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Stock Assessment of Georges Bank Yellowtail Flounder for 2009

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ABSTRACT

The combined Canada/US yellowtail flounder (*Limanda ferruginea*) catch decreased from 2007 (1,686 mt) to 2008 (1,275 mt) due mainly to a decrease in quota. There is more uncertainty in this assessment than previous assessments due to the survey data. Specifically, the US spring 2009 survey was conducted with a new vessel and net, which does not have conversion coefficients available yet to allow its inclusion in the time series. Additionally, the 2008 and 2009 Canadian surveys encountered individual tows that were much larger than any seen previously in the time series and have a strong influence on the time series. The US scallop survey was explored as a means of tuning all ages, instead of just as a recruitment index as has been done in the past. The 18 combinations of survey data were used in both the Base Case and Major Change (splitting the survey time series between 1994 and 1995) VPA formulations, for a total of 36 VPA runs. While all combinations of survey values showed generally similar trends in VPA results, the point estimates differed and led to different advice.

During the TRAC meeting, three decisions were made which reduced the number of runs: 1) the Base Case formulation was abandoned, 2) only two combinations of treating the DFO 2008 and 2009 survey were considered (exclude both values or include both values), and 3) only the age 1 values from the US scallop survey were used as a tuning index. It was determined during the meeting that in three years the US scallop survey did not conduct tows in Canadian waters so these years were dropped from the series (1986, 2000, and 2008). Dropping the 2008 value of the US scallop survey reduced the usefulness of including the older ages in the survey. Since the US scallop survey is expected to conduct tows in Canadian waters in 2009 and future years, this survey series will be explored as an option for including all ages in the assessment next year. It was recommended that instead of excluding or including the 2008 and 2009 DFO survey values, these values could be down-weighted in the fitting process due to their much higher uncertainty than other years in the time series. This down-weighting approach will be explored in the assessment next year.

The two final runs ("Excluding" and "Including" the DFO 2008 and 2009 survey values) were similar in trend and differed only in magnitude of the final years' stock size and fishing mortality rates. Both runs indicated recent increases in spawning stock biomass and age 3+ biomass due to the strong 2005 year class. However, both runs also indicated that the 2007 year class is one of the lowest on record, although this estimate is uncertain. Both runs also estimated 2008 fully recruited fishing mortality (ages 4+) to be well below F_{ref}=0.25.

Assuming a catch in 2009 equal to the 2,100 mt total quota, a combined Canada/US catch of about 5,000 mt (Excluding the 2008/2009 DFO surveys) or 7,000 mt (Including the 2008/2009 DFO surveys) in 2010 would result in a neutral risk (~50%) that the fishing mortality rate in 2010 will exceed F_{ref}. In the US, there is a requirement to provide rebuilding projections when stocks are overfished (F_{reb75}). Solving for F_{reb75} results in a median 2010 catch of 450 mt (Excluding) or 2,600 mt (Including) while projecting the F_{reb75} from last year results in a median catch of 2,300 mt (Excluding) or 3,300 mt (Including) in 2010.

RÉSUMÉ

Les prises combinées du Canada et des États-Unis dans le stock de limande à queue jaune (*Limanda ferruginea*) du banc Georges ont diminué en 2008 (1 275 tm) par rapport à 2007 (1 686 tm), à cause principalement d'une réduction du quota. La présente évaluation comporte plus d'incertitudes que les précédentes, en raison des données du relevé. Le relevé américain du printemps 2009, en particulier, a été effectué à l'aide d'un nouveau bateau et d'un nouveau chalut, pour lesquels on ne dispose pas encore de coefficients de conversion qui permettraient d'inclure les données de ce relevé dans la série chronologique. De plus, les relevés canadiens effectués en 2008 et 2009 ont produit des traits beaucoup plus grands que tous les autres de la série chronologique, ce qui influe beaucoup sur les estimations concernant ces années. On a considéré d'utiliser les données du relevé américain sur les pétoncles pour l'ajustement de tous les âges plutôt comme indice de recrutement seulement, comme cela était le cas par le passé. On a utilisé les 18 combinaisons de données de relevé dans les formules d'APV de base et d'APV avec changement majeur (division de la série chronologique de données de relevé entre 1994 et 1995), ce qui s'est traduit par un total de 36 passages d'APV. Bien que toutes les combinaisons de données de relevé aient montré des tendances généralement semblables dans les résultats d'APV, les estimations ponctuelles ne concordaient pas et ont mené à des avis différents.

Trois décisions ont été prises lors de la réunion du CERT, qui ont mené à une réduction du nombre de passages d'APV. Il a été décidé de ne pas retenir la formule d'APV de base, de ne considérer que deux combinaisons des données de relevé du MPO pour 2008 et 2009 (exclusion ou inclusion des deux indices) et d'utiliser seulement les valeurs pour l'âge 1 provenant du relevé américain sur les pétoncles comme indice de rajustement. Il a également été établi que, lors des relevés américains sur les pétoncles effectués en 1986, 2000 et 2008, aucun trait n'avait été réalisé en eaux canadiennes; les données pour ces années ont donc été retirées de la série chronologique. L'élimination de la valeur pour 2008 a réduit l'utilité d'inclure les âges avancés. Comme l'on s'attend à ce que des traits soient réalisés en eaux canadiennes lors du relevé américain sur les pétoncles de 2009 et des années suivantes, on examinera la possibilité d'utiliser cette série de données de relevé pour inclure tous les âges dans l'évaluation de l'an prochain. Il a été recommandé de diminuer la pondération, dans le processus d'ajustement, des indices de relevé du MPO pour 2008 et 2009 en raison de leurs incertitudes accrues par rapport aux autres années de la série chronologique, plutôt que de les exclure ou de les inclure. Cette approche de pondération réduite sera évaluée lors de l'évaluation de l'an prochain.

Les deux derniers passages (« inclusion » et « exclusion » des indices de relevé du MPO pour 2008 et 2009) ont produit des tendances semblables. Seules la taille du stock et la mortalité par pêche dans les dernières années étaient différentes. Les deux passages ont indiqué des augmentations récentes de la biomasse du stock reproducteur et de la biomasse des individus d'âge 3+ attribuables à la forte classe d'âge 2005. Ils ont toutefois révélé que la classe d'âge 2007 est l'une des plus faibles enregistrées, quoique cette estimation soit incertaine. La mortalité par pêche parmi les classes d'âge pleinement recrutées à la pêche (âges 4+) a été estimée comme étant bien inférieure à $F_{réf}$ = 0,25.

Dans l'hypothèse de prises en 2009 égales au quota de 2 100 tm, des prises combinées du Canada et des États-Unis d'environ 5 000 tm (option « d'exclusion » des indices de relevé du MPO pour 2008 et 2009) ou 7 000 tm (option « d'inclusion » des indices de relevé du MPO pour 2008 et 2009) en 2010 se traduiraient par un risque neutre (~ 50 %) que la mortalité par pêche en 2010 dépasse $F_{réf}$. Les États-Unis doivent faire des prévisions pour le rétablissement d'un stock lorsqu'il est surexploité ($F_{rét75}$). La prise en compte de $F_{rét75}$ pour le stock de limande à queue jaune du banc Georges aboutirait à des prises médianes de 450 tm (option « d'exclusion ») ou 2 600 mt (option « d'inclusion ») en 2010, alors que la prévision de $F_{rét75}$ d'après les résultats de l'an dernier se traduirait par des prises médianes de 2 300 tm (option « d'exclusion ») ou 3 300 tm (option « d'inclusion ») en 2010.

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. 2008a) 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 previous 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 could 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 fishing mortality, F, and total mortality, 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 did not include the Canadian 2008 survey information due to the strong influence of a single large tow. This formulation indicated that fishing mortality had never been as low as the target rate but had declined to nearly F_{ref} = 0.25 in 2007. The Base Case VPA model was rejected as the basis for management advice due to the strong retrospective pattern observed. Projections from the Major Change VPA model indicated that catching the TAC of 2,500 mt in 2008 would result in a fishing mortality rate below F_{ref} (F_{2008} = 0.19). Based on these projections, the catch quota for 2009 was set at 2,100 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 mature earlier than most flatfish with approximately half of age two females being mature and nearly all age 3 females being mature.

MANAGEMENT

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.

In 1985, the world court determined US and Canadian jurisdictions for Georges Bank fishery resources. At that time, there was no Canadian fishery for yellowtail. When a Canadian fishery developed in the early 1990s, Canada and US were exchanging information but doing separate assessments. In the late 1990s, joint assessments were developed, and in 2001 a sharing agreement was formed (TMGC 2002). Since the establishment of the U.S. and Canada sharing agreement in 2001, advice for the Georges Bank yellowtail flounder relied primarily on a bilateral management system provided by the Transboundary Management Guidance Committee (TMGC). The agreement includes total allowable catch for each country based on a formulaic calculation using both historical catch and current spatial stock distribution. 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. Although there is coordination between the US and Canadian fishery management, objectives between the two countries remain inconsistent, with US law requiring stock biomass rebuilding targets that are not part of Canadian management.

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 2,200 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 distant water fleets (Table 1). No catches of yellowtail by nations other than Canada and US have occurred since 1975. Catches averaged around 3,500 mt between 1985 and 1994, then dropped to a record low of 1,135 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 in 1994 (Fig. 1b) and by extension to year-round closure in December 1994, as well as 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 subsequent years. A directed Canadian fishery began on eastern

Georges Bank in 1993, pursued mainly by small otter trawlers (< 20 m). Catches by both nations (including discards) steadily increased (with increasing quotas) from a record low of 1,135 mt in 1995, when the stock was considered to be in a collapsed state, to 7,419 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 3,860 mt (2005), 2,170 mt (2006), 1,686 mt (2007), and 1,275 mt (2008).

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 US landings in recent years, although scallop dredges account for some landings. 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.

Landings of yellowtail flounder from Georges Bank by the US fishery during 1994-2008 were derived from the new trip-based allocation described in the GARM III Data meeting (GARM 2007, Palmer 2008, Wigley et al. 2007a). Changes to previous estimates were minimal and uncertainty in the landings due to the random component of the allocation was insignificant (Legault et al. 2008b). US landings have been limited by quotas in recent years. Total US yellowtail landings (excluding discards) for the 2008 fishery were 748 mt, a decrease of 29% from 2007 (Table 1; Fig. 2).

US discarded catch for years 1994-2008 was estimated using the Standardized Bycatch Reporting Methodology (SBRM) recommended in the GARM III Data meeting (GARM 2007, Wigley et al. 2007b). Observed ratios of discards of yellowtail flounder to kept of all species for large mesh otter trawl, small mesh otter trawl, and scallop dredge were applied to the total landings by these gears by half-year. Uncertainty in the discard estimates was estimated based on the SBRM approach detailed in the GARM III Data meeting (GARM 2007, Wigley at al. 2007b). US discards were approximately 16% of the US catch in years 1994-2008 (Table 1; Fig. 2). Total discards of yellowtail in the US decreased 27% from 2007 (503 mt) to 2008 (370 mt). This decrease was due mainly to a decrease in the small mesh discards, although it should be noted that this fishery has a high coefficient of variation (CV) on the discard estimates and so is expected to be less stable than the large mesh or scallop dredge discard estimates (Table 2).

The total US catch of Georges Bank yellowtail flounder in 2008, including discards, was 1,118 mt. The US Georges Bank yellowtail flounder quota for fishing year 2008 (1 May 2008 to 30 April 2009) was set at 1,950 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. Preliminary reporting on the Regional Office webpage (http://www.nero.noaa.gov/ro/fso/usc.htm) indicates the US fishery caught 83% of its quota for the 2008 fishing year. For calendar year 2008, the monitoring system estimated the total US catch to be 1,350 mt, 21% higher than the amount used in the assessment (D. Caless, pers. comm.) This is due to differences in both data availability (real time quota monitoring versus end of year summation) and estimation algorithms (matching logbooks and dealer records to determine catch area as well as use of kept yellowtail versus kept of all species in d:k ratios). Work is continuing to align these two estimates as closely as possible, but there will continue to be differences between the two approaches for the foreseeable future.

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 100 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 landings reached a peak at 2,913 mt. The majority of Canadian landings of yellowtail flounder were made by otter trawl from vessels less than 20 m (tonnage classes 1-3). The fishery generally occurred from June to December, with most landings in the third quarter. Since 2004, there has been no directed Canadian fishery because fishermen have not been able to find commercial densities of yellowtail flounder. Landings have been less than 100 mt every year since 2004, with a low of 17 mt in 2007 and a slight increase to 41 mt in 2008. In these years, most of the reported yellowtail landings were from trips directed for other groundfish species (i.e. cod or haddock).

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 (TRAC 2005). Discards are not recorded in the Canadian fishery statistics and are therefore estimated from observer deployments using the methodology documented in Van Eeckhaute et al. (2005). Since August 2004, there has been routine observer coverage on vessels in the Canadian scallop fishery on Georges Bank. A total of 5 trips were observed in 2004, 11 in 2005, 11 in 2006, 14 in 2007, and 23 in 2008. The seasonal pattern in bycatch rate for years 2005, 2006 and 2007 is taken into account by applying calculations using 3-month moving-average discard rates. In the past, separate estimates for each quarter were calculated and then added together. Application of this approach to data in 2008 results in a discard estimate of 117 mt. Note that in 2009 the Canadian discard estimates were updated for years 2005-2007, although the changes were small (previous values were 255, 565, and 105 mt for years 2005-2007, respectively) (Gavaris et al., 2009).

Discard estimates from 1973-2008 averaged 514 mt and ranged from a low of 117 mt in 2008 to a high of 815 mt in 2001 (Table 1). For 2008, the total Canadian catch, including discards, was 158 mt, an increase of 29% from 2007, but well below the 2008 TAC of 550 mt.

Length and Age Composition

In 2008, 280 length measurements were available from one port sample in the Canadian fishery of 41 mt (Table 3) and were used to determine size composition of the Canadian catch by sex. No length measurements were utilized from at sea observer deployments because in the past sex determinations from these samples were found to be inaccurate.

The level of US port sampling continued to be strong in 2008, with 7,607 length measurements available from 81 port samples, resulting in 1,017 lengths/100 mt of landings (Table 3). This level of sampling resulted in relatively low CVs for the US landings at age, as estimated by a bootstrapping procedure (Table 4). The 81 port samples also provided 1,643 age measurements for use in age-length keys. The Northeast Fisheries Observer Program provided an additional 16,662 length measurements of discarded fish from 264 trips.

The US landings are classified by market category (large, small, medium, and unclassified) and this categorization is used to determine the size and age distributions. 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 2007 and 2008 proportions were 60%. Examination of the size distributions of the two market categories continues to show some overlap in the 35-38 cm range, but overall differences between the groups were still clearly distinct (Fig. 3).

The size composition of yellowtail flounder discards in the Canadian offshore scallop fishery was estimated by half year using length measurements obtained from 23 observed trips in 2008. 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).

US discard length frequencies were generated from observer data, expanded to the total weight of discards by gear type and half year. Large mesh trawl discards showed a strong peak near the minimum allowed size, but larger fish were also discarded (Fig. 4). Small mesh discards accounted for only a small portion of the total discards but cover a wide range of lengths because this fishery is prohibited from landing groundfish (Fig. 4). Scallop dredge discards were mainly legal sized fish, as has been typically seen for dredge gear in the past (Fig. 4).

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. 5), although the small magnitude of Canadian landings makes this comparison suspect. Canadian discards were quite similar in both mean size and spread in the distributions relative to US discards (Fig. 6). 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. 7).

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 (>80% for most studies) with no indication of bias.

No scale samples were available for the Canadian fishery in 2008. 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 2008 Canadian landings, which only consisted of 3% of the total catch. Canadian discards at age by half year were obtained using half year age length keys based on the following combined ages: Half 1 US commercial fishery + National Marine Fisheries Service (NMFS) spring survey + Department of Fisheries and Oceans (DFO) survey, and Half 2 US commercial fishery + NMFS fall survey.

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. The age-length keys for US landings used only age samples from US port samples, while the age-length keys for US discards added US and DFO survey samples for fish below the minimum size limit.

In 2008, ages 2, 3, and 4 (2006, 2005, and 2004 year classes, respectively) dominated both Canadian and US landings, with age 3 predominant (Fig. 8). 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 5; Fig. 9).

The fishery mean weights at age (WAA) for each of the combinations of Canadian and US landings and discards were derived using the age-length keys, 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 weight at age were calculated from Canadian and US landings and discards, weighted by the respective catch at age (Table 6; Fig. 10). 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 WAA values are within the range of past WAA calculations since 1973, except for age 1 which accounts for less than 1% of the catch by number.

ABUNDANCE INDICES

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by DFO in the spring (February) and by NMFS in the spring (April) and fall (October). Both agencies use a stratified random design, though different strata boundaries are defined (Fig. 11). NMFS spring and fall bottom trawl survey catches (strata 13-21), NMFS scallop survey catches (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 the Albatross IV oval BMV 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.

There is more uncertainty in this assessment than previous assessments due to the survey data. Specifically, the US spring 2009 survey was conducted with a new vessel (FRV Henry B. Bigelow) and net which does not have conversion coefficients available yet to allow its inclusion in the time series. There is currently work being conducted to estimate these conversion coefficients and it is expected they will be available in time for the assessment next year. Additionally, the 2008 and 2009 Canadian surveys encountered individual tows that were much larger than any seen previously in the time series and have a strong influence on the time series. During last year’s assessment, the decision was made to not include the 2008 DFO index due to the influence of a single large tow. However, the additional observations of large catches in single tows combined with the 2009 US spring survey not being available, means that if both the 2008 and 2009 DFO index values are not included, there will be no tuning information for 2009 in the model. Finally, the US scallop survey was explored as a means of tuning all ages, instead of just as a recruitment index as has been done in the past. The length frequency distributions from the scallop survey were converted to ages by applying age-length keys from the US spring and fall surveys combined. Comparison of the trends over time from the scallop and three bottom trawl surveys indicate they are tracking similar trends at all ages (Fig. 12). Since the 2008 US scallop survey did not sample in the Canadian portion of Georges Bank and therefore would not provide additional tuning information in the terminal year, it was decided at the TRAC meeting that only the age-1 index from the US scallop survey would be included. However, it was recommended that these new survey indices from the US scallop survey should be explored as an option in the next assessment given the uncertainties associated with the bottom trawl surveys in recent years.

Yellowtail flounder biomass indices from the four surveys track 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 have since fluctuated (Table 7; Fig. 12). The current index is higher than any observed during the mid-1990s when the stock had collapsed. The strong influence of the single large tows in the DFO 2008 and 2009 surveys is seen by comparing the “a” and “b” rows in Table 7. 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 (the maximum value in the series; Table 8; Fig. 12). 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 time series, also increased from 1995 to 1999, fell slightly in 2000 followed by a large increase in 2001 (Table 9; Fig. 12). The NMFS fall index showed a strong decline between 2001 and 2002, and has generally increased since 2002. The NMFS fall index is at a relatively high level compared to the mid 1990s when the stock was collapsed. The scallop survey shows a strong increase from low levels in the mid 1990s to a peak in 1998 followed by a decline through 2005 and a subsequent increase (Table 10; Fig. 12). Even the low scallop survey value in 2005 was well above the levels in the mid 1990s 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 two surveys in Fig. 13. 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 1995 through 2003 (Fig. 14). However, the past two years have seen almost the entire Canadian survey catch occur in just one or two tows in stratum 5Z1, making interpretation of trends over time difficult.

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 personnel are now ageing scales collected on DFO surveys. From the 2009 DFO survey, 109 male and 109 female fish were aged and used to produce separate-sex age-length keys, subsequently used to generate the 2009 DFO age-specific indices of abundance.

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 (Tables 7-10; Fig. 15). Even though each index is noisy, the age specific trends track relatively well among the four surveys (Tables 7-10; Fig. 16).

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 catch biomass/survey biomass, scaled to the mean for 1987-2005) was quite variable but followed a similar trend for all four surveys, with the early years at high levels and a sharp decline to low levels beginning in 1995 (Fig. 17). In contrast, estimates of total mortality rates from the surveys for ages 2, 3 and 4-6, although noisy, have remained the same over the entire time period (Fig. 18).

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 the population and fishery dynamics assumptions are required to reconcile the fishery and the survey observations. Models that adopt such modifications imply major consequences on underlying processes or fishery monitoring procedures. The magnitude of implied changes to natural mortality rate, survey catchability relationships, or unreported catch is so great that the acceptability of models that incorporate these effects is suspect. However, these models may provide better catch advice for management of this resource than ignoring the changes in underlying processes (ICES 2008).

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 three VPA approaches: Base Case, Minor Change, and Major Change. 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 (Stone and Legault 2005, Legault et al. 2006, Legault et al. 2007, Legault et al. 2008a). The Minor Change VPA was not considered in this assessment and will not be considered in future assessments. The Base Case VPA was continued for a number of years after the benchmark, but has not been accepted for use in providing management advice for the past few years (Legault et al. 2006, Legault et al. 2007, Legault et al. 2008a). At this year’s TRAC meeting, it was agreed that the Base Case model would no longer be considered in either this or future assessments due to its strong retrospective pattern and inability to match trends observed in the surveys.

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 v2.8. 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. 2008a). Both point estimates and bootstrap statistics of the estimated parameters were derived using only the US software for this assessment.

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 precedent of previous assessments, the Major Change VPA was reformulated to be the same as the Base Case VPA, with the exception that the survey time series were split at 1995 (Legault et al. 2006, Legault et al. 2007, Legault et al. 2008a). This one difference has been sufficient 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 split series formulation was used again this year as the Major Change VPA.

The Major Change 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 2008, where t represents the beginning of the time interval during which the catch was taken. 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 2009
(note: s_2 = DFO spring, ages a = 2 to 6+, time t = 1995 to 2007 in the 'excluding' assessment)
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 2008
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 2008.5
s_8 = NMFS scallop, age a = 1, time t = 1982.5 to 1994.5
s_9 = NMFS scallop, age a = 1, time t = 1995.5 to 2008.5
(note: the NMFS scallop survey was not used for years 1986, 1989, 1999, 2000, or 2008)

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 directly for ages 2-5.

Indices Used for This Assessment

As described above, there are a number of additional considerations for this assessment that discourage status quo application of the Base Case and Major Change formulations recommended during the benchmark assessment. The US spring survey does not have 2009 index values available due to the lack of conversion coefficients, meaning only the DFO survey can provide information for 2009. However, as in 2008, the 2009 DFO survey was heavily influenced by an unusually large tow of 5.2 mt (the 2008 survey had a single tow of 7.5 mt). Following the precedent from last year, the 2009 value would not be used, meaning the model would have no information about population trends in the year when it is estimating abundance at age. Also, a new source of information has become available for this assessment, the US scallop survey ages 2-6+ could potentially be added to the formulation to add stability to the estimation process. Thus, 36 separate formulations of the VPA were applied in preparation for the TRAC meeting: Base Case vs Split Series approach to treating the time series of all indices; the DFO 2008 index was treated as missing or else included with low values which dropped the single large tow or as high values which included the large tow; the DFO 2009 index was similarly treated as missing, low, or high; and the US scallop survey was included as either only age 1 or all ages (2x3x3x2=36 formulations).

These 36 formulations were reviewed during the TRAC meeting. The Base Case formulations with and without the large DFO tows both show strong retrospective patterns and so were dropped from consideration in this assessment. The TRAC agreed that the Base Case formulation was no longer viable and does not need to be considered in future assessments. During the meeting, it was determined that the 2008 US scallop survey, as well as the 1986 and 2000 US scallop surveys, did not sample the Canadian portion of Georges Bank, and so were dropped from this time series. The main goal of including the extra ages from this survey was to improve the tuning ability in recent years, but since the most recent year was no longer included, the decision was made to use only age 1 from the US scallop survey for this assessment. However, the consideration of US scallop survey ages 2-6+ as tuning indices in future assessments was recommended. Finally, the TRAC decided to consider only two combinations of how to handle the large tows in the DFO 2008 and 2009 surveys: Exclude both years from the time series or include all tows for both years. These two Major Change formulations, called “Excluding” and “Including”, were considered to bracket the true population trajectory. The DFO survey values for 2008 and 2009 were greatly increased for most ages by the single large tow in each year, but this also greatly increased the variance associated with these observations. When tuning the VPA, this increased variance of the observations should be taken into account. However, software was not readily available to conduct all analyses in this manner. A preliminary examination of down-weighting these observations produced results intermediate between the Excluding and Including formulations.

Diagnostics

The two VPA formulations performed similarly in terms of relative error and bias in the population abundance estimates (Tables 11-12). The Excluding formulation had higher relative error and bias for all ages relative to the Including formulation, but in both models the odler ages had less relative error and bias than younger ages. This pattern of higher uncertainty in the younger ages has been seen in previous assessments and is due to having less information about these cohorts.

Survey calibration constants (q’s) for the two VPA formulations followed similar patterns (Fig. 19). The most notable pattern was the increase in estimated values at nearly all ages between the pre-1995 and recent period (1995 to present), with some ages showing more than a five-fold increase and averaging a three-fold increase. 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. Management strategy evaluations have demonstrated that even if the true source of the retrospective pattern is misreported catch or changes in natural mortality, this approach of splitting the time series to address the retrospective problem produces better performance (true F closer to target F) than ignoring the retrospective pattern (ICES 2008).

The two VPA formulations have similar residual patterns, with mixed positive and negative residuals throughout the time series. The Excluding formulation does not have residuals for the DFO survey in 2008 and 2009 because these survey values did not contribute to the fit of the model (Fig. 20). Including the DFO 2008 and 2009 survey values causes large positive residuals (observations greater than model predictions) as expected in the DFO survey for all ages in 2009 and for most of the ages in 2008 due to the influence of the large tows (Fig. 21). The standard sampling protocol in 2008 did not collect any age 6+ yellowtail in the large tow that year, and so this index value was not high when the tow was included.

Retrospective analysis for both VPA formulations did not indicate a strong tendency to over or underestimate fishing mortality on ages 4-5, spawning stock biomass, or recruitment (Figs. 22-23). The two retrospective analyses are expected to be similar because the runs for years ending in 2007 and prior are identical for the two formulations.

There was no diagnostic basis to select one of the VPA formulations over the other, so both the Excluding and Including formulations were recommended by the TRAC as the basis for management advice.

