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Stock Assessment of Georges Bank (5Zjmnh) Yellowtail Flounder for 2001

Bilan de 2001 de l'état du stock de limande à queue jaune du banc Georges (5Zjmnh).

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Abstract

The combined Canada/USA yellowtail flounder (*Limanda ferruginea*) catch has been increasing since 1995, and in 2000 was 6,895 t. While fishermen reported lower catch rates in 2000 compared with 1999, recent groundfish survey trends in abundance indicate that the stock is still at a relatively high level compared to the early 1990s. Population biomass (age 1+) has increased 10 fold since 1995, and is at the highest observed level since 1973. However, the age structure is truncated and dominated by younger ages. Recent recruitment has improved relative to the 1980s, and the 1997 year-class appears to be the strongest since 1973. The 1996, 1998 and 1999 year-classes appear to be of moderate strength. Exploitation rates on ages 4+ have been less than $F_{0.1}$ (20%) in 1999 and 2000, while exploitation at ages 2 and 3 have not declined to the same extent. At the $F_{0.1}$ yield of 9,200t, which corresponds to about 50% probability of exceeding $F_{0.1}$, the biomass is not likely to decrease and there is an 80% probability of not achieving 10% increase from the beginning of the year 2001 to 2002. The dominant 1997 year-class is expected to contribute about 40% of the expected yield in 2001, and comprises about 32% of the total biomass.

Résumé

Les prises canado-américaines combinées de limande à queue jaune (Limanda ferruginea) sont à la hausse depuis 1995. Elles se chiffraient à 6 895 t en 2000. Bien que les pêcheurs aient signalé de plus faibles taux de capture en 2000 en comparaison de 1999, les récentes tendances de l'abondance issues des relevés du poisson de fond indiquent que les effectifs du stock sont encore relativement élevés par rapport au début des années 90. La biomasse de la population (âge 1+) a décuplé depuis 1995, se situant au plus haut niveau observé depuis 1973. La structure des âges est toutefois tronquée, les jeunes âges étant dominants. Le recrutement récent s'est amélioré par rapport aux années 80, la classe d'âge de 1997 semblant être la plus abondante depuis 1973, tandis que les classes de 1996, 1998 et 1999 semblent être d'abondance modérée. Les taux d'exploitation exercés sur les limandes d'âge 4+ étaient inférieurs à F0.1 (20 %) en 1999 et 2000, tandis que ceux exercés sur les âges 2 et 3 n'avaient pas diminué dans la même mesure. Au rendement à F0.1 de 9 200 t, qui correspond à une probabilité d'environ 50 % que le F0.1 sera dépassé, il est peu probable que la biomasse diminuera alors que la probabilité qu'elle n'augmentera pas par 10 % à partir du début de 2001 à 2002 se chiffre à 80 %. On s'attend à ce que la classe d'âge dominante de 1997 alimente environ 40 % du rendement prévu en 2001 et constitue environ 32 % de la biomasse totale.

Introduction

Georges Bank yellowtail flounder *(Limanda ferruginea)* are a transboundary resource in Canadian and U.S. jurisdictions. This paper updates the last stock assessment of yellowtail flounder on Georges Bank which was completed jointly by Canada and the USA (Cadrin et al., 2000). Similar methods are used in the current assessment, with updated catch information and indices of abundance from both countries.

Yellowtail flounder range from Labrador to Chesapeake Bay and are typically caught at depths between 37 and 73 m. A major concentration occurs on Georges Bank from the northeast peak to the east of the Great South Channel. Yellowtail flounder appear to be relatively sedentary, although seasonal movements have been reported (Royce *et al.* 1959). On Georges Bank, spawning occurs during late spring and summer, peaking in May. Larvae are pelagic for a month or more, then develop demersal form and settle to benthic habitats. Based on the distribution of both ichthyoplankton and mature adults, it appears that spawning occurs on both sides of the international boundary. Growth is sexually dimorphic, with females growing at a faster rate than males (Moseley 1986). Yellowtail flounder appear to have variable maturity schedules, with age two females considered 40% mature during periods of high stock biomass to 90% mature during periods of low stock biomass.

While tagging indicates limited movement from Georges Bank to adjacent areas (Royce et al. 1959; Lux 1963), knowledge of the seasonal movements of yellowtail flounder on Georges Bank is poor. The management unit is considered to include all of Georges Bank east of the Great South Channel, encompassing Canadian fisheries statistical areas 5Zj, 5Zm, 5Zn and 5Zh (Fig. 1a) and U.S. statistical reporting areas 522, 525, 551, 552, 561 and 562 (Fig. 1b). Both Canada and the USA employ the same management unit.

The Fisheries

Historically, landings of Georges Bank yellowtail flounder have been predominantly by the U.S. fleet and increased from 300 t in 1935 to 7,300 t in 1949, then decreased in the early 1950s to 1,600 t in 1956, and increased again in the late 1950s (Fig. 2: top panel). Annual catches including discards are available since 1963 (Fig. 2: bottom panel, Table 1), and have averaged 16,300 t during 1963-1976, with some taken by distant water fleets. No foreign catches of yellowtail have occurred since 1975. Catches averaged around 3,000 t between 1985 and 1994, then dropped to a record low of 788 t in 1995 when fishing effort was drastically reduced in order to allow the stock to rebuild. The USA fishery in the management area has been constrained by spatial expansion of Closed Area II in 1994 (Fig. 1b) and by extension to year-round closure in 1995. Since 1995, landings have steadily increased (with increasing quotas) and total catches in 2000 were 6,895 t.

USA

The principle fishing gear used in the USA fishery to catch yellowtail flounder is the otter trawl, but scallop dredges and sink gillnets contribute some landings. In recent years, otter trawls caught greater than 95% of total landings from the Georges Bank stock, dredges caught 2-5% of annual totals, and gillnet landings were less than 0.1%. U.S. trawlers that land yellowtail flounder generally target multiple species on the 'Southwest Part' of the Bank, and on the northern edge just west of the closed area adjacent to the international boundary. Current levels of recreational and foreign fishing are negligible.

U.S. landings were prorated to stock area using logbook data as described in Cadrin et al. (1998). Since 1995, the proportion of total yellowtail landings accounted for in logbooks had exceeded 90% (e.g., in 1999, 97% of total landings were accounted for). However, in 2000 the proportion dropped to 85% (primarily resulting from low proportions in the fourth quarter of the year). This reduced proportion adds uncertainty to the estimate of yellowtail landings by stock area in 2000. U.S. landings from Georges Bank increased 85% from 1999 to 2000 (Table 1). This estimate of landings may be slightly underestimated, because the biomass of yellowtail landed in New York in December is not yet available. Although New York has traditionally contributed a small portion of Georges Bank yellowtail landings, several large New York draggers were fishing for yellowtail on Georges in December. Therefore, the general magnitude of underestimated catch is not known. Total yellowtail landings (excluding discards) for the 2000 USA fishery were 3,678 t.

Discarding of small yellowtail in the U.S. fishery is an important source of mortality due to intense fishing pressure, discrepancies between minimum size limits and gear selectivity, and recently imposed trip limits for the scallop dredge fishery. Methods of estimating U.S. discards described in Cadrin et al. (1998) indicate that total discards were approximately 358 t in 2000 (scallop dredge: 301 t; otter trawl: 57 t), a decrease of 26% from 1999 (Table 1).

Canada

Canadian fishermen began directing for yellowtail flounder in 1993. Prior to 1993, Canadian landings were small, typically less than 100 t (Table 1, Fig. 2). Landings of 2,139 t of yellowtail occurred in 1994, when the fishery was unrestricted. After a TAC of 400 t was established, yellowtail landings dropped to 472 t in 1995. In the 2000 fishery, landings of yellowtail flounder were 2,859 t against a quota of 3,000 t (Table 1). The majority of Canadian landings of yellowtail flounder are made by otter trawl, from vessels less than 65 ft, tonnage classes (TC) 2 and 3. The fishery takes place from June to December, with peak months for fishing activity in 2000 occurring from July to October.

Canadian landings for 1993, 1994 and 1995 were revised in 1997 to account for catches of unspecified flounder species. While these changes were incorporated into the catch at age (Neilson et al.,1997), the landings table in the 1997 Research Document was not updated to include the revised landings for these three years. The corrected Canadian landings are shown in Table 1 (shaded grey), and differ only slightly from the values reported in 1997 (i.e. 1993: 675 *vs* 696; 1994: 2139 *vs* 2142; 1995: 472 *vs* 495).

Flatfish landed as "unspecified" in the Canadian fishery have been significant in previous years, and generally consist of yellowtail on Georges Bank. The unspecified flounder problem has become less significant recently, due to improved monitoring of the landings. For the 2000 fishery, unspecified flounder landings were obtained by applying the monthly proportions of known yellowtail landings in 5Zm and 5Zj (based on the ratio of known yellowtail catch to known yellowtail + other flounder species catch) to unspecified flounder landings from matching area/month strata. Total unspecified flounder landings in 2000 estimated to be yellowtail, were 23 t and 22 t for 5Zm and 5Zj, respectively, and are included as part of the Canadian landings (Table 1).

Canadian yellowtail directed fishing activity was concentrated in the southern half of the Canadian fishing zone, in the portion of 5Zm referred to as the "Yellowtail Hole". The distribution of fishing activity over the past six years is shown on Fig. 3. Overall, the fishery distribution in 2000 was comparable to that observed in the previous five years, the only difference being additional catches along the international boundary line in the northern portion of 5Zm.

In previous years, there have been some landings of yellowtail flounder in the Canadian scallop fishery on Georges Bank. Management measures established in 1996 prohibit the landing of yellowtail flounder by this fleet, and no records of discarded quantities are available since 1996. This represents a source of mortality for this resource that is of unknown magnitude, and efforts are required to quantify discarded catches. In 1996, at-sea observer records estimated the amount of discarded yellowtail flounder as 11 t. In 2000, the location of the scallop fishery shifted to the northeast peak of Georges Bank, away from the main area where yellowtail are concentrated. A program is being considered for 2001 to examine yellowtail flounder bycatch in the offshore scallop fishery.

Length and Age Composition

In 2000, the Canadian fishery was well sampled for lengths by sex, with 14,168 measurements available from 58 port samples. In addition to regular Department of Fisheries and Oceans (DFO) port sampling staff, the fishing industry funded their own port sampling technician, which greatly increased the number of samples available for the 2000 fishery. Sea samples were obtained from 34 commercial trips by Canadian observers, but only 12 of these trips had complete length information by sex (Fig. 4). For many observed trips, sexes were either undetermined, or only a portion was determined.

The past problem of species misidentification and inaccurate sex determination in the Canadian sea samples was not apparent in 2000. Therefore, length information from the 12 observed trips with sex determinations (9,657 observations) along with length samples from the DFO/Industry port-sampling program were used to characterize the size composition of the Canadian fishery. The comparability of the length-frequency information from the two sources also supports the view that culling on the basis of length was not a major concern in the 2000 fishery (Fig. 4).

Although the overall number of U.S. yellowtail samples increased substantially in 2000 compared to recent years, the number of samples taken from the Georges Bank fishery continues to be poor (Table 2). Only 3300 measurements were available in 2000 (excluding those from the scallop exemption program) compared to 5400 in 1999. Also, there were several strata that were not sampled (i.e. the small market category was not sampled in the second and third quarters). However, there was very good sampling of yellowtail bycatch in the offshore scallop fishery, with over 31,000 length samples from the scallop exemption program in Closed Area II.

The mean length of yellowtail flounder in the Canadian fishery increased between 1996 and 1998 from 33 to 35 cm total length for males and from 35 to 40 cm for females (Fig 5). Over the past three years, size composition in the Canadian fishery has essentially been stable averaging about 35 cm total length for males, and 40 cm for females, with some variation in the relative proportions between sexes. Males represented 46% of the total catch in 2000, compared to 25% in 1999. The catch at length for Canadian and USA fisheries was quite similar in 2000 although it tended to be more peaked in the US fishery (Fig. 6).

As in past assessments, no age determinations were available for the Canadian fishery. Canada collects age determination material, but the age determination program is not yet operational. Therefore, separate-sex age-length keys from combined 2000 USA fall survey and second half commercial port sample ages were applied to Canadian length samples to construct the catch at age (CAA) by sex for the Canadian portion of the management area. A total of 187 male and 277 female ages were available (compared to 274 male and 647 female ages available for the previous assessment). The low number of age determinations has once again compromised the reliability of the age length keys.

For the USA fishery, sample length frequencies were expanded to total landings at size using the ratio of landings to sample weight (predicted from length-weight relationships by sex and season; Lux 1969), and apportioned to age using pooled-sex age-length keys. Commercial landings at age were derived from port sample ages. Discards at age were derived from port sample ages, supplemented with survey ages for sublegal-sized yellowtail.

The combined catch at age and weight at age information for both countries is shown in Tables 3 and 4, respectively. Age 2 and 3 males and 2-4 females represent most of the Canadian catch in 2000 (Fig.7). The high proportion of age 2 males is suprising given that age 2 yellowtail were approximately 30% recruited to the fishery in recent years. While the average length of age 2 and 3 males and females in the Canadian CAA has been fairly consistent over the past 4 years, average sizes for older fish of both sexes has been quite variable, and may reflect variability in aging or spatial differences in sampling (Table 5).

USA age composition is not available by sex (CAA is done for combined sexes) but shows fewer age 2 and more age 4 fish in 2000 compared to 1999, with age 3 most prevalent. Compared to the Canadian fishery, the USA fishery in 2000 had a higher proportion of age 4 fish, while the Canadian fishery had more 2's and 3's. The 1997 year-class (age 3) dominated the catch in 2000, but there is limited indication of year-class tracking in the catch at age overall (Fig. 8, Table 3).

Mean weight at age was calculated from Canadian (separate sex) and USA (combined sex) fishery CAA data and USA discard CAA data (Table 4, Fig. 9). The commercial fishery mean weight at age data was revised to include calculated weights for age 1 fish rather than the assigned value of 0.01 (used in past assessments). An increasing trend in weight at age is apparent for ages 2-5 from 1996 to 1999, with the 2000 fishery weights at age being similar to 1999.

Abundance Indices

Commercial Fishery Catch Rates

Catch (t) and effort (h) data for Canadian otter trawlers < 65' fishing for yellowtail flounder were aggregated by month and year, and monthly catch rates (t/h) calculated for 1993-2000 (Fig. 10). Only trips in 5Zm with more than 0.5 t of yellowtail flounder landed were included in catch rate estimates, since previous analyses have shown that they are most representative of yellowtail directed effort. Fishery catch rates decreased between 1993 and 1994 but increased by a factor of over two between 1994 and 1995, with a further increase in 1996. Catch rates were stable from 1996 to 1998 then increased considerably in 1999 when some of the fleet switched to more efficient flounder gear. In 2000, catch rates dropped to less than half of what they were in 1999.

During past discussions with industry, it was concluded that the increases in catch rates up to 1996 in this relatively new fishery probably reflected increased biomass, but were also influenced by the developing skill of fishermen as well as gear development. It was also noted that the increase in catch rates from 1998 to 1999 may have under-represented the increase in abundance, since a significant number of fishermen did not switch to flounder gear. (Catch rates may have been even higher in 1999 if more of the fleet had switched to using flounder gear).

At the March 2001 industry consultation, it was confirmed that catch rates were lower during the 2000 fishery, but the reason for this apparent decline is unclear. While several factors may have had a negative effect on catch rates, including use of larger mesh gear (165 mm square), the addition new less-experienced participants in the fishery and movement to areas with lower catch rates to avoid skates, fishermen with a history of fishing yellowtail clearly noted a decline. Commercial catch rate indices will require further investigation before they are used as an index of abundance for VPA calibration.

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by DFO in the spring (February) and by the United States National Marine Fisheries Service (NMFS) in the spring (April) and fall (October). Both agencies use a stratified random design, though different strata boundaries are defined (Fig. 11). NMFS spring and fall bottom trawl survey catches (strata 13-21), NMFS scallop survey catches, and DFO spring bottom trawl survey catches (strata 5Z1-5Z4, Fig. 11) were used to estimate relative stock biomass and relative abundance at age for Georges Bank yellowtail. Conversion coefficients, which compensate for survey door, vessel, and net changes in NMFS groundfish surveys (1.22 for old doors, 0.85 for the Delaware II, and 1.76 for the 'Yankee 41' net; Rago et al. 1994) were applied to the catch of each tow. For all three groundfish surveys, the distribution of catches in the most recent survey is comparable with those distributions observed in the previous five years, on the average (see Figs. 12, 13 and 14 for the DFO spring, NMFS spring and fall surveys, respectively).

The DFO spring biomass index shows an increasing trend since 1995 and the 2001 value is the highest in the series. The NMFS spring series is longer, and tracks the DFO series well during the years of overlap up to 1999, but shows a decrease for 2000 (Tables 6 and 7, Fig. 15). The NMFS fall survey, which is the longest running time series, also shows an increase from 1995 to 1999, with a slight drop in 2000 (Table 8, Fig. 15).

The length composition of the catch of yellowtail flounder taken in the DFO surveys has been fairly consistent since 1997 (Fig. 16) and like the commercial fishery size composition, does not show any year class progression. In the 2000 and 2001 surveys, there appears to be an absence of fish in the 20-30 cm range. There has also been an increase in the proportion of males in the catch during the past two years (64% male in 2000/2001 *vs* 50% in 1999).

Age-structured indices of abundance for NMFS spring and fall surveys were derived using survey-specific age-length keys. Since age interpretation of yellowtail structures collected from the DFO survey are not available for any year, age-length keys from NMFS spring surveys were substituted to derive age composition for the DFO spring surveys. All three surveys gave a consistent view that the 1997 (age 3) year class was quite strong in 2000 (Tables 6-8; Fig. 17). Overall, age-structured indices from the survey did not always track cohorts well (Fig. 18). Also, there are some indications of year-effects in the series, as indicated in the DFO spring surveys.

The NMFS scallop survey is used as an index of "mid-year" age 1 yellowtail recruitment since small yellowtail are a common bycatch in this survey. While the 1999 and 2000 values have shown a decrease since 1998, the overall trend since 1990 is one of increasing age 1 year class abundance (Table 9).

As a corresponding age-length key for the DFO spring 2001 survey was not available, an iterative technique using the NMFS spring 2000 length at age information was applied (Kimura and Chikuni 1987). However, yellowtail flounder appear to grow very slowly beyond about 30-35cm, making substitution of age-length keys from other sources and years a questionable practice. Also, the use of iterative methods employing length-at-age templates tends to perform poorly when most of the fish in the population have reached the slow growth phase. The iterative method indicated that the 1998 year-class from the DFO 2001 survey was stronger than the 1997 year-class, contrary to what was expected. Therefore, the use of the iterative method to derive age composition for the DFO 2001 survey was rejected and this index was not used in the VPA assessment analysis.

Estimation of Stock Parameters

Calibration of VPA

The Virtual Population Analysis (VPA) used annual catch at age, $C_{a,t}$, for ages a = 1 to 6+, and time t = 1973 to 2000, where t represents the beginning of the time interval during which the catch was taken. The VPA was calibrated to bottom trawl and scallop survey abundance indices, $I_{s,a,t}$, for

s = DFO spring, ages a = 2 to 6+, time t = 1987 to 2000
s = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 2000
s = NMFS spring (Yankee 41), ages a = 1 to 6+, time t = 1973 to 1981
s = NMFS fall, ages a = 1 to 6+, time t = 1973.5 to 2000.5
s = NMFS scallop, age a = 1, time t = 1982.5 to 2000.5

Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. Data were aggregated for ages 6 and older to mitigate against frequent zero observations. The fishing mortality rate for the 6 plus group was calculated according to the "alpha" method (Restrepo and Legault 1994).

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey abundance trend results. The model formulation employed assumed that the random error in the catch at age was negligible. The errors in the abundance indices were assumed independent and identically distributed after taking natural logarithms of the values. The annual natural mortality rate, M, was assumed constant and equal to 0.2. The fishing mortality rates for age groups 5 and 6+ were assumed equal. These model assumptions and methods were similar to those applied in the last assessment (Cadrin et. al, 2000). Both analytical and bootstrap statistics of the estimated parameters were derived. For consistency with the risk analysis, bias adjusted VPA results were based on bootstrap statistics.

The population abundance estimates show large relative error and substantial bias for ages 2 and 3 while the relative error for older ages is about 34% or less and the bias is small (Table 10). Relative error and bias for all ages are higher than estimates from the previous assessment in 2000. The average magnitude of residuals is large and though several large residuals can be identified, the respective observations do not appear influential and should not impact parameter estimates of current abundance (Figs. 18-23). Retrospective analysis from the USA "Fact" VPA software indicates a strong tendency to overestimate the abundance of fish aged 3 and older since 1994 (Fig. 24). As a result, fishing mortality on ages 3+ has been underestimated in recent assessments.

As in previous assessments, VPA calibration was performed using both DFO (Table 10) and U.S. FACT software (Appendix A). As discussed in Cadrin *et al*. (2000) slight differences in search algorithms, bias correction, and computations produce slightly different results. The following text and figures are based on results from DFO software, except where noted.

Surplus Production Analyses

As was done last year, and recognizing the uncertainties in the age-structured information, an assessment method that does not rely upon age-structured data was also used. The ASPIC non-equilibrium surplus production methodology (Prager 1995) requires total catch and one or more indices of abundance. The indices used were DFO spring survey (1987 to 2001, lagged one year to reflect end of previous year biomass), NMFS spring (1968 to 1972; 1982-2000, lagged one year), and NMFS fall (1963 to 2000). The NMFS spring survey was subdivided into two periods when theYankee-36 trawl was used. The NMFS spring Yankee-41 trawl series (1973-1981) has been omitted from recent assessments since it is not considered to be influential. Yield input (1963-2000) includes estimates of USA discards.

Estimates of initial biomass (B_1), maximum sustainable yield (MSY), intrinsic rate of increase (r), and catchability of each survey (q) were estimated using nonlinear least squares of survey residuals. Following the advice of Prager (1995), the first five years of output from ASPIC are not presented, since the starting biomass in the first year is poorly estimated. For comparative purposes, a Bayesian Surplus Production (BSP) model was examined to provide collaboration of the ASPIC results (Appendix B). The results of the BSP model provided support for the ASPIC results.

Stock Status

Virtual Population Analysis

The results from the standard lognormal model formulation were considered appropriate on which to base the status of the stock. For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias in DFO software and used to construct the history of stock status (Tables 11-12). In the absence of an unbiased point estimator with optimal statistical properties, this approach was considered preferable to using the biased point estimates. The fishery weights at age, assumed to represent mid-year weights, were used to derive beginning of year weights at age, (Table 13) and these were used to calculate beginning of year population biomass (Table 14).

Population biomass (Ages 1-6+) declined from about 32,000 t in 1973 to a historic low of about 3,600 t in 1988 and has subsequently increased steadily to almost 51,000 t at the beginning of 2001 (Table 14, Fig. 25). The increasing trend is due principally to improved recruitment in the 1990s, but was also enhanced by increased survivorship of young yellowtail through reduced exploitation. Biomass for ages 3+ shows a similar trend and was estimated at 41,000 t at the beginning of 2001. Estimates of spawning stock biomass (SSB) from FACT software were 21,000 t in 1973, declined to less than 4,000 t from 1984 to 1988, fluctuated below 6,000 t for 1989 to 1995, and steadily increased to 43,000 t in 2000 (Appendix A). The strength of the 1997 year-class was estimated to be almost 73 million at age 1, the largest since 1973 (Fig. 26), however this estimate was lower than the previous estimate of 83 million from the 2000 assessment. Current indications for the adjacent 1996 and 1998 year-classes indicate that they are also strong relative to those observed in the 1980's, with 47 and 41 million recruits, respectively.

Biomass weighted fishing mortality from the VPA and the surplus production model show similar patterns of exploitation rate. The fully recruited (4+) exploitation rate underwent a marked decline from 1994-2000 and has been below 20% (equivalent to $F_{0.1}$ =0.25) for the last 2 years (Fig. 27). However, exploitation on ages 2 and 3 has not decreased proportionately and the partial recruitment to the fishery for these ages has increased. Fishing mortality on total biomass (the U.S. overfishing definition is F on biomass > 0.3) was 0.12 in 2000. Since 1973, exploitation rate has substantially exceeded $F_{0.1}$ averaging about 50%. Reduced fishing mortality in recent years has resulted in increased survival of incoming year-classes. However, F on age 2 in 2000 was more than double that estimated for age 2 in 1999. Similarly, F on age 3 was also higher in 2000. The large change in PR is a concern given the poor sampling and few age samples available for the 2000 fishery.

Gains in fishable biomass may be partitioned into those associated with somatic growth of yellowtail which have previously recruited to the fishery and those associated with new recruitment to the fishery (Rivard 1980). We used age 2 as a convenient age of first recruitment to the fishery. On average, growth contributes about 50% of total production, ranging from 36-79% since 1973 (Fig. 28). Surplus production is defined as the gains in fishable biomass which are in excess of the needs to offset losses from natural mortality. When the fishery yield is less than the surplus production, there is a net increase in the population biomass. Since 1995, there was considerable production in excess of fishery removals up to 1999. In 2000, surplus production was estimated to be much lower at 8,460 t compared to 21,500 t in 1999. The high value observed in 1999 is likely influenced by the strong 1997 year-class and the trend of increasing size at age (Table 5) observed in males and females after 1998. The yield for Age 2+ has increased steadily since 1995 and in 2000 was estimated to be 5,900 t.

Surplus Production Analyses

Correlations among survey biomass indices were strong (r= 0.79, 0.86, and 0.93; Appendix C). Most of the variance in survey indices was explained by the model (R^2= 0.64, 0.74, and 0.87). There were no apparent residual problems, and biomass residuals in the last year were small and positive for the NMFS fall and DFO spring surveys (*i.e.* surveys indicate greater current biomass than the model) and negative for the NMFS spring survey. The nonlinear solution was sensitive to the starting conditions when default convergence criteria were used (Prager 1995). Therefore, convergence criteria were made more restrictive (same as in previous 2000 assessment). Survey residuals were randomly resampled 1,000 times for bootstrap estimates of precision and model bias. A large portion of bootstrap trials did not meet the convergence criteria, indicating that bootstrap variance is probably underestimated. The bootstrap analysis indicated that MSY, and *r* were very well estimated (the relative interquartile ranges, IQR, were <6%), but that B_1 and survey *q*'s were more variable (relative IQRs=11%-18%). Bootstrap calculations of *K*, B_{MSY}, and F_{MSY} were stable (relative IQRs=6%), but ratios of current conditions to MSY conditions (F_{2000}/F_{MSY} and B_{2001}/B_{MSY}) were less precise (relative IQRs=11-13%).

ASPIC results indicate that a maximum sustainable yield of 14,110 t can be produced when the stock biomass (B_{MSY}) is 43,600 t at equilibrium. The population biomass in 2001 continues to increase, and is now estimated to be 55,550 t. Trends in biomass indicated from the surplus production analyses are very similar to those obtained from the VPA, but showed a greater increase for 2000 (Fig. 26). The exploitation rate on total biomass in 2000 (0.112) increased slightly from 1999 (0.087), but is still low. Trends in exploitation rate indicated from surplus production are qualitatively similar to those obtained from the VPA but do not show the same decline after 1996 indicated in the exploitation rate for ages 3+ from the VPA (Fig. 27).

Fishery Reference Points

Yield per Recruit Reference Points

Although the yield per recruit analysis in was not updated this year, an estimate of $F_{0.1}$ for ages 4+ was calculated based on the equilibrium age structure from the past yield per recruit analysis of Neilson and Cadrin (1998). ($F_{0.1}$ for ages 4+ = 0.25; exploitation rate=20.0%).

MSY Reference Points

The estimate of F_{MSY} from ASPIC (0.324, Appendix C) is slightly greater than those from previous assessments. The estimate of B_{MSY} from ASPIC (43,600 t) is less than the TRAC 2000 estimate, but similar to previous estimates. As discussed in Cadrin *et al.* (2000), B_{MSY} is not well estimated by the production model, because there are too few observations of high biomass in the assessment time series. Based on recent performance of the model and the increasing stock size, estimates of B_{MSY} are subject to change.

Stock and Recruitment

There is evidence of reduced recruitment at low levels of age 3+ biomass (Fig. 29). However, management actions by both countries appear to have been successful in building the population to levels where the probability of good recruitment is enhanced.

Outlook

Surplus Production Analyses

The projection was completed using the bias-corrected 90%F_{MSY} (=0.292) from ASPIC (Appendix D). Absolute biomass at the beginning of 2002 is projected to be 53,020 t. The projected 2001 yield at 90%F_{MSY} projected fishing mortality is 15,920 t, (combined Canada and USA catch). The projection results from the surplus production analyses imply high equilibrium recruitment levels that are not consistent with historical estimates. Accordingly, only the VPA projection results described in the following section are given further consideration.

A phase plot for the surplus production model illustrating observed yields and model (expected) yields for 1963 through 2001 is given in Fig. 30. The last point represents the projected yield in 2001 at 90%F_{MSY} and the beginning of year biomass in 2002. The interpretation of this plot is that harvesting at 90%F_{MSY} will result in a decrease in biomass, as we would be harvesting at a level that exceeds the overall production at the current level of biomass. Continued exploitation at that rate would result in a decline in population/yield.

Virtual Population Analysis

Yield projections were done using the bias adjusted 2001 beginning of year population abundance estimates. The abundance of the 2001 and 2002 year-classes were assumed to be 30 million at age 1. Fishery weights at age and beginning of year population weights at age were averaged over the previous 4 years (1997 through 2000) for use in the 2002 forecasts. Partial recruitment to the fishery for ages 1, 2 and 3, was averaged for the past 4 years (1997 and 2000, Table 15). There has been a considerable increase in PR on ages 2 and 3 since 1998, implying greater exploitation at younger ages.

If this change is real, it has important implications to harvest strategies and conservation (spawning potential). The PR values used in this year's projection calculations (average of 1997-2000) are slightly higher for age 2 but lower for age 3 compared to last year (i.e. age 2: 0.32 *vs* 0.2; age 3: 0.65 *vs* 0.67). Beginning of year weights at age were also higher for most age groups compared to last year's values.

Projected total Canada/USA yield at $F_{0.1}$ = 0.25 in 2001 would be about 9,200 t. If fished at $F_{0.1}$ in 2001, the total biomass is projected to decrease slightly from 50,642 t to 50,178 t by the beginning of 2002, with no change in the 3+ beginning of year biomass (Fig. 31). The 1997 year-class contributes about 40% of the expected yield in 2001, and about 26% of the total beginning of year biomass in 2002.

Uncertainty about year-class abundance generates uncertainty in forecast results. This uncertainty was expressed as risk of achieving reference targets. For example, with a *status quo* combined Canada and USA catch of 6,900 t, there is a small probability (6%) of exceeding $F_{0.1}$, and a high probability (60%) that total biomass will not increase by 10% in 2002 (Fig. 32). At the $F_{0.1}$ yield of 9,200 t, which corresponds to about 50% probability of exceeding $F_{0.1}$, the biomass is not likely to decrease and there is an 80% probability of not achieving 10% increase from the beginning of the year 2001 to 2002.

These uncertainty calculations do not include variations in weight at age, partial recruitment to the fishery and natural mortality, or systematic errors in data reporting and model mismatch. Therefore, overall uncertainty would be greater, but these results provide guidelines.

Although the population age structure has improved in recent years and population biomass has increased, the current age structure remains truncated, with few older fish and is dominated by younger ages (Fig. 33).

Management Considerations

This assessment is hampered by considerable problems in estimating age structure of the catch. The result of poor sampling of the U.S. catch and unavailability of age samples from the Canadian fishery and survey are that abundance of cohorts over time is not well monitored. Increased sampling intensity would allow consideration of sexually dimorphic growth for U.S. catch at age. Availability of Canadian age samples will eliminate the need to borrow samples from other sources which may represent different components of the stock.

Retrospective inconsistencies may reflect inadequate sampling and mis-allocation of catch at age. Retrospective patterns indicate that VPA estimates of biomass and F may be overly optimistic. Updated VPAs may indicate that 2001 biomass levels are lower, and 2001 F was greater than reported here.

Despite these problems, similarity of results from VPA and the production model are somewhat reassuring that conclusions about trends in stock size and fishing mortality are reliable. The stock has responded to low mortality rates in the last several years with substantial increases through growth and recruitment.

The exploitation history since the early 1960s provides little information on productivity of the stock at large biomass. Further evaluation of MSY reference points may require exploration of alternative models and incorporation of historical information. Such investigation is warranted because the biomass dynamics model indicates that the stock is rapidly approaching B_{MSY}, and a desire to shift management goals from rebuilding to optimization.

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Table 1. Annual catch (000s t) of Georges Bank yellowtail flounder. Canadian landings for 1993, 1994 and 1995 were revised (grey shading) for catches of unspecified flounder.

