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Stock Assessment of Georges Bank Yellowtail Flounder for 2007

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ABSTRACT

The combined Canada/US yellowtail flounder (*Limanda ferruginea*) catch decreased from 2005 (4,088 mt) to 2006 (2,206 mt) due mainly to a decrease in quota. Spawning stock biomass has leveled off recently, but is currently low at about 5,000 mt, indicating that stock rebuilding is needed. There are indications of a relatively strong 2005 year-class, appearing as 1 year olds in the 2006 NEFSC Fall, Spring, and Scallop surveys and as 2 year olds in the 2007 DFO and NEFSC Spring surveys. The 2005 year-class is estimated to be 63 million age-1 fish in 2006, similar to the abundance of year-classes from the 1970s. Fishing mortality rates for fully recruited ages 4+ have declined the past two years, but are still well above F_{ref} of 0.25. Truncated age structure in the surveys and contraction in distribution indicate current productivity may be limited relative to historical levels. Assuming a 2007 catch equal to the 1,250 mt quota, a combined Canada/US yield of about 3,500 mt in 2008 is expected to achieve $F_{ref} = 0.25$. However, the projected 2008 yield depends strongly on the 2005 year-class, and recent experience has shown estimates of initially strong year-classes reduced in size over time, so caution should be used when setting the 2008 quota.

RÉSUMÉ

Les prises combinées de limande à queue jaune (*Limanda ferruginea*) du Canada et des États-Unis ont diminué de 2005 à 2006, passant de 4 088 tm à 2 206 tm, principalement en raison d’une baisse du quota. La biomasse du stock de reproducteurs a récemment plafonné, mais elle est actuellement faible (environ 5 000 tm), ce qui indique que le stock doit se rétablir davantage. Il y a des indications que la classe de 2005 est relativement abondante, ce qui s’observe par le nombre de poissons d’âge 1 dans les relevés du NEFSC sur le pétoncle effectués à l’automne et au printemps de 2006, et par le nombre de poissons d’âge 2 dans les relevés du MPO et du NEFSC effectués au printemps de 2007. On estime que la classe de 2005 sera de 63 millions de poissons d’âge 1 en 2006, ce qui est semblable à l’abondance des classes de 1970. La mortalité par pêche parmi les âges pleinement recrutés (4+) a décliné au cours des deux dernières années, mais est encore de beaucoup supérieure au niveau de référence de 0,25. La structure d’âges tronquée dans les relevés et la contraction de la distribution indiquent que la productivité actuelle est peut-être limitée par rapport à ses niveaux historiques. En supposant que les prises de 2007 soient égales au quota de 1 250 tm, on s’attend à ce que le rendement combiné du Canada et des États-Unis d’environ 3 500 tm en 2008 atteigne le niveau de référence de 0,25. Toutefois, le rendement projeté de 2008 dépend en grande partie de la classe de 2005, et de récentes expériences ont montré que les estimations de la taille des classes initialement très abondantes ont diminué au fil du temps; il faudrait donc faire preuve de prudence lorsqu’on établira les quotas de 2008.

INTRODUCTION

The Georges Bank yellowtail flounder *(Limanda ferruginea)* stock is a transboundary resource in Canadian and US jurisdictions. This paper updates the last stock assessment of yellowtail flounder on Georges Bank, completed by Canada and the US (Legault et al. 2006) addressing technical recommendations from the 2005 benchmark review (TRAC 2005). A primary objective of the benchmark review was to address the retrospective pattern that had been apparent from assessments conducted during the past several years. During the benchmark assessment meeting, several analytical models were reviewed, all of which indicated poor correspondence between the catch at age and survey abundance at age that can not be reconciled. Various possible reasons for the retrospective pattern were identified including an increase in natural mortality, large amounts of unreported catch, and changes in survey catchability since 1995. The consensus view from the benchmark meeting was that management advice should be formulated on the basis of results from several approaches:

- Analysis of data from survey and fishery (trends in relative F and Z)
- ‘Base Case VPA’ model formulation from the 2004 assessment
- Two new VPA model formulations with minor & major changes to Base Case

The analytical methods used in the current assessment are based on revised model formulations adopted during the 2005 TRAC benchmark review using updated information from both countries on catches and survey indices of abundance.

Last year, the ‘Major Change VPA’ model used to provide catch advice indicated that fishing mortality had never been as low as the target rate since 1973 and had increased to high levels (>1) in 2004 and 2005 and that stock rebuilding was needed. The Base Case VPA model was rejected as the basis for management advice because trends in age 3+ biomass did not display a decline in recent years as indicated by all three surveys. Projections from the Major Change VPA model indicated that catching the TAC of 3,000 mt in 2006 would result in a fishing mortality rate above F_{ref} = 0.25 (F_{2006} = 0.83). Based on these projections, the catch quota for 2007 was set by the TMGC at 1,250 mt.

Yellowtail flounder range from southern Labrador to Chesapeake Bay and are typically caught at depths between 30 and 70 m. A major concentration occurs on Georges Bank from the northeast peak to the Great South Channel. Yellowtail flounder have previously been described as relatively sedentary, although a growing body of evidence counters this classification with off bottom movements (Walsh and Morgan 2004; Cadrin and Westwood 2004), limited seasonal movements (Royce et al. 1959; Lux 1963; Stone and Nelson 2003), and transboundary movements both east and west across the Hague Line (Stone and Nelson 2003; Cadrin 2005). On Georges Bank, spawning occurs during late spring and summer, peaking in May. Eggs are deposited on or near the bottom and after fertilization float to the surface where they drift during development. Larvae are pelagic for a month or more, then become demersal and settle to benthic habitats. Based on the distribution of both ichthyoplankton and mature adults, spawning occurs on both sides of the Hague Line. Growth is sexually dimorphic, with females growing at a faster rate than males (Lux and Nichy 1969; Moseley 1986; Cadrin 2003). Yellowtail flounder have variable maturity schedules, with age two females 40% mature during periods of high stock biomass to 90% mature during periods of low stock biomass based on analysis of NEFSC spring survey catches.

Historical and new information pertaining to the current management unit for the Georges Bank yellowtail flounder stock was reviewed during the 2005 benchmark assessment. Tagging data, larval distribution, vital population parameters (i.e. growth, survival, recruitment, reproduction, abundance), and geographic patterns of landings and survey data indicate that Georges Bank yellowtail flounder comprise a relatively discrete stock, separate from those on the western Scotian Shelf, off Cape Cod and southern New England (Royce et al. 1959; Lux 1963; Neilson et al. 1986; Begg et al. 1999; Cadrin 2003; Stone and Nelson 2003). Based on information from a comprehensive review by Cadrin (2003) and recent results from cooperative science/industry tagging programs conducted by Canada and the US, there does not appear to be any justification for redefining the geographic boundaries of the Georges Bank yellowtail flounder stock management unit.

The management unit currently recognized by Canada and the US for the transboundary Georges Bank stock includes the entire bank east of the Great South Channel to the Northeast Peak, 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 US employ the same management unit. The quota sharing agreement between the two countries requires that catches from all sources be counted against the national allocations, regardless of whether the catch was landed or discarded.

THE FISHERIES

Exploitation of the Georges Bank stock began in the mid-1930s by the US trawler fleet. Landings (including discards) increased from 400 mt in 1935 to 9,800 mt in 1949, then decreased in the early 1950s to 2,000 mt in 1956, and increased again in the late 1950s (Fig. 2). The highest annual catches occurred during 1963-1976 (average: 17,500 mt) and included modest catches by foreign fleets (Table 1). No catches of yellowtail by nations other than Canada and USA have occurred since 1975. Catches averaged around 3,500 mt between 1985 and 1994, then dropped to a record low of 1,183 mt in 1995 when fishing effort was markedly reduced in order to allow the stock to rebuild. The US fishery in the management area has been constrained by spatial expansion of Closed Area II (Fig. 1b) and by extension to year-round closure in December 1994, as well as larger mesh size and gear regulations and limits on days fished. In 2004, a Yellowtail Special Access Program (SAP) in Closed Area II allowed the US bottom trawl fishery short-term access to the area for the first time since 1995. This SAP did not continue in 2005 or 2006. Catches by both nations (including discards) steadily increased (with increasing quotas) from a record low of 1,183 mt in 1995, when the stock was considered to be in a collapsed state, to 7,857 mt in 2001. Since 2004, decreasing quotas and an inability of Canadian fishermen to fill their portion of the quota have resulted in declining catches of 7,275 mt (2004), 4,088 mt (2005), and 2,206 mt (2006).

United States

The principal fishing gear used in the US fishery to catch yellowtail flounder is the otter trawl, accounting for more than 98% of the total USA landings in recent years, although scallop dredges account for some landings (<2%). US trawlers that land yellowtail flounder generally target multiple species on the southwest part of the Bank, and on the northern edge along the western and southern boundaries of Closed Area II. Current levels of recreational fishing are negligible.

In May of 2004, a new electronic dealer reporting system was implemented in the Northeast for US landings. This new reporting system did not allow the typical proration to stock area scheme using logbook data as described in Cadrin et al. (1998) because neither the area fished nor gear code was included in many of the dealer records. Gear codes were assigned to permits that had only used a single gear based on logbook records. This allowed the typical proration scheme to be used. Examination of patterns of landings reported in the dealer database and those in the logbook records show similar trends in terms of time of year, gear, and port. Thus, there is no indication of a systematic bias in these allocations. Total yellowtail landings (excluding discards) for the 2006 USA fishery were 1,239 mt, a decrease of 63% from 2005 (Table 1; Fig. 2).

Total discards of yellowtail in the US decreased approximately 20% from 2005 (476 mt) to 2006 (377 mt). This decrease was due almost entirely to a decrease in trawl discards, associated with a large decrease in trawl landings, while dredge discards remained the same. Although scallop landings from Georges Bank were high in 2005 and increased in 2006, the high densities of scallops relative to the low densities of yellowtail resulted in a similar discard estimate. In 2006, 28% of yellowtail discards originated from the trawl fishery (106 t), while the majority (72%) came from the scallop fishery (270 t). The trawl fishery estimates of discards were obtained from discard to kept (d:k) ratios of yellowtail based on observer data (Table 2). Comparison of these d:k ratios from observers and logbooks showed that logbook values were slightly lower than observer values for similar time periods, but the same pattern over time was present.

The scallop dredge fishery had two Special Access Programs (SAPs) on Georges Bank, one in Closed Area I and the other in Closed Area II, in addition to fishing in open areas. These SAPs attracted effort to Georges Bank and caused the landings of scallops to increase from 6,800 mt in 2005 to 9,200 mt in 2006. The spatial extent of the Georges Bank stock differs between the yellowtail flounder and scallop assessments, specifically, the scallop assessment includes the Great South Channel while the yellowtail flounder assessment does not. Scallop values presented in this document were calculated for the yellowtail flounder stock definition. Due to the negligible landings of yellowtail in the scallop fishery, the d:k ratio of yellowtail could not be applied. The high landings of scallops caused difficulty for the regression method used in the last benchmark assessment to estimate discards of yellowtail from landings of scallops. Specifically, the observed scallop landings in 2006 were more than double the highest values used to generate the regression. Following the approach of last year, discard of yellowtail to kept scallop ratios were computed from observer data in CAI, CAII, and open areas of Georges Bank (Table 2).

Scallop landings by area were approximated based on ratios of VTR landings by commercial statistical areas with area 522 representing CAI, statistical area 562 representing CAII, and statistical areas 525, 551, 552, and 561 representing open areas. This approximation was necessary because landings are not attributed to sampling programs in the dealer landings database. Since the landings of scallops came mostly from CAII during the second half of 2006, the estimated d:k ratio is most important for this area and time. There were 33 observed trips in CAII during half 2, which resulted in an estimated ratio of discarded yellowtail to kept scallops of approximately 5%, which is similar to the estimate from 2005 of 6% based on 24 observed trips. Multiplying scallop landings by the d:k ratio results in yellowtail discards of 252 mt for CAII in the second half of 2006. There were nine observed trips in CAII during the first half of 2006 which produced a d:k ratio of approximately 1.5% and yellowtail discards of 8 mt. This is also similar to 2005 half 1 when four observed trips produced an estimated d:k ratio of 2%. The second half d:k ratio was 5%. The reason for the difference in discarding rate between the first and second half of 2006 in CAII is unknown, but could relate to seasonal movements of yellowtail on Georges Bank as suggested by comparison of highest densities in DFO and NEFSC spring surveys versus NEFSC fall survey (Fig. 3).

There was only a single observed trip in CAI, and it had a low d:k ratio, as seen last year for this area (0.0016 in 2005), and scallop landings from this area were low (8% of the total) resulting in yellowtail discards of <1 mt. Application of even a much higher d:k ratio to the CAI scallop landings would not substantially change the estimated discards from Georges Bank. There were nine observed trips in open areas of Georges Bank during 2006 which produced a d:k ratio of 0.4%. This ratio is much lower than that observed in CAII, but could be due to the low densities of yellowtail flounder outside of CAII. Multiplying the d:k ratio by the scallop landings from open areas (31% of the total) produces yellowtail discards of 9.9 mt.

This approach differs from last year's assessment when insufficient observer data was available for open areas and so the regression approach was applied. Applying the regression approach this year would result in 292 mt of yellowtail discards and an implied d:k ratio of 10%. However, this was not done this year because the nine observed trips were assumed to be representative of the scallop fishery in open areas during 2006 and the regression approach is based on data from 1994 to 2000 when both scallop and yellowtail densities were much different. Estimation of yellowtail discards in the scallop dredge fishery continues to be a source of uncertainty in the Georges Bank yellowtail flounder assessment.

The total US catch of Georges Bank yellowtail flounder in 2006, including discards, was 1,616 mt. The US Georges Bank yellowtail flounder quota for fishing year 2006 (1 May 2006 to 30 April 2007) was set at 2,070 mt. Monitoring of the US catches relative to the quota was based on Vessel Monitoring Systems (VMS) and a call-in system for both landings and discards. The assessment methodology and the monitoring methodology to estimate landings and discards were compared for the calendar year 2006. The monitoring system estimated catch to be approximately 1700 mt (5% higher than the assessment catch). This match is the same as the second half of 2005 when the monitoring methodology was 6% higher than the assessment methodology.

Canada

Canadian fishermen initiated a directed fishery for yellowtail flounder on Georges Bank in 1993. Prior to 1993, Canadian landings were low, typically less than 60 mt (Table 1, Fig. 2). Landings of 2,139 mt of yellowtail occurred in 1994, when the fishery was unrestricted. After a TAC of

400 mt was established, yellowtail landings dropped to 464 mt in 1995. Subsequently, both quotas and landings increased and in 2001 were 2,913 mt. The majority of Canadian landings of yellowtail flounder are made by otter trawl from vessels less than 20 m, tonnage classes 1-3. The Canadian fishery generally occurs from June to December, with most landings in the third quarter. In 2004, landings were 96 mt (against a quota of 1,900 mt). Unlike other years, Canadian fishermen were unable to find commercial quantities of yellowtail in 2004 and the directed fishery ceased in September. In 2005, landings were 30 mt (against a quota of 1,740 mt) and in 2006 landings were 25 mt (against a quota of 930 mt), because Canadian fishermen were still unable to find commercial quantities of yellowtail (Table 1). Most of the yellowtail landings reported for 2006 were from trips directed for other groundfish species (i.e. cod, haddock). Flatfish landed as “unspecified” in the Canadian fishery are also included in the total Canadian landings and were estimated at 5.3 mt for 2006, following methods used in previous assessments. This amount was added to the reported yellowtail landings of 19.5 mt, bringing the total up to 25 mt for 2006.

The Canadian offshore scallop fishery is the source of Canadian yellowtail flounder discards on Georges Bank. As a result of the 2005 benchmark review, these data are now incorporated into the Canadian fishery catch and catch at age for 1973 onward. Prior to 1996, landing of groundfish bycatch by the Canadian scallop fishery on Georges Bank was allowed; however, not all the yellowtail flounder bycatch was landed. To account for the total bycatch for 1973-1995, it was necessary to augment the yellowtail landings by the yellowtail discarded in the scallop fishery. Management measures established in 1996 prohibit the landing of groundfish (except monkfish) by the Canadian scallop fishery, and all bycatch of yellowtail flounder is now discarded. Discards, whether pre or post 1996, are not recorded in the Canadian fishery statistics and can only be estimated from observer deployments.

Prior to 2001, very few Canadian scallop trips on Georges Bank had at-sea observer coverage; only nine trips were monitored from 1991 to 1998. In response to a Fisheries Resource Conservation Council recommendation, a monitoring program of the Canadian offshore scallop industry was conducted in 2001 and 2002 to gather data on bycatches. Twelve trips were observed which covered all months except January and October. In August 2004, routine observer coverage was initiated on vessels in the Canadian scallop fishery on Georges Bank. A total of 5 trips were observed in 2004, 11 in 2005, and 11 in 2006.

Van Eeckhaute et al. (2005) provide the methodology used for estimating yellowtail flounder discards in the Canadian scallop fishery during 1960-2004 based on observer data (although only estimates for catches since 1973 are used in the stock assessment). For 1996-2004, when yellowtail flounder landings were not permitted, effort in the scallop fishery was prorated by the observed discard rate of yellowtail to effort to obtain an estimate of discards. While the available data do not support any spatial trends in discard rates, higher discard rates occur in April, May and June than in November and December. Therefore, the proration was conducted using discard rate by quarter. Quarterly discard rates for periods when no observed trips were available were derived by interpolation and application of a seasonal pattern. To estimate discards for year 1996 and later, the quarterly discard rates were applied to the total quarterly effort of the scallop fleet. The seasonal pattern in bycatch rate for years 2005 and 2006 is taken into account by applying calculations using 3-month moving windows. In the past, separate estimates for each quarter were calculated and then added together. This new approach has been used to update the 2005 estimate of yellowtail discards in the Canadian scallop dredge fishery from 317 mt to 255 mt. Application of this approach to data in 2006 results in a discard estimate of 565 mt (Table 2). The estimate of discards in 2006 is heavily influenced by a single observed trip which had a high discard rate of yellowtail flounder. Excluding this trip from the calculations produced an estimate of 210 mt. However, there were no reasons other than the high discard rate of yellowtail to exclude this trip from the calculations, so the discards of yellowtail in the Canadian scallop fishery for 2006 are 565 mt.

For 1973-1995, the number of observed trips was very limited and the ratios were subject to influence by anomalous outliers. An effort-based proration was used without seasonal factors because that refinement was not considered warranted given the limitations of the available information for this period. The approach used for both periods is dependent on the assumption that the bycatch population density, i.e. the *discard+landed yellowtail / scallop effort* ratio for observed scallop fishing is representative of that for the scallop fishery as well as on the assumption that discarding practices are representative. Estimation of yellowtail discards in the scallop dredge fishery continues to be a source of uncertainty in the Georges Bank yellowtail flounder assessment.

Discard estimates from 1973-2006 averaged 538 mt and ranged from a low of 255 mt in 2005 to a high of 815 mt in 2001 (Table 1). For 2006, the total Canadian catch, including discards, was 590 mt, an increase of 107% from 2005 but well below the 2006 TAC of 930 mt.

Length and Age Composition

In 2006, 880 length measurements were available from 4 port samples from the Canadian fishery (Table 3) and were used to estimate the Canadian catch at size, by sex and quarter. No length measurements were utilized from at sea observer deployments because sex determinations from these samples were found to be inaccurate.

The US landings are classified by market category (large, small, and unclassified) and this categorization is used to determine the size and age distributions. The number of US port samples increased in 2006, with 9,320 length measurements available from 95 samples, even though US yellowtail landings declined by about 60% from 2005 (Tables 1 and 3). This compares with 8,295 measurements from 81 samples in 2005. The 95 port samples also provided 2,125 age measurements for use in age-length keys. At-sea sampling decreased slightly in 2006 and provided an additional 34,073 length measurements, which were combined with the port samples to characterize the size composition of the ‘unclassified’ market category of US catch.

Both the amount and the proportion of yellowtail landed in the large market category have generally increased since 1995 (from approximately 50% to approximately 75%) although the 2006 proportion was 67%. Examination of the size distributions of the two market categories continues to show some overlap in the 35-38 cm range, but overall discrimination between the groups (Fig. 4). The proportion of the landings in the large market category that are 45 cm and larger increased during 2000 through 2004; 5%, 8%, 12%, 22%, 20%, respectively, but then declined to 7% in 2005 and 12% in 2006.

The size composition of yellowtail flounder discards in the Canadian offshore scallop fishery was estimated by half year using length measurements obtained from 11 observed trips in 2006. These were prorated to the total estimated bycatch at size using the corresponding half year length-weight relationship and the estimated half year bycatch (mt), calculated using the methods of Stone and Gavaris (2005). Discards at age by half year were then obtained using half year age-length keys based on the following combined ages: Half 1 US commercial fishery + NMFS spring survey +DFO survey, and Half 2 US commercial fishery + NMFS fall survey. Yellowtail discards from the Canadian scallop fishery were generally larger during the first half year (Fig.5) indicating a higher catchability of larger fish which is likely related to their gravid condition and peak spawning during April through June.

US discard length frequencies were generated from observer data, expanded to the total weight of discards by gear type and half year. Trawl discards were mostly due to minimum size culling (Fig. 6). Dredge discards were low in the first six months of 2006 and similar in size distribution to the second half discards, in that most discards were mainly legal sized fish which is consistent with previous observations (Fig. 6).

A comparison of the size composition of yellowtail catch by country revealed that the Canadian landings were slightly smaller in size than US landings (Fig. 7a) while Canadian discards were slightly larger in size than US discards (Fig. 7b). The relative magnitude of landings and discards by each country resulted in total catch for Canada having slightly smaller average size than the total catch for the US (Fig. 8).

Although otoliths are used to determine ages for Grand Bank yellowtail (Walsh and Burnett 2001), age determination of Georges Bank yellowtail flounder using otoliths is hampered by the presence of weak, diffuse or split opaque zones and strong checks, which can make interpretation of annuli subjective and difficult (Stone and Perley 2002). Therefore, scales are the preferred structure for aging Georges Bank yellowtail flounder. Percent agreement on scale ages by the US readers continues to be high (>85% for most studies) with no indication of bias (J. Burnett, NMFS, TRAC Working Paper, 2007).

No scale samples were available for the Canadian fishery in 2006. Therefore, age samples from US port sampling, the NMFS spring and fall surveys and the DFO survey were used to construct the catch at age by sex by half year for the 2006 Canadian landings.

For the US 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 season; Lux 1969), and apportioned to age using pooled-sex age-length keys in half year groups. Landings were converted by market category and half-year, while discards were converted by gear and half-year.

In 2006, ages 2, 3, and 4 (2004, 2003, and 2002 year classes, respectively) dominated both Canadian and US landings, with age 3 predominant (Fig. 9). Since the mid 1990s, ages 2-4 have constituted most of the exploited population, with very low catches of age 1 fish due to the implementation of larger mesh in the cod end of commercial trawl gear (Table 4; Fig. 10).

The fishery mean weights at age for each of the Canadian and US landings and discards were derived using the age-length keys, and applicable length frequencies, and length-weight relationships. The mean weight at age (kg) for the Canadian and US landings were quite similar and generally were more variable at older ages (5+) during the mid 1980s to the mid 1990s. The overall fishery weights at age were calculated from Canadian and US landings and discards, weighting by the respective catch at age (Table 5; Fig. 11). A trend of increasing weight at age is apparent in both fisheries for all ages since 1995, returning to levels seen in the late 1970s/early 1980s. Recent weight at age (WAA) values are within the range of past WAA calculations since 1973.

ABUNDANCE INDICES

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by DFO in the spring (February) and by the US 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 for each survey (Fig. 12). NMFS spring and fall bottom trawl survey catches (strata 13-21), NMFS scallop survey catches (scallop strata 54, 55, 58-72, 74), 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 adjust 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.

Yellowtail flounder biomass indices from the three groundfish surveys correspond with each other reasonably well over the past two decades. DFO survey biomass indices increased from 1995 to 2001 (the highest value in the series), declined through 2004 and fluctuated since (Table 6; Fig. 13). The current index is still higher than any observed during the mid-1990s when the stock had collapsed. The NMFS spring series tracks the DFO series well during the years of overlap up to 1999, then shows a decline through to 2001 followed by a sharp increase in 2002 (Table 7; Fig. 13). Similar to the DFO series, the NMFS spring biomass index sharply declined from 2002 to 2004 (the lowest value since 1994) and has generally increased since. The NMFS fall survey, which is the longest running time series, also increased from 1995 to 1999, fell slightly in 2000 followed by a large increase in 2001 (Table 8; Fig. 13). The NMFS fall index showed a strong decline between 2001 and 2002, and has fluctuated since. The NMFS fall index is at a relatively high level compared to the mid 1990’s when the stock was collapsed. Both the NMFS spring and fall survey indices show high inter-annual variability during the periods of high abundance (i.e. the 1960s and 1970s) which may reflect the patchy distribution of yellowtail on Georges Bank and the low sampling density of NMFS surveys.

The distribution of catches (weight/tow) for the most recent year is compared with the previous five year average for all three surveys in Fig. 3. Since 1996, most of the DFO survey biomass and abundance of yellowtail flounder has occurred in Stratum 5Z4, which includes the lower portion of Closed Area II on the US side, where no commercial groundfish fishing was allowed from December 1994 through 2003 (Fig. 14). Survey indices for this stratum tend to be quite variable due to low sampling intensity, but show a higher level since 1996 relative to pre 1995. Stratum 5Z2 (CDN portion of Georges < 90 m depth) has also shown an increasing trend in biomass and abundance since 1996, but at a lower level than 5Z4. Both the 2005 and 2006 surveys indicate that both biomass and abundance declined within strata 5Z2, despite the fact that there was only a limited Canadian fishery in 2004 and 2005, the 2007 values have increased to approximately half the values seen from 1999 through 2004.