STOCK STATUS

Results from both the Excluding and Including VPA model formulations were used to evaluate the status of the stock in 2008 (Tables 13-16). The fishery weights at age, assumed to represent mid-year weights, were used to derive beginning of year weights at age (Table 17), and these were used to calculate beginning of year population biomass (Table 18). In the US, spawning stock biomass is the legal status determination criterion and is computed assuming maturity at age and the proportion of mortality within a year that occurs prior to spawning (p = 0.4167).

Adult population biomass (age 3+) increased from a low of 2,100 mt in 1995 to 11,000 mt in 2003, declined to about 3,300 mt in 2006, and increased to 20,600 mt (Excluding) or 28,000 mt (Including) at the beginning of 2009, the highest adult biomass since 1973 (Table 18, Fig. 24). Spawning stock biomass in 2008 was estimated to be 17,800 mt (80% Confidence Interval: 14,000-27,300 mt) for the "Excluding" run or 22,900 mt (80% Confidence Interval: 18,700-29,000 mt) for the "Including" run. The large increases in both adult biomass and spawning stock biomass at the end of the time series, to levels comparable to the early 1970s, are due to the large 2005 year-class. However, the age structure of the population has not extended to older ages yet. The results of next year’s assessment should indicate whether or not this strong cohort continues to contribute significantly to the adult and spawning stock biomass.

During 1998-2001 recruitment averaged 22.3 million fish at age 1 but has since been below 20 million fish, with the exception of the above average 2005 year class estimated at 46.6 million (Excluding) or 58.1 million (Including), the strongest year class since the 1980 cohort (Tables 13-14). The 2006 year class is about average while the 2007 year class is estimated to be one of the lowest in the time series at 2.8 million (Excluding) or 9.5 million (Including), although this estimate is uncertain because there is little survey information available and only catch at age 1 in 2008 to determine its magnitude. The tuning data available are the NEFSC Fall 2008 age 1 value for both the Excluding and Including series and the DFO 2009 age 2 value for the Including series. The NEFSC Spring 2008 age 1 survey value is zero, which is treated as missing in the tuning process, the US scallop 2008 age 1 survey value is not available due to lack of coverage of the Canadian side of Georges Bank, and the age 1 values from the DFO survey are not used as a tuning index. The use of the large DFO 2009 age 2 value in tuning increases the recruitment estimate for 2008 more than three-fold, but the resulting estimate is still one of the lowest in the time series. As seen in the uncertainty of the age 2 population estimates in 2009 and the retrospective plot, these estimates of the strength of the 2007 year class are highly uncertain and could change dramatically next year, either up or down.

Fishing mortality for fully recruited ages 4+ was close to or above 1.0 between 1973 and 1995, fluctuated between 0.51 and 0.97 during 1996-2003, increased in 2004 to 1.85, and then declined to 0.41 (Excluding) or 0.38 (Including) in 2007 and 0.09 (Excluding) (80% Confidence Interval: 0.07-0.13) or 0.08 (Including) (80% Confidence Interval: 0.07-0.11) in 2008, below the reference point of F_{ref} = 0.25 (Tables 15-16). This pattern in F does not correspond with the relative fishing mortality rate pattern estimated as catch/survey (Fig.17). The relative F pattern shows a sudden decline in 1995 and continued low levels since then. This pattern was seen in previous Base Case assessments. However, these assessments had strong retrospective patterns which increased the F as additional years became available. Given the lack of a strong retrospective pattern in both the Excluding and Including VPA formulations in this assessment, F is not expected to increase substantially with additional years of data. This will depend on the strong 2005 year class continuing to appear in both the catch and surveys in the next few years.

FISHERY REFERENCE POINTS

Yield per Recruit Reference Points

The current reference fishing mortality rate used by the TMGC (F_{ref}=0.25, ages 4+) was derived from both $F_{0.1}$ and $F_{40\%MSP}$ calculations. Although the yield per recruit (YPR) analysis was not updated this year, both the 2002 and 2008 assessment YPR analysis (NEFSC 2002, NEFSC 2008 confirmed that both these values remain at 0.25. This is the same value as the F_{MSY} proxy of $F_{40\%MSP}$ used for US management (NEFSC 2008). This suggests that F_{ref} is robust to the changes in partial recruitment observed over the years.

Stock and Recruitment

The TMGC does not have an explicit biomass target. There is evidence of reduced recruitment at low levels (below 5,000 mt) of spawning stock biomass (Figs. 25-26). In the US, this stock-recruitment relationship was used to estimate the B_{MSY} proxy by projecting the population for many years with F = $F_{40\%MSP}$ and recruitment randomly selecting from the cumulative distribution function of recruitment observed at SSB > 5,000 mt. The B_{MSY} level of 43,200 mt of spawning stock biomass was set as the rebuilding goal in the US for this stock (NEFSC 2008). Current levels of spawning stock biomass (SSB) are below the rebuilding goal (SSB_{2008}/SSB_{MSY} = 41% Excluding, 53% Including).

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2010. Uncertainty about current biomass generates uncertainty in forecast results, which is expressed here as the risk of exceeding F_{ref} = 0.25. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, they are dependent on the data and model assumptions and do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough.

Due to changes in fishery partial recruitment patterns over time and increasing trends in both survey and fishery weights at age, average values from 2006-2008 were used in the projections. Assuming a catch in 2009 equal to the 2,100 mt total quota, a combined Canada/US catch of about 5,000 mt (Excluding) or 7,000 mt (Including) in 2010 would result in a neutral risk (~50%) that the fishing mortality rate in 2010 will exceed F_{ref} (Fig. 27). Fishing at F_{ref} in 2010 will generate a 3% increase in age 3+ biomass from 21,400 mt in 2010 to 22,000 mt in 2011 (Excluding) or a 2% increase in age 3+ biomass from 31,100 mt in 2010 to 31,700 mt in 2011 (Including). The 2005 year class is expected to account for 58-59% of the 2009 catch, 47-51% of the 2010 catch, and 40-44% of the 2010 age 3+ biomass (Tables 19-20).

In the US, there is a requirement to provide rebuilding projections when stocks are overfished. The rebuilding scenario for Georges Bank yellowtail flounder requires solving for a value of F (Freb75) that, when applied in years 2010-2014, results in a 75% probability that SSB in 2014 is greater than SSBmsy (43,200 mt). Using the same starting conditions as the projection described above, the Freb75 was found through iterative search to be 0.02 (Excluding) or 0.085 (Including), resulting in a median 2010 catch of 450 mt (Excluding) or 2,600 mt (Including), well below the F_{ref} projection described above. An alternative interpretation of the rebuilding requirements is to continue to project the Freb75 found last year according the method described above, which was 0.107. Fishing at F=0.107 in years 2010-2014 results in a median catch of 2,300 mt (Excluding) or 3,300 mt (Including) in 2010, but only a 52% (Excluding) or 69% (Including) probability of SSB2014 being greater than the rebuilding target of 43,200 mt.

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 2 through 4 (Fig. 28). The low proportion at age 1 in 2008 is a reflection of the weak 2007 year class, while the strong 2005 year class appears at age 3 in 2008. 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 from the relative F calculations. The spatial distribution patterns from the DFO survey are difficult to interpret due to the large DFO tows in 2008 and 2009. These individual large tows could be indicative of a change in behavior of this species on Georges Bank, although they have not occurred in any of the NEFSC surveys. Truncated age structure in the surveys and change in distribution indicate current productivity may be limited relative to historical levels.

MANAGEMENT CONSIDERATIONS

In the past, realized fishing mortality rates have been higher than the target F used to set the annual quotas. For example in 2005, a catch of 2,100 mt in 2006 was projected to produce a fishing mortality well below 0.25 using the Base Case model and 0.25 using the Major Change model. The realized 2006 fishing mortality was about 1.0 according to the current Major Change model. However, in more recent years the realized Fs are closer to the projected values. The 2007 TRAC Status Report used the Major Change model to project that a catch of 3,500 mt in 2008 would have a neutral risk of exceeding F_{ref}=0.25. The observed 2008 catch of 1,275 mt is now estimated to have generated an F in 2008 of 0.09 (Excluding) or 0.08 (Including). The adult (age 3+) biomass was projected to be 21,400 mt in 2008 and 24,900 mt in 2009, which are greater than the current estimates from the "Excluding" run of 15,200 mt in 2008 and 20,600 mt in 2009 but similar to the estimates from the "Including" run of 18,400 mt in 2008 and 28,000 mt in 2009. This improved consistency from one assessment to the next is another indication that the retrospective problem seen in the Base Case formulation has been addressed through the Major Change formulation.

The Major Change VPA is recommended for management decisions, even though the mechanisms for the large changes in survey catchability are not explained. These changes in survey catchability are most appropriately thought of as an alias for other model mis-specificaitons that produces a better fitting model. Examples of such mis-specifications that could cause a retrospective pattern are misreported catches or changes in the natural mortality rate. The inability to plausibly explain these survey catchability changes causes increased uncertainty in this assessment relative to other assessments. However, as mentioned above, simulation analyses have demonstrated that even when a change in survey catchability is not the actual mechanism causing a retrospective pattern, improved management advice results from the Major Change approach of splitting the survey time series (ICES 2008). These analyses support the use of the Major Change formulation over the Base Case formulation. The Base Case model formulation will not be carried forward in 2010.

The two model formulations recommended for providing management advice differ in how the DFO 2008 and 2009 survey values are viewed. In the Excluding case, these survey values are considered not representative of the stock dynamics due to the influence of the single large tows, even though the observations were made as part of the standard operating procedures of the scientific survey. In the Including case, these survey values are treated the same as all the other observations from the time series, even though the CV associated with these large values is much higher (approximately double) than the rest of the observations. Neither approach is completely satisfactory from a model fitting point of view. The TRAC suggested that down-weighting these large survey values relative to the other survey observations would be a more appropriate statistical approach. This will be attempted next year, although there may be consequences for the bootstrapping procedure that estimates the uncertainty of the current population abundance and fishing mortality rate.

The NEFSC spring and fall surveys will be conducted with a new vessel and net beginning with the spring 2009 survey. These survey observations will need to be calibrated to reflect what would have been caught had the previous vessel and net been used in order to utilize them in the same time series. The calibration approach has recently been reviewed, but there were a number of recommendations requiring additional analyses. It is expected that these calibration coefficients will be available at the assessment next year and be used for the spring 2009, fall 2009, and spring 2010 survey observations. This additional information may decrease the importance of the DFO 2008 and 2009 survey values in terms of model fits.

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Table 1. Annual catch (mt) of Georges Bank yellowtail flounder. The highlighted cells indicate values that were incorrectly reported in GARM III while bold cells indicate updated estimates of Canadian discards for years 2005 to 2007.

Year	US Landings	US Discards	Canada Landings	Canada Discards	Other Landings	Total Catch	% discards
1935	300	100	0	0	0	400	25%
1936	300	100	0	0	0	400	25%
1937	300	100	0	0	0	400	25%
1938	300	100	0	0	0	400	25%
1939	375	125	0	0	0	500	25%
1940	600	200	0	0	0	800	25%
1941	900	300	0	0	0	1200	25%
1942	1575	525	0	0	0	2100	25%
1943	1275	425	0	0	0	1700	25%
1944	1725	575	0	0	0	2300	25%
1945	1425	475	0	0	0	1900	25%
1946	900	300	0	0	0	1200	25%
1947	2325	775	0	0	0	3100	25%
1948	5775	1925	0	0	0	7700	25%
1949	7350	2450	0	0	0	9800	25%
1950	3975	1325	0	0	0	5300	25%
1951	4350	1450	0	0	0	5800	25%
1952	3750	1250	0	0	0	5000	25%
1953	2925	975	0	0	0	3900	25%
1954	2925	975	0	0	0	3900	25%
1955	2925	975	0	0	0	3900	25%
1956	1650	550	0	0	0	2200	25%
1957	2325	775	0	0	0	3100	25%
1958	4575	1525	0	0	0	6100	25%
1959	4125	1375	0	0	0	5500	25%
1960	4425	1475	0	0	0	5900	25%
1961	4275	1425	0	0	0	5700	25%
1962	5775	1925	0	0	0	7700	25%
1963	10990	5600	0	0	100	16690	34%
1964	14914	4900	0	0	0	19814	25%
1965	14248	4400	0	0	800	19448	23%
1966	11341	2100	0	0	300	13741	15%
1967	8407	5500	0	0	1400	15307	36%
1968	12799	3600	122	0	1800	18321	20%
1969	15944	2600	327	0	2400	21271	12%
1970	15506	5533	71	0	300	21410	26%
1971	11878	3127	105	0	500	15610	20%
1972	14157	1159	8	515	2200	18039	9%
1973	15899	364	12	378	300	16953	4%
1974	14607	980	5	619	1000	17211	9%
1975	13205	2715	8	722	100	16750	21%
1976	11336	3021	12	619	0	14988	24%
1977	9444	567	44	584	0	10639	11%
1978	4519	1669	69	687	0	6944	34%

Year	US Landings	US Discards	Canada Landings	Canada Discards	Other Landings	Total Catch	% discards
1979	5475	720	19	722	0	6935	21%
1980	6481	382	92	584	0	7539	13%
1981	6182	95	15	687	0	6979	11%
1982	10621	1376	22	502	0	12520	15%
1983	11350	72	106	460	0	11989	4%
1984	5763	28	8	481	0	6280	8%
1985	2477	43	25	722	0	3267	23%
1986	3041	19	57	357	0	3474	11%
1987	2742	233	69	536	0	3580	21%
1988	1866	252	56	584	0	2759	30%
1989	1134	73	40	536	0	1783	34%
1990	2751	818	25	495	0	4089	32%
1991	1784	246	81	454	0	2564	27%
1992	2859	1873	65	502	0	5299	45%
1993	2089	1089	682	440	0	4300	36%
1994	1431	148	2139	440	0	4158	14%
1995	360	43	464	268	0	1135	27%
1996	743	96	472	388	0	1700	28%
1997	888	327	810	438	0	2464	31%
1998	1619	482	1175	708	0	3985	30%
1999	1818	577	1971	597	0	4963	24%
2000	3373	694	2859	415	0	7341	15%
2001	3613	78	2913	815	0	7419	12%
2002	2476	53	2642	493	0	5663	10%
2003	3236	410	2107	809	0	6562	19%
2004	5837	460	96	422	0	6815	13%
2005	3161	414	30	**246**	0	3851	17%
2006	1196	384	25	**504**	0	2109	42%
2007	1061	503	17	**94**	0	1675	36%
2008	748	370	41	117	0	1275	38%

Table 2. Derivation of Georges Bank yellowtail flounder US discards (mt) calculated as the product of the ratio estimator (d:k - discard to Kept all species on a trip in a stratum) and total kept (K_all) in each stratum. Coefficient of variation (CV) provided by gear and year.

		Small Mesh Trawl					Large Mesh Trawl					Scallop Dredge					Total
Year	**Half**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**D (mt)**
1994	1	1	0.0000	1090	0		16	0.0013	7698	10		1	0.0001	2739	0		11
	2	1	0.0000	1316	0		6	0.0199	6445	128		4	0.0039	2531	10		138
1994 Total		**2**			**0**	**0%**	**22**			**138**	**150%**	**5**			**10**	**6%**	**148**
1995	1	1	0.0000	2331	0		27	0.0023	6256	14		1	0.0017	522	1		15
	2	1	0.0000	919	0		10	0.0055	3844	21		2	0.0017	3634	6		28
1995 Total		**2**			**0**	**0%**	**37**			**36**	**70%**	**3**			**7**	**20%**	**43**
1996	1	2	0.0000	3982	0		12	0.0066	7094	47		2	0.0025	2132	5		52
	2	1	0.0000	1470	0		1	0.0005	7269	4		2	0.0081	4960	40		44
1996 Total		**3**			**0**	**0%**	**13**			**51**	**30%**	**4**			**45**	**0%**	**96**
1997	1	1	0.0000	2102	0		3	0.0247	8215	203		3	0.0048	4044	19		222
	2			1391	0		3	0.0019	4098	8		3	0.0250	3903	97		105
1997 Total		**1**			**0**	**0%**	**6**			**211**	**22%**	**6**			**117**	**74%**	**327**
1998	1	1	0.0000	1808	0		3	0.0219	8059	177		2	0.0065	3849	25		202
	2			3111	0		2	0.0015	5611	8		3	0.0551	4945	272		280
1998 Total		**1**			**0**	**0%**	**5**			**185**	**66%**	**5**			**297**	**46%**	**482**
1999	1	1	0.0000	3868	0		2	0.0010	9391	9		4	0.0152	8806	134		143
	2			2638	0		5	0.0005	4755	2		15	0.0176	24524	432		434
1999 Total		**1**			**0**	**0%**	**7**			**11**	**67%**	**19**			**566**	**13%**	**577**
2000	1	2	0.0000	3665	0		6	0.0014	10869	15		25	0.0457	8320	380		395
	2	2	0.0272	1665	0		11	0.0015	6421	10		154	0.0181	15991	289		299
2000 Total		**4**			**0**	**90%**	**17**			**25**	**71%**	**179**			**669**	**12%**	**694**
2001	1	5	0.0045	2347	0		13	0.0038	13047	49		16	0.0019	7728	14		63
	2	2	0.0000	3461	0		13	0.0002	6716	1			0.0019	7162	13		15
2001 Total		**7**			**0**	**105%**	**26**			**50**	**51%**	**16**			**28**	**7%**	**78**
2002	1	1	0.0000	2420	0		11	0.0010	14525	14			0.0035	2074	7		21
	2	6	0.0001	2243	0		37	0.0015	6196	10		4	0.0035	6134	22		31
2002 Total		**7**			**0**	**79%**	**48**			**24**	**42%**	**4**			**29**	**27%**	**53**
2003	1	7	0.0001	2350	0		61	0.0064	15264	97			0.0149	9612	143		241
	2	7	0.0002	4764	1		46	0.0021	8438	18		2	0.0149	10083	150		169
2003 Total		**14**			**1**	**95%**	**107**			**115**	**39%**	**2**			**293**	**0%**	**410**
2004	1	5	0.0005	2504	1		68	0.0078	14130	111		2	0.0001	2942	0		112
	2	12	0.0215	2508	54		86	0.0179	11958	214		28	0.0058	13885	81		348
2004 Total		**17**			**55**	**62%**	**154**			**324**	**20%**	**30**			**81**	**21%**	**460**
2005	1	41	0.0206	1448	30		369	0.0092	9935	92		8	0.0032	8217	27		148
	2	36	0.0068	3207	22		200	0.0094	8988	85		55	0.0041	38751	159		266
2005 Total		**77**			**52**	**28%**	**569**			**177**	**12%**	**63**			**186**	**20%**	**414**
2006	1	11	0.0004	824	0		182	0.0074	7008	52		13	0.0015	20457	30		83
	2	6	0.0127	1995	25		121	0.0111	4963	55		54	0.0056	39378	221		301
2006 Total		**17**			**26**	**95%**	**303**			**107**	**14%**	**67**			**251**	**19%**	**384**
2007	1	8	0.0016	3501	5		147	0.0166	8366	139		17	0.0031	13186	40		185
	2	3	0.0469	2261	106		156	0.0237	5548	132		42	0.0036	22413	81		319
2007 Total		**11**			**111**	**107%**	**303**			**270**	**12%**	**59**			**121**	**25%**	**503**
2008	1	4	0.0000	1589	0		184	0.0230	5603	129		20	0.0067	6721	45		174
	2	4	0.0221	1043	23		212	0.0144	5960	86		22	0.0078	11109	87		196
2008 Total		**8**			**23**	**297%**	**396**			**215**	**7%**	**42**			**132**	**15%**	**370**

Table 3. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2008 from Canadian and US sources.

	Landings (metric tons)					Port Sampling (Number of Lengths or Ages)						
US	Market Category					Market Category					Lengths	Number
Half	Uncl.	Large	Small	Medium	Total	Uncl.	Large	Small	Medium	Total	per 100mt	of Ages
1	17	244	118	5	384	0	2278	1671	0			765
2	11	221	127	5	364	0	1997	1661	0			878
Total	27	465	246	10	748	0	4275	3332	0	7607	1017	1643
Canada											Lengths	Number
Quarter					Total					Total	per 100mt	of Ages
1					0							
2					30					280		0
3					10							
4					1							
Total					41					280	683	0

Table 4. Georges Bank yellowtail flounder coefficient of variation for US landings at age by year.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1994		57%	6%	14%	27%	41%
1995		27%	11%	13%	22%	40%
1996		23%	7%	15%	26%	60%
1997		17%	11%	8%	30%	35%
1998		64%	31%	16%	36%	30%
1999	97%	21%	9%	25%	33%	34%
2000		11%	9%	11%	20%	32%
2001		17%	11%	10%	22%	48%
2002	76%	15%	11%	11%	15%	22%
2003		16%	8%	9%	11%	16%
2004		53%	8%	6%	9%	11%
2005		11%	4%	6%	12%	16%
2006		10%	5%	6%	6%	13%
2007		12%	5%	6%	14%	18%
2008		16%	4%	6%	17%	34%

Table 5. Total catch at age including discards (number in 000s) for US-Canadian Georges Bank yellowtail flounder, 1973-2008.

	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	71	1336	6302	1819	477	120	20	3	0	0	0	0	10150
1995	47	313	1435	879	170	25	10	1	0	0	0	0	2880
1996	101	681	2064	885	201	13	10	5	0	0	0	0	3960
1997	82	1132	1832	1857	378	39	43	7	1	0	0	0	5371
1998	169	1991	3388	1885	1121	122	18	3	0	3	0	0	8700
1999	60	2753	4195	1548	794	264	32	4	1	0	0	0	9651
2000	132	3864	5714	3173	826	420	66	38	4	0	0	0	14237
2001	176	2884	6956	2893	1004	291	216	13	4	0	0	0	14438
2002	212	4169	3446	1916	683	269	144	57	10	6	0	0	10911
2003	160	3919	4710	2320	782	282	243	96	47	23	2	0	12585
2004	64	1201	3171	3804	1970	884	398	77	72	18	2	0	11661
2005	60	1529	4086	1712	411	122	39	17	0	0	0	0	7977
2006	154	1300	1698	1003	373	125	65	14	7	3	0	0	4742
2007	53	1464	1765	700	142	47	10	1	0	0	0	0	4181
2008	28	489	1618	673	100	11	4	0	0	0	0	0	2922

Table 6. Mean weight at age (kg) for the total catch including US and Canadian discards, for Georges Bank yellowtail flounder, 1973-2008.

	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	0.193	0.260	0.353	0.472	0.621	0.780	0.678	1.148				
1995	0.174	0.275	0.347	0.465	0.607	0.720	0.916	0.532				
1996	0.119	0.276	0.407	0.552	0.707	0.918	1.031	1.216				
1997	0.214	0.302	0.408	0.538	0.718	1.039	0.827	1.136	1.113			
1998	0.178	0.305	0.428	0.546	0.649	0.936	1.063	1.195		1.442		
1999	0.202	0.368	0.495	0.640	0.755	0.870	1.078	1.292	1.822			
2000	0.229	0.383	0.480	0.615	0.766	0.934	1.023	1.023	1.296			
2001	0.251	0.362	0.460	0.612	0.812	1.011	1.024	1.278	1.552			
2002	0.282	0.381	0.480	0.665	0.833	0.985	1.100	1.286	1.389	1.483		
2003	0.228	0.359	0.474	0.653	0.824	0.957	1.033	1.144	1.267	1.418	1.505	
2004	0.211	0.296	0.440	0.586	0.728	0.884	1.004	1.194	1.227	1.305	1.421	
2005	0.119	0.341	0.445	0.594	0.767	0.969	1.002	1.179	1.578	1.578		
2006	0.100	0.309	0.411	0.555	0.760	0.919	1.068	1.184	1.262	1.223	1.599	
2007	0.148	0.288	0.406	0.536	0.764	0.947	1.235	1.189				
2008	0.042	0.306	0.420	0.539	0.696	0.909	1.034					

Table 7. DFO spring survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in 000s of fish and metric tons. Note that two vectors are presented for 2008 and 2009: 2008a and 2009a include the large tows while 2008b and 2009b do not.

Year	age1	age2	age3	age4	age5	age6+	B (mt)
1987	75.2	751.1	1238.5	309.7	54.9	30.9	785.9
1988	0.0	1116.5	801.9	383.6	174.9	14.8	776.7
1989	71.8	645.8	383.2	185.2	41.8	14.1	295.9
1990	0.0	1500.9	2281.1	575.0	131.3	8.6	951.2
1991	15.4	539.6	745.8	2364.1	330.3	9.1	1105.6
1992	34.8	6942.1	2312.0	622.4	219.8	18.8	1556.7
1993	49.4	1528.8	2568.8	2562.9	557.5	81.8	1661.3
1994	0.0	3808.4	2178.6	1890.1	491.4	130.0	1731.4
1995	132.0	786.5	2737.4	1600.8	406.6	63.6	1274.6
1996	280.5	4491.0	5769.2	3399.8	726.5	77.2	3334.9
1997	13.6	7849.2	8742.1	10293.6	2543.2	421.5	8359.0
1998	561.7	2094.3	3085.9	2725.6	1250.4	351.2	2699.4
1999	99.8	13118.5	13101.2	4822.9	3364.5	1383.5	11109.4
2000	6.8	8655.8	17256.5	12100.9	3187.6	2319.8	12544.7
2001	183.3	12511.6	26489.4	8368.0	2881.0	1507.2	13933.8
2002	55.5	7522.3	19503.3	7693.6	3491.7	1781.4	13016.4
2003	56.3	7476.4	15480.7	6971.1	2151.0	1249.9	10217.8
2004	20.6	2263.5	10225.3	5788.7	1429.2	890.5	5693.4
2005	377.3	1007.5	17581.9	12931.4	3581.9	983.8	8399.2
2006	391.5	3076.8	11696.4	4132.7	515.4	149.4	4137.0
2007	108.9	7646.4	17423.7	8048.5	1439.1	156.2	8391.2
2008a	0.0	30382.5	107131.7	35919.3	5067.8	34.5	42333.4
2008b	0.0	2907.3	6882.8	1964.6	367.1	35.9	4104.4
2009a	8.0	8109.7	131266.5	111043.9	18710.6	4200.4	108999.7
2009b	8.0	1770.7	24627.3	24972.5	5122.4	811.7	23690.9

Table 8. NEFSC spring survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in 000s of fish and metric tons. Note the 2009 values are not currently available due to lack of conversion coefficients for the new survey vessel and gear.

