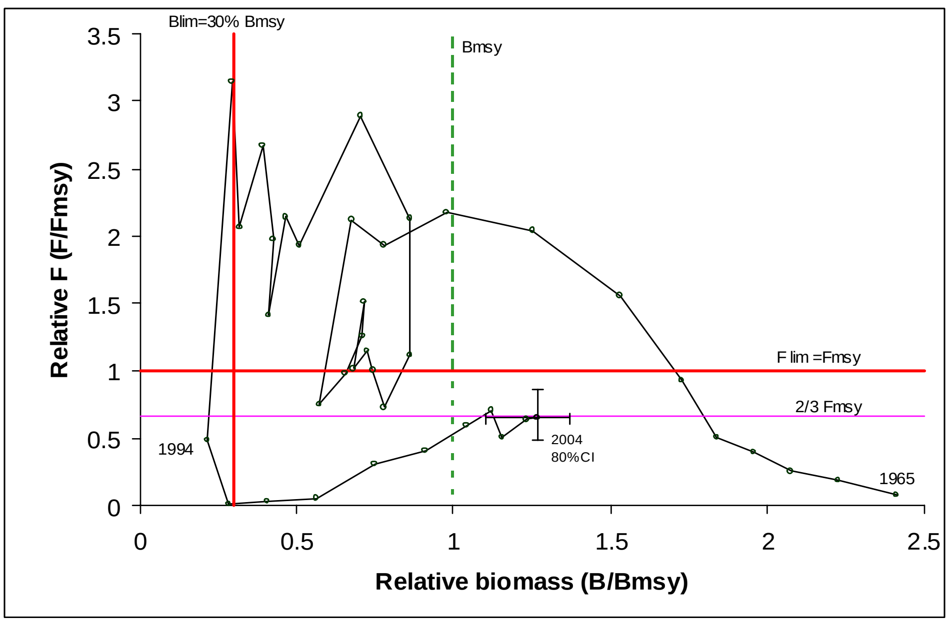

Fig. 12. Results of current assessment of yellowtail in Div. 3LNO placed in contect of a Precautionary Approach framework. 80% confidence limits from ASPIC results are indicated for the 2004 estimates of relative B and relative F.

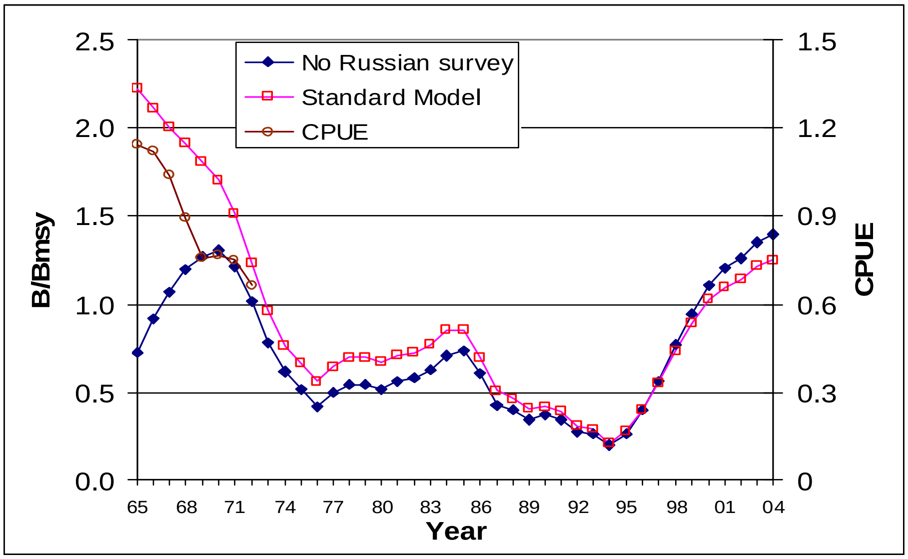

Fig. 13. Biomass/B_{MSY} from standard ASPIC formulation, and a formulation without the Russian survey data. CPUE from Canadian vessels from 1965-72 shown for comparison.

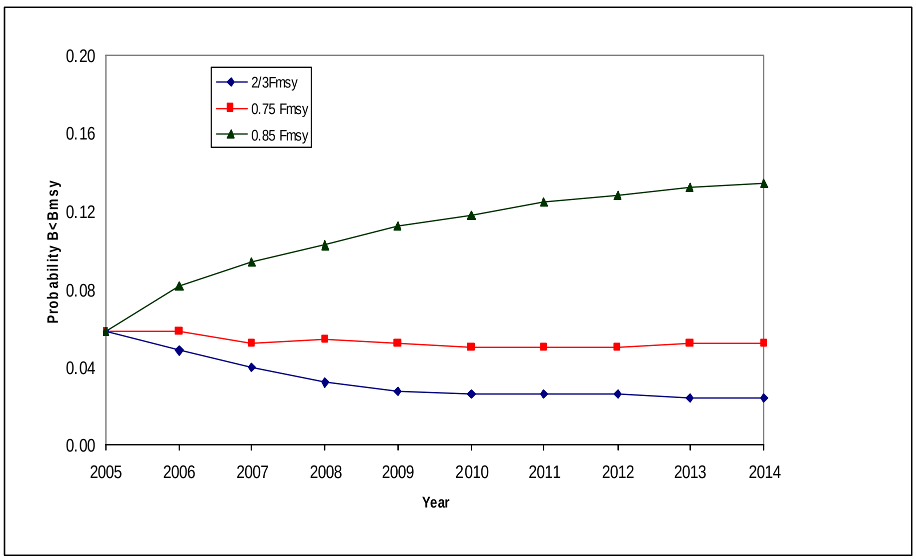

Fig. 14. Yellowtail flounder in Div. 3LNO: The probability of biomass being less than B_{msy} for medium term projections at fishing mortalities of 2/3 F_{msy}, 75% F_{msy}, and 85% F_{msy}. The results are derived from an ASPIC bootstrap run (500 iterations) with catch = TAC of 14 500 tons in 2004.

