Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2002/057 | **Document de recherche 2002/057**

Not to be cited without permission of the authors *

Ne pas citer sans autorisation des auteurs *

Stock Assessment of Georges Bank (5Zjmnh) Yellowtail Flounder for 2002

Bilan de 2002 de l'état du stock de limande à queue jaune du Banc Georges (5Zjmnh)

Heath H. Stone

Department of Fisheries and Oceans,
Biological Station,
531 Brandy Cove Road,
St. Andrews, New Brunswick
E5B 2L9

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at: | Ce document est disponible sur l'Internet à:
http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883

Canada

Abstract

The combined Canada/USA yellowtail flounder (*Limanda ferruginea*) catch has been increasing since 1995, and in 2001 was 6,790 t. While fishermen reported lower catch rates in 2001 compared with 2000, 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 12 fold since 1995, and is at the highest observed level since 1973. The age structure is improving but older fish are still under-represented. Recent recruitment has improved relative to the 1980s, and the 1997 year-class appears to be the strongest since 1980. The 1998 and 2000 year-classes appear to be of moderate strength although the latter is not well estimated. Exploitation rates on ages 4+ have been less than $F_{0.1}$ (20%) in 2000 and 2001, while exploitation at age 3 has not decreased since 1997. At the $F_{0.1}$ yield of 10,300 t, which corresponds to about 45% probability of exceeding $F_{0.1}$, the biomass is not likely to decrease and there is a 75% probability of achieving 10% increase from the beginning of the year 2002 to 2003. The dominant 1997 and 1998 year-classes are expected to contribute about 50% of the expected yield as ages 4 and 5 in 2002, and comprise about 39% of the total biomass. The 2000 year-class is estimated to contribute 26% of total beginning of year biomass in 2003, however, this year-class is not well estimated and was based on only a single survey index value in this year's assessment.

Résumé

En hausse depuis 1995, les prises canado-américaines combinées de limande à queue jaune (*Limanda ferruginea*) se sont chiffrées à 6 790 t en 2001. Alors que les pêcheurs ont signalé des taux de capture en 2001 inférieurs à ceux de 2000, les tendances dans l'abondance observées lors des derniers relevés du poisson de fond montrent que le stock est encore relativement important comparativement aux niveaux constatés au début des années 1990. La biomasse de la population (âge 1+) s'est multipliée par 12 depuis 1995 et atteint un niveau sans précédent depuis 1973. La structure par âge s'améliore, mais les poissons âgés sont encore sous-représentés. Le dernier recrutement est également meilleur comparativement à celui dans les années 1980, et la classe d'âge 1997 semble être la plus importante depuis 1980. Les classes d'âge 1998 et 2000 semblent être modérément abondantes, quoique la dernière ne soit pas bien estimée. Les taux d'exploitation exercés sur les limandes d'âge 4+ ont été inférieurs à $F_{0,1}$ (20 %) en 2000 et en 2001, alors que ceux exercés sur les limandes d'âge 3 n'ont pas fléchi depuis 1997. Au rendement à $F_{0,1}$ de 10 300 t, qui correspond à une probabilité d'environ 45 % de dépassement de $F_{0,1}$, la biomasse ne diminuera probablement pas, et il y a une probabilité de 75 % d'un accroissement de 10 % du début de 2002 jusqu'en 2003. Les classes d'âge dominantes 1997 et 1998 devraient contribuer environ 50 % du rendement attendu aux âges 4 et 5 en 2002, et représenter environ 39 % de la biomasse totale. La classe d'âge 2000 devrait contribuer 26 % de la biomasse totale en début d'année 2003; cependant, elle n'est pas bien estimée et a été basée uniquement sur un seul indice de relevé dans le bilan de cette année.

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 (Stone et al., 2001). 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 (Lux and Nichy 1969; 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

Exploitation of the Georges Bank stock (NAFO Statistical Areas 5Zhjmn) began in the mid-1930's by the US trawler fleet. Landings (including discards) 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). The highest annual catches occurred during 1963-1976 (average: 16,300 t) and included modest catches by foreign fleets. No foreign catches of yellowtail have occurred since 1975. In 1985, the stock became a transboundary resource in Canadian and US jurisdictions. 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. A directed Canadian fishery began in 1993, pursued mainly by small otter trawlers (< 24 m). Landings by both nations have steadily increased (with increasing quotas) from a record low of 788 t in 1995, when the stock was considered to be in a collapsed state, to 6,800 t in 2001.

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%. US 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), then increased to 88% in 2001. This reduced proportion adds uncertainty to the estimate of yellowtail landings by stock area in 2000 and 2001. U.S. landings from Georges Bank inecreased 3% from 2000 to 2001 (Table 1). Total yellowtail landings (excluding discards) for the 2001 USA fishery were 3,792 t.

Discarding of small yellowtail in the U.S. fishery has been 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 within Closed Area II. Since there was no exemption scallop fishery within the closed area in 2001, most discards would have originated from the bottom trawl fishery. Previous estimates of trawl discards based on the method described in Cadrin et al. (1998) were 89 t for 1999 and 57 t for 2000. Since no estimate for 2001 was available at the time of this assessment, an additional 60 t was added to USA landings for 2001 to represent discards from the trawl fishery.

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. Landing have increased considerably since1995 and in 2001 were 2,913 t against a quota of 3,450 t, up slightly (2%) from 2,859 t reported in 2000 (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 2001 occurring from August to November.

Flatfish landed as “unspecified” in the Canadian fishery have been significant in previous years, and generally consist of yellowtail on Georges Bank. Neilson et al. (1997) revised the landings data for earlier years of the fishery (1993-1995) to account for catches of unspecified flounder species. The unspecified flounder problem has become less significant recently, due to improved monitoring of the landings. For the 2001 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 2001 estimated to be yellowtail, were 6.4 t and 45.3 t for 5Zj and 5Zm, respectively, and are included as part of the Canadian landings (Table 1).

Summer flounder (*Paralichthys dentatus*) was also captured in the Canadian fishery (mostly August through October), and was also reported as "unspecified" since it is uncommon in Canadian waters. Therefore, an unknown portion of the unspecified flounder catch for 2001 was likely summer flounder. Two reports of summer flounder landings were provided by fish processors in southwestern Nova Scotia and were used to determine the proportion represented by summer flounder to the total catch of yellowtail. This amount (estimated to be 1%) represents 26 t of the total yellowtail catch and was subtracted from the total landings (including unspecified estimated to be yellowtail) to give the revised total of 2913 t for 2001.

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 four years is shown in Fig. 3. Overall, the fishery distribution in 2001 was comparable to that observed in the previous three years.

In past 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 the 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. A monitoring program was conducted in 2001 to examine yellowtail flounder bycatch in the offshore scallop fishery but results are not yet available.

Length and Age Composition

In 2001, the Canadian fishery was well sampled for lengths by sex, with 7,471 measurements available from 33 port samples (Table 2). 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 2001 fishery. Sea samples were obtained from 14 commercial trips by Canadian observers, but for many of these trips, the length composition by sex appeared to be inaccurate. The size composition by sex from at-sea samples was compared to port samples collected during the same month and for many observed trips, sexes were either undetermined, or incorrectly assigned (Fig. 4). Therefore, only length information from the DFO/Industry port-sampling program was used to characterize the size composition of the Canadian fishery. Although sex determinations appeared to be inaccurate, the at-sea length frequency information does indicate that culling on the basis of length was not a major concern in the 2001 fishery (Fig. 4). While the Canadian fishery currently has a minimum fish size limit of 30 cm total length, this size regulation is seldom enforced. Since 1993, the percentage of undersized fish (i.e. < 30 cm by number) has rarely exceeded 4% of the total reported catch and has been well below 1% for the past three years (Fig. 5).

Although the overall number of US yellowtail samples has increased in recent years, the number of samples taken from the Georges Bank fishery continues to be poor (Table 2). Only 2,937 measurements from 25 samples were available in 2001 compared to 3,300 in 2000 (27 samples) and 1,291 (11 samples) in 1999.

The mean length of yellowtail flounder in the Canadian fishery has increased between 1994 and 2001 from 33 to 35 cm total length for males and from 35 to 41 cm for females (Fig 6). 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 males representing an increasing proportion of the overall catch. Males represented 61% of the total catch in 2001, compared to 46% and 25% in 2000 and 1999, respectively. The catch at size for Canadian and USA fisheries was quite similar in 2001, although it tended to be more peaked in the US fishery, with a modal size of 35 cm for both nations (Fig. 7). The Canadian fishery captured more fish >45 cm and in the 28-32 cm range.

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 2001 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 151 male and 185 female ages were available (compared to 187 male and 277 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 first half commercial port sample ages (n=404) and second half commercial port sample plus fall RV ages (n=381).

The combined catch at age and mean weight at age information for both countries is shown in Tables 3 and 4, respectively. Age 2 and 3 males and 3-5 females represented most of the Canadian catch in 2001 (Fig.8). Compared with the 2000 fishery age composition, age 3 males and 5+ females represented a greater portion of the catch in 2001. The average length at age for males and females in the Canadian CAA has generally been fairly consistent over the past 5 years, although some variability has occurred for males at ages 4 and older (Table 5).

The USA age composition is not available by sex (CAA is done for combined sexes) but shows fewer age 2 and more age 3 fish in 2001 compared to 2000, with age 3 most prevalent. Catches from the Canadian and US fisheries had similar age compositions in 2001, with the Canadian fishery capturing more older fish (age 6+). Overall, the 1998 year-class (age 3) dominated the catch in 2001, and can be tracked along with the 1997 year-class in the catch at age (Fig. 9, Table 3).

Mean weight at age was calculated from Canadian (separate sex) and USA (combined sex) fishery CAA data (Table 4, Fig. 10). The commercial fishery mean weight at age data was revised in the last assessment to include calculated weights for age 1 fish rather than the assigned value of 0.01. Since the actual mean weight at age 1 calculated for 2001 was unusally high (0.259), an average for 1997-2000 was used (0.181) instead. An increasing trend in mean weight at age is apparent for ages 2-5 from 1996 to 1999, dropping off slightly for ages 2-4 in 2000 and 2001, but remaining constant for ages 5 and 6+. The declining trend in mean weight at ages 2-4 may reflect the increasing proportion of males in the catch in recent years (which have a smaller average weight at age than females after age 2), causing a reduction in the average WAA for combined sexes.

Abundance Indices

Commercial Fishery Catch Rates

A standardized catch rate series was developed for the Canadian fishery using a multiplicative model that was solved using standard linear regression techniques after *ln* transformation of nominal CPUE (tonnes per hour) data (Gavaris 1980, 1988a). For this analysis, only trips in 5Zm with ≥ 2.0 t of yellowtail landed were included (*n*=992), and were assumed to represent directed fishing activity for yellowtail flounder. A model with main effects of year (1993-2001), month (June-December) and tonnage class (2,3) was used to standardize the Canadian CPUE series:

$$ln(\text{CPUE}_{ijk}) = \mu + \text{Year}_i + \text{Month}_j + \text{Tonnage Class}_k + e_{ijk}$$

Analysis of variance results (Table 6) indicate that the overall regression and individual main effects were significant ($P < 0.05$) and that the model explained 69% (multiple r^2) of the variability in the data. No trends were apparent in the pattern of residuals (Table 6, bottom) and the standardized series tracked the nominal series (weighted mean) quite well (Fig. 11, upper panel).

Standardized catch rates decreased between 1993 and 1994 but increased by a factor of 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 sharply, with a continued decline in 2001 to the second lowest level in the series. In comparison with the DFO spring survey biomass index for stratum 5Z2 (Canadian portion of the bank <90 m), the CPUE series tracks the index up to 1999, but falls off rapidly thereafter (Fig. 11, lower panel). The Spearman rank correlation coefficient for these two series was not significant (r_s=0.533; P=0.139; n=9), suggesting that catch rates within the Yellowtail Hole have declined more rapidly in recent years than the Canadian portion of the bank (< 90 m) as a whole. Results from tagging studies (Lux 1963, Stone unpublished data) indicate that yellowtail flounder are sedentary and do not move very far, therefore, localized depletion could occur in the Yellowtail Hole area. Although it is assumed that some fish would move in to the Yellowtail Hole from adjacent areas (i.e. Closed Area II), the rate of immigration may not keep up with removals from fishing.

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 and fishermen with a history of fishing yellowtail clearly noted a decline. When the 2001 fishery commenced in August, fishermen noted an absence of fish in the Yellowtail Hole and reported low catches up to early September. Catch rates for yellowtail in 2001 were considered to be much poorer than past years, but more winter flounder and summer flounder were present as bycatch. The presence of summer flounder on the bank may indicate that enviromnental conditions in 2001 may have been different (i.e. warmer bottom water temperatures) when the season commenced, and may have resulted in yellowtail temporarily moving out of traditional fishing areas. 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. 12). 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) 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 (Figs. 13, 14 and 15 for the DFO spring, NMFS spring and fall surveys, respectively).

The DFO spring biomass index continues to be high in 2002. This series follows an increasing trend from 1995 to 2001 (the highest value in the series), then drops off slightly in 2002 (Table 7, Fig. 16). The NMFS spring series is longer, and tracks the DFO series well during the years of overlap up to 1999, but shows a decline though to 2001 (Table 8, Fig. 16). 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 followed by a large increase in 2001 (Table 9, Fig. 16). The 2001 fall survey index value is the third highest in the series and has not been this high since the early 1960's.

Since 1996, most of the DFO spring survey total biomass and total number for yellowtail originates from Stratum 5Z4, which includes much of Closed Area II on the US side where no commercial fishing occurs (Fig. 17). Although survey estimates for this stratum tend to be quite variable due to low sampling intensity, the trend is clearly increasing from 1996 to present. Stratum 5Z2 (CDN portion of Georges < 90 m depth) has also shown an increasing trend in total biomass and total number since 1996, but at a lower level than 5Z4.

The length composition of the catch of yellowtail flounder taken in the DFO surveys has been fairly consistent since 1998 (Fig. 18) with a slight increase in average size for males and females in recent years. In the 2000 and 2001 surveys, there appears to be an absence of fish in the 20-30 cm range although more were present in 2002. Also there are more females > 45 cm in the 2002 survey catches compared with the previous two years. There has been an increase in the proportion of males in the catch during the past three years (>60% male in 2000-2003 *vs* 50% in 1999) similar to the Canadian commercial landings.

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 same-year DFO spring surveys. All three surveys gave a consistent view that the 1998 (age 3) year class was quite strong in 2001 (Tables 7-9; Fig. 19), and is consistent with previous DFO and NMFS spring surveys which indicated a moderately strong 1998 year-class at age 2 in 2000. Also of moderate strength is the 1999 year-class (age 2) apparent in the NMFS 2001 fall survey. Overall, age-structured indices from the surveys do not always track cohorts well and there are some indications of year-effects within the time series.

In the 2001 assessment, it was determined that the iterative method of Kimura and Chikuni (1987) was not reliable for deriving an age composition for the most recent DFO survey indices which have no same-year NMFS age information (Stone et al., 2001). Therefore, no attempt was made to calculate age-specific indices for the 2002 DFO spring survey.

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. No updated 2001 index value was available for the current assessment, so the time series used was the same as in the 2001 assessment (1982-2000). 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 10).

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 2001, 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 2001
s = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 2001
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 2001.5
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 (Stone et. al, 2001). 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 (119%) and substantial bias for age 2 while the relative error for ages 3-5 is much less (<40%) and the bias is small (Table 11). Relative error and bias for age 2 is much higher than estimated from the previous assessment in 2001. The high variability in the estimate for age 2 (2000 year-class) occurs because it is entirely based on the age 1 index value from the NMFS 2001 fall survey which is estimated to be quite high. The average magnitude of residuals was large and negative for both the DFO and NMFS spring surveys (i.e. model predicts higher abundance than surveys), but not the NMFS fall survey (Figs. 20-25). Although these residuals appear to be large, they probably do not impact on parameter estimates of current abundance. Retrospective analysis indicates a strong tendency to overestimate the abundance of age 5 fish since 1994 (Fig. 26). As a result, fishing mortality on ages 4-5 has been underestimated in recent assessments. (Note: These ages were selected as examples of the retrospective pattern). However, no pattern was apparent in the estimates of abundance for younger ages and for total biomass.

In this assessment, VPA calibration was performed using only DFO software. Past assessment have also used the US FACT software, which due to slight differences in search algorithms, bias correction, and computations can produce slightly different results.

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 2002, lagged one year to reflect end of previous year biomass), NMFS spring (1968 to 1972; 1982-2001, lagged one year), and NMFS fall (1963 to 2001). 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 (1963-2001) 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 obtained 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.

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 and used to construct the history of stock status (Tables 12-13). 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 14) and these were used to calculate beginning of year population biomass (Table 15).

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 58,000 t at the beginning of 2002 (Table 15, Fig. 27). The increasing trend is due principally to improved recruitment from the mid-1990’s onward, but was also enhanced by increased survivorship of young yellowtail through reduced exploitation. The biomass of adult fish (ages 3+) shows a similar trend and was estimated at 42,000 t at the beginning of 2002. The strength of the 1997 year-class was estimated to be 59 million at age 1, the largest since 1980 (Table 12, Fig. 28). However, this estimate was lower than previous estimates of 73 million and 83 million recruits from the 2001 and 2000 assessments, respectively. Current indications for the 1998 and 1999 year-classes indicate that they are stronger than predicted in the last assessment. Noteworthy is the 1998 year-class which is now estimated at 49 million recruits compared to 41 million in 2001.

The fully recruited (4+) exploitation rate underwent a marked decline from 1994-2001 and has been near or below 20% (equivalent to $F_{0.1}$ =0.25) for the last 3 years (Fig. 29). It is currently at the lowest level for the time series, at 9% exploitation for 2001. However, exploitation on age 3 has not decreased proportionately, and the partial recruitment to the fishery has increased over the past 5 years (i.e. from 0.344 in 1997 to 1.794 in 2001). The large change in PR is of concern given the poor sampling and few age samples available for the 2001 fishery. Age 3 now appears to be exploited more heavily than recommended by the $F_{0.1}$ harvest strategy (current exploitation rate =15%).

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. 30). 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 2001, surplus production was estimated to be much lower at 9,500 t compared to 17,000 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 2001 was estimated to be 5,000 t, lower than the 2000 estimate of 6,000 t.

Surplus Production Analyses

Correlations among survey biomass indices were strong (r= 0.80, 0.85, and 0.89; Appendix A). Most of the variance in survey indices was explained by the model (R^2= 0.59, 0.81, and 0.87). There were no apparent residual problems, and biomass residuals in the last year were small and negative for the NMFS spring and fall surveys (*i.e.* surveys generally indicate lower current biomass than the model) and small and positive for the DFO 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 2001 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 <7%), but that B_1 and survey q's were more variable (relative IQRs=6%-

17%). Bootstrap calculations of K, B_{MSY}, and F_{MSY} were stable (relative IQRs=4-5%,), but ratios of current conditions to MSY conditions (F_{2001}/F_{MSY} and B_{2002}/B_{MSY}) were less precise (relative IQRs=8-10%).

ASPIC results indicate that a maximum sustainable yield of 14,450 t can be produced when the stock biomass (B_{MSY}) is 43,200 t at equilibrium. The population biomass in 2002 continues to increase, and is now estimated to be 60,900 t. Trends in biomass indicated from the surplus production analyses are very similar to those obtained from the VPA for 1+ biomass (Fig. 27). Biomass estimates from ASPIC have been slightly higher than those from the VPA since 1996. The exploitation rate on total biomass in 2001(0.100) decreased slightly from 2000 (0.114) and is considered to be low.

The surplus production model attempts to describe long term population dynamics in a simple model which projects past stock productivity forward. However, it is not clear whether past stock productivity will always be a good predictor of stock dynamics. Further, surplus production models may fail to capture the dynamic changes that occur in recruitment, growth and exploitation patterns at age.

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%).

Stock and Recruitment

There is evidence of reduced recruitment at low levels of age 3+ biomass (Fig. 31). 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

While the historical population reconstruction from the VPA and the surplus production model show concurrence, projections from the two models diverge significantly. The projection results from the surplus production model imply high equilibrium recruitment levels that are not consistent with historical estimates. Accordingly, only the VPA projection results are considered reliable.

Virtual Population Analysis

Yield projections were done using the bias adjusted 2002 beginning of year population abundance estimates. The abundance of the 2002 and 2003 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 5 years (1997 through 2001) for use in the 2003 forecasts. Partial recruitment to the fishery for ages 1, 2 and 3 was averaged for the past 5 years (1997 and 2001, Table 16). There has been a considerable increase in PR on ages 2 and 3 since 1997, 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 1997-2001) are slightly lower for age 2 but higher for age 3 compared to last year (i.e. age 2: 0.28 *vs* 0.32; age 3: 0.88 *vs* 0.65). Beginning of year weights at age were slightly higher for most age groups compared to last year's values.

Projected total Canada/USA yield at $F_{0.1} = 0.25$ in 2002 would be about 10,285 t. If fished at $F_{0.1}$ in 2002, the total biomass is projected to decrease slightly from 58,108 t to 57,973 t by the beginning of 2003, with a 13% increase in the 3+ beginning of year biomass from 41,670 t to 48,066 t (Fig. 32). The dominant 1997 and 1998 year-classes are expected to contribute about 50% of the expected yield as ages 4 and 5 in 2002, and comprise about 39% of the total biomass. The 2000 year-class is estimated to contribute 26% of total beginning of year biomass in 2003, however, this year-class is not well estimated and was based on only a single survey index value in this year's assessment.

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 6,800 t, there is a very small probability (< 1%) of exceeding $F_{0.1}$, and a high probability (88%) that total biomass will not decrease by 10% in 2003 (Fig. 33). At the $F_{0.1}$ yield of 10,300 t, which corresponds to about 45% probability of exceeding $F_{0.1}$, the biomass is not likely to decrease and there is an 25% probability of not achieving 10% increase from the beginning of the year 2002 to 2003.

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.

The population age structure has improved in recent years and population biomass has increased. The current age structure indicates that some rebuilding of ages 4 and 5 has occurred but there are still fewer older fish (6+) in comparison with a population at equilibrium (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 US 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 US catch at age. Availability of Canadian age samples would eliminate the need to borrow samples from other sources that 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 2002 biomass levels are lower, and 2002 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.

Acknowledgments

Canadian port sampling was provided by Gilbert Donaldson, Susan Arsenault and Emilia Williams. Many people in the Woods Hole lab assisted in the compilation of the US data. Vaughn Silva processed a large volume of age samples in short order, and Jay Burnett and George Bolz processed age data. I would also like to thank Stratis Gavaris for technical assistance and Peter Perley for conducting an editorial review of the manuscript.

Literature Cited

Cadrin, S.X., W.J. Overholtz, J.D. Neilson, S. Gavaris, and S. Wigley. 1998. Stock assessment of Georges Bank yellowtail flounder for 1997. NEFSC Ref. Doc. 98-06.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Gavaris, S. 1988a. Abundance indices from commercial fishing. p. 3-13 In: D. Rivard (ed) Collected papers on stock assessment methods. CAFSAC Res. Doc. 88/61. 167 p.

Gavaris, S. 1988b. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29: 12 p.

Kimura, D.K. and S. Chikuni. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. Biometrics 43: 23-35.

Lux, F.E. 1963. Identification of New England yellowtail flounder groups. Fish. Bull. 63: 1-10.

Lux, F.E. 1969. Length-weight relationships of six New England flatfishes. Trans. Am. Fish. Soc. 98(4): 617-621.

Lux, F.E. and F.E. Nichy. 1969. Growth of yellowtail flounder, *Limanda ferruginea* (Storer), on three New England fishing grounds. ICNAF Res. Bull. No. 6: 5-25.

Mosely, S.D. 1986. Age structure, growth, and intraspecific growth variations of yellowtail flounder, *Limanda ferruginea* (Storer), on four northeastern United States fishing grounds. Univ. Mass. MS thesis.

Neilson, J.D. and S.X. Cadrin. 1998. 1998 Assessment of Georges Bank (5Zjmnh) Yellowtail Flounder. Canadian Stock Assessment Secretariat Res. Doc. 98/67.

Neilson, J.D. , S. Gavaris and J.J. Hunt. 1997. 1997 assessment of Georges Bank (5Zjmnh) yellowtail flounder (*Limanda ferruginea*). Canadian Stock Assessment Secretariat Res. Doc. 97/55.

Prager, M.H. 1995. Users manual for ASPIC: a stock-production model incorporating covariates. SEFSC Miami Lab Doc. MIA-92/93-55.

Restrepo, V.R. and C.M. Legault. 1994. Approximations for solving the catch equation when it involves a "plus group". Fish. Bull. 93(2): 308-314.

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23: 26 p.

Rago, P., W. Gabriel, and M. Lambert. 1994. Georges Bank yellowtail flounder. NEFSC Ref. Doc. 94-20.

Royce, W.F., R.J. Buller, and E.D. Premetz. 1959. Decline of the yellowtail flounder (*Limanda ferruginea*) off New England. Fish. Bull. 146:169-267.