The two NMFS surveys cover a longer time period than the DFO survey and show a greater change in spatial distribution of yellowtail on Georges Bank. Both the NMFS Spring and Fall surveys show a large increase in the importance of stratum 16 over time (Fig. 15). When the DFO survey data is converted to the NEFSC strata using domain estimation (Särndal et al. 1992; see appendix), a similar increasing trend in the importance of stratum 16 over time is also observed (Fig. 15). Stratum 16 contains the lower portion of Closed Area II as well as the "Yellowtail Hole" in Canadian waters. Early in the time series, strata 13 and 19 both contributed substantially to the overall Georges Bank indices for both seasons, but in recent years stratum 16 has accounted for approximately 90% of the survey index in all three series (Fig. 15). The increase in importance of stratum 16 could be due to an increase in density within Closed Area II, a decrease in density in the other strata, or, more likely, both. This indicates that the resource has become much more spatially concentrated on Georges Bank. Given that recent tagging studies have shown that yellowtail move throughout Georges Bank much more than previously thought (Tallack et al. 2005; see also www.cooperative-tagging.org website), changes in density by strata could also be due to a change in behavior over time.

Age-structured indices of abundance for NMFS spring and fall surveys were derived using survey-specific age-length keys. In the past, age-length keys from NMFS spring surveys have been substituted to derive age composition for same-year DFO spring surveys, as no ages were available from the DFO surveys because of difficulties associated with age interpretation from otoliths (Stone and Perley 2002). To avoid having to use substituted age data, NMFS personel are now ageing scales collected on DFO surveys. From the 2007 DFO survey, 342 male and 234 female fish were aged and used to produce separate-sex age-length keys, subsequently used to generate the 2007 DFO age-specific indices of abundance.

All three bottom trawl surveys along with the NMFS scallop survey indicate the possibility of a strong 2005 year-class (Tables 6-9; Figs. 16-17). The NMFS fall 2006 age 1 index is the highest value since 1969 and the NMFS scallop 2006 age 1 index is the highest in the time series, which began in 1982. The NMFS spring 2007 age 2 index is the highest value since 1972 and DFO 2007 age 2 index is the highest value since 2001. The age 1 yellowtail flounder in 2006 would have been too small to be highly selected by the NMFS spring or DFO surveys. Even though all four surveys appear to indicate a strong 2005 year-class, overall, survey age-structured indices do not track cohorts well and there are some indications of year-effects within the time series.

Trends in relative fishing mortality and total mortality from the surveys were examined as part of the consensus benchmark formulations agreed to at the second benchmark assessment meeting in April 2005. Relative fishing mortality (fishery biomass/survey biomass, scaled to the mean for 1987-2005) was quite variable but followed a similar trend for all three surveys, with a sharp decline to low levels in 1995 and a marked increase in 2004 (Fig. 18). In contrast, estimates of total mortality rates from the surveys for ages 2, 3 and 4-6, although noisy, are without trend and indicate no reduction in mortality over time (Fig. 19).

ESTIMATION OF STOCK PARAMETERS

Results from assessment analyses conducted in recent years have displayed: a) retrospective patterns; b) residual patterns that are indicative of a discontinuity starting in 1995; and c) terminal fishing mortality rates (i.e., those associated with the last year of catch in the assessment) that are not consistent with the decline in abundance along cohorts evident in the survey data. Essentially, the catch at age data and assumed natural mortality rate cannot be reconciled with the high survey abundance indices at ages 2 and 3 and low survey abundance at ages 4 and older.

The empirical evidence suggests that significant modifications to assumed population and fishery dynamics are required to reconcile the fishery and the survey observations. Models that adopt such modifications imply major consequences in underlying processes or fishery monitoring procedures. The magnitude of implied changes to natural mortality rate, survey catchability relationships, or unreported catch is beyond realistic expectations.

In view of these reservations, adoption of a benchmark formulation that incorporated these modifications to assumptions, as the sole basis for management advice was not advocated (TRAC 2005). Therefore the TRAC recommended that management advice be formulated after considering the results from two VPA approaches described below. The ‘Minor Change VPA’ developed for the 2005 benchmark assessment was not accepted for subsequent update assessments due to changes in partial recruitment and associated problems in the fitting the model to observed data. The Minor Change VPA was not considered in this assessment.

The VPAs are calibrated using the adaptive framework, ADAPT, (Gavaris 1988) to calibrate the sequential population analysis with the research survey abundance trend results, specifically the NOAA Fisheries Toolbox VPA v2.7. The model formulation employed assumed error in the catch at age was negligible. Errors in the abundance indices were assumed independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data, because the logarithm of zero is undefined. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages. The fishing mortality rates for age groups 5 and 6+ were assumed equal. These model assumptions and methods were the same as those applied in the last assessment (Legault et al. 2006). Both point estimates and bootstrap statistics of the estimated parameters were derived using only the US software for this assessment.

1. Base Case VPA

The Base Case Virtual Population Analysis (VPA) used revised annual catch at age (including US and Canadian discards), $C_{a,t}$, for ages a = 1 to 6+, and time t = 1973 to 2006, 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_1 = DFO spring, ages a = 2 to 6+, time t = 1987 to 2007
s_2 = NMFS spring (Yankee 41), ages a = 1 to 6+, time t = 1973 to 1981
s_3 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 2007
s_4 = NMFS fall, ages a = 1 to 6+, time t = 1973.5 to 2006.5
s_5 = NMFS scallop, age a = 1, time t = 1982.5 to 2006.5

Data were aggregated for ages 6 and older to mitigate against frequent zero observations at older ages. This is the same formulation used since 1996.

2. Major Change VPA
The Major Change VPA recommended during the benchmark assessment expanded the ages from 6+ to 12, assumed a constant small number of fish (1000) survived to the start of age 13, allowed power relationships between indices and population abundance for younger ages (1-3), and split the survey time series at 1995. This model could not be fit well last year or this year due to a lack of catch at old ages creating bimodal bootstrap distributions. Following the procedure of last year, the Major Change VPA was the same as the Base Case VPA with the exception that the survey time series were split at 1995. This one difference was sufficient last year to remove the retrospective pattern and pattern in residuals, and was recommended for management advice because it more closely followed the pattern observed in the indices. This formulation was used again this year as the Major Change VPA. The VPA was calibrated to bottom trawl survey indices, $I_{s,a,t}$, for:

s_1 = DFO spring, ages a = 2 to 6+, time t = 1987 to 1994
s_2 = DFO spring, ages a = 2 to 6+, time t = 1995 to 2007
s_3 = NMFS spring (Yankee 41), ages a = 1 to 6+, time t = 1973 to 1981
s_4 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 1994
s_5 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1995 to 2007
s_6 = NMFS fall, ages a = 1 to 6+, time t = 1973.5 to 1994.5
s_7 = NMFS fall, ages a = 1 to 6+, time t = 1995.5 to 2006.5
s_8 = NMFS scallop, ages a = 1, time t = 1982.5 to 1994.5
s_9 = NMFS scallop, ages a = 1, time t = 1995.5 to 2006.5

Splitting the survey time series at 1995 could not be justified based on changes in the survey design or implementation. Rather the split is considered to alias unknown mechanisms causing the retrospective pattern in the Base Case VPA. Relationships between indices and population abundance for all ages were assumed to be proportional. Population abundance at age 1 in the terminal year was assumed equal to the geometric mean over the most recent 10 years. Population abundance in the terminal year was estimated for ages 2-5.

Diagnostics

Similar to last year, the population abundance estimates for the Base Case VPA show greater relative error in model fit (43%) and relative bias (9%) for age 2 while the relative error for ages 3-5 is lower (28-44%) and the bias is smaller (3-8%; Table 10). The population abundance estimates for the Major Change VPA show less relative error (28-33%) and less relative bias (3-6%) in model fit relative to the Base Case VPA (Table 11).

Survey calibration constants (q's) for the Base Case VPA decline at the oldest age group (6+) for the DFO survey but continue to increase with increasing age for both NMFS surveys (Table 10). Survey calibration constants (q's) for the Major Change VPA follow this pattern for the pre-1995 period, but all three level off or decline at older ages in the recent period (1995 to present) (Table 11). Comparing the q's for each survey by the two time periods shows a large increase in catchability in the recent period, with some ages increasing more than five-fold and a nearly three-fold average increase (Fig. 20). There have been no changes in the survey design or operations that can explain such changes. These changes in q are considered to be aliasing unknown mechanisms for the sole purpose of producing a better fitting model.

The Base Case VPA continues to show a strong residual pattern in the DFO, NMFS Spring, and NMFS Fall surveys (Fig. 21). There is a large block of positive residuals (observed greater than predicted) over all ages from approximately 1996 to 2003 which is preceded by approximately a decade of mostly negative residuals in each of these surveys. The most recent years in the surveys have a mix of positive and negative residuals. The model is predicting an increase in abundance for all ages in recent years that is leveling off while the survey observations have a strong up then down pattern since 1995. The residual pattern for the Major Change VPA is much better than the Base Case VPA with more mixed positive and negative residuals, as expected due to splitting the time series in 1995 (Fig. 22). The average magnitude of residuals has also decreased compared to the Base Case VPA, as expected due to the addition of 18 parameters.

Retrospective analysis for the Base Case VPA indicates a strong tendency to underestimate fishing mortality on ages 4-5 and to overestimate spawning stock biomass (Fig. 23). In contrast, the Major Change VPA did not exhibit a consistent retrospective pattern, updates were both above and below previously estimated values (Fig. 24). The retrospective pattern observed in the Base Case VPA has resulted in decreases to the terminal year spawning stock biomass when updated, averaging a 41% decrease over the past five years (range: 24% to 59% decrease) with the most recent update exhibiting a 37% decrease. The Major Change VPA retrospective results have been both positive and negative over the past five years, averaging a 14% decrease (range: 47% decrease to 59% increase), with the most recent update exhibiting an 18% decrease.

Trends in age 3+ biomass from the Base Case VPA do not follow the same trend in recent years as seen in all three surveys (Figs. 13 and 25), and this model was rejected at the 2007 TRAC meeting as the basis for management advice. The Major Change VPA better reflects the recent trend observed in all three surveys (Figs. 13 and 25) and was recommended by the TRAC as the basis for management advice.

STOCK STATUS

Results from the Major Change VPA model formulation were used to evaluate the status of the stock in 2006 (Tables 12-13). 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). In the US, spawning stock biomass is the preferred metric for biomass and is computed assuming maturity at age and the proportion of mortality within a year that occurs prior to spawning ($p = 0.4167$).

Beginning of year population biomass (Ages 1+) declined from about 32,000 t in 1973 to a historic low of about 4,000 t in 1988, increased through the early 2000s and then declined to 7,093 mt in 2005 and increased to 7,788 mt at the beginning of 2006 (Table 15). Age 3+ (adult) biomass followed a similar trend, with a low of 2,221 mt in 1995, an increase to 11,370 mt in 2003, a decrease to 4,358 mt in 2006, and an increase to 6,232 mt at the beginning of of 2007 (Table 15). Spawning stock biomass also followed a similar pattern, SSB in 2006 was estimated at 5,009 mt (Fig. 26).

Age 1 recruitment improved during the early 2000s compared to the period 1980 to the mid 1990s, but is now returning towards those levels, averaging 24 million age-1 fish during the past five years (Table 12; Fig. 26). Previous assessments had indicated the presence of some larger recruitment in the late 1990s as well, but their magnitudes have subsequently been estimated to be much smaller. The VPA estimates the 2005 year-class as strong (63 million age-1 fish in 2006), comparable to year classes in the 1970s and near the highest value in the time series.

Fishing mortality for fully recruited ages 4+ was close to or above 1.0 between 1973 and 1994, fluctuated between 0.58 and 0.95 during 1996-2003, increased in 2004 to 1.88, and then declined to 0.89 in 2006 (Table 13; Fig. 27, upper panel). Fishing mortality was well above the reference point of F_{ref}=0.25 for the entire time series, which agrees with assessment results from last year, but contrasts with the perception of being below F_{ref} since 1995 as estimated in pre-2005 assessments. The fully recruited (ages 4+) exploitation rate averaged 62% in both VPAs from 1973-1994, declined in 1995, spiked upwards dramatically in 2004 and in 2006 is estimated at 54%, which is well above the 20% exploitation equivalent to F_{ref} (Fig. 27, lower panel). Both the fishing mortality rate and exploitation rate were calculated for ages 4+. Due to the structure of the VPA, the F values for ages 4, 5, and 6+ are all the same. Thus, for these ages the unweighted average F will always be equivalent to the population abundance weighted average F in any year.

FISHERY REFERENCE POINTS

Yield per Recruit Reference Points

Although the yield per recruit analysis was not updated this year, an estimate of $F_{0.1}$ for ages 4+ was calculated from the past yield per recruit analysis of Neilson and Cadrin (1998; $F_{0.1}$ for ages 4+ = 0.25; exploitation rate=20.0%). This is the same value as the F_{MSY} proxy of $F_{40\%MSP}$ used for US management (NEFSC 2002).

Stock and Recruitment

There is evidence of reduced recruitment at low levels (below 5,000 mt) of spawning stock biomass (Fig. 28). Based on the spawning stock biomass and recruitment relationship observed in a previous stock assessment, the B_{MSY} level of 58,800 t of spawning stock biomass was set as the rebuilding goal in the US for this stock (NEFSC 2002). Current levels of SSB are considerably lower than the rebuilding goal (9%).

OUTLOOK

The outlook is typically provided in terms of the possible consequences for alternative catch quotas in 2008 with respect to the harvest reference points. Uncertainty about stock size generates uncertainty in forecast results. It is considered that in this assessment these uncertainties, particularly those associated with the changes in survey catchabilities, are more problematic than in other assessments. As such, the standard risk plots do not capture the extent of uncertainty of the consequences for various catch levels. A sensitivity analysis illustrates the dependence of the projected 2008 catch on the magnitude of the 2005 year-class.

Yield was projected deterministically using 2007 beginning of year population abundance estimates, assuming a 2007 catch equal to the 1,250 mt quota. Recruitment in 2007-2009 was set equal to 20.5 million age-1 fish (geometric mean of the previous ten years), and partial recruitment to the fishery was estimated as the average of the previous three years. Projected total Canada/US yield at F_{ref}= 0.25 in 2008 would be 3,531 mt (Table 16). If fished at F_{ref} in 2008, the total biomass is projected to increase from 25,475 mt in 2008 to 28,951 mt at the beginning of 2009. The 2007 quota of 1,250 t causes projected fully recruited F to be below F_{ref} in 2007(F_{2007}=0.20), due mainly to the 2005 year-class entering the fishery.

The 2005 year-class accounts for 59% of the 2008 catch, 73% of the 2008 age 3+ biomass, and 60% of the 2009 age 3+ biomass. To demonstrate the sensitivity of these projections to the strength of the 2005 year-class, deterministic projections were repeated with the 2007 age 2 value (the 2005 year-class) replaced by the average during 1997-2006 (14.8 million fish at age 2). Catching the 2007 TAC of 1,250 mt and fishing at F_{ref} in 2008 generates a combined Canada/USA catch of 1,989 mt (44% lower than the default projections). The age 3+ biomasses in 2008 and 2009 are 10,018 mt (53% lower than the default) and 13,940 mt (44% lower than the default), respectively. The 2005 year-class now only accounts for 30% of the 2008 catch, 44% of the 2008 age 3+ biomass and 31% of the 2009 age 3+ biomass. This sensitivity analysis is an extreme example because the average age 2 population abundance during 1997-2006 of 14.8 million fish, is well below the lower 80% confidence interval estimated from bootstrapping (34.6 million) and the point estimate (51.5 million) for the 2005 year class at age 2 in 2007. However, in the past, some year-classes that were estimated as strong were later found to be average when the cohort was observed for more years. If a 2008 TAC of 3,531 mt is caught, and the 2005 year-class is only average, the resulting fishing mortality rate would be about twice F_{ref}.

Age structure, fish growth, and spatial distribution reflect stock productivity. The current age structure indicates that very little rebuilding of ages 5 and older has occurred and that the population is still dominated by younger ages 1 through 4 (Fig. 29). Far fewer older fish (6+) are estimated in the VPA in comparison with the population at equilibrium, which is inconsistent with the perception of recent low exploitation. The spatial distribution patterns from the NMFS and DFO surveys suggest a concentration in stratum 16, while the inability of Canadian fishermen to find commercial concentrations of yellowtail the past three years suggests a westward shift in distribution. Truncated age structure in the surveys and change in distribution indicate current productivity may be limited relative to historical levels.

MANAGEMENT CONSIDERATIONS

This assessment is hampered by inconsistencies between the magnitude of the catch, age structure of the catch and the age-specific indices of abundance. Although the catch of old fish has increased in recent years, it is still less than would be expected given the increases seen in the age-specific indices of abundance. The noisy character of the indices cause difficulty in tuning age structured models.

Both VPA formulations have difficulties with interpretation (see benchmark report for full details; TRAC 2005). The Base Case VPA has a strong pattern in residuals and a strong retrospective pattern. The Major Change VPA adds parameters to decrease these patterns in residuals and the retrospective, but the mechanism for the changes in survey catchability are not easily explained. These changes in survey catchability are most appropriately thought of as an aliasing of an unknown mechanism that produces a better fitting model. However, the closer match of the Major Change VPA to the recent trends seen in all three surveys made it the choice for management decisions at the TRAC meeting (O'Boyle and O'Brien, 2007).

Assessments exhibiting retrospective patterns have difficulty making accurate forecasts. This can be observed for Georges Bank yellowtail flounder by comparing the 2006 catch at age from three assessments (Fig. 30). The 2005 assessment made a two year projection of the 2006 catch at age, while the 2006 assessment made a one year projection of the 2006 catch at age, and the 2007 assessment derived the 2006 catch at age from the observed catch. The 2005 assessment projected the 2006 catch at age from the estimated 2004 population abundance assuming the 2005 catch would be 6,000 mt and $F_{2006} = 0.25$. The 2006 assessment projected the 2006 catch at age from the estimated 2005 population abundance assuming the 2006 catch would be 3,000 mt and projected the associated F_{2006} to be 0.30 (Base Case) or 0.83 (Major Change). The 2007 assessment derived the 2006 catch at age from the actual catch of 2,206 mt and estimated F_{2006} to be 0.39 (Base Case) or 0.89 (Major Change). The Base Case shows a progressive increase in F from 0.25, to 0.30 to 0.39 for the 2005-2007 assessments, while the Major Change VPA shows a larger initial change from 0.25 to 0.83 and then a small change to 0.89 for the 2005-2007 assessments, even though the projected catch was much higher in 2005 than actually realized. The distributions at age change more for the Base Case than the Major Change, with the Base Case projecting large numbers of age 4 and 5 fish in the 2005 and 2006 assessments that did not materialize. This highlights the difficulties of assessing this resource because of a strong retrospective pattern of unknown source, truncated age structure, and reliance on incoming year-classes. The current model, while an improvement over the Base Case model, should be used with these uncertainties in mind.

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Table 1. Annual catch (000s mt) of Georges Bank yellowtail flounder.

Year	US landings	US discards	Canadian landings	Canadian discards	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	0.122	-	1.800	18.321
1969	15.944	2.600	0.327	-	2.400	21.271
1970	15.506	5.533	0.071	-	0.250	21.410
1971	11.878	3.127	0.105	-	0.503	15.610
1972	14.157	1.159	0.008	0.515	2.243	18.039
1973	15.899	0.364	0.012	0.378	0.260	16.953
1974	14.607	0.980	0.005	0.619	1.000	17.211
1975	13.205	2.715	0.008	0.722	0.091	16.750
1976	11.336	3.021	0.012	0.619	0.000	14.988
1977	9.444	0.567	0.044	0.584	0.000	10.639
1978	4.519	1.669	0.069	0.687	0.000	6.944
1979	5.475	0.720	0.019	0.722	0.000	6.935
1980	6.481	0.382	0.092	0.584	0.000	7.539
1981	6.182	0.095	0.015	0.687	0.000	6.979
1982	10.621	1.376	0.022	0.502	0.000	12.520
1983	11.350	0.072	0.106	0.460	0.000	11.989
1984	5.763	0.028	0.008	0.481	0.000	6.280
1985	2.477	0.043	0.025	0.722	0.000	3.267
1986	3.041	0.019	0.057	0.357	0.000	3.474
1987	2.742	0.233	0.069	0.536	0.000	3.580
1988	1.866	0.252	0.056	0.584	0.000	2.759
1989	1.134	0.073	0.040	0.536	0.000	1.783
1990	2.751	0.818	0.025	0.495	0.000	4.089
1991	1.784	0.246	0.081	0.454	0.000	2.564
1992	2.859	1.873	0.065	0.502	0.000	5.299
1993	2.089	1.089	0.682	0.440	0.000	4.300
1994	1.589	0.158	2.139	0.440	0.000	4.326
1995	0.292	0.038	0.464	0.268	0.000	1.183
1996	0.751	0.071	0.472	0.388	0.000	1.682
1997	0.966	0.058	0.810	0.438	0.000	2.272
1998	1.822	0.116	1.175	0.708	0.000	3.821
1999	1.987	0.484	1.971	0.597	0.000	5.038
2000	3.678	0.408	2.859	0.415	0.000	7.360
2001	3.792	0.337	2.913	0.815	0.000	7.857
2002	2.532	0.248	2.642	0.493	0.000	5.915
2003	3.343	0.373	2.107	0.809	0.000	6.632
2004	6.208	0.548	0.096	0.422	0.000	7.275
2005	3.327	0.476	0.030	0.255	0.000	4.088
2006	1.239	0.377	0.025	0.565	0.000	2.206

Table 2. Derivation of discards of yellowtail flounder in 2006 by US trawl fishery, US scallop dredge fishery, and Canadian scallop dredge fishery using observer data. The US trawl discards are estimated based on the observed ratio of discarded yellowtail to kept yellowtail. The US dredge discards are estimated based on the observed ratio of discarded yellowtail to kept scallops. The Canadian dredge discards are estimated based on the observed ratio of yellowtail discards per hour fished, using a three month moving window for the d:e values. "N trips" denotes the number of observed trips for each cell. Percentages are for landings, discards, or effort by period for each sector separately.

US Trawl

Period	YT Landings (mt)		d:k ratio	YT Discards (mt)		N trips
Half 1	786.9	64%	0.0440	34.6	33%	154
Half 2	451.3	36%	0.1590	71.7	67%	117
sum	1238.2			**106.4**		271

US Dredge

Area	Period	Scallop Landings (mt meats)		d:k ratio	YT discards (mt)		N trips
CAI	Year	737.7	8%	0.0006	0.5	0%	1
CAII	Half 1	550	6%	0.0149	8.2	3%	9
CAII	Half 2	5058.7	55%	0.0498	251.8	93%	33
Open	Year	2879.6	31%	0.0035	9.9	4%	9
	sum	9226			**270.3**		52

Canadian Dredge

Month	Scallop Effort (hours)		d:e ratio (kg/hour)	YT Discards (mt)		N trips
Jan	507	1%	2.193	1.1	0%	0
Feb	557	2%	5.890	3.3	1%	1
Mar	343	1%	10.466	3.6	1%	1
Apr	1931	5%	15.437	29.8	5%	1
May	3033	8%	53.711	162.9	29%	1
Jun	3383	9%	42.147	142.6	25%	1
Jul	3788	10%	34.556	130.9	23%	1
Aug	4350	12%	8.760	38.1	7%	1
Sep	4540	12%	2.832	12.9	2%	0
Oct	4670	13%	3.017	14.1	2%	2
Nov	5073	14%	2.561	13.0	2%	1
Dec	4817	13%	2.583	12.4	2%	1
sum	36992			**564.7**		11

Table 3. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2006 from Canadian and US sources.

