Northeast Fisheries Science Center Reference Document 02-16

# Assessment of 20 Northeast Groundfish Stocks through 2001

*A Report of the Groundfish Assessment Review Meeting (GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8-11, 2002*

October 2002

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02-12 **Proceedings of the Fifth Meeting of the Transboundary Resources Assessment Committee (TRAC), Woods Hole, Massachusetts, February 5-8, 2002.** By R.N. O'Boyle and W.J. Overholtz, TRAC co-chairmen. [A report of Transboundary Resources Assessment Committee Meeting No. 5]. September 2002.

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02-14 **Report of the 35th Northeast Regional Stock Assessment Workshop (35th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments.** [By Northeast Regional Stock Assessment Workshop No. 35.] September 2002.

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**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
**National Marine Fisheries Service**
**Northeast Region**
**Northeast Fisheries Science Center**
**Woods Hole, Massachusetts**

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## Executive Summary

The Groundfish Assessment Review Meeting (GARM) is a regional peer review process developed this year to provide assessment updates for the 20 stocks managed under the Northeast Multispecies Fishery Management Plan (Multispecies FMP). The meeting occurred during October 8-11, 2002, in Woods Hole, Massachusetts. The terms of reference were to:

(a) provide updated catch information (landings and discards, where appropriate) for the stocks to be assessed. Catch-at-age data (based on port sampling) will be estimated, where applicable,

(b) provide updated research vessel survey indices (through spring 2002) for all appropriate survey series, including NMFS spring and autumn series, Canadian series, and state surveys,

(c) estimate 2001 fishing mortality rates (or appropriate proxies) for all 20 stocks, and provide estimates of 2001 stock sizes and measures of uncertainty,

(d) evaluate stock status relative to applicable biological reference points ($F_{MSY}$ and $B_{MSY}$),

(e) provide updated estimates of F-Rebuild (the fishing mortality rate required to rebuild biomasses to $B_{MSY}$ by 2009) for all applicable stocks,

(f) evaluate and comment on the potential sensitivity of assessment results to trawl warp marking discrepancies that occurred in bottom trawl surveys conducted between winter 2000 and spring 2002.

Initial stock assessments were developed by the Northern and Southern Demersal Working Groups of the Stock Assessment Workshop (SAW), and the ASMFC Winter Flounder Technical Committee. These working groups and the Technical Committee met at various times before the GARM meeting to develop draft assessment documents. Additionally, work related to the trawl warp offset issue was coordinated through the SAW Assessment Methods Working Group.

Most stock assessments reviewed at the GARM were routine updates of assessments previously reviewed in the SAW or elsewhere. However, the Gulf of Maine winter flounder assessment was newly developed (by the ASMFC Technical Committee), and is scheduled to be peer reviewed at SAW 36 (December 2002). Accordingly, the details of the analytical stock assessment modeling are not incorporated herein, pending that "benchmark" review. The results are, however, summarized (Table 1; Figure 1), and input data are presented and evaluated.

The GARM meeting incorporated peer reviews by both regional stock assessment scientists (both NMFS and non-NMFS people) and external experts. The Center for Independent Experts (CIE, University of Miami) provided two individuals for the meeting. The roles of the CIE experts were to comment on analyses presented at the GARM, and to provide written critiques; attached as appendices to this report.

Stock Assessment Results

Results of the stock assessment updates are summarized as fishing mortality rates and biomasses in 2001, relative to management reference points (Table 1; Figure 1). Of the 19 stocks for which 2001 fishing mortality (or its proxy) can be estimated, 10 were fished below F-MSY in 2001, and 9 above. Additionally, the biomass of eight of the stocks was at or above ½ B-MSY, while 12 stocks were below their biomass thresholds. Stock biomasses have improved in 19 of the 20 stocks since 1995 (the exception being Mid-Atlantic yellowtail flounder), with a median percent increase in biomass for all stocks of 177% (range: -33 to 2430 percent). Landings of the complex of 20 groundfish stocks have increased by 40% since 1995, primarily driven by increases from four Georges Bank stocks (haddock, yellowtail flounder, cod and winter flounder). Fishing mortality (F) rates declined for 15 of 19 stocks between 1994 and 2001. In the case of Georges Bank yellowtail flounder, F has declined by about 90% since the mid-1990s. Numerous other stocks have experienced reductions in F of 20-50%, including Georges Bank and Gulf of Maine cod, Georges Bank haddock, witch flounder and American plaice. For several of the stocks where harvest rates are measured by landings to survey biomass ratios (exploitation index methods), relative Fs have been reduced by 50% or more (e.g., Gulf of Maine haddock, pollock and windowpane flounder). The four stocks showing increases in F since 1994 were Cape Cod and Mid-Atlantic yellowtail flounder, white hake and Southern New England/Mid-Atlantic winter flounder.

Two stocks continue to have extremely high fishing mortality rates (Mid-Atlantic yellowtail flounder and Cape Cod yellowtail flounder). In the former case, assessment scientists will present analyses to SARC 36 recommending that the Mid-Atlantic and Southern New England yellowtail resources be combined. The case of Cape Cod yellowtail flounder remains enigmatic, in that the apparent mortality rates on the stock remain exceptionally high despite the reductions in F seen in co-occurring stocks (e.g., Gulf of Maine cod, and winter flounder). The GARM recommended additional biological studies, including tagging, to better understand the relationships between Cape Cod yellowtail and adjacent stocks of the same species.

For the remaining seven stocks where fishing mortality exceeded F-MSY, the average reduction necessary to reach that level was 52% (range: 37% for Southern New England/Mid-Atlantic winter flounder to 64% for witch flounder). Fishing mortality rates on the two cod stocks were below those projected based on 2000 assessment results Maximum fishing mortality rates necessary to rebuild the stocks to B-MSY by the target dates (2009 for most stocks) were computed using medium-term projection methodologies. The percent reductions in F necessary to achieve B-MSY by the target dates varied by stock and were primarily dictated by the strength of incoming recruitment. For Gulf of Maine cod, F in 2001 declined, but F-rebuild also declined despite the presence of a strong 1998 year class, because of below average recruitment in 1999 and a poor 2000 year class.

Short-term projections of target TACs for the 2003-2004 fishing year and medium-term projections for calculating F-Rebuilds assumed that F in 2002 (calendar year) would be 85% of that in 2001, based on assumptions provided by the Multispecies Plan Development Team (PDT).

Evidence for Interventions in Trawl Survey Data Due to Warp Offsets

The GARM reviewed the results of a series of 10 different studies to evaluate evidence for an intervention in the NMFS trawl survey data associated with the use of mis-calibrated trawl warps (the wire ropes attaching the trawl doors to the vessel). There were eight affected surveys (winter 2000, 2001 and 2002; spring 2000, 2001 and 2002; and fall 2000 and 2001). Information collected from dockside warp measurements indicated that the warp mis-calibration was related to the initial biased marking of the 50 meter intervals on one warp and was not due to progressive wire stretch. Therefore, the degree of intervention was thought to be approximately equal in all surveys since winter 2000.

Information on the potential effects of the warp offset on trawl survey performance evaluated by the GARM included studies of rates of gear damage over time, calculations of trawl geometry as a function of the warp offsets, by depth; patterns in mean/variance relationships in trawl survey catch data by stock, and depth-at-capture information from pre- and post-warp misaligned cruises. Additionally, the GARM evaluated trends (directional changes from year-to-year) in abundance measures before and after the warp mis-marking. The results from side-by-side trawling experiments conducted by the *Albatross* and *Delaware* to estimate their relative fishing power, conducted before and after the warp mis-marking on the *Albatross* were also considered. Standardized catch-rates from surveys conducted with mismatched warps were compared to survey CPUEs from surveys with comparable spatial and temporal coverage, and unaffected by the problem (e.g., Canadian trawl surveys and USA sea scallop surveys). The GARM also examined evidence for differences in length distributions from survey catches pre- and post warp offset by evaluating the relative size composition in Canadian and USA spring surveys in overlapping survey areas (e.g. eastern Georges Bank). Monkfish size composition data collected on industry-based surveys and the winter 2001 *Albatross* survey were also compared, as were length compositions with data obtained in side-by-side trawling of the *Albatross* and *Delaware* in spring 2002.

The GARM examined information on wing-spread and headrope height measurements from experimental warp offsets as presented at the Trawl Warp Workshop conducted during October 2-3, 2002. These data were collected during the September 25-27 warp experiment. Additionally, the GARM examined video information collected in that same experiment.

It was postulated by gear experts at the Trawl Warp Workshop that the warp offset would induce changes in gear efficiency resulting from the “long” trawl wing being more prone to damage (as it would be potentially more susceptible to hang-ups). The GARM found no significant change in the frequency of trawl tows experiencing minor or major damage associated with the warp offset as compared to previous surveys.

It was postulated at the Trawl Warp Workshop that one effect of misaligned warps might be the differential loss of large fish in survey catches. Based on examinations of size distributions of cod and haddock, not only was there little difference in the proportions of large fish but there was little apparent difference in the entire size frequency, by survey series, of these stocks pre- and post-warp offset in comparisons of USA and Canadian survey series in areas they overlap (northeast Georges Bank). The small relative differences in USA mean length distributions of cod and haddock for the three years before and three years after the warp offset were similar to the differences in the Canadian series in pre- and post-warp periods. Differences in the size composition of large monkfish between industry and *Albatross* winter surveys were minimal. Size compositions from *Albatross*-*Delaware* paired towing experiments in spring 2002 also indicated no loss of large fish due to the *Albatross* warp mis-marking.

Trawl mensuration data indicate that wing spread and head rope height did not vary appreciably with offsets that occurred in depths where groundfish typically occur (warp offset up to about 9 feet), and the net remained open with warp offsets up to 18 feet. Consistent trawl performance within this range of warp offsets is supported by the absence of detectible effects as indicated by the other information reported herein. The GARM noted that catching efficiency might be related to other factors such as bottom contact by the foot rope and vibrations associated with the offset gear. Video information on the former was equivocal (as concluded at the Trawl Warp Workshop where some participants thought the foot rope contact changed with offsets while others did not). Measurements on vibrations and pressure waves in relation to warp offsets were not made.

Calculations based on geometry of the trawl in the offset condition (a worst-case scenario) and the postulated increase in the potential problem in relation to species catches-at-depth indicate that reductions on the order of 50% in trawl survey catches are implausible.

It was postulated by the GARM that if there were a trawl warp effect, more variable catches might result from a misaligned net, influencing the relationship between the variance and the mean. Empirical plots of catch data indicated no apparent differences in the variance compared to mean relationships for the species examined, and plots of the coefficient of variation (standard deviation divided by the mean) of catches in numbers by survey stratum over time showed no obvious differences pre- and post warp offsets.

Since the warp offset increased proportionally with depth, it was postulated that if the catch efficiency of the trawl decreased accordingly, then this would result in a shallower apparent depth of capture for the deeper-dwelling species in the post-offset period as compared with the pre-offset surveys. There were no detectable differences in the catch-weighted depth of capture of any species examined relative to the warp offset, however (Figure 2).

There was no evidence for a trend in the direction of abundance index changes associated with the warp offset, when comparing pairs of adjacent years. For each pair of years (e.g., 1998 vs. 1999, 1999 vs. 2000, etc.), the direction of the abundance index change was evaluated. While the evaluation of the changes in abundance indices is potentially confounded by underlying changes in resource abundance, the number of stock/index combinations showing positive increases in abundance was virtually identical between 1998-1999 and 1999-2000 (when the intervention was made). The abundance indices for the deepest dwelling stocks did not show differential reductions between years pre- and post-warp offsets.

*Albatross* trawl survey data were compared to independent surveys conducted by other vessels (e.g. Canadian trawl survey and sea scallop dredge surveys aboard *Albatross* but using a single warp). The frequency of species showing positive relative changes in abundance in *Albatross* surveys was nearly the same in the three years before (50%) and the three years after (54%) the warp change. For all species, the relative fishing power of *Albatross* post-warp change was slightly, but not statistically significantly, greater than the comparison vessels.

In examining the stock assessments, there was no obvious improvement in VPA residual patterns (e.g., reduced serial correlation) or tightness of the fit when trawl survey catches were arbitrarily increased by 10%, 25% and 100%. In fact, VPA model fits showed, on average, a 4% decrease in model fit when survey indices in 2000-2002 were arbitrarily increased by 100%. Similarly, retrospective patterns that occur in some VPA models persisted even with the arbitrarily increased survey catches. The stock assessment models integrate catch-at-age information and the full time series from the surveys, thereby damping the influence of variation in recent survey indices.

Fishing power studies were conducted between the *Albatross* and the *Delaware* in 2002 (after the warp change on the *Albatross*) and in 1982, 1983, and 1988. Estimates of fishing power coefficients (ratio of *Albatross* to *Delaware* catches) were similar between vessels in experiments before and after the warp change on the *Albatross IV* (Figure 3). There was only one statistically significant change in this ratio after the warp change in 10 species examined. In this one case, the ratio of *Albatross* to *Delaware* catch of yellowtail flounder increased between the 1980s and 2002. These paired comparison tests (although not intended for that purpose at the time) provide a robust means to test the warp effects (and include any other systematic changes in the fishing system since 1988). Specifically, because these paired trawl studies were conducted simultaneously before and after the warp offset they are not confounded by underlying changes in the abundance of the groundfish stocks. Based on information from 2002, the catch ratio test can detect differences of between 12% and 35%, depending on species. Therefore hypothesized large reductions (greater than 40-50%) in catchability of the *Albatross* survey during the period of the warp offset are highly unlikely. For all species combined, the ratio of *Albatross-Delaware* catches was 0.88 before the warp offset and 0.91 after, suggesting negligible change.

**Based on the evidence cited above, there is no indication of a systematic reduction in trawl survey fish catch efficiency due to the trawl warp offsets.**

Sensitivity of Stock Assessment Calculations to Potential Warp Offsets

Given the absence of measurable intervention effects associated with the warp offsets, the GARM endorsed the nominal assessment calculations as the basis for management decision-making. However, in order to examine the robustness of the management advice to potential variations in the survey catches, the GARM also carried out a series of sensitivity analyses examining survey catchability.

Sensitivity runs conducted for the various assessments included arbitrary increases in trawl survey catches for affected surveys of 10%, 25% and 100%. The first two scenarios consider decreases in survey catch rates that are at or below the limits of detection of the analyses of offset effects carried out at the GARM. The 100% increase is not supported by results of analyses carried out at the meeting, the increase is only included for illustrative purposes. An effect of this magnitude would likely have been detectable in the various exploratory data analyses. It should be noted that these arbitrary increases in survey catches were used in assessment calculations across all species, including those found in shallow depths (and thus less likely to be negatively influenced by warp offsets, e.g., yellowtail flounder, winter flounder, windowpane flounder).

The confidence intervals from the +10% and +25% sensitivity runs overlapped the nominal assessment results for all stocks, thus changes of this magnitude have no statistically significant impact on estimates of F and SSB. The stock assessment models integrate unaffected catch information from commercial and recreational fisheries and the full time series from the research vessel surveys, reducing the influence of variations in recent survey indices.

In only three of 20 stocks did the qualitative status determination for overfished (i.e., B<1/2 B-MSY) change from overfished to not overfished by adding arbitrary increases in survey abundance indices (Table 2). In two cases (American plaice, and Gulf of Maine haddock), the stocks were near ½ BMSY based on nominal assessment results. In these cases the hypothesized 10% increases in survey catches were sufficient to change biomass status determination. Of the 18 other cases, arbitrary increases in recent survey catches of 100% changed only the biomass status for white hake (from overfished to not overfished).

The status determination with respect to overfishing (fishing mortality rate) did not change under this sensitivity analysis in 19 of 20 stocks. The only instance of a change from 'overfishing' to 'not overfishing' was for Southern New England yellowtail flounder under the assumption of a 100% increase in survey catchability.

**The overall management advice is robust to variations in recent survey catch rates.**

Recommendations

The GARM evaluated the level of port sampling used for catch-at-age estimation for all stocks assessed with age-based models. Port sampling provides samples of the length distribution of landings (by market category), and sub-samples for age determination. Overall, the level of port sampling increased in 2000 and 2001 as compared to previous years, in some cases substantially. For example, for several of the most important stocks (Georges Bank and Gulf of Maine cod, Georges Bank and Southern New England yellowtail flounder), the numbers of samples/lengths/ages obtained from the ports in recent years were as follows:

| Stock | 1999 | | | 2000 | | | 2001 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Samples | Lengths | Ages | Samples | Lengths | Ages | Samples | Lengths | Ages |
| GM Cod | 15 | 1305 | 350 | 61 | 4687 | 1300 | 113 | 7326 | 2436 |
| GB Cod | 68 | 5987 | 1503 | 155 | 12219 | 2951 | 108 | 8389 | 2389 |
| GB YTF | 11 | 3066 | 300 | 11 | 3678 | 605 | 30 | 3768 | 814 |
| SNE YTF | 9 | 834 | 333 | 28 | 1146 | 984 | 18 | 1454 | 1224 |

Sustaining relatively high levels of port sampling is considered a priority for these assessments.

The GARM considered short-and medium-term projection methodologies used to estimate target TACs and F-rebuild. In general, it was concluded that all sources of uncertainty are not adequately addressed in such projections, and the GARM recommended a retrospective analysis to evaluate the performance of past projections.

The GARM was concerned about the adequacy of sea sampling to estimate discarded portions of the catch-at-age. Increased sea sampling coverage, initiated in 2002, should allow more precise estimation of discards for inclusion in catch at age estimates.

Numerous recommendations and comments pertaining to individual assessments are provided in the stock-specific chapters of the report.

Table 1. Summary of fishing mortality rate and biomass status for 20 Northeast groundfish stocks in 2001. Projections of maximum F to achieve B-MSY (F-Rebuild) assume F in 2002 = 0.85 * F in 2001, and stocks should be rebuilt by 2009, unless otherwise noted.

| Species | Stock | F-MSY | F-2001 | % F Reduction to achieve F-MSY | F-Rebuild | % F Reduction to achieve F-Rebuild | B-MSY ('000 mt) | B-2001 ('000 mt) | B-2001 % of B-MSY |
|---|---|---|---|---|---|---|---|---|---|
| Cod | GM | 0.23 | 0.47 | 51 | 0.11 | 76 | 82.8 | 22.0 | 27 |
| | GB | 0.18 | 0.38 | 53 | 0.15* | 61 | 216.8 | 29.2 | 14 |
| Haddock | GM | 0.23+ | 0.12 | none | 0.20 | none | 22.17# | 10.31 | 47 |
| | GB | 0.26 | 0.22 | none | 0.20 | 10 | 250.3 | 74.4 | 30 |
| Yellowtail | CC | 0.21 | 1.97 | 89 | 0.12 | 94 | 8.4 | 1.9 | 23 |
| | GB | 0.25 | 0.13 | none | 0.22 | none | 58.8 | 38.9 | 66 |
| | SNE | 0.27 | 0.46 | 41 | 0.10** | 78 | 45.2 | 1.9 | 4 |
| | MA | 0.33+ | 2.17 | 85 | 0.30 | 86 | 12.91# | 0.21 | 2 |
| Witch Flounder | | 0.16 | 0.45 | 64 | - | none | 19.9 | 11.3 | 57 |
| American Plaice | | 0.17 | 0.43 | 60 | 0.10 | 77 | 28.6 | 13.8 | 48 |
| Winter Flounder | GM | 0.26 | 0.14 | none | - | none | 5.4 | 5.37 | 99 |
| | GB | 0.32 | 0.25 | none | - | none | 9.4 | 9.8 | 104 |
| | SNE-MA | 0.32 | 0.51 | 37 | 0.12 | 76 | 30.1 | 7.6 | 25 |
| White Hake | | 0.55+ | 1.36 | 60 | 0.50 | 63 | 7.70# | 2.35 | 31 |
| Pollock | | 5.88+ | 3.55 | none | 4.83 | none | 3.0# | 1.60 | 53 |
| Redfish | | 0.04 | 0.01 | none | 0.01*** | none | 236.7 | 119.6 | 51 |
| Ocean Pout | | 0.31+ | 0.007 | none | n/a | n/a | 4.90# | 2.46 | 50 |
| Windowpane | Northern | 1.11+ | 0.1 | none | - | none | 0.94# | 0.79 | 84 |
| | Southern | 0.98+ | 0.69 | none | 0.73 | none | 0.92# | 0.21 | 23 |
| Atlantic Halibut | | 0.06 | unknown | unknown | unknown | unknown | 5.4 | 0.2 | 4 |

+ = fishing mortality rate proxy is catch divided by the survey abundance index
# = biomass target based on survey abundance index
* = rebuilding period is 2019 for GB cod
** = the SNE YT stock cannot be rebuilt to long-term biomass target by 2009 even if F=0.0 (using recruitment from last 10 years)
*** = rebuilding period is 2051 for redfish

Table 2. Summary of status determinations for 20 New England groundfish stocks. Sensitivity of status determination to arbitrary increases in trawl survey abundance indices for 2000 to spring 2002 are given for three levels of increase (+10%, +25% and +100%). Overfishing refers to the current fishing mortality rate relative to F-MSY. Overfished refers to the current biomass relative to B-MSY. Asterisks (*) indicate cases where the 80% bootstrap confidence interval for a particular criterion does not overlap that from the nominal assessment run. Shaded cells are where status determination changes from the nominal assessment when survey catch data are increased. SSB is spawning stock biomass, TSB is total stock biomass.

| Species | Stock | Status Criterion | Nominal Status | Status +10% | Status +25% | Status +100% |
|---|---|---|---|---|---|---|
| Atlantic Cod | Gulf of Maine | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | overfished * |
| | Georges Bank | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| Haddock | Gulf of Maine | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | overfished | not overfished | not overfished | not overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | overfished | overfished | overfished | overfished * |
| Yellowtail Flounder | Cape Cod | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing * |
| | | SSB | not overfished | not overfished | not overfished | not overfished * |
| | S. New England | F | overfishing | overfishing | overfishing | no overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| | Mid-Atlantic | F | overfishing | overfishing | overfishing | overfishing |
| | | TSB | overfished | overfished | overfished | overfished |
| Witch Flounder | | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | not overfished | not overfished | not overfished | not overfished * |
| American Plaice | | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | not overfished | not overfished | not overfished * |

Table 2 (continued).

| Species | Stock | Criterion | Nominal | +10% | +25% | +100% |
|---|---|---|---|---|---|---|
| Winter Flounder | Gulf of Maine | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | not overfished | not overfished | not overfished | not overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| | S. New England-Mid-Atlantic | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| White Hake | | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | not overfished |
| Pollock | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| Acadian Redfish+ | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | not overfished | not overfished | not overfished | not overfished |
| Ocean Pout | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | Not overfished | not overfished | not overfished | not overfished |
| Windowpane Flounder | Northern | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| | Southern | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | overfished | overfished | overfished | overfished |
| Atlantic Halibut | | F | unknown | unknown | unknown | unknown |
| | | SSB | overfished | overfished | overfished | overfished |

+ = Assessment models were not updated for Acadian redfish
unknown = estimates of F or proxy are not available for Atlantic halibut

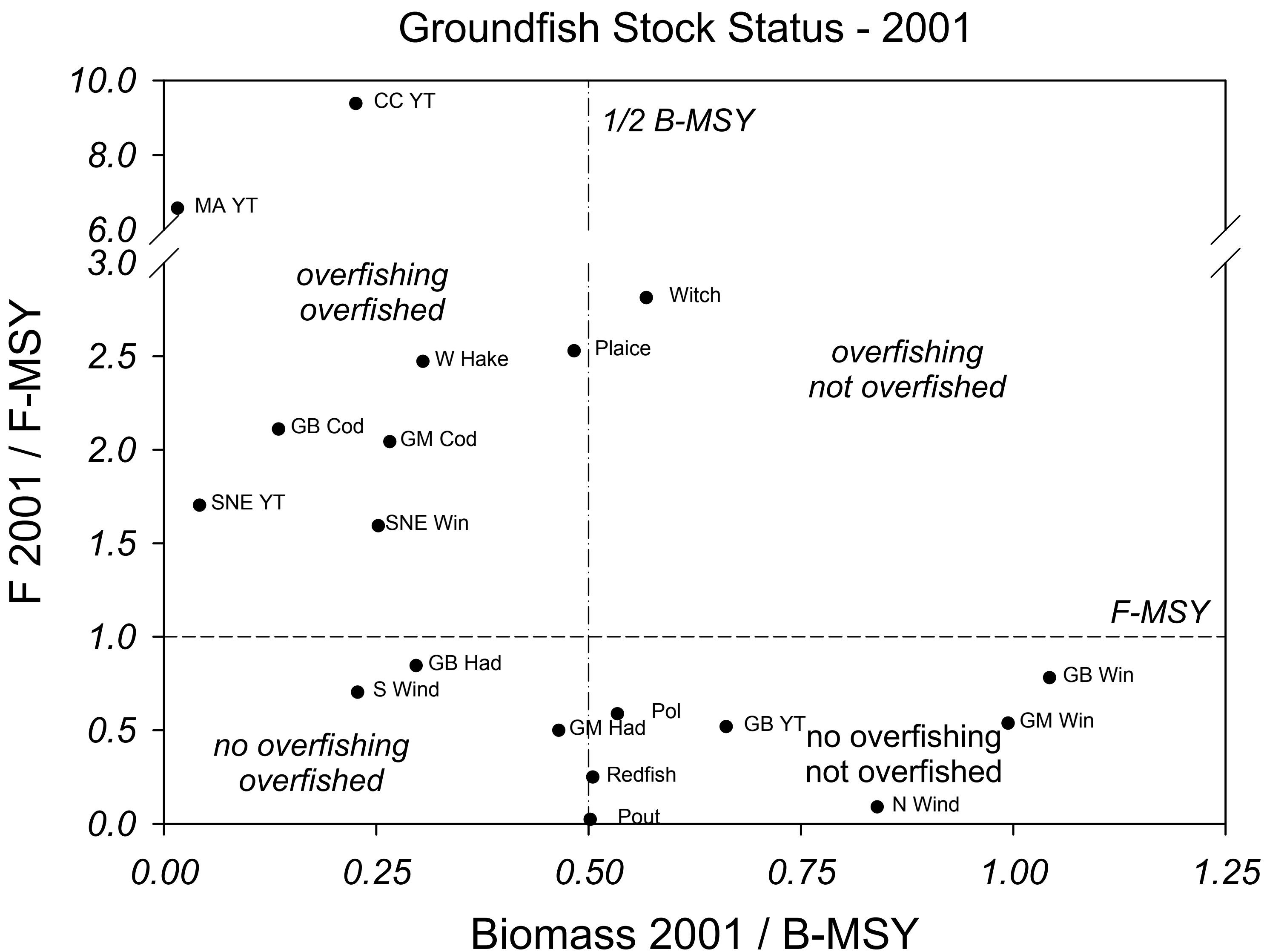


Figure 1. Fishing mortality rate (F) and biomass status of 19 groundfish stocks managed under the Northeast Multispecies FMP. Fishing mortality and biomass in 2001 are expressed as a proportion of F-MSY and B-MSY.Status determination statements are given for each quadrant: overfishing refers to fishing mortality greater that F-MSY; overfished refers to biomasses < ½ B-MSY.

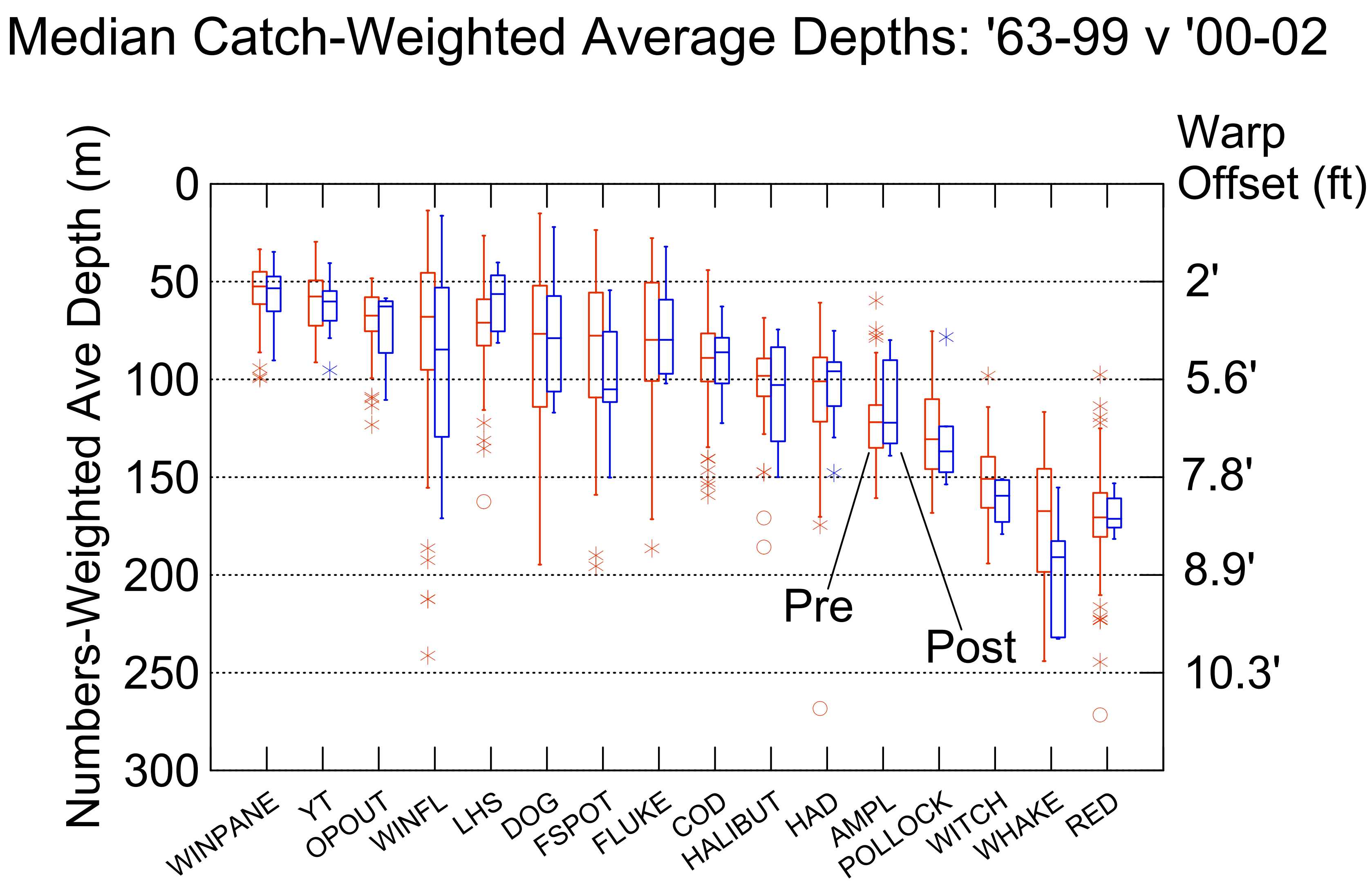


Figure 2. Median catch-weighted depth at capture of various groundfish species in NMFS bottom trawl surveys pre and post trawl warp offset problems. The amount of warp offset, as measured dockside, is also given. Note that most catches of these species are made in depths where the offset was less than about 9 feet. The box plots give the median value surrounded by the 25th and 75th percentiles of the distributions of depths of occurrence.

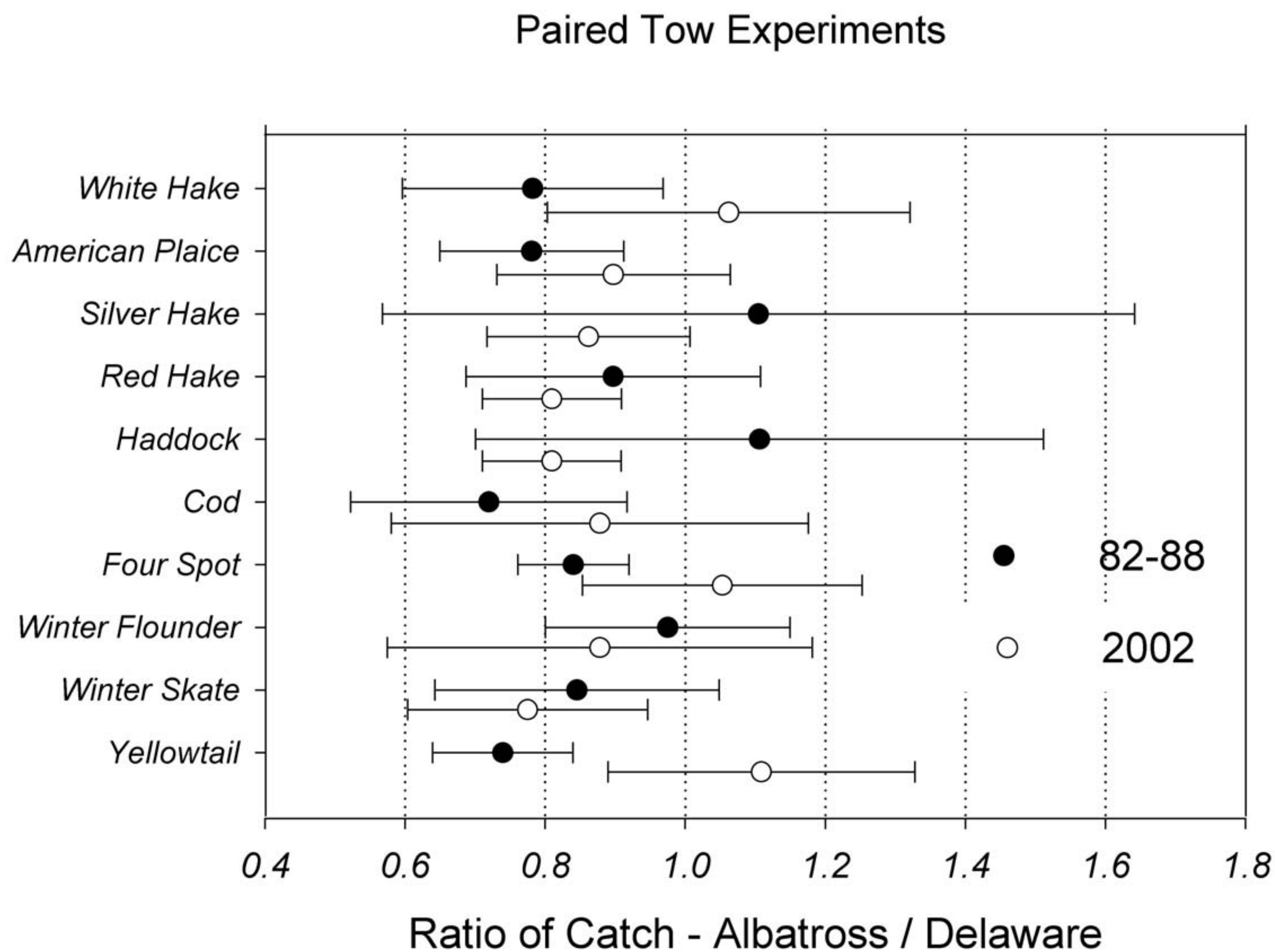


Figure 3. Results of side-by-side tows made by NOAA R/Vs *Albatross IV* and *Delaware II* in paired towing in the 1980s and 2002. Data are mean and 95% confidence intervals of the ratio (*Albatross* to *Delaware*) of catch rates by species. In only one case (yellowtail flounder) was there a significant change between time periods, and that difference was a positive change in the post warp period.

## Section 1

### 1.1 Introduction

The Groundfish Assessment Review Meeting (GARM) is a regional peer review process developed this year to provide assessment updates for the 20 stocks managed under the Northeast Multispecies Fishery Management Plan (Multispecies FMP). The meeting occurred during October 8-11, 2002, in Woods Hole, Massachusetts.

The GARM is distinct from the Northeast Stock Assessment Review Committee (SARC) process, which produces "benchmark" stock assessments and related management advice. The purpose of the GARM was to provide assessment updates, using existing model formulations and data sources.

The goals of the GARM were to provide peer review of assessment updates, summarize stock status for individual components and the resource as a whole, and provide estimates of adjustments in fishing mortality rates, as necessary, to achieve biological reference points. The GARM also reviewed the results of data exploration studies for evidence of changes in trawl survey efficiency associated with trawl warps that were misaligned on the NOAA R/V *Albatross IV* on trawl surveys occurring from winter 2000 to spring 2002. Last, the GARM provided numerous comments and recommendations regarding specific stock assessments and generic data collection and analysis procedures.

Background and History

In the Northeast region, stock assessments are peer reviewed through the Northeast Regional Stock Assessment Workshop (SAW) process. The SAW provides for a thorough review of new or revised assessment methodology over a cycle, for any one stock, that is two to five years long. In addition, the transboundary Georges Bank stocks of cod, haddock and yellowtail flounder are jointly assessed by Canadian and US scientists at regular meetings of the Transboundary Resource Assessment Committee or TRAC. Since the SAW and TRAC cannot reassess every stock every year, the assessment peer review process also includes more frequent stock assessment updates to ensure that management actions are based on the most recent status information available.

There are 12 species of groundfish, comprising 20 distinct stocks, managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (Groundfish FMP). The status of all the stocks in the complex was updated in 1999 and again in 2000 to provide current status information relevant to annual management adjustments. (Northern and Southern Demersal SAW Working Groups, 1999, Assessment of 19 Northeast Groundfish Stocks through 1999; Northern and Southern Demersal SAW Working Groups, 2000, Assessment of 19 Northeast Groundfish Stocks through 2000).

In March of this year, partly in response to a Federal court request for re-evaluation of current stock reference points, a special panel was convened to update reference points for all the stocks in the complex and to determine the fishing mortality rate that would provide for stock recovery (to the biomass target) by 2009 ($F_{REBUILD}$; NEFSC 2002a). The most recent data available to the Working Group, however, was through 2000 (augmented by some 2001 survey indices), now a year old. Since the New England Council is finalizing actions on a major amendment to the Groundfish FMP (Amendment 13) which would readjust management measures so as to attain biomass targets by 2009, it was necessary to update the groundfish assessments through 2001.

In September of this year the NEFSC found that the marks on the wire ropes attaching scientific survey gear to the vessel were not at true 50 m length intervals they are intended to indicate. The marks are used by the vessel crew to determine how much towing wire is deployed. The warps were most recently replaced in February 2000, and used in eight bottom trawl surveys, beginning with Winter 2000 and ending with Spring 2002.

Since the mis-measured warps may have affected survey catchability, two additional sets of analyses are included in the GARM report: analysis of the sensitivity of assessment results to hypothesized increases of 10%, 20% and 100% in abundance indices; and, as an independent study, 10 separate analyses of trawl survey data to determine whether or not the mis-marking could be detected via comparative analysis of existing survey data.