Stone, H.H., C.M. Legault, S.X. Cadrin, S. Gavaris, J.D. Neilson, and P. Perley. 2001. Stock assessment of Georges Bank yellowtail flounder for 2001. CSAS Res. Doc. 2001/068, 87 p.

Table 1. Annual catch (000s t) of Georges Bank yellowtail flounder. Canadian landings have been adjusted for catches of unspecified flounder. US discards for 2001 were estimated based on bottom trawl discard estimates for 1999 and 2000.

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
2001	3.792	*0.060	2.938	-	6.790

Table 2. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2001 from Canadian and US sources.

USA	**Port Samples**				**Sea Samples**			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	All	7	738	194	0	0	0	1473
2	All	8	1013	210	0	0	0	1362
3	All	5	660	148	0	0	0	355
4	All	5	526	45	0	0	0	663
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	3	647	0	0	0	0	37
3	All	17	3915	0	0	0	0	1945
4	All	13	2909	0	0	0	0	931

Table 3. Total catch at age (number in 000's) including US discards, for Georges Bank yellowtail flounder, 1973-2001.

	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
2001	26	1568	5457	2211	957	229	197	17	10663

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
2001	0.181	0.357	0.419	0.569	0.751	0.928	0.987	1.236

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 2001.

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
2001	30.8	34.7	35.4	36.7	42.3	-	-
	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
2001	30.8	35.8	38.3	41.9	43.9	46.4	47.3

Table 6. ANOVA results from a multiplicative model with main effects for year, month and tonnage class for the Canadian yellowtail flounder fishery CPUE, 1993-2001.

ΡΕΓΡΕΣΣΙΟΝ ΟΦ ΜΥΛΤΙΠΛΙΧΑΤΙςΕ ΜΟΔΕΛ

ΜΥΛΤΙΠΛΕ Ρ............ 0.831 ΜΥΛΤΙΠΛΕ Ρ ΣΘΥΑΡΕΔ..... 0.691

ΑΝΑΛΨΣΙΣ ΟΦ ςΑΡΙΑΝΧΕ

ΣΟΥΡΧΕ ΟΦ ςΑΡΙΑΤΙΟΝ	ΔΦ	ΣΥΜΣ ΟΦ ΣΘΥΑΡΕΣ	MEAN ΣΘΥΑΡΕΣ	Φ–ςΑΛΥΕ
ΙΝΤΕΡΧΕΠΤ	1	1.184E3	1.184E3	
ΡΕΓΡΕΣΣΙΟΝ	15	3.731E2	2.487E1	145.435
ΨΕΑΡ	8	3.330E2	4.163E1	243.440
MONTH	6	3.405E1	5.674E0	33.180
TX	1	6.750E↓1	6.750E↓1	3.947
ΡΕΣΙΔΥΑΛΣ	975	1.667E2	1.710E↓1	
ΤΟΤΑΛ	991	1.724E3		

ΠΡΕΔΙΧΤΕΔ ΧΑΤΧΗ ΡΑΤΕ

	ΛΝ ΤΡΑΝΣΦΟΡΜ		ΡΕΤΡΑΝΣΦΟΡΜΕΔ			
ΨΕΑΡ	MEAN	Σ.Ε.	MEAN	Σ.Ε.	ΧΑΤΧΗ	ΕΦΦΟΡΤ
1993	↓1.2196	0.0229	0.318	0.048	111	349
1994	↓2.1132	0.0018	0.132	0.006	1138	8652
1995	↓1.1258	0.0046	0.353	0.024	370	1049
1996	↓0.5515	0.0049	0.626	0.044	369	589
1997	↓0.4870	0.0031	0.668	0.037	723	1082
1998	↓0.6225	0.0026	0.584	0.030	1094	1874
1999	↓0.3366	0.0016	0.777	0.032	1860	2393
2000	↓0.9955	0.0012	0.402	0.014	2500	6214
2001	↓1.6064	0.0012	0.218	0.008	2528	11575

ΡΕΣΙΔΥΑΛΣ

```
    20 20
     3.00+
       |    *
       |
       |
       |
     1.75+
Ρ       |       *
Ε       |          **
Σ       |     * **   **
Ι      |  *    *** *******
Δ    0.50+  * ****************
Υ       |  * ****************
Α       |    ****************
Λ       |    ****************
Σ       |    ****************
   ↓0.75+      **************
       |      * * *** **
       |         **
       |      *
       |
   ↓2.00+            **
      /+----------+----------+
    ↓3.0    ↓1.5     0.0
```

Table 7. 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	0.29	5.97	51.67	16.65	4.41	3.61	82.62	22.157
2002	-	-	-	-	-	-	63.49	20.624

Table 8. 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
2001	0	2.315	6.563	2.411	0.483	0.352	0.101	0	12.225	5.006

Table 9. 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
2001	0.037	3.518	6.268	8.091	2.601	1.718	0.714	1.344	0	24.282	11.553

Table 10. 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 11. Statistical properties of estimates for population abundance and survey calibration constants (10^{-3}) for Georges Bank yellowtail flounder.

Age	Estimate	Bootstrap Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance			
2	77312	91883	1.188	26210	0.339
3	25879	9575	0.370	1451	0.056
4	22286	8786	0.394	1273	0.057
5	18365	3443	0.188	207	0.011
		Survey Calibration Constants			
Scallop–1982-2000					
	0.029	0.005	0.186	0.001	0.018
DFO spring Survey – 1987-2001					
	0.210	0.046	0.218	0.001	0.005
	0.721	0.162	0.225	0.021	0.030
	1.119	0.247	0.220	0.029	0.026
	1.264	0.277	0.219	0.017	0.014
	1.380	0.366	0.265	0.026	0.019
NMFS Spring Survey – Yankee 36 –1982-2001					
	0.008	0.002	0.296	0.000	0.055
	0.083	0.022	0.270	0.004	0.043
	0.106	0.031	0.292	0.006	0.056
	0.104	0.029	0.275	0.002	0.022
	0.083	0.023	0.284	0.002	0.018
	0.084	0.025	0.297	0.004	0.045
NMFS Spring Survey – Yankee 41 – 1973-1981					
	0.003	0.001	0.239	0.000	0.012
	0.068	0.013	0.185	0.002	0.027
	0.163	0.031	0.188	0.001	0.009
	0.242	0.047	0.192	0.005	0.023
	0.340	0.062	0.184	0.006	0.019
	0.518	0.103	0.198	0.013	0.024
NMFS Fall Survey - 1973-2001					
	0.041	0.006	0.148	0.001	0.014
	0.094	0.015	0.156	0.001	0.007
	0.205	0.030	0.145	0.001	0.005
	0.228	0.035	0.152	0.002	0.009
	0.293	0.046	0.158	0.004	0.013
	0.407	0.083	0.204	0.006	0.015

Table 12. 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 2002.

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	11569	6750	11067	1401	187	35	31009	19439	12690
1991	21665	9274	3793	3612	436	89	38869	17204	7929
1992	15615	17366	7544	2009	808	43	43385	27770	10404
1993	11785	10633	6759	3911	520	123	33730	21946	11313
1994	10218	5007	7796	3050	1079	162	27312	17094	12087
1995	13274	8302	3324	1324	254	52	26529	13255	4954
1996	18686	10855	6655	1918	447	40	38602	19916	9060
1997	36313	15254	8542	4092	929	245	65374	29062	13808
1998	59397	29716	11951	5860	2005	331	109260	49864	20148
1999	49037	48607	23453	7275	3162	787	132320	83283	34676
2000	30750	40129	36830	16310	4609	1871	130500	99750	59621
2001	47199	25085	29490	24978	10812	5005	142569	95370	70285
2002	30000	38620	19123	19232	18457	11687	137118	107118	68499

Table 13. Fishing mortality rate for Georges Bank yellowtail from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2002.

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	0.184	0.744	0.457	1.152	1.152	1.152	0.648
1993	0.657	0.110	0.596	1.088	1.088	1.088	0.794
1994	0.008	0.210	1.574	2.287	2.287	2.287	1.827
1995	0.001	0.021	0.351	0.886	0.886	0.886	0.527
1996	0.003	0.040	0.287	0.526	0.526	0.526	0.350
1997	0.000	0.044	0.177	0.514	0.514	0.514	0.306
1998	0.000	0.037	0.296	0.417	0.417	0.417	0.346
1999	0.000	0.077	0.162	0.256	0.256	0.256	0.193
2000	0.003	0.092	0.186	0.209	0.209	0.209	0.195
2001	0.000	0.050	0.181	0.101	0.101	0.101	0.136

Table 14. Beginning of year weight (kg) at age for Georges Bank yellowtail. Age group 6+ is catch weighted. The 2002 value is the average for 1997-2001.

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	0.727
1996	0.091	0.215	0.318	0.455	0.579	0.789
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	0.157	0.263	0.410	0.537	0.637	0.780
2000	0.124	0.282	0.424	0.556	0.693	0.858
2001	0.131	0.251	0.398	0.523	0.678	0.902
2002	0.129	0.246	0.391	0.510	0.643	0.847

Table 15. 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 2002.

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	707	1155	4096	783	133	31	6905	6198	5043
1991	1261	1518	1245	1578	282	69	5954	4693	3175
1992	922	2983	2372	881	450	40	7648	6726	3744
1993	736	1801	2251	1692	282	99	6860	6124	4323
1994	1186	800	2470	1285	609	121	6472	5285	4485
1995	1476	1600	1015	532	133	38	4793	3317	1717
1996	1690	2321	2107	871	258	32	7280	5590	3269
1997	3802	3122	2970	1876	570	226	12566	8764	5642
1998	7640	6684	4447	2745	1179	253	22949	15310	8626
1999	8184	12639	9528	3871	1994	608	36824	28640	16001
2000	4778	12056	15411	8966	3155	1586	45953	41175	29119
2001	8161	7912	12603	12858	7220	4446	53200	45039	37127
2002	3880	12558	9558	10708	11673	9731	58108	54228	41670

Table 16. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2002 at $F_{0.1}$ using the bootstrap bias adjusted population abundance at the beginning of 2002.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
Beginning of Year Population Numbers (000s)									
2002	30000	51102	24428	21013	18150	11493			
2003	30000	24541	38992	16070	13398	18901			
Partial Recruitment to the Fishery									
2002	0.003	0.282	0.875	1.00	1.00	1.00			
Fishing Mortality									
2002	0.001	0.070	0.219	0.250	0.250	0.250			
Weight at beginning of year for population (kg)									
2003	0.129	0.246	0.391	0.510	0.643	0.847			
Beginning of Year Projected Population Biomass (t)									
2003	3870	6037	15246	8196	8615	16009	57973	54103	48066
Projected Catch Numbers (000s)									
2002	23	3156	4367	4230	3654	2314			
Average weight for catch (kg)									
2002	0.181	0.350	0.454	0.576	0.718	0.922			
Projected Yield (t)									
2002	4	1104	1983	2437	2624	2133	10285	10280	9176

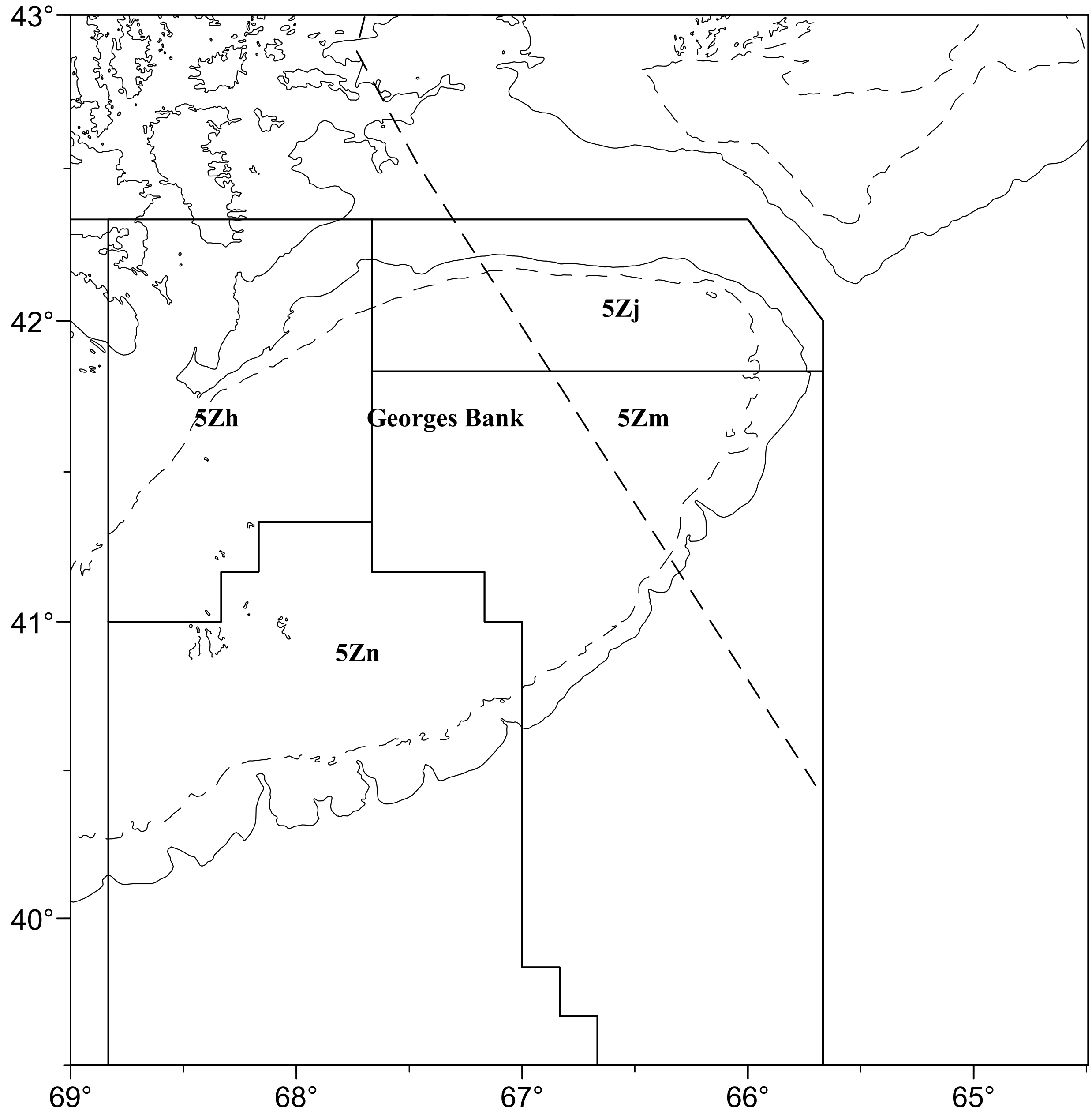

Fig. 1a. Location of Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

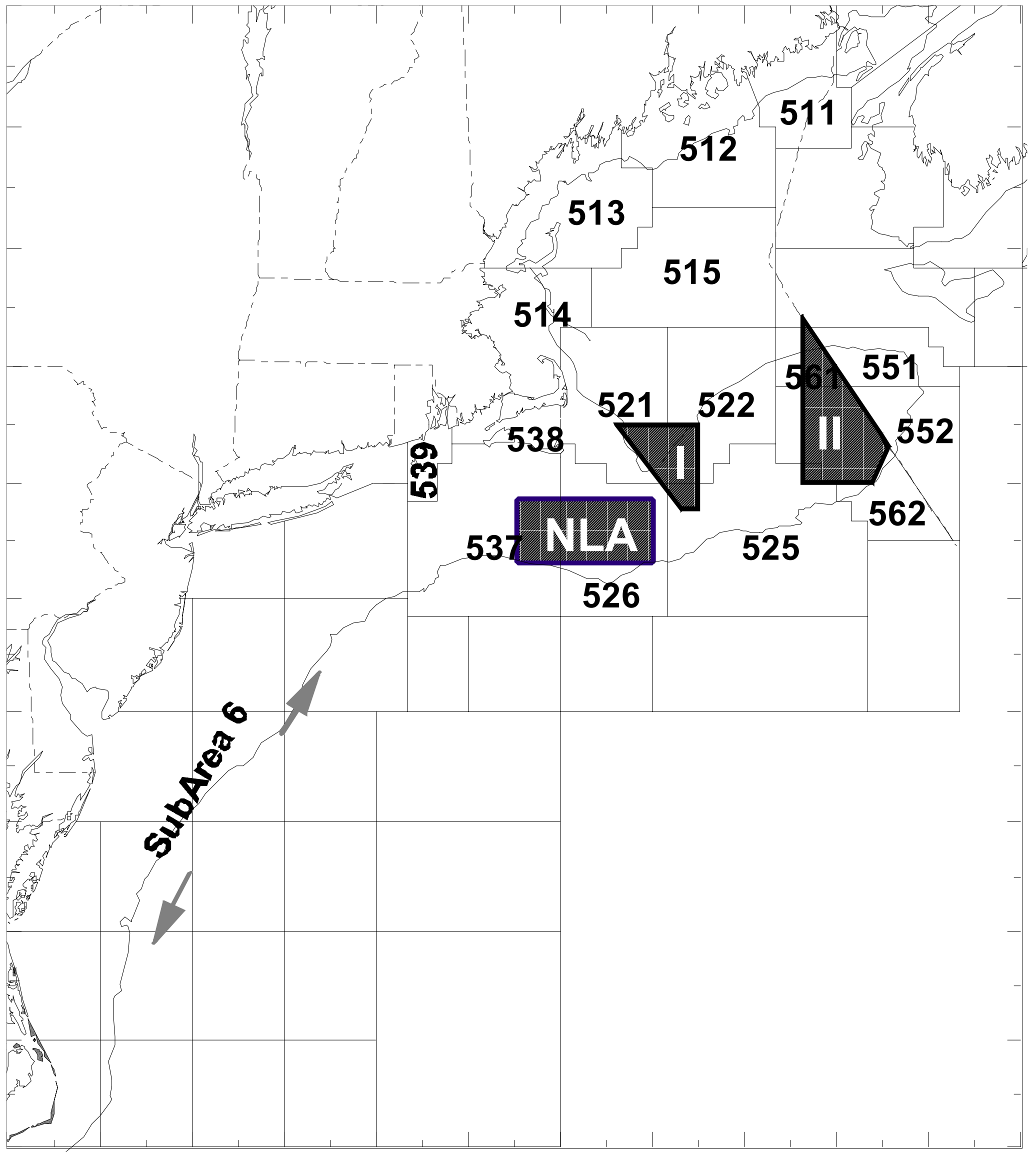

Fig. 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

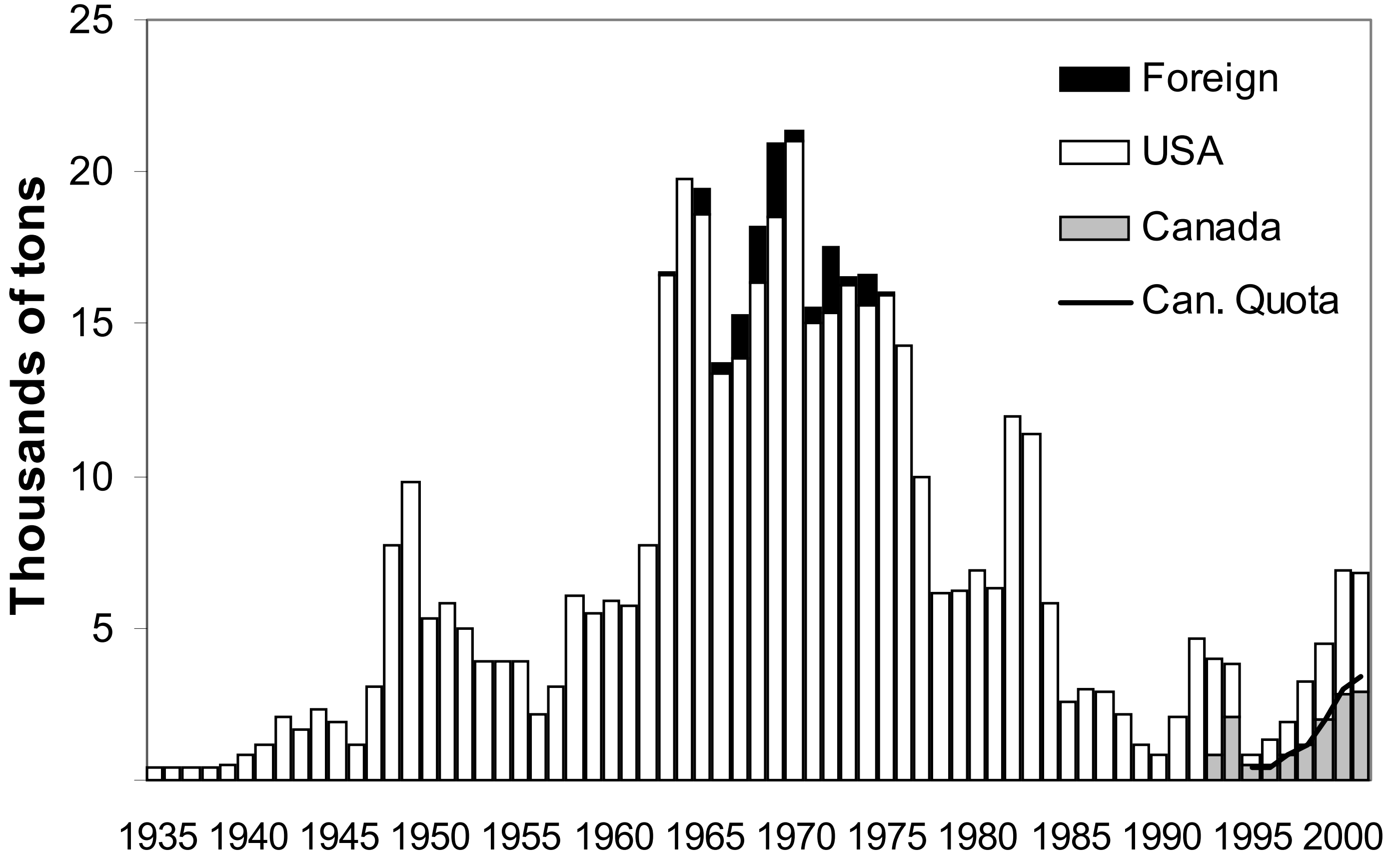

Fig. 2 . Landings (including discards) of Georges Bank yellowtail flounder by nation, 1963-2001.