USA	**Port Samples**				*Sea Samples*			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(mt)
1	All	30	3,045	777	93	11,974	0	415
2	All	28	2,628	492	89	6,654	0	373
3	All	18	1,750	413	129	12,553	0	193
4	All	19	1,897	443	41	2,892	0	258
All	All	95	9,320	2,125	352	34,073	0	1,239
Canada	**Port Samples**				**Sea Samples**			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(mt)
1					0			0
2	All	3	650	0	0			15
3					0			7
4	All	1	230	0	0			3
All	All	4	880	0	0			25

Table 4. Total catch at age including discards (number in 000s) for Georges Bank yellowtail flounder, 1973-2006.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	**Total**
1973	359	5175	13565	9473	3815	1285	283	55	23	4	0	0	34037
1974	2368	9500	8294	7658	3643	878	464	106	71	0	0	0	32982
1975	4636	26394	7375	3540	2175	708	327	132	26	14	0	0	45328
1976	635	31938	5502	1426	574	453	304	95	54	11	2	0	40993
1977	378	9094	10567	1846	419	231	134	82	37	10	0	0	22799
1978	9962	3542	4580	1914	540	120	45	16	17	7	6	0	20748
1979	321	10517	3789	1432	623	167	95	31	27	1	3	0	17006
1980	318	3994	9685	1538	352	96	5	11	1	0	0	0	16000
1981	107	1097	5963	4920	854	135	5	2	3	0	0	0	13088
1982	2164	18091	7480	3401	1095	68	20	7	0	0	0	0	32327
1983	703	7998	16661	2476	680	122	13	16	4	0	0	0	28672
1984	514	2018	4535	5043	1796	294	47	39	0	0	0	0	14285
1985	970	4374	1058	818	517	73	8	0	0	0	0	0	7817
1986	179	6402	1127	389	204	80	17	15	0	1	0	0	8414
1987	156	3284	3137	983	192	48	38	26	25	0	0	0	7890
1988	499	3003	1544	846	227	24	26	3	0	0	0	0	6172
1989	190	2175	1121	428	110	18	12	0	0	0	0	0	4054
1990	231	2114	6996	978	140	21	6	0	0	0	0	0	10485
1991	663	147	1491	3011	383	67	4	0	0	0	0	0	5767
1992	2414	9167	2971	1473	603	33	7	1	1	0	0	0	16671
1993	5233	1386	3327	2326	411	84	5	1	0	0	0	0	12773
1994	59	1432	6631	1856	568	95	23	1	0	0	0	0	10666
1995	62	233	1428	986	211	17	23	4	2	0	0	0	2967
1996	54	566	1922	941	234	11	9	3	0	0	0	0	3740
1997	60	745	1502	1827	442	36	55	11	5	0	0	0	4683
1998	64	1496	3224	2134	782	143	26	3	0	2	0	0	7872
1999	37	3694	3583	1731	743	180	34	1	1	0	0	0	10003
2000	155	3840	5985	3120	832	340	43	36	1	0	0	0	14352
2001	284	3065	7622	2824	1093	293	254	23	9	0	0	0	15468
2002	256	4437	3854	1845	670	263	113	62	11	5	0	0	11517
2003	160	3818	4965	2297	777	328	213	93	39	15	1	0	12708
2004	78	1336	3491	4093	2088	919	429	85	73	20	2	0	12613
2005	52	1590	4292	1820	420	143	39	18	0	0	0	0	8375
2006	49	1221	1660	977	367	126	66	18	7	3	0	0	4495

Table 5. Mean weight at age (kg) for the total catch including US and Canadian discards, for Georges Bank yellowtail flounder, 1973-2006.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.101	0.348	0.462	0.527	0.603	0.690	1.063	1.131	1.275	1.389	1.170	
1974	0.115	0.344	0.496	0.607	0.678	0.723	0.904	1.245	1.090		1.496	1.496
1975	0.113	0.316	0.489	0.554	0.619	0.690	0.691	0.654	1.052	0.812		
1976	0.108	0.312	0.544	0.635	0.744	0.813	0.854	0.881	1.132	1.363	1.923	
1977	0.116	0.342	0.524	0.633	0.780	0.860	1.026	1.008	0.866	0.913		
1978	0.102	0.314	0.510	0.690	0.803	0.903	0.947	1.008	1.227	1.581	0.916	
1979	0.114	0.329	0.462	0.656	0.736	0.844	0.995	0.906	1.357	1.734	1.911	
1980	0.101	0.322	0.493	0.656	0.816	1.048	1.208	1.206	1.239			
1981	0.122	0.335	0.489	0.604	0.707	0.821	0.844	1.599	1.104			
1982	0.115	0.301	0.485	0.650	0.754	1.065	1.037	1.361				
1983	0.140	0.296	0.441	0.607	0.740	0.964	1.005	1.304	1.239			
1984	0.162	0.239	0.379	0.500	0.647	0.743	0.944	1.032				
1985	0.181	0.361	0.505	0.642	0.729	0.808	0.728					
1986	0.181	0.341	0.540	0.674	0.854	0.976	0.950	1.250		1.686		
1987	0.121	0.324	0.524	0.680	0.784	0.993	0.838	0.771	0.809			
1988	0.103	0.328	0.557	0.696	0.844	1.042	0.865	1.385				
1989	0.100	0.327	0.520	0.720	0.866	0.970	1.172	1.128				
1990	0.105	0.290	0.395	0.585	0.693	0.787	1.057					
1991	0.121	0.237	0.369	0.486	0.723	0.850	1.306					
1992	0.101	0.293	0.365	0.526	0.651	1.098	1.125	1.303	1.303			
1993	0.100	0.285	0.379	0.501	0.564	0.843	1.130	1.044				
1994	0.195	0.255	0.348	0.469	0.620	0.810	0.723	1.257				
1995	0.167	0.246	0.352	0.463	0.584	0.766	0.805	0.532	0.810			
1996	0.140	0.292	0.412	0.563	0.721	0.916	1.062	1.287				
1997	0.206	0.319	0.421	0.537	0.690	0.837	0.878	1.184	1.126			
1998	0.184	0.325	0.447	0.543	0.690	0.903	0.932	1.195		1.473		
1999	0.190	0.369	0.503	0.638	0.756	0.900	1.030	1.496	1.822			
2000	0.220	0.379	0.481	0.613	0.762	0.915	1.020	0.996	1.229			
2001	0.225	0.343	0.456	0.624	0.808	1.013	1.023	1.272	1.483			
2002	0.263	0.382	0.489	0.668	0.829	0.983	1.062	1.282	1.389	1.433		
2003	0.226	0.360	0.477	0.652	0.830	0.945	1.033	1.148	1.273	1.432	1.708	
2004	0.194	0.292	0.436	0.581	0.723	0.884	1.001	1.206	1.207	1.306	1.421	
2005	0.129	0.346	0.447	0.599	0.763	0.965	0.984	1.221	1.578	1.578		
2006	0.110	0.320	0.419	0.557	0.762	0.912	1.058	1.178	1.256	1.202	1.599	

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

	Age													Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total	(000 mt)
1987	0.12	0.99	2.00	0.64	0.12	0.00	0.02	0.02	0.00	0.00	0.00	0.00	3.91	1.26
1988	0.00	1.59	1.29	0.76	0.30	0.01	0.02	0.00	0.00	0.00	0.00	0.00	3.96	1.24
1989	0.11	0.94	0.58	0.36	0.09	0.01	0.02	0.01	0.00	0.00	0.00	0.00	2.13	0.47
1990	0.00	2.36	3.38	1.06	0.32	0.01	0.02	0.00	0.00	0.00	0.00	0.00	7.15	1.58
1991	0.02	0.86	1.53	3.23	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.37	1.76
1992	0.06	10.74	3.97	1.03	0.30	0.01	0.00	0.02	0.01	0.00	0.00	0.00	16.14	2.48
1993	0.08	2.24	3.26	4.41	1.64	0.05	0.01	0.00	0.00	0.00	0.00	0.00	11.69	2.64
1994	0.00	6.06	3.46	3.01	0.78	0.13	0.03	0.04	0.00	0.00	0.00	0.00	13.51	2.75
1995	0.21	1.19	4.28	2.55	0.79	0.05	0.04	0.00	0.00	0.00	0.00	0.00	9.11	2.03
1996	0.45	6.65	8.58	6.61	1.01	0.09	0.02	0.03	0.00	0.00	0.00	0.00	23.45	5.30
1997	0.02	9.78	14.67	17.96	4.32	0.53	0.11	0.09	0.00	0.00	0.00	0.00	47.49	13.29
1998	0.89	3.18	4.89	4.50	2.02	0.46	0.03	0.01	0.00	0.02	0.00	0.00	16.01	4.29
1999	0.16	11.84	27.24	7.95	7.30	2.21	0.34	0.04	0.00	0.00	0.00	0.00	57.07	17.67
2000	0.01	9.47	32.90	17.80	5.54	2.96	0.32	0.22	0.00	0.00	0.00	0.00	69.22	19.95
2001	0.29	15.18	47.13	13.35	3.70	1.95	0.90	0.10	0.00	0.00	0.00	0.00	82.60	22.16
2002	0.09	9.67	33.73	11.27	5.97	1.54	0.95	0.38	0.08	0.00	0.00	0.00	63.68	20.62
2003	0.07	6.76	27.36	13.45	3.57	0.86	0.62	0.25	0.12	0.04	0.00	0.00	53.09	16.25
2004	0.03	3.60	16.26	9.21	2.27	0.63	0.23	0.46	0.09	0.00	0.00	0.00	32.79	14.01
2005	0.60	1.60	27.96	20.56	5.70	1.04	0.40	0.10	0.01	0.01	0.00	0.00	57.99	13.36
2006	0.00	4.89	18.60	6.57	0.82	0.16	0.08	0.00	0.00	0.00	0.00	0.00	31.12	6.50
2007	0.05	12.16	27.71	12.80	2.29	0.22	0.03	0.00	0.00	0.00	0.00	0.00	55.26	13.34

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

	Age													Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total	kg/tow
1968	0.15	3.36	3.58	0.32	0.08	0.16	0.13	0.00	0.00	0.00	0.00	0.00	7.78	2.81
1969	1.02	9.41	11.12	3.10	1.42	0.45	0.19	0.06	0.00	0.00	0.00	0.00	26.76	11.17
1970	0.09	4.49	6.03	2.42	0.57	0.12	0.19	0.00	0.00	0.00	0.00	0.00	13.91	5.31
1971	0.79	3.34	4.62	3.75	0.76	0.23	0.05	0.01	0.00	0.02	0.00	0.00	13.56	4.61
1972	0.14	7.14	7.20	3.51	1.09	0.05	0.12	0.00	0.00	0.00	0.00	0.00	19.25	6.45
1973	1.93	3.27	2.37	1.06	0.41	0.17	0.02	0.02	0.00	0.00	0.00	0.00	9.25	2.94
1974	0.32	2.22	1.84	1.26	0.35	0.19	0.09	0.00	0.00	0.00	0.01	0.00	6.27	2.72
1975	0.42	2.94	0.86	0.30	0.21	0.07	0.00	0.01	0.00	0.00	0.00	0.00	4.81	1.68
1976	1.03	4.37	1.25	0.31	0.20	0.03	0.05	0.02	0.02	0.00	0.00	0.00	7.27	2.27
1977	0.00	0.67	1.13	0.38	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	2.27	1.00
1978	0.94	0.80	0.51	0.22	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	2.49	0.74
1979	0.28	1.93	0.39	0.33	0.06	0.05	0.04	0.00	0.00	0.00	0.00	0.00	3.07	1.23
1980	0.06	4.64	5.76	0.47	0.06	0.04	0.00	0.00	0.00	0.00	0.00	0.00	11.03	4.46
1981	0.01	1.03	1.78	0.72	0.21	0.06	0.00	0.03	0.00	0.00	0.00	0.00	3.83	1.96
1982	0.05	3.74	1.12	1.02	0.46	0.07	0.00	0.03	0.00	0.00	0.00	0.00	6.47	2.50
1983	0.00	1.87	2.73	0.53	0.12	0.09	0.06	0.09	0.00	0.00	0.00	0.00	5.49	2.64
1984	0.00	0.09	0.81	0.89	0.83	0.24	0.00	0.00	0.00	0.00	0.00	0.00	2.87	1.65
1985	0.11	2.20	0.26	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.99
1986	0.03	1.81	0.29	0.06	0.14	0.06	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.85
1987	0.00	0.13	0.11	0.13	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.33
1988	0.08	0.28	0.37	0.24	0.20	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.57
1989	0.05	0.42	0.74	0.29	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	1.61	0.73
1990	0.00	0.06	1.11	0.39	0.14	0.01	0.04	0.00	0.00	0.00	0.00	0.00	1.76	0.70
1991	0.44	0.00	0.25	0.68	0.27	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.63
1992	0.00	2.01	1.95	0.60	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.74	1.57
1993	0.05	0.29	0.50	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.48
1994	0.00	0.62	0.64	0.36	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.66
1995	0.04	1.18	4.81	1.49	0.64	0.01	0.00	0.00	0.00	0.00	0.00	0.00	8.17	2.58
1996	0.03	0.99	2.63	2.70	0.61	0.06	0.00	0.00	0.00	0.00	0.00	0.00	7.02	2.85
1997	0.02	1.17	3.73	4.08	0.70	0.13	0.00	0.00	0.00	0.00	0.00	0.00	9.84	4.36
1998	0.00	2.08	1.05	1.16	0.76	0.32	0.03	0.00	0.00	0.00	0.00	0.00	5.40	2.32
1999	0.05	4.75	10.82	2.72	1.62	0.43	0.33	0.00	0.02	0.00	0.00	0.00	20.74	9.31
2000	0.18	4.82	7.67	2.91	0.81	0.42	0.10	0.00	0.00	0.00	0.00	0.00	16.92	6.70
2001	0.00	2.31	6.56	2.41	0.48	0.35	0.10	0.00	0.00	0.00	0.00	0.00	12.23	5.01
2002	0.19	2.41	12.33	4.08	1.74	0.38	0.41	0.09	0.00	0.00	0.00	0.00	21.62	9.57
2003	0.20	4.37	6.76	2.88	0.44	0.13	0.54	0.20	0.00	0.00	0.00	0.00	15.52	6.72
2004	0.05	0.99	2.18	0.68	0.28	0.11	0.05	0.08	0.00	0.00	0.00	0.00	4.42	1.89
2005	0.00	2.01	5.08	2.40	0.27	0.04	0.05	0.03	0.00	0.00	0.00	0.00	9.88	3.40
2006	0.51	0.94	3.52	2.18	0.32	0.08	0.00	0.00	0.00	0.00	0.00	0.00	7.54	2.42
2007	0.09	5.05	6.26	2.85	0.56	0.11	0.02	0.00	0.00	0.00	0.00	0.00	14.93	4.70

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

	Age															Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	(kg/tow)
1963	14.72	7.90	11.23	1.86	0.50	0.28	0.03	0.16	0.07	0.00	0.00	0.00	0.00	0.00	36.75	12.79
1964	1.72	9.72	7.37	6.00	2.69	0.38	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	28.01	13.63
1965	1.14	5.58	5.47	3.86	1.80	0.16	0.28	0.04	0.00	0.00	0.00	0.00	0.00	0.00	18.33	9.10
1966	8.77	4.78	2.07	0.84	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.60	3.99
1967	9.14	9.31	2.70	1.01	0.31	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.60	7.58
1968	11.78	11.95	5.76	0.77	0.94	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.25	10.53
1969	8.11	10.38	5.86	1.66	0.55	0.15	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.89	9.28
1970	4.61	5.13	3.14	1.95	0.45	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.37	4.98
1971	3.63	6.95	4.90	2.25	0.55	0.23	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	18.56	6.36
1972	2.42	6.53	4.82	2.10	0.67	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.82	6.33
1973	2.49	5.50	5.10	2.94	1.22	0.42	0.17	0.00	0.03	0.00	0.00	0.00	0.00	0.00	17.87	6.60
1974	4.62	2.85	1.52	1.06	0.46	0.25	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.90	3.73
1975	4.63	2.51	0.88	0.57	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	8.98	2.36
1976	0.34	1.93	0.48	0.12	0.12	0.03	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	3.08	1.53
1977	0.93	2.16	1.65	0.62	0.11	0.06	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.58	2.83
1978	4.73	1.27	0.77	0.41	0.14	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	7.35	2.38
1979	1.31	2.00	0.32	0.12	0.14	0.04	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	4.00	1.52
1980	0.76	5.09	6.05	0.68	0.22	0.16	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	12.99	6.72
1981	1.58	2.33	1.63	0.50	0.12	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.26	2.62
1982	2.42	2.19	1.59	0.42	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.71	2.27
1983	0.11	2.28	1.91	0.47	0.07	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	4.90	2.13
1984	0.66	0.40	0.31	2.43	0.09	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	3.93	0.59
1985	1.35	0.56	0.16	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.19	0.71
1986	0.28	1.11	0.35	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.82
1987	0.11	0.39	0.40	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.51
1988	0.02	0.21	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.17
1989	0.25	1.99	0.77	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15	0.98
1990	0.00	0.33	1.52	0.28	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.72
1991	2.10	0.28	0.44	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.17	0.73
1992	0.15	0.40	0.71	0.16	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	0.58
1993	0.84	0.14	0.59	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.55
1994	1.20	0.22	0.98	0.71	0.26	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	0.90
1995	0.28	0.12	0.35	0.28	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.35
1996	0.14	0.35	1.87	0.45	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	1.30
1997	1.39	0.53	3.44	2.09	1.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.61	3.78
1998	1.90	4.82	4.20	1.19	0.30	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.48	4.35
1999	3.09	8.42	5.73	1.43	1.44	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.37	7.97
2000	0.63	1.70	4.81	2.42	0.95	0.80	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.34	5.84
2001	3.52	6.27	8.09	2.60	1.72	0.71	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.24	11.55
2002	2.09	5.75	2.13	0.59	0.28	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	10.90	3.76
2003	1.10	5.01	2.81	0.56	0.10	0.09	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	9.77	4.04
2004	0.88	5.51	5.01	2.11	0.92	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.60	5.12
2005	0.31	2.10	3.76	0.57	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.97	2.46
2006	6.19	6.25	3.66	1.17	0.26	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.58	4.52

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

Year	Number per tow
1982	0.313
1983	0.140
1984	0.233
1985	0.549
1986	0.103
1987	0.047
1988	0.116
1989	0.195
1990	0.100
1991	2.117
1992	0.167
1993	1.129
1994	1.503
1995	0.609
1996	0.508
1997	1.062
1998	1.872
1999	1.038
2000	0.912
2001	0.789
2002	1.005
2003	0.880
2004	0.330
2005	0.573
2006	2.422

Table 10. Statistical properties of estimates for population abundance and survey calibration constants (x10^3) for Georges Bank yellowtail flounder for the Base Case VPA using US ADAPT software.

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
	<u>Population Abundance</u>				
2	73601	31920	43%	6406	9%
3	16152	7063	44%	1330	8%
4	8481	3029	36%	456	5%
5	1846	508	28%	51	3%
	<u>Survey Calibration Constants</u>				
DFO Survey: 1987-2007 (Ages 2-6+)					
2	0.290	0.052	18%	0.006	2%
3	1.010	0.197	20%	0.020	2%
4	1.456	0.251	17%	0.030	2%
5	1.511	0.271	18%	0.018	1%
6+	1.092	0.244	22%	0.019	2%
NMFS Spring Survey: Yankee 41, 1973-1981 (Ages 1-6+)					
1	0.007	0.007	90%	0.002	28%
2	0.077	0.014	19%	0.001	1%
3	0.098	0.017	17%	0.001	1%
4	0.096	0.011	11%	0.001	1%
5	0.076	0.014	19%	0.001	2%
6+	0.076	0.028	37%	0.004	5%
NMFS Spring Survey: Yankee 36, 1982-2007 (Ages 1-6+)					
1	0.004	0.001	19%	0.000	2%
2	0.080	0.015	19%	0.003	3%
3	0.216	0.044	20%	0.007	3%
4	0.293	0.049	17%	0.004	1%
5	0.334	0.057	17%	0.007	2%
6+	0.418	0.072	17%	0.009	2%
NMFS Fall Survey: 1973-2006 (Ages 1-6+)					
1	0.046	0.008	18%	0.001	1%
2	0.115	0.019	16%	0.001	1%
3	0.230	0.029	13%	0.002	1%
4	0.235	0.032	14%	0.002	1%
5	0.291	0.047	16%	0.002	1%
6+	0.332	0.071	21%	0.009	3%
NMFS Scallop Survey: 1982-2006 (Age 1)					
1	0.032	0.006	18%	0.000	1%

Table 11. Statistical properties of estimates for population abundance and survey calibration constants (x10^3) for Georges Bank yellowtail flounder for the Major Change VPA using US ADAPT software. (Table continues on next page)

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
	Population Abundance				
2	51480	16057	31%	2416	5%
3	8867	2581	29%	267	3%
4	4146	1141	28%	180	4%
5	610	202	33%	36	6%
	Survey Calibration Constants				
DFO Survey: 1987-1994 (Ages 2-6+)					
2	0.213	0.077	36%	0.014	6%
3	0.365	0.048	13%	0.004	1%
4	0.675	0.101	15%	0.005	1%
5	0.848	0.217	26%	0.031	4%
6+	0.525	0.110	21%	0.010	2%
DFO Survey: 1995-2007 (Ages 2-6+)					
2	0.400	0.067	17%	0.005	1%
3	2.133	0.313	15%	0.020	1%
4	2.652	0.351	13%	0.020	1%
5	2.520	0.449	18%	0.019	1%
6+	1.895	0.418	22%	0.039	2%
NMFS Spring Survey: Yankee 41, 1973-1981 (Ages 1-6+)					
1	0.007	0.006	82%	0.002	24%
2	0.077	0.014	18%	0.002	3%
3	0.098	0.016	17%	0.002	2%
4	0.096	0.011	12%	0.000	0%
5	0.076	0.015	19%	0.001	2%
6+	0.076	0.026	34%	0.004	6%
NMFS Spring Survey: Yankee 36, 1982-1994 (Ages 1-6+)					
1	0.005	0.001	27%	0.000	2%
2	0.049	0.014	29%	0.003	5%
3	0.096	0.016	17%	0.001	1%
4	0.156	0.019	12%	0.001	1%
5	0.237	0.049	21%	0.007	3%
6+	0.441	0.082	19%	0.010	2%
NMFS Spring Survey: Yankee 36, 1995-2007 (Ages 1-6+)					
1	0.005	0.001	31%	0.000	3%
2	0.143	0.017	12%	0.001	1%
3	0.553	0.092	17%	0.007	1%
4	0.626	0.105	17%	0.010	2%
5	0.551	0.118	21%	0.014	2%
6+	0.469	0.102	22%	0.013	3%

NMFS Fall Survey: 1973-1994 (Ages 1-6+)					
1	0.041	0.010	25%	0.001	3%
2	0.089	0.014	16%	0.000	0%
3	0.155	0.015	9%	0.000	0%
4	0.172	0.025	15%	0.002	1%
5	0.218	0.034	16%	0.003	1%
6+	0.315	0.071	23%	0.006	2%
NMFS Fall Survey: 1995-2006 (Ages 1-6+)					
1	0.064	0.016	24%	0.002	2%
2	0.208	0.077	37%	0.010	5%
3	0.531	0.101	19%	0.012	2%
4	0.468	0.086	18%	0.002	0%
5	0.506	0.150	30%	0.018	4%
6+	0.392	0.152	39%	0.021	5%
NMFS Scallop Survey: 1982-1994 (Age 1)					
1	0.024	0.007	31%	0.001	3%
NMFS Scallop Survey: 1995-2006 (Age 1)					
1	0.051	0.005	10%	0.000	0%

Table 12. Beginning of year population abundance numbers (000s) for Georges Bank yellowtail flounder from the Major Change VPA.

	Age Group						
Year	1	2	3	4	5	6+	Total
1973	29386	24172	29516	17301	6967	3013	110355
1974	52186	23735	15136	12051	5733	2392	111234
1975	70632	40589	10932	5010	3078	1708	131951
1976	24731	53646	9853	2427	977	1562	93196
1977	17280	19675	15555	3172	720	851	57252
1978	54436	13807	7988	3391	957	374	80952
1979	25511	35603	8122	2468	1074	560	73337
1980	24034	20596	19711	3267	748	240	68595
1981	62999	19390	13269	7498	1302	221	104679
1982	22847	51482	14885	5537	1783	156	96691
1983	6582	16754	25939	5517	1515	345	56653
1984	10842	4755	6579	6473	2305	486	31441
1985	16748	8413	2089	1379	871	137	29637
1986	8473	12837	2990	767	402	223	25692
1987	9199	6775	4801	1439	281	201	22696
1988	22877	7390	2617	1153	309	72	34419
1989	9732	18280	3364	771	198	54	32399
1990	11542	7796	13006	1749	250	47	34390
1991	22787	9241	4485	4419	562	104	41598
1992	18341	18058	7433	2335	956	67	47189
1993	13958	12841	6612	3427	606	134	37579
1994	10659	6742	9264	2447	749	157	30019
1995	11124	8674	4232	1734	371	83	26217
1996	13179	9051	6891	2185	543	53	31903
1997	18432	10742	6900	3916	947	229	41167
1998	23897	15037	8122	4298	1575	348	53278
1999	25540	19508	10962	3765	1616	470	61861
2000	21029	20877	12647	5762	1537	776	62628
2001	23780	17077	13637	5013	1940	1029	62476
2002	16169	19213	11223	4384	1592	1081	53662
2003	12200	13007	11742	5734	1940	1720	46343
2004	12495	9844	7222	5174	2639	1932	39306
2005	14927	10160	6856	2798	646	307	35694
2006	62932	12174	6886	1807	679	407	84885
2007		51480	8867	4146	610	366	

Table 13. Fishing mortality rate for Georges Bank yellowtail from the Major Change VPA.

