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Stock Assessment of Georges Bank
Yellowtail Flounder for 2011

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ABSTRACT

The combined Canada/US yellowtail flounder (*Limanda ferruginea*) catch decreased from 1,806 mt in 2009 to 1,160 mt in 2010 due mainly to a decrease in quota. The 2005 year class did not appear strong in any of the recent surveys and did not dominate the catch, causing the assessment model to estimate the 2005 year class as only average. The 2005 year class had been estimated as one of the largest since the mid 1970s in the 2009 assessment. This change in perception of the 2005 year class caused the estimated spawning stock biomass to be lower than estimated in the last assessment. The recent trend in estimated spawning stock biomass is increasing, around 8,800 mt in 2010, but still well below the US rebuilding target of 43,200 mt. The 2005 and 2006 year classes are estimated to be about average at 16.8 million and 17.1 million, respectively, the 2007 and 2008 year classes are well below average, and the 2009 year class is estimated to be the lowest in the time series at 0.9 million. Fishing mortality rates for fully recruited ages 4+ was estimated to be 0.13 in 2010, below the F_{ref} of 0.25. However, the retrospective pattern is becoming more pronounced in this assessment, with the estimates of F in 2008 and 2009 in last year's assessment being 0.13 and now estimated at 0.28 and 0.27, respectively. Assuming a 2011 catch equal to the 2,650 mt quota, a combined Canada/US yield of about 1,700 mt in 2012 results in a neutral risk (~50%) that the fishing mortality rate in 2012 will not exceed $F_{ref} = 0.25$.

Despite splitting the survey time series to reduce the retrospective pattern, this assessment now shows a retrospective pattern. Alternative projections were conducted to examine the possible impact of this retrospective pattern on catch advice. The first alternative projections adjusted the population abundance at the start of 2011 estimated by the Split Series model based on the Mohn's rho for spawning stock biomass. These projections had much lower catch advice in 2012 when fishing at F_{ref} (750 mt) but a 20% increase in median biomass from 2012 to 2013. The second alternative projections rho adjusted the population abundance at the start of 2011 estimated by the Single Series model, applying a much larger adjustment, and provided nearly identical catch advice at F_{ref} as the Split Series model without adjustment, but a 13% decrease in median biomass. Thus, if both a low probability of overfishing and maintenance of stock biomass are desired, then lower catches than those from the Split Series model should be considered.

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RÉSUMÉ

Les captures combinées de limande à queue jaune (*Limanda ferruginea*) du Canada et des États-Unis ont diminué, passant de 1 806 tm en 2009 à 1 160 tm en 2010, en raison principalement d'une baisse des quotas. La classe d'âge 2005 n'a pas semblé imposante dans les relevés récents et elle ne dominait pas les captures; par conséquent, le modèle d'évaluation a estimé qu'elle n'était que moyenne. Or, cette classe d'âge avait été considérée comme l'une des plus vastes d'âge depuis le milieu des années 1970 dans l'évaluation de 2009. Cette différence de perception au sujet de la classe d'âge 2005 s'est traduite par une estimation de la biomasse de reproducteurs inférieure à ce que prévoyait l'évaluation précédente. D'après la tendance récente, l'estimation de la biomasse de reproducteurs est en hausse et chiffrée à environ 8 800 tm en 2010, mais elle reste bien en deçà de l'objectif de rétablissement fixé par les États-Unis, soit 43 200 tm. Selon les estimations, les classes d'âge 2005 et 2006 se situent à peu près dans la moyenne, avec des effectifs de 16,8 millions et 17,1 millions, respectivement, tandis que les classes d'âge 2007 et 2008 sont bien inférieures à la moyenne et que la classe d'âge 2009 est jugée la plus basse de la série chronologique, avec un effectif de 0,9 million. Le taux de mortalité par pêche parmi les limandes pleinement recrutées (âges 4 +) a été estimé à 0,13 en 2010, se situant sous $F_{réf.}$, qui est 0,25. Toutefois, la tendance rétrospective devient plus prononcée dans cette évaluation, les estimations de F en 2008 et 2009, qui dans l'évaluation de l'an dernier s'établissaient à 0,13, étant maintenant de 0,28 et 0,27, respectivement. Si on tient pour acquis que les captures de 2011 seront égales au quota de 2 650 tm, des captures combinées du Canada et des États-Unis d'environ 1 700 tm en 2012 aboutiraient à un risque neutre (~ 50 %) que la mortalité par pêche en 2012 ne dépasse pas $F_{réf.} = 0,25$.

Malgré le fractionnement de la série chronologique issue des relevés pour réduire la tendance rétrospective, cette tendance réapparaît maintenant dans l'évaluation. On a procédé à diverses autres projections dans le but d'examiner l'incidence possible de cette tendance rétrospective sur les captures recommandées. Dans les premières de ces projections, on a rajusté l'abondance de la population au début de 2011 estimée d'après le modèle avec série fractionnée, en fonction de la valeur Rho de Mohn appliquée à la biomasse du stock de reproducteurs. Cela a abouti à une recommandation de captures pour 2012 bien plus basse pour une pêche à $F_{réf.}$ (750 tm), mais à une hausse de 20 % de la biomasse médiane de 2012 à 2013. Dans la seconde série de projections, l'abondance de la population au début de 2011 estimée d'après le modèle avec série chronologique non fractionnée, le rajustement en fonction de la valeur Rho était beaucoup plus grand et on a obtenu une recommandation de captures à $F_{réf.}$ quasiment identique à celle que produisait le modèle avec série fractionnée sans rajustement, mais une baisse de 13 % de la biomasse médiane. Par conséquent, si on vise à la fois une faible probabilité de surpêche et le maintien de la biomasse du stock, il faut envisager des captures inférieures à celles qui découlent du modèle avec série chronologique fractionnée.

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. 2010) taking into account advice from the 2005 benchmark review (TRAC 2005). A primary objective of the benchmark review was to address the retrospective pattern that had been apparent from assessments conducted during the past several years. During the benchmark assessment meeting, several analytical models were reviewed, all of which indicated that the catch at age and survey abundance at age show differences which cannot be reconciled. Various possible reasons for the retrospective pattern were identified including an increase in natural mortality, large amounts of unreported catch, and changes in survey catchability since 1995. The consensus view from the benchmark meeting was that management advice should be formulated on the basis of results from several approaches:

- Analysis of data from survey and fishery (trends in relative F and Z)
- Base Case Virtual Population Analysis (VPA) model formulation from 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. During the 2009 TRAC meeting it was decided that neither the Base Case nor Minor Change VPA would be considered any longer because neither had been used for management advice in a number of years (O'Brien and Worcester 2009). The Major Change model will be referred to as the "Split Series" model in this document since it is now the default model.

Last year, the Split Series VPA model was used to provide catch advice. This model downweighted the Canadian 2008 and 2009 surveys in the tuning process to account for their higher uncertainty due to single large catches of yellowtail flounder in those years. This formulation indicated that fishing mortality in 2009 was below the target rate $F_{ref} = 0.25$ and that biomass was increasing. However, the 2005 year class was estimated as only average, in contrast to the previous assessment in which it was estimated as strong. Projections indicated that catching the Total Allowable Catch (TAC) of 1,956 mt in 2010 would result in a fishing mortality rate below F_{ref} ($F_{2010} = 0.15$). US rebuilding projections were also conducted which demonstrated even F=0 in years 2011 through 2014 was insufficient to allow rebuilding. After the 2010 TRAC was completed, the International Fisheries Agreement Clarification Act was signed into law in the US in January of 2011 (Shark and Fishery Conservation Act 2011). This act recognizes the US/Canada Transboundary Resources Sharing Understanding and provides flexibility in the rebuilding period and catch level requirements for Georges Bank yellowtail flounder. In light of passage of this act, the Transboundary Management Guidance Committee (TMGC) negotiated the catch quota for 2011 in February 2011. As a result of these negotiations, the catch quota for 2011 was set at 2,650 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 east of 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 maturation occurs earlier than in most flatfish with approximately half of age two females 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 in southern New England waters (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 1984, the International Court of Justice (ICJ) determined US and Canadian jurisdictions for Georges Bank fishery resources (ICJ 1984). 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 conducting 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 US and Canada sharing agreement in 2001, advice for the Georges Bank yellowtail flounder relied primarily on a bilateral management system provided by the TMGC. The agreement includes total allowable catch for each country based on a formulaic calculation using both historical catch and current spatial stock distribution as determined by the three bottom trawl surveys. 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. In 2001, the decision was made to manage the stock as a transboundary resource in Canadian and US jurisdictions (TMGC 2002). 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 1995, 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. In 2010, a Haddock SAP in Closed Area II allowed the US bottom trawl fishery short-term access to the area and some yellowtail flounder was caught as bycatch in this fishery. 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 a declining trend in catches through 2010 (catch in 2010 = 1,160 mt).

United States

The principle 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 have accounted for some historical 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 1994-2010 were derived from the trip-based allocation described in the GARM III Data meeting (GARM 2007; Legault et al. 2008b; Palmer 2008; Wigley et al. 2007a). Changes to the data in recent years caused a change in the landings values for 2007-2009 from 1,072 mt, 748 mt, and 975 mt to 1,058 mt, 937 mt, and 959 mt, respectively. US landings have been limited by quotas in recent years. Total US yellowtail landings (excluding discards) for the 2010 fishery were 654 mt, a decrease of 32% from 2009 (Table 1; Fig. 2).

US discarded catch for years 1994-2010 was estimated using the Standardized Bycatch Reporting Methodology 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. Large and small mesh otter trawl gears were separated at 5.5 inch (14 cm) cod-end mesh size. The large mesh fishery mainly targets groundfish, monkfish, skates, dogfish, and fluke (summer flounder), while the small mesh fishery mainly targets whiting (silver hake), herring, mackerel, and squid. Uncertainty in the discard estimates was estimated based on the SBRM approach detailed in the GARM III Data meeting (GARM 2007; Wigley et al. 2007b). Changes to the data in recent years caused a change in the discard values for 2007-2009 from 503 mt, 370 mt, and 715 mt to 493 mt, 409 mt, and 759 mt, respectively. US discards were approximately 19% of the US catch in years 1994-2010 (Table 1; Fig. 2). Total discards of yellowtail in the US decreased 62% from 2009 (759 mt) to 2010 (289 mt). This decrease was due mainly to decreases in both the large mesh trawl and scallop dredge discards (Table 2).

The total US catch of Georges Bank yellowtail flounder in 2010, including discards, was 943 mt. This value can be compared to the quota monitoring estimated catch during the calendar year 2010, data kindly provided by Dan Caless of the Northeast Regional Office (Table 3). Landings from the quota monitoring system were 5% higher than used in the assessment, while discards from the quota monitoring system were 26% lower than used in the assessment. Since landings were much larger than discards in magnitude, the total catch estimate from quota monitoring was 5% lower than that used in the assessment. The differences between US catches in the assessment and used in quota monitoring add uncertainty to the provision of catch advice for this stock.

The US Georges Bank yellowtail flounder quota for fishing year 2010 (1 May 2010 to 30 April 2011) was set at 1,200 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. Reporting on the Regional Office webpage (http://www.nero.noaa.gov/ro/fso/usc.htm) indicates the US fishery caught 93% of its quota for the 2010 fishing year.

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 5 mt in 2009 and 17 mt in 2010. 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, 23 in 2008, 21 in 2009, and 24 in 2010. The seasonal pattern in bycatch rate is taken into account by applying calculations using 3-month moving-average discard rates. The result of these calculations for 2010 is a discard estimate of 200 mt (Table 1, Fig. 2).

For 2010, the total Canadian catch, including discards, was 217 mt, an increase of 144% from 2009, but well below the 2010 TAC of 756 mt.

Length and Age Composition

The level of US port sampling continued to be strong in 2010, with 11,064 length measurements available from 118 samples, resulting in 1,693 lengths/100 mt of landings (Table 4). This level of sampling resulted in low CVs for the US landings at age, as estimated by a bootstrapping procedure (Table 5). The port samples also provided 2,234 age measurements for use in age-length keys. The Northeast Fisheries Observer Program provided an additional 3,401 length measurements of discarded fish from 63 trips, which were combined with the port samples to characterize the size composition of the US catch.

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%). Examination of the size distributions of the large and small market categories continues to show some overlap in the 36-38 cm range, but overall discrimination between the groups was apparent (Fig. 3).

In 2010, two port samples (469 length measurements) were collected from the 17 mt of Canadian landings (Table 4). The 2010 US age length key was applied to these catch at size estimates to derive catch at age and associated weights at age. No length measurements were utilized from Canadian at sea observer deployments because with the low catches of yellowtail over the past several years, few length measurements have been recorded at sea for the bottom trawl fishery.

The 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 due to trip limits during the early months of 2010 (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, but the magnitude was notably low due to little fishing effort by this gear on Georges Bank in 2010 (Table 2; Fig. 4).

The size composition of yellowtail flounder discards in the Canadian offshore scallop fishery was estimated by half year using length measurements obtained from 24 observed trips in 2010. 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).

A comparison of the 2010 size composition of yellowtail catch by country shows slightly larger yellowtail in the US landings than in the Canadian landings (Fig. 5). Although the low amount of Canadian landings makes this comparison suspect, the Canadian landings are mainly bycatch in the haddock fishery which uses 130 mm (5 inch) square mesh, while the US landings are mainly from trawls using 152 mm (6 inch), 165 mm (6.5), or 178 mm (7 inch) square or diamond mesh. US discards were quite similar in both mean size and spread in the distributions relative to Canadian discards (Fig. 6). The relative magnitude of landings and discards by each country resulted in total catch for the US having a larger average size than the total catch for Canada (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 (>85% for most studies) with no indication of bias.

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 the US landings used only age samples from US port samples. In the past, the age length keys for the US discards used age samples from at sea observers of the discarded catch supplemented with US surveys. Since 2004, the scales collected by the observers have not been aged and so the US surveys and commercial landings provided ages. Changes to the US landings and discards in years 2007-2009 were carried through to the catch at age and used in this assessment.

No scale samples were available for the Canadian fishery in 2010. 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 2010 Canadian landings, which only consisted of 1.5% 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 + US spring survey + Canadian survey, and Half 2 US commercial fishery + US fall survey.

In 2010, ages 3, 4 and 5 (2007, 2006, and 2005 year classes, respectively) dominated US landings and discards and Canadian discards, with only minor contribution from Canadian landings (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 6; Fig. 9). Despite management measures intended to reduce fishing effort over the past several years, there are few fish greater than age 5 in the catch at age.

The fishery mean weights at age for each of the combinations of Canadian and US landings and discards were derived using the applicable age length keys, length frequencies, and length-weight relationships. The mean weight at age (kg) for the Canadian and US landings were quite similar and generally were more variable at older ages (5+) during the mid 1980s to the mid 1990s. The overall fishery weights at age were calculated from Canadian and US landings and discards, weighting by the respective catch at age (Table 7; 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 weights at age (WAA) values are low but within the range of past WAA calculations since 1973.

ABUNDANCE INDICES

Bottom trawl surveys are conducted annually on Georges Bank by Canadian Department of Fisheries and Oceans (DFO) in February (denoted spring) and by the US National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) in April (denoted spring) and October (denoted fall). Both agencies use a stratified random design, though different strata boundaries are defined (Fig. 11). The 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 BMV oval doors, 0.85 for the Delaware II, and 1.76 for the Yankee 41 net; Rago et al. 1994; Byrne and Forrester 1991) were applied to the catch of each tow for years 1973-2008.

There continues to be high variability in the survey indices. Specifically, beginning in 2009 the US bottom trawl surveys were conducted with a new vessel, the FRV Henry B. Bigelow, which uses a different net and protocols from the previous survey vessel. Conversion coefficients by length have been estimated for yellowtail flounder (Brooks et al. 2010; Table 8) and applied in this assessment. The 2008 and 2009 Canadian surveys encountered individual tows that were much larger than any seen previously in the time series. The US assessment software has been upgraded to allow the 2009 TRAC recommendation to downweight the 2008 and 2009 Canadian survey values.

Trends in yellowtail flounder biomass indices from the four surveys track each other quite well over the past two decades, with the exception of the DFO survey in 2008 and 2009, which were influenced by single large tows (Fig. 12a-b). The minimum swept area biomass estimated from the DFO survey increased from 1995 to 2001, declined through 2004, fluctuated through 2007, and then increased dramatically in 2008 and 2009 due to single large tows in each year, as seen by the indices declining by about an order of magnitude when the single tows were excluded (Table 9; Fig. 12b). The 2011 DFO biomass is the lowest value since 1995. The NMFS spring series was high in the mid 1970s, low in the late 1980s through mid 1990s, high from 1999

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through 2003, sharply decreased to 2004, and has shown a recent increasing trend from 2004 through 2010, but declined in 2011 to the fourth lowest value since 1995 (Table 10; Fig. 12b). The NMFS fall survey, which is the longest time series, was high in the mid 1960s through mid 1970s, low in the mid 1980s through mid 1990s, increased through 2001, declined through 2005, and has remained at levels comparable to the late 1960s for years 2007-2009, but in 2010 declined to the second lowest value since 1995 (Table 11; Fig. 12b). The scallop survey stratified mean catch per tow shows a strong increase from low levels in the mid 1990s to a peak in 1998 followed by a decline through 2005, and has fluctuated since (Table 12; Fig. 12b), although the 2010 value is the second lowest of available years since 1995. 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 compared with the previous ten year average for the three groundfish surveys show that yellowtail flounder distribution on Georges Bank in the most recent year has been consistent relative to the previous ten years (Fig. 13a-b). Note the 2009 through 2011 NEFSC survey values were adjusted from Bigelow to Albatross equivalents by dividing Bigelow catch in weight by 2.244 (spring) or 2.402 (fall). Since 1996, most of the DFO survey biomass and abundance of yellowtail flounder has occurred in strata 5Z2 and 5Z4 (Fig. 14a). However, in 2008 and 2009 almost the entire Canadian survey catch occurred in just one or two tows in stratum 5Z1, making interpretation of trends over time difficult. The NEFSC bottom trawl surveys have been dominated by stratum 16 since the mid 1990s (Fig. 14b-c).

Given the calibration at length for the US spring and fall surveys (Table 8), the question was raised during the TRAC meeting whether there were indications of recruiting year classes in the uncalibrated Bigelow data which were removed by the calibration to Albatross IV units. The raw length distributions from the Bigelow were plotted together with the calibrated length distributions in Albatross IV units and no indication of strong year classes at small lengths (<30 cm) were observed in the US spring 2009-2011 or US fall 2009-2010 surveys (Fig. 15).

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 have been ageing scales collected on DFO surveys since 2004 and continued to do so this year. From the 2011 DFO survey, 183 male and 176 female fish were aged and used to produce separate-sex age-length keys, subsequently used to generate the 2011 DFO age-specific indices of abundance.

Even though all four surveys appeared to indicate a strong 2005 year-class originally, none of the surveys currently indicate the 2005 year class is particularly strong (Tables 9-12; Fig. 16a-e). Even though each index is noisy, the age specific trends track relatively well among the four surveys (Tables 9-12; Fig. 17).

Given the lack of evidence for a strong dome in the partial recruitment of the US scallop survey (Legault et al. *in review*), 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. This approach was advanced in the 2009, 2010, and 2011 TRAC meetings. However, it was not used because the 2008 US scallop survey did not cover the Canadian portion of Georges Bank and because concerns were raised regarding the use of annual age-length keys combined from the NEFSC spring and fall surveys. Scale samples are being collected from the 2011 NEFSC scallop survey in order to allow a direct comparison between the survey specific age-length key and the combined spring and fall age-length key. These results will be presented next year and could indicate whether the combined spring and fall age-length key is sufficient to age the scallop survey. Comparison of the trends over time from the scallop and three bottom trawl surveys indicate they are tracking similar trends at all ages (Fig. 17).

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 1987-2010) was quite variable but followed a similar trend for all four surveys, with a sharp decline to low levels since 1995 (Fig. 18). In contrast, estimates of total mortality rates from the surveys for ages 2, 3 and 4-6, although noisy, were without trend and indicate no overall reduction in mortality since 1995 (Fig. 19). This disparity in the basic data continues to cause difficulty for the stock assessment of George Bank yellowtail flounder.

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) fishing mortality rates 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 was never used in any subsequent assessment (Stone and Legault 2005; Legault et al. 2006, 2007, 2008a) and it was agreed during the 2009 TRAC that it would not be continued in the future (Legault et al. 2009). 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, 2007, 2008a, 2009, 2010). At the 2009 TRAC meeting, it was agreed that the Base Case model would no longer be considered in future assessments due to its strong retrospective pattern and inability to match trends observed in the surveys. To reduce confusion, the (modified) Major Change VPA is referred to as the Split Series VPA in this assessment, and is the default approach for providing management advice.

The VPA is calibrated using the adaptive framework ADAPT (Conser and Powers 1990; Gavaris 1988; Parrack 1986) to calibrate the sequential population analysis with the research survey abundance trend results, specifically the NOAA Fisheries Toolbox VPA v3.0.3. 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. The exception to this assumption is the DFO survey values for 2008 and 2009 were downweighted (residuals multiplied by 0.5) to reflect the higher uncertainty associated with these observations relative to all other survey observations. 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 and years. The fishing mortality rates for age groups 4, 5 and 6+ were assumed equal. These model assumptions and methods were the same as those applied in the last assessment (Legault et al. 2010). Both point estimates and bootstrap statistics of the estimated parameters were derived using only the US software for this assessment.

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 between 1994 and 1995. This model could not be fit well in previous assessments (Legault et al. 2006, 2007, 2008a) 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 (i.e. by reverting to ages 1-6+ for the CAA), with the exception that the survey time series were split at 1995 (Legault et al. 2006, 2007, 2008a, 2009, 2010). This means that indices and population abundance are assumed linearly related at all ages and that a 6+ group is used for all fish aged 6 and older in the population dynamics equations. Splitting the survey series 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 to provide management advice.

The Split Series 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 2010, 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 2011
(note: s_2 = DFO spring, ages a = 2 to 6+, time t = 2008 to 2009 residuals were downweighted)
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 2011
(note: s_5 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 2009-2011 were converted from FSV Henry B. Bigelow to RV Albatross IV equivalent)
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 2010.5
(note: s_7 = NMFS fall, ages a = 1 to 6+, time t = 2009.5-2010.5 were converted from FSV Henry B. Bigelow to RV Albatross IV equivalent)
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 2010.5
(note: the NMFS scallop survey was not used for years 1986, 1989, 1999, 2000, or 2008)

Splitting the survey time series between 1994 and 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 plus one (2011) was assumed equal to the geometric mean over the most recent 10 years (2001-2010). Population abundance in the terminal year plus one (2011) was estimated directly for ages 2-5.

Building the Bridge

The only changes to the data or model formulation from the 2010 TRAC assessment occurred in the US landings and discards data for years 2007-2009. These changes resulted in revising the catch at age and weight at age used in the assessment model. The results were only minor changes to the time series and the 2009 point estimates, so minor in fact that it is difficult to distinguish the two lines in the time series plots (Figs. 20-21a-b).

These revised catch at age and weight at age data were the starting point for the new assessment, which then added a year of catch and survey indices.

Diagnostics

The Split Series VPA performed similar in terms of relative error and bias in the population abundance estimates to previous assessments with lower relative error and bias at older ages than younger ages (Table 13). 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 Split Series VPA also followed similar patterns to previous assessment (Table 13, Fig. 22). The most notable pattern was the increase in estimated values at nearly all ages between the pre-1995 and the 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 Split Series VPA residuals did not show a strong pattern, with mixed positive and negative residuals throughout the time series (Fig. 23). Of interest is the tradeoff observed between the US spring and DFO indices in 2011 where large negative residuals are observed at different ages in the two surveys. The plotted residuals for the 2008 and 2009 DFO survey account for the downweighting used in the fitting, but still appear as strong positive residuals (observed values larger than predicted) except for the age 6+ value in 2008. 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.

An alternative method to view the change in catchability is to plot the relative catchability (the survey observation divided by the estimated beginning of year population abundance) with the Split Series estimate of catchability overlaid as lines (Fig. 24a-c). These plots do not adjust the population abundance to account for the time of the survey. The changes in relative catchability appear strong and consistent for many surveys and ages, as opposed to being driven by just one or two outlier values. These consistent changes give more confidence to the approach of splitting surveys than changes due to one or two outliers would.

Retrospective analysis for the Split Series VPA did not indicate a strong tendency to over or underestimate recruitment (except for the 2005 year class), but did indicate a moderate tendency to underestimate F and overestimate spawning stock biomass, relative to the terminal year (Fig. 25a-b; Table 14). The retrospective pattern for spawning stock biomass is less strong and less consistent than has been seen in the Base Case formulations of previous assessments where rho statistics of more than 1.0 were estimated. However, the retrospective pattern in spawning stock biomass (SSB) should still be considered when providing management advice. The rho statistic for F is artificially kept near zero by a large positive value in the most historical peel offsetting consistent negative values in the remaining six peels. The recruitment retrospective pattern is noisy with both positive and negative changes, but of most concern is the change to the 2005 year class which had been estimated as strong in recent peels but is now estimated as below average.

Despite the moderate retrospective pattern in spawning stock biomass, the Split Series VPA is recommended as the basis for providing management advice (but see discussion regarding alternative projections in the Outlook section).

STOCK STATUS

Results from the Split Series VPA were used to evaluate the status of the stock in 2010. Population abundance at age for the start of the year was estimated for years 1973-2011 along with estimates of fishing mortality rates at age during years 1973-2010 (Tables 15-16). 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 (Jan-1, ages 3+) increased from a low of 2,100 mt in 1995 to 10,900 mt in 2003, declined to about 2,700 mt in 2006, and increased to 9,300 mt at the beginning of 2011, the highest adult biomass since 2003 (Table 18; Fig. 26). Total population biomass (age 1+) has generally tracked the three groundfish surveys, although splitting the series implies high catchability of the surveys in recent years (Table 18; Fig. 27). Spawning stock biomass in 2010 was estimated to be 8,800 mt (80% confidence interval: 7,300-10,800 mt). These 2010 values are well below the TRAC 2010 estimates for 2009 and reflect a continued declining perception of the 2005 year class combined with poor recent recruitment. This change in perception of cohort strength has been seen in previous assessments, and when it occurred, it led to strong retrospective patterns.

During 1973-2010 recruitment averaged 20.3 million fish at age 1 but has been below this average since 2002 (Table 15). The 2005 and 2006 year classes are estimated at 16.8 million and 17.2 million, respectively. The 2007 and 2008 year classes are well below average, and the 2009 year class is estimated to be 0.9 million age-1 fish, which although estimated with high uncertainty is by far the lowest in the time series. The 2005 year class had been estimated as strong in previous assessments, but is now estimated as below average.

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 1.93, and then declined to 0.72 in 2007, and about 0.28 in both 2008 and 2009. In 2010, F was estimated to be 0.13 (80% confidence interval for 2010: 0.10-0.17), below the reference point of $F_{ref} = 0.25$ (Table 16). This pattern in F does not correspond with the relative fishing mortality rate pattern estimated as catch/survey (Fig.18). 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.

Sensitivity Analyses

Two sets of sensitivity analyses were conducted to explore the robustness of the Split Series formulation:
1. Surveys used
2. Timing of the split in the surveys.

The first set of sensitivity analyses used only one survey at a time as tuning indices (Figs. 28a-b-29a-b). The US scallop survey used all ages for this sensitivity run, as opposed to using only age 1 as in the Split Series VPA. Using only the US spring survey to tune the VPA resulted in lower SSB and higher F than the Split Series, but within the 80% confidence intervals, while using only the US fall survey to tune the VPA resulted in higher SSB and lower F than the Split Series VPA, well outside the 80% confidence intervals. In contrast, the DFO survey was well within the 80% confidence intervals, with slightly lower SSB and F than the Split Series VPA. Using only the US scallop survey produced the lowest SSB and highest F of all the sensitivity runs. This

extreme result may be due to the missing 2008 values causing the model difficulty in estimating stock abundance parameters (CVs ranged from 40% to 78%). When ages 2 through 6+ are included in the US scallop survey along with all the other survey values, the SSB is at the lower 80% confidence interval and F is at the upper 80% confidence interval of the Split Series VPA. In summary, the US spring and scallop surveys are pushing the model towards a lower SSB and higher F, the US fall survey is pushing the model towards a higher SSB and lower F, and the DFO survey is tracking fairly well the combined Split Series VPA (Fig. 30).

The second set of sensitivity analyses examined alternative timing for splitting the surveys, including an option of not splitting the surveys at all but treating them as single series as in the benchmark Base Case runs. As the timing of the split changed from 1990/1991 to 1999/2000, the SSB decreased and the F increased (Fig. 29a-b). Treating the surveys as single series caused the highest estimates of SSB and lowest estimates of F of all the sensitivity runs examined. Calculation of the retrospective statistic, Mohn's rho, for each of the different survey splits produced a general pattern of decreasing absolute values as the year increased, with the lowest absolute values in the 1998/1999 split (Fig. 31). However, examination of the actual retrospective plots demonstrates that this low value is an artifact due to a trade-off between the most historical peel in one direction and all six of the other peels in the other direction (Fig. 32a-b). All the other survey splits showed this same pattern. The single series sensitivity run had the highest retrospective statistics: SSB rho of 1.40 and F rho of -0.58. Furthermore, the model goodness of fit, as measured by Akaike information criteria corrected for finite sample size AICc, was best for a split 1996/1997 but not significantly different for splits of 1994/1995 and 1995/1996 (less than 4 AIC units difference) (Fig. 33). The other models would commonly be considered significantly poorer fits, especially the Single Series VPA model which differed from the 1994/1995 split by more than 100 AIC units. The retrospective pattern for the Single Series VPA model is not only larger in magnitude, but is also consistently biased in the same direction for all seven peels (Fig. 34a-d). These sensitivity runs demonstrate that although the retrospective pattern could be reduced by changing the timing of the window, the pattern persists and would be expected to become much larger next year when the most historical peel is removed.

These sensitivity analyses demonstrate the Split Series VPA is generally robust to model assumptions and choices of data used, although the 80% confidence intervals may not fully capture the total uncertainty in the assessment (as described in the Outlook section).

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. Both the 2002 and 2008 assessment yield per recruit 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). The current three year averages for weights at age and fishery partial recruitment produce estimates for

$F_{40\%MSP}$ of 0.244 and $F_{0.1}$ of 0.258. 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 (Fig. 35a-b). In the US, a similar stock-recruitment relationship from the GARM III assessment (NEFSC 2008) 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), but see discussion in the Outlook section. Spawning stock biomass is currently well below the US rebuilding goal ($SSB_{2010}/SSB_{MSY} = 20\%$).

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2012. 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.

Projections for the Split Series VPA were made using 2008-2010 average fishery partial recruitment and survey and fishery weights at age to account for the most recent conditions in the fishery and biological characteristics. Due to the re-emergence of a retrospective pattern in the assessment despite splitting the surveys, alternative projections were considered. Alternative projections were made for the Split Series rho adjusted and the Single Series rho adjusted models. The rho adjustments in both cases were computed as the average Mohn's rho from seven year peels for SSB applied to all ages. The SSB rho values for the Split Series and Single Series models were 0.704 and 1.40, respectively, causing each bootstrap initial abundance at age to be multiplied by $1/(1+rho) = 0.5869$ and 0.4167, respectively. The results of all three projections are described below.

For the Split Series model, assuming a catch in 2011 equal to the 2,650 mt total quota, a combined Canada/US catch of about 1,700 mt in 2012 would result in a neutral risk (~50%) that the fishing mortality rate in 2012 will exceed F_{ref} (Fig. 36). Fishing at F_{ref} in 2012 will generate no change in age 3+ biomass from 2012 to 2013 in the deterministic projection (7,100 mt; Table 19). Catching the quota of 2,650 mt in 2011 is expected to cause a fishing mortality rate of 0.34 in 2011, which is above the F_{ref} of 0.25 (Table 19). Catches of 2,300 mt, 1,500 mt, and 800 mt would be expected to cause increases in median adult biomass from 2012 to 2013 of 0%, 10%, and 20%, respectively in the stochastic projections (Fig. 37).

For the Split Series rho adjusted model, the adjustment to population abundance at the start of 2011 increases the probability of overfishing for a given 2012 catch and reduces the catch associated with 50% probability of overfishing from 1,700 mt to 750 mt (Fig 36). The relative change in median adult biomass from 2012 to 2013 also decreases when the rho adjustment is applied for catches in 2012 greater than 1,000 mt (Fig. 37). For catches in 2012 less than 1,000 mt, the change in median adult biomass is greater for the rho adjusted values because the SSB in 2011 (3,000 mt) is much lower than the split series SSB in 2011 (8,400 mt), and so the relative changes are magnified.

For the Single Series rho adjusted model, the catch associated with any probability of overfishing in 2012 is nearly identical to that of the Split Series model for all catches (Fig. 36). However, the relative change in median adult biomass from 2012 to 2013 is much lower for the Single Series rho adjusted model than for the Split Series model (Fig. 37) due to a change in estimated population abundance at age from the two models. Catch in 2012 would need to be less than 600 mt to have median adult biomass not decrease from 2012 to 2013.

Taking into consideration both the probability of overfishing and the desire to at least maintain stock biomass, a catch in the range of 900-1,400 mt is indicated (Table 20; Figs. 36-37). These catches would have probabilities of overfishing at or below 25% for both the benchmark Split Series model and the Single Series rho adjusted model as well as correspond to relative changes in stock biomass of >10% or else 1% to 16% for the Split Series and Split Series rho adjusted models, respectively. However, these catches would have probabilities of overfishing >75% under the Split Series rho adjusted model and correspond to relative changes in stock biomass of -3 to -9% under the Single Series rho adjusted model. Thus, both management objectives of low probability of overfishing and increasing stock biomass are achieved with catches of 900-1,400 mt under the benchmark Split Series model. However, since there is a retrospective pattern associated with the Split Series model, the two alternative projections which adjust for retrospective patterns indicate there may be problems with either the probability of overfishing or the desire for stock increase under these catches. A catch of 600 mt or lower would be required to meet both objectives in all three projections.

One potential concern with rho adjusting any assessment is that the adjusted stock sizes could be less than the minimum swept area biomass estimated from the surveys (implying survey catchabilities greater than one). For 2011, both the DFO and the NEFSC spring surveys were low, with minimum swept area biomass estimates of 3,800 mt and 2,400 mt, respectively. These values are well below the Split Series 2011 biomass estimate of 10,200 mt and still below the rho adjusted Split Series 2011 biomass estimate of 6,000 mt. The Single Series 2011 biomass estimate is 25,300 mt, which is rho adjusted down to 10,500 mt, both well above the survey biomasses. Thus, in all cases, the survey minimum swept area biomasses are well below the model estimates, even when the model estimates are rho adjusted.

In the US, there is a requirement to provide rebuilding projections when stocks are overfished. The rebuilding target for Georges Bank yellowtail flounder is a spawning stock biomass of 43,200 mt (denoted SSBmsy). This value was set during GARM III (NEFSC 2008) based on using F40% as a proxy for Fmsy and conducting stochastic projections fishing at this rate for 100 years. The median SSB at the end of these 100 year projections was set as the SSBmsy proxy.

These projections depend on weights at age, fishery partial recruitment, maturity at age, natural mortality at age, and recruitment assumptions. If any of these data are changed, the resulting SSBmsy proxy will change, however, these changes are typically assumed to be minor and the accepted value (currently 43,200 mt) is kept as the rebuilding target.

The dependence of the rebuilding target on these data is demonstrated by sequentially updating the data to reflect current estimates. Since maturity and natural mortality have not changed, these are not considered. The weights at age, both catch and SSB, have declined by approximately 10% at ages 4-6+ while the fishery partial recruitment has increased at age 3 by 27% (Table 21). The recruitment series used for projections during GARM III (NEFSC 2008) utilized a two stage cumulative distribution function (cdf) split at SSB of 5,000 mt along with hindcast recruitment values from the NEFSC fall survey. The cdf for high SSB observations from GARM III (NEFSC 2008) has its lower portion shifted to the left (minimum value decreases from 6.6 to 0.9 million) when the same hindcast values are included, but shifted quite dramatically when the hindcast values are not included (median decreases from 24.6 to 22.2 million and maximum decreases from 124.4 to 70.6 million; Fig. 38). The resulting rebuilding targets decrease 10% changing just the weight at age and partial recruitment, decrease 5% using the new stock recruitment data including the hindcast values, decrease 38% using the new stock recruitment data without the hindcast values, and decrease 45% using the new stock recruitment data without hindcast values and the new weights at age and partial recruitment (Table 22). The associated MSY proxy values change in a similar pattern. The F40% value was robust to these changes in weights at age and fishery partial recruitment, using the new values results in F40% of 0.244. The current F_{ref}=0.25 was used in all these projections.

The short term projections used to provide catch advice in 2012 are not influenced by the different stock-recruitment data described above because recruitment in 2011 and 2012 will not play a major role in either SSB or catch in 2011 or 2012 under current maturity, weight, and fishery partial recruitment at age. However, the rebuilding scenarios of medium time frames, five to ten years, or longer will be quite influenced by these differences in stock-recruitment data. Using new data with associated lower rebuilding targets means that F will have to be set lower to achieve the higher 43,200 mt current rebuilding target. For example, in the most extreme case, using the new stock-recruitment data without the GARM III (NEFSC 2008) hindcast values and the new weights at age and fishery partial recruitment requires fishing at F=0.07 to have a median SSB of 43,100 mt in the 100 year stochastic projections. Using the GARM III (NEFSC 2008) stock recruit data and the new weights at age and fishery partial recruitment requires fishing at F=0.21 to have a median SSB of 43,200 mt in the 100 year stochastic projections.