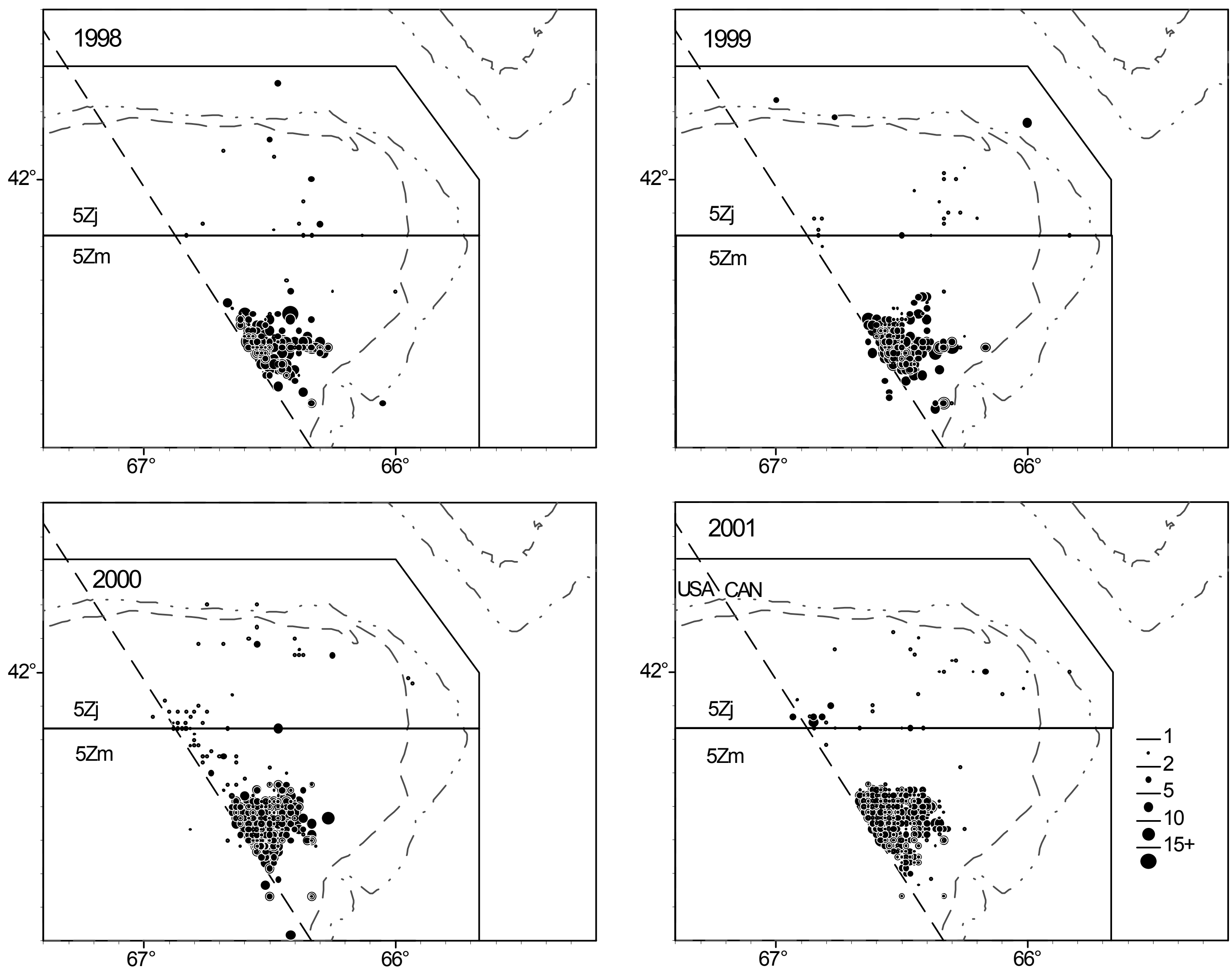

Fig 3. Distribution of Canadian mobile gear (TC 2 & 3) yellowtail flounder catches for 1998-2001 where trip landings were greater than 0.5t. Expanding symbols represent metric tonnes

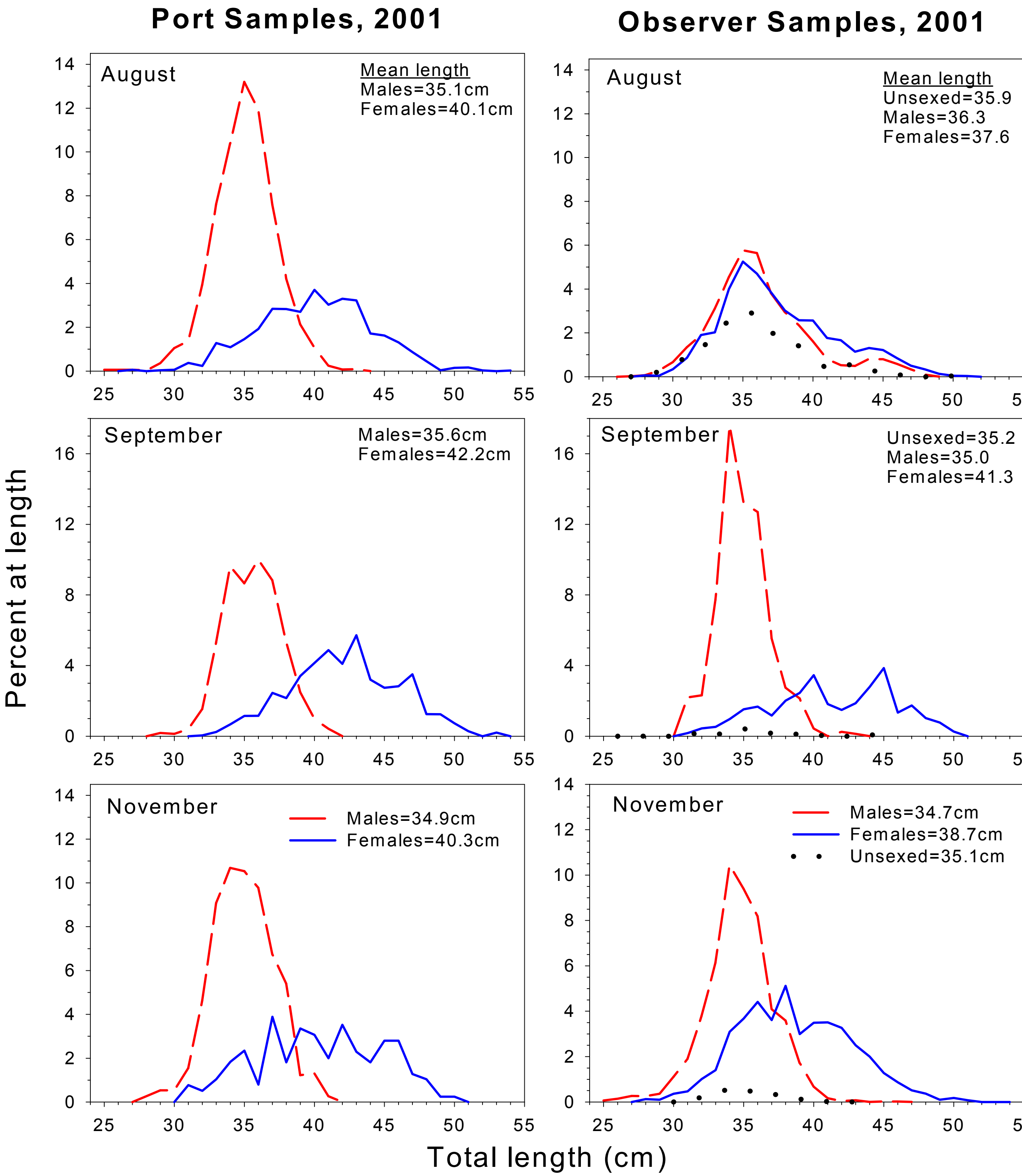

Fig. 4. Length frequencies of Georges Bank yellowtail flounder sampled by sex at dockside (left panels) and at sea (right panels) during the same month for the 2001 fishery.

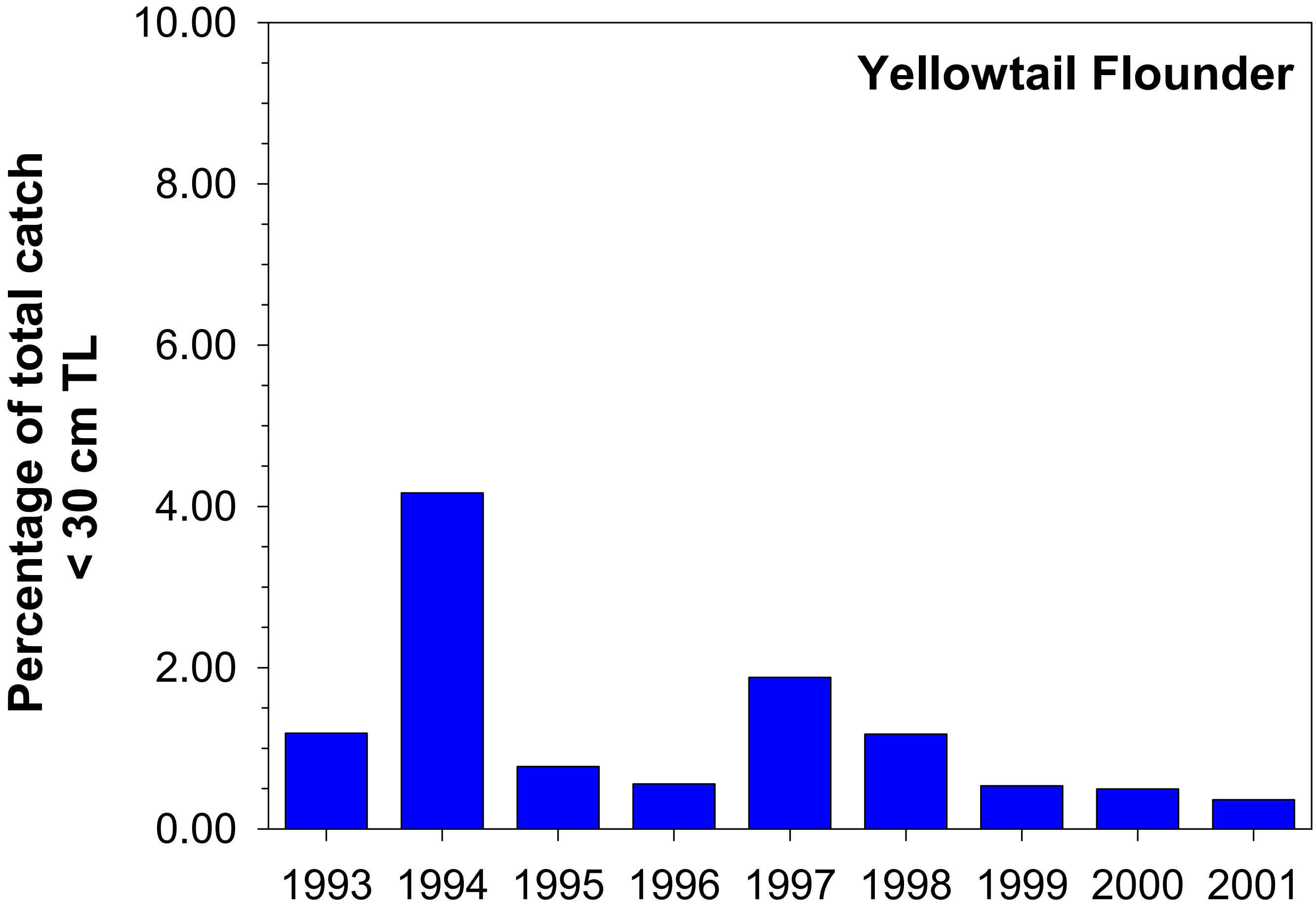

Fig. 5. Percentage of total catch of Georges Bank yellowtail flounder less than 30 cm total length from the Canadian fishery, 1993-2000.

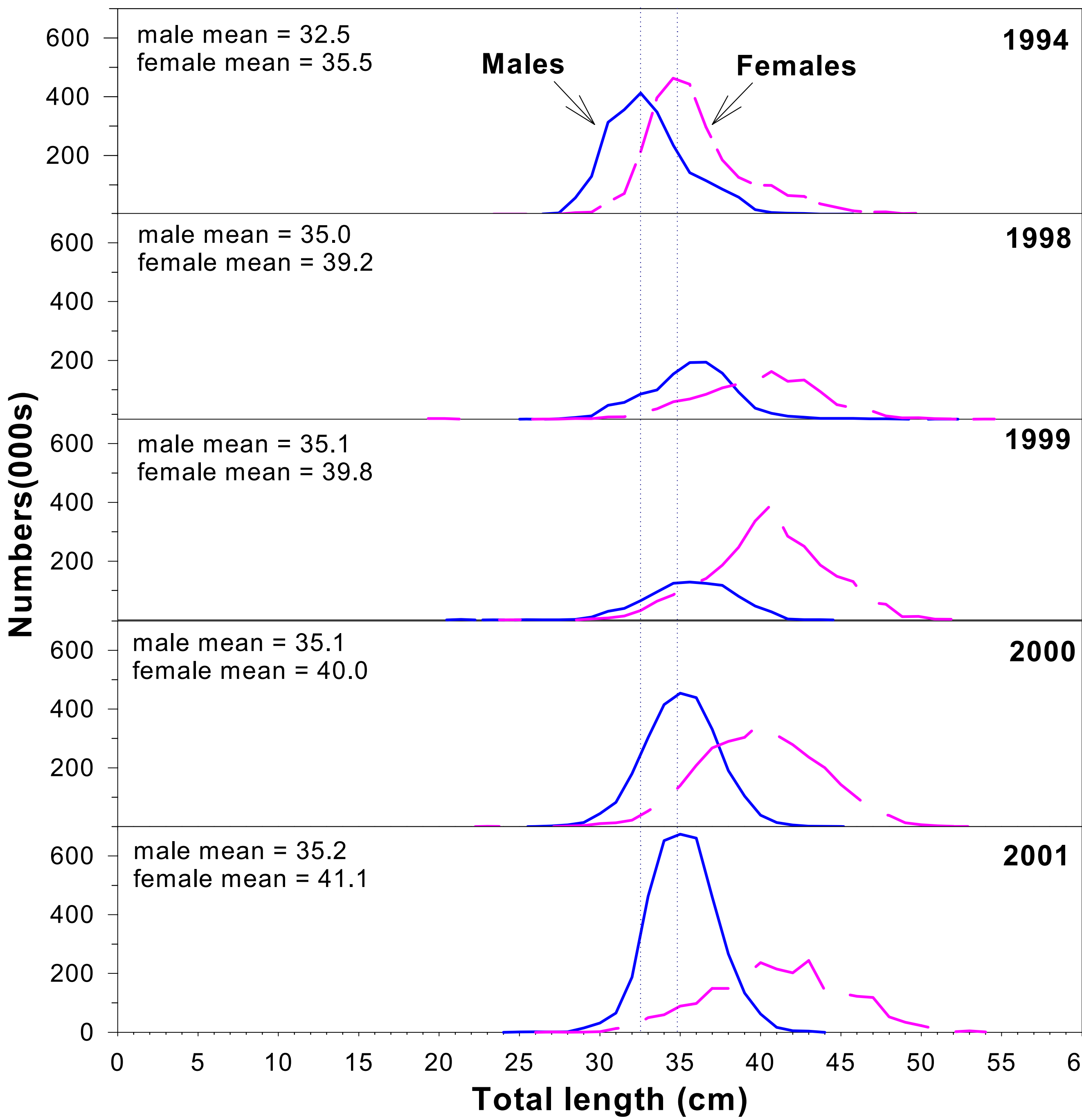

Fig. 6. Georges Bank yellowtail flounder length frequency composition by sex for the Canadian fishery in 1994 (beginning of exploitation period) and from 1998 to 2001.

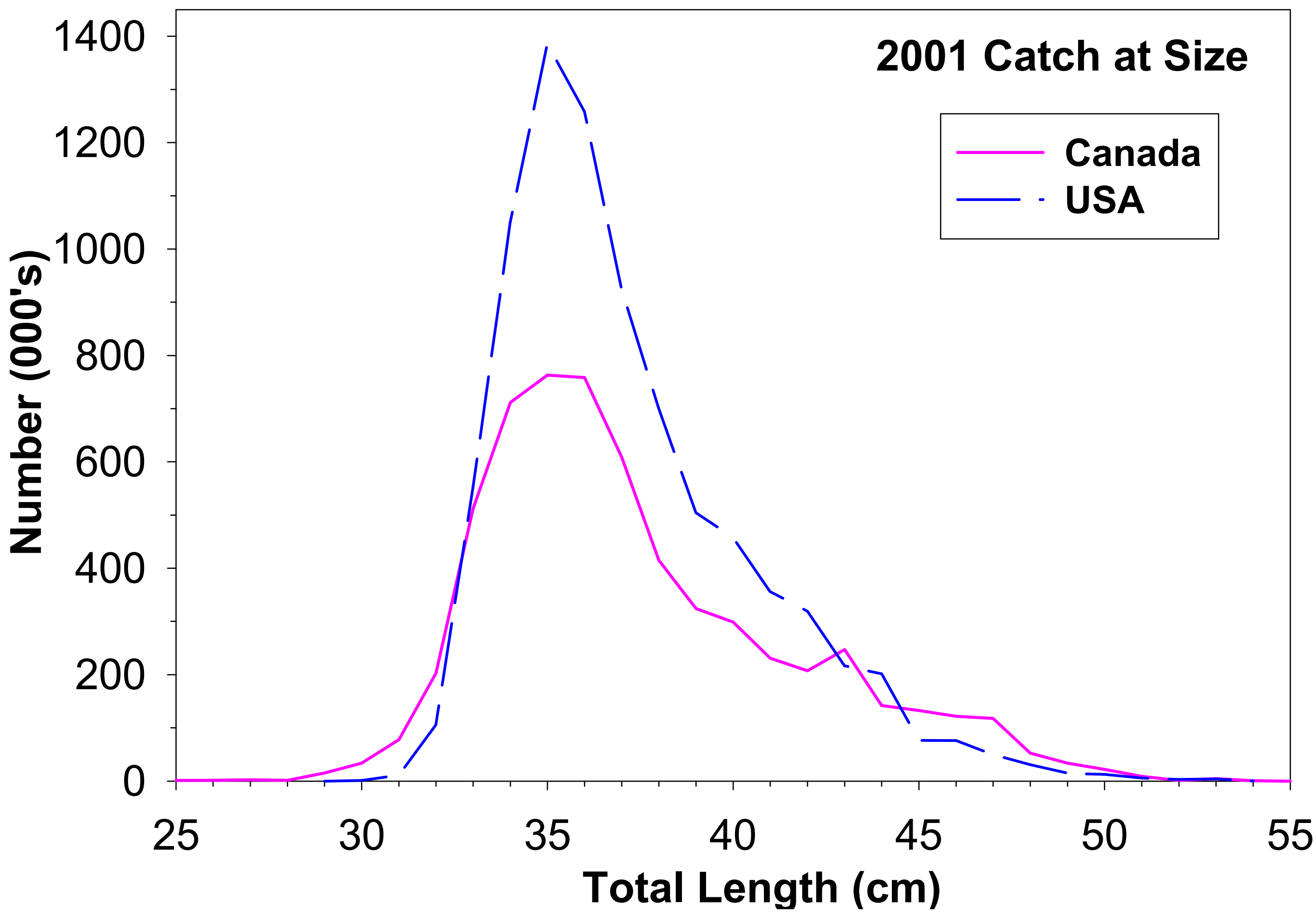

Fig. 7. Comparison of Georges Bank yellowtail flounder catch at size from the 2001 Canadian and USA fisheries.

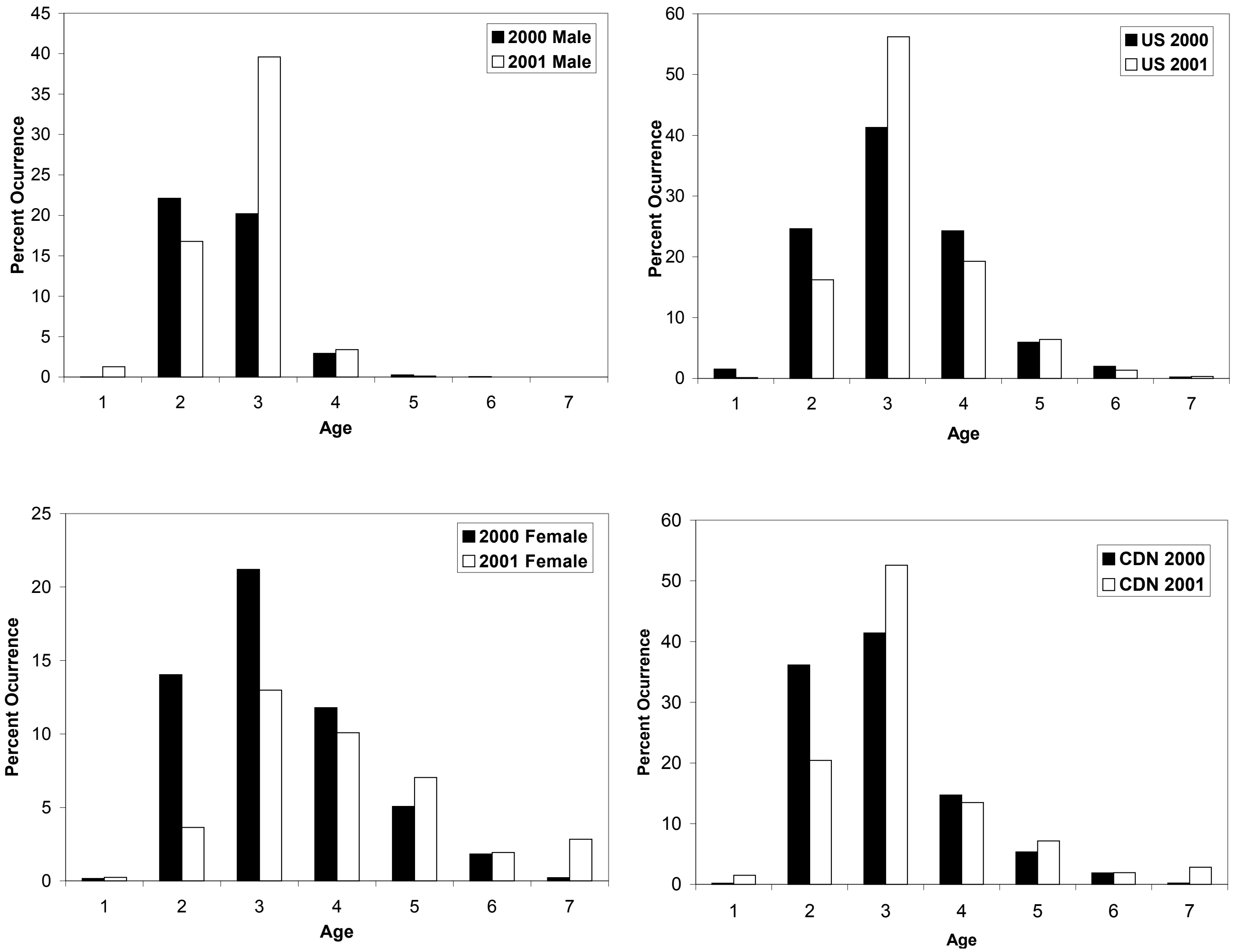

Fig. 8. Comparison of 2000 and 2001 Georges Bank yellowtail flounder fishery age composition for Canadian males and females (left panels), USA sexes aggregated (upper right panel) and Canadian sexes aggregated (lower right panel).

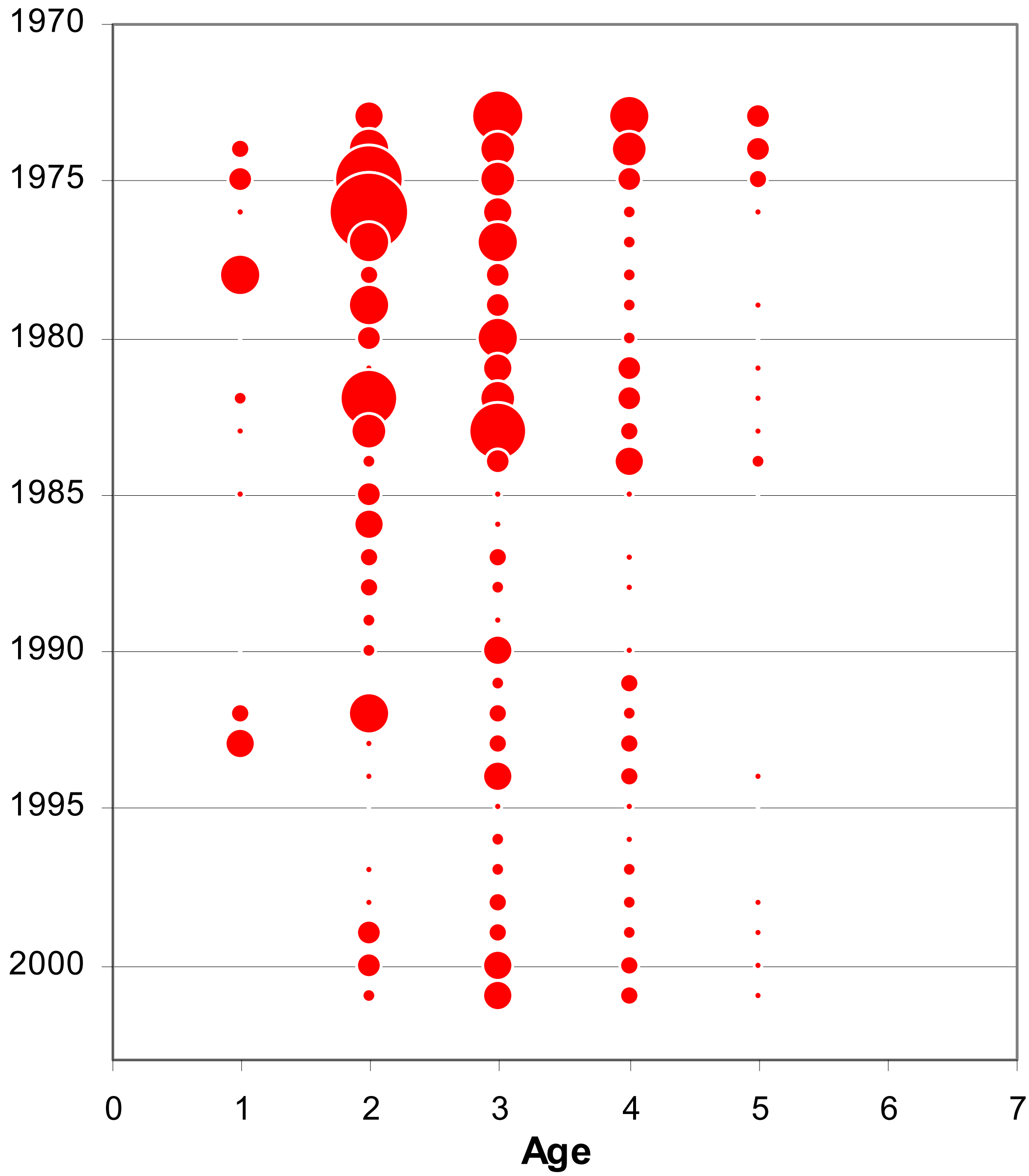

Fig. 9. Catch at age for Georges Bank yellowtail flounder, Canadian and USA fisheries combined, 1970-2001. (The area of the bubble is proportional to the magnitude of the catch).