	Age Group						
Year	1	2	3	4	5	6+	4-5
1973	0.01	0.27	0.70	0.90	0.90	0.90	0.90
1974	0.05	0.58	0.91	1.16	1.16	1.16	1.16
1975	0.08	1.22	1.31	1.43	1.43	1.43	1.43
1976	0.03	1.04	0.93	1.02	1.02	1.02	1.02
1977	0.02	0.70	1.32	1.00	1.00	1.00	1.00
1978	0.22	0.33	0.97	0.95	0.95	0.95	0.95
1979	0.01	0.39	0.71	0.99	0.99	0.99	0.99
1980	0.01	0.24	0.77	0.72	0.72	0.72	0.72
1981	0.00	0.06	0.67	1.24	1.24	1.24	1.24
1982	0.11	0.49	0.79	1.10	1.10	1.10	1.10
1983	0.13	0.73	1.19	0.67	0.67	0.67	0.67
1984	0.05	0.62	1.36	1.81	1.81	1.81	1.81
1985	0.07	0.83	0.80	1.03	1.03	1.03	1.03
1986	0.02	0.78	0.53	0.80	0.80	0.80	0.80
1987	0.02	0.75	1.23	1.34	1.34	1.34	1.34
1988	0.02	0.59	1.02	1.56	1.56	1.56	1.56
1989	0.02	0.14	0.45	0.92	0.92	0.92	0.92
1990	0.02	0.35	0.88	0.94	0.94	0.94	0.94
1991	0.03	0.02	0.45	1.33	1.33	1.33	1.33
1992	0.16	0.80	0.57	1.15	1.15	1.15	1.15
1993	0.53	0.13	0.79	1.32	1.32	1.32	1.32
1994	0.01	0.27	1.48	1.69	1.69	1.69	1.69
1995	0.01	0.03	0.46	0.96	0.96	0.96	0.96
1996	0.00	0.07	0.37	0.64	0.64	0.64	0.64
1997	0.00	0.08	0.27	0.71	0.71	0.71	0.71
1998	0.00	0.12	0.57	0.78	0.78	0.78	0.78
1999	0.00	0.23	0.44	0.70	0.70	0.70	0.70
2000	0.01	0.23	0.73	0.89	0.89	0.89	0.89
2001	0.01	0.22	0.93	0.95	0.95	0.95	0.95
2002	0.02	0.29	0.47	0.62	0.62	0.62	0.62
2003	0.01	0.39	0.62	0.58	0.58	0.58	0.58
2004	0.01	0.16	0.75	1.88	1.88	1.88	1.88
2005	0.00	0.19	1.13	1.22	1.22	1.22	1.22
2006	0.00	0.12	0.31	0.89	0.89	0.89	0.89

Table 14. Beginning of year weight (kg) at age for Georges Bank yellowtail. The 2007 values are set equal to the average of the 2004-2006 values.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	6+
1973	0.01	0.23	0.401	0.493	0.564	0.645	0.856	1.096	1.1	1.3	1.4	1.5	0.704
1974	0.01	0.23	0.415	0.530	0.598	0.660	0.790	1.150	1.1	1.3	1.4	1.5	0.755
1975	0.01	0.23	0.410	0.524	0.613	0.684	0.707	0.769	1.1	1.3	1.4	1.5	0.715
1976	0.01	0.23	0.415	0.557	0.642	0.709	0.768	0.780	1.1	1.3	1.4	1.5	0.767
1977	0.01	0.23	0.404	0.587	0.704	0.800	0.913	0.928	1.1	1.3	1.4	1.5	0.885
1978	0.01	0.23	0.418	0.601	0.713	0.839	0.902	1.017	1.1	1.3	1.4	1.5	0.918
1979	0.01	0.23	0.381	0.578	0.713	0.823	0.948	0.926	1.1	1.3	1.4	1.5	0.900
1980	0.01	0.23	0.403	0.551	0.732	0.878	1.010	1.095	1.1	1.3	1.4	1.5	0.907
1981	0.01	0.23	0.397	0.546	0.681	0.818	0.940	1.390	1.1	1.3	1.4	1.5	0.837
1982	0.01	0.23	0.403	0.564	0.675	0.868	0.923	1.072	1.1	1.3	1.4	1.5	0.895
1983	0.01	0.23	0.364	0.543	0.694	0.853	1.035	1.163	1.1	1.3	1.4	1.5	0.907
1984	0.01	0.23	0.335	0.470	0.627	0.741	0.954	1.018	1.1	1.3	1.4	1.5	0.796
1985	0.01	0.23	0.347	0.493	0.604	0.723	0.735	1.019	1.1	1.3	1.4	1.5	0.724
1986	0.01	0.23	0.442	0.583	0.740	0.844	0.876	0.954	1.1	1.3	1.4	1.5	0.867
1987	0.01	0.23	0.423	0.606	0.727	0.921	0.904	0.856	1.1	1.3	1.4	1.5	0.936
1988	0.01	0.23	0.425	0.604	0.758	0.904	0.927	1.077	1.1	1.3	1.4	1.5	0.925
1989	0.01	0.23	0.413	0.633	0.776	0.905	1.105	0.988	1.1	1.3	1.4	1.5	0.987
1990	0.01	0.23	0.359	0.552	0.706	0.826	1.013	1.135	1.1	1.3	1.4	1.5	0.866
1991	0.01	0.23	0.327	0.438	0.650	0.767	1.014	1.078	1.1	1.3	1.4	1.5	0.782
1992	0.01	0.23	0.294	0.441	0.562	0.891	0.978	1.304	1.1	1.3	1.4	1.5	0.917
1993	0.01	0.23	0.333	0.428	0.545	0.741	1.114	1.084	1.1	1.3	1.4	1.5	0.767
1994	0.01	0.23	0.315	0.422	0.557	0.676	0.781	1.192	1.1	1.3	1.4	1.5	0.702
1995	0.01	0.23	0.300	0.401	0.523	0.689	0.807	0.620	1.1	1.3	1.4	1.5	0.760
1996	0.01	0.23	0.318	0.445	0.578	0.731	0.902	1.018	1.1	1.3	1.4	1.5	0.836
1997	0.01	0.23	0.351	0.470	0.623	0.777	0.897	1.121	1.1	1.3	1.4	1.5	0.889
1998	0.01	0.23	0.378	0.478	0.609	0.789	0.883	1.024	1.1	1.3	1.4	1.5	0.812
1999	0.01	0.23	0.404	0.534	0.641	0.788	0.964	1.181	1.1	1.3	1.4	1.5	0.819
2000	0.01	0.23	0.421	0.555	0.697	0.832	0.958	1.013	1.1	1.3	1.4	1.5	0.861
2001	0.01	0.23	0.416	0.548	0.704	0.879	0.967	1.139	1.1	1.3	1.4	1.5	0.932
2002	0.01	0.23	0.410	0.552	0.719	0.891	1.037	1.145	1.1	1.3	1.4	1.5	0.972
2003	0.01	0.23	0.427	0.565	0.745	0.885	1.008	1.104	1.1	1.3	1.4	1.5	0.974
2004	0.01	0.23	0.396	0.526	0.687	0.857	0.973	1.116	1.1	1.3	1.4	1.5	0.922
2005	0.01	0.23	0.361	0.511	0.666	0.835	0.933	1.105	1.1	1.3	1.4	1.5	0.879
2006	0.01	0.23	0.381	0.499	0.675	0.834	1.011	1.077	1.1	1.3	1.4	1.5	0.922
2007	0.01	0.23	0.379	0.512	0.676	0.842	0.972	1.099	1.1	1.3	1.4	1.5	0.908

Table 15. Beginning of year biomass (mt) and spawning stock biomass (mt) for Georges Bank yellowtail from the Major Change VPA.

	Beginning Biomass		
Year	1+	3+	SSB
1973	32275	26422	21899
1974	23884	17903	14772
1975	20261	10219	8967
1976	19850	7264	9950
1977	14108	9410	8353
1978	10119	6400	6160
1979	14234	5790	8424
1980	15479	10501	10902
1981	15518	10429	10411
1982	22534	10465	13412
1983	17727	13808	11347
1984	8277	7075	4269
1985	4133	2031	3506
1986	5296	2259	4608
1987	4944	3294	3486
1988	4037	2109	3044
1989	6386	2085	6647
1990	7765	5856	5717
1991	6204	3850	4519
1992	8150	3814	4597
1993	7195	4102	4239
1994	6134	4477	2907
1995	4327	2221	2648
1996	5738	3525	4340
1997	7711	5056	5665
1998	10061	6364	6982
1999	12605	7863	9547
2000	15279	10267	10451
2001	14905	10740	9462
2002	13792	9212	10515
2003	14484	11370	10482
2004	11567	9178	5950
2005	7093	4607	4438
2006	7788	4358	5009
2007		6232	

Table 16. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2008 at F_{Ref} using the Major Change VPA.

Year	Age Group							
	1	2	3	4	5	6+	1+	3+
Beginning of Year Population Numbers (000s)								
2007	20487	51480	8867	4146	610	366		
2008	20487	16764	41163	6499	2775	653		
2009	20487	16761	13328	29376	4144	2186		
Partial Recruitment to the Fishery								
	0.003	0.117	0.549	1.000	1.000	1.000		
Fishing Mortality								
2007	0.001	0.024	0.111	0.201	0.201	0.201		
2008	0.001	0.029	0.137	0.250	0.250	0.250		
Weight at beginning of year for population (kg)								
	0.010	0.230	0.379	0.512	0.676	0.908		
Maturity			*Fraction of Z before Spawning =*			0.4167		
	0	0.52	0.86	1	1	1		
Beginning of Year Projected Population Biomass (t)								
2007	205	11840	3364	2124	412	332	18278	6232
2008	205	3856	15617	3329	1876	593	25475	21415
2009	205	3855	5056	15049	2801	1984	28951	24891
Spawning Stock Biomass (t)								
2007	0	7784	2908	2032	386	304	13414	
2008	0	2529	13349	3121	1724	531	21254	
Projected Catch Numbers (000s)								
2007	11	1091	844	688	101	61		
2008	14	440	4799	1308	559	131		
Average weight for catch (kg)								
	0.144	0.319	0.434	0.579	0.749	0.981		
Projected Yield (t)								
2007	2	348	366	399	76	60	**1250**	
2008	2	140	2083	758	419	129	**3531**	

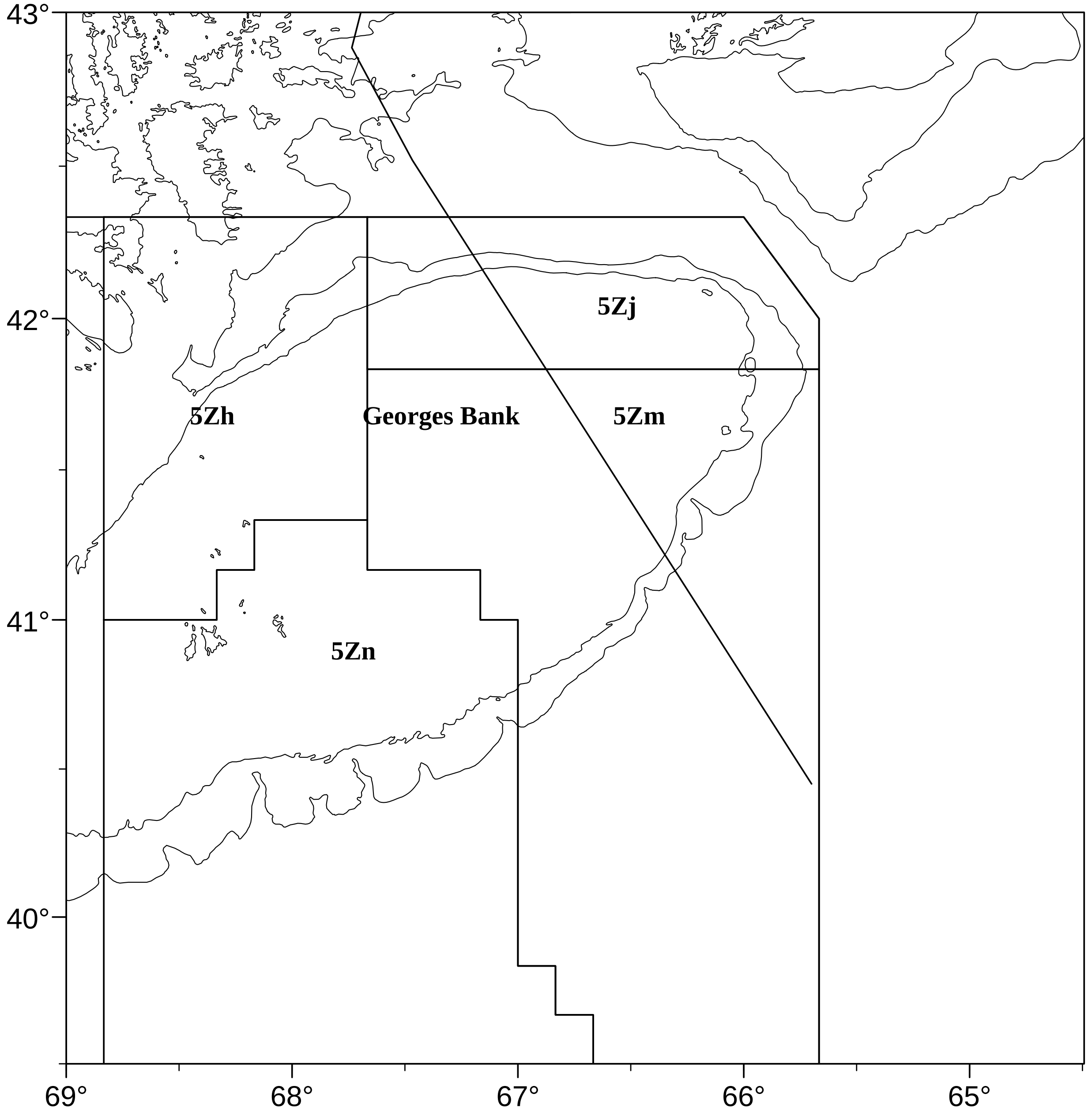


Figure 1a. Location of statistical unit areas for Canadian fisheries in NAFO Subdivision 5Ze.

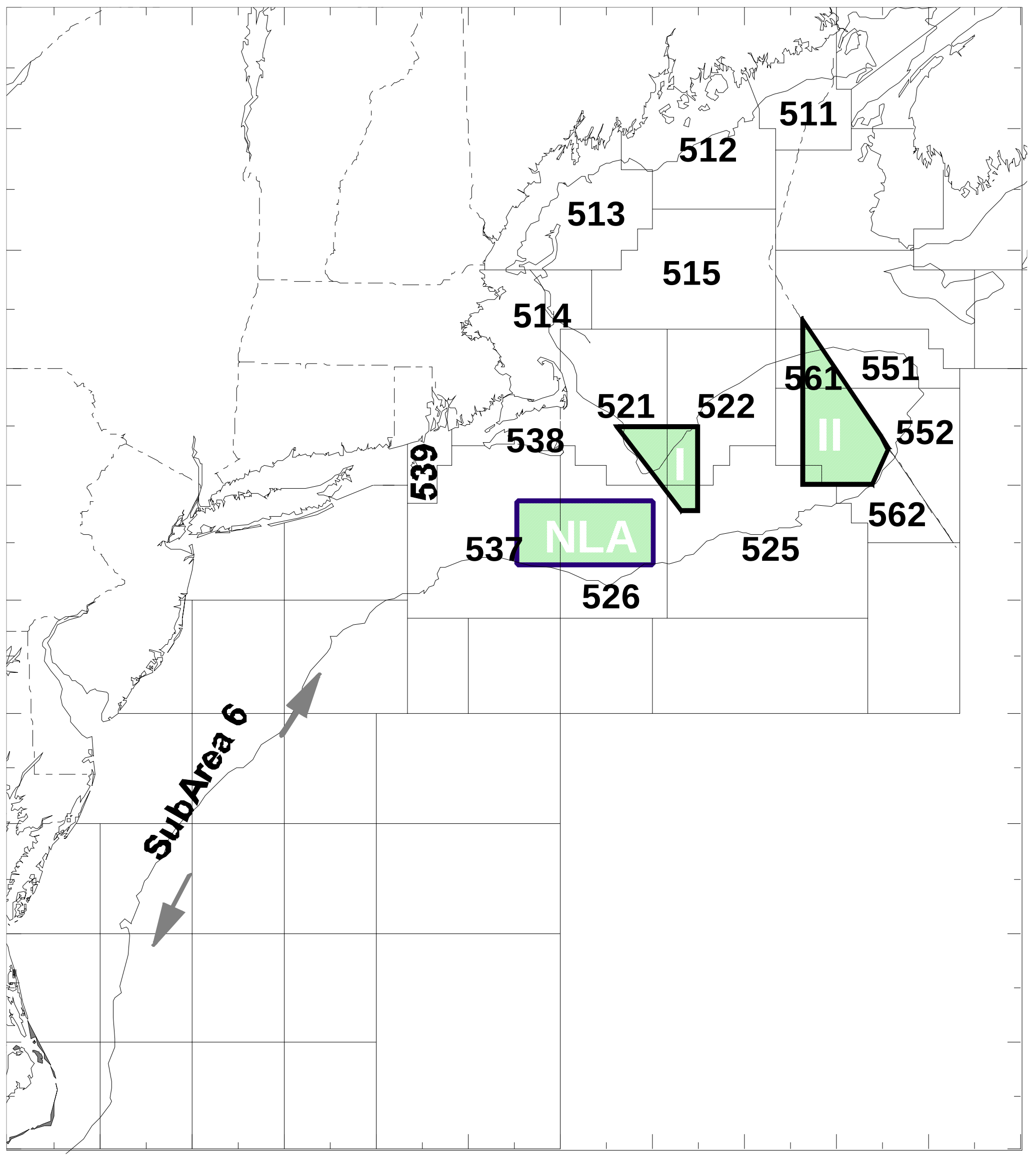


Figure 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

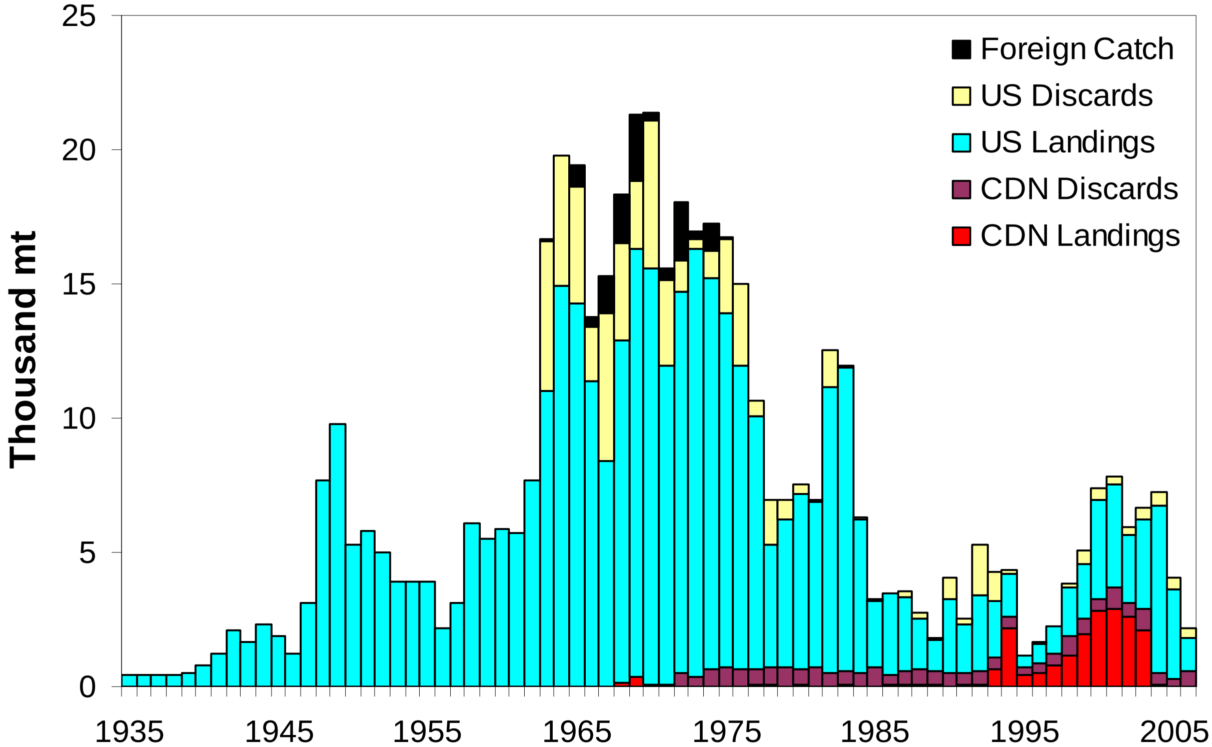


Figure 2. Catch (landings plus discards) of Georges Bank yellowtail flounder by nation, 1935-2006.

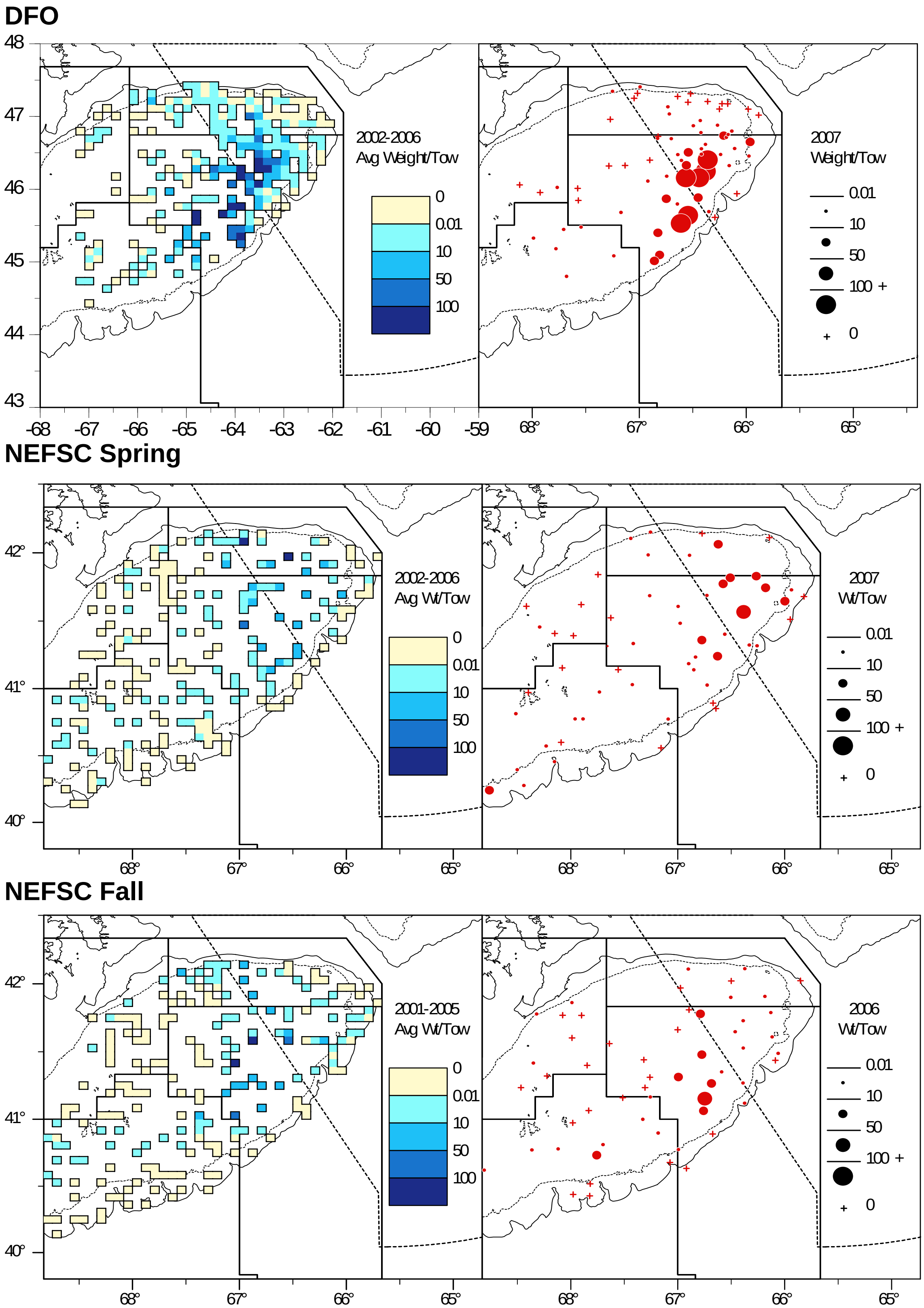


Figure 3. Catch of yellowtail in weight (kg) per tow for DFO, NMFS Spring and NEFSC Fall surveys. Left panels show previous 5 year averages, right panels most recent data.

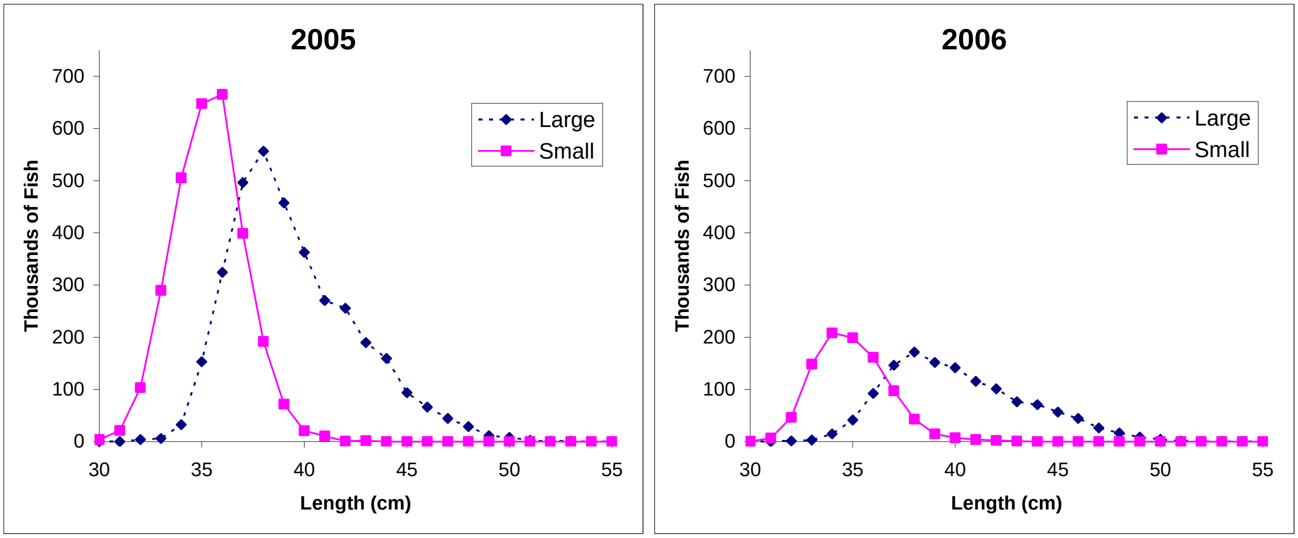


Figure 4. US landings of Georges Bank yellowtail by market category.