Year	US landings	US discards	Canadian Landings	Foreign Catch	Total Catch
1963	10.990	5.600	-	0.100	16.690
1964	14.914	4.900	-	0.000	19.814
1965	14.248	4.400	-	0.800	19.448
1966	11.341	2.100	-	0.300	13.741
1967	8.407	5.500	-	1.400	15.307
1968	12.799	3.600	-	1.800	18.199
1969	15.944	2.600	-	2.400	20.944
1970	15.506	5.533	-	0.250	21.289
1971	11.878	3.127	-	0.503	15.508
1972	14.157	1.159	-	2.243	17.559
1973	15.899	0.364	-	0.260	16.523
1974	14.607	0.980	-	1.000	16.587
1975	13.205	2.715	-	0.091	16.011
1976	11.336	3.021	-	-	14.357
1977	9.444	0.567	-	-	10.011
1978	4.519	1.669	-	-	6.188
1979	5.475	0.720	-	-	6.195
1980	6.481	0.382	-	-	6.863
1981	6.182	0.095	-	-	6.277
1982	10.621	1.376	-	-	11.997
1983	11.350	0.072	-	-	11.422
1984	5.763	0.028	-	-	5.791
1985	2.477	0.043	-	-	2.520
1986	3.041	0.019	-	-	3.060
1987	2.742	0.233	-	-	2.975
1988	1.866	0.252	-	-	2.118
1989	1.134	0.073	-	-	1.207
1990	2.751	0.818	-	-	3.569
1991	1.784	0.246	-	-	2.030
1992	2.859	1.873	-	-	4.732
1993	2.089	1.089	0.675	-	3.853
1994	1.589	0.141	2.139	-	3.869
1995	0.292	0.024	0.472	-	0.788
1996	0.751	0.039	0.483	-	1.273
1997	0.966	0.058	0.810	-	1.834
1998	1.822	0.114	1.175	-	3.111
1999	1.987	0.484	1.971	-	4.442
2000	3.678	0.358	2.859	-	6.895

Table 2. Port and sea samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2000. “Sc exp” denotes samples collected from the scallop exemption program which were used to generate length frequency distributions for bycatch (not landed) for this specific program only. (“Uncl”=unclassified).

USA	**Port Samples**				**Sea Samples**			**Landings**
Half	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	Small		94					615
	Large		668					1592
	Uncl		114					16
	All	11	876	200	7	493	0	2223
2	Small		598					472
	Large		988					968
	Uncl		300					15
	All	17	1886	405	3	40	0	1455
								238
	Sc exp				57	31763		

Canada	**Port Samples**				**Sea Samples**			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	0	0	0	0	0	0	0	0
2	All	5	1120	0	0	0	0	92
3	All	38	9342	0	8	7678	0	2093
4	All	15	3706	0	4	1979	0	674

Table 3. Total catch at age (number in 000's) including US discards, for Georges Bank yellowtail flounder, 1973-2000.

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1973	347	4890	13243	9276	3743	1259	278	81	33117
1974	2143	8971	7904	7398	3544	852	452	173	31437
1975	4372	25284	7057	3392	2084	671	313	164	43337
1976	615	31012	5146	1347	532	434	287	147	39520
1977	330	8580	9917	1721	394	221	129	124	21416
1978	9659	3105	4034	1660	459	102	37	35	19091
1979	233	9505	3445	1242	550	141	79	52	15247
1980	309	3572	8821	1419	321	85	4	10	14541
1981	55	729	5351	4556	796	122	4	0	11613
1982	2063	17491	7122	3246	1031	62	19	3	31037
1983	696	7689	16016	2316	625	109	10	8	27469
1984	428	1917	4266	4734	1592	257	47	17	13258
1985	650	3345	816	652	410	60	5	0	5938
1986	158	5771	978	347	161	52	16	8	7491
1987	140	2653	2751	761	132	39	32	41	6549
1988	483	2367	1191	624	165	15	20	3	4868
1989	185	1516	668	262	68	11	8	0	2718
1990	219	1931	6123	800	107	17	3	0	9200
1991	412	54	1222	2430	293	56	4	0	4471
1992	2389	8359	2527	1269	510	20	7	0	15081
1993	5194	1009	2777	2392	318	65	9	1	11765
1994	71	861	5742	2571	910	99	37	1	10292
1995	14	157	895	715	137	13	11	4	1946
1996	50	383	1509	716	167	9	5	1	2840
1997	16	595	1258	1502	341	26	45	19	3802
1998	26	971	2792	1824	624	82	20	0	6871
1999	21	3287	3209	1498	651	137	25	0	8828
2000	100	3731	5747	2824	798	273	33	18	13524

Table 4. Mean weight at age (kg) for the total catch, including US discards, of Georges Bank yellowtail flounder.

	Age							
Year	1	2	3	4	5	6	7	8+
1973	0.100	0.352	0.462	0.527	0.603	0.689	1.067	1.136
1974	0.108	0.345	0.498	0.609	0.680	0.725	0.906	1.249
1975	0.111	0.316	0.489	0.554	0.618	0.687	0.688	0.649
1976	0.106	0.312	0.542	0.636	0.741	0.814	0.852	0.866
1977	0.109	0.342	0.525	0.634	0.782	0.865	1.036	1.013
1978	0.100	0.315	0.510	0.684	0.793	0.899	0.930	0.948
1979	0.103	0.331	0.460	0.649	0.728	0.835	1.003	0.882
1980	0.100	0.325	0.493	0.656	0.813	1.054	1.256	1.214
1981	0.099	0.347	0.490	0.603	0.707	0.798	0.832	-
1982	0.112	0.301	0.486	0.650	0.748	1.052	1.024	1.311
1983	0.139	0.296	0.440	0.604	0.736	0.952	1.018	0.987
1984	0.162	0.240	0.378	0.500	0.642	0.738	0.944	1.047
1985	0.178	0.363	0.497	0.647	0.733	0.819	0.732	-
1986	0.176	0.342	0.540	0.664	0.823	0.864	0.956	1.140
1987	0.112	0.316	0.522	0.666	0.680	0.938	0.793	0.788
1988	0.100	0.325	0.555	0.688	0.855	1.054	0.873	1.385
1989	0.100	0.345	0.542	0.725	0.883	1.026	1.254	-
1990	0.100	0.293	0.397	0.577	0.697	0.807	1.230	-
1991	0.100	0.268	0.368	0.481	0.726	0.820	1.306	-
1992	0.100	0.295	0.369	0.522	0.647	1.203	1.125	-
1993	0.100	0.287	0.376	0.507	0.562	0.882	1.038	1.044
1994	0.150	0.256	0.350	0.472	0.628	0.848	0.896	1.166
1995	0.155	0.249	0.365	0.462	0.582	0.703	0.785	0.531
1996	0.137	0.298	0.405	0.568	0.725	0.910	1.031	1.209
1997	0.155	0.310	0.410	0.523	0.668	0.869	0.919	1.216
1998	0.185	0.333	0.453	0.542	0.670	0.829	0.886	-
1999	0.210	0.374	0.506	0.637	0.748	0.873	0.892	1.104
2000	0.176	0.378	0.480	0.612	0.754	0.933	1.001	1.278

Table 5. Average length of male and female yellowtail flounder by age group and year for the Canadian fishery, based on catch at age data for 1997 through 2000.

Year	Age						
	1	2	3	4	5	6	7
	Males						
1997	28.2	33.0	34.3	35.7	37.4	-	-
1998	29.2	32.2	36.8	44.2	47.3	51.0	-
1999	27.2	33.8	36.2	38.1	38.2	-	-
2000	26.7	33.9	35.8	38.2	39.4	41.3	48.0
	Females						
1997	-	34.1	37.5	39.8	42.7	42.8	43.7
1998	23.2	34.0	38.4	40.8	41.8	44.9	45.4
1999	28.7	35.7	39.4	41.6	44.1	45.9	46.0
2000	29.1	36.4	39.6	42.1	46.6	48.6	50.8

Table 6. Canadian DFO spring survey indices of Georges Bank yellowtail flounder abundance at age (stratified mean #/tow) and stratified total biomass (000s t).

	Age							Biomass
Year	1	2	3	4	5	6+	Total	(000s t)
1987	0.12	0.68	2.00	1.09	0.06	0.00	3.95	1.264
1988	0.00	0.66	1.89	0.80	0.59	0.01	3.96	1.235
1989	0.11	0.78	0.80	0.32	0.10	0.02	2.13	0.471
1990	0.00	1.27	4.62	1.12	0.43	0.01	7.45	1.578
1991	0.02	0.59	1.72	2.91	0.99	0.00	6.24	1.759
1992	0.22	10.04	4.52	1.21	0.16	0.00	16.14	2.475
1993	0.33	2.16	5.04	3.47	0.62	0.00	11.63	2.642
1994	0.00	6.03	3.33	3.08	0.75	0.33	13.51	2.753
1995	0.21	1.31	4.07	2.22	1.14	0.11	9.07	2.027
1996	0.45	5.54	8.44	7.49	1.37	0.16	23.45	5.304
1997	0.10	9.48	15.16	19.09	3.11	0.54	47.49	13.292
1998	0.92	3.10	3.81	5.15	2.44	0.59	16.01	4.292
1999	0.22	13.05	24.78	9.07	6.85	3.10	57.07	17.666
2000	0.06	9.18	31.22	18.56	5.77	4.42	69.22	19.948
2001	-	-	-	-	-	-	82.62	22.157

Table 7. NMFS spring survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

	Age									Biomass
Year	1	2	3	4	5	6	7	8+	Total	kg/tow
1968	0.149	3.364	3.579	0.316	0.084	0.160	0.127	-	7.779	2.813
1969	1.015	9.406	11.119	3.096	1.423	0.454	0.188	0.057	26.758	11.170
1970	0.093	4.485	6.030	2.422	0.570	0.121	0.190	-	13.911	5.312
1971	0.791	3.335	4.620	3.754	0.759	0.227	0.050	0.029	13.564	4.607
1972	0.138	7.136	7.198	3.514	1.094	0.046	0.122	-	19.247	6.450
1973	1.931	3.266	2.368	1.063	0.410	0.173	0.023	0.020	9.254	2.938
1974	0.316	2.224	1.842	1.256	0.346	0.187	0.085	0.009	6.265	2.719
1975	0.420	2.939	0.860	0.298	0.208	0.068	-	0.013	4.806	1.676
1976	1.034	4.368	1.247	0.311	0.196	0.026	0.048	0.037	7.268	2.273
1977	-	0.671	1.125	0.384	0.074	0.013	-	-	2.267	0.999
1978	0.936	0.798	0.507	0.219	0.026	-	0.008	-	2.494	0.742
1979	0.279	1.933	0.385	0.328	0.059	0.046	0.041	-	3.072	1.227
1980	0.057	4.644	5.761	0.473	0.057	0.037	-	-	11.030	4.456
1981	0.012	1.027	1.779	0.721	0.205	0.061	-	0.026	3.830	1.960
1982	0.045	3.742	1.122	1.016	0.455	0.065	-	0.026	6.472	2.500
1983	-	1.865	2.728	0.531	0.123	0.092	0.061	0.092	5.492	2.642
1984	-	0.093	0.809	0.885	0.834	0.244	-	-	2.865	1.646
1985	0.110	2.198	0.262	0.282	0.148	-	-	-	3.000	0.988
1986	0.027	1.806	0.291	0.056	0.137	0.055	-	-	2.372	0.847
1987	-	0.128	0.112	0.133	0.053	0.055	-	-	0.480	0.329
1988	0.078	0.275	0.366	0.242	0.199	0.027	-	-	1.187	0.566
1989	0.047	0.424	0.740	0.290	0.061	0.022	0.022	-	1.605	0.729
1990	-	0.065	1.108	0.393	0.139	0.012	0.045	-	1.762	0.699
1991	0.435	-	0.254	0.675	0.274	0.020	-	-	1.659	0.631
1992	-	2.010	1.945	0.598	0.189	-	-	-	4.742	1.566
1993	0.046	0.290	0.500	0.317	0.027	-	-	-	1.180	0.482
1994	-	0.621	0.638	0.357	0.145	0.043	-	-	1.804	0.660
1995	0.040	1.180	4.810	1.490	0.640	0.010	-	-	8.170	2.579
1996	0.030	0.990	2.630	2.700	0.610	0.060	-	-	7.020	2.853
1997	0.019	1.169	3.733	4.081	0.703	0.134	-	-	9.837	4.359
1998	-	2.081	1.053	1.157	0.759	0.323	0.027	-	5.400	2.324
1999	0.050	4.746	10.820	2.720	1.623	0.426	0.329	0.024	20.738	9.307
2000	0.183	4.819	7.666	2.914	0.813	0.422	0.102	-	16.916	6.696

Table 8. NMFS fall survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

	Age										Biomass
Year	0	1	2	3	4	5	6	7	8+	Total	kg/tow
1963	-	14.722	7.896	11.226	1.858	0.495	0.281	0.034	0.233	36.746	12.788
1964	-	1.721	9.723	7.370	5.998	2.690	0.383	0.095	0.028	28.007	13.623
1965	0.014	1.138	5.579	5.466	3.860	1.803	0.162	0.284	0.038	18.345	9.104
1966	1.177	8.772	4.776	2.070	0.837	0.092	0.051	-	-	17.775	3.988
1967	0.106	9.137	9.313	2.699	1.007	0.309	0.076	0.061	-	22.708	7.575
1968	-	11.782	11.946	5.758	0.766	0.944	0.059	-	-	31.254	10.536
1969	0.135	8.106	10.381	5.855	1.662	0.553	0.149	0.182	-	27.023	9.279
1970	1.048	4.610	5.133	3.144	1.952	0.451	0.063	0.017	-	16.417	4.979
1971	0.025	3.627	6.949	4.904	2.248	0.551	0.234	0.024	0.024	18.586	6.365
1972	0.785	2.424	6.525	4.824	2.095	0.672	0.279	-	-	17.604	6.328
1973	0.094	2.494	5.497	5.104	2.944	1.216	0.416	0.171	0.031	17.996	6.602
1974	1.030	4.623	2.854	1.524	1.060	0.460	0.249	0.131	-	12.133	3.733
1975	0.361	4.625	2.511	0.877	0.572	0.334	0.033	-	0.031	9.420	2.365
1976	-	0.336	1.929	0.475	0.117	0.122	0.033	-	0.067	3.078	1.533
1977	-	0.928	2.161	1.649	0.618	0.113	0.056	0.036	0.016	5.614	2.829
1978	0.037	4.729	1.272	0.773	0.406	0.139	0.011	-	0.024	7.443	2.383
1979	0.018	1.312	1.999	0.316	0.122	0.138	0.038	0.064	0.007	4.041	1.520
1980	0.078	0.761	5.086	6.050	0.678	0.217	0.162	0.006	0.033	13.217	6.722
1981	-	1.584	2.333	1.630	0.500	0.121	0.083	0.013	-	6.345	2.621
1982	-	2.424	2.185	1.590	0.423	0.089	-	-	-	6.711	2.270
1983	-	0.109	2.284	1.914	0.473	0.068	0.012	-	0.038	4.898	2.131
1984	0.012	0.661	0.400	0.306	2.428	0.090	0.029	-	0.018	3.944	0.593
1985	0.010	1.350	0.560	0.160	0.040	0.080	-	-	-	2.200	0.709
1986	-	0.280	1.110	0.350	0.070	-	-	-	-	1.810	0.820
1987	-	0.113	0.390	0.396	0.053	0.079	-	-	-	1.031	0.509
1988	0.011	0.019	0.213	0.102	0.031	-	-	-	-	0.376	0.171
1989	0.027	0.248	1.992	0.774	0.069	0.066	-	-	-	3.176	0.977
1990	0.147	-	0.326	1.517	0.280	0.014	-	-	-	2.284	0.725
1991	-	2.100	0.275	0.439	0.358	-	-	-	-	3.172	0.730
1992	-	0.151	0.396	0.712	0.162	0.144	0.027	-	-	1.592	0.576
1993	-	0.842	0.136	0.587	0.536	-	-	-	-	2.101	0.545
1994	0.010	1.200	0.220	0.980	0.710	0.260	0.030	0.030	-	3.440	0.897
1995	0.070	0.280	0.120	0.350	0.280	0.050	0.010	-	-	1.160	0.354
1996	-	0.140	0.350	1.870	0.450	0.070	-	-	-	2.880	1.303
1997	-	1.392	0.533	3.442	2.090	1.071	0.082	-	-	8.611	3.781
1998	-	1.900	4.817	4.202	1.190	0.298	0.055	0.019	-	12.481	4.347
1999	-	3.090	8.423	5.527	1.432	1.436	0.260	-	-	20.168	7.973
2000	0.019	0.629	1.697	4.814	2.421	0.948	0.800	0.027	-	11.355	5.838

Table 9. NMFS scallop survey index (stratified mean #/tow) for Georges Bank yellowtail flounder age-1 abundance.

Year	Number per tow
1982	0.313
1983	0.140
1984	0.233
1985	0.549
1986	0.103
1987	0.047
1988	0.116
1989	0.195
1990	0.100
1991	2.117
1992	0.167
1993	1.129
1994	1.503
1995	0.609
1996	0.508
1997	1.062
1998	1.872
1999	1.038
2000	0.912

Table 10. Statistical properties of estimates for population abundance and survey calibration constants (10^{-3}) for Georges Bank yellowtail flounder.

Age	Estimate	Bootstrap				Analytical Approximation			
		Standard Error	Relative Error	Bias	Relative Bias	Standard Error	Relative Error	Bias	Relative Bias
				Population Abundance					
2	27050	15699	0.580	2714	0.100	13435	0.497	3342	0.124
3	26233	10908	0.416	2253	0.086	10263	0.391	1817	0.069
4	33571	11526	0.343	1359	0.040	12002	0.358	1842	0.055
5	16095	3032	0.188	293	0.018	2988	0.186	200	0.012
				Survey Calibration Constants					
Scallop									
1	0.028	0.005	0.188	-	0.006	0.005	0.196	0.001	0.019
DFO spring Survey – 1986-2000									
2	0.201	0.046	0.230	0.005	0.026	0.046	0.227	0.005	0.025
3	0.632	0.136	0.216	0.011	0.018	0.142	0.225	0.016	0.025
4	1.080	0.239	0.222	0.029	0.027	0.243	0.225	0.027	0.025
5	1.274	0.286	0.225	0.029	0.023	0.287	0.225	0.032	0.025
6+	1.330	0.331	0.249	0.015	0.011	0.356	0.268	0.047	0.035
NMFS Spring Survey – Yankee 36 –1982-2000									
1	0.003	0.001	0.240	-	0.029	0.001	0.247	-	0.030
2	0.065	0.012	0.187	-	-0.001	0.013	0.199	0.001	0.019
3	0.153	0.030	0.194	0.002	0.014	0.029	0.193	0.003	0.018
4	0.241	0.049	0.202	0.008	0.035	0.046	0.193	0.004	0.018
5	0.358	0.07	0.194	0.002	0.006	0.069	0.193	0.007	0.018
6+	0.542	0.112	0.206	0.007	0.013	0.114	0.210	0.012	0.022
NMFS Spring Survey – Yankee 41 – 1973-2000									
1	0.008	0.002	0.293	-	0.045	0.002	0.294	-	0.043
2	0.083	0.024	0.284	0.004	0.043	0.023	0.277	0.003	0.038
3	0.106	0.031	0.289	0.004	0.042	0.029	0.277	0.004	0.038
4	0.104	0.028	0.272	0.005	0.044	0.029	0.277	0.004	0.038
5	0.083	0.023	0.276	0.004	0.051	0.023	0.277	0.003	0.038
6+	0.084	0.024	0.285	0.004	0.047	0.023	0.277	0.003	0.038
NMFS Fall Survey - 1963-2000									
1	0.040	0.006	0.153	-	0.004	0.007	0.163	0.001	0.013
2	0.089	0.014	0.153	-	0.004	0.014	0.159	0.001	0.012
3	0.194	0.029	0.152	0.002	0.012	0.031	0.158	0.002	0.013
4	0.223	0.036	0.163	0.004	0.020	0.035	0.159	0.003	0.012
5	0.284	0.051	0.178	0.004	0.014	0.049	0.172	0.004	0.015
6+	0.379	0.074	0.195	0.009	0.022	0.075	0.198	0.007	0.020

Table 11. Beginning of year population abundance numbers (000's) for Georges Bank yellowtail flounder from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2001.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	27857	22950	28577	16854	6801	2940	105977	78120	55171
1974	49338	22494	14392	11572	5543	2310	105649	56311	33817
1975	67297	38460	10389	4748	2917	1607	125418	58122	19662
1976	22618	51153	9102	2265	895	1460	87492	64875	13721
1977	15642	17963	14350	2875	658	792	52280	36638	18675
1978	50294	12509	7049	2986	826	313	73976	23682	11173
1979	23135	32486	7451	2185	967	478	66703	43568	11082
1980	21884	18731	18066	3024	684	211	62600	40717	21986
1981	59983	17638	12121	6922	1209	191	98065	38082	20444
1982	21271	49060	13782	5143	1633	133	91023	69752	20692
1983	5753	15555	24496	4937	1332	271	52344	46592	31036
1984	8501	4083	5878	5872	1975	398	26706	18205	14123
1985	14338	6574	1631	1051	661	105	24360	10022	3448
1986	6565	11152	2400	608	282	133	21140	14576	3423
1987	6957	5232	3988	1090	189	160	17617	10660	5428
1988	19082	5570	1918	834	220	51	27675	8593	3024
1989	8450	15187	2444	514	133	37	26765	18315	3128
1990	11577	6751	11067	1401	187	35	31018	19441	12690
1991	21683	9281	3794	3612	436	89	38894	17211	7931
1992	15687	17380	7550	2010	808	43	43478	27791	10410
1993	12025	10692	6771	3916	521	123	34046	22021	11329
1994	11075	5202	7844	3059	1083	163	28426	17352	12149
1995	15315	9003	3484	1362	261	53	29478	14163	5160
1996	22524	12526	7229	2049	478	43	44849	22325	9799
1997	47414	18396	9910	4562	1036	273	81591	34176	15780
1998	72586	38805	14524	6980	2388	394	135678	63091	24286
1999	40815	59405	30894	9379	4076	1014	145584	104769	45364
2000	29835	33398	45671	22401	6330	2570	140205	110369	76972
2001	30000	24337	23980	32212	15796	6276	132600	102600	78263

Table 12. Fishing mortality rate for Georges Bank yellowtail from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2001.

Year	Age Group						
	1	2	3	4	5	6+	3+
1973	0.014	0.267	0.704	0.912	0.912	0.912	0.804
1974	0.049	0.572	0.909	1.178	1.178	1.178	1.063
1975	0.074	1.241	1.323	1.469	1.469	1.469	1.392
1976	0.030	1.071	0.952	1.036	1.036	1.036	0.981
1977	0.024	0.735	1.370	1.048	1.048	1.048	1.295
1978	0.237	0.318	0.971	0.927	0.927	0.927	0.955
1979	0.011	0.387	0.702	0.961	0.961	0.961	0.787
1980	0.016	0.235	0.759	0.717	0.717	0.717	0.752
1981	0.001	0.047	0.657	1.244	1.244	1.244	0.896
1982	0.113	0.495	0.827	1.151	1.151	1.151	0.935
1983	0.143	0.773	1.228	0.716	0.716	0.716	1.120
1984	0.057	0.717	1.521	1.984	1.984	1.984	1.792
1985	0.051	0.807	0.787	1.115	1.115	1.115	0.960
1986	0.027	0.828	0.589	0.968	0.968	0.968	0.702
1987	0.022	0.803	1.365	1.398	1.398	1.398	1.374
1988	0.028	0.624	1.117	1.633	1.633	1.633	1.305
1989	0.024	0.116	0.356	0.809	0.809	0.809	0.456
1990	0.021	0.376	0.920	0.968	0.968	0.968	0.926
1991	0.021	0.006	0.435	1.298	1.298	1.298	0.885
1992	0.183	0.743	0.457	1.151	1.151	1.151	0.647
1993	0.638	0.110	0.594	1.085	1.085	1.085	0.792
1994	0.007	0.201	1.551	2.262	2.262	2.262	1.803
1995	0.001	0.019	0.331	0.847	0.847	0.847	0.498
1996	0.002	0.034	0.260	0.481	0.481	0.481	0.318
1997	-	0.036	0.149	0.445	0.445	0.445	0.259
1998	-	0.027	0.234	0.334	0.334	0.334	0.274
1999	0.001	0.058	0.119	0.189	0.189	0.189	0.141
2000	0.003	0.114	0.135	0.145	0.145	0.145	0.139

Table 13. Beginning of year weight (kg) at age for Georges Bank yellowtail. Age group 6+ is catch weighted. The 2001 value is the average for 1997-2000.

Year	Age Group					
	1	2	3	4	5	6+
1973	0.054	0.188	0.403	0.493	0.564	0.704
1974	0.063	0.186	0.419	0.530	0.599	0.758
1975	0.066	0.185	0.411	0.525	0.613	0.702
1976	0.059	0.186	0.414	0.558	0.641	0.738
1977	0.064	0.190	0.405	0.586	0.705	0.866
1978	0.055	0.185	0.418	0.599	0.709	0.882
1979	0.058	0.182	0.381	0.575	0.706	0.871
1980	0.054	0.183	0.404	0.549	0.726	0.905
1981	0.057	0.186	0.399	0.545	0.681	0.810
1982	0.069	0.173	0.411	0.564	0.672	0.878
1983	0.106	0.182	0.364	0.542	0.692	0.869
1984	0.108	0.183	0.334	0.469	0.623	0.784
1985	0.128	0.242	0.345	0.495	0.605	0.726
1986	0.131	0.247	0.443	0.574	0.730	0.827
1987	0.066	0.236	0.423	0.600	0.672	0.860
1988	0.054	0.191	0.419	0.599	0.755	0.893
1989	0.058	0.186	0.420	0.634	0.779	1.026
1990	0.061	0.171	0.370	0.559	0.711	0.886
1991	0.058	0.164	0.328	0.437	0.647	0.774
1992	0.059	0.172	0.314	0.438	0.558	0.941
1993	0.063	0.169	0.333	0.433	0.542	0.803
1994	0.116	0.160	0.317	0.421	0.564	0.747
1995	0.112	0.193	0.306	0.402	0.524	0.728
1996	0.091	0.215	0.318	0.455	0.579	0.785
1997	0.106	0.206	0.350	0.460	0.616	0.923
1998	0.130	0.227	0.375	0.471	0.592	0.770
1999	0.158	0.263	0.410	0.537	0.637	0.779
2000	0.110	0.282	0.424	0.556	0.693	0.862
2001	0.126	0.245	0.390	0.506	0.635	0.834

Table 14. Beginning of year biomass (t) for Georges Bank yellowtail from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2001.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	1504	4315	11516	8309	3836	2070	31549	30045	25730
1974	3108	4184	6030	6133	3320	1751	24527	21419	17235
1975	4442	7115	4270	2493	1788	1128	21236	16794	9679
1976	1334	9515	3768	1264	573	1077	17532	16197	6683
1977	1001	3413	5812	1685	464	686	13060	12059	8646
1978	2766	2314	2947	1788	585	276	10677	7910	5596
1979	1342	5912	2839	1256	683	417	12449	11107	5195
1980	1182	3428	7299	1660	497	191	14256	13075	9647
1981	3419	3281	4836	3772	824	155	16287	12868	9588
1982	1468	8487	5665	2900	1098	117	19735	18267	9780
1983	610	2831	8916	2676	922	235	16191	15581	12750
1984	918	747	1963	2754	1230	312	7925	7007	6260
1985	1835	1591	563	520	400	76	4985	3150	1559
1986	860	2755	1063	349	206	110	5343	4483	1728
1987	459	1235	1687	654	127	138	4300	3841	2606
1988	1030	1064	804	499	166	45	3609	2579	1515
1989	490	2825	1026	326	104	38	4809	4319	1494
1990	706	1154	4095	783	133	31	6903	6196	5042
1991	1258	1522	1244	1579	282	69	5953	4696	3174
1992	926	2989	2371	880	451	40	7657	6731	3742
1993	758	1807	2255	1695	282	99	6895	6138	4331
1994	1285	832	2487	1288	611	122	6624	5339	4507
1995	1715	1738	1066	547	137	39	5242	3527	1789
1996	2050	2693	2299	932	277	34	8284	6234	3541
1997	5026	3790	3468	2098	638	252	15272	10246	6457
1998	9436	8809	5447	3287	1414	303	28696	19260	10451
1999	6449	15624	12667	5037	2596	790	43162	36713	21090
2000	3282	9418	19364	12455	4387	2215	51121	47840	38421
2001	3780	5950	9346	16299	10022	5231	50629	46849	40899

Table 15. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2001 at $F_{0.1}$ using the bootstrap bias adjusted population abundance at the beginning of 2001.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
Beginning of Year Population Numbers (000s)									
2001	30000	24337	23980	32212	15976	6276			
2002	30000	24494	17373	16163	20539	14073			
Partial Recruitment to the Fishery									
2001	0.006	0.315	0.648	1.00	1.00	1.00			
Fishing Mortality									
2001	0.002	0.079	0.162	0.250	0.250	0.250			
Weight at beginning of year for population (kg)									
2002	0.126	0.245	0.390	0.506	0.634	0.834			
Beginning of Year Projected Population Biomass (t)									
2002	3780	6009	7183	8448	13022	11737	50178	46398	40389
Projected Catch Numbers (000s)									
2001	41	1672	3261	6485	3180	1263			
Average weight for catch (kg)									
2001	0.181	0.349	0.462	0.578	0.710	0.911			
Projected Yield (t)									
2001	7	583	1507	3748	2258	1151	9254	9247	8663