APPENDIX 1

```
3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=TAC                                             Page 1
                                                                                           13 Jun 2004 at 17:49.47
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:                        40          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
                                       |      20
                                       |
 2  Canadian Yankee Survey             |   0.000   1.000
                                       |       0      12
                                       |
 3  Canadian Fall Survey               |   0.870   0.000   1.000
                                       |      14       0      14
                                       |
 4  Russian Survey                     |   0.933   0.198   1.000   1.000
                                       |       8      11       2      19
                                       |
 5  Spanish Survey Converted biomass   |   0.845   0.000   0.774   0.000   1.000
                                       |       9       0       9       0       9
                                       --------------------------------------------------
                                               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                       1.108E-02     1           N/A    1.000E+00         N/A
Loss( 1)  Fishery-catch/Spring biomass              1.024E+00    20     5.689E-02    1.000E+00   1.237E+00       0.788
Loss( 2)  Canadian Yankee Survey                    2.651E-01    12     2.651E-02    1.000E+00   2.654E+00       0.802
Loss( 3)  Canadian Fall Survey                      1.045E+00    14     8.711E-02    1.000E+00   8.077E-01       0.860
Loss( 4)  Russian Survey                            4.916E+00    19     2.892E-01    1.000E+00   2.433E-01       0.296
Loss( 5)  Spanish Survey Converted biomass          2.969E+00     9     4.241E-01    1.000E+00   1.659E-01       0.485
TOTAL OBJECTIVE FUNCTION:                       1.02306422E+01

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

Number of restarts required for convergence:              18
Est. B-ratio coverage index (0 worst, 2 best):        1.7906                < 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         2.222E+00          2.000E+00            1            1
MSY       Maximum sustainable yield                 1.755E+01          1.300E+01            1            1
r         Intrinsic rate of increase                4.379E-01          5.000E-01            1            1
........  Catchability coefficients by fishery:
q( 1)     Fishery-catch/Spring biomass              3.220E+00          3.000E+00            1            1
q( 2)     Canadian Yankee Survey                    8.261E-01          1.000E+00            1            1
q( 3)     Canadian Fall Survey                      3.647E+00          3.000E+00            1            1
q( 4)     Russian Survey                            1.669E+00          1.000E+00            1            1
q( 5)     Spanish Survey Converted biomass          1.303E+00          3.000E+00            1            1
```

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	Related quantity
MSY	Maximum sustainable yield	1.755E+01	Kr/4	
K	Maximum stock biomass	1.603E+02		
Bmsy	Stock biomass at MSY	8.014E+01	K/2	
Fmsy	Fishing mortality at MSY	2.190E-01	r/2	
F(0.1)	Management benchmark	1.971E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.737E+01	0.99*MSY	
B-ratio	Ratio of B(2005) to Bmsy	1.275E+00		
F-ratio	Ratio of F(2004) to Fmsy	6.536E-01		
F01-mult	Ratio of F(0.1) to F(2004)	1.377E+00		
Y-ratio	Proportion of MSY avail in 2005	9.243E-01	2*Br-Br^2	Ye(2005) = 1.622E+01
....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	Fishery-catch/Spring biomass	6.800E-02	r/2q(1)	f(0.1) = 6.120E-023LNO ytail (v3.81, 2002

formulation with 2004 data) 2004=TAC

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	0.018	1.781E+02	1.731E+02	3.130E+00	3.130E+00	-6.065E+00	8.259E-02	2.222E+00
2	1966	0.043	1.689E+02	1.641E+02	7.026E+00	7.026E+00	-1.741E+00	1.955E-01	2.107E+00
3	1967	0.057	1.601E+02	1.562E+02	8.878E+00	8.878E+00	1.713E+00	2.595E-01	1.998E+00