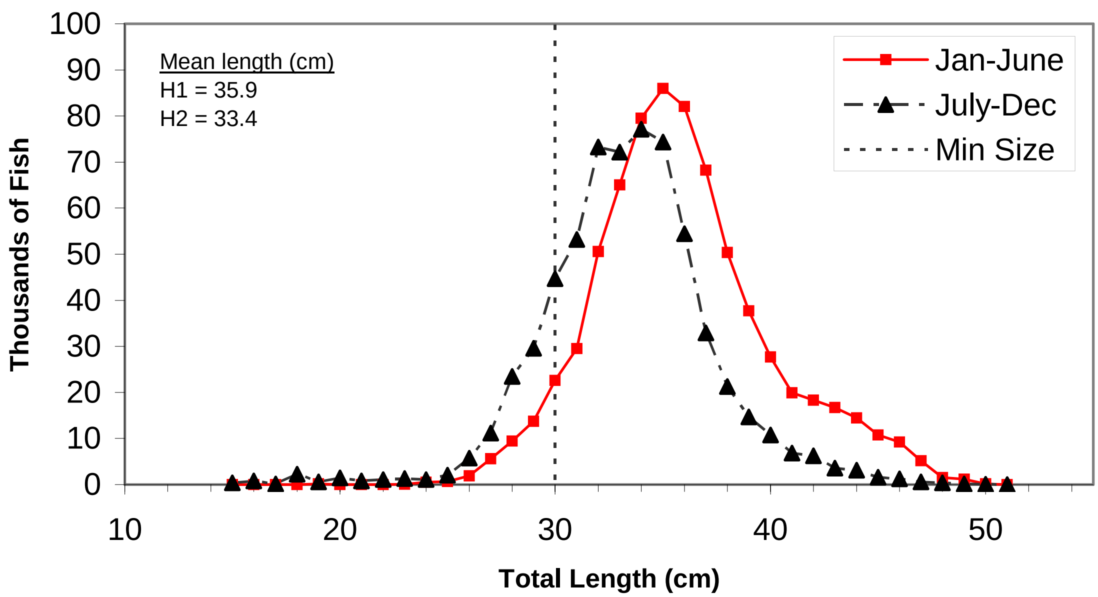


Figure 5. Yellowtail flounder discards at size by half year from the Canadian scallop fishery, 2006. The dashed line indicates the Canadian minimum size limit of 30 cm total length.

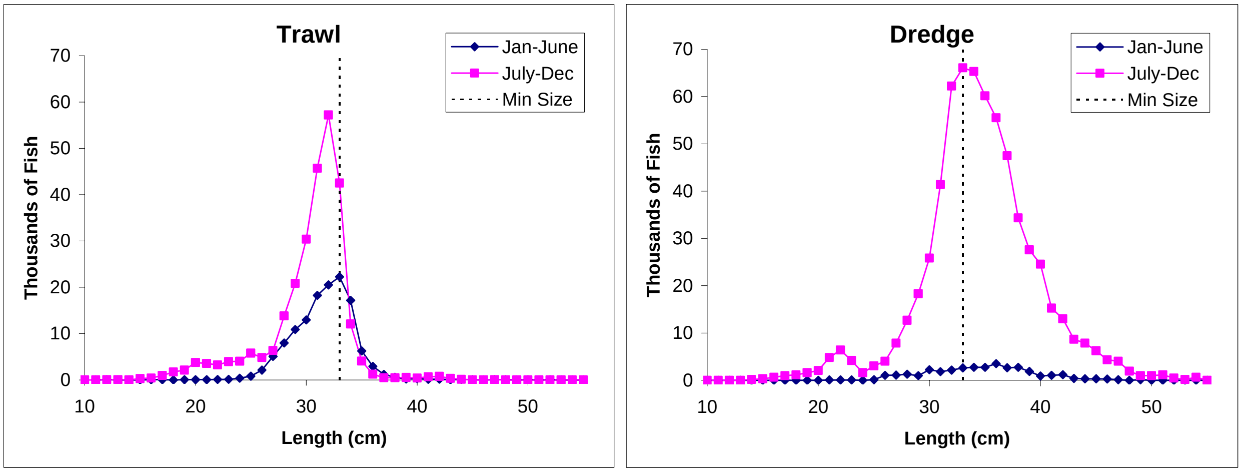


Figure 6. US discard length frequencies by gear and half year.

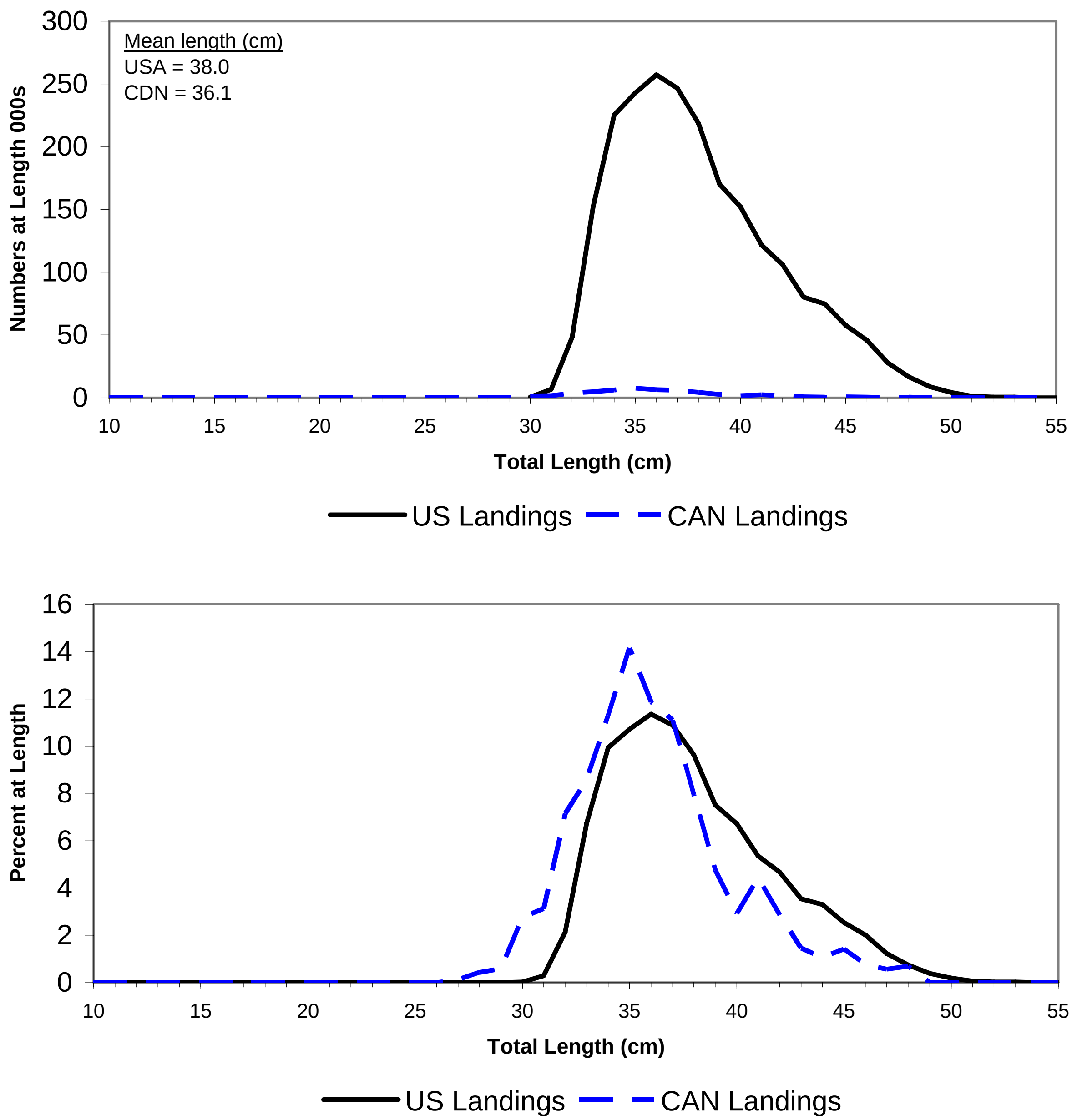
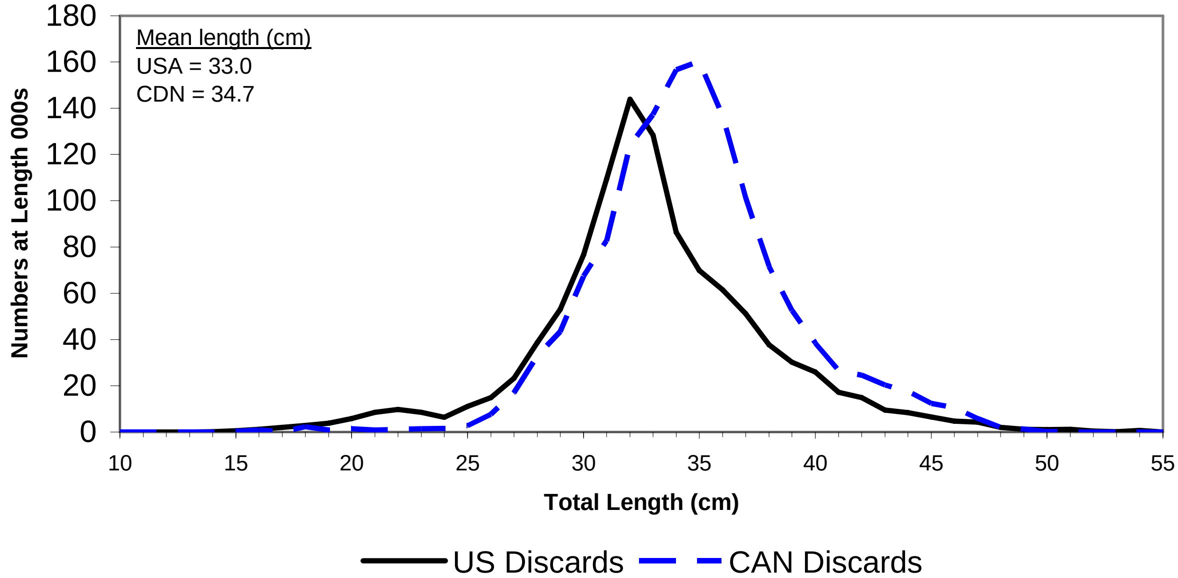


Figure 7a. Comparison of US and Canadian landings at length for Georges Bank yellowtail flounder in 2006.



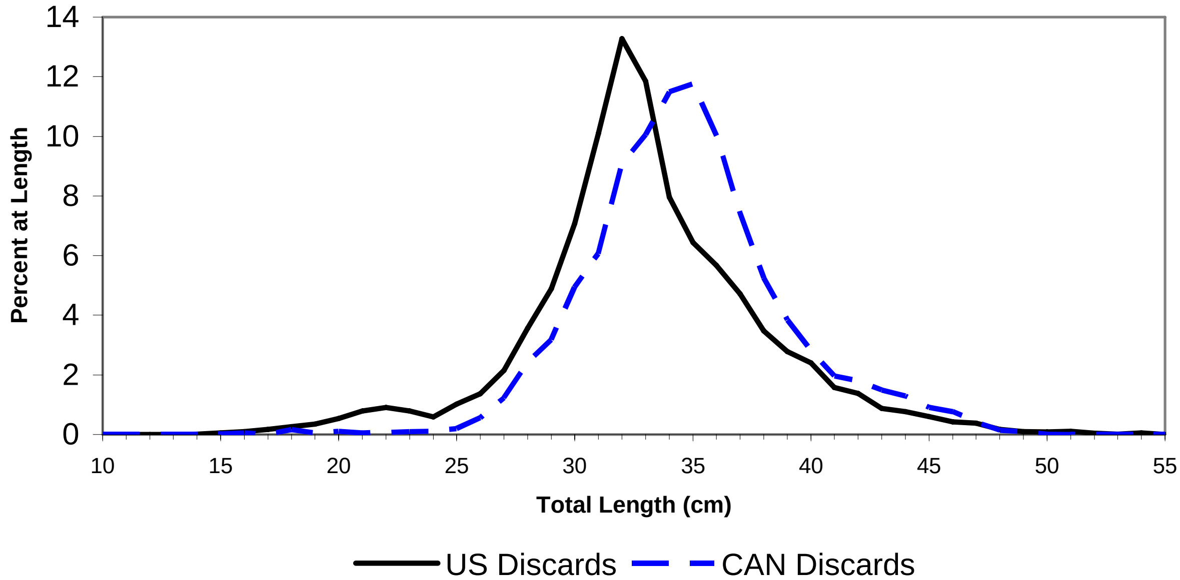


Figure 7b. Comparison of US and Canadian discards at length for Georges Bank yellowtail flounder in 2006.

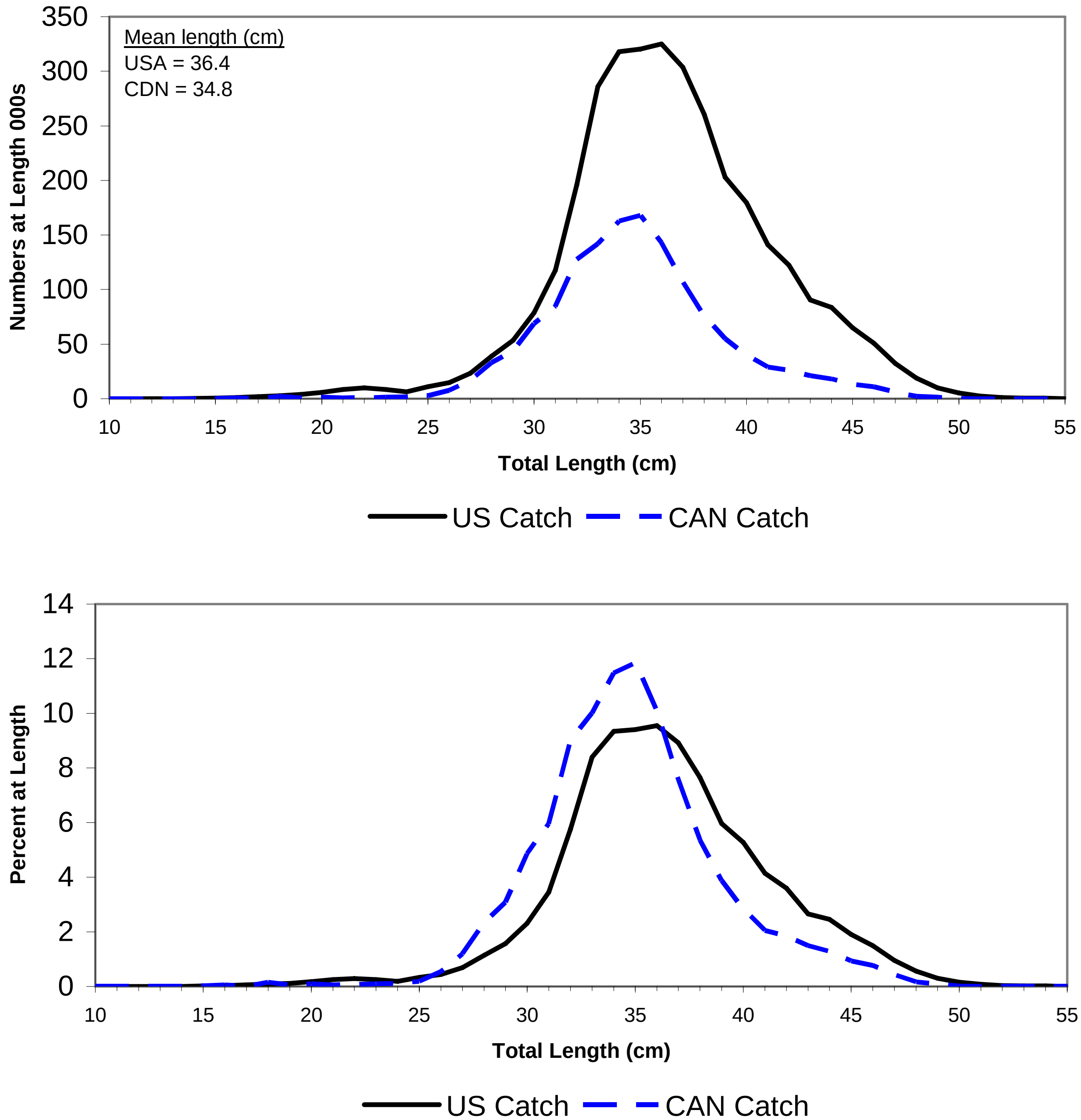


Figure 8. Comparison of US and Canadian catch (landings plus discards) at length for Georges Bank yellowtail flounder in 2006.

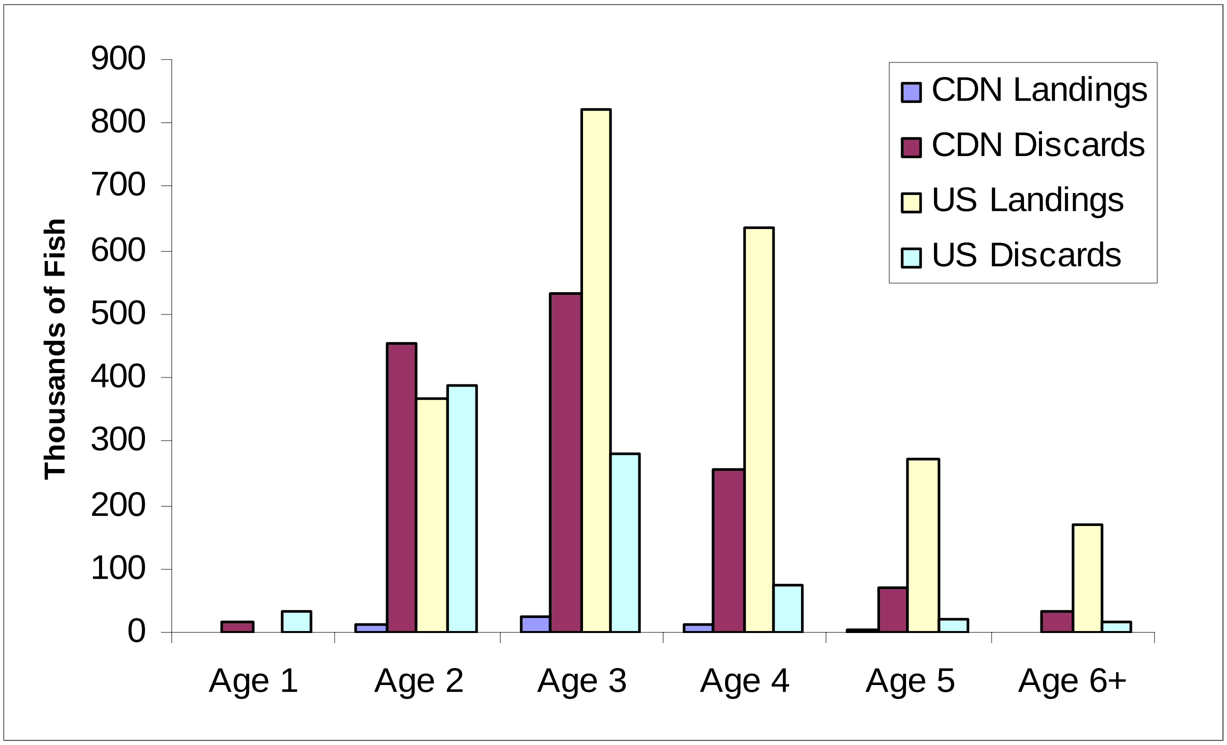


Figure 9. Catch at age of Georges Bank yellowtail flounder in 2006 from the four components of Canadian and US landings and discards.

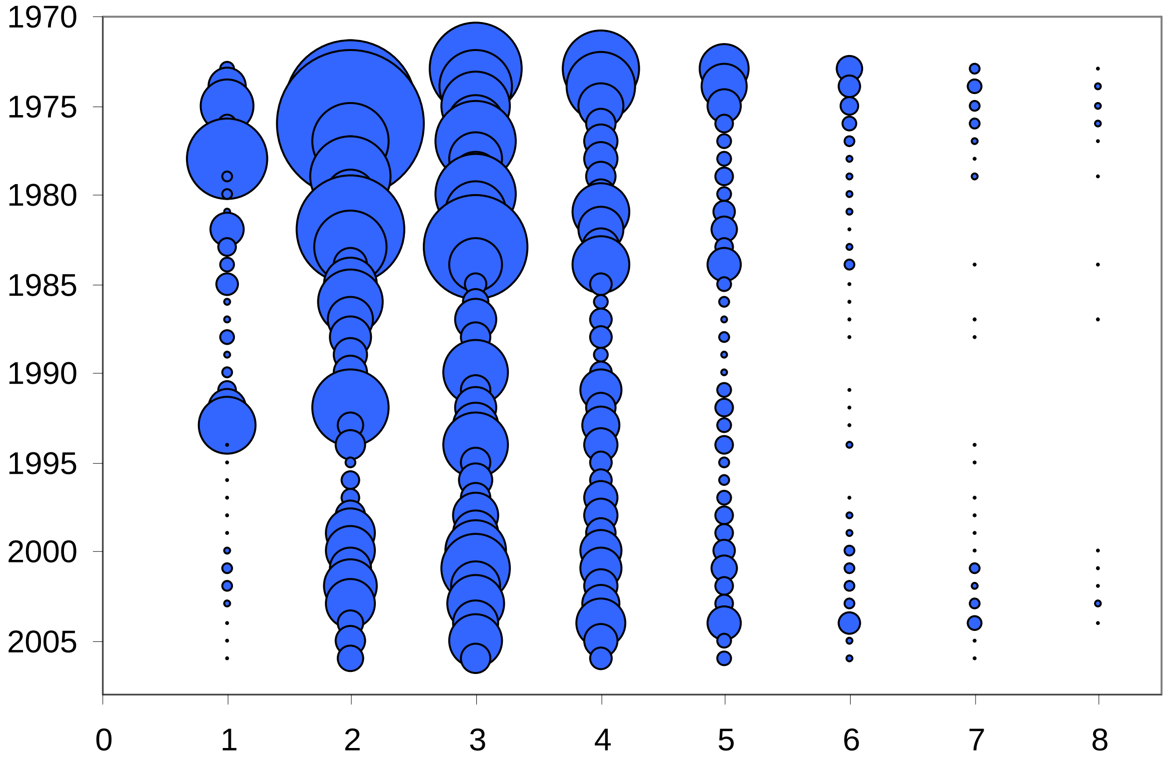


Figure 10. Catch at age for Georges Bank yellowtail flounder, Canadian and USA fisheries combined, 1973-2006. (The area of the bubble is proportional to the magnitude of the catch).

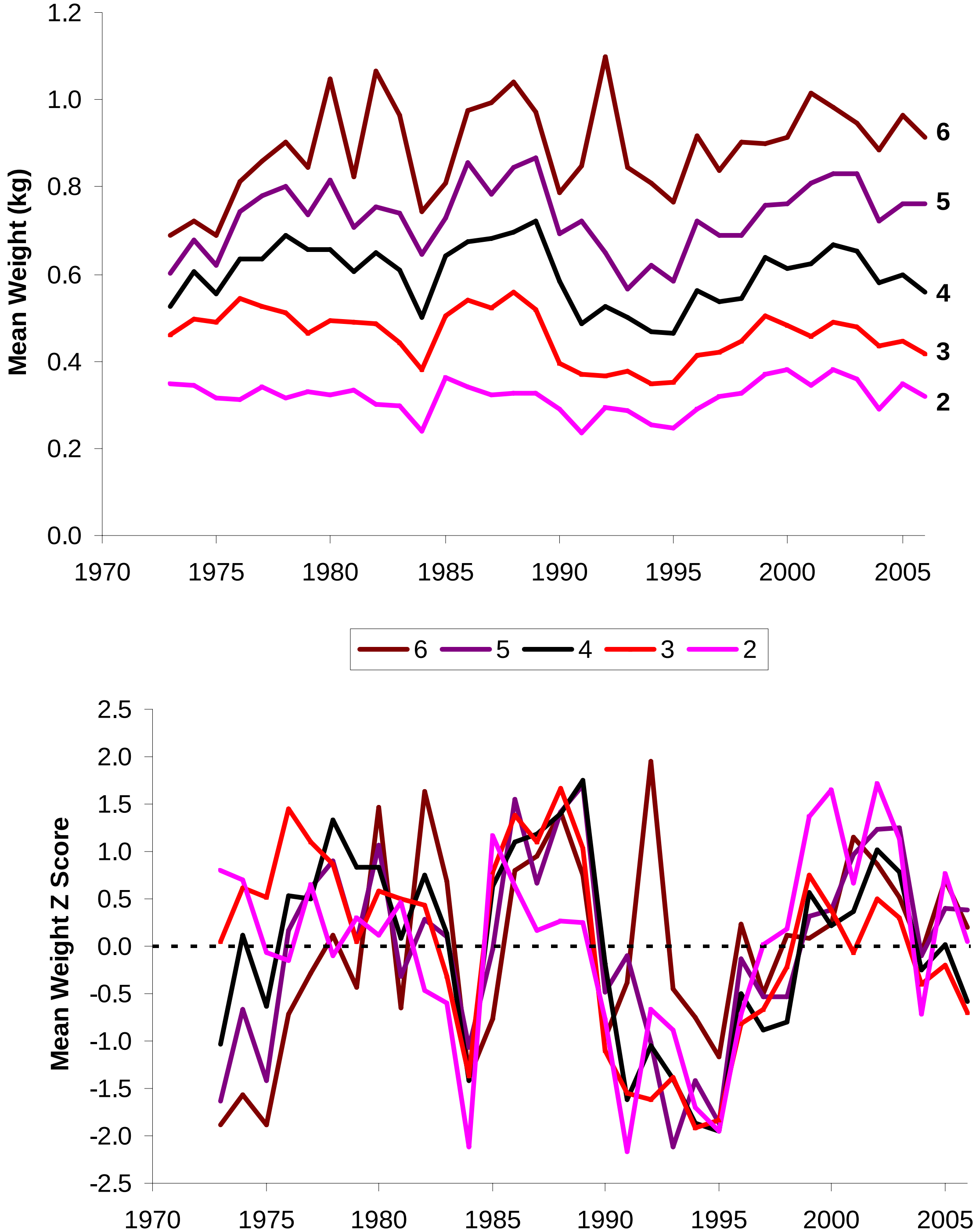


Figure 11. Trends in mean weight at age from the Georges Bank yellowtail fishery, 1973 to 2006 (Canada and USA combined, including discards), top panel. Weights at age converted to Z score (yearly value minus mean divided by standard deviation of time series), bottom panel.