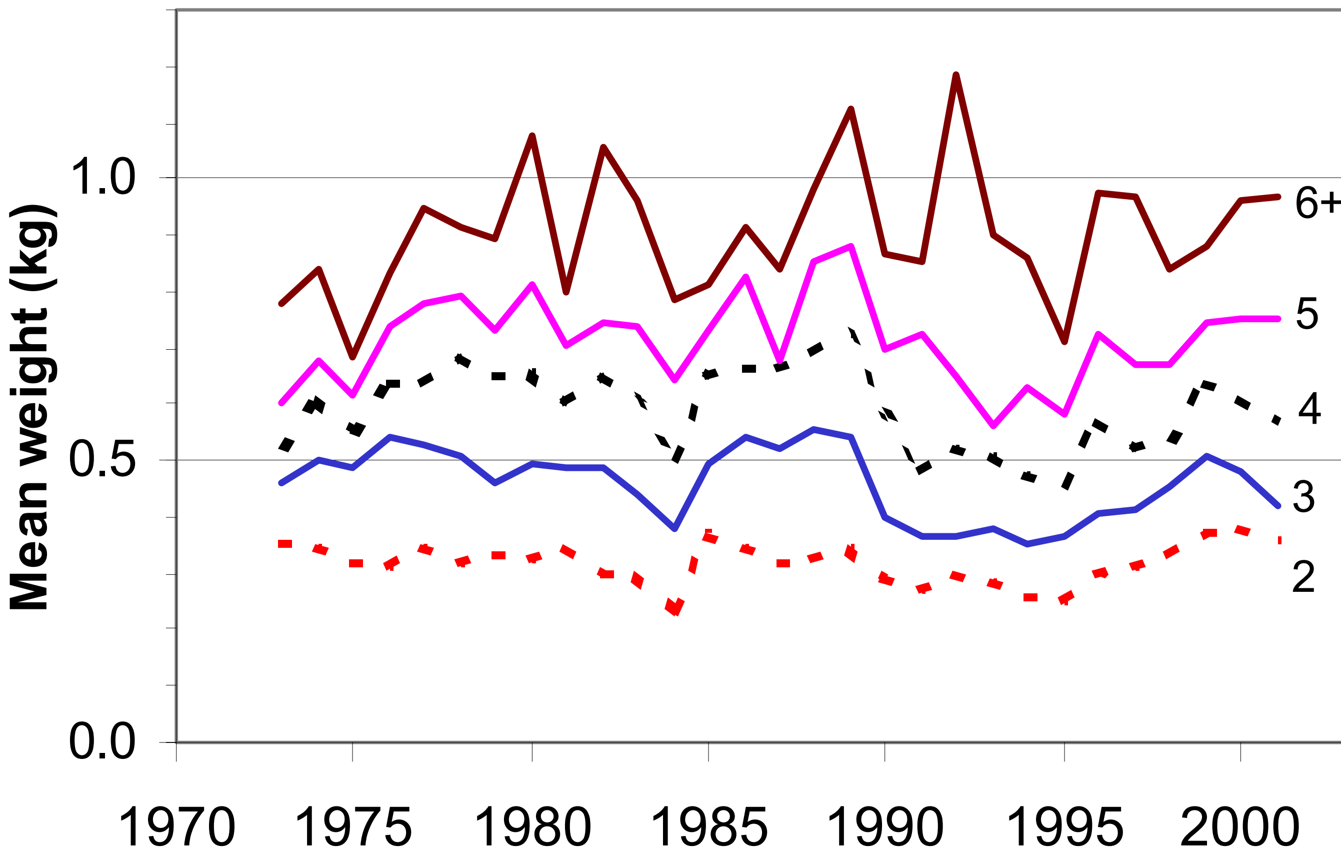

Fig. 10. Trends in mean weight at age from the 5Zjhmn yellowtail fishery, 1973 to 2001 (Canada and USA).

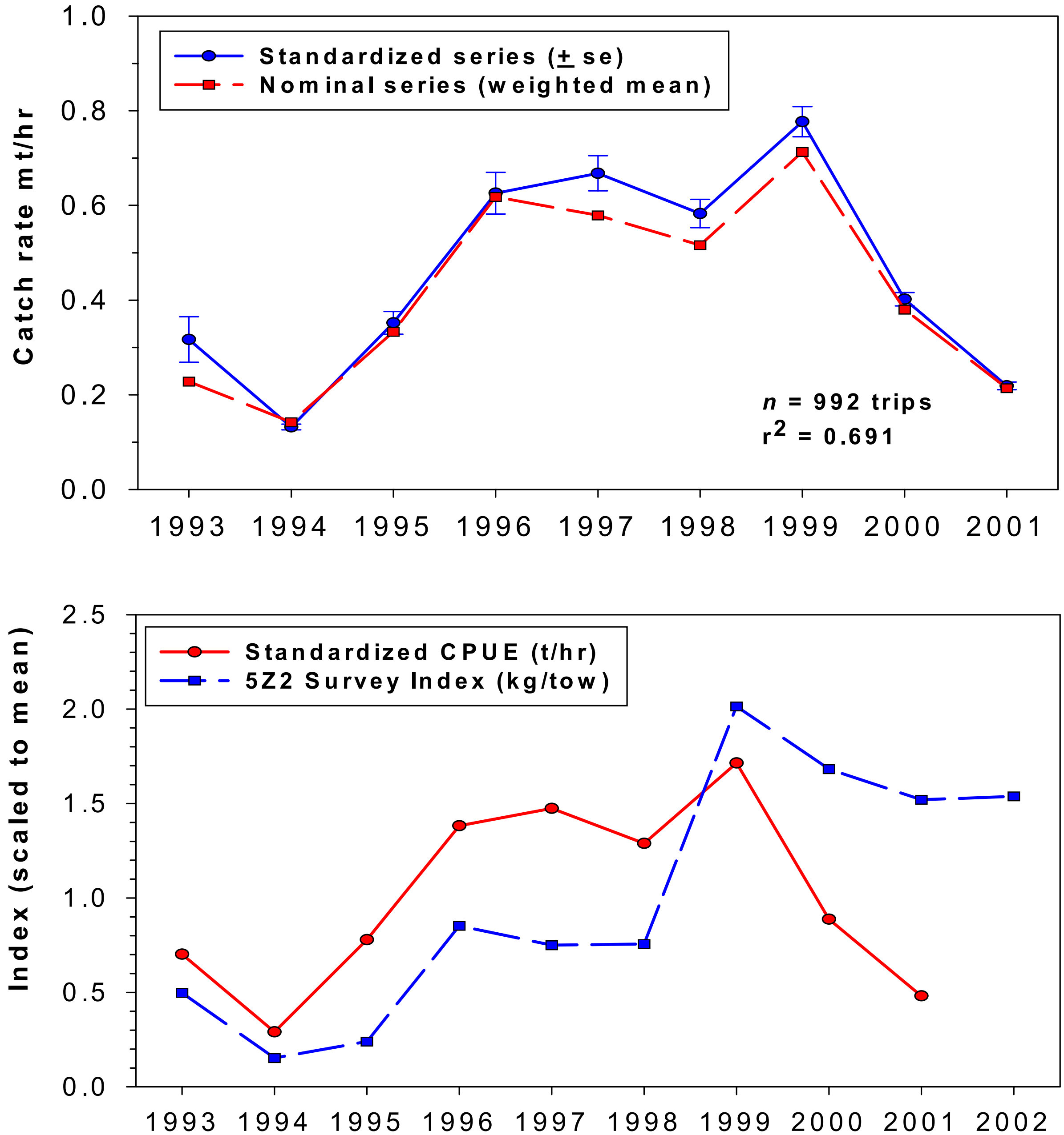

Fig. 11. Upper Panel: Nominal and standardized catch rates (tonnes/hour) for Canadian stern trawlers (TC 2-3) fishing for yellowtail flounder on Georges Bank based on directed trips in 5Zm with catches ≥ 2.0 t, 1993-2001. Lower Panel: Standardized CPUE for the Canadian fishery (1993-2001) and DFO spring survey biomass index for stratum 5Z2 (1993-2002).

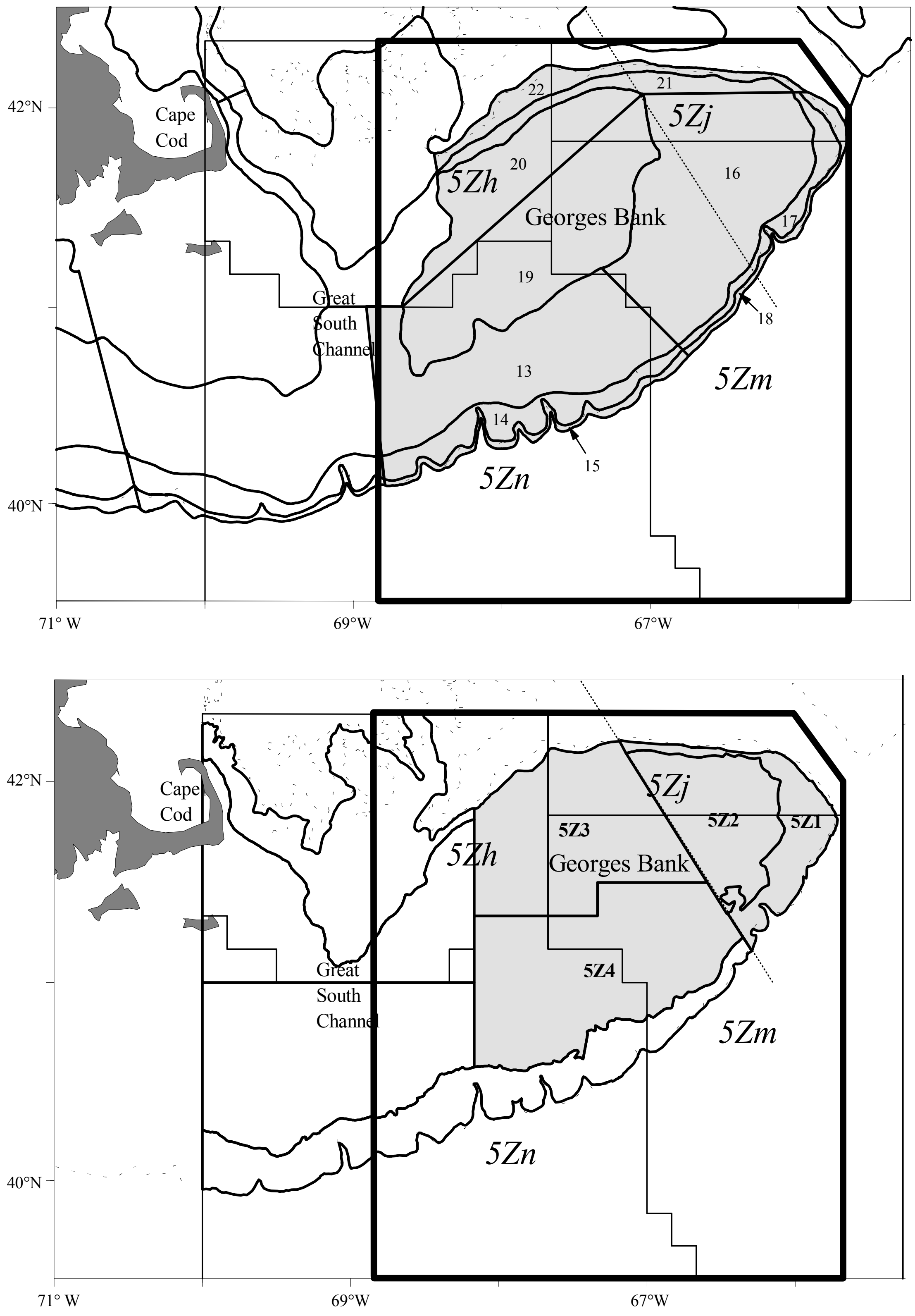

Fig. 12. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys.

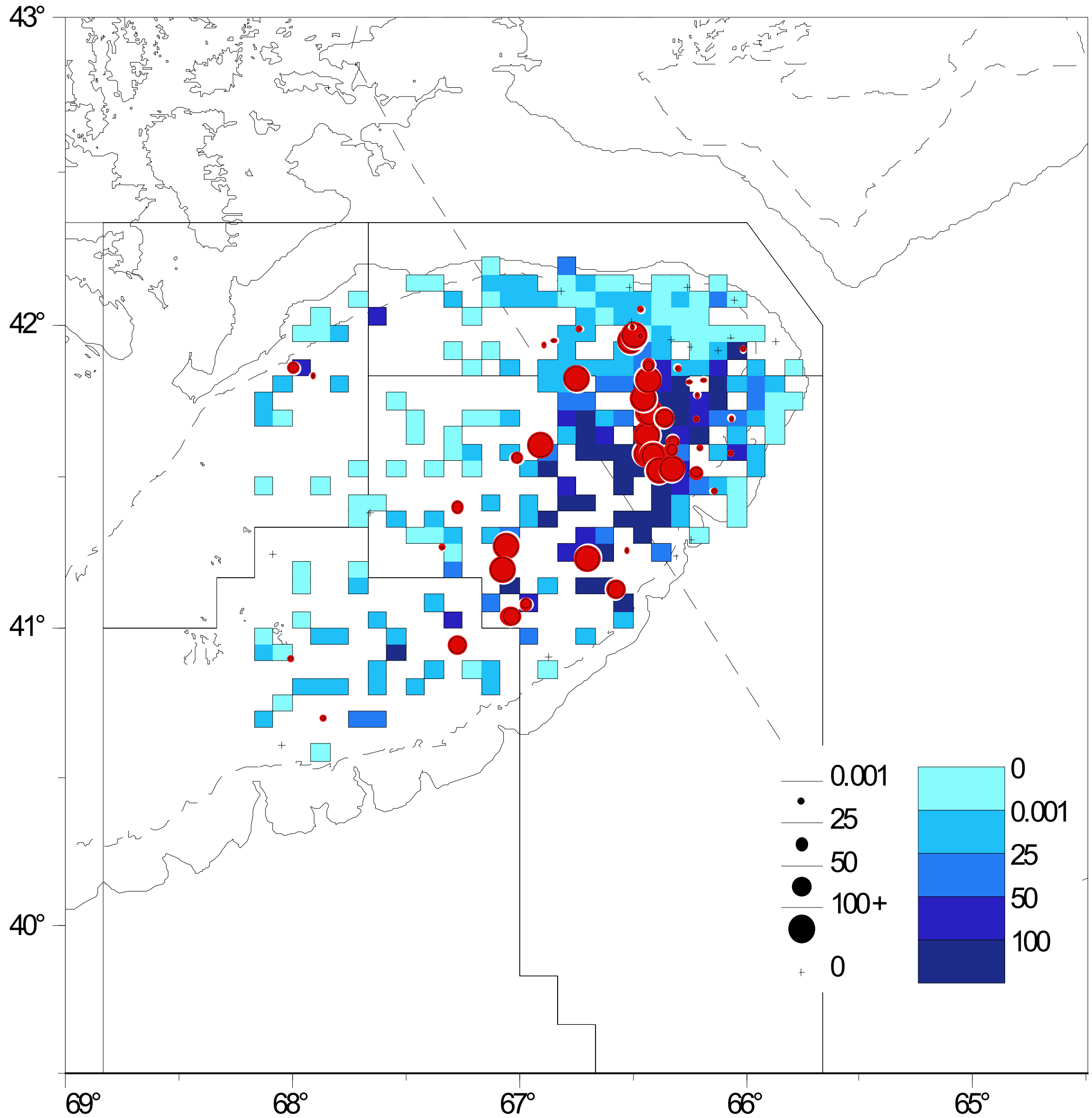

Fig. 13. The distribution of catches (number/tow) of yellowtail flounder (solid circles) in the DFO Georges Bank spring survey in 2002 compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

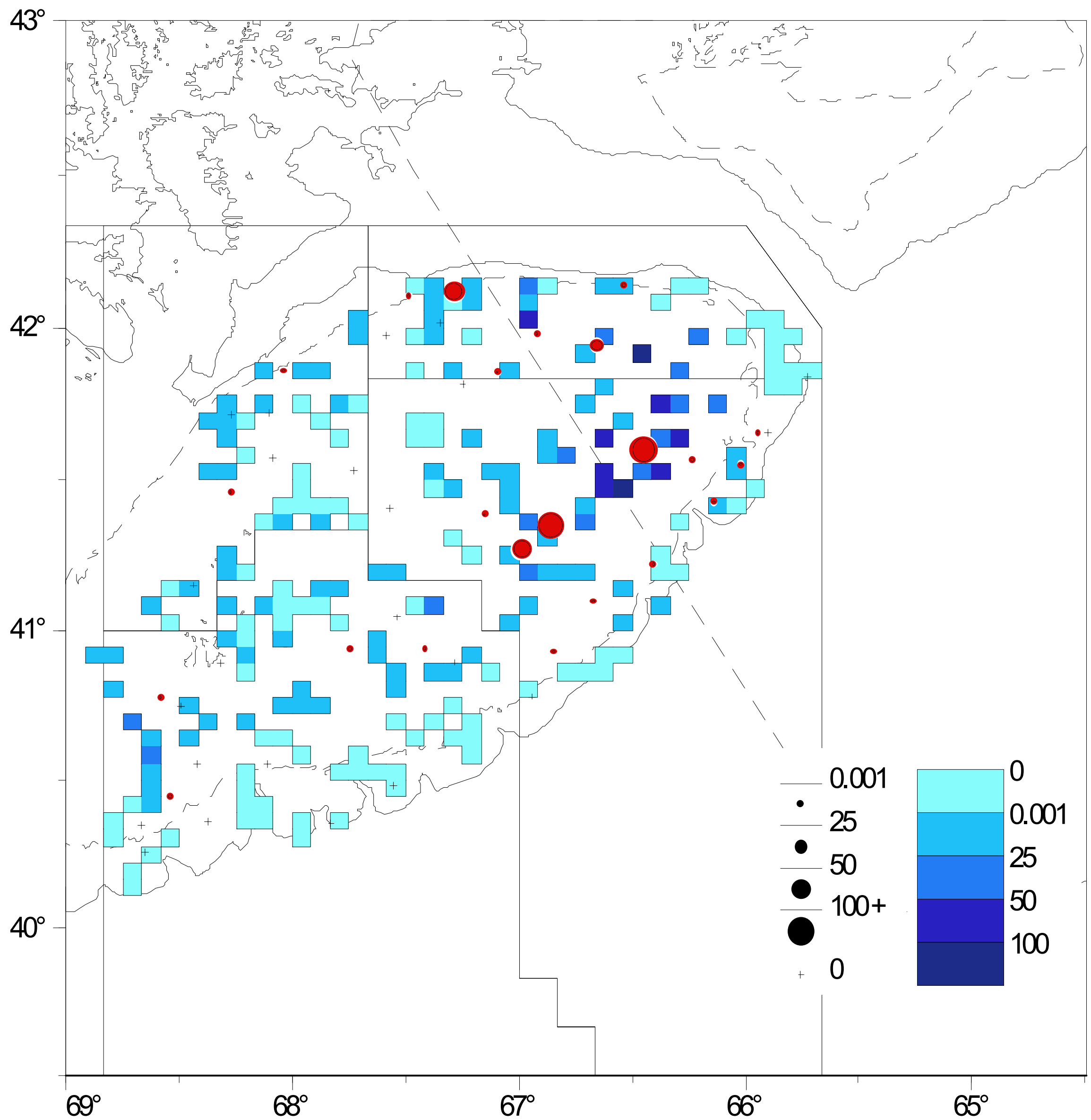

Fig. 14. The distribution of catches (number/tow) of yellowtail flounder in the NMFS Georges Bank spring survey in 2001 (solid circles), compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

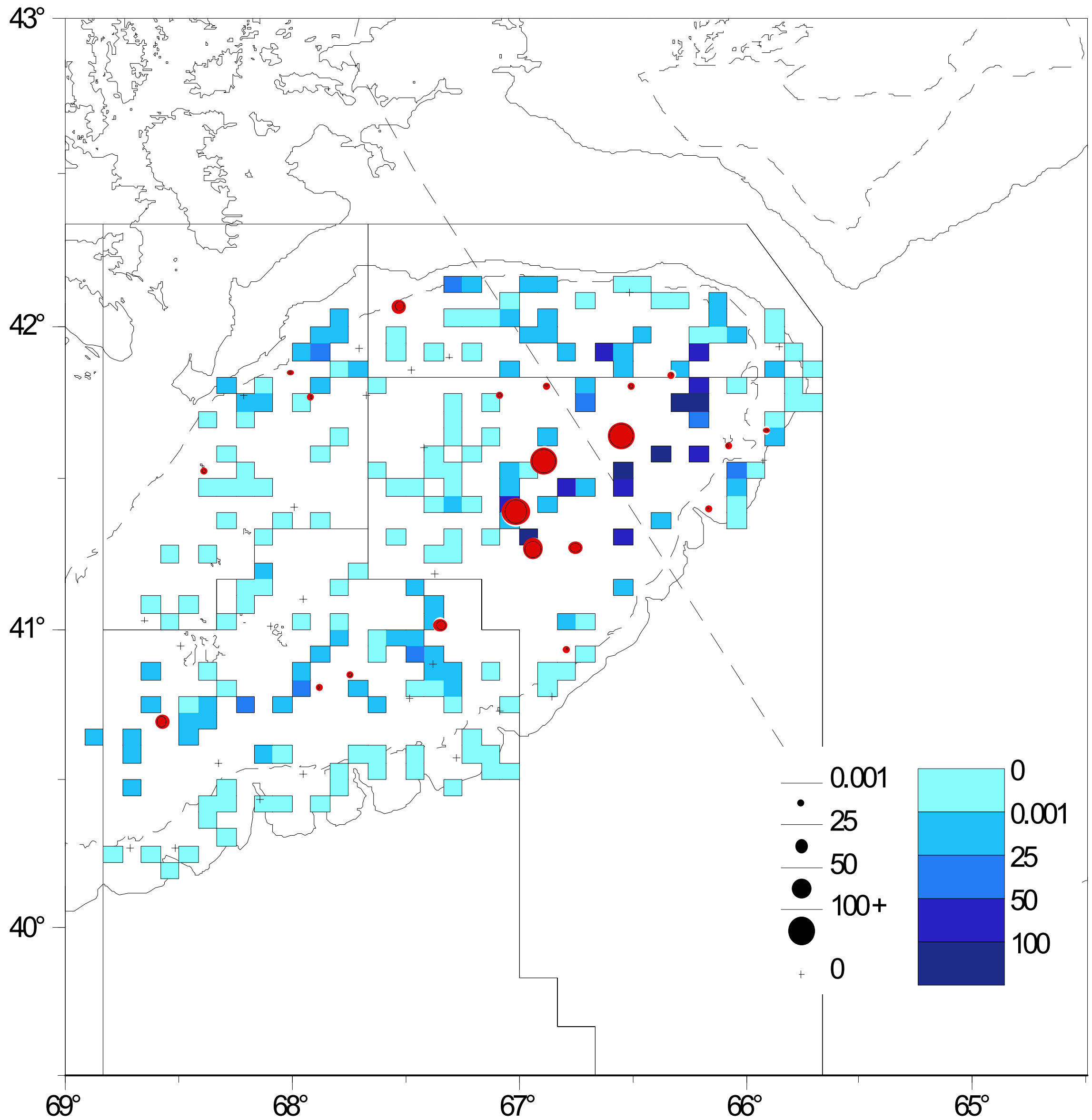

Fig. 15. The distribution of catches (number/tow) of yellowtail flounder in the NMFS Georges Bank fall survey in 2001 (solid circles), compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

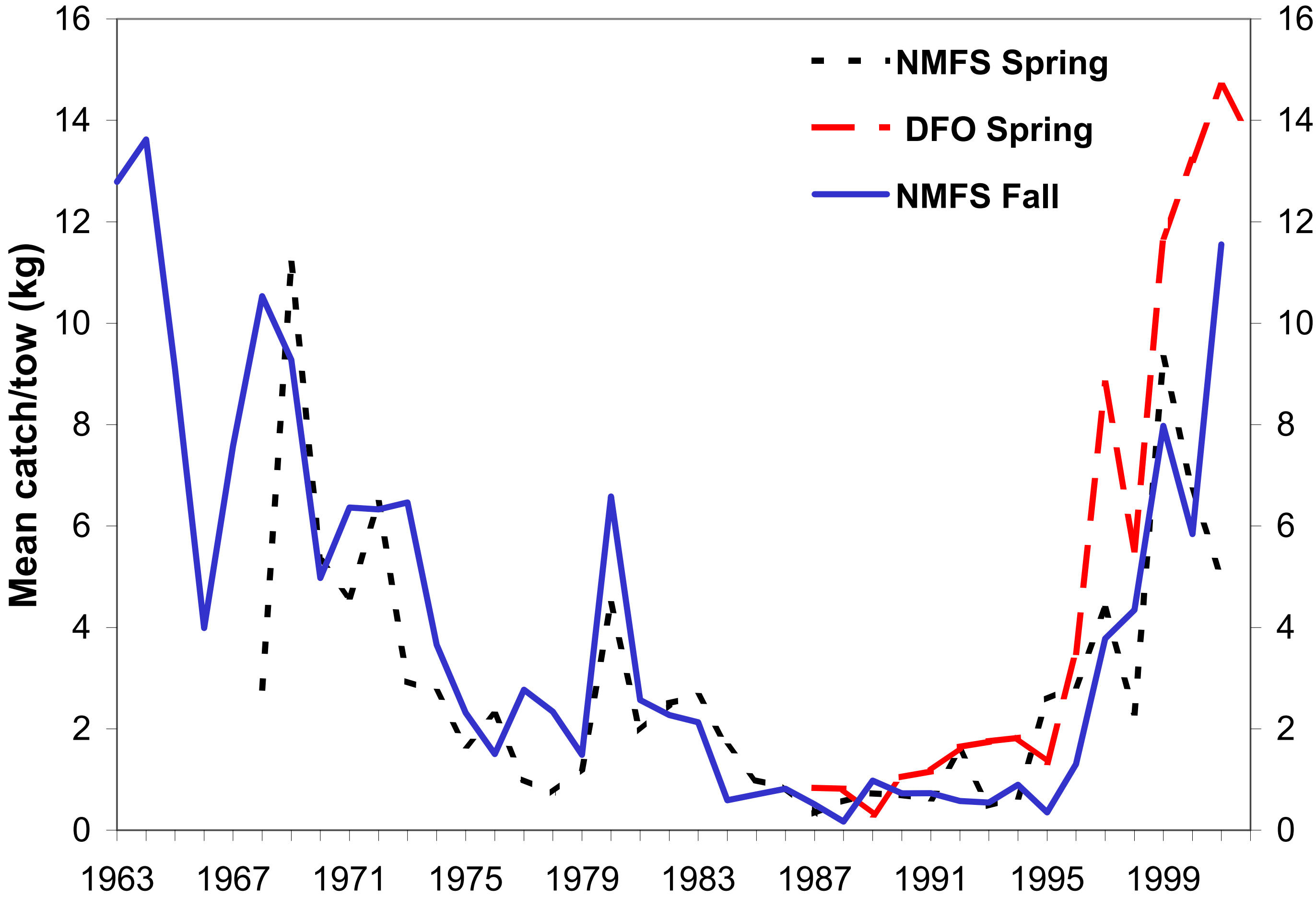

Fig. 16. NMFS and DFO spring and NMFS fall survey results (average biomass) for yellowtail flounder on Georges Bank. The DFO series was also adjusted for catchability differences.