Year	age1	age2	age3	age4	age5	age6+	B (mt)
1968	181.2	3227.3	3474.3	295.2	70.9	300.8	2709.0
1969	1046.8	9067.8	10793.9	3081.4	1305.2	678.2	10842.2
1970	78.4	4364.8	5853.3	2350.9	553.0	302.0	4994.4
1971	810.4	3412.9	4671.6	3202.9	757.1	310.6	4483.1
1972	137.0	6719.3	6843.1	3595.8	1093.7	232.0	6265.7
1973	1882.9	3184.3	2309.4	1036.7	399.4	210.2	2852.2
1974	308.2	2168.5	1795.5	1225.0	336.9	273.8	2639.6
1975	409.2	2918.0	809.1	262.6	201.5	86.3	1626.4
1976	1008.4	4259.0	1216.0	302.4	191.2	108.4	2205.8
1977	0.0	654.0	1097.7	363.7	81.9	12.8	969.8
1978	912.2	778.4	494.4	213.9	25.7	7.7	719.8
1979	394.0	1956.8	395.2	328.3	58.7	88.7	1233.8
1980	55.3	4528.6	5617.2	460.6	55.0	35.3	4325.1
1981	11.4	995.9	1724.2	698.9	206.9	56.9	1902.8
1982	44.1	3656.5	1096.5	992.5	444.5	88.3	2426.3
1983	0.0	1810.0	2647.8	514.4	119.6	237.3	2564.2
1984	0.0	90.3	806.0	837.9	810.4	236.5	1597.6
1985	106.4	2134.2	254.4	273.4	143.4	0.0	959.0
1986	26.6	1753.0	282.6	54.6	132.9	53.2	822.5
1987	26.6	73.3	133.0	129.3	51.0	53.2	319.2
1988	75.5	266.9	355.2	234.7	193.2	26.6	549.1
1989	45.2	391.3	737.7	281.0	59.3	43.5	707.7
1990	0.0	63.7	1074.7	358.4	112.2	100.8	678.3
1991	422.5	0.0	246.9	665.1	255.5	20.0	612.5
1992	0.0	1987.7	1840.7	621.8	160.0	16.7	1520.1
1993	44.7	281.1	485.8	307.9	26.0	0.0	467.9
1994	0.0	602.3	614.7	343.6	140.4	38.7	641.1
1995	39.0	1144.6	4670.4	1441.7	621.5	9.5	2503.6
1996	24.4	958.1	2548.6	2621.8	591.6	56.2	2769.3
1997	18.2	1134.5	3623.1	3960.7	682.3	129.7	4230.6
1998	0.0	2020.1	1022.2	1123.4	737.1	339.6	2255.8
1999	48.7	4606.3	10501.7	2640.5	1575.2	756.3	9033.4
2000	177.3	4677.6	7440.5	2828.5	789.2	508.4	6498.9
2001	0.0	2246.7	6370.5	2340.0	469.2	439.7	4858.8
2002	182.4	2341.5	11971.1	3958.4	1690.3	845.4	9281.7
2003	196.1	4241.4	6564.9	2791.9	428.6	836.9	6524.2
2004	47.1	957.3	2114.4	659.9	247.7	263.8	1835.3
2005	0.0	1953.5	4931.0	2332.7	261.8	111.4	3307.2
2006	493.5	907.8	3419.2	2112.7	307.7	79.8	2349.3
2007	87.1	4899.7	6079.1	2762.3	540.0	125.2	4563.3
2008	0.0	2206.7	4921.5	1681.1	300.3	26.6	3151.6
2009							

Table 9. NEFSC fall survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in 000s of fish and metric tons.

Year	age1	age2	age3	age4	age5	age6+	B (mt)
1963.5	14289.1	7663.6	10897.1	1804.0	480.5	532.7	12412.6
1964.5	1671.3	9517.3	7097.2	5791.2	2634.2	473.3	13168.2
1965.5	1162.1	5537.0	5811.9	3427.8	1600.9	250.6	8851.7
1966.5	11320.3	2184.4	1635.3	871.9	98.3	0.0	3812.7
1967.5	8720.8	9131.0	2646.7	1006.7	299.3	132.3	7444.7
1968.5	11328.3	11702.5	5588.9	722.7	936.8	56.4	10226.5
1969.5	9656.7	10601.8	5064.1	1757.4	327.0	447.7	9519.0
1970.5	4474.9	4981.2	3051.2	1894.7	438.2	77.8	4832.6
1971.5	3520.0	6770.9	4769.9	2183.8	483.4	289.1	6177.7
1972.5	2416.9	6332.8	4682.3	2032.9	592.1	331.7	6142.0
1973.5	2420.4	5336.0	4954.5	2857.4	1181.2	599.9	6299.2
1974.5	4486.7	2779.5	1471.6	1029.1	444.3	368.1	3560.7
1975.5	4548.6	2437.3	851.7	555.2	324.4	61.1	2257.4
1976.5	333.5	1863.9	460.3	113.6	118.5	97.3	1463.3
1977.5	906.7	2147.1	1572.8	615.4	102.3	105.7	2699.0
1978.5	4620.6	1243.3	757.2	399.2	131.6	34.9	2274.3
1979.5	1282.0	2008.5	253.7	116.7	134.3	108.6	1450.4
1980.5	743.6	4970.0	5912.0	662.0	212.3	250.9	6412.4
1981.5	1548.2	2279.4	1592.8	570.5	76.4	52.8	2500.1
1982.5	2353.3	2120.3	1543.4	410.4	86.6	0.0	2203.3
1983.5	105.7	2216.4	1858.5	495.7	29.9	47.7	2068.5
1984.5	641.6	388.1	296.7	236.0	72.7	60.7	575.8
1985.5	1310.2	527.5	165.9	49.1	78.3	0.0	688.4
1986.5	273.4	1075.1	338.7	71.9	0.0	0.0	795.5
1987.5	98.7	388.8	384.6	51.4	77.1	0.0	493.9
1988.5	18.2	206.7	104.0	26.6	0.0	0.0	165.5
1989.5	241.0	1934.1	750.4	76.6	54.0	0.0	948.1
1990.5	0.0	359.2	1429.9	285.8	0.0	0.0	703.2
1991.5	2038.8	267.0	426.2	347.2	0.0	0.0	708.4
1992.5	146.8	383.9	691.0	157.1	139.4	26.6	559.2
1993.5	814.6	135.2	568.8	520.4	0.0	21.4	529.5
1994.5	1159.8	214.6	954.1	692.2	254.9	54.8	870.7
1995.5	267.7	115.4	335.2	267.2	44.6	12.1	343.7
1996.5	144.3	341.3	1813.8	433.5	72.7	0.0	1264.6
1997.5	1351.8	517.7	3341.0	2028.5	1039.8	79.8	3669.7
1998.5	1844.4	4675.3	4078.9	1154.6	289.5	71.7	4219.7
1999.5	2998.7	8175.9	5558.9	1390.3	1394.2	252.8	7738.3
2000.5	610.8	1647.5	4672.5	2350.3	919.7	802.6	5666.1
2001.5	3414.2	6083.6	7853.7	2524.8	1667.8	1988.2	11213.4
2002.5	2031.4	5581.8	2064.5	576.1	295.6	26.6	3643.9
2003.5	1045.3	4882.8	2725.9	548.0	97.0	185.7	3919.2
2004.5	850.3	5346.1	4862.4	2044.4	897.1	170.7	4966.4
2005.5	304.0	2033.6	3652.1	595.9	179.3	0.0	2390.6
2006.5	6012.1	6067.2	3556.7	1132.9	247.7	44.4	4388.4
2007.5	1026.5	11110.9	7634.7	1939.6	371.3	90.9	7911.6
2008.5	162.8	6963.2	9592.7	1002.8	0.0	0.0	6900.5

Table 10. NEFSC scallop survey index of abundance (stratified mean #/tow in numbers) for Georges Bank yellowtail flounder and index of total biomass (stratified mean kg/tow). Note the values for 1989 and 1999 are considered too uncertain for use as a tuning index and the 1986, 2000, and 2008 surveys did not fully cover the Canadian portion of Georges Bank (D. Hart, pers. comm.).

Year	age1	age2	age3	age4	age5	age6+	B (kg/tow)
1982.5	0.4254	0.6043	0.2588	0.1236	0.0406	0.0000	0.527
1983.5	0.0695	0.6963	0.5182	0.0956	0.0127	0.0312	0.699
1984.5	0.3698	0.1231	0.0757	0.1081	0.0391	0.0071	0.244
1985.5	0.5043	0.2212	0.0085	0.0163	0.0170	0.0000	0.143
1986.5							
1987.5	0.0990	0.1328	0.0941	0.0244	0.0069	0.0029	0.187
1988.5	0.0300	0.1077	0.0363	0.0430	0.0377	0.0000	0.108
1989.5							
1990.5	0.0000	0.1339	0.3401	0.0718	0.0141	0.0114	0.245
1991.5	1.8964	0.0208	0.1506	0.1175	0.0168	0.0000	0.377
1992.5	0.3088	0.1724	0.3781	0.1137	0.0696	0.0091	0.409
1993.5	1.1937	0.1289	0.2674	0.1963	0.0046	0.0091	0.427
1994.5	1.4744	0.2180	0.4653	0.2787	0.0780	0.0207	0.603
1995.5	0.5540	0.4299	0.7900	0.5115	0.1015	0.0121	0.846
1996.5	0.2248	0.5565	1.0252	0.5680	0.2122	0.0052	1.271
1997.5	1.0842	0.3110	1.3387	0.7959	0.2111	0.0299	1.659
1998.5	1.8253	1.0909	0.9954	0.7044	0.3290	0.0641	2.041
1999.5							
2000.5							
2001.5	0.9518	0.5907	0.9604	0.3694	0.1470	0.1345	1.525
2002.5	0.8838	0.3517	0.7741	0.3561	0.2272	0.1278	1.336
2003.5	0.7506	0.8302	0.8784	0.4788	0.1162	0.1506	1.783
2004.5	0.3904	0.5192	0.5111	0.1971	0.0774	0.0315	0.777
2005.5	0.4913	0.4154	0.5457	0.1850	0.0669	0.0090	0.623
2006.5	2.2406	0.9730	0.4886	0.1921	0.0237	0.0267	0.880
2007.5	0.5184	1.9402	0.8929	0.2327	0.0434	0.0035	1.265
2008.5							

Table 11. Statistical properties of estimates for population abundance and survey calibration constants (scallop x10^3) for Georges Bank yellowtail flounder for the Major Change VPA **Excluding** the DFO 2008 and 2009 survey values. (Table continues on next page)

		Bootstrap			
		Standard	Relative		Relative
Age	Estimate	Error	Error	Bias	Bias
	Population Abundance				
2	2255	3081	137%	1101	49%
3	12978	5547	43%	992	8%
4	22968	7466	33%	1180	5%
5	6126	1452	24%	120	2%
	Survey Calibration Constants				
DFO Survey: 1987-1994 (Ages 2-6+)					
2	0.145	0.046	32%	0.007	5%
3	0.232	0.031	14%	0.000	0%
4	0.389	0.071	18%	0.007	2%
5	0.436	0.090	21%	0.007	2%
6+	0.254	0.059	23%	0.008	3%
DFO Survey: 1995-2007 (Ages 2-6+)					
2	0.312	0.066	21%	0.006	2%
3	1.290	0.201	16%	0.015	1%
4	1.724	0.238	14%	0.013	1%
5	1.570	0.292	19%	0.009	1%
6+	1.214	0.203	17%	0.015	1%
NMFS Spring Survey: Yankee 41, 1973-1981 (Ages 1-6+)					
1	0.007	0.007	88%	0.002	22%
2	0.076	0.014	19%	0.001	2%
3	0.096	0.017	17%	0.001	1%
4	0.093	0.011	12%	0.001	1%
5	0.076	0.015	20%	0.001	2%
6+	0.072	0.024	33%	0.004	6%
NMFS Spring Survey: Yankee 36, 1982-1994 (Ages 1-6+)					
1	0.004	0.001	24%	0.000	4%
2	0.046	0.014	31%	0.003	6%
3	0.095	0.014	15%	0.001	1%
4	0.152	0.019	13%	0.001	1%
5	0.229	0.045	20%	0.001	0%
6+	0.423	0.088	21%	0.008	2%
NMFS Spring Survey: Yankee 36, 1995-2007 (Ages 1-6+)					
1	0.005	0.001	30%	0.000	4%
2	0.143	0.019	13%	0.001	1%
3	0.499	0.084	17%	0.005	1%
4	0.596	0.109	18%	0.012	2%
5	0.513	0.109	21%	0.013	3%
6+	0.437	0.081	19%	0.008	2%

Age	Estimate	Bootstrap Standard Error	Relative Error	Bias	Relative Bias
NMFS Fall Survey: 1973-1994 (Ages 1-6+)					
1	0.040	0.010	25%	0.002	4%
2	0.088	0.014	16%	0.001	1%
3	0.150	0.016	10%	0.001	1%
4	0.156	0.020	13%	0.003	2%
5	0.205	0.040	20%	0.003	1%
6+	0.306	0.066	21%	0.004	1%
NMFS Fall Survey: 1995-2006 (Ages 1-6+)					
1	0.065	0.015	24%	0.001	2%
2	0.225	0.074	33%	0.013	6%
3	0.539	0.099	18%	0.005	1%
4	0.453	0.091	20%	0.008	2%
5	0.516	0.138	27%	0.018	4%
6+	0.381	0.149	39%	0.024	6%
NMFS Scallop Survey: 1982-1994 (Age 1)					
1	0.027	0.012	46%	0.003	10%
NMFS Scallop Survey: 1995-2006 (Age 1)					
1	0.047	0.007	14%	0.000	0%

Table 12. Statistical properties of estimates for population abundance and survey calibration constants (scallop x10^3) for Georges Bank yellowtail flounder for the Major Change VPA **Including** the DFO 2008 and 2009 survey values. (Table continues on next page)

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
	Population Abundance				
2	7743	6135	79%	1689	22%
3	23371	8025	34%	1397	6%
4	29266	7874	27%	1174	4%
5	6895	1333	19%	96	1%
	Survey Calibration Constants				
DFO Survey: 1987-1994 (Ages 2-6+)					
2	0.145	0.047	33%	0.007	5%
3	0.232	0.032	14%	0.003	1%
4	0.389	0.072	18%	0.009	2%
5	0.436	0.096	22%	0.014	3%
6+	0.254	0.062	24%	0.008	3%
DFO Survey: 1995-2007 (Ages 2-6+)					
2	0.358	0.082	23%	0.013	4%
3	1.485	0.257	17%	0.006	0%
4	1.906	0.271	14%	0.013	1%
5	1.712	0.307	18%	0.024	1%
6+	1.136	0.243	21%	0.024	2%
NMFS Spring Survey: Yankee 41, 1973-1981 (Ages 1-6+)					
1	0.007	0.006	83%	0.002	20%
2	0.076	0.014	18%	0.001	2%
3	0.096	0.016	17%	0.001	1%
4	0.093	0.011	12%	0.001	1%
5	0.076	0.015	20%	0.002	2%
6+	0.072	0.023	32%	0.003	5%
NMFS Spring Survey: Yankee 36, 1982-1994 (Ages 1-6+)					
1	0.004	0.001	24%	0.000	3%
2	0.046	0.015	33%	0.003	6%
3	0.095	0.015	15%	0.001	2%
4	0.152	0.020	13%	0.002	1%
5	0.229	0.047	21%	0.006	3%
6+	0.423	0.089	21%	0.001	0%
NMFS Spring Survey: Yankee 36, 1995-2007 (Ages 1-6+)					
1	0.004	0.001	30%	0.000	3%
2	0.133	0.019	14%	0.002	1%
3	0.486	0.089	18%	0.007	1%
4	0.587	0.109	19%	0.010	2%
5	0.505	0.108	21%	0.015	3%
6+	0.431	0.084	19%	0.008	2%

Age	Estimate	Bootstrap Standard Error	Relative Error	Bias	Relative Bias
NMFS Fall Survey: 1973-1994 (Ages 1-6+)					
1	0.040	0.010	25%	0.001	3%
2	0.088	0.013	15%	0.001	2%
3	0.150	0.015	10%	0.000	0%
4	0.156	0.021	14%	0.001	1%
5	0.205	0.040	19%	0.004	2%
6+	0.306	0.067	22%	0.007	2%
NMFS Fall Survey: 1995-2006 (Ages 1-6+)					
1	0.056	0.014	24%	0.001	2%
2	0.210	0.068	32%	0.012	6%
3	0.523	0.093	18%	0.008	1%
4	0.445	0.092	21%	0.008	2%
5	0.510	0.142	28%	0.019	4%
6+	0.376	0.137	36%	0.028	7%
NMFS Scallop Survey: 1982-1994 (Age 1)					
1	0.027	0.012	46%	0.002	8%
NMFS Scallop Survey: 1995-2006 (Age 1)					
1	0.043	0.007	17%	0.000	1%

Table 13. Beginning of year population abundance numbers (000s) for Georges Bank yellowtail flounder from the Major Change VPA **Excluding** the DFO 2008 and 2009 values.

	Age Group						
Year	1	2	3	4	5	6+	Total
1973	29384	24172	29516	17300	6966	3013	110351
1974	52184	23733	15136	12051	5732	2391	111229
1975	70632	40588	10930	5010	3079	1709	131948
1976	24731	53646	9852	2425	977	1562	93193
1977	17283	19674	15554	3171	719	850	57252
1978	54437	13809	7987	3390	956	373	80953
1979	25508	35604	8124	2468	1073	559	73336
1980	24034	20595	19711	3268	747	239	68594
1981	62997	19390	13268	7499	1302	221	104677
1982	22846	51480	14885	5535	1783	156	96685
1983	6581	16754	25937	5517	1514	345	56648
1984	10843	4755	6579	6472	2305	487	31441
1985	16749	8414	2089	1379	870	136	29636
1986	8473	12837	2991	767	402	224	25695
1987	9193	6776	4801	1440	282	201	22692
1988	22841	7386	2617	1153	309	73	34379
1989	9661	18250	3361	771	198	55	32296
1990	11217	7738	12981	1747	250	47	33980
1991	22557	8975	4437	4399	560	104	41032
1992	17518	17869	7215	2296	940	65	45903
1993	13938	12168	6459	3250	574	126	36516
1994	13179	6725	8713	2323	609	184	31733
1995	11672	10726	4304	1576	305	66	28649
1996	13469	9513	8499	2237	509	70	34297
1997	19798	10937	7175	5104	1040	246	44299
1998	22395	16135	7933	4228	2515	328	53534
1999	24548	18183	11416	3467	1777	675	60066
2000	19841	20044	12408	5589	1456	931	60269
2001	22271	16126	12934	5056	1754	918	59059
2002	15351	18075	10607	4396	1567	1113	51110
2003	11320	12377	11051	5594	1887	1672	43900
2004	8896	9124	6618	4837	2505	1845	33824
2005	19607	7225	6387	2589	622	269	36700
2006	46639	15999	4547	1618	606	349	69758
2007	20077	38047	11970	2253	458	186	72992
2008	2785	16390	29837	8223	1222	182	58640
2009		2255	12978	22968	6126	1046	

Table 14. Beginning of year population abundance numbers (000s) for Georges Bank yellowtail flounder from the Major Change VPA **Including** the DFO 2008 and 2009 values.

	Age Group						
Year	1	2	3	4	5	6+	Total
1973	29384	24172	29516	17300	6966	3013	110351
1974	52184	23733	15136	12051	5732	2391	111229
1975	70632	40588	10930	5010	3079	1709	131948
1976	24731	53646	9852	2425	977	1562	93193
1977	17283	19674	15554	3171	719	850	57252
1978	54437	13809	7987	3390	956	373	80953
1979	25508	35604	8124	2468	1073	559	73336
1980	24034	20595	19711	3268	747	239	68594
1981	62997	19390	13268	7499	1302	221	104677
1982	22846	51480	14885	5535	1783	156	96685
1983	6581	16754	25937	5517	1514	345	56648
1984	10843	4755	6579	6472	2305	487	31441
1985	16749	8414	2089	1379	870	136	29636
1986	8473	12837	2991	767	402	224	25695
1987	9193	6776	4801	1440	282	201	22692
1988	22841	7386	2617	1153	309	73	34379
1989	9661	18250	3361	771	198	55	32296
1990	11217	7738	12981	1747	250	47	33980
1991	22557	8975	4437	4399	560	104	41032
1992	17518	17869	7215	2296	940	65	45903
1993	13938	12168	6459	3250	574	126	36516
1994	13179	6725	8713	2323	609	184	31733
1995	11672	10726	4304	1576	305	66	28649
1996	13469	9514	8499	2237	509	70	34298
1997	19799	10937	7175	5104	1040	246	44300
1998	22396	16136	7934	4228	2515	328	53537
1999	24551	18184	11416	3467	1777	675	60071
2000	19849	20046	12409	5590	1456	931	60280
2001	22282	16132	12936	5057	1755	918	59079
2002	15389	18084	10612	4397	1568	1114	51164
2003	11400	12408	11059	5598	1888	1673	44026
2004	9209	9190	6643	4843	2508	1847	34240
2005	21319	7482	6441	2609	627	271	38750
2006	58115	17401	4757	1661	623	358	82915
2007	35582	47444	13118	2424	493	200	99261
2008	9488	29084	37530	9162	1362	203	86829
2009		7743	23371	29266	6895	1177	

Table 15. Fishing mortality rate for Georges Bank yellowtail from the Major Change VPA **Excluding** the DFO 2008 and 2009 values.

	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	0.93	0.93	0.93	0.93
1990	0.02	0.36	0.88	0.94	0.94	0.94	0.94
1991	0.03	0.02	0.46	1.34	1.34	1.34	1.34
1992	0.16	0.82	0.60	1.19	1.19	1.19	1.19
1993	0.53	0.13	0.82	1.47	1.47	1.47	1.47
1994	0.01	0.25	1.51	1.83	1.83	1.83	1.83
1995	0.00	0.03	0.45	0.93	0.93	0.93	0.93
1996	0.01	0.08	0.31	0.57	0.57	0.57	0.57
1997	0.00	0.12	0.33	0.51	0.51	0.51	0.51
1998	0.01	0.15	0.63	0.67	0.67	0.67	0.67
1999	0.00	0.18	0.51	0.67	0.67	0.67	0.67
2000	0.01	0.24	0.70	0.96	0.96	0.96	0.96
2001	0.01	0.22	0.88	0.97	0.97	0.97	0.97
2002	0.02	0.29	0.44	0.65	0.65	0.65	0.65
2003	0.02	0.43	0.63	0.60	0.60	0.60	0.60
2004	0.01	0.16	0.74	1.85	1.85	1.85	1.85
2005	0.00	0.26	1.17	1.25	1.25	1.25	1.25
2006	0.00	0.09	0.50	1.06	1.06	1.06	1.06
2007	0.00	0.04	0.18	0.41	0.41	0.41	0.41
2008	0.01	0.03	0.06	0.09	0.09	0.09	0.09

Table 16. Fishing mortality rate for Georges Bank yellowtail from the Major Change VPA **Including** the DFO 2008 and 2009 values.

	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	0.93	0.93	0.93	0.93
1990	0.02	0.36	0.88	0.94	0.94	0.94	0.94
1991	0.03	0.02	0.46	1.34	1.34	1.34	1.34
1992	0.16	0.82	0.60	1.19	1.19	1.19	1.19
1993	0.53	0.13	0.82	1.47	1.47	1.47	1.47
1994	0.01	0.25	1.51	1.83	1.83	1.83	1.83
1995	0.00	0.03	0.45	0.93	0.93	0.93	0.93
1996	0.01	0.08	0.31	0.57	0.57	0.57	0.57
1997	0.00	0.12	0.33	0.51	0.51	0.51	0.51
1998	0.01	0.15	0.63	0.67	0.67	0.67	0.67
1999	0.00	0.18	0.51	0.67	0.67	0.67	0.67
2000	0.01	0.24	0.70	0.96	0.96	0.96	0.96
2001	0.01	0.22	0.88	0.97	0.97	0.97	0.97
2002	0.02	0.29	0.44	0.65	0.65	0.65	0.65
2003	0.02	0.42	0.63	0.60	0.60	0.60	0.60
2004	0.01	0.16	0.73	1.84	1.84	1.84	1.84
2005	0.00	0.25	1.16	1.23	1.23	1.23	1.23
2006	0.00	0.08	0.47	1.01	1.01	1.01	1.01
2007	0.00	0.03	0.16	0.38	0.38	0.38	0.38
2008	0.00	0.02	0.05	0.08	0.08	0.08	0.08

Table 17. Beginning of year weight (kg) at age for Georges Bank yellowtail. The 2009 values are set equal to the average of the 2006-2008 values.

	Age Group					
Year	1	2	3	4	5	6+
1973	0.055	0.292	0.403	0.465	0.564	0.778
1974	0.069	0.186	0.416	0.530	0.598	0.832
1975	0.068	0.191	0.410	0.524	0.613	0.695
1976	0.061	0.188	0.415	0.557	0.642	0.861
1977	0.071	0.192	0.404	0.587	0.704	0.931
1978	0.057	0.191	0.418	0.601	0.713	0.970
1979	0.068	0.183	0.381	0.578	0.713	0.950
1980	0.056	0.192	0.403	0.551	0.732	1.072
1981	0.078	0.184	0.397	0.546	0.681	0.840
1982	0.072	0.192	0.403	0.564	0.675	1.082
1983	0.107	0.185	0.364	0.543	0.694	1.010
1984	0.109	0.183	0.335	0.470	0.627	0.797
1985	0.132	0.242	0.347	0.493	0.604	0.800
1986	0.135	0.248	0.442	0.583	0.741	1.015
1987	0.074	0.242	0.423	0.606	0.727	0.875
1988	0.058	0.199	0.425	0.604	0.758	0.975
1989	0.059	0.184	0.413	0.633	0.776	1.053
1990	0.070	0.170	0.359	0.552	0.706	0.845
1991	0.078	0.158	0.327	0.438	0.650	0.877
1992	0.060	0.188	0.294	0.441	0.563	1.110
1993	0.062	0.170	0.333	0.428	0.545	0.863
1994	0.162	0.161	0.317	0.423	0.558	0.775
1995	0.138	0.230	0.300	0.405	0.535	0.768
1996	0.075	0.219	0.335	0.438	0.573	1.012
1997	0.179	0.190	0.336	0.468	0.630	0.947
1998	0.124	0.256	0.360	0.472	0.591	0.966
1999	0.147	0.256	0.389	0.523	0.642	0.901
2000	0.182	0.278	0.420	0.552	0.700	0.954
2001	0.204	0.288	0.420	0.542	0.707	1.027
2002	0.250	0.309	0.417	0.553	0.714	1.068
2003	0.200	0.318	0.425	0.560	0.740	1.048
2004	0.166	0.260	0.397	0.527	0.690	0.956
2005	0.074	0.268	0.363	0.511	0.670	0.997
2006	0.059	0.192	0.374	0.497	0.672	0.998
2007	0.103	0.170	0.354	0.469	0.651	1.002
2008	0.008	0.213	0.348	0.468	0.611	0.941
2009	0.057	0.191	0.359	0.478	0.645	0.980

Table 18. Beginning of year biomass (mt) and spawning stock biomass (mt) for Georges Bank yellowtail from the Major Change VPA Excluding the DFO 2008 and 2009 values and the Major Change VPA Including the DFO 2008 and 2009 values.