## 1.2 Terms of Reference

Terms of reference for the meeting were:

(a) provide updated catch information (landings and discards, where appropriate) for the stocks to be assessed. Catch-at-age data (based on port sampling) will be estimated, where applicable,

(b) provide updated research vessel survey indices (through spring 2002) for all appropriate survey series, including NMFS spring and autumn series, Canadian series, and state surveys,

(c) estimate 2001 fishing mortality rates (or appropriate proxies) for all 20 stocks, and provide estimates of 2001 stock sizes and measures of uncertainty (see Section 2),

(d) evaluate stock status relative to applicable biological reference points ($F_{MSY}$ and $B_{MSY}$; Section 2),

(e) provide updated estimates of F-Rebuild (the fishing mortality rate required to rebuild biomasses to $B_{MSY}$ by 2009) for all applicable stocks (Section 2),

(f) evaluate and comment on the potential sensitivity of assessment results to trawl warp marking discrepancies that occurred in bottom trawl surveys conducted between winter 2000 and spring 2002 (Sections 3-5).

### 1.3 Participants

The following individuals participated in some or all of the GARM (October 8-11, 2002):

*External* -
Steven Correia -Massachusetts Division of Marine Fisheries
Chris Darby - Center for Independent Experts (United Kingdom, England)
Joe Hunt - Department of Fisheries and Oceans (Canada)
Jon Helge Volstad - Center for Independent Experts (Maryland)

Chris Kellogg – New England Fishery Management Council
Chad Demerest – New England Fishery Management Council

*NEFSC* -
Frank Almeida
Jon Brodziak
Steve Cadrin
Laurel Col
Dvora Hart
Lisa Hendrickson
Larry Jacobson
Chris Legault
Ralph Mayo (Chair, Northern Demersal WG)
Steve Murawski (Meeting Chair)
Paul Nitschke
Loretta O'Brien
Paul Rago (Chair, Assessment Methods WG)
Anne Richards
Fred Serchuk
Gary Shepherd
Kathy Sosebee
Mark Terceiro (Chair, Southern Demersal WG)
Michele Thompson
Susan Wigley
Jim Weinberg

Additionally, the following individuals participated in the ASMFC Winter Flounder Technical Committee Meeting ( September 24-25) which supplied Southern New England and Gulf of Maine winter flounder assessments for consideration at the GARM:

Jay Burnett NEFSC
Steve Cadrin NEFSC
Steve Correia MADMF, Chair
Laura Lee ASMFC, RIDMF
Chris Legault NEFSC
Anne Mooney NYDEC
Lydia Munger ASMFC
Paul Nitschke NEFSC
Sally Sherman MEDNR
David Simpson CTDEP
Kathy Sosebee NEFSC
Mark Terceiro NEFSC
Susan Wigley NEFSC

### 1.4 Assessed Stocks

The GARM reviewed the status of 20 fishery stocks included as the large mesh species complex in the Northeast Multispecies Fishery Management Plan (FMP). Earlier assessment reviews for this species complex (e.g., NEFSC 2001) had included 19 stocks, since the status of Gulf of Maine winter flounder had never before been assessed. Stocks considered at this meeting (and letter designations of order in the report) are:

A. Georges Bank Cod
B. Georges Bank Haddock
C. Georges Bank Yellowtail Flounder
D. Southern New England Yellowtail Flounder
E. Cape Cod Yellowtail Flounder
F. Gulf of Maine Cod
G. Witch Flounder
H. American Plaice
I. Georges Bank Winter Flounder
J. Southern New England/Mid Atlantic Winter Flounder
K. White Hake
L. Pollock
M. Acadian Redfish
N. Ocean Pout
O. Gulf of Maine/Georges Bank Windowpane
P. Southern New England/Mid-Atlantic Windowpane
Q. Mid-Atlantic Yellowtail Flounder
R. Gulf of Maine Haddock
S. Atlantic Halibut
T. Gulf of Maine Winter Flounder

## 1.5 Overview

Initial stock assessments were developed by the Northern and Southern Demersal Working Groups of the SAW (Stock Assessment Workshop), and the ASMFC Winter Flounder Technical Committee. These working groups and the Technical Committee met at various times before the GARM meeting to develop draft assessment documents. Additionally, work related to the trawl warp offset issue was coordinated through the Assessment Methods Working Group.

Most stock assessments reviewed at the GARM were routine updates of assessments previously reviewed in the SAW or elsewhere. However, the Gulf of Maine winter flounder assessment was newly developed (by the ASMFC Technical Committee), and is scheduled to be peer reviewed at SAW 36 (December 2002). Accordingly, the details of the analytical stock assessment modeling are not incorporated herein, pending that "benchmark" review. The results are, however summarized, and input data are presented and evaluated.

The GARM meeting incorporated peer reviews by both regional stock assessment scientists (both NMFS and non-NMFS people) and external experts. The Center for Independent Experts (CIE, University of Miami) provided two individuals for the meeting. The roles of the CIE experts were to comment on analyses presented at the GARM, and to provide written critiques, which are attached as appendices to this report.

<u>Stock Assessment Results</u>

Results of the stock assessment updates are provided as fishing mortality rates and biomasses in 2001, relative to management reference points (section 2). The biological reference points (F-MSY and B-MSY) are, in most cases, those proposed by the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a). In one case (white hake) the GARM rejected the analytical stock assessment results (based on an ASPIC surplus production model) and substituted an index-based assessment evaluation. Appropriate index-based reference points based on the replacement ratio method (NEFSC 2002a) are thus proposed for white hake (section 2-K). Additionally, no reference points have yet been proposed for the Gulf of Maine winter flounder stock, although the ASMFC Technical Committee's Report analyzes F40% maximum spawning potential as a candidate for F-MSY, and considers B-MSY based on mean recruitment multiplied by spawning biomass-per-recruit at F-MSY (section 2-T).

Of the 19 stocks for which 2001 fishing mortality (or its proxy) can be estimated, 10 were fished below F-MSY in 2001, and 9 above. Additionally, the biomass of eight of the stocks was at or above ½ B-MSY, while 12 stocks were below the threshold. Stock biomasses have improved in 19 of the 20 stocks since 1995 (the exception being Mid-Atlantic yellowtail), with a median percent increase in biomass for all stocks of 177% (range: -33 to 2430 percent). Landings of the complex of 20 groundfish stocks have increased by 40% since 1995, primarily driven by increases from four Georges Bank stocks (haddock, yellowtail, cod and winter flounder). Fishing mortality (F) rates declined for 15 of 19 stocks between 1994 and 2001, with the median percent decline in F of 70% (range +48 to 95 percent). The four stocks showing increases in F since 1994 were Cape Cod and Mid-Atlantic yellowtail, white hake and Southern New England/Mid-Atlantic winter flounder.

Two stocks continue to have extremely high fishing mortality rates (Mid-Atlantic yellowtail flounder and Cape Cod yellowtail flounder). In the former case, SAW Working Groups will present analyses to SARC 36 recommending that the Mid-Atlantic and Southern New England yellowtail flounder resources be combined. The case of Cape Cod yellowtail flounder remains enigmatic, in that the apparent mortality rates on the stock remain exceptionally high despite the reductions in F seen in co-occurring stocks (e.g., Gulf of Maine cod, and winter flounder). The GARM recommended additional biological studies, including tagging, to better understand the relationships between Cape Cod yellowtail and adjacent stocks of the same species.

The percent reductions in F necessary to achieve B-MSY by the target dates varied by stock and were primarily dictated by the strength of incoming recruitment. Short-term projections of target TACs for the 2003-2004 fishing year and medium-term projections for calculating F-Rebuilds assumed that F in 2002 (calendar year) would be 85% of that in 2001, based on assumptions provided by the Multispecies Plan Development Team (PDT).

<u>Evidence for Interventions in Trawl Survey Data Due to Warp Offsets</u>

The GARM reviewed the results of a series of 10 different studies to evaluate evidence for an intervention in the NMFS trawl survey data associated with the use of mis-calibrated trawl warps (sections 3 and 4). There were eight affected surveys (winter 2000, 2001 and 2002; spring 2000, 2001 and 2002; and fall 2000 and 2001). Information collected from dockside warp measurements indicated that the warp miscalibration was related to the initial biased marking of the 50 meter intervals on one warp and was not due to progressive wire stretch. Therefore, the degree of intervention was thought to be approximately equal in all surveys since winter 2000.

Information on the potential effects of the warp offset on trawl survey performance evaluated by the GARM included studies of rates of gear damage over time, calculations of trawl geometry as a function of the warp offsets, by depth, patterns in mean/variance relationships in trawl survey catch data by stock, and depth-at-capture information from pre- and post-warp misaligned cruises. The results of trawl warp offset experiments, including video and sensor data, presented at the Trawl Warp Workshop (NEFSC 2002b), were also considered. Additionally, the GARM evaluated trends (directional changes from year-to-year) in abundance measures before and after the warp mis-marking. The results from side-by-side trawling experiments conducted by the *Albatross* and *Delaware* vessels to estimate their relative fishing power, conducted before and after the warp mis-marking on the *Albatross* were also considered. Standardized catch-rates from surveys conducted with mismatched warps were compared to survey CPUEs from surveys with comparable spatial and temporal coverage, and unaffected by the problem (e.g., Canadian trawl surveys and USA sea scallop surveys). The GARM also examined evidence for differences in length distributions from survey catches pre- and post warp offset by evaluating the relative size composition from various sources.

Based on evidence reviewed from each of these 10 studies there was no indication of a systematic reduction in trawl survey catch efficiency due to the trawl warp offsets.

Sensitivity of Stock Assessment Calculations to Potential Warp Offsets

Given the absence of measurable intervention effects associated with the warp offsets, the GARM endorsed the nominal assessment calculations as the basis for management decision-making. However, in order to examine the robustness of the management advice to potential variations in the survey catches, the GARM also carried out a series of sensitivity analyses examining survey catchability (Section 5).

Sensitivity runs conducted for the various assessments included arbitrary increases in trawl survey catches for affected surveys of 10%, 25% and 100%. The results of these analyses are presented in each stock assessment section of this report (Section 2). Specifically, each assessment contains a “cross” plot, of the mean and 80% confidence intervals of the estimated 2001 F and biomass. The status determination levels (F-MSY and 1/2 B-MSY) are given in each cross plot as frames of reference. Four such crosses are computed for each stock, giving the nominal, +10%, +25+ and +100% results (e.g., see Figure F6 for Gulf of Maine cod). The confidence intervals from the +10% and +25% sensitivity runs overlapped the nominal assessment results for all stocks, thus changes of this magnitude have no statistically significant impact on estimates of F and SSB. The stock assessment models integrate unaffected catch information from commercial and recreational fisheries and the full time series from the research vessel surveys, reducing the influence of variations in recent survey indices.

In only three of 20 stocks did the status determination for overfished (i.e., B-2001<1/2 BMSY) change from overfished to not overfished (Table 2). In two cases (American plaice, and Gulf of Maine haddock), the stocks were near ½ BMSY based on nominal assessment results. In these cases the hypothetical 10% increases in survey catches were sufficient to change biomass status determination. Of the 18 other cases, arbitrary increases in recent survey catches of 100% (i.e., doubling the catch) changed only the biomass status for white hake.

In only one case (Southern New England yellowtail flounder) did the status determination regarding the overfishing criterion (fishing mortality rate) change with arbitrary increases in survey catches up to 100%. The overall management advice is thus robust to variations in recent survey catch rates.

Recommendations

The GARM participants considered a number of generic recommendations for improving stock assessments and associated management advice:

- Based on considerations outlined in section 6.1, a retrospective evaluation of the performance of stock projections used in support of management is recommended. Such an analysis could shed light on the utility of various recruitment assumptions and other sources of uncertainty in stock and landings projection approaches.

- Index methods for biomass and fishing mortality status determination are used for a number of the groundfish stocks for which age- or length-based catch and abundance information are lacking. The performance of these indices should be evaluated and uncertainty measures routinely incorporated in the determination of stock status.

- Port sampling for estimating landings-at-age is an important component of stock assessment. The overall levels of port sampling have increased since 1998, as landings have increased. Maintenance, and in some cases, improvement in the rates of sampling are required to ensure adequate levels of sampling for estimating the catch-at-age. Further, a simulation (re-sampling) study is recommended to evaluate the reliability of catch-at-age estimates in relation to the rates of sampling.

- Estimation of fishery discards remains problematic for these stocks, as the overall level of sea sampling prior to 2002 was low and variable by fishery type. Increased rates of sea sampling coverage (occurring in 2002) should allow a statistical evaluation of the reliability of discard estimates, and the development of target sampling rates in order to reliably estimate discard mortalities at age for inclusion in assessments.

- Some stocks might have sufficient age and length-based information to upgrade the assessment type from an index basis to an age structured assessment (e.g., Gulf of Maine haddock). Age-structured modeling, even with partial information, may improve the basis for status determination for these stocks, and these improvements should be investigated.

- The GARM considered a variety of studies, including comparative fishing experiments developed to evaluate ship effects, to understand better the potential for effects on survey indices owing to the warp offset issue. The GARM notes that in order to evaluate the warp offset issue more directly, appropriately designed experimentation with warp offset and warp aligned tows is considered the most direct method for testing.

Numerous recommendations and comments pertaining to individual assessments are provided in the stock-specific chapters of the report.

## 1.6 Acknowledgements

The GARM participants extend their appreciation to Mr. Edgar Kleindinst for technical support and in particular the set up and maintenance of the local area network that allowed for a near-paperless meeting environment. Mr. Henry Milliken provided video tape and narration for *Albatross IV* warp offset experiments. Ms. Colleen Close and Ms. Betty Holmes solved innumerable logistical difficulties to allow for the smooth running of the meeting. Additionally, the GARM appreciates the extraordinary efforts of the Working Groups, the ASMFC Technical Committee and other individuals involved in supplying information upon which these assessments and data summaries are based (e.g., aging information, research vessel survey abundance indices, port sampling and sea sampling, and landings data). Last, the GARM appreciates the support of Manoj Shivlani of the University of Miami's Center for Independent Experts, and Stephen Brown, NMFS Office of Science and Technology, for expediting the inclusion of additional external reviewers in the process.

## 1.7 References

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NEFSC 2002a. Final report of the Working Group on re-evaluation of biological reference points for New England groundfish. Northeast Fisheries Science Center Reference Document 02-04. 123 p.

NEFSC 2002b. Report of the Workshop on Trawl Warp Effects on Fishing Gear Performance, 2-3 October, 2002, Woods Hole, MA. Northeast Fisheries Science Center Reference Document 00-15. 80 pp.

# Section 2.  Stock Assessments

**A. Georges Bank Atlantic Cod -** L. O'Brien, N. J. Munroe, and L. Col

## 1.0 Background

This stock was last assessed and peer reviewed in April 2001 (O'Brien and Munroe 2001; Transboundary Resources Assessment Committee 2001). Landings were 9,189 mt in 2000 and fully recruited F (ages 4-8, unweighted average) was estimated to be 0.22 in 2000, the lowest in the time series (1978-2000). Spawning stock biomass was 29,003 mt in 2000 and continued the increasing trend from the record low estimate of 19,233 mt in 1994. Since 1991, recruiting year classes have all been below the long term average and the 1997 and 2000 year classes were the lowest in the time series. The NEFSC spring and autumn bottom trawl survey recruitment indices continued to remain near record low values. Autumn recruitment indices for age 2 fish from the 1994, 1995, 1996, 1997, and 1998 year classes were all below the time series (1963-2000) average. The most recent above-average autumn recruitment index occurred in 1993.

A benchmark assessment review was conducted by the TRAC in February 2002 (NEFSC 2002). Several recommendations were made by the TRAC to rectify the strong retrospective pattern in F. These included estimating the population sizes for ages 1-9 in the terminal year and for age 9 in the three years prior to the terminal year. For the remaining years, F on the oldest age (9) would be estimated as a weighted F of ages 7 and 8. These recommendations will be addressed in the next assessment. The current assessment presented here is considered an update and the methodology has remained the same as used by the Working Group on Re-Evaluation of Biological Reference Points (NEFSC 2002).

## 2.0 Fishery

Total commercial landings of Georges Bank cod (Table A1, Figure A1) increased 39% in 2001 to 12,769 mt. USA landings increased 40% (10,635 mt) and Canadian landings increased 36% (2,134 mt) in 2001 (Table A1). Recreational landings were estimated at 550 mt in 2001, a decline of about 48% from 2000.

## 3.0 Research Surveys

NEFSC spring and autumn survey biomass and abundance indices fluctuated slightly during 2000 to 2002, and continue to remain below the long term average (Table A2, Figure A2-A3). The recruitment indices for age 1 and 2 from the 2001 NEFSC autumn bottom trawl survey were well below average (Table A3a). The Canadian spring survey index of abundance increased in 2002 but also is below the time series average (Figure A3, Table A3b).

## 4.0 Assessment

*Input data and Analyses*

The current assessment is an update assessment and employs the same VPA formulation as in the 2000 assessment (O'Brien and Munroe 2001). A slight variation from the previous assessment is that the number of surveys available as tuning indices in the terminal year increases from two to three since the USA 2002 spring survey was available at the time the assessment was conducted.

Catch at age (1-10+) has been updated with total 2001 landings (USA and Canadian). The total number of commercial length samples in 2001 was less than in 2000, however, the number of samples collected during these two years was the highest since 1985 (Table A4). The number of quarterly samples was adequate for all market categories except for the fourth quarter scrod samples (Table A5). Spatial coverage was poor for eastern Georges Bank (SA 561, 562), as it has been for several years. As in the last assessment, length samples from western Georges Bank and combined US and Canadian age samples from eastern Georges Bank were applied to characterize the landings from eastern Georges Bank. Landings were dominated in numbers by age 3 fish in both the US and Canadian fisheries and in weight by age 3 fish in the USA fishery and by age 3 and age 5 fish in the Canadian fishery. The total catch at age includes total landings from both the USA and Canadian fisheries (Table A6). No discards at age estimates are derived for stock.

Research survey indices were estimated from the 2002 NEFSC and Canadian Department of Fisheries and Oceans (DFO) spring (ages 1-8) and the NEFSC 2001 autumn (ages 1-6) bottom trawl surveys.

The ADAPT calibration method (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to derive estimates of instantaneous fishing mortality and beginning year stock sizes in 2002. A conditional non-parametric bootstrap procedure (Efron 1982) was used to evaluate the precision of fishing mortality, spawning stock biomass, and mean biomass estimates. A retrospective analysis was performed for terminal year fishing mortality, spawning stock biomass, and age 1 recruitment.

*Assessment results*

Fully recruited fishing mortality (age 4-8) was estimated at 0.38 in 2001 (Figure A4). Spawning stock biomass in 2001 was estimated at 29,170 mt, a 12% increase from 2000 and a 53% increase from the record low in 1994 (Table A7, Figure A5). Recruitment of the 2001 year class (1.7 million age 1 fish) is estimated to be similar to the 2000 year class (1.6 million age 1 fish) and the 1994 year class (3.9 million age 1 fish) (Table A7, Figure A5). The survival ratio of recruit/SSB was above average for the 1996 and 1998 year classes and below average for the more recent year classes.

*VPA Diagnostics*

Stock size estimates for ages 1-8 were well estimated with CVs ranging from 0.21 to 0.47. The distribution of F estimates from the bootstrap analysis ranged from 0.25 to 0.56 with an 80% probability that F in 2001 was between 0.33 and 0.44. The distribution of SSB estimates from the bootstrap analysis ranged from 21,000 mt to 43,000 mt with an 80% probability that SSB in 2000 was between 25,250 mt and 31,845 mt.

A retrospective pattern exists in this model formulation back to 1994 (Figure A6). The terminal year estimates of fishing mortality are less than converged estimates since 1993, and SSB estimates are greater than converged estimates since 1993. The terminal year estimates of recruits are less than converged estimates from 1992 to 1999 and more than the converged estimates from 2000-2001. The TRAC recommended a different formulation of the ADAPT calibration to address the retrospective pattern and these recommendations will be applied in the next assessment (NEFSC 2002).

*Sensitivity Analyses*

Analyses were conducted to determine the sensitivity of fishing mortality and spawning stock biomass estimates to changes in the magnitude of the research survey indices used to calibrate the VPA. NEFSC spring and autumn survey indices for 2000-2002 were arbitrarily increased by 10%, 25% and 100% and used to re-calibrate the VPA (Figure A7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

## 5.0 Projections

Long term forecasts of catch and SSB were conducted with $F_{2002}= 0.85\ F_{2001}$. Input data and results for 2002-2004 are presented in Table A8. The $F_{rebuild}$ that would enable 50% probability of reaching Bmsy by 2019 was 0.15 (Table A8). The current estimate of $F_{rebuild}$ is similar to the previous estimate of 0.17 (NEFSC 2002) which was based on the assessment results from 2000 (O'Brien and Munroe 2001). Median SSB and catch with 80% confidence intervals projected under $F_{rebuild}$ = 0.15 are presented in Figure A8.

## 6.0 Biological Reference Points

Biological reference points were established for Georges Bank cod based on a Beverton-Holt stock recruit model (NEFSC 2002) as :

MSY= 35,236 mt
$SSB_{MSY}$ = 216,780 mt and
$F_{MSY}$= 0.175

In 2001, spawning stock biomass was estimated at 29,170 mt, about 13% of the target $SSB_{MSY}$.

The stock is considered to be overfished. F was estimated at 0.38, therefore overfishing is occurring on this stock.

## 7.0 Summary

Georges Bank Atlantic cod are overfished and overfishing is occurring. Fishing mortality had been steadily declining since 1997, however, F increased about 9% in 2001 to 0.38. Spawning stock continues to slowly increase from the record low in 1994, however, the increase appears to be primarily due to growth.

The 1996 year class accounts for the majority of the US catch and both the 1998 and 1996 year classes account for the majority of the Canadian catch. The 1996 (10.5 million age 1 fish) and 1998 (10.3 million age 1 fish) year classes, while below the long term average (14 million age 1 fish), represent the strongest year classes since the last above-average year class that occurred in 1990 (17.9 million age1 fish). The 1999, 2000, and 2001 year classes are among the lowest in the time series.

The NEFSC and DFO survey biomass and abundance indices fluctuated slightly during 2000 to 2002, however, all the indices continue to remain below the long term average The most recent surveys indicate that the 1999 year class may be similar in size to the 1998 year class.

The lack of strong recruitment in the last decade suggests that recovery of this stock will be largely dependent on reducing fishing mortality.

## 8. 0 Sources of Uncertainty

Landings data for 1994-2001 are derived by proration and are provisional.

The retrospective analysis indicates a pattern in the estimates of F, SSB, and recruits in the VPA. The terminal year estimates of fishing mortality are less than the converged estimates and SSB estimates are greater than the converged estimates.

There is inadequate data to characterize both the recreational and discarded catch, particularly if these components increase. The TRAC previously rejected using poorly sampled recreational catch since a recreational catch at age with a similar age structure to the commercial catch at age would only be a scaling factor.

## 9.0 GARM Panel Comments

Sampling of commercial landings is stratified by market category. When evaluating sampling intensity, it may be useful to note the ages that comprise the various market categories to relate sampling to the age structure of the catch.

The residual pattern from the calibrated VPA was discussed at length. It was noted that the residual pattern on the older ages is strongest, and this may lead to the retrospective pattern on F. The retrospective pattern on SSB, however, is not as severe after 1999. A domed-shaped pattern in partial recruitment was again apparent in this assessment. Many factors may be responsible for this pattern which is generally caused by a mismatch between the age composition of the catch and the population as estimated by the survey. This may be influenced by the extensive closed areas on Georges Bank since 1995. The panel reiterated the recommendation of the TRAC that F on the oldest age be estimated directly for several of the most recent years so that a flat-topped PR not be assumed.

## 10.0 References


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Table A1. Commercial landings (metric tons, live) of Atlantic cod from the Georges Bank and South (NAFO Division 5Z and Subarea 6) stock, 1960 - 2001 (* = Provisional data).

| Year | USA | Canada | Country<br>USSR | Spain | Poland | Other | Total |
|---|---|---|---|---|---|---|---|
| 1960 | 10834 | 19 | - | - | - | - | 10853 |
| 1961 | 14453 | 223 | 55 | - | - | - | 14731 |
| 1962 | 15637 | 2404 | 5302 | - | 143 | - | 23486 |
| 1963 | 14139 | 7832 | 5217 | - | - | 1 | 27189 |
| 1964 | 12325 | 7108 | 5428 | 18 | 48 | 238 | 25165 |
| 1965 | 11410 | 10598 | 14415 | 59 | 1851 | - | 38333 |
| 1966 | 11990 | 15601 | 16830 | 8375 | 269 | 69 | 53134 |
| 1967 | 13157 | 8232 | 511 | 14730 | - | 122 | 36752 |
| 1968 | 15279 | 9127 | 1459 | 14622 | 2611 | 38 | 43136 |
| 1969 | 16782 | 5997 | 646 | 13597 | 798 | 119 | 37939 |
| 1970 | 14899 | 2583 | 364 | 6874 | 784 | 148 | 25652 |
| 1971 | 16178 | 2979 | 1270 | 7460 | 256 | 36 | 28179 |
| 1972 | 13406 | 2545 | 1878 | 6704 | 271 | 255 | 25059 |
| 1973 | 16202 | 3220 | 2977 | 5980 | 430 | 114 | 28923 |
| 1974 | 18377 | 1374 | 476 | 6370 | 566 | 168 | 27331 |
| 1975 | 16017 | 1847 | 2403 | 4044 | 481 | 216 | 25008 |
| 1976 | 14906 | 2328 | 933 | 1633 | 90 | 36 | 19926 |
| 1977 | 21138 | 6173 | 54 | 2 | - | - | 27367 |
| 1978 | 26579 | 8778 | - | - | - | - | 35357 |
| 1979 | 32645 | 5978 | - | - | - | - | 38623 |
| 1980 | 40053 | 8063 | - | - | - | - | 48116 |
| 1981 | 33849 | 8499 | - | - | - | - | 42348 |
| 1982 | 39333 | 17824 | - | - | - | - | 57157 |
| 1983 | 36756 | 12130 | - | - | - | - | 48886 |
| 1984 | 32915 | 5763 | - | - | - | - | 38678 |
| 1985 | 26828 | 10443 | - | - | - | - | 37271 |
| 1986 | 17490 | 8411 | - | - | - | - | 25901 |
| 1987 | 19035 | 11845 | - | - | - | - | 30880 |
| 1988 | 26310 | 12932 | - | - | - | - | 39242 |
| 1989 | 25097 | 8001 | - | - | - | - | 33098 |
| 1990 | 28193 | 14310 | - | - | - | - | 42503 |
| 1991 | 24175 | 13455 | - | - | - | - | 37630 |
| 1992 | 16855 | 11712 | - | - | - | - | 28567 |
| 1993 | 14594 | 8519 | - | - | - | - | 23113 |
| 1994 | 9893* | 5276 | - | - | - | - | 15169 |
| 1995 | 6759* | 1100 | - | - | - | - | 7859 |
| 1996 | 7020* | 1885 | - | - | - | - | 8905 |
| 1997 | 7537* | 2898 | - | - | - | - | 10435 |
| 1998 | 6959* | 1873 | - | - | - | - | 8832 |
| 1999 | 8061* | 1819 | - | - | - | - | 9880 |
| 2000 | 7617* | 1572 | - | - | - | - | 9189 |
| 2001 | 10635* | 2134 | - | - | - | - | 12769 |

Table A2. Standardized stratified mean catch per tow in numbers and weight (kg)for Atlantic cod in NEFSC offshore spring and autumn research vessel bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2000. [1,2,3]

| | Spring | | Autumn | |
|---|---|---|---|---|
| Year | No/Tow | Wt/Tow | No/Tow | Wt/Tow |
| 1963 | - | - | 4.37 | 17.8 |
| 1964 | - | - | 2.79 | 11.4 |
| 1965 | - | - | 4.25 | 11.8 |
| 1966 | - | - | 4.90 | 8.1 |
| 1967 | - | - | 10.33 | 13.6 |
| 1968 | 4.73 | 12.7 | 3.31 | 8.6 |
| 1969 | 4.63 | 17.8 | 2.24 | 8.0 |
| 1970 | 4.34 | 15.8 | 5.12 | 12.6 |
| 1971 | 3.39 | 14.3 | 3.19 | 9.8 |
| 1972 | 9.16 | 19.3 | 13.09 | 22.9 |
| 1973 | 57.81 | 94.5 | 12.28 | 30.9 |
| 1974 | 14.74 | 36.4 | 3.49 | 8.2 |
| 1975 | 6.89 | 26.1 | 6.41 | 14.1 |
| 1976 | 7.06 | 18.6 | 10.43 | 17.7 |
| 1977 | 6.19 | 15.3 | 5.44 | 12.5 |
| 1978 | 12.31 | 31.2 | 8.59 | 23.3 |
| 1979 | 5.00 | 16.2 | 5.95 | 16.5 |
| 1980 | 7.68 | 24.1 | 2.91 | 6.7 |
| 1981 | 10.44 | 26.1 | 9.20 | 20.3 |
| 1982 | 32.96 | 101.9 | 3.34 | 6.1 |
| 1983 | 7.70 | 23.5 | 4.14 | 6.1 |
| 1984 | 4.08 | 15.3 | 4.73 | 10.0 |
| 1985 | 7.03 | 21.7 | 2.31 | 3.1 |
| 1986 | 5.04 | 16.7 | 2.99 | 3.7 |
| 1987 | 3.24 | 9.9 | 2.33 | 4.4 |
| 1988 | 5.87 | 13.5 | 3.07 | 5.6 |
| 1989 | 4.80 | 10.9 | 4.84 | 4.7 |
| 1990 | 4.79 | 11.7 | 4.78 | 11.5 |
| 1991 | 4.31 | 8.9 | 0.96 | 1.4 |
| 1992 | 2.67 | 7.4 | 1.72 | 3.0 |
| 1993 | 2.40 | 7.0 | 2.15 | 2.2 |
| 1994 | 0.95 | 1.2 | 1.82 | 3.3 |
| 1995 | 3.29 | 8.4 | 3.62 | 5.6 |
| 1996 | 2.70 | 7.5 | 1.10 | 2.7 |
| 1997 | 2.32 | 5.2 | 0.87 | 1.9 |
| 1998 | 4.36 | 11.7 | 1.87 | 2.8 |
| 1999 | 2.15 | 4.7 | 1.02 | 3.0 |
| 2000 | 3.57 | 8.2 | 1.31 | 1.4 |
| 2001 | 1.86 | 5.5 | 1.05 | 2.1 |
| 2002 | 2.08 | 5.0 | | |
| Average | 7.50 | 19.3 | 4.29 | 9.2 |

Table A3a. Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2002.

| | AGE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | No./tow |
| SPRING | | | | | | | | | | | | |
| 1968 | 0.513 | 0.136 | 1.615 | 0.825 | 0.665 | 0.385 | 0.246 | 0.140 | 0.083 | 0.056 | 0.058 | 4.722 |
| 1969 | 0.000 | 0.123 | 0.546 | 1.780 | 0.888 | 0.451 | 0.326 | 0.215 | 0.128 | 0.072 | 0.112 | 4.641 |
| 1970 | 0.000 | 0.338 | 0.804 | 0.430 | 1.241 | 0.162 | 0.844 | 0.263 | 0.058 | 0.056 | 0.147 | 4.342 |
| 1971 | 0.000 | 0.206 | 0.860 | 0.438 | 0.254 | 0.570 | 0.114 | 0.324 | 0.365 | 0.128 | 0.132 | 3.391 |
| 1972 | 0.056 | 3.000 | 1.838 | 2.732 | 0.445 | 0.166 | 0.323 | 0.084 | 0.285 | 0.071 | 0.158 | 9.159 |
| 1973 | 0.056 | 0.546 | 42.258 | 6.344 | 6.387 | 0.657 | 0.515 | 0.367 | 0.058 | 0.217 | 0.404 | 57.808 |
| 1974 | 0.000 | 0.444 | 4.558 | 5.971 | 0.761 | 1.988 | 0.442 | 0.100 | 0.265 | 0.064 | 0.144 | 14.735 |
| 1975 | 0.000 | 0.064 | 0.327 | 2.092 | 2.941 | 0.377 | 0.744 | 0.084 | 0.115 | 0.147 | 0.000 | 6.890 |
| 1976 | 0.111 | 1.298 | 1.955 | 0.915 | 0.661 | 1.607 | 0.153 | 0.261 | 0.029 | 0.000 | 0.068 | 7.058 |
| 1977 | 0.000 | 0.044 | 3.389 | 1.084 | 0.553 | 0.267 | 0.717 | 0.052 | 0.066 | 0.000 | 0.021 | 6.193 |
| 1978 | 3.312 | 0.372 | 0.192 | 5.531 | 0.972 | 0.778 | 0.142 | 0.712 | 0.065 | 0.141 | 0.096 | 12.312 |
| 1979 | 0.108 | 0.428 | 1.298 | 0.275 | 1.852 | 0.547 | 0.236 | 0.084 | 0.139 | 0.013 | 0.022 | 5.000 |
| 1980 | 0.105 | 0.031 | 2.217 | 2.690 | 0.212 | 1.705 | 0.374 | 0.186 | 0.031 | 0.030 | 0.096 | 7.676 |
| 1981 | 0.301 | 2.302 | 1.852 | 2.811 | 1.685 | 0.106 | 0.879 | 0.258 | 0.132 | 0.000 | 0.113 | 10.438 |
| 1982 | 0.169 | 0.508 | 5.435 | 9.502 | 8.324 | 6.208 | 0.293 | 1.866 | 0.369 | 0.082 | 0.203 | 32.958 |
| 1983 | 0.081 | 0.332 | 1.952 | 3.017 | 0.796 | 0.697 | 0.443 | 0.027 | 0.219 | 0.000 | 0.138 | 7.701 |
| 1984 | 0.000 | 0.402 | 0.431 | 0.761 | 1.238 | 0.422 | 0.400 | 0.209 | 0.000 | 0.215 | 0.000 | 4.078 |
| 1985 | 0.244 | 0.111 | 2.653 | 0.663 | 1.110 | 1.412 | 0.265 | 0.192 | 0.180 | 0.037 | 0.161 | 7.029 |
| 1986 | 0.092 | 0.872 | 0.409 | 1.844 | 0.365 | 0.540 | 0.618 | 0.062 | 0.125 | 0.101 | 0.015 | 5.044 |
| 1987 | 0.000 | 0.020 | 1.613 | 0.378 | 0.763 | 0.062 | 0.179 | 0.136 | 0.033 | 0.027 | 0.025 | 3.235 |
| 1988 | 0.180 | 0.720 | 0.609 | 3.150 | 0.409 | 0.644 | 0.064 | 0.037 | 0.049 | 0.000 | 0.007 | 5.868 |
| 1989 | 0.000 | 0.310 | 1.410 | 0.666 | 1.583 | 0.235 | 0.351 | 0.051 | 0.040 | 0.055 | 0.093 | 4.794 |
| 1990 | 0.042 | 0.173 | 0.922 | 1.737 | 0.674 | 0.912 | 0.130 | 0.143 | 0.013 | 0.016 | 0.027 | 4.790 |
| 1991 | 0.195 | 1.027 | 0.528 | 0.689 | 0.929 | 0.479 | 0.328 | 0.054 | 0.041 | 0.000 | 0.045 | 4.313 |
| 1992 | 0.000 | 0.123 | 1.252 | 0.468 | 0.168 | 0.273 | 0.142 | 0.159 | 0.020 | 0.037 | 0.028 | 2.670 |
| 1993 | 0.110 | 0.009 | 0.399 | 1.306 | 0.205 | 0.090 | 0.138 | 0.029 | 0.034 | 0.021 | 0.055 | 2.396 |
| 1994 | 0.030 | 0.125 | 0.272 | 0.200 | 0.217 | 0.033 | 0.006 | 0.044 | 0.000 | 0.019 | 0.000 | 0.945 |
| 1995 | 0.482 | 0.050 | 0.382 | 0.854 | 0.534 | 0.599 | 0.107 | 0.234 | 0.028 | 0.022 | 0.000 | 3.290 |
| 1996 | 0.000 | 0.073 | 0.214 | 0.736 | 1.247 | 0.174 | 0.209 | 0.028 | 0.018 | 0.000 | 0.000 | 2.699 |
| 1997 | 0.302 | 0.291 | 0.437 | 0.170 | 0.489 | 0.422 | 0.050 | 0.134 | 0.020 | 0.000 | 0.000 | 2.315 |
| 1998 | 0.018 | 0.111 | 0.665 | 1.298 | 0.848 | 0.755 | 0.533 | 0.102 | 0.031 | 0.000 | 0.000 | 4.360 |
| 1999 | 0.067 | 0.212 | 0.291 | 0.609 | 0.510 | 0.238 | 0.119 | 0.064 | 0.031 | 0.007 | 0.000 | 2.148 |
| 2000 | 0.053 | 0.221 | 0.807 | 0.830 | 1.141 | 0.370 | 0.102 | 0.026 | 0.020 | 0.000 | 0.000 | 3.569 |
| 2001 | 0.000 | 0.061 | 0.235 | 0.794 | 0.160 | 0.383 | 0.177 | 0.023 | 0.018 | 0.012 | 0.000 | 1.862 |
| 2002 | 0.018 | 0.065 | 0.093 | 0.383 | 0.993 | 0.239 | 0.225 | 0.039 | 0.000 | 0.000 | 0.028 | 2.083 |
| average | 0.301 | 0.433 | 2.420 | 1.828 | 1.206 | 0.713 | 0.312 | 0.194 | 0.089 | 0.047 | 0.068 | 7.500 |

Table A3a continued. Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2001.

