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Reference Document 2012/02

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Stock Assessment of Georges Bank Yellowtail Flounder for 2012

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ABSTRACT

The combined Canada/US yellowtail flounder catch remained essentially the same at 1,160 mt in 2010 and 1,169 mt in 2011. Recruitment continues to be poor, with the two most recent cohorts estimated to be the lowest in the time series at 3.0 and 3.1 million age 1 fish, and the most recent ten years all below the average of the assessment time series. Although spawning stock biomass and adult (age 3+) beginning year biomass have both increased for the past six years, to 4,600 mt and 4,500 mt in 2011, respectively, both are below the average of the assessment time series. The fishing mortality rate for fully recruited ages 4+ was estimated to be 0.31 in 2011, and has been above the F_{ref} of 0.25 for the entire assessment time series. This assessment updates the Split Series virtual population analysis (VPA) formulation that was approved at the last benchmark assessment to estimate stock size and fishing mortality. However, the Split Series formulation exhibited a strong retrospective pattern this year. If this pattern continues, the 2011 fishing mortality rate is expected to increase from 0.31 to 0.62 while the 2011 spawning stock biomass is expected to decrease from 4,600 mt to 1,700 mt in future assessments.

The Split Series formulation was approved at the last benchmark assessment and is used to estimate current stock size and fishing mortality. In recent years, catches based on this model have not reduced fishing mortality (F) below F_{ref} and have not had the expected effect on adult (age 3+) biomass or spawning stock biomass. If the 2013 catch quota is set based on this model, this pattern of failing to achieve management objectives seems likely to continue given the model's retrospective pattern. The Transboundary Resources Assessment Committee (TRAC) recommends not basing 2013 catches on these unadjusted model projection results.

In light of the increased magnitude of the retrospective bias in the Split Series VPA, five sensitivity analyses were considered to address the retrospective bias to characterize the uncertainty and risk in catch advice. Alternative projections were conducted to examine the possible impact of this retrospective pattern on catch advice using a number of approaches. Both the Split Series and Single Series models had their population abundance at the start of 2012 adjusted based on the Mohn's rho for spawning stock biomass. These projections had much lower catch advice in 2013 compared to the unadjusted projections. Alternative "fixes" to the retrospective pattern within the assessment model were employed by increasing recent catch, natural mortality, or both. These models and projections resulted in similar catch advice to the retrospective adjusted Split Series and Single Series results. The catch advice is robust to how inconsistencies in the data are treated and gives support to the management advice for this stock.

To achieve both a high probability that F in 2013 will be less than F_{ref} and that adult biomass will increase, a 2013 quota of approximately 200 mt would be required. A quota of 400-500 mt implies that either F will be below F_{ref} in 2013 in only one of the five sensitivity analyses or the adult biomass will increase from 2013 to 2014 for the other four. Thus, a 2013 quota of 400-500 mt has both positive and negative aspects. Due to the assumption used for the 2011 year-class in the projections (geometric mean of recent ten years), the increase in adult biomass will be optimistic if the 2011 year-class is as poor as the recent year-classes.

RÉSUMÉ

Les captures combinées de limande à queue jaune par le Canada et les États-Unis sont demeurées essentiellement les mêmes, soit de 1 660 tm en 2010 et de 1 669 tm en 2011. Le recrutement continue d'être faible, les deux dernières cohortes étant jugées les plus faibles de la série chronologique à 3 et 3,1 millions de poissons d'âge 1, et les dix dernières années se situant sous la moyenne de la série chronologique à l'étude. Même si la biomasse du stock reproducteur et celle des adultes (âge 3 et plus) en début d'année ont toutes deux augmenté au cours des six dernières années, pour atteindre respectivement 4 600 tm et 4 500 tm en 2011, ces biomasses se situent en deçà de la moyenne pour la série chronologique à l'étude. Le taux de mortalité des poissons pour les individus pleinement recrutés d'âge 4 et plus était estimé à 0,31 en 2011 et se situe au-dessus du $F_{réf.}$ de 0,25 pour toute la série chronologique à l'étude. La présente évaluation apporte une mise à jour à la formule de l'analyse de population virtuelle (APV) à série fractionnée qui a été approuvée à la dernière évaluation des points de référence et qui sert à estimer la taille du stock et le taux de mortalité des poissons. Cependant, la formule de la série fractionnée a démontré une forte tendance rétrospective cette année. Si cette tendance se maintient, on s'attend à ce que le taux de mortalité par pêche de 2011 augmente de 0,31 à 0,62 et à ce que la biomasse du stock reproducteur de 2011 diminue de 4 600 tm à 1 700 tm dans les évaluations futures.

La formule de la série fractionnée a été approuvée à la dernière évaluation des points de référence et elle sert à estimer la taille du stock actuel et la mortalité par pêche. Au cours des dernières années, les captures calculées d'après ce modèle n'ont pas réduit la mortalité par pêche (F) sous $F_{réf.}$ et elles n'ont pas eu les effets attendus sur la biomasse des adultes (âge 3 et plus) ou sur celle du stock reproducteur. Si le quota des captures en 2013 est établi d'après ce modèle, il est à prévoir que la tendance à ne pas atteindre les objectifs de gestion sera maintenue compte tenu de la tendance rétrospective du modèle. Le Comité d'évaluation des ressources transfrontalières (CERT) recommande de ne pas établir les captures pour 2013 en fonction de ces projections de modèle sans correction.

À la lumière du biais rétrospectif plus important dans l'analyse de population virtuelle à série fractionnée, cinq analyses de sensibilité ont été envisagées pour examiner le biais rétrospectif afin de caractériser l'incertitude et les risques dans la recommandation de captures. Différentes projections ont été réalisées afin d'examiner l'incidence possible de cette tendance rétrospective sur la recommandation de captures à l'aide de différentes méthodes. Au début de 2012, on a ajusté l'abondance de la population pour les modèles à série fractionnée et à série non fractionnée selon la valeur rho de Mohn pour la biomasse du stock reproducteur. Ces projections ont donné des recommandations de captures beaucoup plus faibles en 2013 comparativement aux projections sans correction. D'autres « solutions » à la tendance rétrospective dans le modèle d'évaluation ont été utilisées, notamment l'augmentation des captures récentes, du taux de mortalité naturelle, ou des deux. Ces modèles et ces projections ont donné des recommandations de captures similaires aux résultats des modèles à série fractionnée et à série non fractionnée ajustés selon la rétrospective. La recommandation de captures résiste au traitement des incongruités dans les données et peut servir de soutien aux avis de gestion pour le stock concerné.

Pour accroître la probabilité que le taux de mortalité par pêche (F) soit inférieur à $F_{réf.}$ en 2013 et que la biomasse des adultes augmente, un quota d'environ 200 tm serait nécessaire en 2013. Un quota de 400 à 500 tm signifie que F sera inférieur à $F_{réf.}$ en 2013 dans seulement une des cinq analyses de sensibilité ou que la biomasse des adultes augmentera de 2013 à 2014 dans les quatre autres. Par conséquent, un quota de 400 à 500 tm en 2013 comporte des aspects positifs et négatifs. En raison de l'hypothèse utilisée dans les projections pour la classe d'âge de 2011 (moyenne géométrique des dix dernières années), l'augmentation de la biomasse des adultes sera optimiste si cette classe d'âge est aussi faible que les classes d'âge récentes.

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. 2011) 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 fishery catch at age and survey abundance at age show differences that 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 fishing mortality (F) and total mortality (Z))
- Base Case Virtual Population Analysis (VPA) model formulation from the 2004 assessment
- Two new VPA model formulations with minor and major changes to Base Case

The analytical methods used in the current assessment are based on revised model formulations adopted during the 2005 Transboundary Resources Assessment Committee (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, while the Base Case model will be referred to as the "Single Series" model.

Last year, the Split Series VPA model was used as the basis of status determination. This model downweighted the Canadian 2008 and 2009 surveys in the tuning process to account for their higher uncertainty caused by single large catches of yellowtail flounder in those years. This formulation indicated that fishing mortality in 2010 was below the target rate F_{ref} = 0.25 and that biomass generally was increasing. However, the 2009 cohort (age 1 in 2010) was estimated to be the lowest on record, at less than one million fish. The Split Series VPA model exhibited a strong retrospective pattern, so two additional sets of projections were conducted to provide catch advice. These additional sets of projections applied retrospective adjustments to the terminal year in the VPA results, which resulted in lower initial stock abundance in the projections. The Split Series VPA had the retrospective adjustment applied, as did the Single Series VPA. Based on considering both the probability of overfishing and expected change in population biomass, and assuming the 2011 Total Allowable Catch (TAC) of 2,650 mt was caught, the TRAC recommended a 2012 quota range of 900-1,400 mt. The Transboundary Management Guidance Committee (TMGC) negotiated the catch quota for 2012 initially to be 900 mt, but after the New England Fishery Management Council's Scientific and Statistical Committee set the Acceptable

Biological Catch at 1,150 mt, negotiations were reopened and the final 2012 quota was set at 1,150 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 2 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; 2010) 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 (Figure 1a) and US statistical reporting areas 522, 525, 551, 552, 561 and 562 (Figure 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 TAC 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. When accounting for catch, the assumption has always been made that all discarded fish die. Recent field work has demonstrated high discard mortality rates for yellowtail flounder (Barkley and Cadrin 2012), supporting this assumption. 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 passage of the International Fisheries Clarification Act in 2010 (Shark and Fishery Conservation Act 2011) relaxed the US rebuilding requirements, allowing more consistent management between the two countries.

THE FISHERIES

Exploitation of the Georges Bank yellowtail flounder 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 (Table 1 and Figure 2). The highest annual catches occurred during 1963-1976 (average: 17,500 mt) and included modest catches by distant water fleets (Table 1 and Figure 2). 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, and 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 (Figure 1b) and by extension to year-round closure in December 1994, as well as mesh size and gear regulations and limits on days fished. In 2004, a Yellowtail Special Access Program (SAP) in Closed Area II allowed the US bottom trawl fishery short-term access to the area for the first time since 1995. This SAP did not continue in subsequent years. 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 were 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 2011 (catch in 2011 = 1,169 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 1994-2011 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). US landings have been limited by quotas in recent years. Total US yellowtail landings (excluding discards) for the 2011 fishery were 904 mt, an increase of 38% from 2010 (Table 1 and Figure 2).

US discarded catch for years 1994-2011 was estimated using the Standardized Bycatch Reporting Methodology (SBRM) recommended in the GARM III Data meeting (GARM 2007, Wigley et al. 2007b). Observed ratios of discards of yellowtail flounder to kept of all species for large mesh otter trawl, small mesh otter trawl, and scallop dredge were applied to the total landings by these gears by half-year. 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). US discards were approximately 19% of the US catch in years 1994-2011 (Table 1 and Figure 2). Total discards of yellowtail in the US decreased 33% from 2010 (289 mt) to 2011 (192 mt). This decrease was due to the decrease in the large mesh trawl discards being greater than the increase in scallop dredge discards (Table 2a). An alternative spatial stratification did not produce substantially different discards in the US scallop dredge fishery (Hart and Legault 2012).

The total US catch of Georges Bank yellowtail flounder in 2011, including discards, was 1,096 mt. This value can be compared to the quota monitoring estimated catch during the calendar year 2011, data kindly provided by Dan Caless of the Northeast Regional Office (Table 3). Landings from the quota monitoring system were 1% higher than used in the assessment, while discards from the quota monitoring system were 7% lower than used in the assessment. Since landings were much larger than discards in magnitude, the total catch estimate from quota monitoring was 1% lower than that used in the assessment. The strong similarity from the two estimates is encouraging, as this has not always been the case in the past.

The US Georges Bank yellowtail flounder quota for fishing year 2011 (1 May 2011 to 30 April 2012) was set at 1,458 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/MultiMonReports.htm) indicates the US groundfish fishery caught 86.6% of its sub-quota (1,142 mt) for the 2011 fishing year and the scallop fleet caught 48.7% of its sub-quota (201 mt) for the 2011 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 and Figure 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 22 mt reported in 2011. In these years, most of the reported yellowtail landings were from trips directed for 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 at-sea 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, 24 in 2010, and 22 in 2011. Discards for the years 2004-2011 were obtained by estimating a monthly prorated discard rate (kg/hr), using a 3-month moving-average calculation to account for the seasonal pattern in bycatch rate, applied to a monthly standardized effort (Table 2b-c) (Van Eeckhaute et al. 2010). The result of these calculations for 2011 is a discard estimate of 50 mt, the lowest in the time series (Table 1 and Figure 2).

For 2011, the total Canadian catch, including discards, was 73 mt, a decrease of 67% from 2010, which is 6% of the 2011 TAC of 1,192 mt.

Length and Age Composition

The level of US port sampling continued to be strong in 2011, with 11,546 length measurements available from 120 samples, resulting in 1,277 lengths/100 mt of landings (Table 4). This level of sampling has generally resulted in increased precision (i.e. low coefficients of variation) for the US landings at age from 1994-2011, as estimated by a bootstrapping procedure (Table 5). The port samples also provided 2,379 age measurements for use in age-length keys. The Northeast Fisheries Observer Program provided an additional 4,150 length measurements of discarded fish from 483 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 (Figure 3).

In 2011, two port samples (474 length measurements) were collected from the 22 mt of Canadian landings (Table 4). The 2011 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 (Figure 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 (Figure 4). Scallop dredge discards were mainly legal sized fish, as has been typically seen for dredge gear in the past (Figure 4).

The size composition of yellowtail flounder discards in the Canadian offshore scallop fishery was estimated by half year using length measurements obtained from 22 observed trips in 2011. 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 2011 size composition of yellowtail catch by country shows slightly larger yellowtail in the US landings than in the Canadian landings (Figure 5). Although the low amount of Canadian landings makes this comparison suspect, the Canadian landings are mainly bycatch in the haddock fishery that 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 (Figure 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 (Figure 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, so the US surveys and commercial landings provided ages.

No scale samples were available for the Canadian fishery in 2011. Therefore, the Canadian landings and discards at length were converted to catch at age using the US age-length keys by half-year and catch type (landings or discards). Canadian landings and discards accounted for 2% and 4% of the total 2011 catch, respectively.

In 2011, ages 3 and 4 (2008 and 2007 year-classes, respectively) dominated US landings and discards, with only minor contribution from Canadian landings and discards (Figure 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 and Figure 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 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 and Figure 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 above average for ages 2 and 3 and below average for the other ages, but all ages are within the range of past WAA calculations since 1973.

ABUNDANCE INDICES

Research bottom trawl surveys are conducted annually on Georges Bank by the 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 (Figure 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 NMFS 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 were applied in this assessment. The DFO 2008 and 2009 surveys encountered individual tows that were much larger than any seen previously in the time series.

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 (Figure 12a-d). 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 unusually large coefficients of variation for those years (Table 9 and Figure 12b-d). Exclusion of these single tows resulted in a decline in the indices by about an order of magnitude, as shown in previous assessments (Legault et al. 2009, 2010, 2011). The 2012 DFO biomass is larger than the 2011 value, but still the second lowest value since 1999. The NMFS spring series was high in the mid 1970s, low in the late 1980s through mid 1990s, high from 1999 through 2003, sharply decreased to 2004, and has shown a recent increasing trend from 2004 through 2012 (Table 10 and Figure 12b,d). 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 and 2011 declined to the lowest values since 1997 (Table 11 and Figure 12b,d). 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 and Figure 12b), with the 2010 value 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 coefficients of variation of the three groundfish surveys are generally comparable, with the exception of the unusually large values for the DFO survey in 2008 and 2009 due to the single large tows each year (Tables 9-11 and Figure 12c).

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 (Figure 13a-b). Note the 2009 through 2012 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 (Figure 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 (Figure 14b-c).

Given the calibration at length for the US spring and fall surveys (Table 8), the question was raised during the TRAC meeting last year whether there were indications of recruiting year-classes in the uncalibrated Bigelow data that 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 2009-2012 or US fall 2009-2011 surveys (Figure 15).

Age-structured indices of abundance for NMFS spring and fall surveys were derived using survey specific age-length keys. Prior to 2004, age-length keys from NMFS spring surveys had 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.

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 and Figure 16a-e). Even though each index is noisy, the age specific trends track relatively well among the four surveys (Tables 9-12 and Figure 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 2009-2011 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 were 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 (see Legault and Emery working paper from this meeting). Based on the recommendation of this work, the scallop survey catch at age values have been replaced for the entire time series using only the US spring survey age-length key. The resulting changes in age specific trends were minor. Comparison of the trends over time from the scallop and three bottom trawl surveys indicate they are tracking similar trends at all ages (Figure 17).

Measurements of individual yellowtail flounder length and weight were collected from the US spring and fall surveys to examine whether changes in condition have occurred over time (Figure 18a-b). Median weights at length from both surveys indicate a declining trend for yellowtail flounder 33-44 cm, sizes associated with the majority of commercial catch. A similar pattern was found in the condition factor (Fulton's K) for male and female yellowtail flounder in the DFO survey (Figure 18c). This has implications for the conversion of total weight in metric tons to number of individual fish at age because a constant length-weight equation for all years is used to make the conversion. If the observation of declining weight at length in the surveys also occurs in the commercial fishery landings and discards, then the number of fish in the commercial catch will be underestimated. As an example, when the 2011 observations of mean weight at length by season from the US surveys were used instead of the standard length-weight equations, the total catch in numbers of fish increased by 22%. This is in the correct direction to explain the retrospective pattern, but is too small in magnitude to explain the size of the retrospective pattern. A pilot study has recently been funded in the US to collect individual fish length and weight measurements in the commercial landings for a number of species, including yellowtail flounder. These data should provide an improved ability to convert total catch in metric tons to numbers of fish.

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 (Figure 19). 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 (Figure 20). This disparity in the basic data continues to cause difficulty for the stock assessment of Georges 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 (now called Single Series), Minor Change, and Major Change (now called Split Series). 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 Single Series VPA was continued for a number of years after the benchmark, but was not used to provide management advice for five years (Legault et al. 2006, 2007, 2008a, 2009, 2010). At the 2011 TRAC meeting, the re-emergence of a retrospective pattern in the Split Series VPA model led to the re-evaluation of the Single Series VPA model. The Single Series VPA continued to show a stronger retrospective pattern than the Split Series VPA, but some TRAC participants considered it better to use just a single retrospective adjustment (the Mohn's rho adjustment to starting population abundance for projections) rather than two (splitting the surveys and applying a retrospective adjustment). The Split Series VPA was accepted for providing status determination, but alternative projections using the Split Series VPA with retrospective adjustments and the Single Series VPA with retrospective adjustments were provided for managers. The Split Series VPA remains the default approach for determining current status and 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 v3.1.1. 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. 2011). Both point estimates and bootstrap statistics of the estimated parameters were derived using only the US software for this assessment.

The Split Series 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 older ages creating bimodal bootstrap distributions. Following the precedent of previous assessments, the Split Series VPA was reformulated to be the same as the Single Series VPA (i.e. by reverting to ages 1-6+ for the catch at age), with the exception that the survey time series were split at 1995 (Legault et al. 2006, 2007, 2008a, 2009, 2010, 2011). 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 had been sufficient to remove the retrospective pattern and pattern in residuals until last year's assessment, 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 2012
(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 2012
(note: s_5 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 2009-2012 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 2011.5
(note: s_7 = NMFS fall, ages a = 1 to 6+, time t = 2009.5-2011.5 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 2011.5
(note: the NMFS scallop survey was not used for years 1986, 1989, 1999, 2000, 2008, or 2011)

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 (2012) was assumed equal to the geometric mean over the most recent 10 years (2002-2011). Population abundance in the terminal year plus one (2012) was estimated directly for ages 2-5.

Building the Bridge

Three changes were made to the data from the 2011 TRAC assessment. There were minor changes in the 2010 US landings at age due to changes in the US databases. The US scallop survey time series was updated to reflect the results of the scale study performed in 2011 (Legault and Emery, 2012). The DFO 2011 survey values were discovered to have been shifted one age to the right in the 2011 TRAC assessment. Each of these changes was evaluated relative to the final 2011 TRAC assessment one at a time, then two at a time, and finally all three combined. The first two changes, 2010 US landings and US scallop survey had only a minor impact on results (trend lines not visibly different from 2011 TRAC for F, SSB, or recruitment; Figure 21). The DFO 2011 survey changes did have a noticeable impact, causing the 2010 F and recruitment to be higher and the 2010 SSB to be lower than the 2011 TRAC assessment (Figures 21-22). When all three changes were incorporated, the results were still within the 80% confidence interval from the 2011 TRAC assessment for 2010 F and SSB, but not for 2010 recruitment (Figure 22a-c). However, the 2010 recruitment is still estimated to be the lowest in the time series when all three changes to the data are incorporated.

These revised catch and survey 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 similarly compared to previous assessments in terms of relative error and bias in the population abundance estimates with lower relative error and bias at older ages than at 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) for the Split Series VPA also followed similar patterns to previous assessment (Table 13 and Figure 23). 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 an eight-fold increase and averaging a four-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, and thus better catch advice) than ignoring the retrospective pattern (ICES 2008).

The Split Series VPA residuals exhibit some patterning of periods with mainly positive or negative residuals during different periods throughout the time series (Figure 24). This patterning is worse than has been seen for the Split Series VPA in previous years. 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 age 6+ in 2008. The standard sampling protocol in 2008 did not collect any age 6+ yellowtail flounder in the large tow that year.

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 (Figure 25a-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, further supporting the approach of splitting the surveys.

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 tendency to underestimate F and overestimate spawning stock biomass, relative to the terminal year (Table 14 and Figure 26a-b). The retrospective pattern for spawning stock biomass is about as strong as observed in the Base Case formulations of previous assessments where rho statistics of more than 1.0 were estimated (current Single Series SSB rho = 2.5, see Sensitivity Analyses section below). The retrospective pattern in SSB should still be considered when providing management advice. The rho statistic for F is also a concern as it is consistent and strong. 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 assessments but is now estimated as below average. Note the implication of adjusting the terminal year for F, SSB, and recruitment (R) according the mean Mohn's rho in Figure 26a. These rho adjusted values for 2011 are F=0.62, SSB=1,700 mt, and R=1.7 million age 1 fish.

Despite the strong retrospective pattern in spawning stock biomass and fishing mortality rate, the Split Series VPA is recommended as the basis for estimating current stock size and fishing mortality rate. However, a retrospective adjustment should be applied when providing catch advice (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 2011. Population abundance at age for the start of the year was estimated for years 1973-2012 along with estimates of fishing mortality rates at age during years 1973-2011 (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 2,500 mt in 2006, and increased to 4,300 mt at the beginning of 2012, approximately half the magnitude of the early 2000s (Table 18 and Figure 27). Total population biomass (age 1+) has generally tracked the three groundfish surveys, although splitting the series between 1994 and 1995 implies high catchability of the surveys in recent years (Table 18 and Figure 28). Spawning stock biomass in 2011 was estimated to be 4,600 mt (80% confidence interval: 3,800-5,700 mt). These 2011 values are well below the TRAC 2011 estimates for 2010 and reflect the strong retrospective pattern in spawning stock biomass.

During 1973-2011, recruitment averaged 19.5 million fish at age 1 but has been below this average since 2002 (Table 15). The 2005 year-class is estimated at 10.8 million age 1 fish in 2006, well below previous estimates of this year-class. The 2009 age-class is estimated to be 3.1 million age 1 fish, which is above the estimate from last year's assessment due in large part to the change in the DFO 2011 survey (see bridge building section), but still the lowest in the time series to that point. The only lower year-class is 2010, estimated as 3.0 million age 1 fish in 2011. The low recent recruitment limits the ability of the stock to produce yield or rebuild.

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 1.94, and then declined to 0.67 in 2009 and 0.49 in 2010. In 2011, F was estimated to be 0.31 (80% confidence interval for 2011: 0.24-0.40), above 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 (Figure 19). The relative F pattern shows a sudden decline in 1995 and continued low levels since then. This pattern was seen in previous Single Series VPA assessments. However, those assessments had strong retrospective patterns that increased the F as additional years became available, a pattern that has re-emerged with this Split Series assessment.

Sensitivity Analyses

Four sets of sensitivity analyses were conducted to explore the robustness of the Split Series formulation:

1. Surveys used
2. Single Series VPA (formerly known as Base Case VPA)
3. Natural mortality rate
4. Alternative retrospective pattern "fixes"
    a. Increase the natural mortality rate in recent years
    b. Increase the total catch in recent years
    c. Increase both the natural mortality rate and the total catch in recent years.

The first set of sensitivity analyses used only one survey at a time as tuning indices. The US scallop survey was not considered in this sensitivity analysis because it is only an age 1 tuning index. Attempting to use all ages from only the US scallop survey did not allow the model to converge because there was no tuning information for the age 2 population abundance in 2012, because the 2011 US scallop data are not available. As has been observed in the past, using only one survey series results in larger confidence intervals about the terminal year (2011) point estimates, with the three single survey results located around the Split Series results (Figure 29). The relative location of the results from using the three individual surveys changes from year to year. As a result, the influence of any of these surveys on the direction of the Split Series results will also vary from year to year. All three individual survey series analyses also exhibited strong retrospective patterns, as can be observed by the location of the rho adjusted estimates of SSB and F relative to the confidence intervals around the point estimates. These results confirm that using all three surveys to tune the VPA is justified because the surveys are consistent and use of all three results in more precise estimates than using just one.

The second set of sensitivity analyses examined not splitting the surveys at all, but instead treated them as single series as in the benchmark Base Case runs. As noted above, relative to the Split Series VPA, the Single Series VPA had a stronger retrospective pattern (Figure 30a-b) and worse residual patterning (Figure 31). The point estimates of SSB and F in 2011 from the Single Series VPA are higher and lower, respectively, than the Split Series VPA, but the Single Series VPA rho adjusted estimates are similar to the unadjusted Split Series VPA ones (Figure 32). Based on precedent set during the TRAC meeting last year, projections from the rho adjusted Single Series VPA will be considered below.

The third set of sensitivity analyses examined a range of natural mortality rates. The M values were changed for all years and ages from 0.1 to 0.8 in steps of 0.05. The model goodness of fit, as measured by Akaike information criteria corrected for finite sample size (AICc), was best fit when M=0.45, but was within two AICc units for values of M ranging from 0.1 to 0.6 (Figure 33). Models that differ by less than two AICc units have strong support in the information theory framework (Anderson 2008). The changes in M had the usual impact on fishing mortality, spawning stock biomass, and recruitment estimates (Figure 34). Increasing the natural mortality rate caused the retrospective pattern, as measured by Mohn's rho, to improve slightly for SSB and worsen slightly for F, but none of the retrospective patterns were good (Figure 35). So while changing the natural mortality rate for all years and ages rescales the population estimates, it does not fix the assessment in terms of removing the retrospective pattern.

The fourth and final set of sensitivity analyses examined alternative "fixes" to the retrospective pattern. Specifically, the Single Series VPA was used as a base and then either the natural mortality or catch matrix was multiplied by a constant for a range of years and ages. This approach of increasing M or catch in recent years has been shown in the past to be an alternative way to fix the retrospective pattern (Legault 2009). Due to the inability of the Split Series approach to remove the retrospective pattern, the timing of when to apply the multiplier was not known, so a brute force approach was utilized. The year blocks were defined by starting at 1990 and progressing annually through to 2011. The M or catch within the given year block was multiplied by a value ranging from 1.5 to 5 in steps of 0.5. This resulted in a total of 176 combinations (22 years X 8 multipliers) for both M and catch. For each combination, the Mohn's rho for spawning stock biomass was computed based on the usual seven year peel. These rhos were plotted as a function of the start of the time block and the multiplier to determine which combination produced the least retrospective pattern. For natural mortality, there were a range of year block and multiplier combinations that resulted in essentially zero SSB retrospective pattern

(Figure 36). The zero rho combinations all required M multipliers of more than four. For example, when the year break is 2005 and the M multiplier is 4.5, natural mortality would increase suddenly from 0.2 to 0.9 for all ages between 2004 and 2005 to reduce the SSB rho to 0.05. For catch, none of the combinations reduced the SSB rho to zero or below (Figure 37). The lowest SSB rho was 0.18, which was for the year break staring in 2005 and catch multiplier of 5. Recognizing that retrospective patterns do not have to be confined to a single source, a range of combinations of M and catch multipliers was considered for the year break starting in 2005 (Figure 38). The SSB retrospective pattern could be reduced to zero for a number of combinations of M and catch multipliers, but all required at least one of the multipliers to be 2.5 or greater.

There are a number of alternative “fixes” to the retrospective patterns, but none of them can be explained by biology or fishery practices. Thus, each would have to be considered as aliasing unknown mechanisms in the same manner as the Split Series “fix.” Three alternative “fixes” were selected, all with break year 2005: M multiplier=4.5, catch multiplier=5, and M multiplier=2.5 combined with catch multiplier=3.5 (Figures 36-38). The alternative fixes have different implications for the time series and 2011 estimates of fishing mortality rate, spawning stock biomass, and recruitment (Figure 39a-b). These three alternative retrospective “fixes” will also be considered in the projections described in the Outlook section below.

These sensitivity analyses demonstrate the 80% confidence intervals for the Split Series VPA do not fully capture the total uncertainty in the assessment (as described in the Outlook section).

FISHERY REFERENCE POINTS

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, which were numerically equal in value when the F_{ref} value was selected (TMGC 2003). Both the 2002 and 2008 assessment yield per recruit analysis (NEFSC 2002, 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 0.298 and $F_{0.1}$ of 0.293. This suggests that F_{ref} is relatively robust to the changes in partial recruitment observed over the years, despite the decrease in partial recruitment at age 3, from 0.821 last year to 0.503 this year.

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 (Figure 40a-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). Spawning stock biomass is currently well below the US rebuilding goal (SSB_{2011}/SSB_{MSY} = 11%).

OUTLOOK

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2013. 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 2009-2011 average fishery partial recruitment and survey and fishery weights at age to account for the most recent conditions in the fishery and biological characteristics (Table 19a). Due to the re-emergence of a retrospective pattern in the assessment despite splitting the surveys, a range of additional projections was also considered. The Split Series and Single Series VPA models were both projected using the model estimates for 2012 as the starting conditions and adjusting these estimates to account for the retrospective pattern observed in spawning stock biomass. The spawning stock biomass retrospective rho values for the Split Series and Single Series models were 1.6231 and 2.4828, respectively, causing each bootstrap initial abundance at age to be multiplied by 1/(1+rho) = 0.3812 and 0.2871, respectively. Projections were also conducted for the three alternative "fixes" to the retrospective pattern using catch, natural mortality, or both multipliers described above. Finally, projections were conducted for a range of natural mortality values applied to all years and ages.

For the Split Series model, assuming a catch in 2012 equal to the 1,150 mt total quota, a combined Canada/US catch of about 900 mt in 2013 would result in a neutral risk (~50%) that the fishing mortality rate in 2013 will exceed F_{ref} (Figure 41a-b). Fishing at F_{ref} in 2013 will generate a 23% change in age 3+ biomass from 2013 to 2014 in the deterministic projection (3,900 mt to 4,800 mt; Table 19b). Catching the quota of 1,150 mt in 2012 is expected to cause a fishing mortality rate of 0.33 in 2012, which is above the F_{ref} of 0.25 (Table 19b). Catches of 1,700 mt, 1,300 mt, and 900 mt would be expected to cause increases in median adult biomass from 2013 to 2014 of 0%, 10%, and 20%, respectively in the stochastic projections (Figure 42a-b). These results all ignore the strong retrospective pattern in the Split Series model and thus will overestimate future catch and spawning stock biomass if the retrospective pattern continues, and thus are not considered appropriate to use for management advice. For example, the deterministic projections when the spawning stock biomass retrospective adjustment is applied to the 2012 population are much less optimistic (Table 19c). Similarly, the Single Series model has too strong a retrospective pattern to allow its use in projections for management advice; results are presented for completeness only.

The projections that either adjust the starting population abundance to account for the retrospective pattern, or else change the catch or natural mortality rate in recent years to reduce the retrospective pattern, all result in lower catch advice than the Split Series model. For example, fishing at F_{ref}=0.25 in 2013 results in median catches ranging from 190 to 744 mt (Table 20). The results for the catch multiplier retrospective "fixes" in Table 20 have been divided by the corresponding catch multiplier because the use of catch multipliers means that there is an unaccounted for source of catch, which should not be included when setting the quota (ICES 2008). The largest of these catches, 744 mt, is from the retrospective adjusted Single Series model, which had by far the worst diagnostics and required the largest retrospective adjustment for the projections. This formulation has the largest disconnect between the VPA estimated time series of fishing mortality rate, spawning stock biomass, recruitment, etc. and the starting population abundances at age used in the projections, when the retrospective adjustment is applied. This result is also associated with a 5% decline in median adult (age 3+) biomass from 2013 to 2014. When this model projection is run with 75%F_{ref}, the population is still expected to decline, but catch drops to 573 mt. The three models that attempt to fix the retrospective pattern by increasing catch, natural mortality, or both in recent years result in similar catches to each other and to the adjusted Split Series model. All of these cases project the median adult biomass to increase substantially from 2013 to 2014, but are associated with low catches in 2013.

These seven projection scenarios (including the Split Series and Single Series for completeness only, not for management advice) were examined systematically by setting catch in 2013 equal to a value ranging from zero to 3,000 mt in steps of 100 mt. The Split Series VPA adjusted for retrospective had catch greater than the population size for many of these catch values, so some results are not reported for this scenario. The probability of the 2013 fishing mortality rate exceeding F_{ref}=0.25 changes quickly for most of the scenarios, preventing estimation of the 25% and 75% probability of exceeding F_{ref} (Figure 41a-b). As in Table 20, the catch multiplier runs should have the projected 2013 catch divided by the catch multiplier to be considered as a quota. These results agree with the F_{ref} projections shown in Table 20 and indicate low catches for all scenarios hat account for the retrospective pattern in some way. The change in median biomass is generally positive over a wide range of 2013 catch amounts, except for the Single Species retrospective adjustment scenario and the Split Series retrospective adjustment (Figure 42a-b). Similarly, the probabilities of biomass increases and at least 10% biomass increases from 2013 to 2014 are generally high except for these two scenarios (Figure 43). This dichotomy of expected biomass increase combined with high probability of overfishing in some models versus expected biomass decrease combined with low probability of overfishing in other models was also seen in last year's assessment (but see examination of projection assumptions regarding age 1 in 2012 described below).

Projections were also conducted for the sensitivity analyses that varied the natural mortality rate for Split Series VPA formulation for all years and ages from 0.1 to 0.8 in steps of 0.05. The F_{ref} value for Georges Bank yellowtail flounder was derived based on both $F_{0.1}$ and $F_{40\%MSP}$. Given the large changes in natural mortality rate considered in these sensitivity analyses and the strong dependence of these reference points on the natural mortality rate, both values were estimated for each case and show the expected increase with increasing natural mortality rate (Figure 44). The fishery selectivity pattern for each natural mortality case was also used in the calculation of these reference points. The 2013 median catch (mt) for both F_{ref}=0.25 and the natural mortality specific $F_{0.1}$ for both the unadjusted and spawning stock biomass retrospective adjustment projections all increased with increasing natural mortality rate (Table 21). The higher catches associated with using $F_{0.1}$ instead of F_{ref} come at the expense of smaller increases, or even decreases, in median adult Jan-1 biomass from 2013-2014 (Figure 45). These results indicate that just changing the natural mortality rate for all years and ages does not produce an assessment that leads to much larger catch advice than the standard Split Series VPA when both the probability of overfishing and change in biomass are considered.

All of the projections described above follow the convention used in the deterministic projection table (Table 19a-b). Of particular importance is the assumption that the age 1 abundance in 2012 is set to the geometric mean of the estimated recruitment in the previous ten years. Tracing the cohort that is age 1 in 2012 through the deterministic projection table, it can be seen that the 2013 catch is only impacted a small amount, but the change in adult (age 3+) Jan-1 biomass from 2013 to 2014 can be influenced substantially by this assumption. More recent cohorts have negligible impact on either metric, so recruitment assumptions in the projections are only important for projections of length beyond those considered here. Given the decline in recruitment observed in recent years (Table 15 and Figure 40), a sensitivity analysis was conducted to determine the importance of the ten year geometric mean assumption in the projection results. The age 1 2012 estimate was multiplied by a value ranging from zero to two in steps of 0.1 for the Split Series VPA results and the 2013 fishing mortality rate was set equal to F_{ref}=0.25 in the projections. The 2013 catch changed less than 100 mt while the relative change in median adult Jan-1 biomass from 2013 to 2014 was much more strongly impacted (Figure 46). For example, if the 2012 age 1 abundance was reduced by half, a value more consistent with the most recent recruitments, the relative change in median biomass would be a 0% increase instead of showing a 20% increase. This dependence of the change in biomass metric on the assumption made for the 2012 age 1 abundance should be considered when making catch advice decisions trading off probability of overfishing for expected changes in biomass.

To achieve the TMGC objective of a fishing mortality rate below F_{ref}, catch in 2013 should be no greater than 200 mt (Table 22). Taking into account both the probability of overfishing and the relative change in biomass, as was done by the TRAC last year, as well as the numerous sensitivity runs explored this year, leads to the conclusion that catch in 2013 should be no greater than 500 mt (Table 22).

Rebuilding projections are required in the US when stocks are overfished. The rebuilding target for Georges Bank yellowtail flounder is a spawning stock biomass of 43,200 mt (denoted SSB_{MSY}). This value was set during GARM III (NEFSC 2008) based on using $F_{40\%MSP}$ as a proxy for F_{MSY} 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 SSB_{MSY} 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 SSB_{MSY} 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 original rebuilding target year was 2014. However, the International Fisheries Clarification Act allowed extension of the rebuilding time. The New England Fisheries Management Council has set the new rebuilding end date as 2032. This is so far into the future that no rebuilding projections were considered. As the rebuilding date gets closer, the biomass reference point for this stock should be re-evaluated in light of current fishery, biological, and environmental conditions.

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 (Figure 47). This pattern holds for all the scenarios examined. The 2011 population abundance proportions at age are above the values expected in equilibrium at F_{ref} for ages 3 and 4, 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 condition factor has declined over the last decade. Spatial distribution patterns from the three groundfish surveys generally follow historical averages. Truncated age structure and reduced condition factor 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. Consideration of a number of alternative “fixes” to the retrospective pattern indicate that the catch advice is robust to how these inconsistencies in the data are treated and gives support to the management advice for this stock.

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

The change 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 (Figure 48). 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 estimated spawning stock biomass, similar to the assessment retrospective analysis. However, the retrospective pattern is continuing, despite the reduction in the strength of the 2005 year-class in the last two assessments. So there is more than just a missed year-class that is generating the retrospective pattern.

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. Catch advice was provided which was expected to cause a fishing mortality rate of F_{ref} or lower. The actual catch was usually less than the quota, 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.

An additional perspective on the past performance of catch advice can be made by comparing the catch at age in weight for 2011 projected from previous assessments with the observed values measured for 2011 (Figure 49). The two projections from the 2010 and 2011 TRAC meetings are both from the Split Series model and do not make any retrospective adjustments. The current estimate is simply the catch at age in numbers multiplied by the catch weight at age. The projections and observations are quite similar for ages 1-4, but differ markedly for ages 5 and 6. The two projections resulted in 76% and 69% of the total catch in weight occurring at ages 5 and older, but only 22% of the observations. This difference between projected and observed age structure is due to the retrospective pattern and lies at the heart of the difficulties faced by this assessment.

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

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%
2011	904	192	22	50	0	1169	21%

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

		Small Mesh Trawl					Large Mesh Trawl					Scallop Dredge					Total
Year	Half	ntrips	d:k	K_all (mt)	D (mt)	CV	ntrips	d:k	K_all (mt)	D (mt)	CV	ntrips	d:k	K_all (mt)	D (mt)	CV	D (mt)
1994	1	1	0.0000	1090	0		16	0.0013	7698	10		1	0.0001	2739	0		11
	2	1	0.0000	1316	0		6	0.0199	6445	128		4	0.0039	2531	10		138
1994 Total		**2**			**0**	**0%**	**22**			**138**	**150%**	**5**			**10**	**6%**	**148**
1995	1	1	0.0000	2331	0		27	0.0023	6256	14		1	0.0017	522	1		15
	2	1	0.0000	919	0		10	0.0055	3844	21		2	0.0017	3634	6		28
1995 Total		**2**			**0**	**0%**	**37**			**36**	**70%**	**3**			**7**	**20%**	**43**
1996	1	2	0.0000	3982	0		12	0.0066	7094	47		2	0.0025	2132	5		52
	2	1	0.0000	1470	0		1	0.0005	7269	4		2	0.0081	4960	40		44
1996 Total		**3**			**0**	**0%**	**13**			**51**	**30%**	**4**			**45**	**0%**	**96**
1997	1	1	0.0000	2102	0		3	0.0247	8215	203		3	0.0048	4044	19		222
	2			1391	0		3	0.0019	4098	8		3	0.0250	3903	97		105
1997 Total		**1**			**0**	**0%**	**6**			**211**	**22%**	**6**			**117**	**74%**	**327**
1998	1	1	0.0000	1808	0		3	0.0219	8059	177		2	0.0065	3849	25		202
	2			3111	0		2	0.0015	5611	8		3	0.0551	4945	272		280
1998 Total		**1**			**0**	**0%**	**5**			**185**	**66%**	**5**			**297**	**46%**	**482**
1999	1	1	0.0000	3868	0		2	0.0010	9391	9		4	0.0152	8806	134		143
	2			2638	0		5	0.0005	4755	2		15	0.0176	24524	432		434
1999 Total		**1**			**0**	**0%**	**7**			**11**	**67%**	**19**			**566**	**13%**	**577**
2000	1	2	0.0000	3665	0		6	0.0014	10869	15		25	0.0457	8320	380		395
	2	2	0.0272	1665	0		11	0.0015	6421	10		154	0.0181	15991	289		299
2000 Total		**4**			**0**	**90%**	**17**			**25**	**71%**	**179**			**669**	**12%**	**694**
2001	1	5	0.0045	2347	0		13	0.0038	13047	49		16	0.0019	7728	14		63
	2	2	0.0000	3461	0		13	0.0002	6716	1			0.0019	7162	13		15
2001 Total		**7**			**0**	**105%**	**26**			**50**	**51%**	**16**			**28**	**7%**	**78**
2002	1	1	0.0000	2420	0		11	0.0010	14525	14			0.0035	2074	7		21
	2	6	0.0001	2243	0		37	0.0015	6196	10		4	0.0035	6134	22		31
2002 Total		**7**			**0**	**79%**	**48**			**24**	**42%**	**4**			**29**	**27%**	**53**
2003	1	7	0.0001	2350	0		61	0.0064	15264	97			0.0149	9612	143		241
	2	7	0.0002	4764	1		46	0.0021	8438	18		2	0.0149	10083	150		169
2003 Total		**14**			**1**	**95%**	**107**			**115**	**39%**	**2**			**293**	**0%**	**410**
2004	1	5	0.0005	2504	1		68	0.0078	14130	111		2	0.0001	2942	0		112
	2	12	0.0215	2508	54		86	0.0179	11958	214		28	0.0058	13885	81		348
2004 Total		**17**			**55**	**62%**	**154**			**324**	**20%**	**30**			**81**	**21%**	**460**

Table 2a. continued

		Small Mesh Trawl					Large Mesh Trawl					Scallop Dredge					Total
Year	**Half**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**ntrips**	**d:k**	**K_all (mt)**	**D (mt)**	**CV**	**D (mt)**
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**
2011	1	12	0.0049	2504	12		163	0.0040	7807	31		2	0.0133	2920	39		83
	2	18	0.0094	2162	20		147	0.0050	4735	24		68	0.0017	39557	65		109
2011 Total		**30**			**33**	**38%**	**310**			**55**	**10%**	**70**			**104**	**53%**	**192**

Table 2b. Prorated discards (kg) and fishing effort (hr) for Georges Bank yellowtail flounder from International Observer Program (IOP) trips of the Canadian scallop fishery in 2011.

		Proration			Discards (kg)		Effort (hr)
		Number of Dredges					
IOP Trip	Board Date	Observed	Total	Proportion	Observed	Prorated	
J10-0631	12/2/2010	220	372	0.59	5	8	65
J10-0446	12/7/2010	544	1046	0.52	42	81	232
J11-0010	1/18/2011	507	1061	0.48	22	46	212
J11-0011	1/20/2011	651	1342	0.49	91	188	275
J11-0015	2/6/2011	480	954	0.50	6	12	199
J11-0142	3/30/2011	648	1222	0.53	60	113	179
J11-0144	4/7/2011	140	280	0.50	160	320	42
J11-0043	4/17/2011	312	664	0.47	114	243	130
J11-0168	5/6/2011	246	322	0.76	21	27	46
J11-0218	5/17/2011	330	716	0.46	650	1410	152
J11-0280	6/12/2011	209	417	0.50	76	152	65
J11-0235	6/17/2011	442	918	0.48	246	511	171
J11-0411	7/14/2011	523	1099	0.48	277	582	221
J11-0353	7/25/2011	271	425	0.64	24	38	88
J11-0432	8/12/2011	352	694	0.51	117	231	137
J11-0434	8/19/2011	592	1226	0.48	301	623	196
J11-0447	9/16/2011	193	367	0.53	112	213	103
J11-0507	9/23/2011	528	1180	0.45	54	121	204
J11-0448	10/18/2011	197	389	0.51	79	156	76
J11-0451	10/21/2011	700	1350	0.52	65	125	189
J11-0462	11/20/2011	708	1320	0.54	21	39	201
J11-0465	11/22/2011	583	1128	0.52	44	85	233
J11-0593	12/5/2011	588	1188	0.49	27	55	217
J11-0471	12/7/2011	641	1277	0.50	5	10	235

Table 2c. Three month moving-average (ma) discard rate (kg/hr), standardized fishing effort (hr), and discards (mt) of Georges Bank yellowtail flounder from the Canadian scallop fishery in 2011. Moving-average calculations include trips from Dec. 2010.