4	1968	0.090	1.529E+02	1.483E+02	1.334E+01	1.334E+01	4.819E+00	4.107E-01	1.908E+00
5	1969	0.112	1.444E+02	1.401E+02	1.571E+01	1.571E+01	7.703E+00	5.120E-01	1.802E+00
6	1970	0.206	1.364E+02	1.282E+02	2.643E+01	2.643E+01	1.119E+01	9.413E-01	1.702E+00
7	1971	0.343	1.212E+02	1.090E+02	3.734E+01	3.734E+01	1.510E+01	1.565E+00	1.512E+00
8	1972	0.451	9.893E+01	8.701E+01	3.926E+01	3.926E+01	1.729E+01	2.061E+00	1.234E+00
9	1973	0.479	7.696E+01	6.851E+01	3.281E+01	3.281E+01	1.710E+01	2.187E+00	9.603E-01
10	1974	0.427	6.125E+01	5.688E+01	2.431E+01	2.431E+01	1.605E+01	1.952E+00	7.642E-01
11	1975	0.470	5.298E+01	4.871E+01	2.289E+01	2.289E+01	1.482E+01	2.147E+00	6.611E-01
12	1976	0.167	4.491E+01	4.825E+01	8.057E+00	8.057E+00	1.476E+01	7.627E-01	5.604E-01
13	1977	0.217	5.161E+01	5.361E+01	1.164E+01	1.164E+01	1.562E+01	9.914E-01	6.440E-01
14	1978	0.277	5.559E+01	5.580E+01	1.547E+01	1.547E+01	1.592E+01	1.266E+00	6.937E-01
15	1979	0.336	5.605E+01	5.466E+01	1.835E+01	1.835E+01	1.576E+01	1.533E+00	6.994E-01
16	1980	0.224	5.346E+01	5.520E+01	1.238E+01	1.238E+01	1.584E+01	1.024E+00	6.671E-01
17	1981	0.255	5.692E+01	5.766E+01	1.468E+01	1.468E+01	1.616E+01	1.163E+00	7.103E-01
18	1982	0.222	5.841E+01	5.998E+01	1.332E+01	1.332E+01	1.643E+01	1.014E+00	7.288E-01
19	1983	0.162	6.152E+01	6.478E+01	1.047E+01	1.047E+01	1.689E+01	7.383E-01	7.677E-01
20	1984	0.246	6.794E+01	6.815E+01	1.673E+01	1.673E+01	1.715E+01	1.122E+00	8.478E-01
21	1985	0.470	6.836E+01	6.164E+01	2.896E+01	2.896E+01	1.653E+01	2.146E+00	8.530E-01
22	1986	0.636	5.593E+01	4.744E+01	3.018E+01	3.018E+01	1.454E+01	2.905E+00	6.979E-01
23	1987	0.425	4.029E+01	3.841E+01	1.631E+01	1.631E+01	1.278E+01	1.940E+00	5.028E-01
24	1988	0.469	3.675E+01	3.443E+01	1.616E+01	1.616E+01	1.182E+01	2.144E+00	4.586E-01
25	1989	0.309	3.241E+01	3.304E+01	1.021E+01	1.021E+01	1.148E+01	1.411E+00	4.044E-01
26	1990	0.434	3.369E+01	3.225E+01	1.399E+01	1.399E+01	1.127E+01	1.981E+00	4.204E-01
27	1991	0.585	3.098E+01	2.769E+01	1.620E+01	1.620E+01	1.001E+01	2.673E+00	3.865E-01
28	1992	0.453	2.478E+01	2.378E+01	1.076E+01	1.076E+01	8.864E+00	2.067E+00	3.093E-01
29	1993	0.695	2.289E+01	1.960E+01	1.362E+01	1.362E+01	7.510E+00	3.172E+00	2.856E-01
30	1994	0.107	1.678E+01	1.936E+01	2.069E+00	2.069E+00	7.450E+00	4.881E-01	2.094E-01
31	1995	0.003	2.216E+01	2.677E+01	6.700E-02	6.700E-02	9.742E+00	1.143E-02	2.765E-01
32	1996	0.006	3.184E+01	3.779E+01	2.320E-01	2.320E-01	1.261E+01	2.804E-02	3.973E-01
33	1997	0.013	4.422E+01	5.133E+01	6.580E-01	6.580E-01	1.523E+01	5.855E-02	5.518E-01
34	1998	0.067	5.879E+01	6.501E+01	4.386E+00	4.386E+00	1.689E+01	3.081E-01	7.336E-01
35	1999	0.090	7.129E+01	7.662E+01	6.894E+00	6.894E+00	1.749E+01	4.109E-01	8.896E-01
36	2000	0.131	8.188E+01	8.511E+01	1.116E+01	1.116E+01	1.747E+01	5.989E-01	1.022E+00
37	2001	0.158	8.819E+01	8.981E+01	1.414E+01	1.414E+01	1.729E+01	7.194E-01	1.100E+00
38	2002	0.113	9.133E+01	9.456E+01	1.070E+01	1.070E+01	1.697E+01	5.167E-01	1.140E+00
39	2003	0.139	9.760E+01	9.903E+01	1.381E+01	1.381E+01	1.657E+01	6.367E-01	1.218E+00
40	2004	0.143	1.004E+02	1.013E+02	1.450E+01	1.450E+01	1.632E+01	6.536E-01	1.252E+00
41	2005		1.022E+02						1.275E+00

3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=TAC
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	*	5.573E+02	0.0181	3.130E+00	3.130E+00	0.00000	0.000E+00
2	1966	*	5.285E+02	0.0428	7.026E+00	7.026E+00	0.00000	0.000E+00
3	1967	*	5.031E+02	0.0568	8.878E+00	8.878E+00	0.00000	0.000E+00
4	1968	*	4.777E+02	0.0899	1.334E+01	1.334E+01	0.00000	0.000E+00
5	1969	*	4.512E+02	0.1121	1.571E+01	1.571E+01	0.00000	0.000E+00
6	1970	*	4.128E+02	0.2061	2.643E+01	2.643E+01	0.00000	0.000E+00
7	1971	*	3.510E+02	0.3426	3.734E+01	3.734E+01	0.00000	0.000E+00
8	1972	*	2.802E+02	0.4512	3.926E+01	3.926E+01	0.00000	0.000E+00
9	1973	*	2.206E+02	0.4790	3.281E+01	3.281E+01	0.00000	0.000E+00
10	1974	*	1.831E+02	0.4274	2.431E+01	2.431E+01	0.00000	0.000E+00
11	1975	*	1.568E+02	0.4700	2.289E+01	2.289E+01	0.00000	0.000E+00
12	1976	*	1.554E+02	0.1670	8.057E+00	8.057E+00	0.00000	0.000E+00
13	1977	*	1.726E+02	0.2171	1.164E+01	1.164E+01	0.00000	0.000E+00
14	1978	*	1.797E+02	0.2772	1.547E+01	1.547E+01	0.00000	0.000E+00
15	1979	*	1.760E+02	0.3357	1.835E+01	1.835E+01	0.00000	0.000E+00