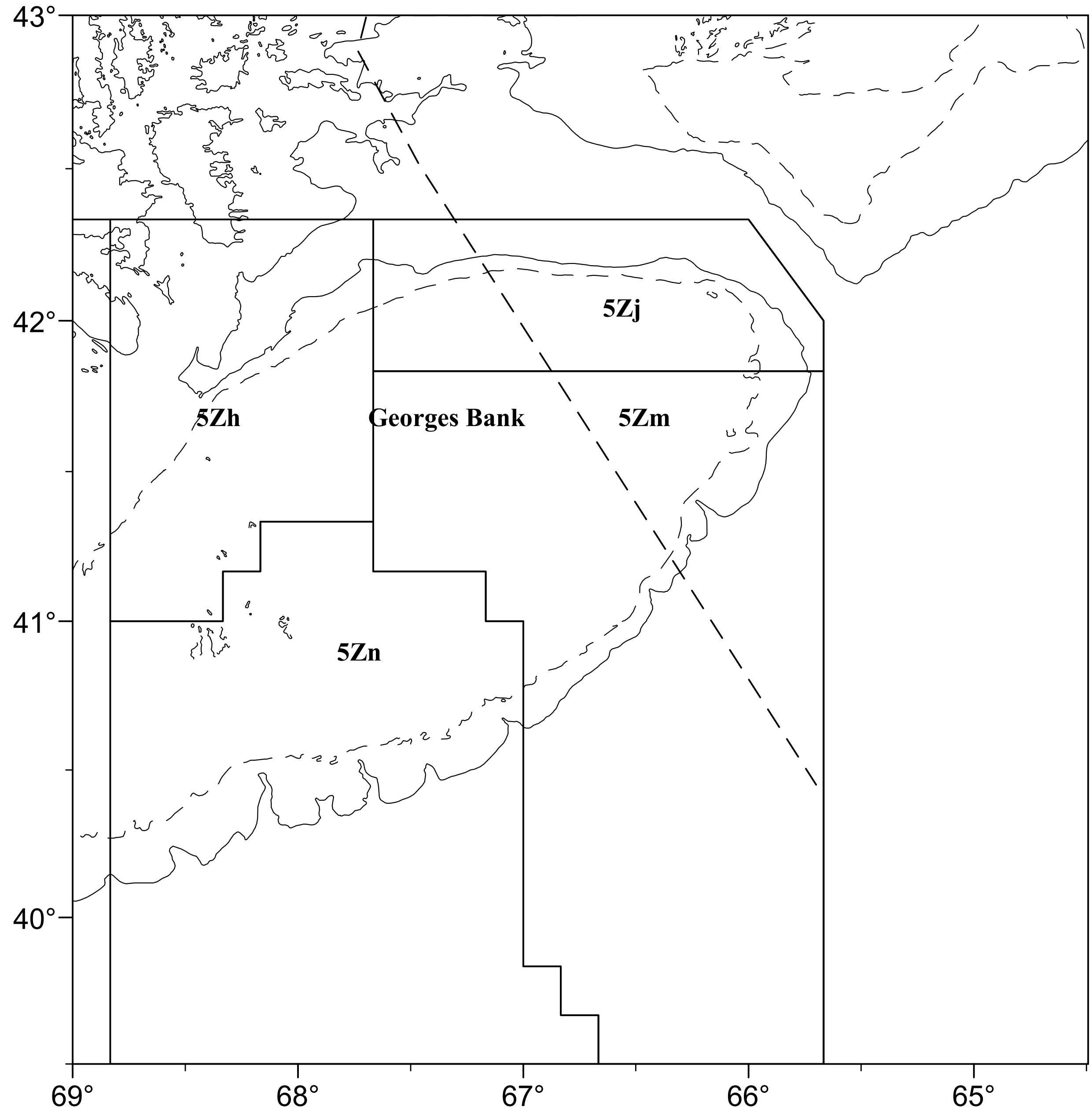

Fig. 1a. Location of Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

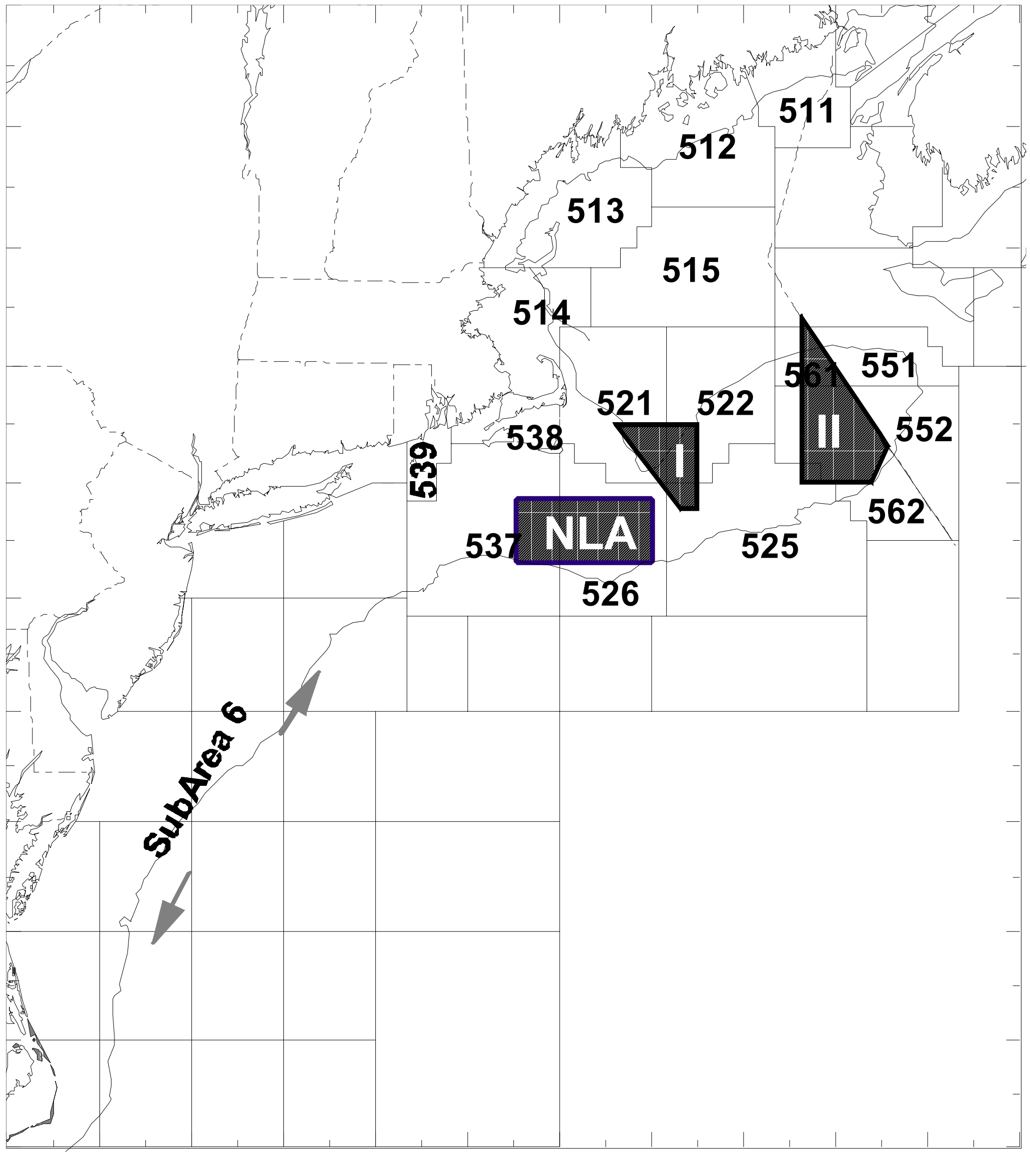

Fig. 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

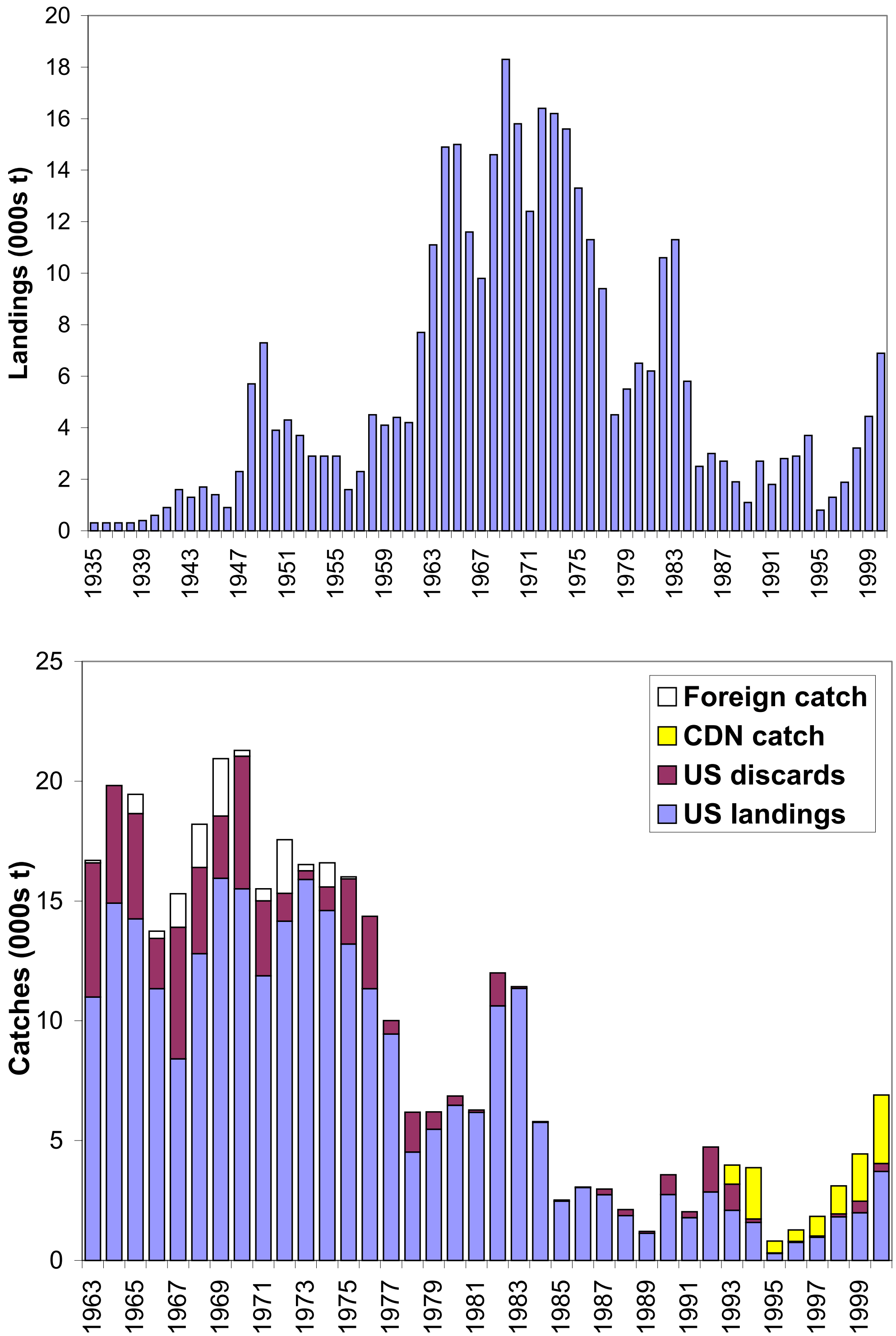

Fig. 2 . Landings of Georges Bank yellowtail flounder. Top panel: landings excluding discards for 1935-2001; bottom panel: national composition of catches including discards.from 1963-2000.

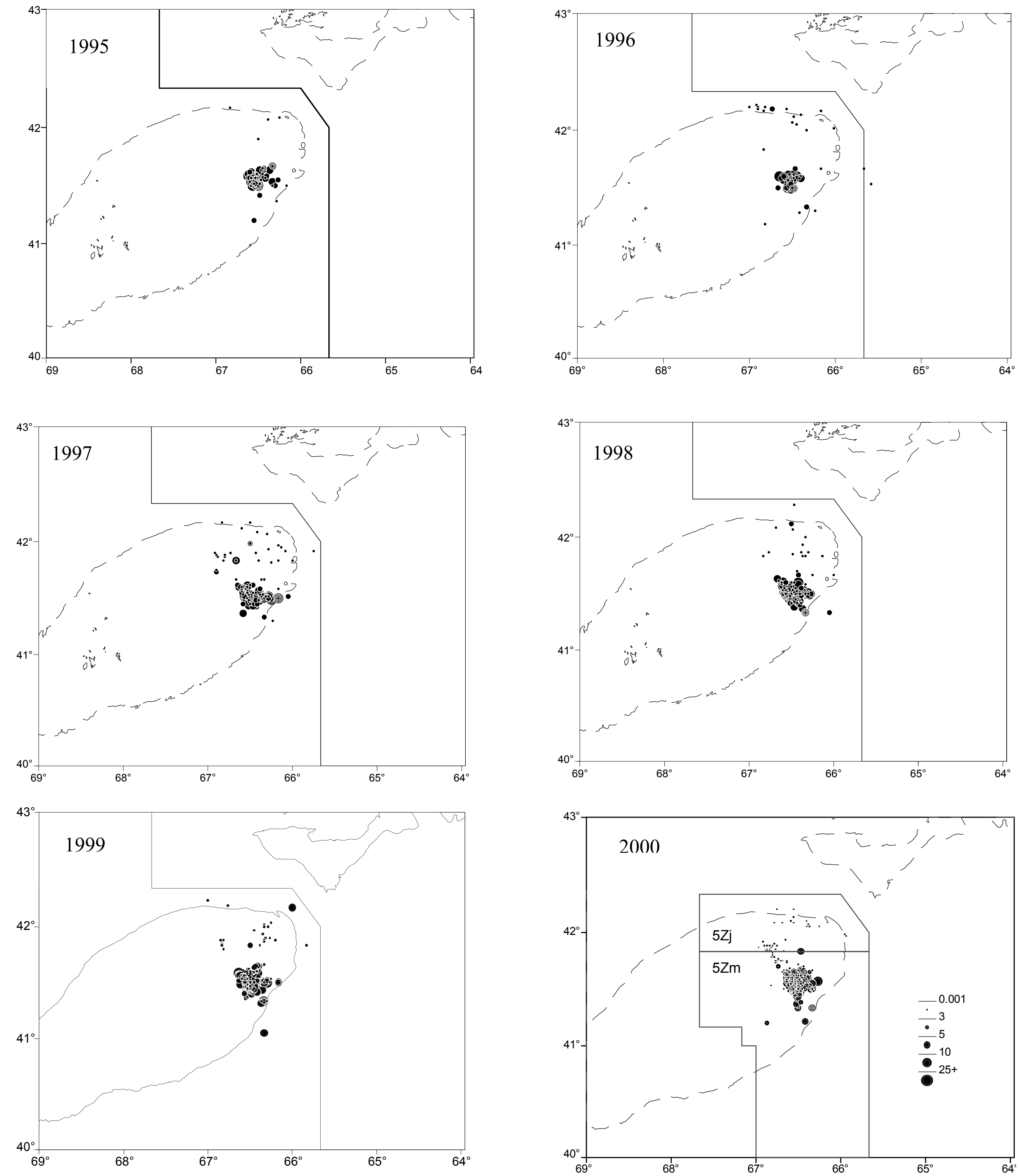

Fig 3. Distribution of Canadian mobile gear (TC 2 & 3) yellowtail flounder catches for 1995-2000 where trip landings were greater than 0.5t. Expanding symbols represent metric tonnes

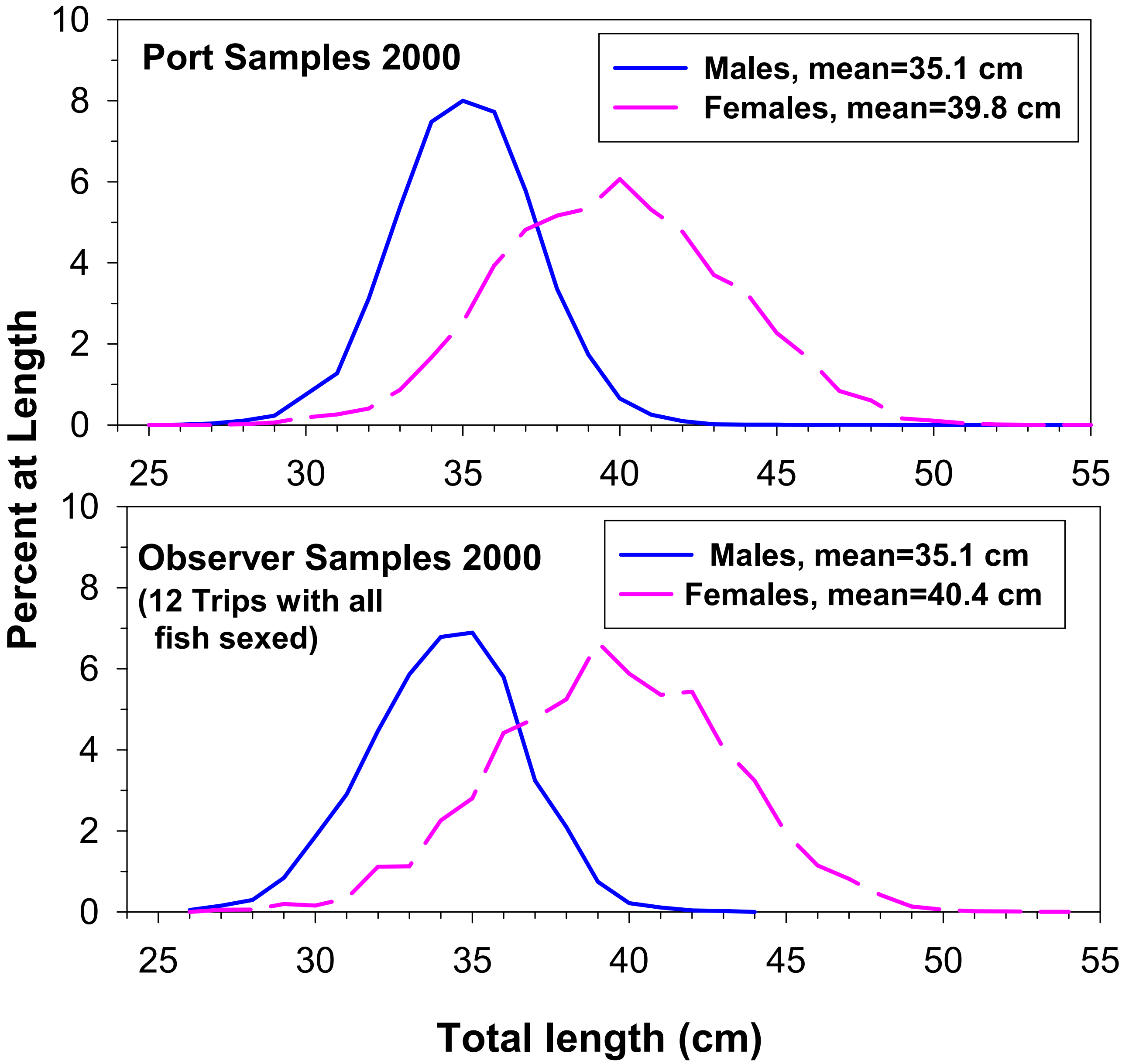

Fig. 4. Length frequencies of Georges Bank yellowtail flounder sampled by sex at dockside (top panel) and at sea (bottom panel) used to construct Canadian catch at age for the 2000 fishery.

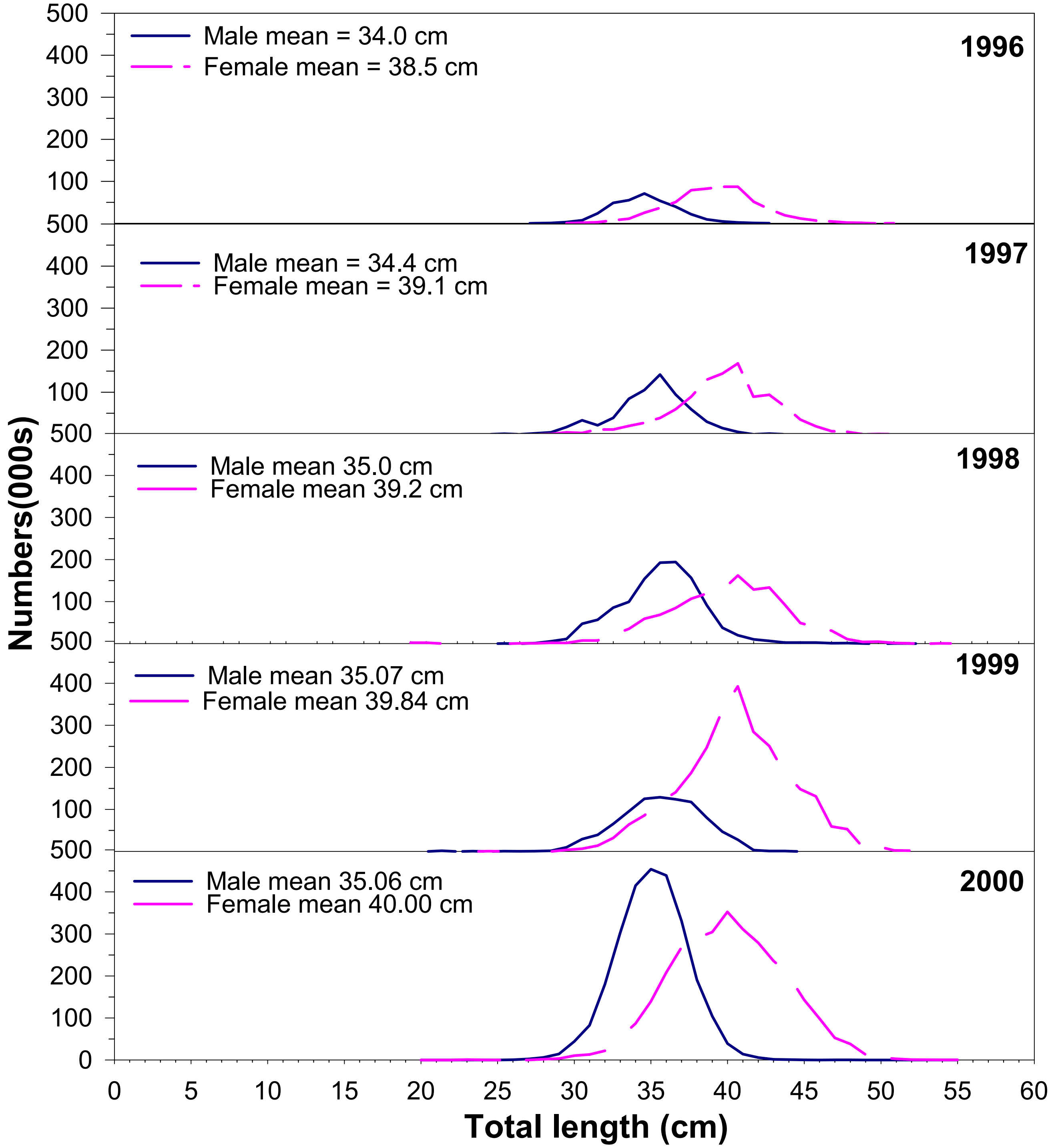

Fig. 5. Georges Bank yellowtail flounder length frequency composition by sex for the Canadian fishery, 1996 to 2000.

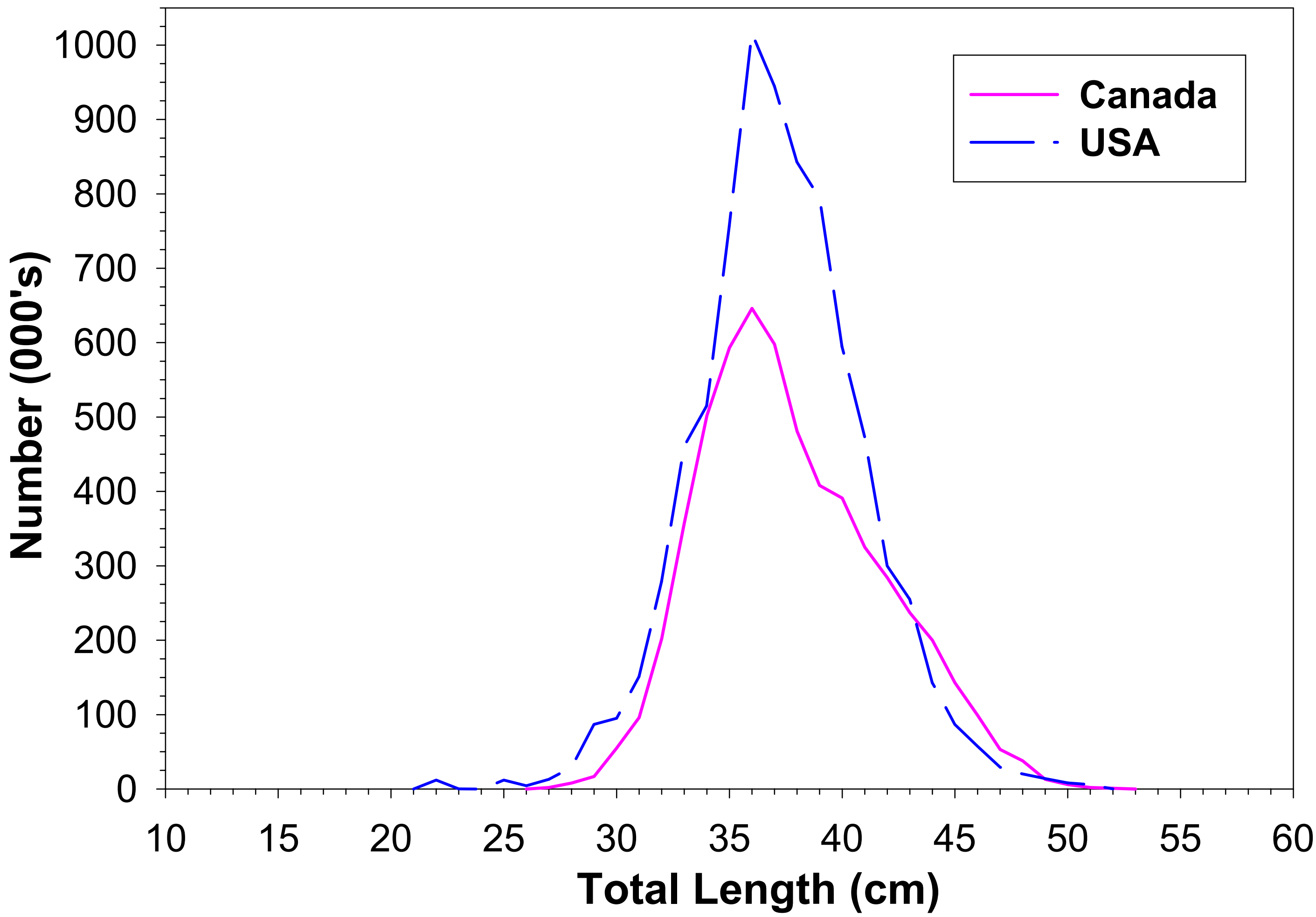

Fig. 6. Comparison of Georges Bank yellowtail flounder length composition from the 2000 Canadian and USA fisheries.

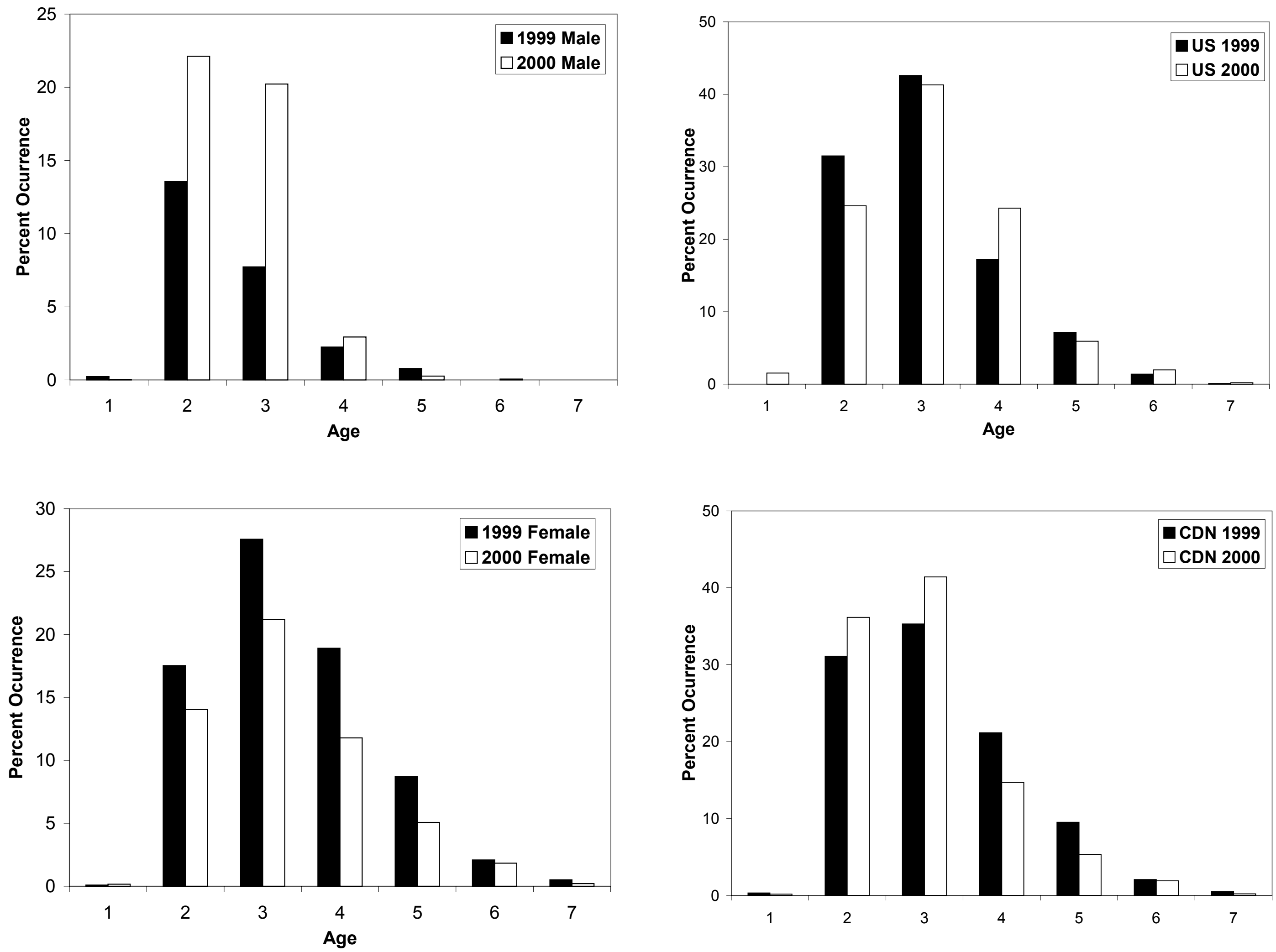

Fig. 7. Comparison of 1999 and 2000 Georges Bank yellowtail flounder fishery age composition for Canadian males and females (left panels), USA sexes aggregated (upper right panel) and Canadian sexes aggregated (lower right panel).

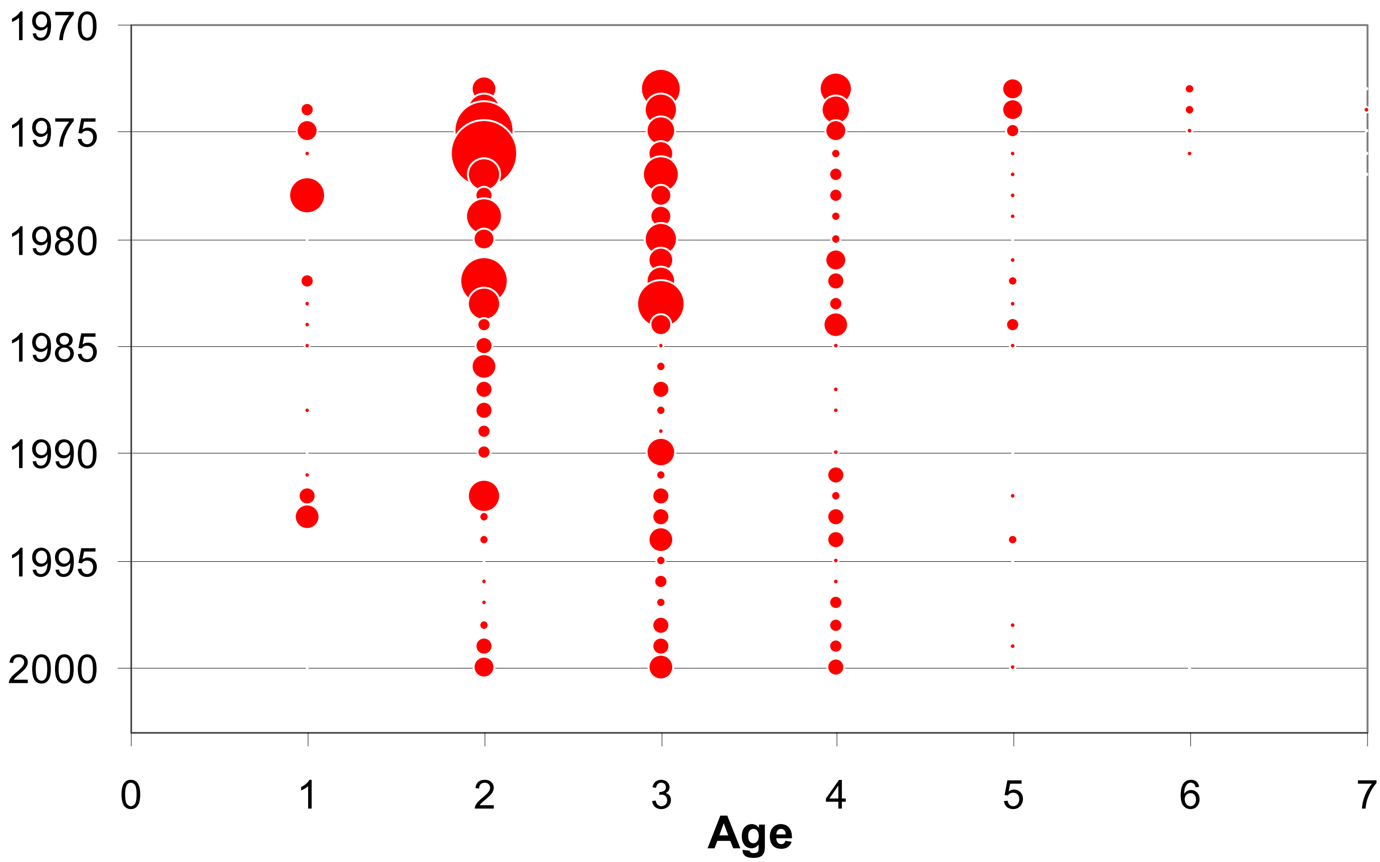

Fig. 8. Catch at age for Georges Bank yellowtail flounder, Canadian and USA fisheries combined, 1970-2000. (The area of the bubble is proportional to the magnitude of the catch).