	Excluding			**Including**		
	Beginning Biomass			Beginning Biomass		
Year	1+	3+	SSB	1+	3+	SSB
1973	34860	26206	22161	34860	26206	22161
1974	26134	18088	14780	26134	18088	14780
1975	22723	10184	9014	22723	10184	9014
1976	18984	7408	10024	18984	7408	10024
1977	14447	9447	8351	14447	9447	8351
1978	12146	6418	6169	12146	6418	6169
1979	14070	5818	8501	14070	5818	8501
1980	15820	10540	10884	15820	10540	10884
1981	18890	10430	10144	18890	10430	10144
1982	21994	10493	12975	21994	10493	12975
1983	17637	13841	11103	17637	13841	11103
1984	9121	7075	3847	9121	7075	3847
1985	6283	2040	2558	6283	2040	2558
1986	6628	2293	3210	6628	2293	3210
1987	5599	3282	2750	5599	3282	2750
1988	4905	2113	2198	4905	2113	2198
1989	6004	2088	4170	6004	2088	4170
1990	7947	5845	4750	7947	5845	4750
1991	7004	3834	3485	7004	3834	3485
1992	8153	3735	4472	8153	3735	4472
1993	6893	3964	3966	6893	3964	3966
1994	7444	4228	2823	7444	4228	2823
1995	6230	2145	2941	6230	2145	2941
1996	7276	4185	4993	7276	4185	4993
1997	11307	5683	6380	11307	5684	6380
1998	13546	6651	7261	13546	6651	7261
1999	16255	8000	9598	16255	8001	9599
2000	19393	10206	10274	19396	10207	10275
2001	19530	10351	9287	19536	10353	9289
2002	18585	9160	10171	18602	9164	10177
2003	17181	10977	10151	17215	10985	10164
2004	12517	8670	5711	12604	8688	5741
2005	7712	4329	3740	7943	4365	3822
2006	9081	3265	4392	10145	3385	4703
2007	14325	5791	9961	18042	6315	11656
2008	18671	15160	17793	24652	18384	22894
2009		20626			27997	

Table 19. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2010 at F_{Ref} using the Major Change VPA **Excluding** the DFO 2008 and 2009 values.

Year	Age Group							
	1	2	3	4	5	6+	1+	3+
Beginning of Year Population Numbers (000s)								
2009	15607	2255	12978	22968	6126	1046		
2010	15607	12715	1808	10006	16742	5228		
2011	15607	12643	9949	1301	6380	14009		
Partial Recruitment to the Fishery								
	0.042	0.181	0.517	1	1	1		
Fishing Mortality								
2009	0.005	0.021	0.060	0.116	0.116	0.116		
2010	0.011	0.045	0.129	0.250	0.250	0.250		
Weight at beginning of year for population (kg)								
	0.057	0.192	0.359	0.478	0.645	0.981		
Maturity			*Fraction of Z before Spawning =*			0.4167		
	0	0.462	0.967	1	1	1		
Beginning of Year Projected Population Biomass (t)								
2009	885	432	4663	10988	3949	1026	21943	20626
2010	885	2436	650	4787	10792	5127	24676	21355
2011	885	2422	3575	622	4112	13738	25355	22048
Spawning Stock Biomass (t)								
2009	0	287	4647	10939	3974	899	20745	
2010	0	1600	629	4507	10271	4250	21257	
Projected Catch Numbers (000s)								
2009	70	43	687	2288	610	104		
2010	149	511	199	2014	3370	1052		
Average weight for catch (kg)								
	0.097	0.302	0.413	0.543	0.740	0.981		
Projected Yield (t)								
2009	7	13	283	1243	452	102	**2100**	
2010	14	154	82	1094	2494	1032	**4871**	

Table 20. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2010 at F_{Ref} using the Major Change VPA **Including** the DFO 2008 and 2009 values.

Year	Age Group							
	1	2	3	4	5	6+	1+	3+
Beginning of Year Population Numbers (000s)								
2009	19344	7743	23371	29266	6895	1177		
2010	19344	15817	6266	18325	21932	6049		
2011	19344	15778	12531	4540	11684	17842		
Partial Recruitment to the Fishery								
	0.015	0.132	0.489	1	1	1		
Fishing Mortality								
2009	0.001	0.012	0.043	0.088	0.088	0.088		
2010	0.004	0.033	0.122	0.250	0.250	0.250		
Weight at beginning of year for population (kg)								
	0.057	0.192	0.359	0.478	0.645	0.981		
Maturity			*Fraction of Z before Spawning =*			0.4167		
	0	0.462	0.967	1	1	1		
Beginning of Year Projected Population Biomass (t)								
2009	1097	1484	8397	14001	4444	1155	30578	27997
2010	1097	3030	2251	8767	14138	5932	35215	31088
2011	1097	3023	4502	2172	7532	17497	35823	31704
Spawning Stock Biomass (t)								
2009	0	988	8427	14100	4524	1024	29064	
2010	0	2001	2186	8254	13455	4918	30814	
Projected Catch Numbers (000s)								
2009	23	81	897	2249	530	90		
2010	66	464	655	3689	4415	1218		
Average weight for catch (kg)								
	0.097	0.302	0.413	0.543	0.740	0.981		
Projected Yield (t)								
2009	2	24	370	1222	392	89	**2100**	
2010	6	140	270	2004	3267	1194	**6882**	

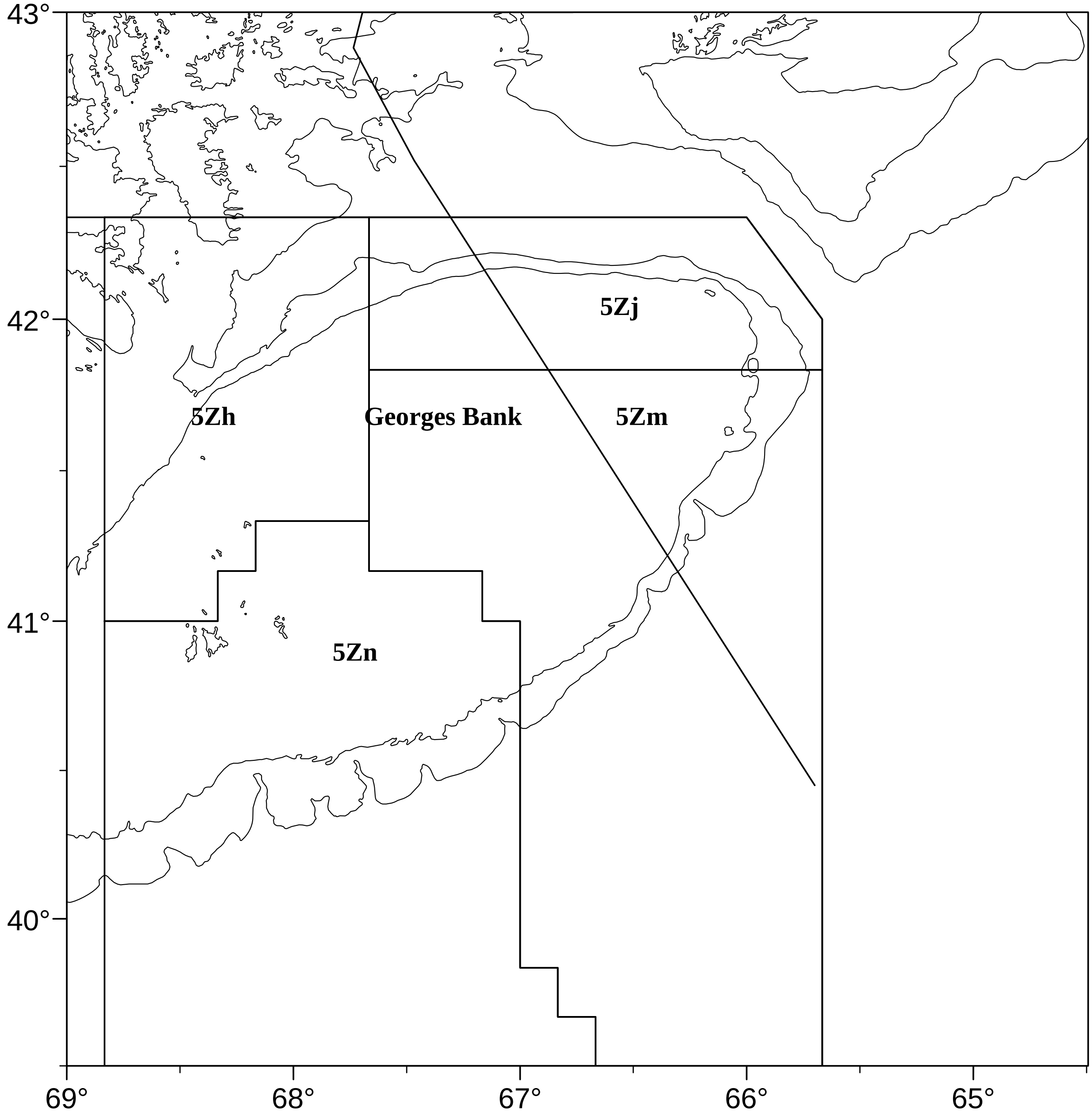


Figure 1a. Location of statistical unit areas for Canadian fisheries in NAFO Subdivision 5Ze.

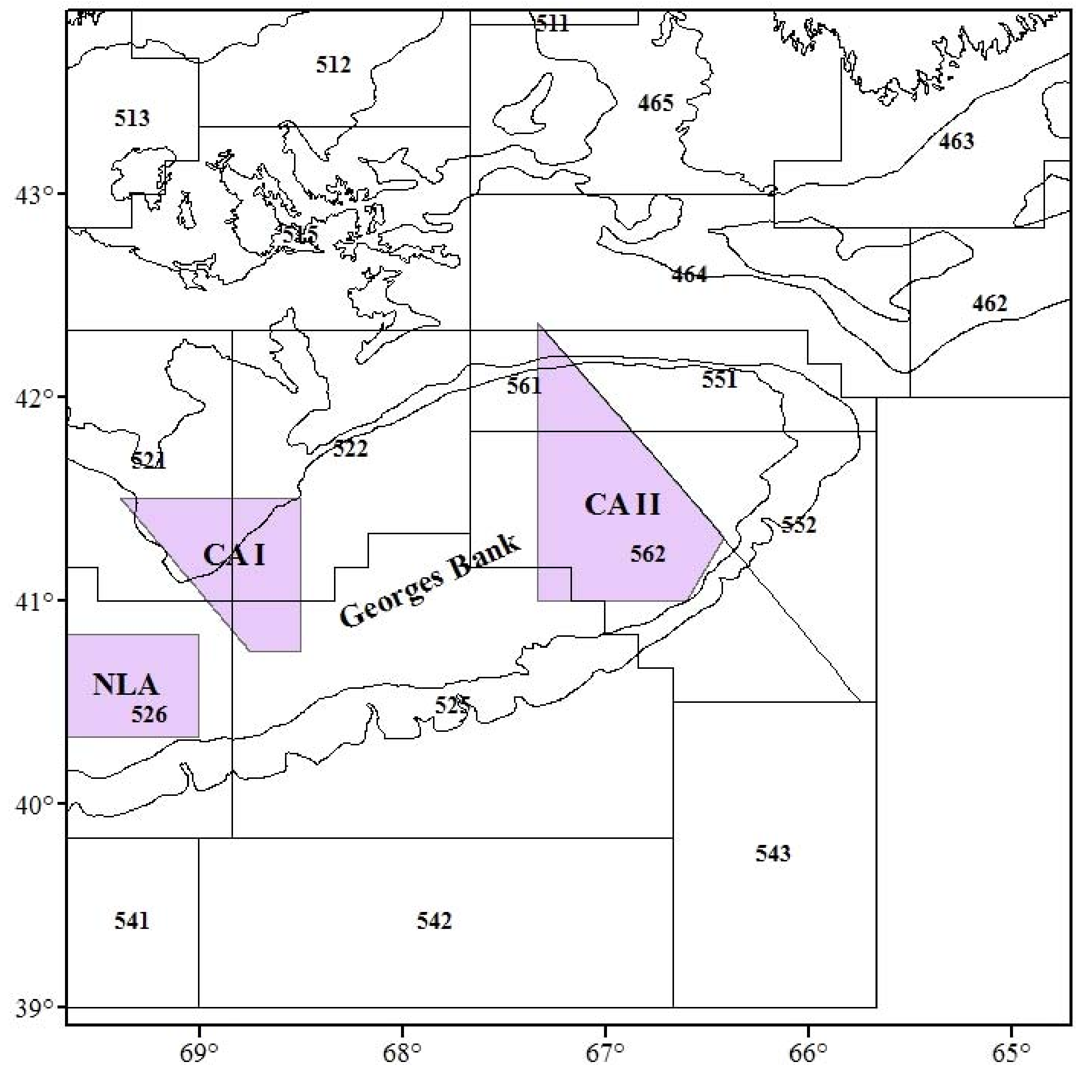


Figure 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas (CA I = Closed Area I,; CA II = Closed Area II; NLA = Nantucket Light Ship Area) have been closed to fishing year-round since 1994, with exceptions.

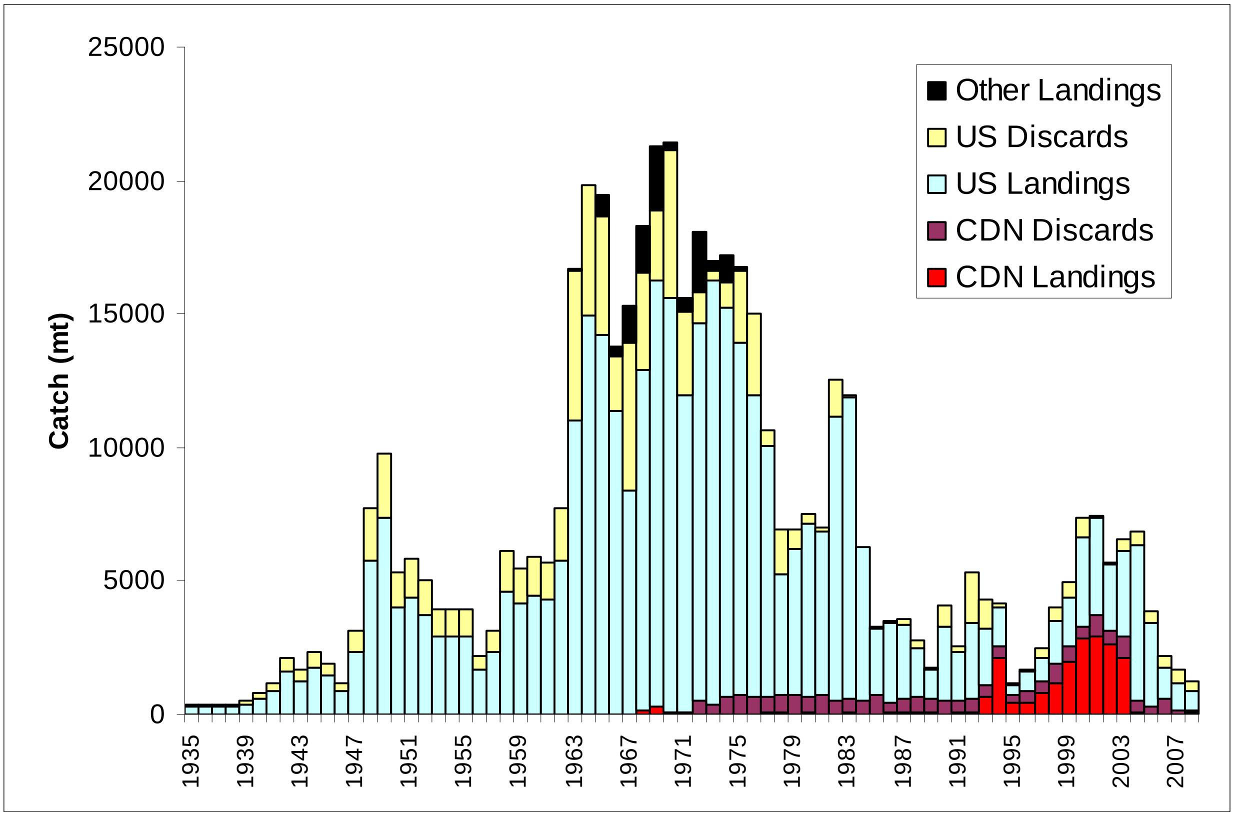


Figure 2. Catch (landings plus discards) of Georges Bank yellowtail flounder by nation, 1935-2008.

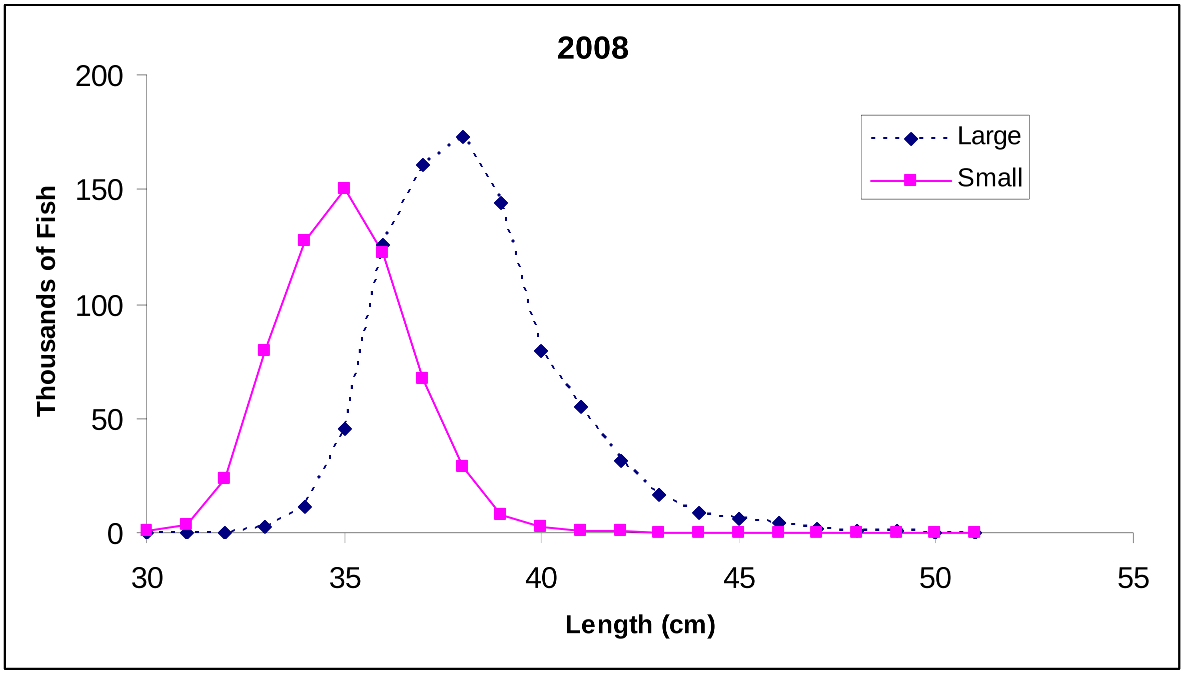


Figure 3. US landings of Georges Bank yellowtail by market category.

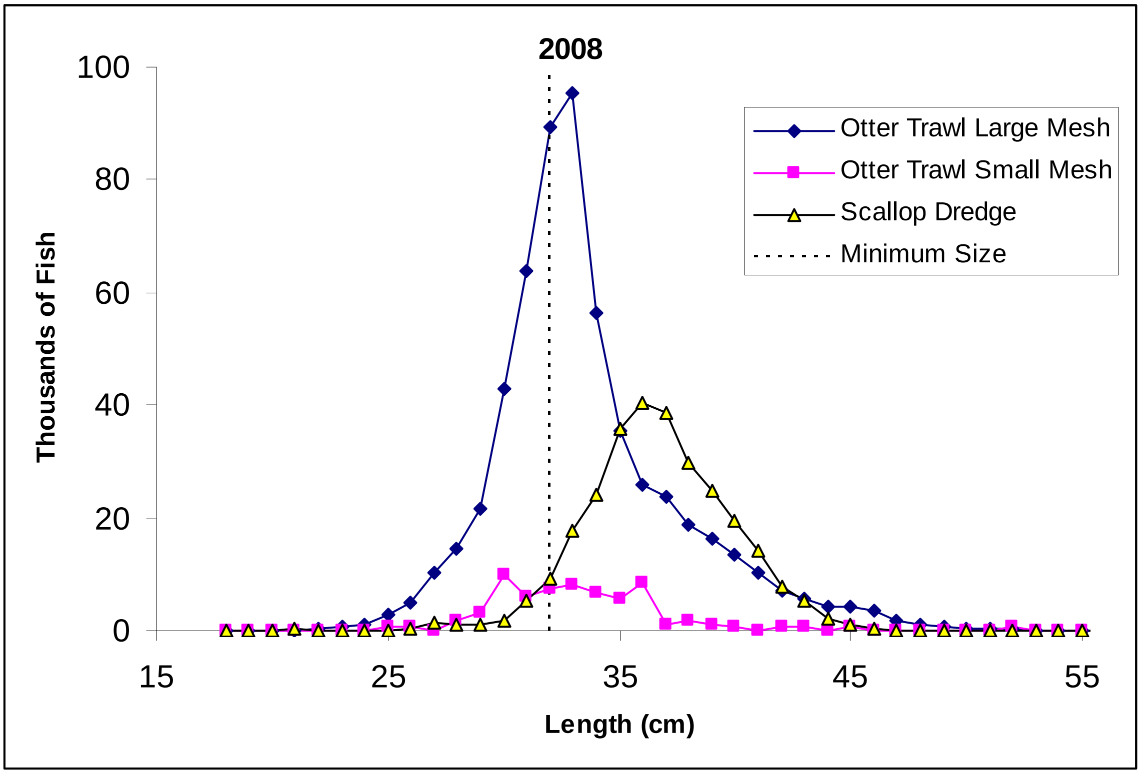
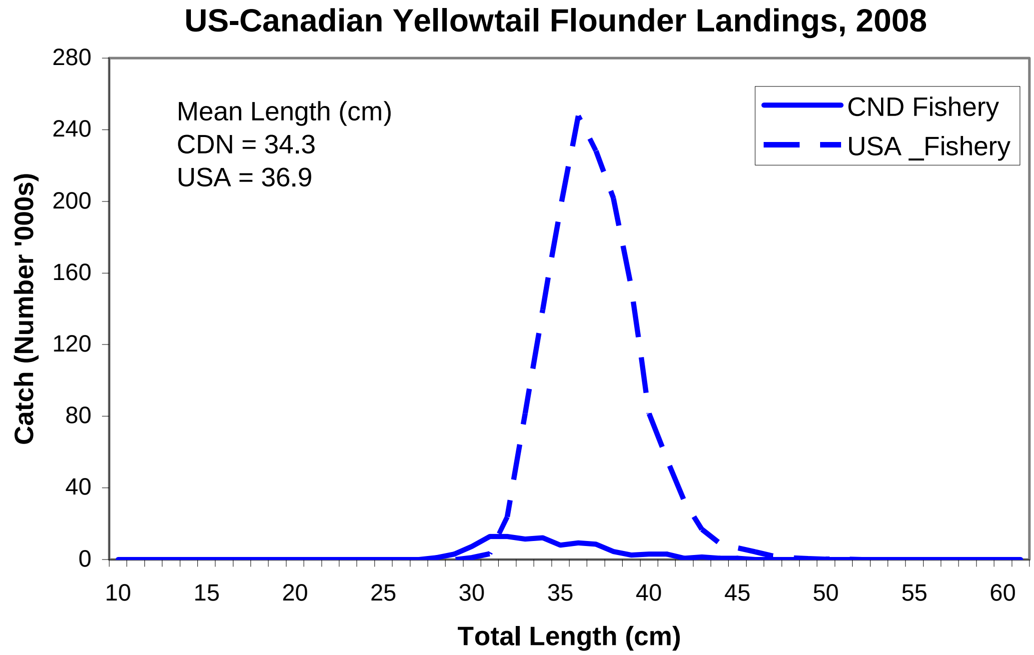


Figure 4. US discard length frequencies by gear.