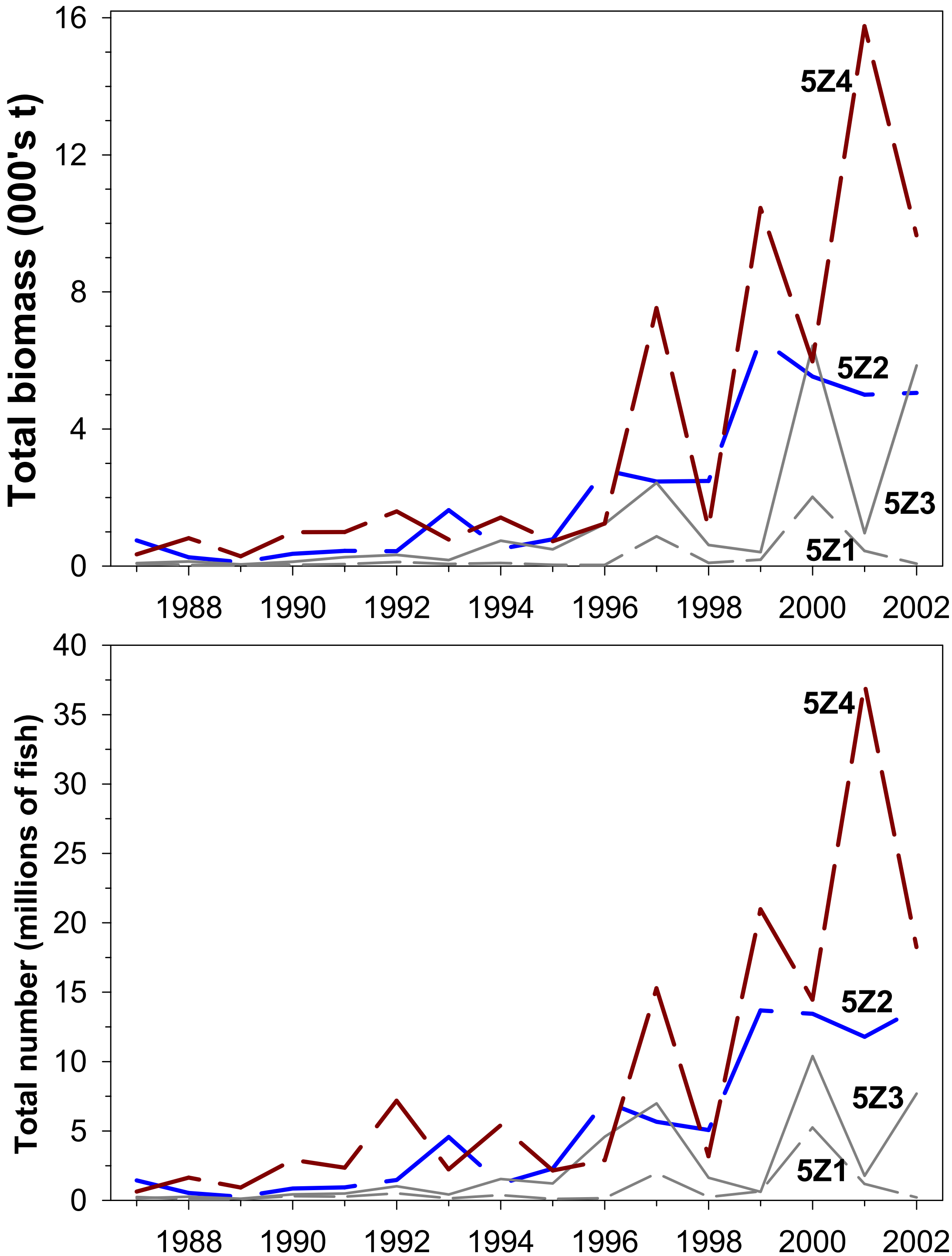

Fig. 17. DFO spring survey estimates of total biomass (top panel) and total number (bottom pannel) by stratum area for yellowtail flounder on Georges Bank, 1987-2002.

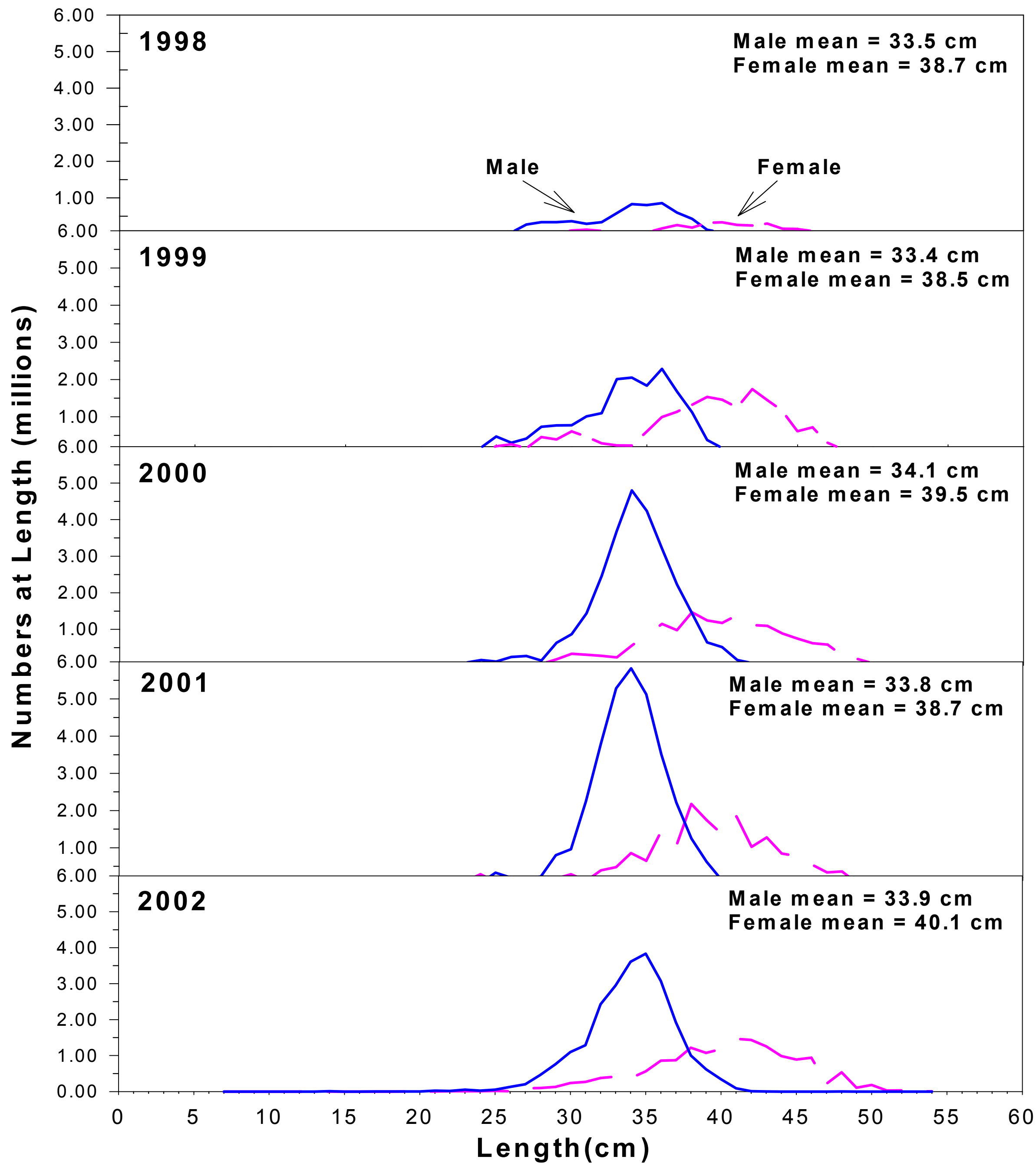

Fig. 18. Comparison of yellowtail flounder length composition in DFO spring surveys on Georges Bank, 1998- 2008.

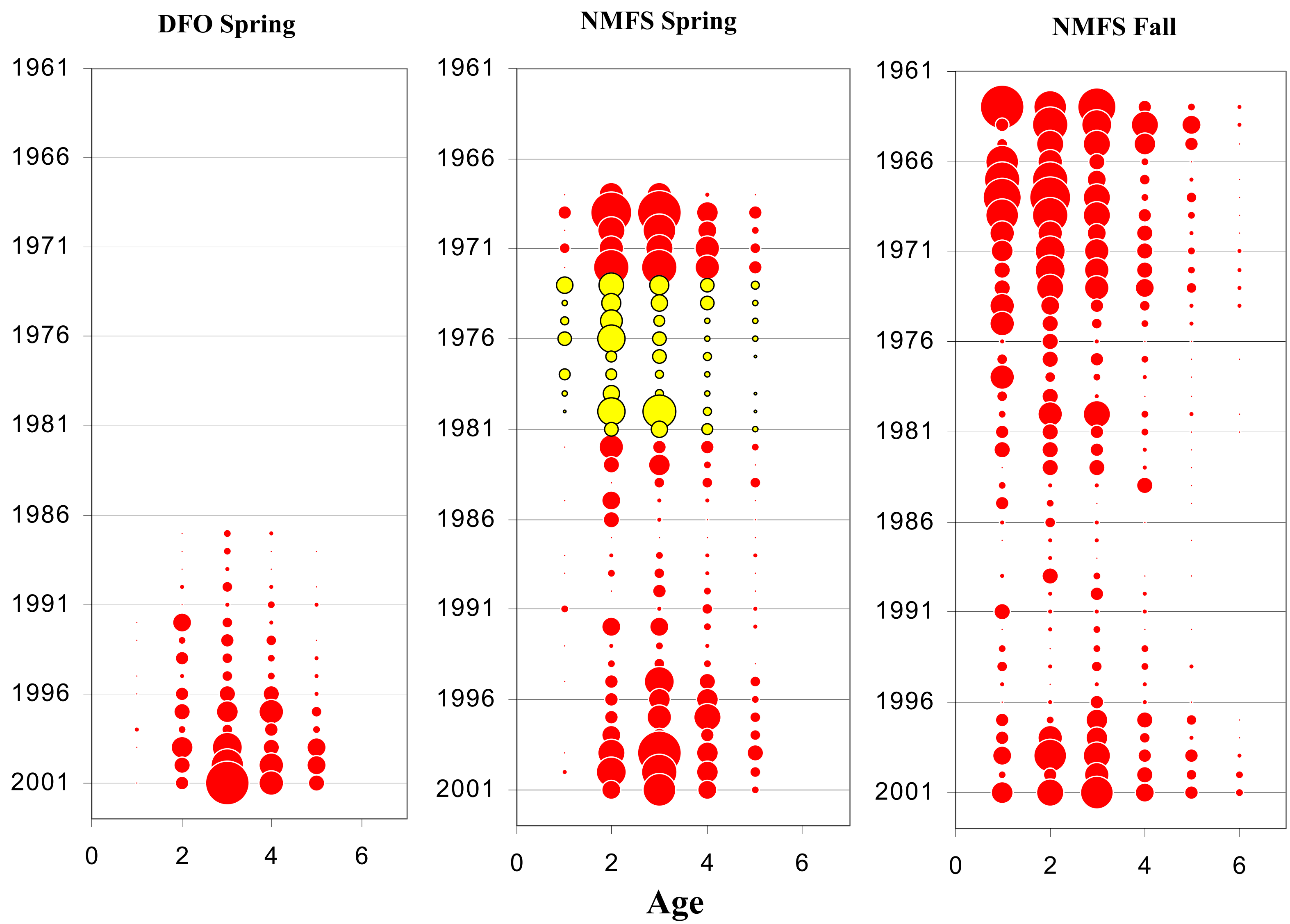

Fig. 19. Age specific indices of abundance for the DFO spring , NMFS spring, and NMFS fall surveys (bubble is proportional to the magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. Refer to Tables 5, 6 and 7 for the absolute value of the indices. The DFO spring 2002 index series was not used in the base assessment analysis.

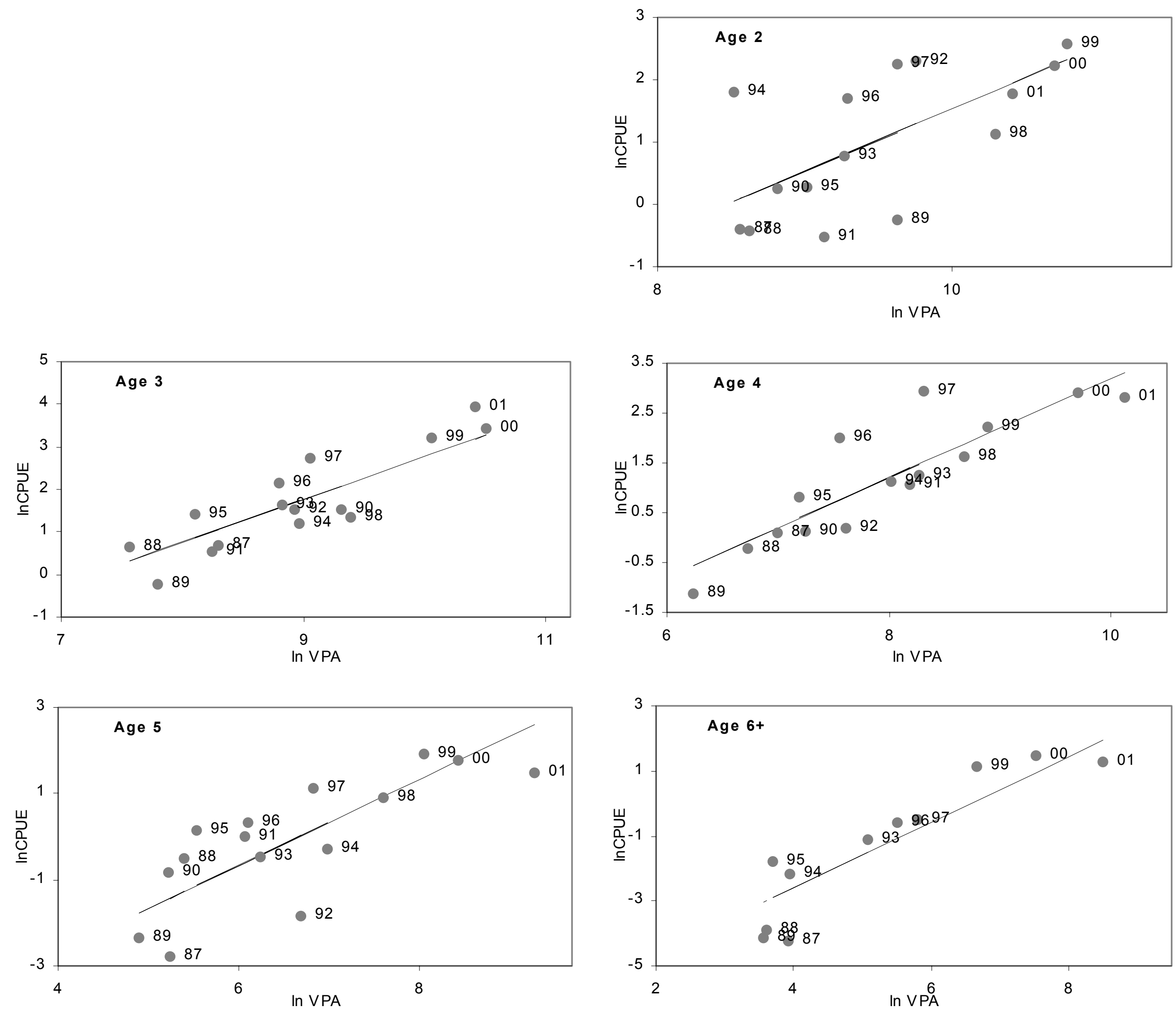

Fig. 20. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the DFO spring survey 1987-2001.

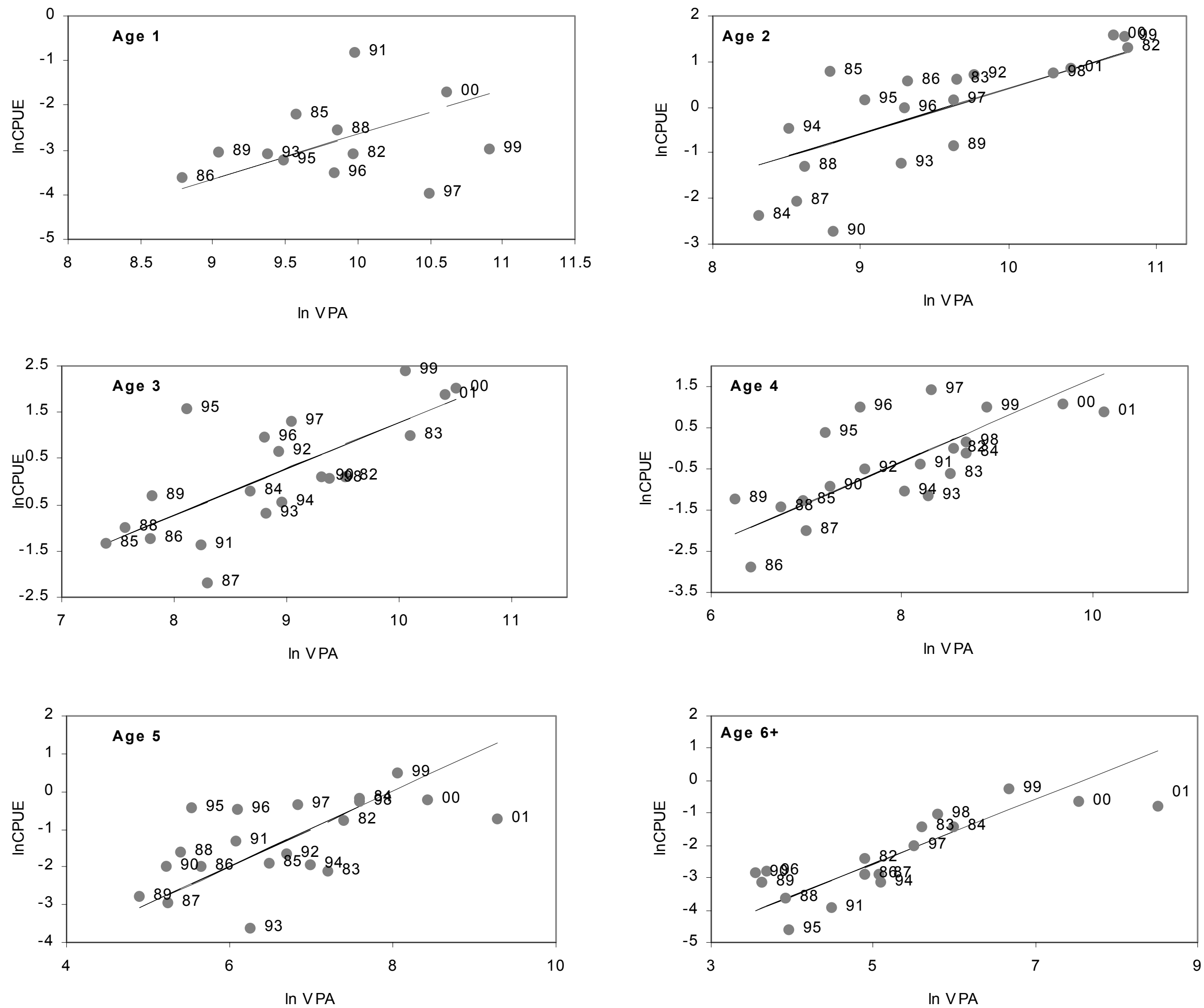

Fig. 21. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey Yankee 36 series, 1982-2001.

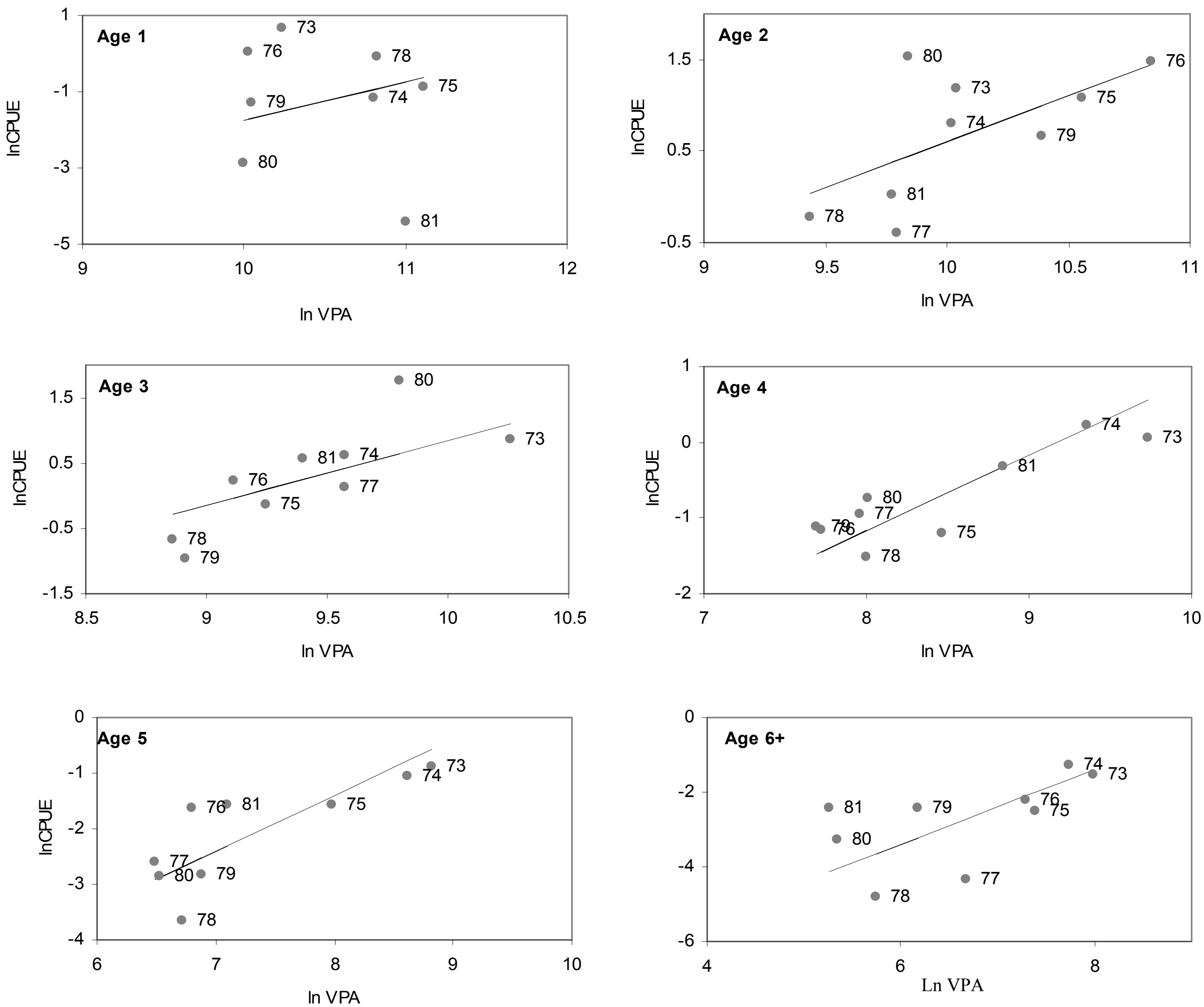

Fig. 22. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey, Yankee 41 series, 1973-1981.