				3-month ma			
Year	Month	Monthly Prorated Discards (kg)	Monthly Effort (hr)	Discard Rate (kg/hr)	***Effort (hr)	ma Discards (mt)	Cum. Annual Discards (mt)
*2010	Dec	89	297				
2011	Jan	234	487	0.341	572	0	0
	Feb	12	199	0.291	1781	1	1
	**Mar	12	199	0.934	827	1	1
	Apr	676	351	2.843	1204	3	5
	May	1438	198	3.539	2671	9	14
	Jun	663	236	3.664	3351	12	27
	Jul	620	309	2.435	3615	9	35
	Aug	854	333	1.907	4027	8	43
	Sep	334	307	1.625	3022	5	48
	Oct	281	265	0.735	2034	1	50
	Nov	124	434	0.408	2010	1	50
	Dec	65	452	0.213	669	0	50

*includes trips from Dec. 2010 for moving-average calculations.
** No observed trips in Mar.; assumed discards and effort were same as Feb.
***Effort hours are standardized to freezer-trawler hour equivalents

Table 3. Comparison of US landings, discards, and catch (mt) in calendar year 2011 estimated by the US quota monitoring system (within year) and the values used in the assessment (end of year).

2011	Landings	Discards	Catch
Quota Monitoring (mt)			
Jan-Jun	465	53	518
Jul-Dec	445	125	570
All Months	910	178	1088
Assessment (mt)			
Jan-Jun	465	83	548
Jul-Dec	439	109	549
All Months	904	192	1096
Diff (QM-Assess) (mt)			
Jan-Jun	1	-30	-30
Jul-Dec	6	16	22
All Months	6	-14	-8
Rel Diff (Diff/Assess)			
Jan-Jun	0%	-36%	-5%
Jul-Dec	1%	14%	4%
All Months	1%	-7%	-1%

Table 4. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2011 from US and Canadian sources.

	Landings (metric tons)					Port Sampling (Number of Lengths or Ages)						
US	Market Category					Market Category					Lengths	Number
Half	Uncl.	Large	Small	Medium	Total	Uncl.	Large	Small	Medium	Total	per 100mt	of Ages
1	56	262	137	9	465	76	3706	3253	0	7035		
2	5	301	131	1	439	0	2189	2322	0	4511		
Total	62	563	269	10	904	76	5895	5575	0	11546	1277	2379
Canada											Lengths	Number
Quarter					Total					Total	per 100mt	of Ages
1												
2												
3					17					234		
4					5					240		
Total					22					474	2155	0

Table 5. Coefficient of variation for US landings at age of Georges Bank yellowtail flounder 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%
2011	98%	19%	6%	4%	7%	15%

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	644	890	445	87	10	2	0	0	0	0	2219
2011	11	161	763	908	312	67	8	1	0	0	0	0	2231

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

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.101	0.348	0.462	0.527	0.603	0.690	1.063	1.131	1.275	1.389	1.170	
1974	0.115	0.344	0.496	0.607	0.678	0.723	0.904	1.245	1.090		1.496	1.496
1975	0.113	0.316	0.489	0.554	0.619	0.690	0.691	0.654	1.052	0.812		
1976	0.108	0.312	0.544	0.635	0.744	0.813	0.854	0.881	1.132	1.363	1.923	
1977	0.116	0.342	0.524	0.633	0.780	0.860	1.026	1.008	0.866	0.913		
1978	0.102	0.314	0.510	0.690	0.803	0.903	0.947	1.008	1.227	1.581	0.916	
1979	0.114	0.329	0.462	0.656	0.736	0.844	0.995	0.906	1.357	1.734	1.911	
1980	0.101	0.322	0.493	0.656	0.816	1.048	1.208	1.206	1.239			
1981	0.122	0.335	0.489	0.604	0.707	0.821	0.844	1.599	1.104			
1982	0.115	0.301	0.485	0.650	0.754	1.065	1.037	1.361				
1983	0.140	0.296	0.441	0.607	0.740	0.964	1.005	1.304	1.239			
1984	0.162	0.239	0.379	0.500	0.647	0.743	0.944	1.032				
1985	0.181	0.361	0.505	0.642	0.729	0.808	0.728					
1986	0.181	0.341	0.540	0.674	0.854	0.976	0.950	1.250		1.686		
1987	0.121	0.324	0.524	0.680	0.784	0.993	0.838	0.771	0.809			
1988	0.103	0.328	0.557	0.696	0.844	1.042	0.865	1.385				
1989	0.100	0.327	0.520	0.720	0.866	0.970	1.172	1.128				
1990	0.105	0.290	0.395	0.585	0.693	0.787	1.057					
1991	0.121	0.237	0.369	0.486	0.723	0.850	1.306					
1992	0.101	0.293	0.365	0.526	0.651	1.098	1.125	1.303	1.303			
1993	0.100	0.285	0.379	0.501	0.564	0.843	1.130	1.044				
1994	0.193	0.260	0.353	0.472	0.621	0.780	0.678	1.148				
1995	0.174	0.275	0.347	0.465	0.607	0.720	0.916	0.532				
1996	0.119	0.276	0.407	0.552	0.707	0.918	1.031	1.216				
1997	0.214	0.302	0.408	0.538	0.718	1.039	0.827	1.136	1.113			
1998	0.178	0.305	0.428	0.546	0.649	0.936	1.063	1.195		1.442		
1999	0.202	0.368	0.495	0.640	0.755	0.870	1.078	1.292	1.822			
2000	0.229	0.383	0.480	0.615	0.766	0.934	1.023	1.023	1.296			
2001	0.251	0.362	0.460	0.612	0.812	1.011	1.024	1.278	1.552			
2002	0.282	0.381	0.480	0.665	0.833	0.985	1.100	1.286	1.389	1.483		
2003	0.228	0.359	0.474	0.653	0.824	0.957	1.033	1.144	1.267	1.418	1.505	
2004	0.211	0.292	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	0.432	0.519	0.661	0.777	0.997	1.175				
2011	0.126	0.336	0.462	0.553	0.646	0.739	0.811	0.851				

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, along with the coefficient of variation (CV) for the biomass estimates. Note the 2011 values have changed from last year's assessment (see text: Building the Bridge for details).

Year	age1	age2	age3	age4	age5	age6+	B(000 mt)	CV(B)
1987	75.2	751.1	1238.5	309.7	54.9	30.9	1.250	27%
1988	0.0	1116.5	801.9	383.6	174.9	14.8	1.235	22%
1989	71.8	645.8	383.2	185.2	41.8	14.1	0.471	26%
1990	0.0	1500.9	2281.1	575.0	131.3	8.6	1.513	22%
1991	15.4	539.6	745.8	2364.1	330.3	9.1	1.758	33%
1992	34.8	6942.1	2312.0	622.4	219.8	18.8	2.475	16%
1993	49.4	1528.8	2568.8	2562.9	557.5	81.8	2.642	15%
1994	0.0	3808.4	2178.6	1890.1	491.4	130.0	2.753	23%
1995	132.0	786.5	2737.4	1600.8	406.6	63.6	2.027	20%
1996	280.5	4491.0	5769.2	3399.8	726.5	77.2	5.303	22%
1997	13.6	7849.2	8742.1	10293.6	2543.2	421.5	13.293	23%
1998	561.7	2094.3	3085.9	2725.6	1250.4	351.2	4.293	24%
1999	99.8	13118.5	13101.2	4822.9	3364.5	1383.5	17.666	32%
2000	6.8	8655.8	17256.5	12100.9	3187.6	2319.8	19.949	25%
2001	183.3	12511.6	26489.4	8368.0	2881.0	1507.2	22.158	42%
2002	55.5	7522.3	19503.3	7693.6	3491.7	1781.4	20.699	31%
2003	56.3	7476.4	15480.7	6971.1	2151.0	1249.9	16.249	32%
2004	20.6	2263.5	10225.3	5788.7	1429.2	890.5	9.054	31%
2005	377.3	1007.5	17581.9	12931.4	3581.9	983.8	13.357	53%
2006	391.5	3076.8	11696.4	4132.7	515.4	149.4	6.579	44%
2007	108.9	7646.4	17423.7	8048.5	1439.1	156.2	13.344	43%
2008	0.0	30382.5	107131.7	35919.3	5067.8	34.5	67.319	94%
2009	13.4	5370.4	86753.6	73553.8	12513.9	2996.1	72.044	79%
2010	0.0	307.6	5906.1	13170.2	2221.7	804.5	9.138	29%
2011	13.9	409.3	3831.5	5159.9	1069.5	205.8	3.830	29%
2012	27.9	405.2	5183.7	7183.4	1946.9	284.9	5.620	36%

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, along with the coefficient of variation (CV) for the biomass estimates.

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)	CV(B)
1968	181.2	3227.3	3474.3	295.2	70.9	300.8	2.709	23%
1969	1046.8	9067.8	10793.9	3081.4	1305.2	678.2	10.842	29%
1970	78.4	4364.8	5853.3	2350.9	553.0	302.0	4.994	15%
1971	810.4	3412.9	4671.6	3202.9	757.1	310.6	4.483	19%
1972	137.0	6719.3	6843.1	3595.8	1093.7	232.0	6.266	21%
1973	1882.9	3184.3	2309.4	1036.7	399.4	210.2	2.852	17%
1974	308.2	2168.5	1795.5	1225.0	336.9	273.8	2.640	18%
1975	409.2	2918.0	809.1	262.6	201.5	86.3	1.626	22%
1976	1008.4	4259.0	1216.0	302.4	191.2	108.4	2.206	17%
1977	0.0	654.0	1097.7	363.7	81.9	12.8	0.970	31%
1978	912.2	778.4	494.4	213.9	25.7	7.7	0.720	19%
1979	394.0	1956.8	395.2	328.3	58.7	88.7	1.234	21%
1980	55.3	4528.6	5617.2	460.6	55.0	35.3	4.325	35%
1981	11.4	995.9	1724.2	698.9	206.9	56.9	1.903	33%
1982	44.1	3656.5	1096.5	992.5	444.5	88.3	2.426	20%
1983	0.0	1810.0	2647.8	514.4	119.6	237.3	2.564	30%
1984	0.0	90.3	806.0	837.9	810.4	236.5	1.598	43%
1985	106.4	2134.2	254.4	273.4	143.4	0.0	0.959	51%
1986	26.6	1753.0	282.6	54.6	132.9	53.2	0.823	31%
1987	26.6	73.3	133.0	129.3	51.0	53.2	0.319	37%
1988	75.5	266.9	355.2	234.7	193.2	26.6	0.549	26%
1989	45.2	391.3	737.7	281.0	59.3	43.5	0.708	26%
1990	0.0	63.7	1074.7	358.4	112.2	100.8	0.678	32%
1991	422.5	0.0	246.9	665.1	255.5	20.0	0.612	25%
1992	0.0	1987.7	1840.7	621.8	160.0	16.7	1.520	46%
1993	44.7	281.1	485.8	307.9	26.0	0.0	0.468	26%
1994	0.0	602.3	614.7	343.6	140.4	38.7	0.641	22%
1995	39.0	1144.6	4670.4	1441.7	621.5	9.5	2.504	60%
1996	24.4	958.1	2548.6	2621.8	591.6	56.2	2.769	31%
1997	18.2	1134.5	3623.1	3960.7	682.3	129.7	4.231	24%
1998	0.0	2020.1	1022.2	1123.4	737.1	339.6	2.256	22%
1999	48.7	4606.3	10501.7	2640.5	1575.2	756.3	9.033	42%
2000	177.3	4677.6	7440.5	2828.5	789.2	508.4	6.499	23%
2001	0.0	2246.7	6370.5	2340.0	469.2	439.7	4.859	33%
2002	182.4	2341.5	11971.1	3958.4	1690.3	845.4	9.282	26%
2003	196.1	4241.4	6564.9	2791.9	428.6	836.9	6.524	40%
2004	47.1	957.3	2114.4	659.9	247.7	263.8	1.835	27%
2005	0.0	1953.5	4931.0	2332.7	261.8	111.4	3.307	33%
2006	493.5	907.8	3419.2	2112.7	307.7	79.8	2.349	19%
2007	87.1	4899.7	6079.1	2762.3	540.0	125.2	4.563	22%
2008	0.0	2206.7	4921.5	1681.1	300.3	26.6	3.152	22%
2009	218.8	546.4	6978.7	4456.8	964.1	186.3	4.619	22%
2010	16.5	662.8	5181.0	8057.2	2584.0	613.9	5.662	27%
2011	26.9	236.6	3116.0	3512.9	914.1	100.6	2.419	23%
2012	92.7	530.1	3476.9	6141.4	1563.6	180.3	3.878	49%

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, along with the coefficient of variation (CV) for the biomass estimates.

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)	CV(B)
1963.5	14289.1	7663.6	10897.1	1804.0	480.5	532.7	12.413	19%
1964.5	1671.3	9517.3	7097.2	5791.2	2634.2	473.3	13.168	40%
1965.5	1162.1	5537.0	5811.9	3427.8	1600.9	250.6	8.852	32%
1966.5	11320.3	2184.4	1635.3	871.9	98.3	0.0	3.813	32%
1967.5	8720.8	9131.0	2646.7	1006.7	299.3	132.3	7.445	26%
1968.5	11328.3	11702.5	5588.9	722.7	936.8	56.4	10.227	23%
1969.5	9656.7	10601.8	5064.1	1757.4	327.0	447.7	9.519	26%
1970.5	4474.9	4981.2	3051.2	1894.7	438.2	77.8	4.833	28%
1971.5	3520.0	6770.9	4769.9	2183.8	483.4	289.1	6.178	21%
1972.5	2416.9	6332.8	4682.3	2032.9	592.1	331.7	6.142	28%
1973.5	2420.4	5336.0	4954.5	2857.4	1181.2	599.9	6.299	30%
1974.5	4486.7	2779.5	1471.6	1029.1	444.3	368.1	3.561	19%
1975.5	4548.6	2437.3	851.7	555.2	324.4	61.1	2.257	16%
1976.5	333.5	1863.9	460.3	113.6	118.5	97.3	1.463	25%
1977.5	906.7	2147.1	1572.8	615.4	102.3	105.7	2.699	20%
1978.5	4620.6	1243.3	757.2	399.2	131.6	34.9	2.274	20%
1979.5	1282.0	2008.5	253.7	116.7	134.3	108.6	1.450	29%
1980.5	743.6	4970.0	5912.0	662.0	212.3	250.9	6.412	22%
1981.5	1548.2	2279.4	1592.8	570.5	76.4	52.8	2.500	32%
1982.5	2353.3	2120.3	1543.4	410.4	86.6	0.0	2.203	30%
1983.5	105.7	2216.4	1858.5	495.7	29.9	47.7	2.068	22%
1984.5	641.6	388.1	296.7	236.0	72.7	60.7	0.576	31%
1985.5	1310.2	527.5	165.9	49.1	78.3	0.0	0.688	26%
1986.5	273.4	1075.1	338.7	71.9	0.0	0.0	0.796	37%
1987.5	98.7	388.8	384.6	51.4	77.1	0.0	0.494	28%
1988.5	18.2	206.7	104.0	26.6	0.0	0.0	0.165	32%
1989.5	241.0	1934.1	750.4	76.6	54.0	0.0	0.948	58%
1990.5	0.0	359.2	1429.9	285.8	0.0	0.0	0.703	33%
1991.5	2038.8	267.0	426.2	347.2	0.0	0.0	0.708	29%
1992.5	146.8	383.9	691.0	157.1	139.4	26.6	0.559	30%
1993.5	814.6	135.2	568.8	520.4	0.0	21.4	0.529	42%
1994.5	1159.8	214.6	954.1	692.2	254.9	54.8	0.871	32%
1995.5	267.7	115.4	335.2	267.2	44.6	12.1	0.344	35%
1996.5	144.3	341.3	1813.8	433.5	72.7	0.0	1.265	58%
1997.5	1351.8	517.7	3341.0	2028.5	1039.8	79.8	3.670	35%
1998.5	1844.4	4675.3	4078.9	1154.6	289.5	71.7	4.220	34%
1999.5	2998.7	8175.9	5558.9	1390.3	1394.2	252.8	7.738	21%

Table 11. continued

Year	age1	age2	age3	age4	age5	age6+	B (000 mt)	CV(B)
2000.5	610.8	1647.5	4672.5	2350.3	919.7	802.6	5.666	49%
2001.5	3414.2	6083.6	7853.7	2524.8	1667.8	1988.2	11.213	40%
2002.5	2031.4	5581.8	2064.5	576.1	295.6	26.6	3.644	51%
2003.5	1045.3	4882.8	2725.9	548.0	97.0	185.7	3.919	33%
2004.5	850.3	5346.1	4862.4	2044.4	897.1	170.7	4.966	46%
2005.5	304.0	2033.6	3652.1	595.9	179.3	0.0	2.391	52%
2006.5	6012.1	6067.2	3556.7	1132.9	247.7	44.4	4.388	27%
2007.5	1026.5	11110.9	7634.7	1939.6	371.3	90.9	7.912	31%
2008.5	162.8	6963.2	9592.7	1002.8	0.0	0.0	6.900	28%
2009.5	445.8	4169.4	11531.5	2072.0	588.3	57.9	6.797	27%
2010.5	115.4	2661.6	4205.3	719.7	272.7	0.0	2.242	30%
2011.5	234.4	2795.0	3756.5	1079.7	141.8	9.6	2.380	26%

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, 2008, and 2011 surveys did not fully cover the Canadian portion of Georges Bank (D. Hart, pers. comm.). These values have changed since last assessment (see text: Building the Bridge).

Year	age1	age2	age3	age4	age5	age6+	B (kg/tow)
1982.5	0.3505	0.5851	0.2863	0.1768	0.0541	0.0000	0.527
1983.5	0.1389	0.5693	0.5811	0.0828	0.0176	0.0339	0.699
1984.5	0.2021	0.2606	0.0935	0.0813	0.0765	0.0089	0.244
1985.5	0.2717	0.4373	0.0131	0.0158	0.0295	0.0000	0.143
1986.5							
1987.5	0.1031	0.0776	0.1154	0.0541	0.0069	0.0029	0.187
1988.5	0.1175	0.0172	0.0324	0.0475	0.0401	0.0000	0.108
1989.5							
1990.5	0.1020	0.0257	0.3312	0.0861	0.0356	0.0126	0.245
1991.5	1.9094	0.0000	0.1248	0.1383	0.0296	0.0000	0.377
1992.5	0.3032	0.1281	0.3407	0.2285	0.0482	0.0030	0.409
1993.5	1.1636	0.1966	0.2860	0.1457	0.0081	0.0000	0.427
1994.5	1.4197	0.3308	0.4193	0.2807	0.0614	0.0246	0.603
1995.5	0.5183	0.4546	0.7705	0.5047	0.1627	0.0091	0.846
1996.5	0.3673	0.3037	0.8574	0.7357	0.3089	0.0188	1.271
1997.5	0.9682	0.3956	1.2006	0.9694	0.2008	0.0362	1.659
1998.5	1.7583	0.8858	0.7353	0.9479	0.5744	0.1074	2.041
1999.5							
2000.5							
2001.5	0.8943	0.4727	1.0595	0.5453	0.1249	0.1669	1.525
2002.5	0.9561	0.2885	0.8333	0.3803	0.2290	0.1358	1.336
2003.5	0.7469	0.6047	0.9887	0.6538	0.1330	0.1980	1.783
2004.5	0.3459	0.4124	0.7100	0.1994	0.0415	0.0175	0.777
2005.5	0.4657	0.3523	0.5743	0.2279	0.0842	0.0090	0.623
2006.5	1.9150	0.9652	0.6833	0.3202	0.0429	0.0247	0.880
2007.5	0.5074	1.6374	1.1764	0.3705	0.0592	0.0040	1.265
2008.5							
2009.5	0.2021	0.0775	0.7519	0.6516	0.1352	0.0162	0.719
2010.5	0.0862	0.2131	0.5783	0.9095	0.2878	0.0581	0.749
2011.5							

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.

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
	Population Abundance				
2	2417	1313	54%	287	12%
3	1951	746	38%	119	6%
4	2990	961	32%	145	5%
5	2219	540	24%	86	4%
	Survey Calibration Constants				
DFO Survey: 1987-1994					
2	0.145	0.049	34%	0.010	7%
3	0.232	0.032	14%	0.002	1%
4	0.389	0.072	18%	0.003	1%
5	0.436	0.094	22%	0.009	2%
6+	0.254	0.062	24%	0.005	2%
DFO Survey: 1995-2012					
2	0.375	0.093	25%	0.006	2%
3	1.898	0.385	20%	0.042	2%
4	2.549	0.519	20%	0.037	1%
5	1.969	0.428	22%	0.035	2%
6+	1.325	0.267	20%	0.018	1%
NMFS Spring Survey: Yankee 41, 1973-1981					
1	0.007	0.006	79%	0.002	25%
2	0.076	0.013	18%	0.001	1%
3	0.096	0.016	17%	0.002	2%
4	0.093	0.011	12%	0.001	1%
5	0.076	0.015	20%	0.001	2%
6+	0.072	0.023	32%	0.004	5%
NMFS Spring Survey: Yankee 36, 1982-1994					
1	0.004	0.001	24%	0.000	2%
2	0.046	0.014	31%	0.002	4%
3	0.095	0.015	15%	0.002	2%
4	0.152	0.020	13%	0.001	1%
5	0.229	0.046	20%	0.006	3%
6+	0.423	0.094	22%	0.016	4%

Table 13. continued

Age	Estimate	Bootstrap Standard Error	Relative Error	Bias	Relative Bias
NMFS Spring Survey: Yankee 36, 1995-2012					
1	0.007	0.002	32%	0.000	4%
2	0.167	0.023	14%	0.002	1%
3	0.715	0.109	15%	0.009	1%
4	0.856	0.156	18%	0.011	1%
5	0.670	0.127	19%	0.017	3%
6+	0.525	0.093	18%	0.005	1%
NMFS Fall Survey: 1973-1994					
1	0.040	0.010	26%	0.002	4%
2	0.088	0.014	16%	0.000	1%
3	0.150	0.016	11%	0.001	1%
4	0.156	0.021	13%	0.001	1%
5	0.205	0.041	20%	0.003	2%
6+	0.306	0.064	21%	0.007	2%
NMFS Fall Survey: 1995-2011					
1	0.075	0.017	23%	0.002	2%
2	0.350	0.125	36%	0.022	6%
3	0.796	0.169	21%	0.019	2%
4	0.554	0.103	19%	0.012	2%
5	0.518	0.132	26%	0.015	3%
6+	0.364	0.136	37%	0.018	5%
NMFS Scallop Survey: 1982-1994					
1	0.026	0.008	32%	0.001	5%
NMFS Scallop Survey: 1995-2011					
1	0.058	0.008	15%	0.001	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	-0.663	0.747	-0.416
2	-0.762	2.256	-0.126
3	-0.729	3.449	-0.440
4	-0.711	2.330	1.536
5	-0.463	1.105	4.410
6	-0.128	0.785	-0.056
7	-0.024	0.689	0.492
mean	-0.497	1.623	0.772

Table 15. Beginning of year population abundance numbers (000s) for Georges Bank yellowtail flounder from the Split Series VPA. The age 1 value in the last year is the geometric mean of the previous ten years.

	Age Group						
Year	1	2	3	4	5	6+	Total
1973	29384	24172	29516	17300	6966	3013	110351
1974	52184	23733	15136	12051	5732	2391	111229
1975	70632	40588	10930	5010	3079	1709	131948
1976	24731	53646	9852	2425	977	1562	93193
1977	17283	19674	15554	3171	719	850	57252
1978	54437	13809	7987	3390	956	373	80953
1979	25508	35604	8124	2468	1073	559	73336
1980	24034	20595	19711	3268	747	239	68594
1981	62997	19390	13268	7499	1302	221	104677
1982	22846	51480	14885	5535	1783	156	96685
1983	6581	16754	25937	5517	1514	345	56648
1984	10843	4755	6579	6472	2305	487	31441
1985	16749	8414	2089	1379	870	136	29636
1986	8473	12837	2991	767	402	224	25695
1987	9193	6776	4801	1440	282	201	22692
1988	22841	7386	2617	1153	309	73	34379
1989	9661	18250	3361	771	198	55	32296
1990	11217	7738	12981	1747	250	47	33980
1991	22557	8975	4437	4399	560	104	41032
1992	17518	17869	7215	2296	940	65	45903
1993	13938	12168	6459	3250	574	126	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	19791	10935	7174	5103	1039	246	44288
1998	22377	16129	7932	4227	2515	328	53508
1999	24509	18169	11411	3465	1777	675	60006
2000	19748	20012	12396	5585	1454	930	60126
2001	22172	16049	12908	5047	1751	916	58843
2002	15125	17994	10545	4374	1560	1108	50706
2003	10600	12192	10985	5543	1869	1657	42846
2004	6895	8534	6467	4783	2463	1838	30981
2005	8847	5591	5949	2455	564	266	23671
2006	10800	7189	3159	1306	502	295	23252
2007	7399	8705	4722	1138	234	95	22294
2008	8225	6012	5785	2339	343	67	22771
2009	6906	6708	4478	3030	1149	164	22434

2010	3130	5638	5236	2529	1265	282	18081
2011	2964	2561	4491	3707	1273	309	15306
2012	7269	2417	1951	2990	2219	947	17794

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

	Age Group						
Year	1	2	3	4	5	6+	4-5
1973	0.01	0.27	0.70	0.90	0.90	0.90	0.90
1974	0.05	0.58	0.91	1.16	1.16	1.16	1.16
1975	0.08	1.22	1.31	1.43	1.43	1.43	1.43
1976	0.03	1.04	0.93	1.02	1.02	1.02	1.02
1977	0.02	0.70	1.32	1.00	1.00	1.00	1.00
1978	0.22	0.33	0.97	0.95	0.95	0.95	0.95
1979	0.01	0.39	0.71	0.99	0.99	0.99	0.99
1980	0.01	0.24	0.77	0.72	0.72	0.72	0.72
1981	0.00	0.06	0.67	1.24	1.24	1.24	1.24
1982	0.11	0.49	0.79	1.10	1.10	1.10	1.10
1983	0.13	0.73	1.19	0.67	0.67	0.67	0.67
1984	0.05	0.62	1.36	1.81	1.81	1.81	1.81
1985	0.07	0.83	0.80	1.03	1.03	1.03	1.03
1986	0.02	0.78	0.53	0.80	0.80	0.80	0.80
1987	0.02	0.75	1.23	1.34	1.34	1.34	1.34
1988	0.02	0.59	1.02	1.56	1.56	1.56	1.56
1989	0.02	0.14	0.45	0.93	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	0.77	1.94	1.94	1.94	1.94
2005	0.01	0.37	1.32	1.39	1.39	1.39	1.39
2006	0.02	0.22	0.82	1.52	1.52	1.52	1.52
2007	0.01	0.21	0.50	1.00	1.00	1.00	1.00
2008	0.00	0.09	0.45	0.51	0.51	0.51	0.51
2009	0.00	0.05	0.37	0.67	0.67	0.67	0.67
2010	0.00	0.03	0.15	0.49	0.49	0.49	0.49
2011	0.00	0.07	0.21	0.31	0.31	0.31	0.31

Table 17. Beginning of year weight (kg) at age for Georges Bank yellowtail. The 2012 values are set equal to the average of the 2009-2011 values.

	Age Group					
Year	1	2	3	4	5	6+
1973	0.055	0.292	0.403	0.465	0.564	0.778
1974	0.069	0.186	0.416	0.530	0.598	0.832
1975	0.068	0.191	0.410	0.524	0.613	0.695
1976	0.061	0.188	0.415	0.557	0.642	0.861
1977	0.071	0.192	0.404	0.587	0.704	0.931
1978	0.057	0.191	0.418	0.601	0.713	0.970
1979	0.068	0.183	0.381	0.578	0.713	0.950
1980	0.056	0.192	0.403	0.551	0.732	1.072
1981	0.078	0.184	0.397	0.546	0.681	0.840
1982	0.072	0.192	0.403	0.564	0.675	1.082
1983	0.107	0.185	0.364	0.543	0.694	1.010
1984	0.109	0.183	0.335	0.470	0.627	0.797
1985	0.132	0.242	0.347	0.493	0.604	0.800
1986	0.135	0.248	0.442	0.583	0.741	1.015
1987	0.074	0.242	0.423	0.606	0.727	0.875
1988	0.058	0.199	0.425	0.604	0.758	0.975
1989	0.059	0.184	0.413	0.633	0.776	1.053
1990	0.070	0.170	0.359	0.552	0.706	0.845
1991	0.078	0.158	0.327	0.438	0.650	0.877
1992	0.060	0.188	0.294	0.441	0.563	1.110
1993	0.062	0.170	0.333	0.428	0.545	0.863
1994	0.162	0.161	0.317	0.423	0.558	0.775
1995	0.138	0.230	0.300	0.405	0.535	0.768
1996	0.075	0.219	0.335	0.438	0.573	1.012
1997	0.179	0.190	0.336	0.468	0.630	0.947
1998	0.124	0.256	0.360	0.472	0.591	0.966
1999	0.147	0.256	0.389	0.523	0.642	0.901
2000	0.182	0.278	0.420	0.552	0.700	0.954
2001	0.204	0.288	0.420	0.542	0.707	1.027
2002	0.250	0.309	0.417	0.553	0.714	1.068
2003	0.202	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	0.125	0.224	0.376	0.475	0.596	0.808
2011	0.066	0.242	0.386	0.489	0.579	0.747
2012	0.099	0.197	0.375	0.479	0.595	0.828

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+	3+	SSB
1973	34860	26206	22161
1974	26134	18088	14780
1975	22723	10184	9014
1976	18984	7408	10024
1977	14447	9447	8351
1978	12146	6418	6169
1979	14070	5818	8501
1980	15820	10540	10884
1981	18890	10430	10144
1982	21994	10493	12975
1983	17637	13841	11103
1984	9121	7075	3847
1985	6283	2040	2558
1986	6628	2293	3210
1987	5599	3282	2750
1988	4905	2113	2198
1989	6004	2088	4170
1990	7947	5845	4750
1991	7004	3834	3485
1992	8153	3735	4472
1993	6893	3964	3966
1994	7443	4228	2823
1995	6229	2145	2941
1996	7275	4185	4992
1997	11304	5683	6379
1998	13541	6649	7259
1999	16242	7997	9592

Year	Beginning Biomass 1+	3+	SSB
2000	19359	10197	10259
2001	19468	10331	9253
2002	18455	9111	10106
2003	16907	10892	10032
2004	11883	8536	5423
2005	6197	4045	3176
2006	4488	2473	2379
2007	4770	2473	2922
2008	4814	3371	3662
2009	5481	3906	4194
2010	5807	4153	4445
2011	5329	4515	4554
2012		4267	

Table 19a. Recent three year averages of partial recruitment to the fishery, maturity, beginning of year weights at age and catch weights at age used in projections.

	Age Group					
	1	2	3	4	5	6+
Partial Recruitment to the Fishery						
	0.006	0.119	0.503	1	1	1
Maturity						
	0	0.462	0.967	1	1	1
Fraction of M before Spawning =				0.4167		
Fraction of F before Spawning =				0.4167		
Jan-1 Weight for Population (kg)						
	0.099	0.197	0.375	0.479	0.595	0.828
Average Weight for Catch (kg)						
	0.152	0.329	0.443	0.537	0.669	0.828

Table 19b. Deterministic projections from the Split Series VPA for Georges Bank yellowtail assuming the quota is caught next year and F_{ref} is applied in the quota year.

	Age Group							
Year	1	2	3	4	5	6+	1+	3+
Fishing Mortality								
2012	0.002	0.04	0.167	0.333	0.333	0.333		
2013	0.002	0.03	0.126	0.25	0.25	0.25		
Jan-1 Population Numbers (000s)								
2012	7269	2417	1951	2990	2219	947		
2013	7269	5940	1902	1352	1755	1859		
2014	7269	5943	4720	1373	862	2304		
Jan-1 Population Biomass (mt)								
2012	720	476	732	1432	1320	784	5464	4268
2013	720	1170	713	647	1044	1539	5834	3944
2014	720	1171	1770	658	513	1908	6739	4849
Spawning Stock Biomass (mt)								
2012	0	333	717	1286	1189	628	4153	
2013	0	820	711	602	974	1276	4383	
Catch Numbers (000s)								
2012	13	85	273	771	572	244		
2013	10	158	204	272	353	374		
Fishery Yield (mt including discards)								
2012	2	28	121	414	383	202	**1150**	
2013	2	52	90	146	236	310	**836**	

Table 19c. Deterministic projections from the Split Series VPA with SSB rho adjustment applied to all ages in the first year for Georges Bank yellowtail assuming the quota is caught next year and F_{ref} is applied in the quota year.

	Age Group							
Year	1	2	3	4	5	6+	1+	3+
Fishing Mortality								
2012	0.007	0.147	0.623	1.238	1.238	1.238		
2013	0.002	0.03	0.126	0.25	0.25	0.25		
Jan-1 Population Numbers (000s)								
2012	2771	922	744	1140	846	361		
2013	2771	2252	651	327	271	287		
2014	2771	2265	1790	470	208	355		
Jan-1 Population Biomass (mt)								
2012	274	182	279	546	503	299	2083	1627
2013	274	444	244	157	161	237	1517	799
2014	274	446	671	225	124	294	2035	1315
Spawning Stock Biomass (mt)								
2012	0	121	226	336	311	164	1159	
2013	0	311	244	145	150	197	1047	
Catch Numbers (000s)								
2012	19	115	316	748	555	237		
2013	4	60	70	66	54	58		
Fishery Yield (mt including discards)								
2012	3	38	140	402	372	196	**1150**	
2013	1	20	31	35	36	48	**171**	

Table 20. Projection results under two fishing mortality rates: F_{ref}=0.25 and 75% F_{ref}=0.1875. The rows definitions are Catch=median Catch (mt) in 2013, Adult Jan-1 B=median beginning year age 3+ biomass in 2013, delta B = change in median adult Jan-1 biomass from 2013 to 2014, P(B inc) = probability that adult Jan-1 biomass will increase from 2013 to 2014, P(B inc 10%) = probability that adult Jan-1 biomass will increase by at least 10% from 2013 to 2014. The column definitions are Split=Split Series VPA, adjSp=Split Series VPA adjusted for SSB retrospective, Single=Single Series VPA, adjSi=Single Series VPA adjusted for SSB retrospective, Cmults=catch in years 2005-2011 multiplied by 5, Mmults=natural mortality in years 2005-2011 multiplied by 4.5, M&C=natural mortality in years 2005-2011 multiplied by 2.5 and catch in years 2005-2011 multiplied by 3.5. Note that the Catch results reported for Cmults and M&C have been divided by the catch multiplier associated with that run. The Split and Single results are shown in a different font to indicate that they do not sufficiently address the retrospective problem.

	Split	adjSp	Single	adjSi	Cmults	Mmults	M&C
Fref = 0.25							
Catch	882	190	3183	744	319	331	232
Adult Jan-1 B	4163	881	14900	3441	7497	1931	4270
delta B	20%	56%	-10%	-5%	61%	86%	69%
P(B inc)	1	1	0.001	0.127	1	1	1
P(B inc 10%)	0.974	1	0	0.001	1	1	1
F75%Fref = 0.1875							
Catch	679	146	2454	573	245	253	178
Adult Jan-1 B	4163	881	14900	3441	7497	1931	4270
delta B	25%	61%	-5%	-1%	66%	89%	73%
P(B inc)	1	1	0.045	0.494	1	1	1
P(B inc 10%)	0.998	1	0	0.016	1	1	1

Table 21. Median catch (mt) in 2013 for the Split Series VPA formulation used with a range of natural mortality values for all years and ages. The F_{ref} was assumed to be 0.25 for all cases, while the $F_{0.1}$ was calculated for each natural mortality rate. The prefix "adj" means that the results from the VPA were adjusted according to the spawning stock biomass retrospective pattern for that natural mortality value. The bolded cells indicate the standard Split Series VPA formulation results.

M	Fref	adjFref	F0.1	adjF0.1
0.10	834	136	556	90
0.15	858	161	786	148
0.20	**882**	**190**	1015	218
0.25	912	221	1263	307
0.30	949	258	1542	421
0.35	991	298	1857	561
0.40	1042	344	2230	741
0.45	1096	393	2651	957
0.50	1151	443	3121	1212
0.55	1211	496	3672	1518
0.60	1282	552	4319	1882
0.65	1365	612	5099	2311
0.70	1475	678	6063	2819
0.75	1617	744	7275	3380
0.80	1804	830	8858	4114

Table 22. Implications of four 2013 quotas (200 mt, 400 mt, 500 mt and 600 mt) in seven projection scenarios described in Table 20: B2013 = Median 2013 Jan-1 adult (ages 3+) biomass (these biomass values are the same for all 2013 quotas), P(F>Fref) = probability fishing mortality rate in 2013 will exceed F_{ref}, F2013 = median 2013 F, deltaB = relative change in median biomass from 2013 to 2014, P(B inc) = probability median adult Jan-1 biomass will increase or P(B inc 10%) = increase by at least 10%. The Split and Single results are shown in a different font to indicate that they do not sufficiently address the retrospective problem. The Cmults and M&C results are derived from runs which had projected catches of 5.0 and 3.5 times the quota values (e.g. the 500 mt quota corresponds to catches of 2,500 mt for Cmults and 1,750 mt for M&C).

	Split	adjSp	Single	adjSi	Cmults	Mmults	M&C
B2013	4163	881	14900	3441	7497	1931	4270
200 mt quota							
P(F>Fref)	0.00	0.56	0.00	0.00	0.03	0.02	0.25
F2013	0.05	0.27	0.01	0.06	0.15	0.15	0.21
deltaB	36%	55%	9%	10%	70%	91%	72%
P(B inc)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(B inc 10%)	1.00	1.00	0.47	0.55	1.00	1.00	1.00
400 mt quota							
P(F>Fref)	0.00	0.99	0.00	0.01	0.83	0.80	1.00
F2013	0.11	0.60	0.03	0.13	0.32	0.31	0.46
deltaB	32%	33%	8%	4%	56%	84%	58%
P(B inc)	1.00	1.00	1.00	0.96	1.00	1.00	1.00
P(B inc 10%)	1.00	1.00	0.28	0.01	1.00	1.00	1.00
500 mt quota							
P(F>Fref)	0.01	1.00	0.00	0.04	0.98	0.98	1.00
F2013	0.14	0.80	0.04	0.16	0.42	0.39	0.61
deltaB	29%	22%	7%	1%	50%	81%	51%
P(B inc)	1.00	1.00	1.00	0.76	1.00	1.00	1.00
P(B inc 10%)	1.00	1.00	0.20	0.00	1.00	1.00	1.00
600 mt quota							
P(F>Fref)	0.04	1.00	0.00	0.17	1.00	1.00	1.00
F2013	0.16	1.03	0.04	0.20	0.52	0.48	0.77
deltaB	27%	12%	7%	-1%	43%	77%	44%
P(B inc)	1.00	1.00	1.00	0.31	1.00	1.00	1.00
P(B inc 10%)	1.00	0.75	0.13	0.00	1.00	1.00	1.00

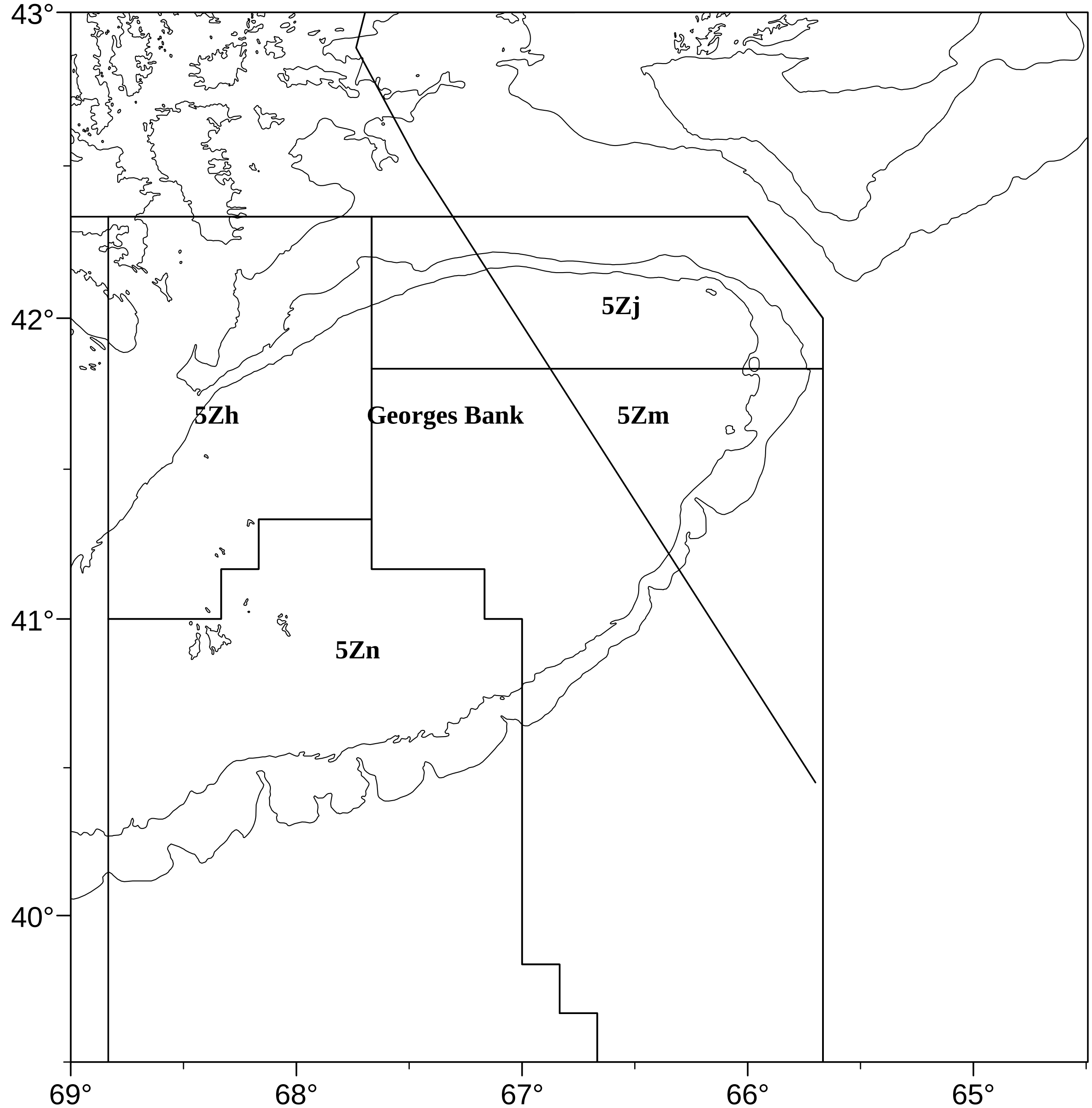


Figure 1a. Location of statistical unit areas for Canadian fisheries in NAFO Subdivision 5Ze.