Assuming a rebuilding target of 43,200 mt and using new weights at age and partial recruitment, but the GARM III (NEFSC) stock-recruitment data, and the quota of 2,650 mt is caught in 2011, projections were made under a range of F values through year 2020. For each projection, the probability of achieving the rebuilding target was computed each year (Table 23). If the desired probability of rebuilding is 75%, then rebuilding is not possible even under F=0 by 2017, but is possible with an F of 0.05, 0.08, and 0.11 when the rebuilding year is 2018, 2019, and 2020, respectively. If the desired probability of rebuilding is 50%, then rebuilding is not possible even under F=0 by 2016, but is possible with an F of 0.08, 0.14, 0.17, and 0.18 when the rebuilding year is 2017, 2018, 2019, and 2020, respectively. The distributions of 2012 catches associated

with these rebuilding scenarios are quite wide and many are well below the catch advice associated with fishing at 75%Fmsy (F=0.1875) or Fmsy (F=0.25) (Table 24; Fig. 39).

Age structure, fish growth, and spatial distribution reflect stock productivity. The current age structure indicates that very little rebuilding of ages 6 and older has occurred (Fig. 40). The 2010 population abundance proportions at age are above the values expected in equilibrium at F_{ref} for ages 3, 4, and 5, but this is partially due to being well below the expected proportions at ages 1 and 2. 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. Growth has been variable without strong trends, but weights at age in recent years have trended down. Spatial distribution patterns from the three groundfish surveys generally follow historical averages. Truncated age structure and lower weights at age indicate current resource productivity is lower than historical levels.

MANAGEMENT CONSIDERATIONS

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

Although the Split Series VPA is used for management decisions, the mechanisms for the large changes in survey catchability are not easily explained. These changes in survey catchability are most appropriately thought of as aliasing an unknown mechanism that produces a better fitting model. The inability to plausibly explain these survey catchability changes causes increased uncertainty in this assessment relative to other assessments. Although the intention of the split series VPA was to eliminate the retrospective pattern, the pattern has re-emerged but at a lower magnitude.

Consistent management by Canada and the US is required to ensure that conservation objectives are not compromised.

The change in perception of this stock from previous assessments can be seen by examining the historical retrospective analysis, which plots the results from previous assessments instead of peeling back years from the current assessment (Fig. 41). The historical retrospective analysis incorporates all data and model formulation changes as well as the number of years in the assessment. The change in the strength of the 2005 year class (shown at age-1 in 2006 in the recruitment panel) contributes to the change in perception, similar to the assessment retrospective analysis. The reduction in the 2005 year class translates into a reduced spawning stock biomass and a higher fishing mortality rate than estimated in previous assessments. As noted in the 2009 TRAC assessment referring to the 2005 year class "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." Since none of the surveys now determine the 2005 year class to be strong, and the catch was not dominated by this year class in the past year, the model estimates a below average instead of strong 2005 year class.

Another way to examine the impact of the change in perception of the 2005 year class is to compare the proportion of yield and biomass expected from this year class from projections of previous assessments with that now estimated. In the 2009 assessment, the 2005 year class was expected to account for 47-51% of the 2010 catch and 40-44% of the 2010 age 3+ biomass. In the 2010 assessment these proportions were estimated to be 33% and 32%, respectively. The current assessment uses data in 2010 which shows the 2005 year class accounts for 26% of the 2010 catch and estimates the 2005 year class to account for 27% of the 2010 age 3+ biomass. Thus, the 2005 year class has not contributed as much to catch or biomass as was originally projected.

The performance of the catch advice provided historically for this stock can be examined by comparing the expectation when the advice was provided with what the current assessment estimates for fishing mortality rates and biomass changes. These comparisons were kindly provided by Tom Nies (staff member of the New England Fishery Management Council, NEFMC) and are shown in the Appendix. The results demonstrate the impact of the retrospective pattern whereby catch advice was provided which was expected to cause a fishing mortality rate of F_{ref} or lower, the actual catch was sometimes even less than this amount, yet the current assessment estimates a fishing mortality rate much higher than F_{ref}. This is due to the directional bias of the retrospective pattern. Since the biomass was estimated too high, the catch advice was set too high. Once the biomass is estimated at a lower amount, then that same catch has an associated fishing mortality rate well above the one originally used to set the catch advice. Changes in weight at age, partial recruitment to the fishery, and recruitment can also impact the accuracy of the projections. The past performance of catch advice should be considered when setting future catch quotas.

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Table 1. Annual catch (mt) of Georges Bank yellowtail flounder. The bold cells indicate updated estimates of US landings and discards for 2007-2009 (see text for previous values).

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%

Table 1. continued

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	**1058**	**493**	17	94	0	1662	35%
2008	**937**	**409**	41	117	0	1504	35%
2009	**959**	**759**	5	84	0	1806	47%
2010	654	289	17	200	0	1160	42%

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.

Year	Half	Small Mesh Trawl ntrips	d:k	K_all (mt)	D (mt)	CV	Large Mesh Trawl ntrips	d:k	K_all (mt)	D (mt)	CV	Scallop Dredge ntrips	d:k	K_all (mt)	D (mt)	CV	Total 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**

Table 2. continued

Year	Half	Small Mesh Trawl					Large Mesh Trawl					Scallop Dredge					Total
		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)
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	3521	5		148	0.0166	8392	139		17	0.0031	12737	39		184
	2	4	0.0438	2377	104		156	0.0237	5236	124		42	0.0036	22445	81		309
2007 Total		**12**			**110**	**86%**	**304**			**264**	**10%**	**59**			**120**	**24%**	**493**
2008	1	4	0.0000	1557	0		184	0.0224	6966	156		20	0.0066	6322	42		198
	2	4	0.0223	1145	26		213	0.0144	6904	99		22	0.0079	10951	86		211
2008 Total		**8**			**26**	**264%**	**397**			**255**	**8%**	**42**			**128**	**15%**	**409**
2009	1	10	0.0000	1158	0		180	0.0339	8008	271		36	0.0079	18403	146		417
	2	13	0.0157	1546	24		162	0.0364	8066	294		22	0.0013	18287	24		342
2009 Total		**23**			**24**	**73%**	**342**			**565**	**13%**	**58**			**170**	**17%**	**759**
2010	1	17	0.0035	2341	8		181	0.0222	9814	218		3	0.0041	1352	5		231
	2	17	0.0106	2079	22		130	0.0064	5097	33		5	0.0005	6000	3		58
2010 Total		**34**			**30**	**39%**	**311**			**250**	**17%**	**8**			**8**	**48%**	**289**

Table 3. Comparison of US landings, discards, and catch (mt) in calendar year 2010 estimated by the US quota monitoring system (within year) and the values used in the assessment (end of year).

2010	Landings (mt)	Discards (mt)	Catch (mt)
Quota Monitoring			
Jan-Jun	483	183	666
Jul-Dec	202	32	233
All Months	684	215	899
Assessment			
Jan-Jun	454	231	685
Jul-Dec	200	58	258
All Months	654	289	943
Diff (QM-Assess)			
Jan-Jun	29	-48	-19
Jul-Dec	2	-26	-25
All Months	30	-74	-44
Rel Diff (Diff/Assess)			
Jan-Jun	6%	-21%	-3%
Jul-Dec	1%	-45%	-10%
All Months	5%	-26%	-5%

Table 4. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2010 from US and Canadian sources.

| US | Landings (metric tons) | | | | | Port Sampling (Number of Lengths or Ages) | | | | | Lengths | Number |
| | Market Category | | | | | Market Category | | | | | | |
Half	Uncl.	Large	Small	Medium	Total	Uncl.	Large	Small	Medium	Total	per 100mt	of Ages
1	32	324	94	3	454	0	3315	2118	0	5433		
2	10	127	62	1	200	0	3215	2416	0	5631		
Total	42	451	156	4	654	0	6530	4534	0	11064	1693	2234

| Canada | | | | | | | | | | | Lengths | Number |
Quarter					Total					Total	per 100mt	of Ages
1												
2					5					226		
3					12					243		
4												
Total					17					469	2690	0

Table 5. 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	103%	10%	5%	6%	14%	19%
2008		17%	4%	6%	17%	33%
2009		14%	4%	4%	6%	23%
2010		20%	5%	4%	6%	14%

Table 6. Total catch at age including discards (number in 000s of fish) for Georges Bank yellowtail flounder.

							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	61	1152	3184	3824	1970	889	409	78	74	18	2	0	11661
2005	60	1579	4031	1707	392	132	37	16	0	0	0	0	7954
2006	152	1293	1626	947	364	124	66	14	7	3	0	0	4596
2007	51	1491	1705	662	136	44	9	2	0	0	0	0	4101
2008	29	493	1903	855	125	17	8	0	0	0	0	0	3430
2009	17	284	1266	1361	516	59	10	4	0	0	0	0	3517
2010	2	139	646	889	444	87	10	2	0	0	0	0	2219

Table 7. Mean weight at age (kg) for the total catch including US and Canadian discards, for Georges Bank yellowtail flounder.

Year	Age											
	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	0.292	0.438	0.585	0.726	0.883	1.002	1.192	1.222	1.305	1.421	
2005	0.119	0.341	0.447	0.597	0.763	0.965	0.993	1.198	1.578	1.578		
2006	0.100	0.310	0.415	0.557	0.761	0.917	1.066	1.185	1.263	1.224	1.599	
2007	0.154	0.290	0.409	0.542	0.784	0.968	1.108	1.766				
2008	0.047	0.302	0.415	0.533	0.675	0.882	1.130					
2009	0.155	0.328	0.434	0.538	0.699	0.879	1.050	1.328				
2010	0.174	0.323	0.433	0.519	0.661	0.777	0.997	1.175				

Table 8. Length based calibration factors for yellowtail flounder (see Brooks et al. 2010 for details of derivation). Numbers at length from FRV Henry B. Bigelow tows should be divided by the calibration factor in the corresponding length bin. It is recommended that these calibration factors be applied with all 6 digits to the right of the decimal point.

Length	Calibration
≤18	3.857302
19	3.857302
20	3.857302
21	3.621597
22	3.385892
23	3.150187
24	2.914482
25	2.678777
26	2.443072
27	2.207367
28	1.971662
29	1.971657
≥30	1.971657

Table 9. DFO spring survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in thousands of fish and thousands of 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(000 mt)
1987	75.2	751.1	1238.5	309.7	54.9	30.9	1.250
1988	0.0	1116.5	801.9	383.6	174.9	14.8	1.235
1989	71.8	645.8	383.2	185.2	41.8	14.1	0.471
1990	0.0	1500.9	2281.1	575.0	131.3	8.6	1.513
1991	15.4	539.6	745.8	2364.1	330.3	9.1	1.758
1992	34.8	6942.1	2312.0	622.4	219.8	18.8	2.475
1993	49.4	1528.8	2568.8	2562.9	557.5	81.8	2.642
1994	0.0	3808.4	2178.6	1890.1	491.4	130.0	2.753
1995	132.0	786.5	2737.4	1600.8	406.6	63.6	2.027
1996	280.5	4491.0	5769.2	3399.8	726.5	77.2	5.303
1997	13.6	7849.2	8742.1	10293.6	2543.2	421.5	13.293
1998	561.7	2094.3	3085.9	2725.6	1250.4	351.2	4.293
1999	99.8	13118.5	13101.2	4822.9	3364.5	1383.5	17.666
2000	6.8	8655.8	17256.5	12100.9	3187.6	2319.8	19.949
2001	183.3	12511.6	26489.4	8368.0	2881.0	1507.2	22.158
2002	55.5	7522.3	19503.3	7693.6	3491.7	1781.4	20.699
2003	56.3	7476.4	15480.7	6971.1	2151.0	1249.9	16.249
2004	20.6	2263.5	10225.3	5788.7	1429.2	890.5	9.054
2005	377.3	1007.5	17581.9	12931.4	3581.9	983.8	13.357
2006	391.5	3076.8	11696.4	4132.7	515.4	149.4	6.579
2007	108.9	7646.4	17423.7	8048.5	1439.1	156.2	13.344
2008a	0.0	30382.5	107131.7	35919.3	5067.8	34.5	67.319
2008b	0.0	2907.3	6882.8	1964.6	367.1	35.9	4.105
2009a	13.4	5370.4	86753.6	73553.8	12513.9	2996.1	72.044
2009b	13.4	1184.0	16326.6	16738.5	3568.2	613.0	15.703
2010	0.0	307.6	5906.1	13170.2	2221.7	804.5	9.138
2011	0.0	13.9	409.3	3831.5	5159.9	1275.3	3.830

Table 10. NEFSC spring survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in thousands of fish and thousands of metric tons.

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)
1968	181.2	3227.3	3474.3	295.2	70.9	300.8	2.709
1969	1046.8	9067.8	10793.9	3081.4	1305.2	678.2	10.842
1970	78.4	4364.8	5853.3	2350.9	553.0	302.0	4.994
1971	810.4	3412.9	4671.6	3202.9	757.1	310.6	4.483
1972	137.0	6719.3	6843.1	3595.8	1093.7	232.0	6.266
1973	1882.9	3184.3	2309.4	1036.7	399.4	210.2	2.852
1974	308.2	2168.5	1795.5	1225.0	336.9	273.8	2.640
1975	409.2	2918.0	809.1	262.6	201.5	86.3	1.626
1976	1008.4	4259.0	1216.0	302.4	191.2	108.4	2.206
1977	0.0	654.0	1097.7	363.7	81.9	12.8	0.970
1978	912.2	778.4	494.4	213.9	25.7	7.7	0.720
1979	394.0	1956.8	395.2	328.3	58.7	88.7	1.234
1980	55.3	4528.6	5617.2	460.6	55.0	35.3	4.325
1981	11.4	995.9	1724.2	698.9	206.9	56.9	1.903
1982	44.1	3656.5	1096.5	992.5	444.5	88.3	2.426
1983	0.0	1810.0	2647.8	514.4	119.6	237.3	2.564
1984	0.0	90.3	806.0	837.9	810.4	236.5	1.598
1985	106.4	2134.2	254.4	273.4	143.4	0.0	0.959
1986	26.6	1753.0	282.6	54.6	132.9	53.2	0.823
1987	26.6	73.3	133.0	129.3	51.0	53.2	0.319
1988	75.5	266.9	355.2	234.7	193.2	26.6	0.549
1989	45.2	391.3	737.7	281.0	59.3	43.5	0.708
1990	0.0	63.7	1074.7	358.4	112.2	100.8	0.678
1991	422.5	0.0	246.9	665.1	255.5	20.0	0.612
1992	0.0	1987.7	1840.7	621.8	160.0	16.7	1.520
1993	44.7	281.1	485.8	307.9	26.0	0.0	0.468
1994	0.0	602.3	614.7	343.6	140.4	38.7	0.641
1995	39.0	1144.6	4670.4	1441.7	621.5	9.5	2.504
1996	24.4	958.1	2548.6	2621.8	591.6	56.2	2.769
1997	18.2	1134.5	3623.1	3960.7	682.3	129.7	4.231
1998	0.0	2020.1	1022.2	1123.4	737.1	339.6	2.256
1999	48.7	4606.3	10501.7	2640.5	1575.2	756.3	9.033
2000	177.3	4677.6	7440.5	2828.5	789.2	508.4	6.499
2001	0.0	2246.7	6370.5	2340.0	469.2	439.7	4.859
2002	182.4	2341.5	11971.1	3958.4	1690.3	845.4	9.282
2003	196.1	4241.4	6564.9	2791.9	428.6	836.9	6.524
2004	47.1	957.3	2114.4	659.9	247.7	263.8	1.835
2005	0.0	1953.5	4931.0	2332.7	261.8	111.4	3.307
2006	493.5	907.8	3419.2	2112.7	307.7	79.8	2.349
2007	87.1	4899.7	6079.1	2762.3	540.0	125.2	4.563
2008	0.0	2206.7	4921.5	1681.1	300.3	26.6	3.152
2009	218.8	546.4	6978.7	4456.8	964.1	186.3	4.619
2010	16.5	662.8	5181.0	8057.2	2584.0	613.9	5.662
2011	26.9	236.6	3116.0	3512.9	914.1	100.6	2.419

Table 11. NEFSC fall survey indices of minimum swept area abundance for Georges Bank yellowtail flounder in thousands of fish and thousands of metric tons.

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)
1963.5	14289.1	7663.6	10897.1	1804.0	480.5	532.7	12.413
1964.5	1671.3	9517.3	7097.2	5791.2	2634.2	473.3	13.168
1965.5	1162.1	5537.0	5811.9	3427.8	1600.9	250.6	8.852
1966.5	11320.3	2184.4	1635.3	871.9	98.3	0.0	3.813
1967.5	8720.8	9131.0	2646.7	1006.7	299.3	132.3	7.445
1968.5	11328.3	11702.5	5588.9	722.7	936.8	56.4	10.227
1969.5	9656.7	10601.8	5064.1	1757.4	327.0	447.7	9.519
1970.5	4474.9	4981.2	3051.2	1894.7	438.2	77.8	4.833
1971.5	3520.0	6770.9	4769.9	2183.8	483.4	289.1	6.178
1972.5	2416.9	6332.8	4682.3	2032.9	592.1	331.7	6.142
1973.5	2420.4	5336.0	4954.5	2857.4	1181.2	599.9	6.299
1974.5	4486.7	2779.5	1471.6	1029.1	444.3	368.1	3.561
1975.5	4548.6	2437.3	851.7	555.2	324.4	61.1	2.257
1976.5	333.5	1863.9	460.3	113.6	118.5	97.3	1.463
1977.5	906.7	2147.1	1572.8	615.4	102.3	105.7	2.699
1978.5	4620.6	1243.3	757.2	399.2	131.6	34.9	2.274
1979.5	1282.0	2008.5	253.7	116.7	134.3	108.6	1.450
1980.5	743.6	4970.0	5912.0	662.0	212.3	250.9	6.412
1981.5	1548.2	2279.4	1592.8	570.5	76.4	52.8	2.500
1982.5	2353.3	2120.3	1543.4	410.4	86.6	0.0	2.203
1983.5	105.7	2216.4	1858.5	495.7	29.9	47.7	2.068
1984.5	641.6	388.1	296.7	236.0	72.7	60.7	0.576
1985.5	1310.2	527.5	165.9	49.1	78.3	0.0	0.688
1986.5	273.4	1075.1	338.7	71.9	0.0	0.0	0.796
1987.5	98.7	388.8	384.6	51.4	77.1	0.0	0.494
1988.5	18.2	206.7	104.0	26.6	0.0	0.0	0.165
1989.5	241.0	1934.1	750.4	76.6	54.0	0.0	0.948
1990.5	0.0	359.2	1429.9	285.8	0.0	0.0	0.703
1991.5	2038.8	267.0	426.2	347.2	0.0	0.0	0.708
1992.5	146.8	383.9	691.0	157.1	139.4	26.6	0.559
1993.5	814.6	135.2	568.8	520.4	0.0	21.4	0.529
1994.5	1159.8	214.6	954.1	692.2	254.9	54.8	0.871
1995.5	267.7	115.4	335.2	267.2	44.6	12.1	0.344
1996.5	144.3	341.3	1813.8	433.5	72.7	0.0	1.265
1997.5	1351.8	517.7	3341.0	2028.5	1039.8	79.8	3.670
1998.5	1844.4	4675.3	4078.9	1154.6	289.5	71.7	4.220
1999.5	2998.7	8175.9	5558.9	1390.3	1394.2	252.8	7.738

Table 11. continued

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)
2000.5	610.8	1647.5	4672.5	2350.3	919.7	802.6	5.666
2001.5	3414.2	6083.6	7853.7	2524.8	1667.8	1988.2	11.213
2002.5	2031.4	5581.8	2064.5	576.1	295.6	26.6	3.644
2003.5	1045.3	4882.8	2725.9	548.0	97.0	185.7	3.919
2004.5	850.3	5346.1	4862.4	2044.4	897.1	170.7	4.966
2005.5	304.0	2033.6	3652.1	595.9	179.3	0.0	2.391
2006.5	6012.1	6067.2	3556.7	1132.9	247.7	44.4	4.388
2007.5	1026.5	11110.9	7634.7	1939.6	371.3	90.9	7.912
2008.5	162.8	6963.2	9592.7	1002.8	0.0	0.0	6.900
2009.5	445.8	4169.4	11531.5	2072.0	588.3	57.9	6.797
2010.5	115.4	2661.6	4205.3	719.7	272.7	0.0	2.242

Table 12. NEFSC scallop survey index of abundance (stratified mean #/tow) 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							
2009.5	0.2126	0.2289	0.8925	0.4029	0.0886	0.0090	0.719
2010.5	0.0900	0.3751	0.7095	0.6943	0.2152	0.0403	0.749

Table 13. Statistical properties of estimates for population abundance and survey calibration constants (scallop x10^3) for Georges Bank yellowtail flounder for the Split Series VPA.

Age	Estimate	Bootstrap Standard Error	Bootstrap Relative Error	Bias	Relative Bias
Population Abundance					
2	764	318	42%	61	8%
3	3027	1046	35%	112	4%
4	3568	1148	32%	129	4%
5	5656	1145	20%	116	2%
Survey Calibration Constants					
DFO Survey: 1987-1994					
2	0.145	0.046	32%	0.005	3%
3	0.232	0.033	14%	0.003	1%
4	0.389	0.069	18%	0.005	1%
5	0.436	0.094	21%	0.010	2%
6+	0.254	0.064	25%	0.006	2%
DFO Survey: 1995-2011					
2	0.321	0.096	30%	0.015	5%
3	1.497	0.351	23%	0.033	2%
4	2.154	0.392	18%	0.035	2%
5	1.774	0.392	22%	0.040	2%
6+	1.194	0.222	19%	0.017	1%
NMFS Spring Survey: Yankee 41, 1973-1981					
1	0.007	0.006	82%	0.002	22%
2	0.076	0.014	18%	0.002	2%
3	0.096	0.016	17%	0.002	2%
4	0.093	0.011	12%	0.000	0%
5	0.076	0.015	20%	0.001	2%
6+	0.072	0.022	31%	0.004	5%
NMFS Spring Survey: Yankee 36, 1982-1994					
1	0.004	0.001	23%	0.000	3%
2	0.046	0.015	33%	0.002	4%
3	0.095	0.015	16%	0.002	2%
4	0.152	0.019	13%	0.001	1%
5	0.229	0.045	20%	0.006	3%
6+	0.423	0.090	21%	0.008	2%

Table 13. continued

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias

NMFS Spring Survey: Yankee 36, 1995-2011

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
1	0.007	0.003	37%	0.000	6%
2	0.164	0.020	12%	0.002	1%
3	0.622	0.087	14%	0.007	1%
4	0.697	0.108	15%	0.014	2%
5	0.523	0.101	19%	0.010	2%
6+	0.414	0.095	23%	0.008	2%

NMFS Fall Survey: 1973-1994

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
1	0.040	0.010	26%	0.001	3%
2	0.088	0.013	15%	0.001	2%
3	0.150	0.015	10%	0.001	0%
4	0.156	0.021	13%	0.001	1%
5	0.205	0.041	20%	0.002	1%
6+	0.306	0.061	20%	0.006	2%

NMFS Fall Survey: 1995-2010

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
1	0.074	0.018	24%	0.002	3%
2	0.298	0.097	33%	0.014	5%
3	0.683	0.123	18%	0.011	2%
4	0.462	0.090	20%	0.006	1%
5	0.471	0.131	28%	0.017	4%
6+	0.390	0.141	36%	0.021	5%

NMFS Scallop Survey: 1982-1994

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
1	0.027	0.011	41%	0.001	6%

NMFS Scallop Survey: 1995-2010

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
1	0.058	0.008	14%	0.000	1%

Table 14. Retrospective rho statistics for fishing mortality rate (ages 4+), spawning stock biomass, and age-1 recruitment based on seven peels.

Peel	F	SSB	R
1	-0.412	0.472	0.291
2	-0.507	1.316	-0.421
3	-0.598	1.227	0.100
4	-0.398	0.740	2.605
5	-0.102	0.721	-0.267
6	-0.019	0.673	0.435
7	1.326	-0.223	0.480
mean	-0.101	0.704	0.460

Table 15. Beginning of year population abundance numbers (000s) for Georges Bank yellowtail flounder from the Split Series VPA.

Year	Age Group 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	36515
1994	13178	6725	8713	2323	609	184	31732
1995	11670	10725	4304	1576	305	66	28646
1996	13467	9512	8499	2237	509	70	34293
1997	19792	10935	7174	5103	1039	246	44289
1998	22380	16130	7932	4227	2515	328	53512
1999	24514	18171	11412	3465	1777	675	60014
2000	19760	20016	12398	5586	1455	930	60144
2001	22191	16059	12912	5048	1752	916	58877
2002	15189	18010	10553	4377	1561	1109	50798
2003	10735	12245	10997	5549	1872	1659	43057
2004	7404	8645	6510	4793	2469	1842	31662
2005	11629	6007	6040	2490	572	270	27007
2006	16787	9467	3499	1378	530	312	31972
2007	17172	13607	6586	1413	291	118	39188
2008	7974	14014	9796	3861	566	111	36321
2009	4721	6503	11028	6308	2392	341	31293
2010	936	3850	5068	7888	3941	877	22560

Table 16. Fishing mortality rate for Georges Bank yellowtail from the Split Series VPA.

Year	Age Group						
	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	0.61	0.61	0.61	0.61
2004	0.01	0.16	0.76	1.93	1.93	1.93	1.93
2005	0.01	0.34	1.28	1.35	1.35	1.35	1.35
2006	0.01	0.16	0.71	1.35	1.35	1.35	1.35
2007	0.00	0.13	0.33	0.72	0.72	0.72	0.72
2008	0.00	0.04	0.24	0.28	0.28	0.28	0.28
2009	0.00	0.05	0.14	0.27	0.27	0.27	0.27
2010	0.00	0.04	0.15	0.13	0.13	0.13	0.13

Table 17. Beginning of year weight (kg) at age for Georges Bank yellowtail. The 2011 values are set equal to the average of the 2008-2010 values.

Year	Age Group					
	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	0.202	0.318	0.425	0.560	0.740	1.048
2004	0.166	0.258	0.397	0.527	0.689	0.956
2005	0.074	0.268	0.361	0.511	0.668	0.991
2006	0.059	0.192	0.376	0.499	0.674	0.996
2007	0.110	0.170	0.356	0.474	0.661	1.023
2008	0.018	0.216	0.347	0.467	0.605	0.962
2009	0.107	0.124	0.362	0.473	0.610	0.929
2010	0.135	0.224	0.377	0.475	0.596	0.808
2011	0.087	0.188	0.362	0.471	0.604	0.900

Table 18. Beginning of year biomass (mt) and spawning stock biomass (mt) for Georges Bank yellowtail from the Split Series VPA.

Year	Beginning Biomass 1+	Beginning Biomass 3+	SSB
1973	34860	26207	22161
1974	26134	18088	14780
1975	22722	10183	9014
1976	18984	7408	10024
1977	14447	9448	8350
1978	12145	6417	6169
1979	14069	5817	8500
1980	15820	10540	10885
1981	18891	10430	10143
1982	21995	10493	12973
1983	17637	13841	11103
1984	9122	7075	3846
1985	6283	2040	2558
1986	6629	2294	3211
1987	5599	3282	2749
1988	4904	2113	2197
1989	6004	2088	4169
1990	7946	5844	4750
1991	7003	3833	3485
1992	8154	3736	4473
1993	6893	3964	3965
1994	7444	4229	2824
1995	6229	2145	2941
1996	7276	4186	4991
1997	11305	5683	6380
1998	13542	6650	7259
1999	16244	7998	9593
2000	19364	10200	10260
2001	19477	10334	9257
2002	18482	9117	10114
2003	16964	10905	10054
2004	12025	8566	5472
2005	6572	4104	3315
2006	5474	2670	2902
2007	7534	3328	4437
2008	8814	5649	7127
2009	10064	8749	9337
2010	9702	8713	8802
2011		9301	

Table 19. Deterministic projection input assumptions and results for Georges Bank yellowtail for F_{ref} from the Split Series VPA.

Year	Age Group 1	2	3	4	5	6+	1+	3+
Jan-1 Population Numbers (000s)								
2011	8913	764	3027	3568	5656	3455		
2012	8913	7258	583	1870	2072	5292		
2013	8913	7269	5644	389	1192	4696		
Partial Recruitment to the Fishery								
	0.016	0.206	0.821	1	1	1		
Fishing Mortality								
2011	0.005	0.071	0.282	0.343	0.343	0.343		
2012	0.004	0.051	0.205	0.250	0.250	0.250		
Jan-1 Weight for Population (kg)								
	0.087	0.188	0.362	0.471	0.604	0.900		
Maturity								
	0	0.462	0.967	1	1	1		
Jan-1 Population Biomass (mt)								
2011	774	144	1095	1681	3416	3108	10219	9301
2012	774	1364	211	881	1251	4761	9243	7105
2013	774	1366	2043	183	720	4225	9310	7171
Spawning Stock Biomass (mt)								
2011	0	100	1023	1508	3060	2479	8170	
2012	0	959	203	821	1165	3947	7097	
Catch Numbers (000s)								
2011	43	47	677	945	1498	915		
2012	32	330	98	376	417	1065		
Average Weight for Catch (kg)								
	0.125	0.318	0.427	0.530	0.678	0.900		
Fishery Yield (mt including discards)								
2011	5	15	289	501	1016	823	**2650**	
2012	4	105	42	199	283	959	**1592**	

Table 20. Catch (mt) in 2012 for the three VPA formulations and three probabilities of F exceeding Fref (top) and relative change in median biomass from 2012 to 2013 for the three VPA formulations and a range of catch in 2012 (bottom).

VPA formulation	25%	50%	75%
Split Series	1,400	1,700	1,900
Split Series rho adjusted	600	750	900
Single Series rho adjusted	1,400	1,700	1,900

2012 Catch (mt)	Split Series	Split Series rho adjusted	Single Series rho adjusted
600	22%	25%	0%
750	20%	20%	-2%
900	18%	16%	-3%
1,400	12%	1%	-9%
1,700	8%	-8%	-13%
1,900	5%	-14%	-15%

Table 21. Catch and spawning stock biomass weights at age (kg) and partial recruitment used to set the US rebuilding target during GARM III (NEFSC 2008) and the recent five year averages from the split series VPA of this assessment (denoted new).

	Weights (Catch and SSB)			Partial Recruitment		
Age	GARM III	New	change	GARM III	New	change
1	0.161	0.125	-22%	0.0069	0.016	132%
2	0.319	0.318	0%	0.2015	0.206	2%
3	0.435	0.427	-2%	0.6490	0.821	27%
4	0.585	0.53	-9%	1	1	0%
5	0.769	0.678	-12%	1	1	0%
6	1.000	0.900	-10%	1	1	0%

Table 22. The US rebuilding target (SSBmsy) and associated yield (MSY) from stochastic projections of F=0.25 under combinations of weights at age and partial recruitment (PR) and stock-recruitment data (SR data) from GARM III (NEFSC 2008) and the split series VPA of this assessment (denoted new). HC denotes the hindcast recruitment values used in GARM III (NEFSC 2008).

SSBmsy (mt)				MSY (mt)		
	Weight and PR at Age				Weight and PR at Age	
SR data	GARM III	New		SR data	GARM III	New
GARM III	43,200	38,800		GARM III	9,400	8,600
New with HC	41,000	36,600		New with HC	8,800	8,100
New, No HC	26,600	23,600		New, No HC	5,700	5,200

Table 23. Probability of spawning stock biomass being greater than 43,200 mt for a range of fishing mortality rates and projection years. The bolded cells correspond to the first seven strategies in Table 24**.**

Fishing Mortality Rate 2012-2020

Year	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0.021	0.019	0.017	0.015	0.014	0.013	0.012	0.011	0.010	0.008	0.007	0.006	0.005	0.004	0.004	0.004
2015	0.181	0.169	0.157	0.147	0.137	0.131	0.122	0.114	0.108	0.101	0.093	0.087	0.081	0.076	0.070	0.066
2016	0.456	0.436	0.417	0.397	0.376	0.355	0.335	0.314	0.296	0.279	0.263	0.249	0.233	0.218	0.205	0.190
2017	0.706	0.686	0.662	0.640	0.619	0.594	0.570	0.545	**0.519**	0.496	0.471	0.444	0.420	0.397	0.374	0.351
2018	0.853	0.831	0.813	0.795	0.772	**0.752**	0.728	0.703	0.677	0.650	0.622	0.592	0.559	0.533	**0.505**	0.477
2019	0.929	0.914	0.899	0.880	0.861	0.842	0.819	0.798	**0.773**	0.746	0.716	0.689	0.657	0.626	0.595	0.563
2020	0.969	0.958	0.945	0.930	0.916	0.898	0.877	0.859	0.834	0.810	0.781	**0.751**	0.721	0.690	0.661	0.627

Fishing Mortality Rate 2012-2020

Year	0.16	0.17	0.18	0.19	0.2	0.21	0.22	0.23	0.24	0.25
2011	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0
2014	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001
2015	0.062	0.058	0.054	0.049	0.046	0.043	0.039	0.035	0.032	0.030
2016	0.179	0.167	0.157	0.146	0.135	0.124	0.115	0.105	0.096	0.090
2017	0.325	0.305	0.283	0.264	0.246	0.229	0.213	0.199	0.185	0.169
2018	0.446	0.416	0.391	0.366	0.341	0.319	0.295	0.270	0.248	0.229
2019	0.533	**0.502**	0.471	0.438	0.409	0.375	0.347	0.322	0.295	0.273
2020	0.590	0.557	**0.521**	0.487	0.452	0.420	0.389	0.355	0.325	0.295

Table 24. Percentiles of the distributions of catch (mt) in 2012 under a range of strategies for rebuilding or harvest rates. The first seven strategies correspond to US rebuilding options where year denotes the time and P(reb) the probability when the spawning stock biomass should be greater than 43,200 mt. The median catch values are bolded.