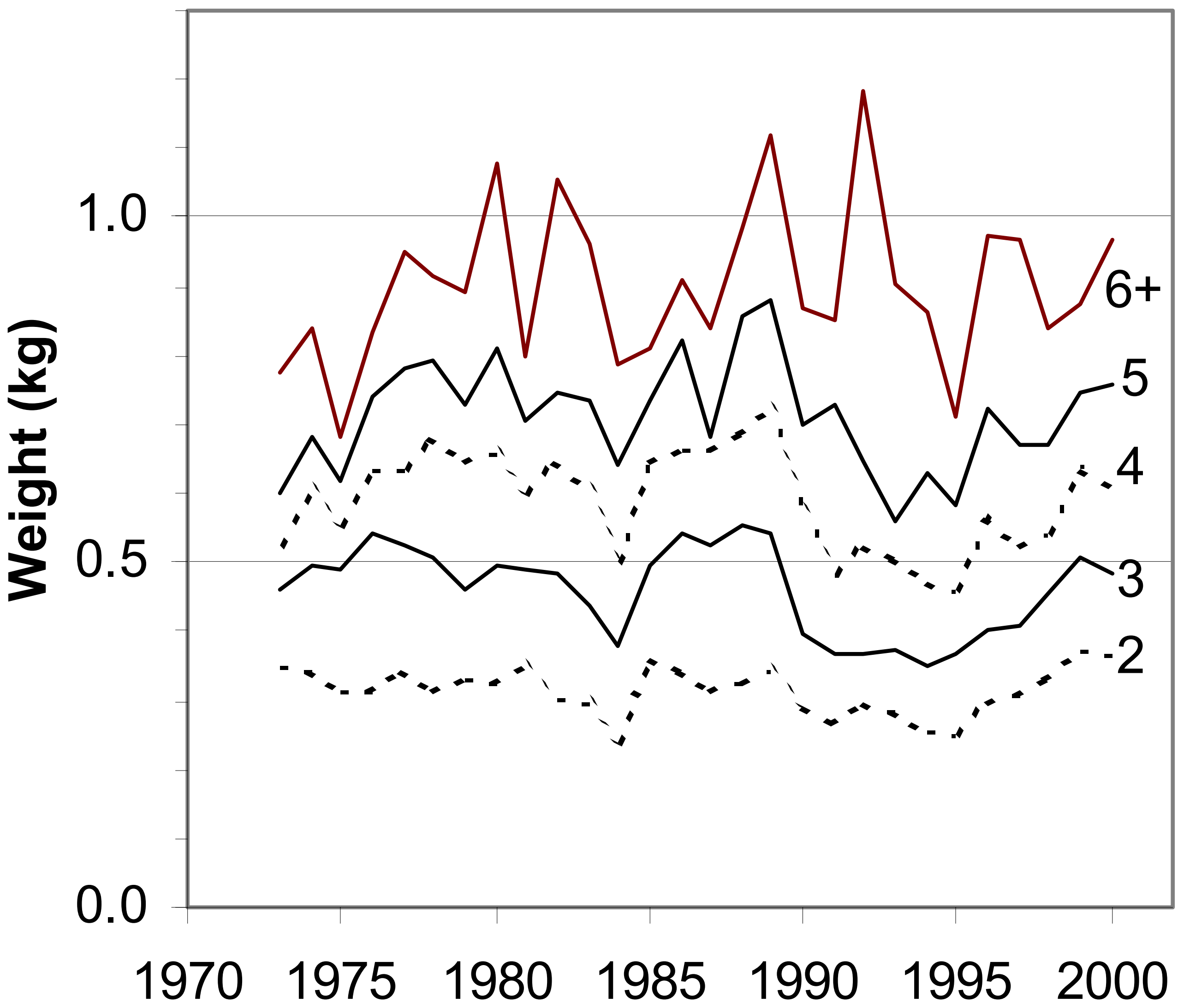

Fig. 9. Trends in mean weight at age from the 5Zjhmn yellowtail fishery, 1973 to 2000 (Canada and USA).

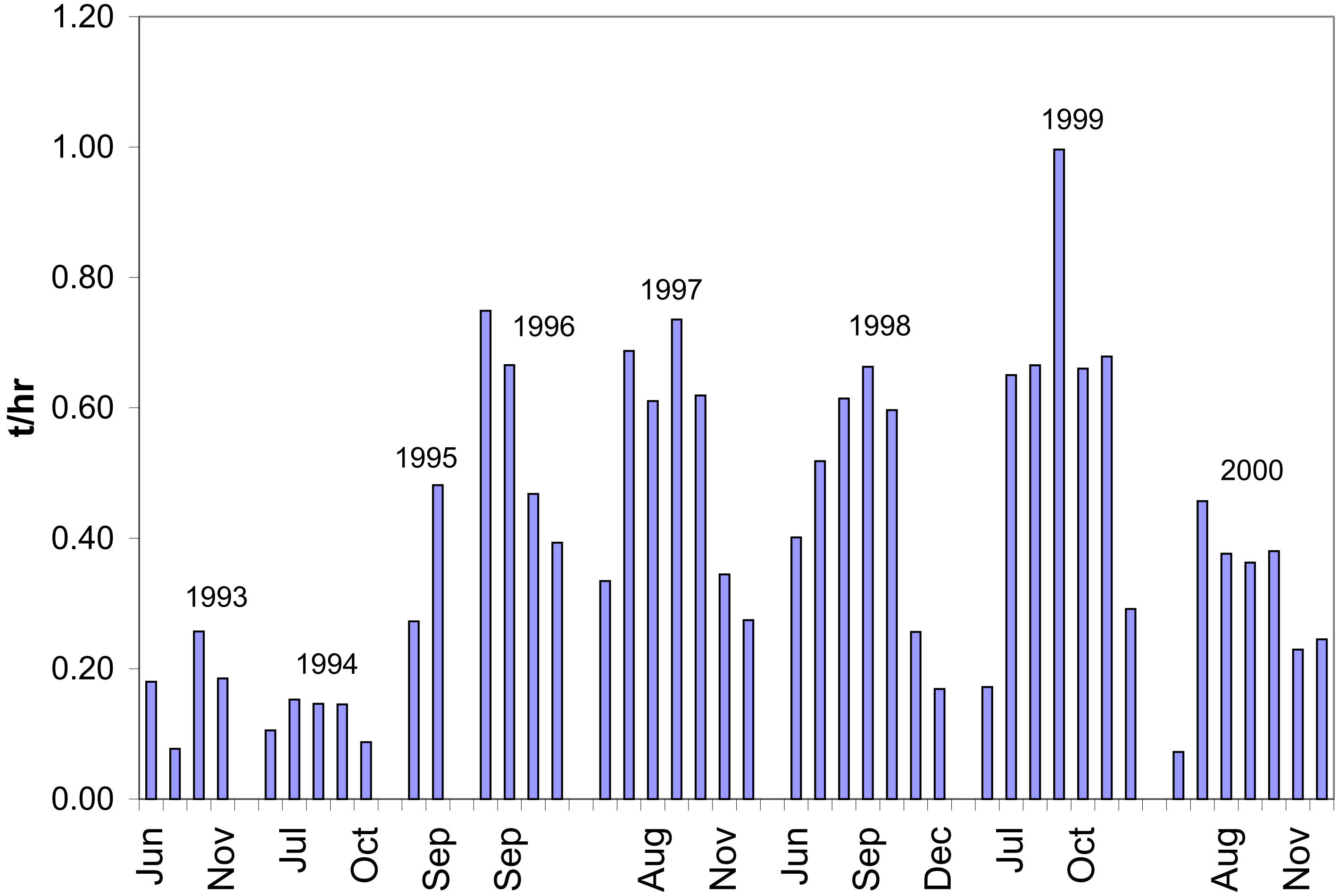

Fig. 10. Monthly catch rates (tonnes/hour) for Canadian stern trawlers (TC 2-3) fishing for yellowtail flounder on Georges Bank, 1993 to 2000 (based on directed trips in 5Zm with catches >0.5 t.).

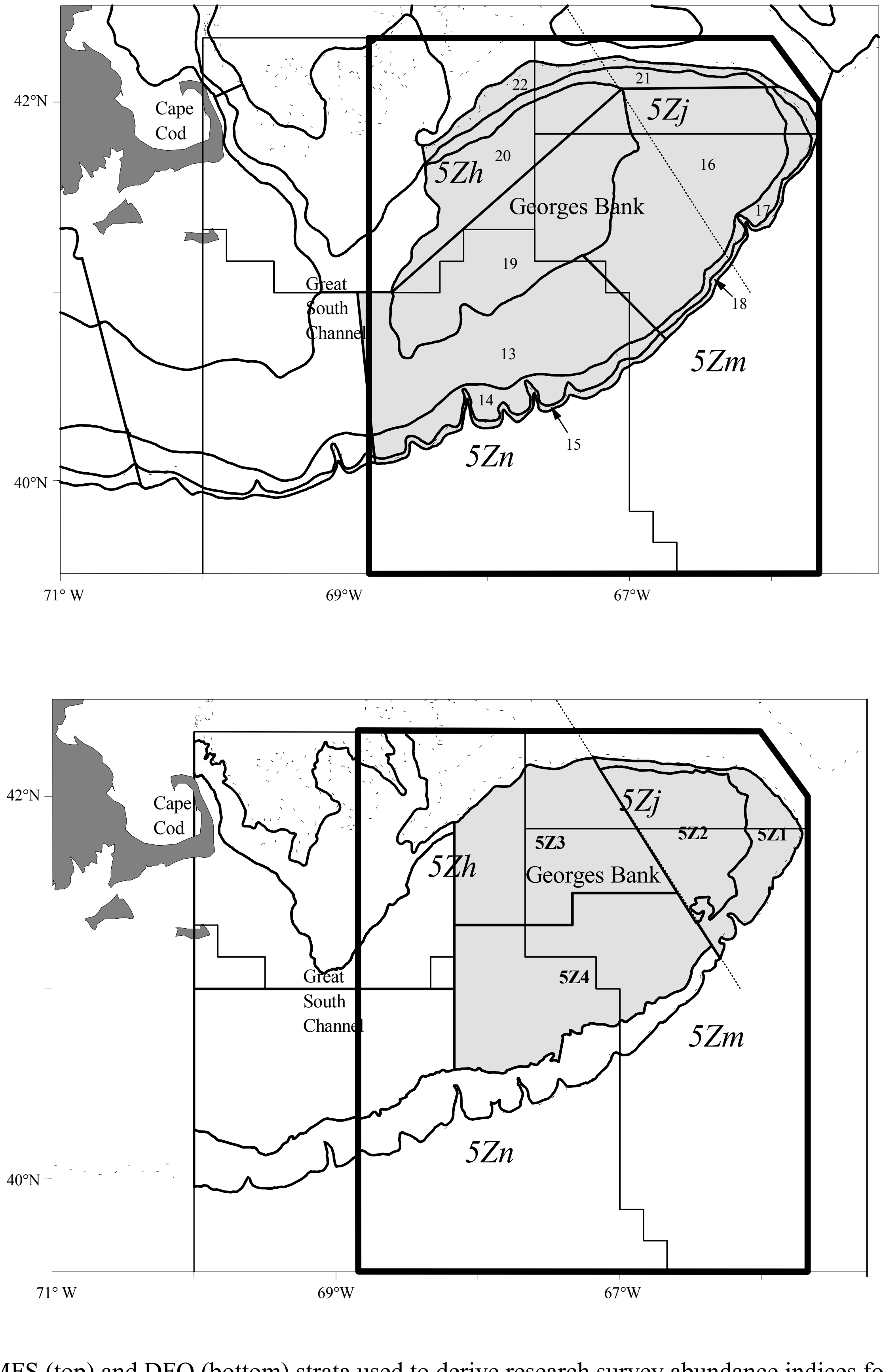

Fig. 11. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys.

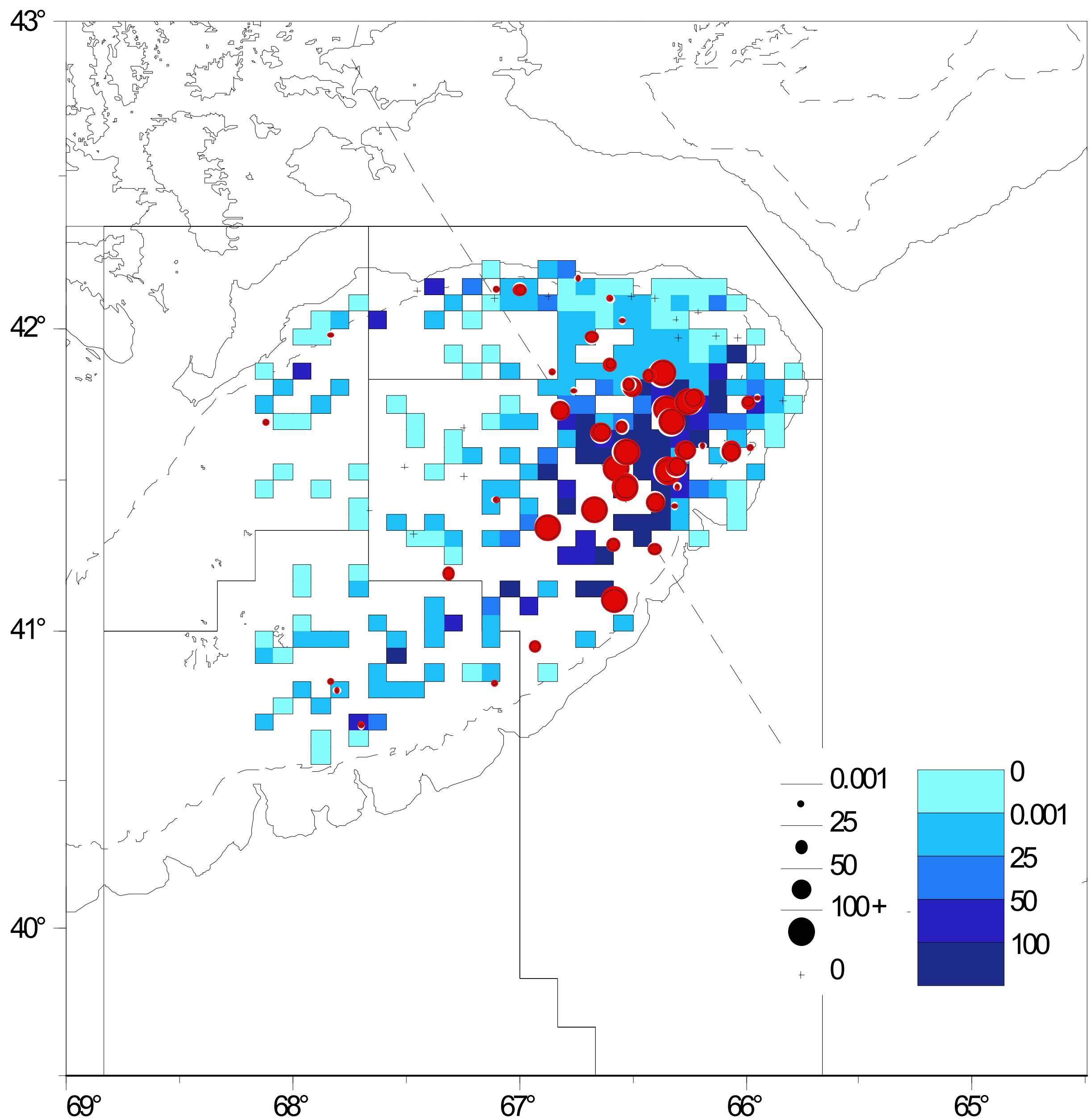

Fig. 12. The distribution of catches (number/tow) of yellowtail flounder (solid circles) in the DFO Georges Bank spring survey in 2001 compared with the average distribution in the previous five years (3x5 minuteshaded rectangles).

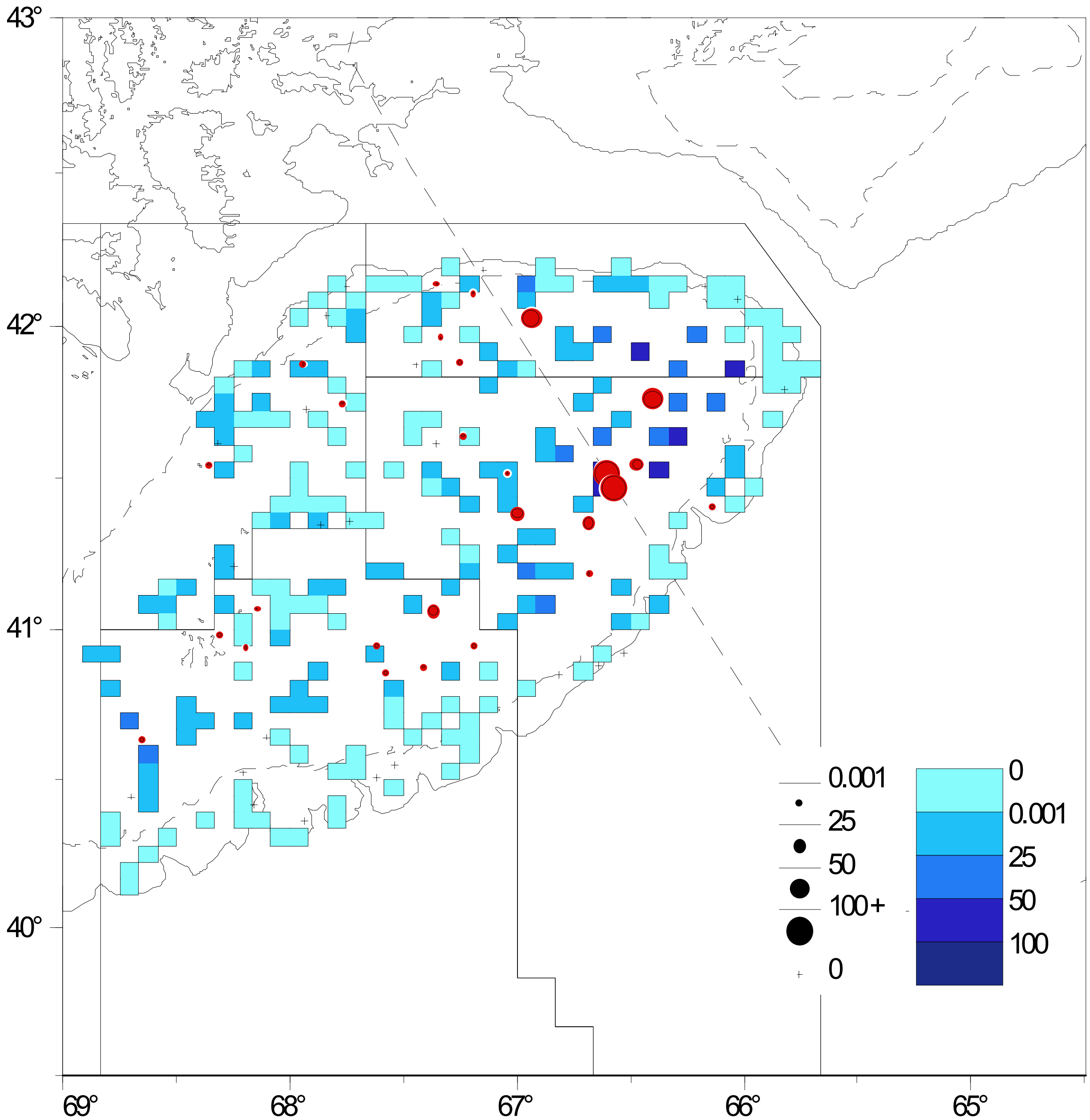

Fig. 13. The distribution of catches (number/tow) of yellowtail flounder in the NMFS Georges Bank spring survey in 2000 (solid circles), compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

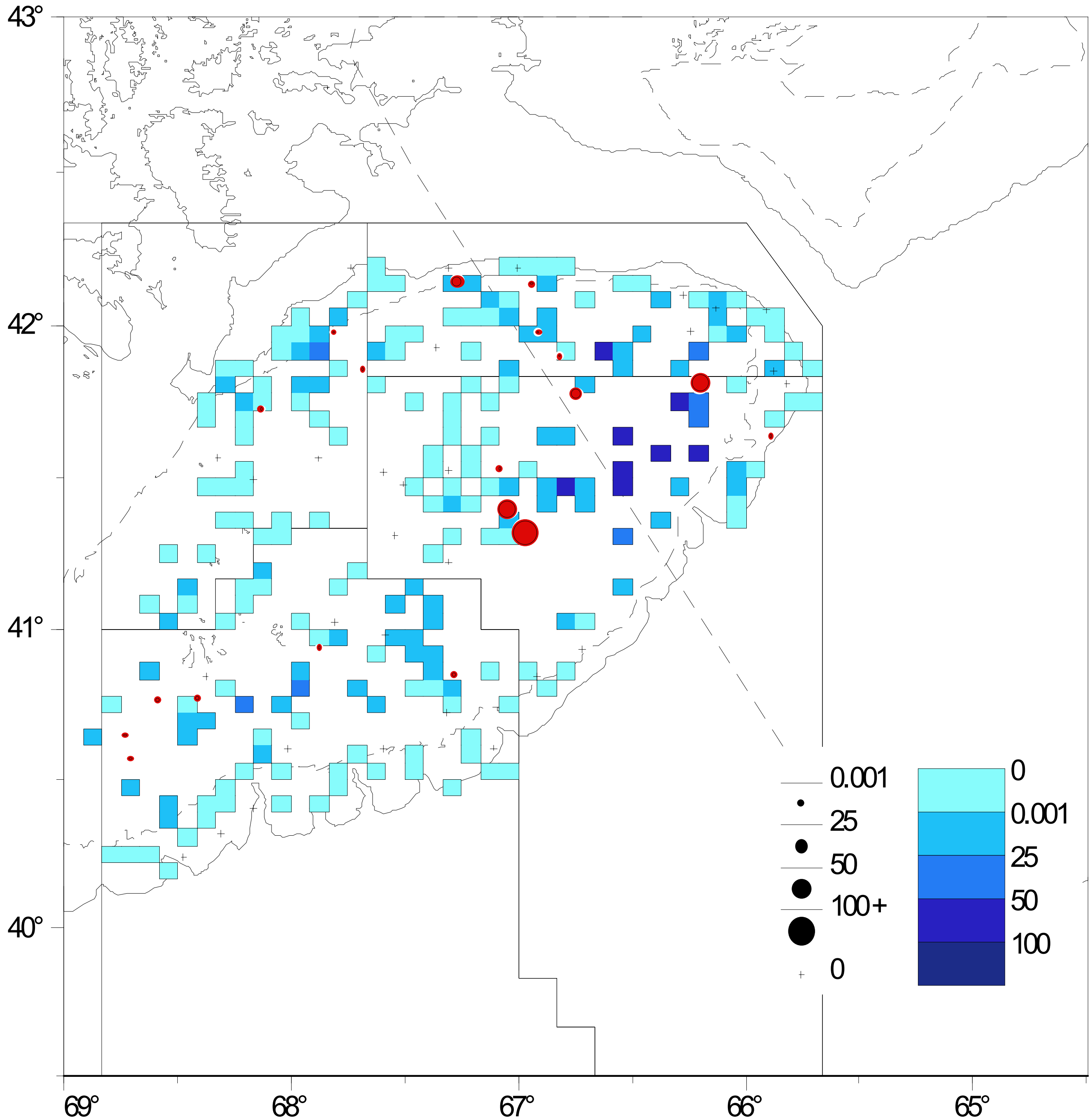

Fig. 14. The distribution of catches (number/tow) of yellowtail flounder in the NMFS Georges Bank fall survey in 2000 (solid circles), compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

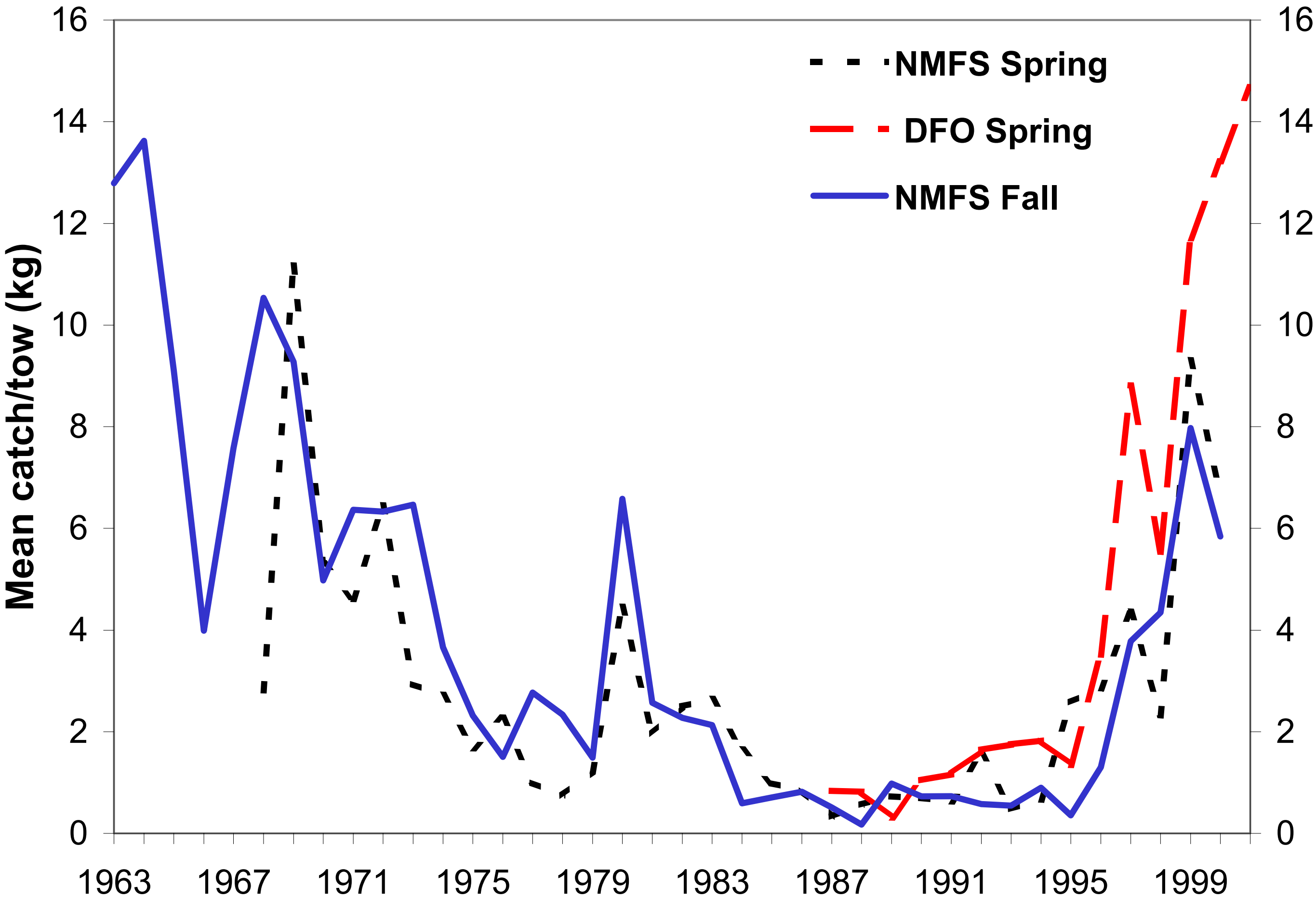

Fig. 15. NMFS and DFO spring and NMFS fall survey results (average biomass) for yellowtail flounder on Georges Bank. The DFO series was also adjusted for catchability differences.

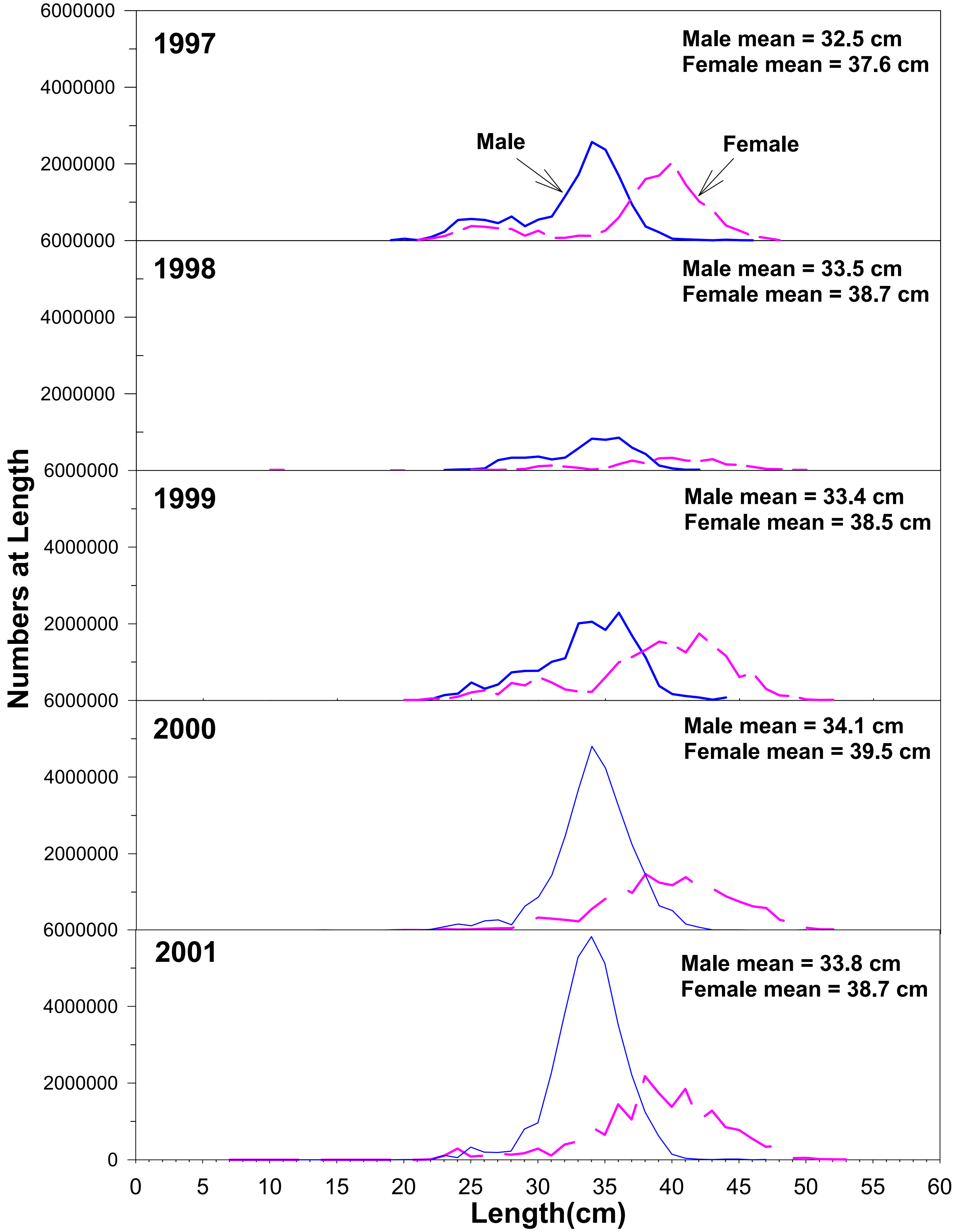

Fig. 16. Comparison of yellowtail flounder length composition in DFO spring surveys on Georges Bank, 1997- 2001.

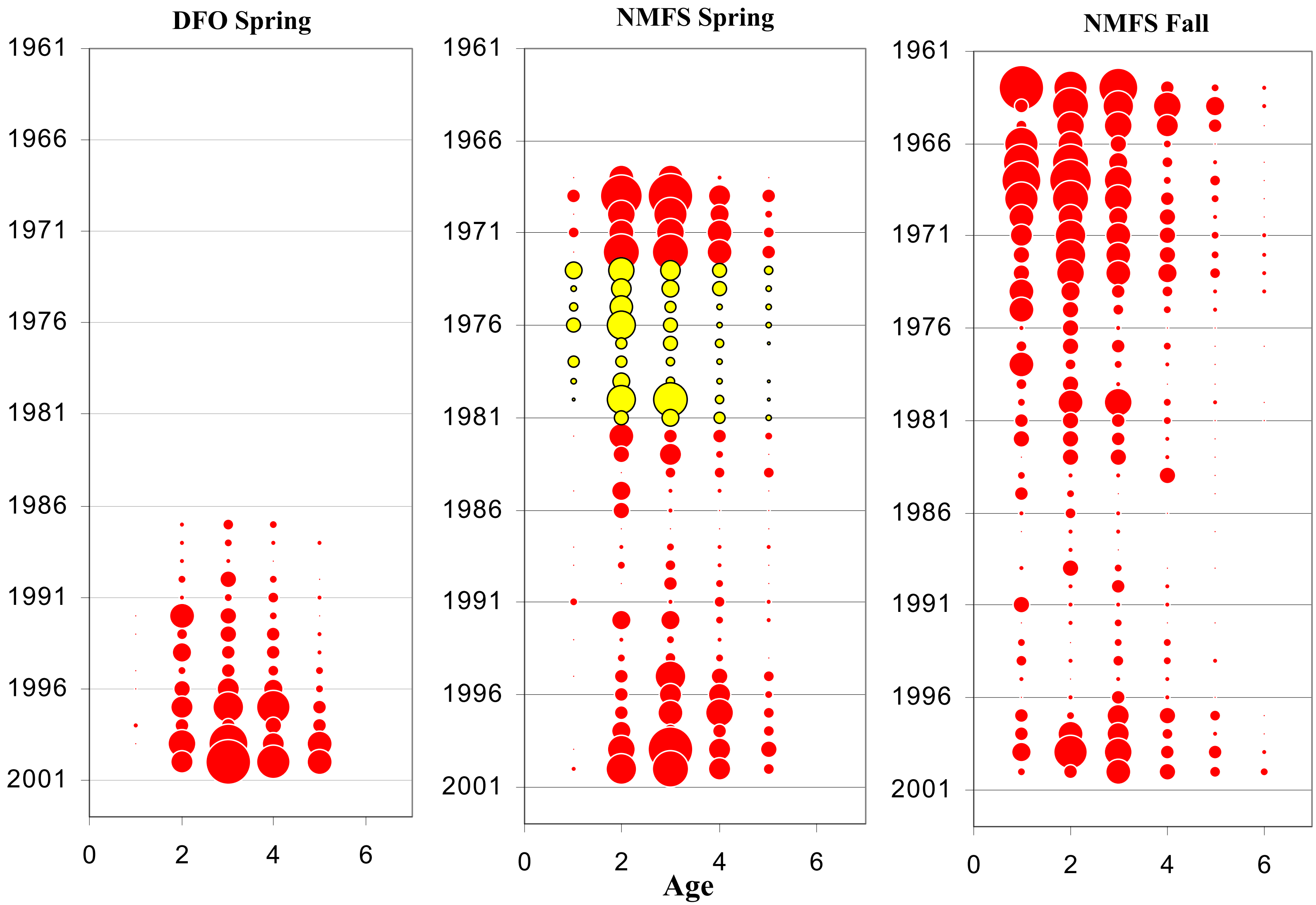

Fig. 17. Age specific indices of abundance for the DFO spring , NMFS spring, and NMFS fall surveys (bubble is proportional to the magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. Refer to Tables 5, 6 and 7 for the absolute value of the indices. The DFO spring 2001 index series was not used in the base assessment analysis.