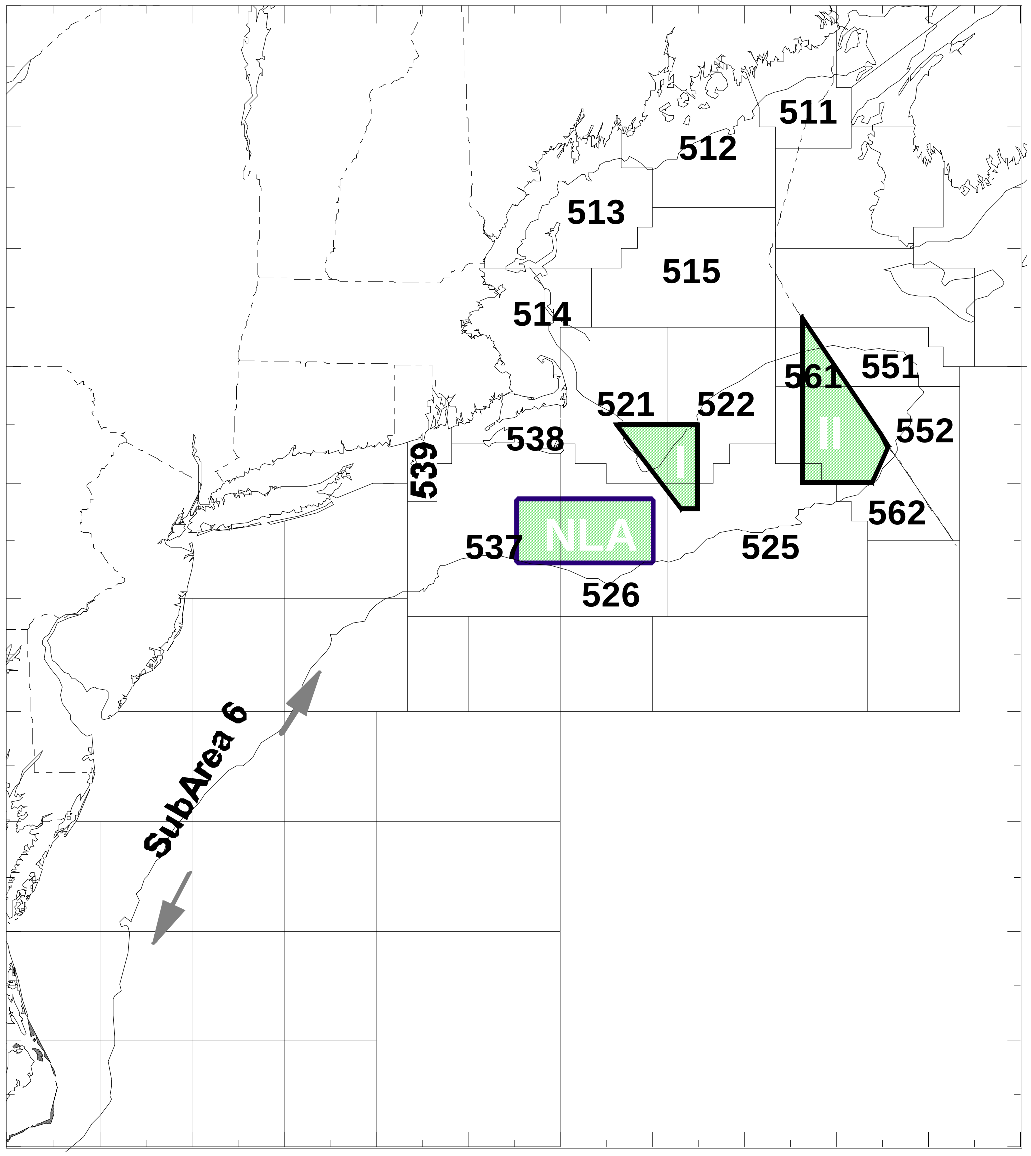


Figure 1b. Statistical areas used for monitoring northeast US fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

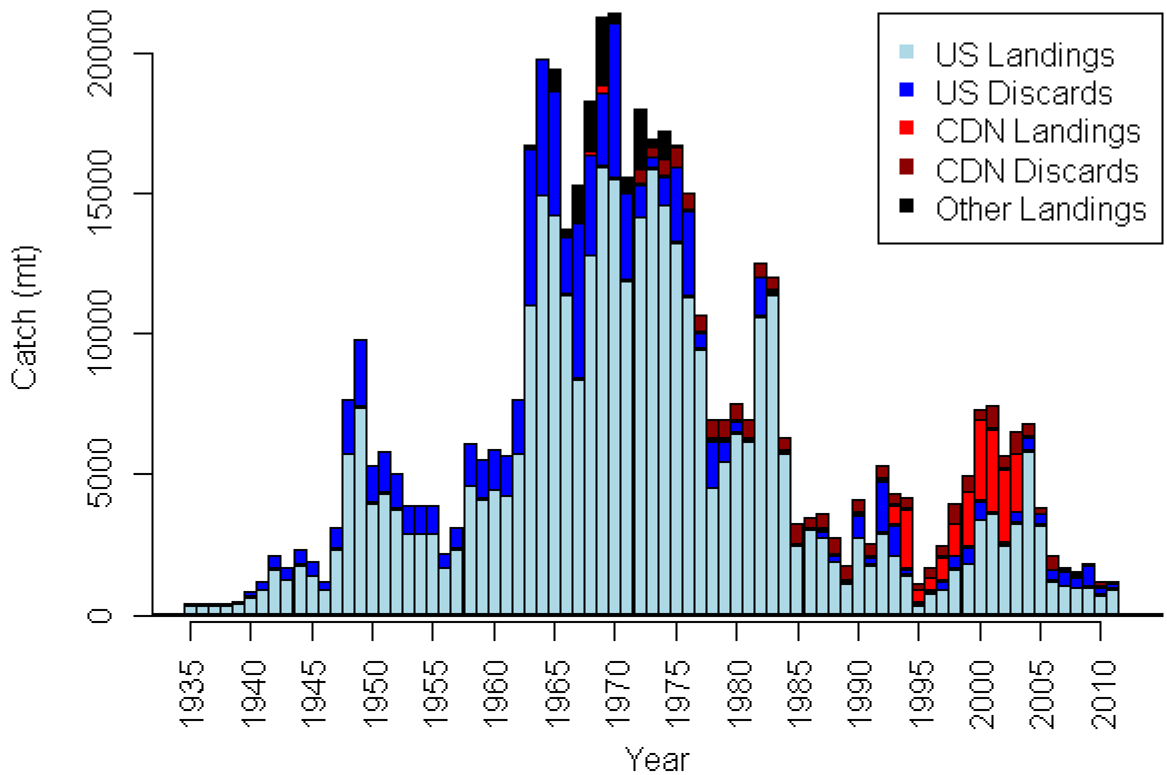


Figure 2. Catch (landings plus discards) of Georges Bank yellowtail flounder by nation and year.

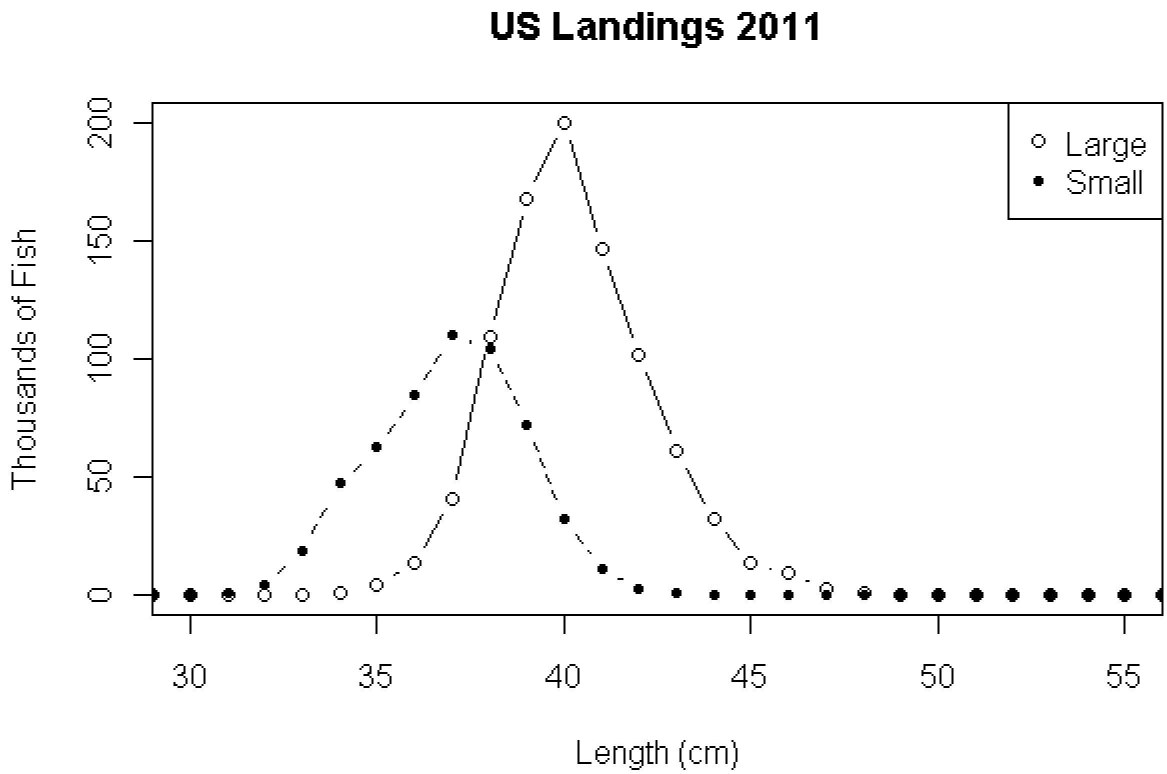


Figure 3. US landings of Georges Bank yellowtail by market category.

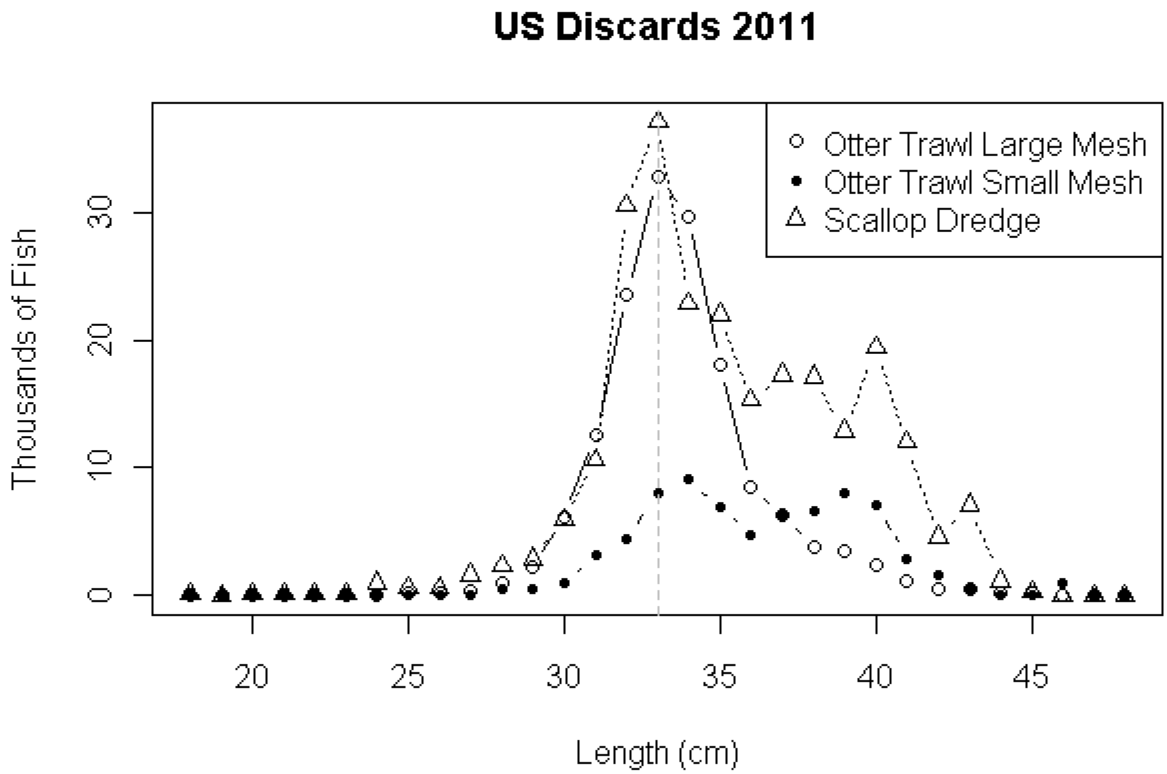


Figure 4. US yellowtail flounder discard length frequencies by gear. The vertical line at 33 cm denotes the US minimum legal size for landing yellowtail flounder. The distinction between large and small mesh in the cod end of the trawl occurs at 5.5 inches (14 cm).

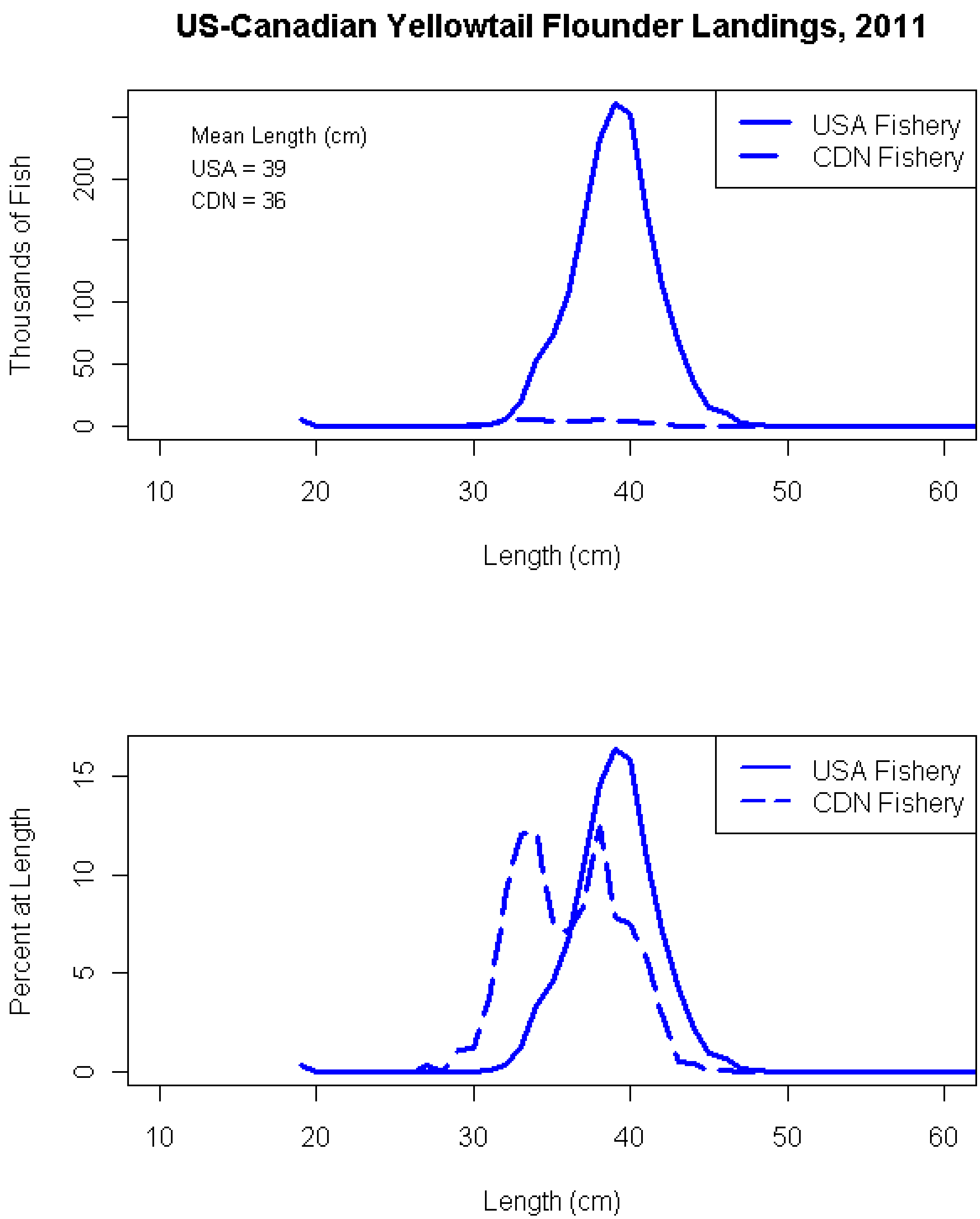


Figure 5. Comparison of US and Canadian landings at length for Georges Bank yellowtail flounder.

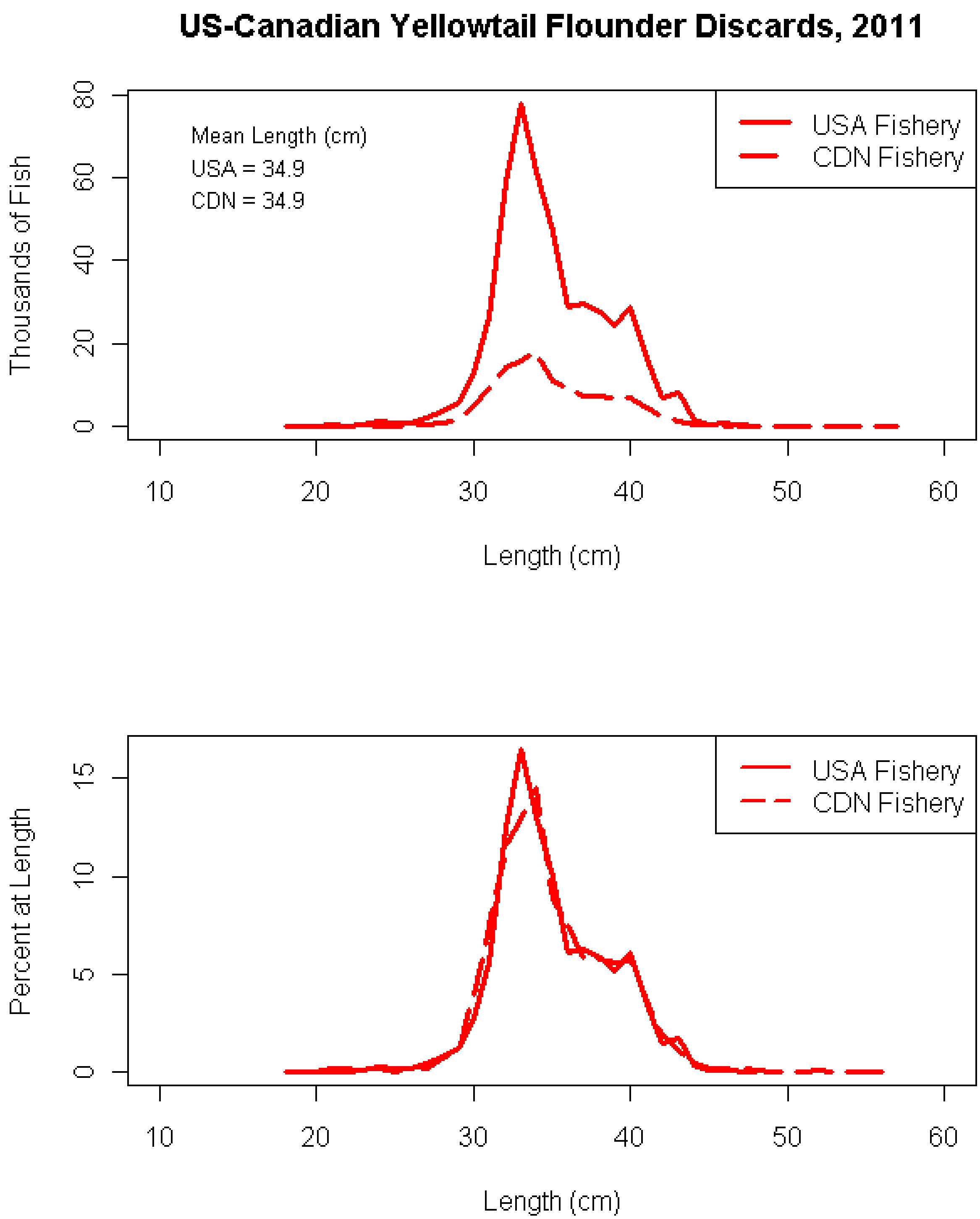


Figure 6. Comparison of US and Canadian discards at length for Georges Bank yellowtail flounder.

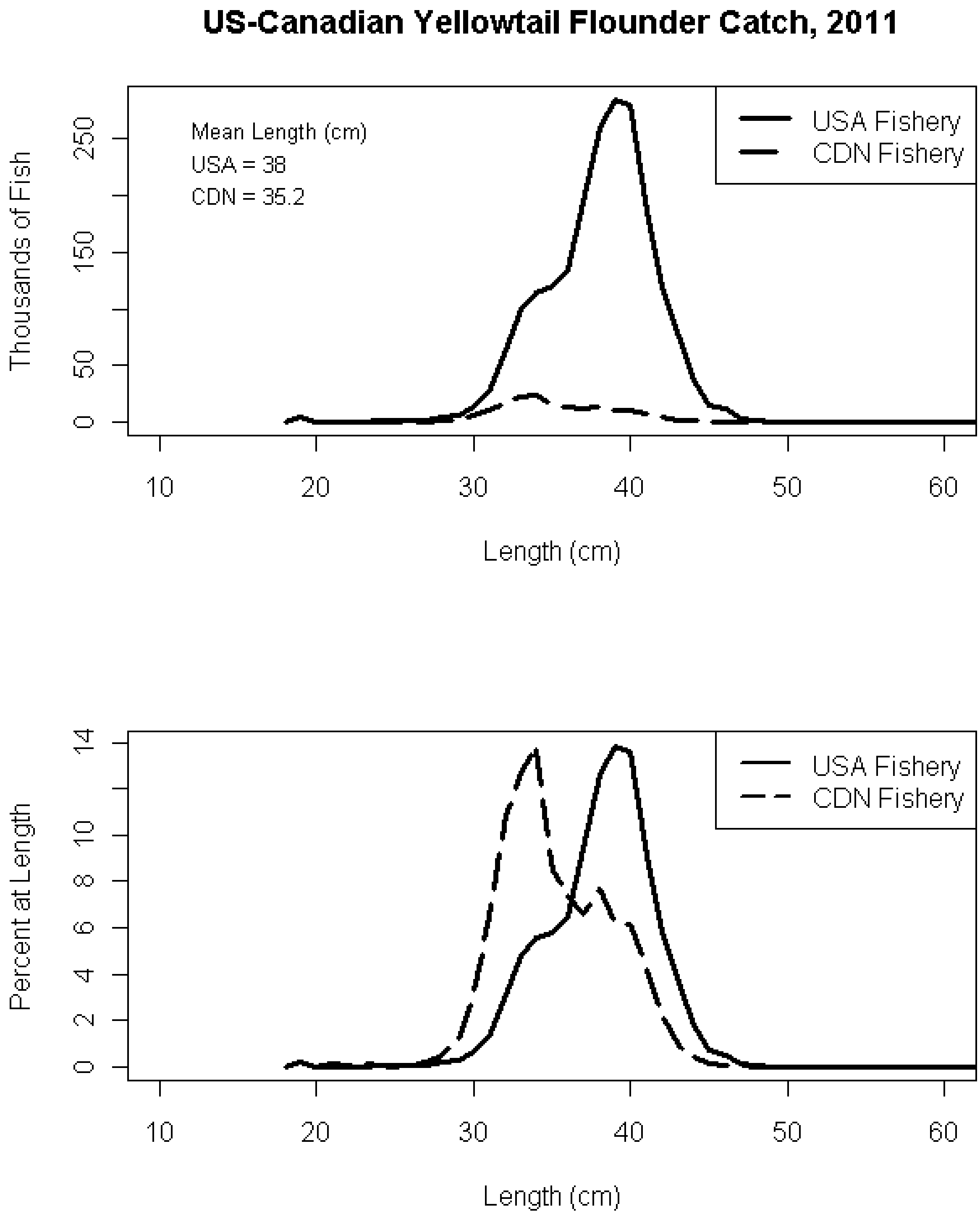


Figure 7. Comparison of US and Canadian catch (landings plus discards) at length for Georges Bank yellowtail flounder.

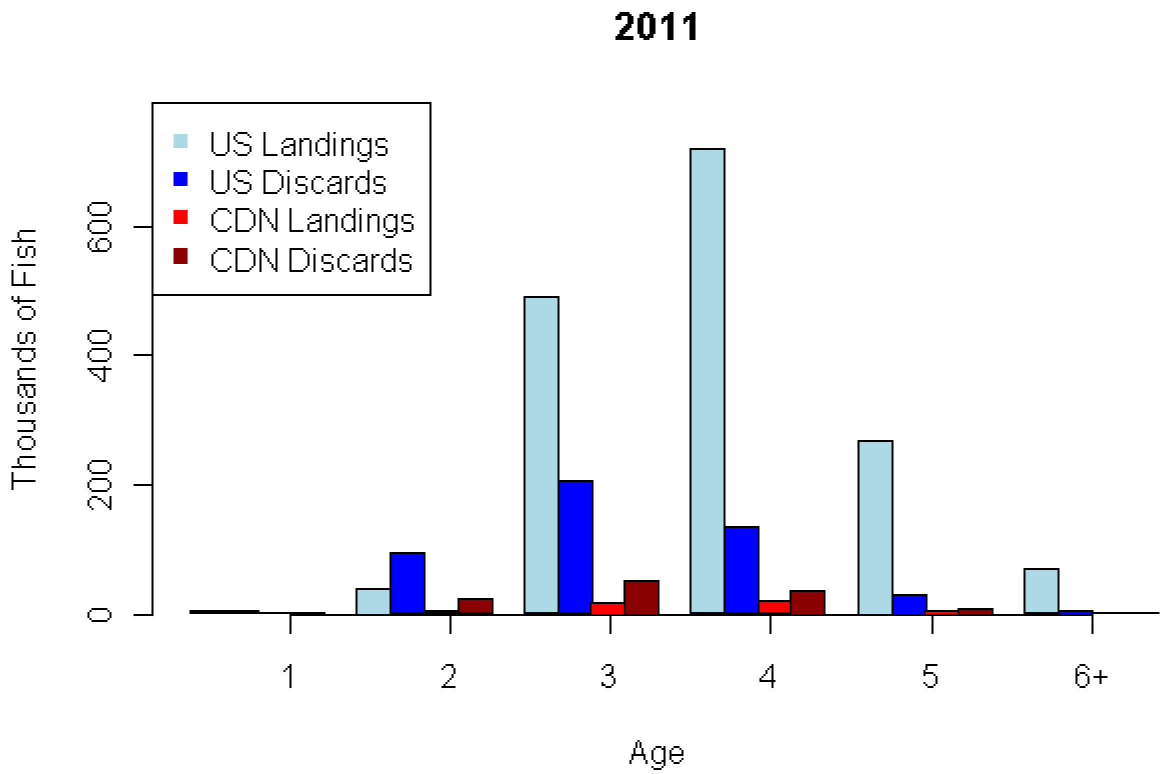


Figure 8. Catch at age of Georges Bank yellowtail flounder from the four components of Canadian and US landings and discards.

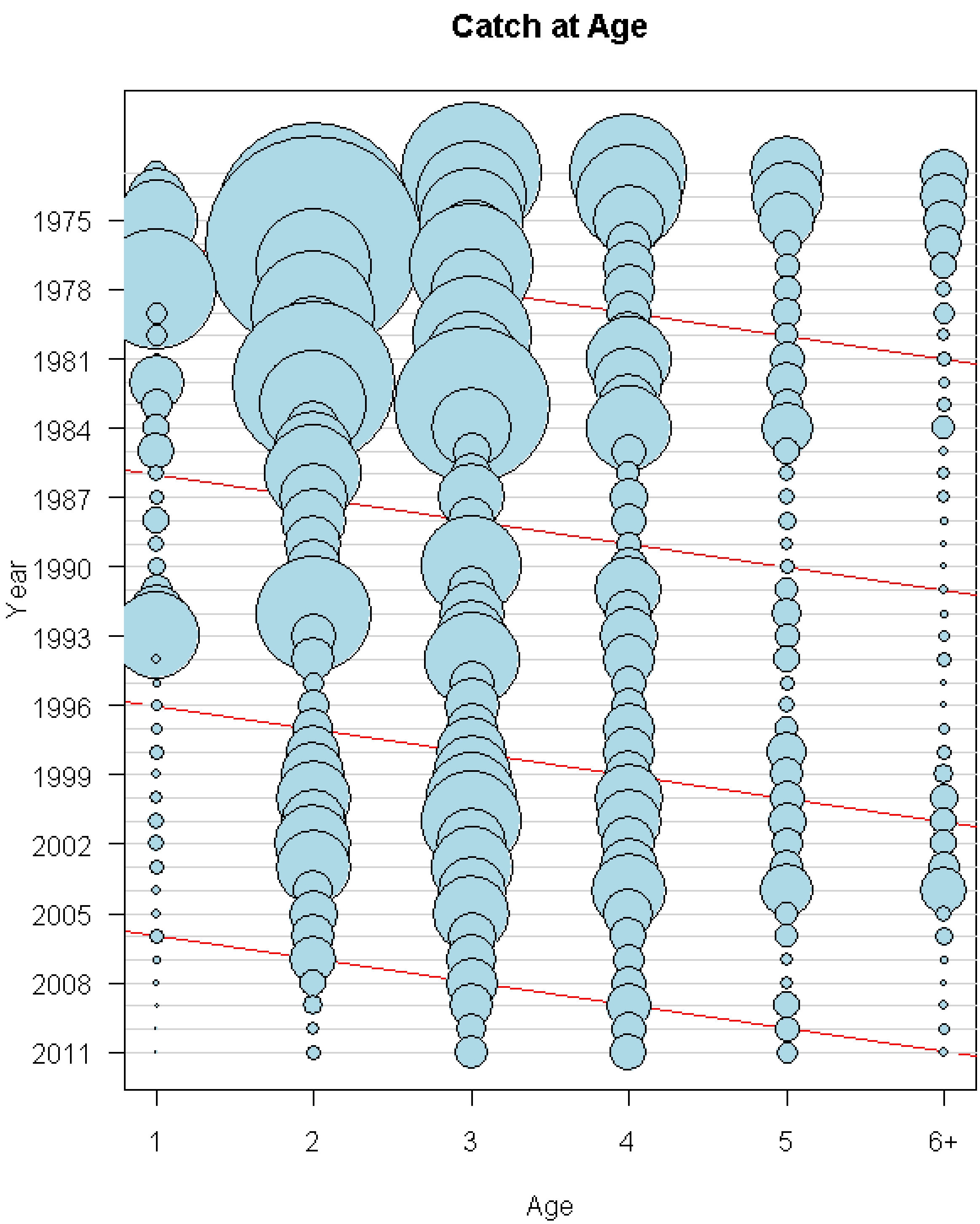


Figure 9. Catch at age for Georges Bank yellowtail flounder, Canadian and US fisheries combined. (The area of the bubble is proportional to the magnitude of the catch). Diagonal red lines denote the 1975, 1985, 1995, and 2005 year-classes.

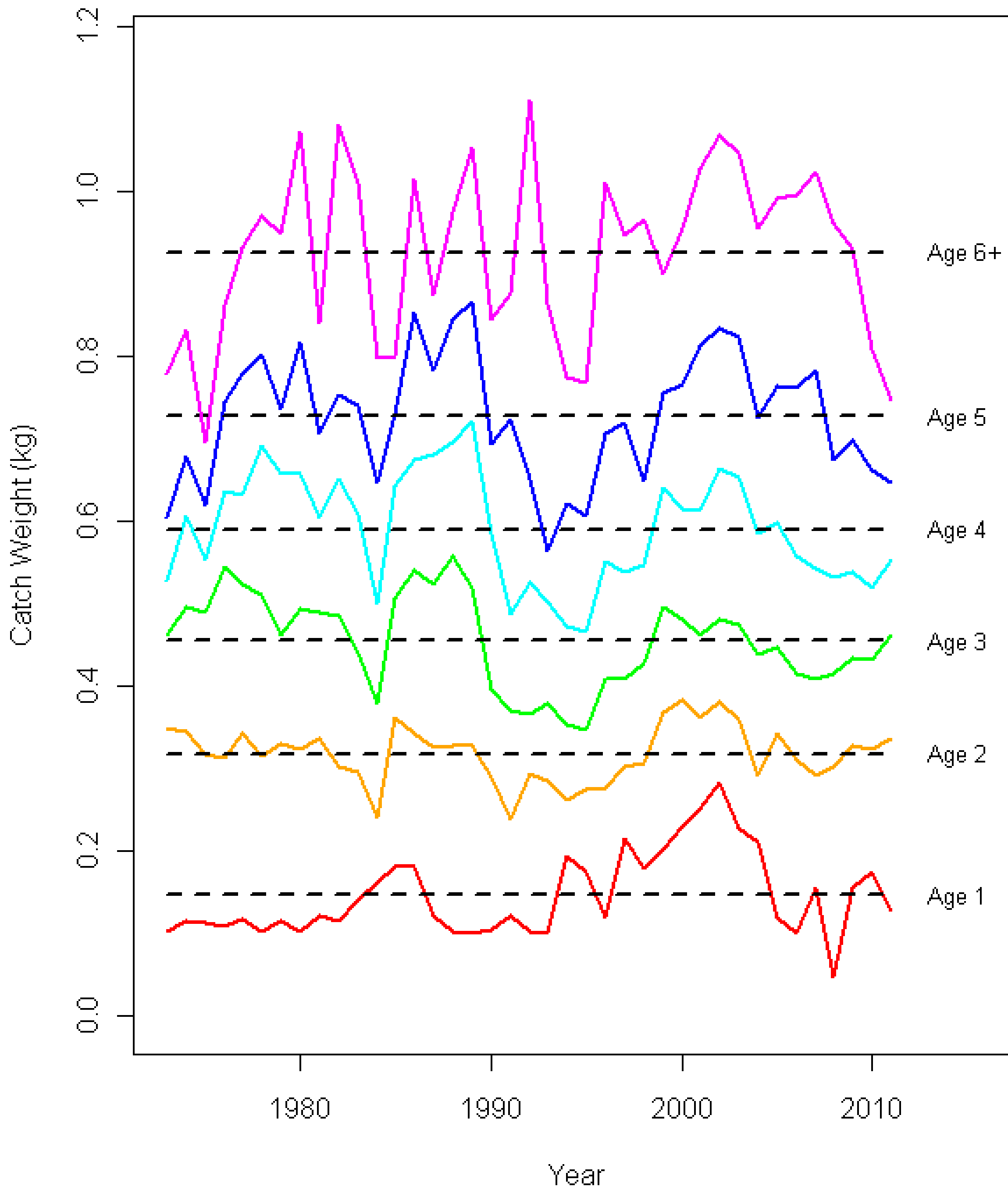


Figure 10. Trends in mean weight at age from the Georges Bank yellowtail fishery (Canada and US combined, including discards). Dashed lines denote average of time series.

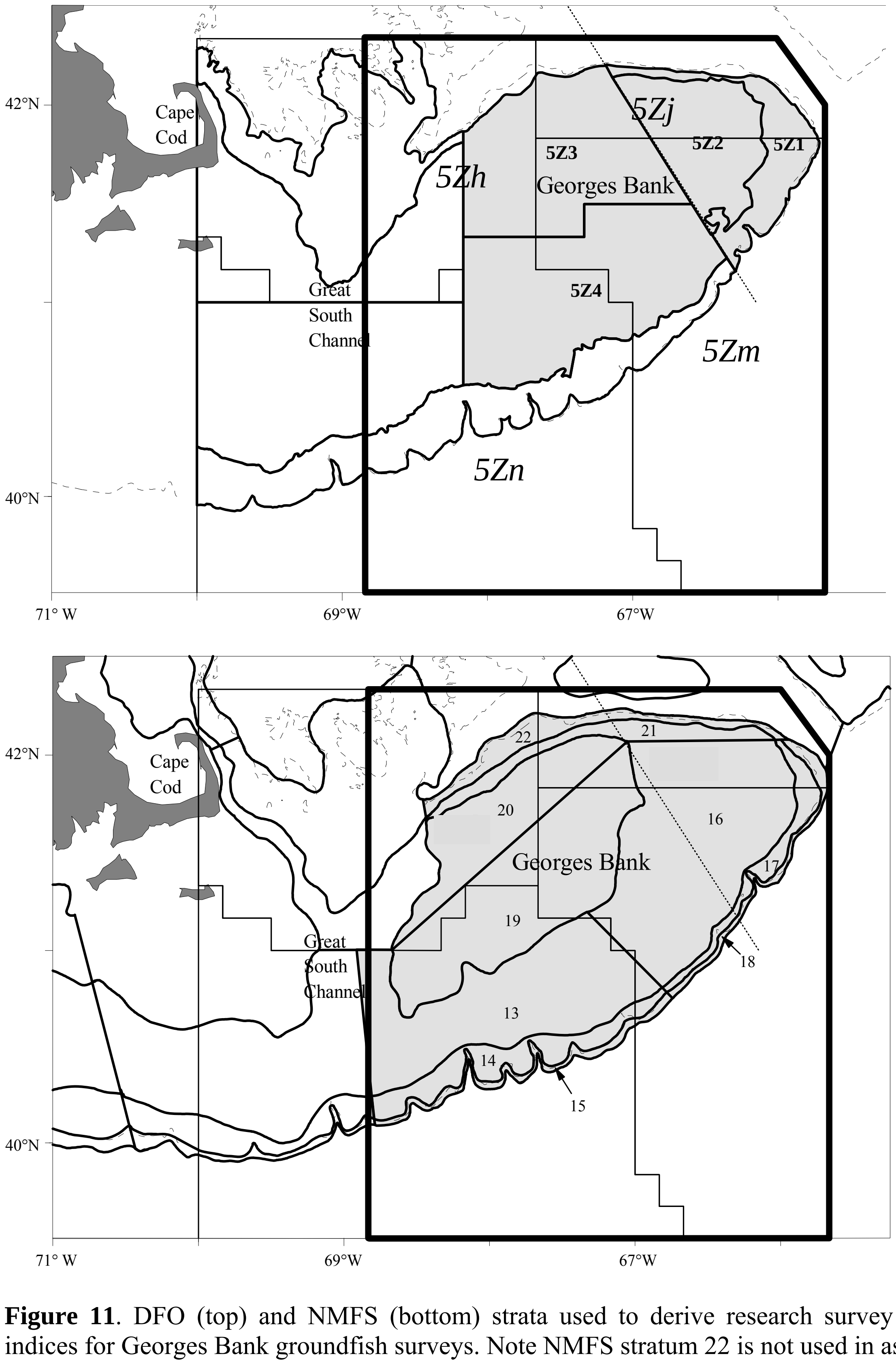


Figure 11. DFO (top) and NMFS (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in assessment.

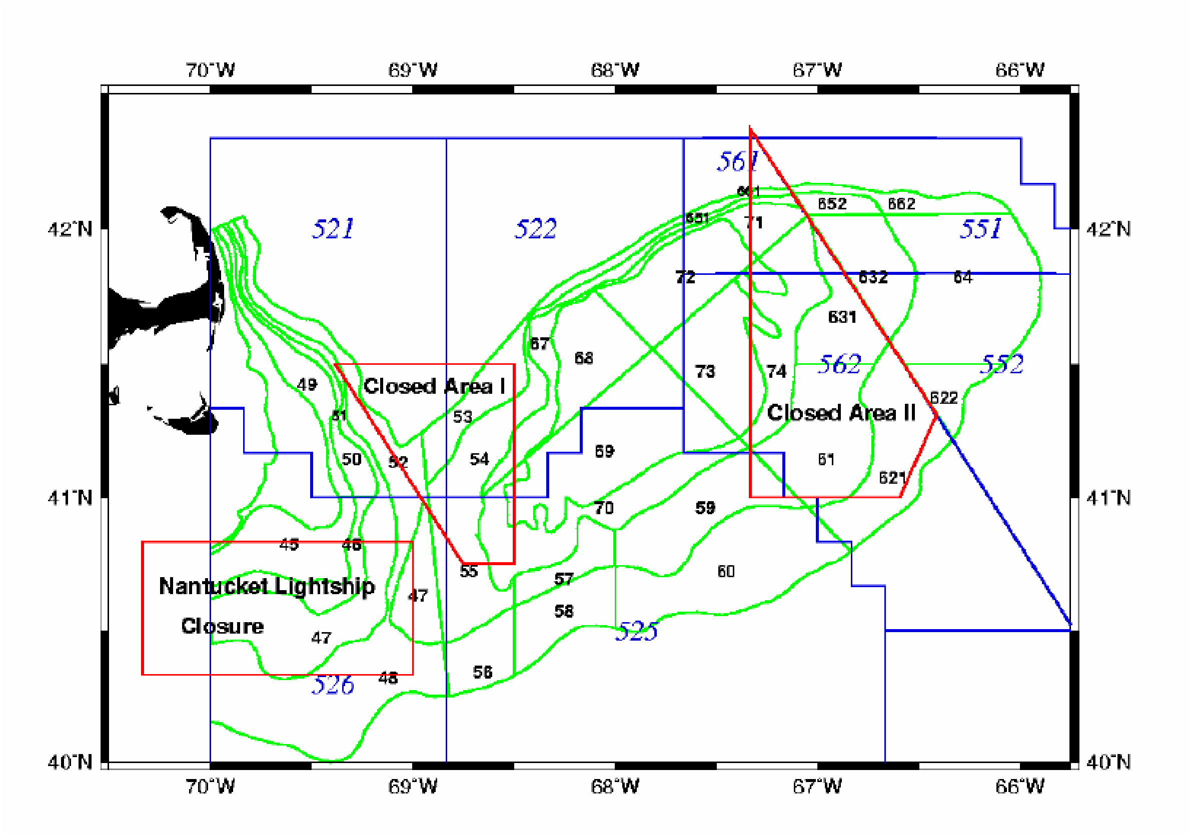


Figure 11. (continued) NMFS scallop survey strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Strata 54, 55, 58-72, and 74 are used to estimate the abundance of yellowtail flounder for this assessment.

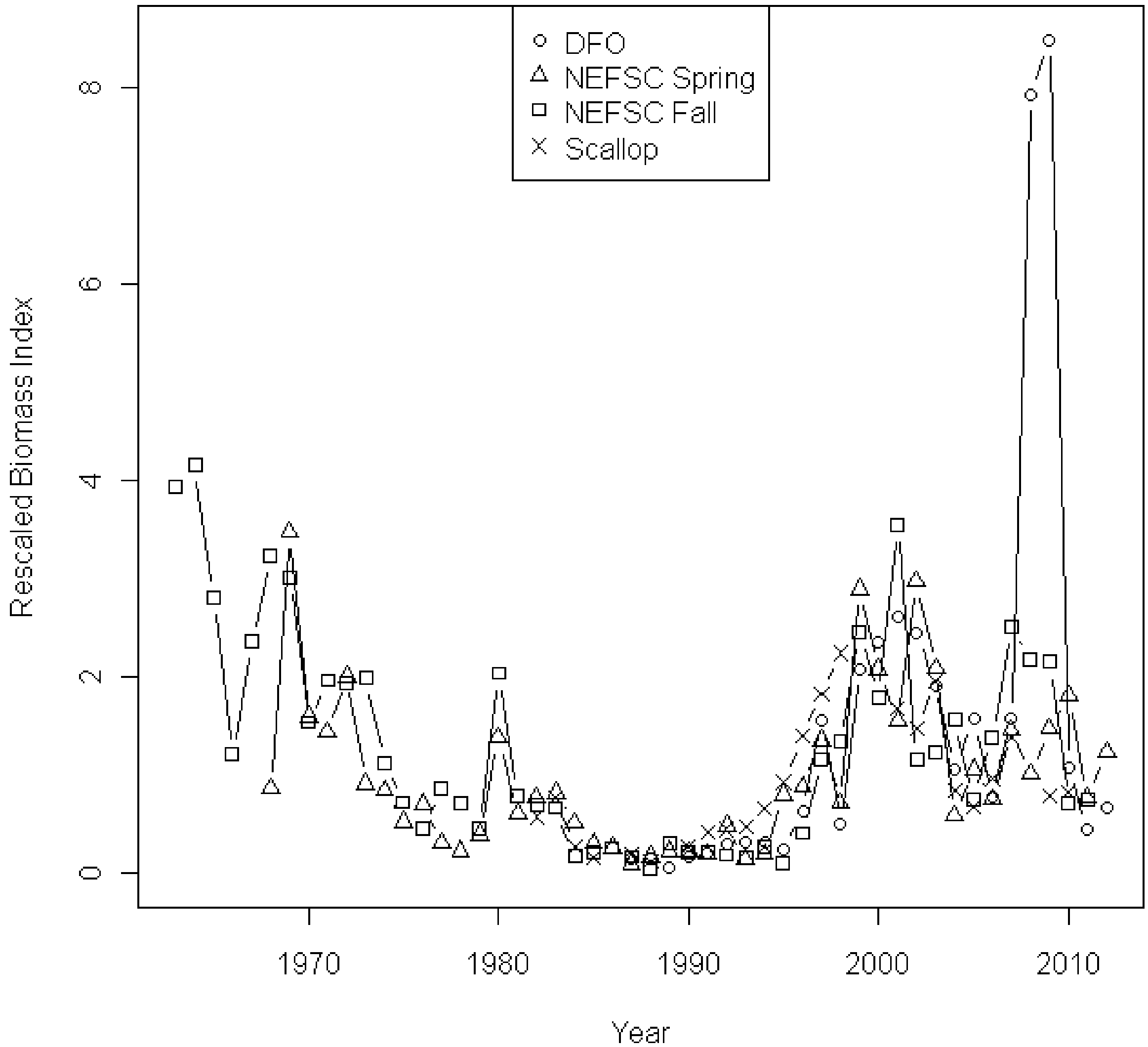


Figure 12a. Four survey biomass indices (DFO, NEFSC spring, NEFSC fall and NEFSC scallop) for yellowtail flounder on Georges Bank rescaled to their respective means for years 1987-2007.

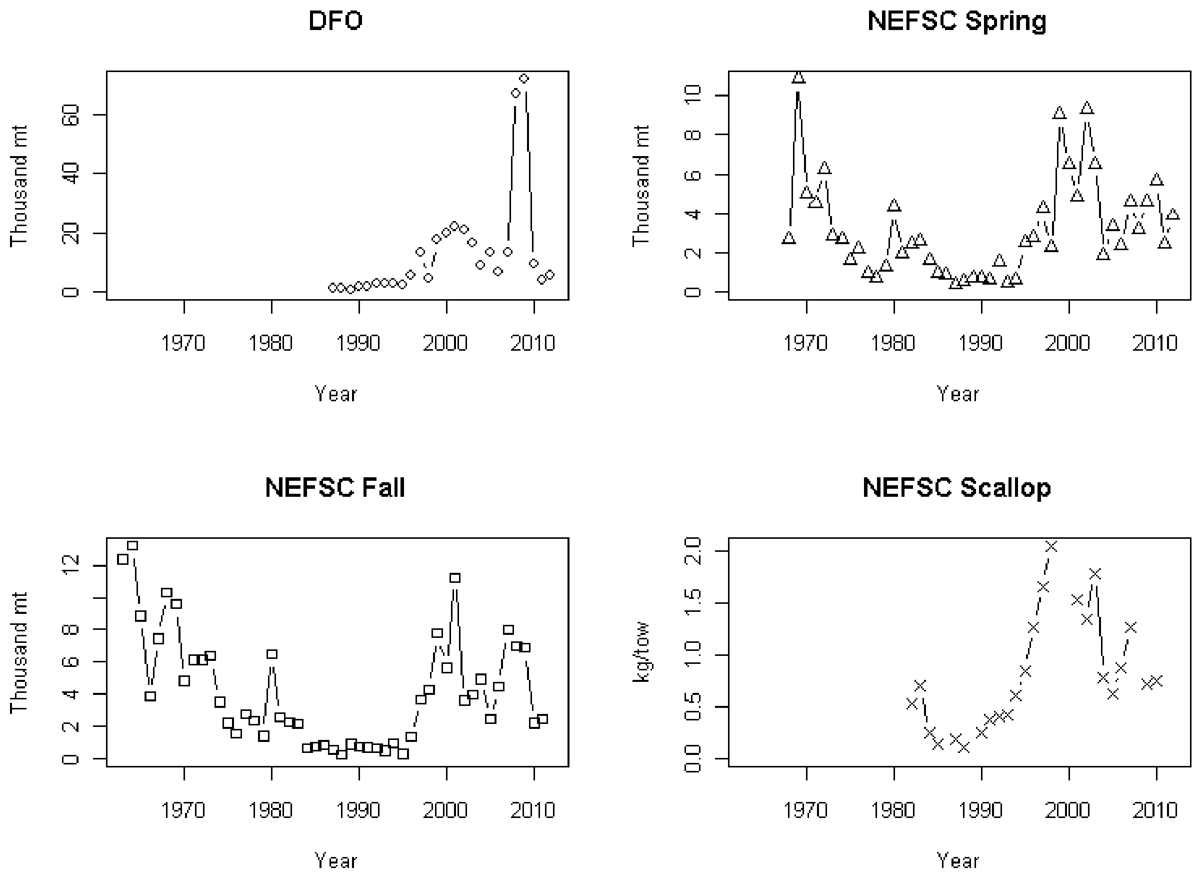


Figure 12b. Survey biomass for yellowtail flounder on Georges Bank in units of thousand metric tons (DFO, NEFSC spring, NEFSC fall, all three are minimum swept area biomass values) or kg/tow (NEFSC scallop, stratified mean catch per tow).