| | | | | | AGE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | No./tow |
| AUTUMN | | | | | | | | | | | | |
| 1963 | 0.019 | 0.719 | 0.778 | 0.920 | 0.897 | 0.354 | 0.326 | 0.175 | 0.103 | 0.014 | 0.069 | 4.374 |
| 1964 | 0.009 | 0.640 | 0.699 | 0.588 | 0.538 | 0.145 | 0.136 | 0.062 | 0.050 | 0.030 | 0.083 | 2.980 |
| 1965 | 0.173 | 1.299 | 0.998 | 0.707 | 0.484 | 0.167 | 0.179 | 0.112 | 0.081 | 0.023 | 0.023 | 4.246 |
| 1966 | 1.025 | 1.693 | 1.000 | 0.515 | 0.264 | 0.100 | 0.095 | 0.062 | 0.039 | 0.002 | 0.017 | 4.812 |
| 1967 | 0.072 | 7.596 | 1.334 | 0.523 | 0.406 | 0.133 | 0.133 | 0.055 | 0.051 | 0.012 | 0.070 | 10.385 |
| 1968 | 0.070 | 0.314 | 1.611 | 0.783 | 0.271 | 0.073 | 0.067 | 0.027 | 0.023 | 0.008 | 0.048 | 3.295 |
| 1969 | 0.000 | 0.343 | 0.622 | 0.626 | 0.331 | 0.094 | 0.061 | 0.019 | 0.023 | 0.022 | 0.059 | 2.200 |
| 1970 | 0.434 | 1.699 | 1.361 | 0.532 | 0.696 | 0.153 | 0.000 | 0.033 | 0.055 | 0.055 | 0.098 | 5.116 |
| 1971 | 0.400 | 0.602 | 0.617 | 0.408 | 0.310 | 0.478 | 0.164 | 0.042 | 0.090 | 0.000 | 0.075 | 3.186 |
| 1972 | 0.948 | 7.473 | 1.191 | 1.841 | 0.399 | 0.241 | 0.568 | 0.116 | 0.204 | 0.021 | 0.084 | 13.085 |
| 1973 | 0.203 | 1.748 | 6.060 | 1.164 | 2.039 | 0.210 | 0.225 | 0.175 | 0.062 | 0.137 | 0.253 | 12.276 |
| 1974 | 0.461 | 0.410 | 0.667 | 1.509 | 0.161 | 0.089 | 0.112 | 0.000 | 0.059 | 0.021 | 0.000 | 3.489 |
| 1975 | 2.377 | 0.992 | 0.421 | 0.628 | 1.682 | 0.111 | 0.156 | 0.000 | 0.000 | 0.000 | 0.037 | 6.406 |
| 1976 | 0.000 | 6.144 | 2.073 | 0.762 | 0.275 | 0.738 | 0.054 | 0.269 | 0.037 | 0.052 | 0.021 | 10.425 |
| 1977 | 0.152 | 0.237 | 3.434 | 0.691 | 0.253 | 0.173 | 0.394 | 0.007 | 0.027 | 0.000 | 0.077 | 5.444 |
| 1978 | 0.395 | 1.845 | 0.391 | 4.058 | 0.964 | 0.336 | 0.165 | 0.343 | 0.050 | 0.030 | 0.014 | 8.590 |
| 1979 | 0.115 | 1.625 | 1.677 | 0.162 | 1.687 | 0.321 | 0.184 | 0.031 | 0.113 | 0.010 | 0.025 | 5.948 |
| 1980 | 0.280 | 0.820 | 0.564 | 0.774 | 0.053 | 0.265 | 0.057 | 0.067 | 0.027 | 0.000 | 0.000 | 2.905 |
| 1981 | 0.261 | 3.525 | 2.250 | 1.559 | 0.589 | 0.054 | 0.579 | 0.057 | 0.064 | 0.018 | 0.083 | 9.039 |
| 1982 | 0.362 | 0.577 | 1.910 | 0.242 | 0.068 | 0.115 | 0.000 | 0.031 | 0.033 | 0.000 | 0.000 | 3.337 |
| 1983 | 1.283 | 0.850 | 1.089 | 0.740 | 0.069 | 0.033 | 0.004 | 0.010 | 0.015 | 0.000 | 0.044 | 4.136 |
| 1984 | 0.179 | 1.909 | 0.682 | 0.929 | 0.825 | 0.024 | 0.059 | 0.039 | 0.000 | 0.039 | 0.044 | 4.728 |
| 1985 | 1.002 | 0.181 | 0.843 | 0.067 | 0.106 | 0.077 | 0.028 | 0.000 | 0.000 | 0.000 | 0.003 | 2.306 |
| 1986 | 0.076 | 2.279 | 0.129 | 0.329 | 0.008 | 0.049 | 0.073 | 0.016 | 0.000 | 0.007 | 0.022 | 2.987 |
| 1987 | 0.204 | 0.414 | 1.353 | 0.108 | 0.200 | 0.028 | 0.012 | 0.000 | 0.000 | 0.000 | 0.007 | 2.325 |
| 1988 | 0.550 | 0.875 | 0.437 | 0.904 | 0.060 | 0.194 | 0.000 | 0.011 | 0.039 | 0.000 | 0.000 | 3.069 |
| 1989 | 0.251 | 2.798 | 1.046 | 0.161 | 0.507 | 0.055 | 0.015 | 0.007 | 0.000 | 0.000 | 0.000 | 4.841 |
| 1990 | 0.157 | 0.364 | 1.624 | 1.814 | 0.412 | 0.286 | 0.069 | 0.022 | 0.011 | 0.000 | 0.022 | 4.781 |
| 1991 | 0.041 | 0.408 | 0.175 | 0.274 | 0.031 | 0.029 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.957 |
| 1992 | 0.035 | 0.412 | 0.949 | 0.174 | 0.100 | 0.044 | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 | 1.724 |
| 1993 | 0.178 | 0.970 | 0.532 | 0.383 | 0.017 | 0.025 | 0.022 | 0.000 | 0.000 | 0.022 | 0.000 | 2.149 |
| 1994 | 0.067 | 0.406 | 0.664 | 0.433 | 0.153 | 0.068 | 0.021 | 0.000 | 0.006 | 0.000 | 0.000 | 1.819 |
| 1995 | 0.160 | 0.245 | 1.811 | 1.249 | 0.087 | 0.054 | 0.011 | 0.000 | 0.000 | 0.000 | 0.000 | 3.616 |
| 1996 | 0.022 | 0.240 | 0.196 | 0.414 | 0.143 | 0.060 | 0.027 | 0.000 | 0.000 | 0.000 | 0.000 | 1.101 |
| 1997 | 0.006 | 0.236 | 0.321 | 0.109 | 0.129 | 0.049 | 0.009 | 0.007 | 0.000 | 0.000 | 0.000 | 0.867 |
| 1998 | 0.070 | 0.336 | 1.026 | 0.352 | 0.041 | 0.035 | 0.004 | 0.000 | 0.004 | 0.000 | 0.000 | 1.867 |
| 1999 | 0.070 | 0.140 | 0.154 | 0.310 | 0.255 | 0.087 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.016 |
| 2000 | 0.020 | 0.571 | 0.538 | 0.071 | 0.079 | 0.031 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.308 |
| 2001 | 0.028 | 0.047 | 0.381 | 0.459 | 0.059 | 0.055 | 0.008 | 0.008 | 0.000 | 0.000 | 0.000 | 1.045 |

Table A3b. Stratified mean catch per tow at age (numbers) of Atlantic cod in Canadian spring bottom trawl survey on Georges Bank, 1986 - 2002.

| | AGE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | 0+ |
| SPRING | | | | | | | | | | | |
| 1986 | 0.60 | 2.27 | 2.81 | 0.37 | 0.65 | 0.44 | 0.26 | 0.04 | 0.07 | 0.03 | 7.54 |
| 1987 | 0.25 | 2.13 | 0.93 | 1.09 | 0.34 | 0.12 | 0.22 | 0.08 | 0.03 | 0.07 | 5.26 |
| 1988 | 0.28 | 1.01 | 4.66 | 0.58 | 1.02 | 0.13 | 0.08 | 0.17 | 0.04 | 0.07 | 8.04 |
| 1989 | 1.63 | 2.78 | 1.38 | 2.85 | 0.36 | 0.42 | 0.05 | 0.10 | 0.12 | 0.06 | 9.75 |
| 1990 | 0.42 | 2.44 | 3.78 | 2.08 | 3.87 | 0.42 | 0.93 | 0.12 | 0.12 | 0.35 | 14.53 |
| 1991 | 1.18 | 1.16 | 1.84 | 2.15 | 1.05 | 1.31 | 0.16 | 0.22 | 0.03 | 0.09 | 9.19 |
| 1992 | 0.11 | 2.86 | 1.77 | 0.80 | 0.98 | 0.60 | 0.43 | 0.12 | 0.07 | 0.02 | 7.76 |
| *1993 | 0.05 | 0.60 | 2.83 | 1.04 | 0.62 | 1.23 | 0.44 | 0.42 | 0.07 | 0.12 | 7.42 |
| *1994 | 0.02 | 0.80 | 0.89 | 1.65 | 0.60 | 0.23 | 0.45 | 0.11 | 0.15 | 0.04 | 4.94 |
| 1995 | 0.07 | 0.67 | 1.50 | 0.86 | 0.60 | 0.19 | 0.04 | 0.05 | 0.02 | 0.02 | 4.02 |
| 1996 | 0.14 | 0.49 | 2.31 | 4.02 | 1.09 | 0.79 | 0.33 | 0.08 | 0.11 | 0.03 | 9.39 |
| 1997 | 0.32 | 0.53 | 0.55 | 1.25 | 1.23 | 0.27 | 0.06 | 0.03 | 0.02 | 0.01 | 4.27 |
| 1998 | 0.01 | 0.67 | 0.95 | 0.35 | 0.35 | 0.28 | 0.07 | 0.02 | 0.00 | 0.02 | 2.72 |
| 1999 | 0.33 | 0.32 | 1.49 | 1.09 | 0.41 | 0.26 | 0.15 | 0.01 | 0.02 | 0.01 | 4.09 |
| 2000 | 0.10 | 0.44 | 1.05 | 3.92 | 1.71 | 0.78 | 0.40 | 0.24 | 0.01 | 0.03 | 8.68 |
| 2001 | 0.00 | 0.06 | 0.64 | 0.42 | 1.11 | 0.52 | 0.26 | 0.17 | 0.16 | 0.06 | 3.40 |
| 2002 | 0.01 | 0.09 | 0.57 | 2.05 | 0.68 | 1.22 | 0.40 | 0.17 | 0.05 | 0.08 | 5.32 |
| | | | | | | | | | | | 6.84 |

* indices not included in VPA calibration

Table A4. USA and Canadian sampling of commercial Atlantic cod landings from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 2001.

| | USA | | | | Canada | | | |
|---|---|---|---|---|---|---|---|---|
| | Length Samples | | Age Samples | | Length Samples | | Age Samples | |
| Year | No. | # Fish Measured | No. | # Fish Aged | No. | # Fish Measured | No. | # Fish Aged |
| 1978 | 88 | 6841 | 76 | 1463 | 29 | 7684 | 29 | 1308 |
| 1979 | 80 | 6973 | 79 | 1647 | 13 | 3991 | 12 | 656 |
| 1980 | 69 | 4990 | 67 | 1119 | 10 | 2784 | 10 | 536 |
| 1981 | 57 | 4304 | 57 | 1231 | 17 | 4147 | 16 | 842 |
| 1982 | 151 | 11970 | 147 | 2579 | 17 | 4756 | 8 | 858 |
| 1983 | 146 | 12544 | 138 | 2945 | 15 | 3822 | 14 | 604 |
| 1984 | 100 | 8721 | 100 | 2431 | 7 | 1889 | 7 | 385 |
| 1985 | 100 | 8366 | 100 | 2321 | 29 | 7644 | 20 | 1062 |
| 1986 | 94 | 7515 | 94 | 2222 | 19 | 5745 | 19 | 888 |
| 1987 | 80 | 6395 | 79 | 1704 | 33 | 9477 | 33 | 1288 |
| 1988 | 76 | 6483 | 76 | 1576 | 40 | 11709 | 40 | 1984 |
| 1989 | 66 | 5547 | 66 | 1350 | 32 | 8716 | 32 | 1561 |
| 1990 | 83 | 7158 | 83 | 1700 | 40 | 9901 | 40 | 2012 |
| 1991 | 88 | 7708 | 88 | 1865 | 45 | 10873 | 45 | 1782 |
| 1992 | 77 | 6549 | 77 | 1631 | 48 | 10878 | 48 | 1906 |
| 1993 | 82 | 6636 | 82 | 1598 | 51 | 12158 | 51 | 2146 |
| 1994 | 58 | 4688 | 54 | 1064 | 104 | 25845 | 101 | 1268 |
| 1995 | 40 | 2879 | 40 | 778 | 36 | 11598 | 36 | 548 |
| 1996 | 55 | 4600 | 54 | 1080 | 129 | 26663 | 129 | 879 |
| 1997 | 80 | 6638 | 80 | 1581 | 118 | 31882 | 38 | 1244 |
| 1998 | 80 | 7076 | 81 | 1545 | 139 | 26549 | 139 | 1720 |
| 1999 | 68 | 5987 | 67 | 1503 | 84 | 24954 | 84 | 918 |
| 2000 | 155 | 12219 | 154 | 2951 | 107 | 20782 | 107 | 1436 |
| 2001 | 108 | 8389 | 108 | 2389 | 108 | 18190 | 108 | 1509 |

Table A5. USA sampling of commercial Atlantic cod landings, by market category, for the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 2001.

| | Number of Samples, by Market Category & Quarter | | | | | | | | | | | | | | | Annual Sampling Intensity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Scrod | | | | | Market | | | | | Large | | | | | No. of Tons Landed/Sample | | | |
| Year | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Scrd | Mkt | Lge | ∑ |
| 1978 | 17 | 15 | 6 | 3 | 41 | 9 | 12 | 13 | 9 | 43 | 1 | 0 | 1 | 2 | 4 | 69 | 374 | 1922 | 302 |
| 1979 | 2 | 5 | 14 | 8 | 29 | 6 | 19 | 11 | 8 | 44 | 2 | 0 | 4 | 1 | 7 | 88 | 407 | 1742 | 408 |
| 1980 | 7 | 10 | 13 | 4 | 34 | 12 | 14 | 5 | 1 | 32 | 3 | 0 | 0 | 0 | 3 | 136 | 588 | 5546 | 580 |
| 1981 | 4 | 10 | 11 | 3 | 28 | 6 | 9 | 10 | 2 | 27 | 2 | 0 | 0 | 0 | 2 | 149 | 634 | 6283 | 594 |
| 1982 | 5 | 9 | 32 | 9 | 55 | 6 | 20 | 27 | 13 | 66 | 8 | 8 | 9 | 5 | 30 | 156 | 279 | 410 | 260 |
| 1983 | 4 | 12 | 17 | 10 | 43 | 12 | 19 | 22 | 14 | 67 | 2 | 15 | 16 | 3 | 36 | 185 | 291 | 259 | 252 |
| 1984 | 6 | 8 | 8 | 7 | 29 | 8 | 15 | 8 | 11 | 42 | 18 | 5 | 3 | 3 | 29 | 138 | 441 | 358 | 329 |
| 1985 | 6 | 7 | 16 | 5 | 34 | 11 | 11 | 12 | 8 | 42 | 4 | 8 | 7 | 5 | 24 | 201 | 299 | 310 | 268 |
| 1986 | 6 | 7 | 7 | 6 | 26 | 8 | 10 | 10 | 11 | 39 | 6 | 5 | 10 | 8 | 29 | 142 | 215 | 186 | 186 |
| 1987 | 7 | 8 | 6 | 8 | 29 | 6 | 8 | 9 | 10 | 33 | 6 | 6 | 4 | 2 | 18 | 240 | 220 | 267 | 238 |
| 1988 | 8 | 6 | 7 | 5 | 26 | 13 | 7 | 9 | 9 | 38 | 4 | 4 | 3 | 1 | 12 | 283 | 331 | 532 | 346 |
| 1989 | 2 | 7 | 9 | 9 | 27 | 7 | 8 | 8 | 7 | 30 | 3 | 4 | 1 | 1 | 9 | 210 | 450 | 660 | 380 |
| 1990 | 8 | 9 | 10 | 4 | 31 | 10 | 13 | 9 | 8 | 40 | 4 | 4 | 4 | 0 | 12 | 295 | 315 | 538 | 340 |
| 1991 | 6 | 11 | 7 | 5 | 29 | 12 | 13 | 8 | 8 | 41 | 4 | 6 | 3 | 5 | 18 | 158 | 293 | 423 | 275 |
| 1992 | 6 | 7 | 7 | 10 | 30 | 8 | 10 | 6 | 9 | 33 | 5 | 5 | 3 | 1 | 14 | 149 | 215 | 377 | 219 |
| 1993 | 5 | 16 | 7 | 6 | 34 | 10 | 10 | 7 | 9 | 36 | 6 | 1 | 3 | 2 | 12 | 126 | 173 | 339 | 178 |
| 1994 | 3 | 9 | 8 | 2 | 22 | 5 | 11 | 7 | 4 | 27 | 1 | 4 | 3 | 1 | 9 | 92 | 187 | 290 | 167 |
| 1995 | 2 | 3 | 13 | 2 | 20 | 2 | 4 | 10 | 2 | 18 | 0 | 1 | 0 | 1 | 2 | 83 | 181 | 880 | 167 |
| 1996 | 6 | 2 | 12 | 3 | 23 | 5 | 6 | 11 | 6 | 28 | 0 | 2 | 1 | 1 | 4 | 59 | 143 | 400 | 127 |
| 1997 | 3 | 11 | 3 | 10 | 27 | 5 | 16 | 9 | 9 | 39 | 3 | 6 | 0 | 5 | 14 | 50 | 105 | 148 | 94 |
| 1998 | 3 | 7 | 23 | 5 | 38 | 10 | 10 | 15 | 3 | 38 | 1 | 2 | 1 | 0 | 3 | 44 | 92 | 573 | 88 |
| 1999 | 5 | 3 | 10 | 1 | 21 | 7 | 13 | 10 | 5 | 38 | 2 | 4 | 2 | 0 | 9 | 80 | 118 | 205 | 118 |
| 2000 | 22 | 20 | 16 | 27 | 85 | 19 | 14 | 13 | 18 | 64 | 2 | 1 | 2 | 2 | 7 | 18 | 71 | 219 | 49 |
| 2001 | 11 | 9 | 13 | 3 | 36 | 9 | 10 | 8 | 10 | 37 | 6 | 12 | 6 | 10 | 34 | 72 | 163 | 55 | 98 |

Table A6. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of total commercial landings of Atlantic cod from the Georges Bank and South stock (NAFO Division 5Z and Subarea 6), 1978-2000.

| | Age | | | | | | | | | | | % of Total Landings | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Total | USA | Canada |
| | | | | | | Total Commercial Landings in Numbers (000's) at Age | | | | | | | |
| 1978 | 2 | 393 | 7748 | 2303 | 830 | 131 | 345 | 47 | 40 | 15 | 11854 | 73.7 | 26.3 |
| 1979 | 34 | 1989 | 900 | 4870 | 1212 | 458 | 77 | 253 | 4 | 48 | 9845 | 81.2 | 18.8 |
| 1980 | 89 | 3777 | 5828 | 500 | 2308 | 1076 | 445 | 87 | 167 | 10 | 14287 | 80.9 | 19.1 |
| 1981 | 27 | 3205 | 4221 | 2464 | 235 | 1406 | 417 | 123 | 130 | 62 | 12290 | 84.1 | 15.9 |
| 1982 | 331 | 9138 | 3824 | 2787 | 2000 | 281 | 673 | 213 | 71 | 83 | 19401 | 74.1 | 25.9 |
| 1983 | 108 | 4286 | 8063 | 2456 | 1055 | 776 | 95 | 235 | 100 | 65 | 17239 | 72.2 | 27.8 |
| 1984 | 81 | 1307 | 3423 | 3336 | 840 | 516 | 458 | 44 | 171 | 121 | 10297 | 89.0 | 11.0 |
| 1985 | 134 | 6426 | 2443 | 1368 | 1885 | 412 | 218 | 203 | 21 | 97 | 13207 | 68.4 | 31.6 |
| 1986 | 156 | 1326 | 4573 | 797 | 480 | 627 | 87 | 72 | 47 | 29 | 8194 | 71.7 | 28.3 |
| 1987 | 26 | 7473 | 1406 | 2121 | 279 | 252 | 270 | 63 | 38 | 24 | 11952 | 64.2 | 35.8 |
| 1988 | 10 | 1577 | 8022 | 1012 | 1497 | 244 | 161 | 197 | 50 | 47 | 12817 | 71.6 | 28.4 |
| 1989 | - | 2088 | 2922 | 4155 | 331 | 541 | 82 | 43 | 50 | 18 | 10230 | 81.1 | 18.9 |
| 1990 | 7 | 4942 | 5042 | 1882 | 2264 | 229 | 245 | 36 | 17 | 38 | 14702 | 74.3 | 25.7 |
| 1991 | 52 | 1525 | 3243 | 3281 | 1458 | 1088 | 126 | 70 | 23 | 23 | 10889 | 67.7 | 32.3 |
| 1992 | 70 | 4177 | 2170 | 1038 | 1482 | 404 | 309 | 34 | 33 | 10 | 9727 | 58.7 | 41.3 |
| 1993 | 4 | 1033 | 4246 | 1115 | 440 | 472 | 159 | 143 | 32 | 17 | 7661 | 67.0 | 33.0 |
| 1994 | 2 | 398 | 1526 | 1825 | 394 | 96 | 137 | 46 | 38 | 6 | 4468 | 68.5 | 31.5 |
| 1995 | 0.1 | 392 | 1058 | 692 | 290 | 44 | 26 | 15 | 2 | 1 | 2520 | 86.9 | 13.1 |
| 1996 | 0.7 | 207 | 903 | 1234 | 241 | 123 | 15 | 3 | 5 | 0.2 | 2731 | 80.0 | 20.0 |
| 1997 | 3 | 517 | 639 | 881 | 794 | 131 | 84 | 16 | 9 | 4 | 3078 | 74.2 | 25.8 |
| 1998 | 0.2 | 739 | 1188 | 423 | 324 | 237 | 39 | 14 | 6 | 4 | 2975 | 81.9 | 18.1 |
| 1999 | 2 | 285 | 1927 | 706 | 201 | 97 | 119 | 16 | 2 | 3 | 3359 | 83.7 | 16.3 |
| 2000 | 6 | 811 | 710 | 1024 | 306 | 72 | 38 | 25 | 2 | 1 | 2994 | 84.5 | 15.5 |
| 2001 | - | 682 | 2381 | 647 | 595 | 163 | 46 | 22 | 11 | 2 | 4548 | 86.6 | 13.4 |
| | | | | | | Total Commercial Landings in Weight (Tons) at Age | | | | | | | |
| 1978 | 1 | 515 | 18890 | 7990 | 3597 | 757 | 2549 | 395 | 465 | 198 | 35357 | 75.2 | 24.8 |
| 1979 | 30 | 2970 | 1936 | 20504 | 5923 | 3288 | 711 | 2611 | 44 | 606 | 38623 | 84.5 | 15.5 |
| 1980 | 75 | 5516 | 14382 | 1833 | 13036 | 7184 | 3735 | 793 | 1408 | 154 | 48116 | 83.2 | 16.8 |
| 1981 | 24 | 4789 | 9953 | 8416 | 1224 | 10156 | 3575 | 1212 | 1848 | 1151 | 42348 | 79.9 | 20.1 |
| 1982 | 253 | 12812 | 10187 | 10681 | 10705 | 1827 | 6303 | 2110 | 891 | 1388 | 57157 | 68.8 | 31.2 |
| 1983 | 105 | 6387 | 19167 | 8126 | 4891 | 4963 | 763 | 2418 | 1120 | 946 | 48886 | 75.2 | 24.8 |
| 1984 | 85 | 2137 | 8389 | 12074 | 4271 | 3401 | 4078 | 447 | 1938 | 1858 | 38678 | 85.1 | 14.9 |
| 1985 | 121 | 9111 | 5095 | 5319 | 9588 | 2644 | 1765 | 2073 | 246 | 1309 | 37271 | 72.0 | 28.0 |
| 1986 | 145 | 1955 | 11189 | 2917 | 2692 | 4505 | 776 | 717 | 596 | 409 | 25901 | 67.5 | 32.5 |
| 1987 | 19 | 11071 | 3509 | 8882 | 1619 | 1945 | 2416 | 633 | 426 | 360 | 30880 | 61.6 | 38.4 |
| 1988 | 8 | 2399 | 18923 | 3552 | 8085 | 1618 | 1412 | 1960 | 566 | 719 | 39242 | 67.0 | 33.0 |
| 1989 | - | 3375 | 6633 | 15673 | 1783 | 3625 | 669 | 455 | 588 | 298 | 33098 | 75.8 | 24.2 |
| 1990 | 5 | 7709 | 12412 | 6629 | 11075 | 1448 | 2069 | 382 | 222 | 552 | 42503 | 66.3 | 33.7 |
| 1991 | 59 | 2481 | 8265 | 11221 | 6955 | 6411 | 933 | 736 | 223 | 346 | 37630 | 64.2 | 35.8 |
| 1992 | 80 | 6441 | 5348 | 3991 | 6971 | 2486 | 2322 | 334 | 402 | 192 | 28567 | 59.0 | 41.0 |
| 1993 | 3 | 1585 | 9566 | 3717 | 2184 | 3012 | 1195 | 1315 | 316 | 220 | 23113 | 63.1 | 36.9 |
| 1994 | 2 | 581 | 3308 | 6673 | 1892 | 716 | 1095 | 430 | 364 | 103 | 15165 | 65.2 | 34.8 |
| 1995 | 0.1 | 577 | 2215 | 2649 | 1595 | 327 | 273 | 174 | 20 | 20 | 7851 | 86.1 | 13.9 |
| 1996 | 0.6 | 311 | 2199 | 4178 | 1183 | 817 | 127 | 21 | 59 | 2 | 8898 | 78.9 | 21.1 |
| 1997 | 3 | 816 | 1483 | 3114 | 3256 | 790 | 674 | 135 | 111 | 53 | 10435 | 72.2 | 27.8 |
| 1998 | 0.1 | 1096 | 2735 | 1477 | 1532 | 1408 | 323 | 117 | 82 | 61 | 8832 | 78.8 | 21.2 |
| 1999 | 1 | 446 | 4283 | 2437 | 985 | 622 | 874 | 159 | 27 | 45 | 9880 | 81.6 | 18.4 |
| 2000 | 6 | 1386 | 1731 | 3644 | 1478 | 424 | 283 | 213 | 14 | 9 | 9189 | 82.9 | 17.1 |
| 2001 | - | 1034 | 5627 | 2038 | 2582 | 899 | 283 | 180 | 110 | 20 | 12772 | 83.3 | 16.7 |

Table A6 continued. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of total commercial landings of Atlantic cod from the Georges Bank and South stock (NAFO Division 5Z and Subarea 6), 1978-2001.

| Year | Age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Commercial Landings Mean Weight (kg) at Age** | | | | | | | | | | | |
| 1978 | 0.707 | 1.310 | 2.461 | 3.469 | 4.336 | 5.787 | 7.374 | 8.492 | 11.785 | 13.200 | 2.983 |
| 1979 | 0.889 | 1.494 | 2.149 | 4.211 | 4.888 | 7.178 | 9.183 | 10.313 | 11.699 | 12.625 | 3.923 |
| 1980 | 0.836 | 1.460 | 2.468 | 3.668 | 5.647 | 6.676 | 8.390 | 9.089 | 8.432 | 15.400 | 3.368 |
| 1981 | 0.882 | 1.495 | 2.358 | 3.415 | 5.213 | 7.222 | 8.565 | 9.888 | 14.170 | 18.565 | 3.446 |
| 1982 | 0.765 | 1.402 | 2.664 | 3.834 | 5.352 | 6.511 | 9.363 | 9.897 | 12.503 | 16.723 | 2.946 |
| 1983 | 0.971 | 1.490 | 2.377 | 3.309 | 4.637 | 6.393 | 7.964 | 10.286 | 11.227 | 14.554 | 2.836 |
| 1984 | 1.053 | 1.635 | 2.451 | 3.619 | 5.083 | 6.582 | 8.909 | 10.104 | 11.303 | 15.356 | 3.756 |
| 1985 | 0.907 | 1.418 | 2.086 | 3.887 | 5.087 | 6.412 | 8.097 | 10.236 | 11.418 | 13.494 | 2.822 |
| 1986 | 0.929 | 1.475 | 2.447 | 3.660 | 5.603 | 7.191 | 8.915 | 9.955 | 12.687 | 14.104 | 3.161 |
| 1987 | 0.726 | 1.481 | 2.495 | 4.187 | 5.810 | 7.726 | 8.949 | 10.013 | 11.414 | 15.000 | 2.584 |
| 1988 | 0.786 | 1.520 | 2.359 | 3.511 | 5.401 | 6.647 | 8.776 | 9.987 | 11.143 | 15.298 | 3.062 |
| 1989 | - | 1.617 | 2.269 | 3.772 | 5.396 | 6.694 | 8.222 | 10.718 | 11.665 | 17.111 | 3.235 |
| 1990 | 0.831 | 1.560 | 2.462 | 3.522 | 4.892 | 6.333 | 8.456 | 10.648 | 12.580 | 14.526 | 2.891 |
| 1991 | 1.114 | 1.627 | 2.548 | 3.420 | 4.769 | 5.891 | 7.410 | 10.520 | 9.686 | 15.373 | 3.456 |
| 1992 | 1.148 | 1.542 | 2.464 | 3.843 | 4.704 | 6.156 | 7.509 | 9.846 | 12.059 | 19.025 | 2.937 |
| 1993 | 0.872 | 1.534 | 2.253 | 3.333 | 4.967 | 6.379 | 7.510 | 9.217 | 9.699 | 13.236 | 3.017 |
| 1994 | 0.906 | 1.459 | 2.168 | 3.657 | 4.804 | 7.432 | 8.013 | 9.368 | 9.698 | 16.659 | 3.394 |
| 1995 | 0.906 | 1.471 | 2.095 | 3.830 | 5.492 | 7.384 | 10.715 | 11.617 | 10.383 | 14.953 | 3.087 |
| 1996 | 0.882 | 1.507 | 2.435 | 3.387 | 4.912 | 6.622 | 8.369 | 8.438 | 12.883 | 12.002 | 3.212 |
| 1997 | 0.954 | 1.577 | 2.321 | 3.532 | 4.103 | 6.019 | 8.050 | 8.631 | 11.870 | 12.795 | 3.390 |
| 1998 | 0.579 | 1.483 | 2.302 | 3.497 | 4.735 | 5.934 | 8.185 | 8.610 | 12.684 | 14.606 | 2.969 |
| 1999 | 0.830 | 1.565 | 2.223 | 3.452 | 4.891 | 6.422 | 7.341 | 9.685 | 12.153 | 13.735 | 2.941 |
| 2000 | 1.055 | 1.710 | 2.437 | 3.558 | 4.836 | 5.923 | 7.406 | 8.498 | 8.267 | 10.594 | 3.069 |
| 2001 | 0.880 | 1.517 | 2.363 | 3.152 | 4.337 | 5.510 | 6.217 | 8.230 | 9.818 | 12.477 | 2.808 |
| 1978-2000 | 0.888 | 1.514 | 2.361 | 3.634 | 5.028 | 6.589 | 8.338 | 9.747 | 11.365 | 14.434 | |
| 1996-2000 | 0.879 | 1.565 | 2.346 | 3.487 | 4.712 | 6.191 | 7.890 | 8.797 | 11.570 | 12.735 | |
| **Total Commercial Landings Mean Length (cm) at Age** | | | | | | | | | | | |
| 1978 | 39.5 | 50.0 | 60.8 | 67.9 | 72.7 | 80.4 | 80.2 | 93.1 | 103.4 | 106.5 | 64.1 |
| 1979 | 44.7 | 52.2 | 57.7 | 73.2 | 76.8 | 87.5 | 95.3 | 99.5 | 103.4 | 106.4 | 69.6 |
| 1980 | 43.8 | 51.8 | 61.2 | 69.7 | 80.9 | 86.0 | 92.4 | 93.8 | 92.4 | 114.6 | 65.6 |
| 1981 | 44.4 | 52.2 | 60.2 | 68.4 | 78.2 | 88.0 | 93.5 | 97.5 | 110.3 | 119.5 | 65.6 |
| 1982 | 42.2 | 51.2 | 62.4 | 70.5 | 79.1 | 84.3 | 96.0 | 97.4 | 105.8 | 115.0 | 61.9 |
| 1983 | 45.5 | 52.3 | 60.4 | 67.0 | 75.3 | 84.4 | 90.7 | 99.1 | 101.9 | 111.4 | 62.4 |
| 1984 | 47.2 | 54.0 | 61.5 | 69.8 | 77.8 | 85.5 | 94.4 | 98.6 | 102.3 | 112.8 | 68.6 |
| 1985 | 44.9 | 51.1 | 57.5 | 71.4 | 78.0 | 84.3 | 91.3 | 98.8 | 102.3 | 108.2 | 61.1 |
| 1986 | 45.0 | 51.9 | 61.1 | 69.2 | 80.7 | 87.7 | 94.4 | 98.0 | 105.9 | 108.4 | 64.3 |
| 1987 | 40.7 | 51.8 | 61.2 | 73.0 | 81.8 | 90.1 | 94.5 | 98.2 | 102.5 | 111.2 | 59.7 |
| 1988 | 40.8 | 52.8 | 60.4 | 68.5 | 79.5 | 85.3 | 93.6 | 97.7 | 101.5 | 111.2 | 64.1 |
| 1989 | - | 53.8 | 60.0 | 70.4 | 79.2 | 85.2 | 91.7 | 100.3 | 103.2 | 113.3 | 65.7 |
| 1990 | 41.7 | 53.5 | 61.0 | 68.7 | 76.6 | 83.2 | 92.1 | 100.2 | 106.0 | 110.8 | 62.9 |
| 1991 | 47.7 | 53.6 | 62.2 | 67.7 | 75.8 | 80.9 | 87.8 | 99.4 | 95.9 | 113.9 | 67.0 |
| 1992 | 46.2 | 52.4 | 60.8 | 70.6 | 75.1 | 82.2 | 87.9 | 96.0 | 104.3 | 116.0 | 62.4 |
| 1993 | 42.2 | 52.7 | 59.6 | 67.0 | 76.3 | 83.6 | 88.2 | 95.1 | 95.9 | 107.0 | 63.0 |
| 1994 | 43.1 | 51.7 | 58.9 | 69.6 | 75.8 | 88.2 | 90.7 | 95.3 | 95.9 | 115.8 | 65.8 |
| 1995 | 43.0 | 50.6 | 58.2 | 70.9 | 80.5 | 88.5 | 100.9 | 103.8 | 99.1 | 113.0 | 64.6 |
| 1996 | 45.1 | 52.7 | 61.2 | 68.0 | 76.9 | 85.5 | 90.7 | 91.0 | 106.9 | 104.6 | 66.4 |
| 1997 | 43.7 | 53.4 | 60.2 | 68.8 | 72.1 | 82.3 | 91.2 | 93.1 | 104.2 | 106.5 | 66.7 |
| 1998 | 37.8 | 52.4 | 60.1 | 68.8 | 76.0 | 82.2 | 91.4 | 93.1 | 106.4 | 111.9 | 61.7 |
| 1999 | 41.5 | 53.4 | 59.6 | 68.6 | 76.9 | 84.1 | 88.5 | 96.6 | 103.4 | 109.0 | 64.0 |
| 2000 | 47.3 | 55.1 | 61.6 | 69.6 | 76.9 | 82.2 | 88.6 | 93.1 | 92.5 | 107.9 | 65.2 |
| 2001 | 43.0 | 53.1 | 60.9 | 66.7 | 74.0 | 80.2 | 83.0 | 91.6 | 97.7 | 102.2 | 63.4 |

Table A7. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F), mean biomass (mt), spawning stock biomass (mt), and percent mature of Georges Bank cod, estimated from virtual population analysis (VPA), calibrated using the commercial catch at age ADAPT formulation, 1978-2001.

**Stock Numbers (Jan 1 ) in thousands**

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 27711 | 23512 | 20109 | 41393 | 17470 | 9614 | 27389 | 8671 | 42749 | 16376 | 23445 | 15674 | 9196 | 17857 | 6619 | 8175 | 5335 | 3940 | 6884 | 10464 | 4307 | 10259 | 4969 | 1556 | 1651 |
| 2 | 4270 | 22686 | 19219 | 16383 | 33865 | 14004 | 7774 | 22351 | 6978 | 34859 | 13384 | 19186 | 12833 | 7523 | 14573 | 5356 | 6690 | 4366 | 3226 | 5636 | 8565 | 3526 | 8398 | 4063 | 1274 |
| 3 | 25527 | 3140 | 16774 | 12318 | 10513 | 19458 | 7587 | 5182 | 12485 | 4513 | 21778 | 9531 | 13819 | 6035 | 4779 | 8152 | 3450 | 5117 | 3220 | 2454 | 4146 | 6344 | 2629 | 6142 | 2709 |
| 4 | 7933 | 13889 | 1756 | 8460 | 6266 | 5148 | 8635 | 3115 | 2032 | 6084 | 2423 | 10572 | 5159 | 6752 | 2006 | 1949 | 2832 | 1444 | 3232 | 1819 | 1431 | 2320 | 3450 | 1510 | 2874 |
| 5 | 2877 | 4411 | 6965 | 986 | 4697 | 2608 | 1992 | 4051 | 1312 | 943 | 3062 | 1068 | 4896 | 2521 | 2559 | 703 | 587 | 667 | 556 | 1530 | 692 | 789 | 1260 | 1898 | 651 |
| 6 | 1127 | 1604 | 2515 | 3614 | 594 | 2036 | 1181 | 871 | 1611 | 640 | 519 | 1152 | 575 | 1960 | 745 | 754 | 178 | 124 | 284 | 237 | 534 | 273 | 464 | 755 | 1016 |
| 7 | 1414 | 804 | 899 | 1085 | 1687 | 232 | 965 | 500 | 340 | 752 | 296 | 204 | 454 | 263 | 620 | 244 | 191 | 59 | 62 | 121 | 76 | 223 | 136 | 315 | 471 |
| 8 | 67 | 846 | 588 | 334 | 511 | 772 | 104 | 375 | 212 | 200 | 371 | 97 | 93 | 150 | 102 | 228 | 56 | 32 | 25 | 37 | 23 | 27 | 75 | 77 | 216 |
| 9 | 147 | 12 | 463 | 403 | 162 | 226 | 419 | 46 | 124 | 108 | 107 | 126 | 40 | 44 | 60 | 52 | 57 | 4 | 13 | 17 | 16 | 6 | 7 | 39 | 43 |
| 10+ | 55 | 148 | 27 | 191 | 187 | 145 | 293 | 208 | 76 | 68 | 99 | 45 | 89 | 43 | 18 | 27 | 9 | 2 | 1 | 1 | 10 | 9 | 4 | 7 | 25 |
| 1 + | 71127 | 71052 | 69317 | 85166 | 75953 | 54244 | 56341 | 45370 | 67920 | 64543 | 65484 | 57655 | 47154 | 43147 | 32080 | 25642 | 19384 | 15755 | 17501 | 22317 | 19800 | 23776 | 21392 | 16361 | 10931 |

**Fishing Mortality**

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0.02 | 0.01 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.11 | 0.1 | 0.24 | 0.24 | 0.35 | 0.41 | 0.21 | 0.38 | 0.24 | 0.27 | 0.14 | 0.13 | 0.55 | 0.25 | 0.38 | 0.24 | 0.07 | 0.1 | 0.07 | 0.11 | 0.1 | 0.09 | 0.11 | 0.21 |
| 3 | 0.41 | 0.38 | 0.48 | 0.48 | 0.51 | 0.61 | 0.69 | 0.74 | 0.52 | 0.42 | 0.52 | 0.41 | 0.52 | 0.9 | 0.7 | 0.86 | 0.67 | 0.26 | 0.37 | 0.34 | 0.38 | 0.41 | 0.35 | 0.56 |
| 4 | 0.39 | 0.49 | 0.38 | 0.39 | 0.68 | 0.75 | 0.56 | 0.66 | 0.57 | 0.49 | 0.62 | 0.57 | 0.52 | 0.77 | 0.85 | 1 | 1.25 | 0.75 | 0.55 | 0.77 | 0.4 | 0.41 | 0.4 | 0.64 |
| 5 | 0.38 | 0.36 | 0.46 | 0.31 | 0.64 | 0.59 | 0.63 | 0.72 | 0.52 | 0.4 | 0.78 | 0.42 | 0.72 | 1.02 | 1.02 | 1.18 | 1.35 | 0.65 | 0.65 | 0.85 | 0.73 | 0.33 | 0.31 | 0.43 |
| 6 | 0.14 | 0.38 | 0.64 | 0.56 | 0.74 | 0.55 | 0.66 | 0.74 | 0.56 | 0.57 | 0.73 | 0.73 | 0.58 | 0.95 | 0.91 | 1.18 | 0.91 | 0.5 | 0.65 | 0.94 | 0.67 | 0.5 | 0.19 | 0.27 |
| 7 | 0.31 | 0.11 | 0.79 | 0.55 | 0.58 | 0.6 | 0.74 | 0.66 | 0.33 | 0.51 | 0.92 | 0.59 | 0.91 | 0.75 | 0.8 | 1.27 | 1.58 | 0.67 | 0.31 | 1.45 | 0.84 | 0.89 | 0.37 | 0.18 |
| 8 | 1.49 | 0.4 | 0.18 | 0.52 | 0.62 | 0.41 | 0.63 | 0.91 | 0.47 | 0.43 | 0.88 | 0.68 | 0.56 | 0.72 | 0.46 | 1.18 | 2.37 | 0.73 | 0.15 | 0.65 | 1.1 | 1.09 | 0.46 | 0.38 |
| 9 | 0.36 | 0.44 | 0.51 | 0.44 | 0.66 | 0.67 | 0.6 | 0.71 | 0.54 | 0.49 | 0.73 | 0.58 | 0.63 | 0.87 | 0.95 | 1.12 | 1.31 | 0.72 | 0.57 | 0.85 | 0.54 | 0.43 | 0.36 | 0.38 |
| 10+ | 0.36 | 0.44 | 0.51 | 0.44 | 0.66 | 0.67 | 0.6 | 0.71 | 0.54 | 0.49 | 0.73 | 0.58 | 0.63 | 0.87 | 0.95 | 1.12 | 1.31 | 0.72 | 0.57 | 0.85 | 0.54 | 0.43 | 0.36 | 0.38 |
| mn4-8,u | 0.542 | 0.348 | 0.49 | 0.466 | 0.652 | 0.58 | 0.644 | 0.738 | 0.49 | 0.48 | 0.786 | 0.598 | 0.658 | 0.842 | 0.808 | 1.162 | 1.492 | 0.66 | 0.462 | 0.932 | 0.748 | 0.644 | 0.346 | 0.38 |

Table A7 continued. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F), mean biomass (mt), spawning stock biomass (mt), and percent mature of Georges Bank cod, estimated from virtual population analysis (VPA), calibrated using the commercial catch at age ADAPT formulation, 1978-2001.