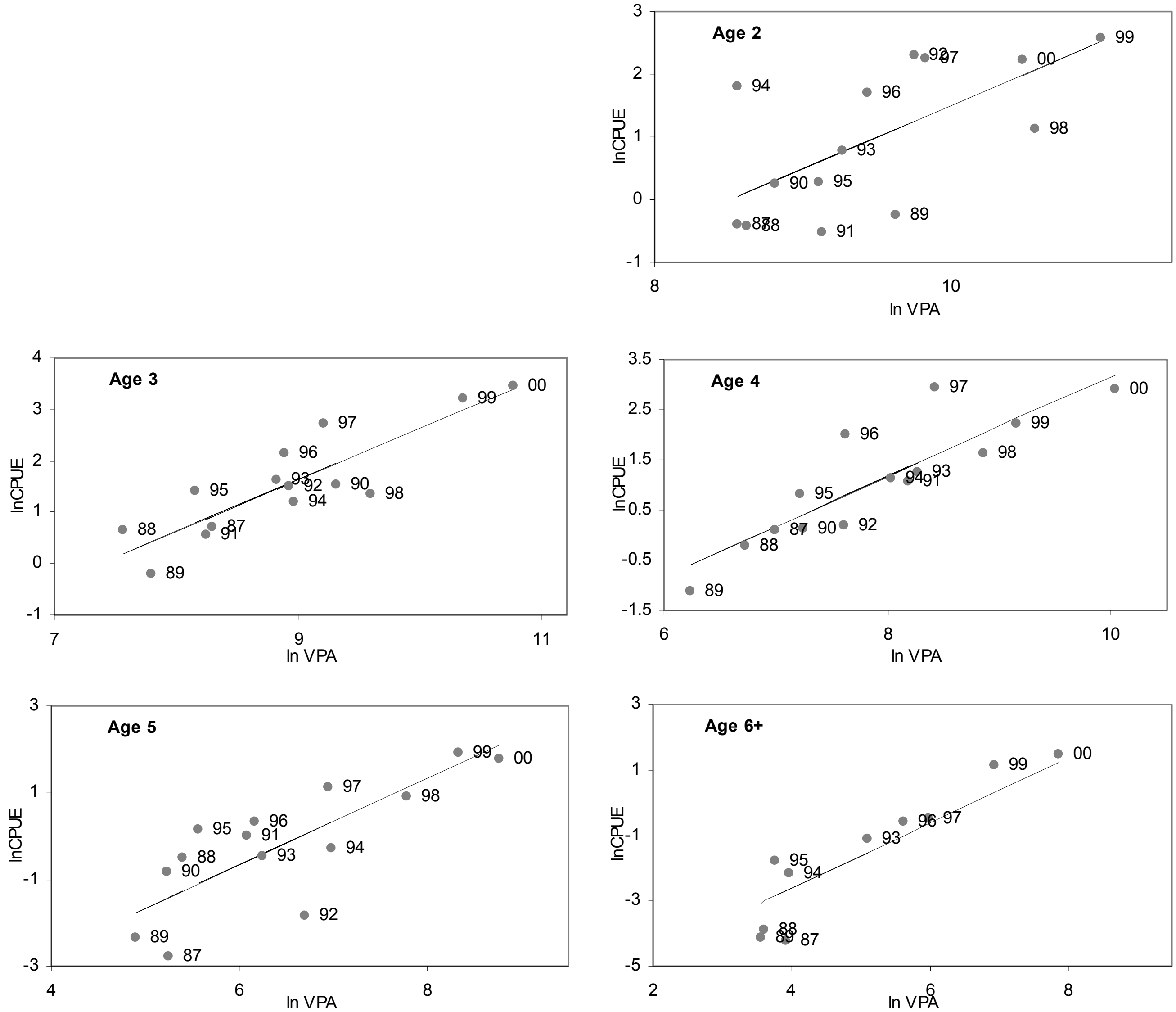

Fig. 18. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the DFO spring survey 1987-2000.

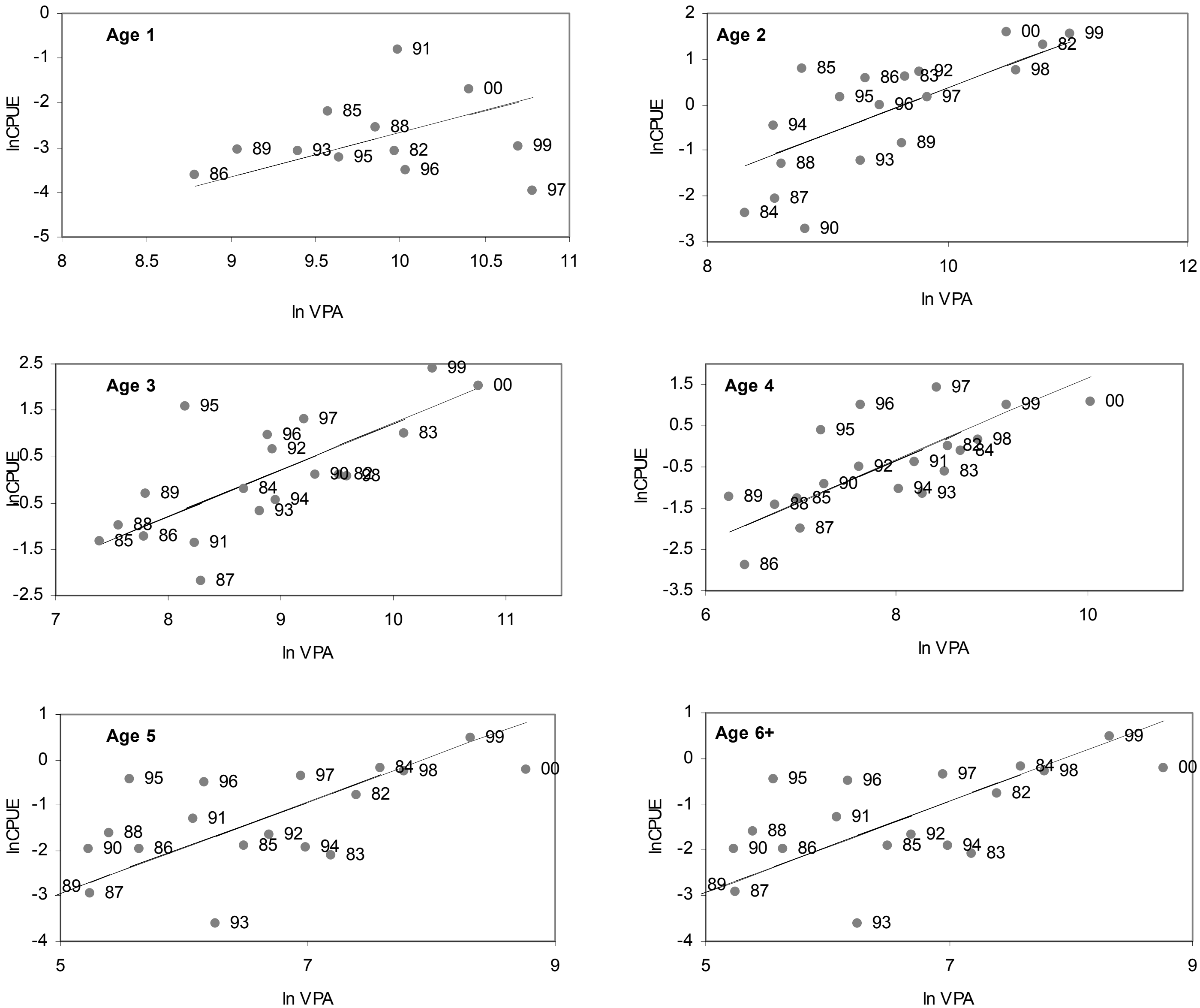

Fig. 19. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey Yankee 36 series, 1982-2000.

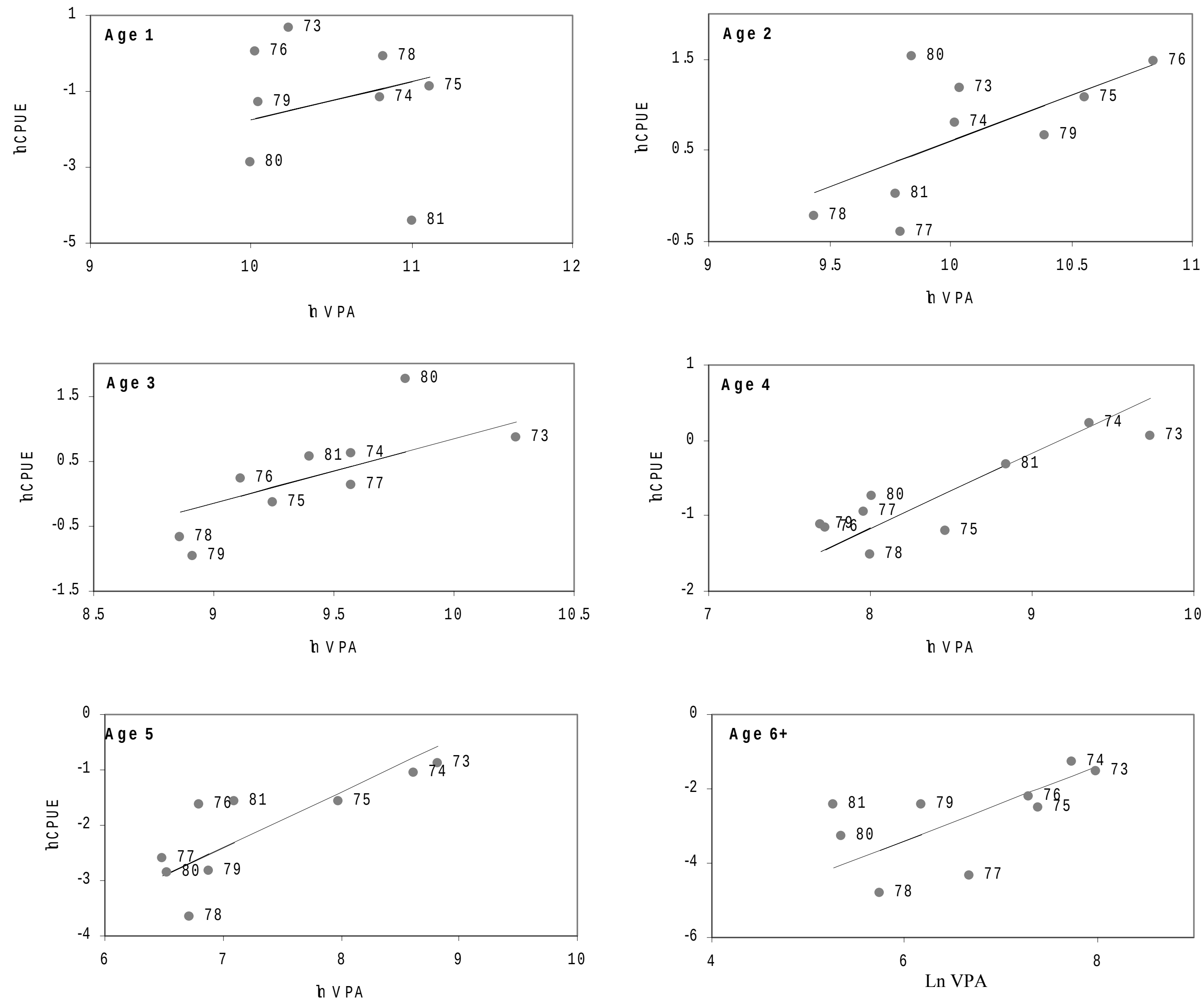

Fig. 20. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey, Yankee 41 series, 1973-1981.

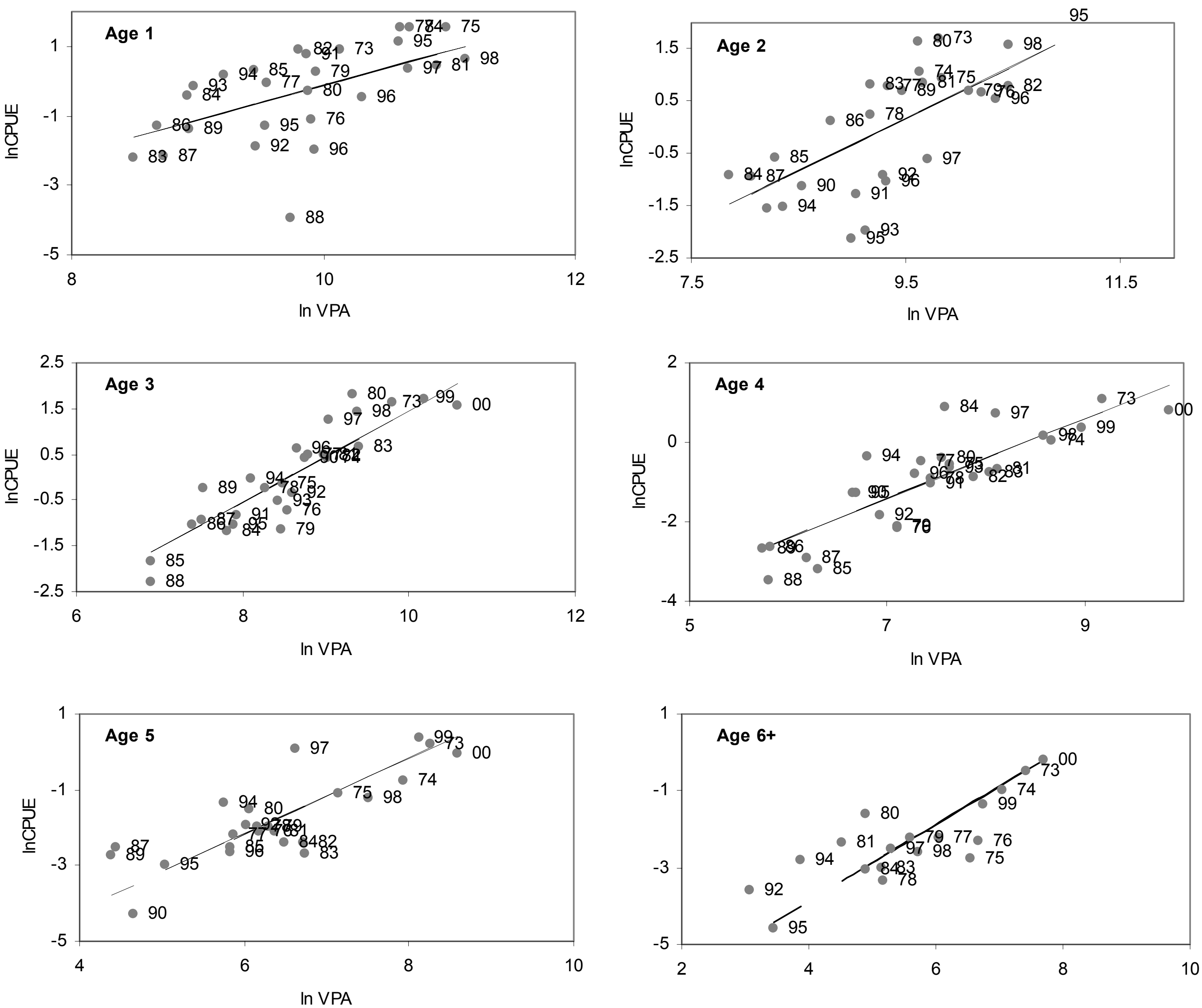

Fig. 21. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS fall survey, 1973-2000.

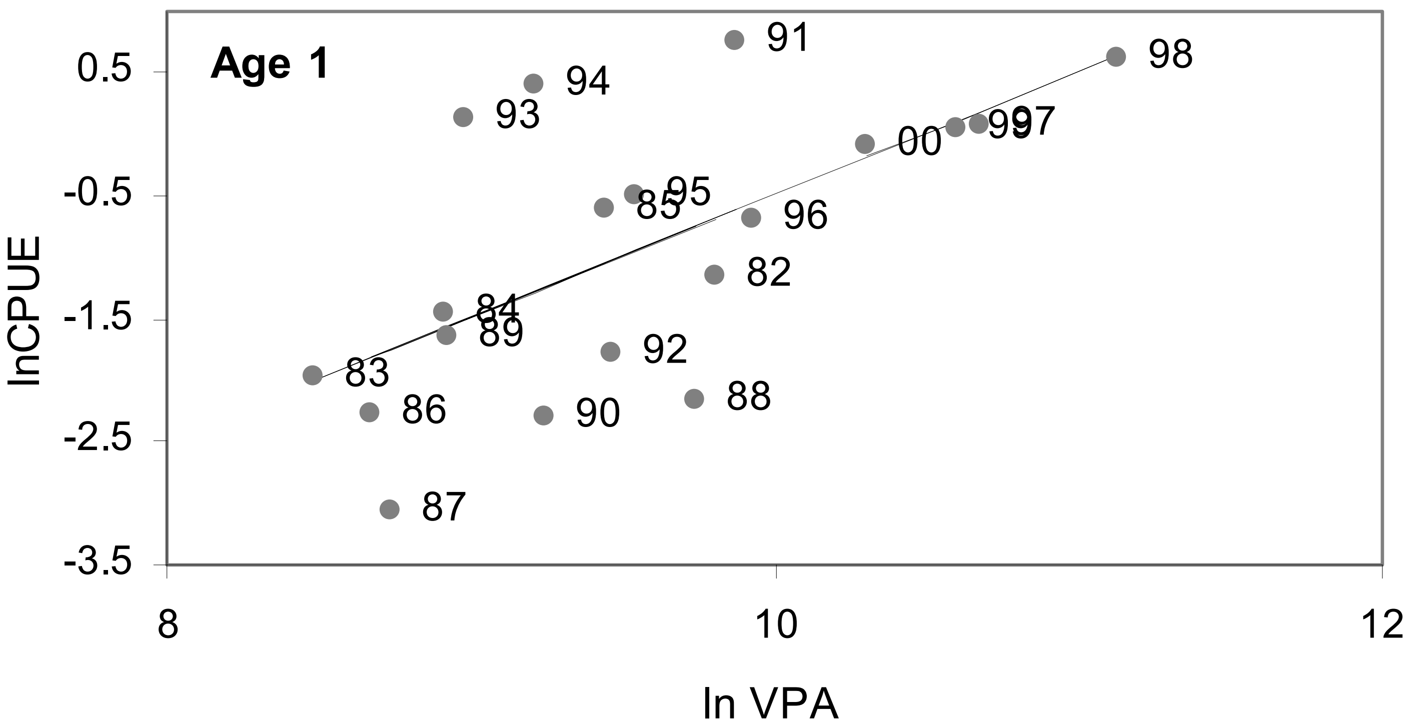

Fig. 22. Observed and predicted ln abundance index vs population numbers for Georges Bank age 1 yellowtail flounder from the NMFS scallop survey, 1982-2000

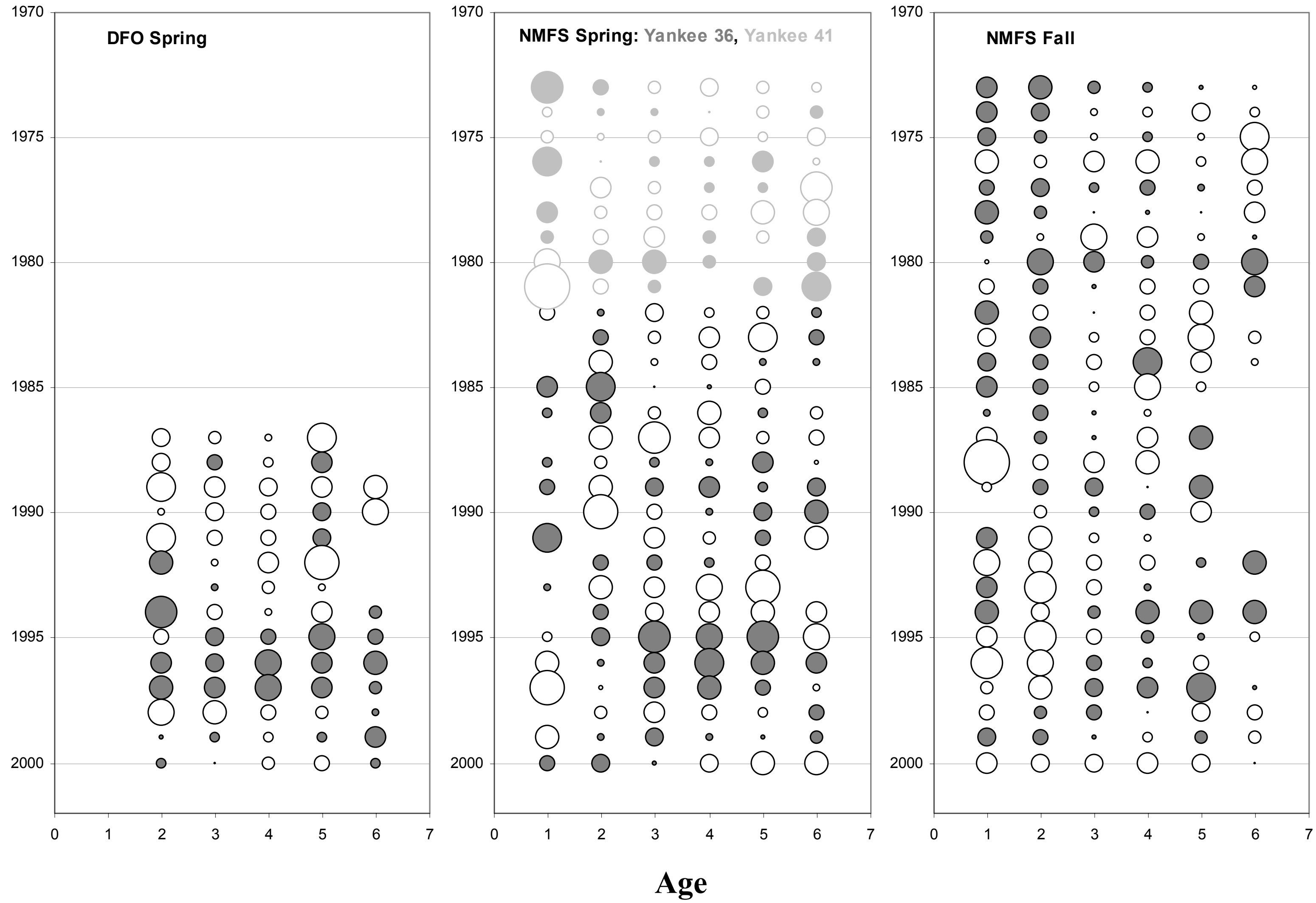

Fig. 2 Age by age residuals for the relationships between ln abundance index versus ln population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and closed symbols denote positive residuals.

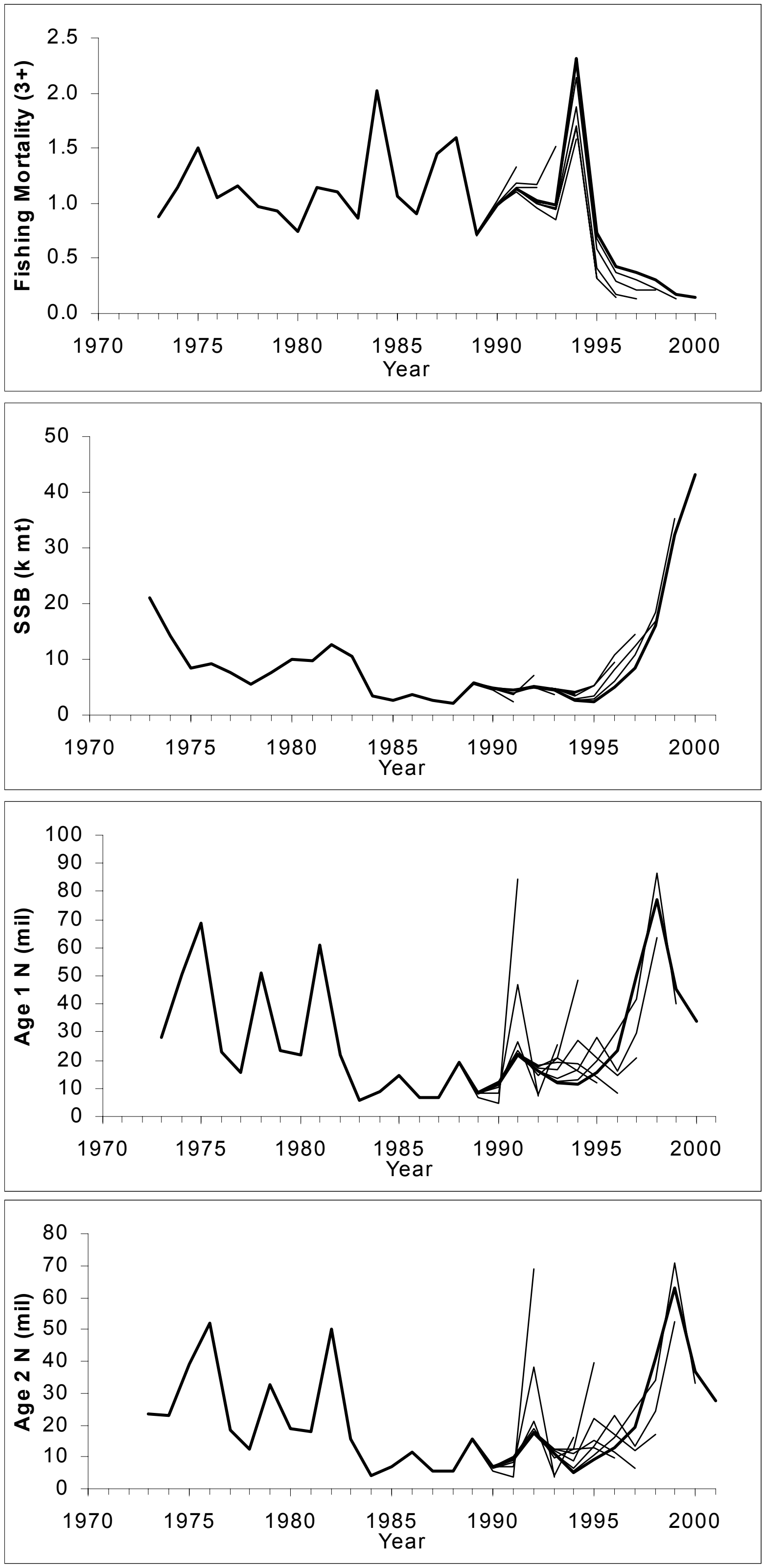

Fig. 24. Retrospective analysis of Georges Bank yellowtail flounder VPA from USA "FACT" software.

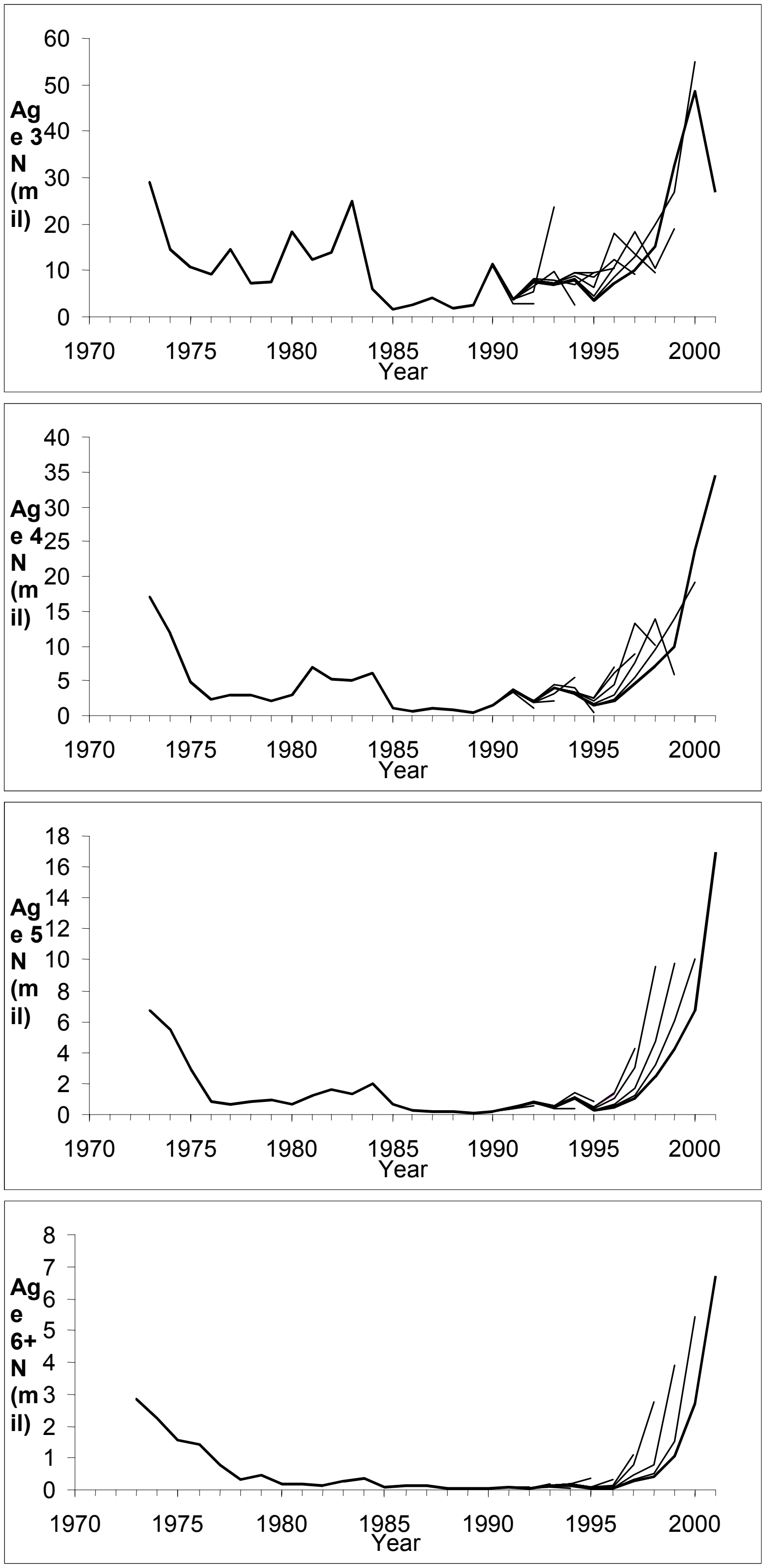

Fig. 24 (cont'd). Retrospective analysis of Georges Bank yellowtail flounder VPA from USA "FACT" software.

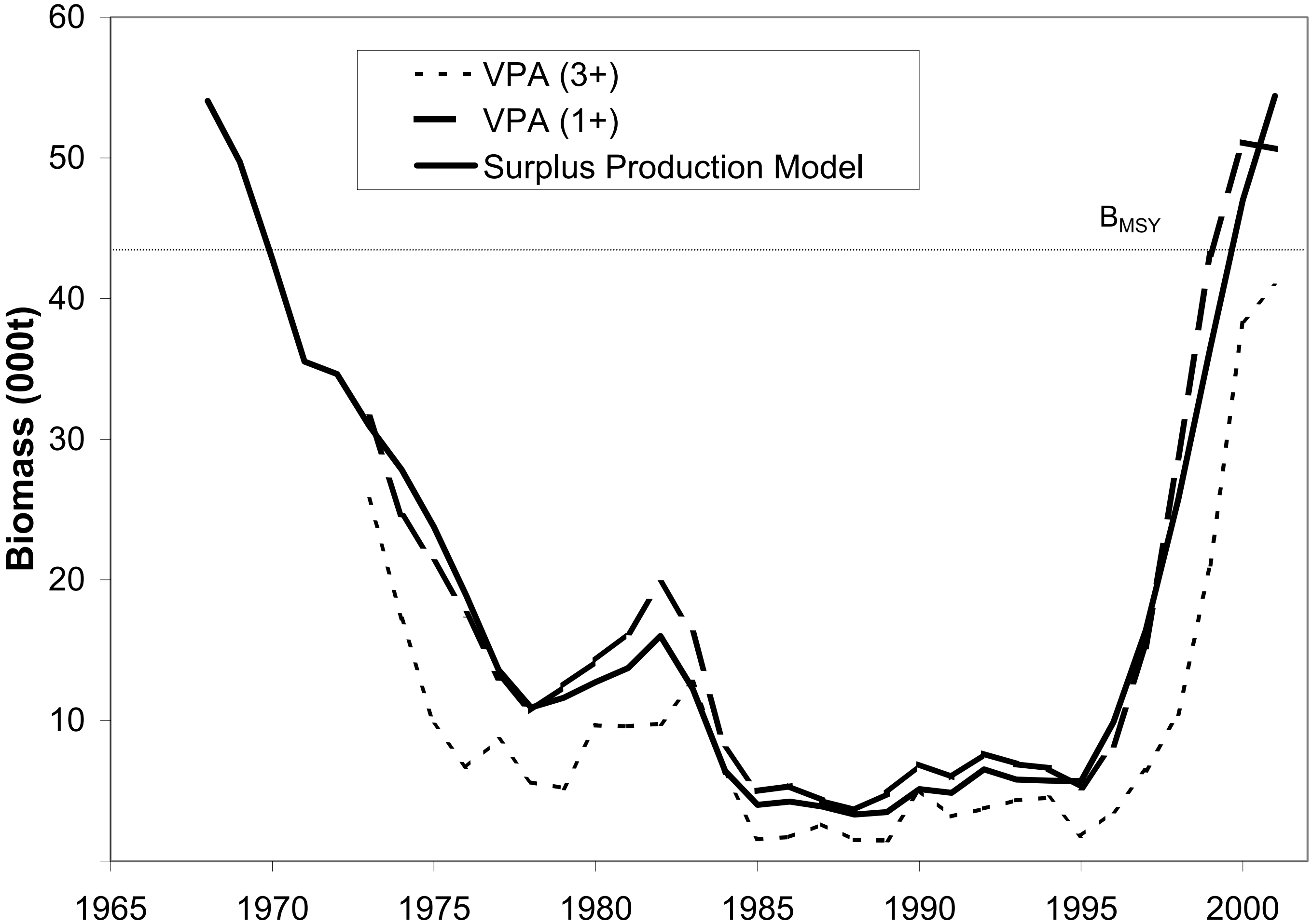

Fig. 25. Trends in total (1+) and adult (3+) beginning of year biomass (000s t) as indicated from the VPA and surplus production models for yellowtail flounder on Georges Bank. The B_{MSY} level of 42,740 (from the surplus production model) is also shown.