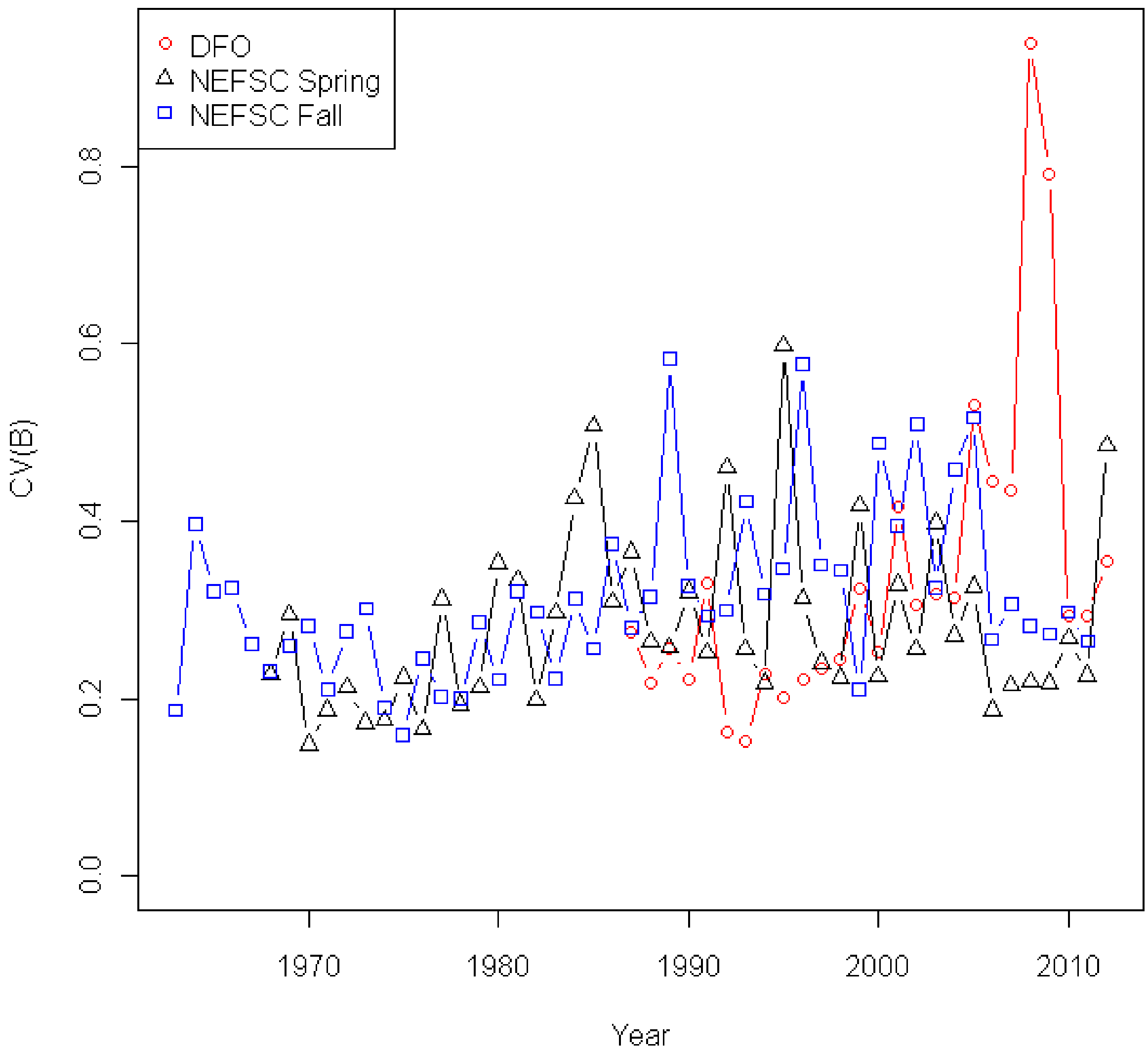


Figure 12c. Survey biomass coefficients of variation for yellowtail flounder on Georges Bank for the three bottom trawl surveys.

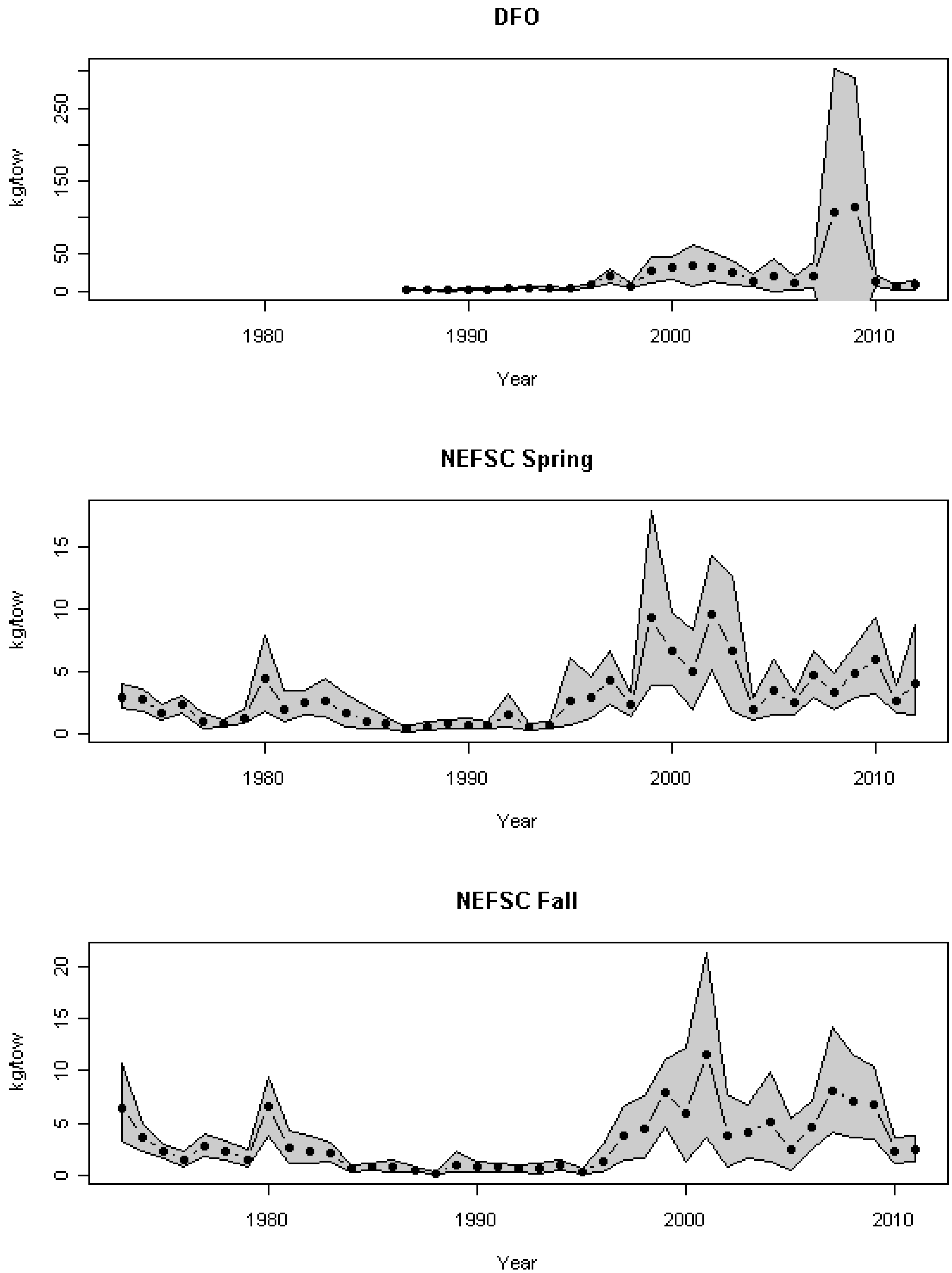


Figure 12d. Survey biomass for yellowtail flounder on Georges Bank in units of kg/tow with 95% confidence intervals from +/- 1.96*stdev (DFO) or bootstrapping (NEFSC spring and NEFSC fall) for years in the assessment.

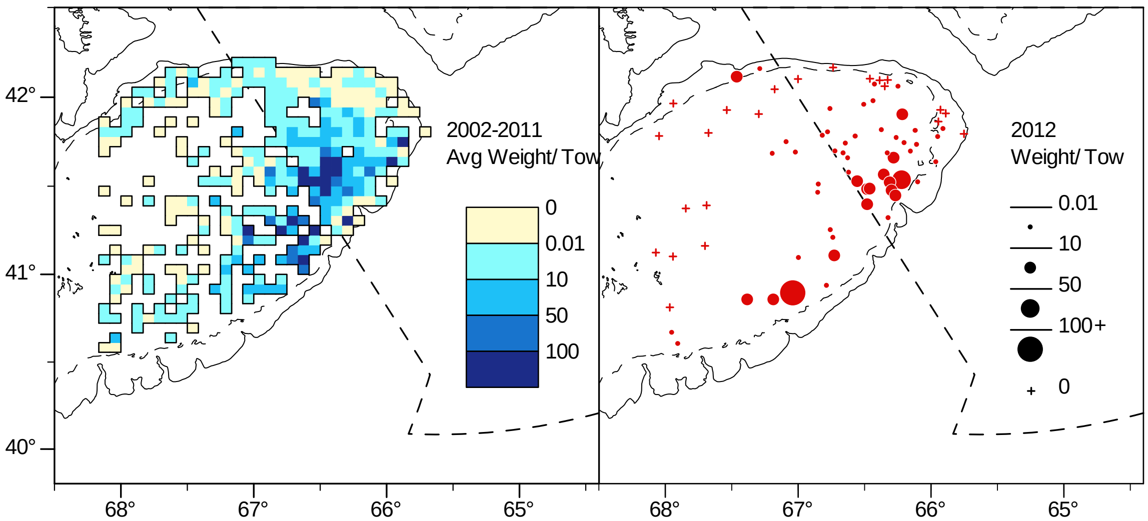


Figure 13a. Catch of yellowtail in weight (kg) per tow for DFO survey. Left panel shows previous 10 year averages, right panel most recent data.

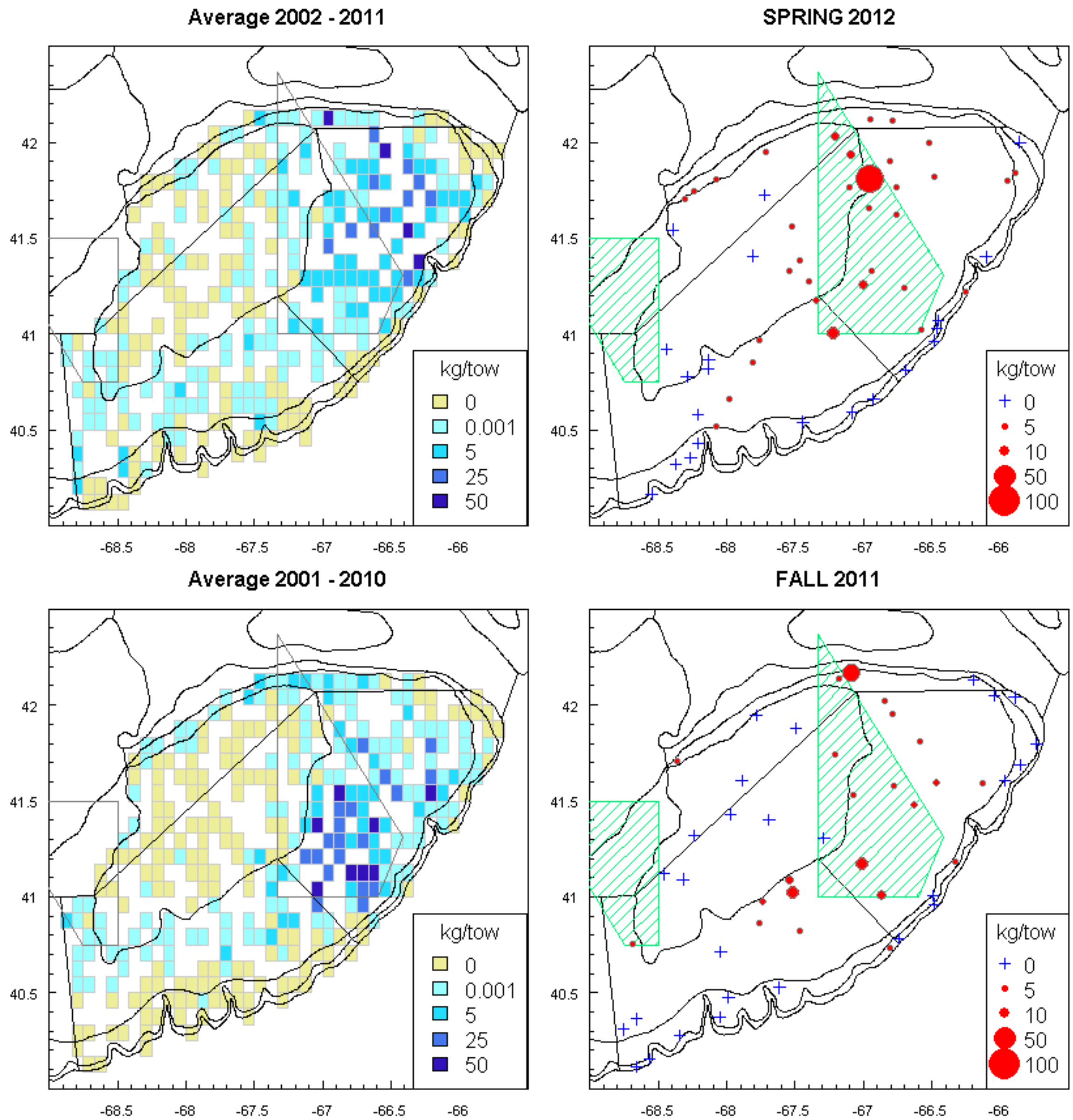


Figure 13b. Catch of yellowtail in weight (kg) per tow for NEFSC spring (top) and NEFSC fall (bottom) surveys. Left panels show previous 10 year averages, right panels most recent data. Note the 2009 - 2012 survey values were adjusted from Bigelow to Albatross IV equivalents by dividing Bigelow catch in weight by 2.244 (spring) or 2.402 (fall).

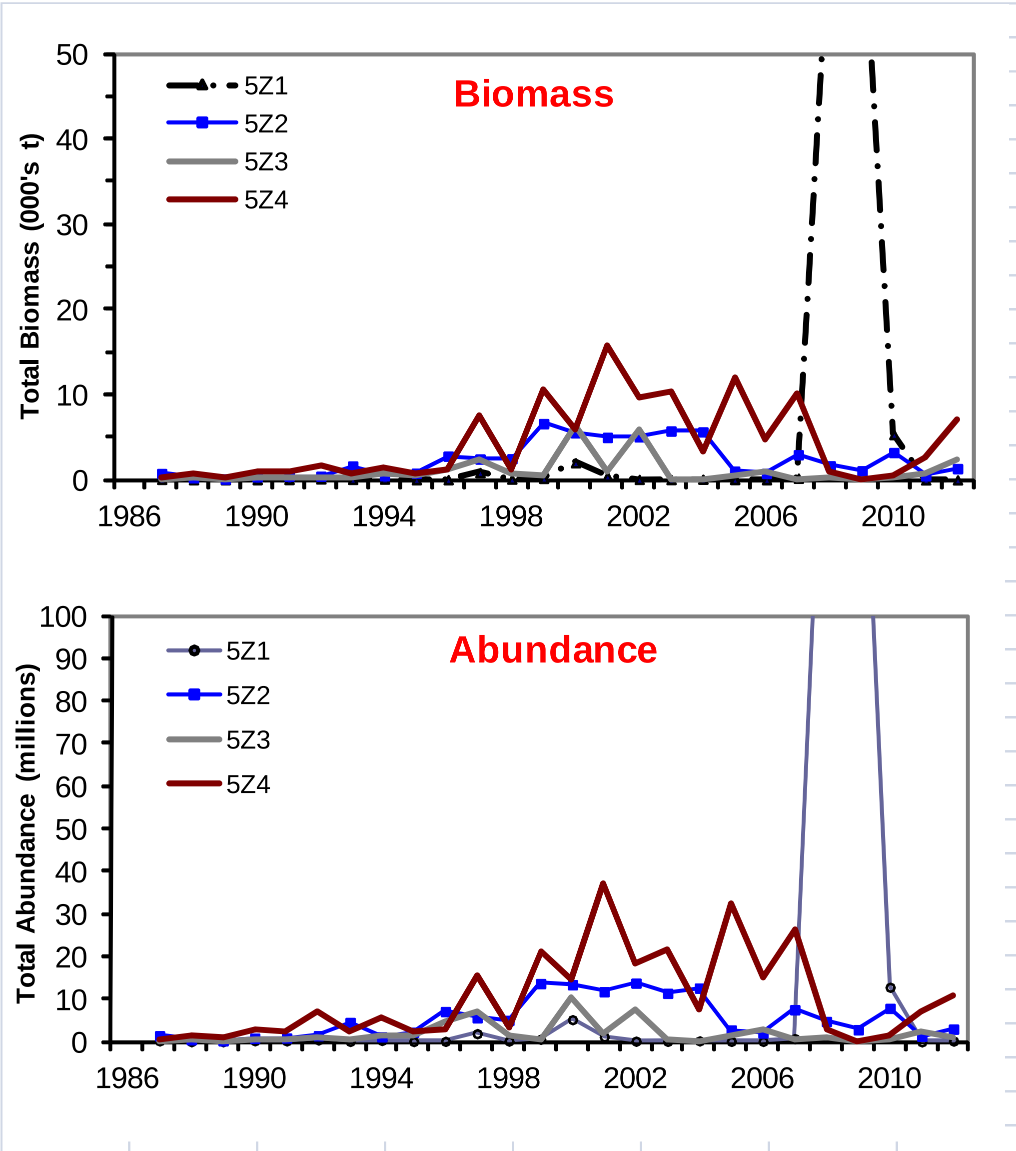
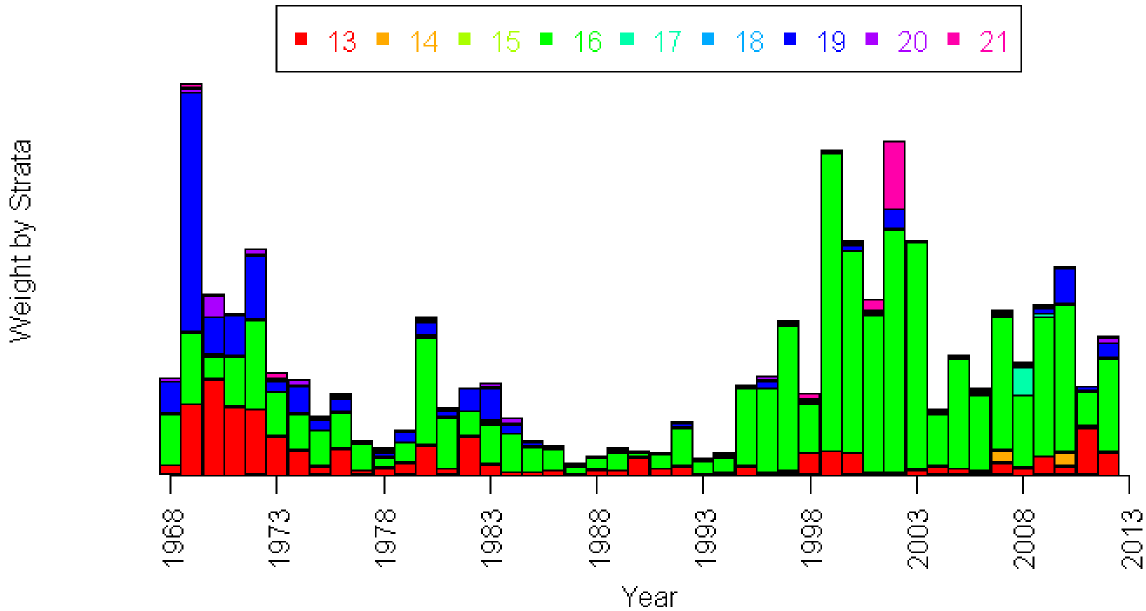


Figure 14a. DFO spring survey estimates of total biomass (top panel) and total number (bottom panel) by stratum area for yellowtail flounder on Georges Bank.



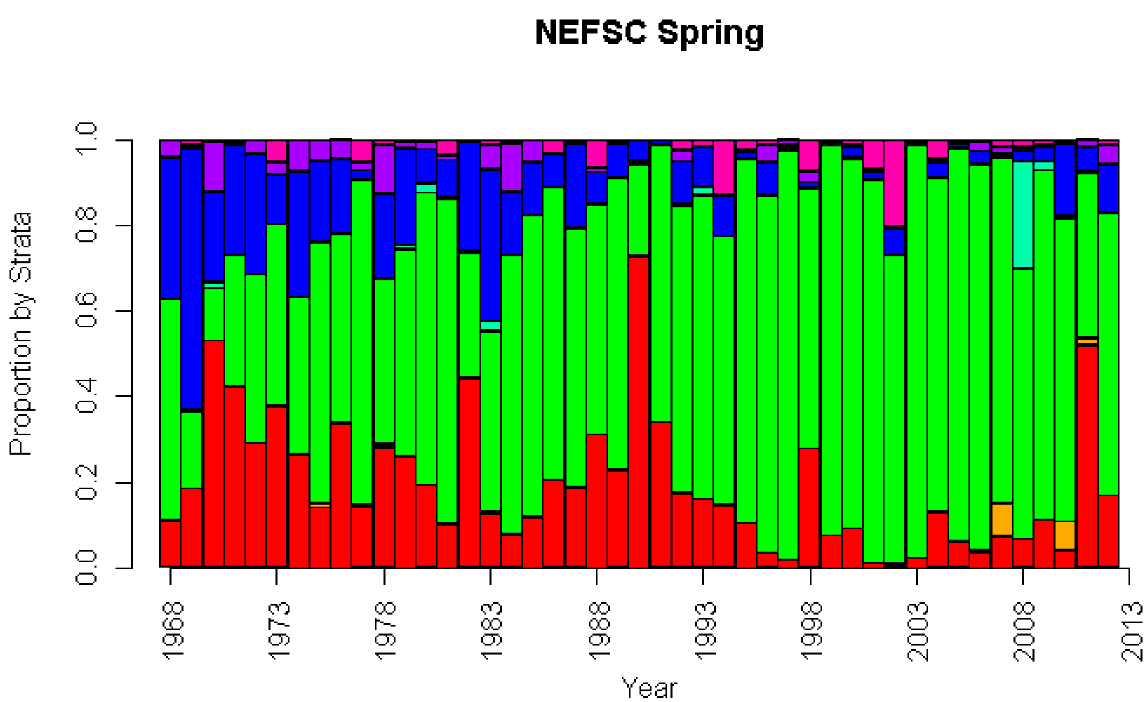


Figure 14b. NEFSC spring survey estimates of total biomass (top panel) and proportion (bottom panel) by stratum for yellowtail flounder on Georges Bank.

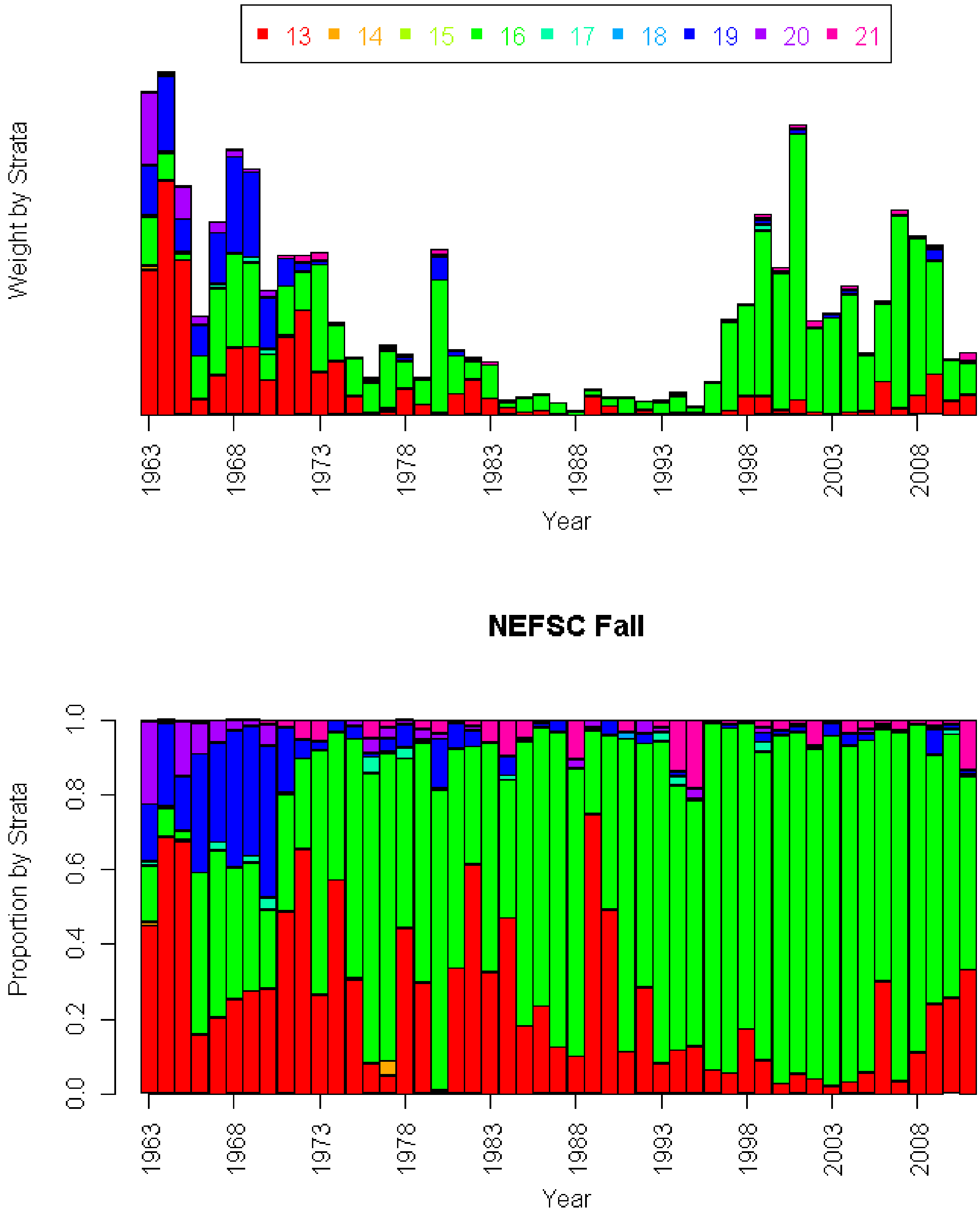


Figure 14c. NEFSC fall survey estimates of total biomass (top panel) and proportion (bottom panel) by stratum for yellowtail flounder on Georges Bank.

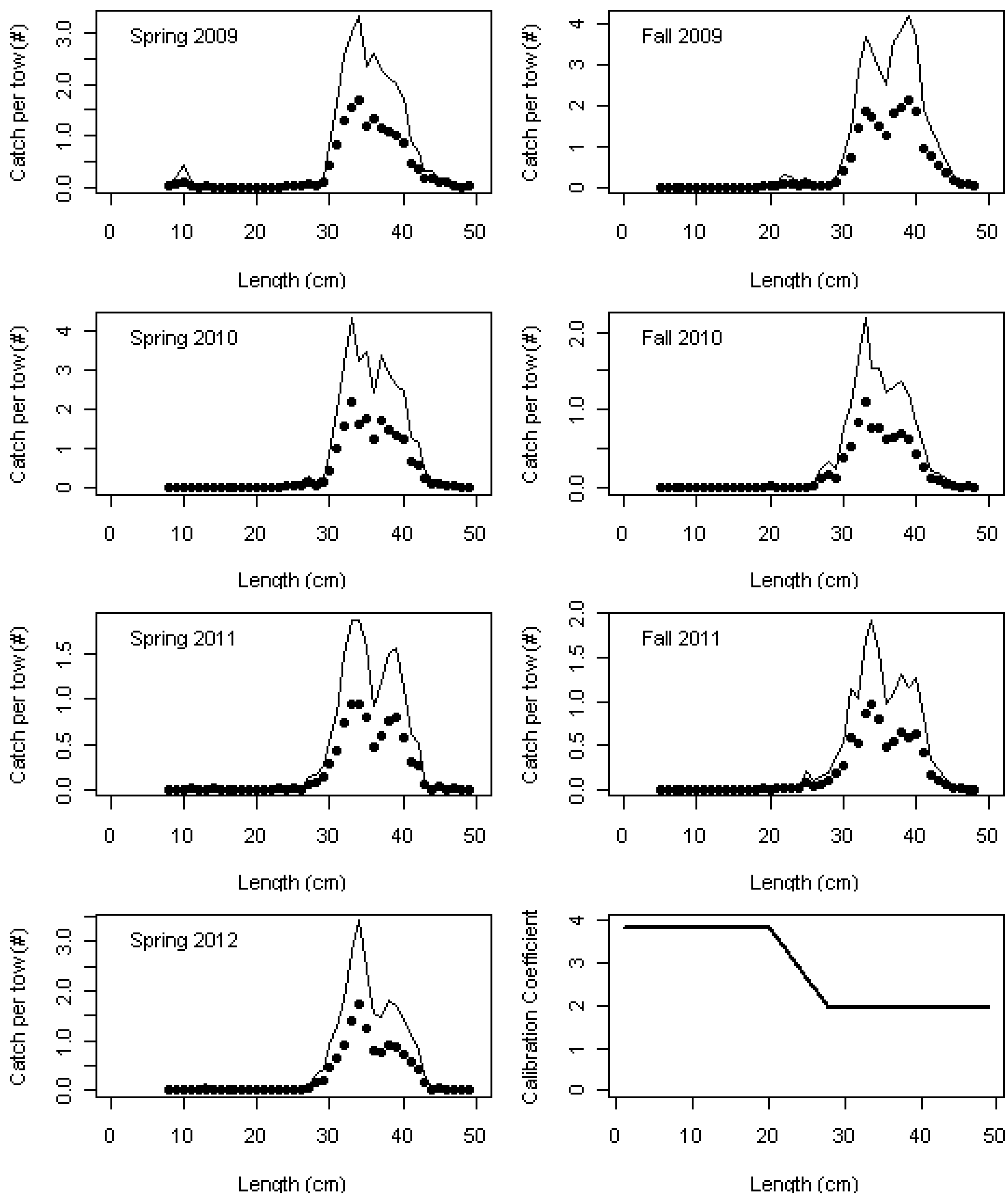


Figure 15. Catch per tow in numbers of fish for the US spring and fall surveys by the FSV Henry B. Bigelow. The lines denote the original observations and the dots the calibrated values converted to RV Albatross IV units. The calibration is calculated using the curve in the lower right panel (Calibrated = Original/Calibration Coefficient).

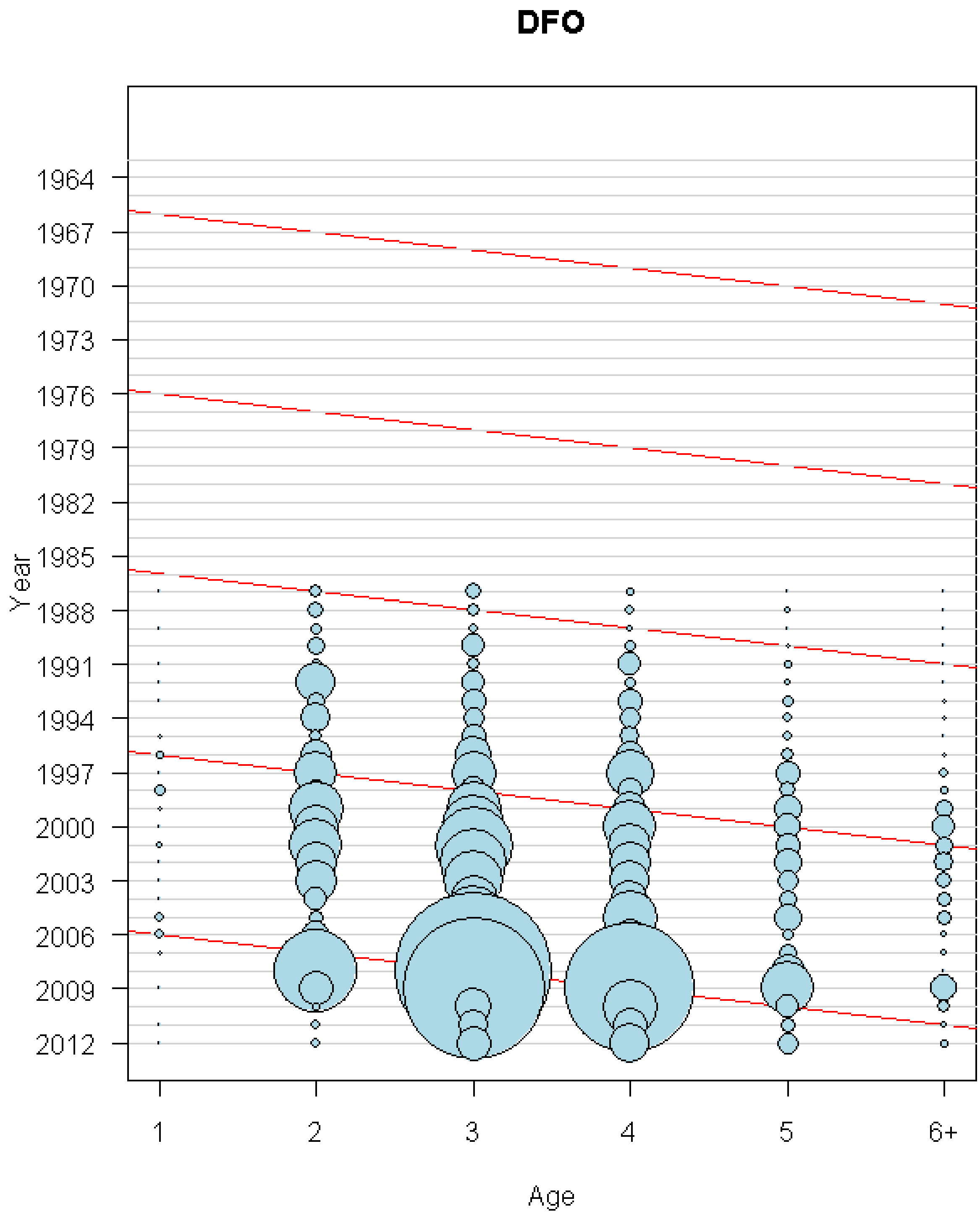


Figure 16a. Age specific indices of abundance for the DFO spring survey including the large tows in 2008 and 2009 (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year-classes.

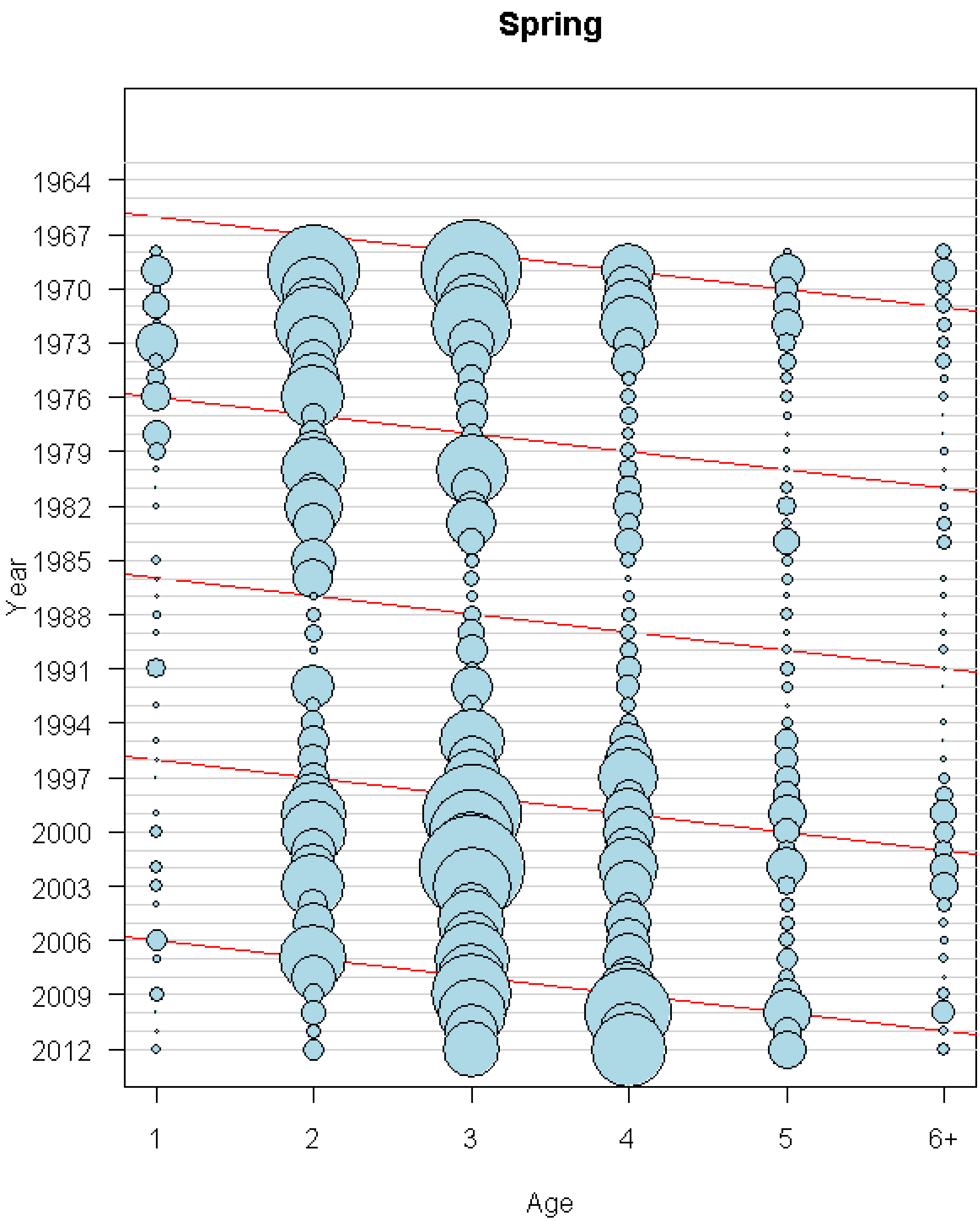


Figure 16b. Age specific indices of abundance for the NMFS spring survey (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year-classes.

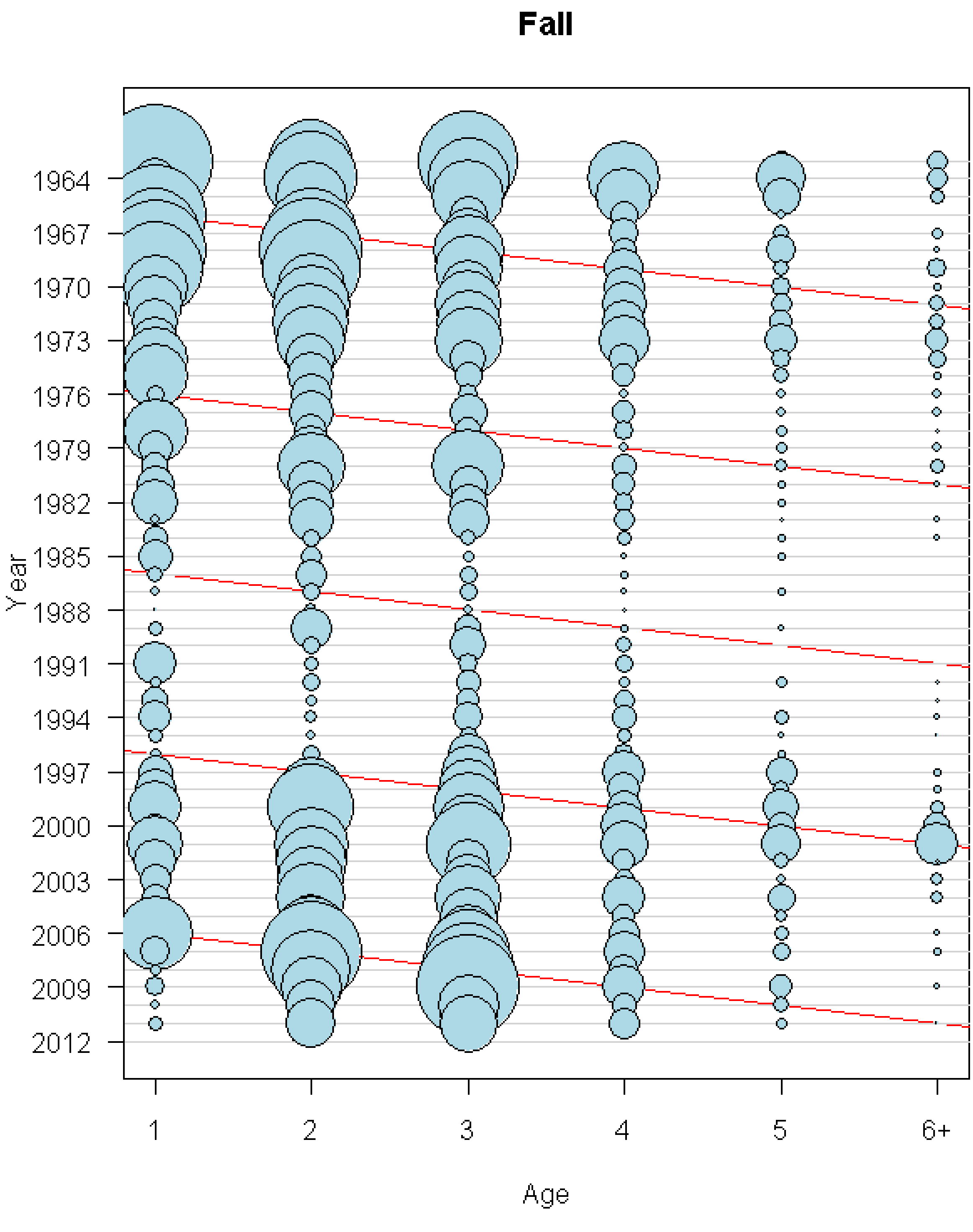


Figure 16c. Age specific indices of abundance for the NMFS fall survey (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year-classes.

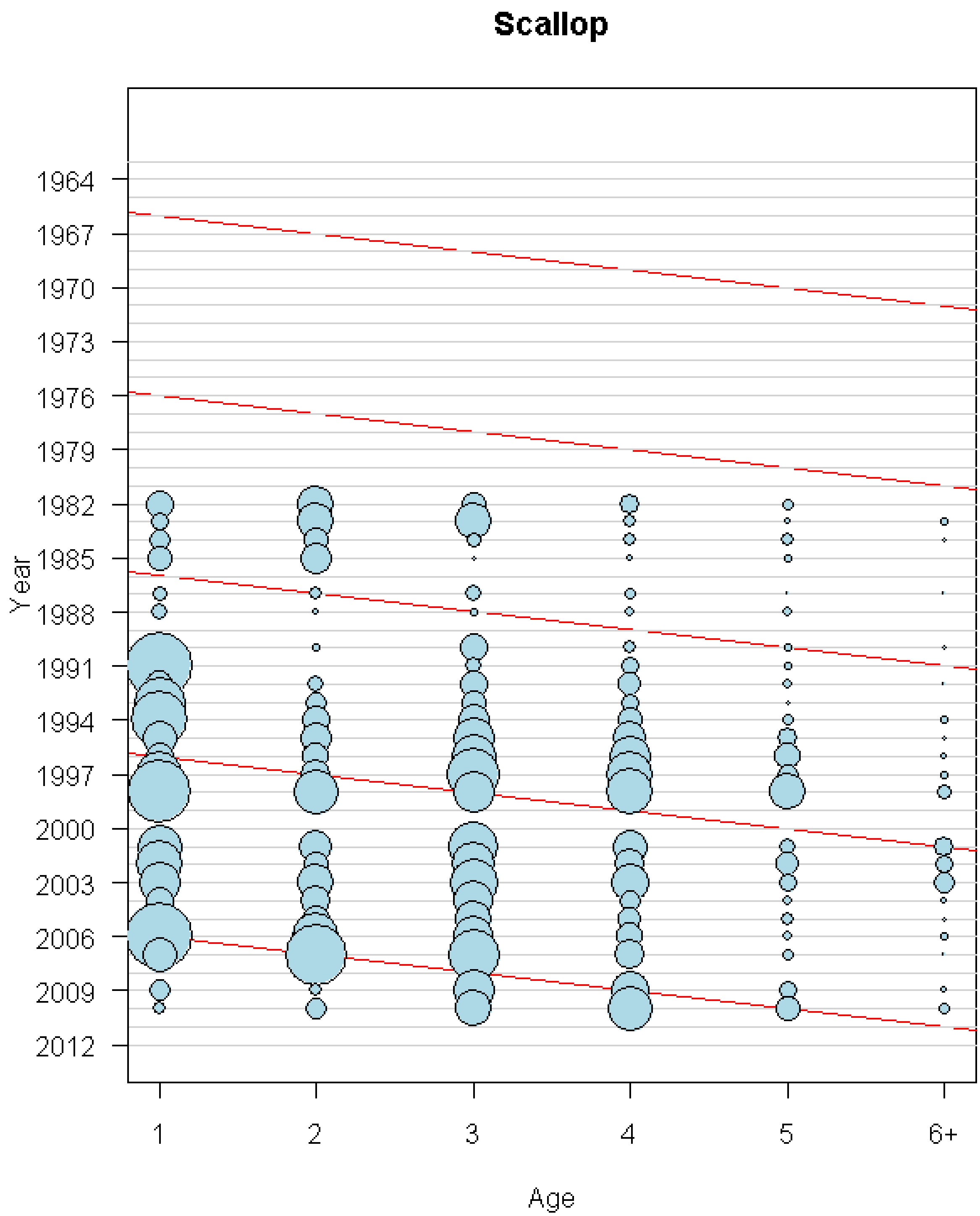


Figure 16d. Age specific indices of abundance for the NMFS scallop survey, note years 1986, 1989, 1999, 2000, and 2008 are not included (the area of the bubble is proportional to the magnitude). Diagonal red lines denote the 1965, 1975, 1985, 1995, and 2005 year-classes.