**Mean biomass (mt)**

| Age | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17756 | 18930 | 15201 | 33078 | 11990 | 8411 | 26099 | 7069 | 35925 | 10766 | 16698 | 11493 | 6923 | 18001 | 6848 | 6460 | 4380 | 3235 | 5503 | 9047 | 2260 | 7717 | 4749 | 1241 |
| 2 | 4816 | 29255 | 22650 | 19782 | 36452 | 15600 | 10449 | 24024 | 8343 | 41183 | 17250 | 26448 | 14056 | 9839 | 17044 | 6647 | 8562 | 5536 | 4253 | 7653 | 10972 | 4782 | 12331 | 5068 |
| 3 | 47057 | 5118 | 29978 | 21112 | 20017 | 31666 | 12313 | 7019 | 21789 | 8384 | 36579 | 16162 | 24293 | 9321 | 7775 | 11337 | 4993 | 8595 | 5973 | 4402 | 7240 | 10561 | 4918 | 10168 |
| 4 | 20817 | 42243 | 4894 | 21839 | 16000 | 10999 | 21920 | 8106 | 5191 | 18429 | 5806 | 27812 | 12975 | 14781 | 4777 | 3783 | 5477 | 3563 | 7708 | 4119 | 3770 | 5995 | 9241 | 3217 |
| 5 | 9449 | 16495 | 28841 | 4033 | 17037 | 8352 | 6888 | 13463 | 5247 | 4126 | 10555 | 4295 | 15689 | 6947 | 6950 | 1899 | 1431 | 2464 | 1838 | 3882 | 2135 | 2993 | 4770 | 6120 |
| 6 | 5533 | 8742 | 11357 | 18264 | 2510 | 9170 | 5214 | 3621 | 8109 | 3448 | 2245 | 5019 | 2527 | 6859 | 2764 | 2614 | 799 | 660 | 1266 | 851 | 2112 | 1265 | 2277 | 3316 |
| 7 | 8154 | 6341 | 4785 | 6532 | 10957 | 1273 | 5563 | 2718 | 2353 | 4828 | 1564 | 1164 | 2322 | 1259 | 2944 | 961 | 713 | 420 | 405 | 478 | 384 | 995 | 769 | 1630 |
| 8 | 275 | 6555 | 4453 | 2347 | 3458 | 5943 | 717 | 2321 | 1538 | 1486 | 2266 | 691 | 696 | 1030 | 732 | 1141 | 189 | 243 | 175 | 216 | 112 | 145 | 464 | 482 |
| 9 | 1326 | 107 | 2801 | 4217 | 1355 | 1693 | 3264 | 341 | 1107 | 894 | 774 | 1020 | 345 | 260 | 427 | 282 | 287 | 29 | 114 | 128 | 142 | 58 | 46 | 287 |
| 10+ | 553 | 1376 | 303 | 2611 | 2091 | 1408 | 3101 | 1838 | 751 | 735 | 985 | 532 | 880 | 406 | 201 | 201 | 76 | 21 | 4 | 11 | 108 | 97 | 30 | 66 |
| Total | 115735 | 135163 | 125262 | 133816 | 121866 | 94514 | 95527 | 70520 | 90352 | 94279 | 94721 | 94636 | 80706 | 68704 | 50461 | 35323 | 26906 | 24767 | 27239 | 30784 | 29235 | 34605 | 39593 | 31595 |

**SSB at the start of the spawning season - males and females (mt)**

| Age | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 912 | 1104 | 850 | 1962 | 1200 | 902 | 3122 | 773 | 8515 | 2226 | 3479 | 2475 | 634 | 1962 | 761 | 639 | 73 | 54 | 88 | 1006 | 191 | 746 | 127 | 28 |
| 2 | 1411 | 7540 | 6911 | 5784 | 16138 | 6347 | 4303 | 11650 | 5030 | 25330 | 8897 | 13716 | 6608 | 4218 | 9018 | 3434 | 2814 | 1868 | 1404 | 3598 | 5521 | 1822 | 4177 | 2114 |
| 3 | 33839 | 3730 | 22412 | 15924 | 15649 | 26065 | 10500 | 6878 | 18776 | 7101 | 32836 | 14539 | 22020 | 9014 | 7415 | 11466 | 5170 | 7871 | 5264 | 3858 | 6596 | 9575 | 4447 | 10333 |
| 4 | 20179 | 38255 | 4300 | 21375 | 15792 | 12655 | 21656 | 8075 | 4841 | 17022 | 6131 | 27183 | 12814 | 16502 | 5219 | 4528 | 6388 | 3549 | 7601 | 4541 | 3691 | 5907 | 8782 | 3637 |
| 5 | 8796 | 16541 | 30441 | 3962 | 17468 | 9635 | 7117 | 14908 | 5434 | 3936 | 12372 | 4192 | 18056 | 8431 | 8374 | 2444 | 1813 | 2594 | 2092 | 4785 | 2425 | 2985 | 4728 | 6718 |
| 6 | 4892 | 8127 | 12487 | 20324 | 2961 | 10514 | 5653 | 4251 | 8583 | 3704 | 2763 | 5933 | 2950 | 8685 | 3351 | 3286 | 898 | 658 | 1486 | 1066 | 2277 | 1342 | 2340 | 3602 |
| 7 | 8094 | 5563 | 5914 | 7240 | 12174 | 1464 | 6221 | 3163 | 2355 | 5363 | 2023 | 1326 | 2841 | 1539 | 3492 | 1299 | 1012 | 453 | 446 | 672 | 446 | 1225 | 854 | 1793 |
| 8 | 366 | 6672 | 5047 | 2693 | 4108 | 6842 | 815 | 2980 | 1702 | 1701 | 2931 | 811 | 769 | 1213 | 777 | 1508 | 307 | 265 | 220 | 273 | 156 | 191 | 528 | 546 |
| 9 | 1339 | 111 | 3841 | 4111 | 1557 | 2059 | 3957 | 420 | 1245 | 1030 | 965 | 1192 | 408 | 372 | 554 | 411 | 422 | 36 | 136 | 146 | 147 | 59 | 60 | 320 |
| 10+ | 657 | 1674 | 376 | 3178 | 2704 | 1825 | 3942 | 2407 | 941 | 907 | 1296 | 673 | 1126 | 554 | 279 | 290 | 115 | 27 | 5 | 15 | 135 | 117 | 35 | 79 |
| Total | 80484 | 89318 | 92581 | 86551 | 89751 | 78309 | 67286 | 55506 | 57423 | 68318 | 73693 | 72041 | 68226 | 52488 | 39239 | 29305 | 19012 | 17375 | 18744 | 19961 | 21585 | 23970 | 26078 | 29170 |

**Percent Mature (females)**

| Age | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 7 | 7 | 7 | 13 | 13 | 13 | 13 | 28 | 28 | 28 | 28 | 12 | 12 | 12 | 12 | 2 | 2 | 2 | 13 | 13 | 13 | 3 | 3 |
| 2 | 34 | 34 | 34 | 34 | 47 | 47 | 47 | 47 | 67 | 67 | 67 | 67 | 52 | 52 | 52 | 52 | 39 | 39 | 39 | 57 | 57 | 57 | 44 | 44 |
| 3 | 78 | 78 | 78 | 78 | 84 | 84 | 84 | 84 | 91 | 91 | 91 | 91 | 90 | 90 | 90 | 90 | 95 | 95 | 95 | 92 | 92 | 92 | 95 | 95 |
| 4 | 96 | 96 | 96 | 96 | 97 | 97 | 97 | 97 | 98 | 98 | 98 | 98 | 99 | 99 | 99 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 5-10+ | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Table A8. Input parameters and results of stochastic projection analysis using a Beverton-Holt stock recruit model for Georges Bank Atlantic cod for 2002-2019 for F2002 =0.85 F2001.

**Input for Projections**:

| Age | Fishing Mortality(PR) | % Mature | Average Weight Stock | Average Weight Landed |
|---|---|---|---|---|
| 1 | 0.00 | 0.03 | 0.677 | 0.884 |
| 2 | 0.15 | 0.44 | 1.151 | 1.515 |
| 3 | 0.60 | 0.95 | 1.887 | 2.361 |
| 4 | 1.00 | 1.00 | 2.920 | 3.614 |
| 5 | 1.00 | 1.00 | 4.232 | 4.996 |
| 6 | 1.00 | 1.00 | 5.693 | 6.543 |
| 7 | 1.00 | 1.00 | 7.332 | 8.245 |
| 8 | 1.00 | 1.00 | 8.914 | 9.679 |
| 9 | 1.00 | 1.00 | 10.432 | 11.301 |
| 10+ | 1.00 | 1.00 | 15.231 | 14.642 |

**Projection results for 2002-2004**

| Year | Recruitment (000 fish) | F | Median Landings (000 mt) | Median SSB (000 mt) |
|---|---|---|---|---|
| F2002= 0.85 F2001 | | | | |
| 2002 | 7295 | 0.32 | 8.083 | 27.031 |
| 2003 | 6994 | 0.15 | 3.787 | 25.250 |
| 2004 | 7626 | 0.15 | 3.979 | 28.781 |

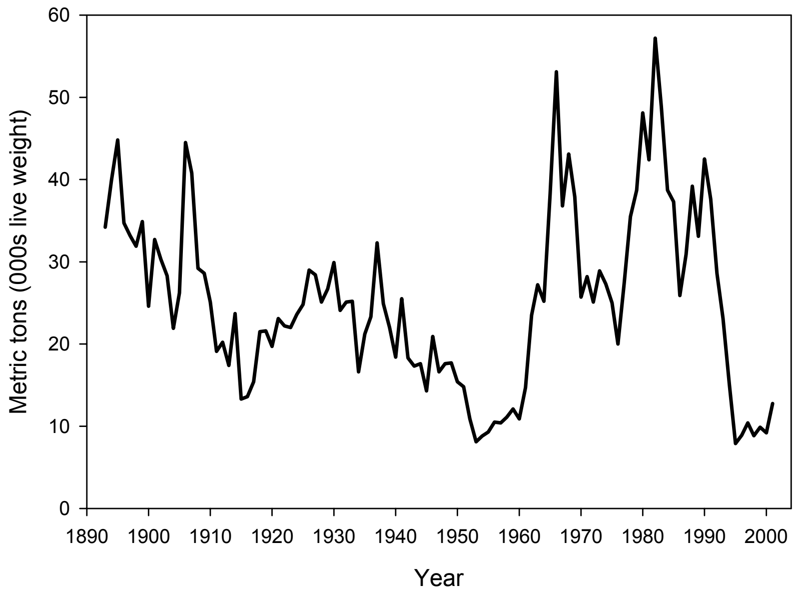



Figure A1a. Total commercial landings of Georges Bank cod (NAFO Division 5Z and Subarea 6), 1893-2001.

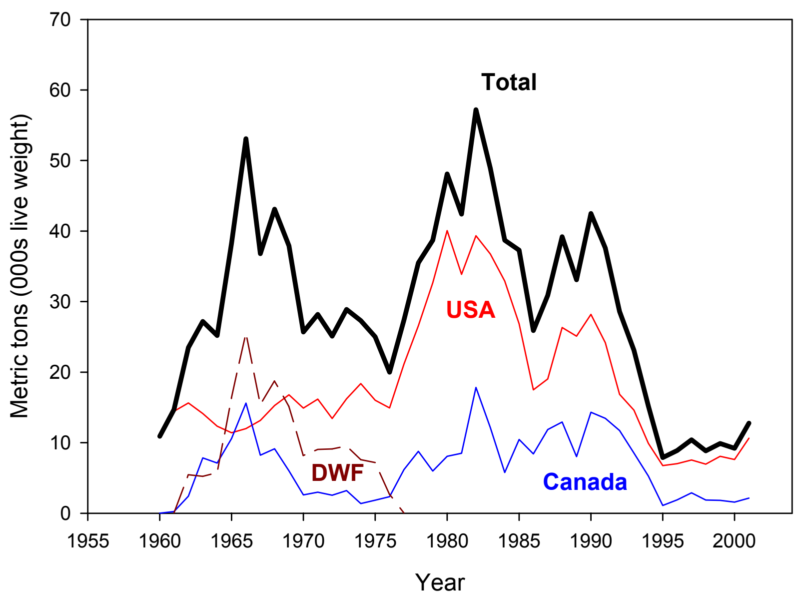



Figure A1b. Total commercial landings of Georges Bank cod (NAFO Division 5Z and Subarea 6), 1960-2001.

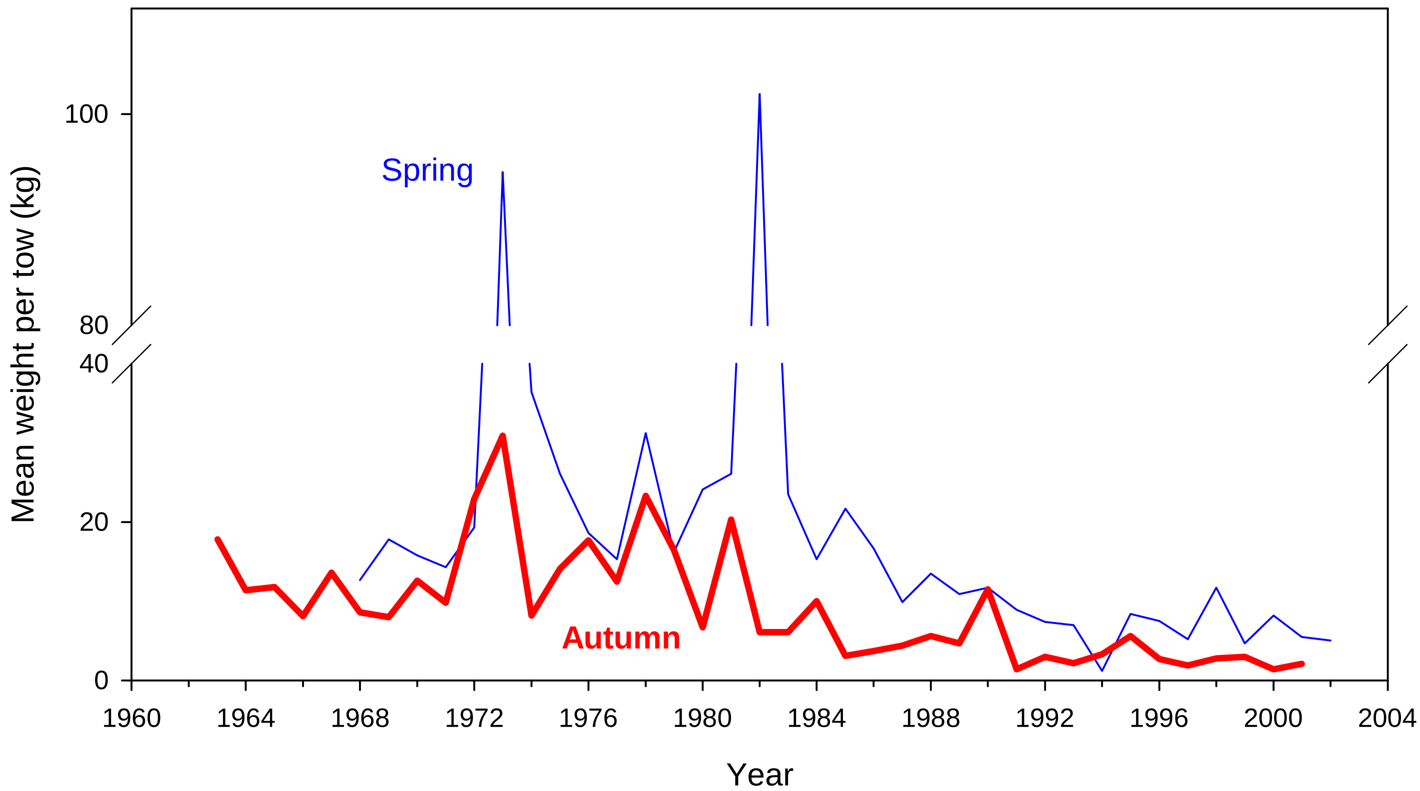



Figure A2. Standardized stratified mean catch per tow (kg) of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-2001.

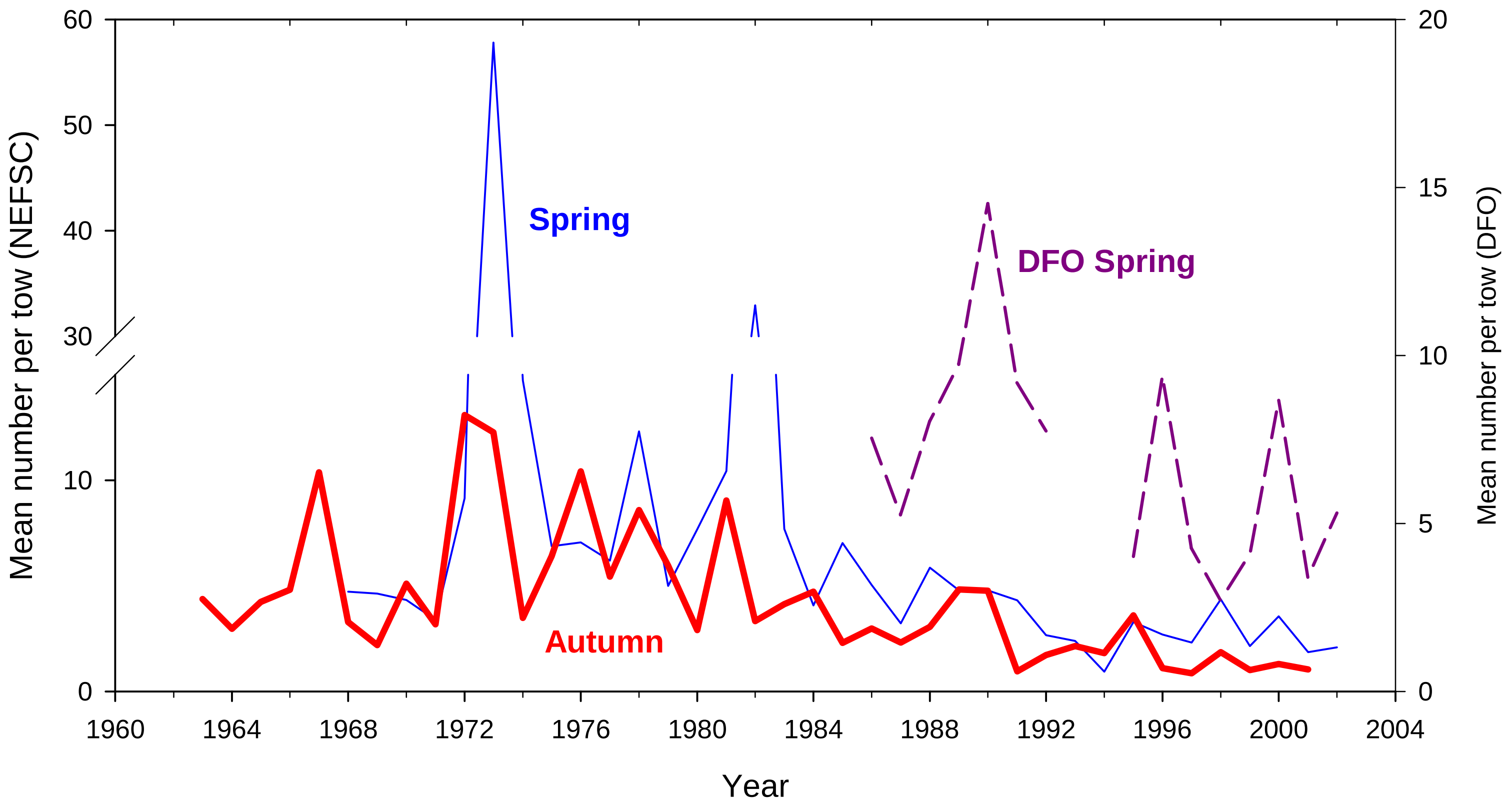



Figure A3. Standardized stratified mean number per tow of Atlantic cod in NEFSC and DFO spring and NEFSC autumn research vessel bottom trawl surveys on Georges Bank, 1963-2002.

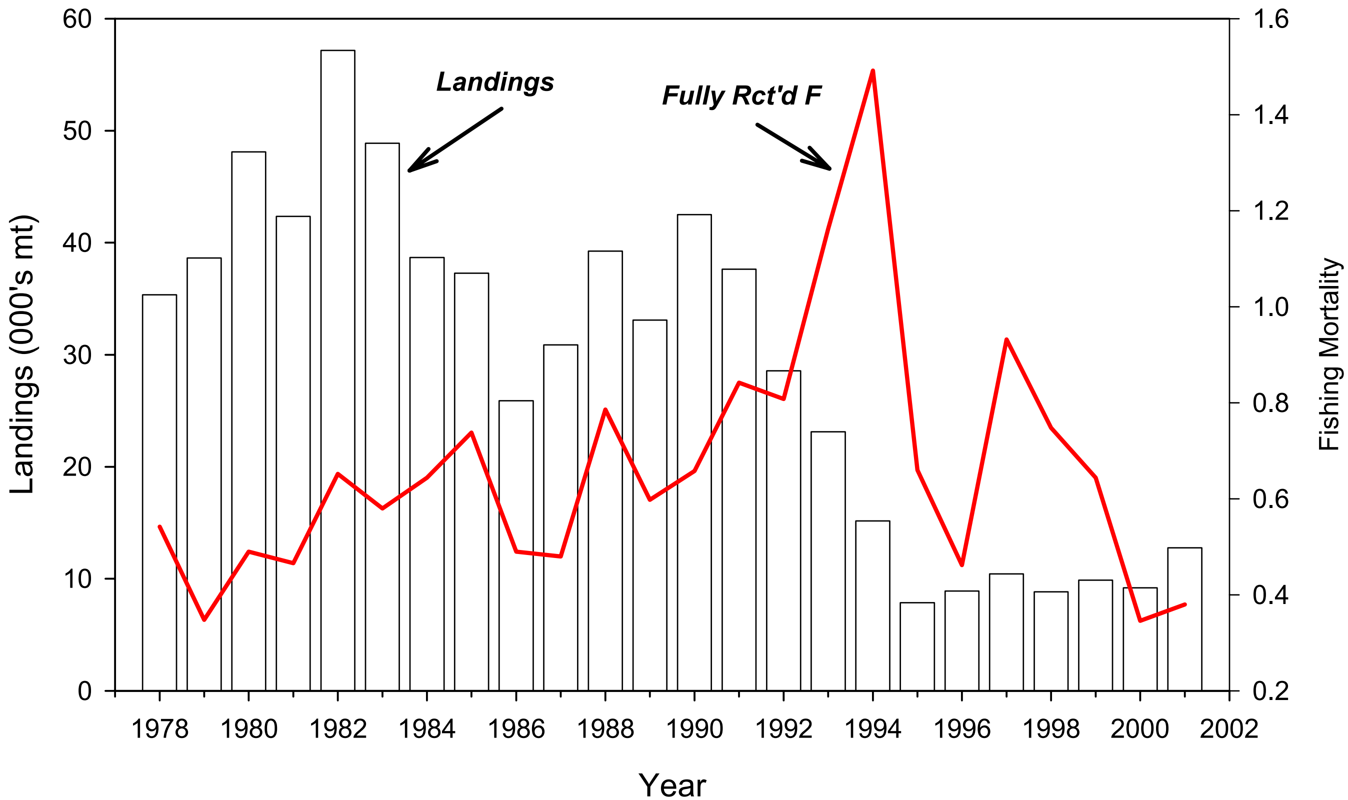



Figure A4. Trends in total commercial landings and fishing mortality for Georges Bank cod, 1978-2001.

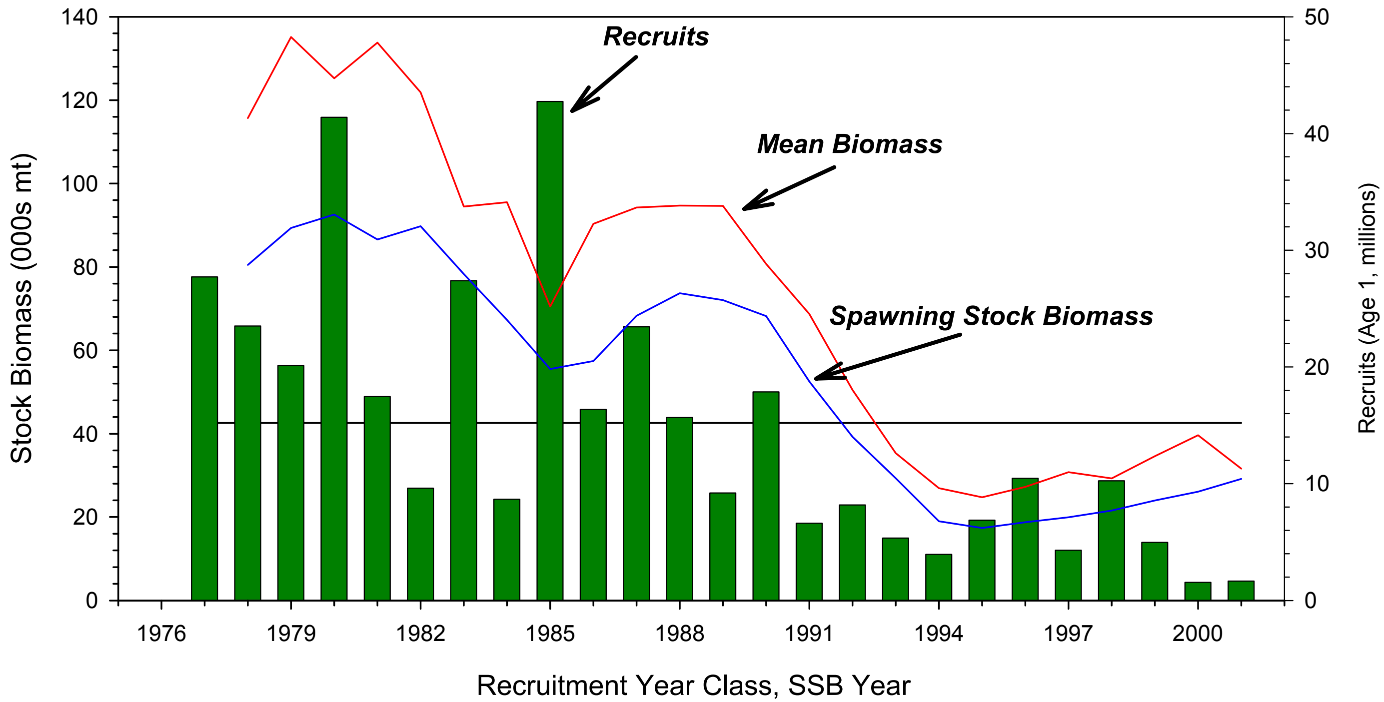



Figure A5. Trends in stock biomass and recruitment for Georges Bank Atlantic cod, 1978-2001. Horizontal line is the average recruitment for the time serioes.

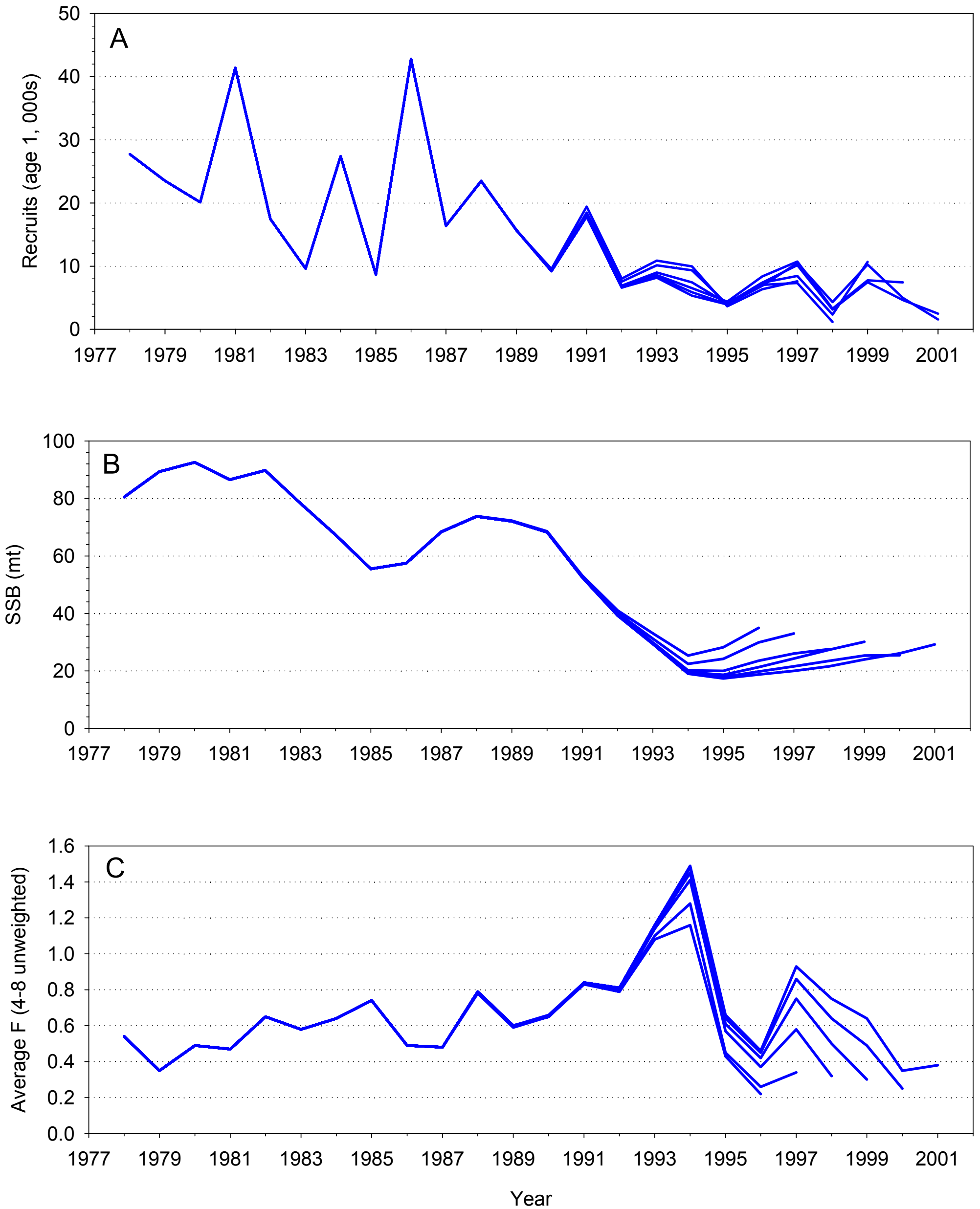



Figure A6. Retrospective analysis of Georges Bank cod recruits at age 1(A), spawning stock biomass (B), and fishing mortality (C) (average F, aged 4-8, unweighted), based on the final ADAPT VPA formulation, 2001-1996.

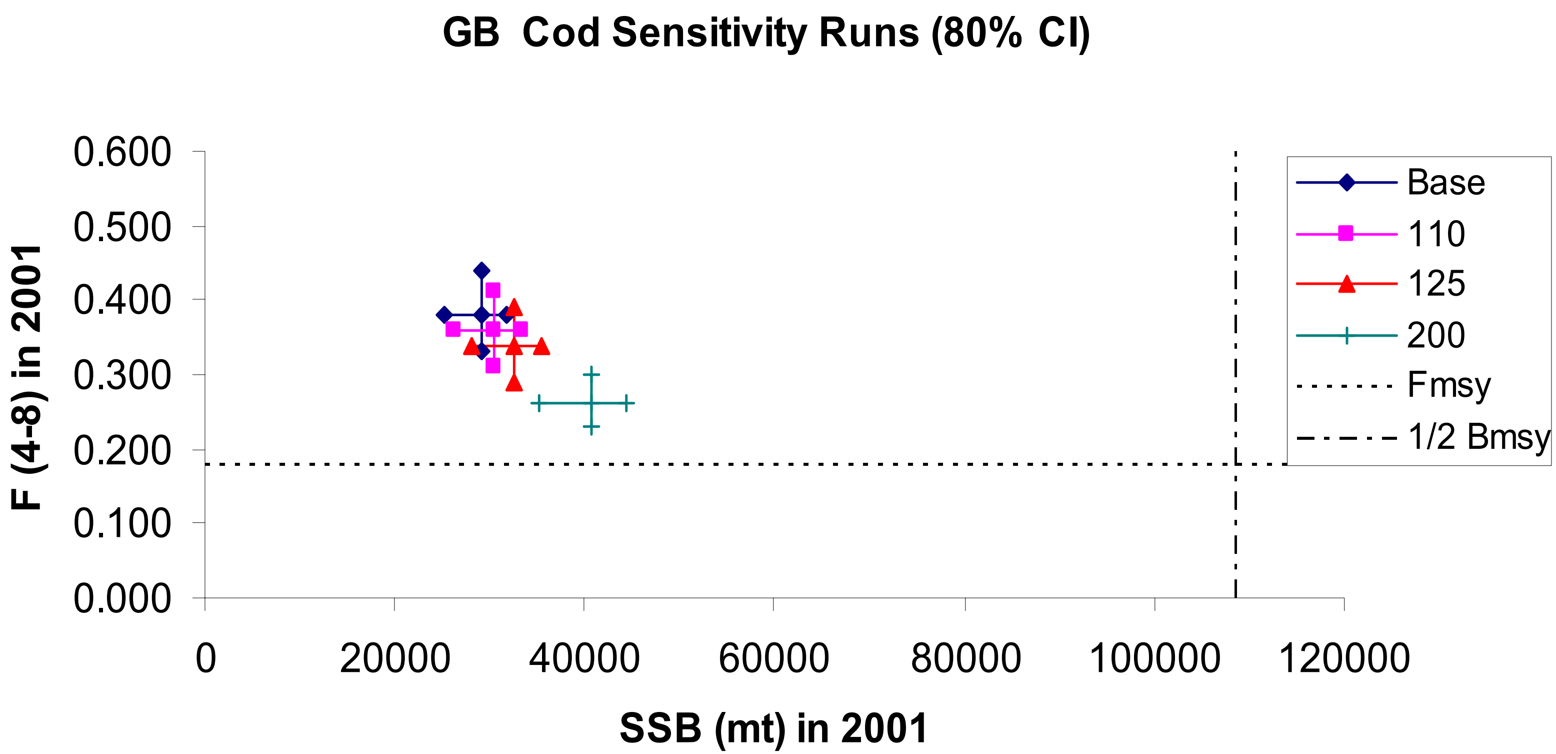



Figure A7. Fishing mortality and spawning stock biomass estimates from VPA calibrated using survey indices increased by 0% (base), 10% (110), 25% (125), and 100 %(200).