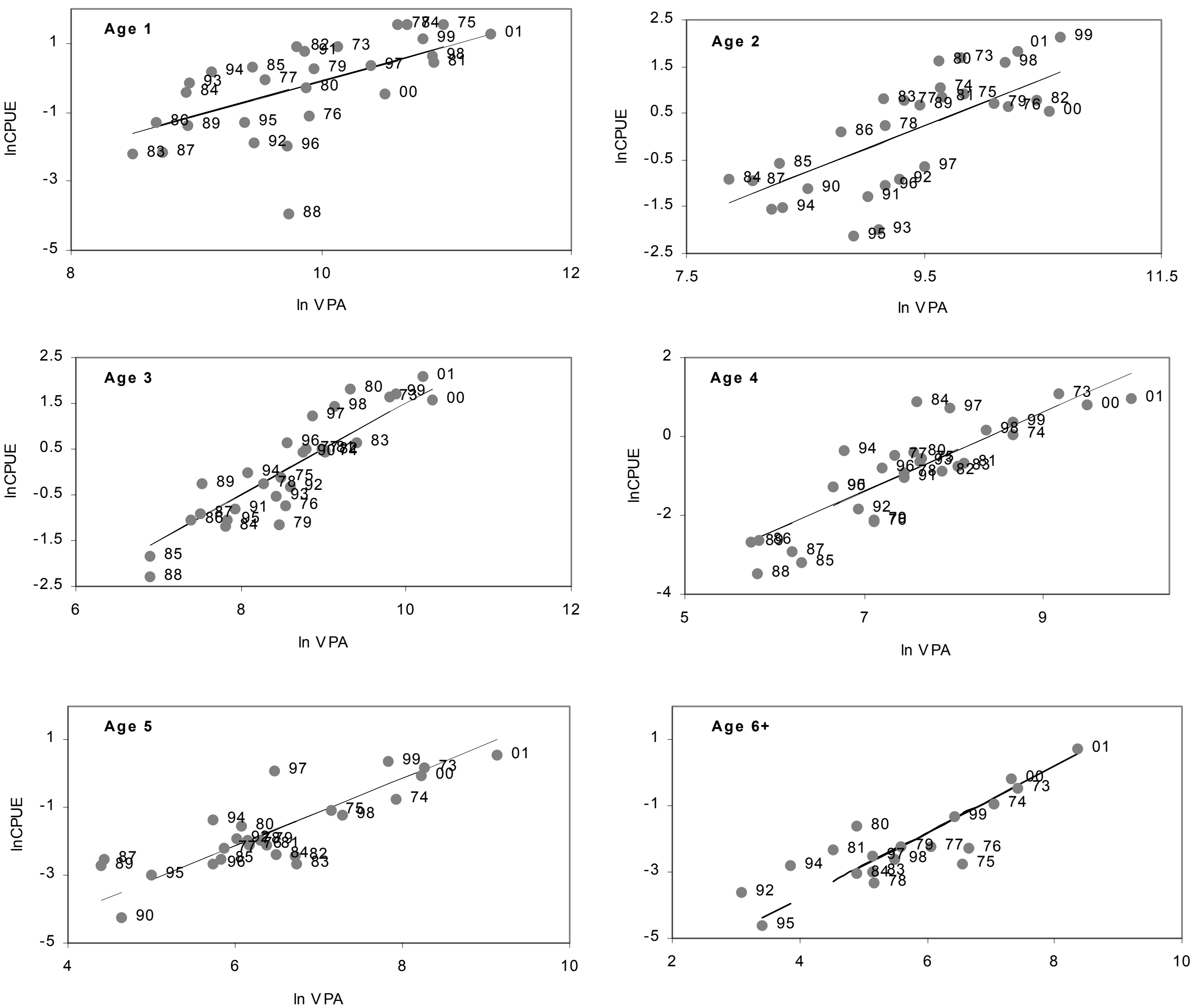

Fig. 23. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS fall survey, 1973-2001.

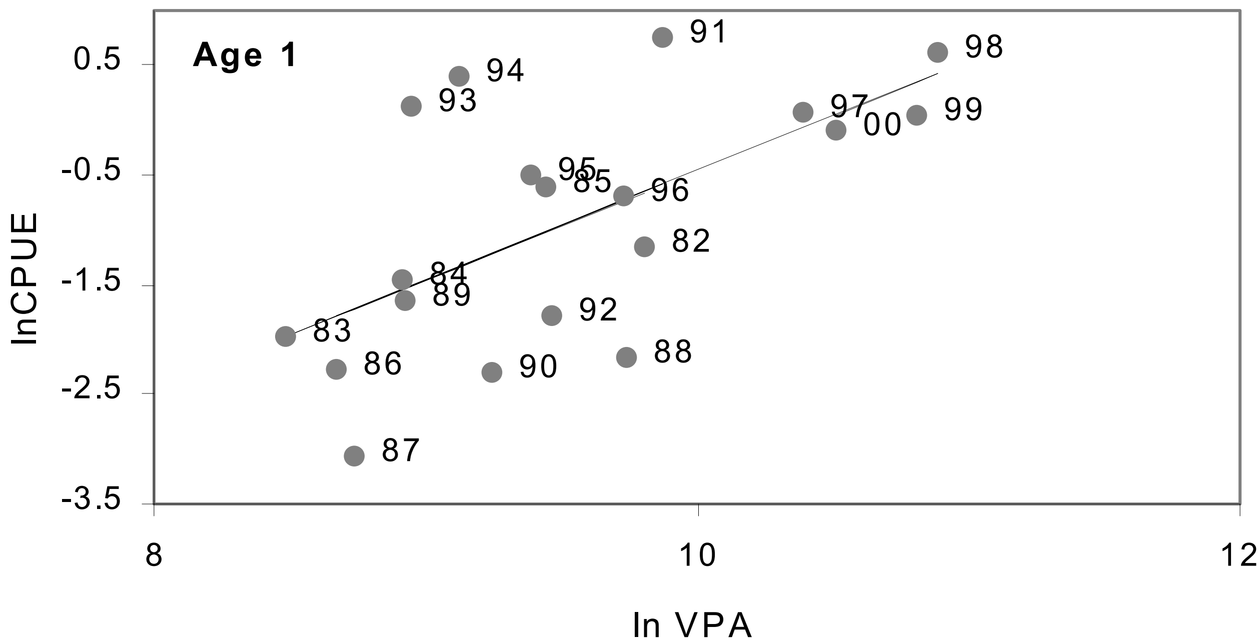

Fig. 24. Observed and predicted ln abundance index vs population numbers for Georges Bank age 1 yellowtail flounder from the NMFS scallop survey, 1982-2000.

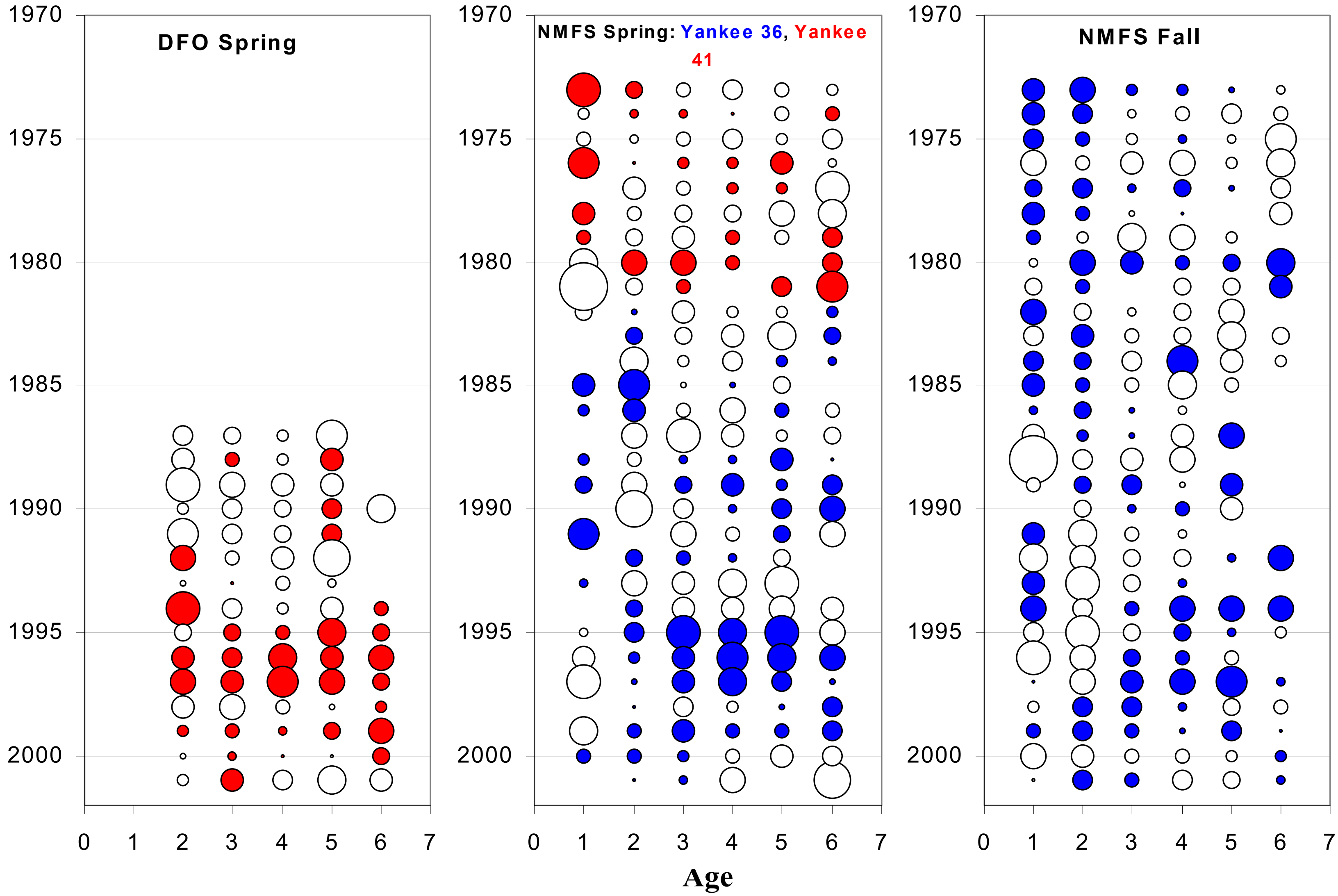

Fig. 25 Age by age residuals for the relationships between ln abundance index versus ln population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and closed symbols denote positive residuals.

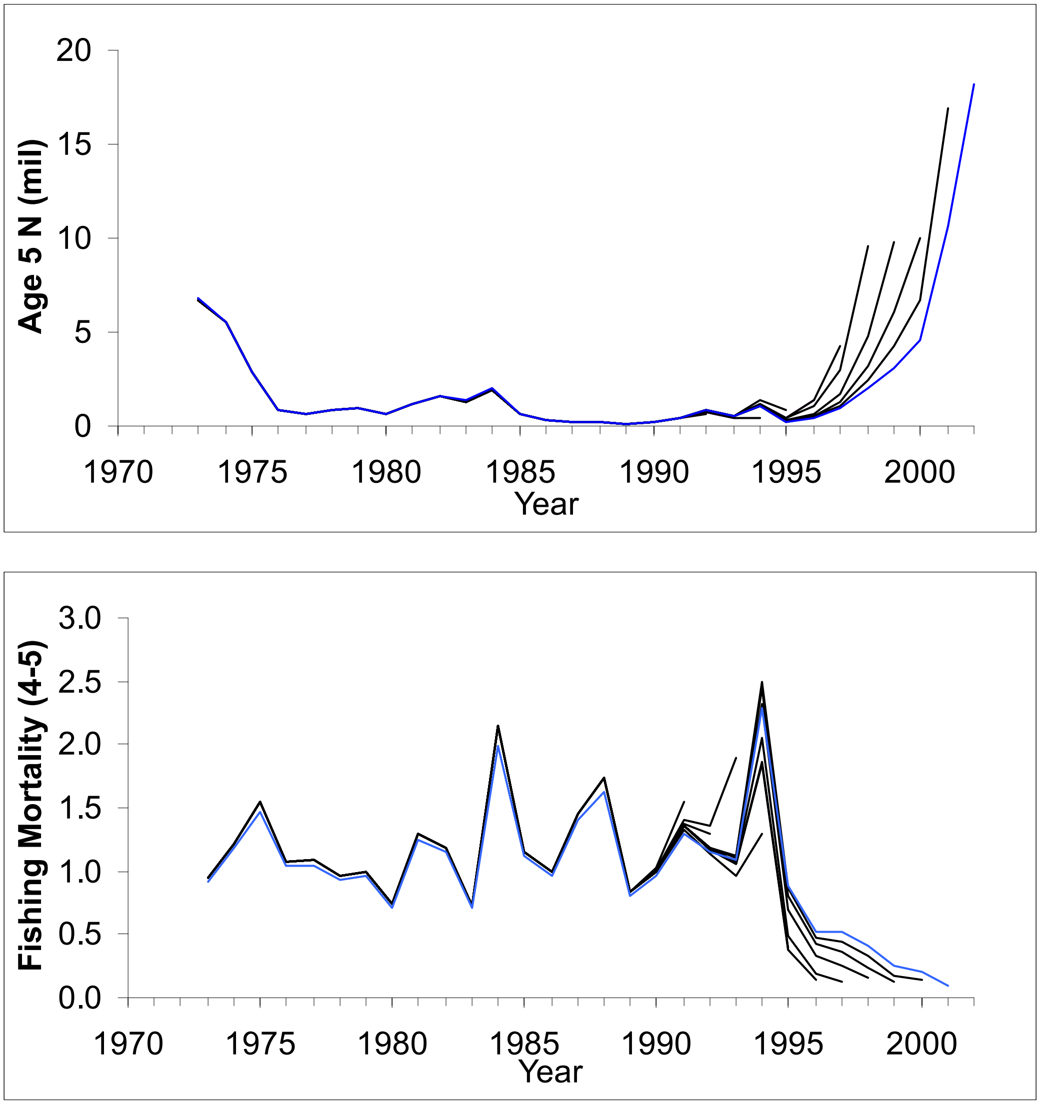

Fig. 26. Retrospective analysis of Georges Bank yellowtail flounder VPA for population estimates of age 5 fish and fishing mortality on age 4-5. (Note: These ages were selected as examples of the retrospective pattern).

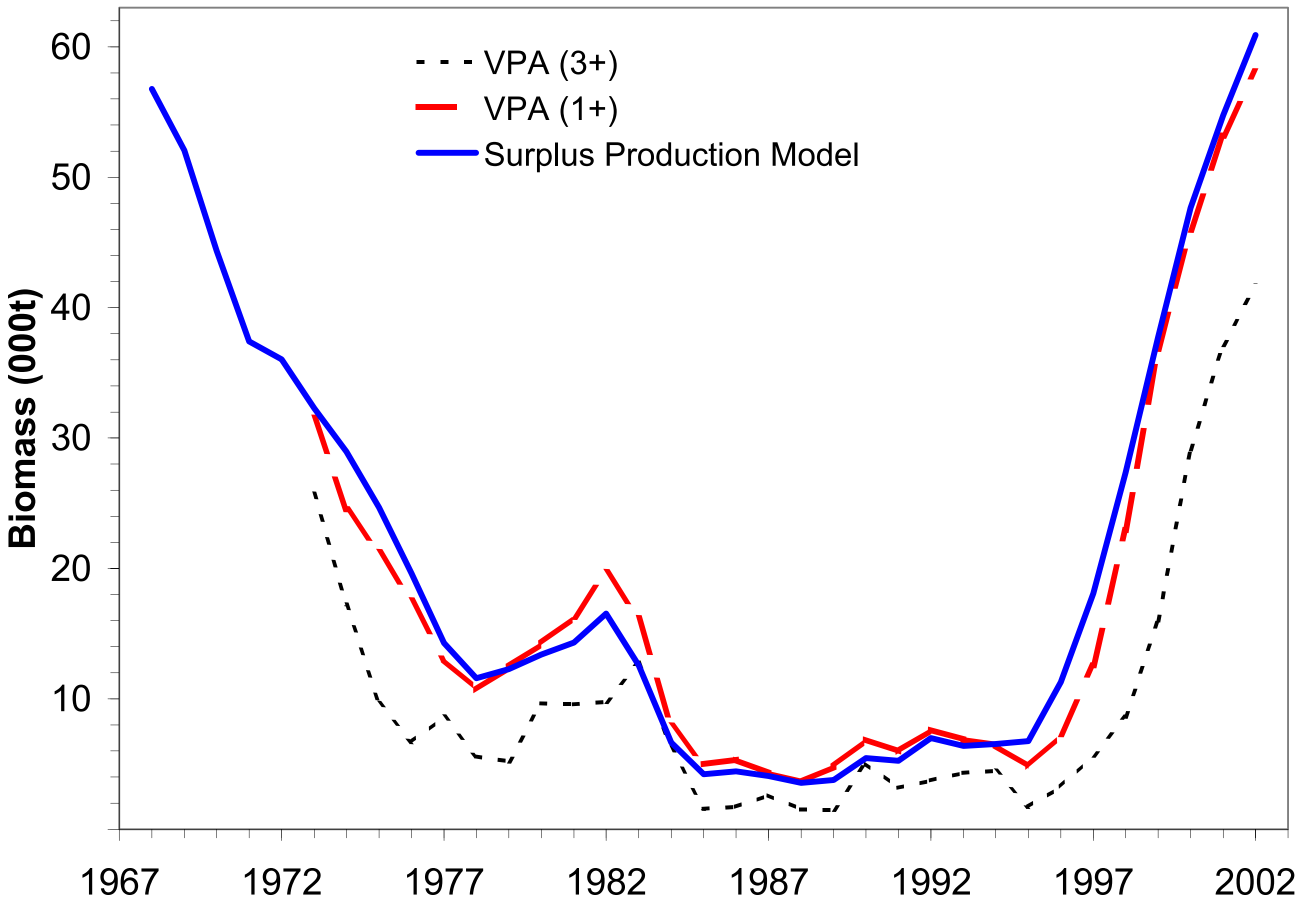

Fig. 27. Trends in total (1+) and adult (3+) beginning of year biomass (000s t) as indicated from the VPA and surplus production models for yellowtail flounder on Georges Bank.

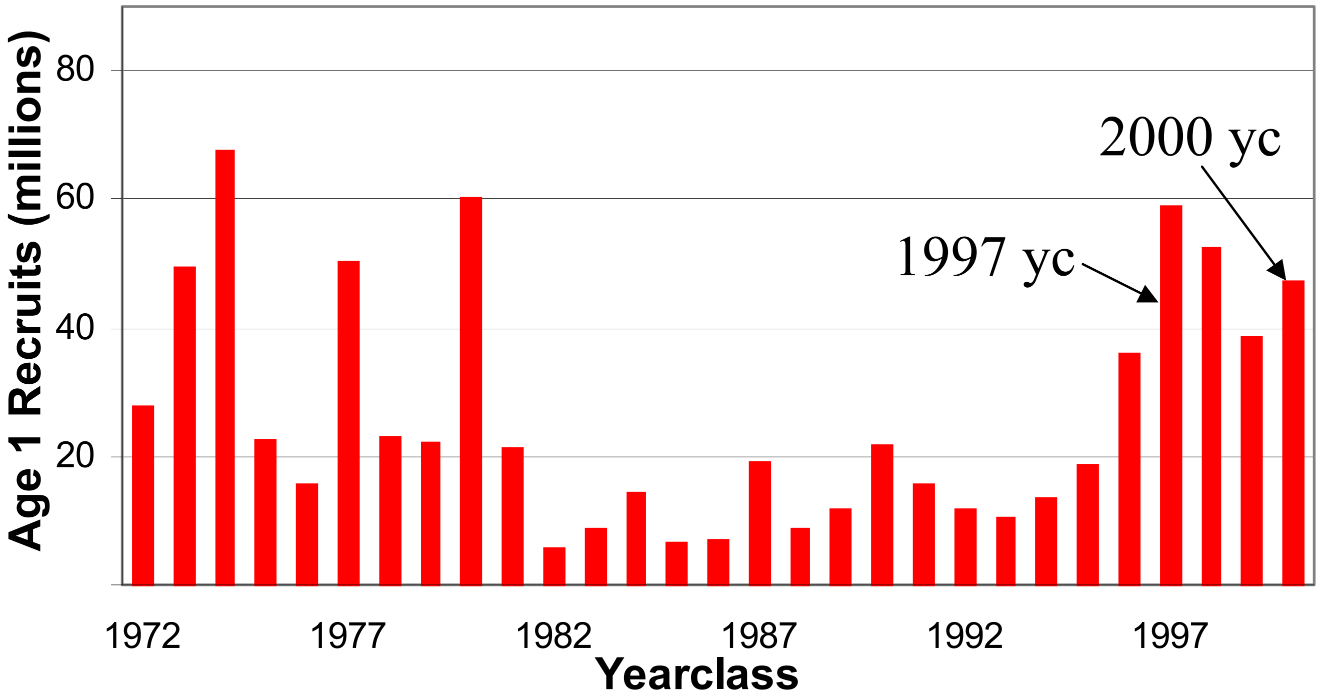

Fig. 28. Age-1 recruitment estimates for Georges Bank yellowtail flounder, 1972-2000. The 1997 and 2000 yearclasses are highlighted.

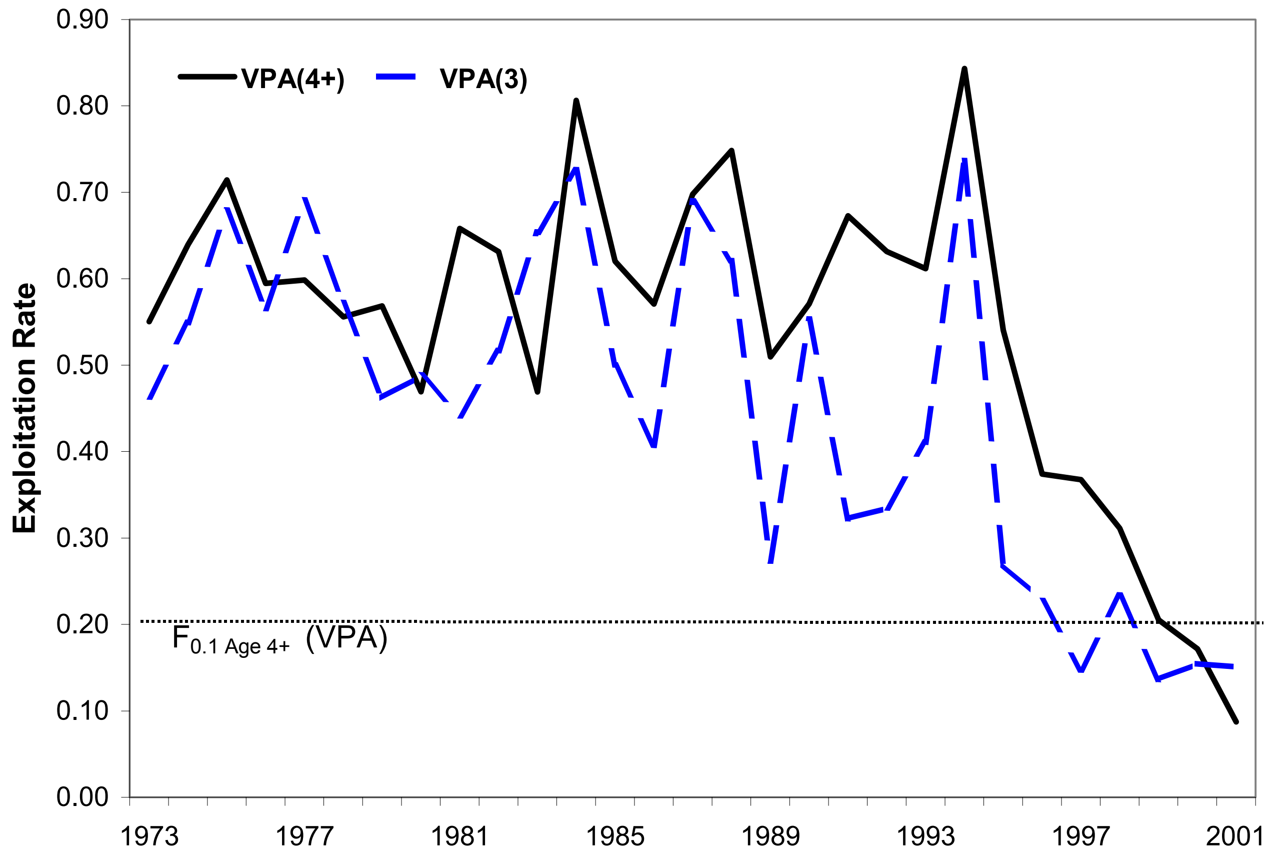

Fig. 29. Trends in fully recruited (4+) and age 3 exploitation rate from the VPA and total exploitation rate from the surplus production model for yellowtail flounder on Georges Bank. Reference levels are shown for VPA Age 4+.