16	1980	*	1.778E+02	0.2242	1.238E+01	1.238E+01	0.00000	0.000E+00
17	1981	*	1.857E+02	0.2546	1.468E+01	1.468E+01	0.00000	0.000E+00
18	1982	*	1.931E+02	0.2221	1.332E+01	1.332E+01	0.00000	0.000E+00
19	1983	*	2.086E+02	0.1617	1.047E+01	1.047E+01	0.00000	0.000E+00
20	1984	2.177E+02	2.194E+02	0.2456	1.673E+01	1.673E+01	0.00789	0.000E+00
21	1985	1.468E+02	1.985E+02	0.4698	2.896E+01	2.896E+01	0.30165	0.000E+00
22	1986	1.382E+02	1.528E+02	0.6361	3.018E+01	3.018E+01	0.10018	0.000E+00
23	1987	1.246E+02	1.237E+02	0.4247	1.631E+01	1.631E+01	-0.00739	0.000E+00
24	1988	8.100E+01	1.108E+02	0.4694	1.616E+01	1.616E+01	0.31371	0.000E+00
25	1989	1.038E+02	1.064E+02	0.3089	1.021E+01	1.021E+01	0.02463	0.000E+00
26	1990	1.031E+02	1.038E+02	0.4336	1.399E+01	1.399E+01	0.00723	0.000E+00
27	1991	9.340E+01	8.916E+01	0.5852	1.620E+01	1.620E+01	-0.04647	0.000E+00
28	1992	6.140E+01	7.657E+01	0.4525	1.076E+01	1.076E+01	0.22084	0.000E+00
29	1993	9.330E+01	6.312E+01	0.6945	1.362E+01	1.362E+01	-0.39077	0.000E+00
30	1994	5.560E+01	6.234E+01	0.1069	2.069E+00	2.069E+00	0.11442	0.000E+00
31	1995	7.060E+01	8.618E+01	0.0025	6.700E-02	6.700E-02	0.19945	0.000E+00
32	1996	1.756E+02	1.217E+02	0.0061	2.320E-01	2.320E-01	-0.36668	0.000E+00
33	1997	1.749E+02	1.653E+02	0.0128	6.580E-01	6.580E-01	-0.05662	0.000E+00
34	1998	2.022E+02	2.093E+02	0.0675	4.386E+00	4.386E+00	0.03470	0.000E+00
35	1999	3.657E+02	2.467E+02	0.0900	6.894E+00	6.894E+00	-0.39356	0.000E+00
36	2000	2.875E+02	2.741E+02	0.1311	1.116E+01	1.116E+01	-0.04788	0.000E+00
37	2001	3.660E+02	2.892E+02	0.1575	1.414E+01	1.414E+01	-0.23563	0.000E+00
38	2002	1.995E+02	3.045E+02	0.1131	1.070E+01	1.070E+01	0.42282	0.000E+00
39	2003	3.865E+02	3.189E+02	0.1394	1.381E+01	1.381E+01	-0.19233	0.000E+00
40	2004	*	3.262E+02	0.1431	1.450E+01	1.450E+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     0.0079                                             |
1985     0.3017                                             |============
1986     0.1002                                             |====
1987    -0.0074                                             |
1988     0.3137                                             |=============
1989     0.0246                                             |=
1990     0.0072                                             |
1991    -0.0465                                           ==|
1992     0.2208                                             |=========
1993    -0.3908                             ================|
1994     0.1144                                             |=====
1995     0.1995                                             |========
1996    -0.3667                              ===============|
1997    -0.0566                                           ==|
1998     0.0347                                             |=
1999    -0.3936                             ================|
2000    -0.0479                                           ==|
2001    -0.2356                                    =========|
2002     0.4228                                             |=================
2003    -0.1923                                     ========|
2004     0.0000                                             |
                   -------------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=TAC
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	*	1.430E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	1.356E+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	*	1.226E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.158E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.059E+02	0.00000	0.0
7	1971	1.000E+00	1.000E+00	0.0	9.690E+01	9.005E+01	0.07334	6.852E+00
8	1972	1.000E+00	1.000E+00	0.0	7.920E+01	7.188E+01	0.09694	7.318E+00
9	1973	1.000E+00	1.000E+00	0.0	5.170E+01	5.660E+01	-0.09058	-4.901E+00
10	1974	1.000E+00	1.000E+00	0.0	4.030E+01	4.699E+01	-0.15360	-6.691E+00
11	1975	1.000E+00	1.000E+00	0.0	3.740E+01	4.024E+01	-0.07317	-2.839E+00
12	1976	1.000E+00	1.000E+00	0.0	4.170E+01	3.986E+01	0.04511	1.839E+00
13	1977	1.000E+00	1.000E+00	0.0	6.500E+01	4.429E+01	0.38361	2.071E+01
14	1978	1.000E+00	1.000E+00	0.0	4.430E+01	4.610E+01	-0.03975	-1.796E+00