Strategy	Year	P(reb)	F	1%	5%	10%	25%	**50%**	75%	90%	95%	99%
								2012 Catch (mt)				
Rebuild	2018	75%	0.05	221	255	279	318	**369**	414	465	500	568
Rebuild	2019	75%	0.08	349	403	440	503	**583**	654	734	790	897
Rebuild	2020	75%	0.11	474	548	597	682	**790**	887	995	1072	1218
Rebuild	2017	50%	0.08	349	403	440	503	**583**	654	734	790	897
Rebuild	2018	50%	0.14	595	688	750	857	**993**	1115	1250	1346	1530
Rebuild	2019	50%	0.17	715	825	899	1027	**1190**	1336	1498	1612	1833
Rebuild	2020	50%	0.18	754	870	947	1083	**1254**	1408	1579	1700	1931
75%Fmsy	NA	NA	0.1875	783	903	984	1124	**1302**	1462	1640	1764	2005
Fmsy	NA	NA	0.25	1018	1172	1277	1459	**1691**	1899	2127	2290	2601
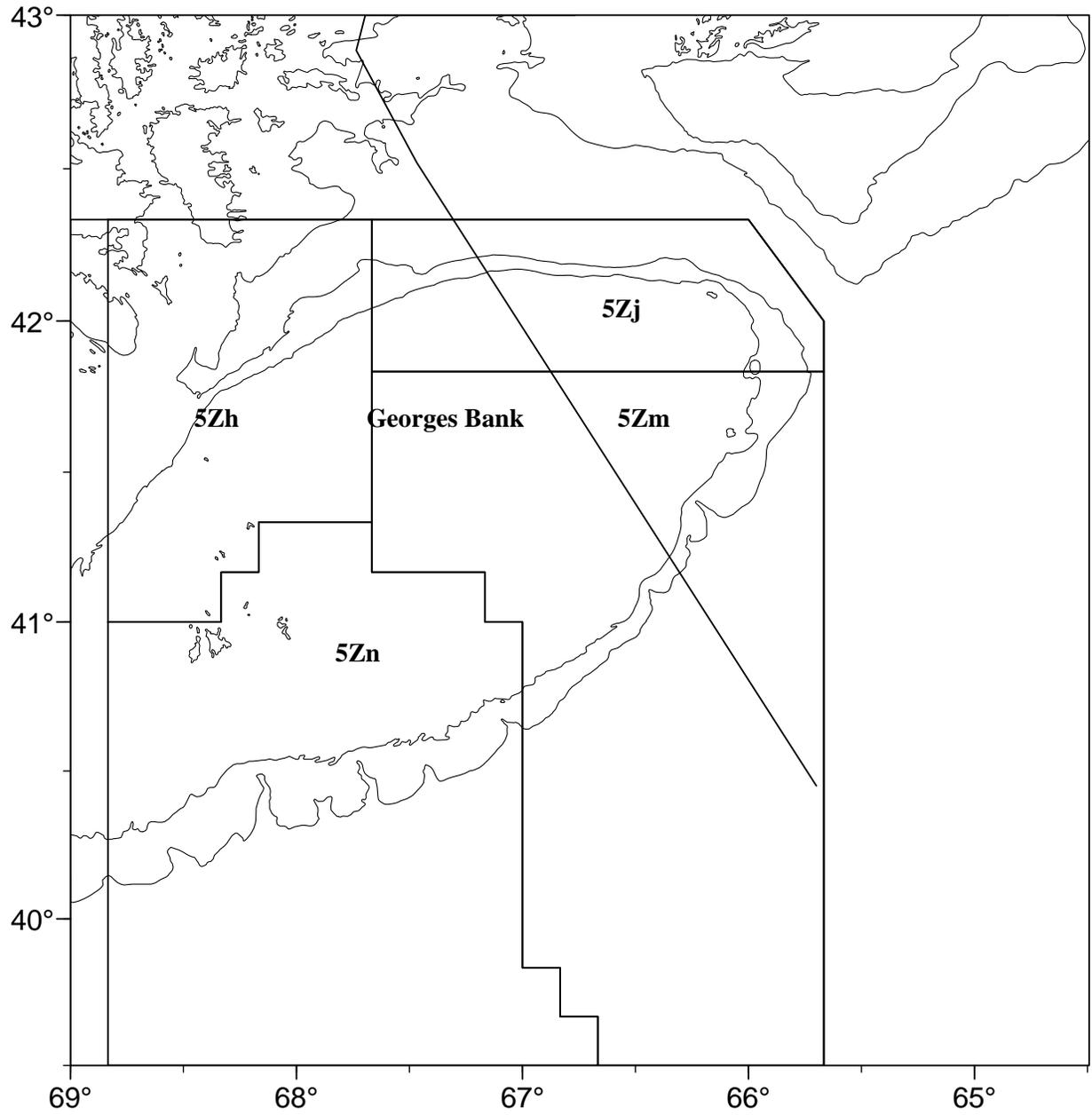
Figure 1a. Location of statistical unit areas for Canadian fisheries in NAFO Subdivision 5Ze.
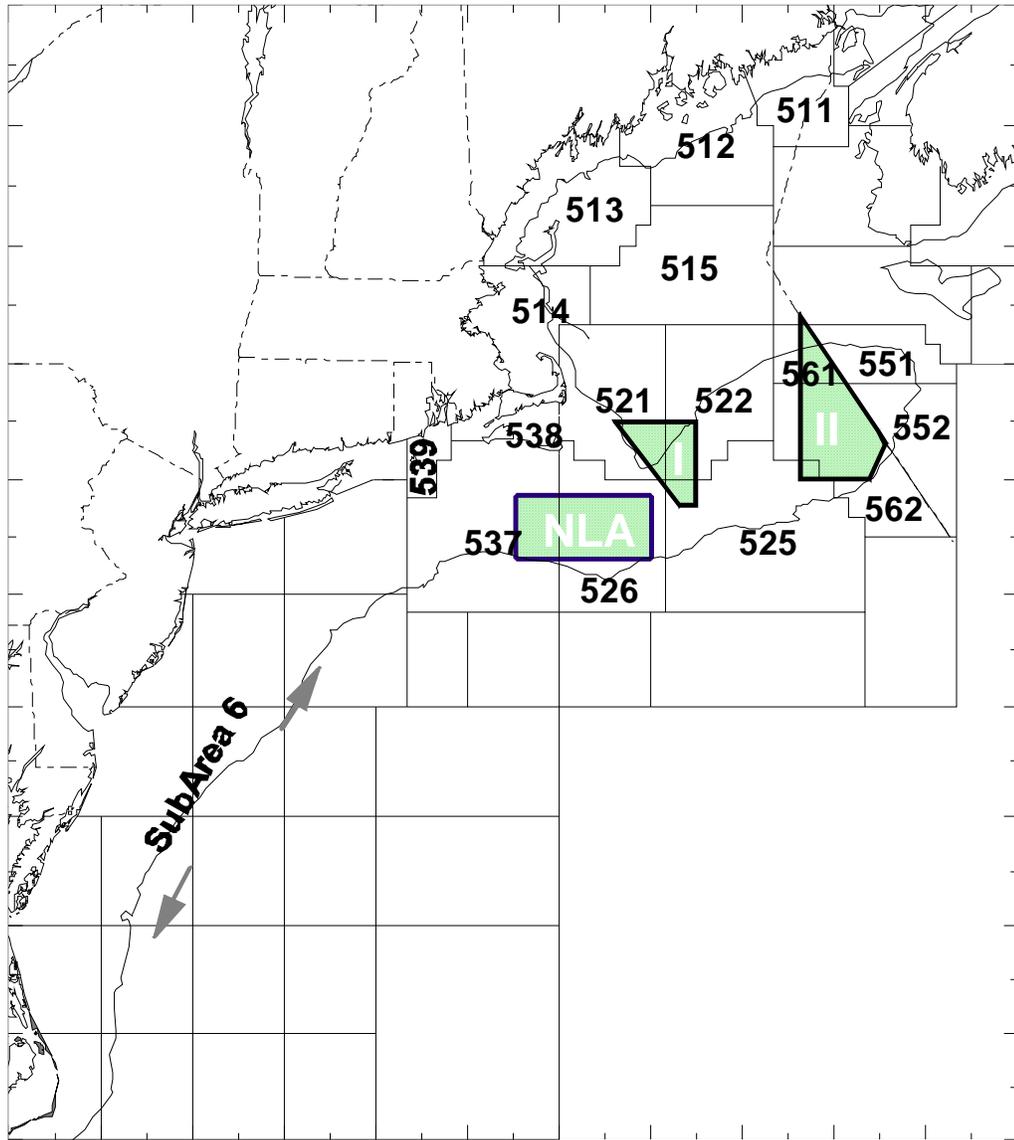
Figure 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.
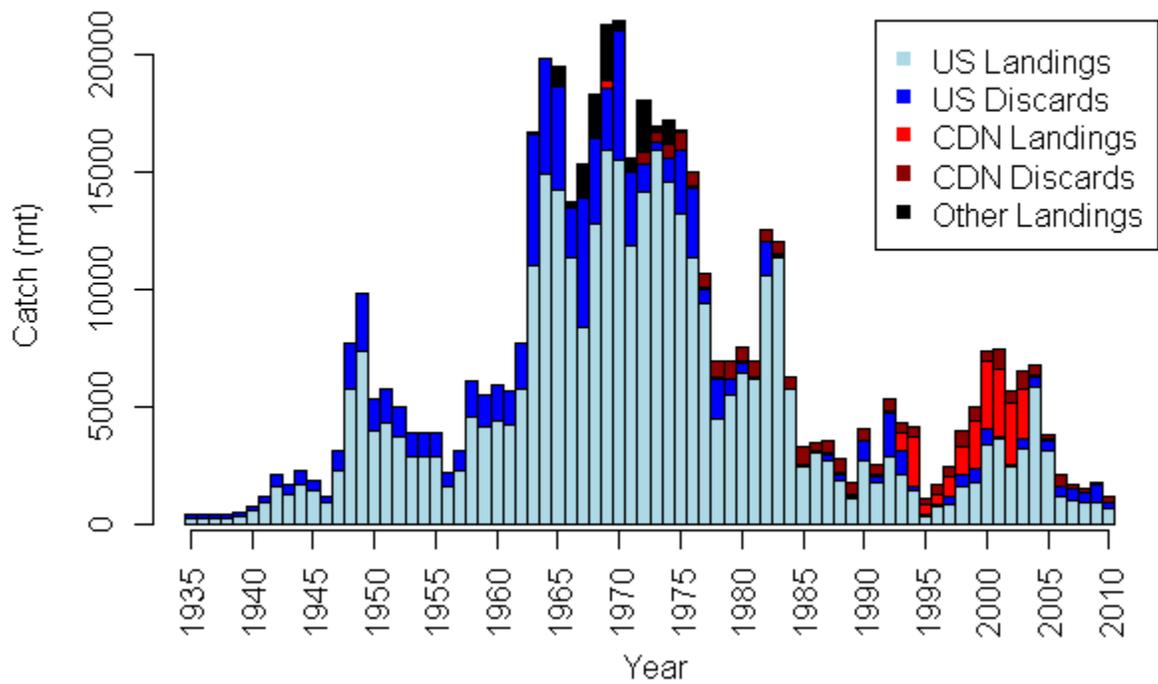
Figure 2. Catch (landings plus discards) of Georges Bank yellowtail flounder by nation and year.
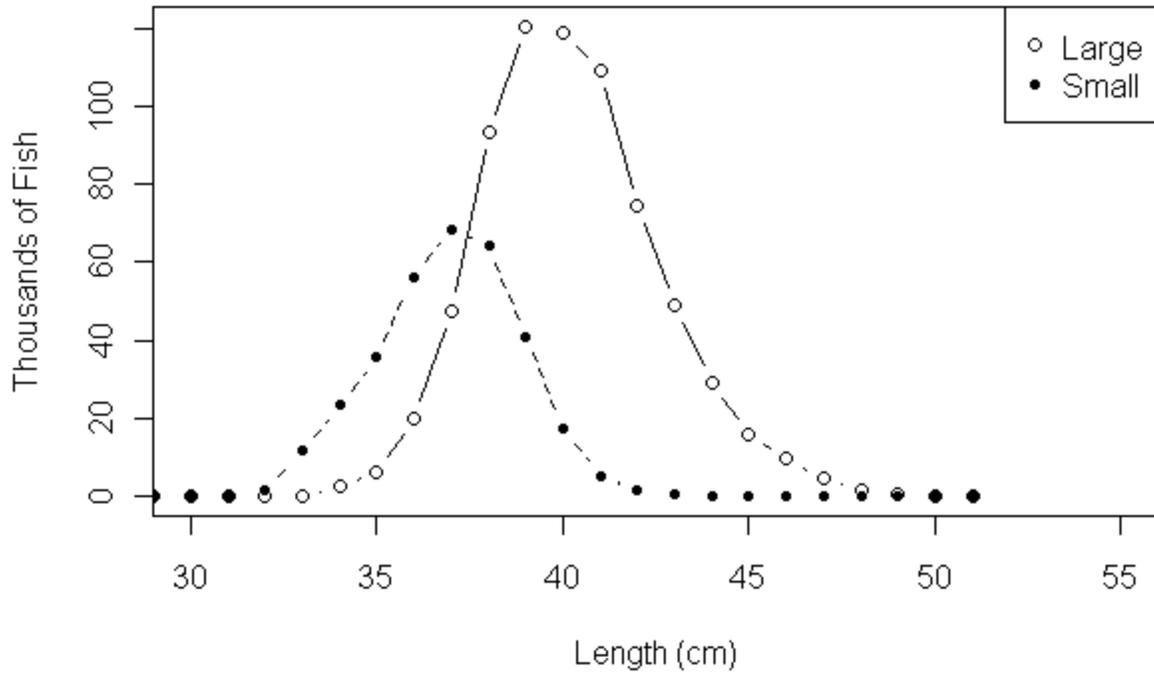
Figure 3. US landings of Georges Bank yellowtail by market category.
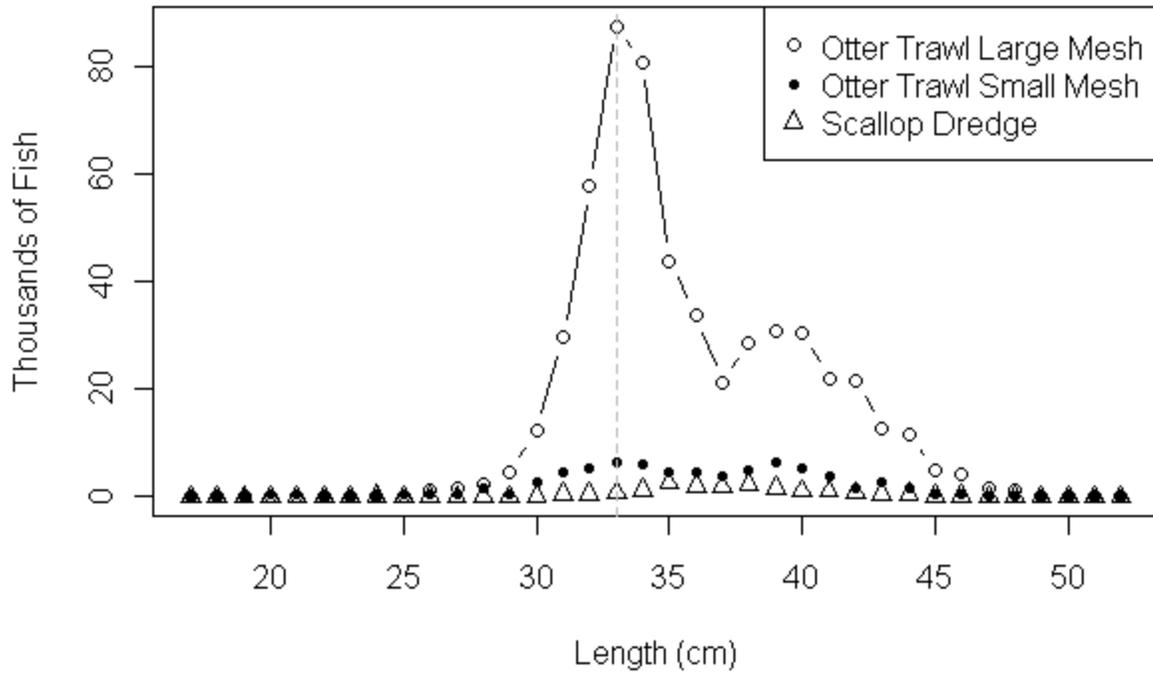
Figure 4. US yellowtail flounder discard length frequencies by gear. The vertical line at 33 cm denotes the US minimum legal size for landing yellowtail flounder. The distinction between large and small mesh in the cod end of the trawl occurs at 5.5 inches (14 cm).
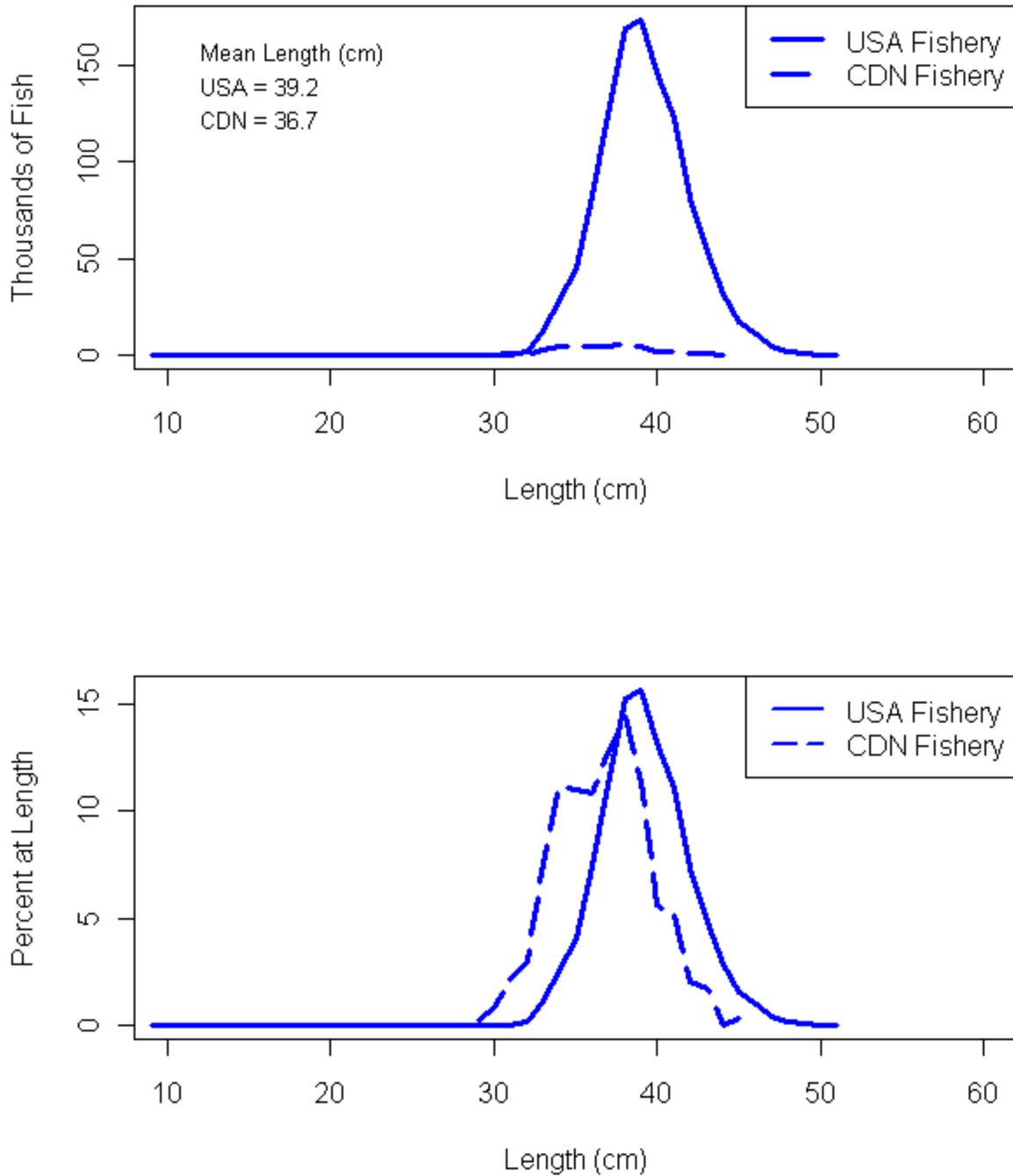
Figure 5. Comparison of US and Canadian landings at length for Georges Bank yellowtail flounder.
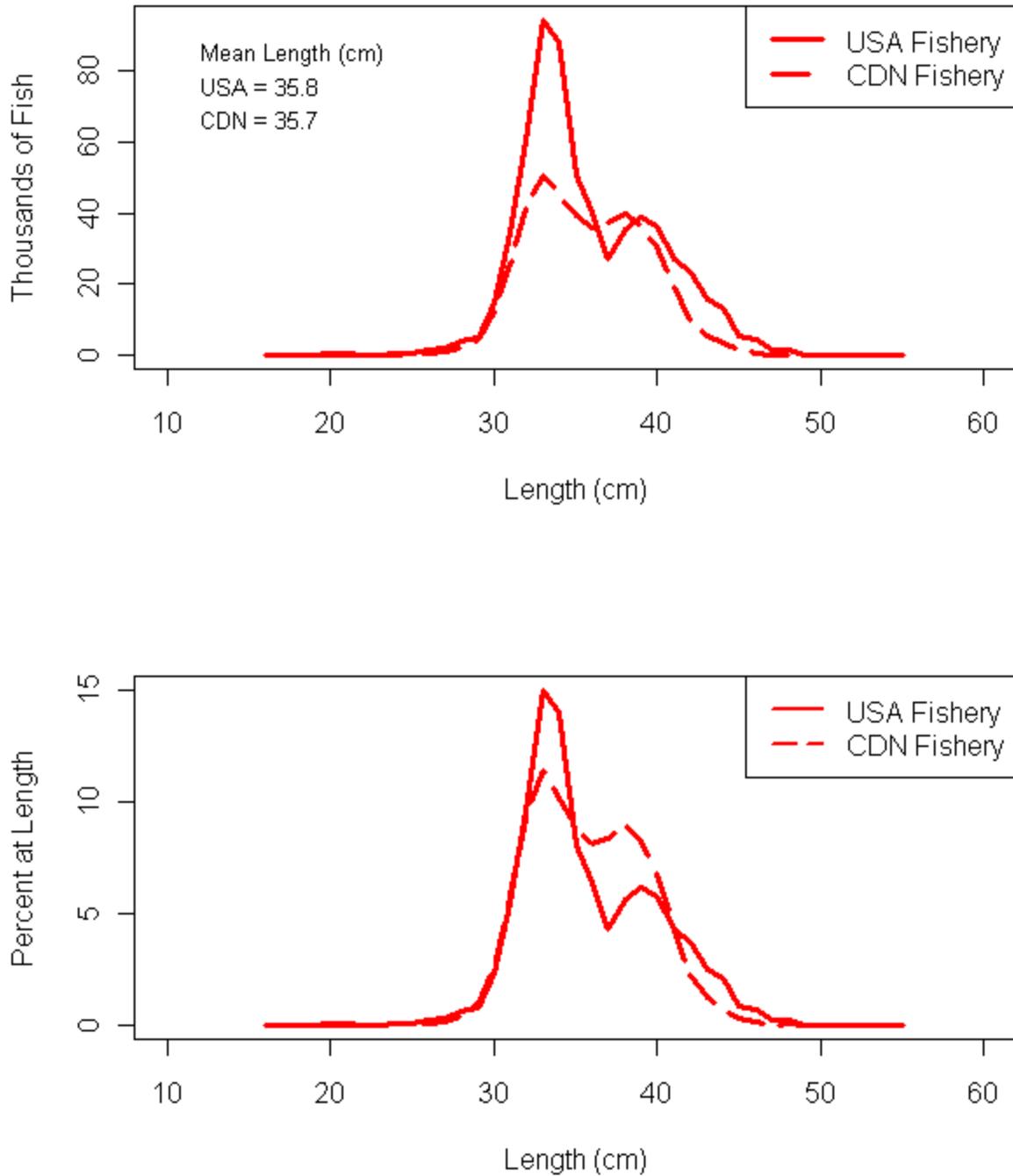
Figure 6. Comparison of US and Canadian discards at length for Georges Bank yellowtail flounder.
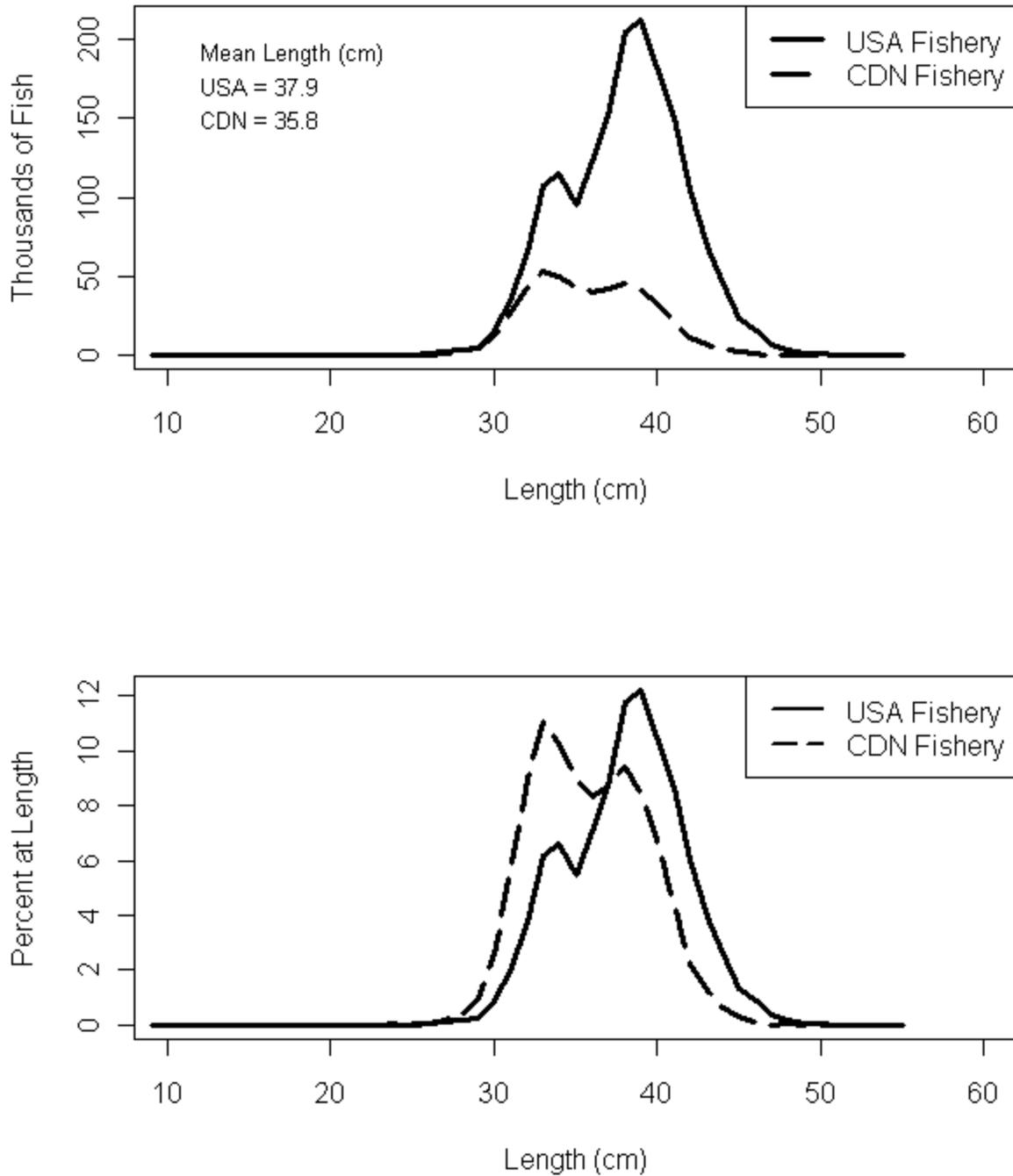
Figure 7. Comparison of US and Canadian catch (landings plus discards) at length for Georges Bank yellowtail flounder.