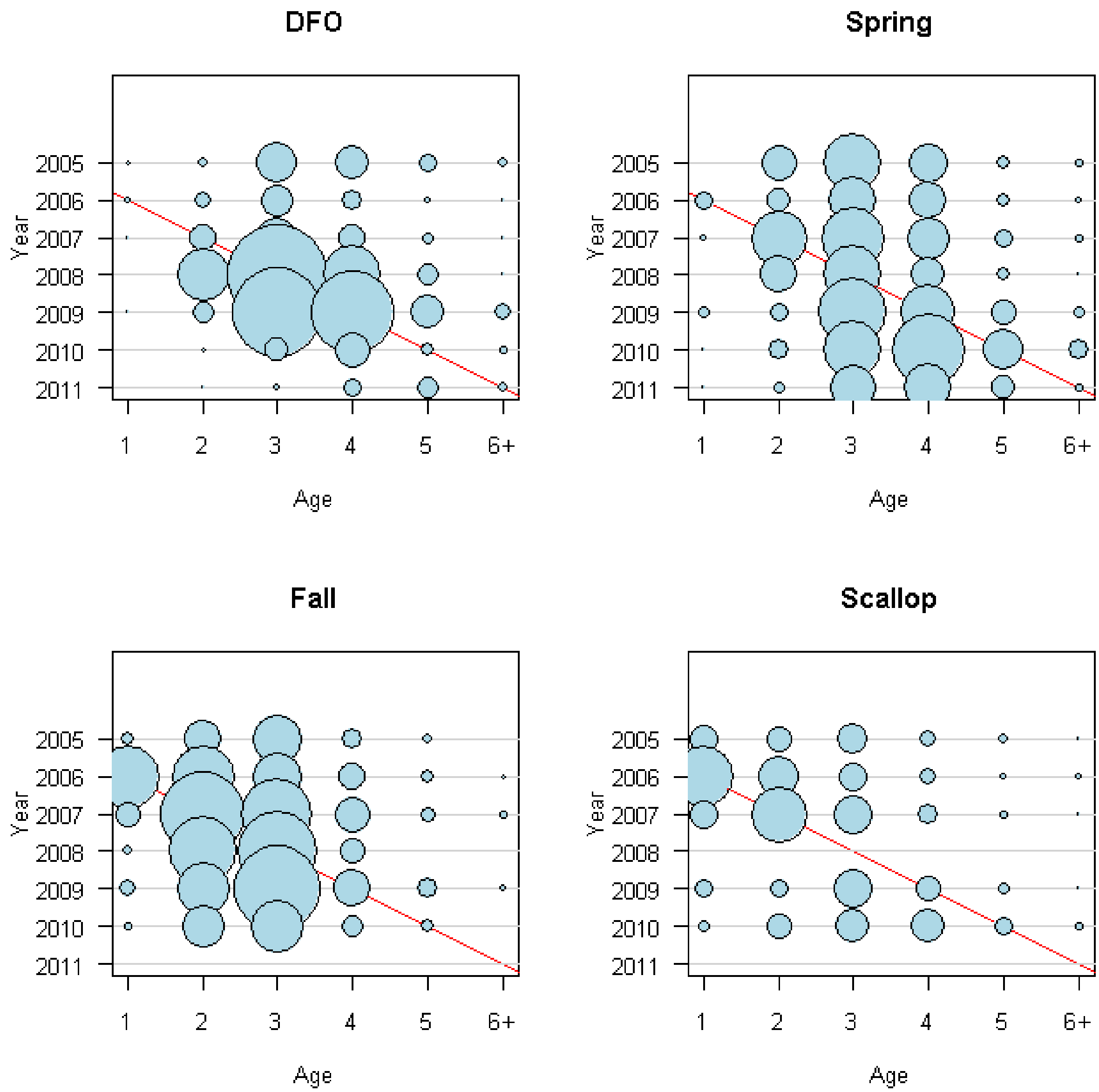


Figure 16e. Age specific indices of abundance for the recent years of the four surveys, note year 2008 is not included in the scallop plot (the area of the bubble is proportional to the magnitude). The red diagonal line denotes the 2005 year-class.

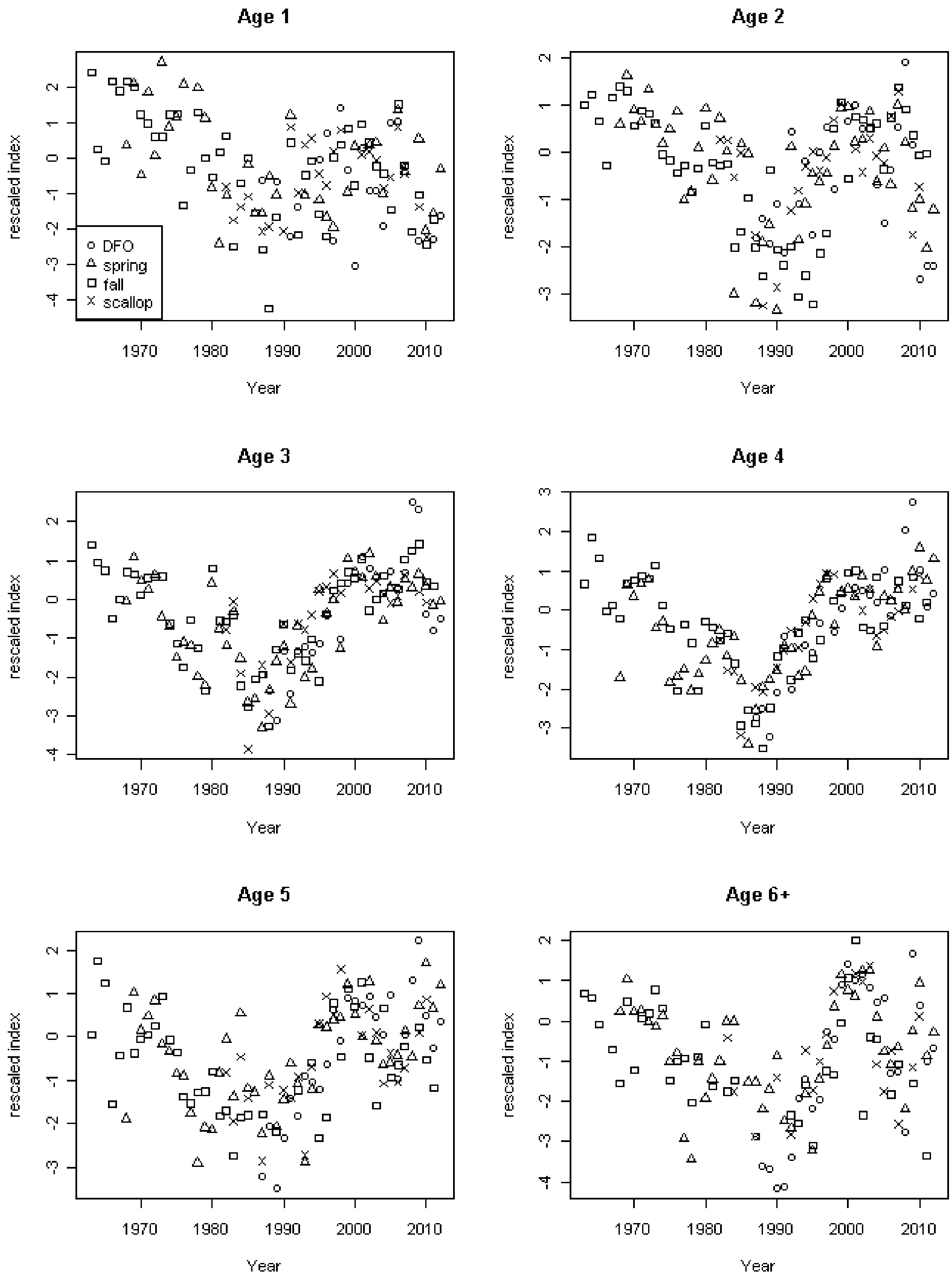


Figure 17a. Standardized catch/tow in numbers at age for the four surveys plotted on natural log scale. The standardization was merely the division of each index value by the mean of the associated time series. Circles denote the DFO survey, triangles the NEFSC spring survey, squares the NEFSC fall survey, and crosses the NEFSC scallop survey.

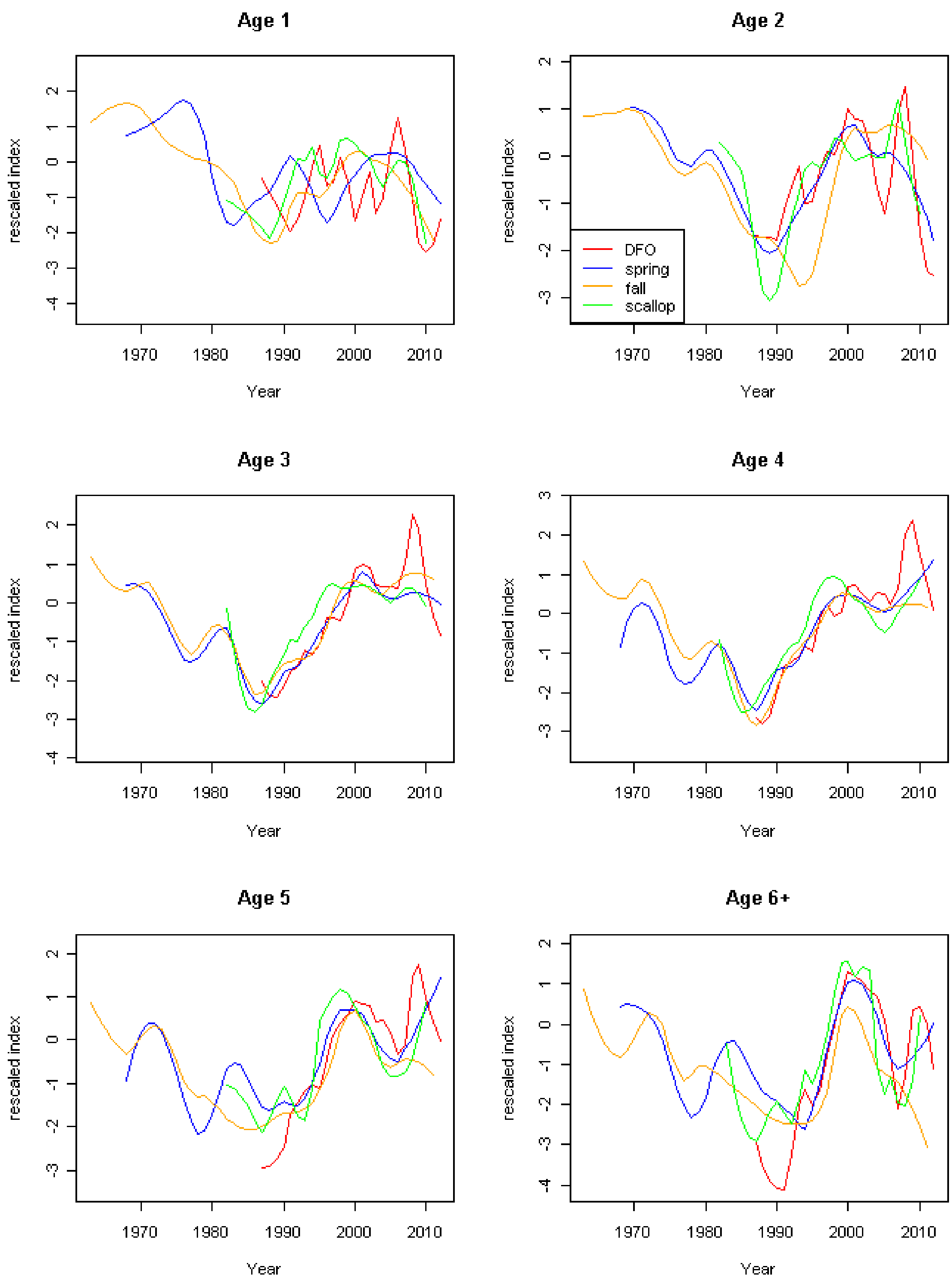


Figure 17b. Same as Figure 17a except the rescaled index values have been smoothed with a loess fit using 30% span to more clearly demonstrate similarities or differences among the surveys.

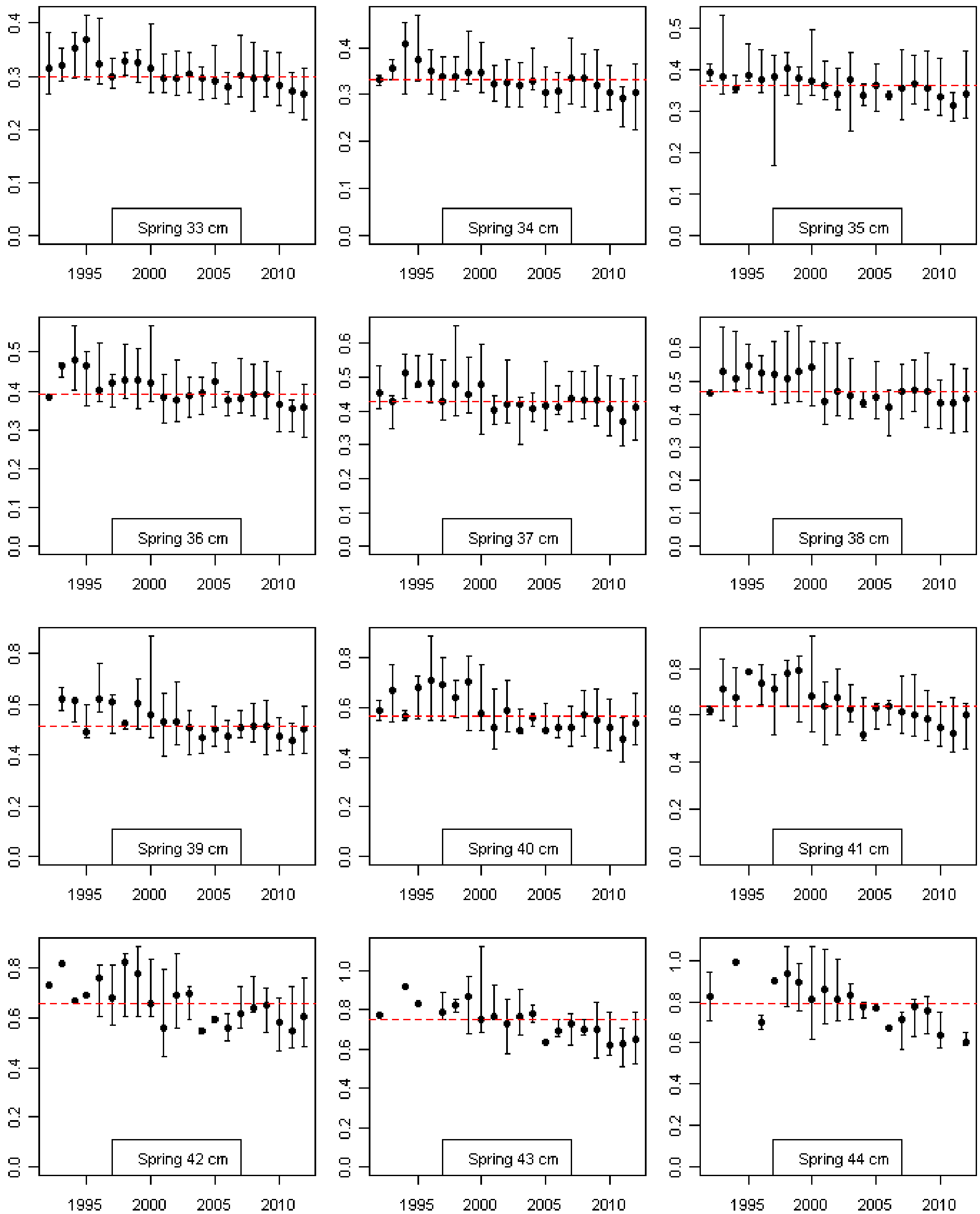


Figure 18a. Median and 2.5%ile and 97.5%ile of measured weight (kg) at length by year from the NEFSC spring survey. The horizontal dashed red line denotes the median of the medians.

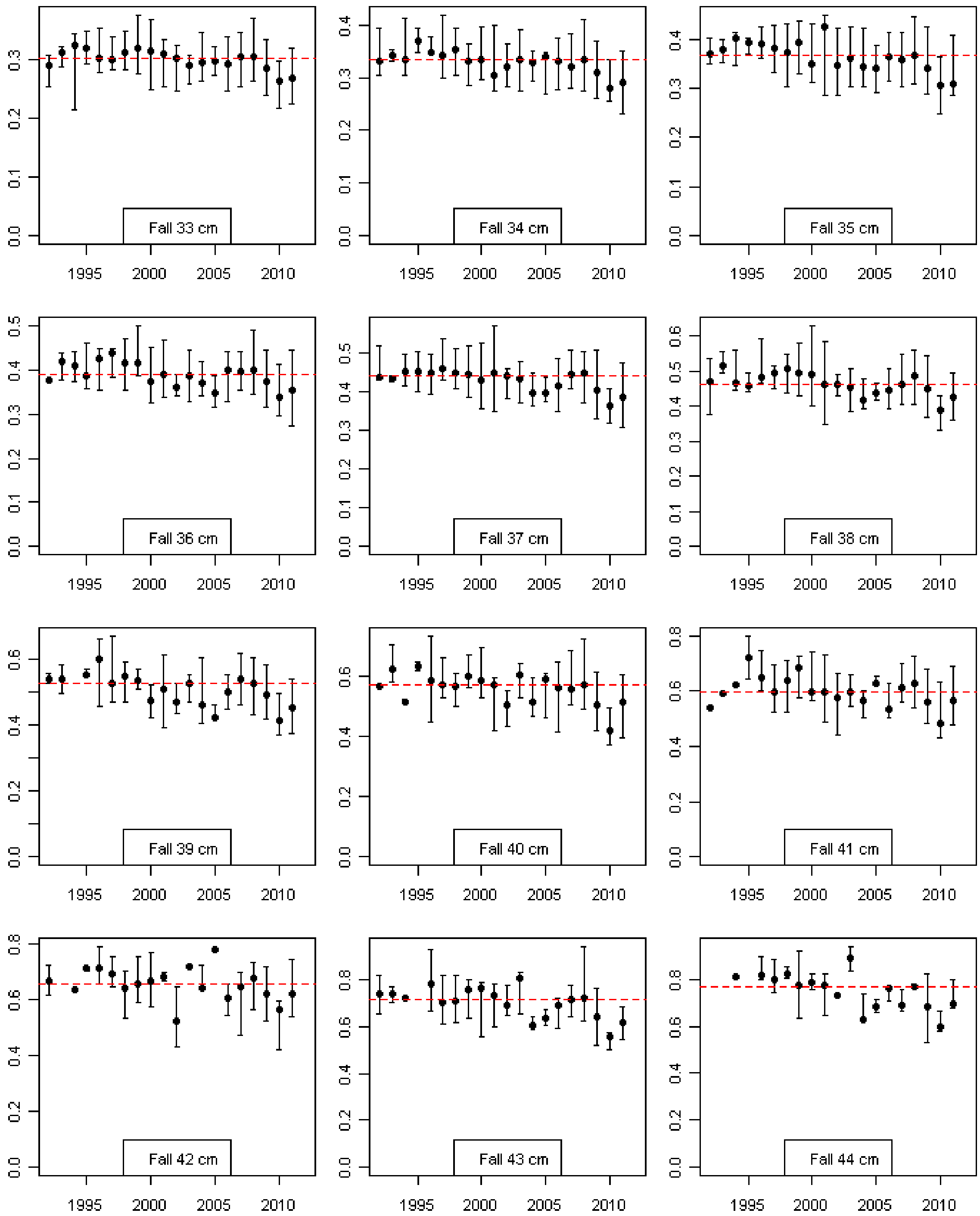


Figure 18b. Median and 2.5%ile and 97.5%ile of measured weight (kg) at length by year from the NEFSC fall survey. The horizontal dashed red line denotes the median of the medians.

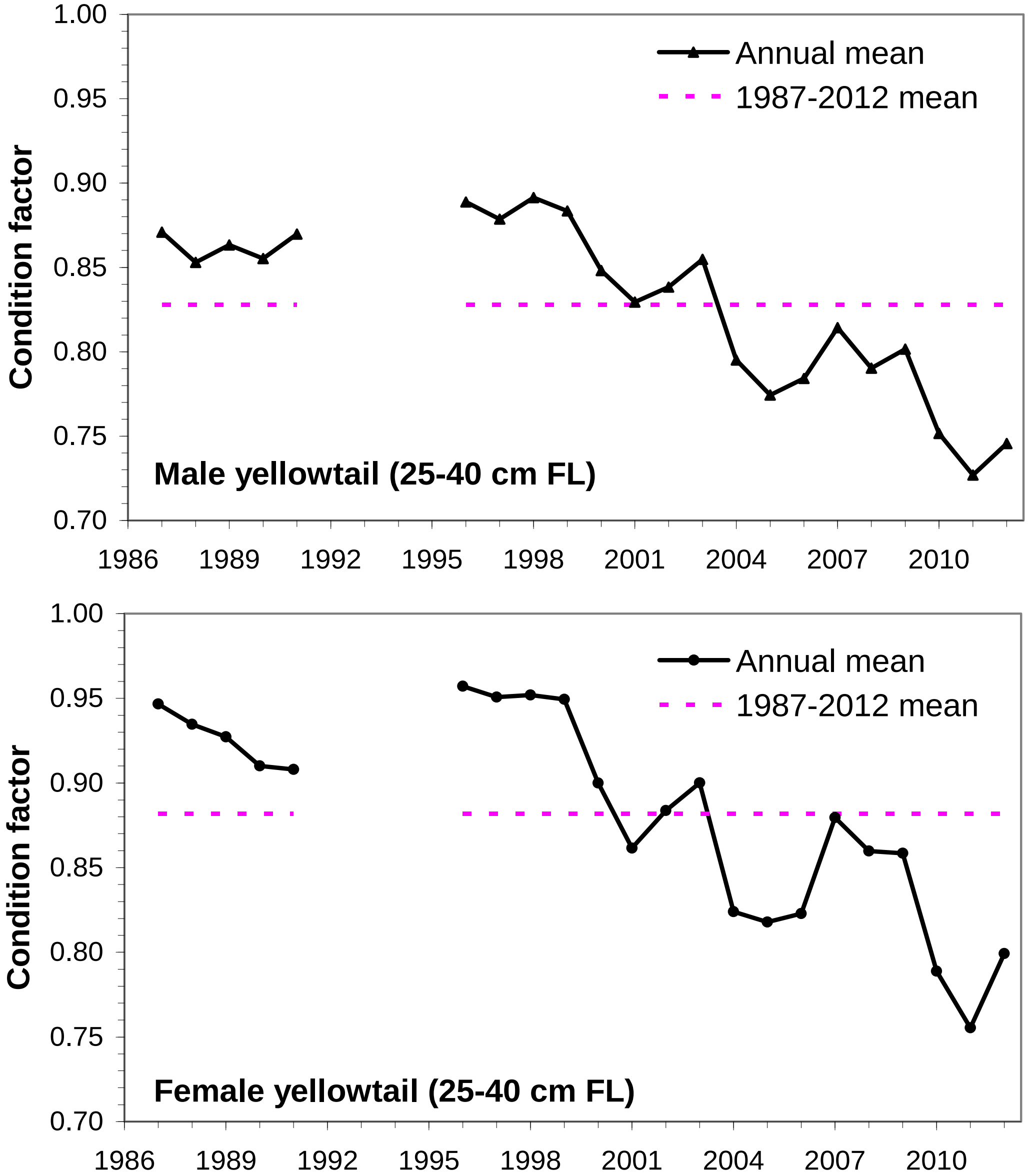


Figure 18c. Condition factor (Fulton's K) for male and female yellowtail flounder in the DFO survey.

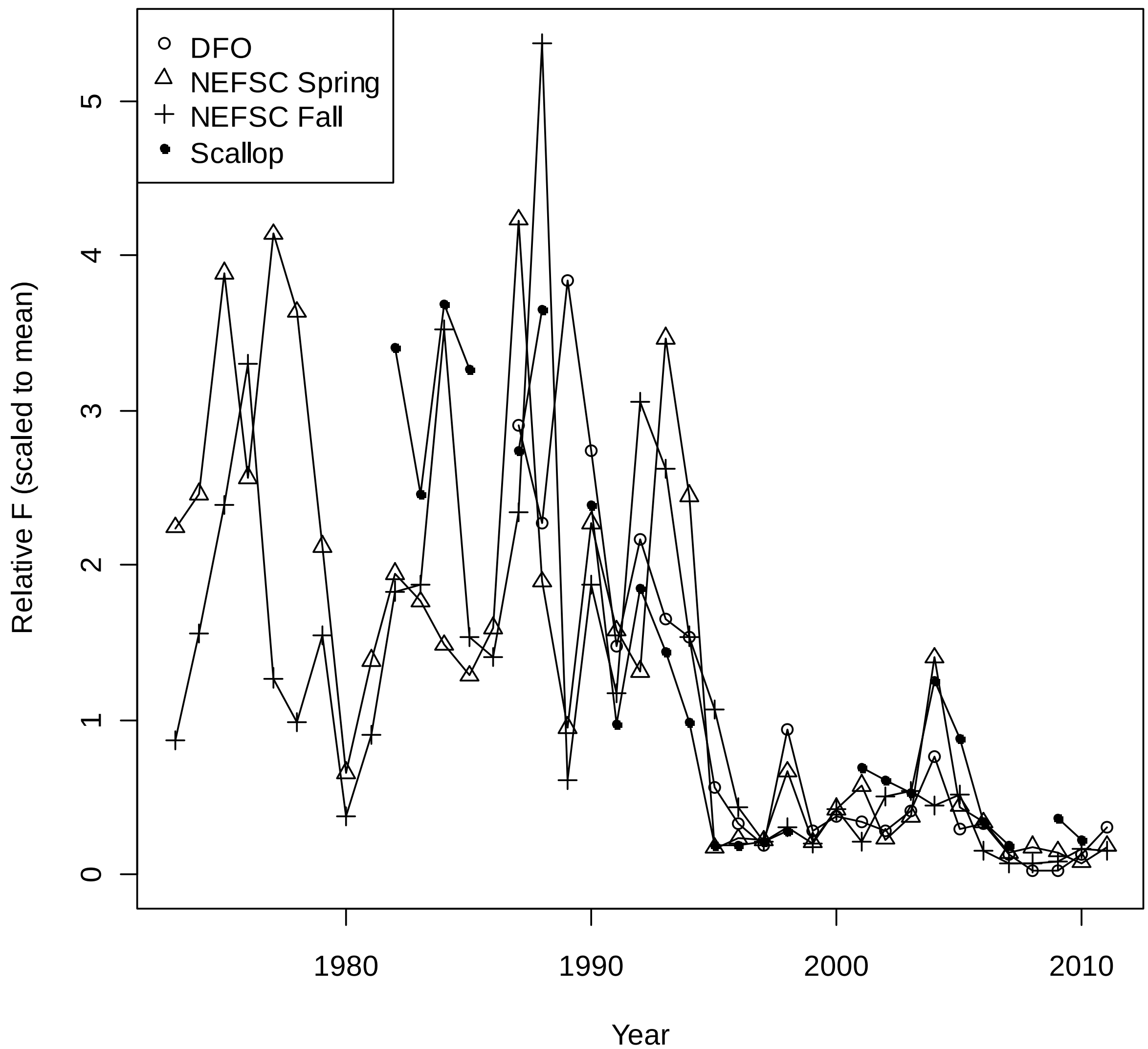


Figure 19. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2010.

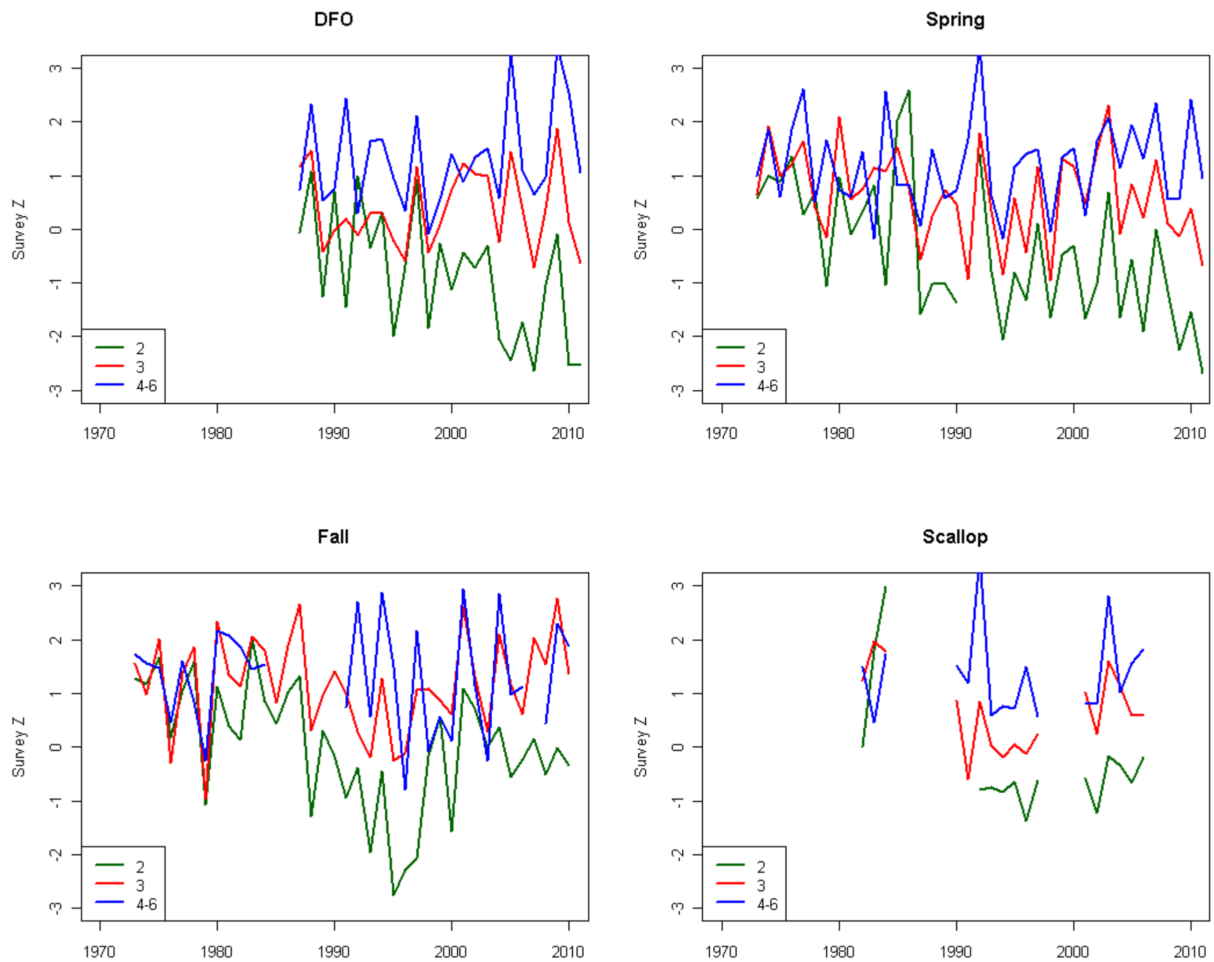


Figure 20. Trends in total mortality (Z) for ages 2, 3, and 4-6 from the four surveys.

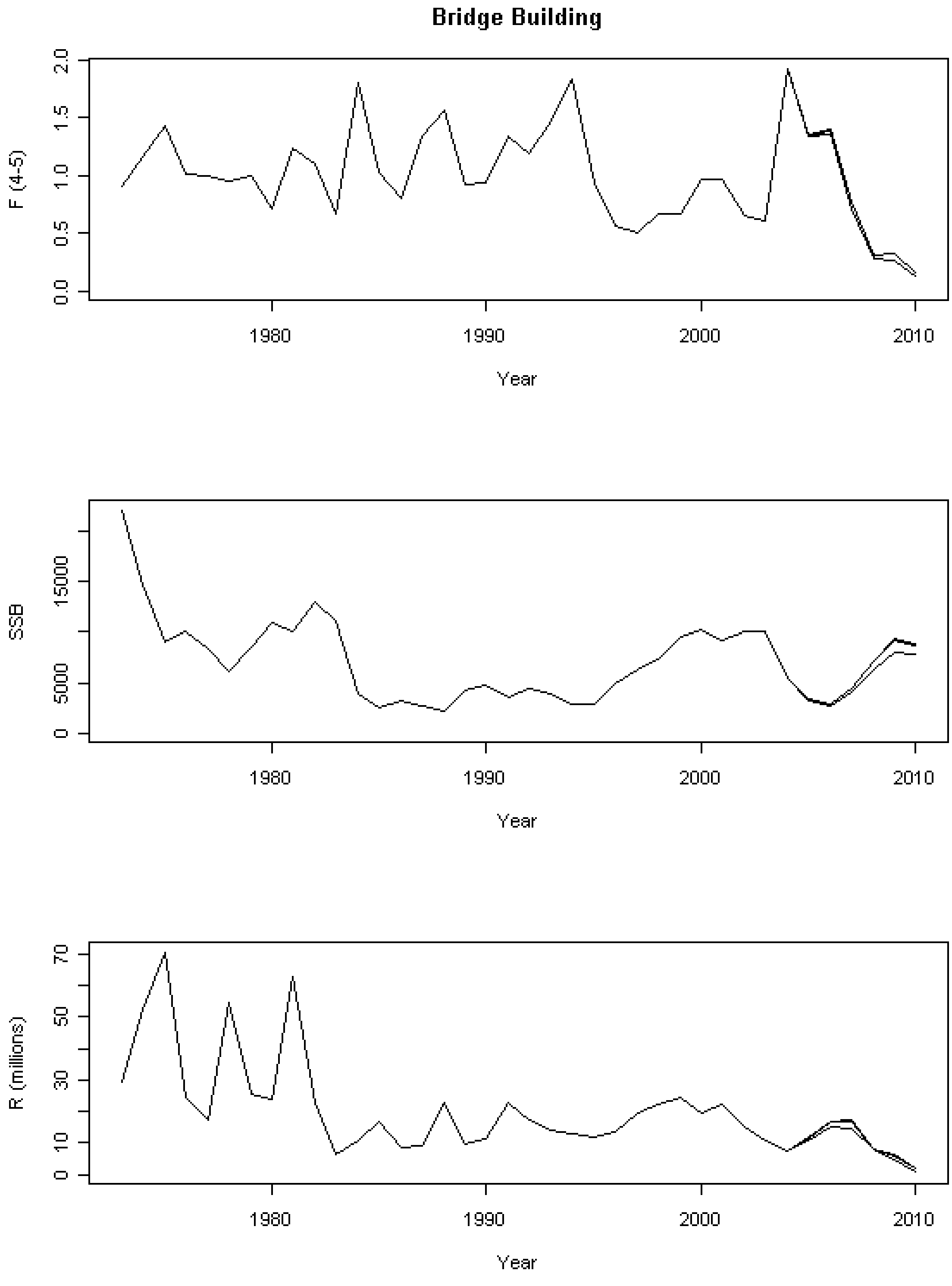


Figure 21. Fishing mortality rate (ages 4+, top panel), spawning stock biomass (mt, middle panel) and recruitment (millions of age 1 fish, bottom panel) for the TRAC 2011 assessment and seven updates to the catch and survey data (see text: Sensitivity Analyses). The higher F and R lines and the lower SSB lines all have the updated DFO 2011 survey data.

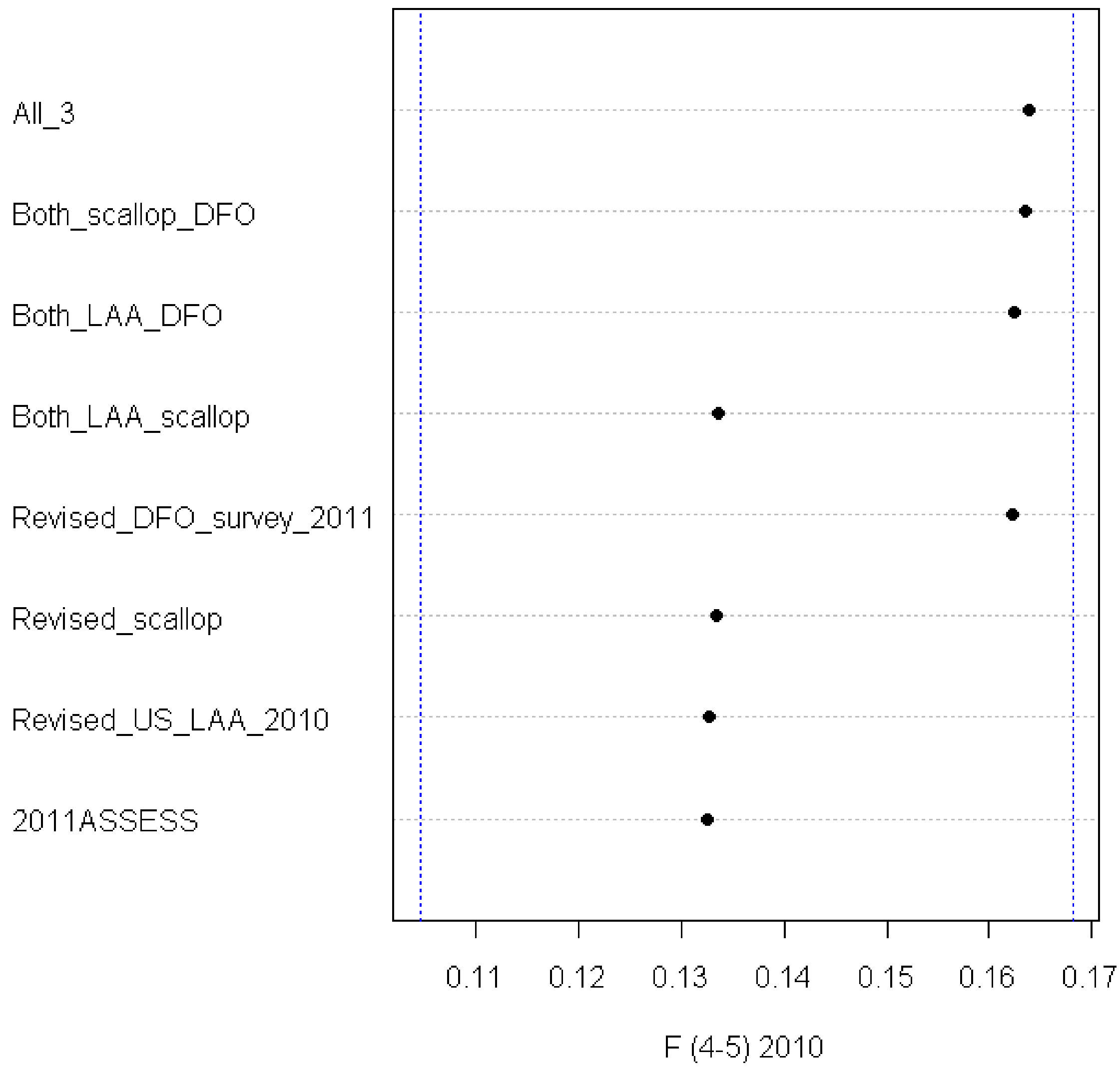


Figure 22a. Fishing mortality rate (ages 4+) in 2010 from the TRAC 2011 assessment and seven combinations of updated US landings for 2010, scallop survey time series, and DFO 2011 survey. The vertical dotted blue lines denote the 80% confidence interval for the TRAC 2011 assessment.

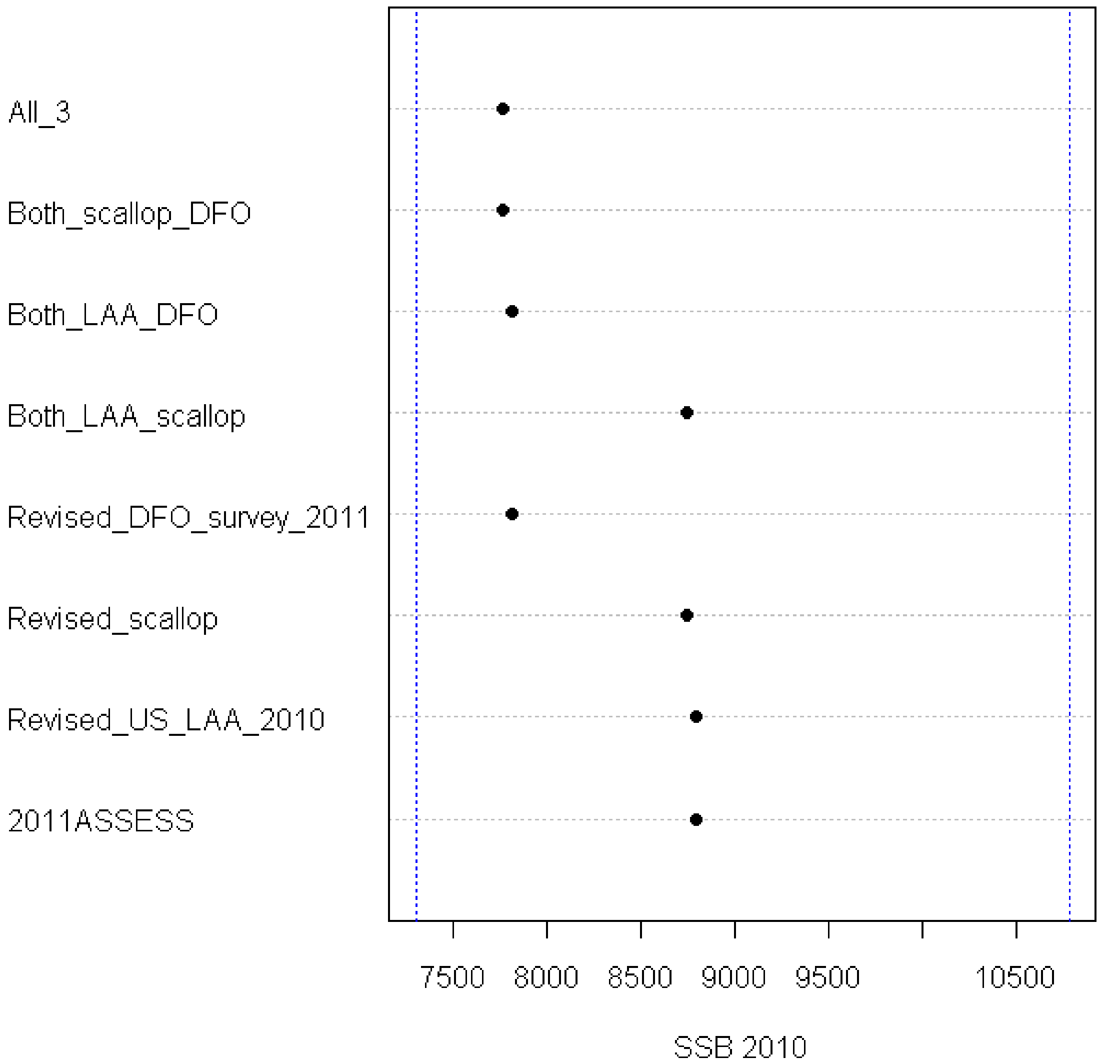


Figure 22b. Spawning stock biomass (mt) in 2010 from the TRAC 2011 assessment and seven combinations of updated US landings for 2010, scallop survey time series, and DFO 2011 survey. The vertical dotted blue lines denote the 80% confidence interval for the TRAC 2011 assessment.