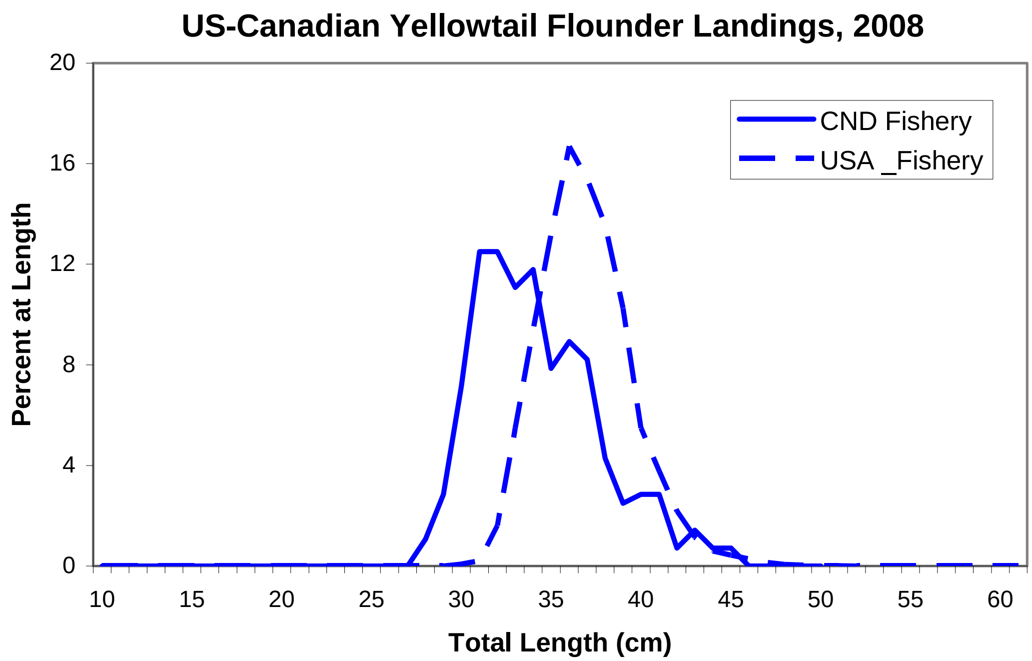
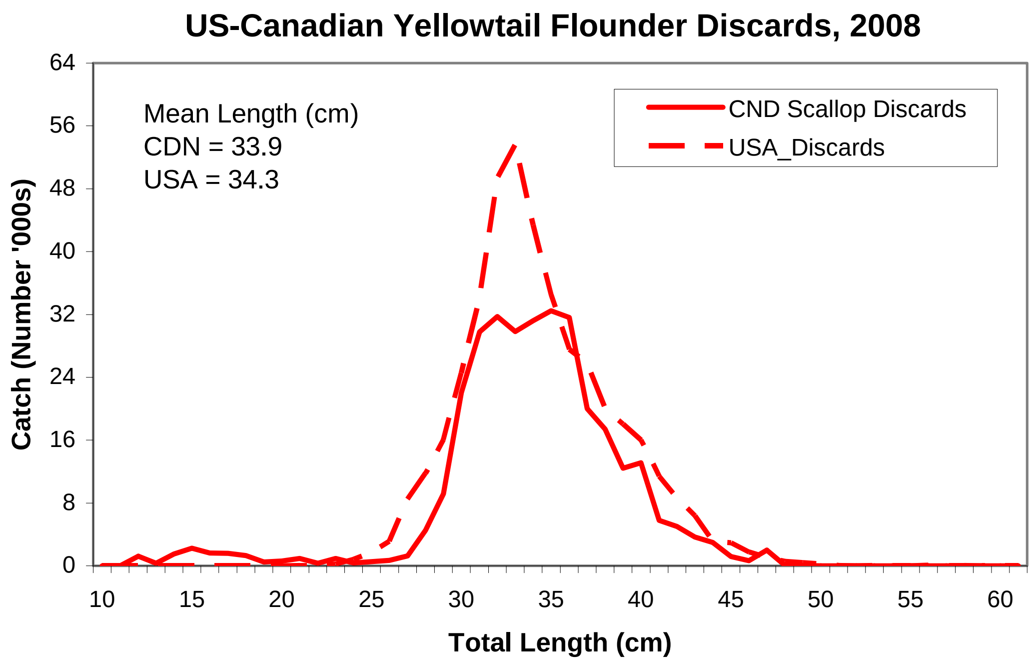


Figure 5. Comparison of US and Canadian landings at length for Georges Bank yellowtail flounder in 2008.



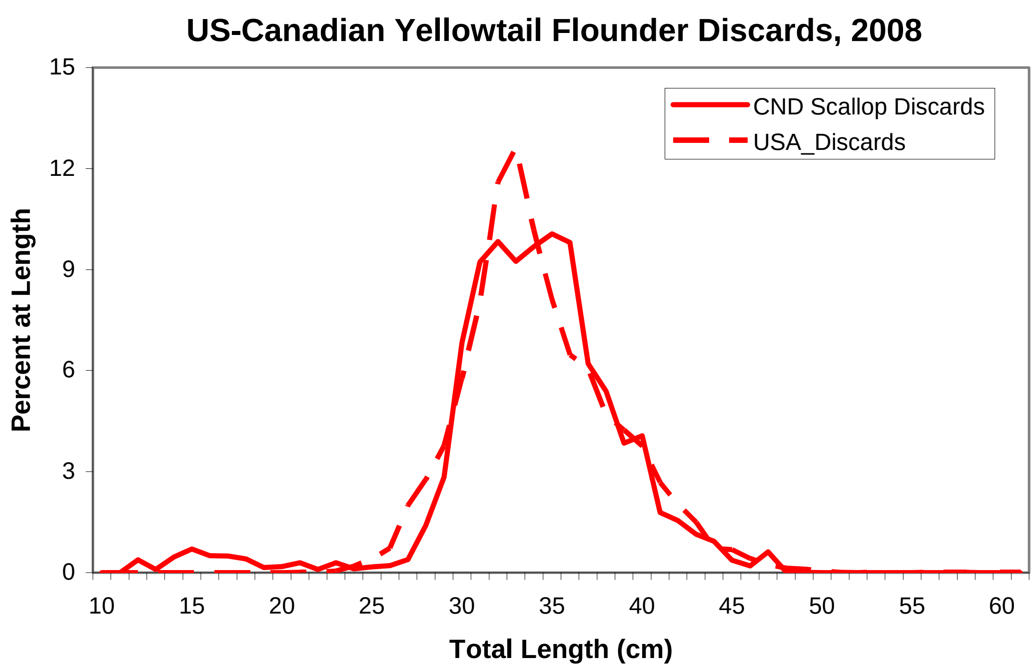
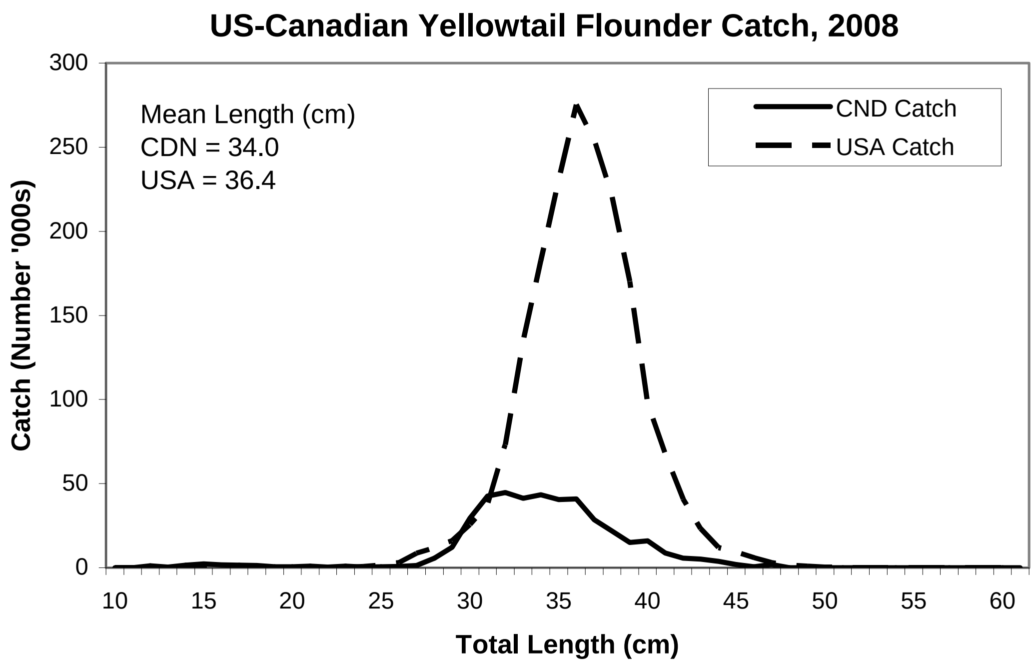


Figure 6. Comparison of US and Canadian discards at length for Georges Bank yellowtail flounder in 2008.



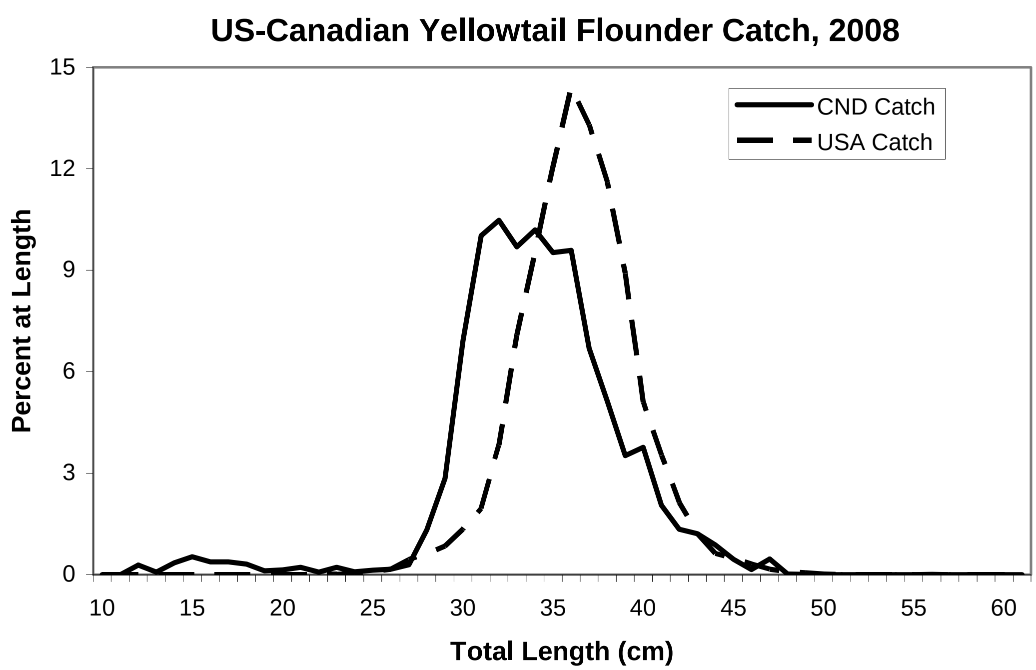


Figure 7. Comparison of US and Canadian catch (landings plus discards) at length for Georges Bank yellowtail flounder in 2008.

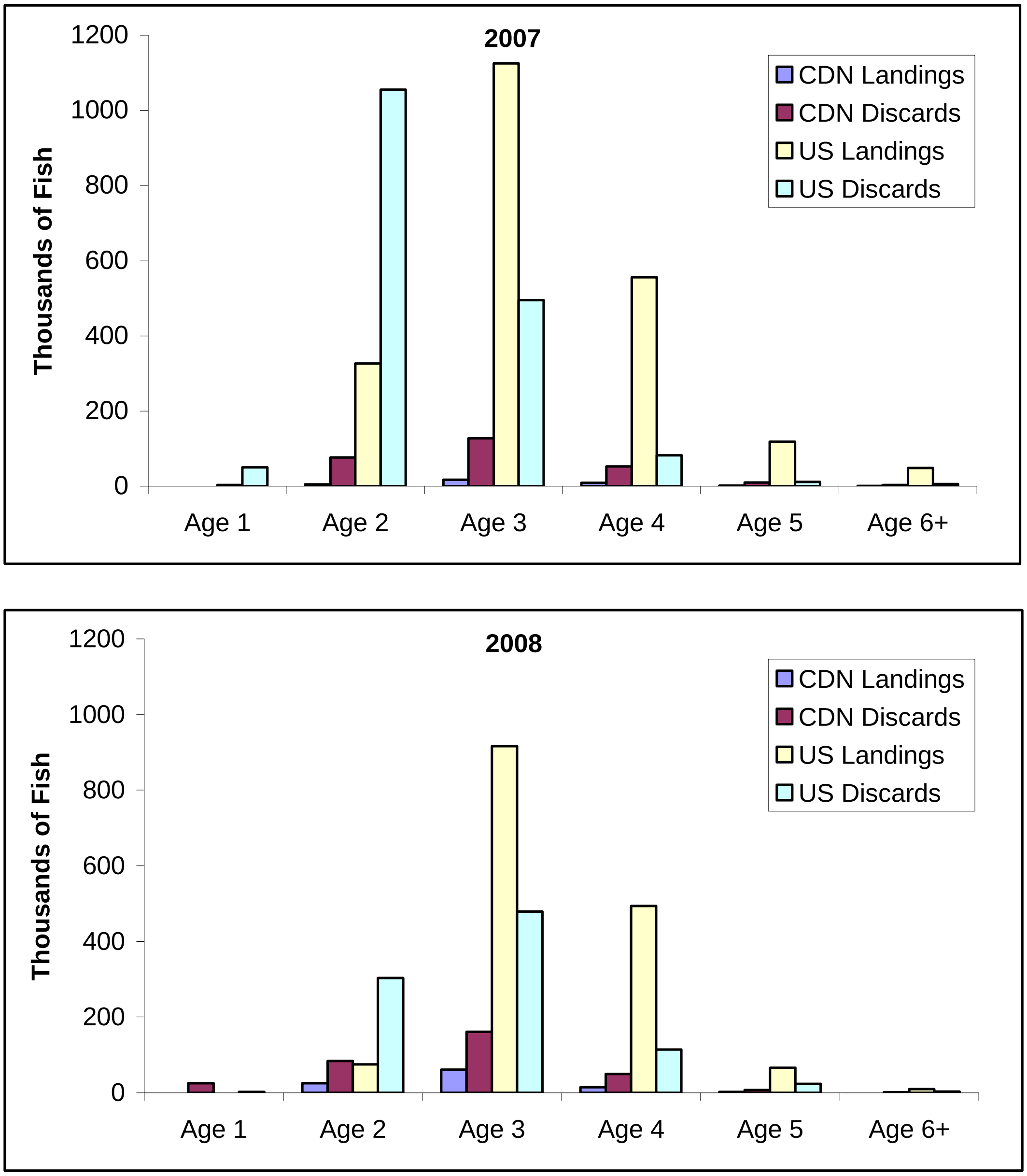


Figure 8. Catch at age of Georges Bank yellowtail flounder in 2007 and 2008 from the four components of Canadian and US landings and discards.

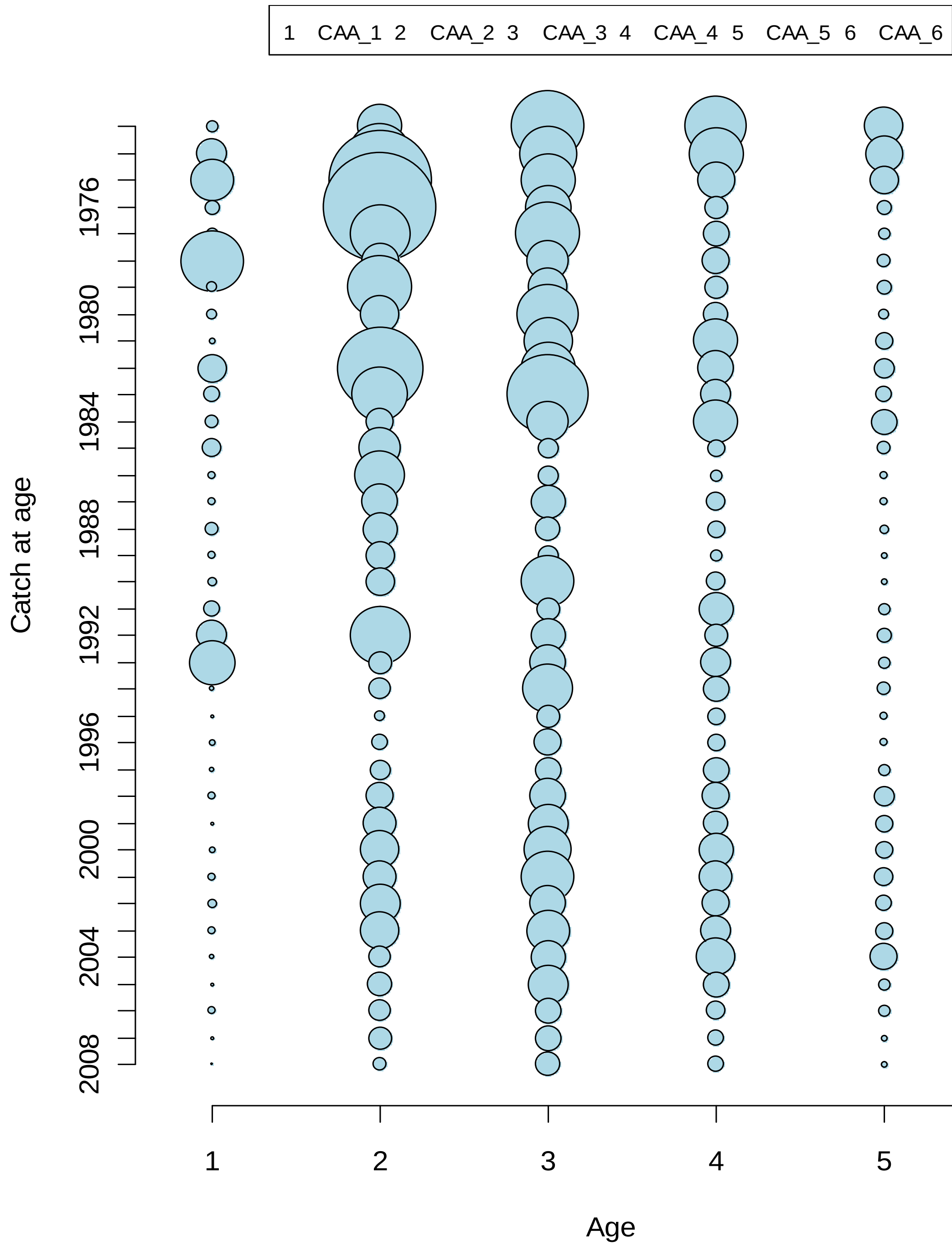


Figure 9. Catch at age for Georges Bank yellowtail flounder, Canadian and US fisheries combined, 1973-2008. (The area of the bubble is proportional to the magnitude of the catch).

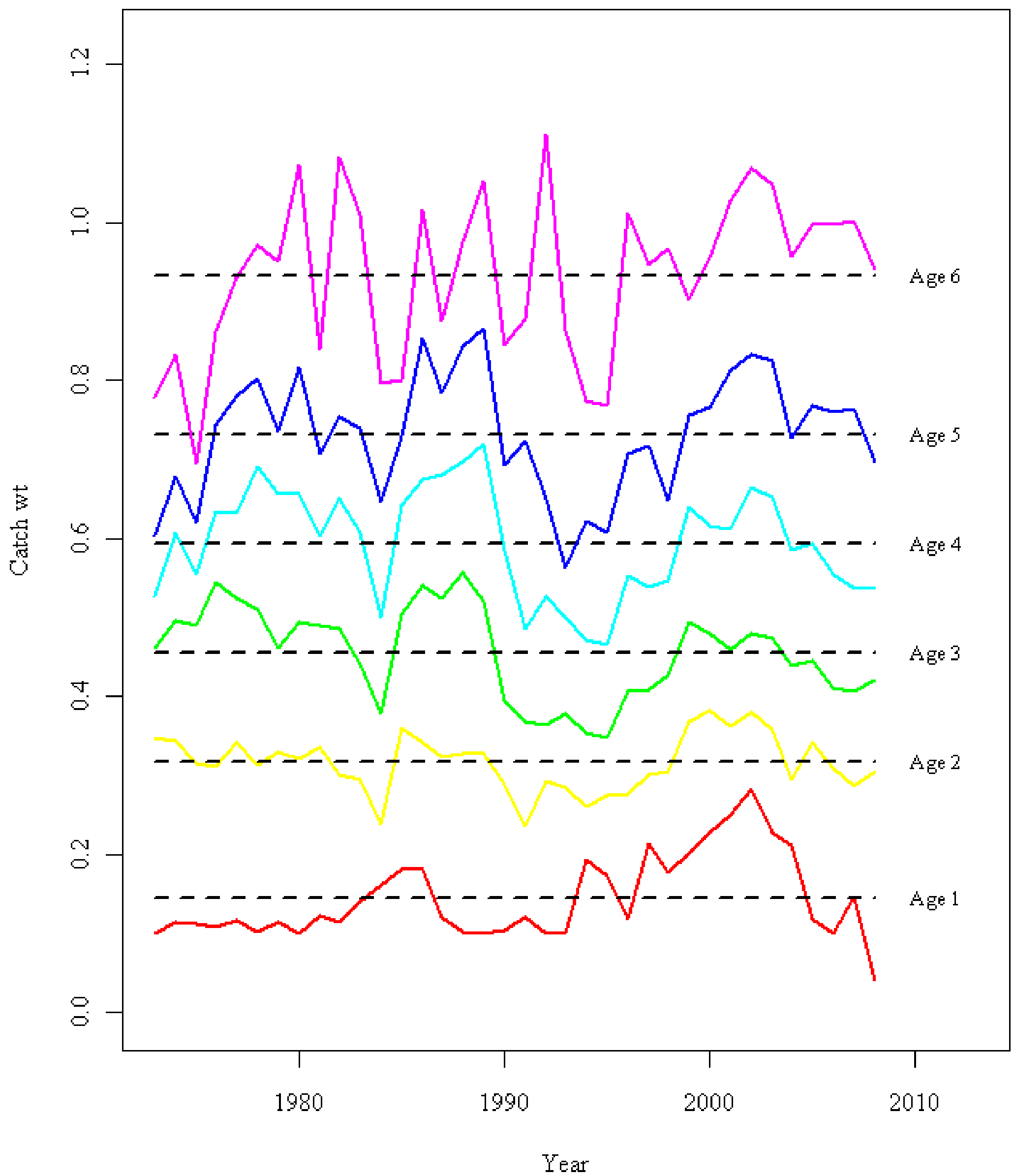


Figure 10. Trends in mean weight at age from the Georges Bank yellowtail fishery, 1973 to 2008 (Canada and US combined, including discards).

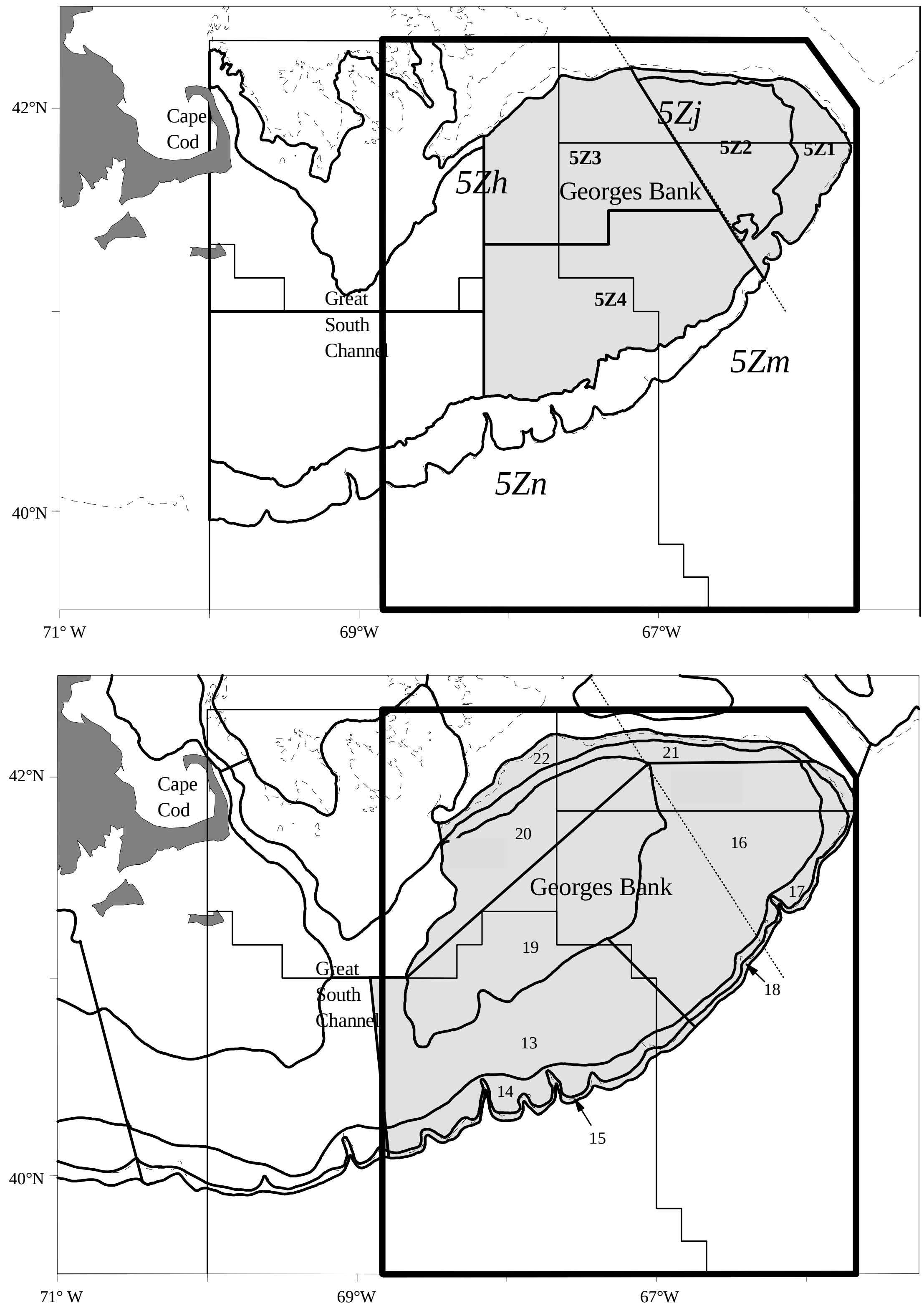
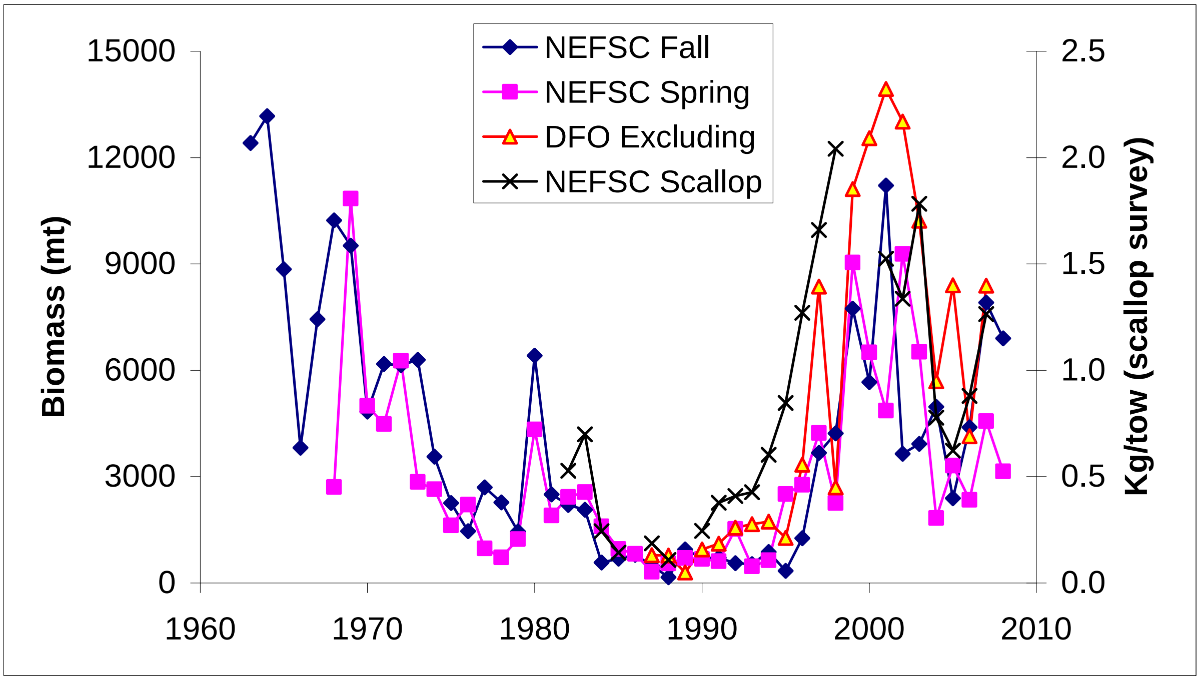


Figure 11. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in assessment.