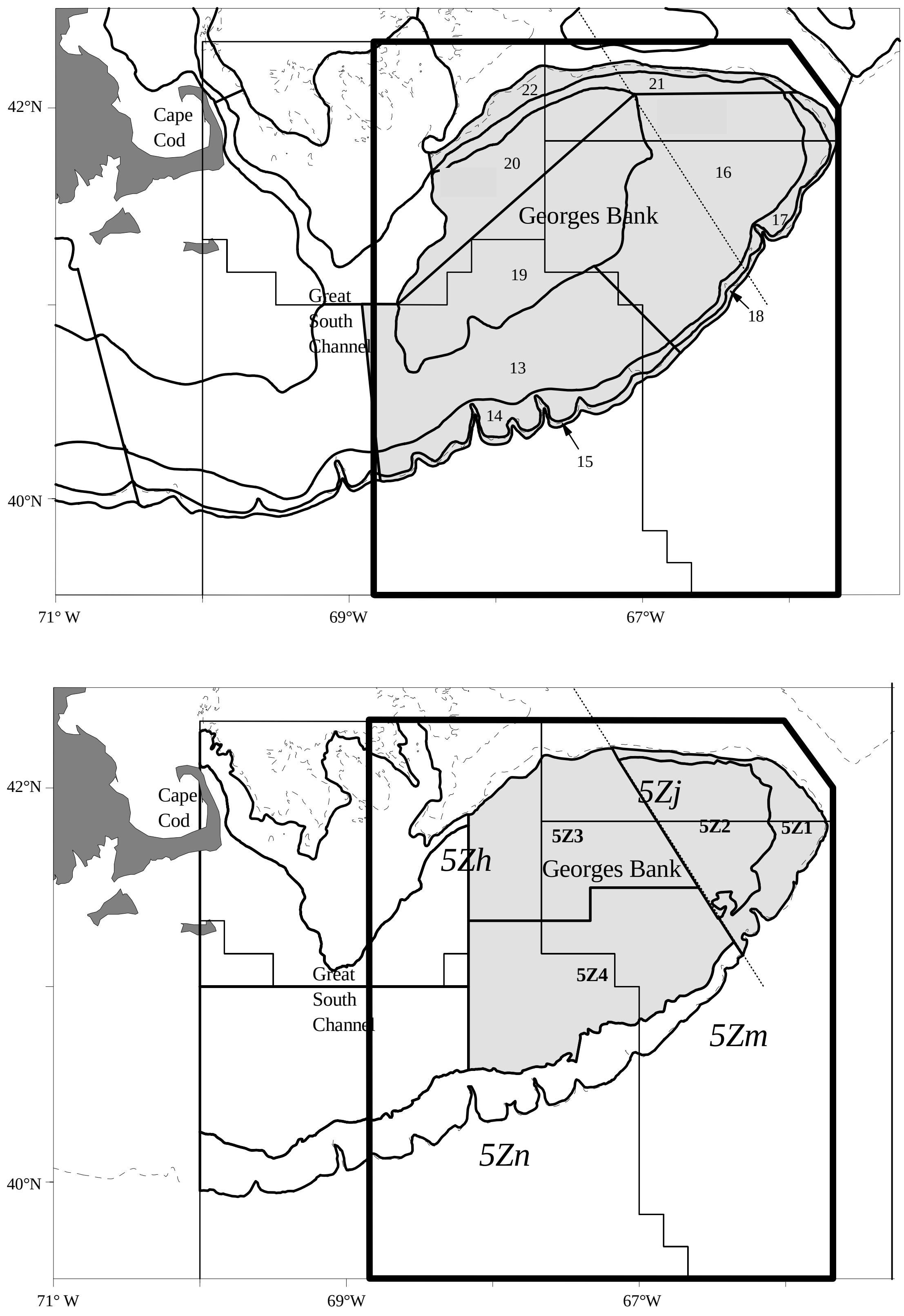


Figure 12. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in the yellowtail flounder assessment.

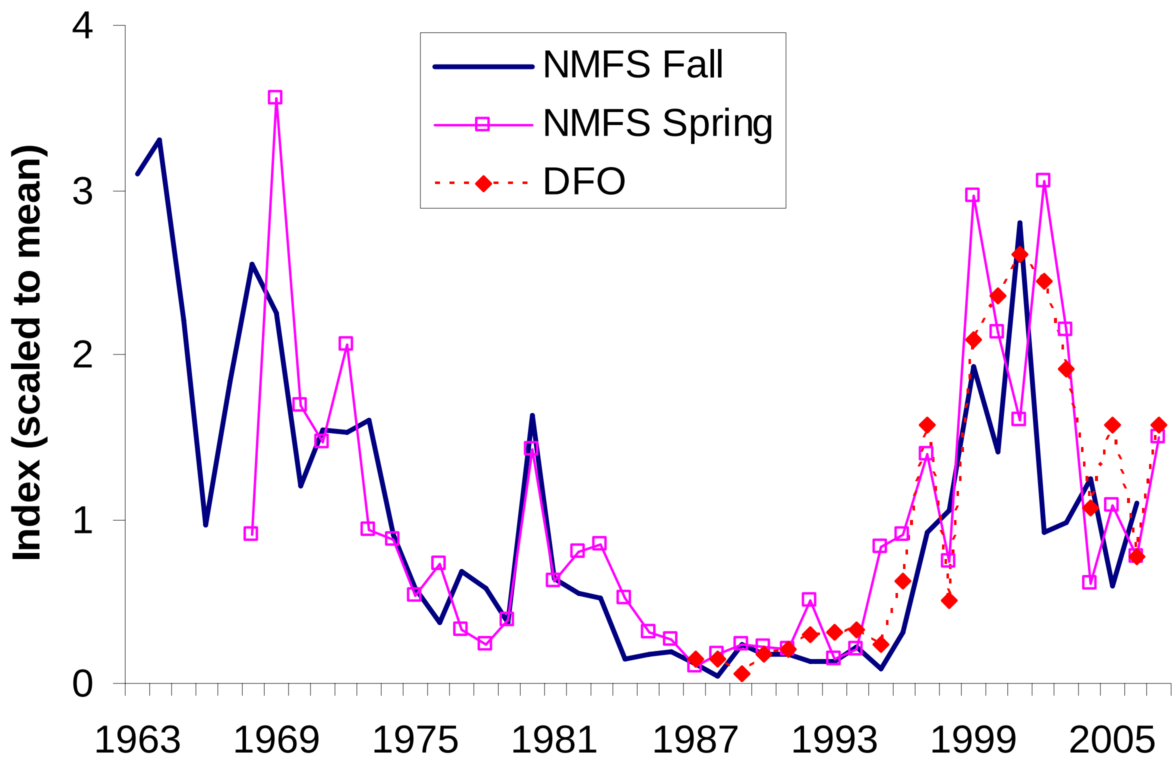


Figure 13. NMFS and DFO spring and NMFS fall survey biomass indices for yellowtail flounder on Georges Bank.

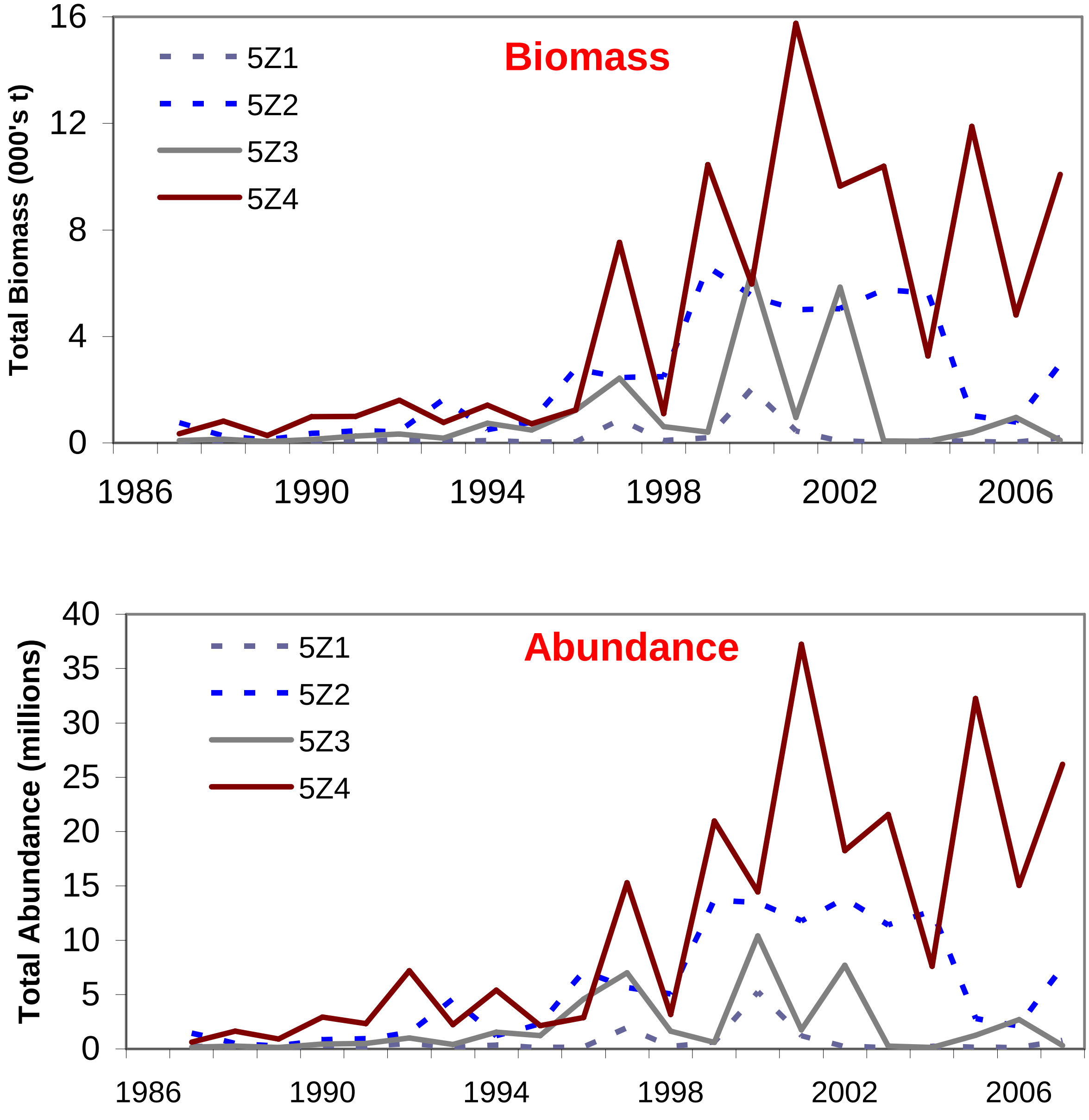


Figure 14. DFO spring survey estimates of total biomass (top panel) and total number (bottom panel) by stratum area for yellowtail flounder on Georges Bank, 1987-2007.

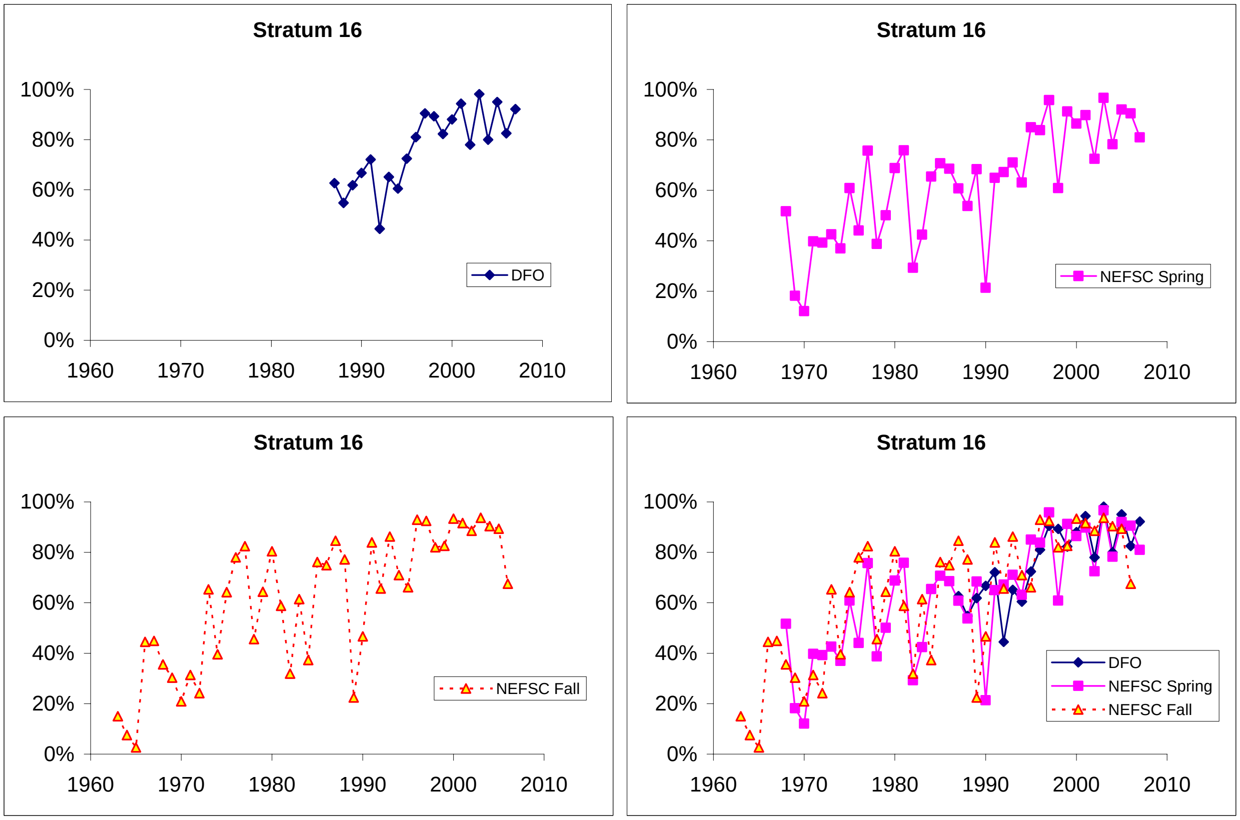


Figure 15. Proportion of survey biomass for yellowtail flounder on Georges Bank found in stratum 16 for DFO spring, NMFS spring, and NMFS fall surveys.

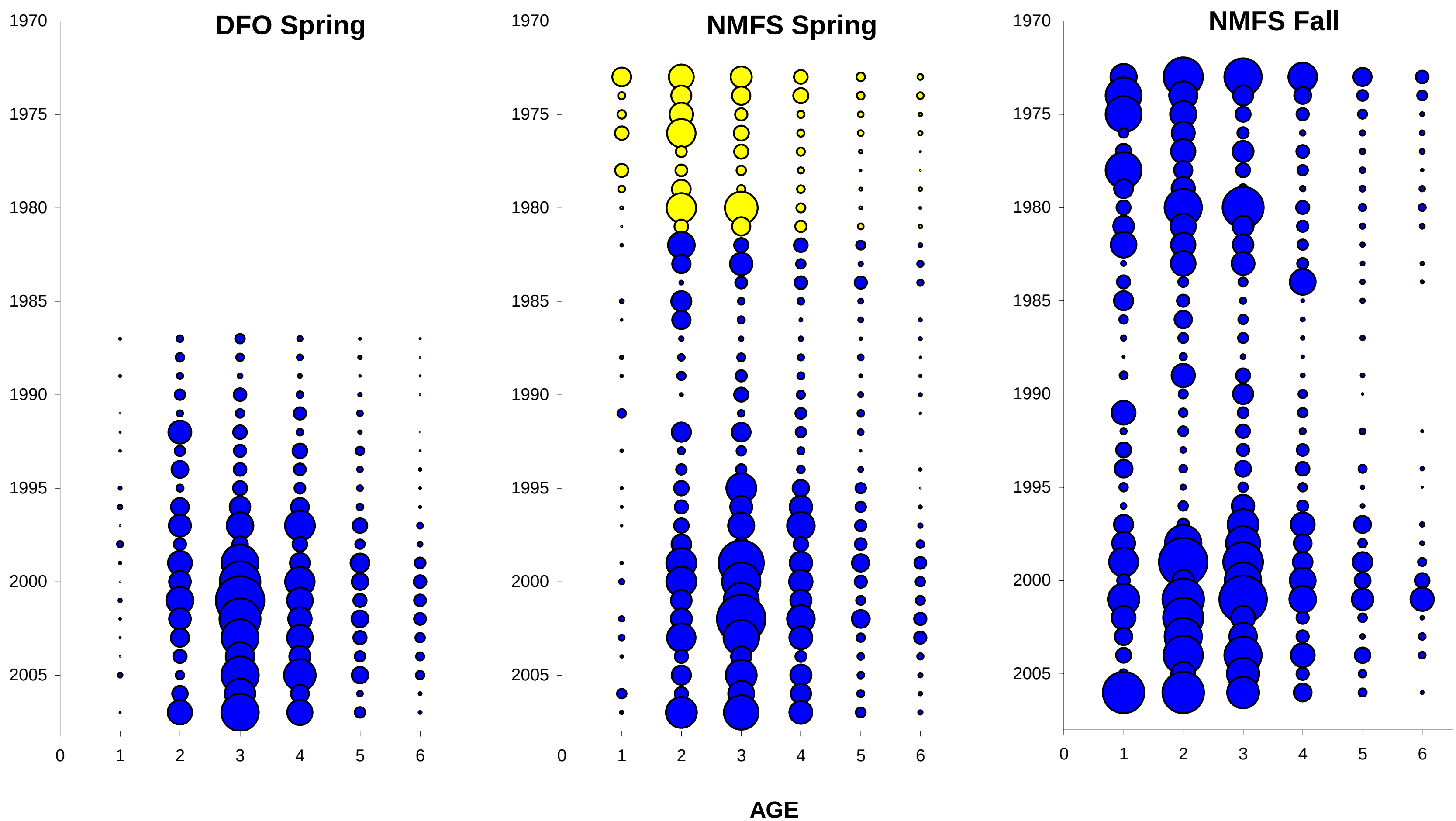


Figure 16. Age specific indices of abundance for the DFO spring (1987-2007), NMFS spring (1968-2007), and NMFS fall (1963-2006) surveys (bubble is proportional to the magnitude). The yellow symbols in the NMFS spring series denote the period when the Yankee 41 net was used (1973-1981). Age 6 denotes ages 6 and older. Refer to Tables 6, 7, and 8 for the specific values of the indices.

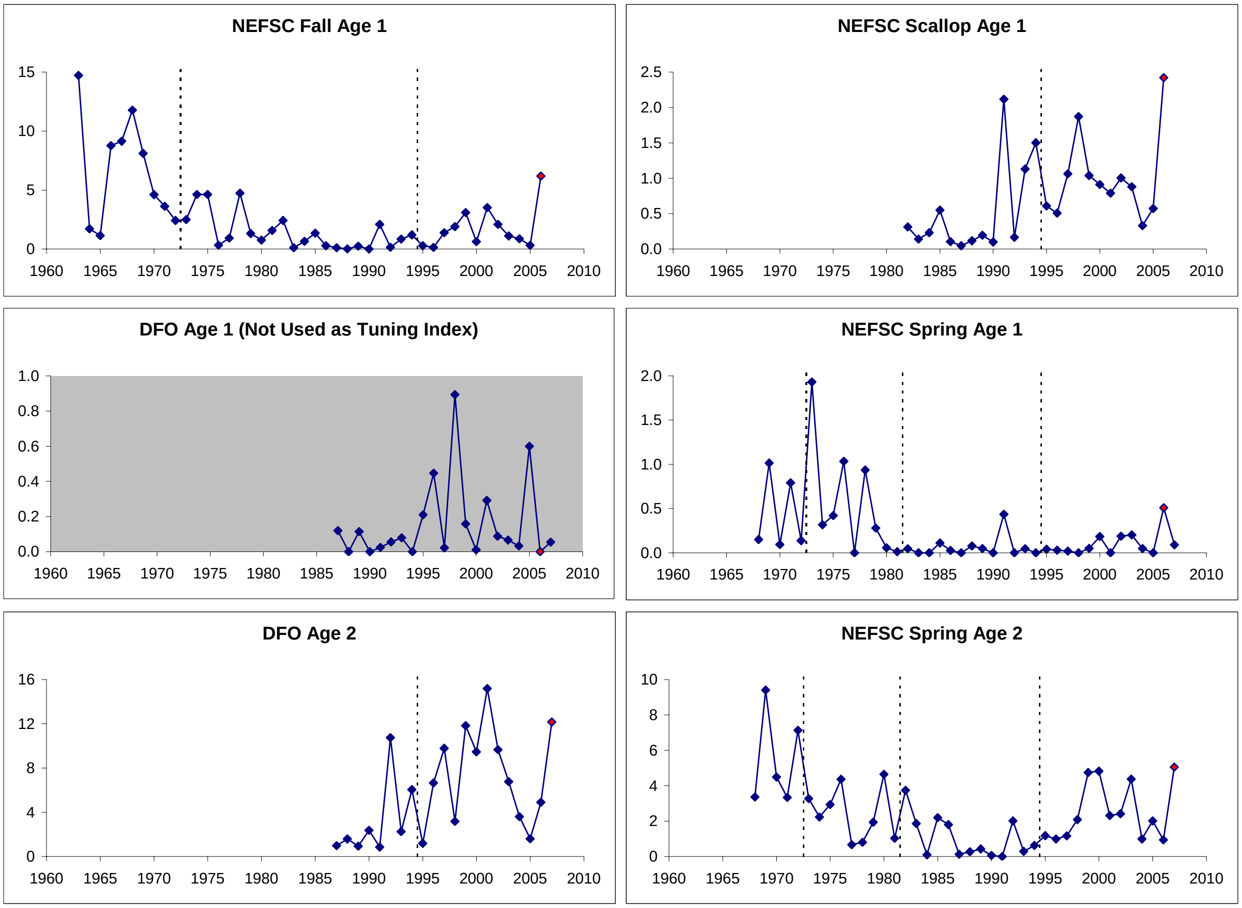


Figure 17. Survey indications of a strong 2005 year-class (denoted by red symbol; age-1 in 2006, age-2 in 2007). Vertical dashed lines indicate start of VPA time series (1973), switch from Yankee 41 to Yankee 36 net in Spring Survey (1982), and split of survey time series in Major Change VPA (1995). Refer to Tables 6-9 for the specific values of the indices.

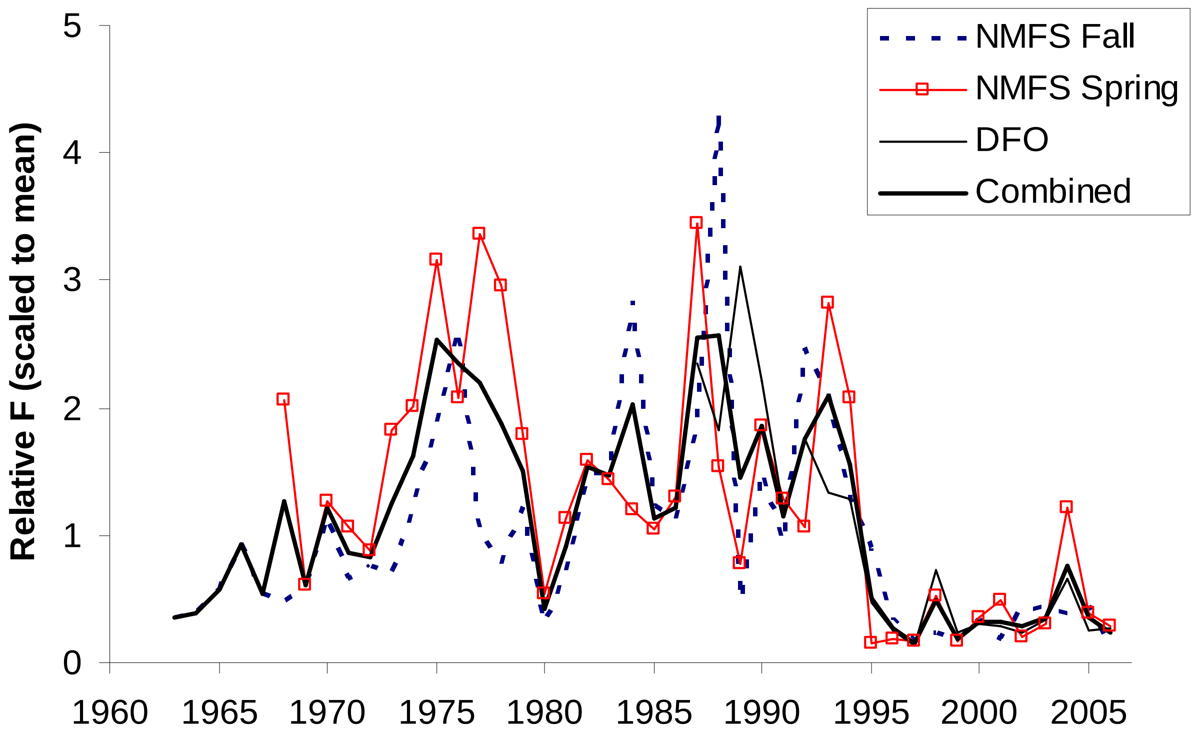


Figure 18. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2005.