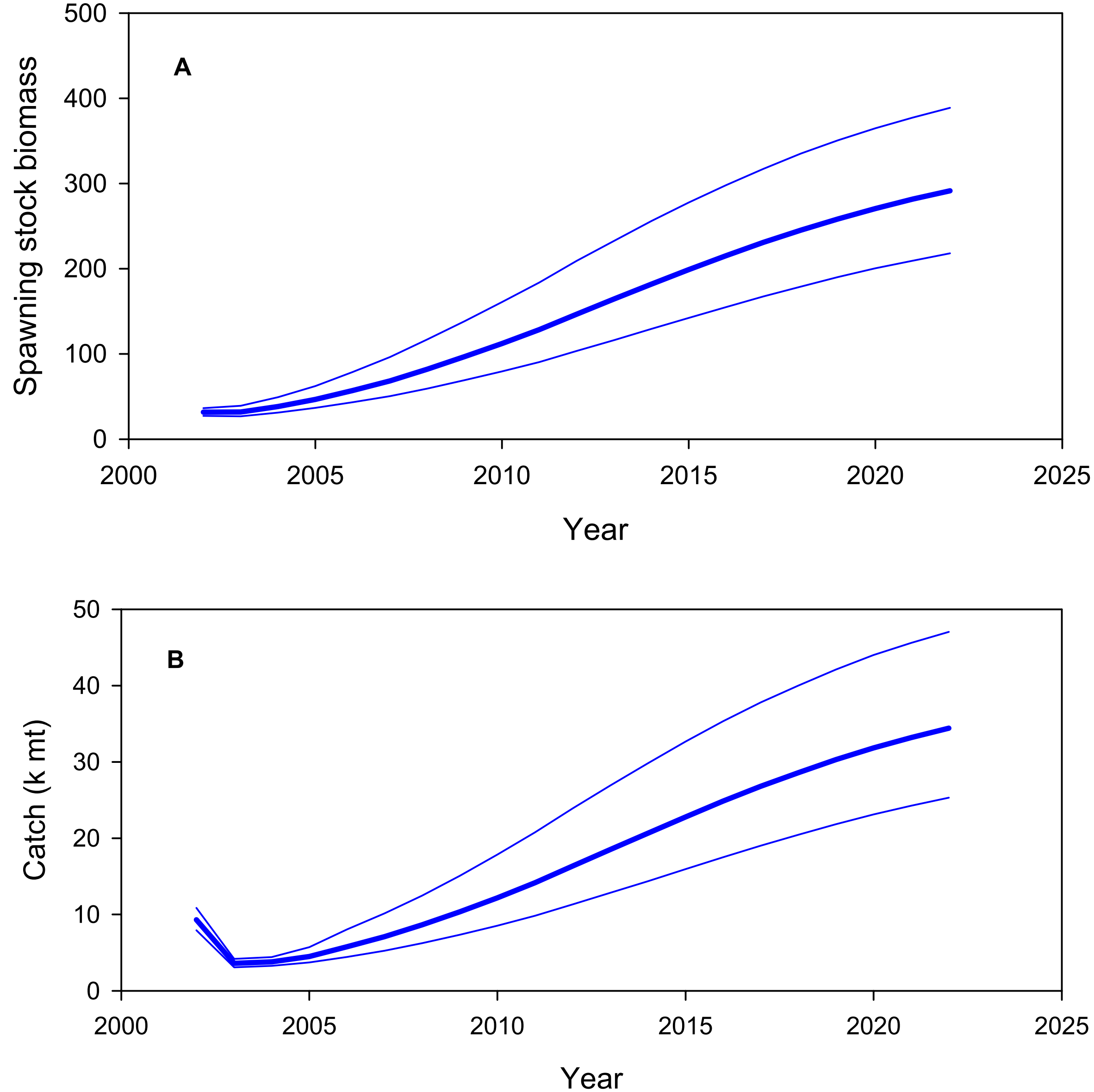



Figure A8. Median and 80% confidence intervals of predicted spawning stock biomass (panel A) and predicted catch (panel B) for Georges Bank Atlantic cod under Frebuild = 0.10.

**B. Georges Bank Haddock** by **Jon Brodziak, Michele Thompson and Russell Brown**

**1.0 Background**

The Georges Bank haddock stock was last assessed at the Transboundary Resources Assessment Committee Meeting in 2001. Based on the 2001 assessment, spawning biomass was increasing (59,700 mt in 2000) from a near-record low of 11,400 mt in 1993 and fishing mortality was relatively low (F=0.19 in 2000). In this report, we update the Georges Bank haddock assessment using fishery data for 2001 and available survey data for 2001-2002. Updated estimates of spawning biomass and fishing mortality are used for stock status determination. Sensitivity of assessment results to survey trawl warp marking discrepancies during 2000-2002 is evaluated. An updated estimate of the fishing mortality required to rebuild the spawning biomass to $B_{MSY}$ by 2009 ($F_{REBUILD}$) is provided.

**2.0 Assessment for 2002**

2.1 2001 Landings

US haddock landings were prorated into Georges Bank and Gulf of Maine stock components using a standard algorithm. US Georges Bank haddock landings totaled 4,637 mt in 2001, a 38% increase over 2000 (Table B1, Figure B1). Canadian landings totaled 6,712 mt in 2001, a 24% increase over 2000. US sea sampling data indicated discard rates of 0-5% in 2001 for primary fishing gears. There were no changes in regulatory measures which might have increased discarding. As a result, discards were assumed to be negligible as in the 2000 and 2001 assessments (Brown and Munroe 2000).

US Commercial fishery sampling increased in 2001 (Table B2) for total number of samples (+41%), fish lengths (+43%), and fish ages (+58%) over 2000 sampling. Commercial fishery sampling on western Georges Bank was adequate to compute US catch-at-age on a quarterly basis (Table B2). Sampling was not adequate on eastern Georges Bank to characterize fishery length compositions due to a lack of large and scrod haddock sampling in the second half of the year (Table B2). US Landings are relatively low on eastern Georges Bank (608 mt in 2001) versus western Georges Bank (4,028 mt in 2001). Fisheries in both areas use otter trawl gear and length selectivity is similar. As a result, US catch-at-age data for eastern Georges Bank was computed on a quarterly basis using the commercial fishery length composition of western Georges Bank landings with the addition of all US length samples from eastern Georges Bank (Table B2). Canadian commercial fishery age-length keys from eastern Georges Bank were used for quarters 2, 3, and 4, while the Canadian spring survey age-length key was used for quarter 1. Canadian commercial fishery length sampling (n=67,905 fish) was over 10-fold greater than US fishery length sampling (n=5,276 fish). Canadian commercial fishery age sampling (n=1,393 fish) was comparable to US fishery length sampling (n=1,985 fish). The US fishery catch-at-age data was combined with the Canadian fishery catch-at-age data to compute total catch at age (Table B3).

2.2 Survey Indices

US spring survey indices were computed for 2001-2002 (Table B4) and US autumn survey indices were computed for 2001 (Table B5) using standardized data. Canadian survey indices for 2001-2002 (Table B6) were provided by DFO, Canada (Stratis Gavaris, personal communication). Canadian survey indices in 2001-2002 were lower than the record high 2000 index which included unusually large catches in stratum 5Z8. Survey maturity-at-age analyses from the 2001 assessment were used for computing spawning biomass.

## 3.0 Assessment Results

### 3.1 VPA Results

An updated VPA analysis for Georges Bank haddock was conducted. The VPA formulation was identical to that used for the 2001 assessment, with the exception that the US spring survey was used for tuning in the terminal year. The updated VPA had a total of 30 new survey index values for calibration. VPA diagnostics indicated a good fit to the survey data with maximal coefficients of variation of catchability ranging from 0.14 to 0.34 across surveys.

VPA results indicate that total stock size increased (Table B7) from 80.5 million fish in 2000 to 111.4 million fish in 2002 (+38%). Spawning biomass increased (Table B8, Figure B3) from 59,000 mt in 2000 to 74,400 mt in 2001 (+26%). Fishing mortality (average ages 4-7, unweighted) increased from 0.19 in 2000 to 0.22 in 2001 (+16%; Table B9, Figure B4). Results indicate that the 1998 (39.5 million) and 2000 (75.1) year classes are the strongest since 1978. Preliminary indications are that the 2001 year class may be well below average. Retrospective analysis suggests a random pattern of retrospective estimation errors (Figure B5). Bootstrap analysis indicates that estimates of spawning biomass and F in 2001 are relatively precise with coefficients of variation of 9-10%.

### 3.2 Sensitivity Analyses

*3.2.1 Potential Survey Trawl Warp Inconsistencies during 2000-2002*

Measurements of NEFSC survey trawl warps in autumn 2002 suggested that right and left warps may have been offset by up to several feet during winter 2000 through spring 2002 surveys. To evaluate the sensitivity of VPA results to potential undercapture of fish, NEFSC spring and autumn survey indices were arbitrarily adjusted upwards by 10%, 25%, and 100% for spring 2000 through spring 2002 (Figure B6). Results are summarized in Section 5.2 (Summary of Assessment Advice).

*3.2.2 Influence of Survey Index Time Series Selection*

VPA analysis for Georges Bank haddock includes three survey index time series (US spring, US fall, and Canadian spring). To evaluate sensitivity of baseline results to selection of survey index time series, VPA analyses were conducted using only one index for calibration. Results indicate that the baseline results are closely matched by one-index results for US spring and US fall indices while one-index results for the Canadian spring index produce higher spawning biomass and lower F estimates than the baseline.

## 4.0 Sources of Uncertainty

- US catch-at-age data for eastern Georges Bank haddock landings are less certain than for western Georges Bank haddock. Improved sampling of US landings from eastern Georges Bank haddock would improve precision of US catch-at-age data.

- Proration of landings are based on preliminary logbook data and are subject to change.

## 5.0 Summary Stock Status

5.1 Biological Reference Points

For Georges Bank haddock, spawning biomass ($B_{MSY}$) and the proxy fishing mortality ($F_{MSY}$) to produce MSY are $B_{MSY}$ = 250,300 mt and $F_{MSY}$ = 0.263 (NEFSC 2002). The overfished threshold ($B_{THRESHOLD}$) for Georges Bank haddock is $B_{THRESHOLD}$ = ½ $B_{MSY}$ = 125,200 mt. The overfishing threshold ($F_{THRESHOLD}$) for Georges Bank haddock is $F_{THRESHOLD} = F_{MSY}$ = 0.26.

5.2 Stock Status in 2001

In 2001, spawning biomass was 74,400 mt (59% of $B_{THRESHOLD}$ and 30% of $B_{MSY}$). Therefore, the Georges Bank haddock stock was overfished in 2001. In 2001, the fishing mortality was 0.22 (85% of $F_{THRESHOLD}$). Therefore, overfishing was not occurring on the Georges Bank haddock stock in 2001.

5.3 Projections

Age-structured projections were conducted to compute $F_{REBUILD}$ for 2003-2009. A two-stage resampling model using the cumulative distribution function of observed recruitment with a cutoff spawning biomass value of 75,000 mt was updated using recruitment results from the baseline VPA and updated mean weights at age and selectivities based on 1999-2001 averages. The assumed value of fishing mortality in 2002 was $F_{2002} = 0.85*F_{2001} = 0.19$. The assumed 15% reduction in F from 2001 to 2002 is based on environmental impact analyses of the probable impacts of implementing the Settlement Agreement for the Amendment 9 groundfish lawsuit during fishing year 2002.

Projection results indicate that $F_{REBUILD}$ = 0.197 (Table B10, Figure B7). Median projected spawning biomass and landings in 2009 under $F_{REBUILD}$ are 250,300 mt and 38,300 mt. Median projected landings in 2002, 2003, and 2004 are 12,500 , 17,800 , and 19,400 mt, respectively. Average projected landings for fishing years 2002-2003 and 2003-2004 are 15,000 and 18,600 mt.

## 6.0 References

Brown, R. W., and N. J. Munroe. 2000. Stock assessment of Georges Bank haddock, 1931-1999. Northeast Fisheries Science Center Ref. Doc. 00-12, NEFSC, Woods Hole, MA 02543.

Northeast Fisheries Science Center [NEFSC]. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. NEFSC Reference Document 02-04, Woods Hole, MA, 02543.

Table B1. Commercial landings (mt) of haddock from Georges Bank and south (NAFO Division 5Z and Subarea 6), 1960-2001.[1]

| Year | U.S. | Canada | USSR | Spain | Other | Total |
|---|---|---|---|---|---|---|
| 1960 | 40800 | 77 | 0 | 0 | 0 | 40877 |
| 1961 | 46384 | 266 | 0 | 0 | 0 | 46650 |
| 1962 | 49409 | 3461 | 1134 | 0 | 0 | 54004 |
| 1963 | 44150 | 8379 | 2317 | 0 | 0 | 54846 |
| 1964 | 46512 | 11625 | 5483 | 2 | 464 | 64086 |
| 1965 | 52823 | 14889 | 81882 | 10 | 758 | 150362 |
| 1966 | 52918 | 18292 | 48409 | 1111 | 544 | 121274 |
| 1967 | 34728 | 13040 | 2316 | 1355 | 30 | 51469 |
| 1968 | 25469 | 9323 | 1397 | 3014 | 1720 | 40923 |
| 1969 | 16456 | 3990 | 65 | 1201 | 540 | 22252 |
| 1970 | 8415 | 1978 | 103 | 782 | 22 | 11300 |
| 1971 | 7306 | 1630 | 374 | 1310 | 242 | 10862 |
| 1972 | 3869 | 609 | 137 | 1098 | 20 | 5733 |
| 1973 | 2777 | 1563 | 602 | 386 | 3 | 5331 |
| 1974 | 2396 | 462 | 109 | 764 | 559 | 4290 |
| 1975 | 3989 | 1358 | 8 | 61 | 4 | 5420 |
| 1976 | 2904 | 1361 | 4 | 46 | 9 | 4324 |
| 1977 | 7934 | 2909 | 0 | 0 | 0 | 10843 |
| 1978 | 12160 | 10179 | 0 | 0 | 0 | 22339 |
| 1979 | 14279 | 5182 | 0 | 0 | 0 | 19461 |
| 1980 | 17470 | 10017 | 0 | 0 | 0 | 27487 |
| 1981 | 19176 | 5658 | 0 | 0 | 0 | 24834 |
| 1982 | 12625 | 4872 | 0 | 0 | 0 | 17497 |
| 1983 | 8682 | 3208 | 0 | 0 | 0 | 11890 |
| 1984 | 8807 | 1463 | 0 | 0 | 0 | 10270 |
| 1985 | 4273 | 3484 | 0 | 0 | 0 | 7757 |
| 1986 | 3339 | 3415 | 0 | 0 | 0 | 6754 |
| 1987 | 2156 | 4703 | 0 | 0 | 0 | 6859 |
| 1988 | 2492 | 4046[2] | 0 | 0 | 0 | 6538 |
| 1989 | 1430 | 3059 | 0 | 0 | 0 | 4489 |
| 1990 | 2001 | 3340 | 0 | 0 | 0 | 5341 |
| 1991 | 1395 | 5446 | 0 | 0 | 0 | 6841 |
| 1992 | 2005 | 4061 | 0 | 0 | 0 | 6066 |
| 1993 | 687 | 3727 | 0 | 0 | 0 | 4414 |
| 1994 | 218[3] | 2411 | 0 | 0 | 0 | 2629 |
| 1995 | 218[3] | 2064 | 0 | 0 | 0 | 2282 |
| 1996 | 313[3] | 3643 | 0 | 0 | 0 | 3956 |
| 1997 | 888[3] | 2622 | 0 | 0 | 0 | 3510 |
| 1998 | 1841[3] | 3371 | 0 | 0 | 0 | 5212 |
| 1999 | 2775[3] | 3680 | 0 | 0 | 0 | 6455 |
| 2000 | 3366[3] | 5402 | 0 | 0 | 0 | 8768 |
| 2001 | 4637[3] | 6712 | 0 | 0 | 0 | 11349 |

[1]All landings 1960-1979 are from Clark et al. (1982); U.S. landings 1980-1981 are from Overholtz et al. (1983); U.S. landings 1982-1993 are from NMFS, NEFSC Detailed Weighout Files and Canvas data; Canadian landings 1980-1998 from Gavaris and Van Eeckhaute (1999); Canadian landings in 1999-2001 from S. Gavaris (Personal Communication).
[2]1895 tons were excluded because of suspected misreporting (Gavaris and Van Eeckhaute 1995).
[3]U.S. landings from 1994-1999 are prorated using Vessel Trip Report data and are considered provisional.

Table B2. U.S. sampling of commercial haddock landings for length and age composition from Georges Bank and south (NAFO Division 5Z and Subarea 6), 1982-2001. Eastern Georges (statistical areas 561, 562, 523 and 524), Western Georges (521, 522, 525, 526, 537, 538, 539 and Subarea 6). Q1, Q2, Q3, Q4, denote quarters 1, 2, 3, and 4, respectively.

| Number of Samples | | | | Number of Samples by Market Category, Area, and Quarter | | | | | | | | | | | | | | | | | | | | Annual Sampling Intensity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Scrod | | | | | | | | | | Large | | | | | | | | | | No. of Tons Landed/Sample | | | |
| | | | | Eastern Georges | | | | | Western Georges | | | | | Eastern Georges | | | | | Western Georges | | | | | East | West | East | West |
| Year | No. | # Fish Meas. | # Fish Aged | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Scrod | | Large | |
| 1982 | 89 | 7851 | 1788 | 6 | 7 | 6 | 3 | 22 | 1 | 4 | 15 | 4 | 24 | 3 | 9 | 8 | 4 | 24 | 1 | 4 | 7 | 7 | 19 | 96 | 54 | 172 | 264 |
| 1983 | 104 | 8955 | 2000 | 3 | 9 | 4 | 4 | 20 | 2 | 5 | 8 | 2 | 17 | 7 | 9 | 6 | 5 | 27 | 2 | 12 | 17 | 5 | 38 | 54 | 35 | 139 | 95 |
| 1984 | 57 | 4762 | 1142 | 11 | 4 | 2 | 1 | 18 | 0 | 1 | 2 | 3 | 6 | 9 | 7 | 1 | 5 | 22 | 3 | 3 | 2 | 3 | 11 | 56 | 65 | 122 | 299 |
| 1985 | 32 | 2528 | 627 | 7 | 4 | 2 | 0 | 13 | 0 | 1 | 2 | 1 | 4 | 7 | 1 | 1 | 0 | 9 | 1 | 0 | 4 | 1 | 6 | 18 | 136 | 161 | 338 |
| 1986 | 30 | 2276 | 571 | 2 | 3 | 1 | 0 | 6 | 0 | 1 | 2 | 1 | 4 | 4 | 2 | 3 | 2 | 11 | 1 | 2 | 3 | 3 | 9 | 186 | 77 | 98 | 92 |
| 1987 | 36 | 2573 | 837 | 2 | 7 | 0 | 1 | 10 | 0 | 0 | 3 | 1 | 4 | 3 | 4 | 1 | 3 | 11 | 2 | 1 | 6 | 2 | 11 | 51 | 41 | 168 | 52 |
| 1988 | 34 | 2542 | 1096 | 2 | 4 | 2 | 4 | 12 | 1 | 2 | 2 | 0 | 5 | 5 | 4 | 1 | 4 | 14 | 1 | 1 | 1 | 0 | 3 | 61 | 47 | 69 | 186 |
| 1989 | 23 | 1548 | 856 | 4 | 1 | 1 | 1 | 7 | 0 | 1 | 7 | 1 | 9 | 2 | 2 | 0 | 1 | 5 | 1 | 1 | 0 | 0 | 2 | 50 | 29 | 87 | 189 |
| 1990 | 27 | 2001 | 945 | 5 | 5 | 1 | 2 | 13 | 1 | 1 | 1 | 1 | 4 | 1 | 5 | 0 | 1 | 7 | 2 | 0 | 1 | 0 | 3 | 46 | 77 | 84 | 167 |
| 1991 | 32 | 1065 | 439 | 3 | 3 | 0 | 3 | 9 | 0 | 0 | 7 | 0 | 7 | 0 | 9 | 0 | 3 | 12 | 4 | 0 | 0 | 0 | 4 | 56 | 48 | 35 | 31 |
| 1992 | 54 | 2456 | 922 | 7 | 10 | 5 | 0 | 22 | 3 | 4 | 0 | 0 | 7 | 3 | 8 | 2 | 0 | 11 | 3 | 4 | 5 | 0 | 12 | 46 | 38 | 56 | 9 |
| 1993 | 31 | 1140 | 533 | 3 | 3 | 0 | 0 | 6 | 2 | 3 | 3 | 2 | 10 | 0 | 11 | 0 | 0 | 11 | 0 | 0 | 2 | 2 | 4 | 30 | 27 | 13 | 20 |
| 1994 | 8 | 546 | 212 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 4 | 11 | 46 | 22 | 23 |
| 1995 | 3 | 198 | 58 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ∞ | 25 | ∞ | ∞ |
| 1996 | 6 | 524 | 191 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 6 | 30 | ∞ | 50 |
| 1997 | 34 | 3203 | 848 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 3 | 10 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 7 | 13 | 22 | ∞ | 22 | 33 | 10 |
| 1998 | 24 | 1692 | 686 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 1 | 2 | 12 | 1 | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 2 | 11 | ∞ | 26 | 271 | 111 |
| 1999 | 28 | 2268 | 595 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 6 | 12 | 0 | 1 | 1 | 0 | 2 | 4 | 4 | 1 | 5 | 14 | ∞ | 60 | 131 | 122 |
| 2000 | 51 | 3699 | 1256 | 1 | 3 | 1 | 4 | 9 | 5 | 2 | 6 | 8 | 21 | 0 | 0 | 1 | 0 | 1 | 7 | 5 | 2 | 6 | 20 | 6 | 37 | 54 | 114 |
| 2001 | 72 | 5276 | 1985 | 1 | 1 | 1 | 0 | 3 | 6 | 4 | 9 | 6 | 25 | 2 | 3 | 0 | 0 | 5 | 7 | 10 | 13 | 9 | 39 | 99 | 56 | 62 | 67 |

Table B3. Total catch at age (000's) and mean weight (kg) at age of commercial landings and discards of haddock from Georges Bank and south (NAFO Division 5Z and Statistical Area 6), 1982-2001.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total Commercial Catch in Numbers (000's) at Age | | | | | |
| 1963 | 2910 | 4047 | 7418 | 11152 | 8198 | 2205 | 1405 | 721 | 1096 | 39152 |
| 1964 | 10101 | 15935 | 4554 | 4776 | 8722 | 5794 | 2082 | 1028 | 1332 | 54324 |
| 1965 | 9601 | 125818 | 44496 | 5356 | 4391 | 6690 | 3772 | 1094 | 1366 | 202584 |
| 1966 | 114 | 6843 | 100810 | 19167 | 2768 | 2591 | 2332 | 1268 | 867 | 136760 |
| 1967 | 1150 | 168 | 2891 | 20667 | 10338 | 1209 | 993 | 917 | 698 | 39031 |
| 1968 | 8 | 2994 | 709 | 1921 | 14519 | 3499 | 667 | 453 | 842 | 25612 |
| 1969 | 2 | 11 | 1698 | 448 | 654 | 5954 | 1574 | 225 | 570 | 11136 |
| 1970 | 46 | 158 | 16 | 570 | 186 | 214 | 2308 | 746 | 464 | 4708 |
| 1971 | 1 | 1375 | 223 | 40 | 289 | 246 | 285 | 1469 | 928 | 4856 |
| 1972 | 156 | 2 | 450 | 81 | 32 | 120 | 78 | 66 | 1236 | 2221 |
| 1973 | 2560 | 2075 | 3 | 386 | 53 | 30 | 77 | 15 | 447 | 5646 |
| 1974[2] | 46 | 4320[2] | 657 | 2 | 70 | 2 | 2 | 53 | 249 | 5401 |
| 1975 | 192 | 1034 | 1864 | 375 | 4 | 42 | 4 | 4 | 88 | 3607 |
| 1976 | 144 | 473 | 550 | 880 | 216 | 0 | 23 | 4 | 112 | 2402 |
| 1977[3] | 1 | 19585[3] | 187 | 680 | 515 | 357 | 4 | 39 | 111 | 21479 |
| 1978[4] | 1 | 761 | 14395[4] | 305 | 567 | 517 | 139 | 14 | 67 | 16766 |
| 1979 | 1 | 26 | 1726 | 7169 | 525 | 410 | 315 | 96 | 46 | 10314 |
| 1980[5] | 8 | 31000[5] | 347 | 975 | 6054 | 594 | 546 | 153 | 81 | 39758 |
| 1981 | 1 | 1743 | 10998 | 831 | 937 | 2572 | 331 | 158 | 94 | 17665 |
| 1982 | 1 | 1165 | 1633 | 3733 | 391 | 569 | 1119 | 106 | 110 | 8827 |
| 1983 | 0 | 214 | 813 | 690 | 2239 | 272 | 186 | 800 | 76 | 5290 |
| 1984 | 0 | 93 | 297 | 727 | 397 | 1482 | 234 | 267 | 543 | 4041 |
| 1985 | 0 | 2406 | 550 | 194 | 461 | 228 | 526 | 78 | 152 | 4596 |
| 1986 | 6 | 54 | 2810 | 223 | 146 | 173 | 150 | 266 | 60 | 3888 |
| 1987 | 0 | 1995 | 129 | 1613 | 122 | 73 | 89 | 106 | 135 | 4262 |
| 1988 | 4 | 52 | 2384 | 134 | 931 | 149 | 55 | 64 | 106 | 3879 |
| 1989 | 0 | 1263 | 86 | 877 | 143 | 358 | 46 | 28 | 45 | 2846 |
| 1990 | 2 | 11 | 1445 | 172 | 868 | 98 | 177 | 46 | 44 | 2863 |
| 1991 | 6 | 448 | 91 | 2149 | 102 | 410 | 73 | 154 | 72 | 3505 |
| 1992 | 7 | 247 | 320 | 132 | 1527 | 111 | 323 | 27 | 94 | 2788 |
| 1993 | 7 | 290 | 350 | 299 | 104 | 659 | 38 | 159 | 76 | 1980 |
| 1994[6] | 1.2 | 268.9 | 810.4 | 170.3 | 65.6 | 69.3 | 150.8 | 43.4 | 42.7 | 1623 |
| 1995[6] | 9.2 | 89.4 | 596.5 | 457.2 | 59.9 | 31.5 | 8.2 | 56.6 | 18.0 | 1327 |
| 1996[6] | 5.1 | 53.6 | 569.6 | 946.0 | 463.6 | 68.2 | 21.9 | 5.4 | 7.9 | 2141 |
| 1997[6] | 29.6 | 174.7 | 285.3 | 755.0 | 547.0 | 212.1 | 18.8 | 15.8 | 39.6 | 2078 |
| 1998[6] | 1.0 | 198.9 | 414.6 | 501.1 | 691.6 | 526.0 | 148.5 | 21.1 | 41.0 | 2544 |
| 1999 | 0.9 | 39.7 | 1062.2 | 582.3 | 497.8 | 509.9 | 335.2 | 142.8 | 40.9 | 3211 |
| 2000 | 0.1 | 390.3 | 618.3 | 1578.2 | 555.9 | 494.9 | 361.1 | 245.6 | 85.3 | 4249 |
| 2001 | 2.1 | 193.8 | 2684.2 | 1128.5 | 1632.7 | 883.2 | 580.2 | 436.6 | 345.9 | 7887 |

Table B3. Continued.

Total Commercial Landings Mean Weight[1](kg) at Age

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ |
|---|---|---|---|---|---|---|---|---|---|
| 1963 | 0.57 | 0.87 | 1.18 | 1.47 | 1.68 | 2.15 | 2.35 | 3.04 | 3.10 |
| 1964 | 0.50 | 0.83 | 1.12 | 1.43 | 1.64 | 2.01 | 2.40 | 2.64 | 2.97 |
| 1965 | 0.58 | 0.69 | 1.03 | 1.35 | 1.67 | 1.99 | 2.26 | 2.66 | 3.11 |
| 1966 | 0.58 | 0.73 | 0.89 | 1.26 | 1.70 | 2.07 | 2.28 | 2.87 | 3.18 |
| 1967 | 0.66 | 0.70 | 0.95 | 1.18 | 1.42 | 2.05 | 2.31 | 2.66 | 3.10 |
| 1968 | 0.59 | 0.81 | 1.05 | 1.32 | 1.57 | 2.10 | 2.32 | 2.62 | 2.86 |
| 1969 | 0.52 | 0.78 | 1.10 | 1.69 | 1.75 | 1.99 | 2.52 | 2.99 | 3.63 |
| 1970 | 0.71 | 1.27 | 1.22 | 1.93 | 2.19 | 2.39 | 2.58 | 3.23 | 3.75 |
| 1971 | (0.67) | 1.03 | 1.31 | 1.74 | 2.39 | 2.81 | 2.92 | 3.10 | 3.72 |
| 1972 | 0.62 | 1.03 | 1.74 | 2.04 | 2.42 | 2.92 | 3.06 | 3.44 | 3.66 |
| 1973 | 0.60 | 1.03 | 1.58 | 2.13 | 2.41 | 3.29 | 3.42 | 3.86 | 3.94 |
| 1974 | 0.72 | 1.06 | 1.82 | 2.32 | 2.83 | 3.76 | 4.05 | 3.92 | 4.26 |
| 1975 | 0.62 | 0.98 | 1.63 | 2.21 | 2.20 | 2.94 | 4.00 | 4.05 | 4.33 |
| 1976 | 0.50 | 0.99 | 1.39 | 1.99 | 2.66 | (3.08) | 3.69 | 4.67 | 4.94 |
| 1977 | (0.53) | 1.07 | 1.44 | 2.17 | 2.73 | 3.21 | 4.15 | 4.00 | 4.99 |
| 1978 | (0.53) | 0.94 | 1.50 | 2.04 | 2.79 | 3.19 | 3.37 | 3.61 | 5.11 |
| 1979 | (0.53) | 1.00 | 1.28 | 2.02 | 2.51 | 3.14 | 3.78 | 3.79 | 4.87 |
| 1980 | 0.55 | 0.94 | 1.21 | 1.73 | 2.17 | 2.82 | 3.60 | 3.56 | 3.87 |
| 1981 | 0.39 | 0.87 | 1.24 | 1.83 | 2.30 | 2.72 | 3.71 | 4.04 | 4.44 |
| 1982 | 0.22 | 0.97 | 1.45 | 1.88 | 2.37 | 2.76 | 3.24 | 3.96 | 4.09 |
| 1983 | (0.33) | 1.02 | 1.37 | 1.83 | 2.21 | 2.65 | 3.25 | 3.36 | 4.27 |
| 1984 | (0.33) | 0.92 | 1.32 | 1.83 | 2.20 | 2.67 | 2.96 | 3.41 | 3.72 |
| 1985 | (0.33) | 0.99 | 1.39 | 1.98 | 2.46 | 2.72 | 3.06 | 3.72 | 3.80 |
| 1986 | 0.45 | 0.94 | 1.36 | 1.83 | 2.56 | 2.83 | 2.96 | 3.46 | 3.78 |
| 1987 | (0.43) | 0.83 | 1.43 | 2.00 | 2.25 | 2.63 | 3.02 | 3.77 | 4.29 |
| 1988 | 0.42 | 0.98 | 1.34 | 1.68 | 2.06 | 2.45 | 2.97 | 3.49 | 3.96 |
| 1989 | (0.53) | 0.89 | 1.48 | 1.79 | 2.21 | 2.57 | 3.24 | 3.56 | 3.82 |
| 1990 | 0.64 | 0.97 | 1.48 | 1.78 | 2.12 | 2.55 | 2.81 | 2.99 | 4.16 |
| 1991 | 0.581 | 1.201 | 1.311 | 1.817 | 2.183 | 2.645 | 2.852 | 3.048 | 4.337 |
| 1992 | 0.538 | 1.175 | 1.639 | 1.768 | 2.186 | 2.519 | 2.967 | 3.365 | 4.267 |
| 1993 | 0.659 | 1.169 | 1.728 | 2.171 | 2.119 | 2.628 | 2.649 | 3.123 | 4.014 |
| 1994 | 0.447 | 1.093 | 1.643 | 2.209 | 2.628 | 2.728 | 2.902 | 3.783 | 4.546 |
| 1995 | 0.429 | 0.967 | 1.489 | 2.025 | 2.542 | 2.815 | 3.275 | 3.091 | 3.981 |
| 1996 | 0.456 | 1.098 | 1.497 | 1.838 | 2.325 | 2.543 | 3.423 | 3.516 | 3.712 |
| 1997 | 0.416 | 0.998 | 1.690 | 1.891 | 2.213 | 2.547 | 3.1.4 | 3.380 | 3.655 |
| 1998 | 0.511 | 0.968 | 1.485 | 1.917 | 2.333 | 2.688 | 3.027 | 3.038 | 4.070 |
| 1999 | 0.678 | 1.101 | 1.527 | 1.830 | 2.111 | 2.339 | 2.697 | 2.973 | 3.682 |
| 2000 | 0.664 | 1.133 | 1.464 | 1.893 | 2.252 | 2.372 | 2.732 | 2.991 | 3.298 |
| 2001 | 0.394 | 1.228 | 1.465 | 1.761 | 2.159 | 2.527 | 2.622 | 2.736 | 3.395 |

[1]Data 1963-1979 from Clark et al. (1982); Data 1980-1981 from Overholtz et al. (1983); Data 1982-1990 from Hayes and Buxton (1992); data from 1991-1994 from O'Brien and Brown (1996); data from 1995-2001 from current assessment, Gavaris and Van Eekhaute (1999), and S. Gavaris (personal communication).
[2]Of this total, approximately 1.0 million fish were added to the catch at age to account for high discards in 1974.
[3]Of this total, approximately 12.8 million fish were added to the catch at age to account for high discards in 1977.
[4]Of this total, approximately 5.0 million fish were added to the catch at age to account for high discards in 1978.
[5]Of this total, approximately 20.0 million fish were added to the catch at age to account for high discards in 1980.
[6]Total includes discards resulting from trip limit regulations for most year classes.

Table B4. Stratified mean catch per tow (numbers) for haddock in NEFSC offshore spring research vessel bottom trawl surveys on Georges Bank (Strata 01130-01250, 01290-01300), 1968-2002. Indices have been corrected to account for changes in catchability due to changes in research vessels and doors.

| Year | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 0.40 | 2.83 | 0.46 | 0.70 | 6.72 | 1.68 | 0.25 | 0.45 | 0.34 | 13.83 |
| 1969 | 0.00 | 0.07 | 0.58 | 0.25 | 0.42 | 4.23 | 1.03 | 0.28 | 0.46 | 7.32 |
| 1970 | 0.67 | 0.25 | 0.00 | 0.33 | 0.46 | 0.46 | 2.00 | 0.98 | 0.85 | 6.00 |
| 1971 | 0.00 | 1.16 | 0.25 | 0.00 | 0.12 | 0.12 | 0.09 | 0.82 | 0.22 | 2.78 |
| 1972 | 4.02 | 0.09 | 0.61 | 0.12 | 0.03 | 0.04 | 0.13 | 0.03 | 1.30 | 6.37 |
| 1973 | 30.68 | 4.84 | 0.00 | 0.54 | 0.09 | 0.00 | 0.18 | 0.01 | 1.28 | 37.62 |
| 1974 | 2.13 | 13.29 | 2.86 | 0.00 | 0.24 | 0.00 | 0.01 | 0.10 | 0.37 | 19.00 |
| 1975 | 0.94 | 0.97 | 3.32 | 0.63 | 0.00 | 0.13 | 0.09 | 0.01 | 0.15 | 6.24 |
| 1976 | 80.79 | 0.30 | 0.60 | 0.92 | 0.43 | 0.00 | 0.04 | 0.00 | 0.10 | 83.18 |
| 1977 | 0.61 | 33.41 | 0.42 | 1.22 | 0.60 | 0.45 | 0.00 | 0.04 | 0.12 | 36.87 |
| 1978 | 0.07 | 0.97 | 15.93 | 0.36 | 0.94 | 0.82 | 0.16 | 0.06 | 0.10 | 19.41 |
| 1979 | 36.12 | 1.58 | 1.13 | 5.71 | 0.33 | 0.16 | 0.37 | 0.06 | 0.04 | 45.50 |
| 1980 | 5.20 | 46.70 | 0.51 | 1.04 | 4.87 | 0.67 | 0.37 | 0.46 | 0.24 | 60.06 |
| 1981 | 3.30 | 3.29 | 19.49 | 2.19 | 0.76 | 1.78 | 0.24 | 0.11 | 0.05 | 31.21 |
| 1982 | 0.76 | 1.53 | 0.94 | 4.07 | 0.42 | 0.28 | 0.61 | 0.00 | 0.00 | 8.61 |
| 1983 | 0.43 | 0.55 | 0.58 | 0.22 | 2.41 | 0.01 | 0.04 | 1.16 | 0.18 | 5.58 |
| 1984 | 2.09 | 1.18 | 0.64 | 0.63 | 0.58 | 0.72 | 0.07 | 0.04 | 0.30 | 6.25 |
| 1985 | 0.00 | 4.96 | 0.76 | 0.40 | 0.87 | 0.34 | 1.17 | 0.10 | 0.25 | 8.85 |
| 1986 | 2.49 | 0.18 | 2.06 | 0.24 | 0.11 | 0.21 | 0.12 | 0.33 | 0.11 | 5.85 |
| 1987 | 0.00 | 3.62 | 0.06 | 0.81 | 0.08 | 0.10 | 0.05 | 0.22 | 0.01 | 4.95 |
| 1988 | 1.55 | 0.04 | 0.99 | 0.13 | 0.32 | 0.12 | 0.11 | 0.12 | 0.00 | 3.38 |
| 1989 | 0.02 | 3.49 | 0.45 | 0.71 | 0.14 | 0.41 | 0.06 | 0.05 | 0.01 | 5.34 |
| 1990 | 0.86 | 0.00 | 5.72 | 0.33 | 0.58 | 0.06 | 0.13 | 0.00 | 0.01 | 7.69 |
| 1991 | 0.54 | 1.07 | 0.24 | 1.85 | 0.09 | 0.10 | 0.02 | 0.04 | 0.02 | 3.97 |
| 1992 | 0.40 | 0.18 | 0.11 | 0.07 | 0.33 | 0.03 | 0.03 | 0.03 | 0.00 | 1.18 |
| 1993 | 1.17 | 0.65 | 0.18 | 0.14 | 0.12 | 0.37 | 0.06 | 0.02 | 0.02 | 2.73 |
| 1994 | 0.70 | 2.68 | 1.00 | 0.15 | 0.10 | 0.07 | 0.16 | 0.02 | 0.05 | 4.92 |
| 1995 | 0.50 | 1.29 | 2.32 | 0.91 | 0.17 | 0.11 | 0.03 | 0.18 | 0.11 | 5.61 |
| 1996 | 1.09 | 4.59 | 8.86 | 5.21 | 2.62 | 0.35 | 0.07 | 0.08 | 0.00 | 22.86 |
| 1997 | 1.79 | 1.02 | 3.35 | 3.66 | 2.01 | 0.89 | 0.13 | 0.07 | 0.00 | 12.92 |
| 1998 | 0.82 | 2.95 | 1.25 | 1.06 | 0.85 | 0.21 | 0.06 | 0.01 | 0.06 | 7.28 |
| 1999 | 10.21 | 2.03 | 2.14 | 0.72 | 0.64 | 0.51 | 0.20 | 0.20 | 0.02 | 16.67 |
| 2000 | 1.83 | 2.37 | 4.10 | 2.01 | 1.11 | 1.11 | 1.01 | 0.48 | 0.27 | 14.29 |
| 2001 | 10.01 | 0.86 | 2.44 | 0.83 | 0.30 | 0.21 | 0.12 | 0.08 | 0.07 | 14.92 |
| 2002 | 0.18 | 19.25 | 6.72 | 3.22 | 1.09 | 0.48 | 0.61 | 0.17 | 0.53 | 32.25 |