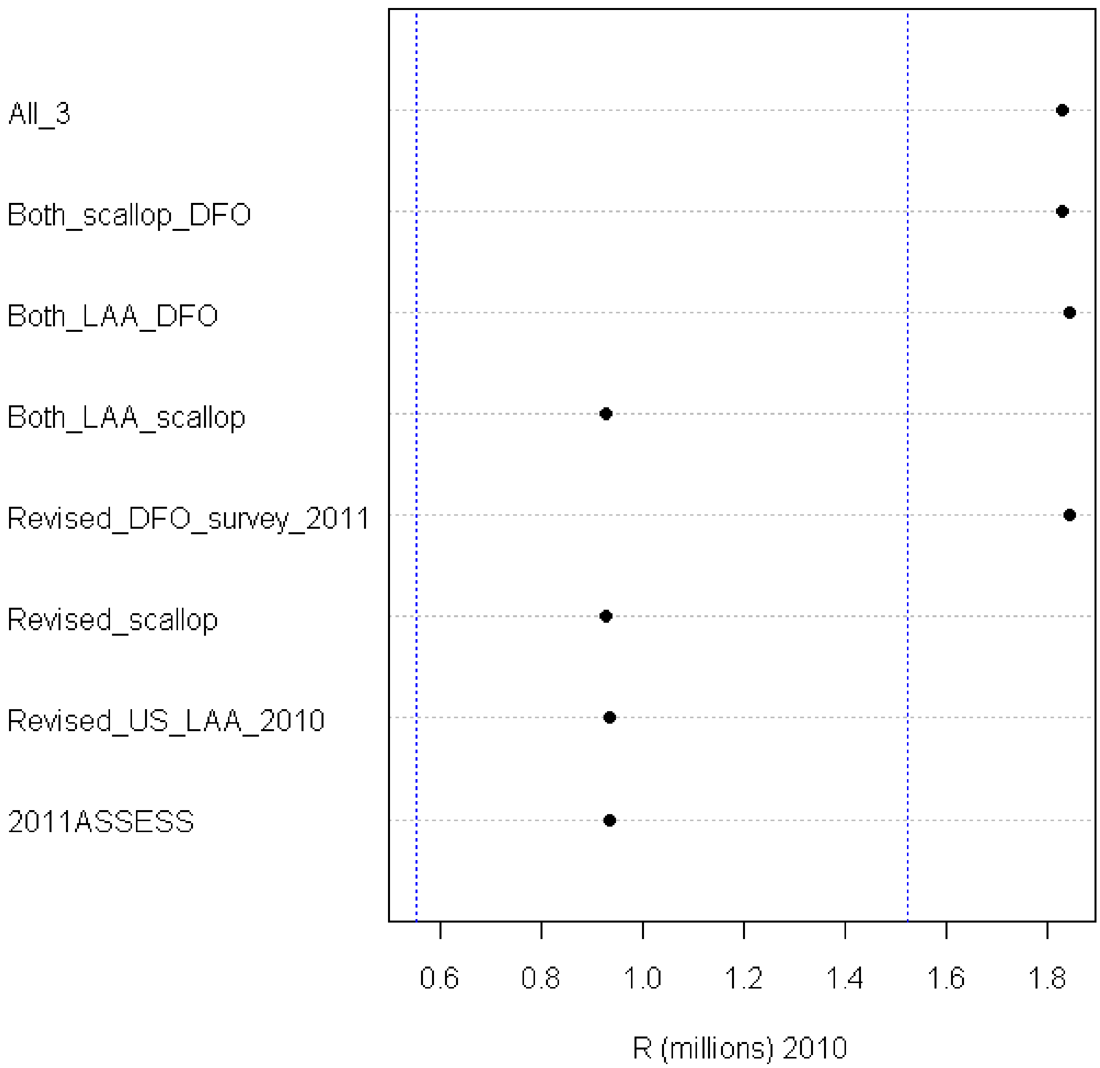


Figure 22c. Recruitment (millions of age 1 fish) in 2010 from the TRAC 2011 assessment and seven combinations of updated US landings for 2010, scallop survey time series, and DFO 2011 survey. The vertical dotted blue lines denote the 80% confidence interval for the TRAC 2011 assessment.

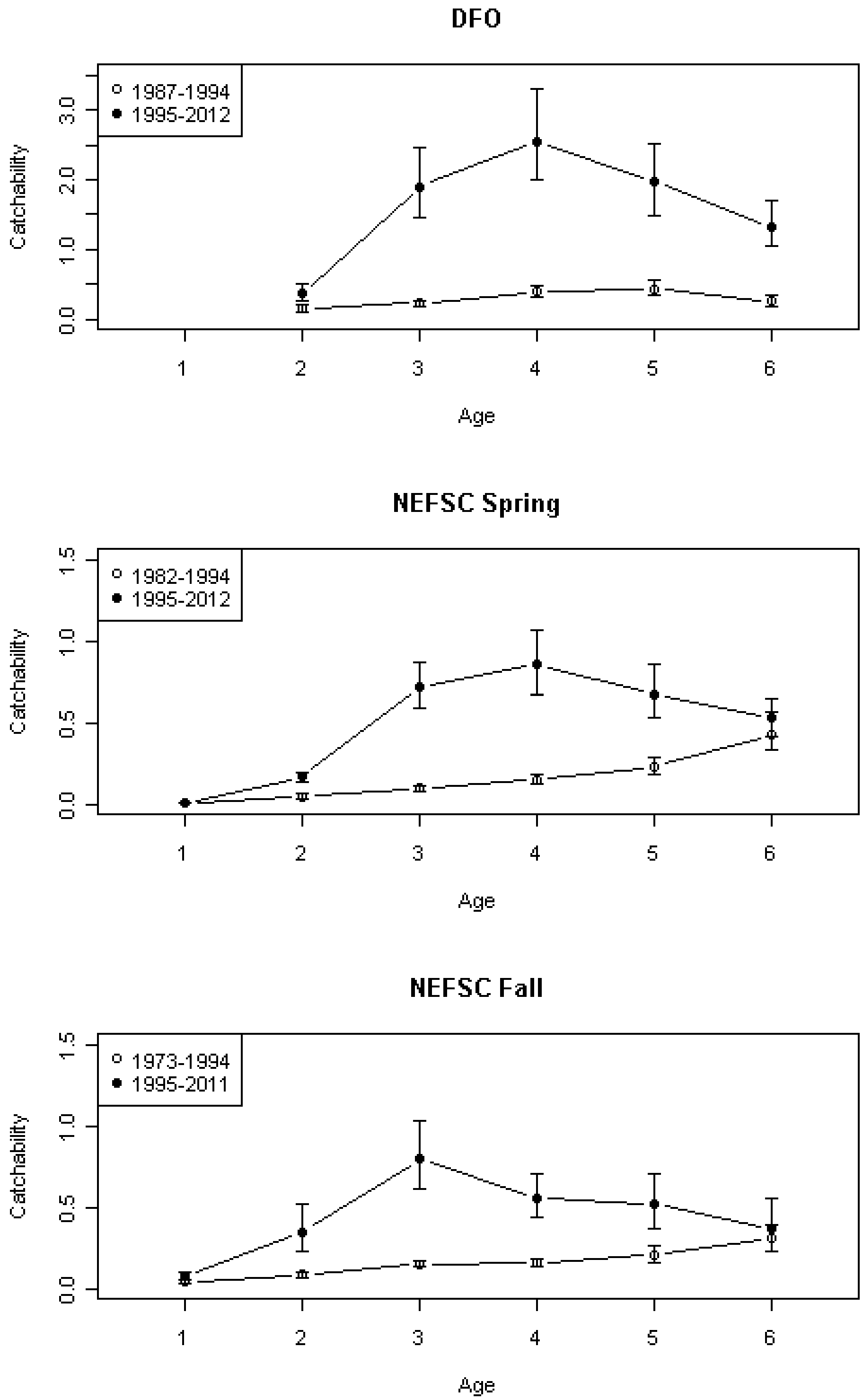


Figure 23. Catchability coefficients (q) from the Split Series VPA with bootstrapped 80% confidence intervals.

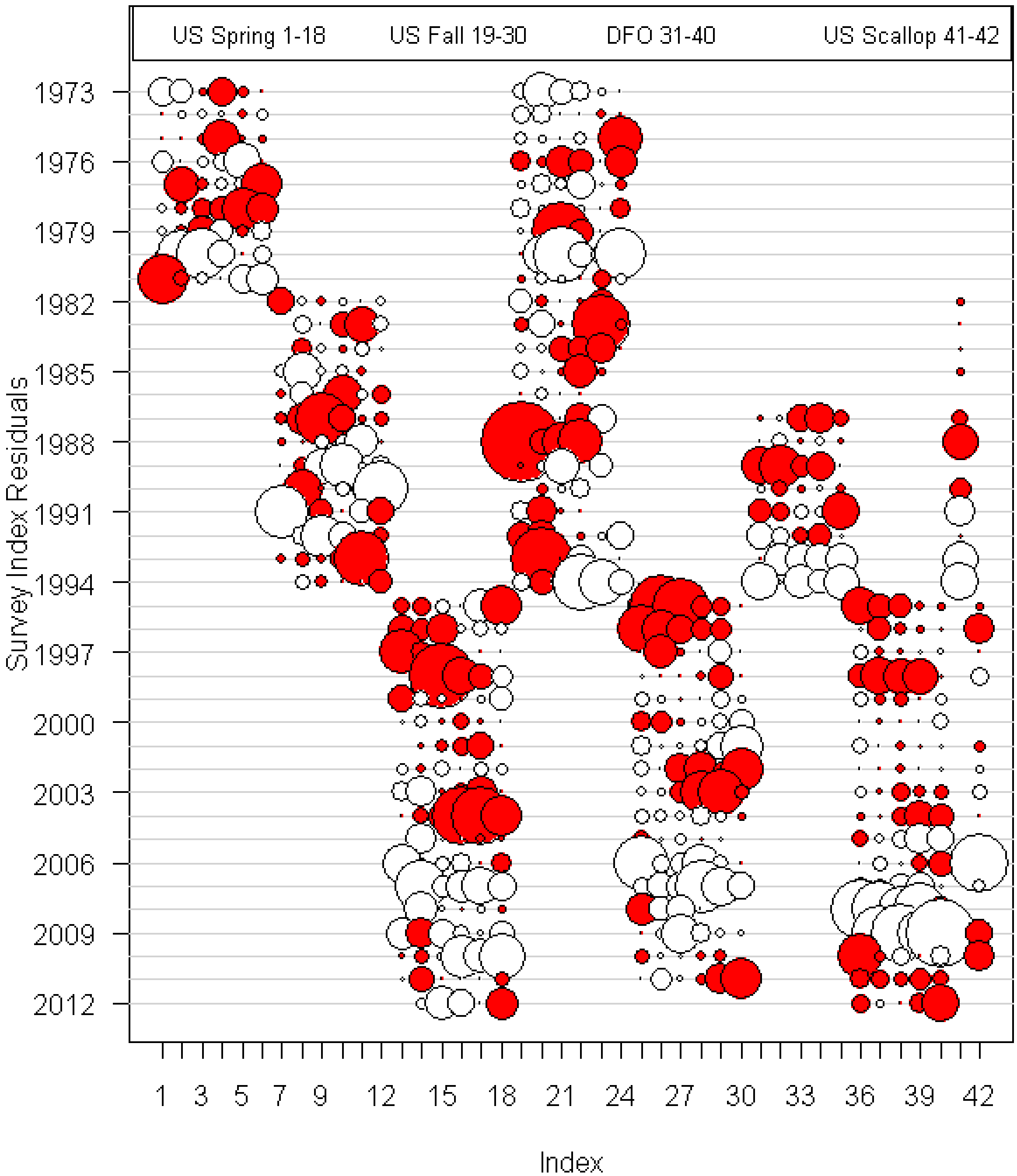


Figure 24. Age by age residuals from the Split Series VPA for log scale predicted minus observed population abundances, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The red symbols denote negative residuals, and white symbols denote positive residuals.

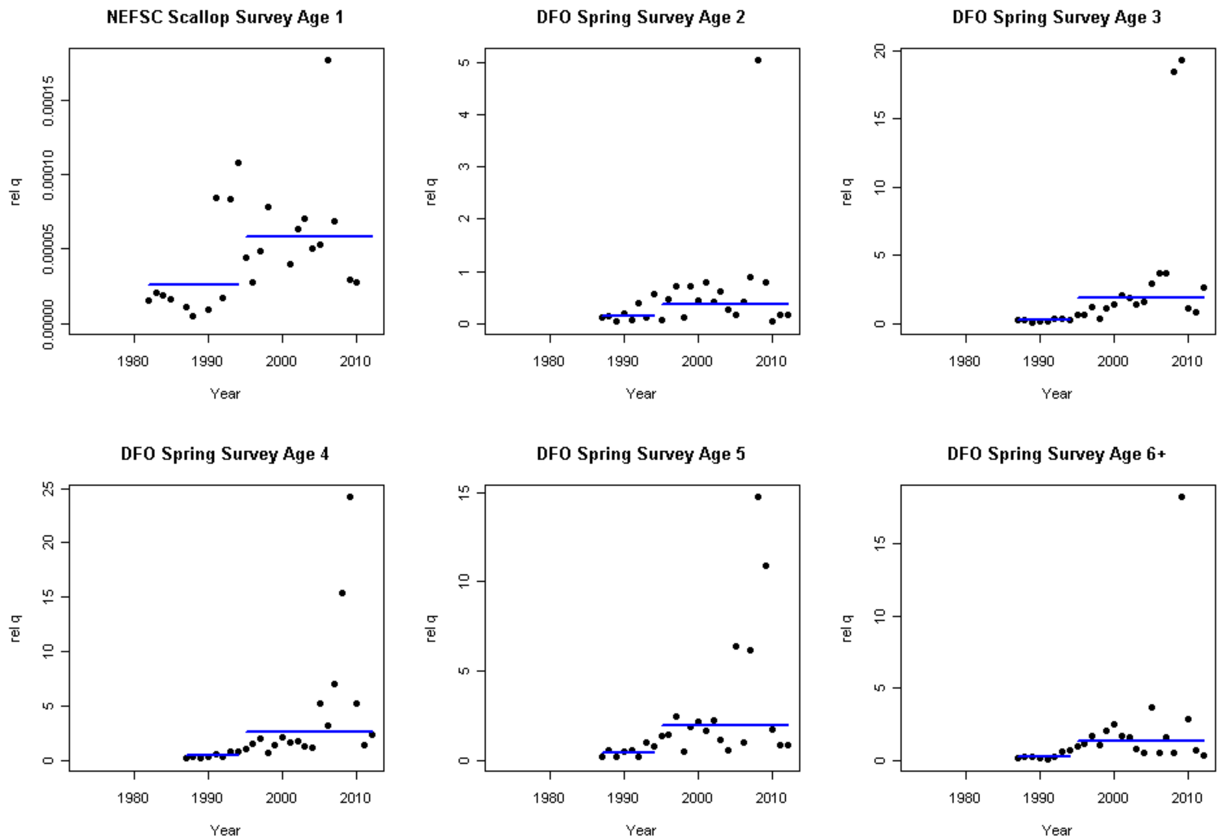


Figure 25a. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC scallop survey at age 1 and the DFO survey at ages 2 through 6+. The relative q values are computed as the observed survey value (as a minimum swept area estimate) divided by the population abundance at that age at the start of that year (no adjustment for timing of the survey).

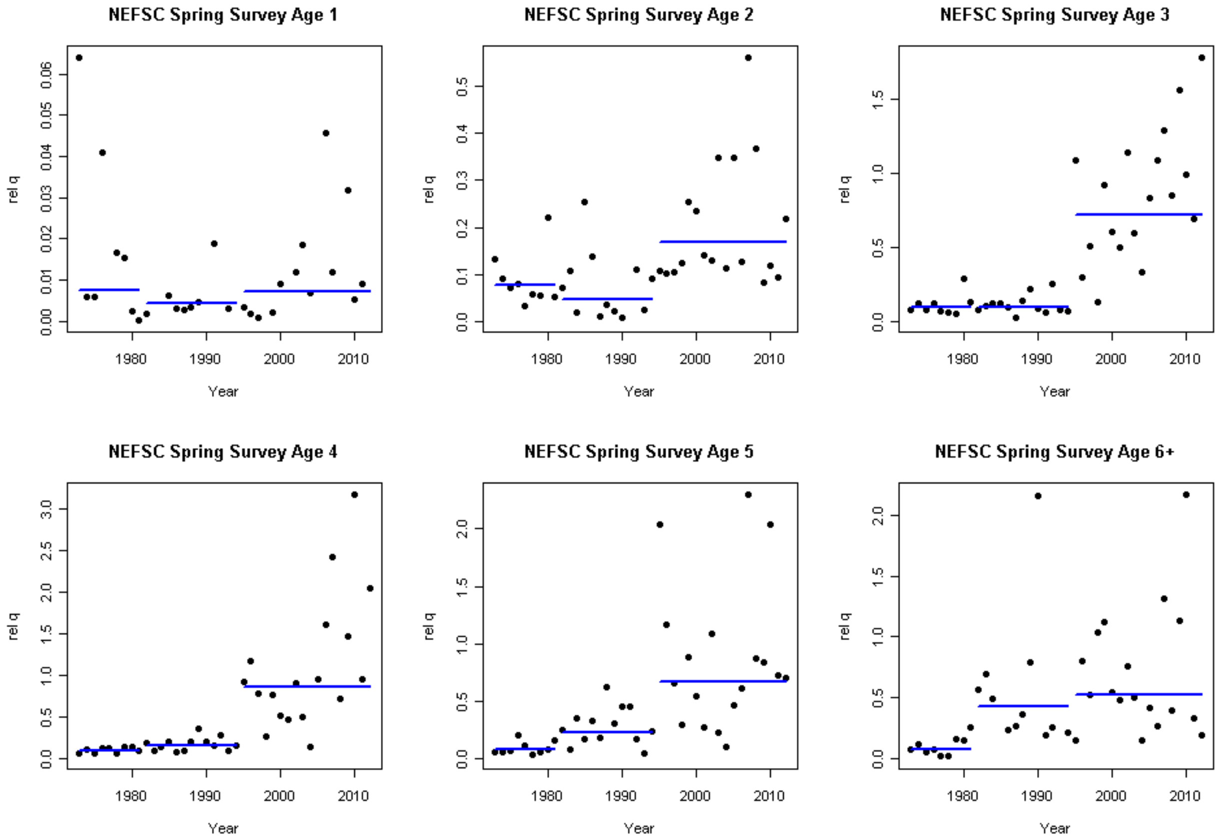


Figure 25b. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC spring survey.

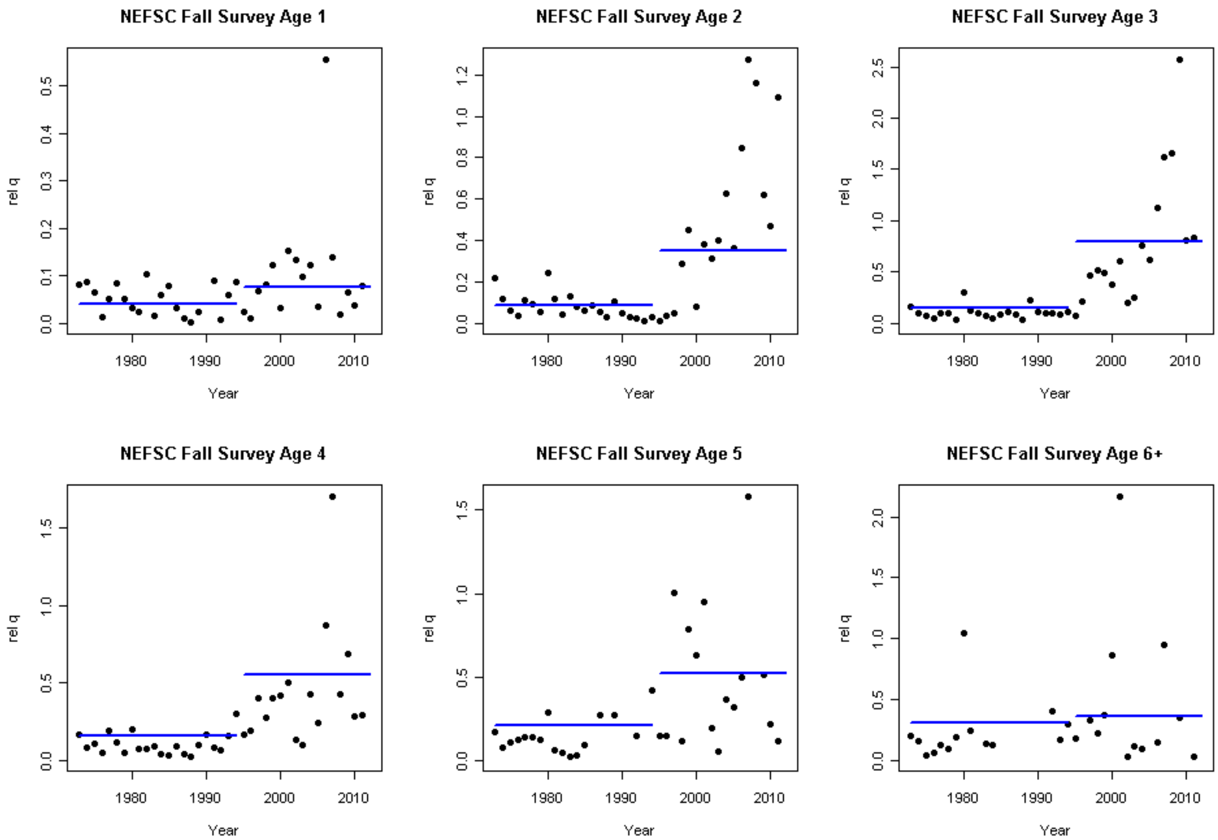


Figure 25c. Estimated catchability coefficients (q) from the split series VPA (lines) and relative q values for the NEFSC fall survey.

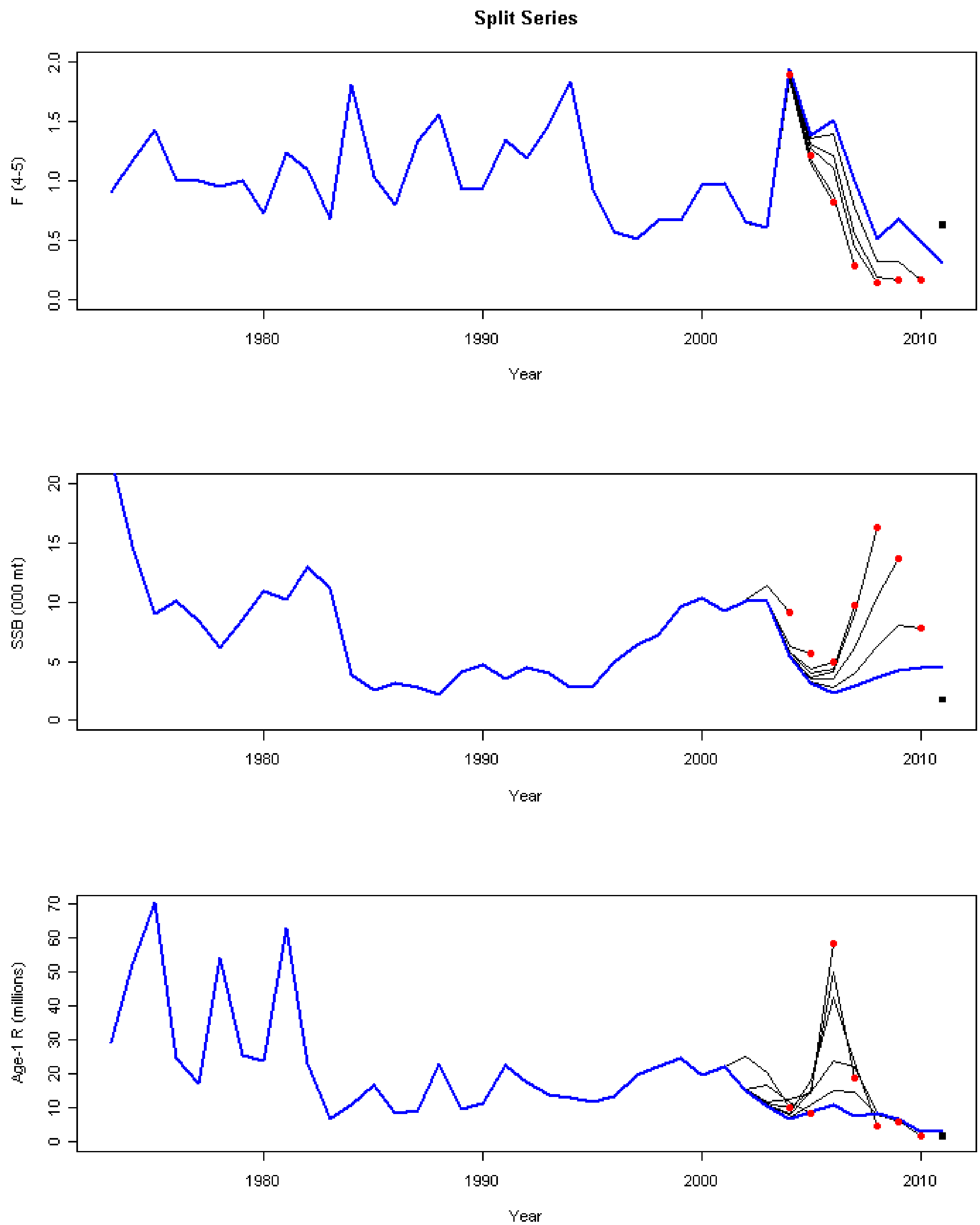


Figure 26a. Retrospective analysis of Georges Bank yellowtail flounder from the Split Series VPA for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel). The black squares show the rho adjusted values for 2011.

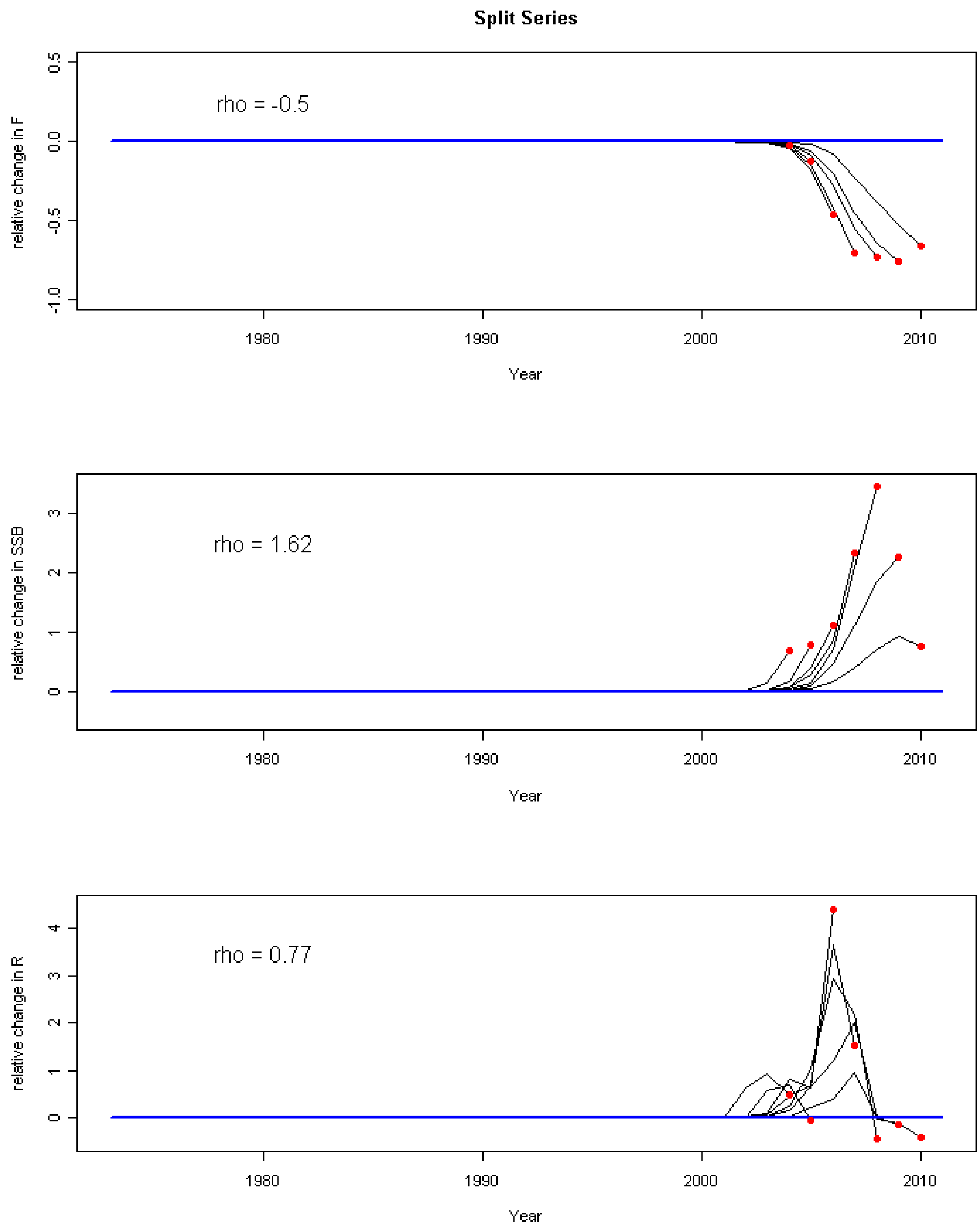


Figure 26b. Relative retrospective plots for Georges Bank yellowtail flounder from Split Series VPA with Mohn's rho calculated from seven year peel for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel).

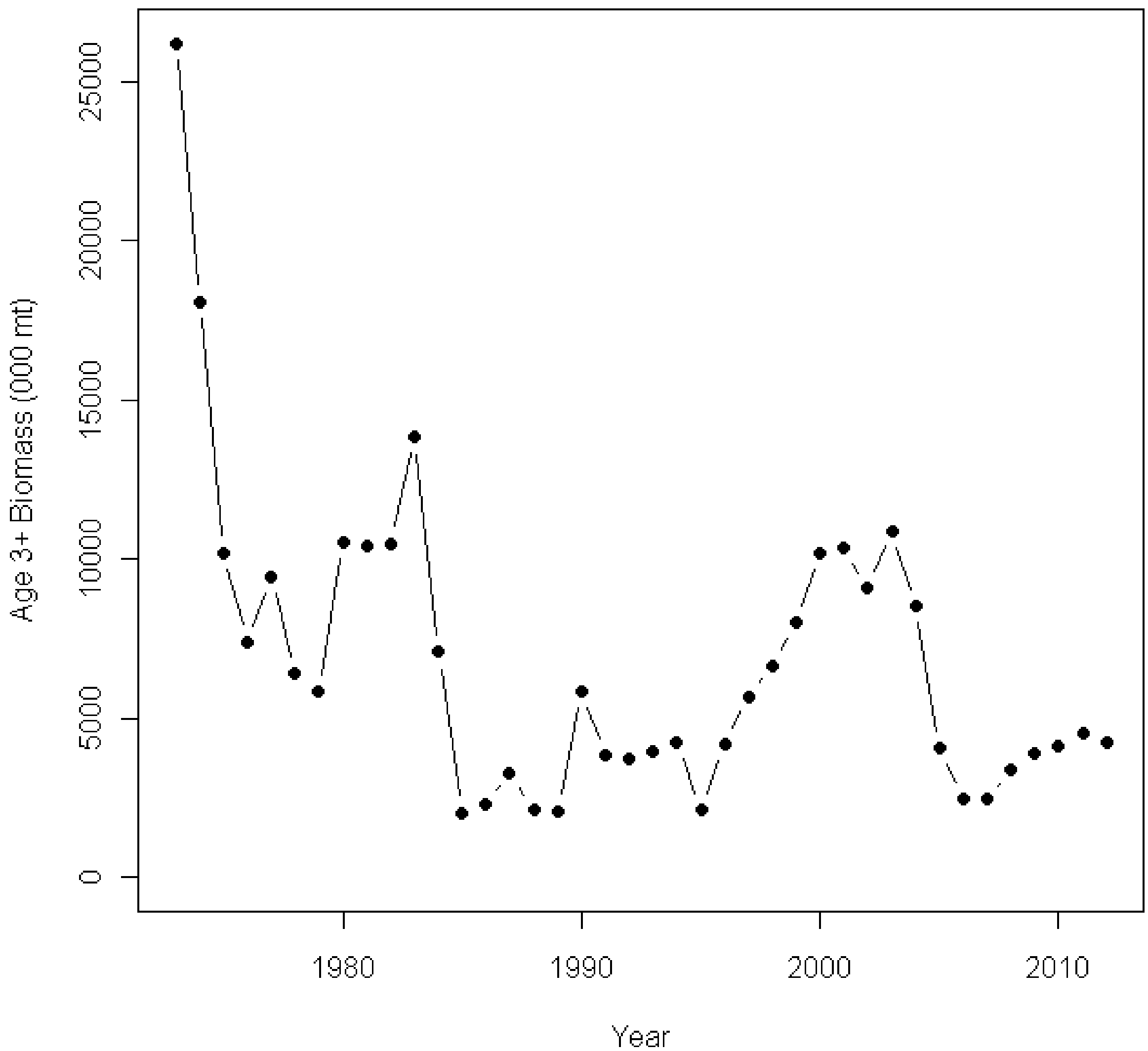


Figure 27. Adult biomass (ages 3+, Jan-1) from the Split Series VPA.

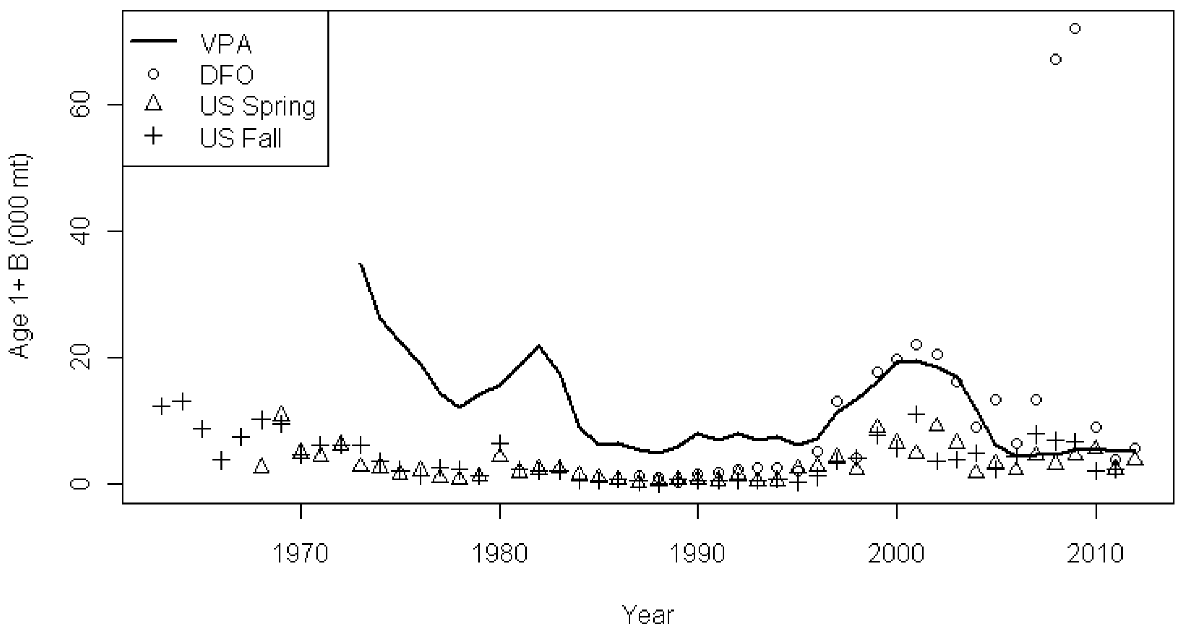


Figure 28. Jan-1 age 1+ biomass estimated by the split series VPA and from the three groundfish surveys in minimum swept area values. The final VPA value uses the geometric mean of the previous ten years for the age 1 recruitment.

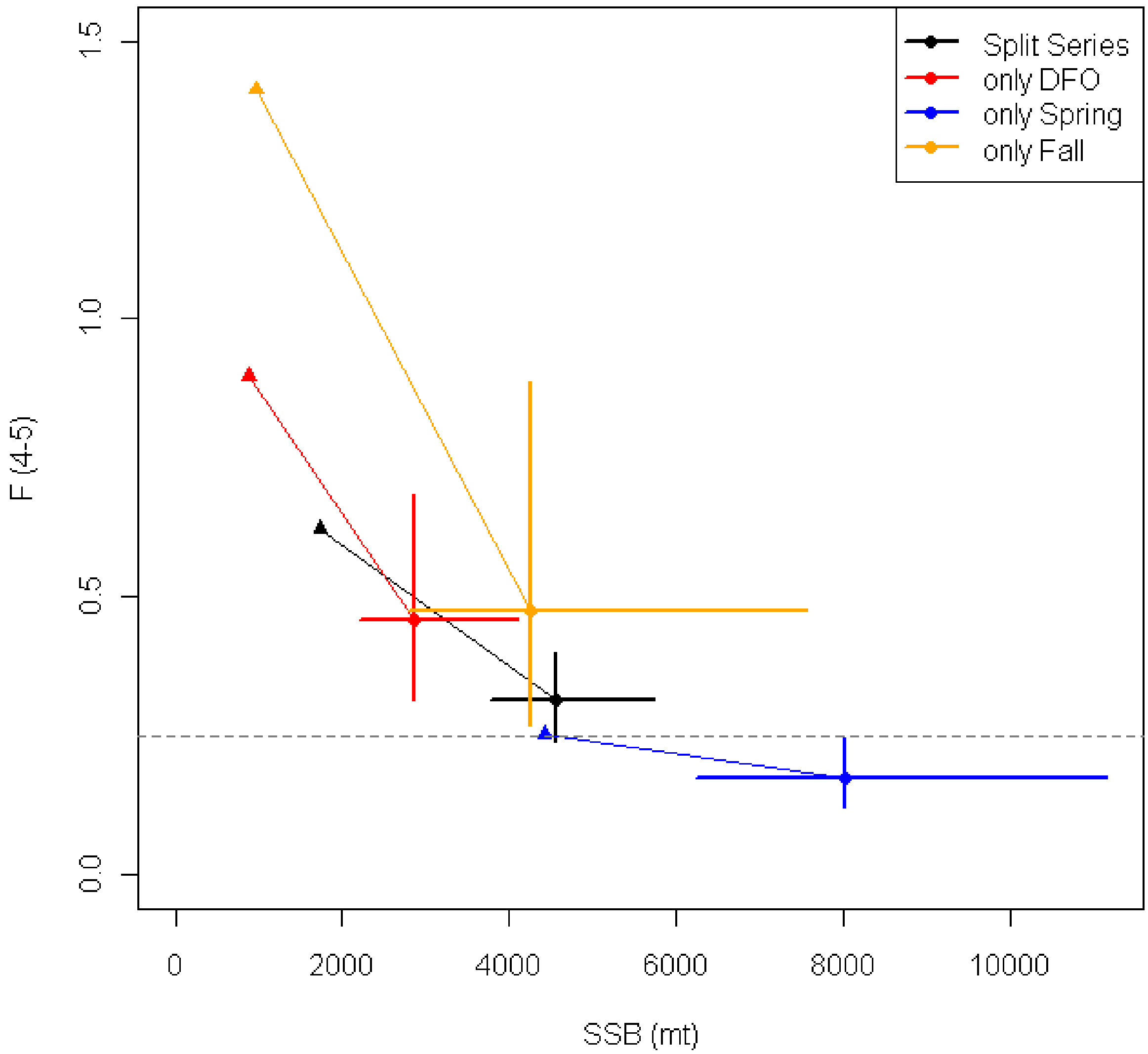


Figure 29. Point estimates of 2011 SSB (mt) and F (ages 4+) with 80% confidence intervals (horizontal and vertical lines) and rho adjusted estimates of SSB and F (triangles) for the Split Series VPA and using each survey one at a time. The horizontal dashed line denotes F_{ref}=0.25.

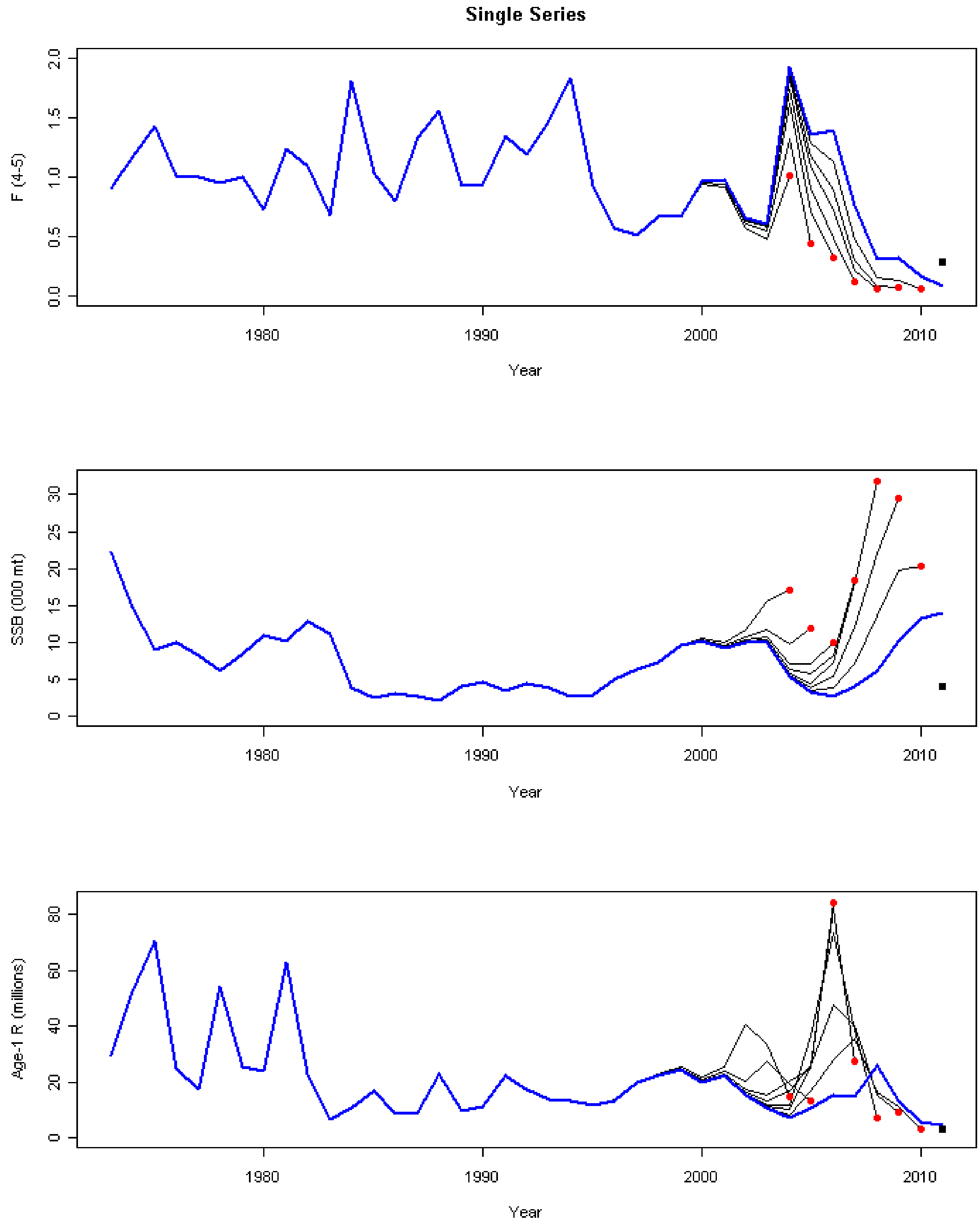


Figure 30a. Retrospective analysis of Georges Bank yellowtail flounder from the Single Series VPA for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel). The black squares show the rho adjusted values for 2011.

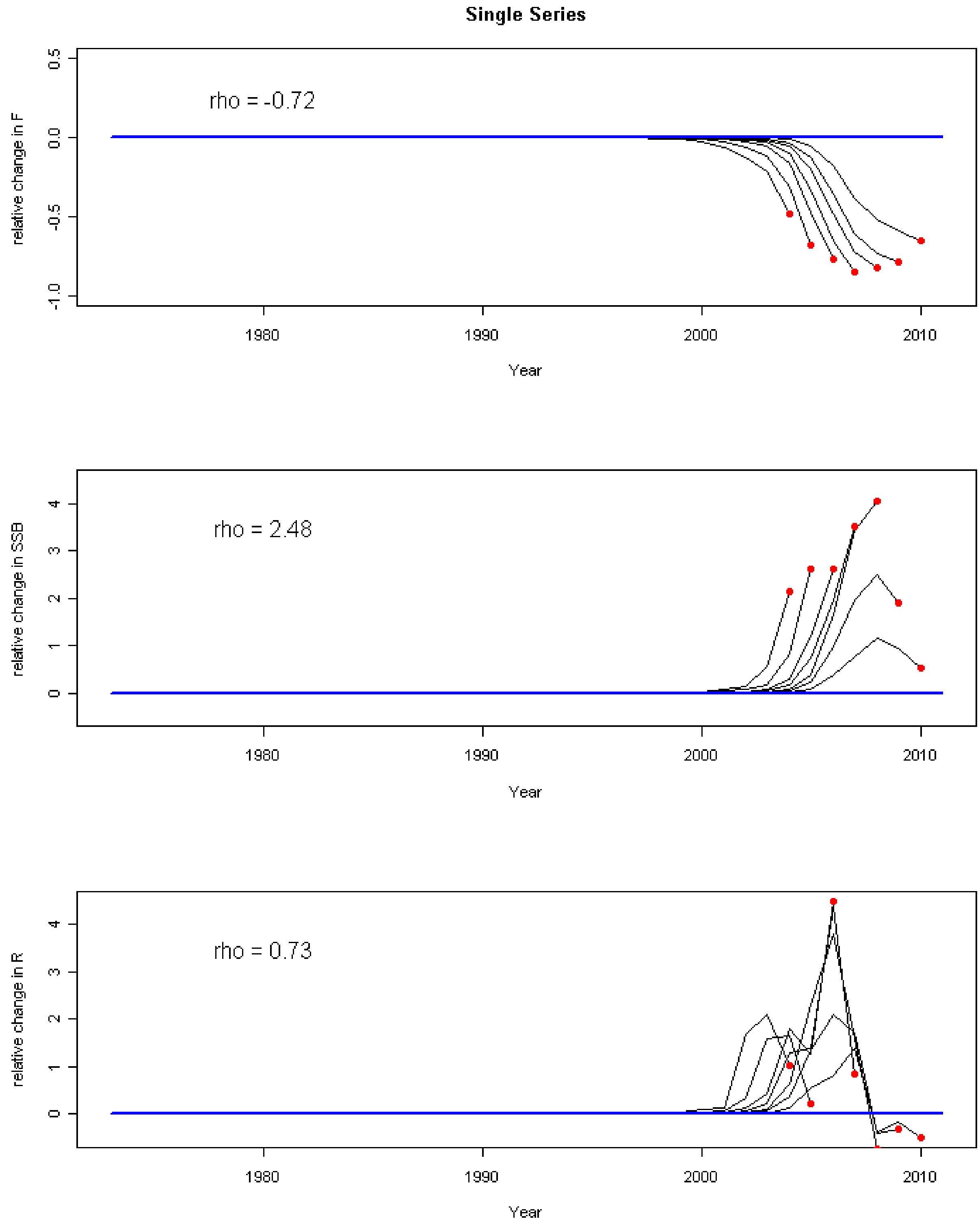


Figure 30b. Relative retrospective plots for Georges Bank yellowtail flounder from Single Series VPA with Mohn's rho calculated from seven year peel for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel).