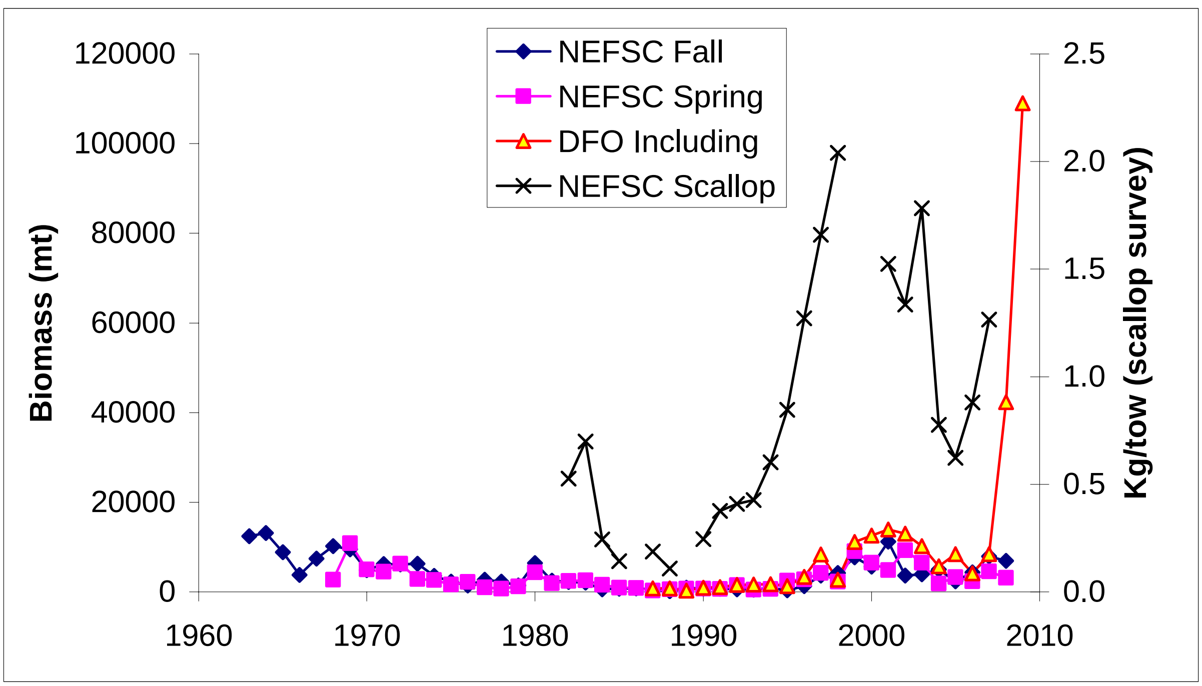
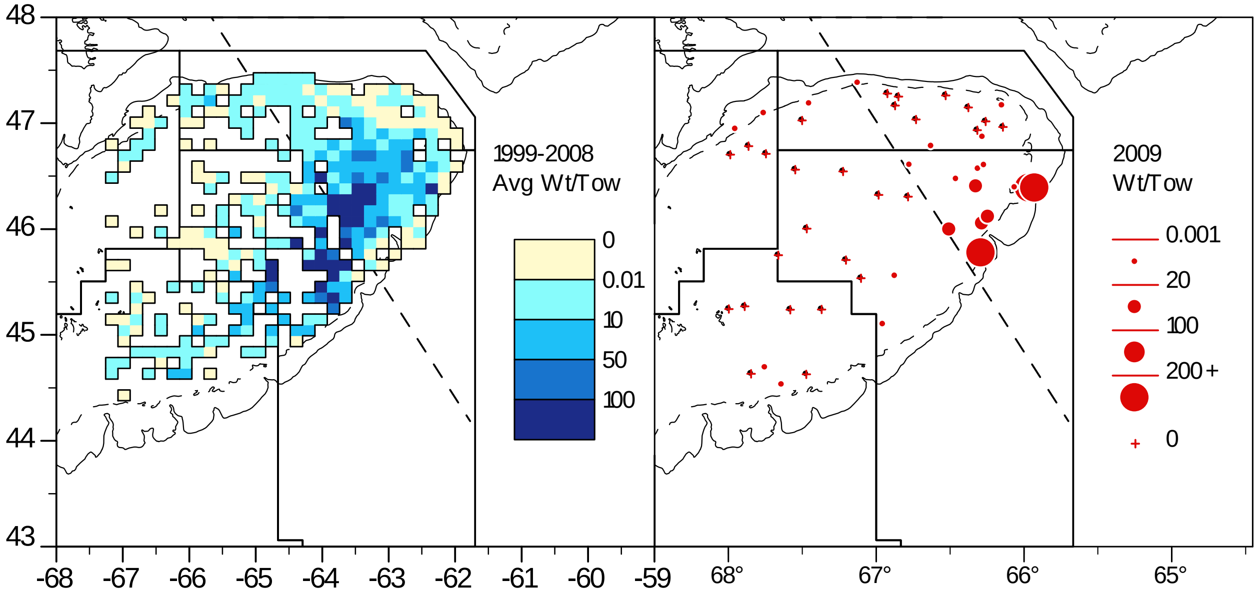


Figure 12. Four survey biomass indices for yellowtail flounder on Georges Bank. The DFO, NMFS fall, and NMFS spring surveys are minimum swept area estimates of total biomass (mt) while the NMFS scallop survey is the stratified mean kg/tow. Note the DFO 2008 and 2009 values are not shown in the top panel but are shown in the bottom panel with the left y-axis rescaled.

DFO



NEFSC Spring

Not available due to lack of conversion coefficients.

NEFSC Fall

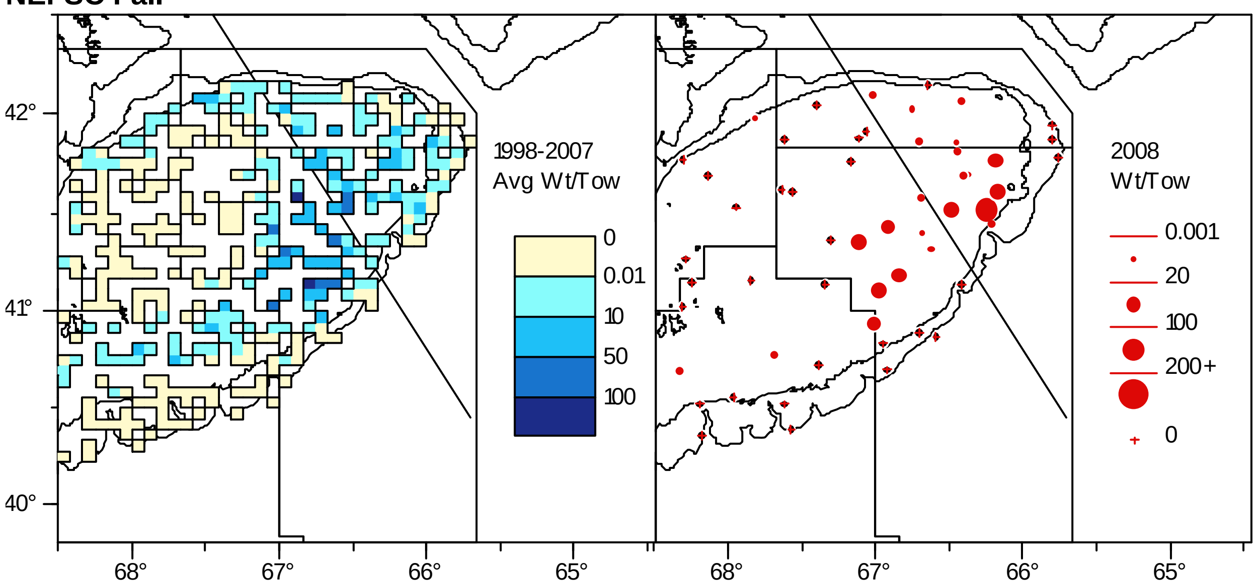


Figure 13. Catch of yellowtail in weight (kg) per tow for DFO, NMFS spring and NEFSC fall surveys. Left panels show previous 10 year averages, right panels most recent data.

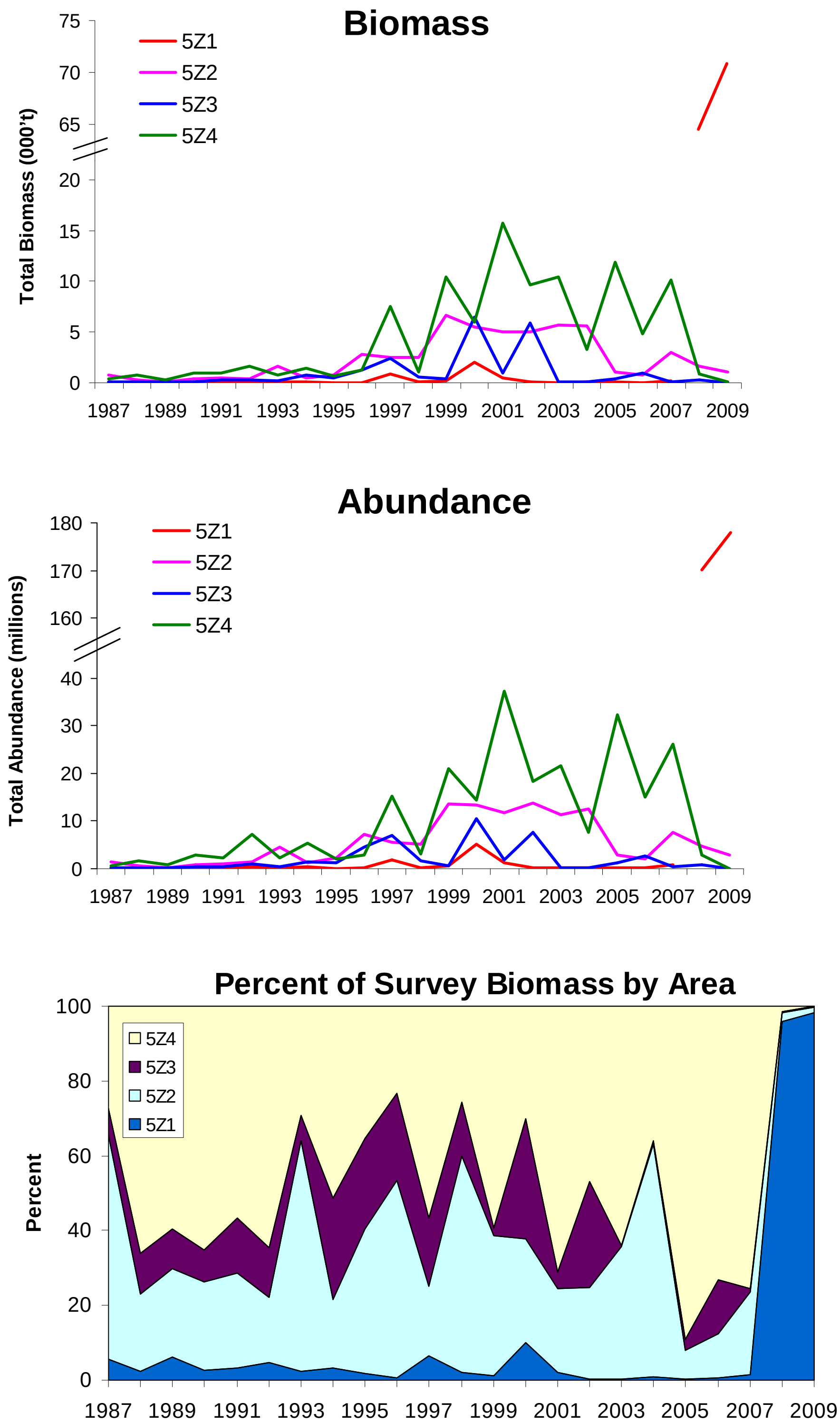


Figure 14. DFO spring survey estimates of total biomass (top panel), total number (middle panel) and percent of survey biomass (bottom Panel) by stratum area for yellowtail flounder on Georges Bank, 1987-2009.

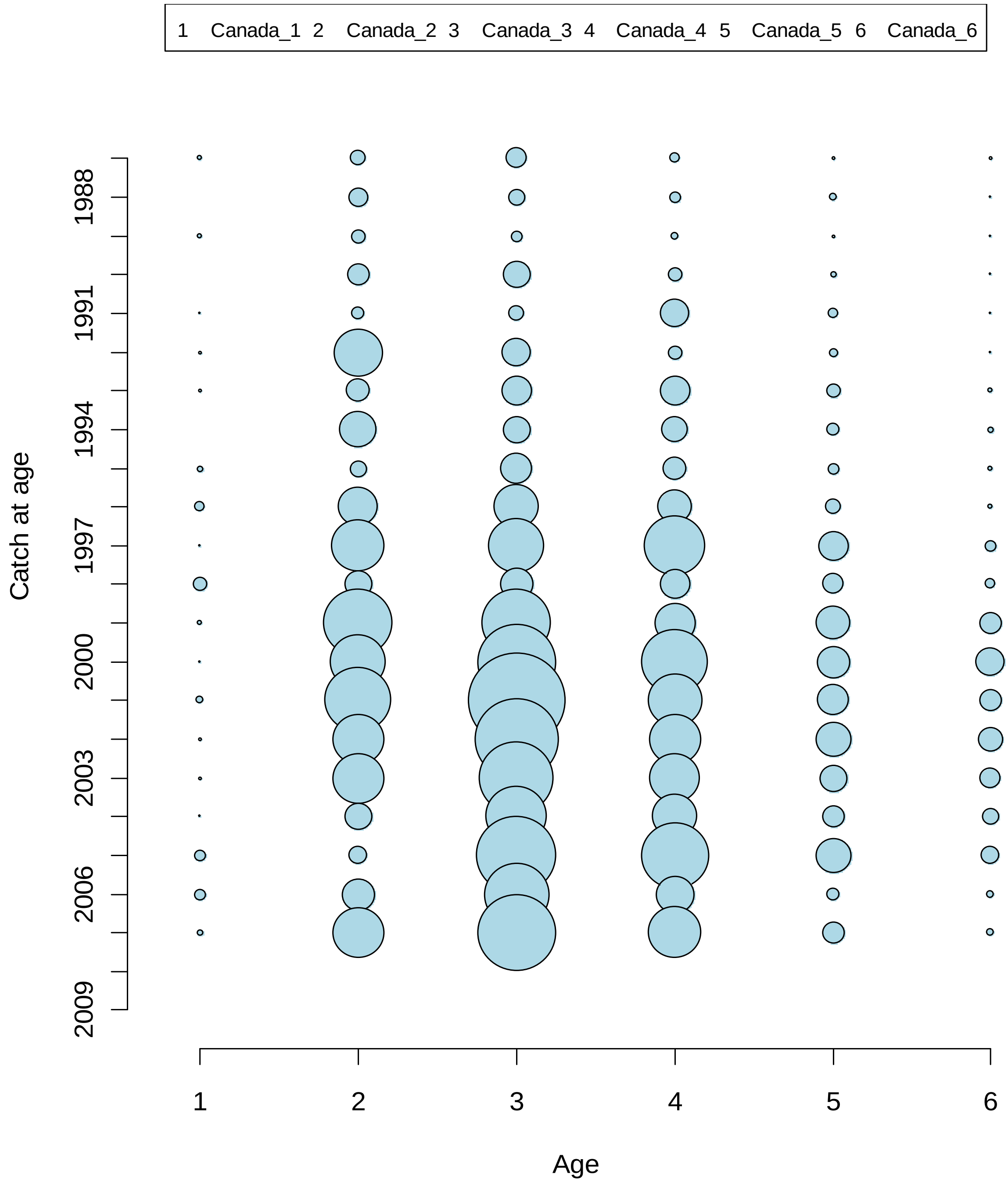


Figure 15a. Age specific indices of abundance for the DFO spring survey (1987-2007), values for 2008 and 2009 not plotted due to strong influence of individual tows (bubble is proportional to the magnitude). Age 6 denotes ages 6 and older. Refer to Table 7 for the specific values of the indices.

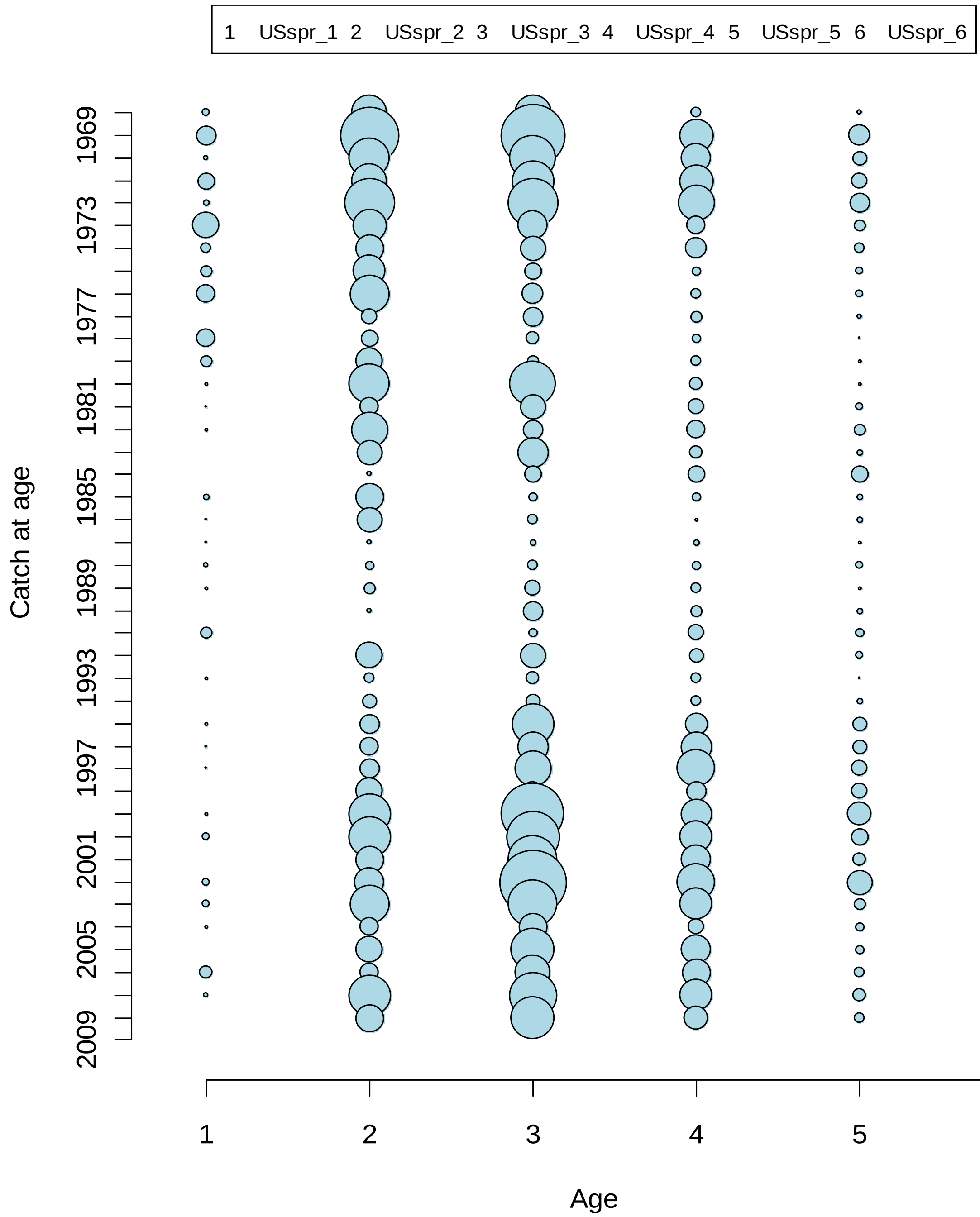


Figure 15b. Age specific indices of abundance for the NMFS spring survey (1982-2008), the early years when the Yankee 41 net was used are not shown and the 2009 values are not available due to lack of a conversion coefficient for the new vessel and gear (bubble is proportional to the magnitude). Age 6 denotes ages 6 and older. Refer to Table 8 for the specific values of the indices.

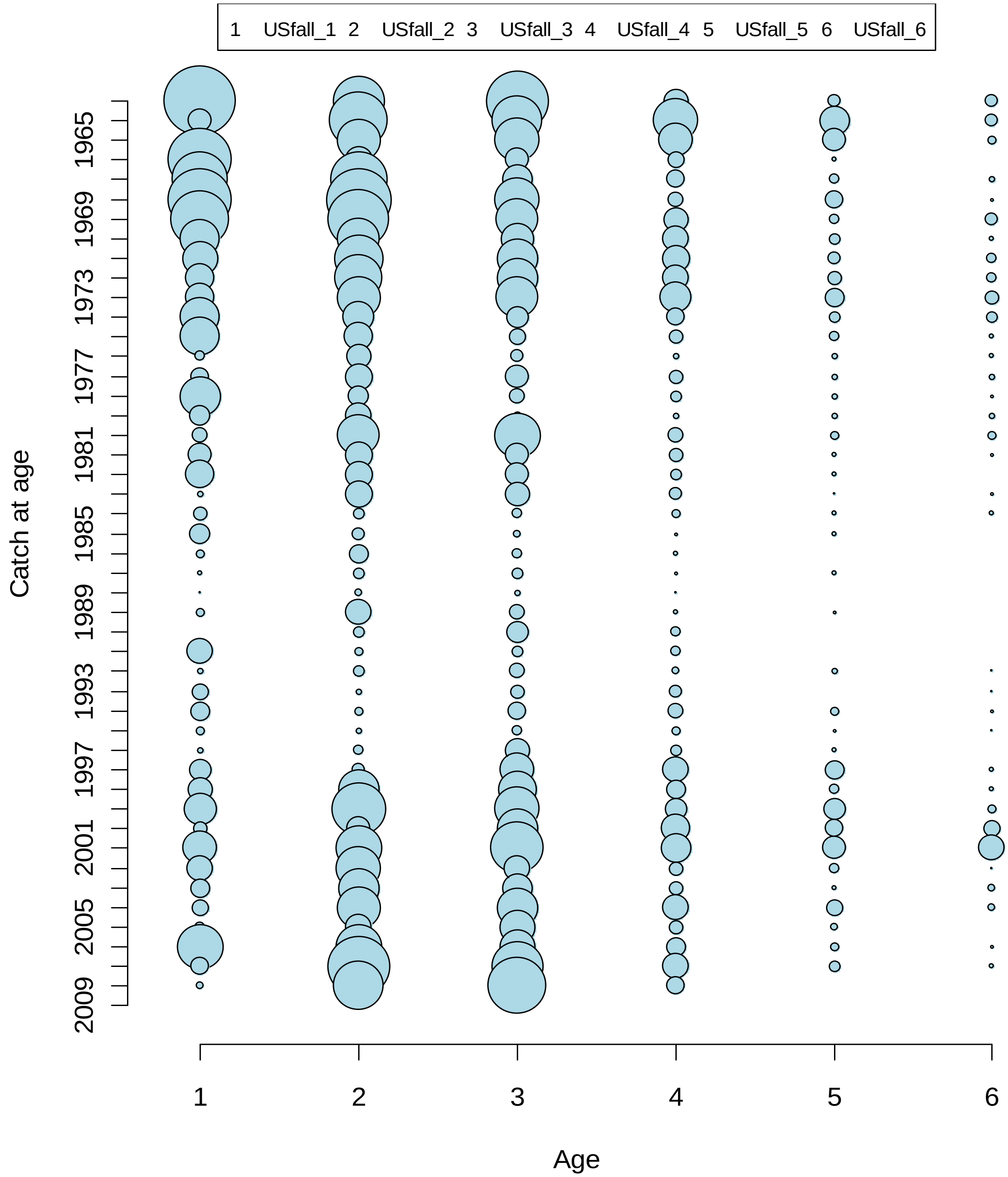


Figure 15c. Age specific indices of abundance for the NMFS fall survey (1973-2008, bubble is proportional to the magnitude). Age 6 denotes ages 6 and older. Refer to Table 9 for the specific values of the indices.