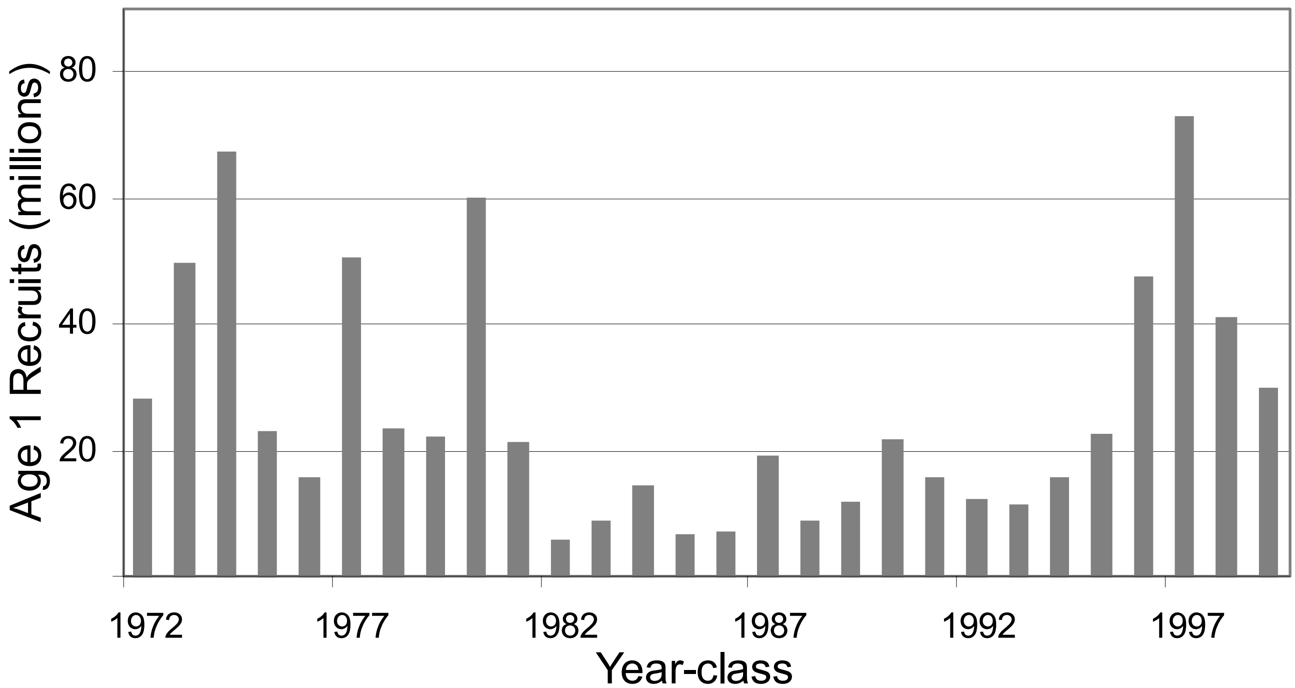

Fig. 26. Age-1 recruitment estimates for Georges Bank yellowtail flounder, 1972-1999.

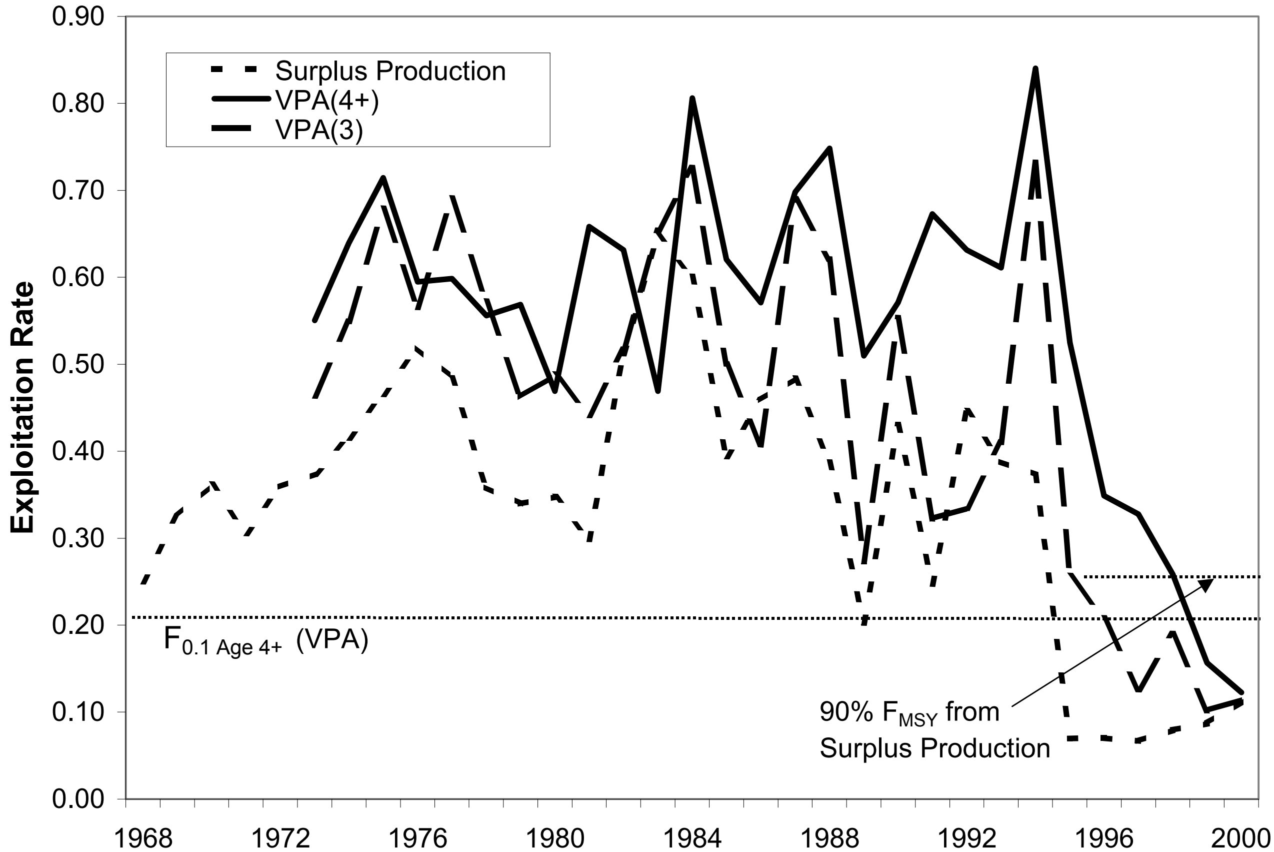

Fig. 27. Trends in fully recruited (4+) and age 3 exploitation rate from the VPA and total exploitation rate from the surplus production model for yellowtail flounder on Georges Bank. Reference levels are shown for VPA Age 4and for surplus production.

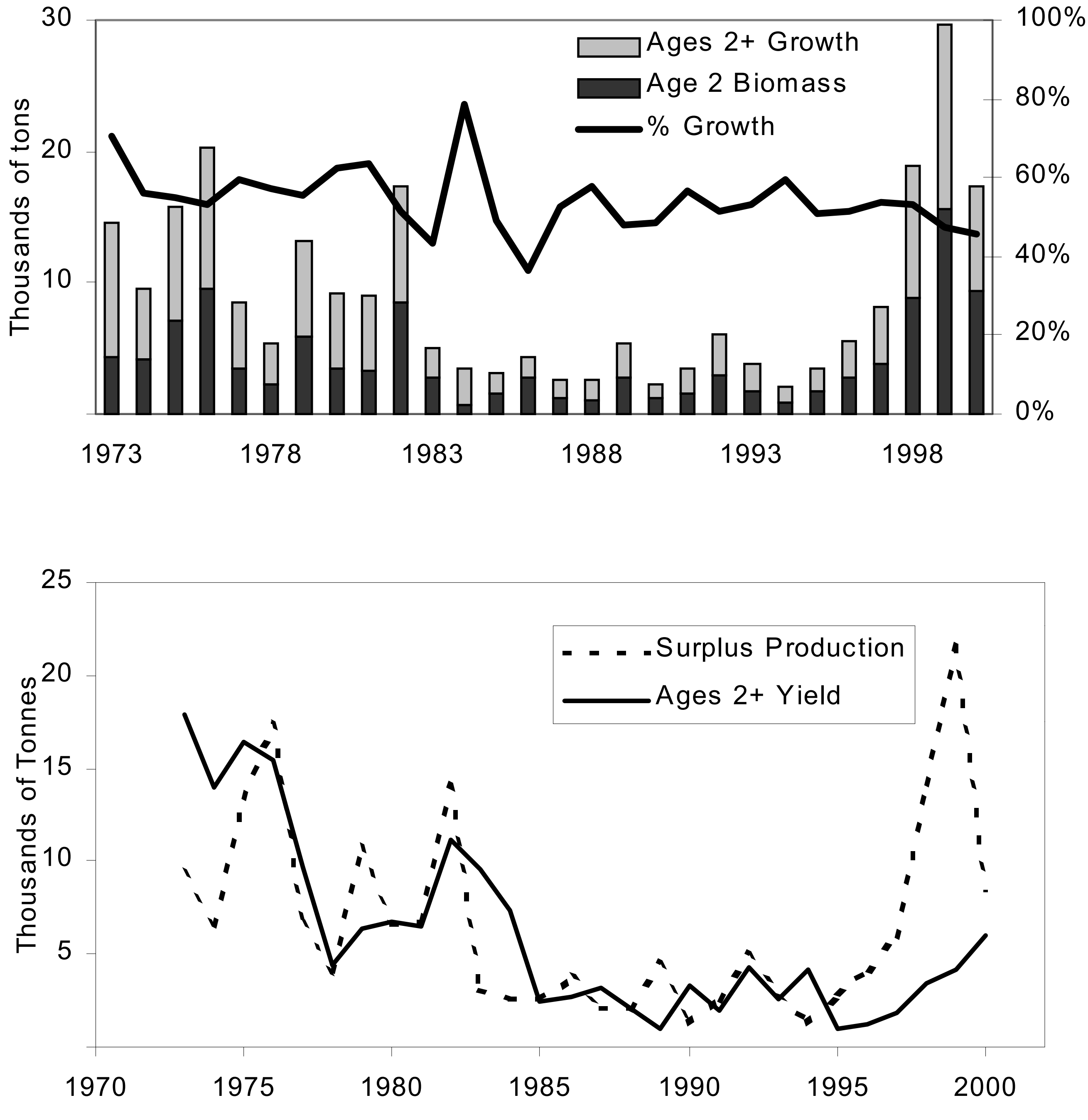

Fig. 28. Components of production (top panel), and production as indicated by the VPA, compared with fishery yield for Georges Bank yellowtail flounder.

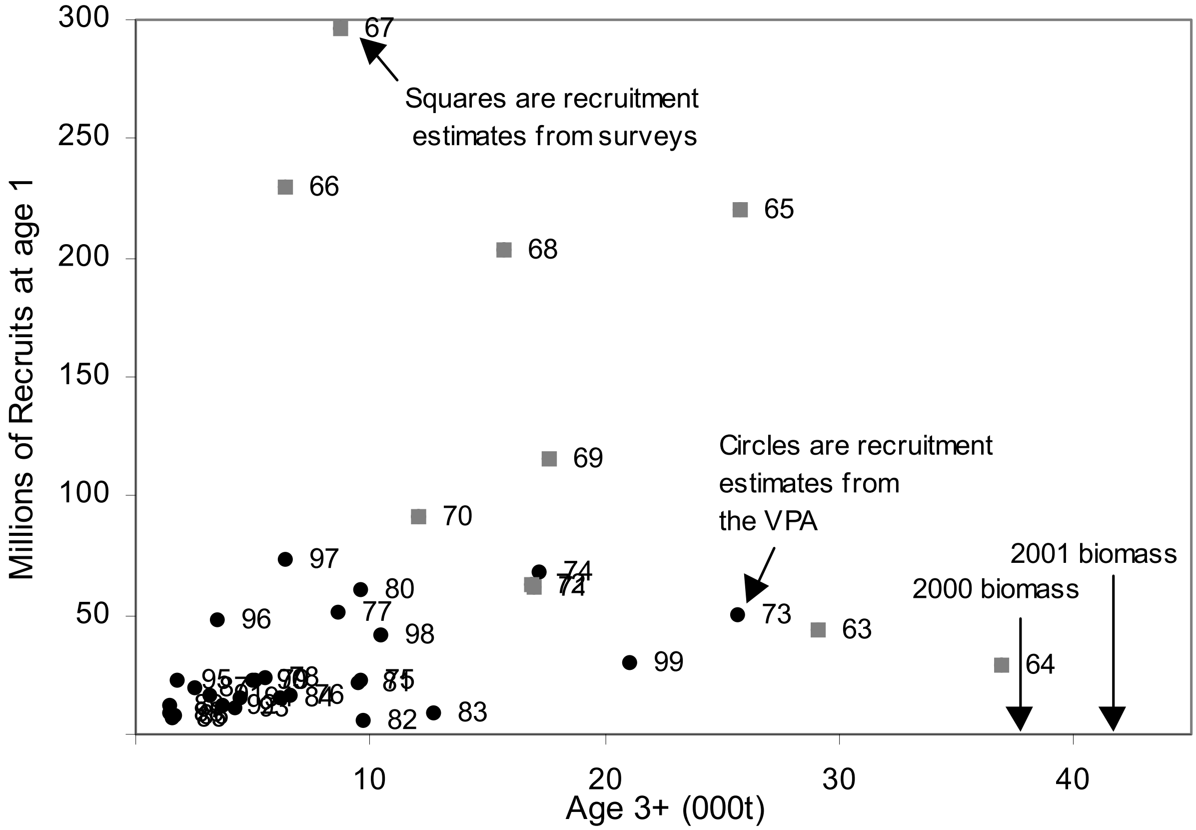

Fig. 29. Age 3+ biomass and age 1 recruitment relationship from the VPA for Georges Bank yellowtail flounder. The beginning of year age 3+ biomass for 2000 and 2001 from the VPA is also shown.

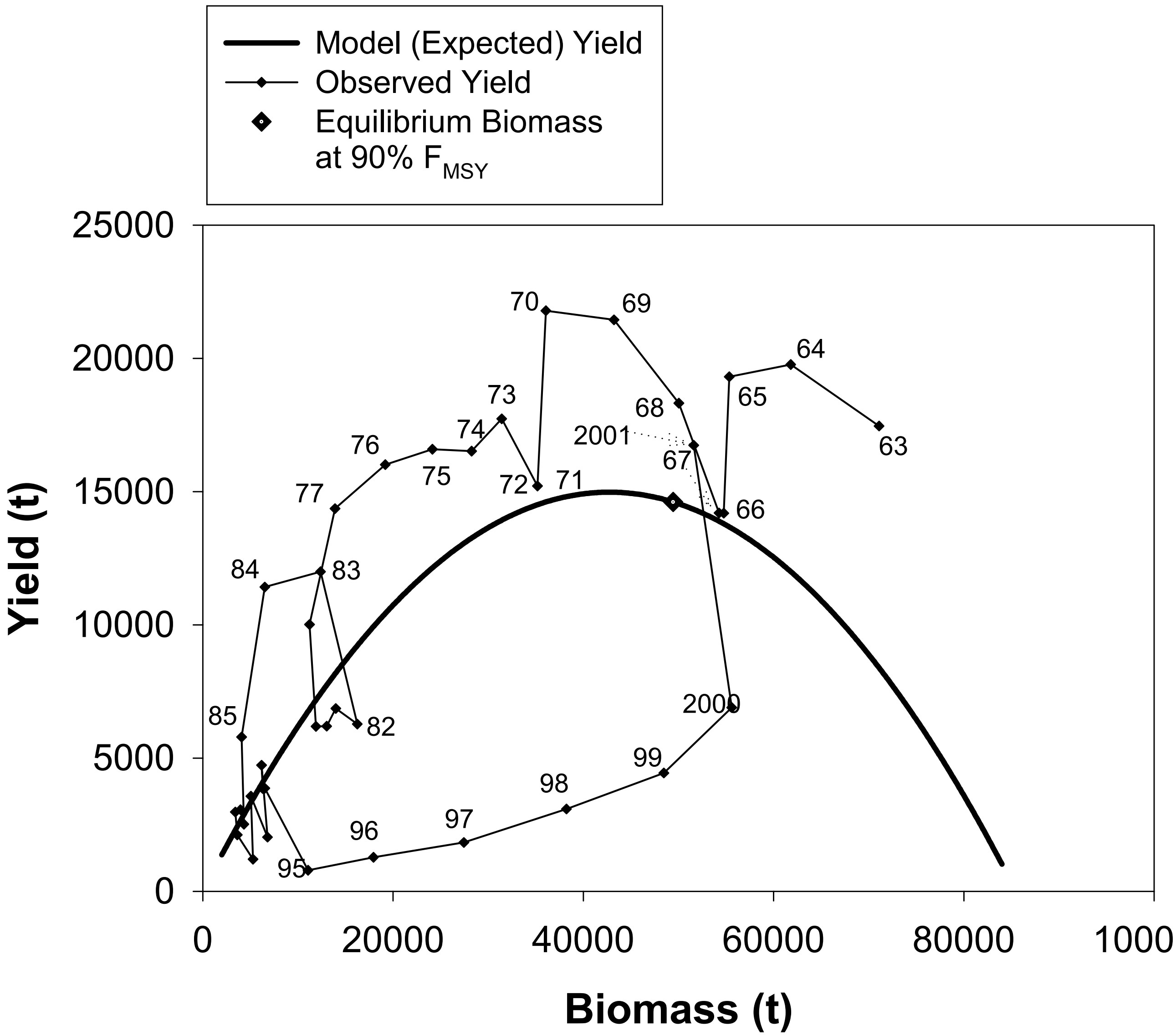

Fig. 30. Phase plot of surplus production biomass from ASPIC showing the models expected yield and observed yield for 1963 through 2001. The last point represents the equilibrium biomass in 2001 (and beginning of year biomass in 2002) at 90% F_{MSY}.

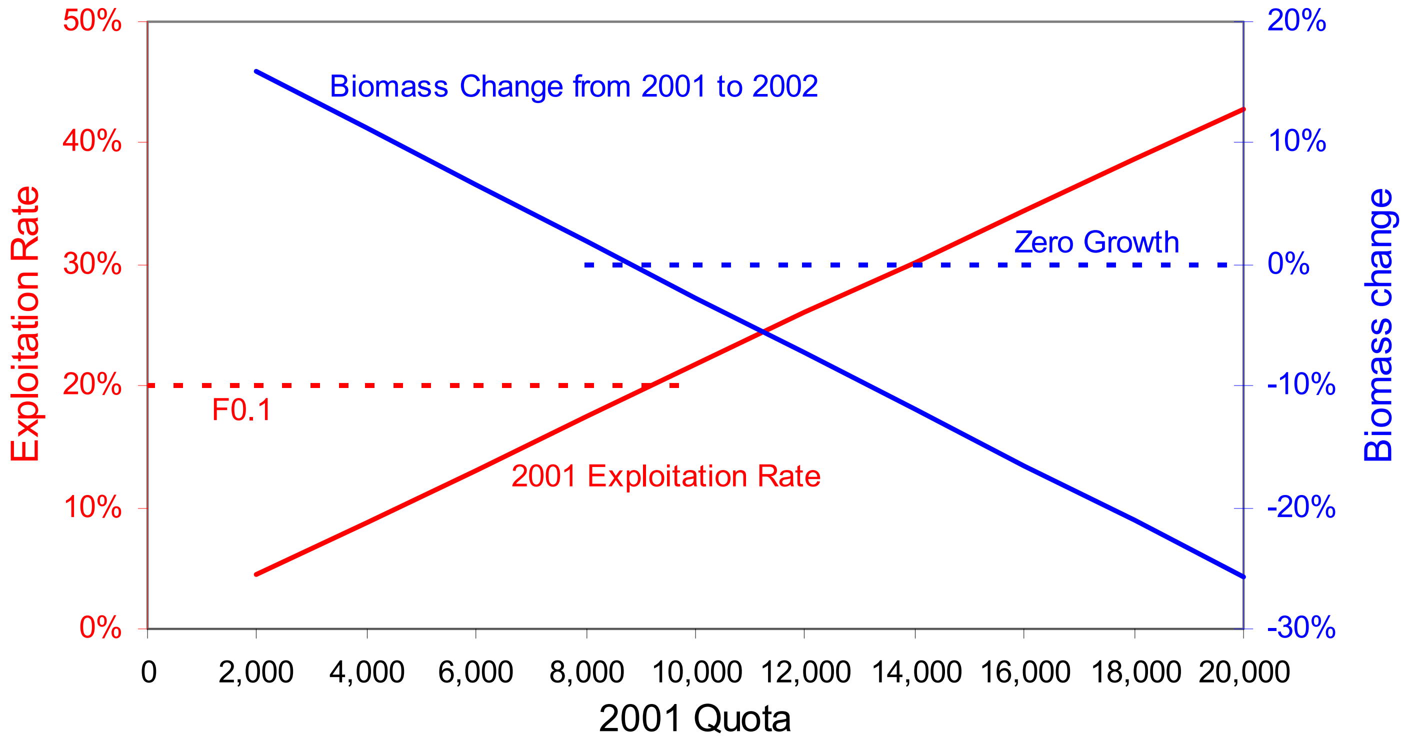

Fig. 31. Implications of various 2001 quotas (combined Canada and USA) on exploitation rate and change in the 3+ population biomass from 2001 to 2002.

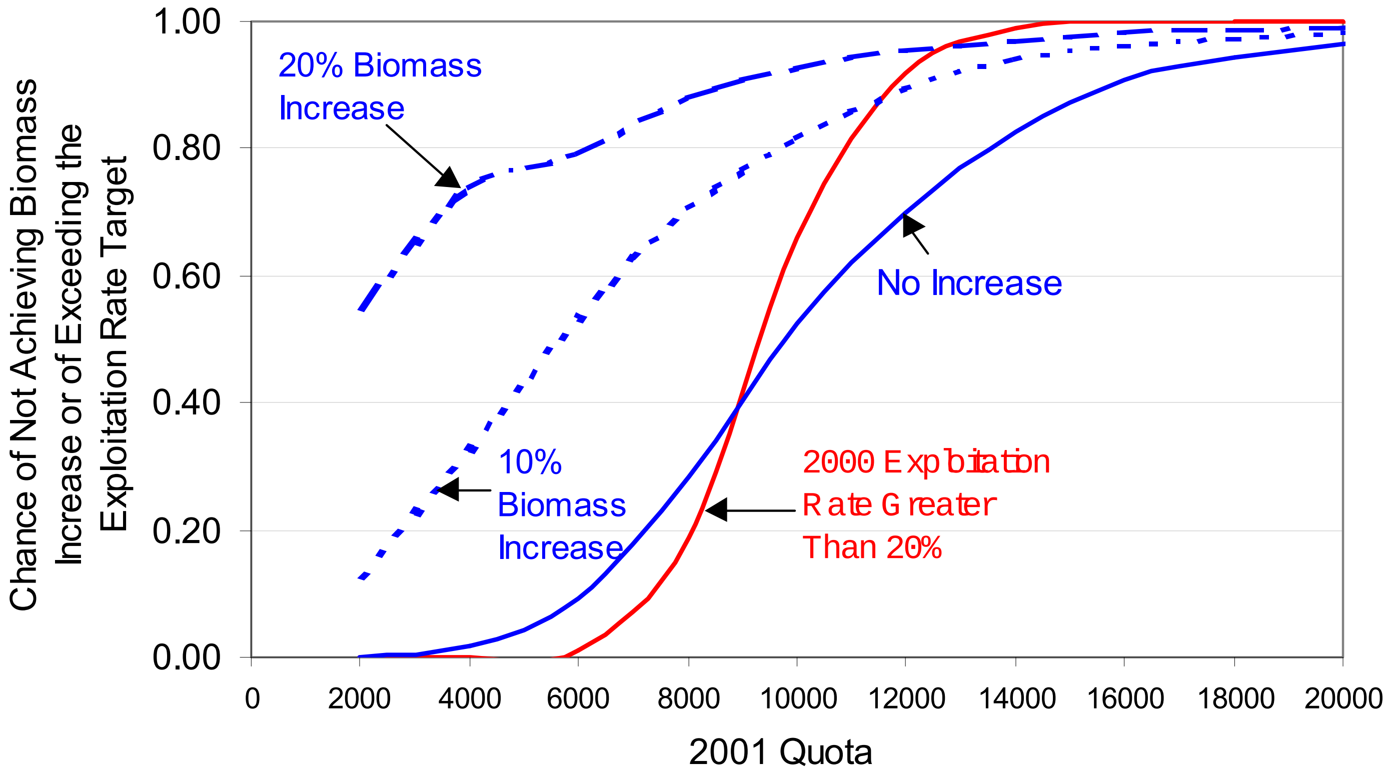

Fig. 32. Risk of exceeding the $F_{0.1}$ fishing mortality or not achieving increments of population biomass growth at various quotas for the 2001 fishery, Georges Bank yellowtail flounder.

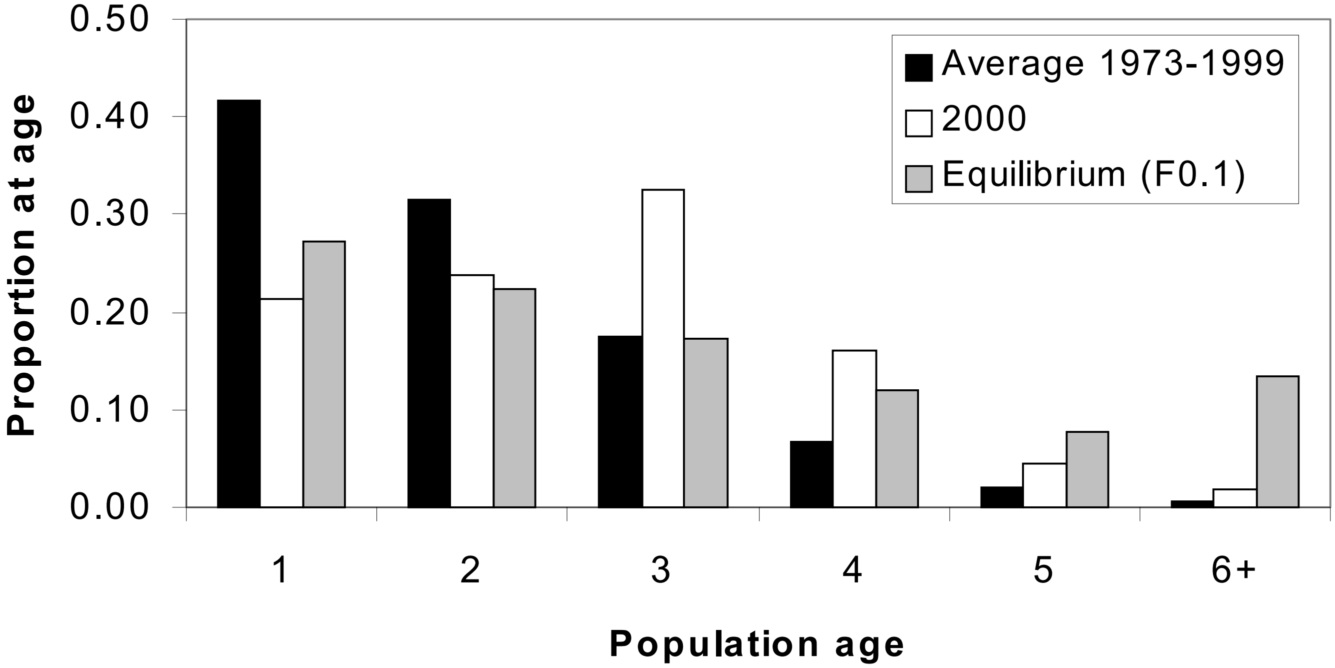

Fig. 33. Proportions at age for the Georges Bank yellowtail flounder population in 2000, for the average of 1973-1999 and when the population is at equilibrium.

Appendix A

Summary of US FACT virtual population analysis results

Table A1. Statistical properties of estimates for population abundance and survey calibration constants (10^{-3}) for Georges Bank yellowtail flounder from US FACT software. Compare with Table 10.

Age	Estimate	Standard Error	CV
Population Abundance			
2	27600	13800	0.50
3	26900	10600	0.39
4	34600	12400	0.36
5	16900	3130	0.18
Survey Calibration Constants			
Scallop			
1	0.027	0.005	0.20
DFO Spring Survey - 1986-2000			
2	0.197	0.045	0.23
3	0.620	0.141	0.23
4	1.060	0.240	0.23
5	1.270	0.289	0.23
6	1.230	0.332	0.27
NMFS Spring Survey - Yankee 36 - 1982-2000			
1	0.003	0.001	0.25
2	0.064	0.013	0.20
3	0.150	0.029	0.19
4	0.238	0.046	0.19
5	0.359	0.070	0.19
6	0.553	0.117	0.21
NMFS Spring Survey - Yankee 41 - 1973-1981			
1	0.008	0.002	0.30
2	0.082	0.023	0.28
3	0.104	0.029	0.28
4	0.103	0.029	0.28
5	0.084	0.023	0.28
6	0.087	0.024	0.28
NMFS Fall Survey - 1963-2000			
1	0.040	0.006	0.16
2	0.085	0.014	0.16
3	0.183	0.029	0.16
4	0.207	0.033	0.16
5	0.274	0.047	0.17
6	0.372	0.074	0.20

Table A2. Beginning of year population abundance numbers at age (000's), mean biomass (t), and spawning stock biomass (t) for Georges Bank yellowtail flounder from the US FACT software. Compare with Table 11.

Year	Age Group							Mean	
	1	2	3	4	5	6+	1+	Biomass	SSB
1973	28290	23279	28937	16960	6729	2859	107054	26984	21143
1974	50265	22848	14635	11709	5492	2240	107189	21520	14130
1975	68516	39214	10589	4830	2893	1551	127593	18464	8398
1976	22919	52140	9228	2284	885	1417	88873	16201	9271
1977	15760	18208	14628	2899	651	768	52914	11173	7592
1978	50823	12605	7144	3003	816	304	74695	11128	5469
1979	23375	32871	7510	2199	957	465	67377	14162	7702
1980	22099	18927	18312	3032	677	206	63253	14577	10112
1981	61066	17814	12264	7011	1198	185	99538	17718	9716
1982	21627	49947	13925	5199	1618	129	92445	19722	12537
1983	5818	15840	25067	4957	1319	264	53265	12312	10427
1984	8620	4134	6011	6031	1962	382	27140	4749	3485
1985	14594	6670	1650	1062	654	102	24732	5028	2732
1986	6660	11361	2434	613	279	129	21476	4830	3763
1987	7023	5310	4079	1108	188	155	17863	3329	2638
1988	19350	5623	1947	851	219	49	28039	3940	2198
1989	8530	15405	2462	516	132	36	27081	6678	5739
1990	11696	6816	11241	1411	185	34	31383	5820	4851
1991	22072	9378	3834	3663	432	86	39465	6395	4362
1992	15974	17698	7629	2033	800	41	44175	7661	4892
1993	12153	10917	6926	3960	516	119	34591	6664	4441
1994	11268	5250	8025	3158	1078	154	28933	4765	2517
1995	15778	9161	3520	1375	259	50	30143	5768	2497
1996	23440	12905	7358	2072	479	43	46297	9864	5111
1997	49970	19146	10219	4659	1048	274	85316	18361	8522
1998	76980	40898	15137	7229	2455	402	143101	35255	16114
1999	45134	63002	32606	9867	4268	1057	155934	52134	32306
2000	33771	36933	48608	23792	6723	2719	152546	55957	43064
2001		27559	26862	34597	16924	6716	112658		

Table A3. Fishing mortality rates for Georges Bank yellowtail flounder from US FACT software. F4-5 denotes the average F for ages 4 and 5 weighted by population abundance in numbers, FonB denotes the average F weighted by biomass at age. Compare with Table 12.