Table B5. Stratified mean catch per tow (numbers) for haddock in NEFSC offshore autumn research vessel bottom trawl surveys on Georges Bank (Strata 01130-01250, 01290-01300), 1963-2001. Indices have been corrected to account for changes in catchability due to changes in research vessels and doors.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 83.93 | 25.39 | 9.22 | 6.81 | 8.34 | 5.95 | 2.04 | 1.68 | 1.18 | 0.46 | 145.01 |
| 1964 | 2.37 | 112.87 | 63.74 | 5.83 | 1.79 | 3.81 | 1.56 | 0.69 | 0.25 | 0.33 | 193.24 |
| 1965 | 0.33 | 10.16 | 77.39 | 9.70 | 1.07 | 0.80 | 0.91 | 0.80 | 0.25 | 0.27 | 101.69 |
| 1966 | 6.14 | 0.95 | 2.89 | 18.39 | 3.35 | 0.52 | 0.49 | 0.33 | 0.12 | 0.07 | 33.26 |
| 1967 | 0.03 | 6.72 | 0.36 | 1.00 | 6.76 | 1.62 | 0.49 | 0.21 | 0.33 | 0.18 | 17.70 |
| 1968 | 0.09 | 0.06 | 0.95 | 0.13 | 0.33 | 3.86 | 1.27 | 0.27 | 0.16 | 0.39 | 7.51 |
| 1969 | 0.39 | 0.03 | 0.00 | 0.28 | 0.13 | 0.16 | 1.52 | 0.51 | 0.09 | 0.27 | 3.38 |
| 1970 | 0.04 | 4.13 | 0.21 | 0.01 | 0.28 | 0.27 | 0.51 | 1.37 | 0.48 | 0.40 | 7.70 |
| 1971 | 2.43 | 0.00 | 0.31 | 0.07 | 0.01 | 0.22 | 0.03 | 0.09 | 0.75 | 0.28 | 4.20 |
| 1972 | 6.75 | 2.52 | 0.00 | 0.52 | 0.09 | 0.00 | 0.09 | 0.06 | 0.03 | 1.30 | 11.35 |
| 1973 | 3.23 | 9.00 | 1.61 | 0.00 | 0.19 | 0.04 | 0.00 | 0.07 | 0.01 | 0.72 | 14.89 |
| 1974 | 0.75 | 1.77 | 0.98 | 0.31 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.22 | 4.05 |
| 1975 | 23.48 | 0.63 | 0.72 | 4.86 | 0.92 | 0.00 | 0.03 | 0.00 | 0.01 | 0.30 | 30.95 |
| 1976 | 4.32 | 64.17 | 0.52 | 0.54 | 0.82 | 0.30 | 0.00 | 0.04 | 0.10 | 0.25 | 71.07 |
| 1977 | 0.13 | 2.14 | 18.73 | 0.56 | 0.57 | 0.64 | 0.34 | 0.04 | 0.01 | 0.09 | 23.25 |
| 1978 | 13.22 | 0.84 | 1.04 | 9.27 | 0.18 | 0.26 | 0.45 | 0.01 | 0.00 | 0.01 | 25.30 |
| 1979 | 1.32 | 45.57 | 0.04 | 0.90 | 3.81 | 0.26 | 0.28 | 0.05 | 0.01 | 0.00 | 52.24 |
| 1980 | 11.68 | 2.71 | 12.72 | 0.45 | 0.18 | 1.70 | 0.48 | 0.46 | 0.09 | 0.06 | 30.54 |
| 1981 | 0.38 | 6.13 | 2.08 | 3.70 | 0.21 | 0.42 | 0.53 | 0.00 | 0.00 | 0.01 | 13.45 |
| 1982 | 1.36 | 0.00 | 1.33 | 0.34 | 1.40 | 0.13 | 0.07 | 0.21 | 0.01 | 0.10 | 4.96 |
| 1983 | 5.80 | 0.24 | 0.21 | 0.27 | 0.30 | 0.94 | 0.12 | 0.00 | 0.10 | 0.01 | 7.99 |
| 1984 | 0.03 | 3.32 | 0.88 | 0.24 | 0.28 | 0.06 | 0.45 | 0.00 | 0.00 | 0.12 | 5.38 |
| 1985 | 11.35 | 0.65 | 1.53 | 0.22 | 0.05 | 0.10 | 0.07 | 0.17 | 0.00 | 0.05 | 14.19 |
| 1986 | 0.00 | 5.11 | 0.09 | 1.21 | 0.06 | 0.13 | 0.13 | 0.02 | 0.03 | 0.03 | 6.81 |
| 1987 | 1.80 | 0.00 | 0.79 | 0.10 | 0.77 | 0.06 | 0.06 | 0.02 | 0.02 | 0.00 | 3.62 |
| 1988 | 0.07 | 3.02 | 0.18 | 1.30 | 0.12 | 0.40 | 0.12 | 0.11 | 0.00 | 0.03 | 5.35 |
| 1989 | 0.47 | 0.05 | 2.71 | 0.20 | 0.66 | 0.09 | 0.13 | 0.02 | 0.02 | 0.00 | 4.34 |
| 1990 | 0.77 | 0.67 | 0.02 | 1.19 | 0.05 | 0.17 | 0.04 | 0.00 | 0.00 | 0.00 | 2.92 |
| 1991 | 2.16 | 0.21 | 0.24 | 0.05 | 0.22 | 0.02 | 0.02 | 0.00 | 0.00 | 0.02 | 2.92 |
| 1992 | 2.85 | 2.08 | 0.23 | 0.24 | 0.00 | 0.47 | 0.02 | 0.08 | 0.03 | 0.06 | 6.06 |
| 1993 | 1.52 | 4.04 | 2.01 | 0.30 | 0.00 | 0.06 | 0.15 | 0.02 | 0.00 | 0.00 | 8.09 |
| 1994 | 0.91 | 0.77 | 0.81 | 0.67 | 0.12 | 0.05 | 0.02 | 0.17 | 0.06 | 0.00 | 3.58 |
| 1995 | 2.27 | 7.14 | 4.90 | 2.32 | 0.38 | 0.01 | 0.00 | 0.07 | 0.02 | 0.00 | 17.11 |
| 1996 | 1.31 | 0.54 | 0.93 | 1.04 | 0.49 | 0.14 | 0.01 | 0.01 | 0.00 | 0.01 | 4.47 |
| 1997 | 0.32 | 2.47 | 1.47 | 0.75 | 0.55 | 0.33 | 0.13 | 0.00 | 0.07 | 0.08 | 6.16 |
| 1998 | 4.32 | 2.79 | 2.47 | 0.72 | 0.41 | 0.18 | 0.16 | 0.02 | 0.00 | 0.01 | 11.07 |
| 1999 | 1.82 | 0.84 | 3.37 | 8.05 | 3.52 | 2.32 | 0.82 | 1.32 | 0.75 | 0.31 | 23.13 |
| 2000 | 4.14 | 2.82 | 5.48 | 3.10 | 1.10 | 0.66 | 0.13 | 0.27 | 0.09 | 0.19 | 17.99 |
| 2001 | 0.85 | 8.77 | 1.68 | 7.44 | 2.12 | 1.16 | 0.36 | 0.22 | 0.13 | 0.01 | 22.74 |

Table B6. Stratified mean catch per tow (numbers) for haddock in Canadian offshore research vessel bottom trawl surveys on Georges Bank, 1986-2002.[1] The Georges Bank strata set includes strata 5Z1-5Z8.

| | Age group | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1986 | 0.00 | 4.06 | 0.22 | 6.05 | 1.07 | 0.19 | 0.29 | 0.34 | 0.37 | 0.42 | 13.01 |
| 1987 | 0.00 | 0.03 | 3.04 | 0.69 | 2.51 | 0.67 | 0.08 | 0.30 | 0.10 | 0.86 | 8.28 |
| 1988 | 0.00 | 1.47 | 0.05 | 8.53 | 0.17 | 2.85 | 0.18 | 0.17 | 0.11 | 0.50 | 14.03 |
| 1989 | 0.00 | 0.03 | 5.34 | 0.72 | 2.12 | 0.19 | 0.42 | 0.03 | 0.03 | 0.23 | 9.11 |
| 1990 | 0.00 | 0.93 | 0.11 | 9.87 | 0.13 | 3.36 | 0.23 | 1.09 | 0.13 | 0.34 | 16.19 |
| 1991 | 0.00 | 0.75 | 1.67 | 0.14 | 8.99 | 0.11 | 1.60 | 0.09 | 0.44 | 0.21 | 14.00 |
| 1992 | 0.00 | 3.30 | 2.95 | 1.13 | 0.17 | 3.82 | 0.03 | 1.06 | 0.04 | 0.58 | 13.08 |
| 1993 | 0.00 | 3.96 | 2.16 | 0.55 | 0.45 | 0.04 | 1.28 | 0.02 | 0.32 | 0.16 | 8.94 |
| 1994 | 0.00 | 3.32 | 11.52 | 4.08 | 0.42 | 0.24 | 0.02 | 0.70 | 0.01 | 0.27 | 20.59 |
| 1995 | 0.00 | 1.94 | 2.62 | 4.30 | 2.22 | 0.56 | 0.28 | 0.00 | 0.48 | 0.66 | 13.06 |
| 1996 | 0.00 | 5.37 | 2.54 | 4.25 | 4.43 | 2.57 | 0.23 | 0.21 | 0.03 | 0.50 | 20.14 |
| 1997 | 0.00 | 1.74 | 1.15 | 0.81 | 2.36 | 2.47 | 1.77 | 0.24 | 0.09 | 0.59 | 11.22 |
| 1998 | 0.00 | 2.41 | 8.18 | 3.08 | 2.57 | 3.76 | 3.67 | 1.98 | 0.24 | 0.48 | 26.37 |
| 1999 | 0.00 | 19.75 | 3.41 | 7.16 | 2.21 | 1.40 | 1.35 | 1.26 | 0.33 | 0.13 | 37.00 |
| 2000 | 0.00 | 18.33 | 68.60 | 9.32 | 8.91 | 2.11 | 1.55 | 1.94 | 1.14 | 0.59 | 112.50 |
| 2001 | 0.00 | 22.28 | 2.83 | 10.88 | 3.09 | 4.13 | 1.29 | 1.15 | 1.41 | 1.65 | 48.71 |
| 2002 | 0.00 | 1.98 | 31.70 | 6.65 | 15.36 | 4.32 | 5.32 | 1.59 | 1.32 | 7.73 | 75.97 |

[1] S. Gavaris Personal communication.

Table B7. Beginning year stock size (000s) of Georges Bank haddock estimated from the VPA, 1963 to 2002.

| Age | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1 | 192405 | 486215 | 32602 | 4081 | 13172 | 420 | 984 |
| 2 | 32188 | 154895 | 388939 | 18005 | 3238 | 9744 | 336 |
| 3 | 33117 | 22691 | 112399 | 204592 | 8549 | 2499 | 5268 |
| 4 | 46437 | 20401 | 14458 | 51763 | 76289 | 4384 | 1405 |
| 5 | 29224 | 27929 | 12382 | 6991 | 25037 | 43760 | 1851 |
| 6 | 9696 | 16509 | 14974 | 6164 | 3219 | 11144 | 22690 |
| 7 | 6014 | 5943 | 8274 | 6207 | 2702 | 1541 | 5958 |
| 8 | 2799 | 3652 | 2982 | 3361 | 2971 | 1314 | 658 |
| 9 | 4224 | 4695 | 3685 | 2274 | 2242 | 2419 | 1652 |
| 1+ | 356105 | 742932 | 590695 | 303437 | 137420 | 77225 | 40804 |

| Age | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| 1 | 4773 | 473 | 8507 | 19485 | 10792 | 7623 | 102890 |
| 2 | 804 | 3866 | 387 | 6824 | 13636 | 8794 | 6067 |
| 3 | 265 | 515 | 1921 | 315 | 3709 | 7256 | 6265 |
| 4 | 2777 | 203 | 220 | 1166 | 255 | 2443 | 4254 |
| 5 | 745 | 1758 | 130 | 107 | 605 | 207 | 1660 |
| 6 | 924 | 441 | 1178 | 77 | 40 | 432 | 166 |
| 7 | 13190 | 562 | 139 | 856 | 36 | 31 | 316 |
| 8 | 3454 | 8710 | 203 | 43 | 631 | 28 | 21 |
| 9 | 2135 | 5475 | 3761 | 1271 | 2954 | 610 | 598 |
| 1+ | 29066 | 22004 | 16444 | 30143 | 32659 | 27422 | 122237 |

| Age | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|
| 1 | 14364 | 5984 | 84420 | 10102 | 7221 | 2502 | 3099 |
| 2 | 84109 | 11760 | 4898 | 69116 | 8264 | 5911 | 2048 |
| 3 | 4540 | 51141 | 8939 | 3987 | 28537 | 5189 | 3786 |
| 4 | 4631 | 3548 | 28846 | 5757 | 2950 | 13413 | 2770 |
| 5 | 2686 | 3177 | 2628 | 17130 | 3831 | 1663 | 7604 |
| 6 | 1164 | 1733 | 2088 | 1677 | 8547 | 2289 | 1008 |
| 7 | 136 | 630 | 951 | 1338 | 836 | 4670 | 1359 |
| 8 | 238 | 107 | 390 | 494 | 602 | 385 | 2811 |
| 9 | 673 | 512 | 186 | 259 | 355 | 396 | 265 |
| 1+ | 112541 | 78592 | 133346 | 109861 | 61143 | 36419 | 24750 |

Table B7. Continued.

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|
| 1 | 17284 | 1752 | 14732 | 2199 | 16921 | 1081 | 2653 |
| 2 | 2537 | 14151 | 1434 | 12056 | 1800 | 13850 | 885 |
| 3 | 1483 | 1993 | 9409 | 1125 | 8065 | 1427 | 10197 |
| 4 | 2364 | 945 | 1134 | 5161 | 805 | 4446 | 1091 |
| 5 | 1644 | 1277 | 598 | 727 | 2766 | 538 | 2847 |
| 6 | 4200 | 987 | 629 | 358 | 485 | 1422 | 311 |
| 7 | 579 | 2097 | 602 | 358 | 227 | 262 | 840 |
| 8 | 945 | 263 | 1241 | 357 | 213 | 136 | 173 |
| 9 | 1906 | 507 | 278 | 451 | 349 | 217 | 164 |
| 1+ | 32941 | 23973 | 30057 | 22791 | 31631 | 23379 | 19160 |

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|
| 1 | 2419 | 9903 | 13861 | 14240 | 9802 | 10908 | 19940 |
| 2 | 2171 | 1975 | 8102 | 11342 | 11658 | 8017 | 8926 |
| 3 | 715 | 1372 | 1393 | 6371 | 9043 | 9464 | 6515 |
| 4 | 7041 | 503 | 834 | 824 | 4483 | 6864 | 7233 |
| 5 | 737 | 3820 | 292 | 412 | 521 | 3256 | 4764 |
| 6 | 1545 | 511 | 1746 | 145 | 278 | 372 | 2247 |
| 7 | 166 | 894 | 318 | 833 | 56 | 199 | 243 |
| 8 | 528 | 70 | 440 | 226 | 546 | 39 | 143 |
| 9 | 245 | 240 | 208 | 221 | 173 | 56 | 362 |
| 1+ | 15565 | 19287 | 27193 | 34614 | 36559 | 39175 | 50373 |

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| 1 | 14198 | 39479 | 17692 | 75115 | 4453 |
| 2 | 16299 | 11623 | 32322 | 14485 | 61497 |
| 3 | 7147 | 13164 | 9480 | 26110 | 11745 |
| 4 | 5074 | 5476 | 9817 | 7202 | 19432 |
| 5 | 5218 | 3700 | 3957 | 6609 | 5169 |
| 6 | 3387 | 3647 | 2579 | 2737 | 4334 |
| 7 | 1640 | 2297 | 2524 | 1664 | 1741 |
| 8 | 181 | 1208 | 1578 | 1740 | 1020 |
| 9 | 351 | 345 | 545 | 1358 | 2028 |
| 1+ | 53495 | 80941 | 80495 | 137020 | 111419 |

Table B8. Spawning stock biomass (mt) of Georges Bank haddock estimated from the VPA, 1963 to 2001.

| Age | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 00 | 00 | 00 | 00 | 00 | 1710 | 60 |
| 3 | 24532 | 15607 | 66805 | 97767 | 4700 | 1409 | 3221 |
| 4 | 56925 | 23391 | 14829 | 49168 | 68052 | 3958 | 1597 |
| 5 | 38916 | 37115 | 16069 | 8724 | 27362 | 50539 | 2364 |
| 6 | 17459 | 25531 | 21711 | 9324 | 4999 | 16457 | 35028 |
| 7 | 11770 | 11365 | 14076 | 10997 | 4935 | 2718 | 11957 |
| 8 | 6545 | 7884 | 6294 | 7116 | 6272 | 2727 | 1465 |
| 9 | 11456 | 12085 | 9574 | 6011 | 5958 | 5837 | 5067 |
| 1+ | 167603 | 132978 | 149358 | 189106 | 122279 | 85355 | 60760 |

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 164 | 777 | 85 | 1592 | 3156 | 2307 | 1502 |
| 3 | 184 | 409 | 1725 | 350 | 4208 | 7675 | 6237 |
| 4 | 3609 | 264 | 301 | 1904 | 463 | 4449 | 6829 |
| 5 | 1257 | 3416 | 234 | 185 | 1365 | 442 | 3684 |
| 6 | 1668 | 820 | 2873 | 181 | 112 | 1152 | 410 |
| 7 | 26943 | 1151 | 304 | 2506 | 124 | 109 | 969 |
| 8 | 8755 | 22254 | 546 | 125 | 2144 | 103 | 83 |
| 9 | 7114 | 18399 | 11711 | 4218 | 11683 | 2405 | 2652 |
| 1+ | 49694 | 47490 | 17779 | 11061 | 23256 | 18642 | 22367 |

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 17917 | 2558 | 1118 | 12908 | 1680 | 1073 | 295 |
| 3 | 4128 | 45484 | 7116 | 3295 | 20671 | 4034 | 3143 |
| 4 | 7321 | 5641 | 44086 | 7738 | 3804 | 17772 | 3961 |
| 5 | 5612 | 7039 | 5316 | 30147 | 6720 | 3057 | 13359 |
| 6 | 2917 | 4403 | 5529 | 3748 | 17850 | 5064 | 2200 |
| 7 | 458 | 1838 | 2804 | 3684 | 2226 | 12214 | 3717 |
| 8 | 826 | 381 | 1225 | 1552 | 2003 | 1280 | 8028 |
| 9 | 3039 | 2395 | 794 | 859 | 1377 | 1407 | 979 |
| 1+ | 42218 | 69739 | 67988 | 63931 | 56331 | 45902 | 35682 |

Table B8. Continued.

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|
| 1 | 377 | 78 | 1113 | 143 | 1116 | 97 | 118 |
| 2 | 434 | 4751 | 489 | 4330 | 717 | 5095 | 337 |
| 3 | 1445 | 1782 | 8547 | 1091 | 6672 | 1462 | 10030 |
| 4 | 3208 | 1336 | 1586 | 7136 | 1105 | 6037 | 1588 |
| 5 | 2903 | 2271 | 1184 | 1333 | 4754 | 903 | 4757 |
| 6 | 8576 | 2133 | 1442 | 829 | 976 | 2869 | 631 |
| 7 | 1331 | 5258 | 1498 | 919 | 558 | 665 | 2009 |
| 8 | 2724 | 750 | 3591 | 1026 | 594 | 394 | 469 |
| 9 | 6141 | 1660 | 935 | 1665 | 1190 | 740 | 595 |
| 1+ | 27139 | 20018 | 20385 | 18472 | 17682 | 18263 | 20534 |

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|
| 1 | 94 | 344 | 472 | 288 | 50 | 64 | 98 |
| 2 | 950 | 837 | 1815 | 2730 | 2472 | 1775 | 1938 |
| 3 | 694 | 1597 | 1236 | 5742 | 10124 | 10006 | 7842 |
| 4 | 9811 | 662 | 1239 | 1349 | 7548 | 10362 | 11219 |
| 5 | 1325 | 6260 | 475 | 892 | 1134 | 6440 | 8819 |
| 6 | 3189 | 1065 | 3478 | 275 | 695 | 850 | 5052 |
| 7 | 360 | 2097 | 755 | 2070 | 153 | 569 | 634 |
| 8 | 1332 | 178 | 1121 | 642 | 1508 | 119 | 448 |
| 9 | 916 | 846 | 699 | 901 | 635 | 190 | 1216 |
| 1+ | 18672 | 13886 | 11291 | 14889 | 24319 | 30376 | 37266 |

| | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|
| 1 | 94 | 394 | 164 | 246 |
| 2 | 3530 | 2817 | 9127 | 4220 |
| 3 | 7939 | 14799 | 10566 | 29361 |
| 4 | 8299 | 8639 | 15117 | 10647 |
| 5 | 9552 | 6685 | 7325 | 12026 |
| 6 | 7098 | 7408 | 5173 | 5831 |
| 7 | 4185 | 5333 | 5814 | 3672 |
| 8 | 569 | 3302 | 4065 | 4279 |
| 9 | 1253 | 1166 | 1632 | 4146 |
| 1+ | 42518 | 50541 | 58984 | 74429 |

Table B9. Fishing mortality (F) at age and average F (ages 4-7, unweighted) for Georges Bank haddock estimated from VPA, 1963 to 2001.

| Age | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.02 | 0.39 | 0.03 | 0.10 | 0.02 | 0.00 |
| 2 | 0.15 | 0.12 | 0.44 | 0.54 | 0.06 | 0.41 | 0.04 |
| 3 | 0.28 | 0.25 | 0.58 | 0.79 | 0.47 | 0.38 | 0.44 |
| 4 | 0.31 | 0.30 | 0.53 | 0.53 | 0.36 | 0.66 | 0.43 |
| 5 | 0.37 | 0.42 | 0.50 | 0.58 | 0.61 | 0.46 | 0.50 |
| 6 | 0.29 | 0.49 | 0.68 | 0.62 | 0.54 | 0.43 | 0.34 |
| 7 | 0.30 | 0.49 | 0.70 | 0.54 | 0.52 | 0.65 | 0.35 |
| 8 | 0.34 | 0.37 | 0.52 | 0.54 | 0.42 | 0.48 | 0.47 |
| 9 | 0.34 | 0.37 | 0.52 | 0.54 | 0.42 | 0.48 | 0.47 |
| 4-7 | 0.32 | 0.43 | 0.60 | 0.57 | 0.51 | 0.55 | 0.40 |

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.00 | 0.02 | 0.16 | 0.00 | 0.03 | 0.00 |
| 2 | 0.24 | 0.50 | 0.01 | 0.41 | 0.43 | 0.14 | 0.09 |
| 3 | 0.07 | 0.65 | 0.30 | 0.01 | 0.22 | 0.33 | 0.10 |
| 4 | 0.26 | 0.25 | 0.52 | 0.46 | 0.01 | 0.19 | 0.26 |
| 5 | 0.32 | 0.20 | 0.32 | 0.79 | 0.14 | 0.02 | 0.16 |
| 6 | 0.30 | 0.96 | 0.12 | 0.56 | 0.06 | 0.11 | 0.00 |
| 7 | 0.21 | 0.82 | 0.97 | 0.10 | 0.06 | 0.16 | 0.08 |
| 8 | 0.27 | 0.21 | 0.45 | 0.49 | 0.10 | 0.17 | 0.23 |
| 9 | 0.27 | 0.21 | 0.45 | 0.49 | 0.10 | 0.17 | 0.23 |
| 4-7 | 0.27 | 0.56 | 0.48 | 0.48 | 0.07 | 0.12 | 0.12 |

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.30 | 0.07 | 0.01 | 0.68 | 0.27 | 0.25 | 0.12 |
| 3 | 0.05 | 0.37 | 0.24 | 0.10 | 0.55 | 0.43 | 0.27 |
| 4 | 0.18 | 0.10 | 0.32 | 0.21 | 0.37 | 0.37 | 0.32 |
| 5 | 0.24 | 0.22 | 0.25 | 0.50 | 0.32 | 0.30 | 0.39 |
| 6 | 0.41 | 0.40 | 0.24 | 0.50 | 0.40 | 0.32 | 0.35 |
| 7 | 0.03 | 0.28 | 0.46 | 0.60 | 0.58 | 0.31 | 0.16 |
| 8 | 0.20 | 0.16 | 0.32 | 0.42 | 0.34 | 0.36 | 0.38 |
| 9 | 0.20 | 0.16 | 0.32 | 0.42 | 0.34 | 0.36 | 0.38 |
| 4-7 | 0.22 | 0.25 | 0.32 | 0.45 | 0.42 | 0.32 | 0.31 |

Table B9. Continued.

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.04 | 0.21 | 0.04 | 0.20 | 0.03 | 0.11 | 0.01 |
| 3 | 0.25 | 0.36 | 0.40 | 0.14 | 0.40 | 0.07 | 0.17 |
| 4 | 0.42 | 0.26 | 0.25 | 0.42 | 0.20 | 0.25 | 0.19 |
| 5 | 0.31 | 0.51 | 0.31 | 0.21 | 0.47 | 0.35 | 0.41 |
| 6 | 0.49 | 0.29 | 0.36 | 0.26 | 0.42 | 0.33 | 0.43 |
| 7 | 0.59 | 0.32 | 0.32 | 0.32 | 0.31 | 0.22 | 0.26 |
| 8 | 0.37 | 0.40 | 0.27 | 0.40 | 0.40 | 0.26 | 0.35 |
| 9 | 0.37 | 0.40 | 0.27 | 0.40 | 0.40 | 0.26 | 0.35 |
| 4-7 | 0.45 | 0.35 | 0.31 | 0.30 | 0.35 | 0.28 | 0.32 |

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.26 | 0.15 | 0.04 | 0.03 | 0.01 | 0.01 | 0.02 |
| 3 | 0.15 | 0.30 | 0.33 | 0.15 | 0.08 | 0.07 | 0.05 |
| 4 | 0.41 | 0.34 | 0.50 | 0.26 | 0.12 | 0.17 | 0.13 |
| 5 | 0.17 | 0.58 | 0.50 | 0.19 | 0.14 | 0.17 | 0.14 |
| 6 | 0.35 | 0.27 | 0.54 | 0.75 | 0.13 | 0.23 | 0.11 |
| 7 | 0.67 | 0.51 | 0.14 | 0.22 | 0.18 | 0.13 | 0.09 |
| 8 | 0.39 | 0.56 | 0.51 | 0.24 | 0.12 | 0.17 | 0.13 |
| 9 | 0.39 | 0.56 | 0.51 | 0.24 | 0.12 | 0.17 | 0.13 |
| 4-7 | 0.40 | 0.43 | 0.42 | 0.36 | 0.14 | 0.17 | 0.12 |

| | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.01 | 0.00 | 0.01 | 0.01 |
| 3 | 0.07 | 0.09 | 0.07 | 0.10 |
| 4 | 0.12 | 0.13 | 0.20 | 0.13 |
| 5 | 0.16 | 0.16 | 0.17 | 0.22 |
| 6 | 0.19 | 0.17 | 0.24 | 0.25 |
| 7 | 0.11 | 0.18 | 0.17 | 0.29 |
| 8 | 0.14 | 0.14 | 0.19 | 0.22 |
| 9 | 0.14 | 0.14 | 0.19 | 0.22 |
| 4-7 | 0.14 | 0.16 | 0.19 | 0.22 |

Table B10. Input data and results for short-term (2002-2005) stochastic stock biomass and catch projections for Georges Bank haddock.

```
Input for Projections:
----------------------
Number of Years:  3; Initial Year: 2002; Final Year: 2005
Number of Ages : 9; Age at Recruitment: 1; Last Age: 9
Natural Mortality is assumed Constant over time at:  .200
Proportion of F before spawning:  .25
Proportion of M before spawning:  .25
Last age is a PLUS group;
```

Age-specific Input data for Projection # 1

| Age | Fish Mort Pattern | Nat Mort Pattern | Proportion Mature | Average Weights Catch | Average Weights Stock |
|---|---|---|---|---|---|
| 1 | .0010 | 1.0000 | .0400 | 0.579 | 0.395 |
| 2 | .0460 | 1.0000 | .4900 | 1.154 | 0.843 |
| 3 | .4880 | 1.0000 | .9500 | 1.485 | 1.282 |
| 4 | .8290 | 1.0000 | 1.0000 | 1.828 | 1.672 |
| 5 | 1.0000 | 1.0000 | 1.0000 | 2.174 | 2.010 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 2.413 | 2.284 |
| 7 | 1.0000 | 1.0000 | 1.0000 | 2.684 | 2.524 |
| 8 | 1.0000 | 1.0000 | 1.0000 | 2.900 | 2.850 |
| 9+ | 1.0000 | 1.0000 | 1.0000 | 3.458 | 3.458 |

Projections for 2002-2005; F(2002)=0.19; Basis: 85% of 2001 point estimate. Recruitment (age 1) 2002-2004 year classes derived from two-stage resampling of 1931-2001 stock-recruitment data excluding the 1963 year class with a 75,000 mt spawning biomass cutoff.

SSB was estimated to be 74,400 mt in 2001.

| 2002 F | 2002 Catch | 2002 SSB | 2003 F | 2003 Catch | 2003 SSB |
|---|---|---|---|---|---|
| 0.19 | 12462 | 99737 | $F_{rebuild}$ =0.197 | 17840 | 122264 |
| 0.19 | 12462 | 99737 | $F_{SQ}$ =0.190 | 17252 | 122415 |

| 2004 F | 2004 Catch | 2004 SSB | 2005 F | 2005 Catch | 2005 SSB |
|---|---|---|---|---|---|
| 0.197 | 19432 | 131712 | 0.197 | 22488 | 158330 |
| 0.190 | 18887 | 132413 | 0.190 | 21929 | 159533 |

Figure B1. Total commercial landings (thousand mt) of haddock from Georges Bank and south, 1904-2001.

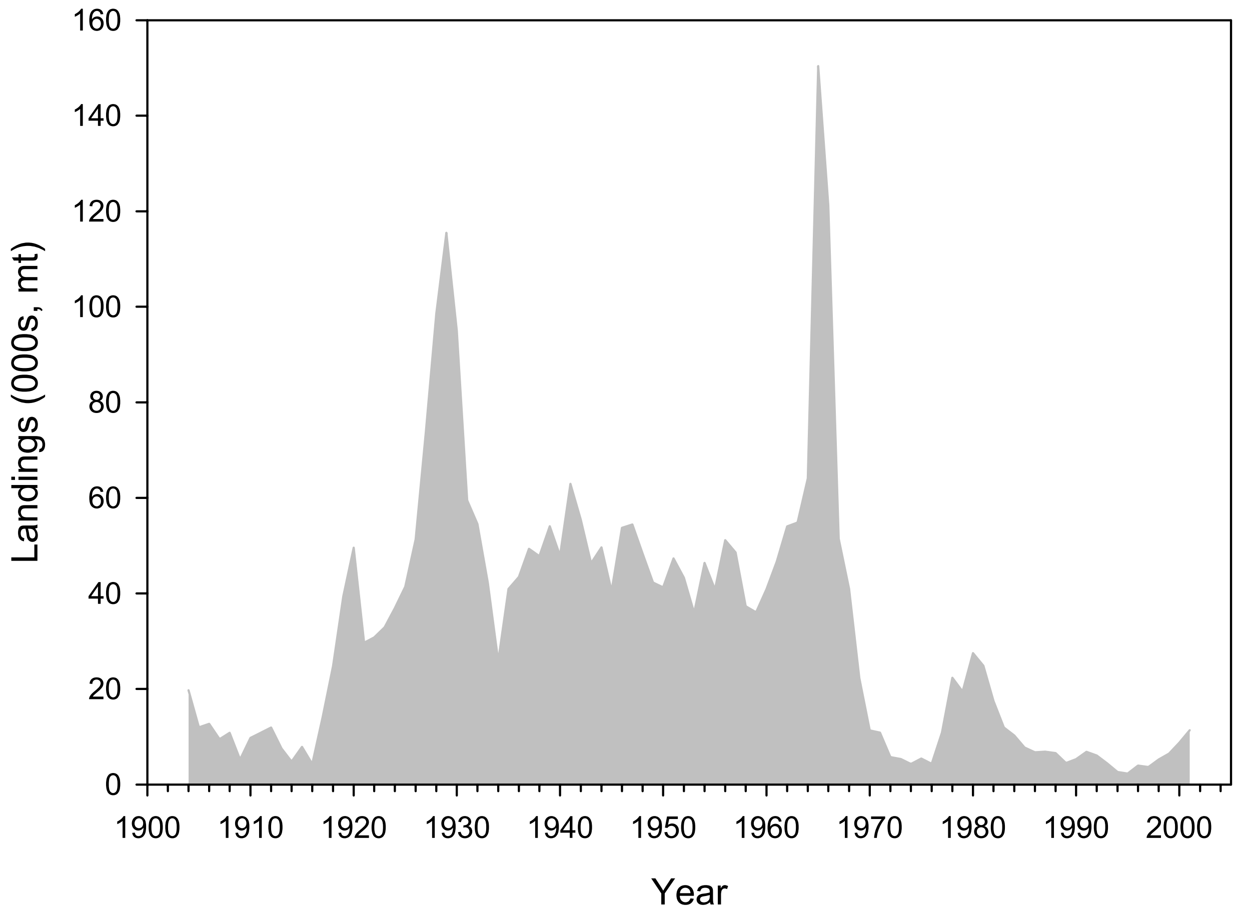


Figure B2. Georges Bank haddock research survey indices, 1963-2002.

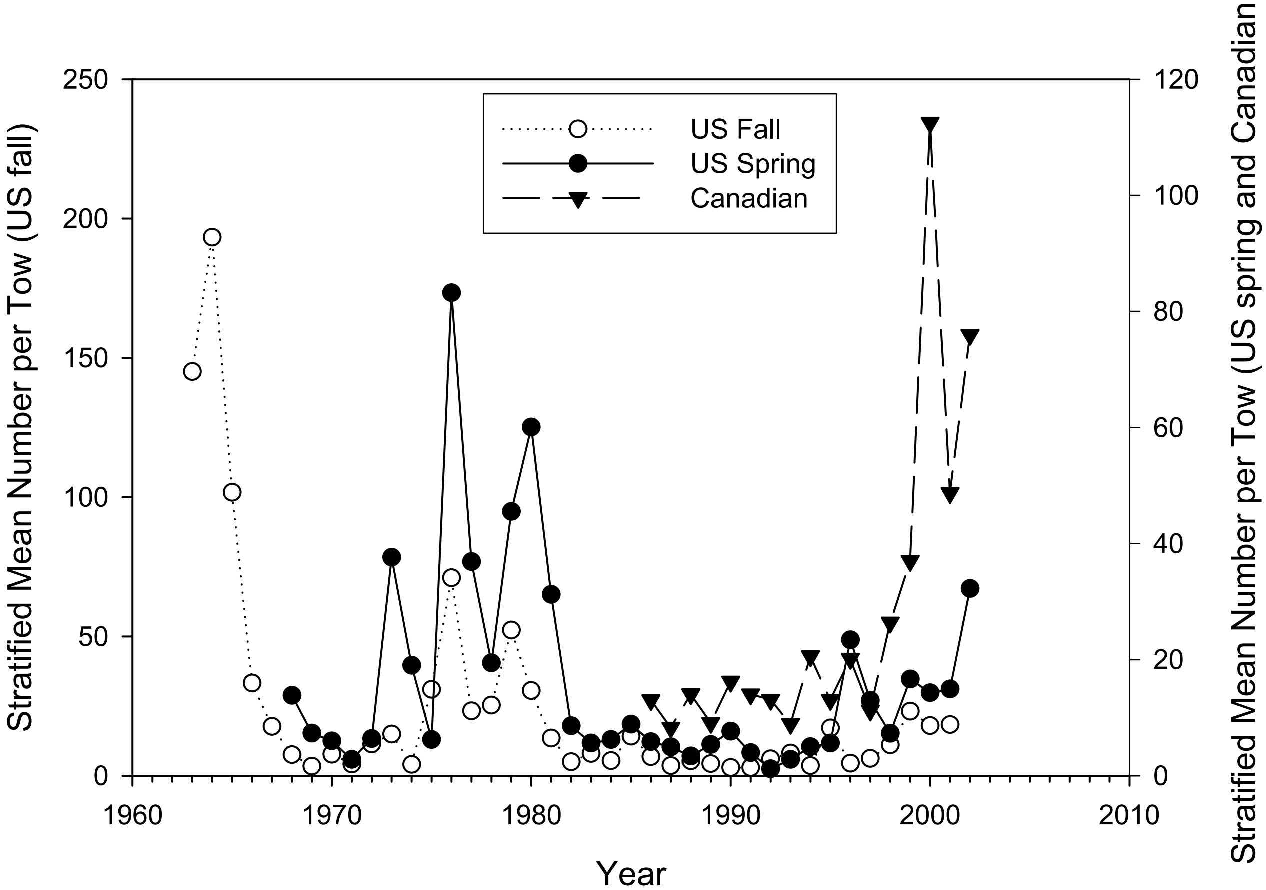


Figure B3. Trends in spawning stock biomass (line) and recruitment (bars) for Georges Bank haddock from 1931-2001.