15	1979	1.000E+00	1.000E+00	0.0	3.850E+01	4.515E+01	-0.15944	-6.655E+00
16	1980	1.000E+00	1.000E+00	0.0	5.140E+01	4.561E+01	0.11959	5.794E+00
17	1981	1.000E+00	1.000E+00	0.0	4.500E+01	4.764E+01	-0.05695	-2.637E+00
18	1982	1.000E+00	1.000E+00	0.0	4.310E+01	4.955E+01	-0.13952	-6.453E+00
19	1983	0.000E+00	0.000E+00	0.0	*	5.352E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	5.630E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	5.093E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	3.919E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	3.173E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	2.844E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	2.730E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	2.664E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	2.288E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	1.965E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	1.619E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	1.599E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	2.211E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	3.122E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	4.240E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	5.371E+01	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	6.330E+01	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	7.032E+01	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	7.419E+01	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	7.812E+01	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	8.181E+01	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	8.370E+01	0.00000	0.0

* Asterisk indicates missing value(s).

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     0.0733                                             |===
1972     0.0969                                             |====
1973    -0.0906                                         ====|
1974    -0.1536                                       ======|
1975    -0.0732                                          ===|
1976     0.0451                                             |==
1977     0.3836                                             |===============
1978    -0.0397                                           ==|
1979    -0.1594                                       ======|
1980     0.1196                                             |=====
1981    -0.0570                                           ==|
1982    -0.1395                                       ======|
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                                             |
                   -------------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=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	*	6.158E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	5.839E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	5.577E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	5.266E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	4.975E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	4.419E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	3.608E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	2.806E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	2.233E+02	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	1.932E+02	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	1.638E+02	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	1.882E+02	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	2.027E+02	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	2.044E+02	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	1.949E+02	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	2.076E+02	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	2.130E+02	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	2.244E+02	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	2.478E+02	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	2.493E+02	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	2.040E+02	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	1.469E+02	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	1.340E+02	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	1.182E+02	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	1.229E+02	0.00000	0.0