Year	Age Group							
	1	2	3	4	5	6+	F4-5	FonB
1973	0.01	0.26	0.70	0.93	0.95	0.95	0.94	0.61
1974	0.05	0.57	0.91	1.20	1.25	1.25	1.22	0.73
1975	0.07	1.25	1.33	1.50	1.59	1.59	1.54	0.88
1976	0.03	1.07	0.96	1.05	1.09	1.09	1.07	0.91
1977	0.02	0.74	1.38	1.07	1.10	1.10	1.09	0.91
1978	0.24	0.32	0.98	0.94	0.97	0.97	0.96	0.52
1979	0.01	0.39	0.71	0.98	1.01	1.01	0.99	0.44
1980	0.02	0.23	0.76	0.73	0.74	0.74	0.74	0.48
1981	0.00	0.05	0.66	1.27	1.33	1.33	1.30	0.36
1982	0.11	0.49	0.83	1.17	1.22	1.22	1.19	0.61
1983	0.14	0.77	1.22	0.73	0.74	0.74	0.73	0.94
1984	0.06	0.72	1.53	2.02	2.27	2.27	2.14	1.25
1985	0.05	0.81	0.79	1.14	1.18	1.18	1.16	0.51
1986	0.03	0.82	0.59	0.98	1.01	1.01	1.00	0.62
1987	0.02	0.80	1.37	1.42	1.50	1.50	1.46	0.91
1988	0.03	0.63	1.13	1.66	1.79	1.79	1.73	0.54
1989	0.02	0.12	0.36	0.82	0.84	0.84	0.83	0.18
1990	0.02	0.38	0.92	0.98	1.02	1.02	1.00	0.62
1991	0.02	0.01	0.43	1.32	1.39	1.39	1.35	0.31
1992	0.18	0.74	0.46	1.17	1.22	1.22	1.19	0.62
1993	0.64	0.11	0.59	1.10	1.14	1.14	1.12	0.50
1994	0.01	0.20	1.56	2.30	2.71	2.71	2.50	0.90
1995	0.00	0.02	0.33	0.86	0.88	0.88	0.87	0.14
1996	0.00	0.03	0.26	0.48	0.49	0.49	0.48	0.13
1997	0.00	0.03	0.15	0.44	0.45	0.45	0.44	0.10
1998	0.00	0.03	0.23	0.33	0.33	0.33	0.33	0.09
1999	0.00	0.06	0.12	0.18	0.18	0.18	0.18	0.09
2000	0.00	0.12	0.14	0.14	0.14	0.14	0.14	0.12

Appendix B

Bayesian Surplus Production (BSP) Model Results

Due to the convergence problems found with ASPIC, both in the point estimate varying depending upon initial guesses and the relatively high proportion of bootstraps rejected due to convergence problems (123 out of 1000), an alternative surplus production model was explored. This alternative model was the Bayesian Surplus Production (BSP) model of Meyer and Millar (1999) modified to emulate the ASPIC calculations. The modification consisted of adding a variable to account for the ratio of biomass in the first year of the simulation to biomass at maximum sustainable yield.

The model was run with non-informative priors (wide uniform distributions for r, K and B1ratio) which in theory should produce posteriors with median equal to the maximum likelihood estimate and confidence intervals corresponding to the bootstrap ones. This alternative model was examined to provide collaboration of the ASPIC results, not to replace them. The results of the BSP model do in fact provide support for the ASPIC results. The bias corrected point estimate from ASPIC is similar to the median value from BSP and the confidence intervals from the two methods overlap considerably (Appendix Table A1 and Fig. A2).

Meyer R., and R.B. Millar. 1999. BUGS in Bayesian stock assessments. Can. J. Fish. Aquat. Sci. 56: 1078-1086.

Table B1. Comparison of surplus production model estimates between ASPIC and BSP. The ASPIC results are the bias corrected point estimate and approximate 80% confidence intervals from 1000 bootstraps. The BSP results are the median and 80% confidence intervals from the posterior distributions generated by 45,000 iterations of the Gibbs sampler after a 5,000 iteration burn-in using two chains. The units for MSY and Bmsy are thousand metric tons.

	ASPIC			**BSP**		
		80% CI			80% CI	
Variable	BC Est	Lower	Upper	Median	Lower	Upper
MSY	14.76	13.80	15.82	14.97	13.86	16.09
Bmsy	42.74	40.58	48.09	42.96	36.47	51.92
Fmsy	0.350	0.318	0.374	0.348	0.281	0.423
Bratio2001	1.300	1.110	1.433	1.479	1.225	1.699
Fratio2000	0.379	0.336	0.439	0.346	0.286	0.433
B1ratio	1.918	0.944	3.426	2.172	1.405	2.790

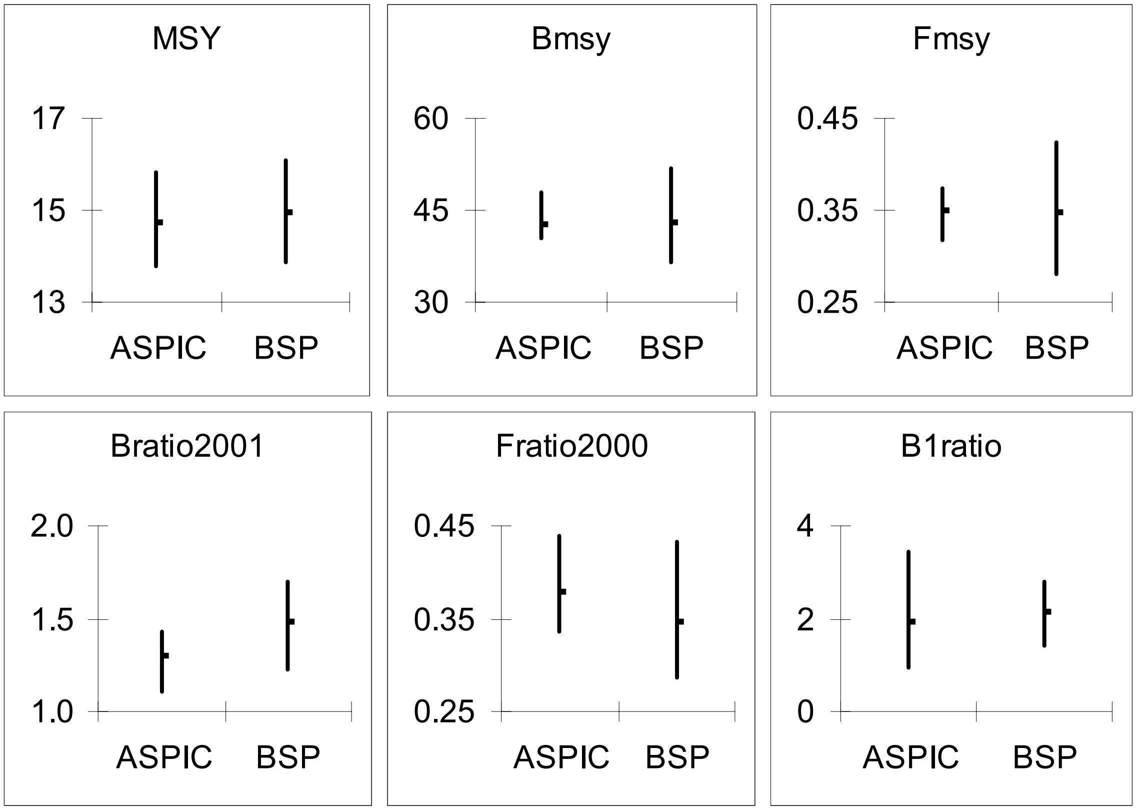

Fig. B1. Comparison of point estimates and 80% confidence intervals from two surplus production models. (See Table B1 for values).

Appendix C
Surplus Production Analyses

```
Georges Bank Yellowtail (yield and biomass in k mt)                                                             Page 1
                                                                                                  26 Apr 2001 at 09:53.21
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.86)                                          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:                        38           Number of bootstrap trials:                          1000
Number of data series:                            3           Lower bound on MSY:                             5.000E+00
Objective function computed:              in effort           Upper bound on MSY:                             5.000E+01
Relative conv. criterion (simplex):       1.000E-09           Lower bound on r:                               1.000E-01
Relative conv. criterion (restart):       3.000E-09           Upper bound on r:                               5.000E+00
Relative conv. criterion (effort):        1.000E-05           Random number seed:                               5844285
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  USA Fall                          |   1.000
                                      |      38
                                      |
 2  USA Spring -lagged                |   0.798   1.000
                                      |      24      24
                                      |
 3  Canada - lagged                   |   0.861   0.934   1.000
                                      |      15      14      15
                                      --------------------------------------------------
                                              1       2       3


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                      0.000E+00    1           N/A     0.000E+00           N/A
Loss( 1)  USA Fall                                 8.077E+00   38     2.244E-01     1.000E+00     9.920E-01         0.807
Loss( 2)  USA Spring -lagged                       5.226E+00   24     2.375E-01     1.000E+00     9.370E-01         0.629
Loss( 3)  Canada - lagged                          2.581E+00   15     1.985E-01     1.000E+00     1.121E+00         0.813
TOTAL OBJECTIVE FUNCTION:                     1.58835087E+01

Number of restarts required for convergence:              33
Est. B-ratio coverage index (0 worst, 2 best):        1.9150               < 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 1963	3.021E+00	1.000E+00	1	1
MSY	Maximum sustainable yield	1.414E+01	1.400E+01	1	1
r	Intrinsic rate of increase	6.505E-01	6.000E-01	1	1
....	Catchability coefficients by fishery:				
q(1)	USA Fall	1.281E-01	1.000E-01	1	1
q(2)	USA Spring -lagged	1.459E-01	1.000E-01	1	1
q(3)	Canada - lagged	3.103E-01	3.000E-01	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	Related quantity
MSY	Maximum sustainable yield	1.414E+01	Kr/4	
K	Maximum stock biomass	8.694E+01		
Bmsy	Stock biomass at MSY	4.347E+01	K/2	
Fmsy	Fishing mortality at MSY	3.252E-01	r/2	
F(0.1)	Management benchmark	2.927E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.400E+01	0.99*MSY	
B-ratio	Ratio of B(2001) to Bmsy	1.285E+00		
F-ratio	Ratio of F(2000) to Fmsy	4.020E-01		
F01-mult	Ratio of F(0.1) to F(2000)	2.239E+00		
Y-ratio	Proportion of MSY avail in 2001	9.186E-01	2*Br-Br^2	Ye(2001) = 1.299E+01
....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	USA Fall	2.539E+00	r/2q(1)	f(0.1) = 2.286E+00

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	1963	0.152	1.313E+02	1.098E+02	1.669E+01	1.669E+01	-1.955E+01	4.674E-01	3.021E+00
2	1964	0.234	9.508E+01	8.453E+01	1.981E+01	1.981E+01	1.318E+00	7.207E-01	2.187E+00
3	1965	0.276	7.658E+01	7.054E+01	1.945E+01	1.945E+01	8.586E+00	8.477E-01	1.762E+00
4	1966	0.214	6.572E+01	6.419E+01	1.374E+01	1.374E+01	1.092E+01	6.582E-01	1.512E+00
5	1967	0.251	6.290E+01	6.101E+01	1.531E+01	1.531E+01	1.183E+01	7.714E-01	1.447E+00
6	1968	0.322	5.942E+01	5.652E+01	1.820E+01	1.820E+01	1.285E+01	9.901E-01	1.367E+00
7	1969	0.442	5.407E+01	4.964E+01	2.194E+01	2.194E+01	1.381E+01	1.359E+00	1.244E+00
8	1970	0.506	4.594E+01	4.205E+01	2.129E+01	2.129E+01	1.409E+01	1.557E+00	1.057E+00
9	1971	0.409	3.874E+01	3.790E+01	1.551E+01	1.551E+01	1.390E+01	1.258E+00	8.912E-01
10	1972	0.501	3.714E+01	3.503E+01	1.756E+01	1.756E+01	1.360E+01	1.541E+00	8.543E-01
11	1973	0.527	3.318E+01	3.133E+01	1.652E+01	1.652E+01	1.303E+01	1.622E+00	7.631E-01
12	1974	0.607	2.968E+01	2.734E+01	1.659E+01	1.659E+01	1.218E+01	1.865E+00	6.827E-01
13	1975	0.711	2.527E+01	2.251E+01	1.601E+01	1.601E+01	1.084E+01	2.187E+00	5.814E-01
14	1976	0.835	2.010E+01	1.720E+01	1.436E+01	1.436E+01	8.956E+00	2.567E+00	4.623E-01
15	1977	0.754	1.470E+01	1.328E+01	1.001E+01	1.001E+01	7.315E+00	2.318E+00	3.381E-01
16	1978	0.501	1.200E+01	1.236E+01	6.188E+00	6.188E+00	6.895E+00	1.540E+00	2.760E-01
17	1979	0.467	1.271E+01	1.327E+01	6.195E+00	6.195E+00	7.312E+00	1.436E+00	2.923E-01
18	1980	0.481	1.382E+01	1.428E+01	6.863E+00	6.863E+00	7.761E+00	1.478E+00	3.180E-01
19	1981	0.398	1.472E+01	1.578E+01	6.277E+00	6.277E+00	8.398E+00	1.223E+00	3.386E-01
20	1982	0.817	1.684E+01	1.468E+01	1.200E+01	1.200E+01	7.925E+00	2.513E+00	3.874E-01
21	1983	1.210	1.277E+01	9.439E+00	1.142E+01	1.142E+01	5.451E+00	3.721E+00	2.938E-01
22	1984	1.059	6.800E+00	5.469E+00	5.791E+00	5.791E+00	3.330E+00	3.256E+00	1.564E-01
23	1985	0.566	4.339E+00	4.453E+00	2.520E+00	2.520E+00	2.748E+00	1.740E+00	9.981E-02
24	1986	0.697	4.567E+00	4.389E+00	3.060E+00	3.060E+00	2.711E+00	2.144E+00	1.051E-01
25	1987	0.753	4.217E+00	3.949E+00	2.975E+00	2.975E+00	2.452E+00	2.317E+00	9.702E-02
26	1988	0.554	3.694E+00	3.823E+00	2.118E+00	2.118E+00	2.377E+00	1.703E+00	8.498E-02
27	1989	0.253	3.953E+00	4.768E+00	1.207E+00	1.207E+00	2.929E+00	7.784E-01	9.094E-02
28	1990	0.638	5.676E+00	5.592E+00	3.569E+00	3.569E+00	3.404E+00	1.962E+00	1.306E-01
29	1991	0.318	5.510E+00	6.382E+00	2.030E+00	2.030E+00	3.844E+00	9.780E-01	1.268E-01
30	1992	0.670	7.325E+00	7.064E+00	4.732E+00	4.732E+00	4.222E+00	2.060E+00	1.685E-01
31	1993	0.552	6.814E+00	6.974E+00	3.853E+00	3.853E+00	4.173E+00	1.699E+00	1.568E-01
32	1994	0.523	7.134E+00	7.401E+00	3.869E+00	3.869E+00	4.404E+00	1.607E+00	1.641E-01
33	1995	0.079	7.669E+00	9.964E+00	7.880E-01	7.880E-01	5.723E+00	2.432E-01	1.764E-01
34	1996	0.080	1.260E+01	1.600E+01	1.273E+00	1.273E+00	8.460E+00	2.446E-01	2.900E-01
35	1997	0.075	1.979E+01	2.439E+01	1.834E+00	1.834E+00	1.136E+01	2.312E-01	4.553E-01
36	1998	0.090	2.931E+01	3.445E+01	3.111E+00	3.111E+00	1.346E+01	2.776E-01	6.743E-01
37	1999	0.100	3.967E+01	4.457E+01	4.442E+00	4.442E+00	1.407E+01	3.064E-01	9.125E-01
38	2000	0.131	4.930E+01	5.273E+01	6.895E+00	6.895E+00	1.347E+01	4.020E-01	1.134E+00
39	2001		5.587E+01						1.285E+00

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) USA Fall

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 log yield
1	1963	1.279E+01	1.406E+01	0.1520	1.669E+01	1.669E+01	0.09484	0.000E+00
2	1964	1.362E+01	1.083E+01	0.2344	1.981E+01	1.981E+01	-0.22982	0.000E+00
3	1965	9.104E+00	9.034E+00	0.2757	1.945E+01	1.945E+01	-0.00775	0.000E+00
4	1966	3.988E+00	8.220E+00	0.2141	1.374E+01	1.374E+01	0.72334	0.000E+00
5	1967	7.575E+00	7.814E+00	0.2509	1.531E+01	1.531E+01	0.03107	0.000E+00
6	1968	1.054E+01	7.238E+00	0.3220	1.820E+01	1.820E+01	-0.37543	0.000E+00
7	1969	9.279E+00	6.358E+00	0.4420	2.194E+01	2.194E+01	-0.37804	0.000E+00
8	1970	4.979E+00	5.385E+00	0.5063	2.129E+01	2.129E+01	0.07848	0.000E+00
9	1971	6.365E+00	4.853E+00	0.4092	1.551E+01	1.551E+01	-0.27112	0.000E+00
10	1972	6.328E+00	4.487E+00	0.5012	1.756E+01	1.756E+01	-0.34385	0.000E+00
11	1973	6.602E+00	4.012E+00	0.5274	1.652E+01	1.652E+01	-0.49806	0.000E+00
12	1974	3.733E+00	3.502E+00	0.6066	1.659E+01	1.659E+01	-0.06394	0.000E+00
13	1975	2.365E+00	2.883E+00	0.7112	1.601E+01	1.601E+01	0.19819	0.000E+00
14	1976	1.533E+00	2.203E+00	0.8348	1.436E+01	1.436E+01	0.36244	0.000E+00
15	1977	2.829E+00	1.701E+00	0.7538	1.001E+01	1.001E+01	-0.50877	0.000E+00
16	1978	2.383E+00	1.582E+00	0.5008	6.188E+00	6.188E+00	-0.40941	0.000E+00
17	1979	1.520E+00	1.699E+00	0.4670	6.195E+00	6.195E+00	0.11138	0.000E+00
18	1980	6.722E+00	1.828E+00	0.4807	6.863E+00	6.863E+00	-1.30197	0.000E+00
19	1981	2.621E+00	2.021E+00	0.3978	6.277E+00	6.277E+00	-0.26001	0.000E+00
20	1982	2.270E+00	1.880E+00	0.8175	1.200E+01	1.200E+01	-0.18873	0.000E+00
21	1983	2.131E+00	1.209E+00	1.2101	1.142E+01	1.142E+01	-0.56691	0.000E+00
22	1984	5.930E-01	7.005E-01	1.0588	5.791E+00	5.791E+00	0.16653	0.000E+00
23	1985	7.090E-01	5.702E-01	0.5660	2.520E+00	2.520E+00	-0.21779	0.000E+00
24	1986	8.200E-01	5.621E-01	0.6972	3.060E+00	3.060E+00	-0.37765	0.000E+00
25	1987	5.090E-01	5.057E-01	0.7534	2.975E+00	2.975E+00	-0.00647	0.000E+00
26	1988	1.710E-01	4.896E-01	0.5540	2.118E+00	2.118E+00	1.05193	0.000E+00
27	1989	9.770E-01	6.106E-01	0.2532	1.207E+00	1.207E+00	-0.46998	0.000E+00
28	1990	7.250E-01	7.162E-01	0.6382	3.569E+00	3.569E+00	-0.01222	0.000E+00
29	1991	7.300E-01	8.173E-01	0.3181	2.030E+00	2.030E+00	0.11301	0.000E+00
30	1992	5.760E-01	9.047E-01	0.6698	4.732E+00	4.732E+00	0.45154	0.000E+00
31	1993	5.450E-01	8.932E-01	0.5524	3.853E+00	3.853E+00	0.49407	0.000E+00
32	1994	8.970E-01	9.479E-01	0.5228	3.869E+00	3.869E+00	0.05515	0.000E+00
33	1995	3.540E-01	1.276E+00	0.0791	7.880E-01	7.880E-01	1.28228	0.000E+00
34	1996	1.303E+00	2.049E+00	0.0796	1.273E+00	1.273E+00	0.45279	0.000E+00
35	1997	3.781E+00	3.123E+00	0.0752	1.834E+00	1.834E+00	-0.19111	0.000E+00
36	1998	4.347E+00	4.412E+00	0.0903	3.111E+00	3.111E+00	0.01492	0.000E+00
37	1999	7.973E+00	5.709E+00	0.0997	4.442E+00	4.442E+00	-0.33407	0.000E+00
38	2000	5.838E+00	6.753E+00	0.1308	6.895E+00	6.895E+00	0.14565	0.000E+00

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1963     0.0948                                             |==
1964    -0.2298                                        =====|
1965    -0.0078                                             |
1966     0.7233                                             |==============
1967     0.0311                                             |=
1968    -0.3754                                     ========|
1969    -0.3780                                     ========|
1970     0.0785                                             |==
1971    -0.2711                                        =====|
1972    -0.3439                                      =======|
1973    -0.4981                                   ==========|
1974    -0.0639                                            =|
1975     0.1982                                             |====
1976     0.3624                                             |=======
1977    -0.5088                                   ==========|
1978    -0.4094                                     ========|
1979     0.1114                                             |==
1980    -1.3020                   ==========================|
1981    -0.2600                                        =====|
1982    -0.1887                                         ====|
1983    -0.5669                                  ===========|
1984     0.1665                                             |===
1985    -0.2178                                         ====|
1986    -0.3776                                     ========|
1987    -0.0065                                             |
1988     1.0519                                             |=====================
1989    -0.4700                                    =========|
1990    -0.0122                                             |
1991     0.1130                                             |==
1992     0.4515                                             |=========
1993     0.4941                                             |==========
1994     0.0552                                             |=
1995     1.2823                                             |==========================
1996     0.4528                                             |=========
1997    -0.1911                                         ====|
1998     0.0149                                             |
1999    -0.3341                                      =======|
2000     0.1456                                             |===
                   ------------------------------------------------------------------------------------
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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) USA Spring -lagged

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1963	0.000E+00	0.000E+00	0.0	*	1.387E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	1.117E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	9.585E+00	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	9.174E+00	0.00000	0.0
5	1967	1.000E+00	1.000E+00	0.0	2.813E+00	8.667E+00	-1.12529	-5.854E+00
6	1968	1.000E+00	1.000E+00	0.0	1.117E+01	7.887E+00	0.34806	3.283E+00
7	1969	1.000E+00	1.000E+00	0.0	5.312E+00	6.701E+00	-0.23223	-1.389E+00
8	1970	1.000E+00	1.000E+00	0.0	4.607E+00	5.651E+00	-0.20422	-1.044E+00
9	1971	1.000E+00	1.000E+00	0.0	6.450E+00	5.417E+00	0.17456	1.033E+00
10	1972	0.000E+00	0.000E+00	0.0	*	4.839E+00	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	4.329E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	3.686E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	2.931E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	2.144E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	1.750E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	1.853E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	2.016E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	2.147E+00	0.00000	0.0
19	1981	1.000E+00	1.000E+00	0.0	2.500E+00	2.457E+00	0.01747	4.330E-02
20	1982	1.000E+00	1.000E+00	0.0	2.642E+00	1.863E+00	0.34950	7.793E-01
21	1983	1.000E+00	1.000E+00	0.0	1.646E+00	9.918E-01	0.50656	6.542E-01
22	1984	1.000E+00	1.000E+00	0.0	9.880E-01	6.329E-01	0.44543	3.551E-01
23	1985	1.000E+00	1.000E+00	0.0	8.470E-01	6.661E-01	0.24026	1.809E-01
24	1986	1.000E+00	1.000E+00	0.0	3.290E-01	6.151E-01	-0.62580	-2.861E-01
25	1987	1.000E+00	1.000E+00	0.0	5.660E-01	5.388E-01	0.04923	2.719E-02
26	1988	1.000E+00	1.000E+00	0.0	7.290E-01	5.766E-01	0.23447	1.524E-01
27	1989	1.000E+00	1.000E+00	0.0	6.990E-01	8.279E-01	-0.16920	-1.289E-01
28	1990	1.000E+00	1.000E+00	0.0	6.310E-01	8.037E-01	-0.24197	-1.727E-01
29	1991	1.000E+00	1.000E+00	0.0	1.566E+00	1.068E+00	0.38237	4.976E-01
30	1992	1.000E+00	1.000E+00	0.0	4.820E-01	9.939E-01	-0.72374	-5.119E-01
31	1993	1.000E+00	1.000E+00	0.0	6.600E-01	1.041E+00	-0.45529	-3.806E-01
32	1994	1.000E+00	1.000E+00	0.0	2.579E+00	1.119E+00	0.83530	1.460E+00
33	1995	1.000E+00	1.000E+00	0.0	2.853E+00	1.838E+00	0.43942	1.015E+00
34	1996	1.000E+00	1.000E+00	0.0	4.359E+00	2.887E+00	0.41209	1.472E+00
35	1997	1.000E+00	1.000E+00	0.0	2.324E+00	4.276E+00	-0.60968	-1.952E+00
36	1998	1.000E+00	1.000E+00	0.0	9.307E+00	5.786E+00	0.47538	3.521E+00
37	1999	1.000E+00	1.000E+00	0.0	6.696E+00	7.190E+00	-0.07121	-4.942E-01
38	2000	0.000E+00	0.000E+00	0.0	*	8.149E+00	0.00000	0.0

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2

```
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967    -1.1253                       =======================|
1968     0.3481                                             |=======
1969    -0.2322                                        =====|
1970    -0.2042                                         ====|
1971     0.1746                                             |===
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     0.0175                                             |
1982     0.3495                                             |=======
1983     0.5066                                             |==========
1984     0.4454                                             |=========
1985     0.2403                                             |=====
1986    -0.6258                                =============|
1987     0.0492                                             |=
1988     0.2345                                             |=====
1989    -0.1692                                          ===|
1990    -0.2420                                        =====|
1991     0.3824                                             |========
1992    -0.7237                               ==============|
1993    -0.4553                                    =========|
1994     0.8353                                             |=================
1995     0.4394                                             |=========
1996     0.4121                                             |========
1997    -0.6097                                 ============|
1998     0.4754                                             |==========
1999    -0.0712                                            =|
2000     0.0000                                             |
                   -------------------------------------------------------------------------------------
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RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canada - lagged

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

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1963	0.000E+00	0.000E+00	0.0	*	2.950E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	2.376E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	2.039E+01	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	1.952E+01	0.00000	0.0
5	1967	0.000E+00	0.000E+00	0.0	*	1.844E+01	0.00000	0.0
6	1968	0.000E+00	0.000E+00	0.0	*	1.678E+01	0.00000	0.0
7	1969	0.000E+00	0.000E+00	0.0	*	1.425E+01	0.00000	0.0
8	1970	0.000E+00	0.000E+00	0.0	*	1.202E+01	0.00000	0.0
9	1971	0.000E+00	0.000E+00	0.0	*	1.152E+01	0.00000	0.0
10	1972	0.000E+00	0.000E+00	0.0	*	1.029E+01	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	9.209E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	7.841E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	6.236E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	4.560E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	3.723E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	3.942E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	4.289E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	4.568E+00	0.00000	0.0
19	1981	0.000E+00	0.000E+00	0.0	*	5.226E+00	0.00000	0.0
20	1982	0.000E+00	0.000E+00	0.0	*	3.962E+00	0.00000	0.0
21	1983	0.000E+00	0.000E+00	0.0	*	2.110E+00	0.00000	0.0
22	1984	0.000E+00	0.000E+00	0.0	*	1.346E+00	0.00000	0.0
23	1985	0.000E+00	0.000E+00	0.0	*	1.417E+00	0.00000	0.0
24	1986	1.000E+00	1.000E+00	0.0	1.264E+00	1.309E+00	-0.03462	-4.452E-02
25	1987	1.000E+00	1.000E+00	0.0	1.235E+00	1.146E+00	0.07466	8.885E-02
26	1988	1.000E+00	1.000E+00	0.0	4.710E-01	1.227E+00	-0.95714	-7.556E-01
27	1989	1.000E+00	1.000E+00	0.0	1.578E+00	1.761E+00	-0.10974	-1.830E-01
28	1990	1.000E+00	1.000E+00	0.0	1.759E+00	1.710E+00	0.02843	4.931E-02
29	1991	1.000E+00	1.000E+00	0.0	2.475E+00	2.273E+00	0.08529	2.023E-01
30	1992	1.000E+00	1.000E+00	0.0	2.642E+00	2.114E+00	0.22281	5.277E-01
31	1993	1.000E+00	1.000E+00	0.0	2.753E+00	2.213E+00	0.21812	5.395E-01
32	1994	1.000E+00	1.000E+00	0.0	2.027E+00	2.380E+00	-0.16035	-3.525E-01
33	1995	1.000E+00	1.000E+00	0.0	5.304E+00	3.911E+00	0.30472	1.393E+00
34	1996	1.000E+00	1.000E+00	0.0	1.329E+01	6.141E+00	0.77221	7.151E+00
35	1997	1.000E+00	1.000E+00	0.0	4.292E+00	9.095E+00	-0.75101	-4.803E+00
36	1998	1.000E+00	1.000E+00	0.0	1.767E+01	1.231E+01	0.36146	5.359E+00
37	1999	1.000E+00	1.000E+00	0.0	1.995E+01	1.529E+01	0.26571	4.655E+00
38	2000	1.000E+00	1.000E+00	0.0	2.216E+01	1.733E+01	0.24543	4.822E+00

* Asterisk indicates missing value(s).

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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    ------------------------------------------------------------------------------------
1963     0.0000                                             |
1964     0.0000                                             |
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    -0.0346                                            =|
1987     0.0747                                             |===
1988    -0.9571       ======================================|
1989    -0.1097                                         ====|
1990     0.0284                                             |=
1991     0.0853                                             |===
1992     0.2228                                             |=========
1993     0.2181                                             |=========
1994    -0.1603                                       ======|
1995     0.3047                                             |============
1996     0.7722                                             |===============================
1997    -0.7510               ==============================|
1998     0.3615                                             |==============
1999     0.2657                                             |===========
2000     0.2454                                             |==========
                   ------------------------------------------------------------------------------------
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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	3.018E+00	3.021E+00	0.09%	2.709E+00	3.357E+00	2.916E+00	3.142E+00	2.254E-01	0.075
K	8.725E+01	8.694E+01	-0.35%	8.393E+01	9.287E+01	8.589E+01	8.926E+01	3.374E+00	0.039
r	6.477E-01	6.505E-01	0.44%	6.017E-01	6.860E-01	6.295E-01	6.639E-01	3.443E-02	0.053
q(1)	1.290E-01	1.281E-01	-0.74%	1.188E-01	1.396E-01	1.249E-01	1.343E-01	9.327E-03	0.072
q(2)	1.466E-01	1.459E-01	-0.50%	1.281E-01	1.663E-01	1.373E-01	1.561E-01	1.882E-02	0.128
q(3)	3.138E-01	3.103E-01	-1.12%	2.656E-01	3.789E-01	2.898E-01	3.465E-01	5.673E-02	0.181
MSY	1.411E+01	1.414E+01	0.18%	1.372E+01	1.436E+01	1.396E+01	1.421E+01	2.535E-01	0.018
Ye(2001)	1.307E+01	1.299E+01	-0.60%	1.205E+01	1.383E+01	1.257E+01	1.351E+01	9.417E-01	0.072
Bmsy	4.363E+01	4.347E+01	-0.35%	4.196E+01	4.643E+01	4.295E+01	4.463E+01	1.687E+00	0.039
Fmsy	3.238E-01	3.252E-01	0.44%	3.008E-01	3.430E-01	3.147E-01	3.319E-01	1.721E-02	0.053
fmsy(1)	2.503E+00	2.539E+00	1.44%	2.319E+00	2.691E+00	2.413E+00	2.579E+00	1.661E-01	0.066
fmsy(2)	2.205E+00	2.230E+00	1.13%	1.942E+00	2.479E+00	2.066E+00	2.332E+00	2.666E-01	0.121
fmsy(3)	1.035E+00	1.048E+00	1.27%	8.708E-01	1.217E+00	9.540E-01	1.126E+00	1.717E-01	0.166
F(0.1)	2.914E-01	2.927E-01	0.39%	2.707E-01	3.087E-01	2.833E-01	2.987E-01	1.549E-02	0.053
Y(0.1)	1.397E+01	1.400E+01	0.18%	1.359E+01	1.422E+01	1.382E+01	1.407E+01	2.510E-01	0.018
B-ratio	1.276E+00	1.285E+00	0.71%	1.143E+00	1.393E+00	1.202E+00	1.336E+00	1.337E-01	0.105
F-ratio	4.068E-01	4.020E-01	-1.18%	3.651E-01	4.632E-01	3.837E-01	4.357E-01	5.197E-02	0.128
Y-ratio	9.239E-01	9.186E-01	-0.57%	8.455E-01	9.794E-01	8.871E-01	9.590E-01	7.198E-02	0.078
f0.1(1)	2.253E+00	2.286E+00	1.29%	2.087E+00	2.422E+00	2.171E+00	2.321E+00	1.495E-01	0.066
f0.1(2)	1.984E+00	2.007E+00	1.01%	1.748E+00	2.231E+00	1.859E+00	2.099E+00	2.400E-01	0.121
f0.1(3)	9.316E-01	9.434E-01	1.14%	7.837E-01	1.095E+00	8.586E-01	1.013E+00	1.546E-01	0.166
q2/q1	1.132E+00	1.139E+00	0.63%	9.813E-01	1.296E+00	1.049E+00	1.208E+00	1.587E-01	0.140
q3/q1	2.413E+00	2.423E+00	0.39%	2.025E+00	2.871E+00	2.206E+00	2.650E+00	4.447E-01	0.184

NOTES ON BOOTSTRAPPED ESTIMATES

- The bootstrapped results shown were computed from 1000 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.