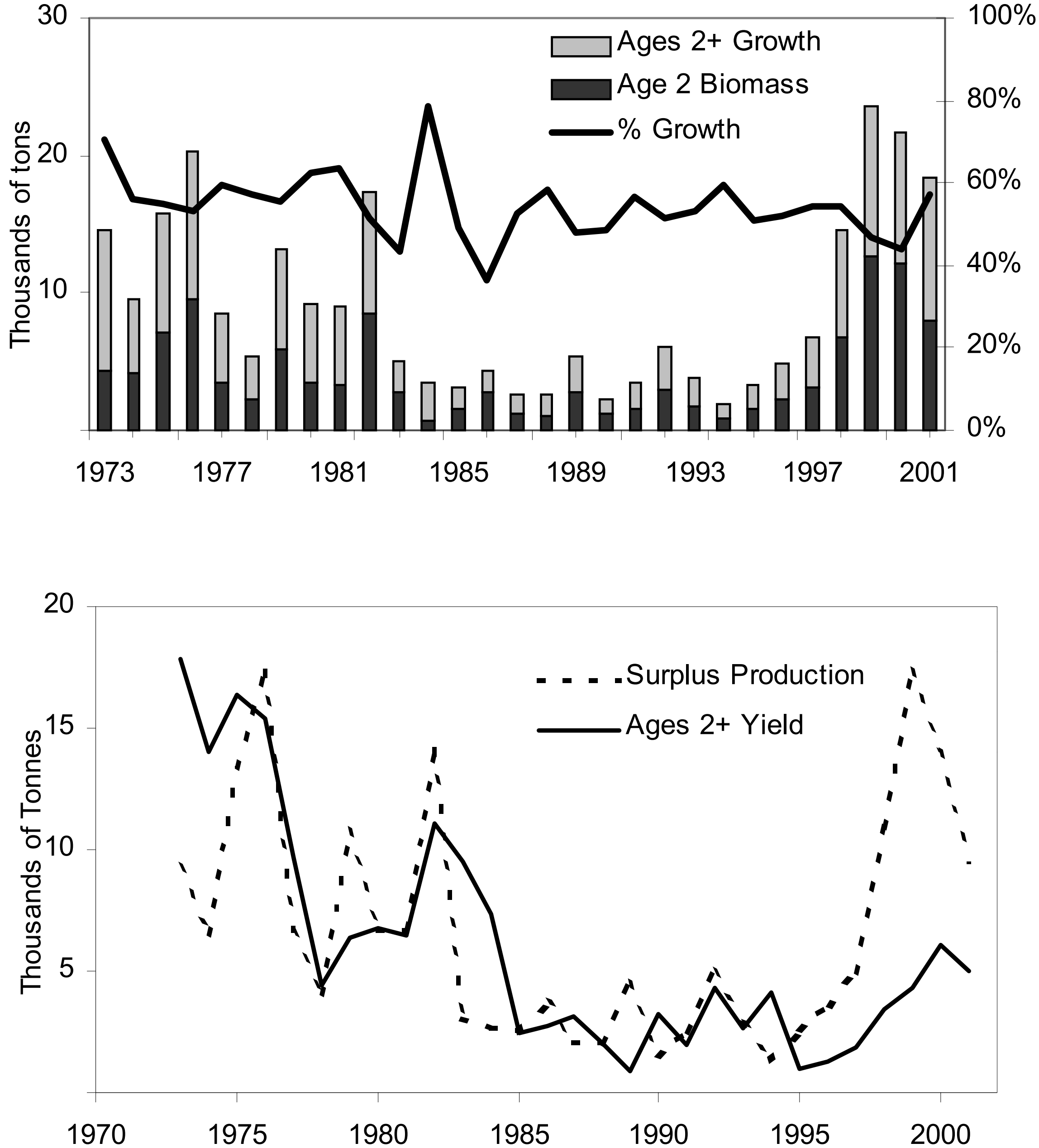

Fig. 30. Components of production (top panel), and production as indicated by the VPA, compared with fishery yield for Georges Bank yellowtail flounder.

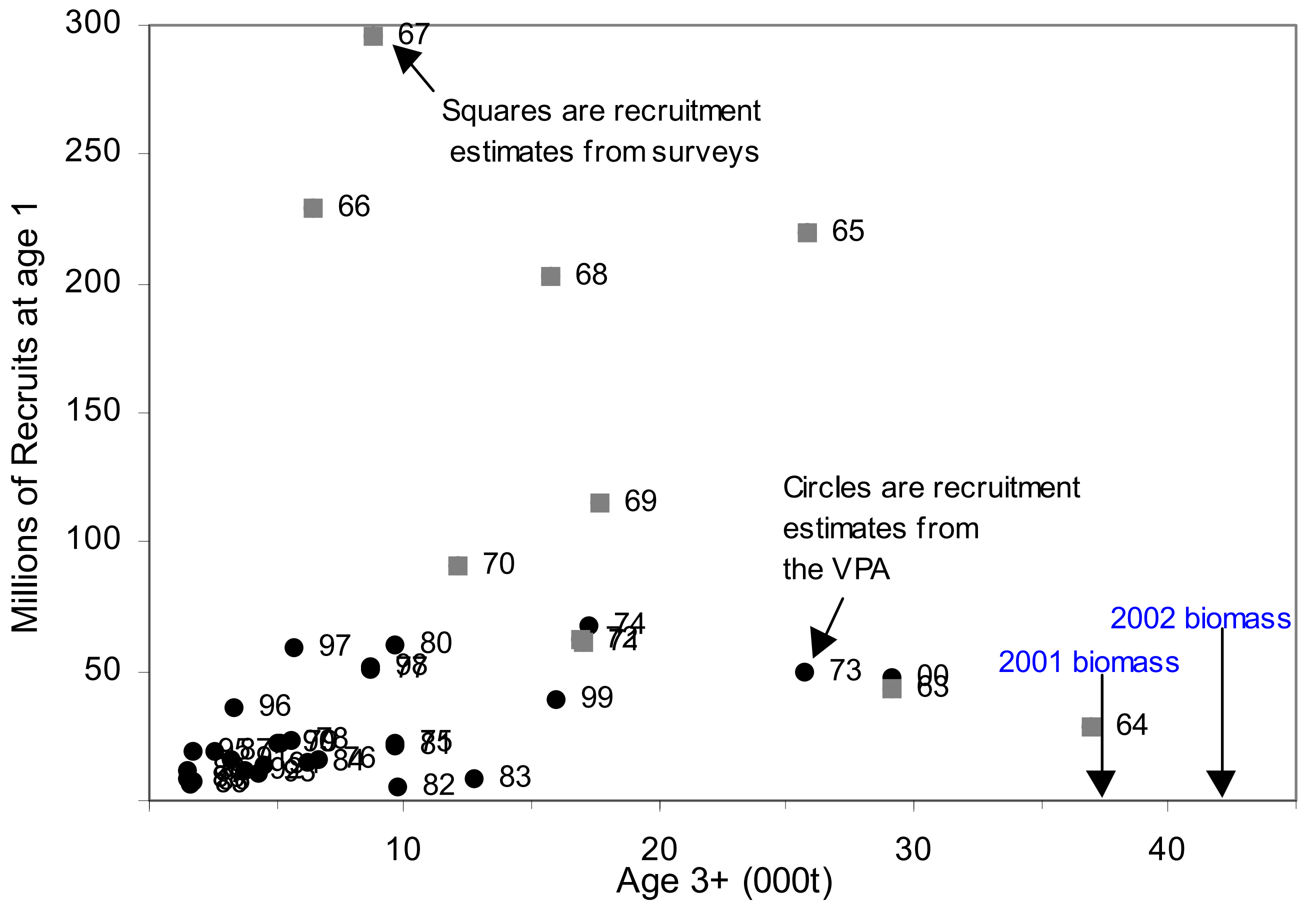

Fig. 31. Age 3+ biomass and age 1 recruitment relationship from the VPA for Georges Bank yellowtail flounder. The beginning of year age 3+ biomass for 2001 and 2002 from the VPA is also shown.

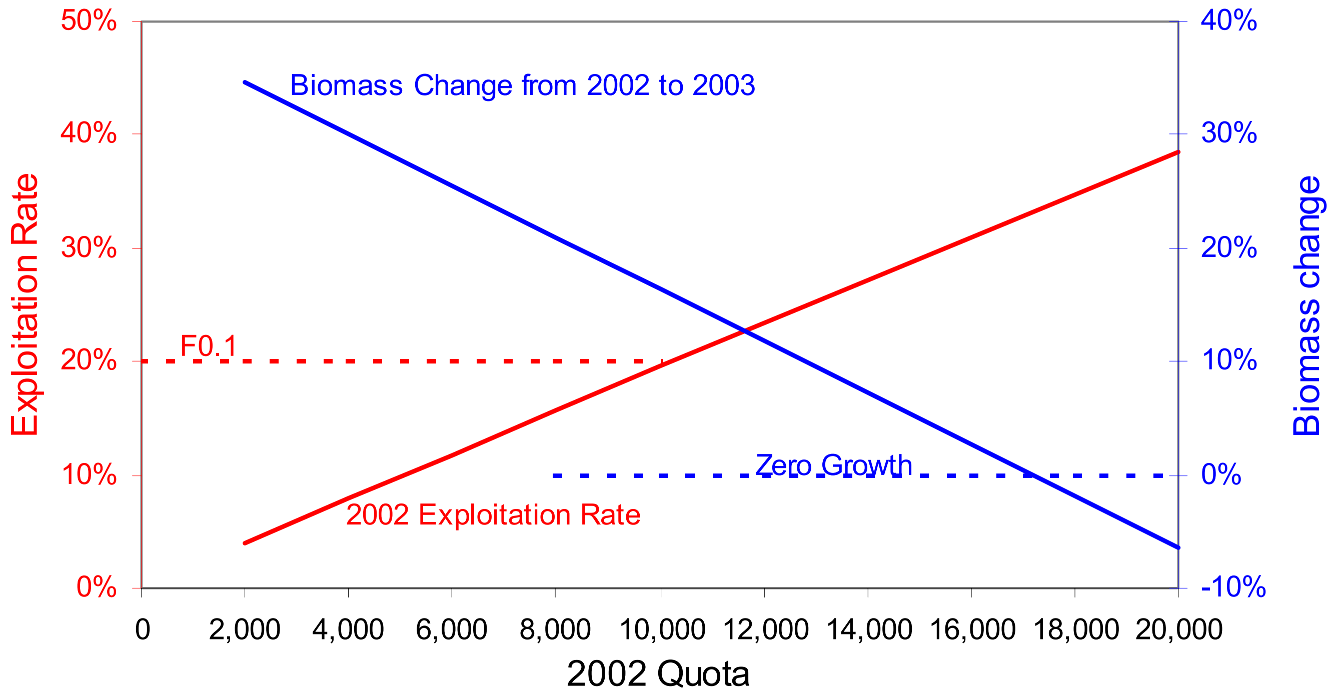

Fig. 32. Implications of various 2002 quotas (combined Canada and USA) on exploitation rate and change in the 3+ population biomass from 2002 to 2003.

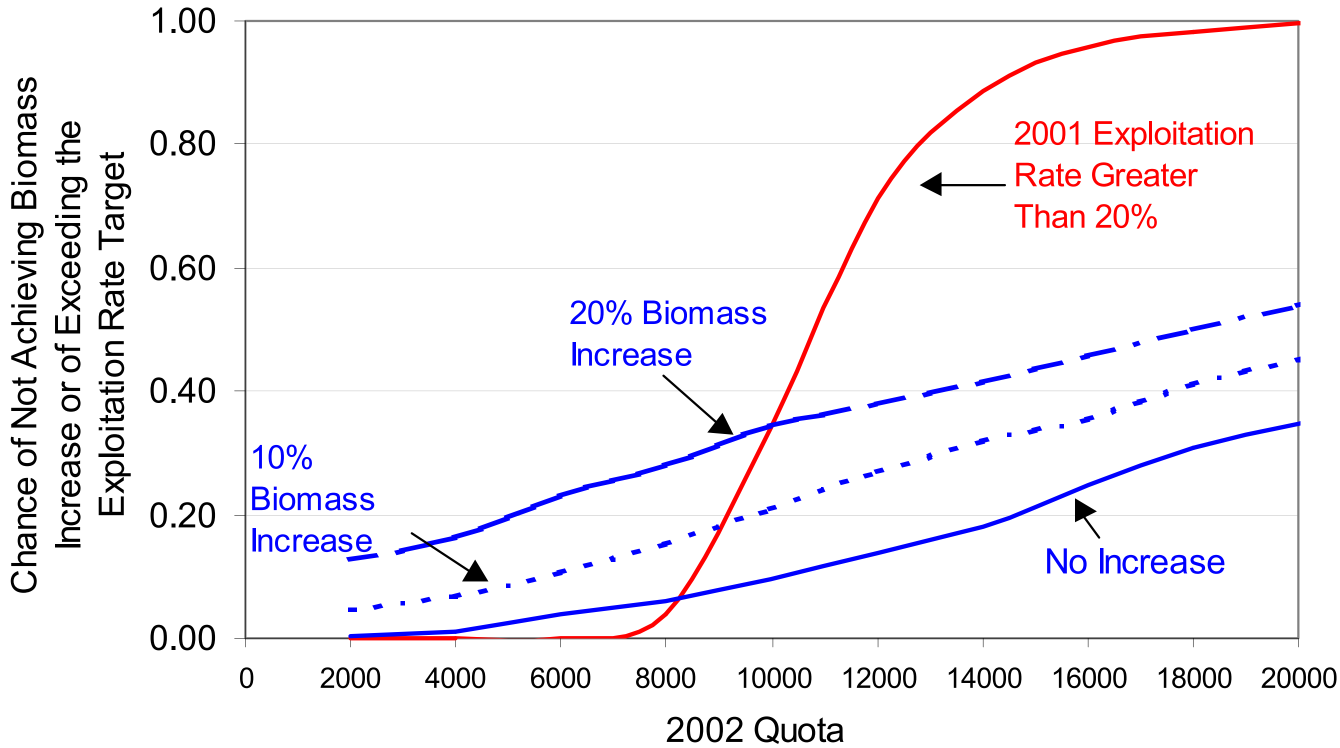

Fig. 33. Risk of exceeding the $F_{0.1}$ fishing mortality or not achieving increments of population biomass growth at various quotas for the 2002 fishery, Georges Bank yellowtail flounder.

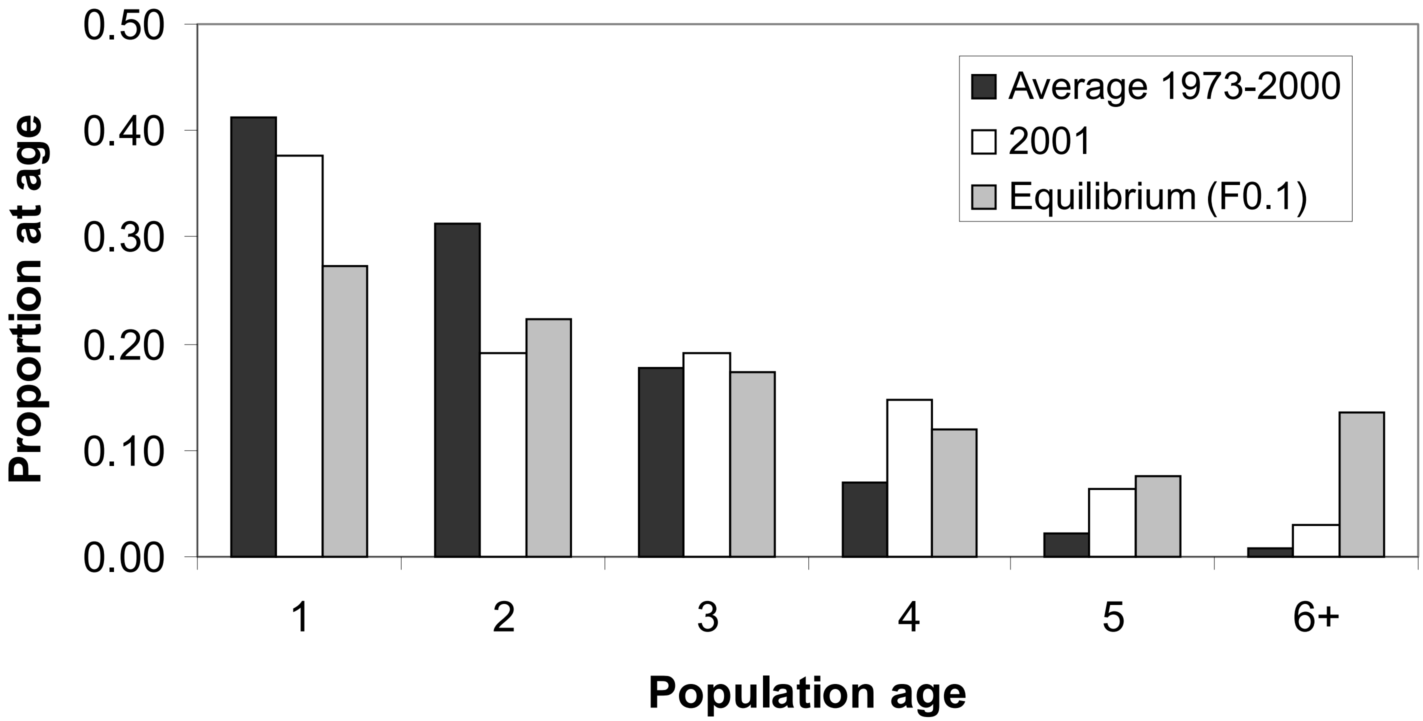

Fig. 34. Proportions at age for the Georges Bank yellowtail flounder population in 2001, for the average of 1973-2000 and when the population is at equilibrium.

Appendix A
Surplus Production Analysis

```
Georges Bank Yellowtail (yield and biomass in k mt)                                                       Page 1
                                                                                           27 Mar 2002 at 14:54.23
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.86)                                      FIT 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:                         39            Number of bootstrap trials:                            0
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
                                       |      39
                                       |
 2  USA Spring -lagged                 |   0.802   1.000
                                       |      25      25
                                       |
 3  Canada - lagged                    |   0.849   0.886   1.000
                                       |      16      15      16
                                       --------------------------------------------------
                                              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	7.901E+00	39	2.136E-01	1.000E+00	1.002E+00	0.812
Loss(2)	USA Spring -lagged	5.530E+00	25	2.404E-01	1.000E+00	8.897E-01	0.590
Loss(3)	Canada - lagged	2.563E+00	16	1.831E-01	1.000E+00	1.168E+00	0.867
TOTAL OBJECTIVE FUNCTION:		1.59945319E+01					

Number of restarts required for convergence:	36	
Est. B-ratio coverage index (0 worst, 2 best):	1.9179	< 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	2.372E+00	1.000E+00	1	1
MSY	Maximum sustainable yield	1.446E+01	1.400E+01	1	1
r	Intrinsic rate of increase	6.692E-01	6.000E-01	1	1
....	Catchability coefficients by fishery:				
q(1)	USA Fall	1.374E-01	1.000E-01	1	1
q(2)	USA Spring -lagged	1.485E-01	1.000E-01	1	1
q(3)	Canada - lagged	3.305E-01	3.000E-01	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	Related quantity
MSY	Maximum sustainable yield	1.446E+01	Kr/4	
K	Maximum stock biomass	8.643E+01		
Bmsy	Stock biomass at MSY	4.321E+01	K/2	
Fmsy	Fishing mortality at MSY	3.346E-01	r/2	
F(0.1)	Management benchmark	3.011E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.431E+01	0.99*MSY	
B-ratio	Ratio of B(2002) to Bmsy	1.421E+00		
F-ratio	Ratio of F(2001) to Fmsy	3.447E-01		
F01-mult	Ratio of F(0.1) to F(2001)	2.611E+00		
Y-ratio	Proportion of MSY avail in 2002	8.229E-01	2*Br-Br^2	Ye(2002) = 1.190E+01
....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	USA Fall	2.434E+00	r/2q(1)	f(0.1) = 2.191E+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	1.249E+01	0.1836	1.669E+01	1.669E+01	-0.02323	0.000E+00
2	1964	1.362E+01	1.030E+01	0.2644	1.981E+01	1.981E+01	-0.27974	0.000E+00
3	1965	9.104E+00	8.855E+00	0.3019	1.945E+01	1.945E+01	-0.02772	0.000E+00
4	1966	3.988E+00	8.225E+00	0.2296	1.374E+01	1.374E+01	0.72389	0.000E+00
5	1967	7.575E+00	7.949E+00	0.2647	1.531E+01	1.531E+01	0.04816	0.000E+00
6	1968	1.054E+01	7.442E+00	0.3361	1.820E+01	1.820E+01	-0.34767	0.000E+00
7	1969	9.279E+00	6.573E+00	0.4589	2.194E+01	2.194E+01	-0.34485	0.000E+00
8	1970	4.979E+00	5.577E+00	0.5246	2.129E+01	2.129E+01	0.11350	0.000E+00
9	1971	6.365E+00	5.040E+00	0.4229	1.551E+01	1.551E+01	-0.23331	0.000E+00
10	1972	6.328E+00	4.676E+00	0.5161	1.756E+01	1.756E+01	-0.30256	0.000E+00
11	1973	6.602E+00	4.192E+00	0.5418	1.652E+01	1.652E+01	-0.45421	0.000E+00
12	1974	3.733E+00	3.666E+00	0.6218	1.659E+01	1.659E+01	-0.01803	0.000E+00
13	1975	2.365E+00	3.021E+00	0.7285	1.601E+01	1.601E+01	0.24469	0.000E+00
14	1976	1.533E+00	2.302E+00	0.8573	1.436E+01	1.436E+01	0.40643	0.000E+00
15	1977	2.829E+00	1.768E+00	0.7784	1.001E+01	1.001E+01	-0.47024	0.000E+00
16	1978	2.383E+00	1.640E+00	0.5185	6.188E+00	6.188E+00	-0.37340	0.000E+00
17	1979	1.520E+00	1.765E+00	0.4824	6.195E+00	6.195E+00	0.14955	0.000E+00
18	1980	6.722E+00	1.906E+00	0.4948	6.863E+00	6.863E+00	-1.26019	0.000E+00
19	1981	2.621E+00	2.120E+00	0.4069	6.277E+00	6.277E+00	-0.21195	0.000E+00
20	1982	2.270E+00	1.982E+00	0.8319	1.200E+01	1.200E+01	-0.13561	0.000E+00
21	1983	2.131E+00	1.273E+00	1.2328	1.142E+01	1.142E+01	-0.51488	0.000E+00
22	1984	5.930E-01	7.327E-01	1.0862	5.791E+00	5.791E+00	0.21160	0.000E+00
23	1985	7.090E-01	5.941E-01	0.5830	2.520E+00	2.520E+00	-0.17674	0.000E+00
24	1986	8.200E-01	5.853E-01	0.7186	3.060E+00	3.060E+00	-0.33721	0.000E+00
25	1987	5.090E-01	5.236E-01	0.7809	2.975E+00	2.975E+00	0.02826	0.000E+00
26	1988	1.710E-01	5.033E-01	0.5784	2.118E+00	2.118E+00	1.07945	0.000E+00
27	1989	9.770E-01	6.288E-01	0.2638	1.207E+00	1.207E+00	-0.44074	0.000E+00
28	1990	7.250E-01	7.373E-01	0.6653	3.569E+00	3.569E+00	0.01685	0.000E+00
29	1991	7.300E-01	8.404E-01	0.3320	2.030E+00	2.030E+00	0.14078	0.000E+00
30	1992	5.760E-01	9.267E-01	0.7018	4.732E+00	4.732E+00	0.47550	0.000E+00
31	1993	5.450E-01	9.025E-01	0.5868	3.853E+00	3.853E+00	0.50443	0.000E+00
32	1994	8.970E-01	9.407E-01	0.5653	3.869E+00	3.869E+00	0.04755	0.000E+00
33	1995	3.540E-01	1.264E+00	0.0857	7.880E-01	7.880E-01	1.27251	0.000E+00
34	1996	1.303E+00	2.063E+00	0.0848	1.273E+00	1.273E+00	0.45930	0.000E+00
35	1997	3.781E+00	3.198E+00	0.0788	1.834E+00	1.834E+00	-0.16733	0.000E+00
36	1998	4.347E+00	4.592E+00	0.0931	3.111E+00	3.111E+00	0.05483	0.000E+00
37	1999	7.973E+00	6.019E+00	0.1014	4.442E+00	4.442E+00	-0.28111	0.000E+00
38	2000	5.838E+00	7.186E+00	0.1319	6.895E+00	6.895E+00	0.20772	0.000E+00
39	2001	1.155E+01	8.062E+00	0.1153	6.765E+00	6.765E+00	-0.35976	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    -0.0232                                             |
1964    -0.2797                                       ======|
1965    -0.0277                                            =|
1966     0.7239                                             |==============
1967     0.0482                                             |=
1968    -0.3477                                      =======|
1969    -0.3449                                      =======|
1970     0.1135                                             |==
1971    -0.2333                                        =====|
1972    -0.3026                                       ======|
1973    -0.4542                                    =========|
1974    -0.0180                                             |
1975     0.2447                                             |=====
1976     0.4064                                             |========
1977    -0.4702                                    =========|
1978    -0.3734                                      =======|
1979     0.1496                                             |===
1980    -1.2602                    =========================|
1981    -0.2120                                         ====|
1982    -0.1356                                          ===|
1983    -0.5149                                   ==========|
1984     0.2116                                             |====
1985    -0.1767                                         ====|
1986    -0.3372                                      =======|
1987     0.0283                                             |=
1988     1.0794                                             |======================
1989    -0.4407                                    =========|
1990     0.0169                                             |
1991     0.1408                                             |===
1992     0.4755                                             |==========
1993     0.5044                                             |==========
1994     0.0476                                             |=
1995     1.2725                                             |=========================
1996     0.4593                                             |=========
1997    -0.1673                                          ===|
1998     0.0548                                             |=
1999    -0.2811                                       ======|
2000     0.2077                                             |====
2001    -0.3598                                      =======|
                   ------------------------------------------------------------------------------------
```