2010
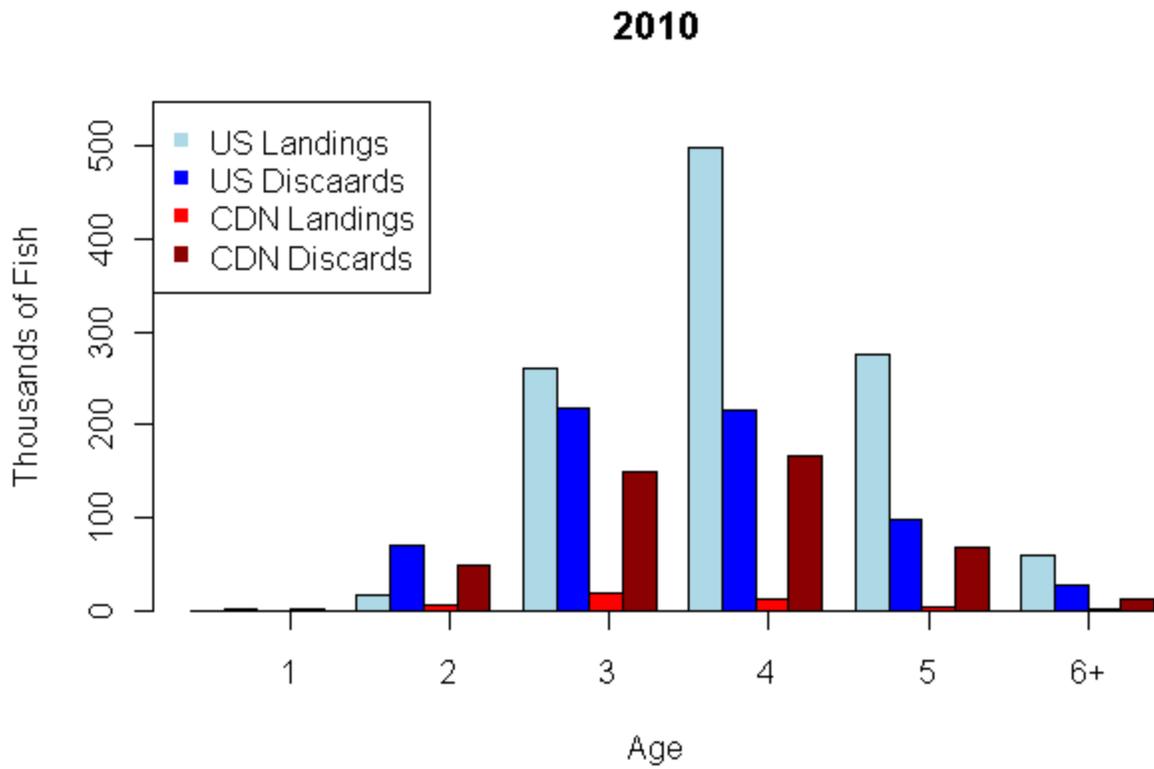
Figure 8. Catch at age of Georges Bank yellowtail flounder from the four components of Canadian and US landings and discards.
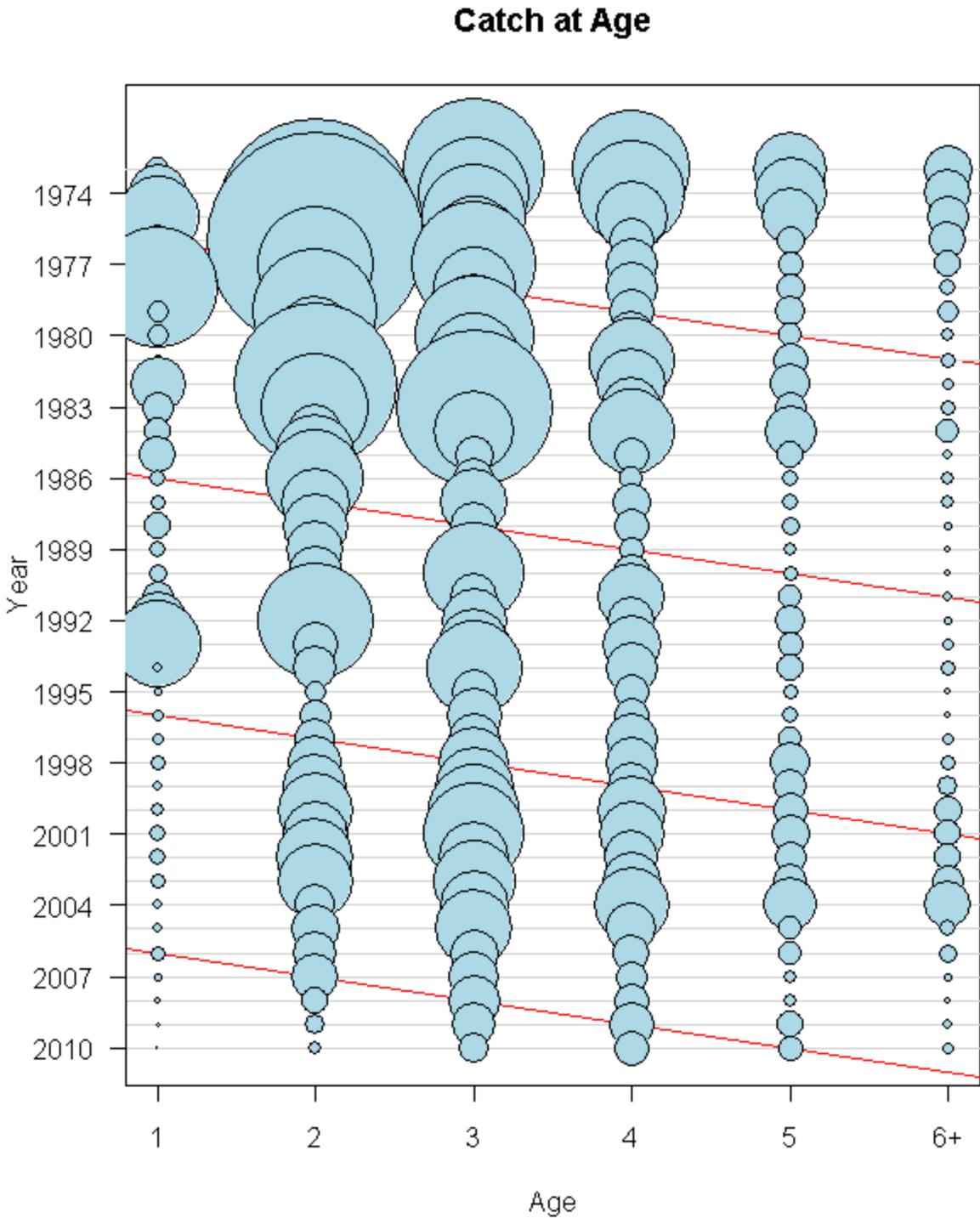
Figure 9. Catch at age for Georges Bank yellowtail flounder, Canadian and US fisheries combined. (The area of the bubble is proportional to the magnitude of the catch). Diagonal red lines denote the 1975, 1985, 1995, and 2005 year classes.
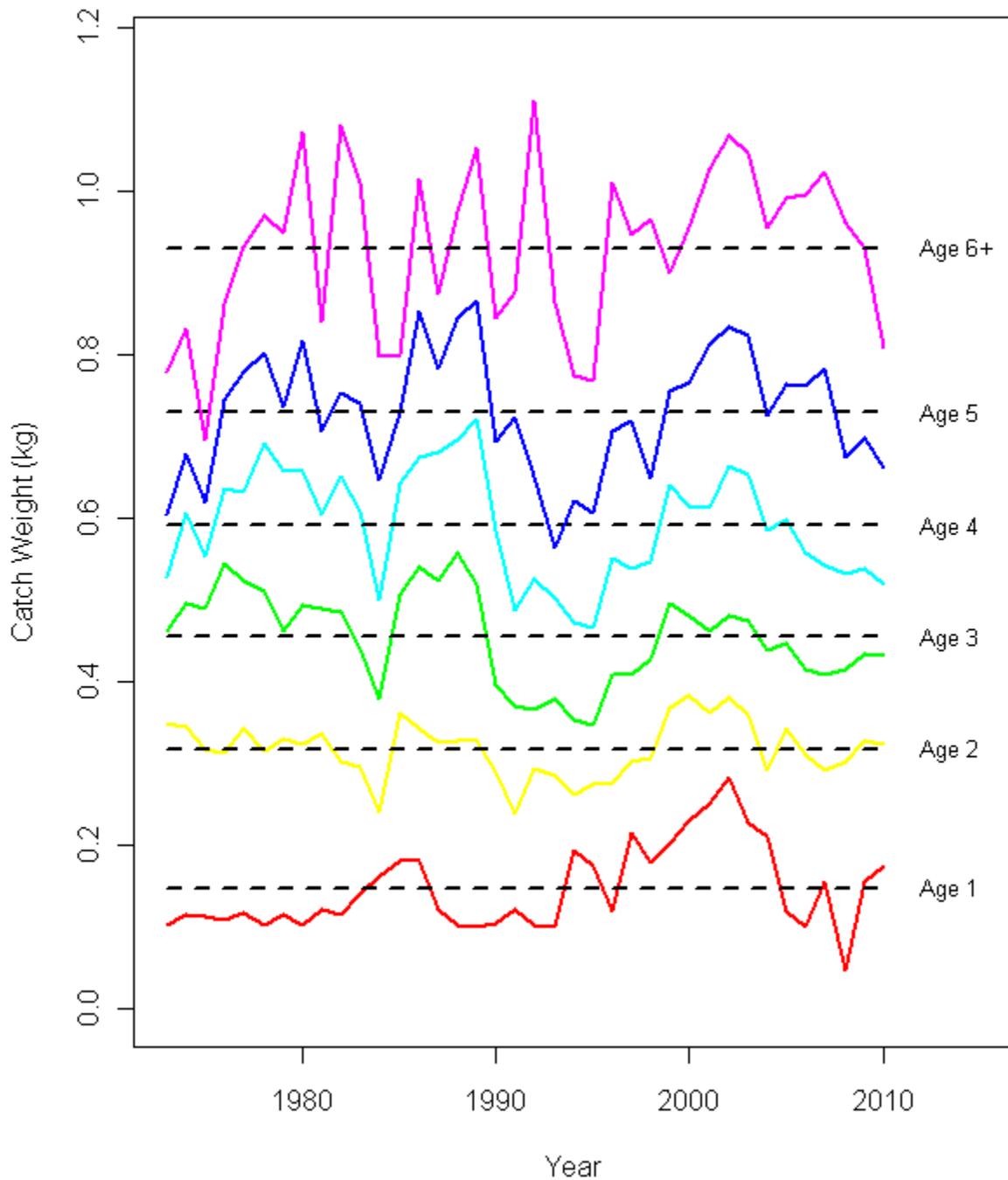
Figure 10. Trends in mean weight at age from the Georges Bank yellowtail fishery (Canada and US combined, including discards). Dashed lines denote average of time series.
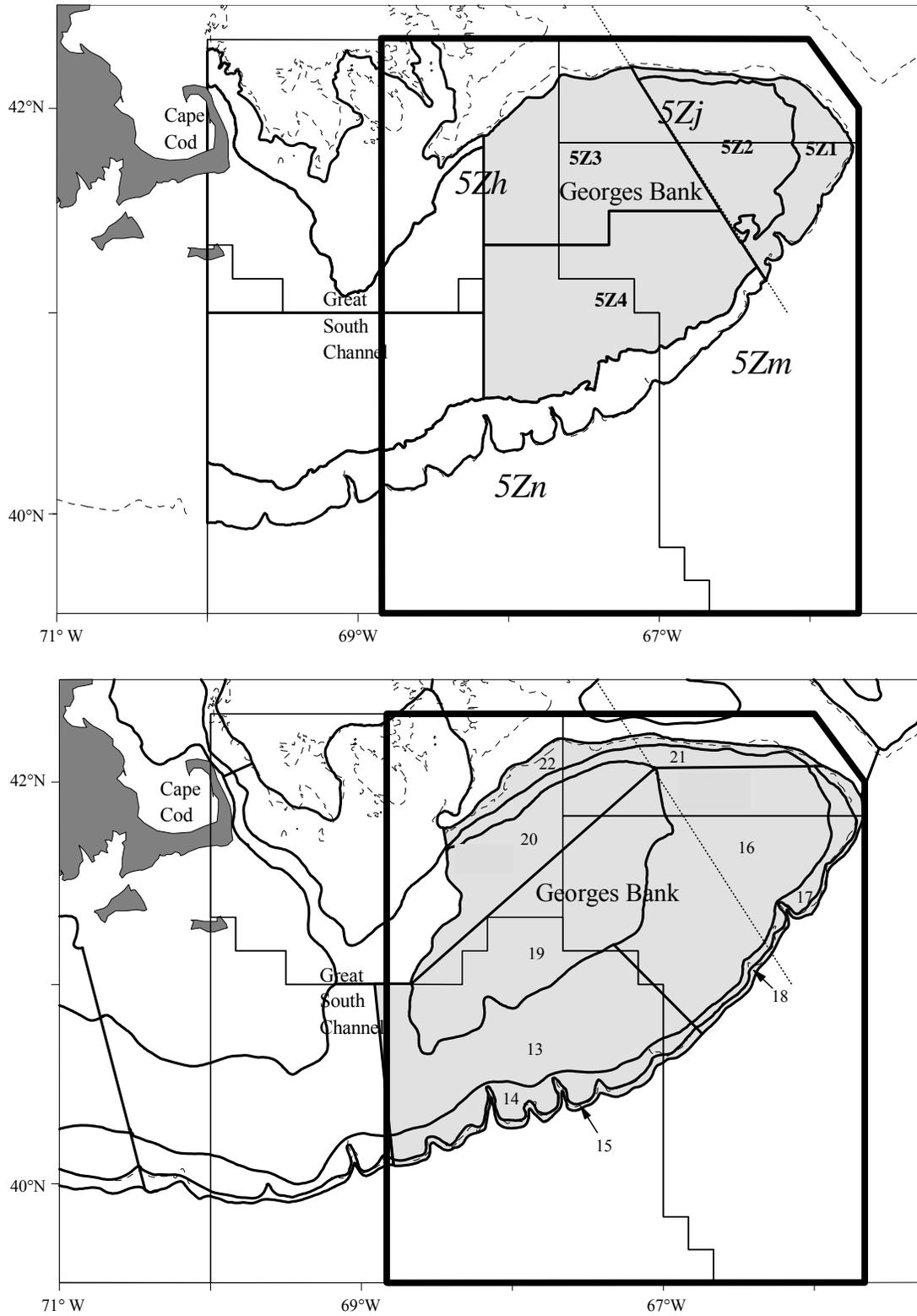
Figure 11. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in assessment.
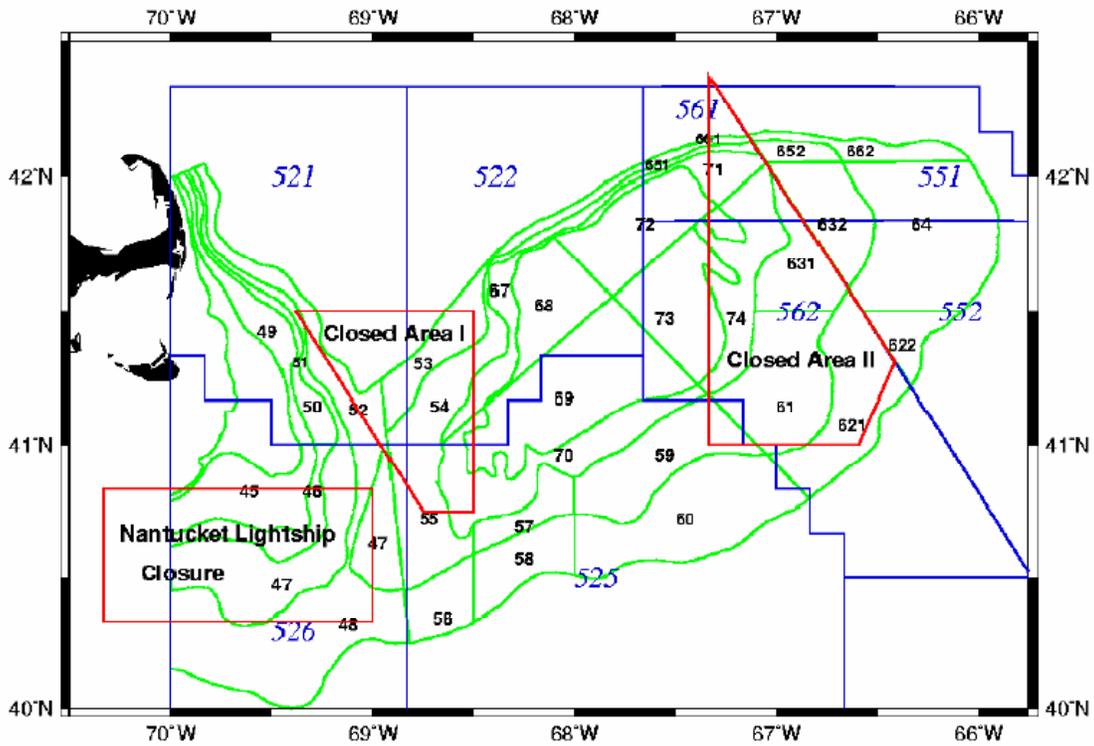
Figure 11. (continued) NMFS scallop survey strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Strata 54, 55, 58-72, and 74 are used to estimate the abundance of yellowtail flounder for this assessment.
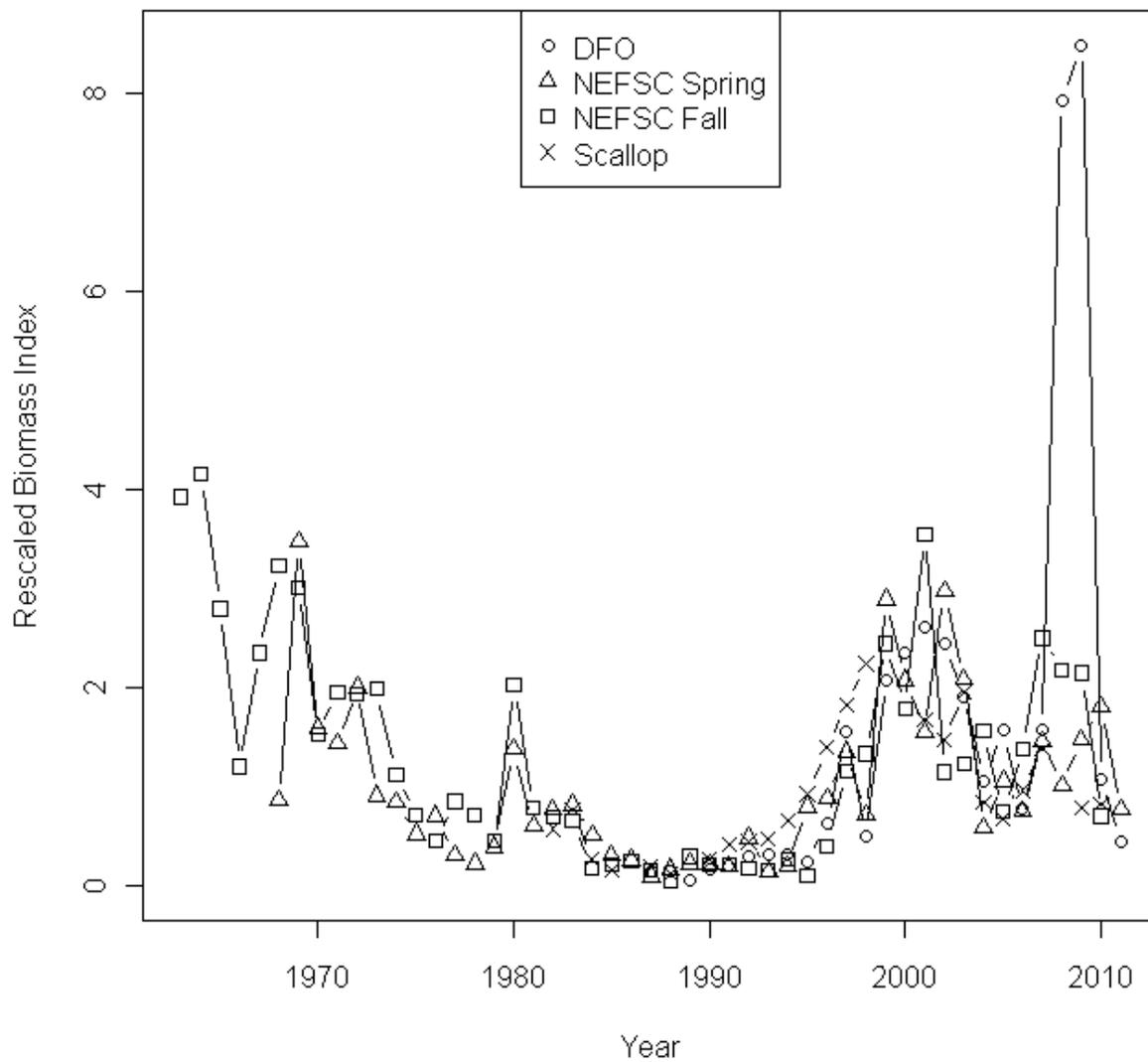
Figure 12a. Four survey biomass indices (DFO, NEFSC spring, NEFSC fall and NEFSC scallop) for yellowtail flounder on Georges Bank rescaled to their respective means for years 1987-2007.
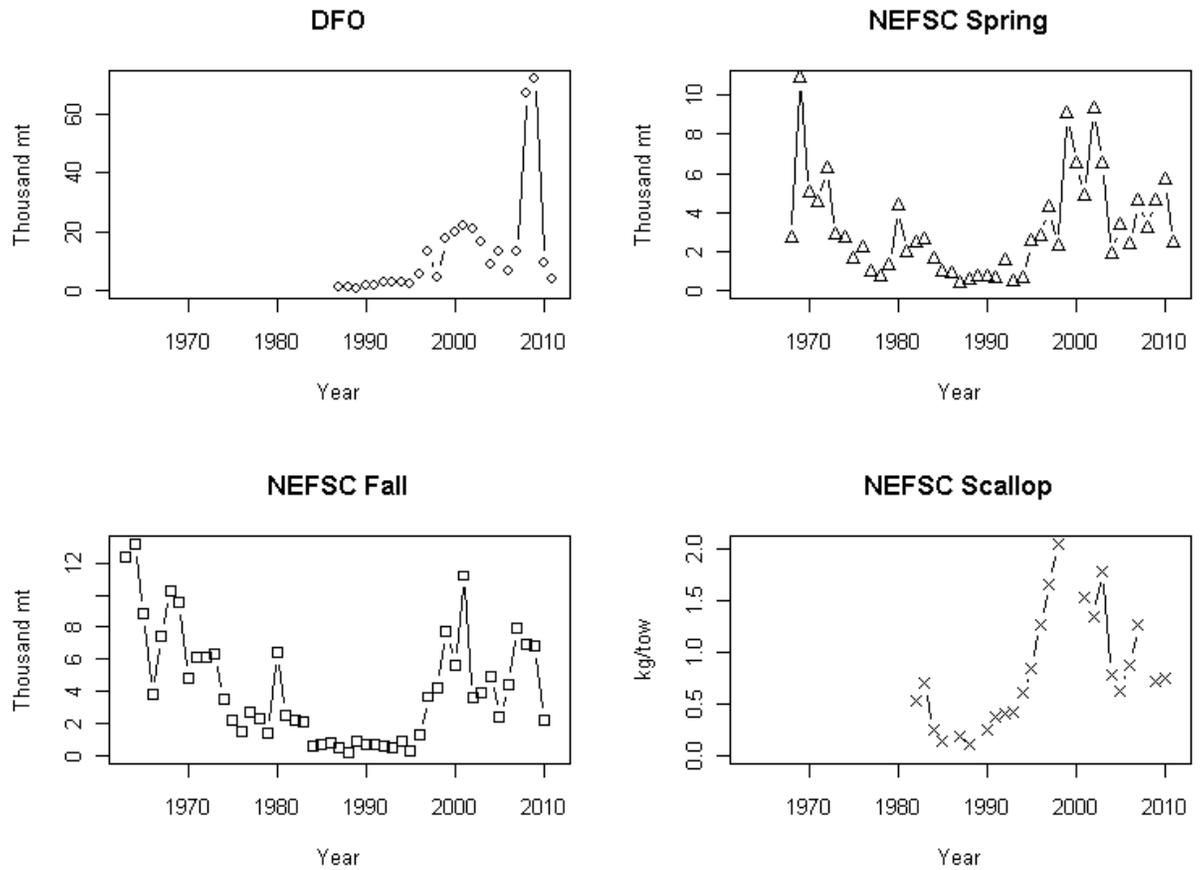
Figure 12b. Survey biomass for yellowtail flounder on Georges Bank in units of thousand metric tons (DFO, NEFSC spring, NEFSC fall, all three are minimum swept area biomass values) or kg/tow (NEFSC scallop, stratified mean catch per tow).
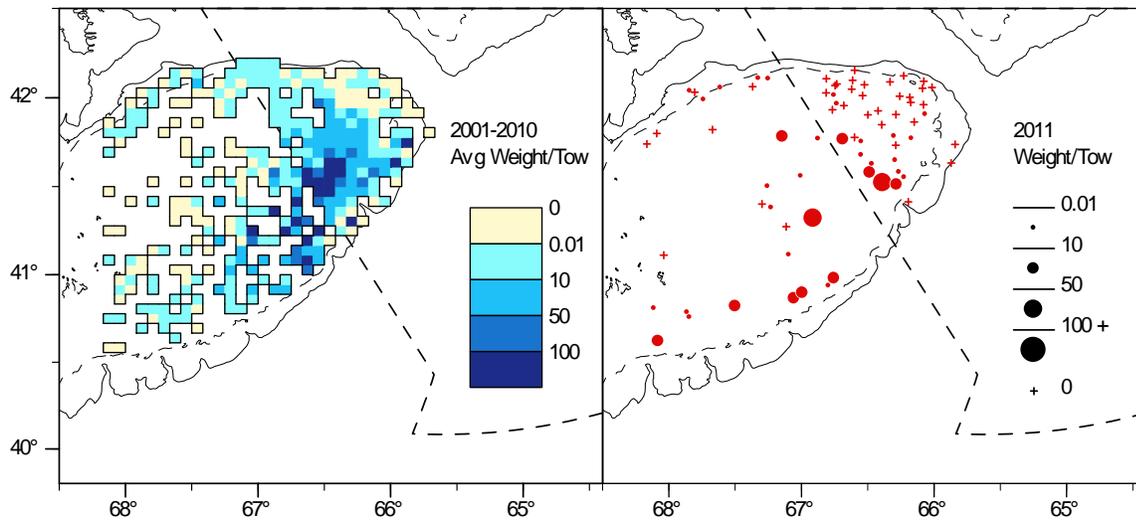
Figure 13a. Catch of yellowtail in weight (kg) per tow for DFO survey. Left panel shows previous 10 year averages, right panel most recent data.
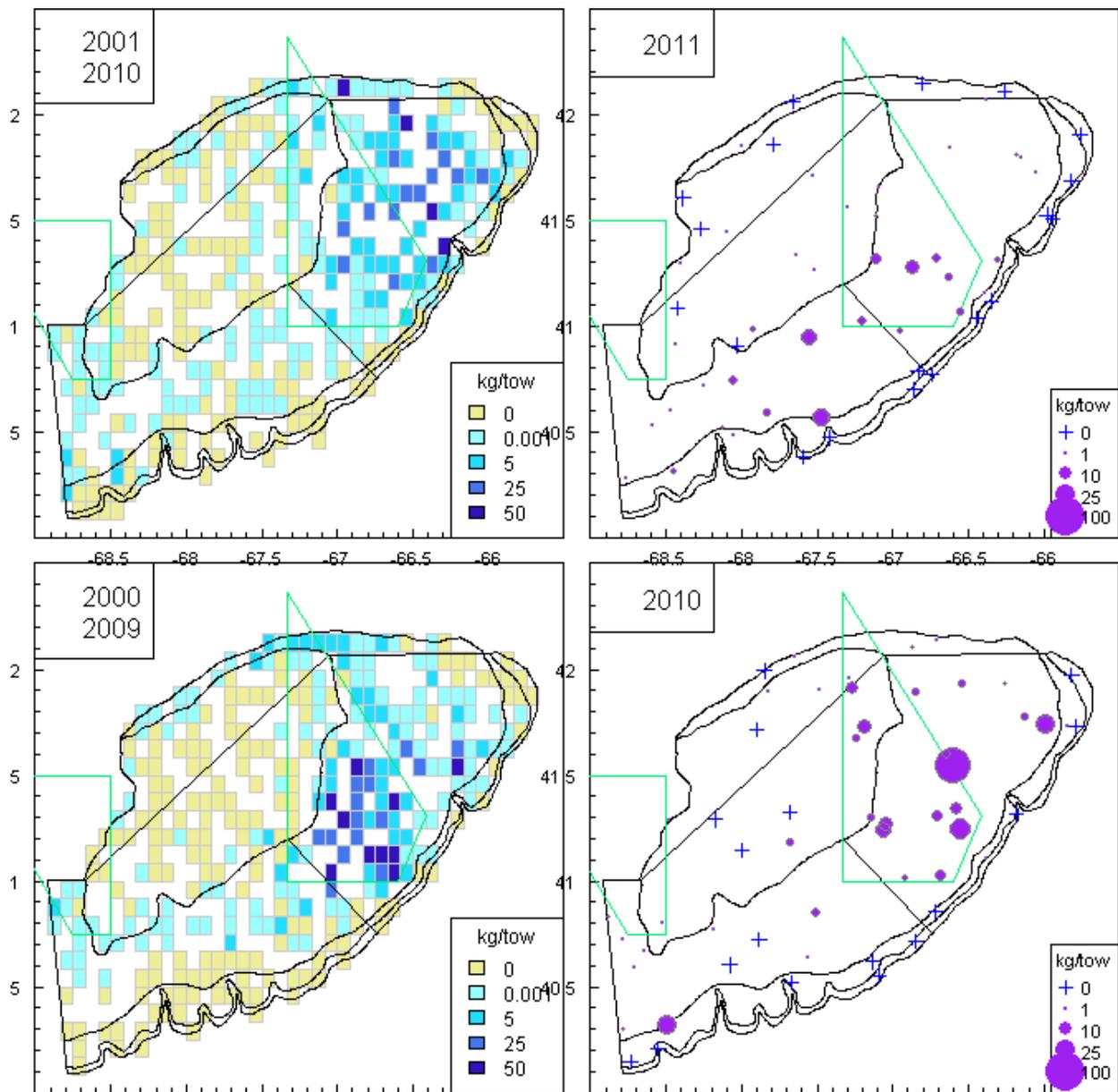
Figure 13b. Catch of yellowtail in weight (kg) per tow for NEFSC spring (top) and NEFSC fall (bottom) surveys. Left panels show previous 10 year averages, right panels most recent data. Note the 2009 - 2011 survey values were adjusted from Bigelow to Albatross IVequivalents by dividing Bigelow catch in weight by 2.244 (spring) or 2.402 (fall).
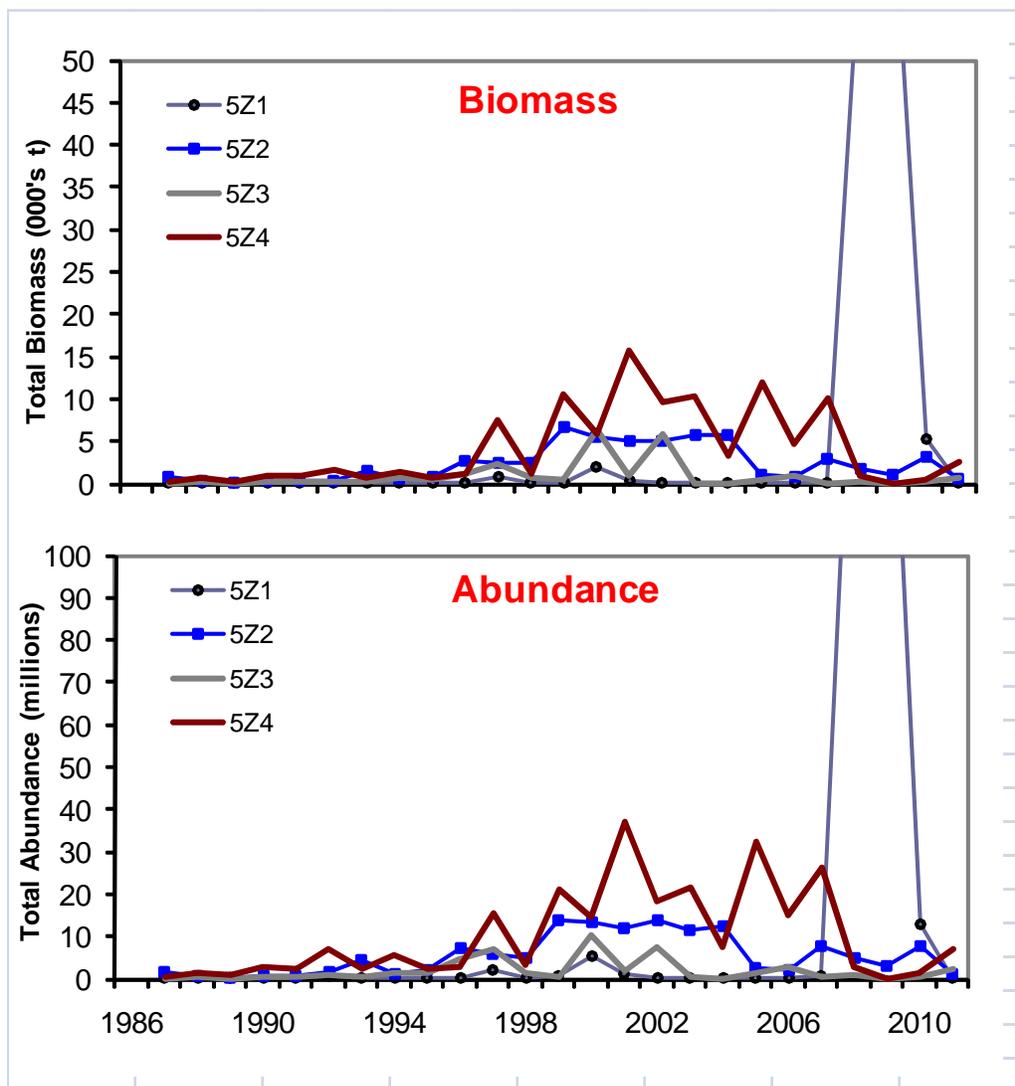
Figure 14a. DFO spring survey estimates of total biomass (top panel) and total number (bottom panel) by stratum area for yellowtail flounder on Georges Bank.
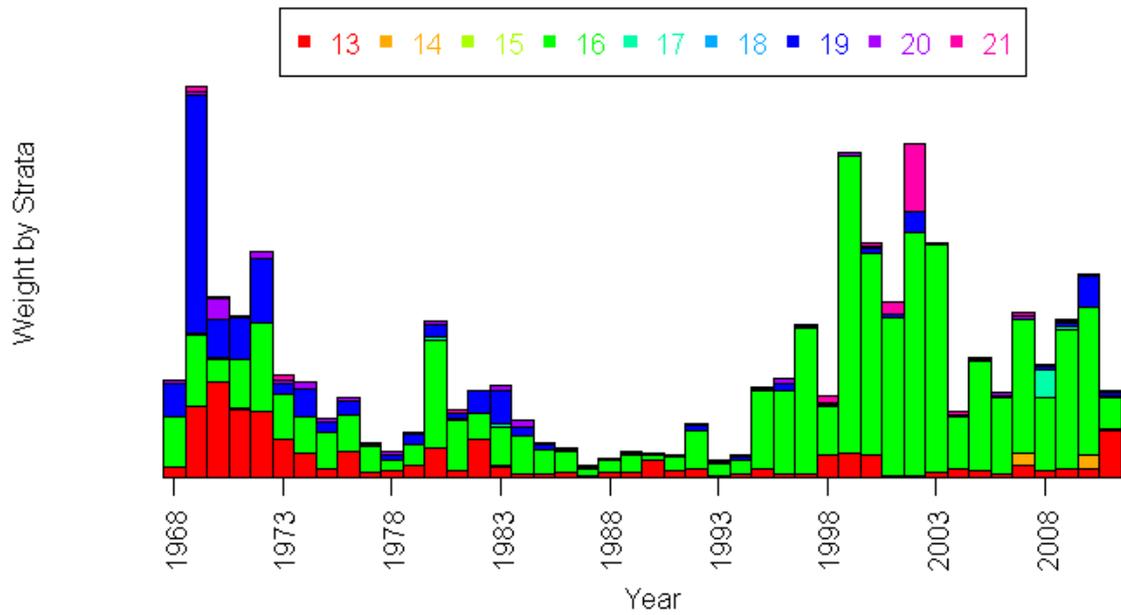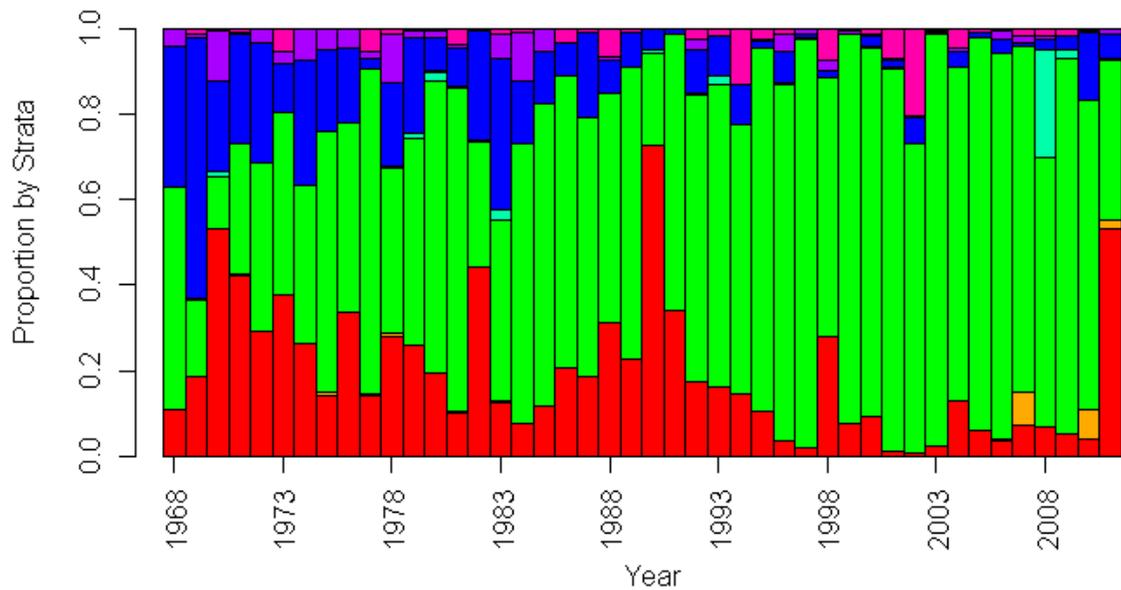
Figure 14b. NEFSC spring survey estimates of total biomass (top panel) and proportion (bottom panel) by stratum for yellowtail flounder on Georges Bank.
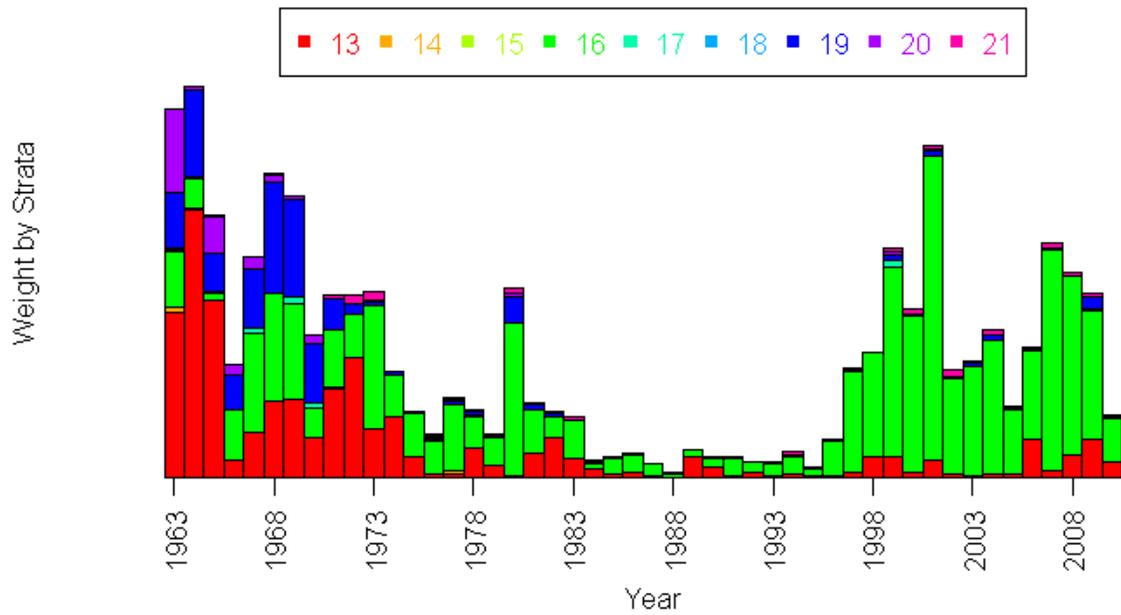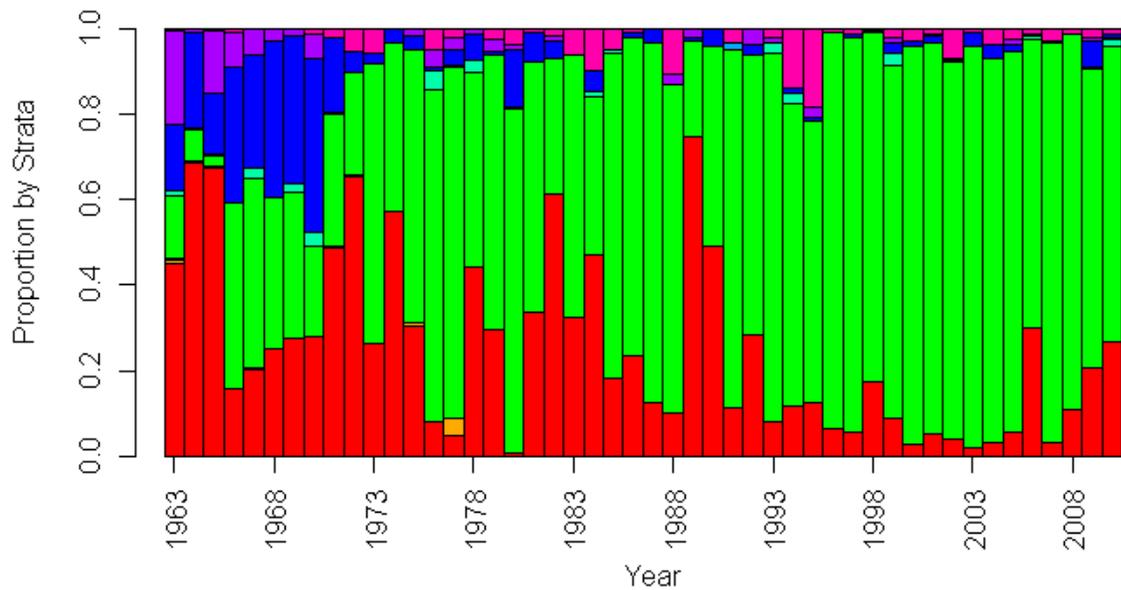
Figure 14c. NEFSC fall survey estimates of total biomass (top panel) and proportion (bottom panel) by stratum for yellowtail flounder on Georges Bank.
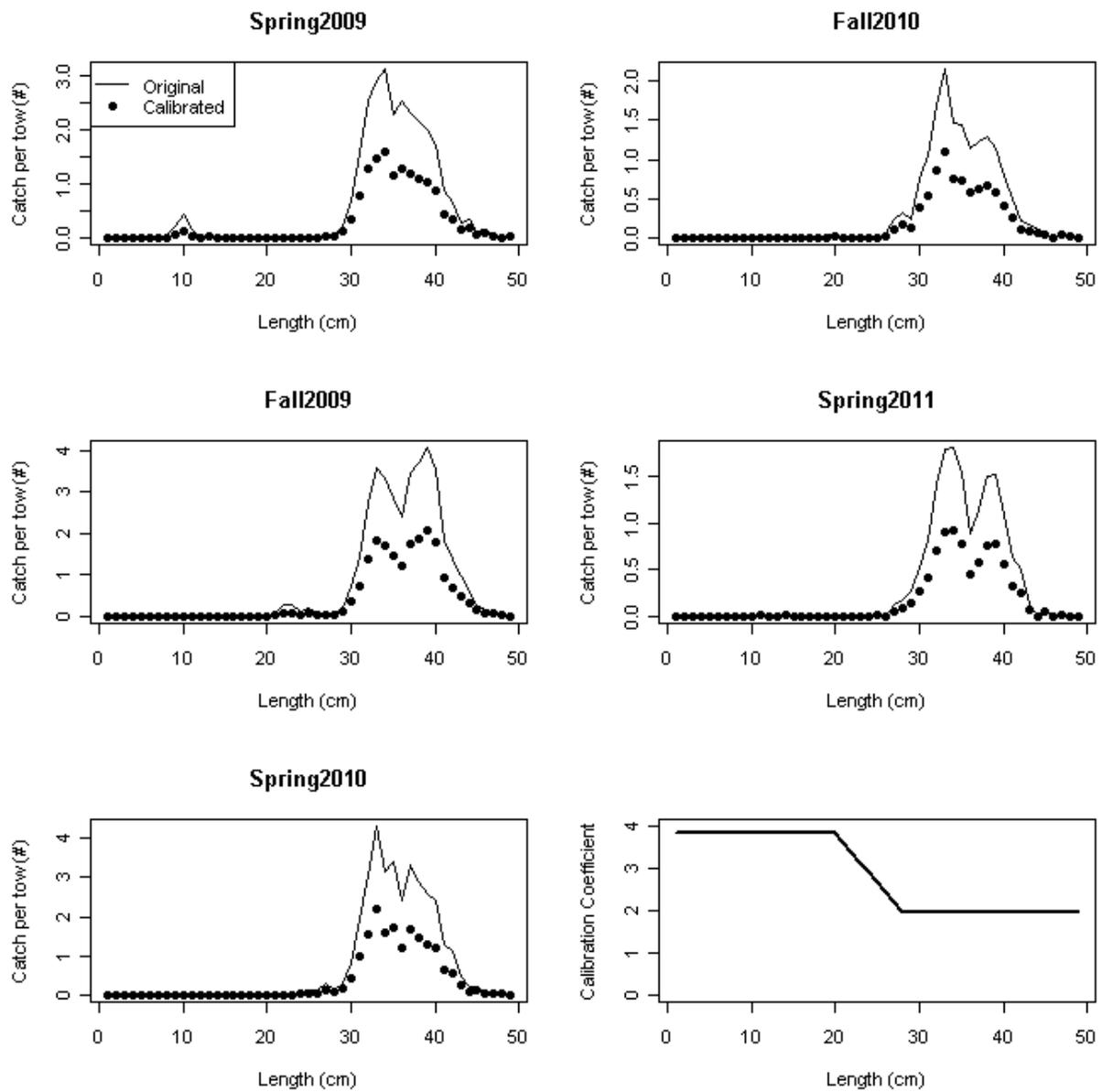
Figure 15. Catch per tow in numbers of fish for the US spring and fall surveys by the FSV Henry B. Bigelow. The lines denote the original observations and the dots the calibrated values converted to RV Albatross IV units. The calibration is calculated using the curve in the lower right panel (Calibrated = Original/Calibration Coefficient).
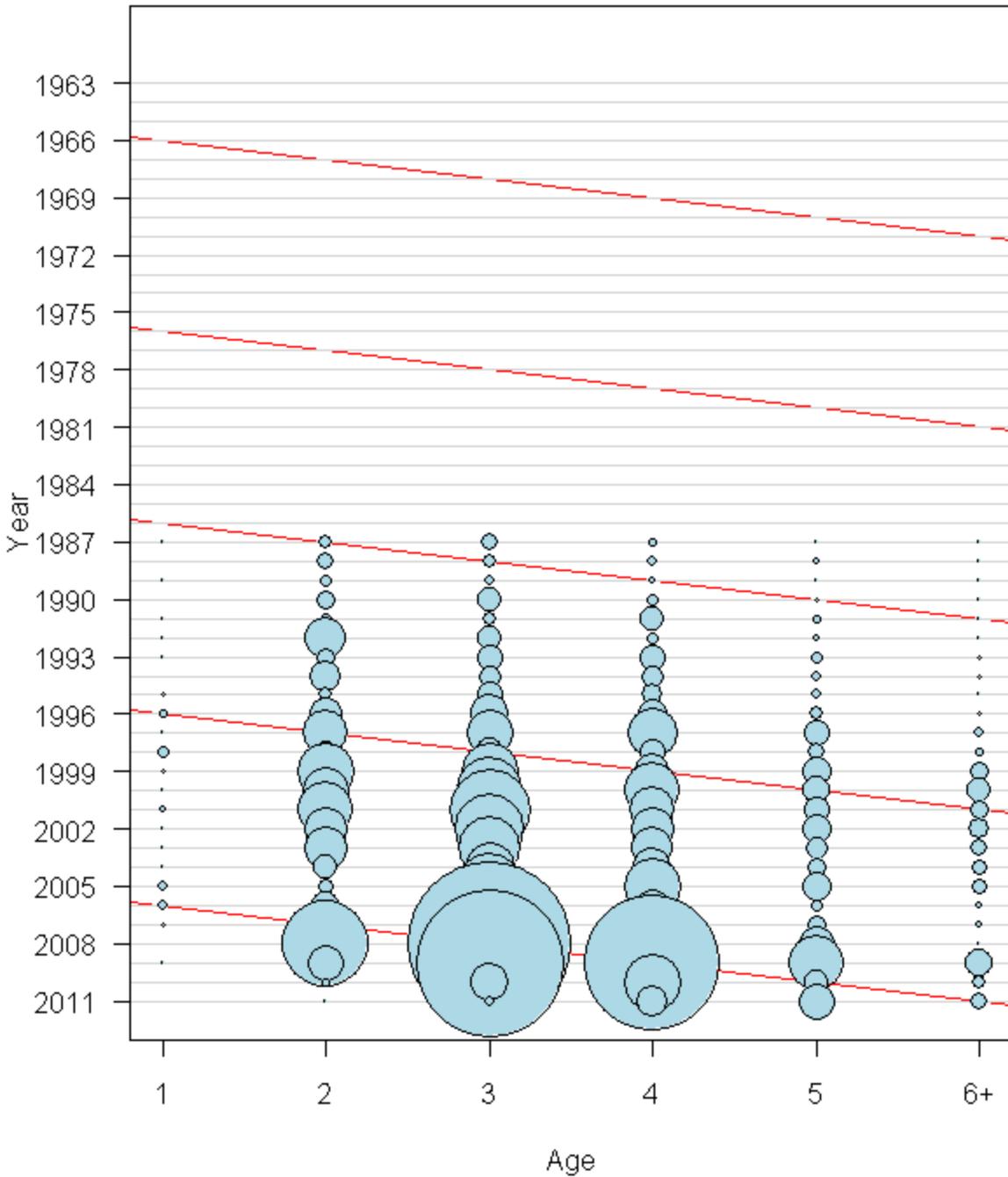
Figure 16a. Age specific indices of abundance for the DFO spring survey including the large tows in 2008 and 2009 (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year classes.