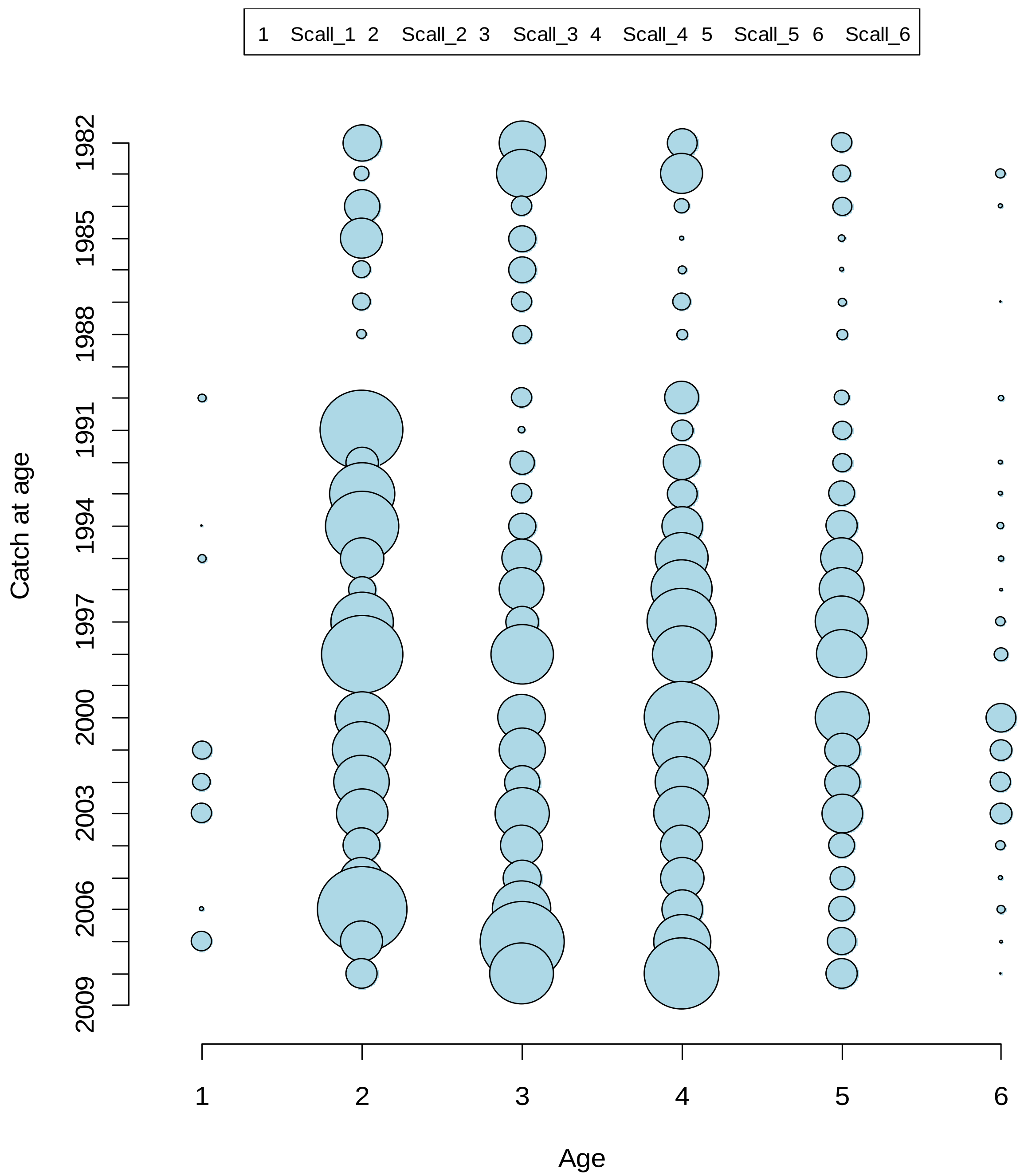


Figure 15d. Age specific indices of abundance for the NMFS scallop survey (1982-2008), note years 1989 and 1999 are not included (bubble is proportional to the magnitude, but on a different scale from the three bottom trawl surveys). Age 6 denotes ages 6 and older. Refer to Table 10 for the specific values of the indices.

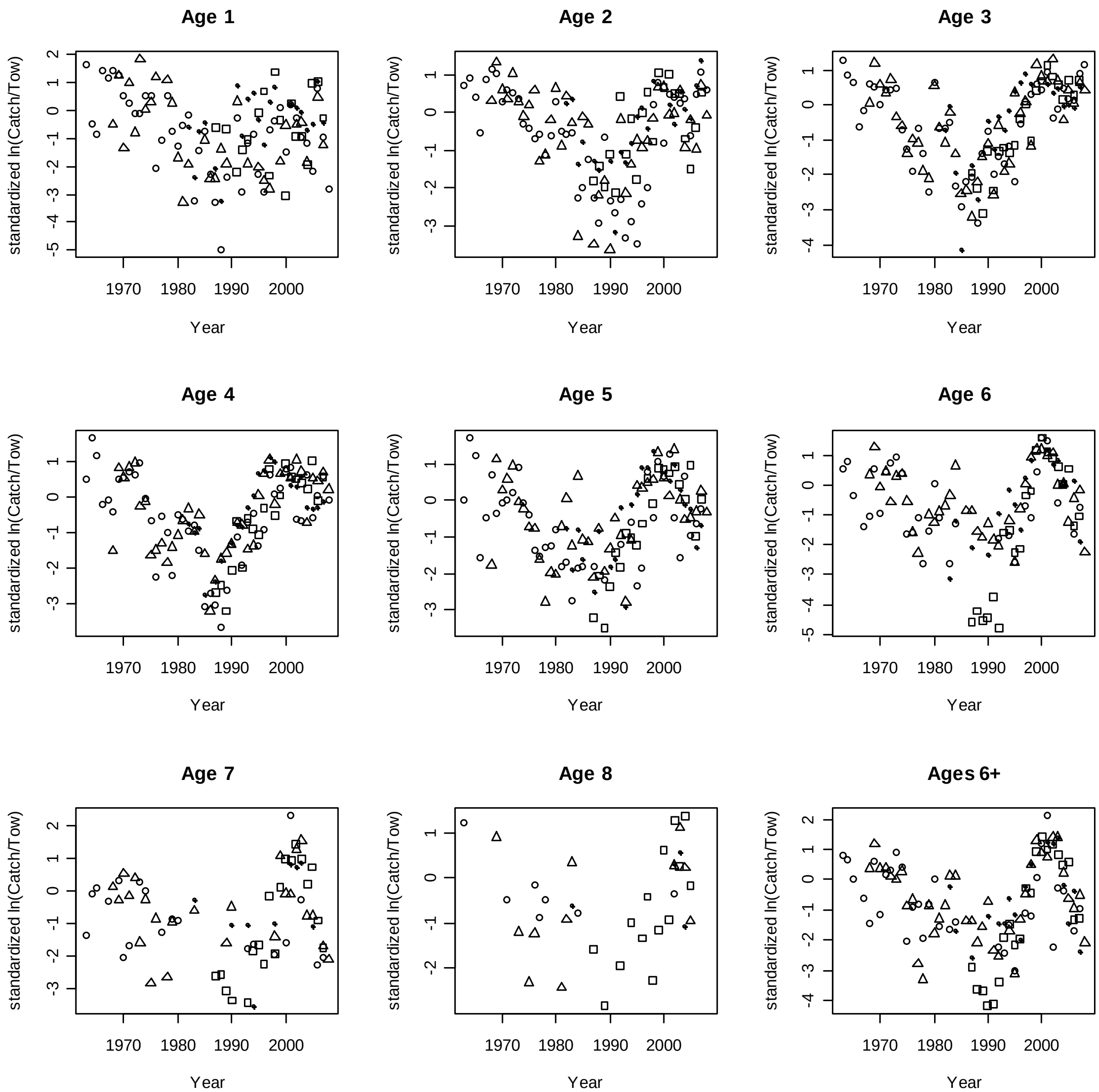


Figure 16. Standardized catch/tow in numbers at age for the four surveys plotted on natural log scale. The standardization was merely the division of each index value by the mean of the associated time series. *Squares* denote the DFO survey (2008 and 2009 not shown), *triangles* the NEFSC spring survey, *open circles* the NEFSC fall survey, and *closed circles* the NEFSC scallop survey.

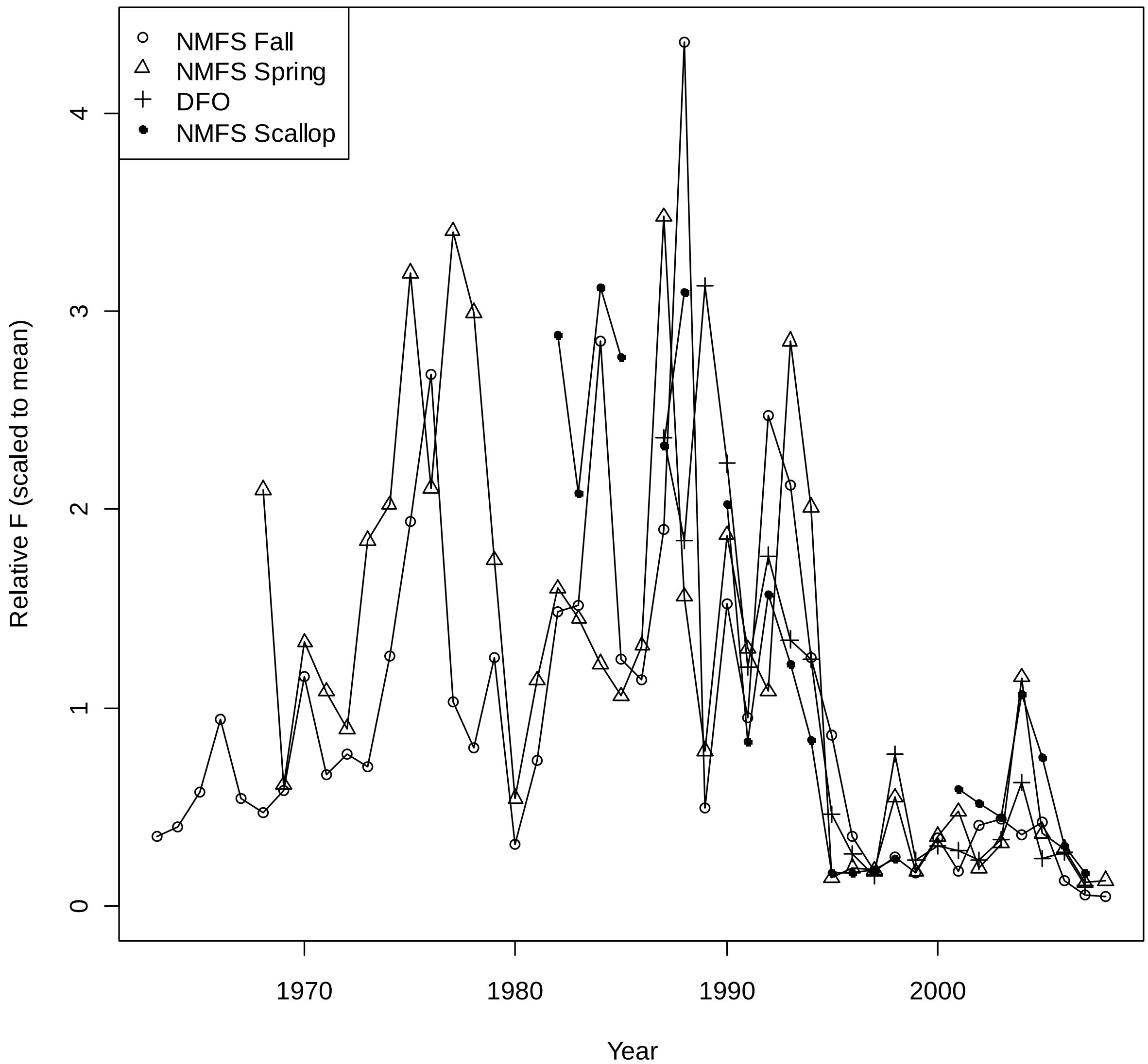


Figure 17. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2008 (DFO values for 2008 and 2009 not shown).

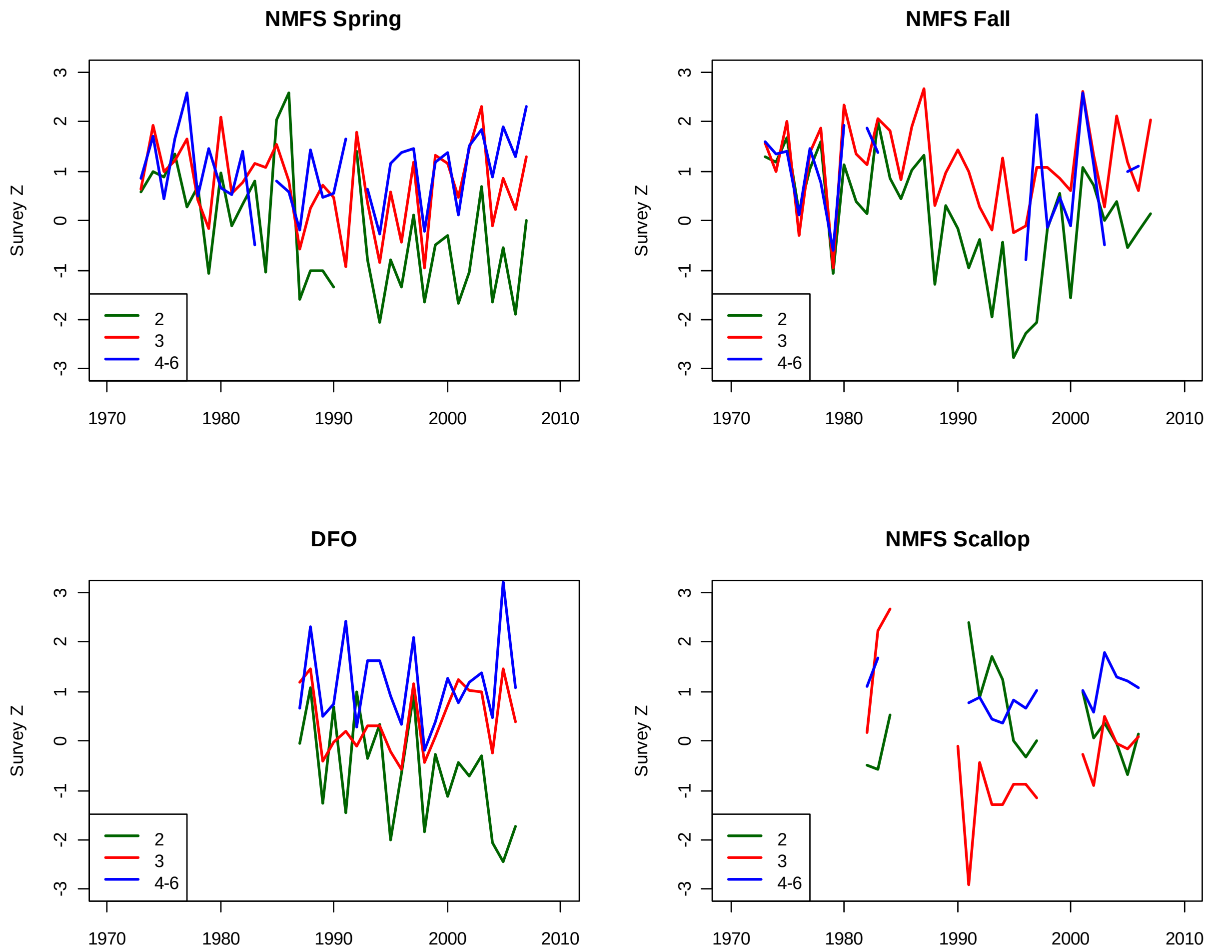


Figure 18. Trends in total mortality (Z) for ages 2, 3, and 4-6 from NMFS spring, NMFS fall, DFO (2008 and 2009 not shown), and NMFS scallop surveys.

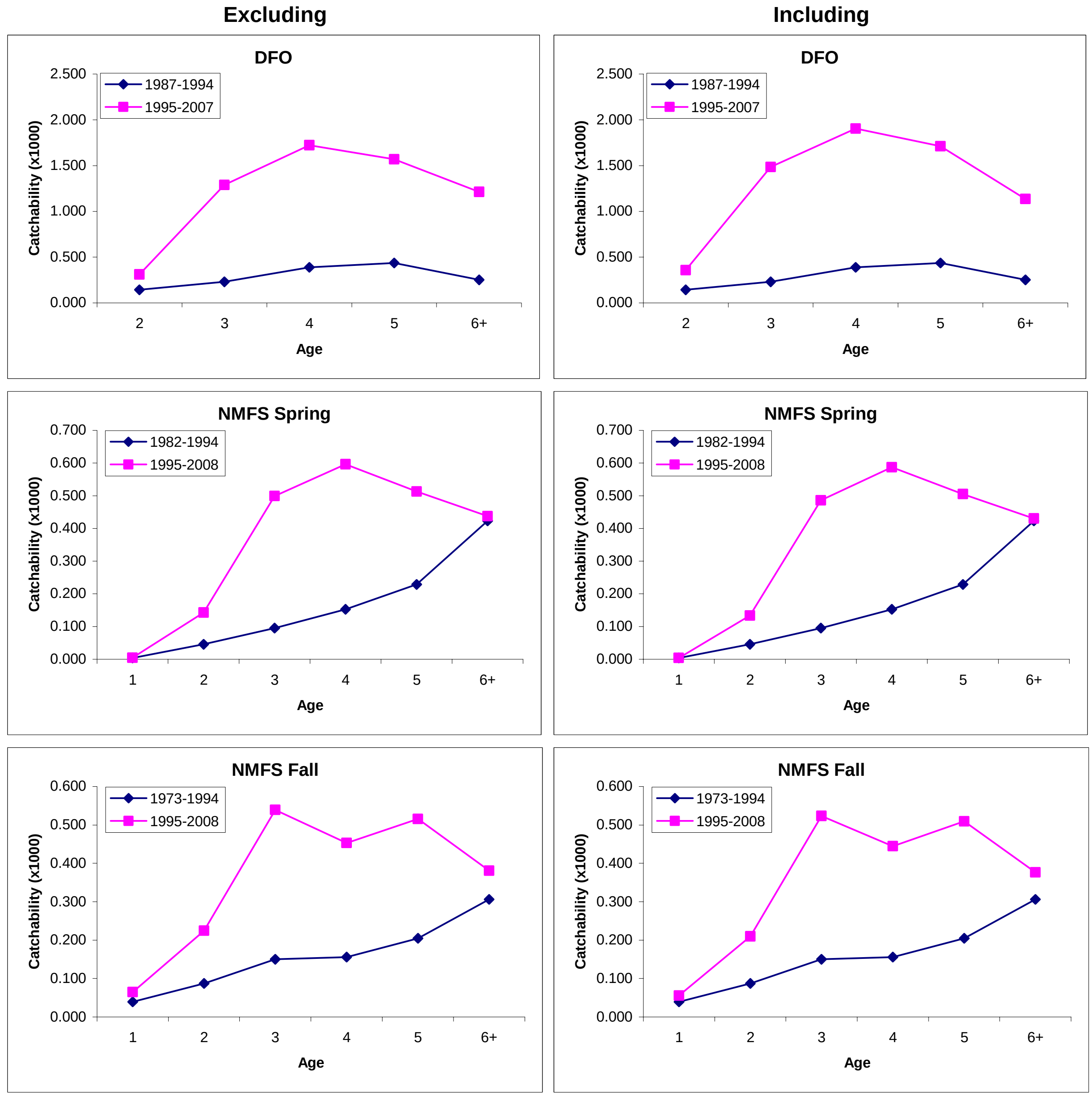


Figure 19. Catchability coefficients (q) from the two Major Change VPA runs; Excluding the DFO 2008 and 2009 survey values (left panels) and Including the DFO 2008 and 2009 survey values (right panels).

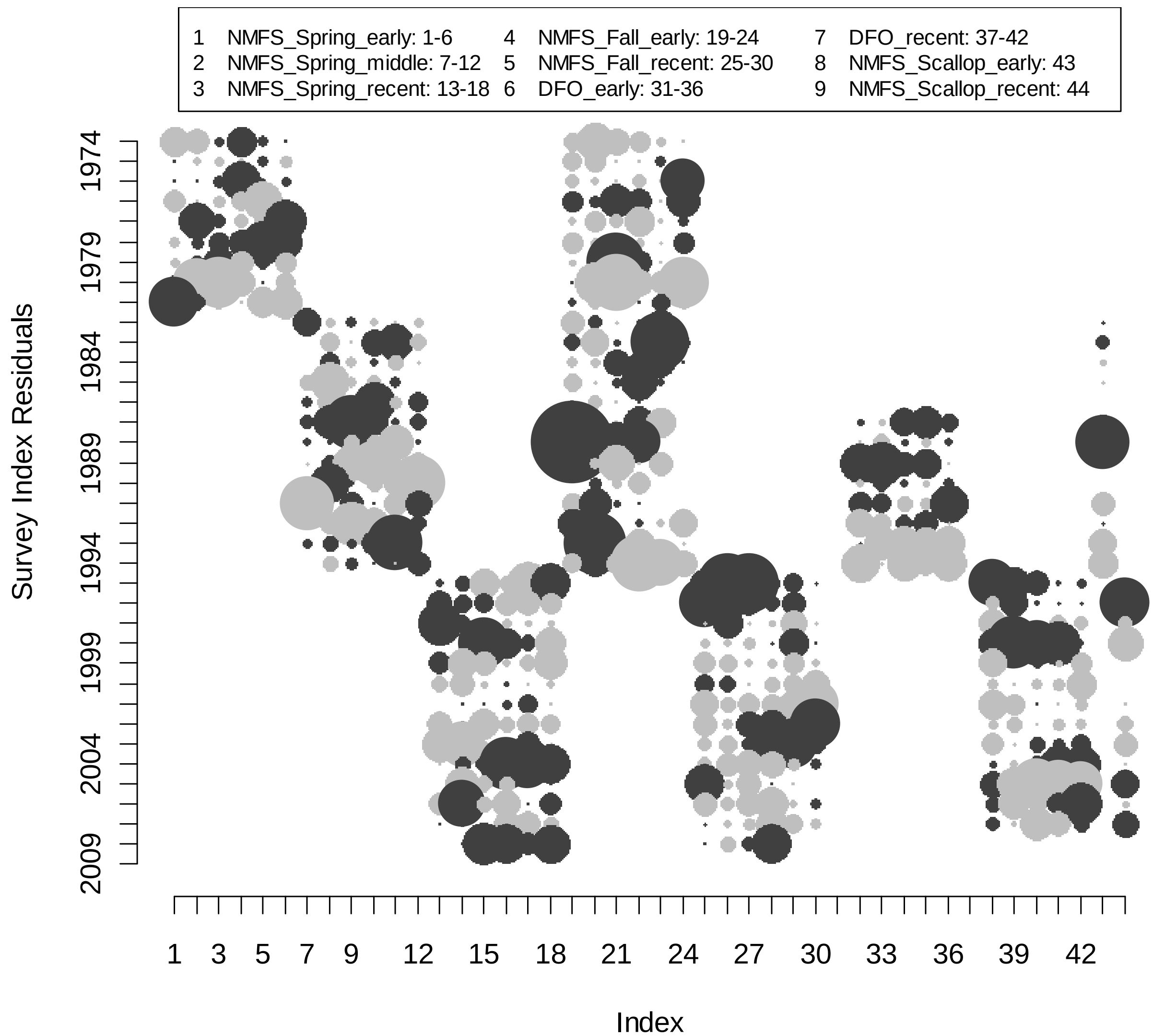


Figure 20. Age by age residuals from the Major Change VPA **Excluding** the DFO 2008 and 2009 survey values for *ln* abundance index minus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The black symbols denote negative residuals, and grey symbols denote positive residuals. Indices 1-18 are the NMFS Spring series (early, middle, recent) ages 1-6+, 19-30 are the NMFS Fall series (early, recent), 31-42 are the DFO series (age 1 not used as a tuning index, early, recent), and 43-44 are the NMFS Scallop survey age 1 (early, recent).

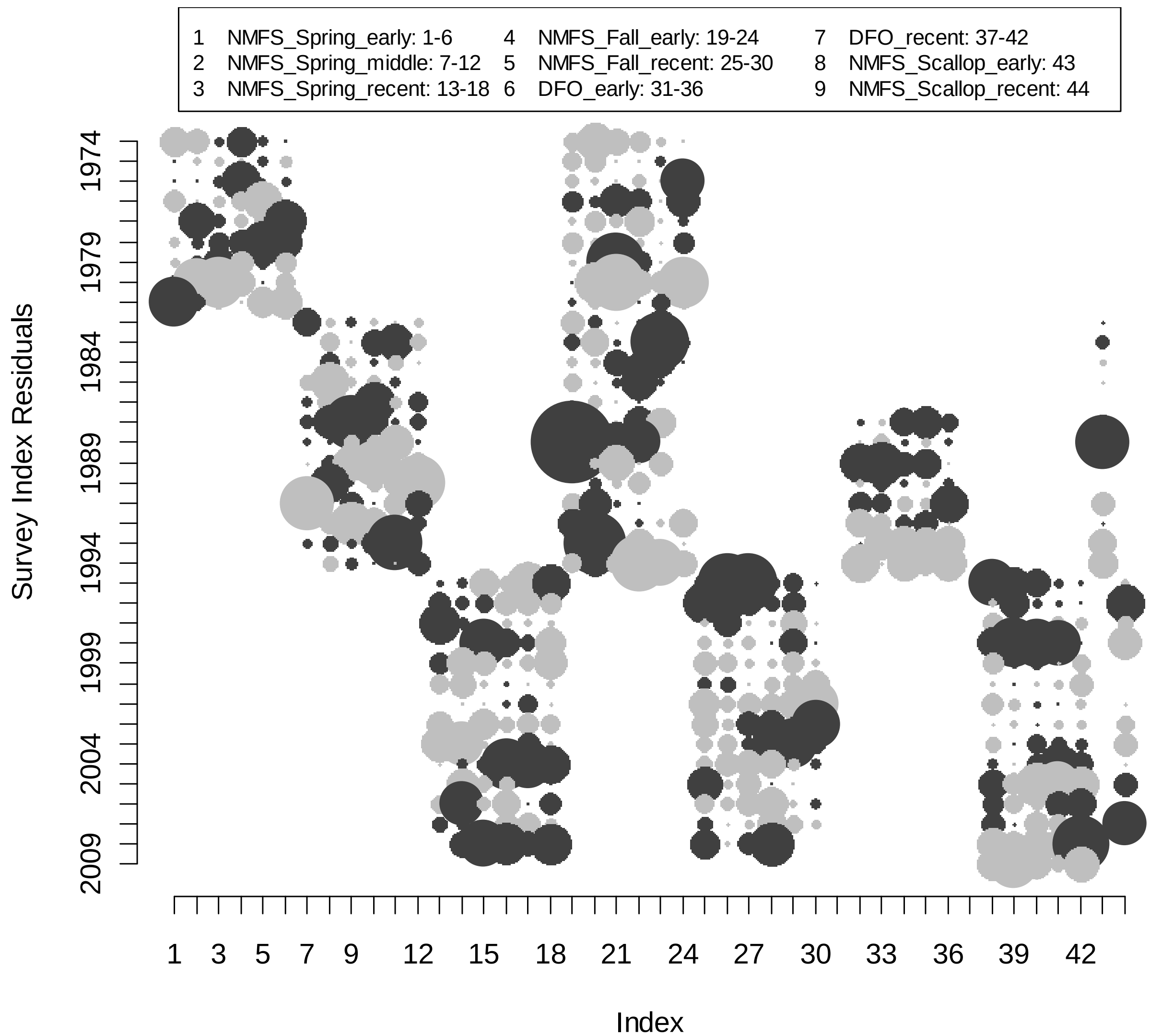


Figure 21. Age by age residuals from the Major Change VPA **Including** the DFO 2008 and 2009 survey values for *ln* abundance index minus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The black symbols denote negative residuals, and grey symbols denote positive residuals. Indices 1-18 are the NMFS Spring series (early, middle, recent) ages 1-6+, 19-30 are the NMFS Fall series (early, recent), 31-42 are the DFO series (age 1 not used as a tuning index, early, recent), and 43-44 are the NMFS Scallop survey age 1 (early, recent).