APPENDIX D

Surplus Production Projection Results

Georges Bank Yellowtail (yield and biomass in k mt) — Page 1
Trial Projection — Output from ASPIC-P.EXE

Year	Input data	User data type
2001	2.234E+00	F/F(2000)

TRAJECTORY OF RELATIVE BIOMASS (BOOTSTRAPPED)

Year	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
1963	3.018E+00	3.021E+00	0.09%	2.709E+00	3.357E+00	2.916E+00	3.142E+00	2.254E-01	0.075
1964	2.189E+00	2.187E+00	-0.08%	2.047E+00	2.367E+00	2.142E+00	2.252E+00	7.989E-02	0.037
1965	1.764E+00	1.762E+00	-0.12%	1.716E+00	1.853E+00	1.747E+00	1.793E+00	4.566E-02	0.026
1966	1.514E+00	1.512E+00	-0.13%	1.482E+00	1.576E+00	1.502E+00	1.534E+00	3.280E-02	0.022
1967	1.448E+00	1.447E+00	-0.09%	1.427E+00	1.491E+00	1.440E+00	1.462E+00	2.178E-02	0.015
1968	1.368E+00	1.367E+00	-0.07%	1.353E+00	1.397E+00	1.362E+00	1.377E+00	1.505E-02	0.011
1969	1.245E+00	1.244E+00	-0.06%	1.233E+00	1.266E+00	1.240E+00	1.251E+00	1.119E-02	0.009
1970	1.057E+00	1.057E+00	-0.07%	1.047E+00	1.077E+00	1.054E+00	1.064E+00	1.020E-02	0.010
1971	8.920E-01	8.912E-01	-0.09%	8.814E-01	9.103E-01	8.880E-01	8.977E-01	9.630E-03	0.011
1972	8.548E-01	8.543E-01	-0.05%	8.484E-01	8.677E-01	8.524E-01	8.591E-01	6.697E-03	0.008
1973	7.635E-01	7.631E-01	-0.05%	7.587E-01	7.730E-01	7.617E-01	7.667E-01	5.039E-03	0.007
1974	6.829E-01	6.827E-01	-0.02%	6.793E-01	6.896E-01	6.816E-01	6.850E-01	3.413E-03	0.005
1975	5.814E-01	5.814E-01	-0.01%	5.786E-01	5.857E-01	5.804E-01	5.830E-01	2.623E-03	0.005
1976	4.625E-01	4.623E-01	-0.03%	4.582E-01	4.703E-01	4.608E-01	4.656E-01	2.534E-03	0.005
1977	3.385E-01	3.381E-01	-0.14%	3.335E-01	3.475E-01	3.365E-01	3.421E-01	5.374E-03	0.016
1978	2.767E-01	2.760E-01	-0.25%	2.701E-01	2.868E-01	2.740E-01	2.808E-01	6.834E-03	0.025
1979	2.930E-01	2.923E-01	-0.23%	2.865E-01	3.028E-01	2.903E-01	2.970E-01	6.630E-03	0.023
1980	3.186E-01	3.180E-01	-0.18%	3.134E-01	3.275E-01	3.166E-01	3.223E-01	5.680E-03	0.018
1981	3.389E-01	3.386E-01	-0.08%	3.331E-01	3.450E-01	3.376E-01	3.414E-01	3.462E-03	0.010
1982	3.871E-01	3.874E-01	0.08%	3.800E-01	3.924E-01	3.855E-01	3.891E-01	2.699E-03	0.007
1983	2.935E-01	2.938E-01	0.09%	2.873E-01	2.963E-01	2.919E-01	2.945E-01	2.677E-03	0.009
1984	1.564E-01	1.564E-01	-0.01%	1.533E-01	1.597E-01	1.554E-01	1.577E-01	6.118E-04	0.004
1985	1.000E-01	9.981E-02	-0.20%	9.813E-02	1.032E-01	9.922E-02	1.012E-01	2.002E-03	0.020
1986	1.052E-01	1.051E-01	-0.17%	1.035E-01	1.083E-01	1.045E-01	1.065E-01	1.908E-03	0.018
1987	9.722E-02	9.702E-02	-0.21%	9.469E-02	1.006E-01	9.605E-02	9.860E-02	2.276E-03	0.023
1988	8.528E-02	8.498E-02	-0.36%	8.220E-02	8.967E-02	8.378E-02	8.707E-02	3.294E-03	0.039
1989	9.137E-02	9.094E-02	-0.47%	8.712E-02	9.694E-02	8.936E-02	9.367E-02	4.311E-03	0.047
1990	1.309E-01	1.306E-01	-0.27%	1.269E-01	1.366E-01	1.289E-01	1.333E-01	4.376E-03	0.033
1991	1.272E-01	1.268E-01	-0.32%	1.216E-01	1.351E-01	1.243E-01	1.307E-01	6.462E-03	0.051
1992	1.687E-01	1.685E-01	-0.11%	1.591E-01	1.785E-01	1.634E-01	1.749E-01	8.314E-03	0.049
1993	1.568E-01	1.568E-01	-0.01%	1.458E-01	1.715E-01	1.506E-01	1.639E-01	1.336E-02	0.085
1994	1.635E-01	1.641E-01	0.38%	1.448E-01	1.863E-01	1.531E-01	1.750E-01	2.190E-02	0.134
1995	1.753E-01	1.764E-01	0.62%	1.431E-01	2.126E-01	1.581E-01	1.943E-01	3.627E-02	0.207
1996	2.869E-01	2.900E-01	1.07%	2.363E-01	3.478E-01	2.616E-01	3.197E-01	5.807E-02	0.202
1997	4.505E-01	4.553E-01	1.07%	3.726E-01	5.384E-01	4.120E-01	4.978E-01	8.575E-02	0.190
1998	6.660E-01	6.743E-01	1.25%	5.562E-01	7.846E-01	6.076E-01	7.268E-01	1.192E-01	0.179
1999	9.023E-01	9.125E-01	1.13%	7.725E-01	1.042E+00	8.325E-01	9.757E-01	1.432E-01	0.159
2000	1.123E+00	1.134E+00	0.96%	9.853E-01	1.256E+00	1.046E+00	1.195E+00	1.489E-01	0.133
2001	1.276E+00	1.285E+00	0.71%	1.143E+00	1.393E+00	1.202E+00	1.336E+00	1.337E-01	0.105
2002	1.216E+00	1.224E+00	0.68%	1.092E+00	1.316E+00	1.148E+00	1.268E+00	1.201E-01	0.099

TRAJECTORY OF RELATIVE FISHING MORTALITY RATE (BOOTSTRAPPED)

Year	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
1963	4.687E-01	4.674E-01	-0.27%	4.409E-01	5.263E-01	4.591E-01	4.833E-01	2.419E-02	0.052
1964	7.215E-01	7.207E-01	-0.11%	6.927E-01	7.818E-01	7.114E-01	7.368E-01	2.030E-02	0.028
1965	8.484E-01	8.477E-01	-0.08%	8.308E-01	8.858E-01	8.419E-01	8.578E-01	1.582E-02	0.019
1966	6.590E-01	6.582E-01	-0.11%	6.494E-01	6.848E-01	6.554E-01	6.655E-01	1.016E-02	0.015
1967	7.725E-01	7.714E-01	-0.14%	7.621E-01	7.998E-01	7.683E-01	7.789E-01	1.062E-02	0.014
1968	9.913E-01	9.901E-01	-0.12%	9.784E-01	1.022E+00	9.862E-01	9.994E-01	1.318E-02	0.013
1969	1.360E+00	1.359E+00	-0.10%	1.345E+00	1.396E+00	1.354E+00	1.370E+00	1.593E-02	0.012
1970	1.558E+00	1.557E+00	-0.08%	1.544E+00	1.591E+00	1.552E+00	1.567E+00	1.465E-02	0.009
1971	1.259E+00	1.258E+00	-0.09%	1.246E+00	1.284E+00	1.254E+00	1.267E+00	1.303E-02	0.010
1972	1.543E+00	1.541E+00	-0.11%	1.524E+00	1.576E+00	1.535E+00	1.554E+00	1.913E-02	0.012
1973	1.624E+00	1.622E+00	-0.13%	1.602E+00	1.661E+00	1.615E+00	1.637E+00	2.244E-02	0.014
1974	1.868E+00	1.865E+00	-0.13%	1.840E+00	1.912E+00	1.857E+00	1.885E+00	2.826E-02	0.015
1975	2.189E+00	2.187E+00	-0.12%	2.158E+00	2.236E+00	2.177E+00	2.207E+00	2.990E-02	0.014
1976	2.569E+00	2.567E+00	-0.08%	2.546E+00	2.602E+00	2.560E+00	2.581E+00	2.154E-02	0.008
1977	2.317E+00	2.318E+00	0.02%	2.299E+00	2.339E+00	2.310E+00	2.326E+00	4.231E-03	0.002
1978	1.539E+00	1.540E+00	0.06%	1.528E+00	1.549E+00	1.534E+00	1.543E+00	8.511E-03	0.006
1979	1.435E+00	1.436E+00	0.02%	1.427E+00	1.447E+00	1.432E+00	1.440E+00	2.444E-03	0.002
1980	1.479E+00	1.478E+00	-0.04%	1.465E+00	1.497E+00	1.473E+00	1.486E+00	7.705E-03	0.005
1981	1.225E+00	1.223E+00	-0.13%	1.206E+00	1.253E+00	1.217E+00	1.235E+00	1.872E-02	0.015
1982	2.518E+00	2.513E+00	-0.19%	2.457E+00	2.600E+00	2.492E+00	2.548E+00	5.664E-02	0.022
1983	3.727E+00	3.721E+00	-0.17%	3.647E+00	3.831E+00	3.693E+00	3.766E+00	7.269E-02	0.020
1984	3.258E+00	3.256E+00	-0.06%	3.220E+00	3.305E+00	3.241E+00	3.276E+00	2.184E-02	0.007
1985	1.740E+00	1.740E+00	-0.02%	1.731E+00	1.751E+00	1.737E+00	1.745E+00	2.457E-03	0.001
1986	2.144E+00	2.144E+00	-0.01%	2.124E+00	2.158E+00	2.135E+00	2.151E+00	6.181E-03	0.003
1987	2.314E+00	2.317E+00	0.10%	2.274E+00	2.346E+00	2.296E+00	2.330E+00	3.090E-02	0.013
1988	1.700E+00	1.703E+00	0.19%	1.647E+00	1.742E+00	1.677E+00	1.721E+00	4.383E-02	0.026
1989	7.774E-01	7.784E-01	0.12%	7.543E-01	7.944E-01	7.670E-01	7.862E-01	1.917E-02	0.025
1990	1.961E+00	1.962E+00	0.06%	1.896E+00	2.009E+00	1.931E+00	1.988E+00	5.686E-02	0.029
1991	9.787E-01	9.780E-01	-0.07%	9.404E-01	1.011E+00	9.594E-01	9.962E-01	3.690E-02	0.038
1992	2.065E+00	2.060E+00	-0.25%	1.927E+00	2.197E+00	1.990E+00	2.132E+00	1.168E-01	0.057
1993	1.706E+00	1.699E+00	-0.45%	1.546E+00	1.889E+00	1.617E+00	1.787E+00	1.704E-01	0.100
1994	1.621E+00	1.607E+00	-0.84%	1.382E+00	1.886E+00	1.482E+00	1.742E+00	2.600E-01	0.160
1995	2.463E-01	2.432E-01	-1.28%	2.032E-01	2.980E-01	2.209E-01	2.697E-01	4.881E-02	0.198
1996	2.478E-01	2.446E-01	-1.28%	2.054E-01	2.998E-01	2.243E-01	2.716E-01	4.732E-02	0.191
1997	2.348E-01	2.312E-01	-1.50%	1.978E-01	2.828E-01	2.146E-01	2.590E-01	4.442E-02	0.189
1998	2.816E-01	2.776E-01	-1.41%	2.411E-01	3.334E-01	2.594E-01	3.095E-01	5.006E-02	0.178
1999	3.103E-01	3.064E-01	-1.25%	2.724E-01	3.610E-01	2.902E-01	3.380E-01	4.780E-02	0.154
2000	4.068E-01	4.020E-01	-1.18%	3.651E-01	4.632E-01	3.837E-01	4.357E-01	5.197E-02	0.128
2001	9.089E-01	8.982E-01	-1.18%	8.156E-01	1.035E+00	8.572E-01	9.733E-01	1.161E-01	0.128

TABLE OF PROJECTED YIELDS

2001	1.592E+01	1.590E+01	-0.12%	1.568E+01	1.616E+01	1.580E+01	1.605E+01	2.533E-01	0.016

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

TRAJECTORY OF ABSOLUTE BIOMASS (BOOTSTRAPPED)

Year	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
1963	1.317E+02	1.313E+02	-0.27%	1.212E+02	1.499E+02	1.280E+02	1.379E+02	9.842E+00	0.075
1964	9.544E+01	9.508E+01	-0.38%	8.967E+01	1.045E+02	9.316E+01	9.845E+01	5.298E+00	0.056
1965	7.694E+01	7.658E+01	-0.47%	7.269E+01	8.446E+01	7.527E+01	7.973E+01	4.454E+00	0.058
1966	6.605E+01	6.572E+01	-0.51%	6.275E+01	7.245E+01	6.479E+01	6.861E+01	3.818E+00	0.058
1967	6.319E+01	6.290E+01	-0.45%	6.025E+01	6.789E+01	6.199E+01	6.502E+01	3.030E+00	0.048
1968	5.966E+01	5.942E+01	-0.40%	5.703E+01	6.348E+01	5.856E+01	6.113E+01	2.569E+00	0.043
1969	5.429E+01	5.407E+01	-0.41%	5.190E+01	5.737E+01	5.326E+01	5.551E+01	2.250E+00	0.041
1970	4.612E+01	4.594E+01	-0.40%	4.407E+01	4.884E+01	4.522E+01	4.733E+01	2.101E+00	0.046
1971	3.890E+01	3.874E+01	-0.40%	3.707E+01	4.133E+01	3.813E+01	3.997E+01	1.841E+00	0.047
1972	3.728E+01	3.714E+01	-0.37%	3.563E+01	3.940E+01	3.657E+01	3.816E+01	1.593E+00	0.043
1973	3.330E+01	3.318E+01	-0.37%	3.188E+01	3.515E+01	3.268E+01	3.408E+01	1.402E+00	0.042
1974	2.978E+01	2.968E+01	-0.35%	2.855E+01	3.138E+01	2.925E+01	3.041E+01	1.163E+00	0.039
1975	2.536E+01	2.527E+01	-0.34%	2.432E+01	2.672E+01	2.491E+01	2.587E+01	9.631E-01	0.038
1976	2.017E+01	2.010E+01	-0.35%	1.929E+01	2.132E+01	1.979E+01	2.060E+01	8.089E-01	0.040
1977	1.476E+01	1.470E+01	-0.42%	1.398E+01	1.580E+01	1.442E+01	1.515E+01	7.275E-01	0.049
1978	1.206E+01	1.200E+01	-0.51%	1.130E+01	1.308E+01	1.173E+01	1.245E+01	7.156E-01	0.059
1979	1.277E+01	1.271E+01	-0.49%	1.199E+01	1.380E+01	1.243E+01	1.316E+01	7.293E-01	0.057
1980	1.389E+01	1.382E+01	-0.44%	1.311E+01	1.489E+01	1.355E+01	1.427E+01	7.162E-01	0.052
1981	1.478E+01	1.472E+01	-0.38%	1.406E+01	1.570E+01	1.447E+01	1.513E+01	6.617E-01	0.045
1982	1.689E+01	1.684E+01	-0.27%	1.631E+01	1.764E+01	1.664E+01	1.718E+01	5.344E-01	0.032
1983	1.280E+01	1.277E+01	-0.24%	1.241E+01	1.332E+01	1.263E+01	1.300E+01	3.675E-01	0.029
1984	6.822E+00	6.800E+00	-0.32%	6.548E+00	7.208E+00	6.704E+00	6.973E+00	2.691E-01	0.039
1985	4.358E+00	4.339E+00	-0.43%	4.110E+00	4.710E+00	4.250E+00	4.495E+00	2.450E-01	0.056
1986	4.585E+00	4.567E+00	-0.41%	4.344E+00	4.949E+00	4.480E+00	4.728E+00	2.477E-01	0.054
1987	4.237E+00	4.217E+00	-0.46%	3.998E+00	4.617E+00	4.132E+00	4.388E+00	2.561E-01	0.060
1988	3.716E+00	3.694E+00	-0.58%	3.453E+00	4.141E+00	3.597E+00	3.879E+00	2.816E-01	0.076
1989	3.978E+00	3.953E+00	-0.61%	3.669E+00	4.478E+00	3.843E+00	4.187E+00	3.438E-01	0.086
1990	5.704E+00	5.676E+00	-0.50%	5.332E+00	6.256E+00	5.533E+00	5.920E+00	3.873E-01	0.068
1991	5.541E+00	5.510E+00	-0.54%	5.121E+00	6.142E+00	5.340E+00	5.806E+00	4.661E-01	0.084
1992	7.355E+00	7.325E+00	-0.40%	6.830E+00	8.047E+00	7.091E+00	7.649E+00	5.577E-01	0.076
1993	6.842E+00	6.814E+00	-0.40%	6.208E+00	7.754E+00	6.504E+00	7.269E+00	7.650E-01	0.112
1994	7.134E+00	7.134E+00	0.00%	6.206E+00	8.372E+00	6.619E+00	7.728E+00	1.109E+00	0.155
1995	7.622E+00	7.669E+00	0.62%	6.123E+00	9.393E+00	6.788E+00	8.508E+00	1.720E+00	0.226
1996	1.244E+01	1.260E+01	1.29%	1.014E+01	1.515E+01	1.123E+01	1.390E+01	2.667E+00	0.214
1997	1.956E+01	1.979E+01	1.20%	1.609E+01	2.342E+01	1.785E+01	2.165E+01	3.801E+00	0.194
1998	2.893E+01	2.931E+01	1.34%	2.432E+01	3.390E+01	2.670E+01	3.169E+01	4.989E+00	0.172
1999	3.916E+01	3.967E+01	1.28%	3.378E+01	4.483E+01	3.669E+01	4.236E+01	5.673E+00	0.145
2000	4.886E+01	4.930E+01	0.89%	4.323E+01	5.415E+01	4.615E+01	5.176E+01	5.609E+00	0.115
2001	5.553E+01	5.587E+01	0.61%	5.046E+01	5.995E+01	5.315E+01	5.812E+01	4.966E+00	0.089
2002	5.298E+01	5.320E+01	0.41%	4.829E+01	5.684E+01	5.075E+01	5.520E+01	4.445E+00	0.084

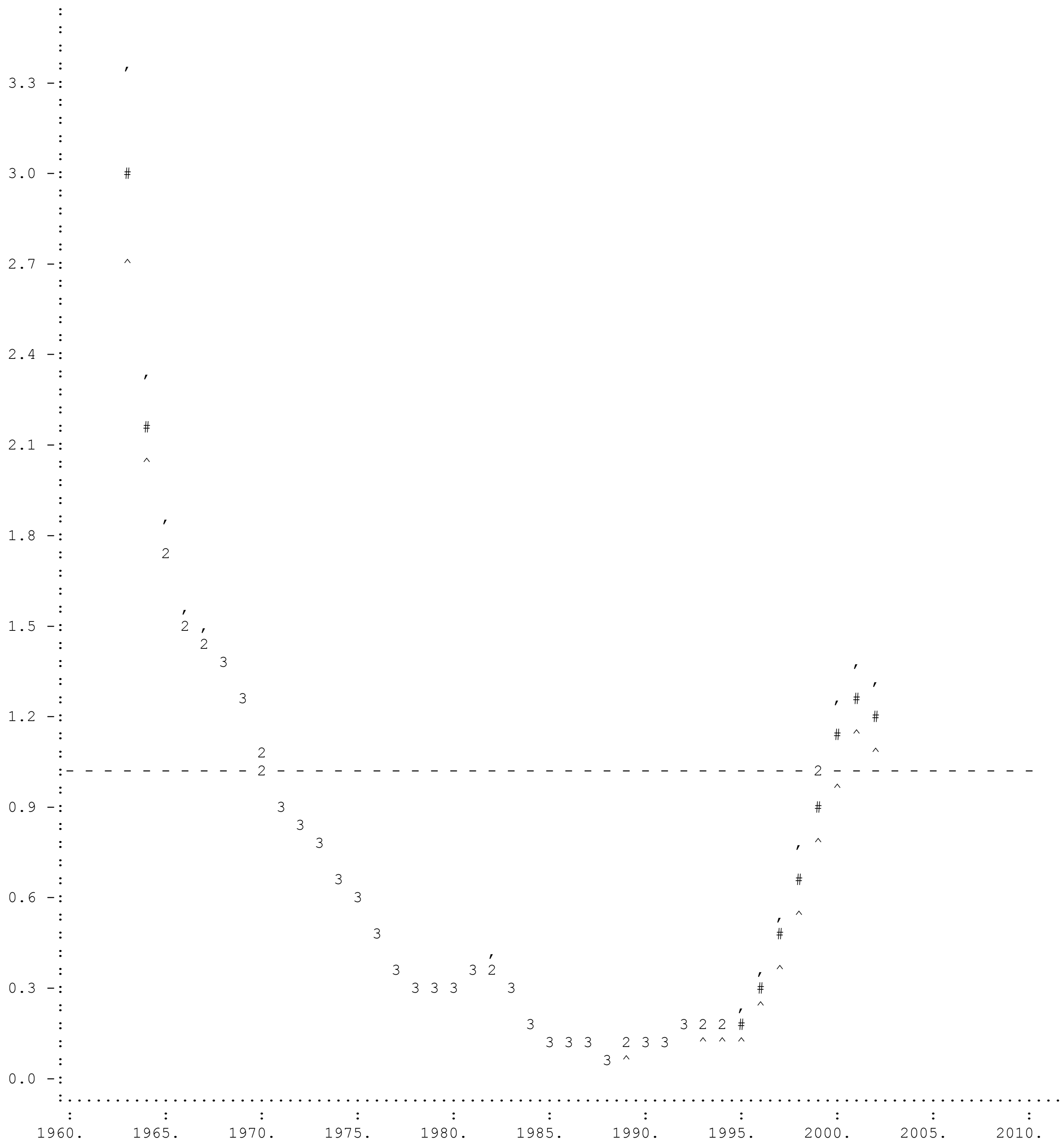
NOTE: Printed BC confidence intervals are always approximate.
At least 500 trials are recommended when estimating confidence intervals.

TRAJECTORY OF ABSOLUTE FISHING MORTALITY RATE (BOOTSTRAPPED)

Year	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
1963	1.515E-01	1.520E-01	0.32%	1.353E-01	1.620E-01	1.460E-01	1.552E-01	9.206E-03	0.061
1964	2.334E-01	2.344E-01	0.41%	2.125E-01	2.481E-01	2.253E-01	2.387E-01	1.341E-02	0.057
1965	2.744E-01	2.757E-01	0.49%	2.497E-01	2.896E-01	2.643E-01	2.801E-01	1.583E-02	0.058
1966	2.130E-01	2.141E-01	0.50%	1.966E-01	2.241E-01	2.064E-01	2.174E-01	1.107E-02	0.052
1967	2.498E-01	2.509E-01	0.45%	2.336E-01	2.614E-01	2.434E-01	2.546E-01	1.127E-02	0.045
1968	3.208E-01	3.220E-01	0.39%	3.025E-01	3.357E-01	3.135E-01	3.268E-01	1.333E-02	0.042
1969	4.403E-01	4.420E-01	0.40%	4.159E-01	4.607E-01	4.294E-01	4.489E-01	1.947E-02	0.044
1970	5.040E-01	5.063E-01	0.45%	4.751E-01	5.287E-01	4.908E-01	5.144E-01	2.356E-02	0.047
1971	4.076E-01	4.092E-01	0.39%	3.847E-01	4.272E-01	3.979E-01	4.158E-01	1.789E-02	0.044
1972	4.993E-01	5.012E-01	0.38%	4.728E-01	5.222E-01	4.877E-01	5.090E-01	2.121E-02	0.042
1973	5.256E-01	5.274E-01	0.36%	4.982E-01	5.488E-01	5.144E-01	5.354E-01	2.102E-02	0.040
1974	6.046E-01	6.066E-01	0.35%	5.736E-01	6.307E-01	5.928E-01	6.157E-01	2.293E-02	0.038
1975	7.087E-01	7.112E-01	0.34%	6.713E-01	7.401E-01	6.942E-01	7.220E-01	2.778E-02	0.039
1976	8.315E-01	8.348E-01	0.39%	7.816E-01	8.734E-01	8.120E-01	8.494E-01	3.739E-02	0.045
1977	7.503E-01	7.538E-01	0.47%	6.964E-01	7.964E-01	7.290E-01	7.697E-01	4.069E-02	0.054
1978	4.983E-01	5.008E-01	0.51%	4.604E-01	5.314E-01	4.832E-01	5.122E-01	2.893E-02	0.058
1979	4.648E-01	4.670E-01	0.47%	4.318E-01	4.935E-01	4.517E-01	4.769E-01	2.521E-02	0.054
1980	4.787E-01	4.807E-01	0.42%	4.486E-01	5.050E-01	4.668E-01	4.898E-01	2.302E-02	0.048
1981	3.965E-01	3.978E-01	0.33%	3.766E-01	4.134E-01	3.887E-01	4.036E-01	1.499E-02	0.038
1982	8.154E-01	8.175E-01	0.26%	7.820E-01	8.427E-01	8.021E-01	8.269E-01	2.481E-02	0.030
1983	1.207E+00	1.210E+00	0.28%	1.152E+00	1.251E+00	1.184E+00	1.225E+00	4.111E-02	0.034
1984	1.055E+00	1.059E+00	0.37%	9.876E-01	1.108E+00	1.028E+00	1.077E+00	4.964E-02	0.047
1985	5.636E-01	5.660E-01	0.42%	5.216E-01	5.961E-01	5.467E-01	5.774E-01	3.073E-02	0.055
1986	6.942E-01	6.972E-01	0.44%	6.401E-01	7.343E-01	6.720E-01	7.113E-01	3.930E-02	0.057
1987	7.494E-01	7.534E-01	0.53%	6.796E-01	8.001E-01	7.209E-01	7.709E-01	5.001E-02	0.067
1988	5.508E-01	5.540E-01	0.58%	4.913E-01	5.944E-01	5.246E-01	5.693E-01	4.465E-02	0.081
1989	2.516E-01	2.532E-01	0.61%	2.263E-01	2.708E-01	2.407E-01	2.601E-01	1.940E-02	0.077
1990	6.345E-01	6.382E-01	0.59%	5.789E-01	6.858E-01	6.111E-01	6.576E-01	4.652E-02	0.073
1991	3.164E-01	3.181E-01	0.52%	2.877E-01	3.408E-01	3.028E-01	3.282E-01	2.545E-02	0.080
1992	6.676E-01	6.698E-01	0.34%	5.992E-01	7.274E-01	6.351E-01	6.976E-01	6.251E-02	0.094
1993	5.516E-01	5.524E-01	0.14%	4.791E-01	6.201E-01	5.148E-01	5.885E-01	7.372E-02	0.134
1994	5.240E-01	5.228E-01	-0.24%	4.339E-01	6.260E-01	4.765E-01	5.760E-01	9.955E-02	0.190
1995	7.991E-02	7.908E-02	-1.03%	6.521E-02	9.887E-02	7.148E-02	8.907E-02	1.759E-02	0.220
1996	8.043E-02	7.956E-02	-1.08%	6.704E-02	9.840E-02	7.238E-02	8.860E-02	1.622E-02	0.202
1997	7.628E-02	7.520E-02	-1.41%	6.413E-02	9.118E-02	6.897E-02	8.287E-02	1.389E-02	0.182
1998	9.146E-02	9.030E-02	-1.26%	7.907E-02	1.077E-01	8.434E-02	9.866E-02	1.432E-02	0.157
1999	1.006E-01	9.965E-02	-0.92%	8.951E-02	1.151E-01	9.412E-02	1.070E-01	1.292E-02	0.128
2000	1.317E-01	1.308E-01	-0.72%	1.207E-01	1.468E-01	1.252E-01	1.386E-01	1.339E-02	0.102
2001	2.942E-01	2.921E-01	-0.72%	2.696E-01	3.280E-01	2.797E-01	3.096E-01	2.992E-02	0.102

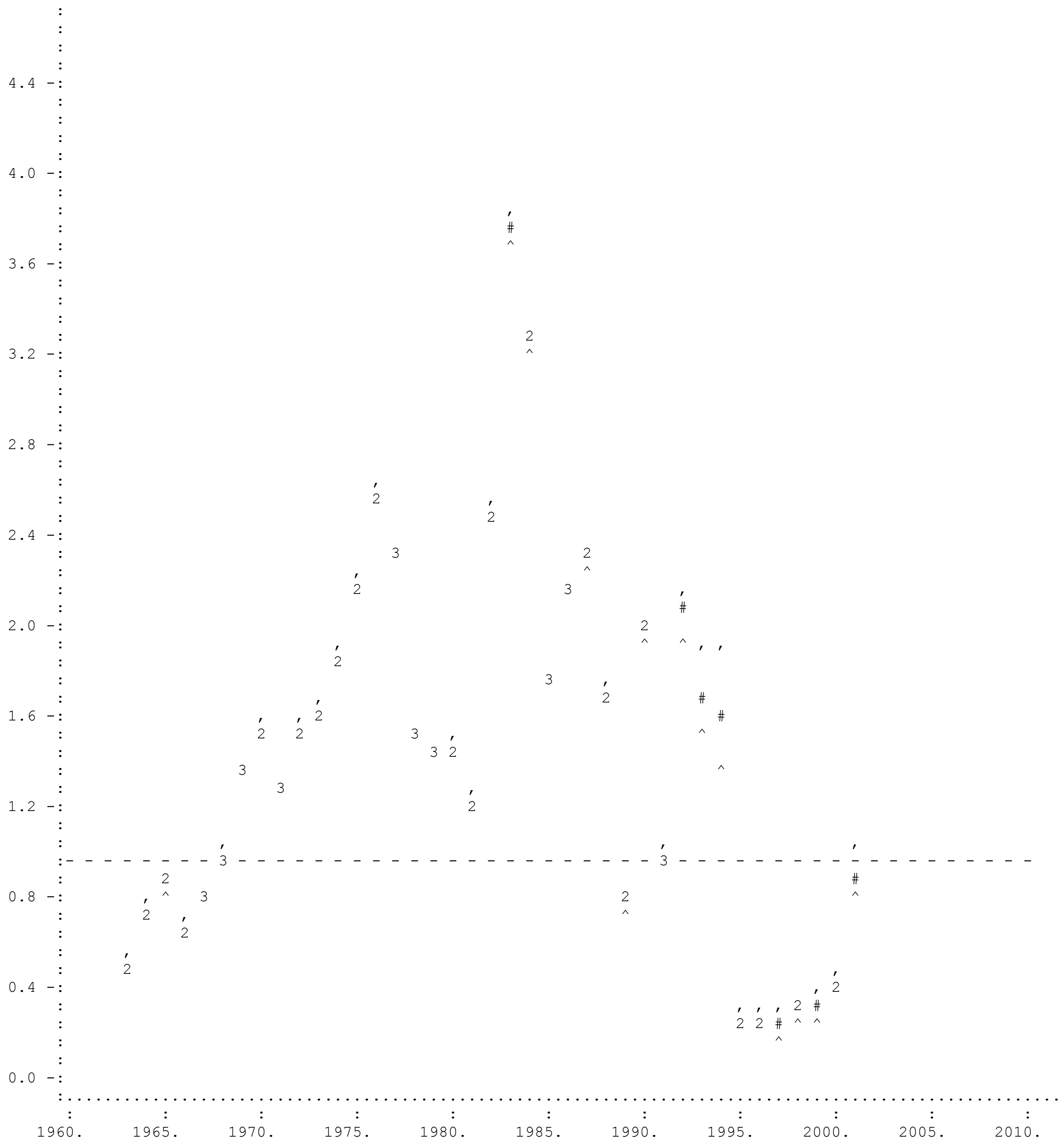
NOTE: Printed BC confidence intervals are always approximate.

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



NOTE: Estimates beginning in 2002 depend on the user projection data listed on page 1.

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



NOTE: Estimates beginning in 2001 depend on the user projection data listed on page 1.