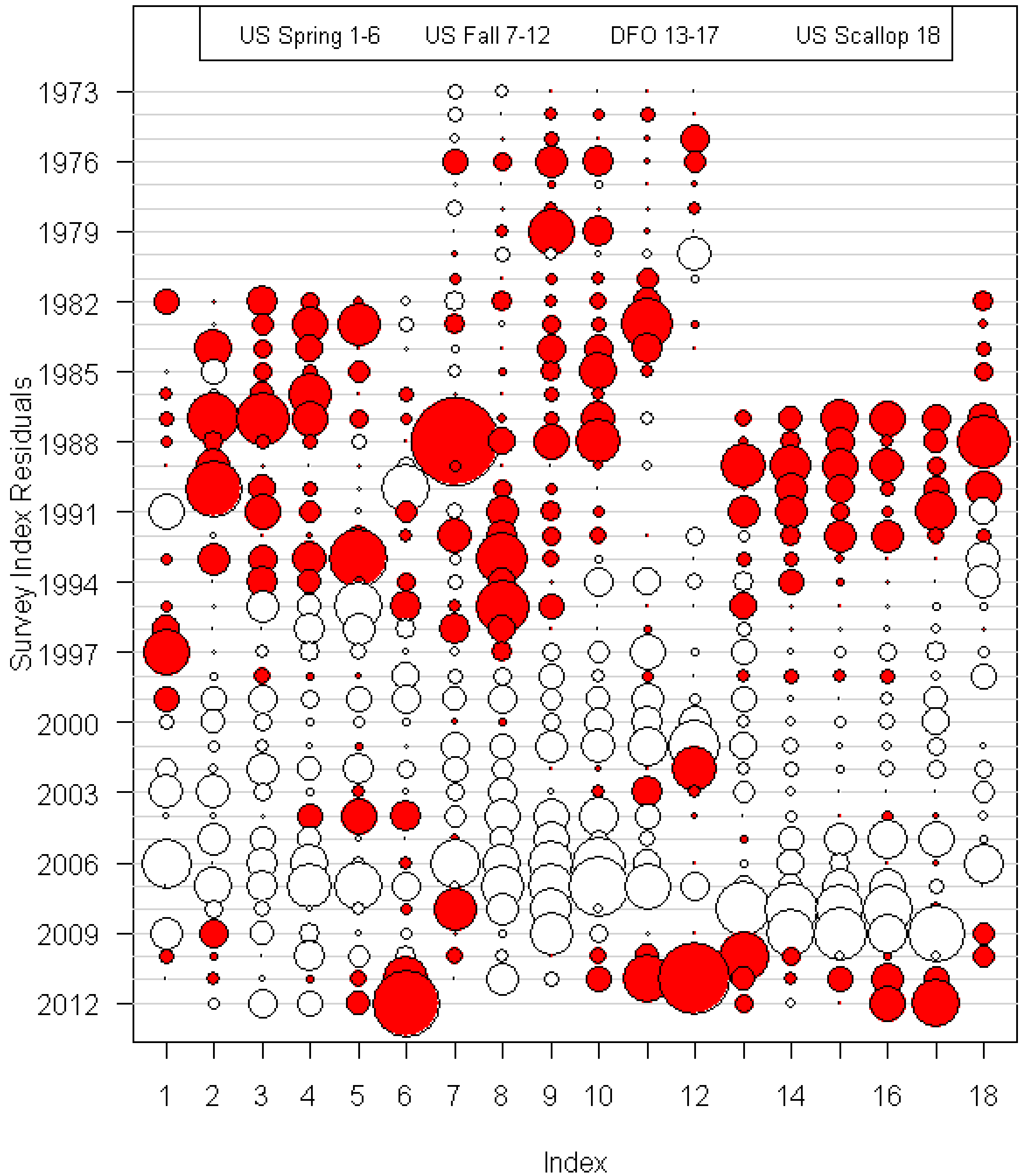


Figure 31. Age by age residuals from the Single Series VPA for log scale predicted minus observed population abundances, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The red symbols denote negative residuals, and white symbols denote positive residuals.

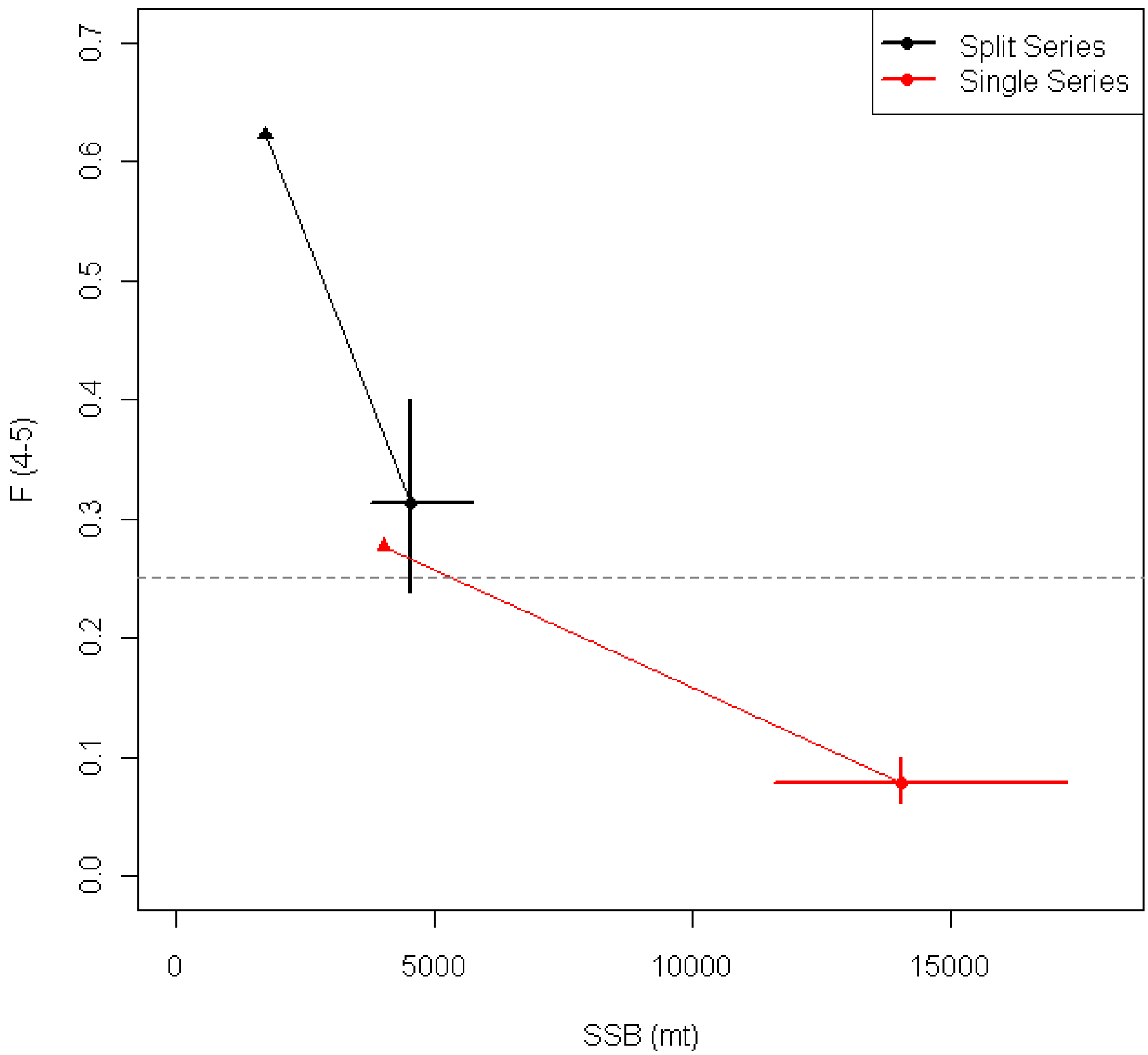


Figure 32. Point estimates of SSB (mt) and F (ages 4+) with 80% confidence intervals (horizontal and vertical lines) and rho adjusted estimates of SSB and F (triangles) for the Split Series VPA and the Single Series VPA. The horizontal dashed line denotes F_{ref}=0.25.

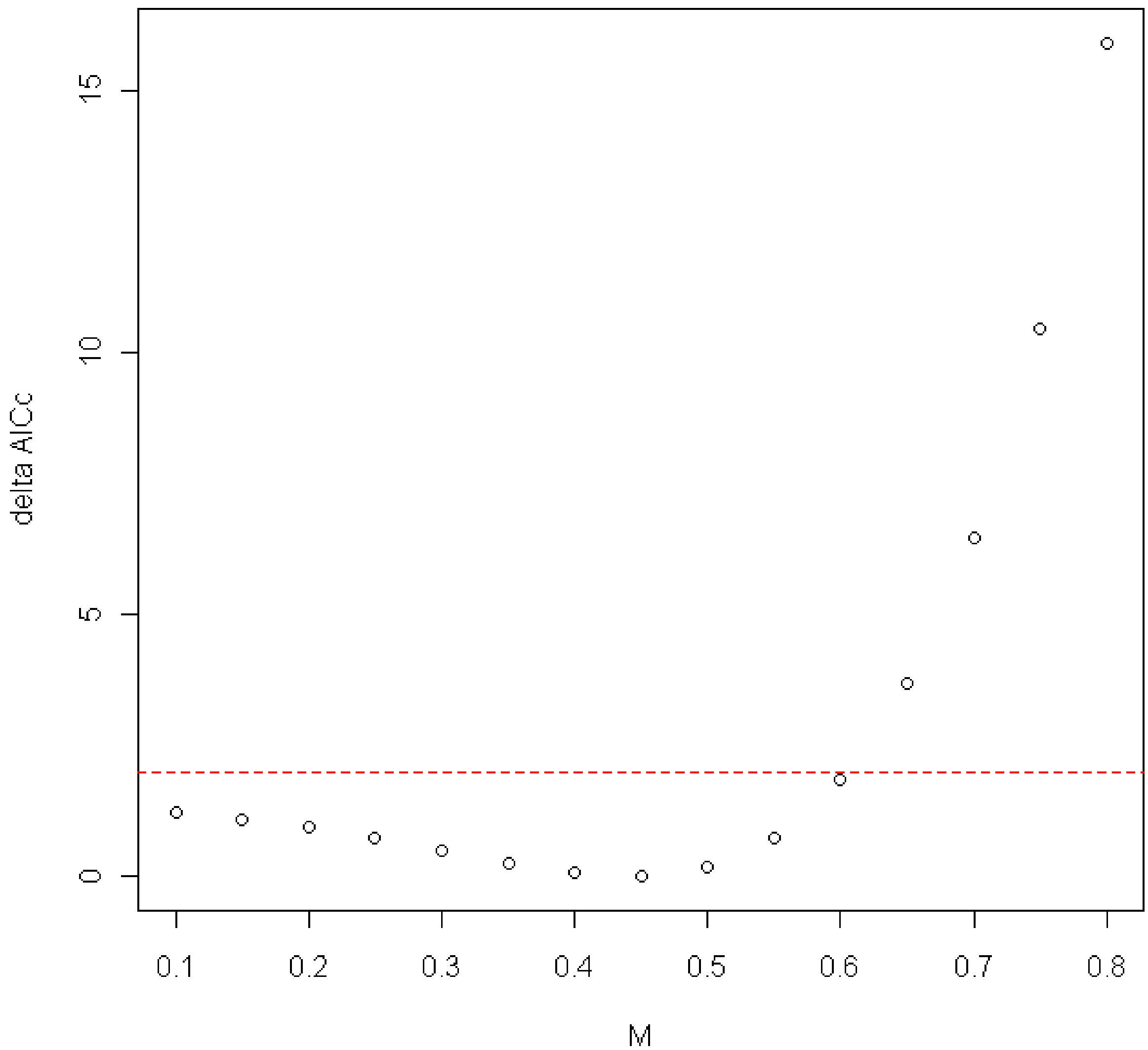


Figure 33. Change in AICc relative to the best fit model for a range of natural mortality (M) values applied to all ages and year. The horizontal line denotes a change of two AICc units.

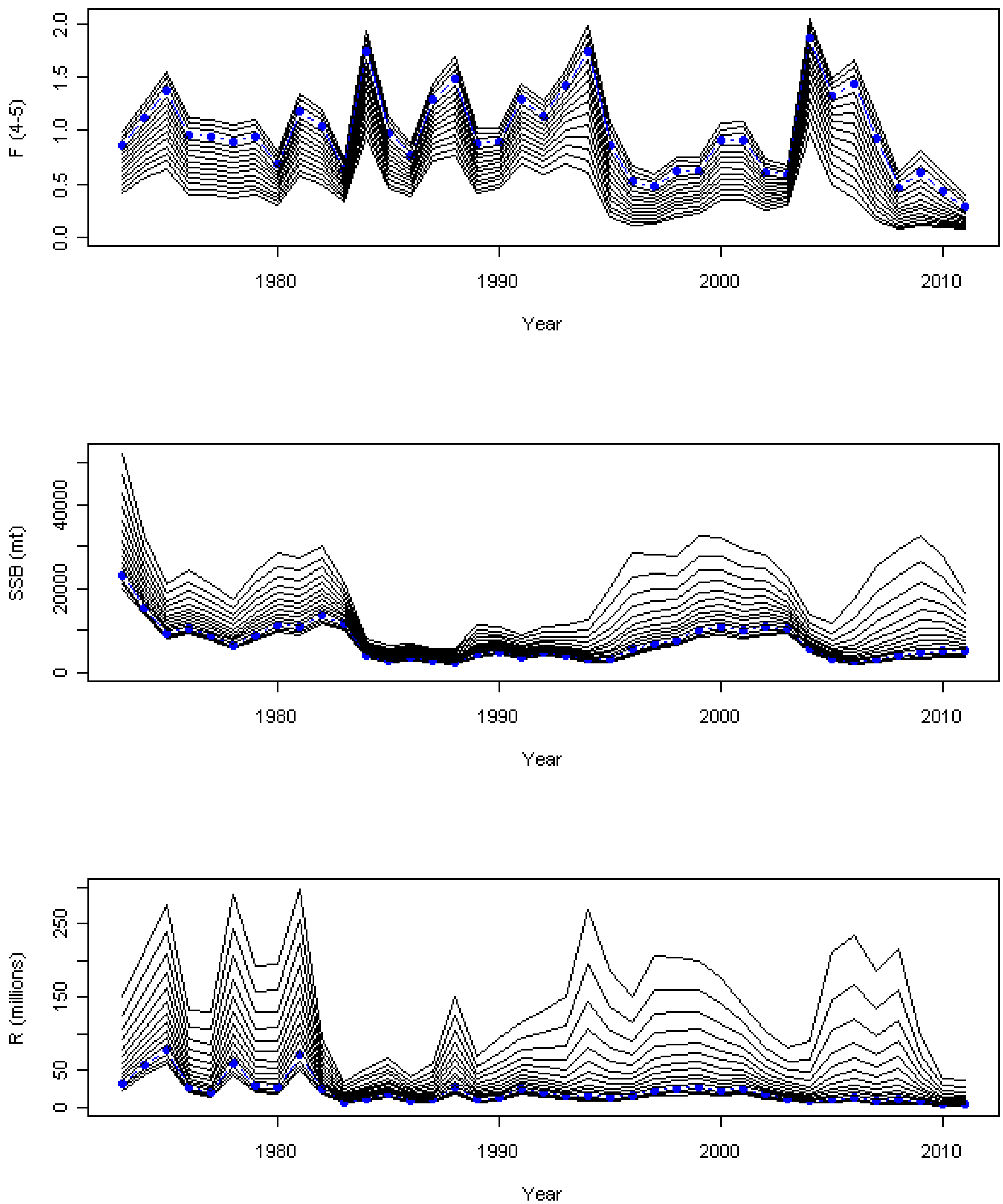


Figure 34. Fishing mortality rate (ages 4-5; top panel), spawning stock biomass (mt; middle panel), and age 1 recruitment (millions of fish; bottom panel) for natural mortality rates ranging from 0.1 to 0.8 in steps of 0.05. The results for M=0.2 are shown as blue dots.

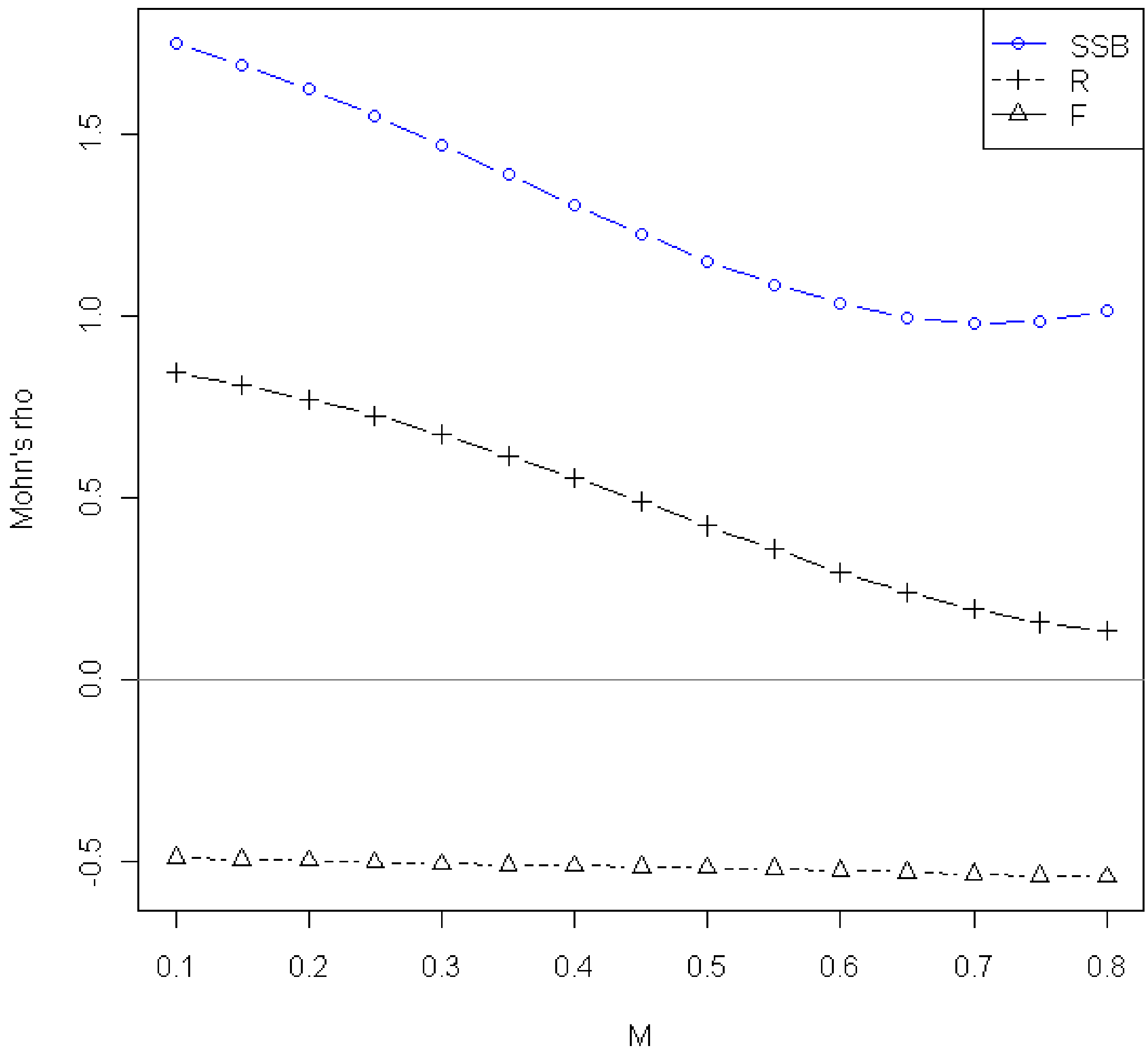


Figure 35. Mohn’s rho for spawning stock biomass, recruitment, and fishing mortality rate for a range of natural mortality values.

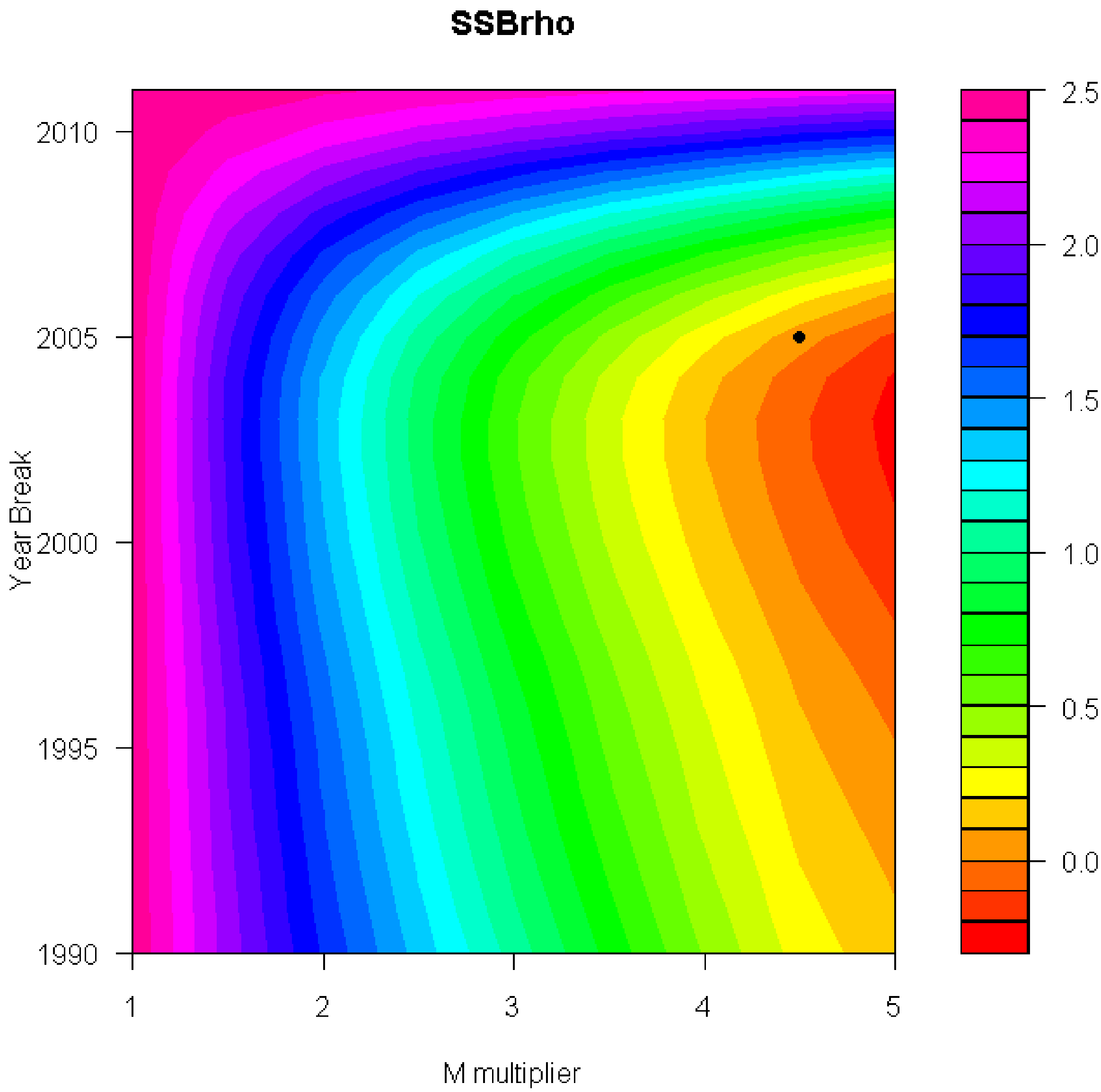


Figure 36. Mohn's rho for spawning stock biomass for combinations of year blocks (identified as the first year in the block) and natural mortality multiplier. The dot denotes the specific case examined.

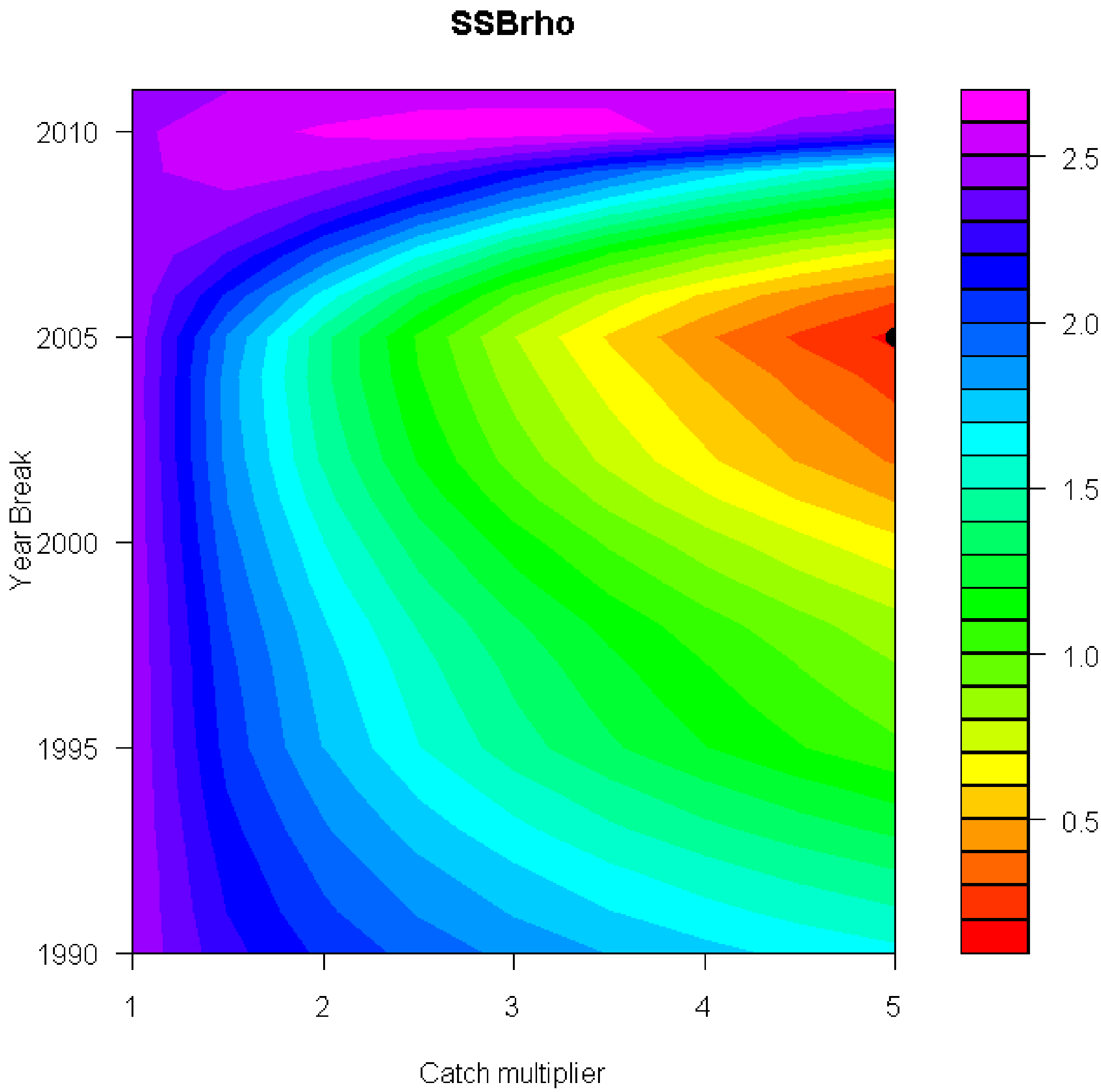


Figure 37. Mohn's rho for spawning stock biomass for combinations of year blocks (identified as the first year in the block) and catch multiplier. The dot denotes the specific case examined.

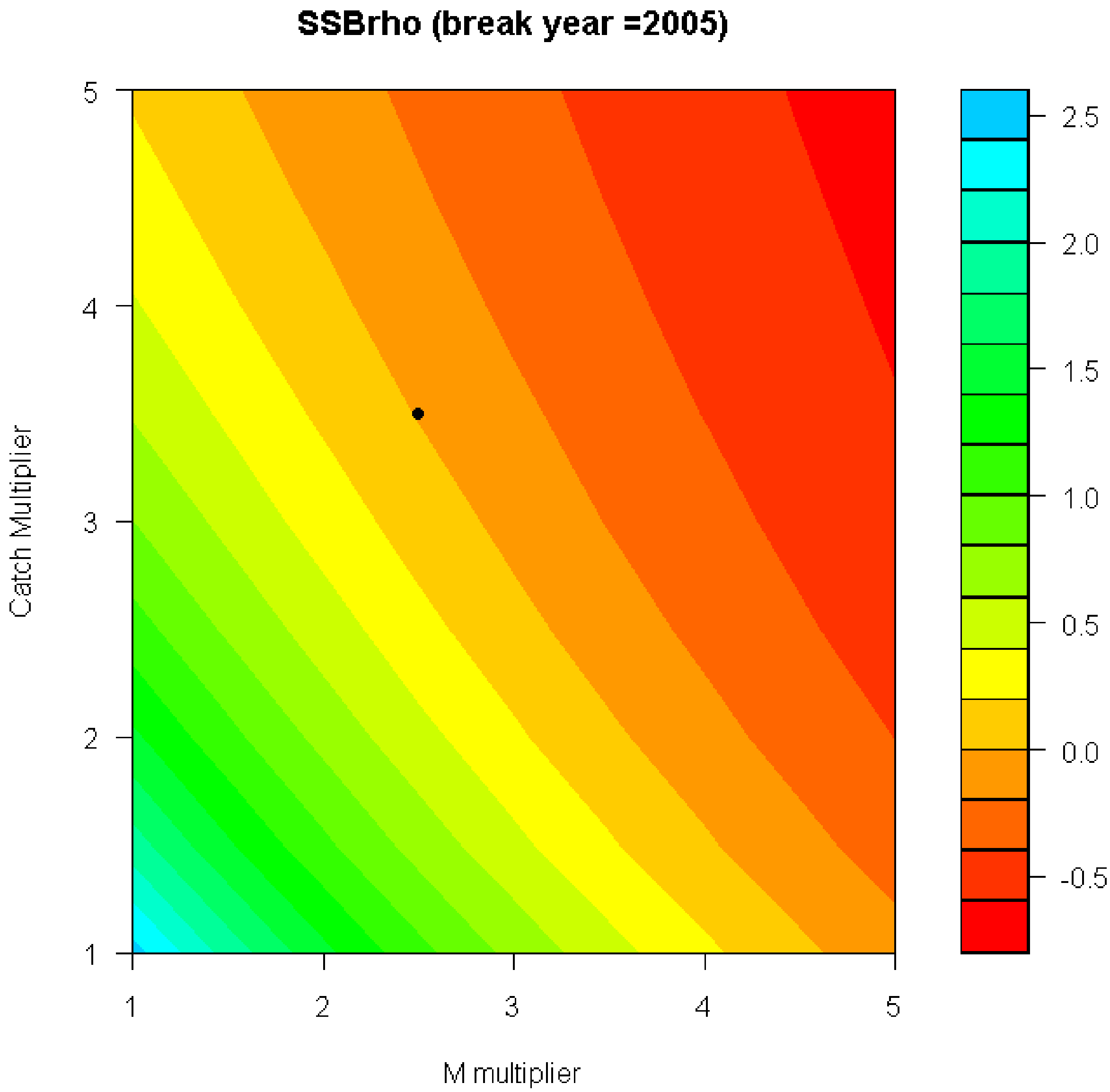


Figure 38. Mohn's rho for spawning stock biomass for combinations of natural mortality and catch multipliers applied to years 2005-2012. The dot denotes the specific case examined.

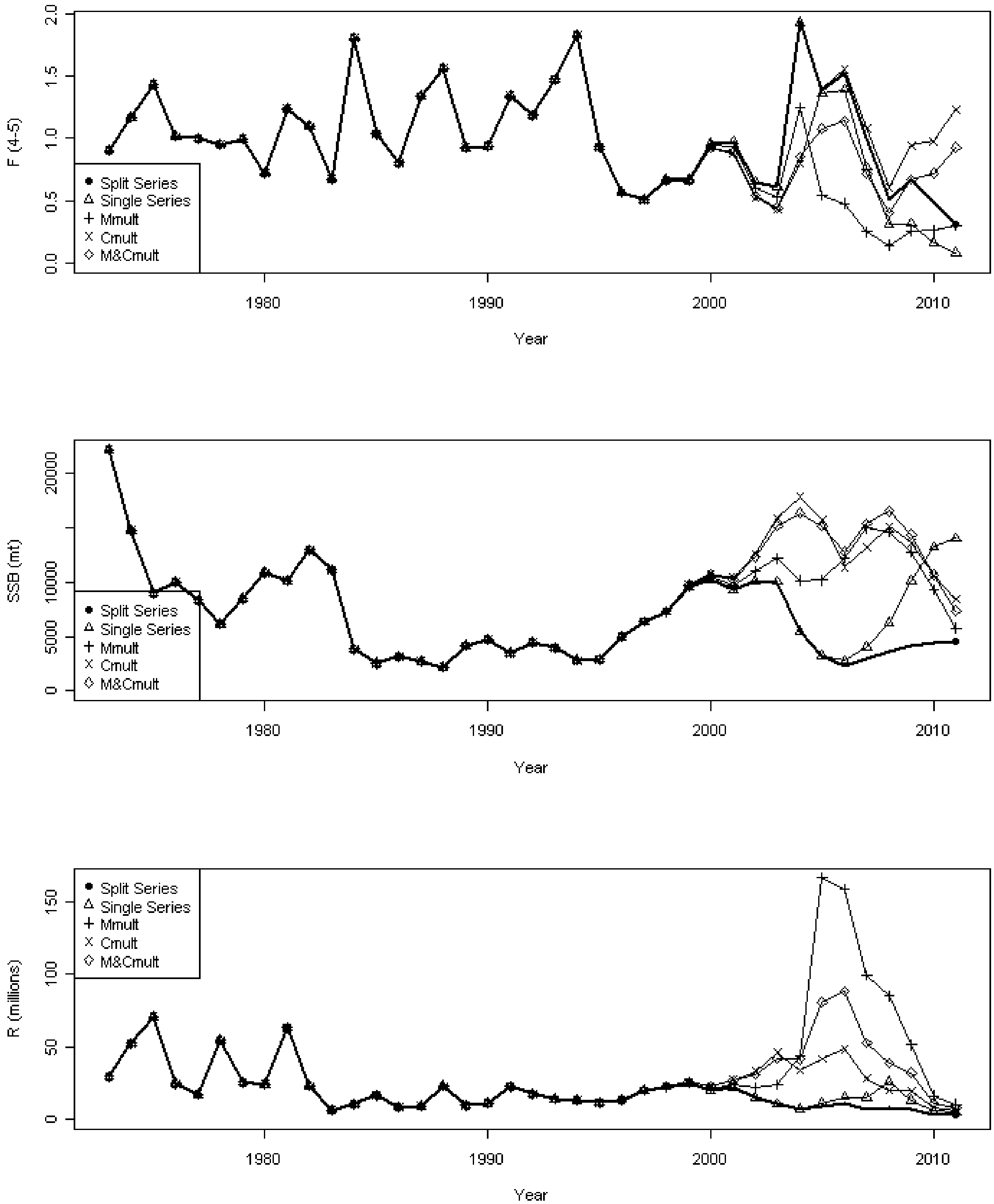


Figure 39a. Fishing mortality rate (ages 4-5; top panel), spawning stock biomass (mt; middle panel), and age 1 recruitment (millions of fish; bottom panel) for the Split Series VPA, Single Series VPA, and three alternative fixes with the break year in 2005 (Mmult=4.5, Cmult=5, M&Cmult=2.5&3.5, respectively).

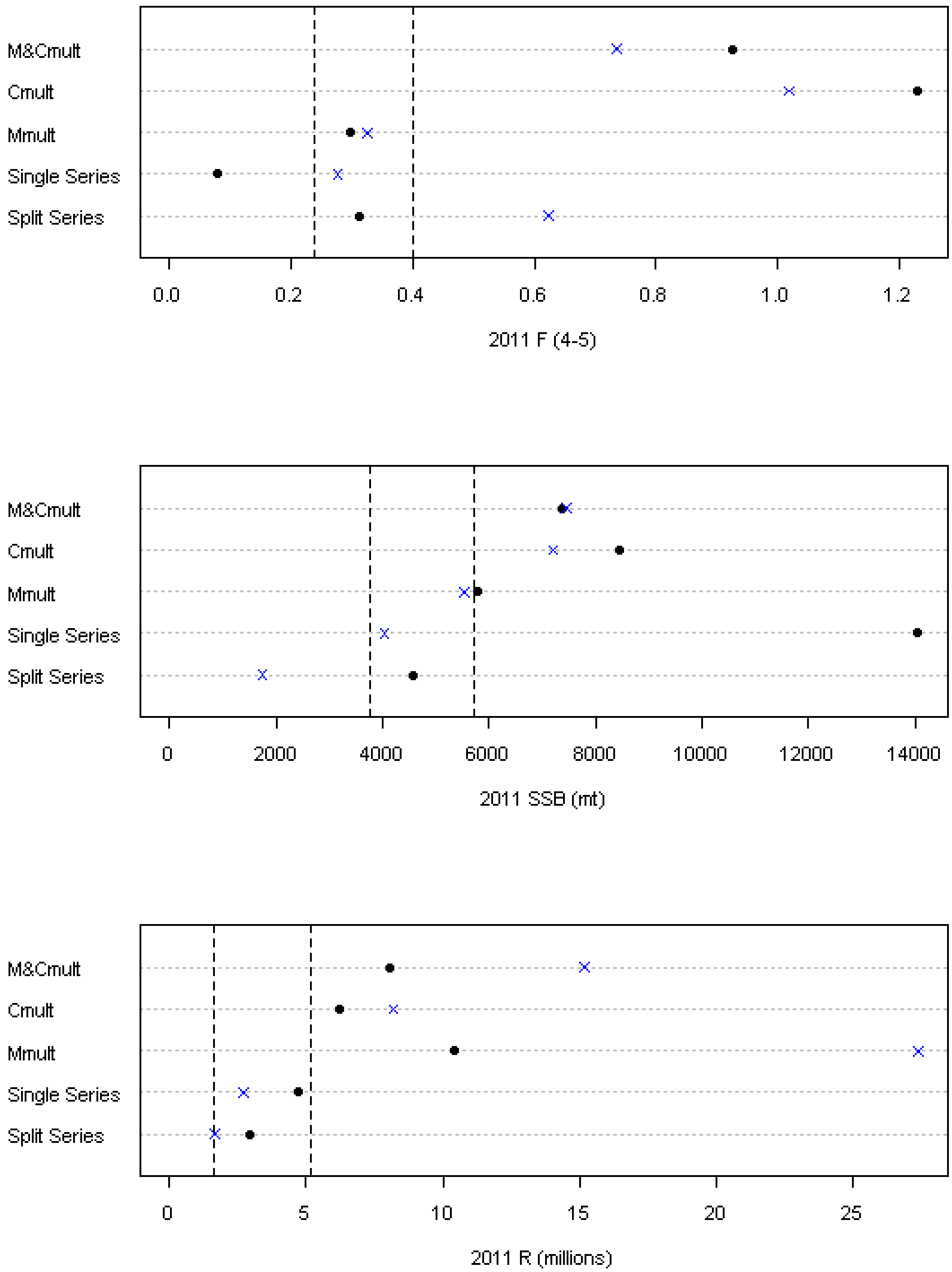


Figure 39b. Dotcharts of 2011 fishing mortality rate (ages 4-5; top panel), spawning stock biomass (mt; middle panel), and age 1 recruitment (millions of fish; bottom panel) for the same five runs identified in Figure 39a. The filled circles denote the point estimates while the blue crosses denote the rho adjusted values for each run. The vertical lines denote the 80% confidence interval for the Split Series VPA.

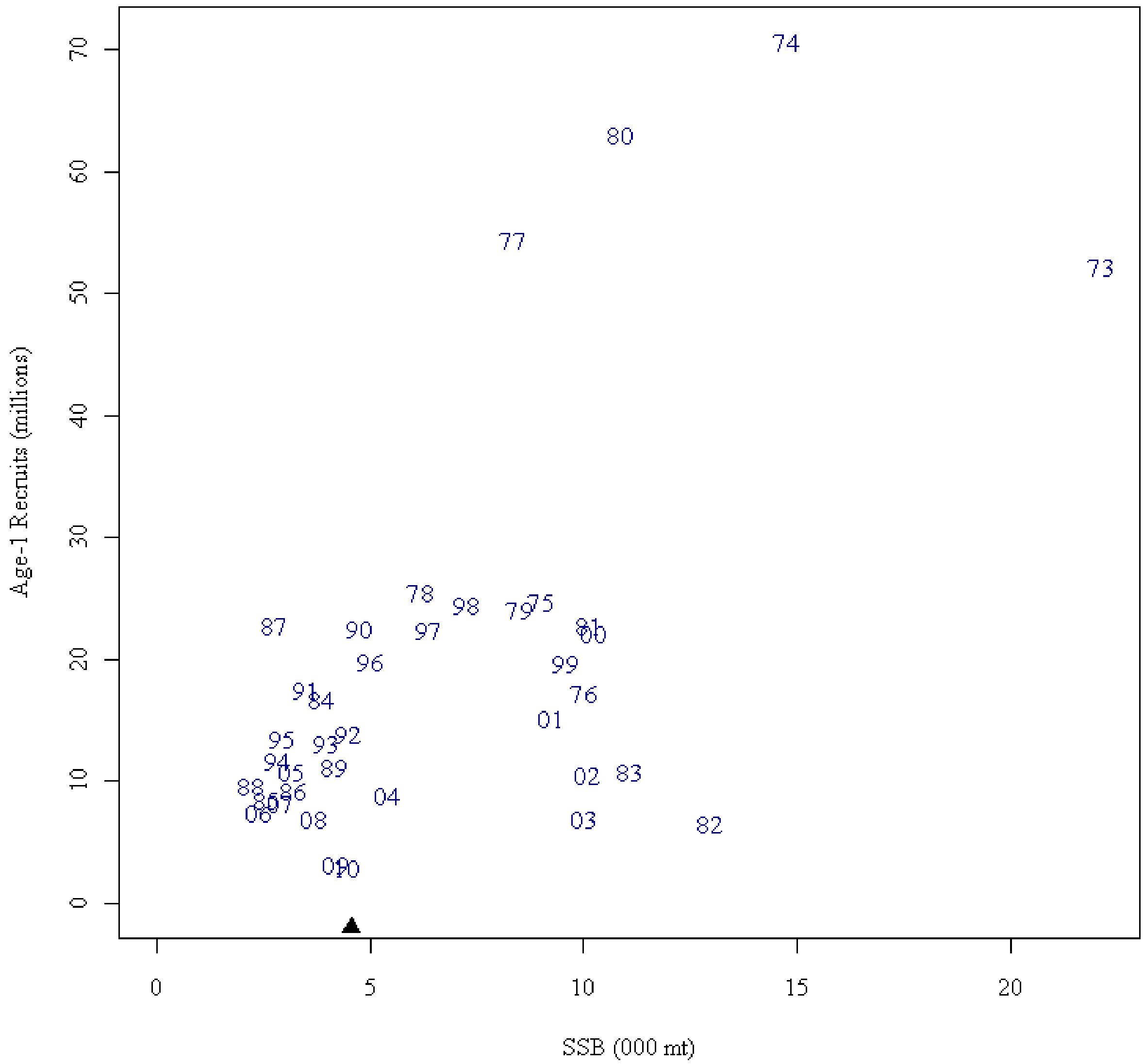


Figure 40a. Stock recruitment relationship from the Split Series VPA. The number denotes year-class (year of SSB and year when recruitment was age 0). The triangle denotes the spawning stock biomass in 2010.

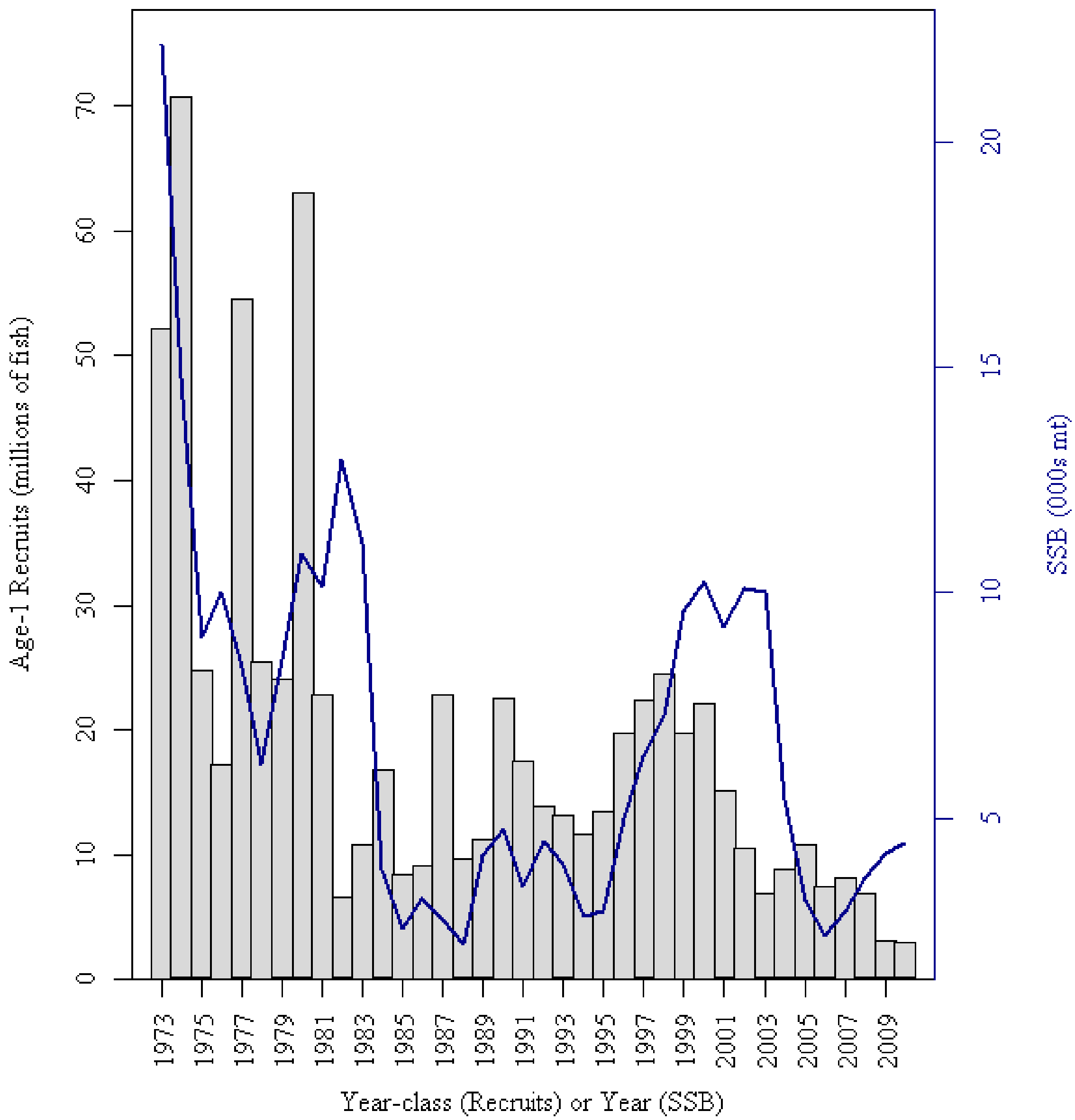


Figure 40b. Estimated age 1 recruitment in millions of fish (denoted by bars) and spawning stock biomass in thousands of metric tons (denoted by solid line) by year-class (recruitment) or year (SSB) from the Split Series VPA.