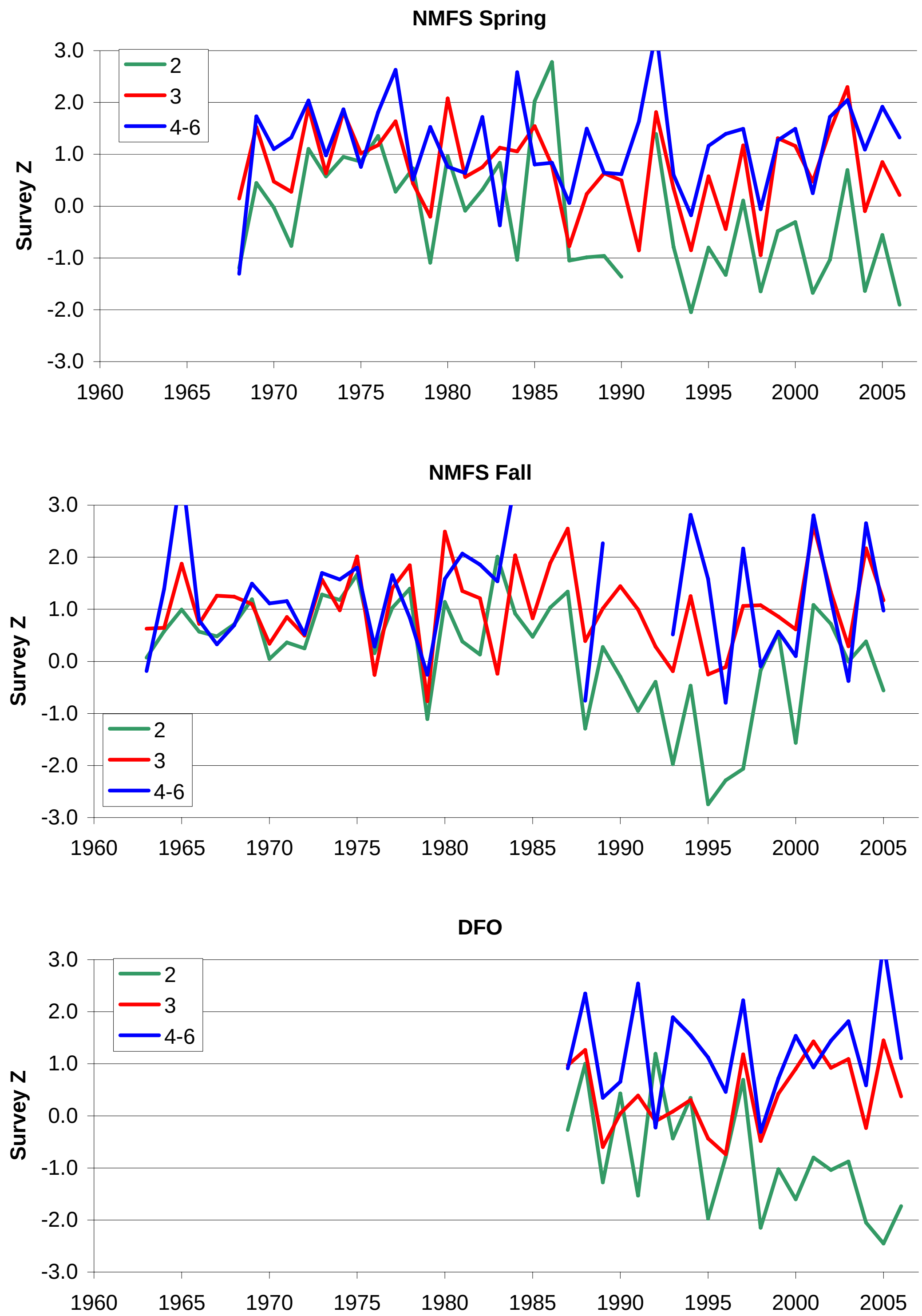


Figure 19. Trends in total mortality (Z) for ages 2, 3, and 4-6 from DFO, NMFS Spring and NMFS Fall bottom trawl surveys.

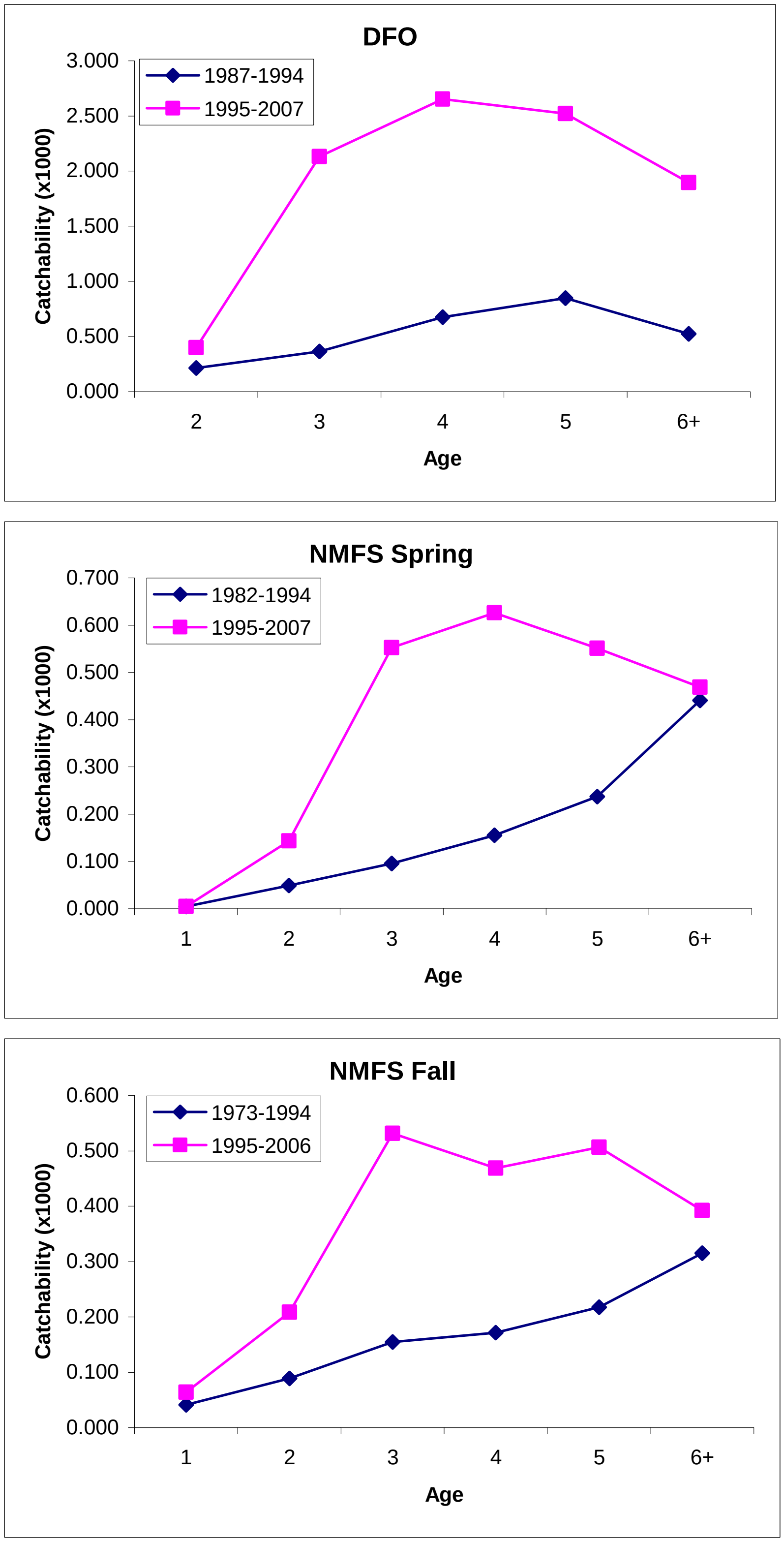


Figure 20. Catchability coefficients (q) from the Major Change VPA.

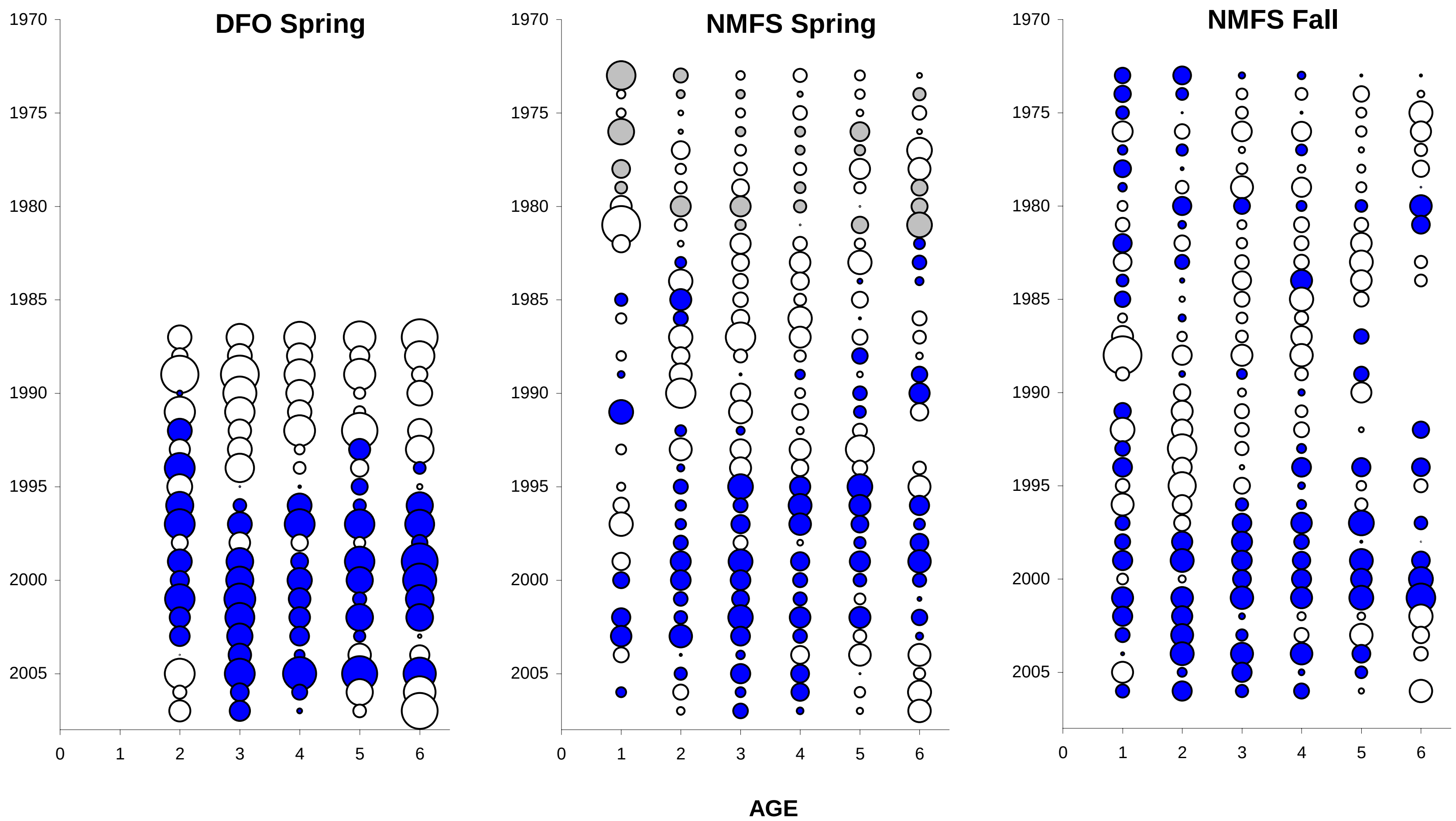


Figure 21. Age by age residuals from the Base Case VPA model formulation for *ln* abundance index minus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and filled symbols denote positive residuals.

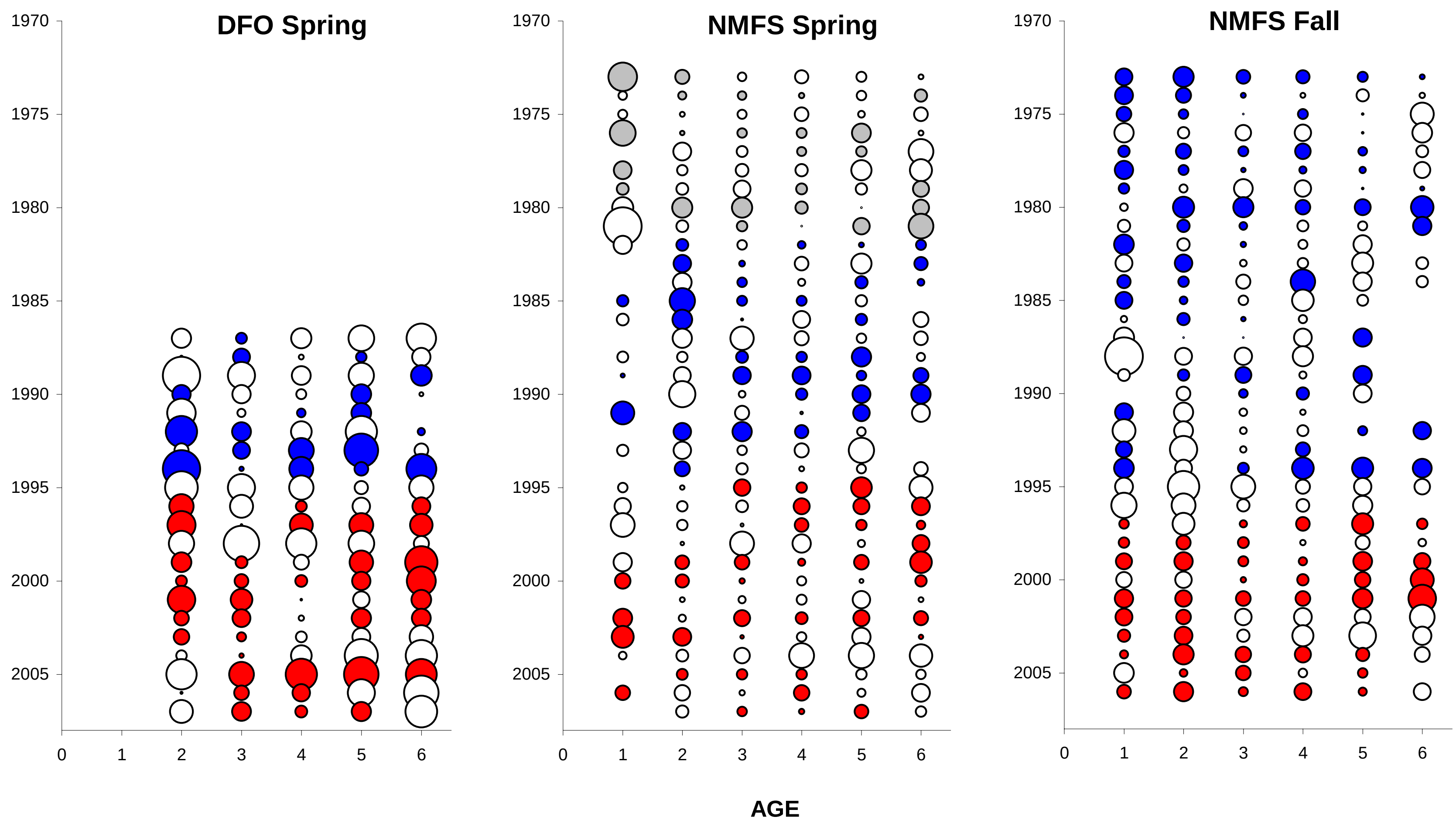


Figure 22. Age by age residuals from the Major Change VPA formulation for *ln* abundance index minus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The different colors denote separate series. The open symbols denote negative residuals, and filled symbols denote positive residuals.

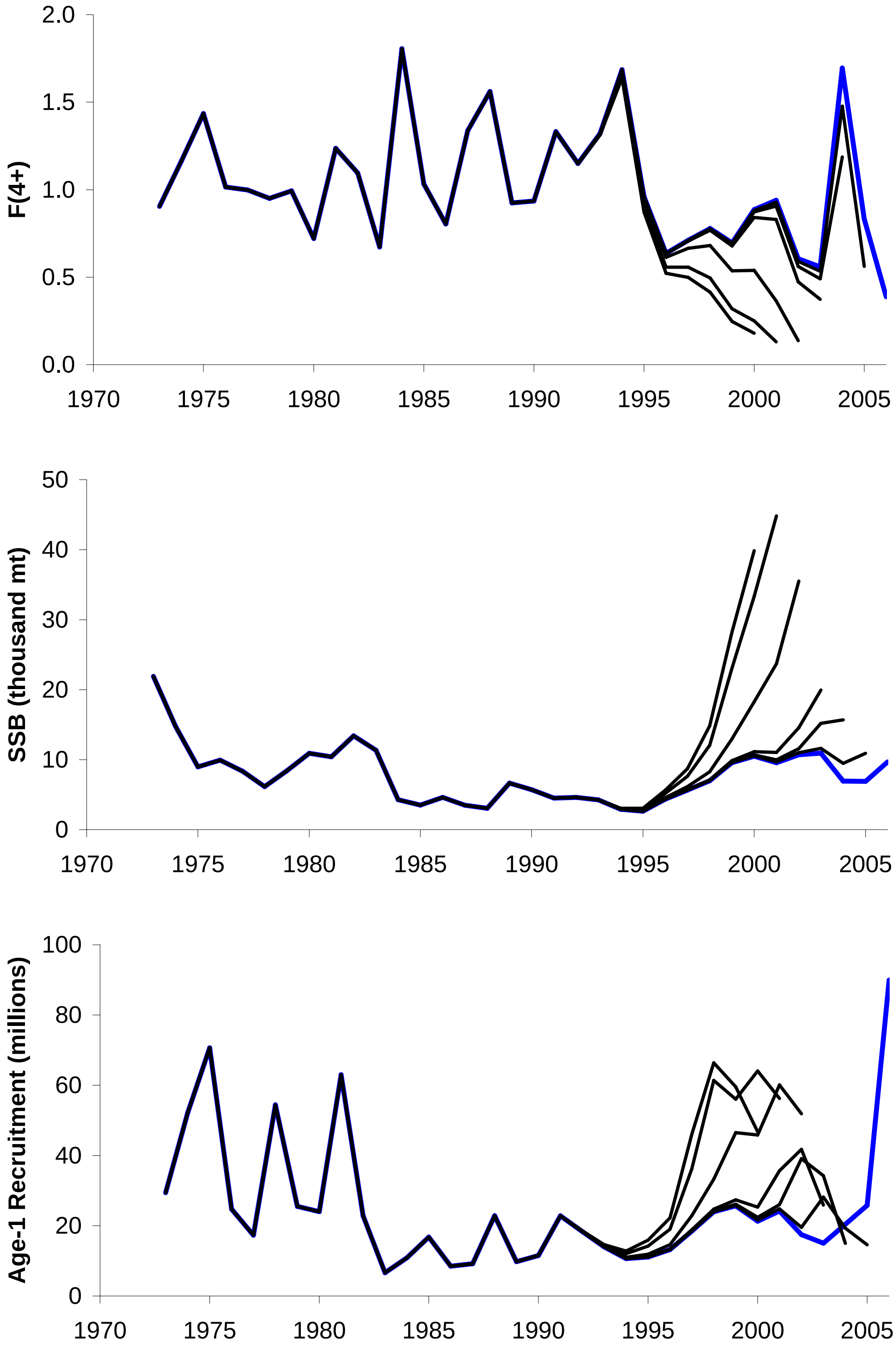


Figure 23. Retrospective analysis of Georges Bank yellowtail flounder from the Base Case VPA for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel) and age 1 recruits (lower panel).

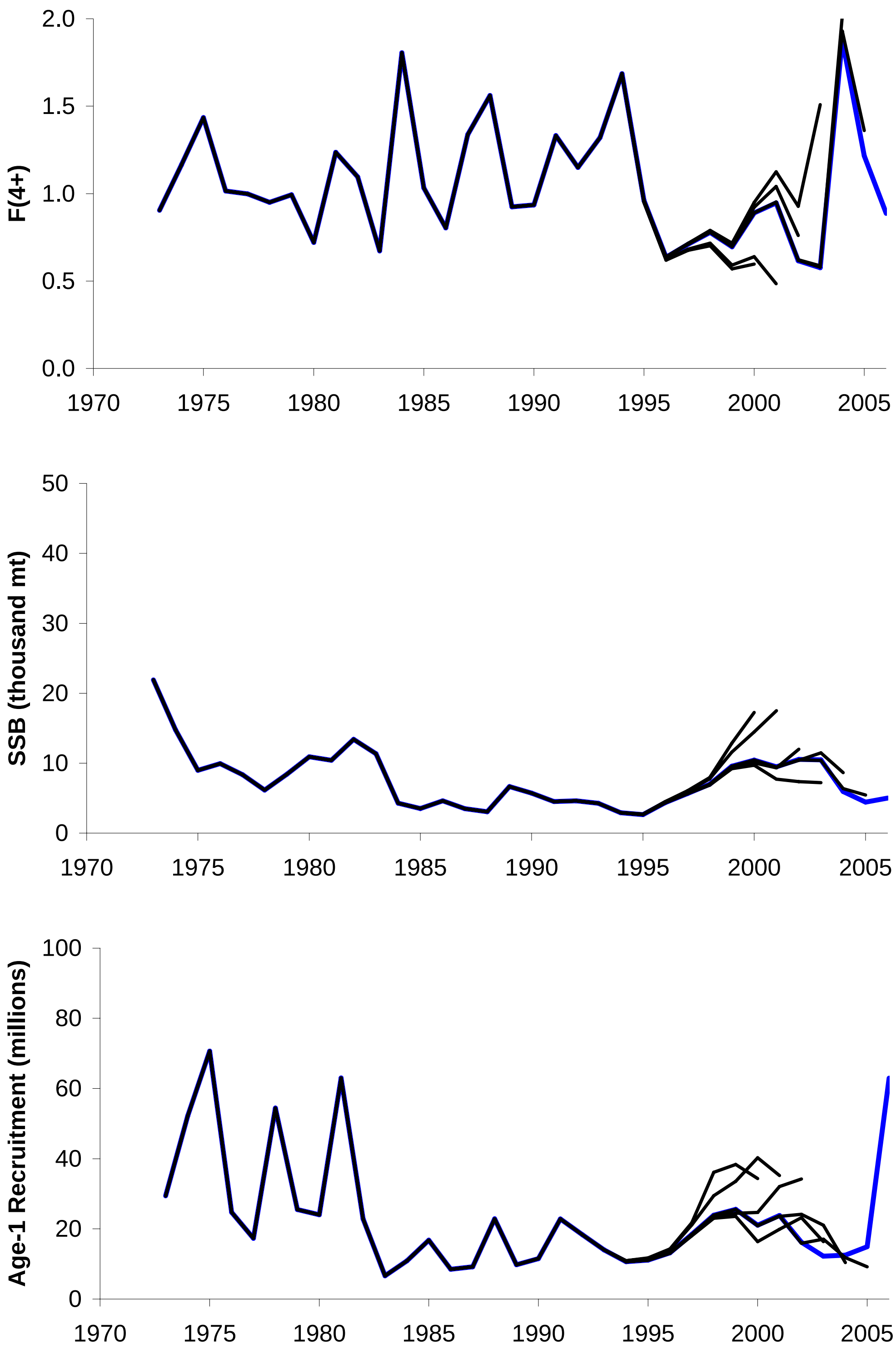


Figure 24. Retrospective analysis of Georges Bank yellowtail flounder from the Major Change VPA for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel) and age 1 recruits (lower panel).

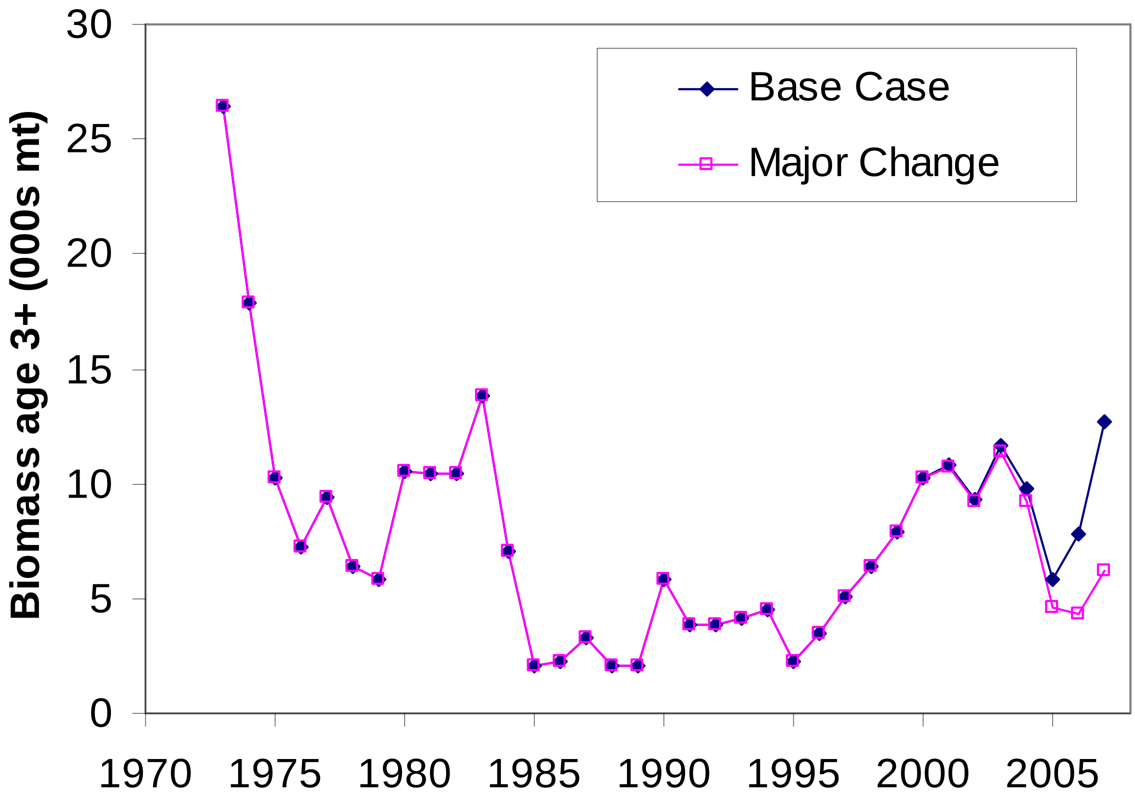
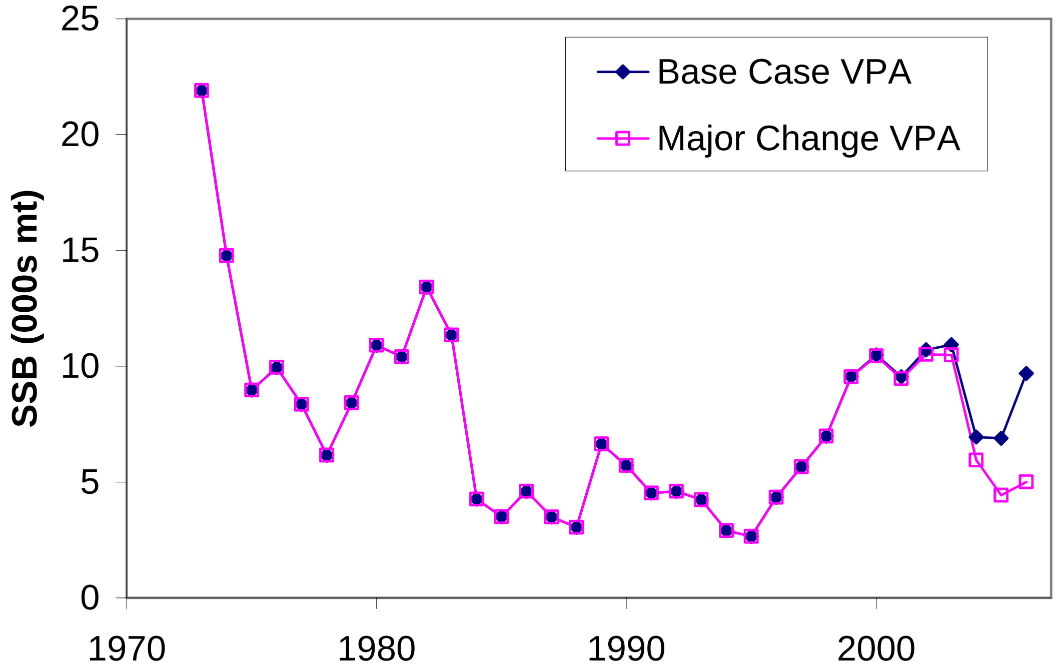


Figure 25. Trends in age 3+ biomass for Georges Bank yellowtail flounder as indicated from the Base Case VPA and Major Change VPA.