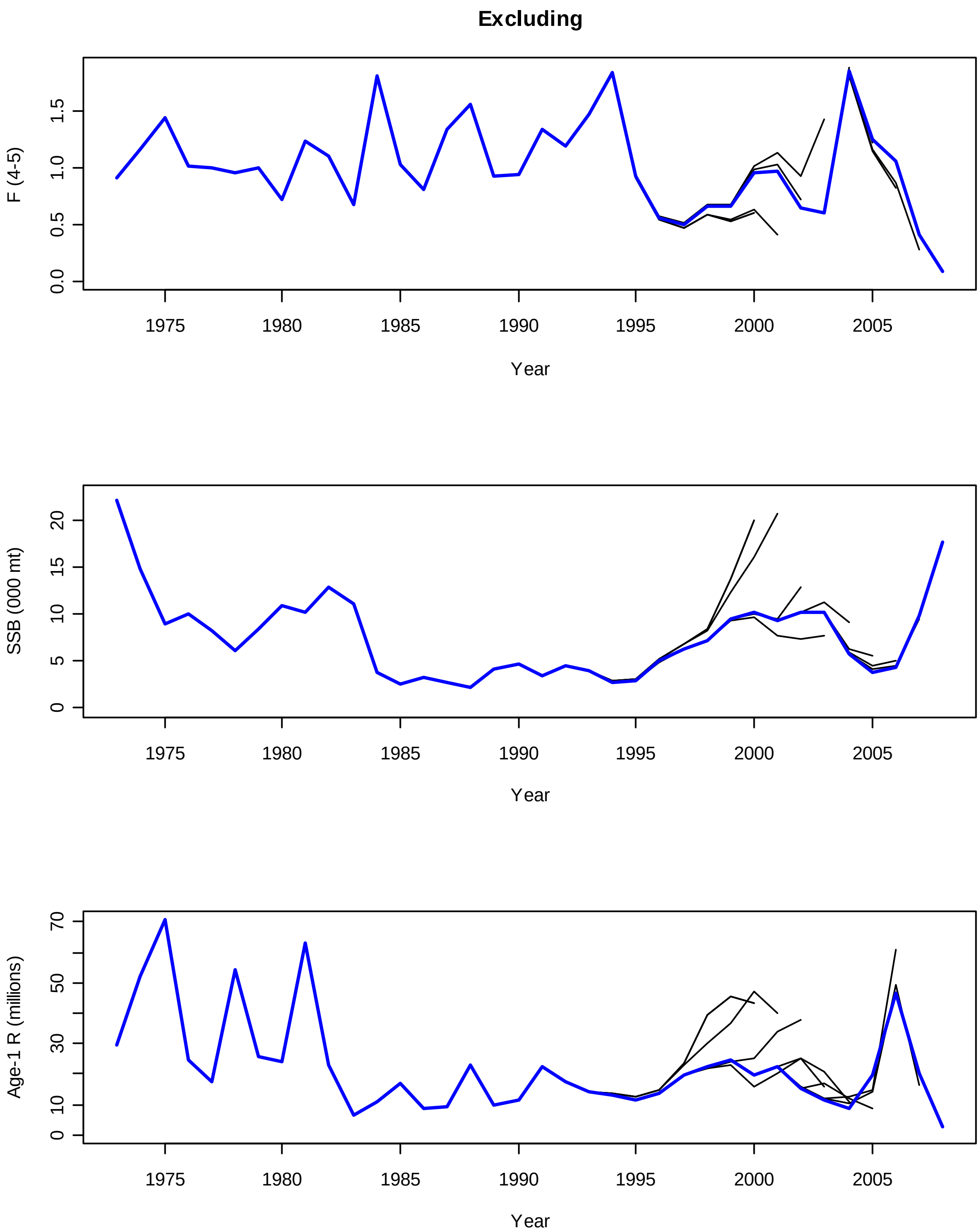


Figure 22. Retrospective analysis of Georges Bank yellowtail flounder from the Major Change VPA **Excluding** the DFO 2008 and 2009 survey values for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel) and age 1 recruits (lower panel).

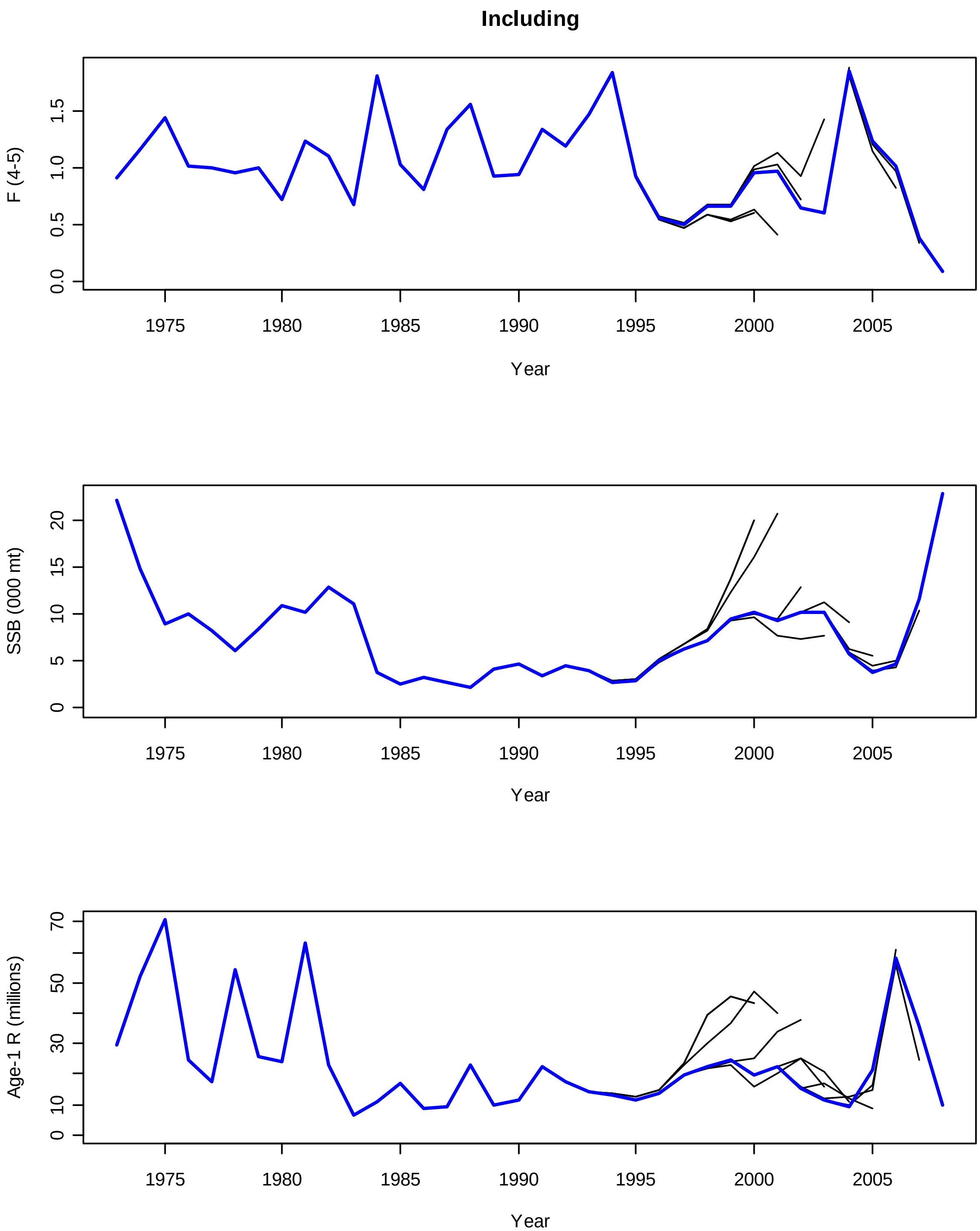


Figure 23. Retrospective analysis of Georges Bank yellowtail flounder from the Major Change VPA **Including** the DFO 2008 and 2009 survey values for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel) and age 1 recruits (lower panel).

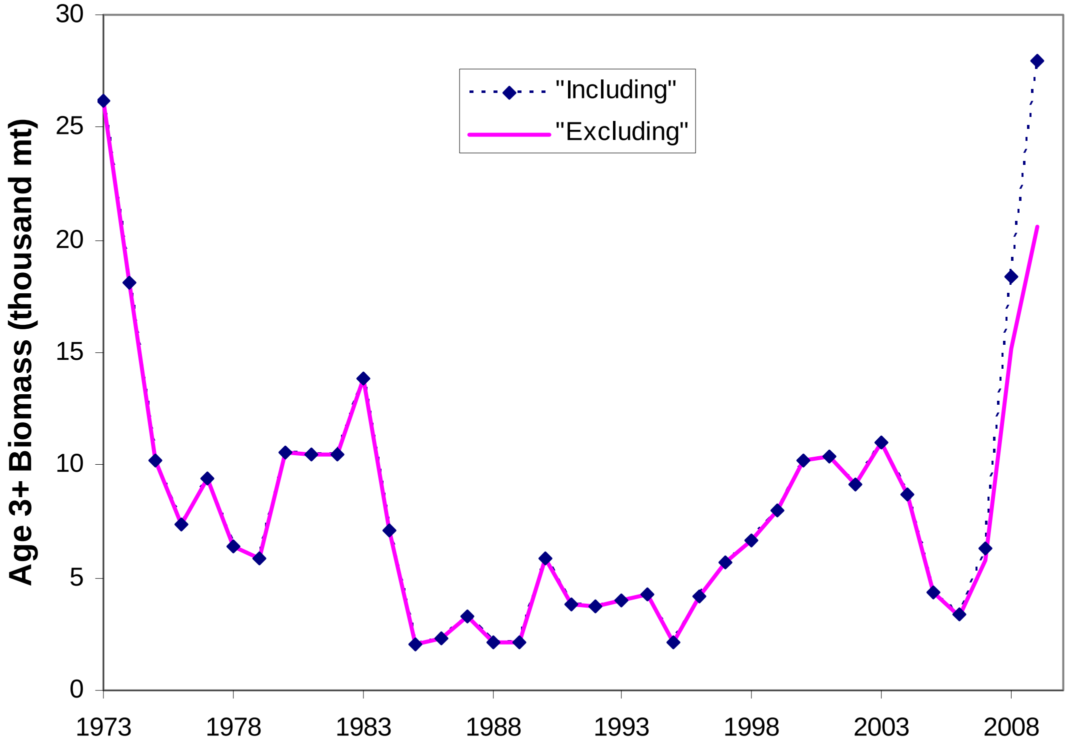


Figure 24. Adult biomass (ages 3+, Jan-1) from the two VPA formulations.

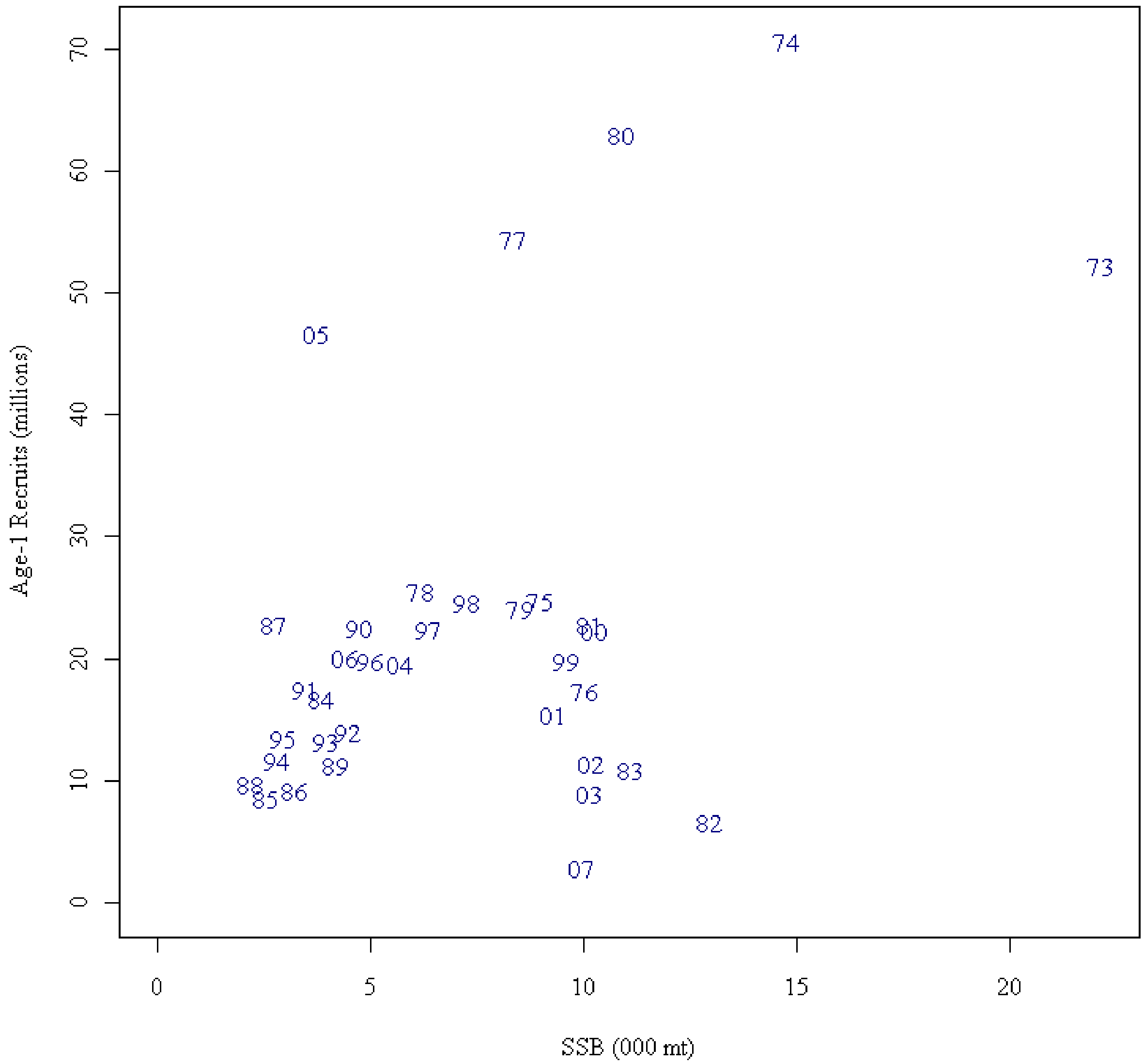


Figure 25. Stock recruitment relationship from the Major Change VPA **Excluding** the DFO 2008 and 2009 survey values.

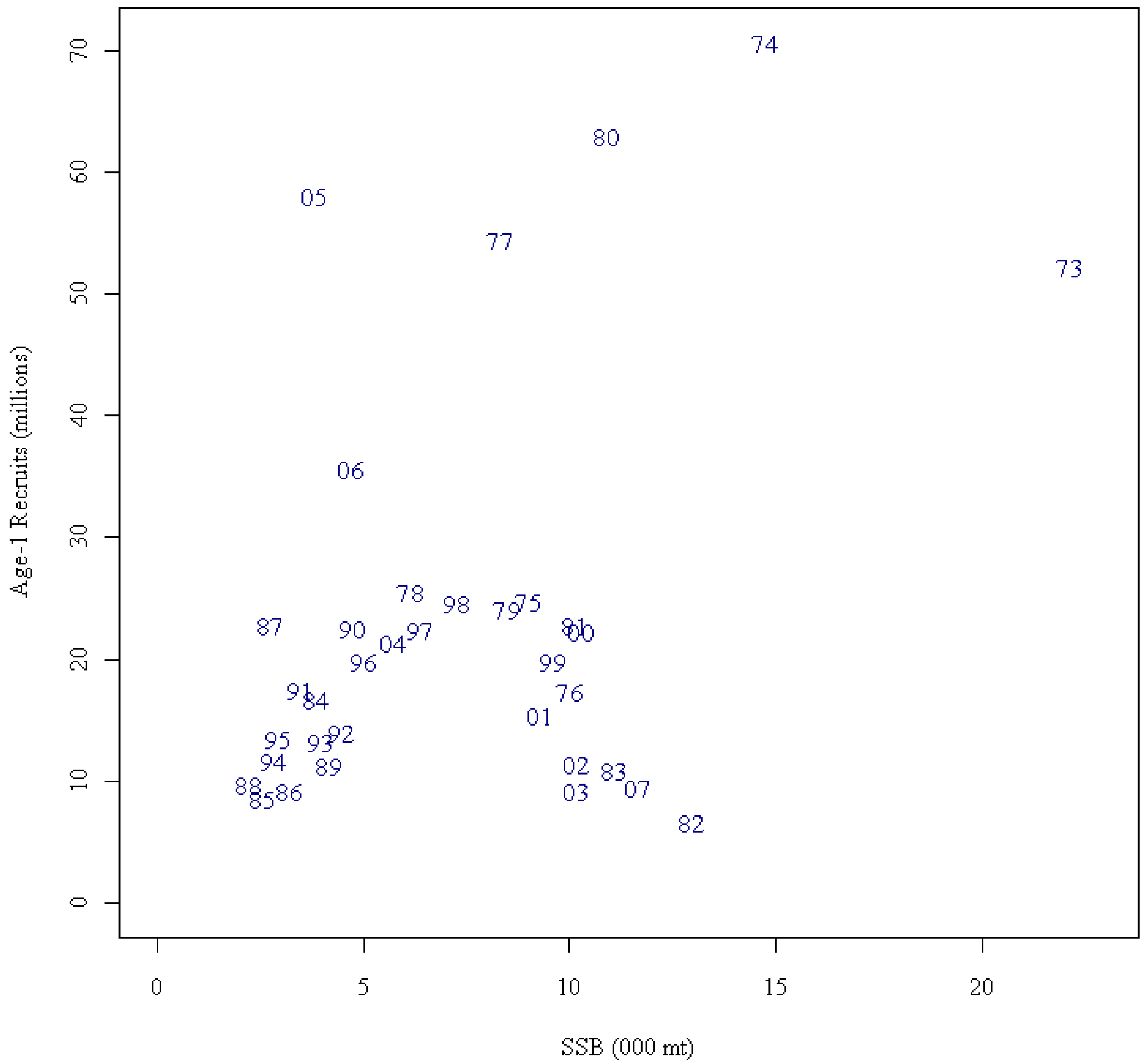


Figure 26. Stock recruitment relationship from the Major Change VPA **Including** the DFO 2008 and 2009 survey values.

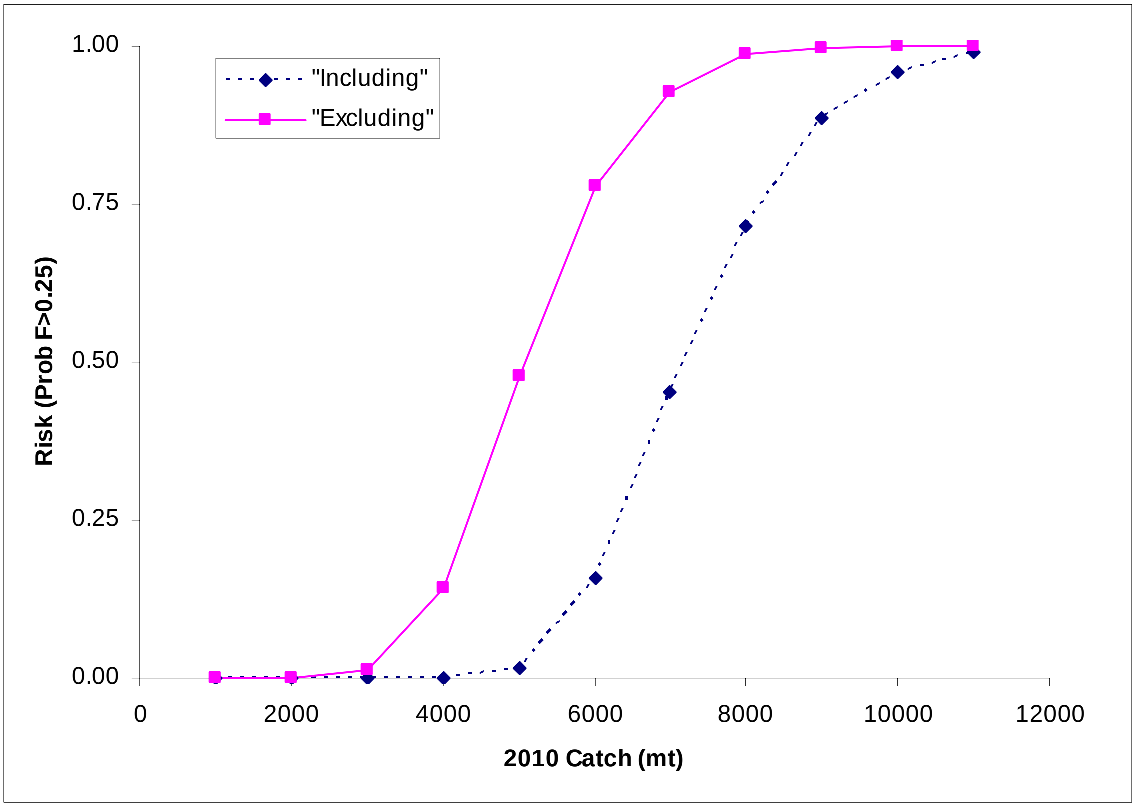


Figure 27. Risk of F exceeding F_{ref}=0.25 for a range of 2010 catch.

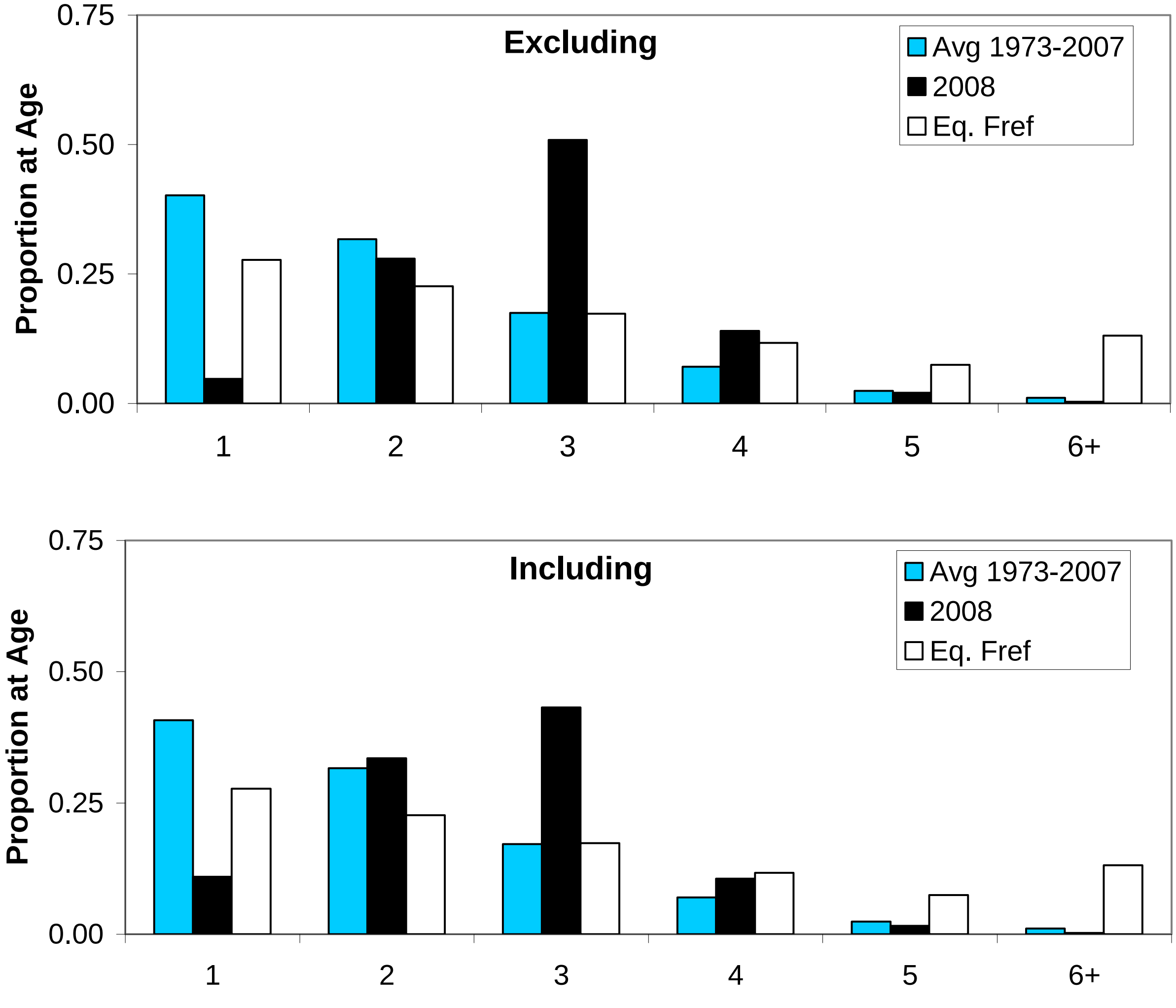


Figure 28. Comparison of age distributions for the two VPA formulations among the average of 1973-2007 population abundance at age, the 2008 abundance at age, and the proportion expected when the population is fished in equilibrium at F_{ref}=0.25.