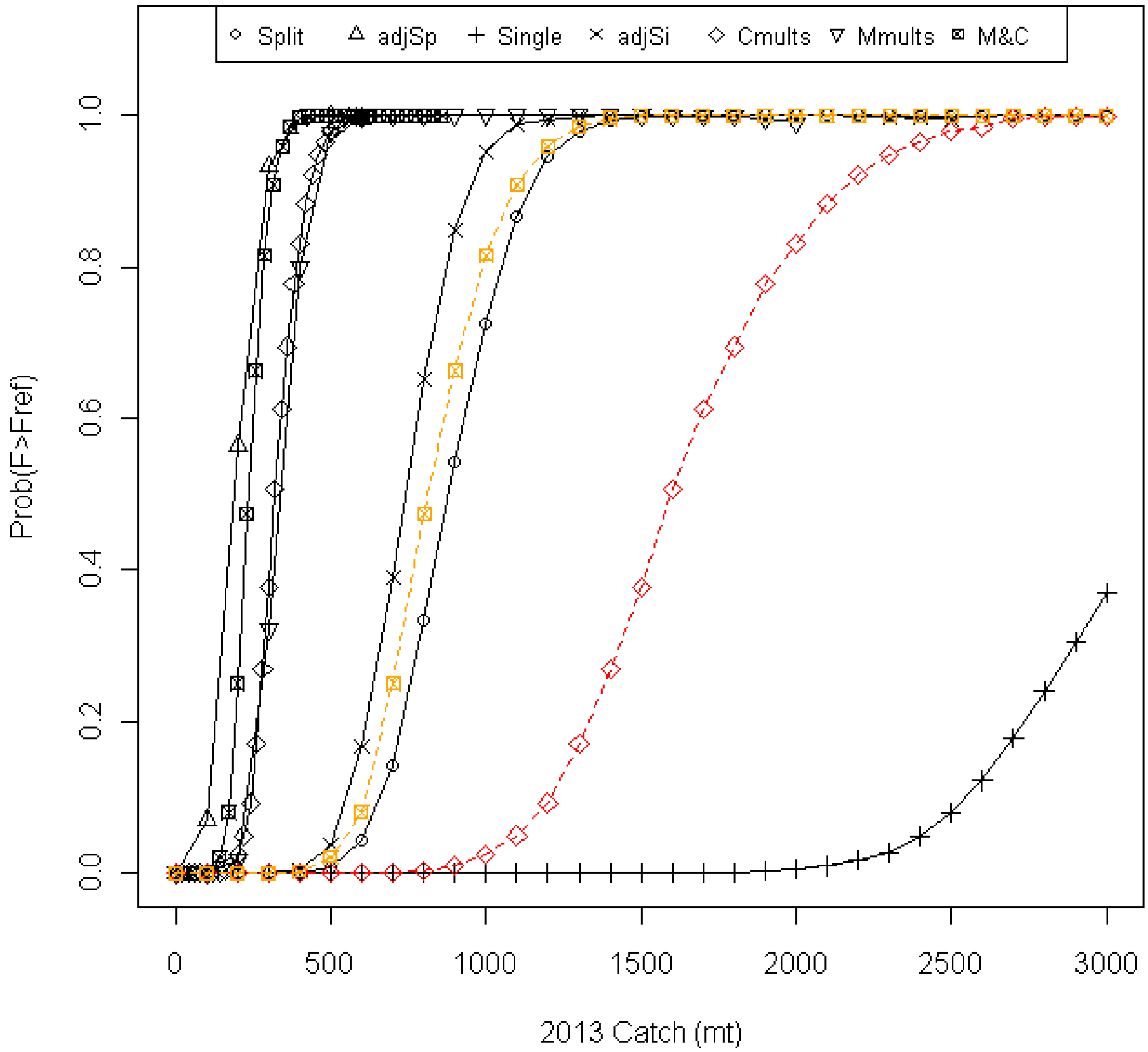


Figure 41a. Probability the fishing mortality rate in 2013 is greater than F_{ref}=0.25 for a range of catch values in 2013 and seven projection scenarios. The seven scenarios labels are defined in Table 20. Note the two catch multiplier runs have two lines shown. The colored and dashed lines are the actual projection results, while the black lines denote the catch that would be set as the quota (projected catch divided by the catch multiplier for that scenario).

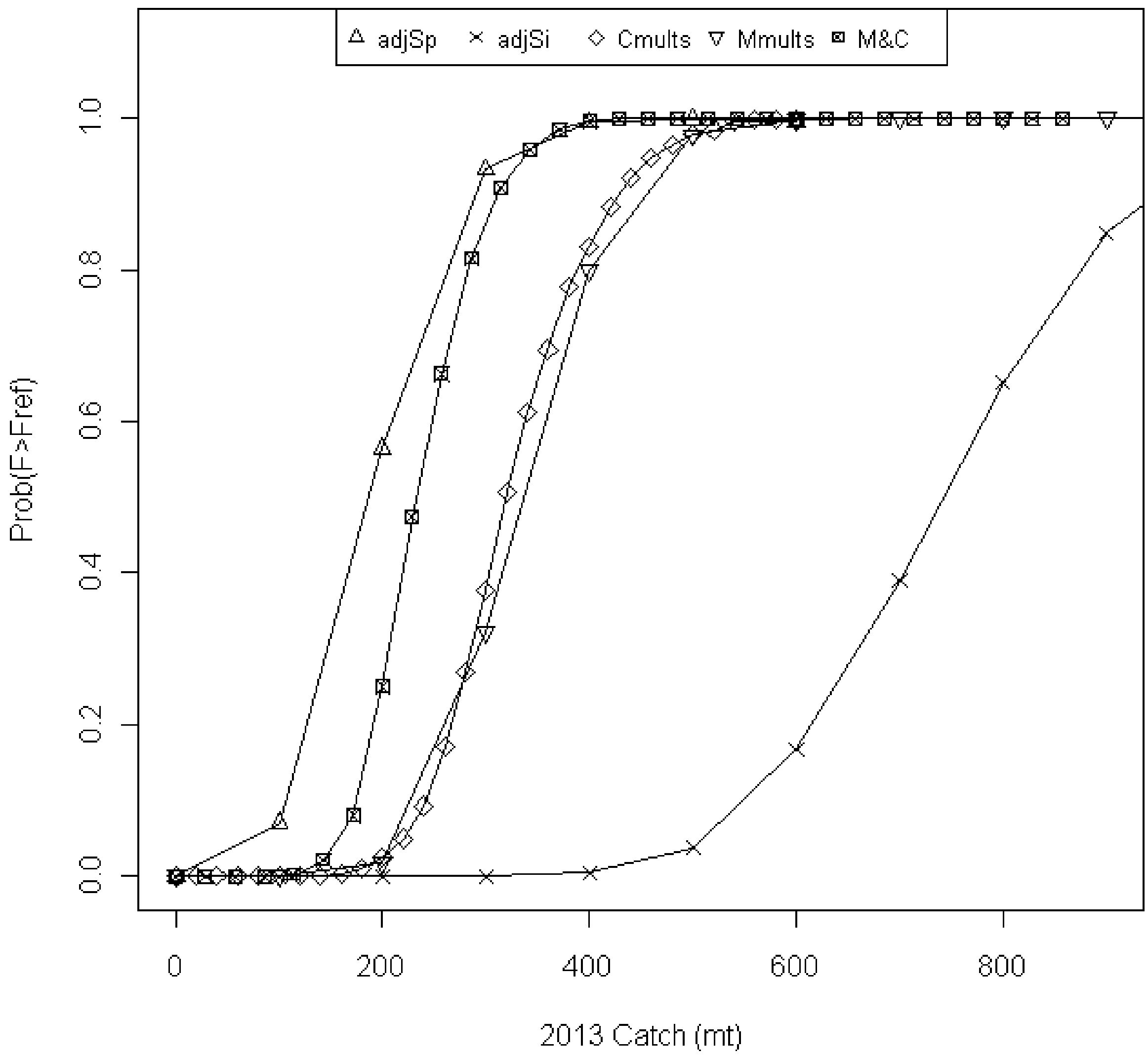


Figure 41b. Same as Figure 41a, except only five scenarios are shown and the 2013 catch values are limited to 900 mt or less.

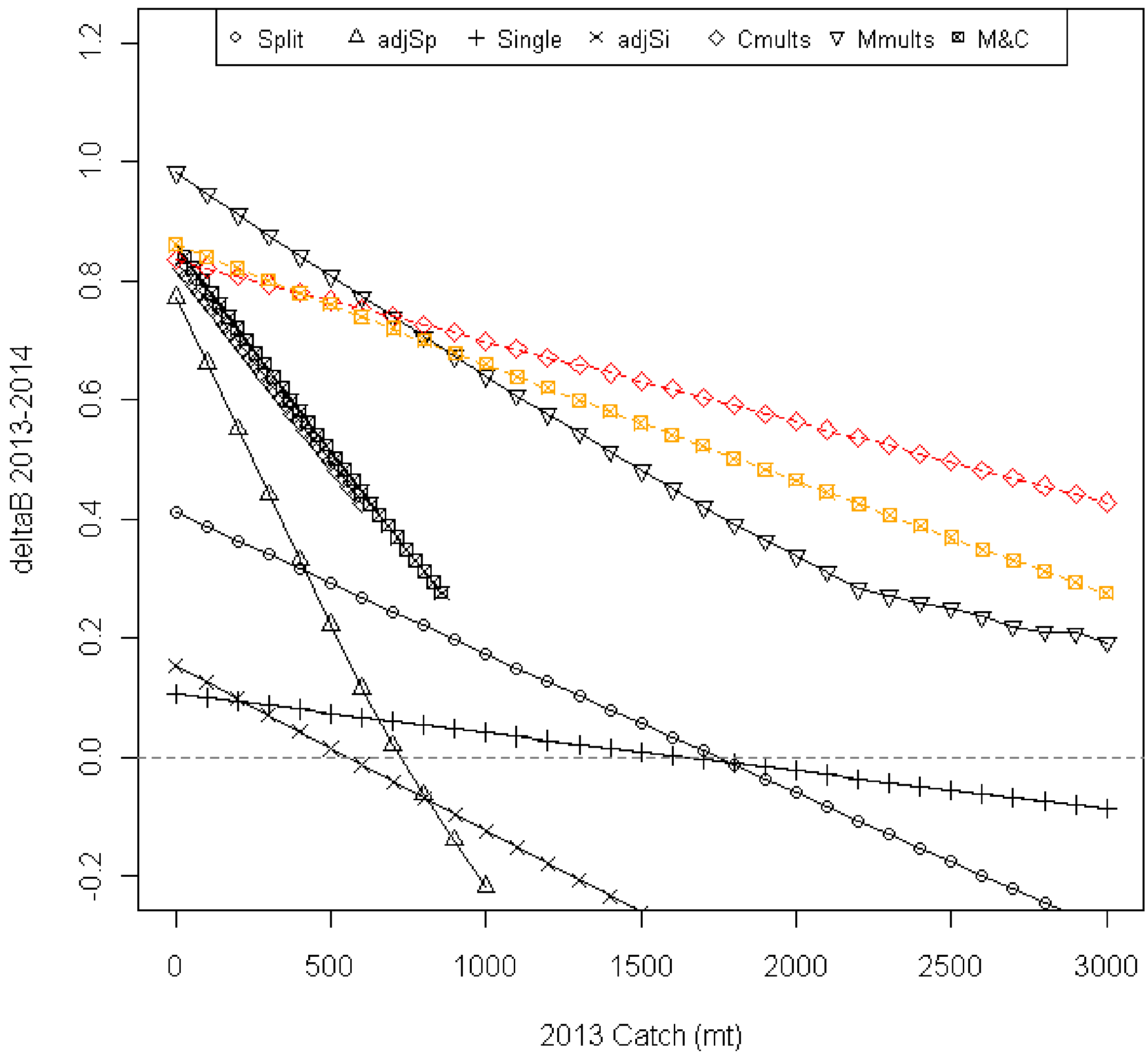


Figure 42a. Relative change in median adult Jan-1 biomass from 2013 to 2014 for a range of catch values in 2013 and seven projection scenarios. The seven scenarios labels are defined in Table 20. Note the two catch multiplier runs have two lines shown. The colored and dashed lines are the actual projection results, while the black lines denote the catch that would be set as the quota (projected catch divided by the catch multiplier for that scenario).

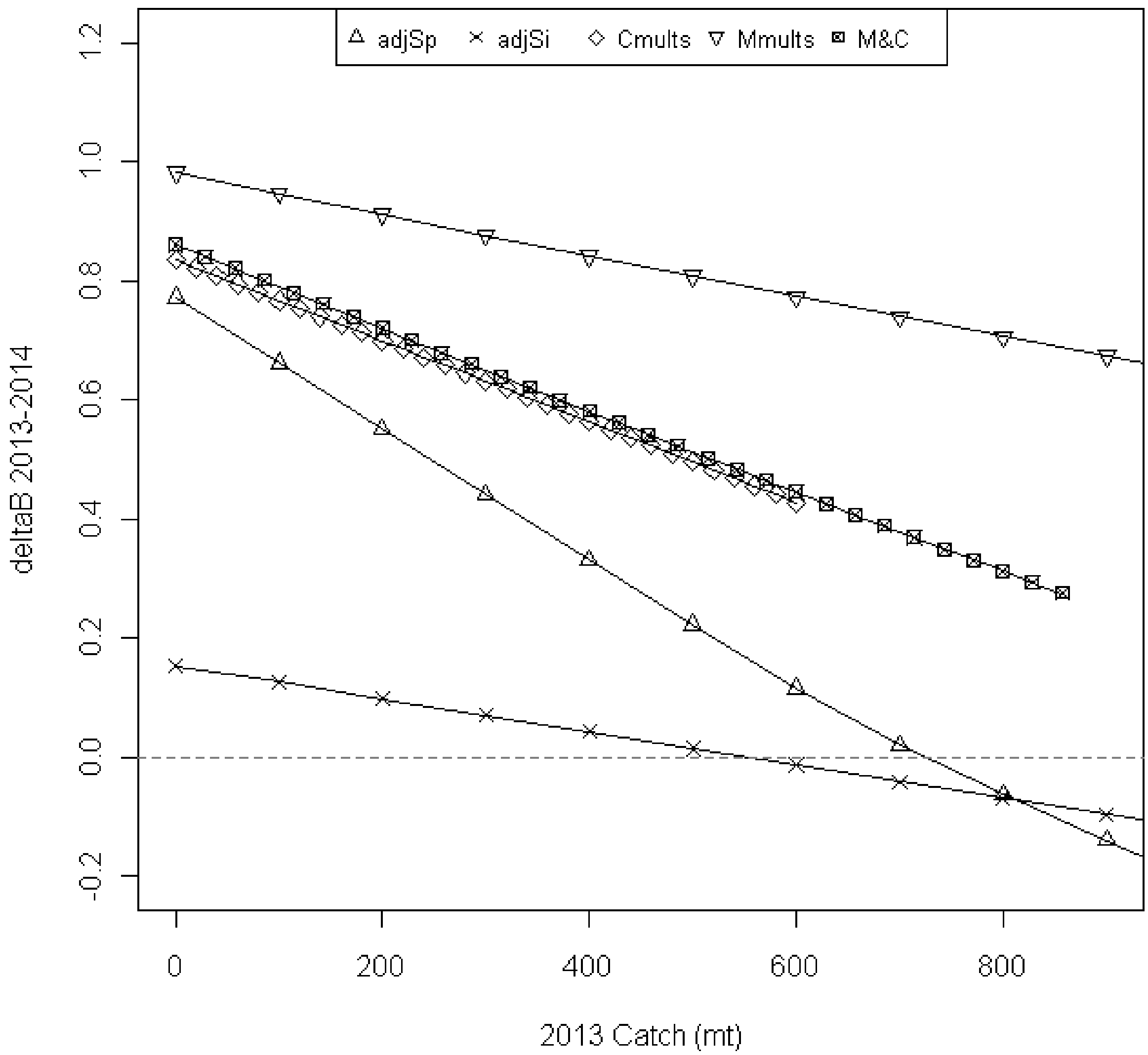


Figure 42b. Same as Figure 42a, except only five scenarios are shown and the 2013 catch values are limited to 900 mt or less.

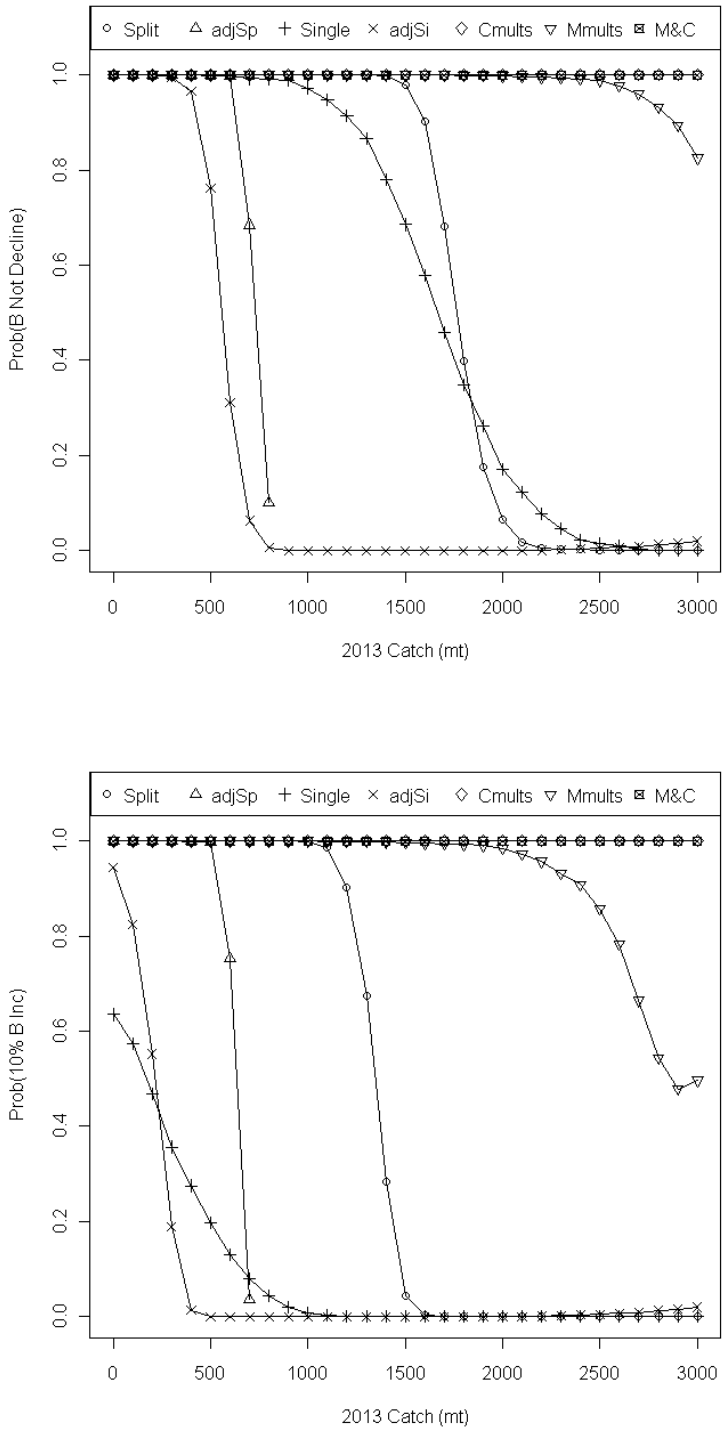


Figure 43. Probability adult Jan-1 biomass will not decline (top panel) or will increase by at least 10% (bottom panel) from 2013 to 2014 for a range of catch values in 2013 and seven projection scenarios. The seven scenarios labels are defined in Table 20.

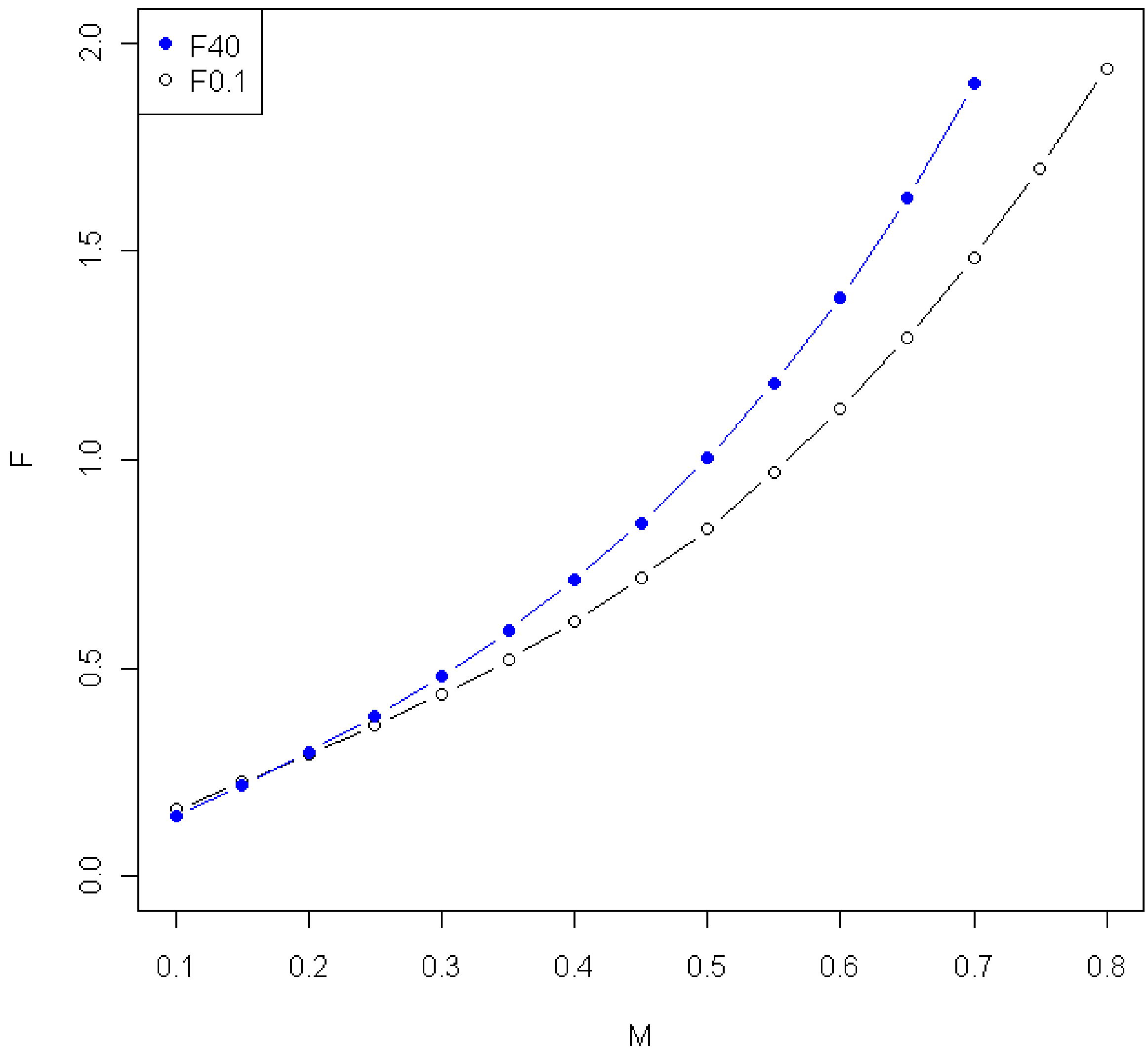


Figure 44. Calculated $F_{40\%MSP}$ and $F_{0.1}$ values for a range of natural mortality rates (M). These values depend on the natural mortality rate as well as the fishery characteristics estimated by the Split Series VPA formulation with these different natural mortality values.

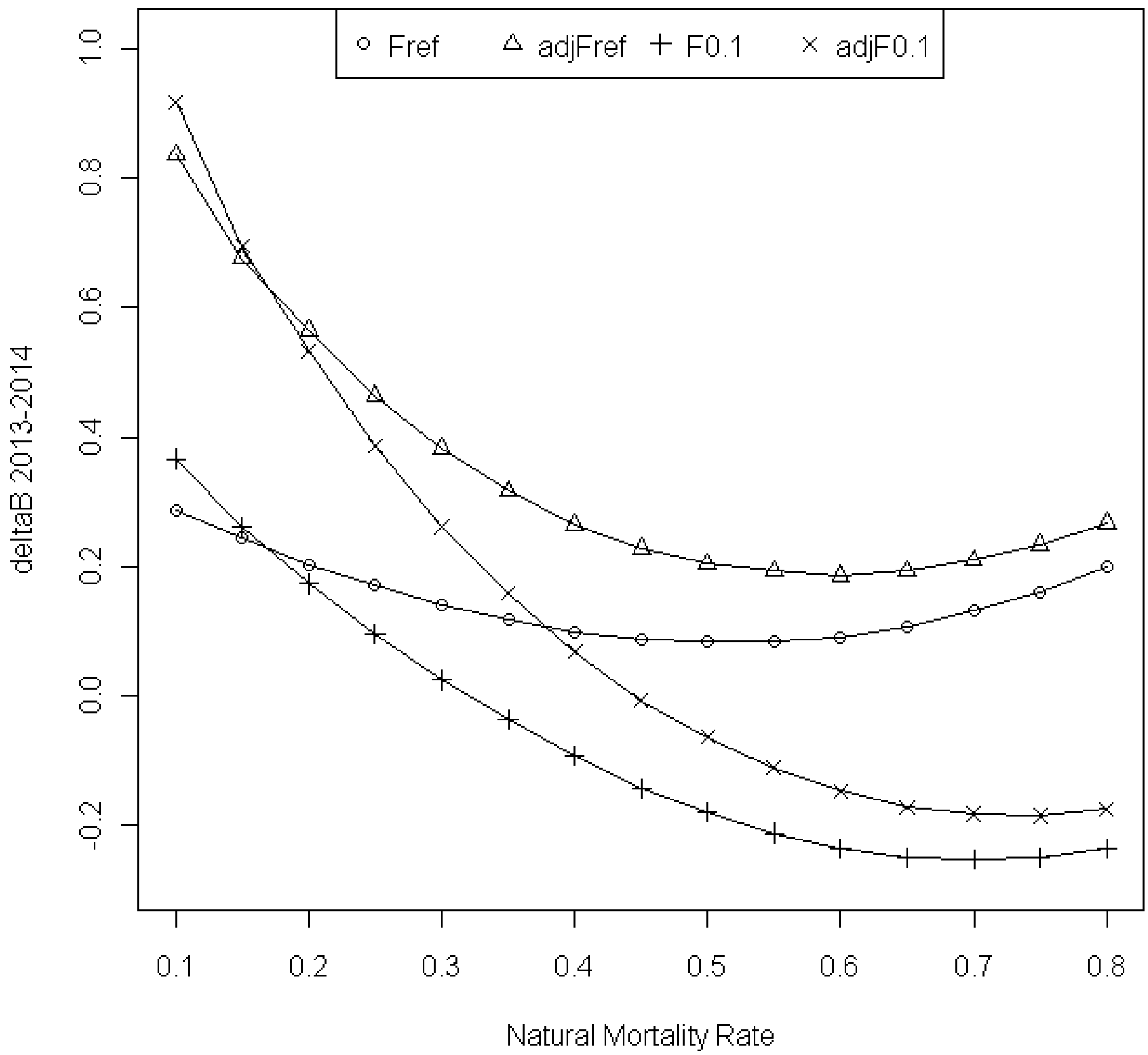


Figure 45. Relative change in median adult Jan-1 biomass from 2013 to 2014 for a range of natural mortality rates and four projection scenarios (described in Table 21).

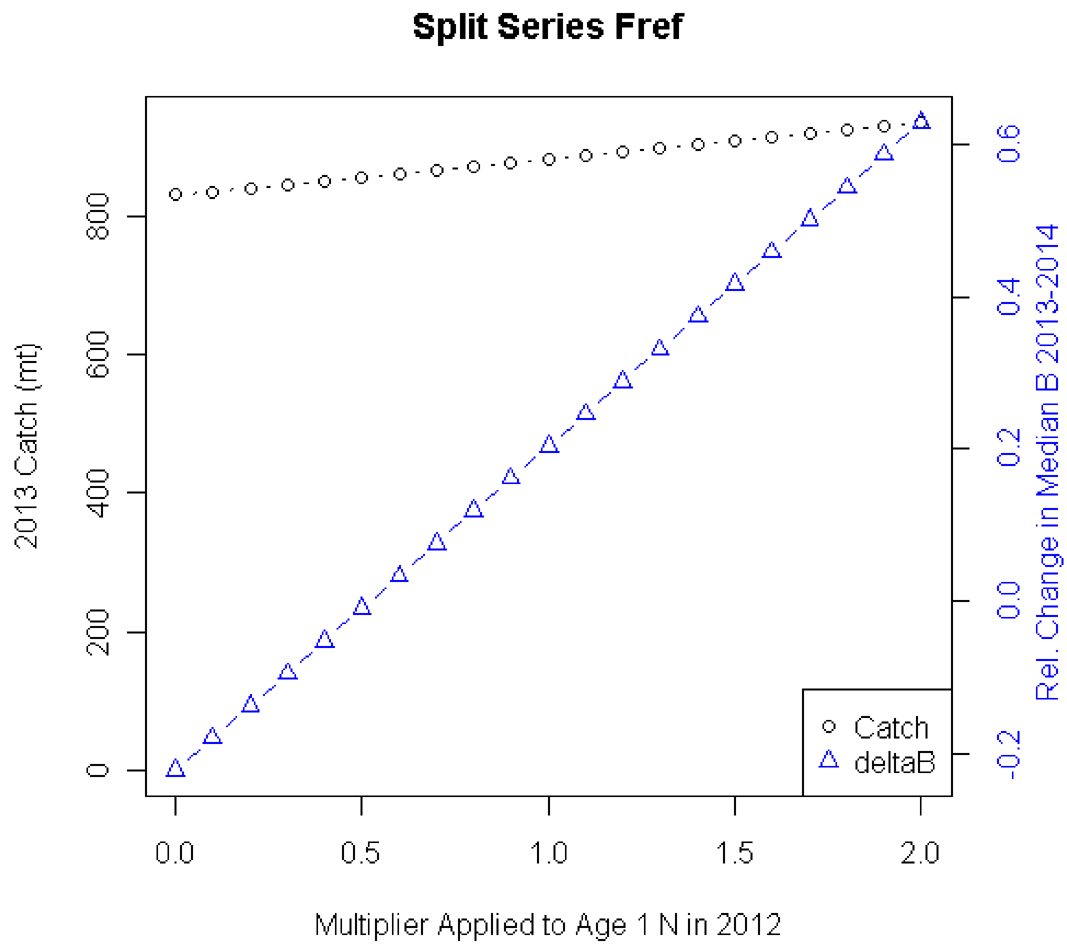


Figure 46. Median catch (mt) in 2013 and relative change in median adult Jan-1 biomass from 2013 to 2014 for a range of multipliers applied to the age 1 abundance in 2012 used in the Split Series projections.

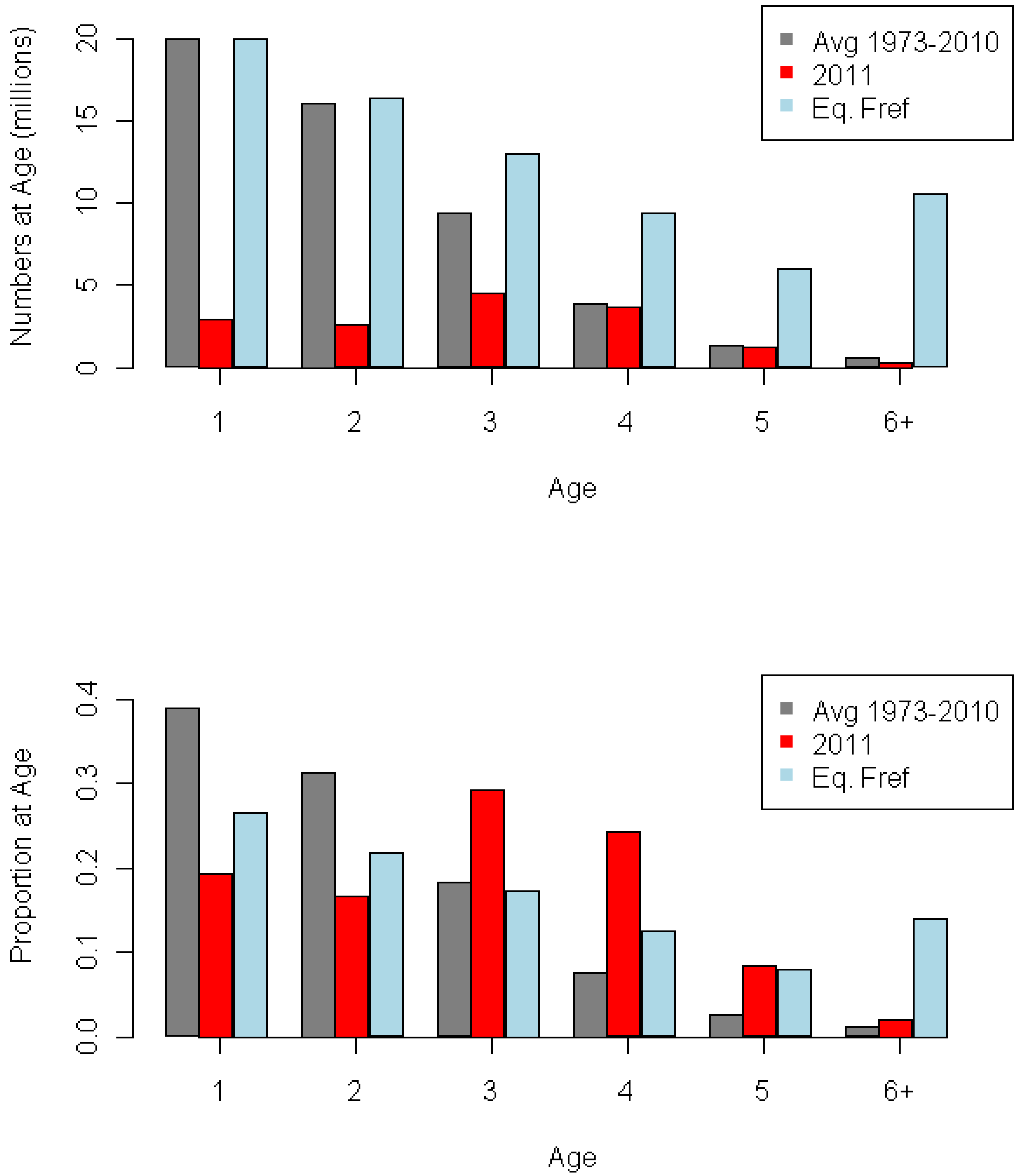


Figure 47. Comparison of the population abundance at age distributions for the Split Series VPA among the average of 1973-2010, 2011, and that expected when the population is fished in equilibrium at F_{ref}=0.25. The equilibrium numbers at age 1 in the top panel are set equal to the average for years 1973-2010. The bottom panel shows the proportions at age instead of numbers.

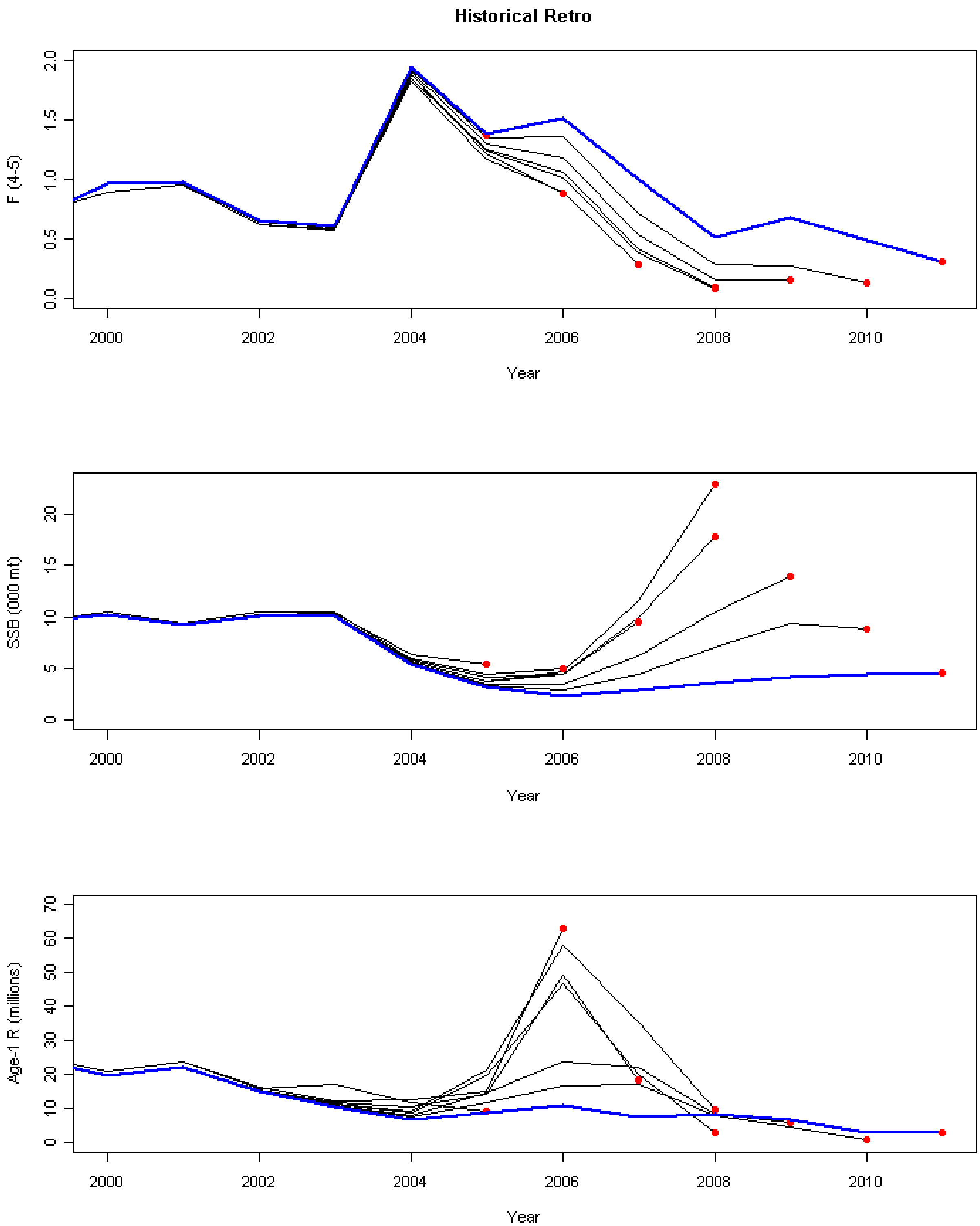


Figure 48. Historical retrospective analysis of Georges Bank yellowtail flounder assessments from this and the previous four TRAC VPAs for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel). Note there are two lines plotted for TRAC 2009 (terminal year 2008), the "Including" and "Excluding" formulations.

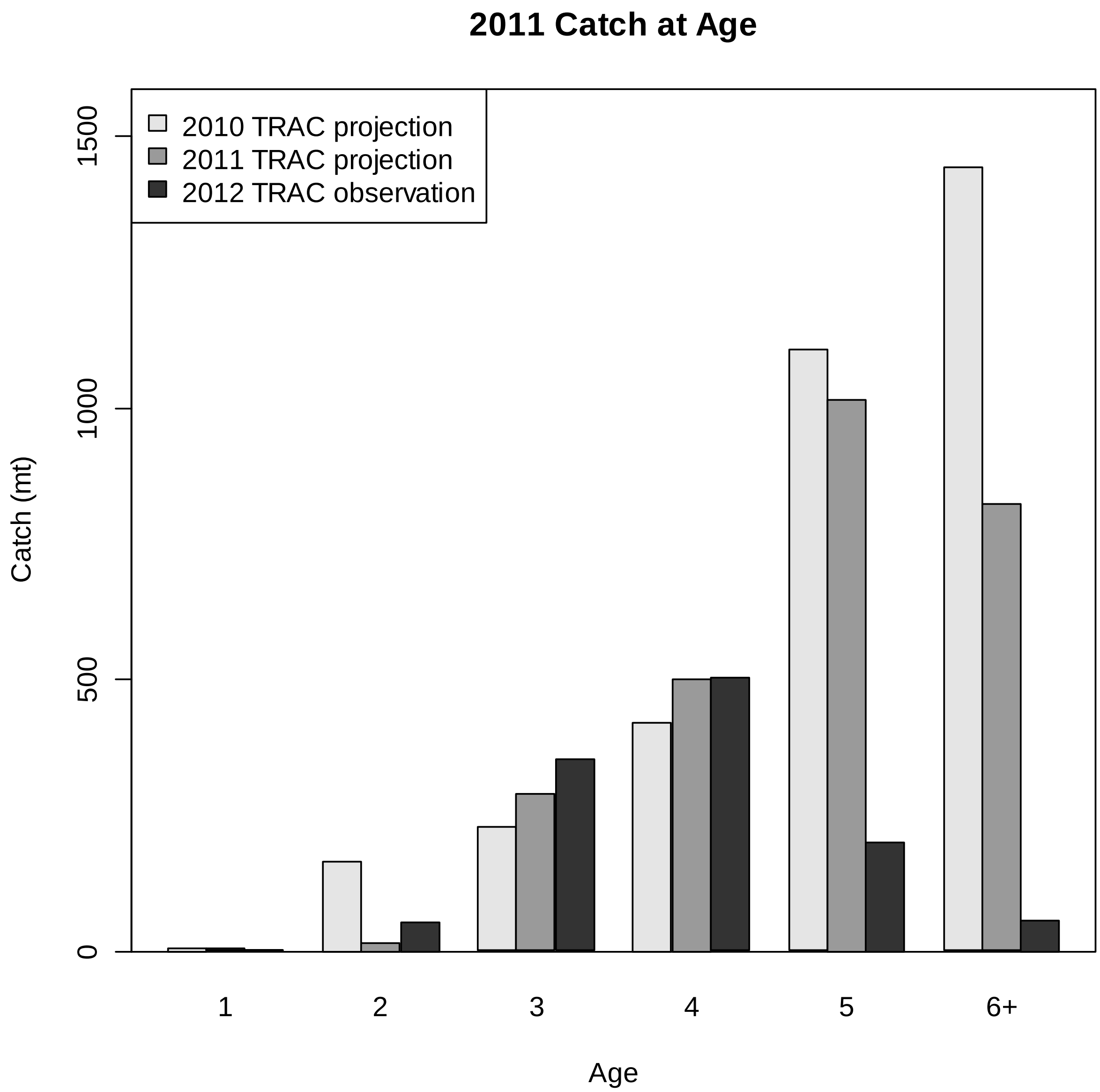


Figure 49. Catch (mt) at age in 2011 projected from the previous two TRAC assessments compared to the 2011 values observed in this assessment. Both projections are from the Split Series deterministic table in their respective assessment documents and do not include any retrospective adjustments.

APPENDIX

The table below was kindly provided by Tom Nies (NEFMC). It 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	6,815 mt	*F above 1.0* Now F = 1.94 Age 3+ biomass decreased 53% 04-05
2004	2005	4,000 mt	Deterministic; other models give higher catch but less than 2004 quota	6,000 mt	Moving towards Fref	3,851 mt	*F = 1.37* *Age 3+ biomass decreased 5% 05-06* Now F = 1.39 Age 3+ biomass decreased 39% 05-06

[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)	2,109 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 = 1.52 Age 3+ biomass did not change 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	1,662 mt About 75 percent probability of exceeding Fref	*F = 0.29* *Age 3+ biomass increased 211% 07-08* Now F=1.00 Age 3+ biomass increased 36% 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	1,504 mt No risk plot; expected less than median risk of exceeding Fref	*F~0.09* *Age 3+ biomass increased between 35%-52%* Now F=0.51 Age 3+ biomass increased 16% 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	1,806 mt No risk of exceeding Fref	*F=0.15* *Age 3+ biomass increased 11%* Now F=0.67 Age 3+ biomass increased 6% 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* Now F=0.49 Age 3+ biomass increased 9% 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	1,169 mt No risk of exceeding Fref About 15% increase in biomass expected	*F=0.31* *Age 3+ biomass decreased 5% 11-12*
2011	2012	(1) 900-1,400 mt	(1) trade-off between risk of overfishing and change in biomass from three projections	1,150 mt			