26	1990	1.000E+00	1.000E+00	0.0	6.640E+01	1.130E+02	-0.53136	-4.656E+01
27	1991	1.000E+00	1.000E+00	0.0	8.280E+01	9.038E+01	-0.08762	-7.582E+00
28	1992	1.000E+00	1.000E+00	0.0	6.420E+01	8.346E+01	-0.26235	-1.926E+01
29	1993	1.000E+00	1.000E+00	0.0	1.148E+02	6.119E+01	0.62914	5.361E+01
30	1994	1.000E+00	1.000E+00	0.0	1.068E+02	8.082E+01	0.27878	2.598E+01
31	1995	1.000E+00	1.000E+00	0.0	1.268E+02	1.161E+02	0.08816	1.070E+01
32	1996	1.000E+00	1.000E+00	0.0	1.360E+02	1.613E+02	-0.17030	-2.525E+01
33	1997	1.000E+00	1.000E+00	0.0	2.150E+02	2.144E+02	0.00283	6.079E-01
34	1998	1.000E+00	1.000E+00	0.0	2.316E+02	2.600E+02	-0.11558	-2.838E+01
35	1999	1.000E+00	1.000E+00	0.0	2.499E+02	2.986E+02	-0.17805	-4.870E+01
36	2000	1.000E+00	1.000E+00	0.0	3.350E+02	3.216E+02	0.04080	1.339E+01
37	2001	1.000E+00	1.000E+00	0.0	4.758E+02	3.331E+02	0.35666	1.427E+02
38	2002	1.000E+00	1.000E+00	0.0	3.397E+02	3.559E+02	-0.04667	-1.623E+01
39	2003	1.000E+00	1.000E+00	0.0	3.683E+02	3.660E+02	0.00626	2.297E+00
40	2004	0.000E+00	0.000E+00	0.0	*	3.726E+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    -0.5314                         =====================|
1991    -0.0876                                         ====|
1992    -0.2624                              ==========|
1993     0.6291                                             |=========================
1994     0.2788                                             |===========
1995     0.0882                                             |====
1996    -0.1703                                 =======|
1997     0.0028                                             |
1998    -0.1156                                   =====|
1999    -0.1780                                 =======|
2000     0.0408                                             |==
2001     0.3567                                             |==============
2002    -0.0467                                           ==|
2003     0.0063                                             |
2004     0.0000                                             |
                  -------------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004=
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	*	2.888E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.739E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.607E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	2.476E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	2.338E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	2.140E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.819E+02	0.00000	0.0
8	1972	1.000E+00	1.000E+00	0.0	1.060E+02	1.452E+02	-0.31474	-3.921E+01
9	1973	1.000E+00	1.000E+00	0.0	2.170E+02	1.143E+02	0.64072	1.027E+02
10	1974	1.000E+00	1.000E+00	0.0	1.290E+02	9.493E+01	0.30672	3.407E+01
11	1975	1.000E+00	1.000E+00	0.0	1.260E+02	8.129E+01	0.43830	4.471E+01
12	1976	1.000E+00	1.000E+00	0.0	1.310E+02	8.052E+01	0.48667	5.048E+01
13	1977	1.000E+00	1.000E+00	0.0	1.880E+02	8.947E+01	0.74252	9.853E+01
14	1978	1.000E+00	1.000E+00	0.0	1.100E+02	9.312E+01	0.16661	1.688E+01
15	1979	1.000E+00	1.000E+00	0.0	9.800E+01	9.122E+01	0.07173	6.783E+00
16	1980	1.000E+00	1.000E+00	0.0	1.640E+02	9.213E+01	0.57668	7.187E+01
17	1981	1.000E+00	1.000E+00	0.0	1.580E+02	9.623E+01	0.49584	6.177E+01
18	1982	1.000E+00	1.000E+00	0.0	1.250E+02	1.001E+02	0.22213	2.490E+01
19	1983	0.000E+00	0.000E+00	0.0	*	1.081E+02	0.00000	0.0
20	1984	1.000E+00	1.000E+00	0.0	1.320E+02	1.137E+02	0.14900	1.827E+01
21	1985	1.000E+00	1.000E+00	0.0	8.500E+01	1.029E+02	-0.19086	-1.787E+01
22	1986	1.000E+00	1.000E+00	0.0	4.200E+01	7.918E+01	-0.63400	-3.718E+01
23	1987	1.000E+00	1.000E+00	0.0	3.000E+01	6.410E+01	-0.75931	-3.410E+01
24	1988	1.000E+00	1.000E+00	0.0	2.300E+01	5.745E+01	-0.91545	-3.445E+01
25	1989	1.000E+00	1.000E+00	0.0	4.400E+01	5.514E+01	-0.22570	-1.114E+01
26	1990	1.000E+00	1.000E+00	0.0	2.700E+01	5.382E+01	-0.68988	-2.682E+01
27	1991	1.000E+00	1.000E+00	0.0	2.750E+01	4.621E+01	-0.51902	-1.871E+01
28	1992	0.000E+00	0.000E+00	0.0	*	3.969E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	3.272E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	3.231E+01	0.00000	0.0
31	1995	0.000E+00	0.000E+00	0.0	*	4.467E+01	0.00000	0.0