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	*	1.224E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	1.027E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	9.003E+00	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	8.791E+00	0.00000	0.0
5	1967	1.000E+00	1.000E+00	0.0	2.813E+00	8.419E+00	-1.09621	-5.606E+00
6	1968	1.000E+00	1.000E+00	0.0	1.117E+01	7.724E+00	0.36893	3.446E+00
7	1969	1.000E+00	1.000E+00	0.0	5.312E+00	6.582E+00	-0.21438	-1.270E+00
8	1970	1.000E+00	1.000E+00	0.0	4.607E+00	5.555E+00	-0.18713	-9.481E-01
9	1971	1.000E+00	1.000E+00	0.0	6.450E+00	5.350E+00	0.18701	1.100E+00
10	1972	0.000E+00	0.000E+00	0.0	*	4.791E+00	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	4.297E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	3.665E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	2.913E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	2.120E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	1.721E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	1.824E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	1.991E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	2.129E+00	0.00000	0.0
19	1981	1.000E+00	1.000E+00	0.0	2.500E+00	2.455E+00	0.01797	4.452E-02
20	1982	1.000E+00	1.000E+00	0.0	2.642E+00	1.866E+00	0.34758	7.757E-01
21	1983	1.000E+00	1.000E+00	0.0	1.646E+00	9.887E-01	0.50975	6.573E-01
22	1984	1.000E+00	1.000E+00	0.0	9.880E-01	6.252E-01	0.45766	3.628E-01
23	1985	1.000E+00	1.000E+00	0.0	8.470E-01	6.590E-01	0.25092	1.880E-01
24	1986	1.000E+00	1.000E+00	0.0	3.290E-01	6.069E-01	-0.61235	-2.779E-01
25	1987	1.000E+00	1.000E+00	0.0	5.660E-01	5.270E-01	0.07144	3.902E-02
26	1988	1.000E+00	1.000E+00	0.0	7.290E-01	5.609E-01	0.26212	1.681E-01
27	1989	1.000E+00	1.000E+00	0.0	6.990E-01	8.120E-01	-0.14983	-1.130E-01
28	1990	1.000E+00	1.000E+00	0.0	6.310E-01	7.820E-01	-0.21453	-1.510E-01
29	1991	1.000E+00	1.000E+00	0.0	1.566E+00	1.045E+00	0.40462	5.211E-01
30	1992	1.000E+00	1.000E+00	0.0	4.820E-01	9.599E-01	-0.68886	-4.779E-01
31	1993	1.000E+00	1.000E+00	0.0	6.600E-01	9.907E-01	-0.40615	-3.307E-01
32	1994	1.000E+00	1.000E+00	0.0	2.579E+00	1.042E+00	0.90587	1.537E+00
33	1995	1.000E+00	1.000E+00	0.0	2.853E+00	1.740E+00	0.49455	1.113E+00
34	1996	1.000E+00	1.000E+00	0.0	4.359E+00	2.779E+00	0.45026	1.580E+00
35	1997	1.000E+00	1.000E+00	0.0	2.324E+00	4.188E+00	-0.58889	-1.864E+00
36	1998	1.000E+00	1.000E+00	0.0	9.307E+00	5.752E+00	0.48120	3.555E+00
37	1999	1.000E+00	1.000E+00	0.0	6.696E+00	7.230E+00	-0.07673	-5.340E-01
38	2000	1.000E+00	1.000E+00	0.0	5.006E+00	8.254E+00	-0.50010	-3.248E+00
39	2001	0.000E+00	0.000E+00	0.0	*	9.120E+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    -1.0962                       ======================|
1968     0.3689                                             |=======
1969    -0.2144                                         ====|
1970    -0.1871                                         ====|
1971     0.1870                                             |====
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     0.0180                                             |
1982     0.3476                                             |=======
1983     0.5097                                             |==========
1984     0.4577                                             |=========
1985     0.2509                                             |=====
1986    -0.6124                                 ============|
1987     0.0714                                             |=
1988     0.2621                                             |=====
1989    -0.1498                                          ===|
1990    -0.2145                                         ====|
1991     0.4046                                             |========
1992    -0.6889                               ==============|
1993    -0.4061                                     ========|
1994     0.9059                                             |==================
1995     0.4946                                             |==========
1996     0.4503                                             |=========
1997    -0.5889                                 ============|
1998     0.4812                                             |==========
1999    -0.0767                                           ==|
2000    -0.5001                                   ==========|
2001     0.0000                                             |
                   ------------------------------------------------------------------------------------
```

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	*	2.723E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	2.285E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	2.003E+01	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	1.956E+01	0.00000	0.0
5	1967	0.000E+00	0.000E+00	0.0	*	1.874E+01	0.00000	0.0
6	1968	0.000E+00	0.000E+00	0.0	*	1.719E+01	0.00000	0.0
7	1969	0.000E+00	0.000E+00	0.0	*	1.465E+01	0.00000	0.0
8	1970	0.000E+00	0.000E+00	0.0	*	1.236E+01	0.00000	0.0
9	1971	0.000E+00	0.000E+00	0.0	*	1.191E+01	0.00000	0.0
10	1972	0.000E+00	0.000E+00	0.0	*	1.066E+01	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	9.563E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	8.156E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	6.484E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	4.718E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	3.829E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	4.059E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	4.430E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	4.737E+00	0.00000	0.0
19	1981	0.000E+00	0.000E+00	0.0	*	5.464E+00	0.00000	0.0
20	1982	0.000E+00	0.000E+00	0.0	*	4.153E+00	0.00000	0.0
21	1983	0.000E+00	0.000E+00	0.0	*	2.200E+00	0.00000	0.0
22	1984	0.000E+00	0.000E+00	0.0	*	1.391E+00	0.00000	0.0
23	1985	0.000E+00	0.000E+00	0.0	*	1.467E+00	0.00000	0.0
24	1986	1.000E+00	1.000E+00	0.0	1.264E+00	1.351E+00	-0.06631	-8.666E-02
25	1987	1.000E+00	1.000E+00	0.0	1.235E+00	1.173E+00	0.05173	6.226E-02
26	1988	1.000E+00	1.000E+00	0.0	4.710E-01	1.248E+00	-0.97464	-7.772E-01
27	1989	1.000E+00	1.000E+00	0.0	1.578E+00	1.807E+00	-0.13550	-2.290E-01
28	1990	1.000E+00	1.000E+00	0.0	1.759E+00	1.740E+00	0.01073	1.878E-02
29	1991	1.000E+00	1.000E+00	0.0	2.475E+00	2.325E+00	0.06239	1.497E-01
30	1992	1.000E+00	1.000E+00	0.0	2.642E+00	2.136E+00	0.21255	5.059E-01
31	1993	1.000E+00	1.000E+00	0.0	2.753E+00	2.205E+00	0.22212	5.483E-01
32	1994	1.000E+00	1.000E+00	0.0	2.027E+00	2.320E+00	-0.13491	-2.928E-01
33	1995	1.000E+00	1.000E+00	0.0	5.304E+00	3.872E+00	0.31470	1.432E+00
34	1996	1.000E+00	1.000E+00	0.0	1.329E+01	6.184E+00	0.76524	7.108E+00
35	1997	1.000E+00	1.000E+00	0.0	4.292E+00	9.320E+00	-0.77537	-5.028E+00
36	1998	1.000E+00	1.000E+00	0.0	1.767E+01	1.280E+01	0.32214	4.865E+00
37	1999	1.000E+00	1.000E+00	0.0	1.995E+01	1.609E+01	0.21505	3.860E+00
38	2000	1.000E+00	1.000E+00	0.0	2.216E+01	1.837E+01	0.18748	3.788E+00
39	2001	1.000E+00	1.000E+00	0.0	2.062E+01	2.029E+01	0.01610	3.294E-01

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3

```
                   -1       -0.75    -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
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    -0.0663                                          ===|
1987     0.0517                                             |==
1988    -0.9746      =======================================|
1989    -0.1355                                        =====|
1990     0.0107                                             |
1991     0.0624                                             |==
1992     0.2126                                             |=========
1993     0.2221                                             |=========
1994    -0.1349                                        =====|
1995     0.3147                                             |=============
1996     0.7652                                             |===============================
1997    -0.7754              ===============================|
1998     0.3221                                             |=============
1999     0.2151                                             |=========
2000     0.1875                                             |=======
2001     0.0161                                             |=
                   ------------------------------------------------------------------------------------
```

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.372E+00	2.372E+00	0.00%	2.122E+00	2.632E+00	2.295E+00	2.442E+00	1.463E-01	0.062
K	8.645E+01	8.643E+01	-0.02%	8.291E+01	9.256E+01	8.469E+01	8.857E+01	3.878E+00	0.045
r	6.692E-01	6.692E-01	0.00%	6.141E-01	7.081E-01	6.480E-01	6.881E-01	4.009E-02	0.060
q(1)	1.394E-01	1.374E-01	-1.39%	1.280E-01	1.504E-01	1.351E-01	1.445E-01	9.473E-03	0.068
q(2)	1.501E-01	1.485E-01	-1.04%	1.317E-01	1.684E-01	1.421E-01	1.590E-01	1.695E-02	0.113
q(3)	3.342E-01	3.305E-01	-1.10%	2.809E-01	3.980E-01	3.085E-01	3.659E-01	5.744E-02	0.172
MSY	1.445E+01	1.446E+01	0.10%	1.400E+01	1.470E+01	1.431E+01	1.455E+01	2.424E-01	0.017
Ye(2002)	1.203E+01	1.190E+01	-1.13%	1.084E+01	1.335E+01	1.148E+01	1.273E+01	1.248E+00	0.104
Bmsy	4.322E+01	4.321E+01	-0.02%	4.146E+01	4.628E+01	4.235E+01	4.429E+01	1.939E+00	0.045
Fmsy	3.346E-01	3.346E-01	0.00%	3.071E-01	3.541E-01	3.240E-01	3.440E-01	2.005E-02	0.060
fmsy(1)	2.402E+00	2.434E+00	1.37%	2.225E+00	2.571E+00	2.324E+00	2.472E+00	1.480E-01	0.062
fmsy(2)	2.241E+00	2.253E+00	0.53%	2.010E+00	2.544E+00	2.120E+00	2.376E+00	2.557E-01	0.114
fmsy(3)	9.999E-01	1.012E+00	1.24%	8.459E-01	1.175E+00	9.160E-01	1.078E+00	1.625E-01	0.163
F(0.1)	3.011E-01	3.011E-01	0.00%	2.764E-01	3.187E-01	2.916E-01	3.096E-01	1.804E-02	0.060
Y(0.1)	1.430E+01	1.431E+01	0.09%	1.386E+01	1.455E+01	1.416E+01	1.440E+01	2.400E-01	0.017
B-ratio	1.411E+00	1.421E+00	0.66%	1.274E+00	1.510E+00	1.347E+00	1.462E+00	1.146E-01	0.081
F-ratio	3.472E-01	3.447E-01	-0.74%	3.181E-01	3.904E-01	3.319E-01	3.679E-01	3.608E-02	0.104
Y-ratio	8.309E-01	8.229E-01	-0.96%	7.400E-01	9.244E-01	7.869E-01	8.794E-01	9.250E-02	0.111
f0.1(1)	2.161E+00	2.191E+00	1.23%	2.002E+00	2.314E+00	2.092E+00	2.225E+00	1.332E-01	0.062
f0.1(2)	2.017E+00	2.027E+00	0.48%	1.809E+00	2.289E+00	1.908E+00	2.139E+00	2.301E-01	0.114
f0.1(3)	8.999E-01	9.111E-01	1.12%	7.613E-01	1.057E+00	8.244E-01	9.706E-01	1.462E-01	0.163
q2/q1	1.065E+00	1.081E+00	1.45%	9.211E-01	1.202E+00	9.870E-01	1.127E+00	1.399E-01	0.131
q3/q1	2.381E+00	2.405E+00	1.02%	1.968E+00	2.791E+00	2.150E+00	2.563E+00	4.124E-01	0.173

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.

```
Trials replaced for lack of convergence:          100
Trials replaced for MSY out-of-bounds:              0
Trials replaced for r out-of-bounds:                0
```

Residual-adjustment factor: 1.0398

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	1.029E+02	1.025E+02	-0.38%	9.586E+01	1.212E+02	1.003E+02	1.067E+02	6.435E+00	0.063
1964	8.265E+01	8.239E+01	-0.32%	7.781E+01	9.481E+01	8.069E+01	8.516E+01	4.473E+00	0.054
1965	6.935E+01	6.913E+01	-0.32%	6.563E+01	7.787E+01	6.776E+01	7.157E+01	3.810E+00	0.055
1966	6.079E+01	6.061E+01	-0.29%	5.751E+01	6.737E+01	5.944E+01	6.268E+01	3.241E+00	0.053
1967	5.931E+01	5.919E+01	-0.21%	5.627E+01	6.433E+01	5.801E+01	6.088E+01	2.873E+00	0.048
1968	5.677E+01	5.668E+01	-0.16%	5.412E+01	6.098E+01	5.562E+01	5.822E+01	2.598E+00	0.046
1969	5.205E+01	5.200E+01	-0.10%	4.981E+01	5.551E+01	5.105E+01	5.339E+01	2.344E+00	0.045
1970	4.434E+01	4.432E+01	-0.05%	4.234E+01	4.739E+01	4.343E+01	4.549E+01	2.061E+00	0.046
1971	3.742E+01	3.740E+01	-0.06%	3.564E+01	4.006E+01	3.660E+01	3.846E+01	1.859E+00	0.050
1972	3.603E+01	3.602E+01	-0.03%	3.447E+01	3.842E+01	3.529E+01	3.694E+01	1.652E+00	0.046
1973	3.227E+01	3.226E+01	-0.03%	3.090E+01	3.439E+01	3.161E+01	3.309E+01	1.478E+00	0.046
1974	2.894E+01	2.893E+01	-0.02%	2.777E+01	3.083E+01	2.838E+01	2.966E+01	1.271E+00	0.044
1975	2.468E+01	2.468E+01	-0.01%	2.370E+01	2.626E+01	2.421E+01	2.527E+01	1.064E+00	0.043
1976	1.962E+01	1.962E+01	-0.01%	1.880E+01	2.096E+01	1.922E+01	2.012E+01	9.002E-01	0.046
1977	1.428E+01	1.428E+01	-0.01%	1.356E+01	1.548E+01	1.393E+01	1.475E+01	8.186E-01	0.057
1978	1.159E+01	1.159E+01	-0.01%	1.088E+01	1.277E+01	1.124E+01	1.205E+01	8.067E-01	0.070
1979	1.228E+01	1.228E+01	-0.01%	1.155E+01	1.348E+01	1.193E+01	1.275E+01	8.252E-01	0.067
1980	1.340E+01	1.340E+01	-0.01%	1.268E+01	1.458E+01	1.305E+01	1.387E+01	8.155E-01	0.061
1981	1.433E+01	1.433E+01	-0.01%	1.365E+01	1.542E+01	1.401E+01	1.476E+01	7.585E-01	0.053
1982	1.653E+01	1.653E+01	0.00%	1.598E+01	1.742E+01	1.627E+01	1.688E+01	6.146E-01	0.037
1983	1.257E+01	1.257E+01	0.00%	1.219E+01	1.318E+01	1.239E+01	1.280E+01	4.184E-01	0.033
1984	6.657E+00	6.656E+00	-0.01%	6.396E+00	7.103E+00	6.530E+00	6.828E+00	2.979E-01	0.045
1985	4.210E+00	4.209E+00	-0.01%	3.975E+00	4.613E+00	4.094E+00	4.365E+00	2.708E-01	0.064
1986	4.437E+00	4.437E+00	0.00%	4.206E+00	4.841E+00	4.323E+00	4.593E+00	2.702E-01	0.061
1987	4.086E+00	4.086E+00	0.00%	3.857E+00	4.500E+00	3.973E+00	4.242E+00	2.697E-01	0.066
1988	3.548E+00	3.548E+00	0.01%	3.296E+00	4.011E+00	3.424E+00	3.716E+00	2.920E-01	0.082
1989	3.772E+00	3.776E+00	0.11%	3.462E+00	4.300E+00	3.622E+00	3.953E+00	3.312E-01	0.088
1990	5.456E+00	5.467E+00	0.21%	5.099E+00	6.038E+00	5.285E+00	5.659E+00	3.738E-01	0.069
1991	5.245E+00	5.265E+00	0.37%	4.833E+00	5.872E+00	5.037E+00	5.473E+00	4.359E-01	0.083
1992	6.995E+00	7.035E+00	0.58%	6.556E+00	7.674E+00	6.746E+00	7.247E+00	5.014E-01	0.072
1993	6.393E+00	6.463E+00	1.08%	5.832E+00	7.242E+00	6.079E+00	6.728E+00	6.488E-01	0.101
1994	6.538E+00	6.670E+00	2.02%	5.766E+00	7.724E+00	6.100E+00	7.030E+00	9.296E-01	0.142
1995	6.761E+00	7.018E+00	3.80%	5.614E+00	8.649E+00	6.103E+00	7.583E+00	1.480E+00	0.219
1996	1.129E+01	1.171E+01	3.73%	9.401E+00	1.414E+01	1.019E+01	1.262E+01	2.433E+00	0.215
1997	1.809E+01	1.871E+01	3.42%	1.529E+01	2.203E+01	1.639E+01	2.009E+01	3.692E+00	0.204
1998	2.737E+01	2.820E+01	3.02%	2.358E+01	3.242E+01	2.501E+01	2.994E+01	4.934E+00	0.180
1999	3.773E+01	3.873E+01	2.63%	3.303E+01	4.353E+01	3.502E+01	4.080E+01	5.775E+00	0.153
2000	4.766E+01	4.868E+01	2.14%	4.280E+01	5.330E+01	4.493E+01	5.074E+01	5.805E+00	0.122
2001	5.477E+01	5.557E+01	1.47%	5.013E+01	5.976E+01	5.221E+01	5.735E+01	5.141E+00	0.094
2002	6.091E+01	6.140E+01	0.80%	5.700E+01	6.491E+01	5.883E+01	6.294E+01	4.110E+00	0.067
2003	5.603E+01	5.634E+01	0.55%	5.267E+01	5.959E+01	5.434E+01	5.780E+01	3.462E+00	0.062

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	1.828E-01	1.836E-01	0.41%	1.536E-01	1.943E-01	1.765E-01	1.872E-01	1.067E-02	0.058
1964	2.635E-01	2.644E-01	0.34%	2.346E-01	2.794E-01	2.559E-01	2.701E-01	1.418E-02	0.054
1965	3.009E-01	3.019E-01	0.32%	2.699E-01	3.184E-01	2.920E-01	3.081E-01	1.615E-02	0.054
1966	2.290E-01	2.296E-01	0.25%	2.091E-01	2.418E-01	2.228E-01	2.343E-01	1.147E-02	0.050
1967	2.642E-01	2.647E-01	0.19%	2.448E-01	2.777E-01	2.573E-01	2.700E-01	1.262E-02	0.048
1968	3.357E-01	3.361E-01	0.12%	3.141E-01	3.515E-01	3.274E-01	3.425E-01	1.514E-02	0.045
1969	4.585E-01	4.589E-01	0.07%	4.292E-01	4.796E-01	4.470E-01	4.679E-01	2.085E-02	0.045
1970	5.243E-01	5.246E-01	0.06%	4.909E-01	5.500E-01	5.107E-01	5.360E-01	2.533E-02	0.048
1971	4.227E-01	4.229E-01	0.03%	3.952E-01	4.429E-01	4.119E-01	4.319E-01	2.005E-02	0.047
1972	5.160E-01	5.161E-01	0.03%	4.840E-01	5.391E-01	5.033E-01	5.268E-01	2.349E-02	0.046
1973	5.416E-01	5.418E-01	0.02%	5.080E-01	5.650E-01	5.288E-01	5.527E-01	2.386E-02	0.044
1974	6.217E-01	6.218E-01	0.02%	5.838E-01	6.476E-01	6.067E-01	6.339E-01	2.721E-02	0.044
1975	7.285E-01	7.285E-01	0.01%	6.833E-01	7.596E-01	7.109E-01	7.431E-01	3.223E-02	0.044
1976	8.573E-01	8.573E-01	0.01%	7.965E-01	8.985E-01	8.328E-01	8.768E-01	4.405E-02	0.051
1977	7.783E-01	7.784E-01	0.01%	7.121E-01	8.241E-01	7.514E-01	8.000E-01	4.864E-02	0.062
1978	5.184E-01	5.185E-01	0.01%	4.713E-01	5.516E-01	4.992E-01	5.340E-01	3.488E-02	0.067
1979	4.823E-01	4.824E-01	0.01%	4.414E-01	5.113E-01	4.656E-01	4.959E-01	3.033E-02	0.063
1980	4.948E-01	4.948E-01	0.01%	4.574E-01	5.212E-01	4.795E-01	5.072E-01	2.766E-02	0.056
1981	4.068E-01	4.069E-01	0.01%	3.824E-01	4.238E-01	3.969E-01	4.148E-01	1.793E-02	0.044
1982	8.319E-01	8.319E-01	0.00%	7.912E-01	8.590E-01	8.155E-01	8.447E-01	2.921E-02	0.035
1983	1.233E+00	1.233E+00	0.01%	1.166E+00	1.276E+00	1.206E+00	1.254E+00	4.747E-02	0.039
1984	1.086E+00	1.086E+00	0.01%	1.005E+00	1.140E+00	1.053E+00	1.112E+00	5.800E-02	0.053
1985	5.829E-01	5.830E-01	0.01%	5.330E-01	6.160E-01	5.626E-01	5.986E-01	3.601E-02	0.062
1986	7.186E-01	7.186E-01	0.00%	6.555E-01	7.596E-01	6.932E-01	7.384E-01	4.521E-02	0.063
1987	7.810E-01	7.809E-01	-0.01%	6.996E-01	8.337E-01	7.485E-01	8.063E-01	5.774E-02	0.074
1988	5.787E-01	5.784E-01	-0.05%	5.087E-01	6.262E-01	5.519E-01	6.011E-01	4.913E-02	0.085
1989	2.642E-01	2.638E-01	-0.12%	2.358E-01	2.850E-01	2.534E-01	2.740E-01	2.066E-02	0.078
1990	6.673E-01	6.653E-01	-0.30%	5.998E-01	7.180E-01	6.408E-01	6.917E-01	5.090E-02	0.076
1991	3.336E-01	3.320E-01	-0.46%	3.022E-01	3.594E-01	3.215E-01	3.471E-01	2.561E-02	0.077
1992	7.075E-01	7.018E-01	-0.80%	6.352E-01	7.649E-01	6.764E-01	7.381E-01	6.168E-02	0.087
1993	5.958E-01	5.868E-01	-1.52%	5.163E-01	6.641E-01	5.620E-01	6.319E-01	6.989E-02	0.117
1994	5.806E-01	5.653E-01	-2.63%	4.731E-01	6.785E-01	5.292E-01	6.333E-01	1.041E-01	0.179
1995	8.855E-02	8.570E-02	-3.21%	7.059E-02	1.070E-01	7.970E-02	9.853E-02	1.882E-02	0.213
1996	8.769E-02	8.483E-02	-3.26%	7.135E-02	1.048E-01	7.914E-02	9.746E-02	1.832E-02	0.209
1997	8.119E-02	7.881E-02	-2.93%	6.765E-02	9.479E-02	7.395E-02	8.944E-02	1.548E-02	0.191
1998	9.561E-02	9.312E-02	-2.61%	8.188E-02	1.103E-01	8.802E-02	1.038E-01	1.579E-02	0.165
1999	1.037E-01	1.014E-01	-2.22%	9.164E-02	1.172E-01	9.693E-02	1.112E-01	1.427E-02	0.138
2000	1.341E-01	1.319E-01	-1.68%	1.216E-01	1.481E-01	1.272E-01	1.415E-01	1.431E-02	0.107
2001	1.166E-01	1.153E-01	-1.06%	1.084E-01	1.259E-01	1.122E-01	1.216E-01	9.397E-03	0.081
2002	3.044E-01	3.011E-01	-1.06%	2.829E-01	3.288E-01	2.930E-01	3.176E-01	2.453E-02	0.081

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