Spring
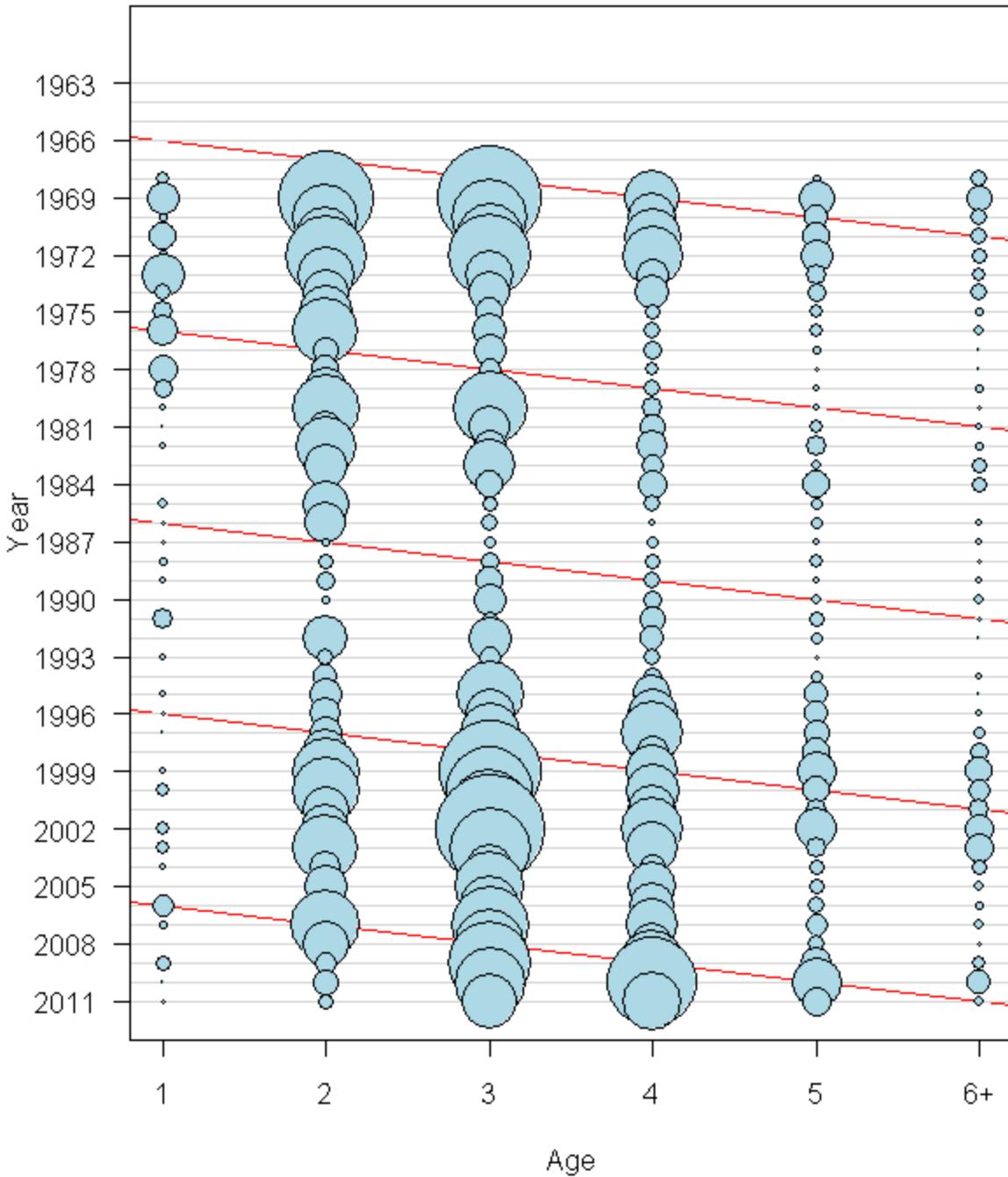
Figure 16b. Age specific indices of abundance for the NMFS spring survey (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year classes.
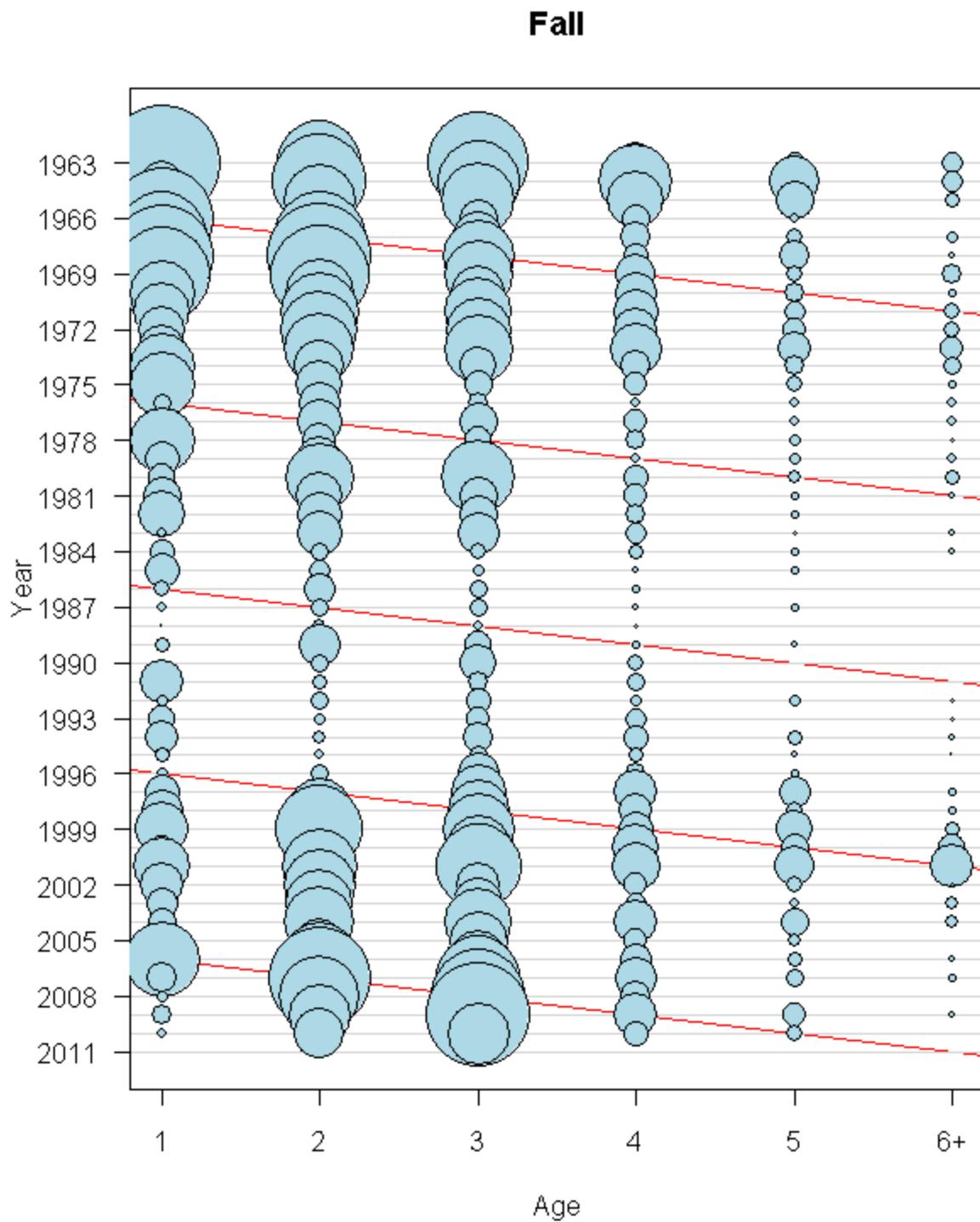
Figure 16c. Age specific indices of abundance for the NMFS fall survey (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year classes.

Scallop
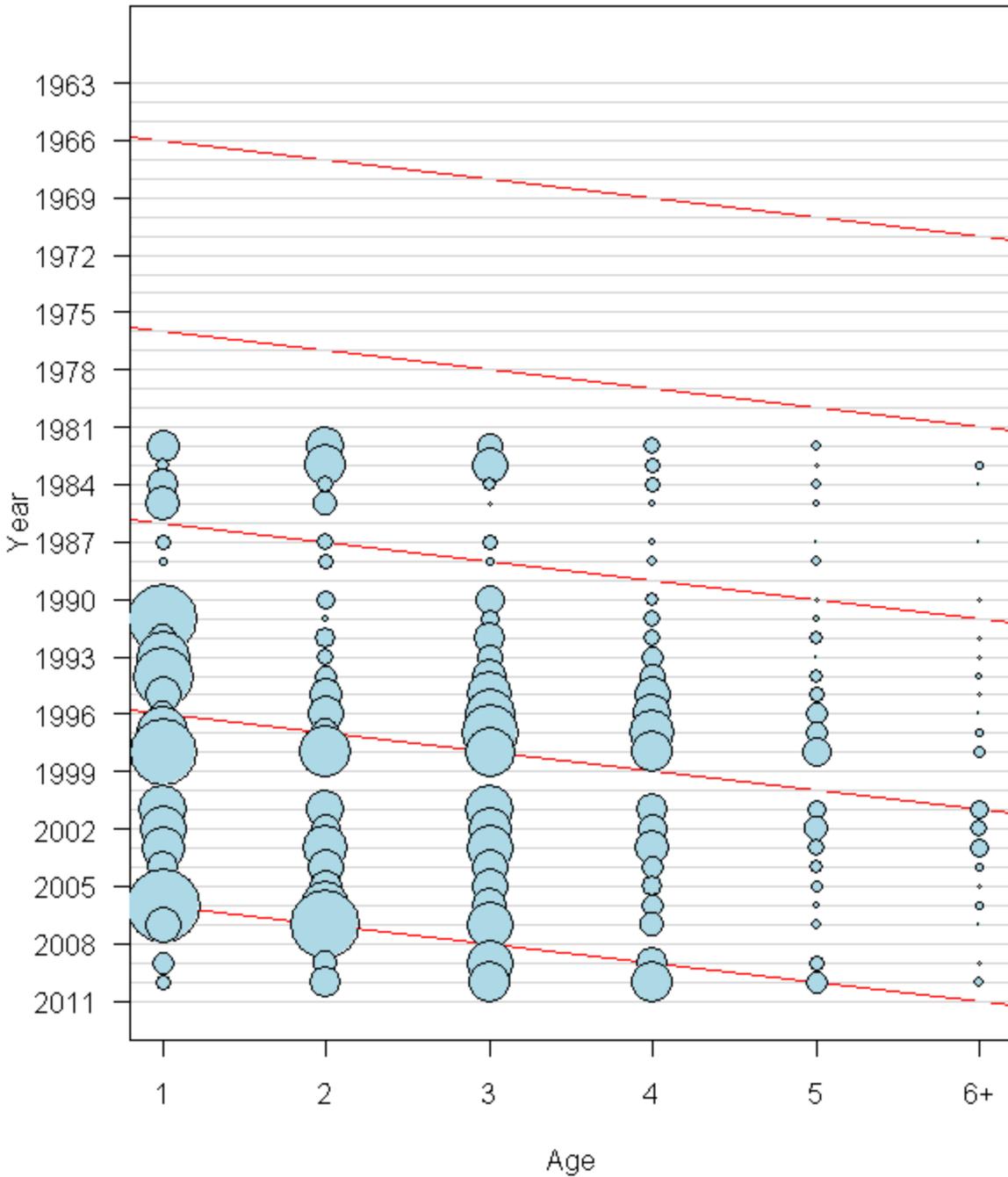
Figure 16d. Age specific indices of abundance for the NMFS scallop survey, note years 1986, 1989, 1999, 2000, and 2008 are not included (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year classes.
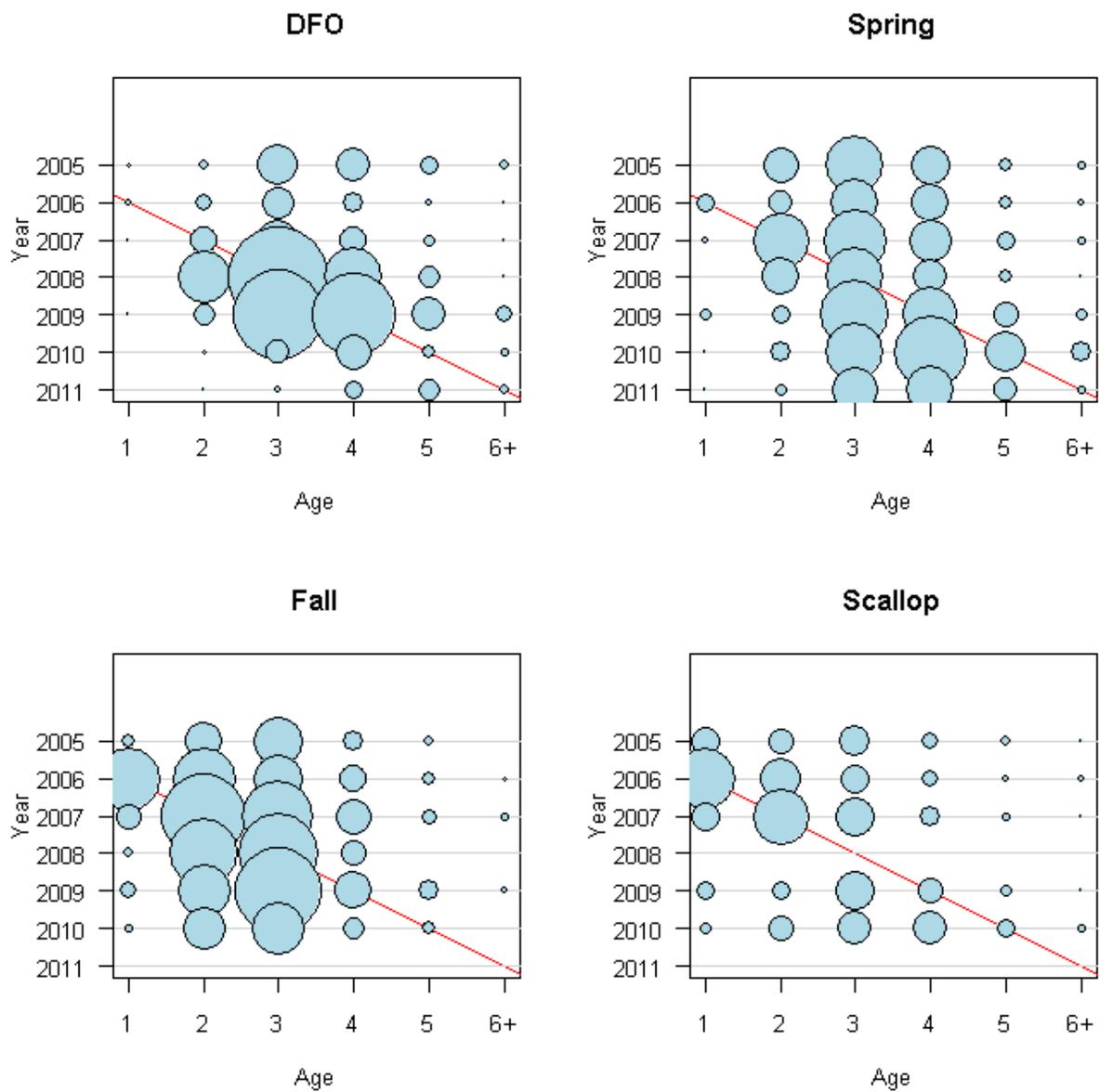
Figure 16e. Age specific indices of abundance for the recent years of the four surveys, note year 2008 is not included in the scallop plot (the area of the bubble is proportional to the magnitude). The red diagonal line denotes the 2005 year class.
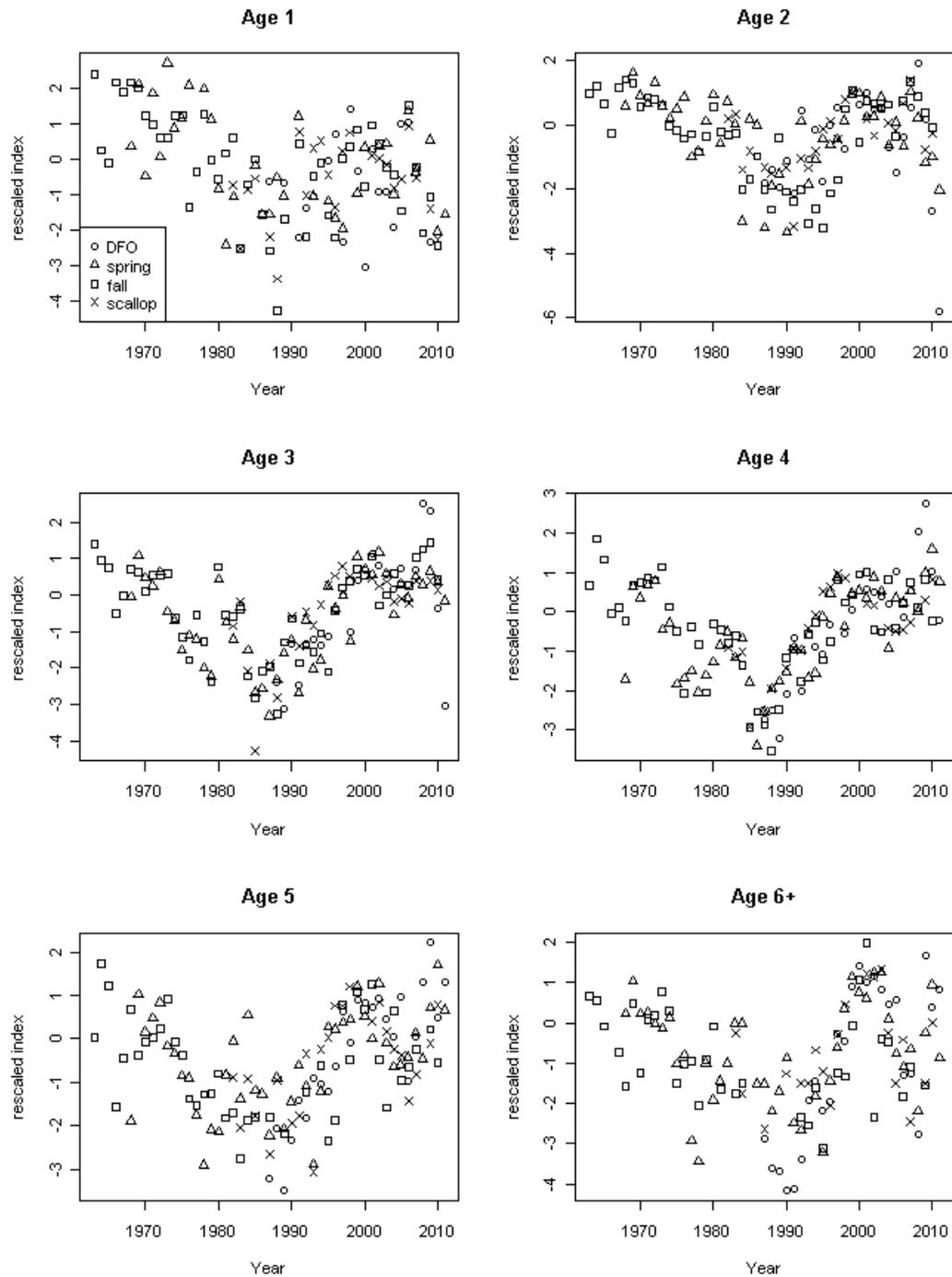
Figure 17. Standardized catch/tow in numbers at age for the four surveys plotted on natural log scale. The standardization was merely the division of each index value by the mean of the associated time series. Circles denote the DFO survey, triangles the NEFSC spring survey, squares the NEFSC fall survey, and crosses the NEFSC scallop survey.

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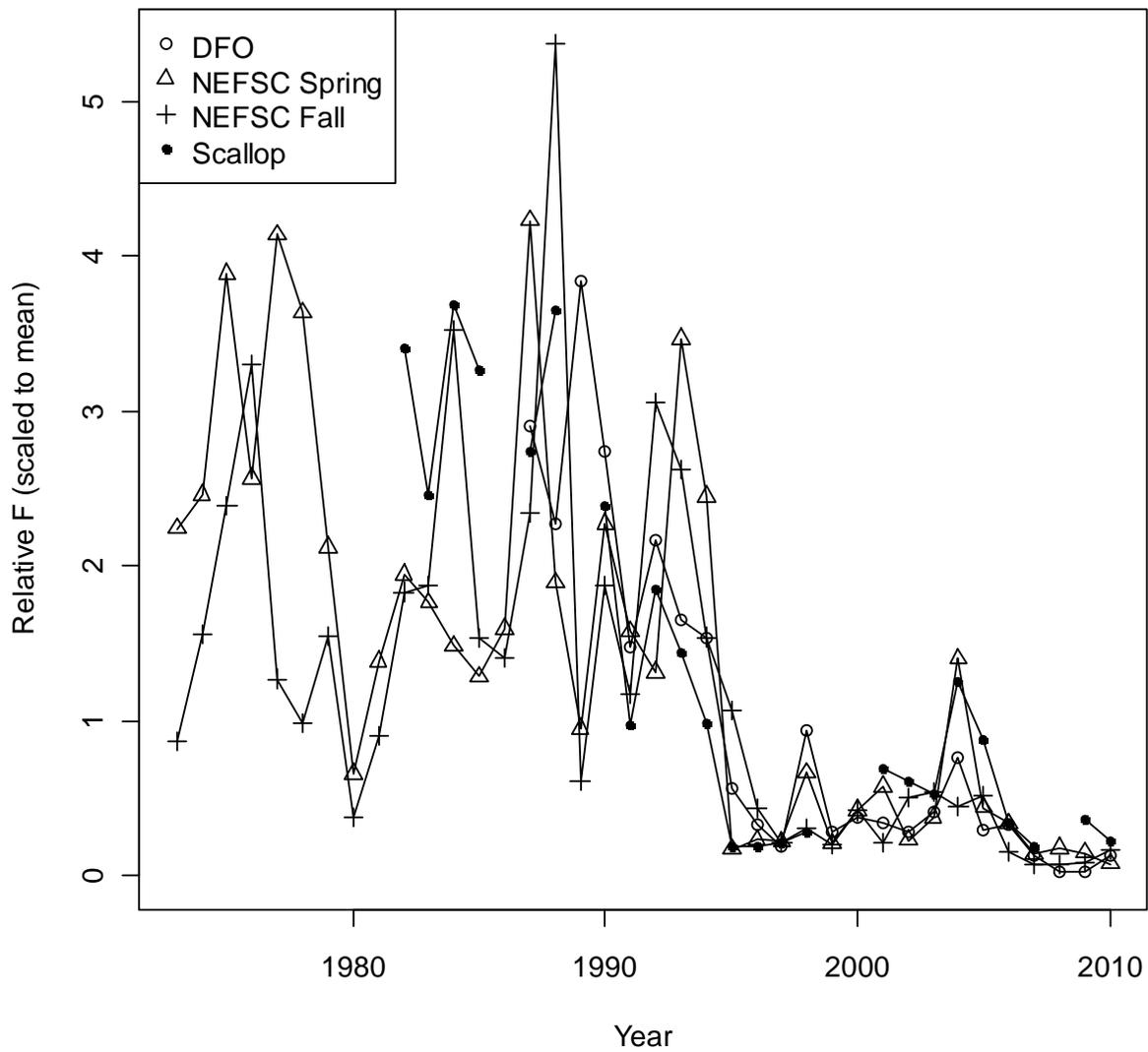
Figure 18. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2010.
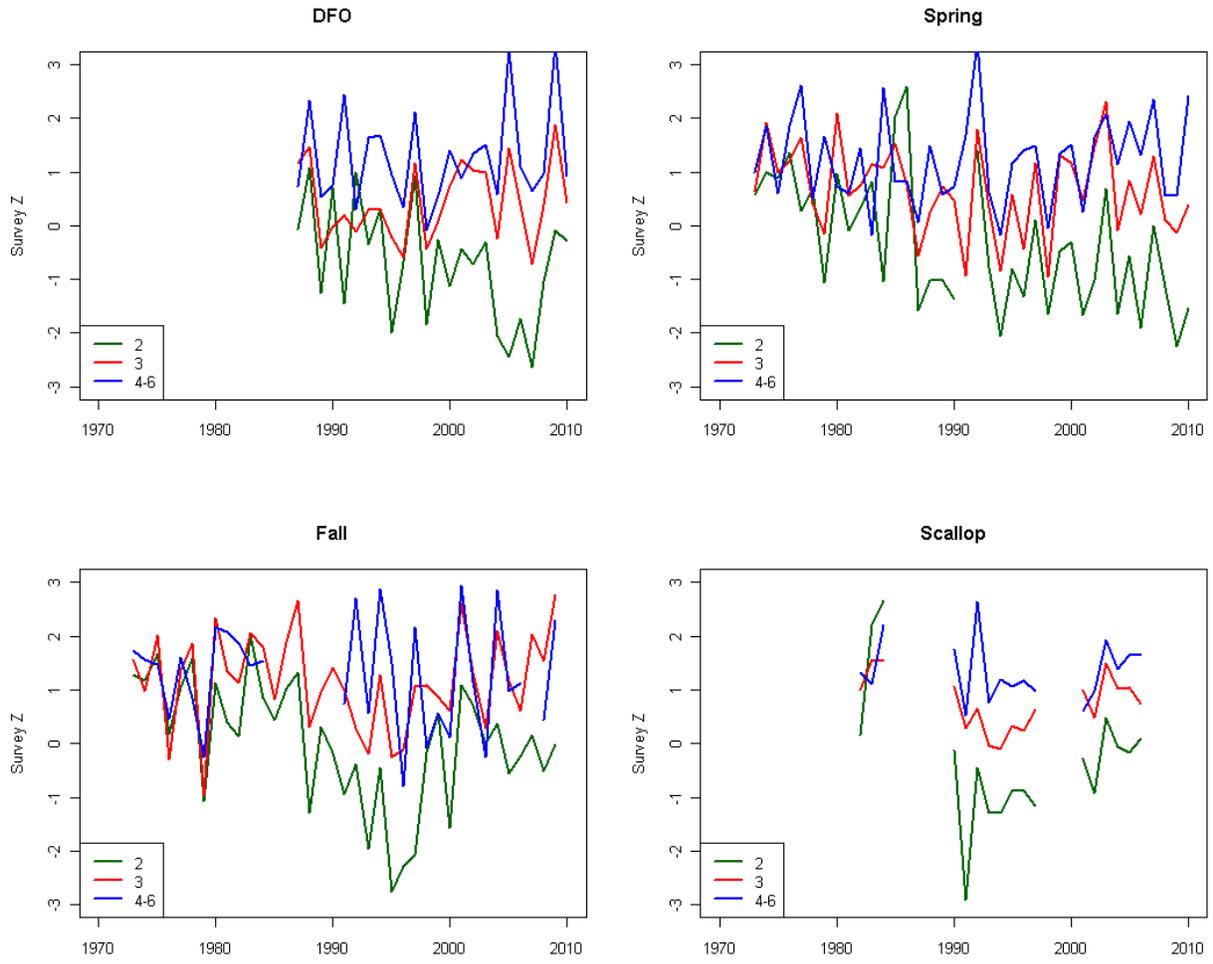
Figure 19. Trends in total mortality (Z) for ages 2, 3, and 4-6 from the four surveys.

Bridge Building
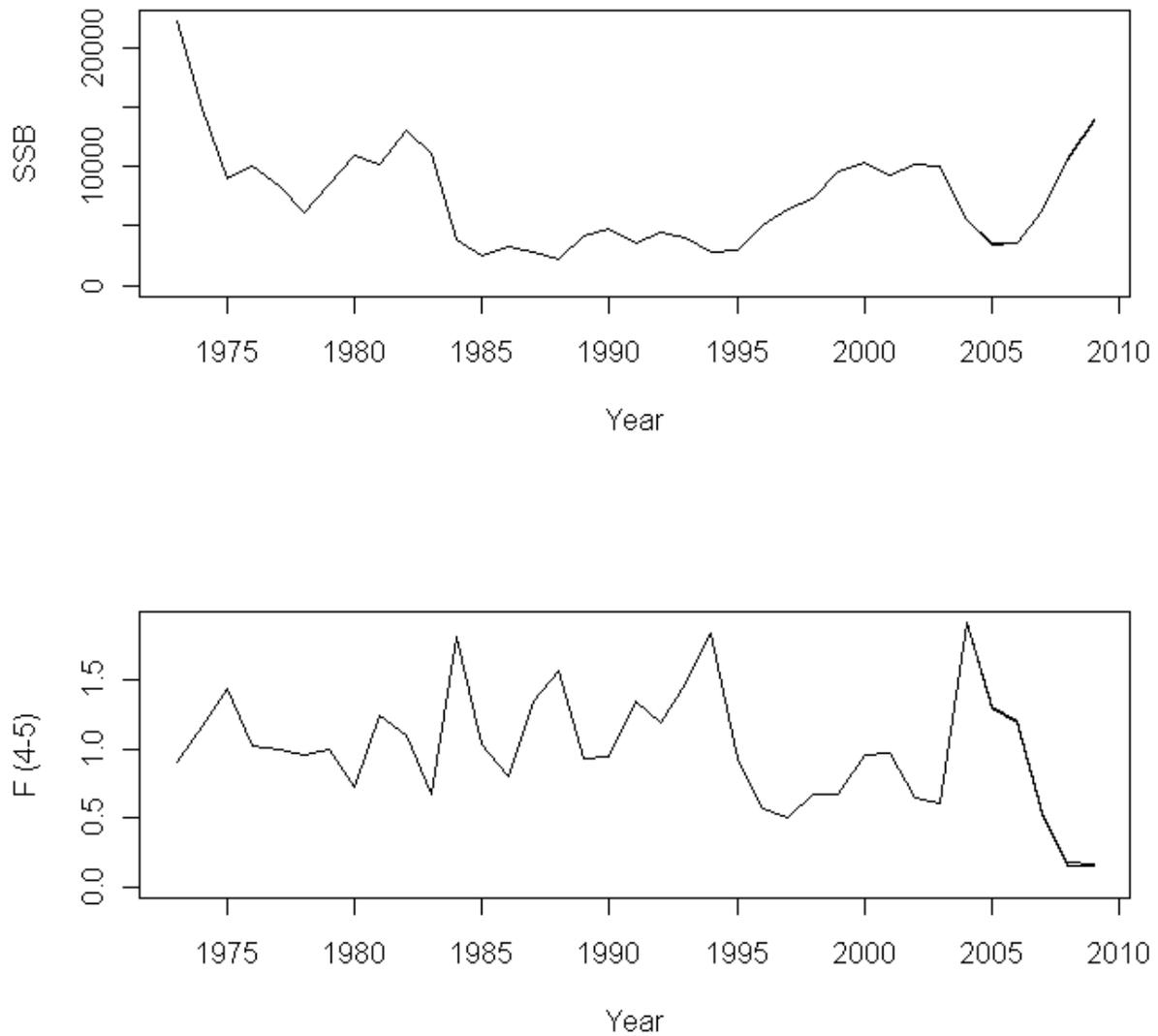
Figure 20. Spawning stock biomass (mt, top panel) and fishing mortality rate (ages 4+, bottom panel) for the TRAC 2010 assessment and updated US catch for years 2007-2009 (the two lines are so similar it is difficult to distinguish them).
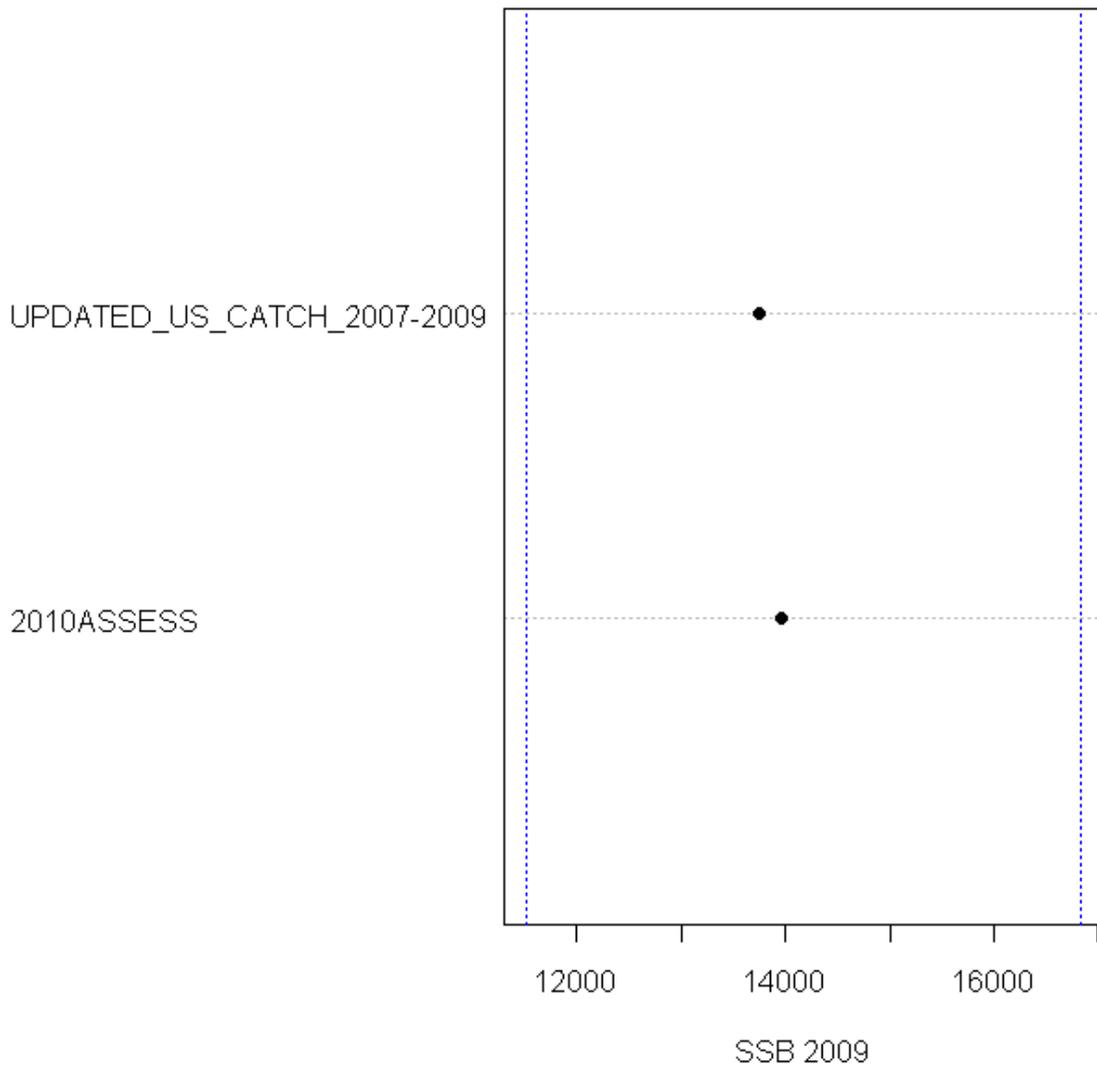
Figure 21a. Spawning stock biomass (mt) in 2009 from the TRAC 2010 assessment and updated US catch for years 2007-2009. The vertical dotted blue lines denote the 80% confidence interval for the run with updated US catch.
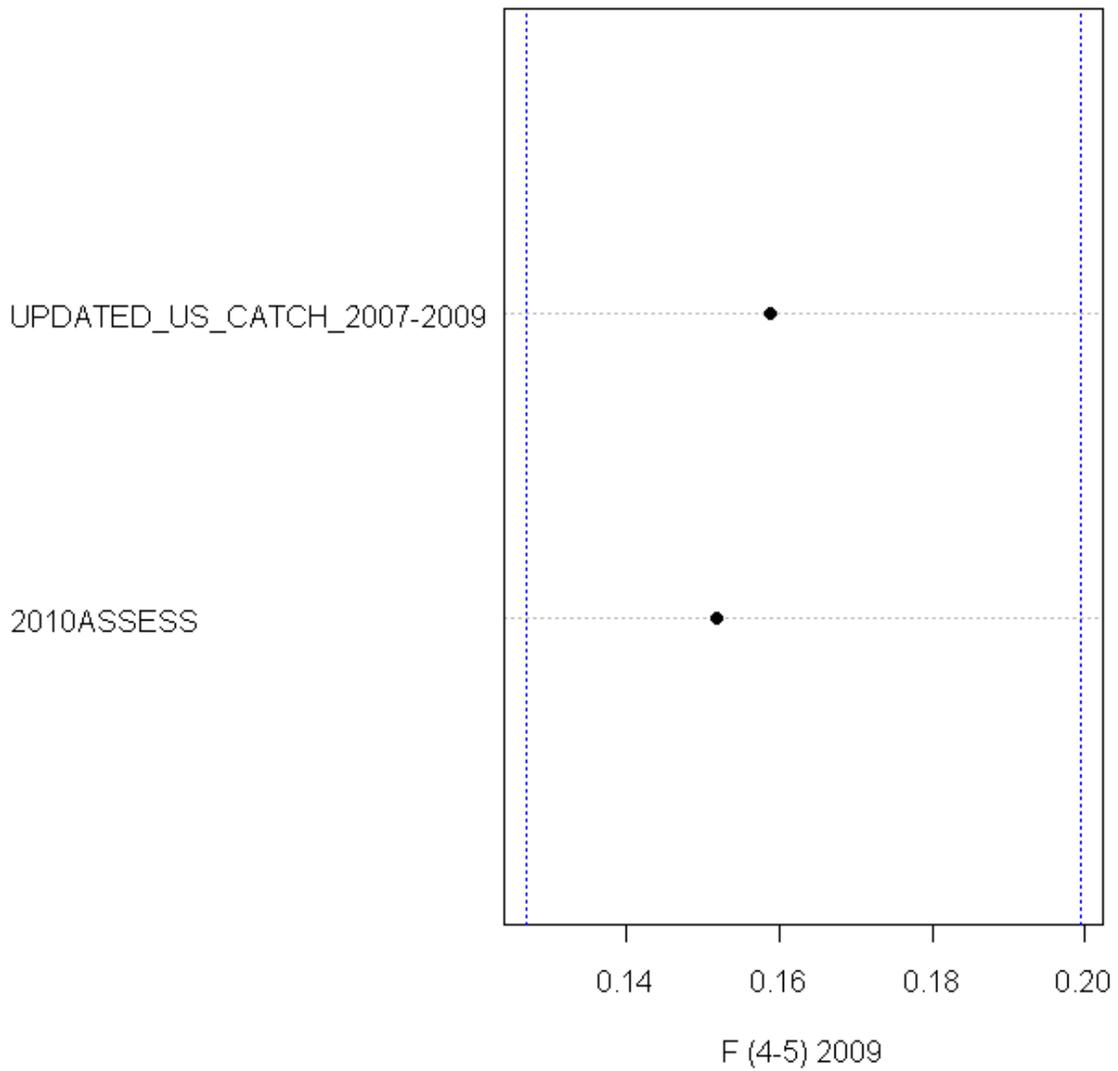
Figure 21b. Fishing mortality rate (ages 4+) in 2009 from the TRAC 2010 assessment and updated US catch for years 2007-2009. The vertical dotted blue lines denote the 80% confidence interval for the run with updated US catch.
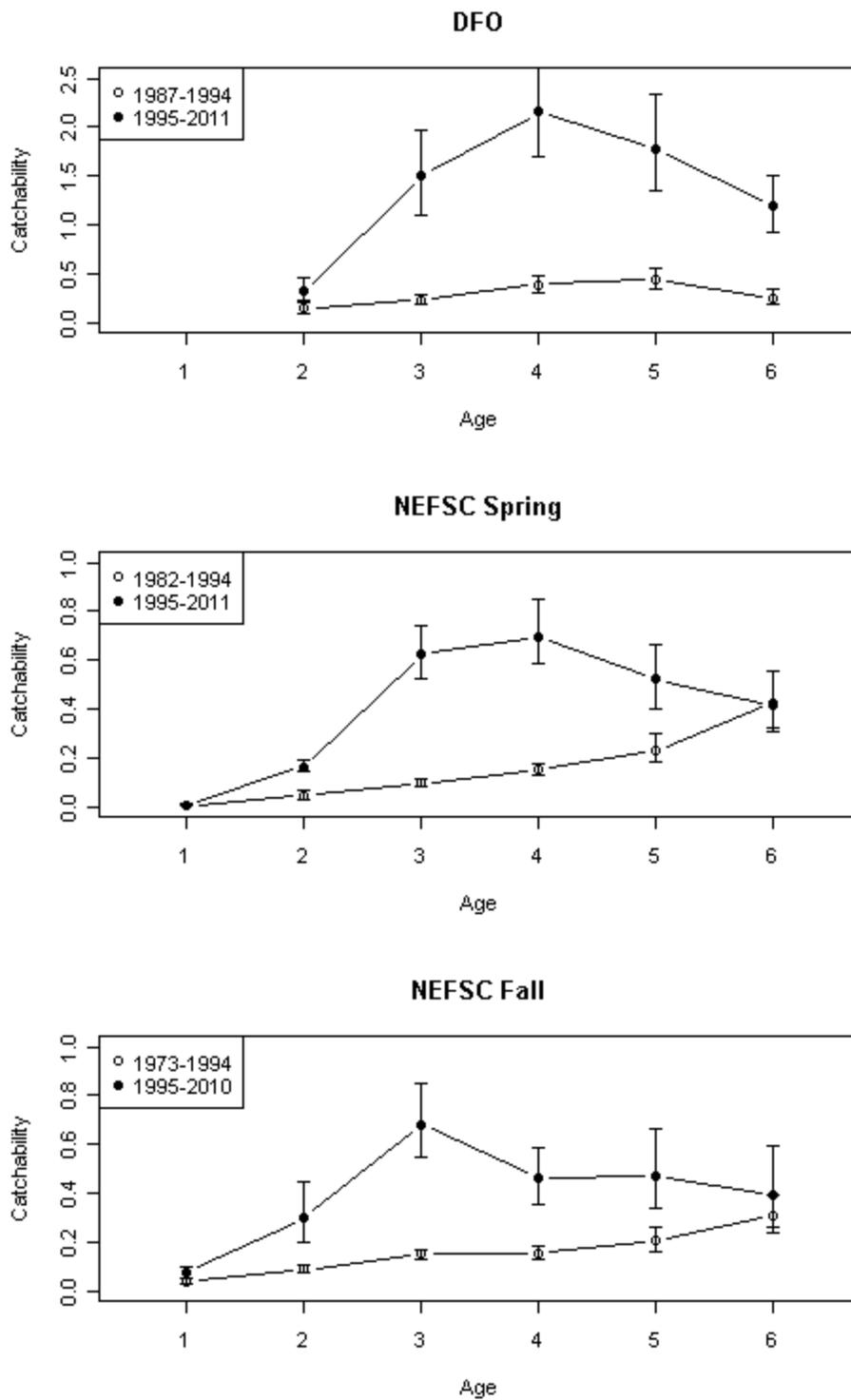
Figure 22. Catchability coefficients (q) from the Split Series VPA with bootstrapped 80% confidence intervals.
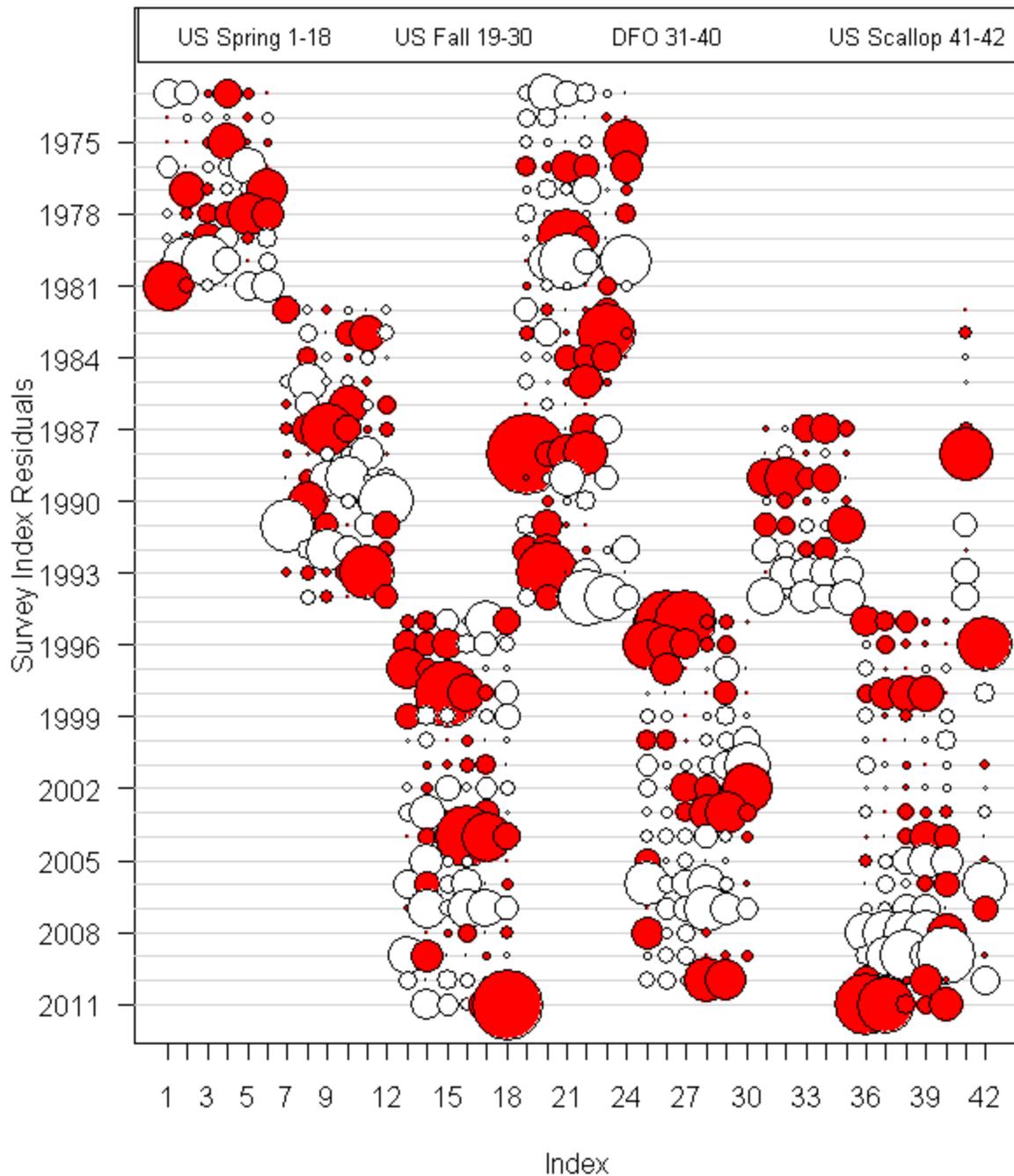
Figure 23. Age by age residuals from the Split Series VPA for log scale predicted minus observed population abundances, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The red symbols denote negative residuals, and white symbols denote positive residuals.