32	1996	0.000E+00	0.000E+00	0.0	*	6.307E+01	0.00000	0.0
33	1997	0.000E+00	0.000E+00	0.0	*	8.566E+01	0.00000	0.0
34	1998	0.000E+00	0.000E+00	0.0	*	1.085E+02	0.00000	0.0
35	1999	0.000E+00	0.000E+00	0.0	*	1.279E+02	0.00000	0.0
36	2000	0.000E+00	0.000E+00	0.0	*	1.420E+02	0.00000	0.0
37	2001	0.000E+00	0.000E+00	0.0	*	1.499E+02	0.00000	0.0
38	2002	0.000E+00	0.000E+00	0.0	*	1.578E+02	0.00000	0.0
39	2003	0.000E+00	0.000E+00	0.0	*	1.653E+02	0.00000	0.0
40	2004	0.000E+00	0.000E+00	0.0	*	1.691E+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    -0.3147                                =============|
1973     0.6407                                             |==========================
1974     0.3067                                             |============
1975     0.4383                                             |==================
1976     0.4867                                             |===================
1977     0.7425                                             |==============================
1978     0.1666                                             |=======
1979     0.0717                                             |===
1980     0.5767                                             |=======================
1981     0.4958                                             |====================
1982     0.2221                                             |=========
1983     0.0000                                             |
1984     0.1490                                             |======
1985    -0.1909                                     ========|
1986    -0.6340                    =========================|
1987    -0.7593               ==============================|
1988    -0.9155        =====================================|
1989    -0.2257                                    =========|
1990    -0.6899                 ============================|
1991    -0.5190                        =====================|
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                                             |
                   ------------------------------------------------------------------------------------
```

3LNO ytail (v3.81, 2002 formulation with 2004 data) 2004= RESULTS FOR DATA SERIES # 5 (NON-BOOTSTRAPPED)
Spanish Survey Converted biomass

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1965	0.000E+00	0.000E+00	0.0	*	2.255E+02	0.00000	0.0
2	1966	0.000E+00	0.000E+00	0.0	*	2.138E+02	0.00000	0.0
3	1967	0.000E+00	0.000E+00	0.0	*	2.035E+02	0.00000	0.0
4	1968	0.000E+00	0.000E+00	0.0	*	1.933E+02	0.00000	0.0
5	1969	0.000E+00	0.000E+00	0.0	*	1.825E+02	0.00000	0.0
6	1970	0.000E+00	0.000E+00	0.0	*	1.670E+02	0.00000	0.0
7	1971	0.000E+00	0.000E+00	0.0	*	1.420E+02	0.00000	0.0
8	1972	0.000E+00	0.000E+00	0.0	*	1.134E+02	0.00000	0.0
9	1973	0.000E+00	0.000E+00	0.0	*	8.926E+01	0.00000	0.0
10	1974	0.000E+00	0.000E+00	0.0	*	7.410E+01	0.00000	0.0
11	1975	0.000E+00	0.000E+00	0.0	*	6.346E+01	0.00000	0.0
12	1976	0.000E+00	0.000E+00	0.0	*	6.286E+01	0.00000	0.0
13	1977	0.000E+00	0.000E+00	0.0	*	6.984E+01	0.00000	0.0
14	1978	0.000E+00	0.000E+00	0.0	*	7.269E+01	0.00000	0.0
15	1979	0.000E+00	0.000E+00	0.0	*	7.121E+01	0.00000	0.0
16	1980	0.000E+00	0.000E+00	0.0	*	7.192E+01	0.00000	0.0
17	1981	0.000E+00	0.000E+00	0.0	*	7.512E+01	0.00000	0.0
18	1982	0.000E+00	0.000E+00	0.0	*	7.814E+01	0.00000	0.0
19	1983	0.000E+00	0.000E+00	0.0	*	8.440E+01	0.00000	0.0
20	1984	0.000E+00	0.000E+00	0.0	*	8.878E+01	0.00000	0.0
21	1985	0.000E+00	0.000E+00	0.0	*	8.031E+01	0.00000	0.0
22	1986	0.000E+00	0.000E+00	0.0	*	6.181E+01	0.00000	0.0
23	1987	0.000E+00	0.000E+00	0.0	*	5.004E+01	0.00000	0.0
24	1988	0.000E+00	0.000E+00	0.0	*	4.485E+01	0.00000	0.0
25	1989	0.000E+00	0.000E+00	0.0	*	4.304E+01	0.00000	0.0
26	1990	0.000E+00	0.000E+00	0.0	*	4.202E+01	0.00000	0.0
27	1991	0.000E+00	0.000E+00	0.0	*	3.607E+01	0.00000	0.0
28	1992	0.000E+00	0.000E+00	0.0	*	3.098E+01	0.00000	0.0
29	1993	0.000E+00	0.000E+00	0.0	*	2.554E+01	0.00000	0.0
30	1994	0.000E+00	0.000E+00	0.0	*	2.522E+01	0.00000	0.0
31	1995	1.000E+00	1.000E+00	0.0	9.300E+00	3.487E+01	-1.32161	-2.557E+01
32	1996	1.000E+00	1.000E+00	0.0	4.330E+01	4.924E+01	-0.12852	-5.938E+00
33	1997	1.000E+00	1.000E+00	0.0	3.870E+01	6.687E+01	-0.54689	-2.817E+01