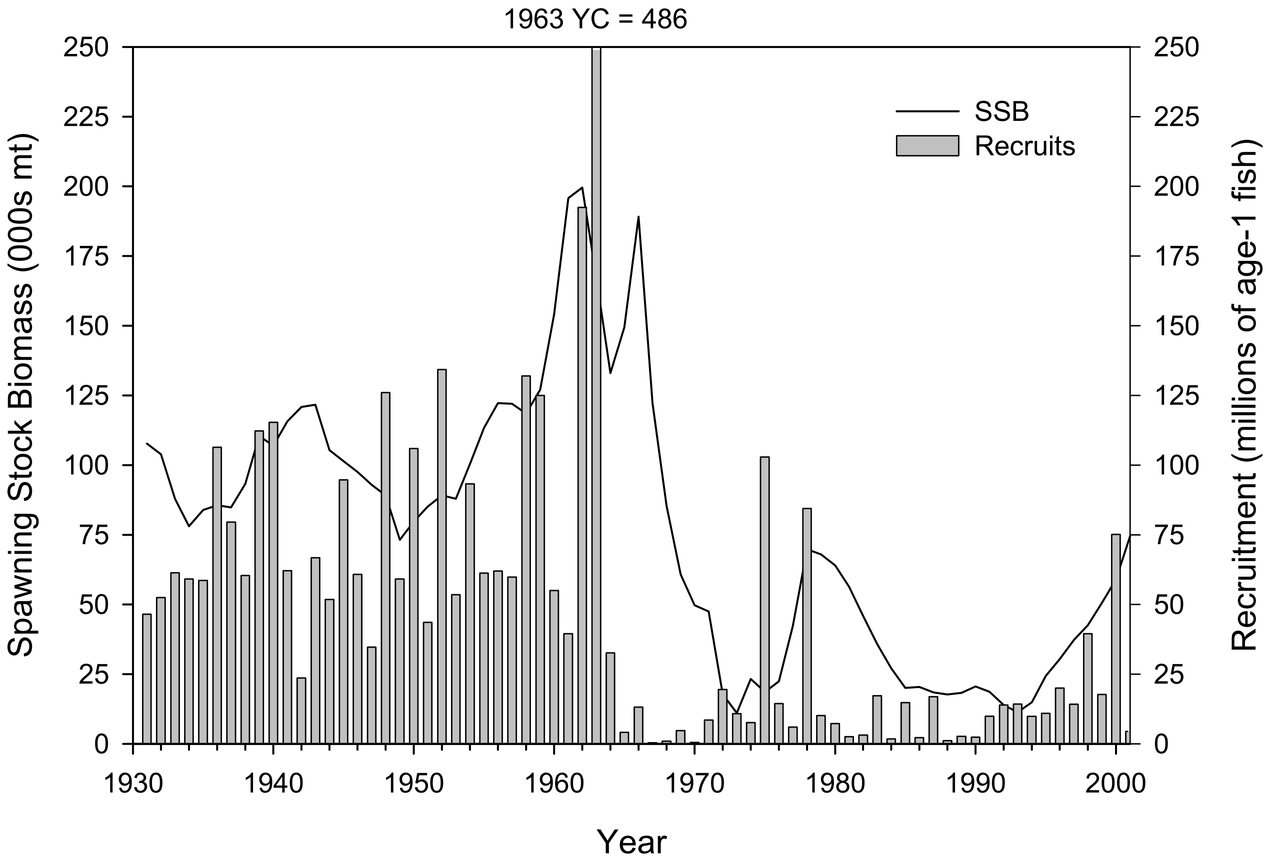
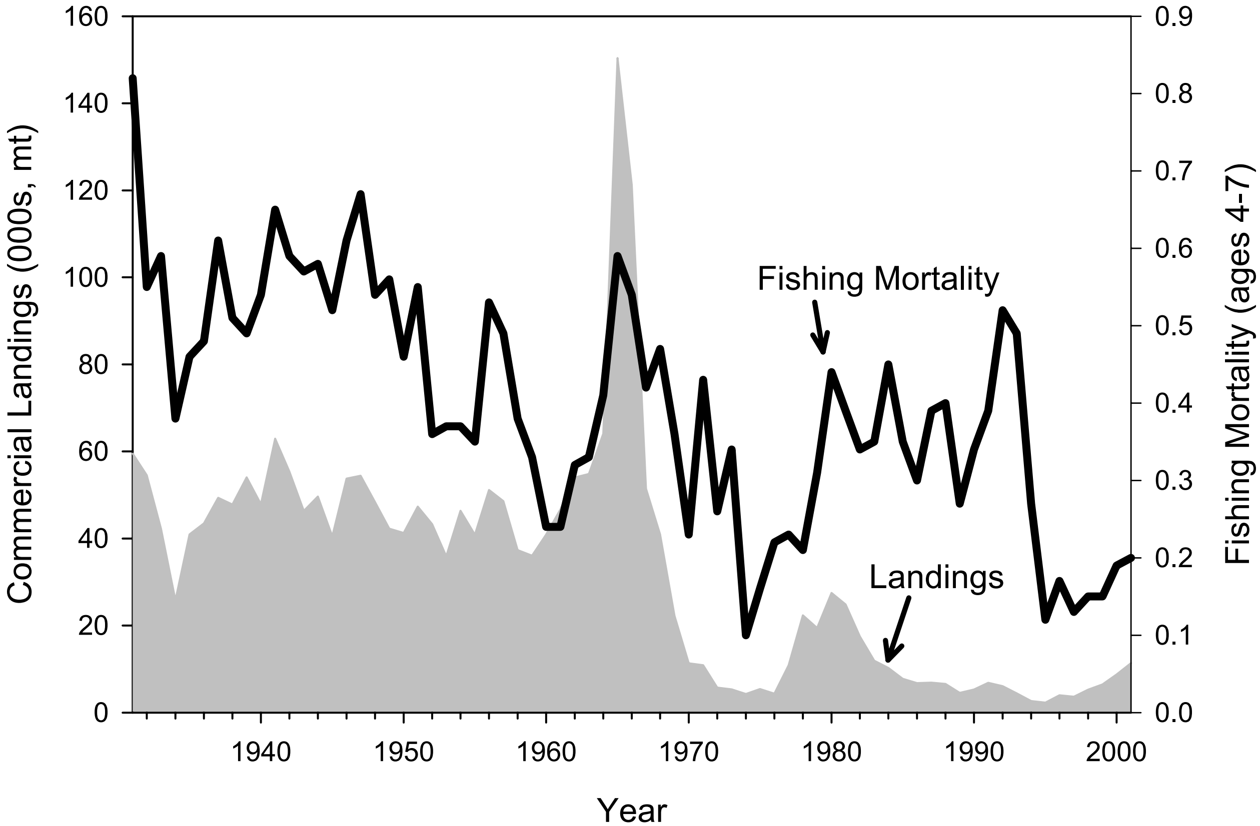


Figure B4. Trends in commercial landings (thousand mt, live weight) and fishing mortality (unweighted mean, ages 4-7) for Georges Bank haddock from 1931-2001.



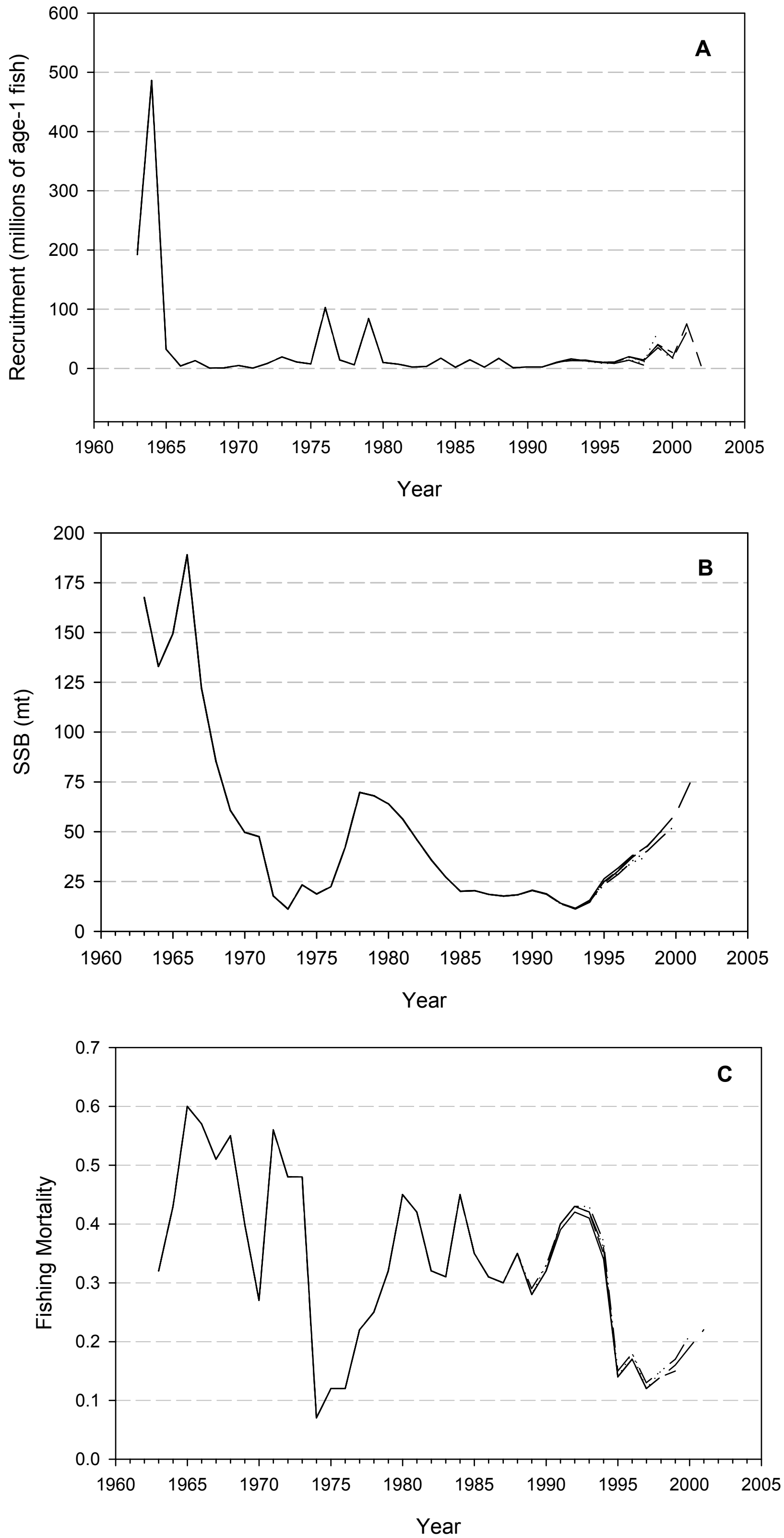



Figure B5. Retrospective analysis of Georges Bank haddock recruitment (A), spawning stock biomass (B) and fishing mortality (C).

Figure B6. Georges Bank haddock sensitivity to hypothetical NEFSC survey index adjustments due to trawl warp offsets during 2000-2002.

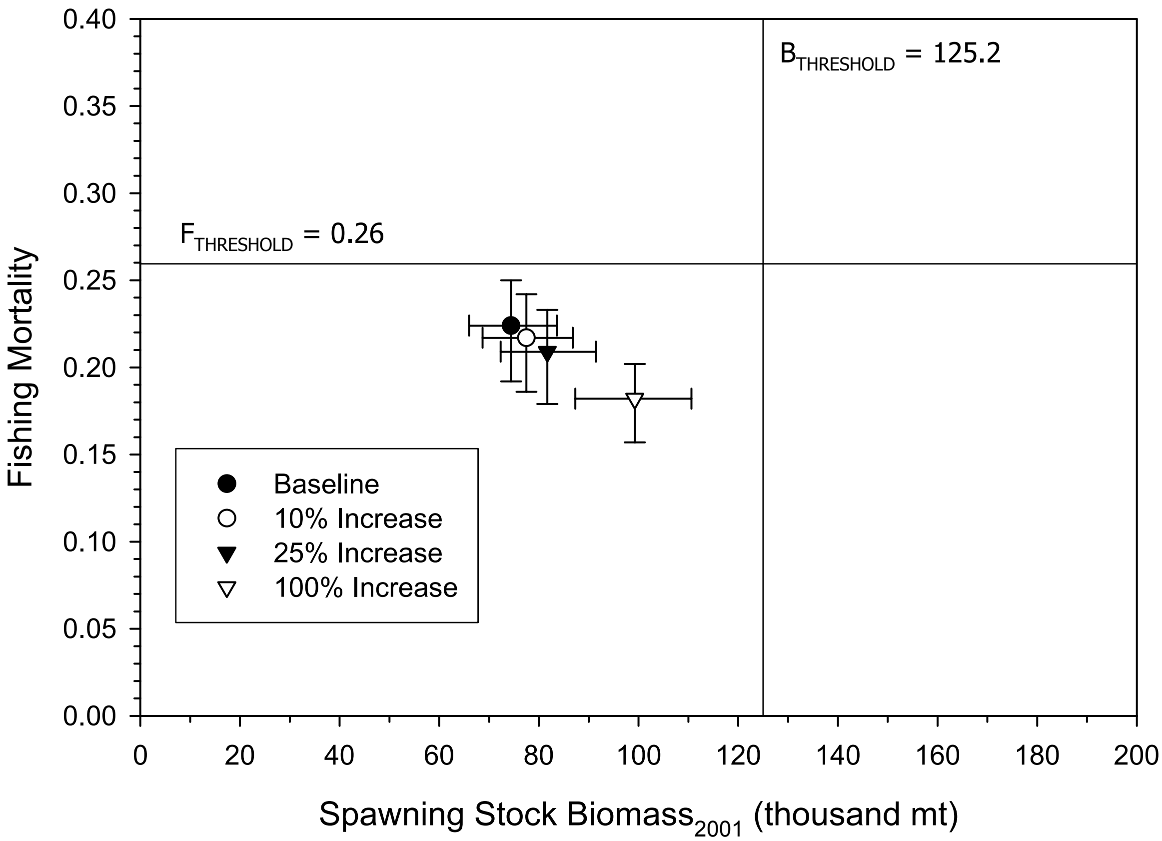
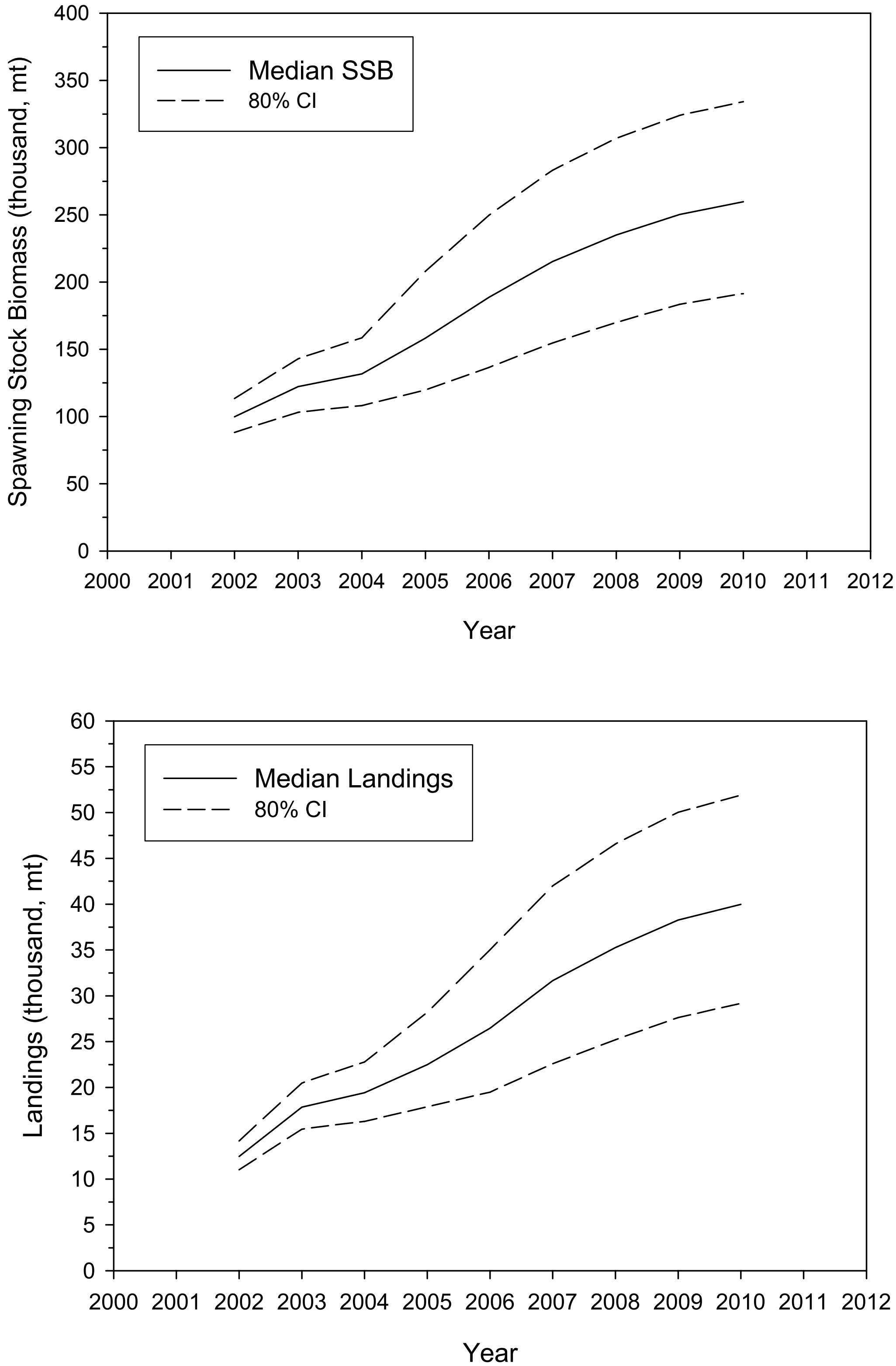


Figure B7. Georges Bank haddock projection results for $F=F_{REBUILD}$.



**C. Georges Bank Yellowtail Flounder** by C.M. Legault

**1.0 Background**

Spawning stock biomass of Georges Bank yellowtail flounder in 2000 approached $SSB_{msy}$ and fishing mortality was low (SSB was 43,000 mt and fully recruited F was 0.14; Stone et al. 2001). This report updates catch and survey indices and estimates 2001 fishing mortality and 2002 stock size.

**2.0 Assessment Data**

2.1 US 2001 Landings

U.S. landings were prorated as described in Cadrin et al. (1998; Table C1; Figure C1). US landings from Georges Bank in 2001 increased only slightly from 2000 (2% increase). Sampling intensity of landings in 2001 was comparable to that in 2000 (Table C2). Both the large and small categories were sampled in both halves of the year. Half year-specific age-length keys were applied to landings at length by half year and market category to estimate landings and mean weights at age.

2.2 US 2001 Discards

US discarded catch was estimated from logbook information on discard: kept ratios by half-year for trawl gear and by whole year for dredge gear (due to fewer observations for dredge gear), (Cadrin et al. 2000; Table C1). US discards were 13% of US landings by weight in 2001. Discards at age and associated mean weights at age were estimated from sea sampled lengths and pooled commercial-survey age-length keys. However, length distributions of trawl discards were only sampled in the first half of 2001; those samples were used to characterize all 2001 trawl discards. No dredge length frequencies were collected in 2001. Average length distributions for dredge gear by half year for 1998 through 2000 were used to age the dredge discards. It should be noted that the US discard estimate of 505 mt is substantially higher than the estimate used in the recent Canadian assessment (60 mt; Stone 2002) due to differences in the dredge discard estimate.

2.3 Canadian Landings

The Canadian landings contain a proration of flatfish landed as "unspecified" which were prorated as described in Stone et al. (2001). Canadian 2001 landings were provided by H. Stone (DFO, pers. comm.) and increased slightly relative to those in 2000 (2%; Table C1; Figure C1). Length frequencies collected by Canadian samplers were used with sex specific age-length keys provided from US landings to generate the Canadian landings by age and associated average weight at age (Stone et al. 2001; Table C2).

2.4 Total Catch at Age

Total catch at age was formed by adding the US landings, US discards and Canadian landings (Table C3a). Average weight at age was computed as the catch weighted average of the weights at age from these three sources (Table C3b).

2.5 Research Vessel Survey Indices

Survey abundance and biomass indices are reported in Table C4. Estimates from research vessel surveys are from valid tows on Georges Bank (NEFSC offshore strata 13-21; Canadian strata 5Z1-5Z4; NEFSC scallop strata 54, 55, 58-72, 74) standardized according to net, vessel, and door changes (Stone et al. 2001). All survey indices of total abundance and total biomass are either high, increasing, or both in recent years (Figure C2). This trend is also seen in numbers by age (Figure C3).

**3.0 Assessment Results**

3.1 Age-Based Analysis

An updated VPA calibration of Georges Bank yellowtail flounder is summarized in Table C4. This analysis updates the assessment reported by Stone et al. (2001) by including 2001 landings and discards, 2001 NEFSC fall and scallop survey indices, 2001 Canadian survey indices, and 2001-2002 NEFSC spring survey indices. Results indicate that the fully recruited fishing mortality rate remains low in 2001 at 0.13 (Figure C4). Spawning biomass has increased every year since 1995 and recruitment remains high (Figure C4). The age structure of the stock has improved and is approaching levels corresponding to those expected in equilibrium when the stock is at MSY (Figure C5). However, this analysis found a strong retrospective pattern of underestimating F and overestimating SSB in the terminal year, as seen in previous assessments (Figure C6). The estimate of F for 2000 increased from 0.14 in the 2001 assessment (Stone et al. 2001) to 0.24. Thus, the value of F for 2001 may be underestimated. The 2001 SSB estimate of 39,000 t is less than the 2000 SSB estimate from the Stone et al. 2001 stock assessment (43,000 t), again reflecting the retrospective pattern found in previous assessments. Bootstrap analysis indicates that abundance was estimated with moderate precision (CV=14%-43%). These results cannot be directly compared to the most recent Canadian stock assessment (Stone 2002) because the Canadian VPA results are all bias-corrected while these are not. However, trends are similar between these two assessments.

3.2 Sensitivity Analyses

Sensitivity analyses of the VPA assessment were conducted to examine hypothetical changes in the recent NEFSC spring and fall survey values due to warp misalignment (Figure C7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

3.3 Stock Status

Proxies for MSY reference points were derived from yield and SSB per recruit analyses and the assumption of constant recruitment (NEFSC 2002). Long-term average recruitment is 53.8 million at age-1.

MSY = 12,900 mt

SSBmsy = 58,800 mt.

Fmsy = 0.25 fully recruited (derived from $F_{40\%}$)

Therefore, according to VPA results, the stock is not overfished and overfishing is not occurring, e.g. $SSB_{2001}$=39,000 mt > 29,400 mt = ½ $SSB_{Threshold}$ of 58,800 and $F_{2001}$=0.13 < 0.25 = Fmsy.

3.4 Projection
A projection assuming F in 2002 is 15% lower than in 2001, with recruitment similar to that observed when SSB was greater than 5,000 mt, suggests that $F_{rebuild}$ remains at 0.22, just below the Fmsy value of 0.25 (Figure C8). The total catch, F and SSB that occur in the short term under these projections are presented along with the input in Table C6.

3.5 Biomass-Based Analysis
For comparative purposes, surplus production analysis (ASPIC) was updated to provide alternative perspectives on stock status. Biomass and F estimates are generally similar to estimates from VPA, but biomass estimates in recent years are higher from ASPIC than from VPA (Figure C9). The surplus production model estimates of Bmsy and Fmsy also produce the conclusion as the VPA, viz., the Georges Bank yellowtail flounder stock is not overfished and overfishing is not occurring ($B_{2001}$/Bmsy = 1.38; $F_{2001}$/Fmsy = 0.37).

**4.0 Sources of Uncertainty**
- Dredge discards were insufficiently sampled both in magnitude as well as length composition in 2001.
- Retrospective patterns continue in the VPA for this assessment. Updated VPAs may indicate higher F and lower SSB in 2001 than the values reported here.
- Estimates of prorated landings and discard ratios are based on preliminary logbook data and are subject to change.

**5.0 GARM Panel Comments**
The use of logbook data to estimate discards was questioned. It was noted that there were very few observer samples from the trawl fishery, and none from the scallop dredge fishery. Discards accounted for approximately 7% of the total catch by weight, and is not considered to be a major component of the catch. Discard ratios from recent years were less than those for 2001, but the GARM concluded that increased discard ratios may result from increasing stock sizes and constant trip limits.

Information on discard reason (e.g., sublegal size, regulatory trip limit, quality) is needed to evaluate the general size structure of discards. Observer information from recent years indicates that trawl discards are primarily undersized, but the reasons for dredge discards are a combination of undersized fish, regulations, and poor quality.

The GARM noted the importance of appropriately scaling survey indices in overlaying NEFSC and Canadian data. The short time series and greater catchability of the Canadian survey suggests a greater rate of increase in recent years when overlayed with NEFSC data.

Strong year classes did not appear consistently in all surveys and could not be followed clearly over time within survey series. Similar discrepancies exist in both Canadian and NEFSC survey data and may stem from use of NEFSC age data to derive abundance at age indices from the Canadian survey.

The GARM questioned if survey data adjusted for presumed warp effects improves the retrospective pattern or makes it worse. Retrospective analyses of sensitivity runs showed that the retrospective pattern persisted in all runs, but was slightly less with survey adjustments.

The sensitivity of results to the NEFSC spring survey was discussed. Presumably the higher F and lower SSB result from decreased catches of the 2001 spring survey at all ages. The influence of the relatively short Canadian series was discussed. Further sensitivity analyses truncated the spring and fall series and showed high sensitivity of results when survey indices were used one at a time.

The GARM noted that the current ADAPT configuration is slightly different than that used in previous assessments, because the spring survey data had not been available in previous spring assessments. A sensitivity analysis without the current year NEFSC spring survey had very a similar retrospective pattern.

The issue of undeclared landings was raised. The GARM felt that U.S. dealer records were among the most reliable sources of information in the assessment, however proration of total yellowtail catch to stock area imposes some uncertainty to the estimate of catch. There was also some discussion of the possibility of unreported yellowtail landings in Canadian fisheries (e.g., from the scallop fishery).

The GARM requested information on current size structure compared to historical size structure. Survey length frequencies indicate that the size structure is now similar to that observed in the 1960s. Furthermore, the age structure is similar to that expected under $F_{40\%}$ over the lifetime of a cohort with long-term median abundance, with the exception of fewer fish older that 6. Given the recent reduction in F and increase in recruitment, abundance of age-6+ fish is expected to increase.

**6.0 References**

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Stone, H. 2002. Stock assessment of Georges Bank (5Zjmnh) yellowtail flounder for 2002. Can. Science Advisory Secretariat Res. Doc. 2002. 79 p.

Stone, H., C. Legault, S. Cadrin, S. Gavaris, J. Neilson, and P. Perley. 2001. Stock assessment of Georges Bank (5Zjmnh) yellowtail flounder for 2001. Can. Science Advisory Secretariat Res. Doc. 2001/068. 87 p.

Table C1. Catch of Georges Bank yellowtail flounder (thousand mt).

| Year | US Landings | US Discards | Canada | Foreign | Total Catch |
|---|---|---|---|---|---|
| 1963 | 11.0 | 5.6 | 0.0 | 0.1 | 16.7 |
| 1964 | 14.9 | 4.9 | 0.0 | 0.0 | 19.8 |
| 1965 | 14.2 | 4.4 | 0.0 | 0.8 | 19.4 |
| 1966 | 11.3 | 2.1 | 0.0 | 0.3 | 13.7 |
| 1967 | 8.4 | 5.5 | 0.0 | 1.4 | 15.3 |
| 1968 | 12.8 | 3.6 | 0.0 | 1.8 | 18.2 |
| 1969 | 15.9 | 2.6 | 0.0 | 2.4 | 20.9 |
| 1970 | 15.5 | 5.5 | 0.0 | 0.3 | 21.3 |
| 1971 | 11.9 | 3.1 | 0.0 | 0.5 | 15.5 |
| 1972 | 14.2 | 1.2 | 0.0 | 2.2 | 17.6 |
| 1973 | 15.9 | 0.4 | 0.0 | 0.3 | 16.5 |
| 1974 | 14.6 | 1.0 | 0.0 | 1.0 | 16.6 |
| 1975 | 13.2 | 2.7 | 0.0 | 0.1 | 16.0 |
| 1976 | 11.3 | 3.0 | 0.0 | 0.0 | 14.4 |
| 1977 | 9.4 | 0.6 | 0.0 | 0.0 | 10.0 |
| 1978 | 4.5 | 1.7 | 0.0 | 0.0 | 6.2 |
| 1979 | 5.5 | 0.7 | 0.0 | 0.0 | 6.2 |
| 1980 | 6.5 | 0.4 | 0.0 | 0.0 | 6.9 |
| 1981 | 6.2 | 0.1 | 0.0 | 0.0 | 6.3 |
| 1982 | 10.6 | 1.4 | 0.0 | 0.0 | 12.0 |
| 1983 | 11.4 | 0.1 | 0.0 | 0.0 | 11.4 |
| 1984 | 5.8 | 0.0 | 0.0 | 0.0 | 5.8 |
| 1985 | 2.5 | 0.0 | 0.0 | 0.0 | 2.5 |
| 1986 | 3.0 | 0.0 | 0.0 | 0.0 | 3.1 |
| 1987 | 2.7 | 0.2 | 0.0 | 0.0 | 3.0 |
| 1988 | 1.9 | 0.3 | 0.0 | 0.0 | 2.1 |
| 1989 | 1.1 | 0.1 | 0.0 | 0.0 | 1.2 |
| 1990 | 2.8 | 0.8 | 0.0 | 0.0 | 3.6 |
| 1991 | 1.8 | 0.2 | 0.0 | 0.0 | 2.0 |
| 1992 | 2.9 | 1.9 | 0.0 | 0.0 | 4.7 |
| 1993 | 2.1 | 1.1 | 0.7 | 0.0 | 3.9 |
| 1994 | 1.6 | 0.1 | 2.1 | 0.0 | 3.9 |
| 1995 | 0.3 | 0.0 | 0.5 | 0.0 | 0.8 |
| 1996 | 0.8 | 0.0 | 0.5 | 0.0 | 1.3 |
| 1997 | 1.0 | 0.1 | 0.8 | 0.0 | 1.8 |
| 1998 | 1.8 | 0.1 | 1.2 | 0.0 | 3.1 |
| 1999 | 2.0 | 0.5 | 2.0 | 0.0 | 4.4 |
| 2000 | 3.7 | 0.4 | 2.9 | 0.0 | 6.9 |
| 2001 | 3.8 | 0.5 | 2.9 | 0.0 | 7.2 |
| mean | 7.2 | 1.5 | 0.3 | 0.3 | 9.3 |

Table C2. Sampling history of the Georges Bank yellowtail flounder fishery.

| | | US | | | | | Canada | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Length Samples | | | | | | |
| Year | Half | Trips | Small | Large | Ages | Landings | Trips | Lengths | Landings |
| 1991 | 1 | | 227 | 352 | 173 | 1011 | | | |
| | 2 | | 627 | 438 | 295 | 724 | | | |
| | All | | 854 | 790 | 468 | 1735 | | | |
| 1992 | 1 | | 401 | 308 | 204 | 1162 | | | |
| | 2 | | 716 | 517 | 331 | 1631 | | | |
| | All | | 1117 | 825 | 535 | 2793 | | | |
| 1993 | 1 | | 468 | 326 | 227 | 1199 | | | |
| | 2 | | 632 | 774 | 387 | 857 | | | |
| | All | | 1100 | 1100 | 614 | 2056 | | | |
| 1994 | 1 | 1 | 95 | 93 | 53 | 198 | | | |
| | 2 | 7 | 847 | 596 | 353 | 1391 | | | |
| | All | 8 | 942 | 689 | 406 | 1589 | | | |
| 1995 | 1 | 4 | 235 | 345 | 166 | 161 | | | |
| | 2 | 1 | 0 | 81 | 23 | 132 | | | |
| | All | 5 | 235 | 426 | 189 | 292 | | | |
| 1996 | 1 | 3 | 250 | 254 | 146 | 521 | | | |
| | 2 | 3 | 382 | 274 | 173 | 230 | | | |
| | All | 6 | 632 | 528 | 319 | 751 | | | |
| 1997 | 1 | 11 | 957 | 726 | 516 | 654 | 3 | 600 | 100 |
| | 2 | 1 | 0 | 103 | 63 | 312 | 10 | 2308 | 709 |
| | All | 12 | 957 | 829 | 579 | 966 | 13 | 2908 | 810 |
| 1998 | 1 | 7 | 453 | 490 | 231 | 578 | 1 | 2380 | 36 |
| | 2 | 2 | 199 | 284 | 62 | 1245 | 16 | 3741 | 1123 |
| | All | 9 | 652 | 774 | 293 | 1823 | 17 | 6121 | 1159 |
| 1999 | 1 | 7 | 451 | 266 | 195 | 1160 | 0 | 0 | |
| | 2 | 4 | 251 | 574 | 105 | 906 | 22 | 4944 | |
| | All | 11 | 702 | 840 | 300 | 2066 | 22 | 4944 | 1971 |
| 2000 | 1 | | 94 | 782 | 200 | 2223 | 5 | 1120 | 92 |
| | 2 | | 598 | 1288 | 405 | 1455 | 53 | 13048 | 2767 |
| | All | 11 | 692 | 2070 | 605 | 3678 | 58 | 14168 | 2859 |
| 2001 | 1 | 15 | 696 | 1055 | 433 | 2779 | | | |
| | 2 | 15 | 1073 | 576 | 381 | 989 | | | |
| | All | 30 | 1769 | 1631 | 814 | 3768 | | | |

Table C3a. Total catch (thousands) at age of Georges Bank yellowtail flounder.

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6+ | Total |
| 1973 | 347 | 4890 | 13243 | 9276 | 3743 | 1618 | 33117 |
| 1974 | 2143 | 8971 | 7904 | 7398 | 3544 | 1477 | 31437 |
| 1975 | 4372 | 25284 | 7057 | 3392 | 2084 | 1148 | 43337 |
| 1976 | 615 | 31012 | 5146 | 1347 | 532 | 868 | 39520 |
| 1977 | 330 | 8580 | 9917 | 1721 | 394 | 474 | 21416 |
| 1978 | 9659 | 3105 | 4034 | 1660 | 459 | 174 | 19091 |
| 1979 | 233 | 9505 | 3445 | 1242 | 550 | 272 | 15247 |
| 1980 | 309 | 3572 | 8821 | 1419 | 321 | 99 | 14541 |
| 1981 | 55 | 729 | 5351 | 4556 | 796 | 126 | 11613 |
| 1982 | 2063 | 17491 | 7122 | 3246 | 1031 | 84 | 31037 |
| 1983 | 696 | 7689 | 16016 | 2316 | 625 | 127 | 27469 |
| 1984 | 428 | 1917 | 4266 | 4734 | 1592 | 321 | 13258 |
| 1985 | 650 | 3345 | 816 | 652 | 410 | 65 | 5938 |
| 1986 | 158 | 5771 | 978 | 347 | 161 | 76 | 7491 |
| 1987 | 140 | 2653 | 2751 | 761 | 132 | 112 | 6549 |
| 1988 | 483 | 2367 | 1191 | 624 | 165 | 38 | 4868 |
| 1989 | 185 | 1516 | 668 | 262 | 68 | 19 | 2718 |
| 1990 | 219 | 1931 | 6123 | 800 | 107 | 20 | 9200 |
| 1991 | 412 | 54 | 1222 | 2430 | 293 | 60 | 4471 |
| 1992 | 2389 | 8359 | 2527 | 1269 | 510 | 27 | 15081 |
| 1993 | 5194 | 1009 | 2777 | 2392 | 318 | 75 | 11765 |
| 1994 | 71 | 861 | 5742 | 2571 | 910 | 136 | 10291 |
| 1995 | 14 | 157 | 895 | 715 | 137 | 27 | 1944 |
| 1996 | 50 | 383 | 1509 | 716 | 167 | 15 | 2841 |
| 1997 | 16 | 595 | 1258 | 1502 | 341 | 90 | 3802 |
| 1998 | 26 | 971 | 2792 | 1824 | 624 | 103 | 6338 |
| 1999 | 21 | 3287 | 3209 | 1498 | 651 | 162 | 8829 |
| 2000 | 100 | 3731 | 5747 | 2824 | 798 | 324 | 13524 |
| 2001 | 217 | 2754 | 6866 | 2585 | 1007 | 478 | 13907 |
| mean | 1089 | 5603 | 4807 | 2279 | 775 | 297 | 14850 |

Table C3b. Total weight (kg) at age of George Bank yellowtail flounder from US and Canadian commercial samples.

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6+ | mean wt |
| 1973 | 0.100 | 0.352 | 0.462 | 0.527 | 0.603 | 0.776 | 0.492 |
| 1974 | 0.108 | 0.345 | 0.498 | 0.609 | 0.680 | 0.842 | 0.491 |
| 1975 | 0.111 | 0.316 | 0.489 | 0.554 | 0.618 | 0.682 | 0.366 |
| 1976 | 0.106 | 0.312 | 0.542 | 0.636 | 0.741 | 0.835 | 0.367 |
| 1977 | 0.109 | 0.342 | 0.525 | 0.634 | 0.782 | 0.950 | 0.468 |
| 1978 | 0.100 | 0.315 | 0.510 | 0.684 | 0.793 | 0.915 | 0.297 |
| 1979 | 0.103 | 0.331 | 0.460 | 0.649 | 0.728 | 0.893 | 0.407 |
| 1980 | 0.100 | 0.325 | 0.493 | 0.656 | 0.813 | 1.078 | 0.470 |
| 1981 | 0.099 | 0.347 | 0.490 | 0.603 | 0.707 | 0.799 | 0.542 |
| 1982 | 0.112 | 0.301 | 0.486 | 0.650 | 0.748 | 1.055 | 0.384 |
| 1983 | 0.139 | 0.296 | 0.440 | 0.604 | 0.736 | 0.959 | 0.415 |
| 1984 | 0.162 | 0.240 | 0.378 | 0.500 | 0.642 | 0.785 | 0.436 |
| 1985 | 0.178 | 0.363 | 0.497 | 0.647 | 0.733 | 0.812 | 0.423 |
| 1986 | 0.176 | 0.342 | 0.540 | 0.664 | 0.823 | 0.912 | 0.396 |
| 1987 | 0.112 | 0.316 | 0.522 | 0.666 | 0.680 | 0.842 | 0.455 |
| 1988 | 0.100 | 0.325 | 0.555 | 0.688 | 0.855 | 0.985 | 0.429 |
| 1989 | 0.100 | 0.345 | 0.542 | 0.725 | 0.883 | 1.122 | 0.432 |
| 1990 | 0.100 | 0.293 | 0.397 | 0.577 | 0.697 | 0.870 | 0.388 |
| 1991 | 0.100 | 0.268 | 0.368 | 0.481 | 0.726 | 0.852 | 0.434 |
| 1992 | 0.100 | 0.295 | 0.369 | 0.522 | 0.647 | 1.183 | 0.309 |
| 1993 | 0.100 | 0.288 | 0.377 | 0.507 | 0.562 | 0.882 | 0.282 |
| 1994 | 0.150 | 0.256 | 0.350 | 0.472 | 0.628 | 0.863 | 0.402 |
| 1995 | 0.155 | 0.249 | 0.365 | 0.462 | 0.582 | 0.712 | 0.410 |
| 1996 | 0.137 | 0.298 | 0.405 | 0.568 | 0.725 | 0.975 | 0.449 |
| 1997 | 0.155 | 0.310 | 0.410 | 0.523 | 0.668 | 0.968 | 0.474 |
| 1998 | 0.185 | 0.333 | 0.453 | 0.542 | 0.670 | 0.840 | 0.487 |
| 1999 | 0.210 | 0.374 | 0.506 | 0.637 | 0.748 | 0.877 | 0.503 |
| 2000 | 0.185 | 0.379 | 0.480 | 0.612 | 0.756 | 0.962 | 0.506 |
| 2001 | 0.108 | 0.287 | 0.435 | 0.610 | 0.812 | 1.016 | 0.480 |
| mean | 0.128 | 0.316 | 0.461 | 0.593 | 0.713 | 0.901 | 0.425 |

Table C4a. Survey indices of Georges Bank yellowtail abundance and biomass.