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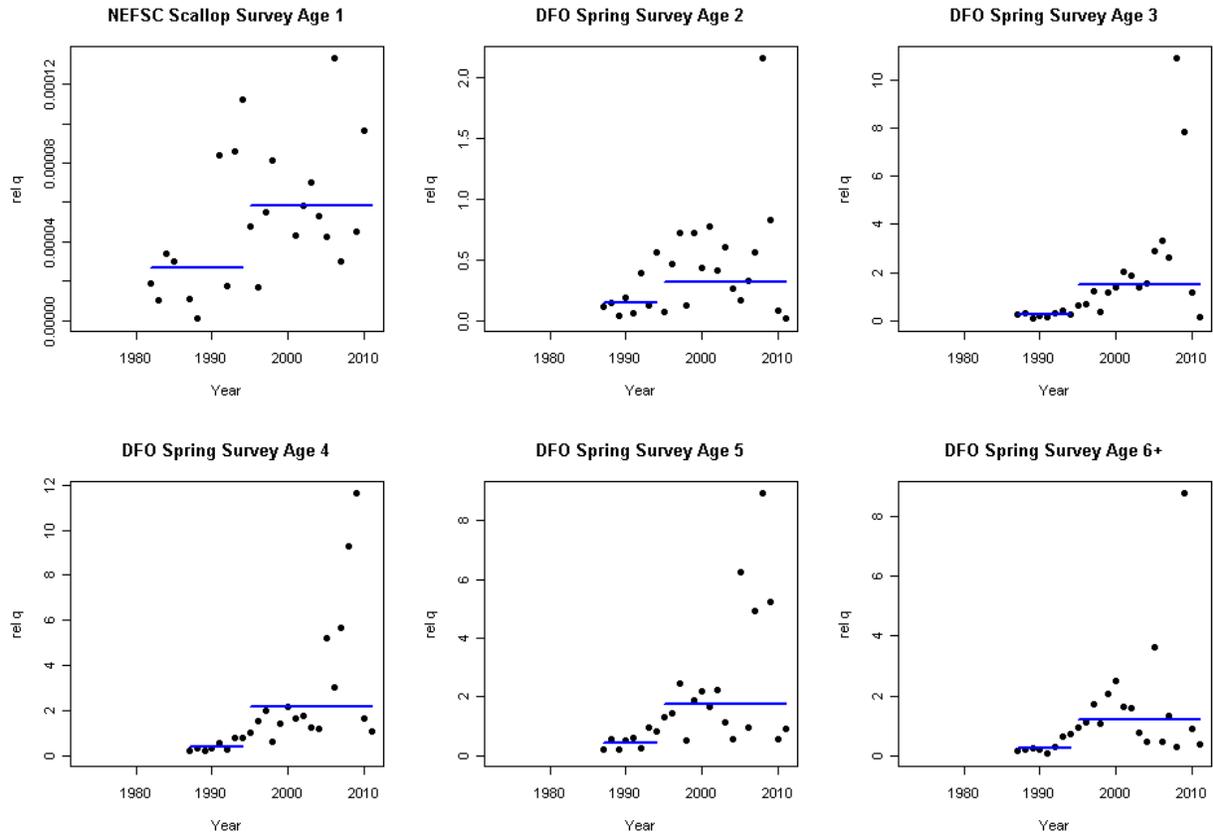
Figure 24a. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC scallop survey at age 1 and the DFO survey at ages 2 through 6+. The relative q values are computed as the observed survey value (as a minimum swept area estimate) divided by the population abundance at that age at the start of that year (no adjustment for timing of the survey).
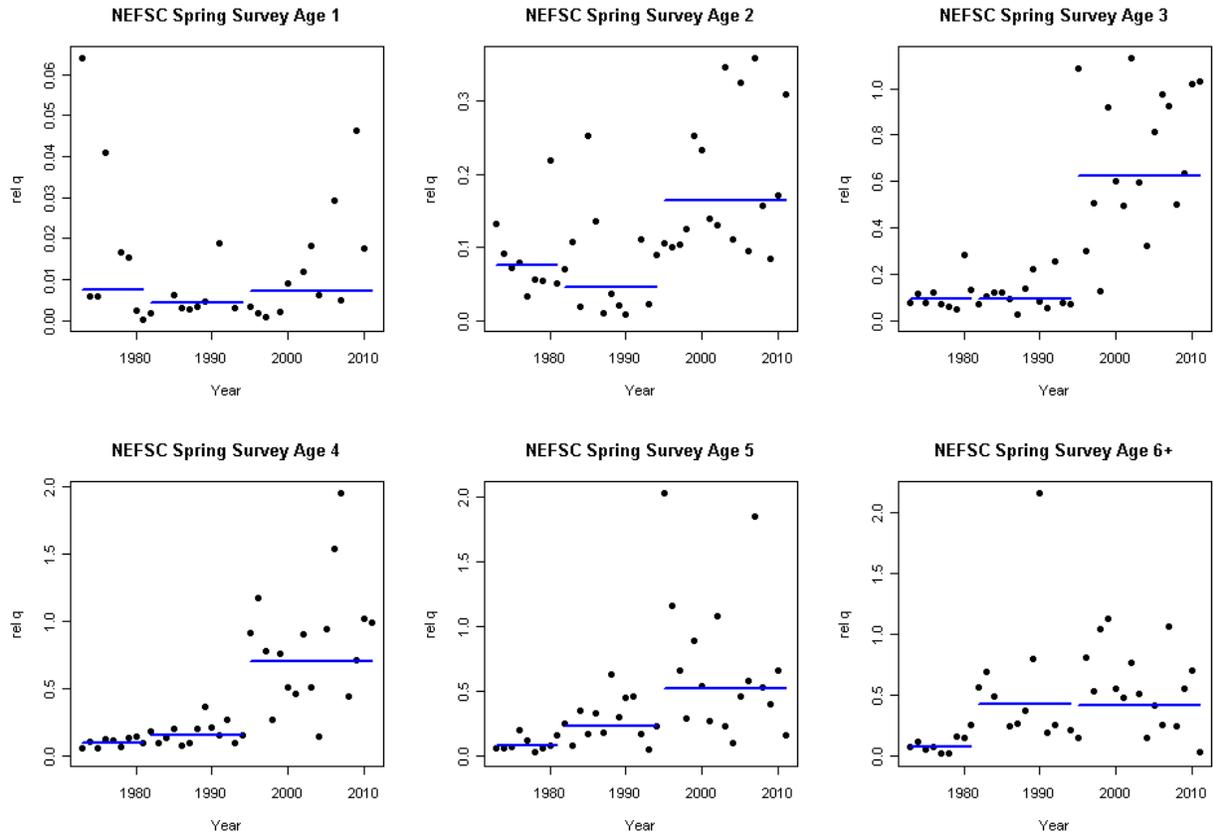
Figure 24b. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC spring survey.
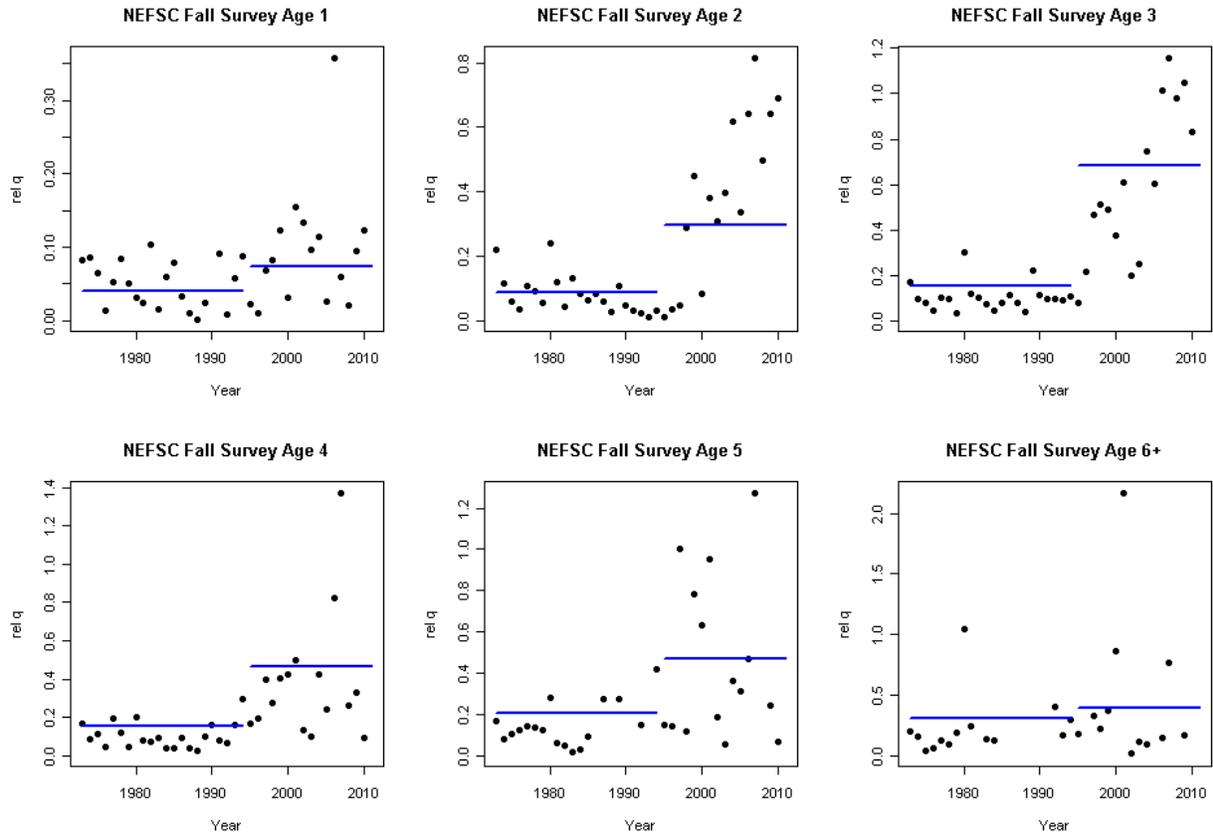
Figure 24c. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC fall survey.
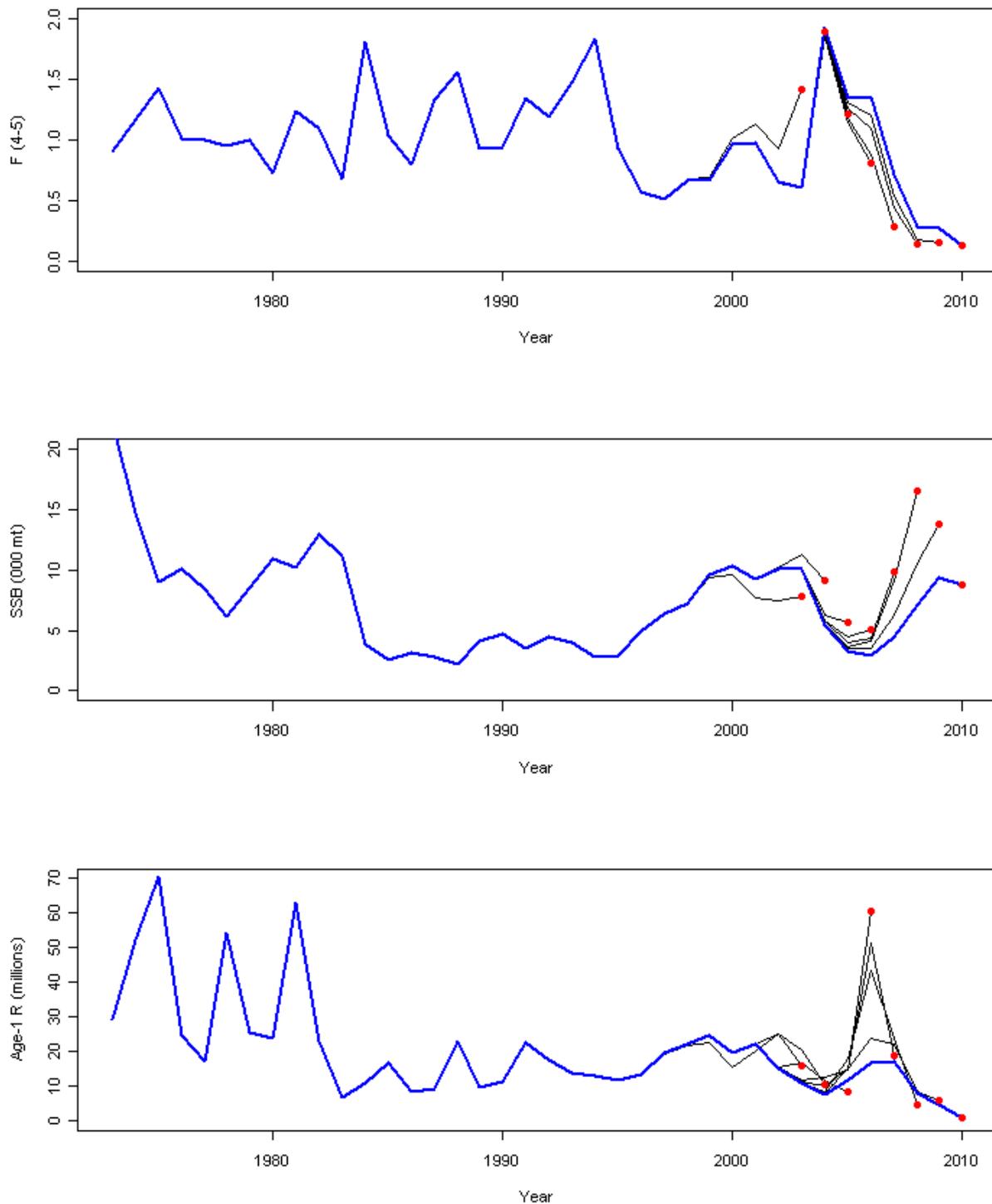
Figure 25a. Retrospective analysis of Georges Bank yellowtail flounder from the Split Series VPA for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age-1 recruitment (lower panel).
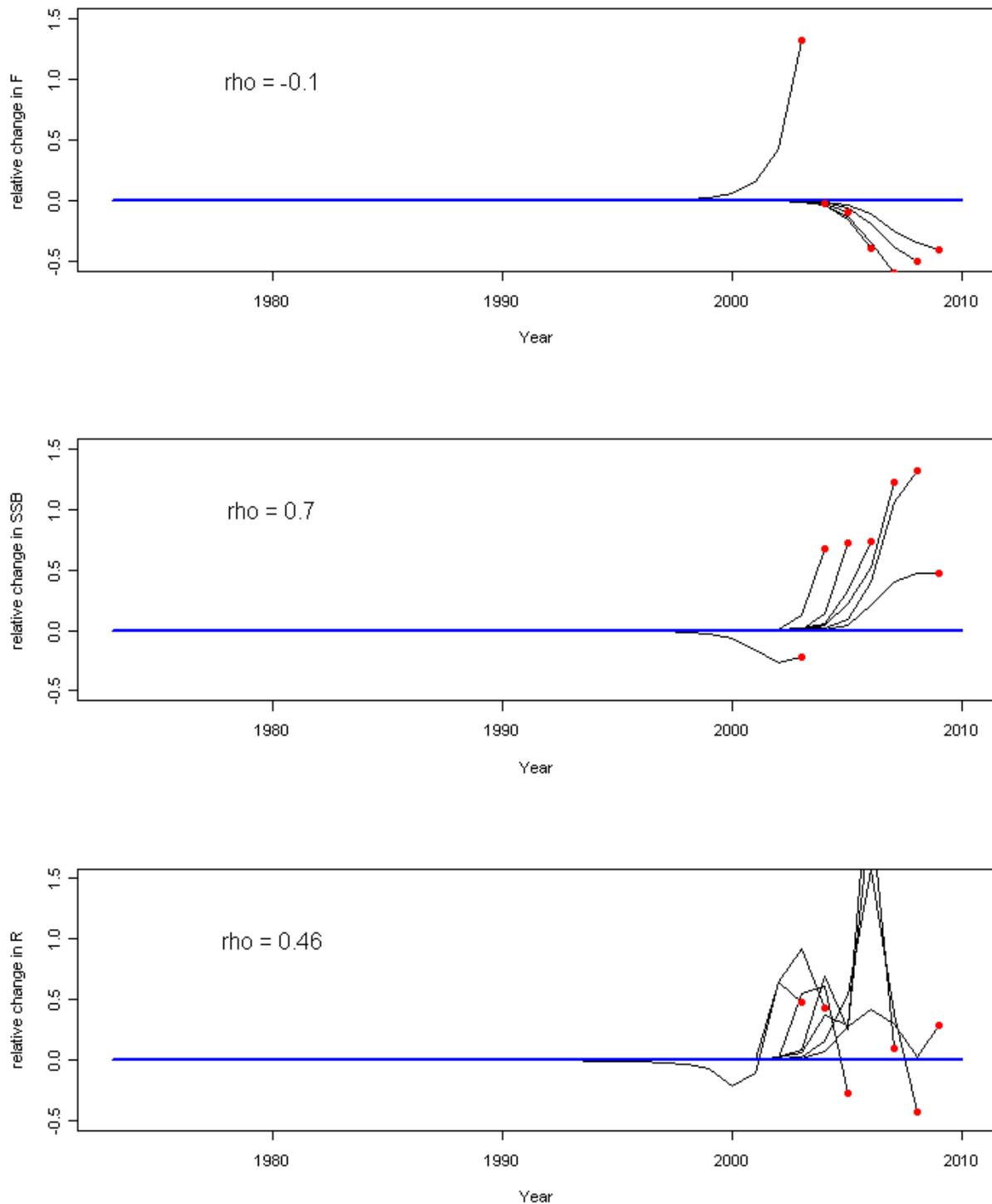
Figure 25b. Relative retrospective plots for Georges Bank yellowtail flounder from Split Series VPA with Mohn's rho calculated from seven year peel for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age-1 recruitment (lower panel).
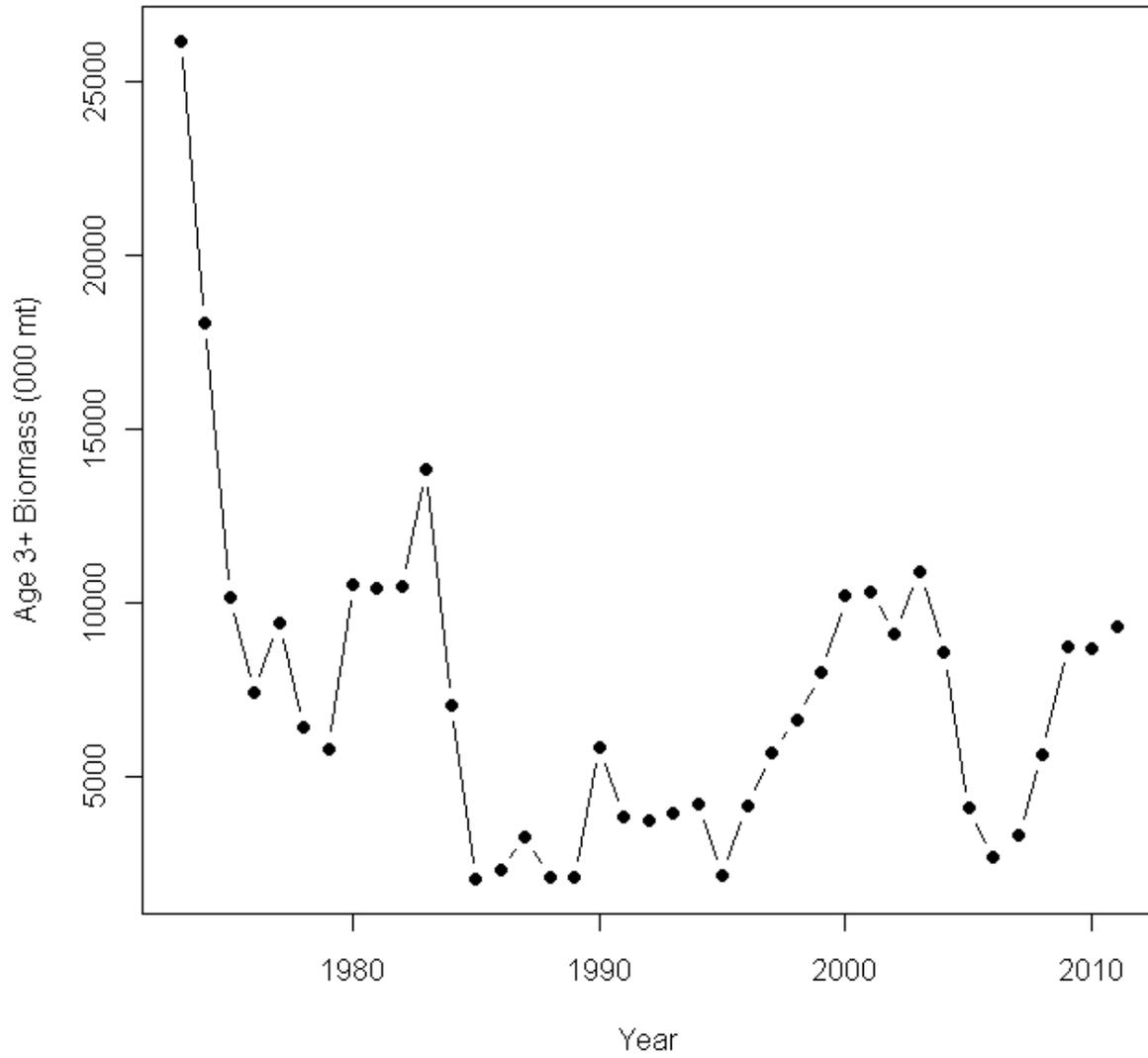
Figure 26. Adult biomass (ages 3+, Jan-1) from the Split Series VPA.
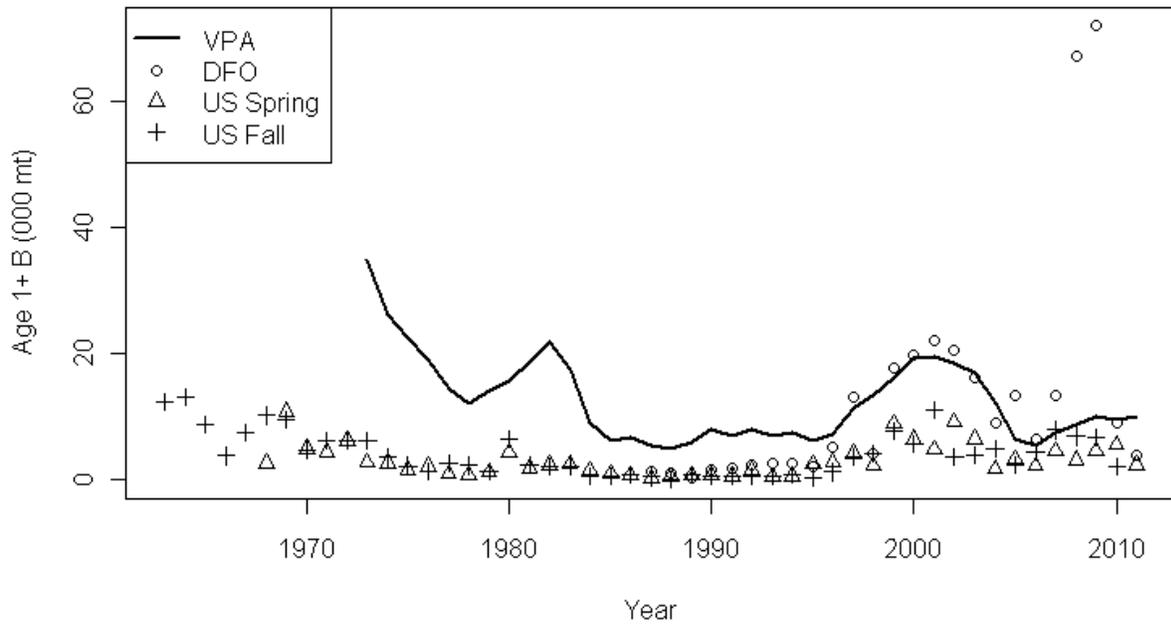
Figure 27. Jan-1 age 1+ biomass estimated by the split series VPA and from the three groundfish surveys in minimum swept area values.
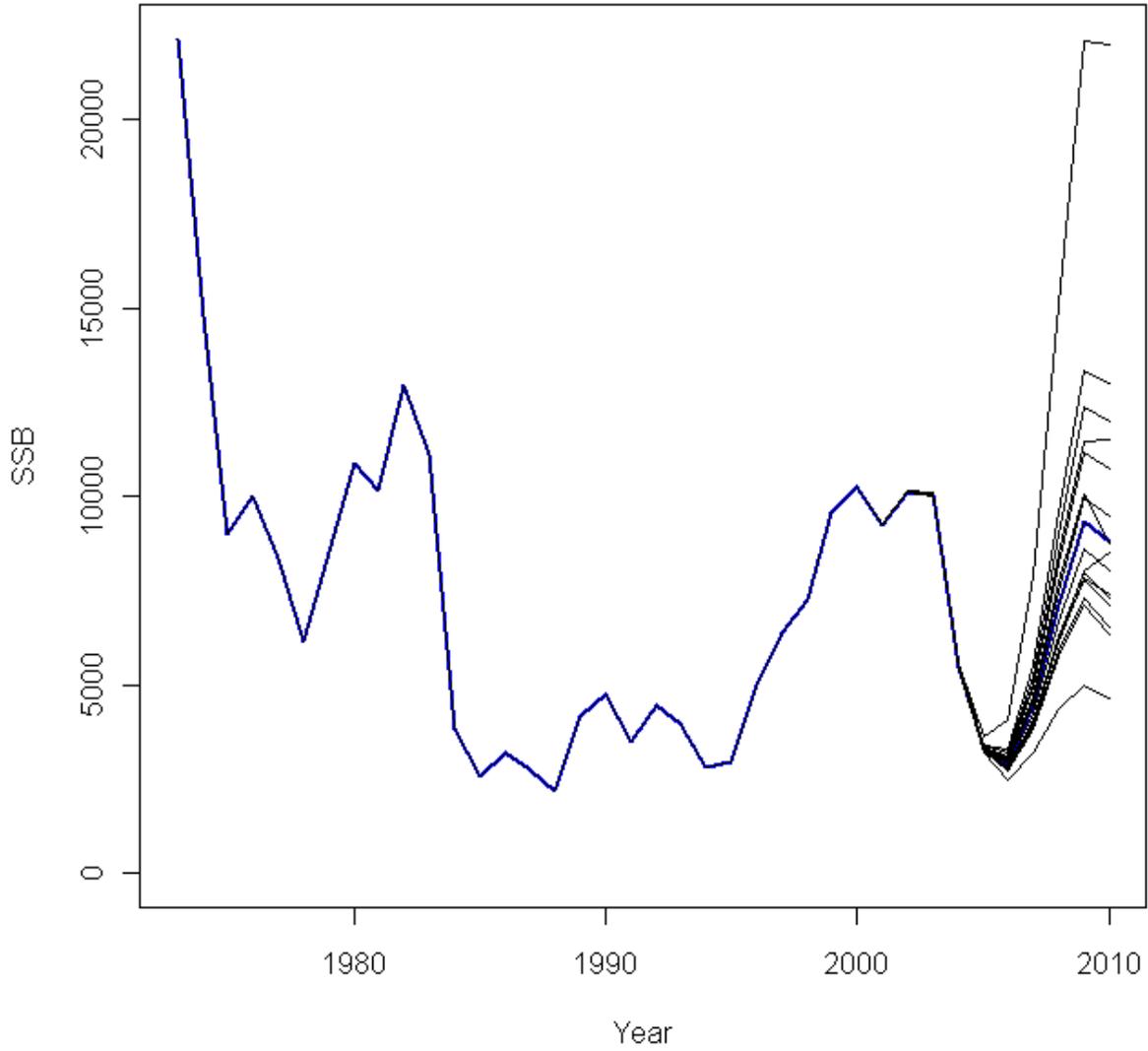
Figure 28a. Spawning stock biomass (mt) from the Split Series VPA (heavy blue line) and 16 sensitivity runs (black lines).
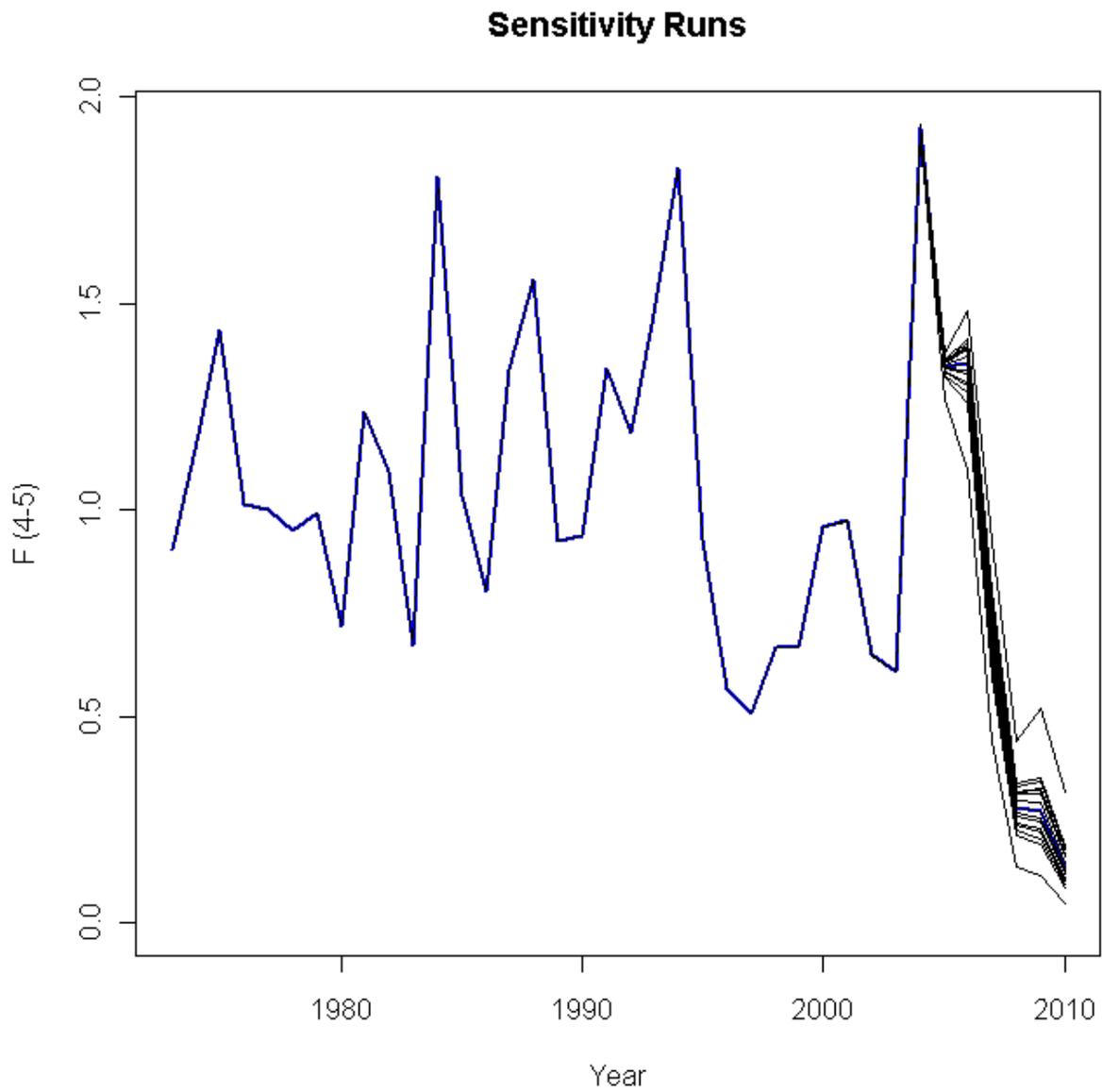
Figure 28b. Fishing mortality rate (ages 4+) from the Split Series VPA (heavy blue line) and 16 sensitivity runs (black lines).
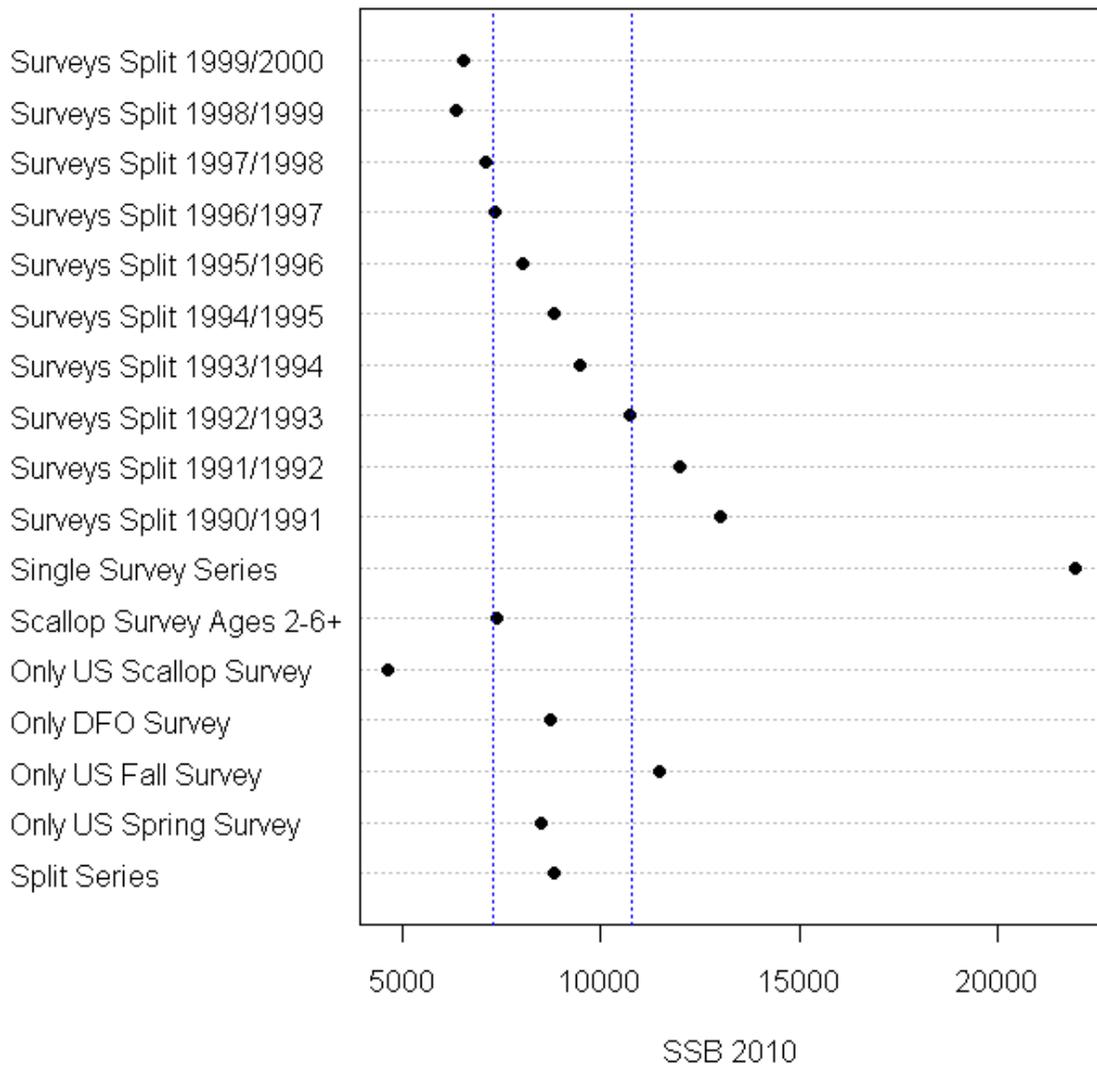
Figure 29a. Spawning stock biomass (mt) in 2010 from the Split Series VPA and 16 sensitivity runs. The vertical dotted blue lines denote the 80% confidence interval for the Split Series VPA.
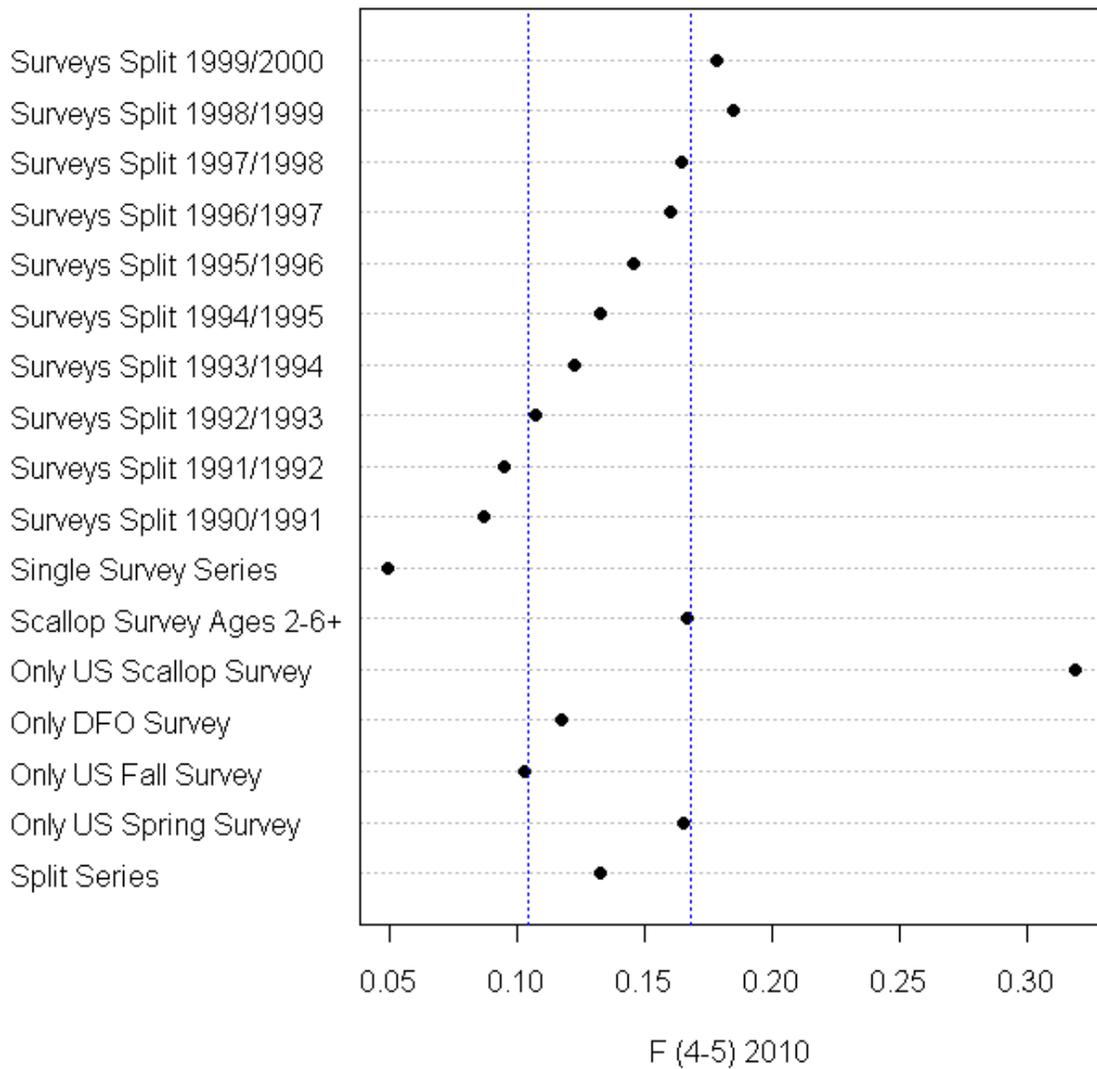
Figure 29b. Fishing mortality rate (ages 4+) in 2010 from the Split Series VPA and 16 sensitivity runs. The vertical dotted blue lines denote the 80% confidence interval for the Split Series VPA.
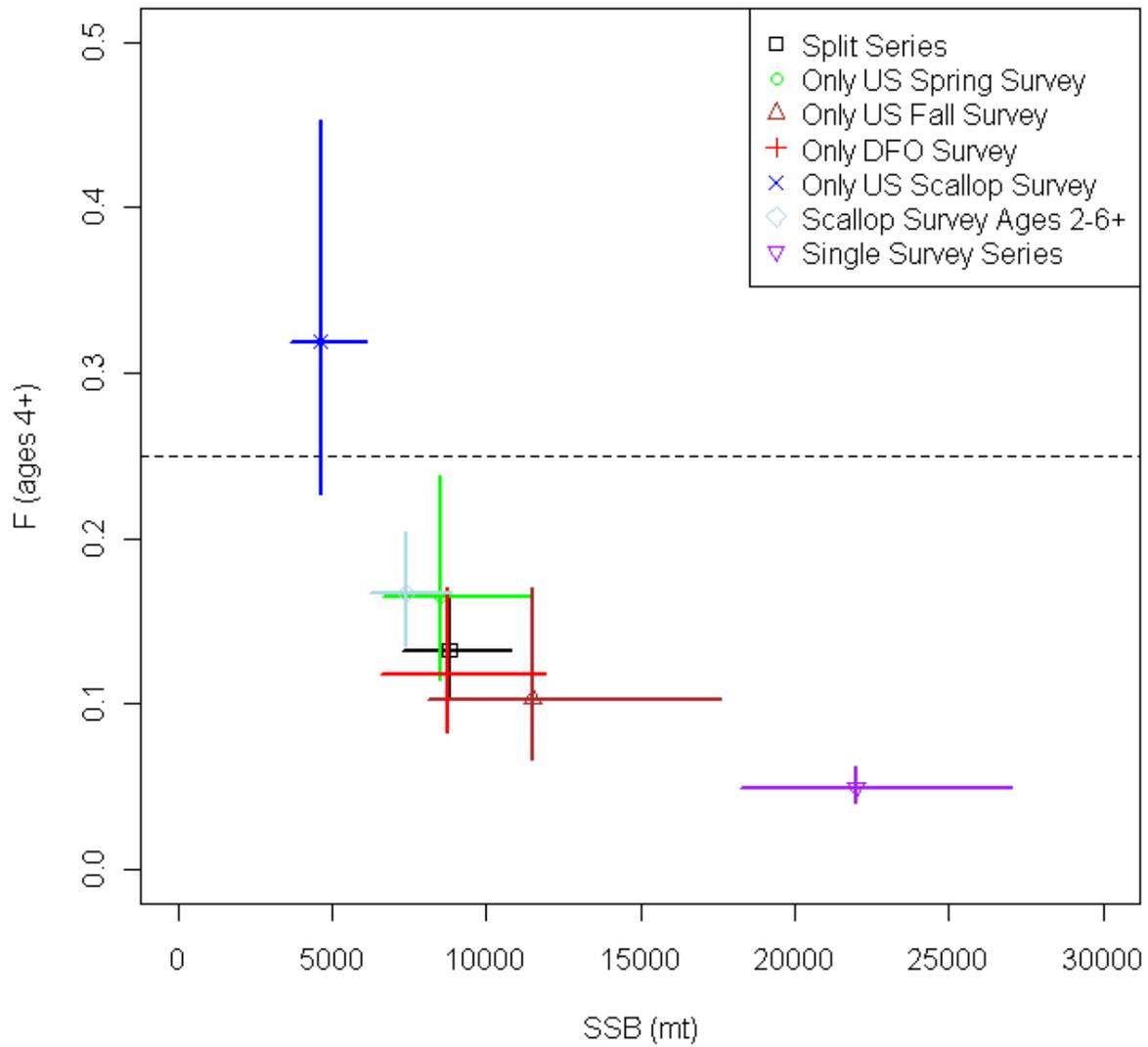
Figure 30. Point estimates of SSB (mt) and F (ages 4+) with 80% confidence intervals for the split series run and six sensitivity runs. The horizontal line denotes F_{ref}=0.25.
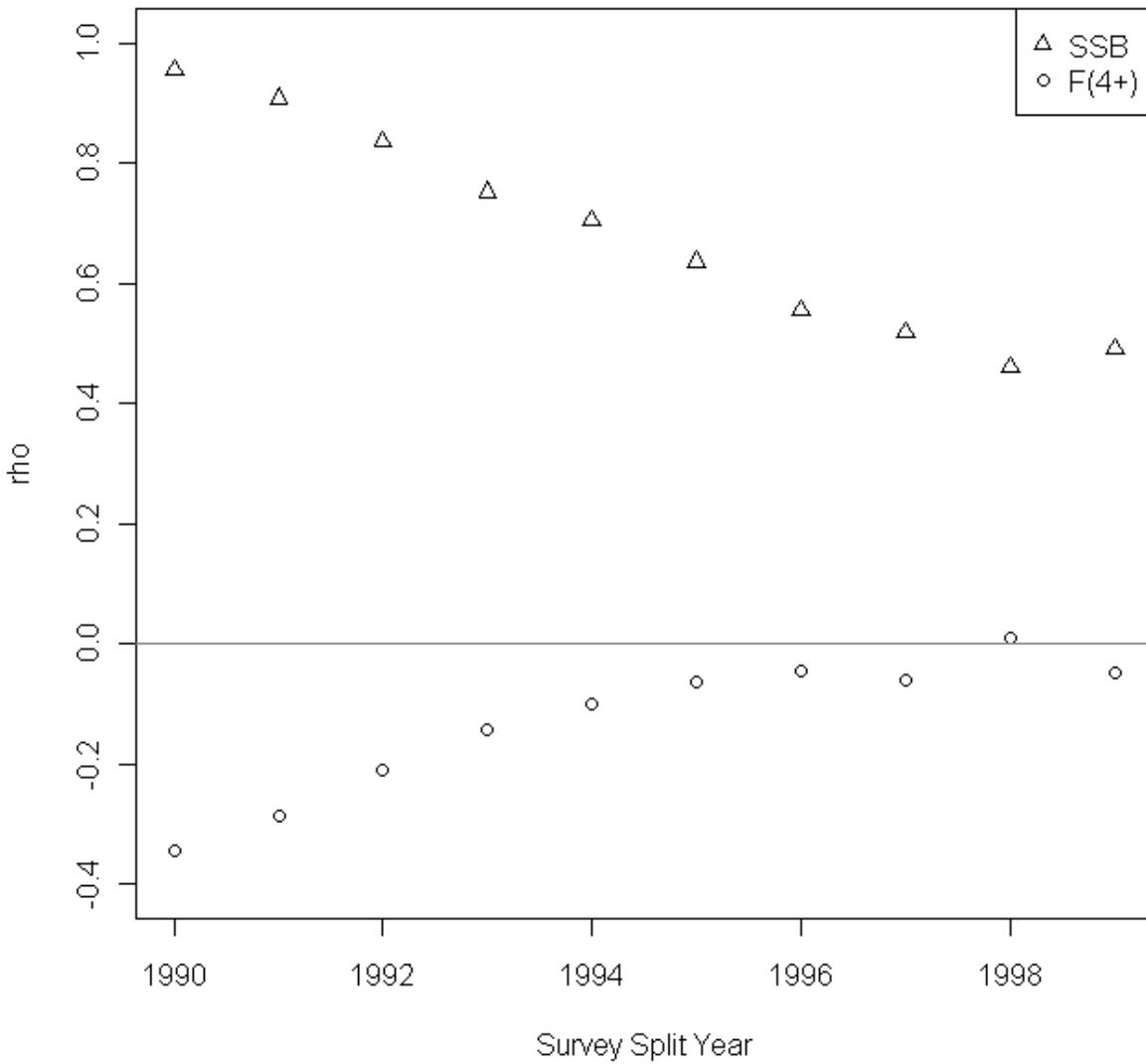
Figure 31. Retrospective statistic rho for F ages 4+ and SSB for a range of years to split the surveys. Survey split year 1990 denotes splitting the surveys 1990/1991.
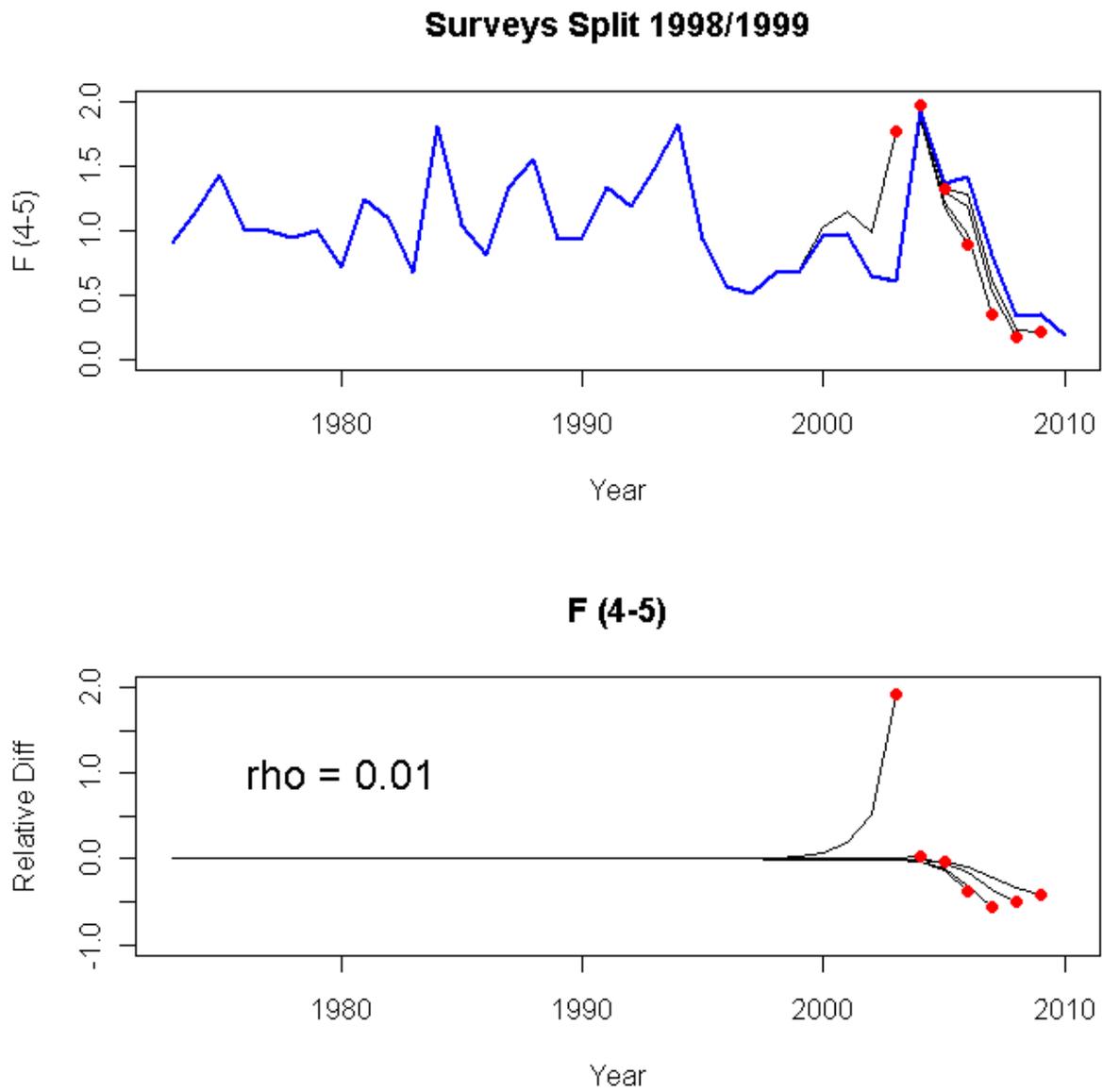
Figure 32a. Retrospective analysis for F when surveys are split 1998/1999.
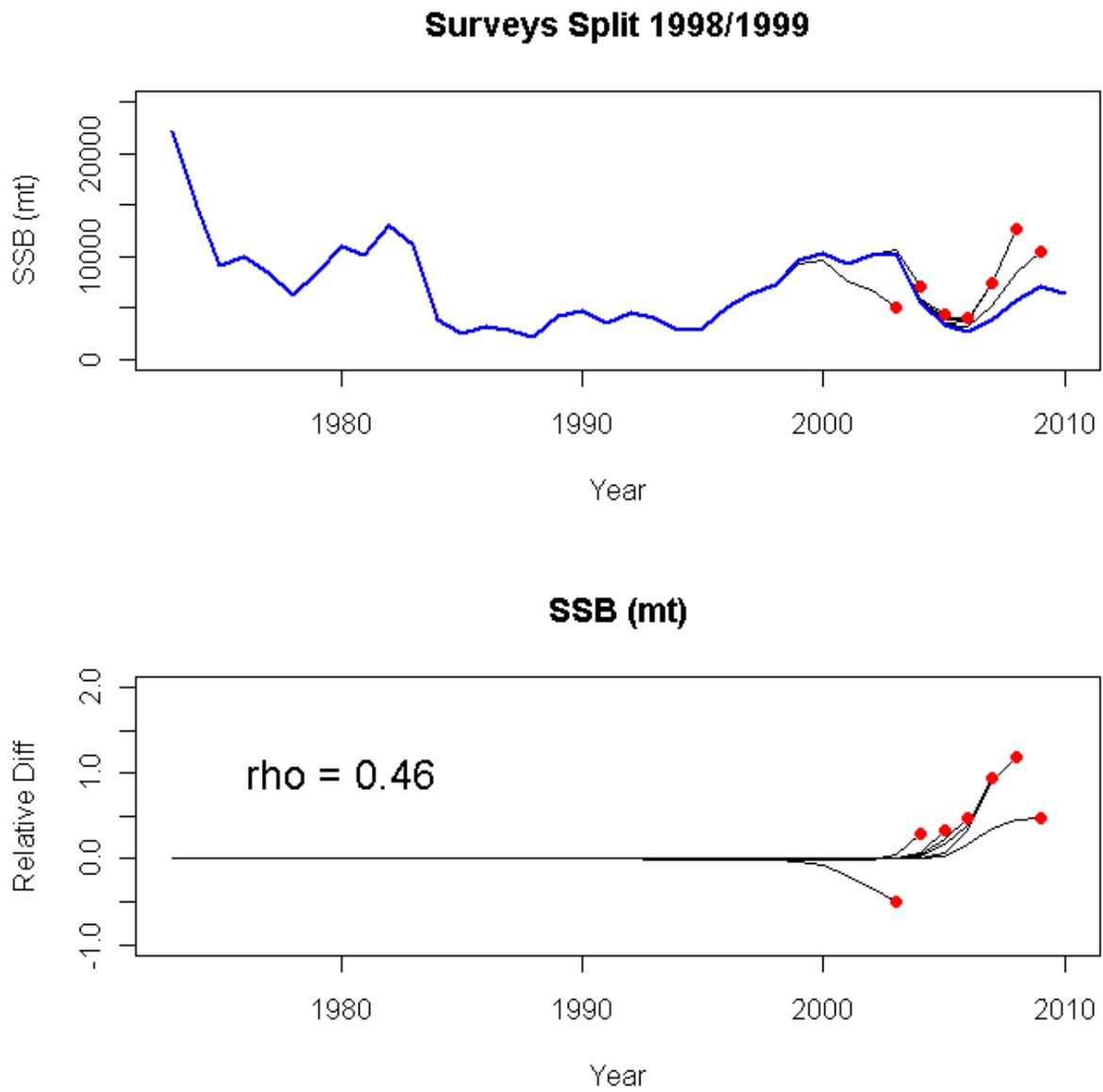
Figure 32b. Retrospective analysis for SSB when surveys are split 1998/1999.
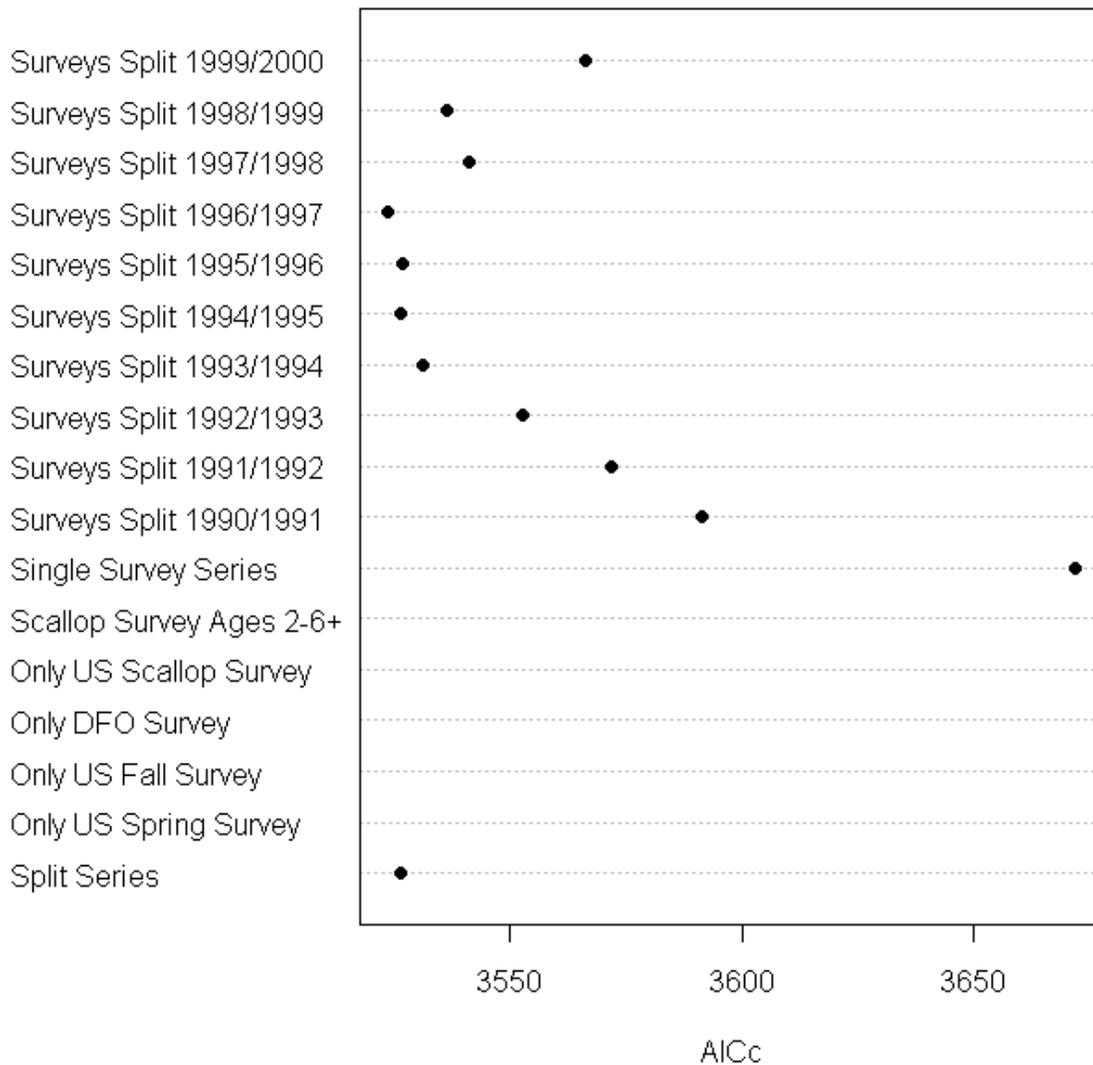
Figure 33. Goodness of fit, as measured by Akaike information criterion, corrected (AICc), for all the sensitivity runs which used the same number of index observations. Lower AICc values indicate better fit.
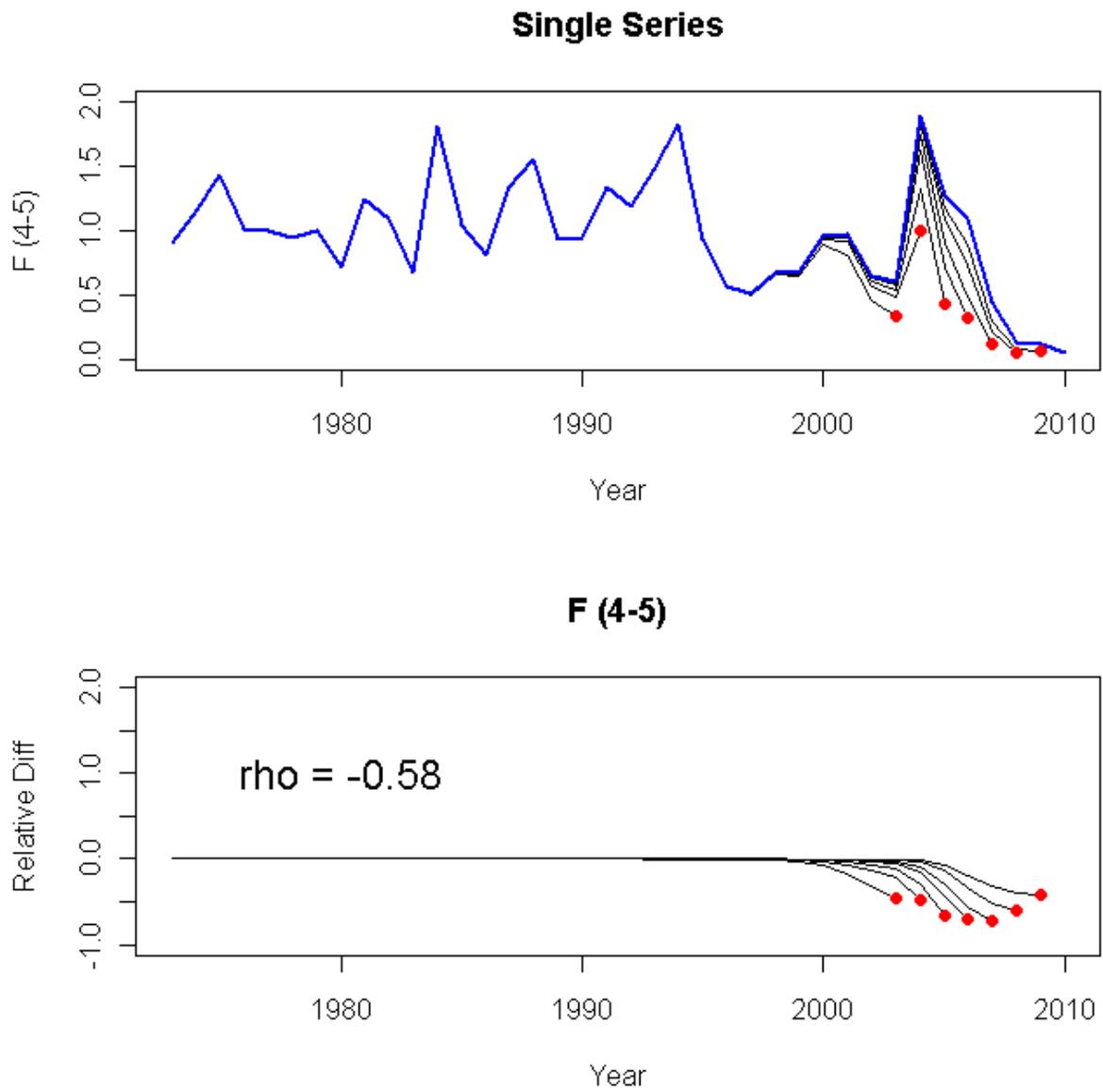
Figure 34a. Retrospective analysis for F when surveys are not split, but rather treated as a single series.