34	1998	1.000E+00	1.000E+00	0.0	1.226E+02	8.470E+01	0.36983	3.790E+01
35	1999	1.000E+00	1.000E+00	0.0	1.970E+02	9.982E+01	0.67981	9.718E+01
36	2000	1.000E+00	1.000E+00	0.0	1.447E+02	1.109E+02	0.26618	3.382E+01
37	2001	1.000E+00	1.000E+00	0.0	1.827E+02	1.170E+02	0.44570	6.570E+01
38	2002	1.000E+00	1.000E+00	0.0	1.485E+02	1.232E+02	0.18681	2.530E+01
39	2003	1.000E+00	1.000E+00	0.0	1.368E+02	1.290E+02	0.05858	7.783E+00
40	2004	0.000E+00	0.000E+00	0.0	*	1.320E+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    -1.3216                   ==========================|
1996    -0.1285                                          ===|
1997    -0.5469                                  ===========|
1998     0.3698                                             |=======
1999     0.6798                                             |==============
2000     0.2662                                             |=====
2001     0.4457                                             |=========
2002     0.1868                                             |====
2003     0.0586                                             |=
2004     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

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

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	2.412E+00	2.222E+00	-7.89%	2.287E+00	2.698E+00	2.525E+00	2.698E+00	1.727E-01	0.072
K	1.580E+02	1.603E+02	1.46%	1.449E+02	1.734E+02	1.499E+02	1.649E+02	1.503E+01	0.095
r	4.421E-01	4.379E-01	-0.94%	3.885E-01	5.102E-01	4.148E-01	4.761E-01	6.138E-02	0.139
q(1)	3.232E+00	3.220E+00	-0.36%	2.702E+00	3.896E+00	2.941E+00	3.557E+00	6.158E-01	0.191
q(2)	8.187E-01	8.261E-01	0.91%	6.674E-01	9.826E-01	7.325E-01	8.998E-01	1.674E-01	0.204
q(3)	3.613E+00	3.647E+00	0.94%	2.829E+00	4.504E+00	3.164E+00	4.062E+00	8.981E-01	0.249
q(4)	1.670E+00	1.669E+00	-0.09%	1.402E+00	1.984E+00	1.545E+00	1.845E+00	2.998E-01	0.180
q(5)	1.289E+00	1.303E+00	1.08%	1.020E+00	1.680E+00	1.140E+00	1.478E+00	3.373E-01	0.262
MSY	1.735E+01	1.755E+01	1.12%	1.643E+01	1.833E+01	1.696E+01	1.782E+01	8.525E-01	0.049
Ye(2005)	1.610E+01	1.622E+01	0.74%	1.469E+01	1.721E+01	1.551E+01	1.666E+01	1.151E+00	0.071
Bmsy	7.899E+01	8.014E+01	1.46%	7.243E+01	8.668E+01	7.495E+01	8.247E+01	7.516E+00	0.095
Fmsy	2.210E-01	2.190E-01	-0.94%	1.942E-01	2.551E-01	2.074E-01	2.381E-01	3.069E-02	0.139
fmsy(1)	6.823E-02	6.800E-02	-0.34%	5.674E-02	8.180E-02	6.150E-02	7.508E-02	1.359E-02	0.199
fmsy(2)	2.693E-01	2.650E-01	-1.60%	2.347E-01	3.144E-01	2.507E-01	2.921E-01	4.134E-02	0.154
fmsy(3)	6.061E-02	6.004E-02	-0.93%	4.811E-02	7.681E-02	5.393E-02	6.879E-02	1.486E-02	0.245
fmsy(4)	1.322E-01	1.312E-01	-0.77%	1.184E-01	1.494E-01	1.246E-01	1.407E-01	1.608E-02	0.122
fmsy(5)	1.701E-01	1.681E-01	-1.18%	1.290E-01	2.244E-01	1.476E-01	1.974E-01	4.986E-02	0.293
F(0.1)	1.989E-01	1.971E-01	-0.84%	1.748E-01	2.296E-01	1.866E-01	2.143E-01	2.762E-02	0.139
Y(0.1)	1.718E+01	1.737E+01	1.11%	1.627E+01	1.815E+01	1.679E+01	1.764E+01	8.439E-01	0.049
B-ratio	1.290E+00	1.275E+00	-1.14%	1.080E+00	1.437E+00	1.186E+00	1.370E+00	1.843E-01	0.143
F-ratio	6.538E-01	6.536E-01	-0.03%	5.496E-01	8.225E-01	5.928E-01	7.212E-01	1.284E-01	0.196
Y-ratio	9.173E-01	9.243E-01	0.76%	8.092E-01	9.897E-01	8.640E-01	9.656E-01	1.015E-01	0.111
f0.1(1)	6.141E-02	6.120E-02	-0.31%	5.107E-02	7.362E-02	5.535E-02	6.758E-02	1.223E-02	0.199
f0.1(2)	2.424E-01	2.385E-01	-1.44%	2.113E-01	2.829E-01	2.257E-01	2.629E-01	3.721E-02	0.154
f0.1(3)	5.455E-02	5.404E-02	-0.84%	4.330E-02	6.913E-02	4.854E-02	6.191E-02	1.337E-02	0.245
f0.1(4)	1.190E-01	1.181E-01	-0.69%	1.065E-01	1.344E-01	1.122E-01	1.266E-01	1.447E-02	0.122
f0.1(5)	1.531E-01	1.513E-01	-1.06%	1.161E-01	2.020E-01	1.328E-01	1.777E-01	4.487E-02	0.293
q2/q1	2.550E-01	2.566E-01	0.62%	2.047E-01	3.175E-01	2.291E-01	2.879E-01	5.882E-02	0.231
q3/q1	1.134E+00	1.133E+00	-0.14%	9.458E-01	1.379E+00	1.033E+00	1.264E+00	2.303E-01	0.203
q4/q1	5.156E-01	5.183E-01	0.52%	4.099E-01	6.269E-01	4.585E-01	5.674E-01	1.090E-01	0.211
q5/q1	4.018E-01	4.046E-01	0.71%	3.292E-01	4.932E-01	3.584E-01	4.496E-01	9.121E-02	0.227

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:	22
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	0
Residual-adjustment factor:	1.0589