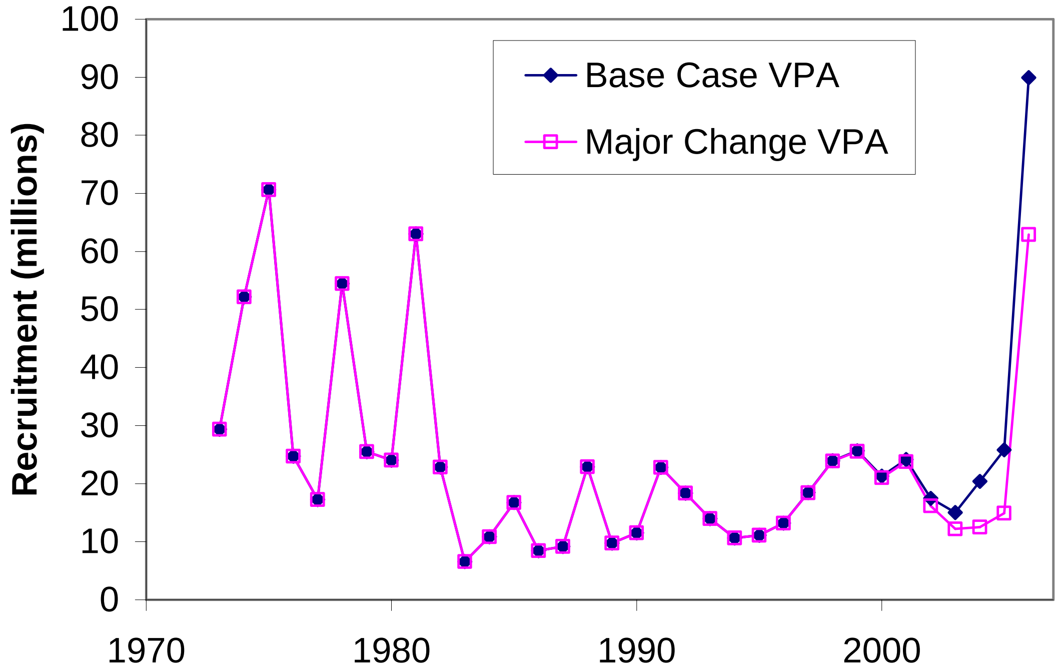


Figure 26. Trends in and spawning stock biomass and age 1 recruits for Georges Bank yellowtail flounder as indicated from the Base Case VPA and Major Change VPA.

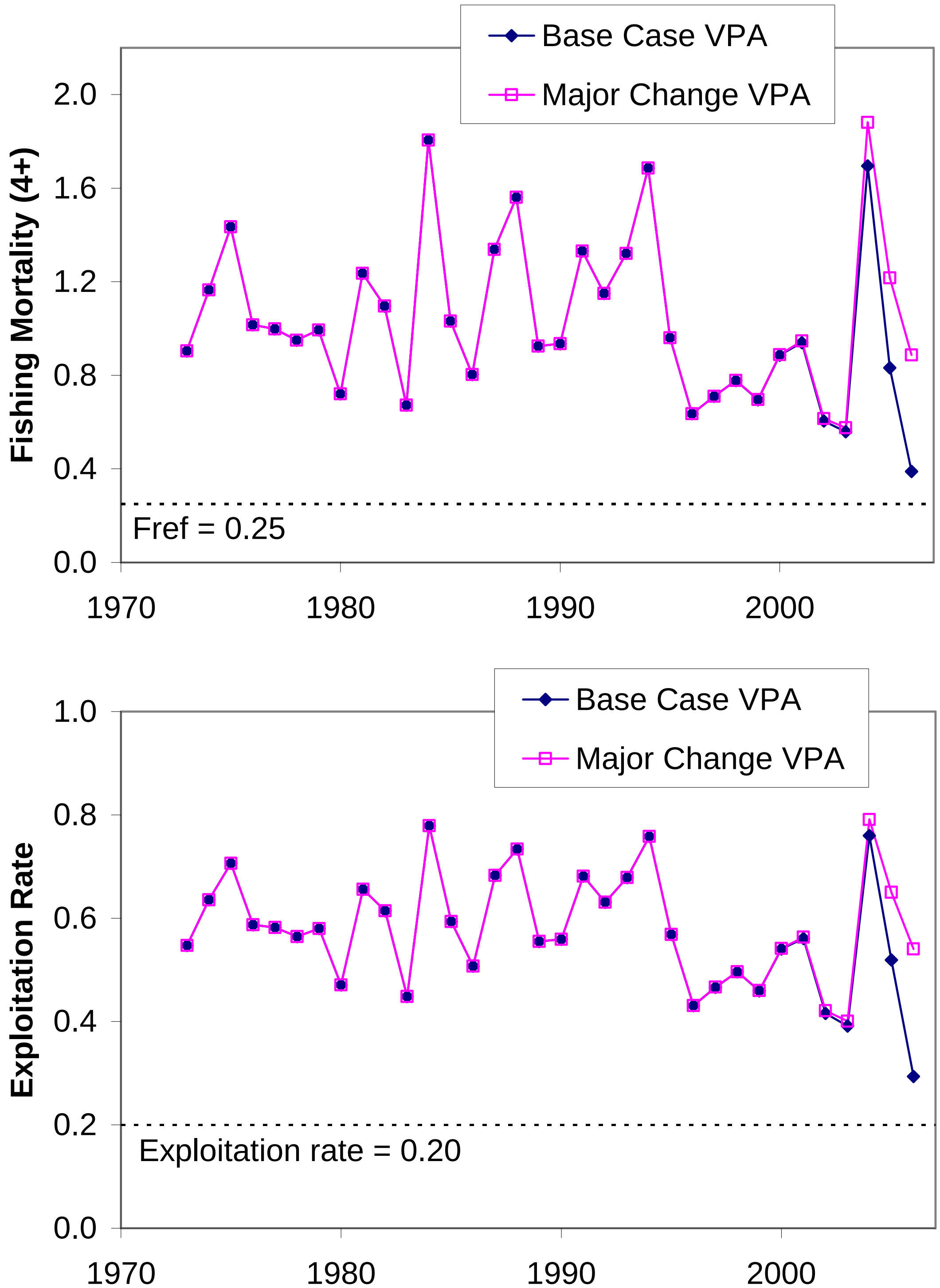


Figure 27. Trends in fully recruited (age 4+) fishing mortality (upper panel) and exploitation rate (lower panel) for Georges Bank yellowtail flounder as indicated from the Base Case VPA and Major Change VPA.

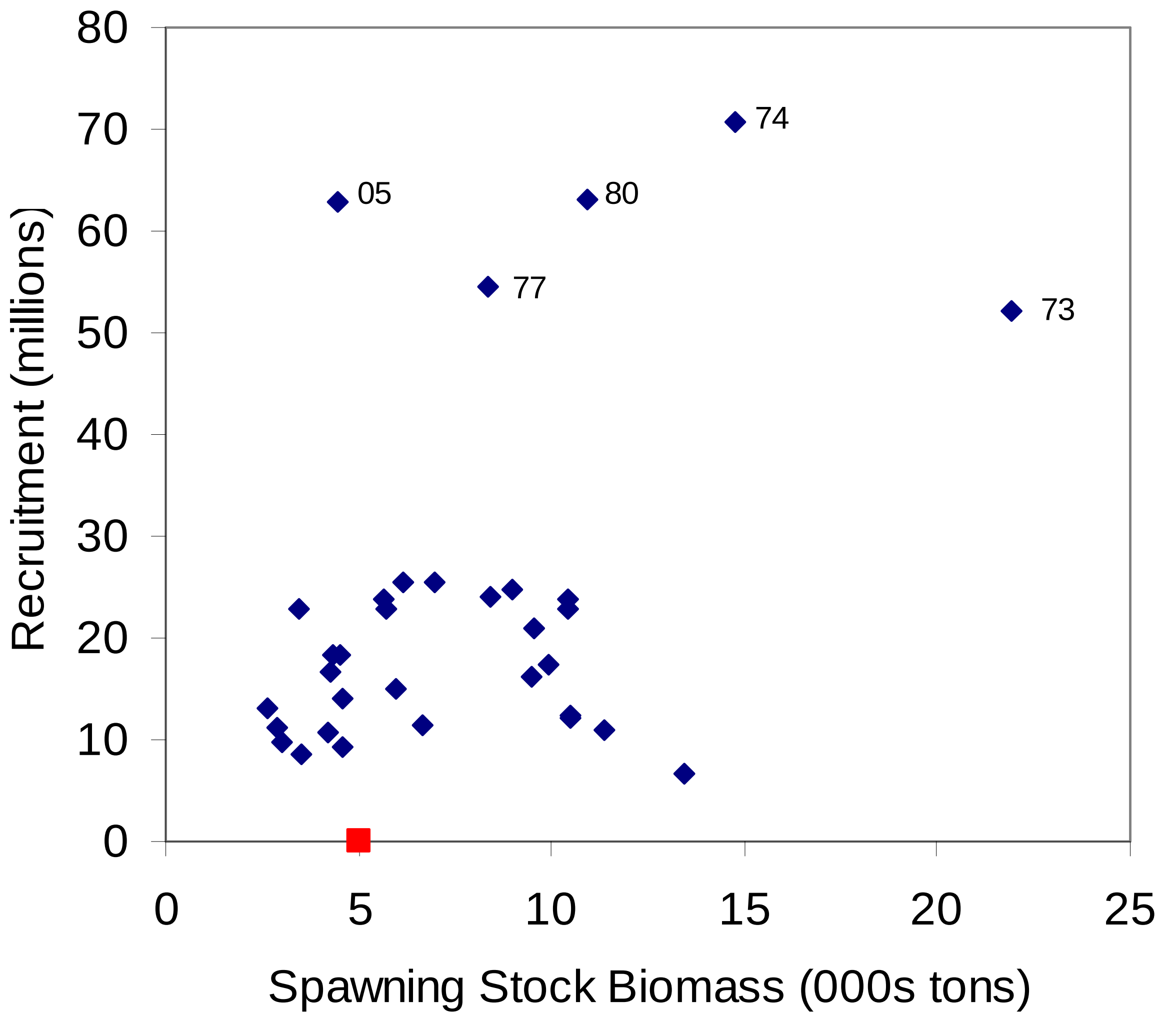
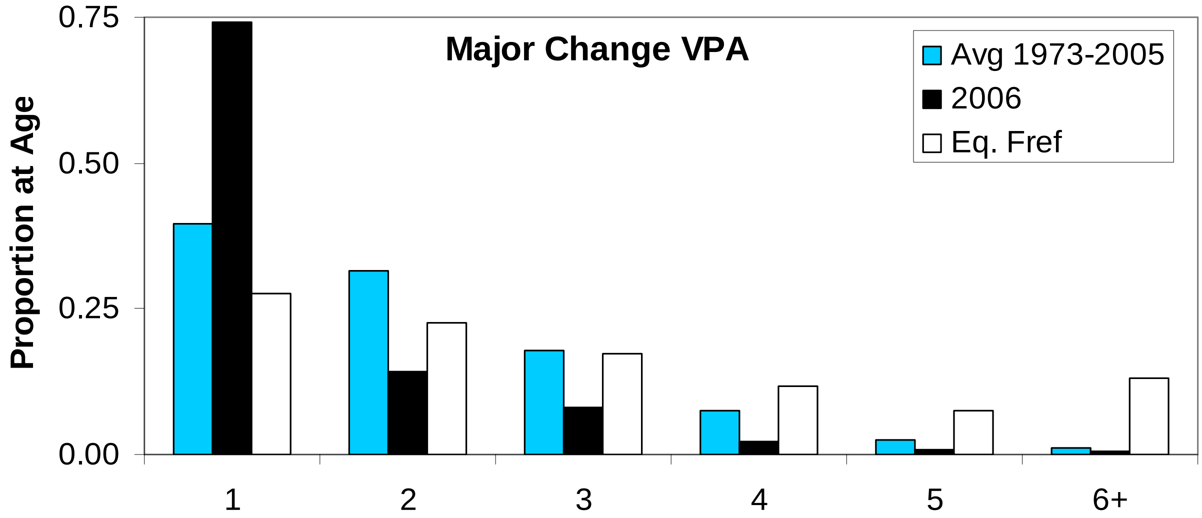


Figure 28. Spawning stock biomass and age 1 recruitment relationship for Georges Bank yellowtail flounder from the Major Change VPA formulation. Strong year-classes of recruitment are noted by the year of SSB and year-class for recruitment. The spawning stock biomass for 2006 (red square) is also shown on the x-axis.



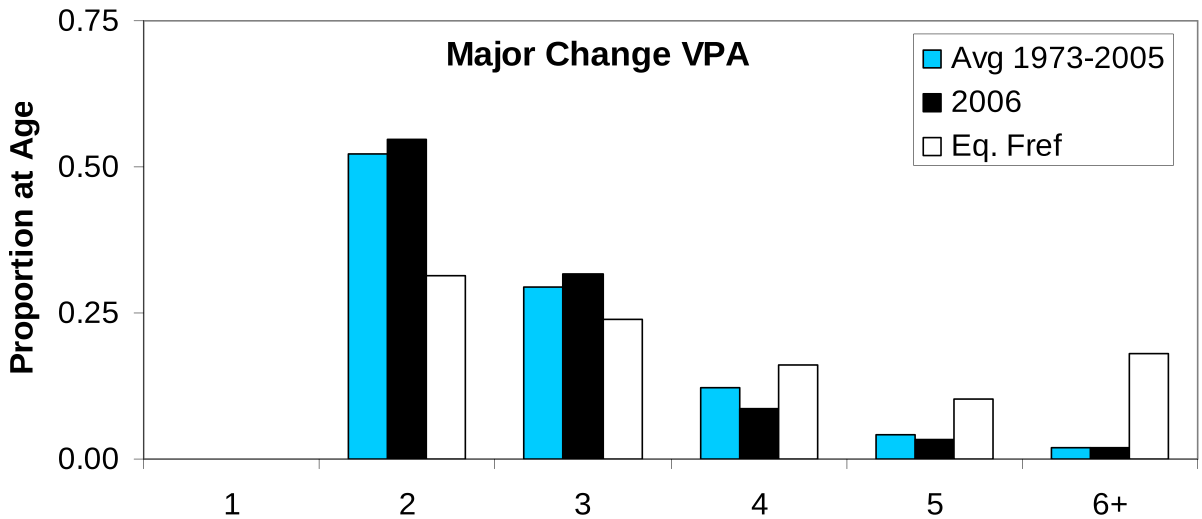
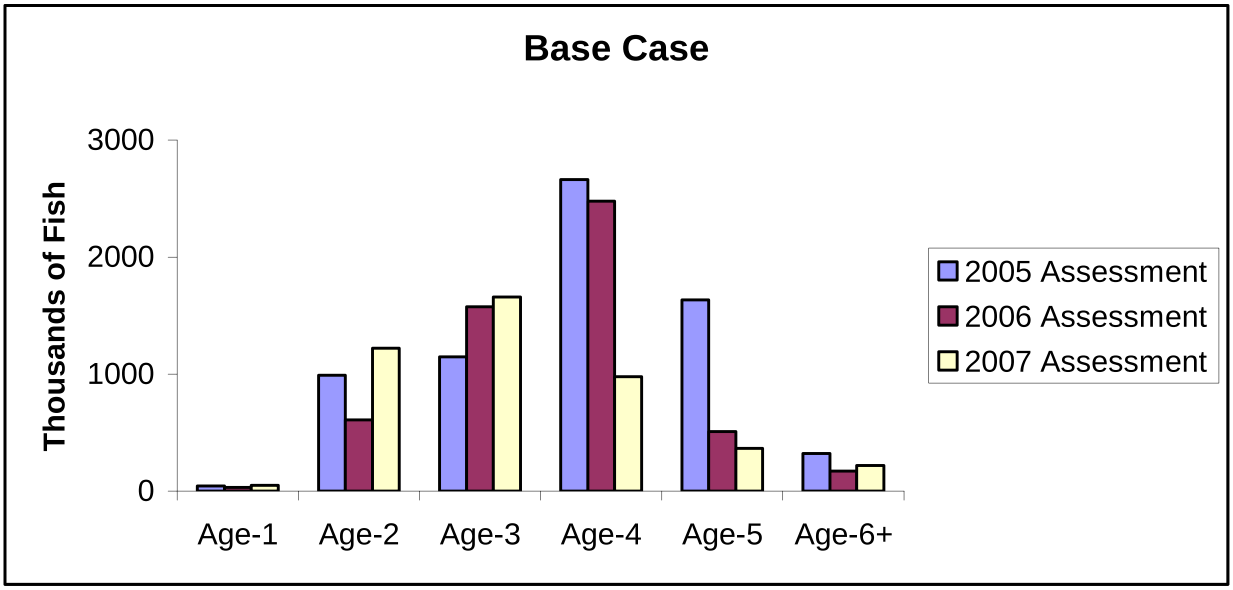


Figure 29. Proportions at age for the Georges Bank yellowtail flounder population in 2006, for the average of 1973-2005, and when the population is at equilibrium at the Fref of 0.25, based on results from the Major Change VPA. The lower panel shows the same information but without inclusion of age 1 values, which were high in 2006.



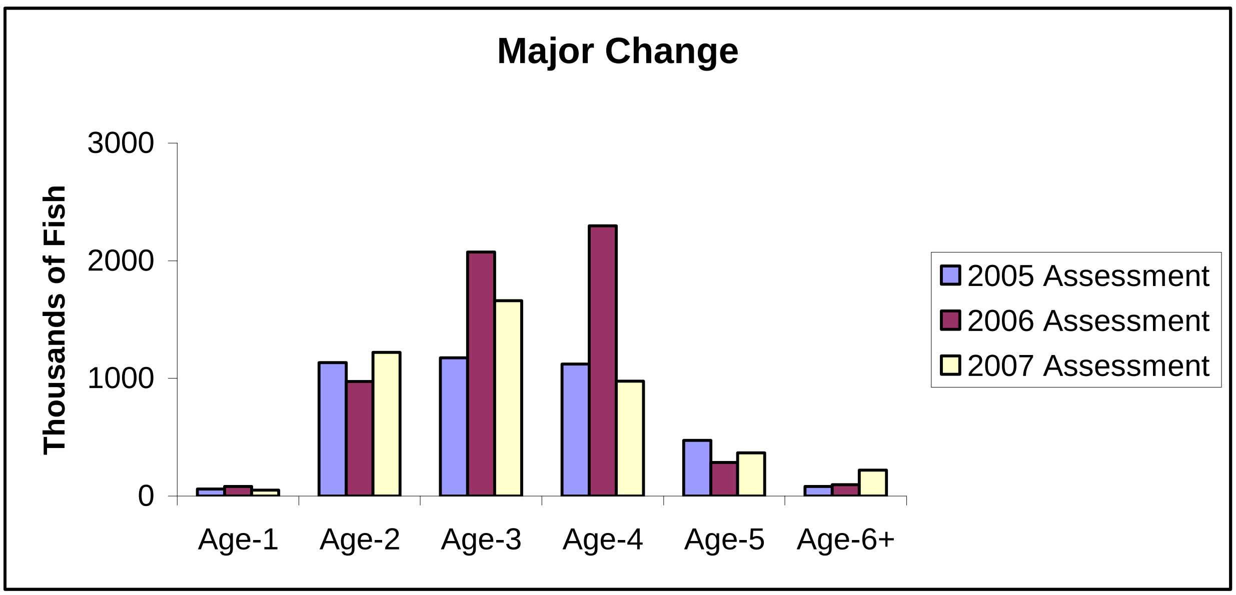


Figure 30. Comparison of the projected and observed 2006 catch at age from the two models and three assessments. The 2005 assessment projected the 2006 catch at age from the estimated 2004 population abundance assuming the 2005 catch would be 6,000 mt and F_{2006} = 0.25. The 2006 assessment projected the 2006 catch at age from the estimated 2005 population abundance assuming the 2006 catch would be 3,000 mt and projected the associated F_{2006} to be 0.30 (Base Case) or 0.83 (Major Change). The 2007 assessment derived the 2006 catch at age from the actual catch of 2,206 mt and estimated F_{2006} to be 0.39 (Base Case) or 0.89 (Major Change).

Appendix

Domain Estimation for Converting DFO Survey to NEFSC Strata

Special thanks to Stephen Smith (DFO) for this work

The DFO and NEFSC surveys are both stratified random designs, but use different stratifications. In order to compare the DFO survey to the NEFSC survey in terms of the concentration of yellowtail flounder on Georges Bank, a conversion between the stratifications must be made. This conversion is known as domain estimation (Särndal et al. 1992). The average catch by the DFO survey in the NEFSC strata cannot be used directly because the tows were not selected randomly from within the NEFSC strata, but rather from within the DFO strata. Domain estimation accounts for the original sampling scheme while computing the mean catch per new stratum using the following process. Define y_k as the kth observation that falls into DFO stratum h and NEFSC domain d, where n_{dh} is the sample size for this combination and H is the total number of DFO strata. The sample size (number of tows) for DFO stratum h is n_h while N_h is the total number of possible samples that could be taken from DFO stratum h. Hence the probability of choosing observation y_k is n_h/N_h in NEFSC domain d. The mean for NEFSC domain d is estimated as

$$\hat{\bar{y}}_d = \sum_{h=1}^{H} \frac{N_h}{n_h} \sum_{k=1}^{n_{dh}} y_k \bigg/ \sum_{h=1}^{H} \frac{N_h}{n_h} n_{dh} \quad .$$

An example of domain estimation for the converting the DFO survey to NEFSC strata is provided in Fig A1. The raw survey data are in the top two boxes on the left side, the sum of yellowtail flounder caught and the number of tows that occurred in the intersections of the DFO and NEFSC strata. For example, the DFO survey randomly allocated 10 tows in stratum 5Z1, which happened to occur in NEFSC strata 1160, 1170, and 1210. The box below the raw data contains the total number of tows by DFO strata (nh), the total number of possible tows (Nh) and the ratio of these values. The boxes on the right show the partial calculations for the estimated means, while the box at the bottom left contains the final estimates.

Sum of Yellowtail Caught (kg)				
NEFSC	DFO Strata			
Strata	5Z1	5Z2	5Z3	5Z4
1130				8.19
1160	28.30	976.15	3.71	570.31
1170	0.00			
1190			0.15	1.43
1200			0.00	
1210	0.74	0.00	1.89	

Numerator Calculation					
NEFSC	DFO Strata				
Strata	5Z1	5Z2	5Z3	5Z4	sum
1130				142384	142384
1160	190638	2876843	65521	9920304	13053305
1170	0				0
1190			2611	24842	27453
1200			0		0
1210	4968	0	33449		38416

Number of Tows				
NEFSC	DFO Strata			
Strata	5Z1	5Z2	5Z3	5Z4
1130				2
1160	5	30	2	9
1170	4			
1190			6	4
1200			2	
1210	1	6	1	

Denominator Calculation					
NEFSC	DFO Strata				
Strata	5Z1	5Z2	5Z3	5Z4	sum
1130				34789	34789
1160	33685	88414	35360	156551	314010
1170	26948				26948
1190			106081	69578	175659
1200			35360		35360
1210	6737	17683	17680		42100

n_h	10	36	11	15
N_h	67369	106096	194482	260919
N_h/n_h	6737	2947	17680	17395

NEFSC Strata	Mean Catch per Tow (kg)
1130	4.09
1160	41.57
1170	0.00
1190	0.16
1200	0.00
1210	0.91

Figure A1. Domain estimation of mean catch in NEFSC strata by DFO survey in 2007.