Single Series

SSB (mt)

rho = 1.4
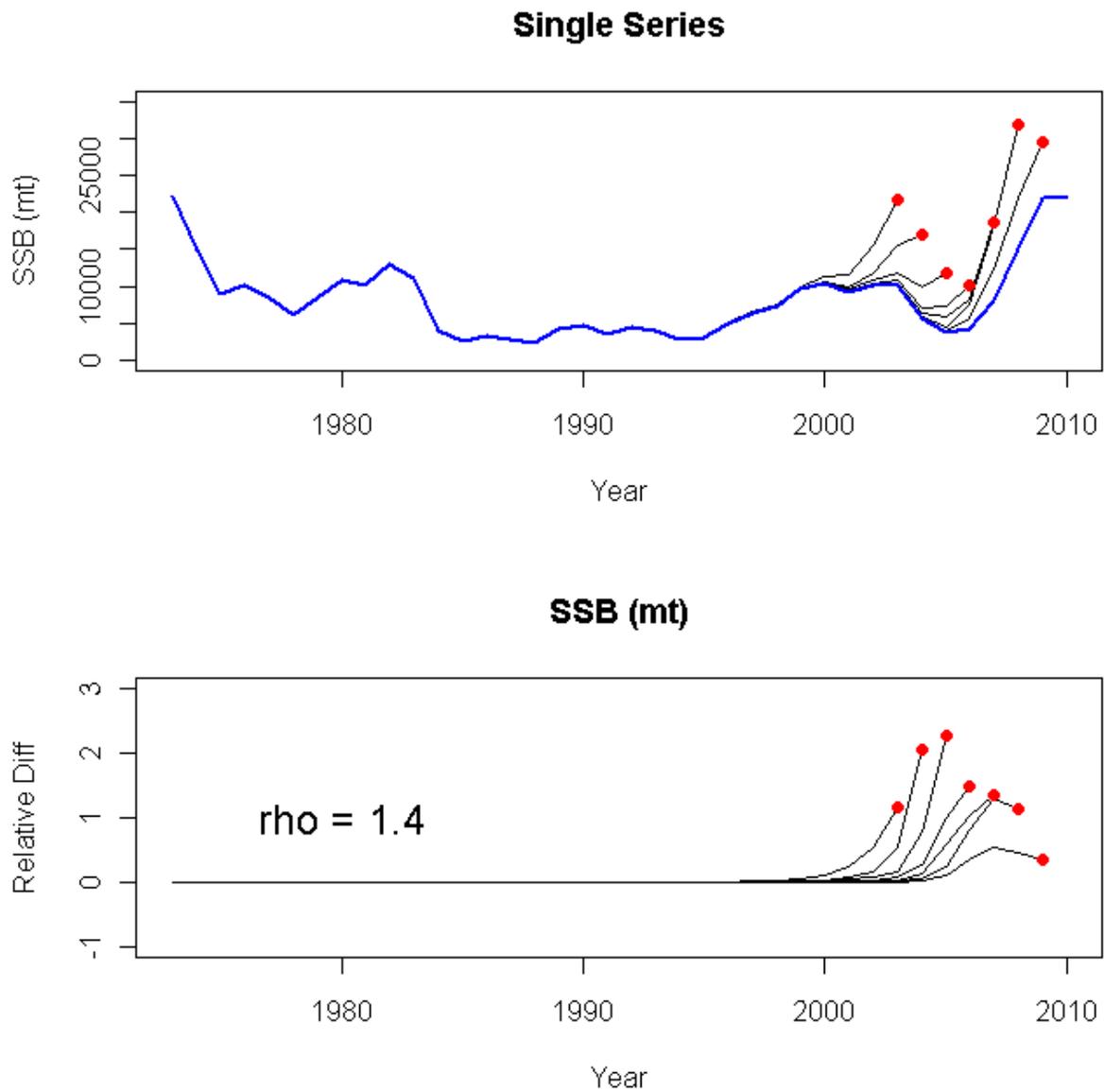
Figure 34b. Retrospective analysis for SSB when surveys are not split, but rather treated as a single series (note the change in y-axes from previous retrospective plots).
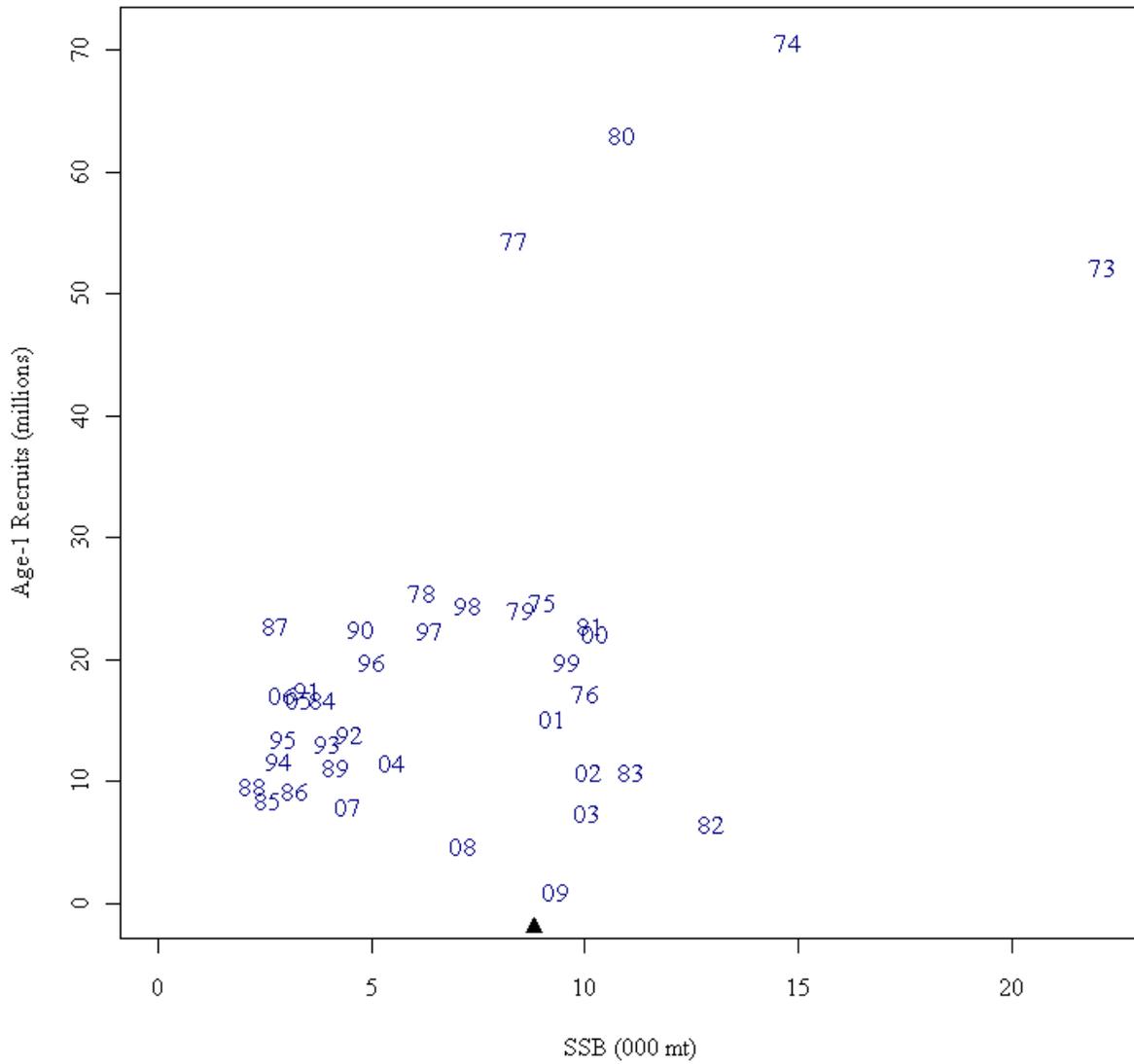
Figure 35a. Stock recruitment relationship from the Split Series VPA. The number denotes year class (age of SSB and age-0). The triangle denotes the spawning stock biomass in 2010.

li
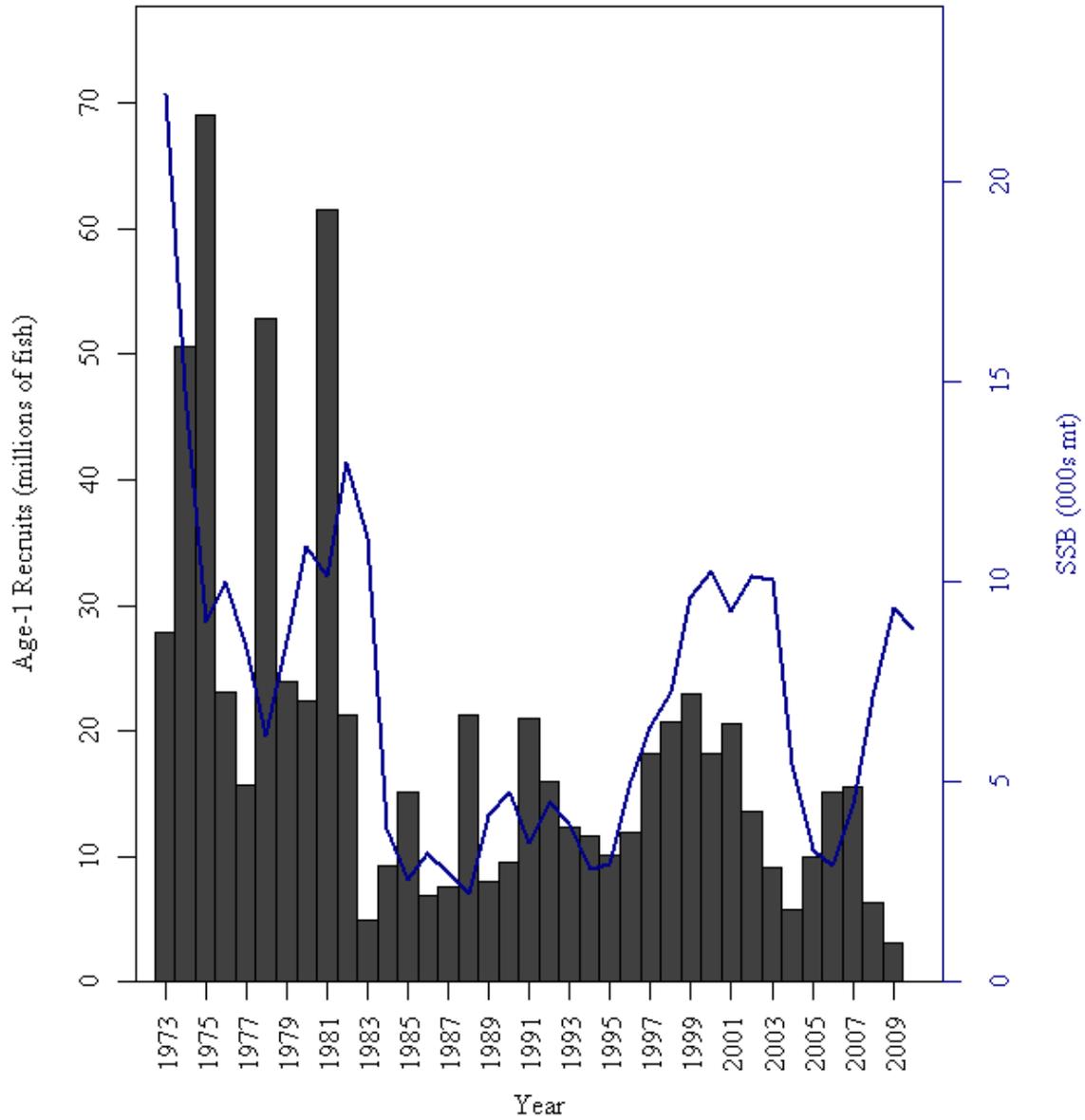
Figure 35b. Estimated age-1 recruitment in millions of fish (denoted by bars) and spawning stock biomass in thousands of metric tons (denoted by solid line) by year-class (recruitment) or year (SSB) from the split series VPA.
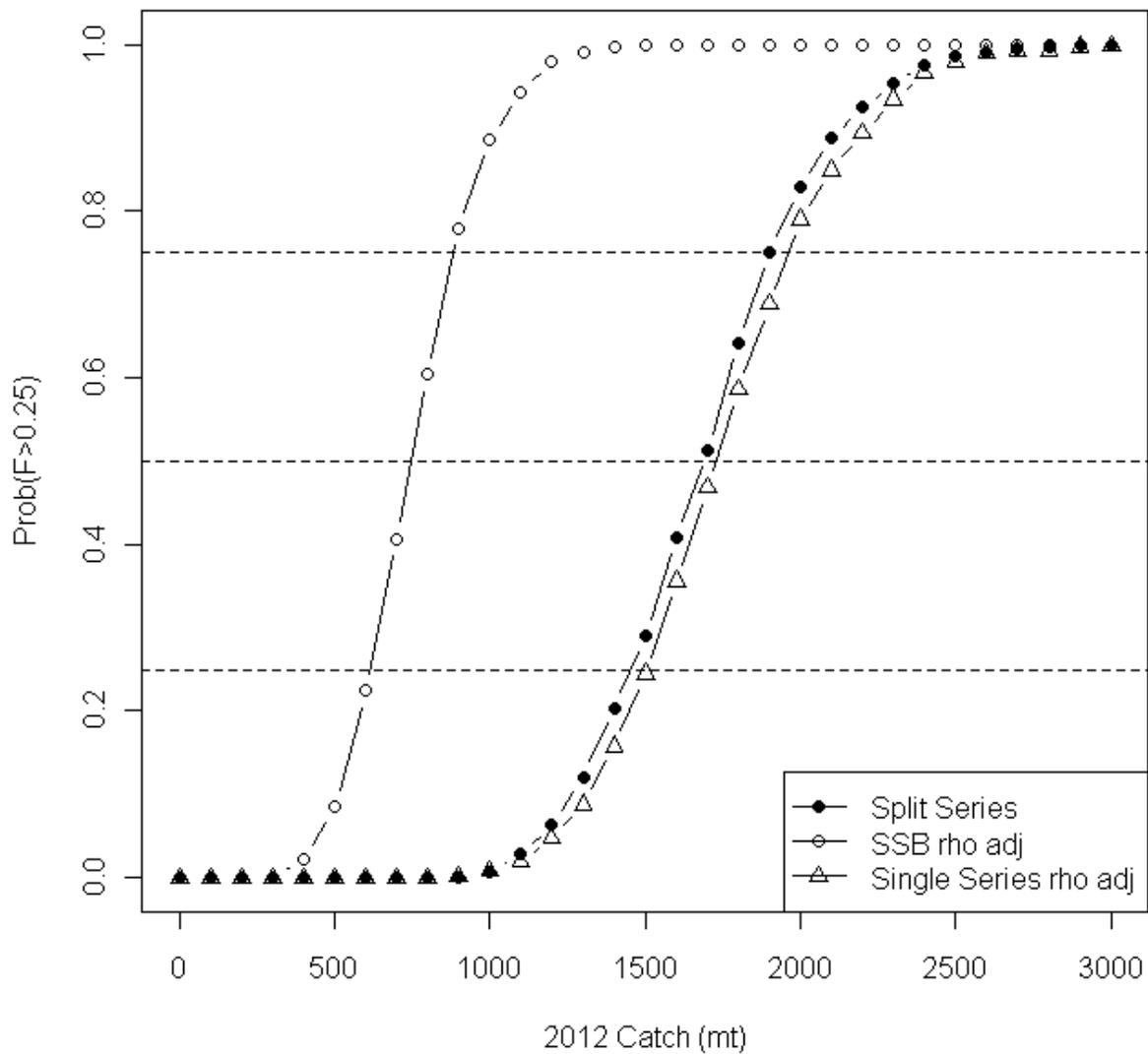
Figure 36. Risk of F exceeding $F_{ref}=0.25$ for a range of 2012 catch in 100 mt increments and two initial conditions: the split series VPA estimates and adjusted starting population numbers based on the retrospective pattern in SSB. Horizontal dashed lines denote 25%, 50%, and 75% probabilities.
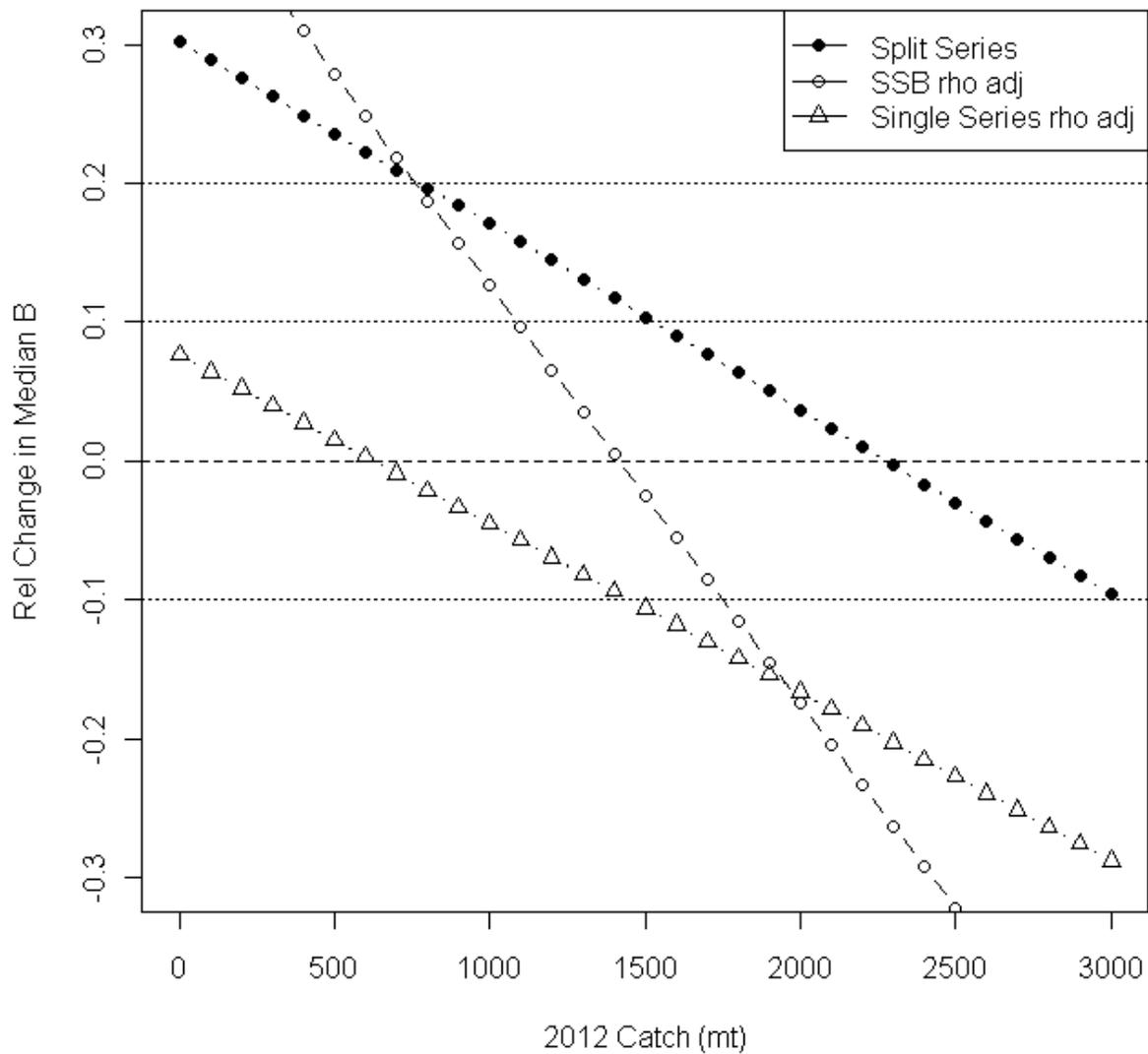
Figure 37. Relative change in median Jan-1 age 3+ biomass for a range of 2012 catch in 100 mt increments and two initial conditions: the split series VPA estimates and adjusted starting population numbers based on the retrospective pattern in SSB. Horizontal dashed line denotes no change. Horizontal dotted lines denote 10% decrease, 10% increase, and 20% increase.
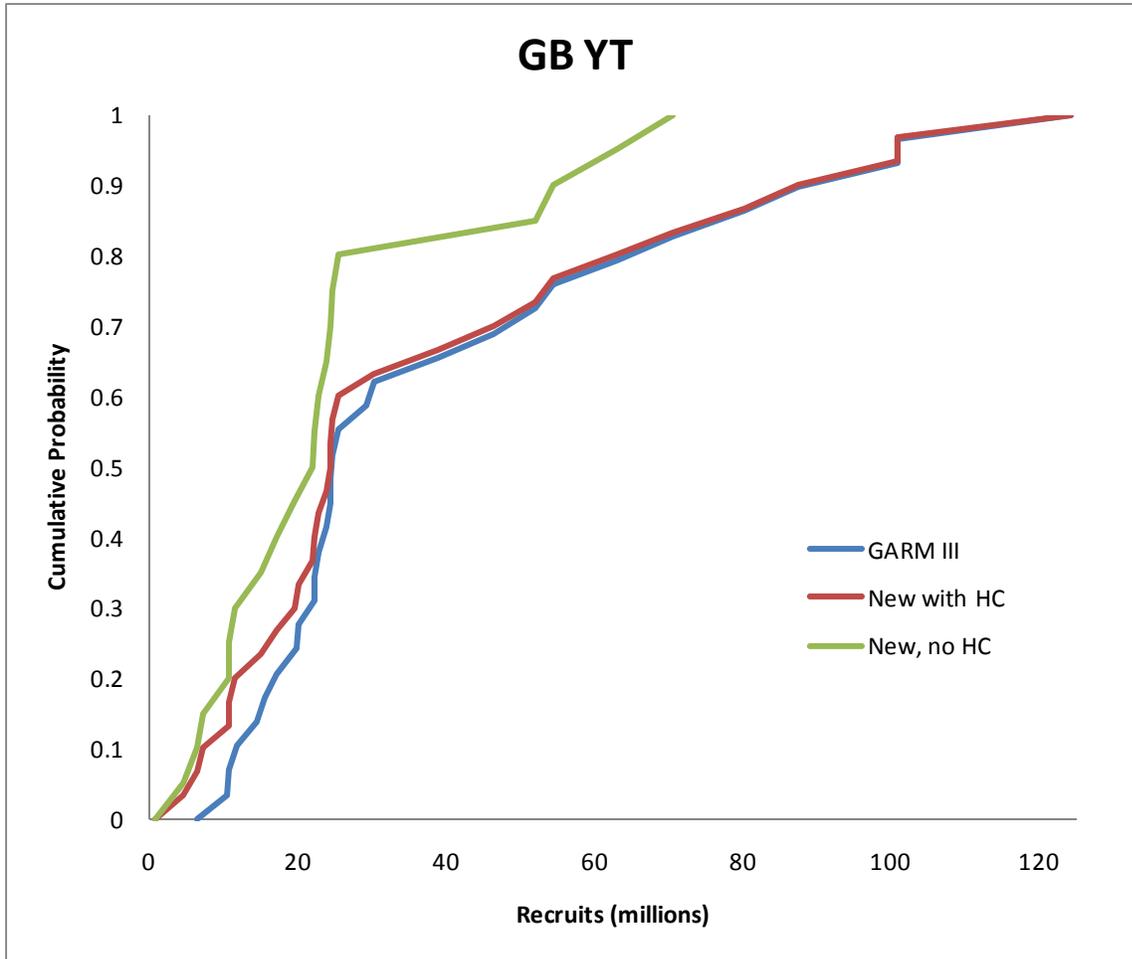
Figure 38. Cumulative probability distribution of recruitment associated with SSB greater than 5,000 mt from GARM III (NEFSC 2008), the split series (denoted new) including the same hindcast (HC) values as used in GARM III (NEFSC 2008), and new without the HC.
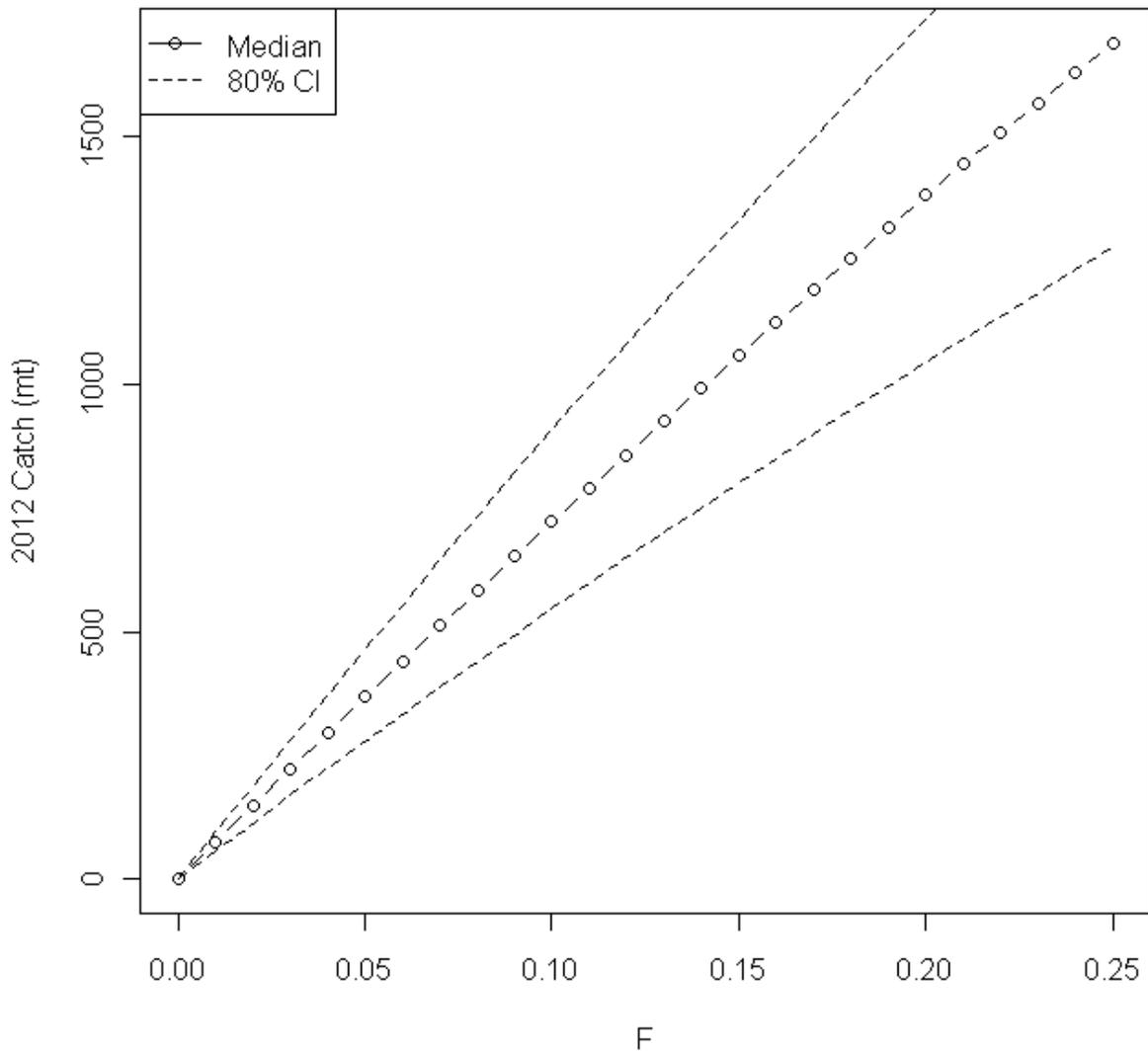
Figure 39. Catch (mt) in 2012 under a range of F values in increments of 0.01. Line with symbols denotes median while dashed lines denote 80% confidence interval. See Table 23 for values of F associated with different US rebuilding scenarios.
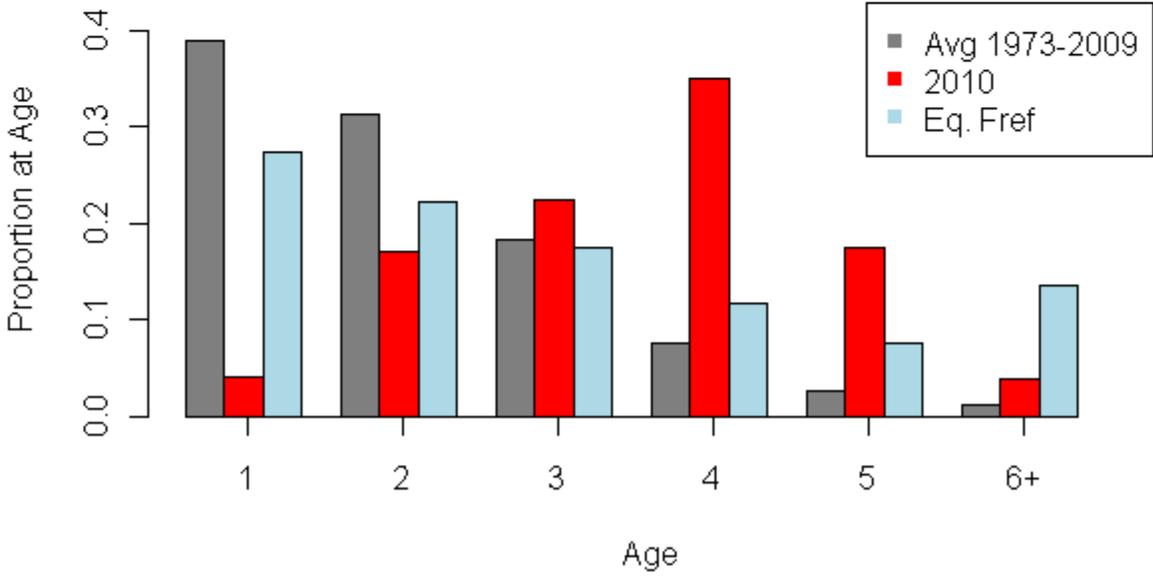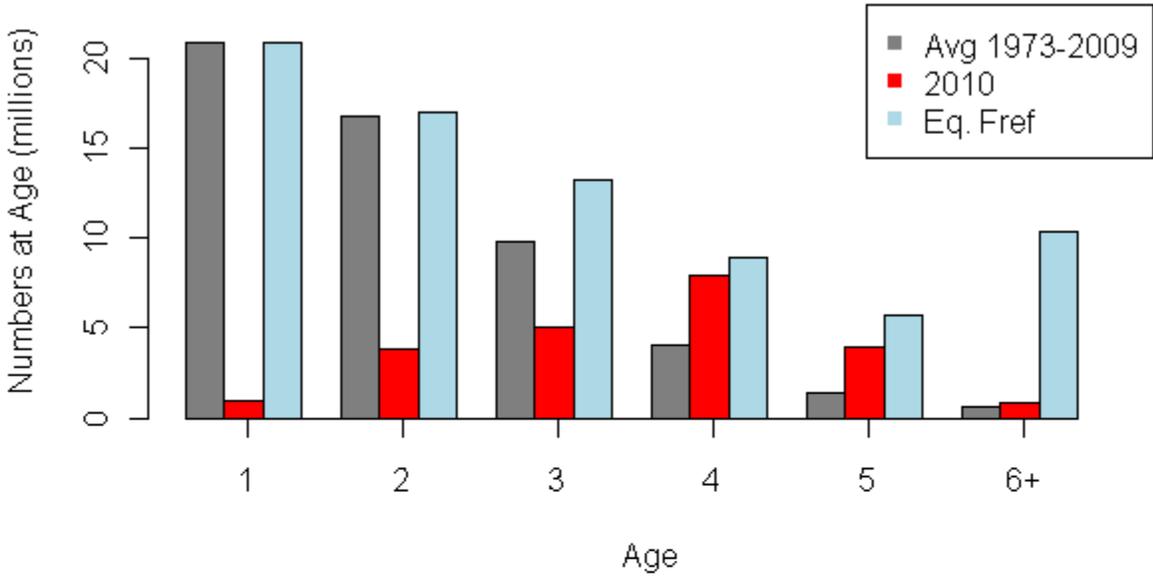
Figure 40. Comparison of the population abundance at age distributions for the Split Series VPA among the average of 1973-2009, 2010, and that expected when the population is fished in equilibrium at F_{ref}=0.25. The equilibrium numbers at age-1 in the top panel are set equal to the average for years 1973-2009. The bottom panel shows the proportions at age instead of numbers.
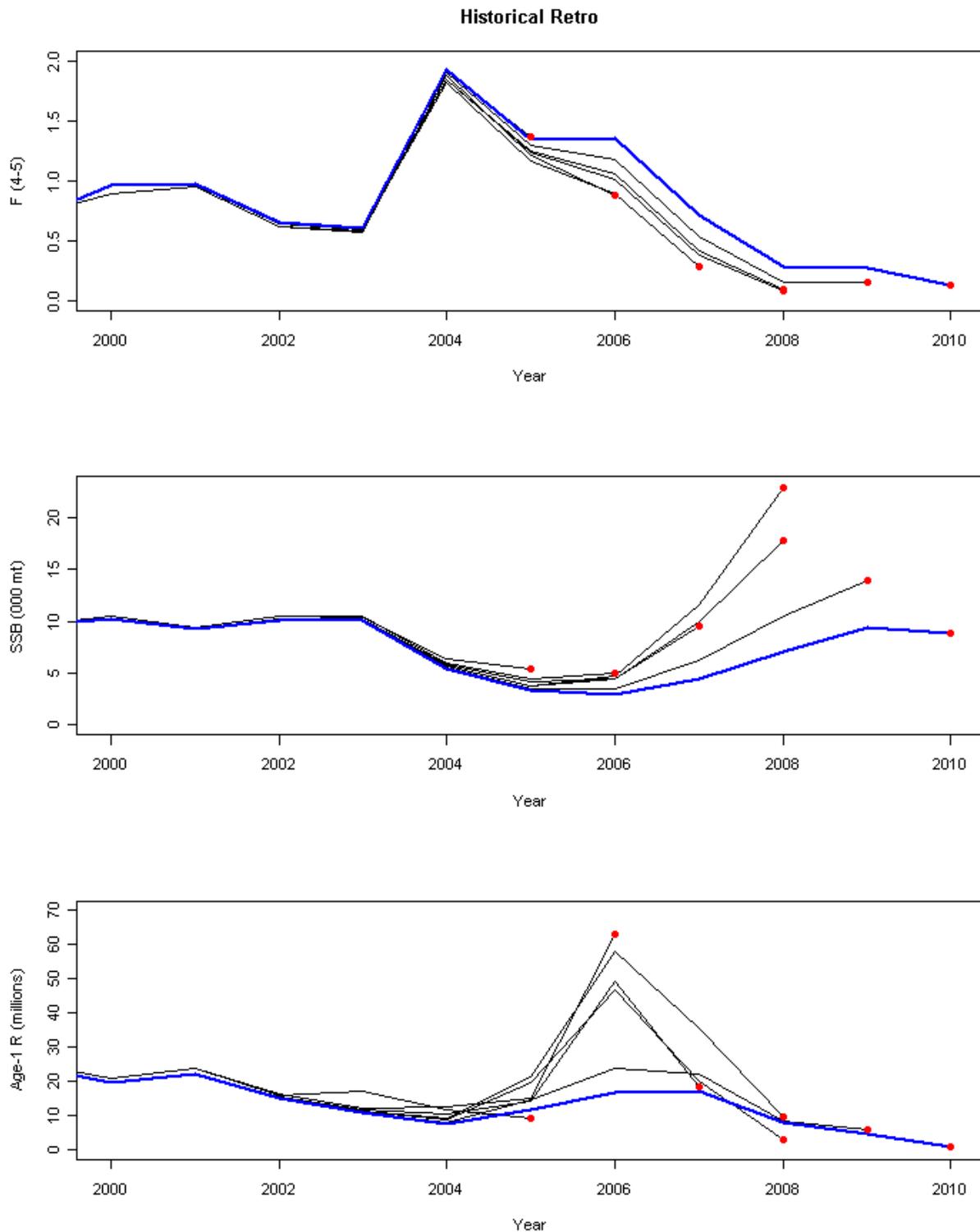
Figure 41. Historical retrospective analysis of Georges Bank yellowtail flounder assessments from this and the previous four TRAC VPAs for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age-1 recruitment (lower panel). Note there are two lines plotted for TRAC 2009 (terminal year 2008), the Including and Excluding formulations.

Appendix

The table below was kindly provided by Tom Nies (NEFMC) and summarizes the performance of the management system. It reports the TRAC advice, TMGC quota decision, actual catch, and realized stock conditions for Georges Bank yellowtail flounder.

(1) All catches are calendar year catches
(2) Values in italics are assessment results in year immediately following the catch year; values in normal font are results from this assessment

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch[1]/Compared to Risk Analysis	Actual Result[2]
		Amount	Rationale	Amount	Rationale		
1999[1]	1999	(1) 4,383 mt (2) 6,836 mt	Neutral risk of exceeding Fref (1)VPA (2)SPM	NA	NA	4,441 mt/ 50% risk of exceeding Fref (VPA)	Exceeded Fref (2.6X)
2000	2000	7,800 mt	Neutral risk of exceeding Fref	NA	NA	6,895 mt/About 30% risk of exceeding Fref	Exceeded Fref (3.6X)
2001	2001	9,200 mt	Neutral risk of exceeding Fref	NA	NA	6,790 mt/Less than 10% risk of exceeding Fref	Exceeded Fref (3.8X)
2002	2002	10,300 mt	Neutral risk of exceeding Fref	NA	NA	6,100 mt/Less than 1% risk of exceeding Fref	Exceeded Fref (2.5X)
Transition to TMGC process in following year; note catch year differs from TRAC year in following lines							
2003	2004		No confidence in projections; status quo catch may be appropriate	7,900 mt	Neutral risk of exceeding Fref, biomass stable; recent catches between 6,100-7,800 mt	7,275 mt	*F above 1.0* Now F = 1.93 Age 3+ biomass decreased 52% 04-05
2004	2005	4,000 mt	Deterministic; other models give higher catch but less than 2004 quota	6,000 mt	Moving towards Fref	4,150 mt	*F = 1.37 Age 3+ biomass decreased 5% 05-06* Now F = 1.35 Age 3+ biomass decreased 35% 05-06

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[1] Prior to implementation of US/CA Understanding

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch[1]/Compared to Risk Analysis	Actual Result[2]
2005	2006	(1) 4,200 (2) 2,100 (3) 3,000 - 3,500	Neutral risk of exceeding F ref (1-base case; 2 – major change) (3) Low risk of not achieving 20% biomass increase	3,000 mt	Base case TAC adjusted for retrospective pattern, result is similar to major change TAC (projections redone at TMGC)	2,206 mt/ (1) Less than 10% risk of exceeding Fref (2) Neutral risk of exceeding Fref	*F = 0.89 Age 3+ biomass increased 41% 06-07* Now F = 1.35 Age 3+ biomass increased 25% 06-07
2006	2007	1,250 mt	Neutral risk of exceeding Fref; 66% increase in SSB from 2007 to 2008	1,250 mt (revised after US objections to a 1,500 mt TAC)	Neutral risk of exceeding Fref	1,686 mt About 75 percent probability of exceeding Fref	*F = 0.29 Age 3+ biomass increased 211% 07-08* Now F=0.72 Age 3+ biomass increased 70% 07-08
2007	2008	3,500 mt	Neutral risk of exceeding Fref; 16% increase in age 3+ biomass from 2008 to 2009	2,500 mt	Expect F=0.17, less than neutral risk of exceeding Fref	1,275 mt No risk plot; expected less than median risk of exceeding Fref (1504)	*F~0.09 Age 3+ biomass increased between 35%-52%* Now F=0.28 Age 3+ biomass increased 55% 08-09
2008	2009	(1) 4,600 mt 2) 2,100 mt	(1) Neutral risk of exceeding Fref; 9% increase from 2009-2010 (2) U.S. rebuilding plan	2,100 mt	U.S. rebuilding requirements; expect F=0.11; no risk of exceeding Fref	1,778 mt No risk of exceeding Fref at 1,806	*F=0.15 Age 3+ biomass increased 11%* Now F=0.27 Age 3+ biomass decreased 0.4% 09-10

TRAC	Catch Year	TRAC Analysis/Recommendation		TMGC Decision		Actual Catch[1]/Compared to Risk Analysis	Actual Result[2]
2009	2010	(1) 5,000 – 7,000 mt (2) 450 – 2,600 mt	(1) Neutral risk of exceeding Fref under two model formulations (2) U.S. rebuilding requirements	No agreement. Individual TACs total 1,975 mt	No agreement	1,160 mt No risk of exceeding Fref About 15% increase in median biomass expected	F=0.13 3+ Biomass increased 6% 10-11
2010	2011	(1) 3,400 mt	(1) Neutral risk of exceeding Fref; no change in age 3+ biomass	2,650 mt	Low probability of exceeding Fref; expected 5% increase in biomass from 11 to 12		