Stratified Mean Number per tow at Age

| **NEFSC Spring Survey** | | | | Age | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | kg/tow |
| 1968 | 0.149 | 3.364 | 3.579 | 0.316 | 0.084 | 0.160 | 0.127 | 0.000 | 7.779 | 2.813 |
| 1969 | 1.015 | 9.406 | 11.119 | 3.096 | 1.423 | 0.454 | 0.188 | 0.057 | 26.758 | 11.170 |
| 1970 | 0.093 | 4.485 | 6.030 | 2.422 | 0.570 | 0.121 | 0.190 | 0.000 | 13.911 | 5.312 |
| 1971 | 0.791 | 3.335 | 4.620 | 3.754 | 0.759 | 0.227 | 0.050 | 0.029 | 13.564 | 4.607 |
| 1972 | 0.138 | 7.136 | 7.198 | 3.514 | 1.094 | 0.046 | 0.122 | 0.000 | 19.247 | 6.450 |
| 1973 | 1.931 | 3.266 | 2.368 | 1.063 | 0.410 | 0.173 | 0.023 | 0.020 | 9.254 | 2.938 |
| 1974 | 0.316 | 2.224 | 1.842 | 1.256 | 0.346 | 0.187 | 0.085 | 0.009 | 6.265 | 2.719 |
| 1975 | 0.420 | 2.939 | 0.860 | 0.298 | 0.208 | 0.068 | 0.000 | 0.013 | 4.806 | 1.676 |
| 1976 | 1.034 | 4.368 | 1.247 | 0.311 | 0.196 | 0.026 | 0.048 | 0.037 | 7.268 | 2.273 |
| 1977 | 0.000 | 0.671 | 1.125 | 0.384 | 0.074 | 0.013 | 0.000 | 0.000 | 2.267 | 0.999 |
| 1978 | 0.936 | 0.798 | 0.507 | 0.219 | 0.026 | 0.000 | 0.008 | 0.000 | 2.494 | 0.742 |
| 1979 | 0.279 | 1.933 | 0.385 | 0.328 | 0.059 | 0.046 | 0.041 | 0.000 | 3.072 | 1.227 |
| 1980 | 0.057 | 4.644 | 5.761 | 0.473 | 0.057 | 0.037 | 0.000 | 0.000 | 11.030 | 4.456 |
| 1981 | 0.012 | 1.027 | 1.779 | 0.721 | 0.205 | 0.061 | 0.000 | 0.026 | 3.830 | 1.960 |
| 1982 | 0.045 | 3.742 | 1.122 | 1.016 | 0.455 | 0.065 | 0.000 | 0.026 | 6.472 | 2.500 |
| 1983 | 0.000 | 1.865 | 2.728 | 0.531 | 0.123 | 0.092 | 0.061 | 0.092 | 5.492 | 2.642 |
| 1984 | 0.000 | 0.093 | 0.809 | 0.885 | 0.834 | 0.244 | 0.000 | 0.000 | 2.865 | 1.646 |
| 1985 | 0.110 | 2.198 | 0.262 | 0.282 | 0.148 | 0.000 | 0.000 | 0.000 | 3.000 | 0.988 |
| 1986 | 0.027 | 1.806 | 0.291 | 0.056 | 0.137 | 0.055 | 0.000 | 0.000 | 2.372 | 0.847 |
| 1987 | 0.000 | 0.128 | 0.112 | 0.133 | 0.053 | 0.055 | 0.000 | 0.000 | 0.480 | 0.329 |
| 1988 | 0.078 | 0.275 | 0.366 | 0.242 | 0.199 | 0.027 | 0.000 | 0.000 | 1.187 | 0.566 |
| 1989 | 0.047 | 0.424 | 0.740 | 0.290 | 0.061 | 0.022 | 0.022 | 0.000 | 1.605 | 0.729 |
| 1990 | 0.000 | 0.065 | 1.108 | 0.393 | 0.139 | 0.012 | 0.045 | 0.000 | 1.762 | 0.699 |
| 1991 | 0.435 | 0.000 | 0.254 | 0.675 | 0.274 | 0.020 | 0.000 | 0.000 | 1.659 | 0.631 |
| 1992 | 0.000 | 2.010 | 1.945 | 0.598 | 0.189 | 0.000 | 0.000 | 0.000 | 4.742 | 1.566 |
| 1993 | 0.046 | 0.290 | 0.500 | 0.317 | 0.027 | 0.000 | 0.000 | 0.000 | 1.180 | 0.482 |
| 1994 | 0.000 | 0.621 | 0.638 | 0.357 | 0.145 | 0.043 | 0.000 | 0.000 | 1.804 | 0.660 |
| 1995 | 0.040 | 1.180 | 4.810 | 1.490 | 0.640 | 0.010 | 0.000 | 0.000 | 8.170 | 2.579 |
| 1996 | 0.030 | 0.990 | 2.630 | 2.700 | 0.610 | 0.060 | 0.000 | 0.000 | 7.020 | 2.853 |
| 1997 | 0.019 | 1.169 | 3.733 | 4.081 | 0.703 | 0.134 | 0.000 | 0.000 | 9.837 | 4.359 |
| 1998 | 0.000 | 2.081 | 1.053 | 1.157 | 0.759 | 0.323 | 0.027 | 0.000 | 5.400 | 2.324 |
| 1999 | 0.050 | 4.746 | 10.820 | 2.720 | 1.623 | 0.426 | 0.329 | 0.024 | 20.738 | 9.307 |
| 2000 | 0.183 | 4.819 | 7.666 | 2.914 | 0.813 | 0.422 | 0.102 | 0.000 | 16.919 | 6.696 |
| 2001 | 0.000 | 2.315 | 6.563 | 2.411 | 0.483 | 0.352 | 0.101 | 0.000 | 12.225 | 5.008 |
| 2002 | 0.188 | 2.412 | 12.333 | 4.078 | 1.742 | 0.378 | 0.408 | 0.086 | 21.624 | 9.566 |
| mean | 0.242 | 2.366 | 3.111 | 1.299 | 0.448 | 0.125 | 0.056 | 0.012 | 7.660 | 3.038 |

Table C4b. Survey indices of Georges Bank yellowtail abundance and biomass.

Stratified Mean Number per tow at Age

| **NEFSC Fall Survey** | | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | kg/tow |
| 1963 | 14.722 | 7.896 | 11.226 | 1.858 | 0.495 | 0.281 | 0.034 | 0.233 | 36.746 | 12.791 |
| 1964 | 1.721 | 9.723 | 7.370 | 5.998 | 2.690 | 0.383 | 0.095 | 0.028 | 28.007 | 13.625 |
| 1965 | 1.138 | 5.579 | 5.466 | 3.860 | 1.803 | 0.162 | 0.284 | 0.038 | 18.345 | 9.104 |
| 1966 | 8.772 | 4.776 | 2.070 | 0.837 | 0.092 | 0.051 | 0.000 | 0.000 | 17.775 | 3.989 |
| 1967 | 9.137 | 9.313 | 2.699 | 1.007 | 0.309 | 0.076 | 0.061 | 0.000 | 22.708 | 7.577 |
| 1968 | 11.782 | 11.946 | 5.758 | 0.766 | 0.944 | 0.059 | 0.000 | 0.000 | 31.254 | 10.535 |
| 1969 | 8.106 | 10.381 | 5.855 | 1.662 | 0.553 | 0.149 | 0.182 | 0.000 | 27.023 | 9.278 |
| 1970 | 4.610 | 5.133 | 3.144 | 1.952 | 0.451 | 0.063 | 0.017 | 0.000 | 16.417 | 4.978 |
| 1971 | 3.627 | 6.949 | 4.904 | 2.248 | 0.551 | 0.234 | 0.024 | 0.024 | 18.586 | 6.362 |
| 1972 | 2.424 | 6.525 | 4.824 | 2.095 | 0.672 | 0.279 | 0.000 | 0.000 | 17.604 | 6.328 |
| 1973 | 2.494 | 5.497 | 5.104 | 2.944 | 1.216 | 0.416 | 0.171 | 0.031 | 17.967 | 6.600 |
| 1974 | 4.623 | 2.854 | 1.524 | 1.060 | 0.460 | 0.249 | 0.131 | 0.000 | 11.931 | 3.734 |
| 1975 | 4.625 | 2.511 | 0.877 | 0.572 | 0.334 | 0.033 | 0.000 | 0.031 | 9.344 | 2.365 |
| 1976 | 0.336 | 1.929 | 0.475 | 0.117 | 0.122 | 0.033 | 0.000 | 0.067 | 3.079 | 1.533 |
| 1977 | 0.928 | 2.161 | 1.649 | 0.618 | 0.113 | 0.056 | 0.036 | 0.016 | 5.577 | 2.828 |
| 1978 | 4.729 | 1.272 | 0.773 | 0.406 | 0.139 | 0.011 | 0.000 | 0.024 | 7.391 | 2.383 |
| 1979 | 1.312 | 1.999 | 0.316 | 0.122 | 0.138 | 0.038 | 0.064 | 0.007 | 4.014 | 1.520 |
| 1980 | 0.761 | 5.086 | 6.050 | 0.678 | 0.217 | 0.162 | 0.006 | 0.033 | 13.071 | 6.722 |
| 1981 | 1.584 | 2.333 | 1.630 | 0.500 | 0.121 | 0.083 | 0.013 | 0.000 | 6.264 | 2.621 |
| 1982 | 2.424 | 2.185 | 1.590 | 0.423 | 0.089 | 0.000 | 0.000 | 0.000 | 6.711 | 2.271 |
| 1983 | 0.109 | 2.284 | 1.914 | 0.473 | 0.068 | 0.012 | 0.000 | 0.038 | 4.898 | 2.131 |
| 1984 | 0.661 | 0.400 | 0.306 | 2.428 | 0.090 | 0.029 | 0.000 | 0.018 | 3.944 | 0.593 |
| 1985 | 1.350 | 0.560 | 0.160 | 0.040 | 0.080 | 0.000 | 0.000 | 0.000 | 2.200 | 0.709 |
| 1986 | 0.280 | 1.110 | 0.350 | 0.070 | 0.000 | 0.000 | 0.000 | 0.000 | 1.810 | 0.820 |
| 1987 | 0.113 | 0.390 | 0.396 | 0.053 | 0.079 | 0.000 | 0.000 | 0.000 | 1.031 | 0.509 |
| 1988 | 0.019 | 0.213 | 0.102 | 0.031 | 0.000 | 0.000 | 0.000 | 0.000 | 0.376 | 0.171 |
| 1989 | 0.248 | 1.992 | 0.774 | 0.069 | 0.066 | 0.000 | 0.000 | 0.000 | 3.176 | 0.977 |
| 1990 | 0.000 | 0.326 | 1.517 | 0.280 | 0.014 | 0.000 | 0.000 | 0.000 | 2.284 | 0.725 |
| 1991 | 2.100 | 0.275 | 0.439 | 0.358 | 0.000 | 0.000 | 0.000 | 0.000 | 3.172 | 0.730 |
| 1992 | 0.151 | 0.396 | 0.712 | 0.162 | 0.144 | 0.027 | 0.000 | 0.000 | 1.592 | 0.576 |
| 1993 | 0.842 | 0.136 | 0.587 | 0.536 | 0.000 | 0.000 | 0.000 | 0.000 | 2.101 | 0.545 |
| 1994 | 1.200 | 0.220 | 0.980 | 0.710 | 0.260 | 0.030 | 0.030 | 0.000 | 3.440 | 0.897 |
| 1995 | 0.280 | 0.120 | 0.350 | 0.280 | 0.050 | 0.010 | 0.000 | 0.000 | 1.160 | 0.354 |
| 1996 | 0.140 | 0.350 | 1.870 | 0.450 | 0.070 | 0.000 | 0.000 | 0.000 | 2.880 | 1.303 |
| 1997 | 1.392 | 0.533 | 3.442 | 2.090 | 1.071 | 0.082 | 0.000 | 0.000 | 8.611 | 3.781 |
| 1998 | 1.900 | 4.817 | 4.202 | 1.190 | 0.298 | 0.055 | 0.019 | 0.000 | 12.531 | 4.347 |
| 1999 | 3.090 | 8.423 | 5.727 | 1.432 | 1.436 | 0.260 | 0.000 | 0.000 | 20.394 | 7.973 |
| 2000 | 0.629 | 1.697 | 4.814 | 2.421 | 0.948 | 0.800 | 0.027 | 0.000 | 11.355 | 5.838 |
| 2001 | 3.518 | 6.268 | 8.091 | 2.601 | 1.718 | 0.714 | 1.334 | 0.000 | 24.282 | 11.553 |
| mean | 2.766 | 3.501 | 2.821 | 1.164 | 0.459 | 0.124 | 0.065 | 0.015 | 11.053 | 4.146 |

Table C4c. Survey indices of Georges Bank yellowtail abundance and biomass.

Stratified Mean Number per tow at Age

| **Canadian Survey** | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6+ | Total | kg/tow |
| 1987 | 0.12 | 0.68 | 2.00 | 1.09 | 0.06 | 0.00 | 3.95 | 1.26 |
| 1988 | 0.00 | 0.66 | 1.89 | 0.80 | 0.59 | 0.01 | 3.96 | 1.24 |
| 1989 | 0.11 | 0.78 | 0.80 | 0.32 | 0.10 | 0.02 | 2.13 | 0.47 |
| 1990 | 0.00 | 1.27 | 4.62 | 1.12 | 0.43 | 0.01 | 7.45 | 1.58 |
| 1991 | 0.02 | 0.59 | 1.72 | 2.91 | 0.99 | 0.00 | 6.24 | 1.76 |
| 1992 | 0.22 | 10.04 | 4.52 | 1.21 | 0.16 | 0.00 | 16.14 | 2.48 |
| 1993 | 0.33 | 2.16 | 5.04 | 3.47 | 0.62 | 0.00 | 11.63 | 2.64 |
| 1994 | 0.00 | 6.03 | 3.33 | 3.08 | 0.75 | 0.33 | 13.51 | 2.75 |
| 1995 | 0.21 | 1.31 | 4.07 | 2.22 | 1.14 | 0.11 | 9.07 | 2.03 |
| 1996 | 0.45 | 5.54 | 8.44 | 7.49 | 1.37 | 0.16 | 23.45 | 5.30 |
| 1997 | 0.10 | 9.48 | 15.16 | 19.09 | 3.11 | 0.54 | 47.49 | 13.29 |
| 1998 | 0.92 | 3.10 | 3.81 | 5.15 | 2.44 | 0.59 | 16.01 | 4.29 |
| 1999 | 0.22 | 13.05 | 24.78 | 9.07 | 6.85 | 3.10 | 57.07 | 17.67 |
| 2000 | 0.06 | 9.18 | 31.22 | 18.56 | 5.77 | 4.42 | 69.22 | 19.95 |
| 2001 | 0.29 | 5.97 | 51.67 | 16.65 | 4.41 | 3.61 | 82.62 | 22.16 |
| 2002 | | | | | | | 63.49 | 20.62 |
| mean | 0.20 | 4.66 | 10.87 | 6.15 | 1.92 | 0.86 | 27.09 | 7.47 |

| **Scallop Survey** | |
|---|---|
| Year | age 1 |
| 1982 | 0.313 |
| 1983 | 0.140 |
| 1984 | 0.233 |
| 1985 | 0.549 |
| 1986 | 0.103 |
| 1987 | 0.047 |
| 1988 | 0.116 |
| 1989 | 0.195 |
| 1990 | 0.100 |
| 1991 | 2.117 |
| 1992 | 0.167 |
| 1993 | 1.129 |
| 1994 | 1.503 |
| 1995 | 0.609 |
| 1996 | 0.508 |
| 1997 | 1.062 |
| 1998 | 1.872 |
| 1999 | 1.038 |
| 2000 | 0.912 |
| 2001 | 0.789 |
| 2002 | 1.005 |
| mean | 0.691 |

Table C5a. Estimates of stock size from virtual population analysis.

STOCK NUMBERS (Jan 1) in thousands

| Age | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 28290 | 50265 | 68516 | 22919 | 15760 | 50823 | 23375 |
| 2 | 23279 | 22848 | 39214 | 52140 | 18208 | 12605 | 32871 |
| 3 | 28937 | 14635 | 10589 | 9228 | 14628 | 7144 | 7510 |
| 4 | 16960 | 11709 | 4830 | 2284 | 2899 | 3003 | 2199 |
| 5 | 6729 | 5492 | 2893 | 885 | 651 | 816 | 957 |
| 6 | 2859 | 2240 | 1551 | 1417 | 768 | 304 | 465 |
| 1+ | 107055 | 107189 | 127593 | 88873 | 52914 | 74695 | 67376 |

| Age | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 22099 | 61066 | 21627 | 5818 | 8620 | 14594 | 6660 |
| 2 | 18927 | 17814 | 49947 | 15840 | 4134 | 6670 | 11361 |
| 3 | 18312 | 12264 | 13925 | 25067 | 6011 | 1650 | 2434 |
| 4 | 3032 | 7011 | 5199 | 4957 | 6031 | 1062 | 613 |
| 5 | 677 | 1198 | 1618 | 1319 | 1962 | 654 | 279 |
| 6 | 206 | 185 | 129 | 264 | 382 | 102 | 129 |
| 1+ | 63252 | 99538 | 92445 | 53266 | 27141 | 24732 | 21476 |

| Age | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 7023 | 19349 | 8528 | 11685 | 22048 | 15873 | 11798 |
| 2 | 5310 | 5623 | 15405 | 6815 | 9369 | 17679 | 10834 |
| 3 | 4079 | 1947 | 2462 | 11241 | 3832 | 7622 | 6910 |
| 4 | 1108 | 851 | 516 | 1411 | 3663 | 2032 | 3954 |
| 5 | 188 | 219 | 132 | 185 | 432 | 800 | 515 |
| 6 | 155 | 49 | 36 | 34 | 86 | 41 | 119 |
| 1+ | 17863 | 28037 | 27079 | 31372 | 39430 | 44047 | 34131 |

| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 9988 | 12714 | 17661 | 33375 | 58222 | 53641 | 48490 |
| 2 | 4960 | 8113 | 10397 | 14414 | 27311 | 47645 | 43898 |
| 3 | 7957 | 3282 | 6500 | 8165 | 11263 | 21482 | 36034 |
| 4 | 3145 | 1319 | 1877 | 3957 | 5547 | 6695 | 14684 |
| 5 | 1073 | 249 | 433 | 889 | 1880 | 2891 | 4126 |
| 6 | 154 | 48 | 38 | 232 | 308 | 715 | 1666 |
| 1+ | 27276 | 25724 | 36906 | 61032 | 104531 | 133068 | 148898 |

| Age | 2001 | 2002 |
|---|---|---|
| 1 | 50544 | 00 |
| 2 | 39609 | 41186 |
| 3 | 32565 | 29938 |
| 4 | 24302 | 20449 |
| 5 | 9467 | 17558 |
| 6 | 4477 | 10074 |
| 1+ | 160964 | 119205 |

Table C5b. Estimates of fishing mortality from VPA.

FISHING MORTALITY

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.05 | 0.07 | 0.03 | 0.02 | 0.24 | 0.01 |
| 2 | 0.26 | 0.57 | 1.25 | 1.07 | 0.74 | 0.32 | 0.39 |
| 3 | 0.70 | 0.91 | 1.33 | 0.96 | 1.38 | 0.98 | 0.71 |
| 4 | 0.93 | 1.20 | 1.50 | 1.05 | 1.07 | 0.94 | 0.98 |
| 5 | 0.95 | 1.25 | 1.59 | 1.09 | 1.10 | 0.97 | 1.01 |
| 6 | 0.95 | 1.25 | 1.59 | 1.09 | 1.10 | 0.97 | 1.01 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.00 | 0.11 | 0.14 | 0.06 | 0.05 | 0.03 |
| 2 | 0.23 | 0.05 | 0.49 | 0.77 | 0.72 | 0.81 | 0.82 |
| 3 | 0.76 | 0.66 | 0.83 | 1.22 | 1.53 | 0.79 | 0.59 |
| 4 | 0.73 | 1.27 | 1.17 | 0.73 | 2.02 | 1.14 | 0.98 |
| 5 | 0.74 | 1.33 | 1.22 | 0.74 | 2.27 | 1.18 | 1.01 |
| 6 | 0.74 | 1.33 | 1.22 | 0.74 | 2.27 | 1.18 | 1.01 |

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.18 | 0.67 |
| 2 | 0.80 | 0.63 | 0.12 | 0.38 | 0.01 | 0.74 | 0.11 |
| 3 | 1.37 | 1.13 | 0.36 | 0.92 | 0.43 | 0.46 | 0.59 |
| 4 | 1.42 | 1.66 | 0.82 | 0.98 | 1.32 | 1.17 | 1.10 |
| 5 | 1.50 | 1.79 | 0.84 | 1.02 | 1.39 | 1.22 | 1.15 |
| 6 | 1.50 | 1.79 | 0.84 | 1.02 | 1.39 | 1.22 | 1.15 |

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.21 | 0.02 | 0.04 | 0.05 | 0.04 | 0.08 | 0.10 |
| 3 | 1.60 | 0.36 | 0.30 | 0.19 | 0.32 | 0.18 | 0.19 |
| 4 | 2.34 | 0.91 | 0.55 | 0.54 | 0.45 | 0.28 | 0.24 |
| 5 | 2.77 | 0.94 | 0.56 | 0.55 | 0.46 | 0.29 | 0.24 |
| 6 | 2.77 | 0.94 | 0.56 | 0.55 | 0.46 | 0.29 | 0.24 |

| | 2001 |
|---|---|
| 1 | 0.00 |
| 2 | 0.08 |
| 3 | 0.27 |
| 4 | 0.13 |
| 5 | 0.13 |
| 6 | 0.13 |

Table C5c. Estimates of spawning biomass from VPA.

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT) (using SSB mean weights)

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 2836 | 2575 | 3052 | 4310 | 1898 | 1440 | 3837 |
| 3 | 8895 | 4500 | 2678 | 3026 | 3891 | 2185 | 2320 |
| 4 | 5531 | 3982 | 1319 | 861 | 1084 | 1275 | 873 |
| 5 | 2509 | 2042 | 848 | 383 | 296 | 397 | 421 |
| 6 | 1372 | 1031 | 502 | 691 | 424 | 171 | 251 |
| 1+ | 21143 | 14130 | 8398 | 9271 | 7592 | 5469 | 7702 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 2310 | 2733 | 5527 | 1534 | 629 | 1480 | 2358 |
| 3 | 5930 | 4161 | 4356 | 6031 | 1103 | 543 | 947 |
| 4 | 1351 | 2295 | 1908 | 2035 | 1195 | 394 | 248 |
| 5 | 371 | 449 | 670 | 656 | 450 | 270 | 139 |
| 6 | 150 | 78 | 75 | 171 | 107 | 46 | 71 |
| 1+ | 10112 | 9716 | 12537 | 10427 | 3485 | 2732 | 3763 |

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 1027 | 1205 | 4334 | 1461 | 2143 | 1834 | 1422 |
| 3 | 1108 | 621 | 1058 | 2797 | 1083 | 2139 | 1610 |
| 4 | 375 | 269 | 244 | 497 | 935 | 599 | 1164 |
| 5 | 63 | 82 | 75 | 78 | 162 | 286 | 165 |
| 6 | 64 | 21 | 26 | 18 | 38 | 27 | 60 |
| 1+ | 2638 | 2198 | 5739 | 4850 | 4360 | 4885 | 4421 |

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 556 | 958 | 1457 | 2097 | 4279 | 8248 | 7639 |
| 3 | 1133 | 816 | 1841 | 2451 | 3533 | 7978 | 12623 |
| 4 | 516 | 383 | 781 | 1518 | 2292 | 3486 | 7484 |
| 5 | 195 | 90 | 229 | 434 | 958 | 1766 | 2596 |
| 6 | 38 | 21 | 27 | 164 | 196 | 512 | 1334 |
| 1+ | 2438 | 2268 | 4335 | 6663 | 11258 | 21989 | 31677 |

| | 2001 |
|---|---|
| 1 | 00 |
| 2 | 5260 |
| 3 | 10035 |
| 4 | 12946 |
| 5 | 6713 |
| 6 | 3976 |
| 1+ | 38932 |

Table C6. Projection input and short term output from the age based assessment. The fishing mortality rate in 2003 and 2004 is $F_{rebuild.}$

M = 0.2

| Age | Weight (kg) | Maturity | Selectivity |
|---|---|---|---|
| 1 | 0.181 | 0 | 0.006 |
| 2 | 0.349 | 0.52 | 0.315 |
| 3 | 0.462 | 0.86 | 0.648 |
| 4 | 0.578 | 0.98 | 1 |
| 5 | 0.710 | 1 | 1 |
| 6+ | 0.948 | 1 | 1 |

| Year | F | SSB | Catch |
|---|---|---|---|
| 2002 | 0.11 | 47.73 | 4.60 |
| 2003 | 0.22 | 50.87 | 10.10 |
| 2004 | 0.22 | 50.71 | 10.11 |

Figure C1. Total catch of Georges Bank yellowtail flounder.

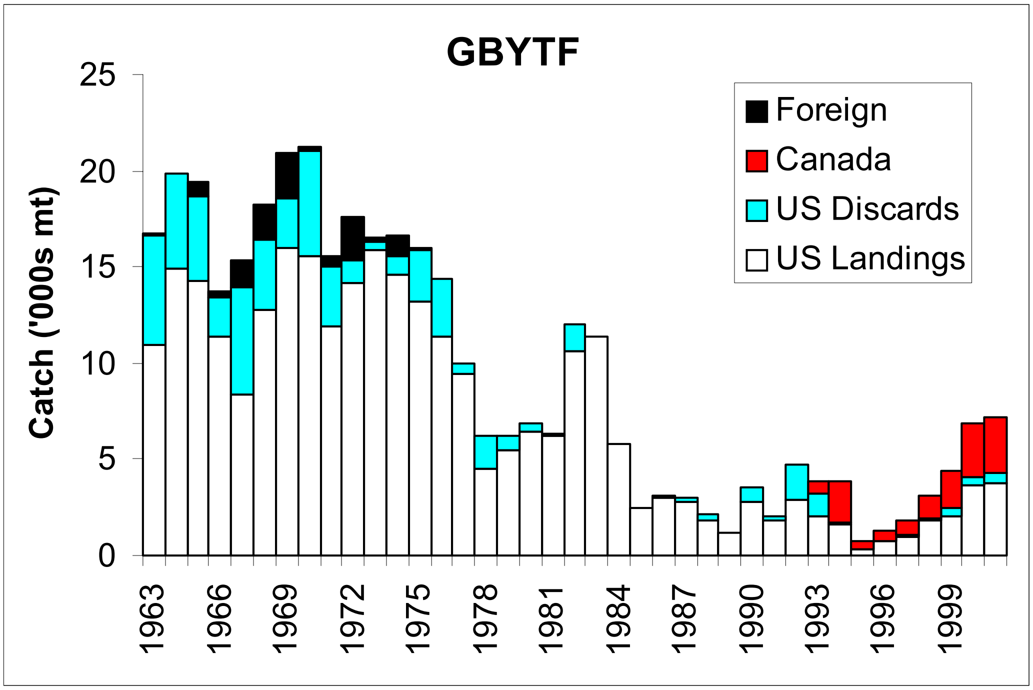



Figure C2. Survey indices of Georges Bank yellowtail flounder biomass.

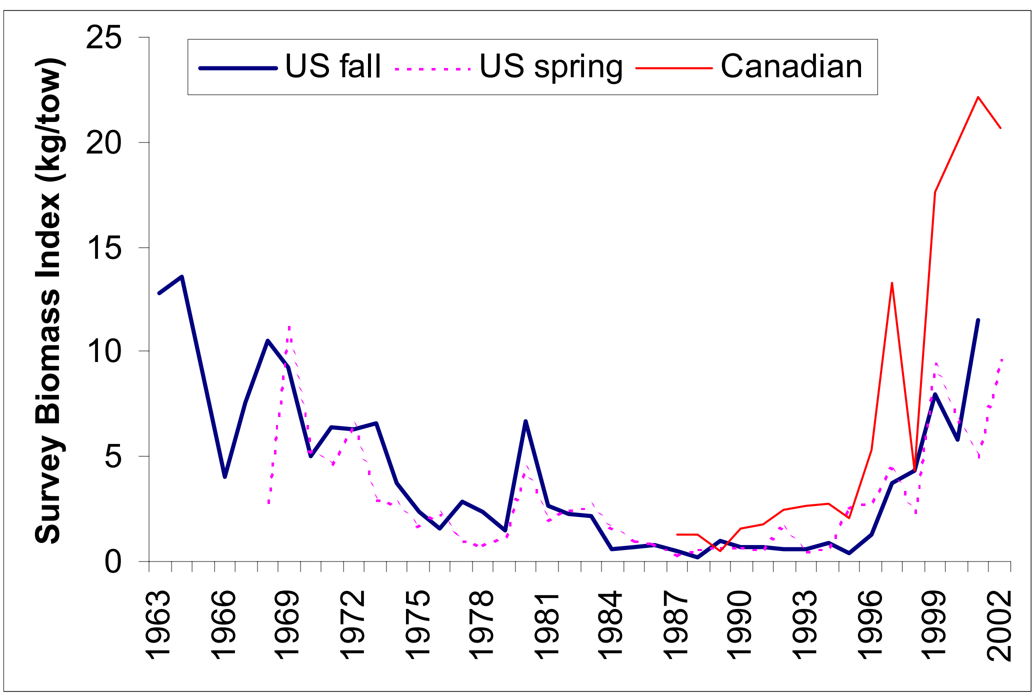


Figure C3. Survey indices of abundance at age. Note that the NEFSC Spring and Fall surveys correspond to the left axes in each plot while the NEFSC scallop and the Canadian surveys correspond to the right axes in each plot.

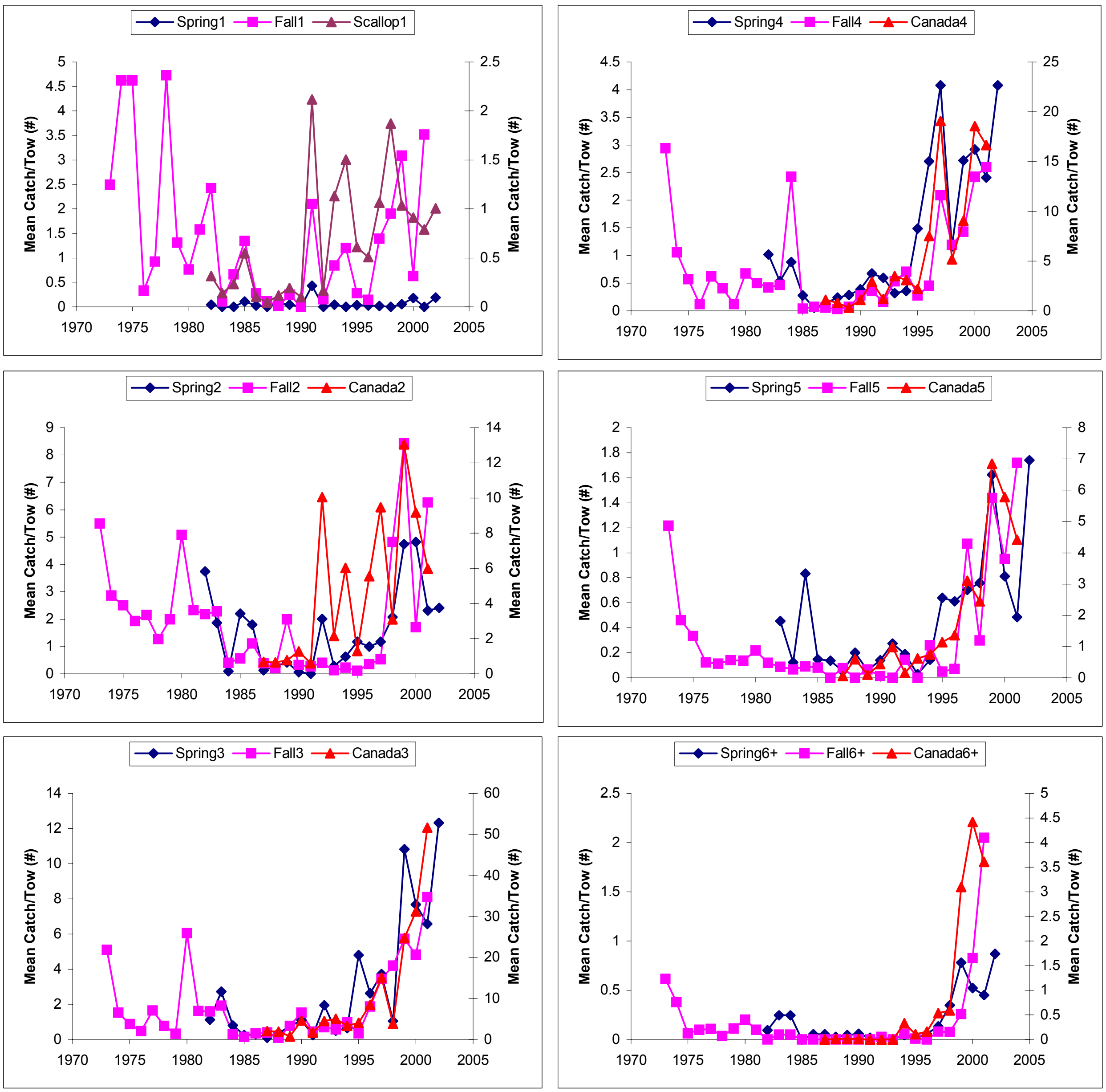
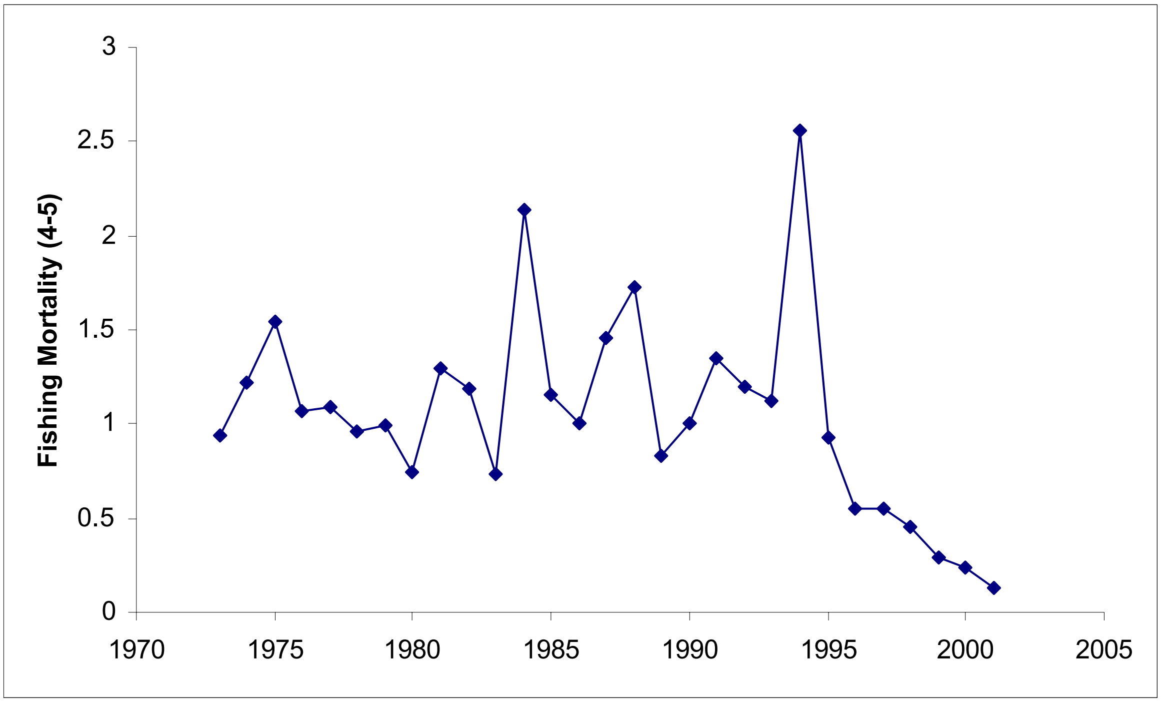


Figure C4. Summary of Georges Bank yellowtail flounder VPA results.



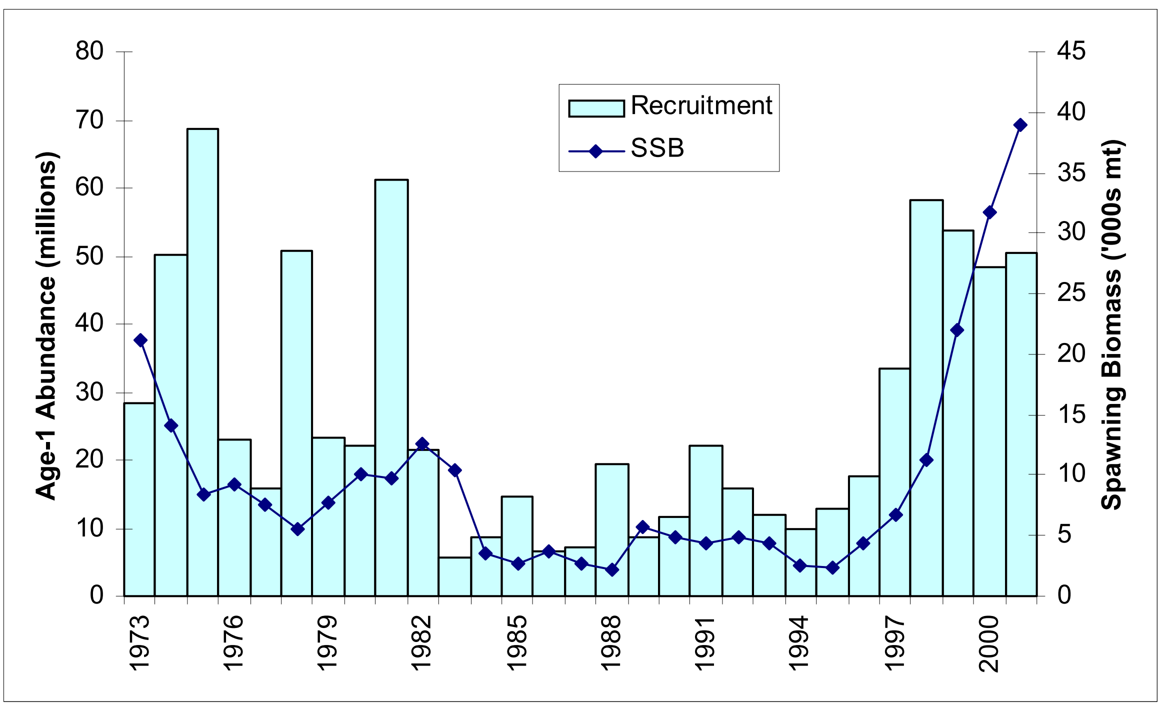



Figure C5. Population abundance at age from VPA compared to equilibrium levels at MSY.

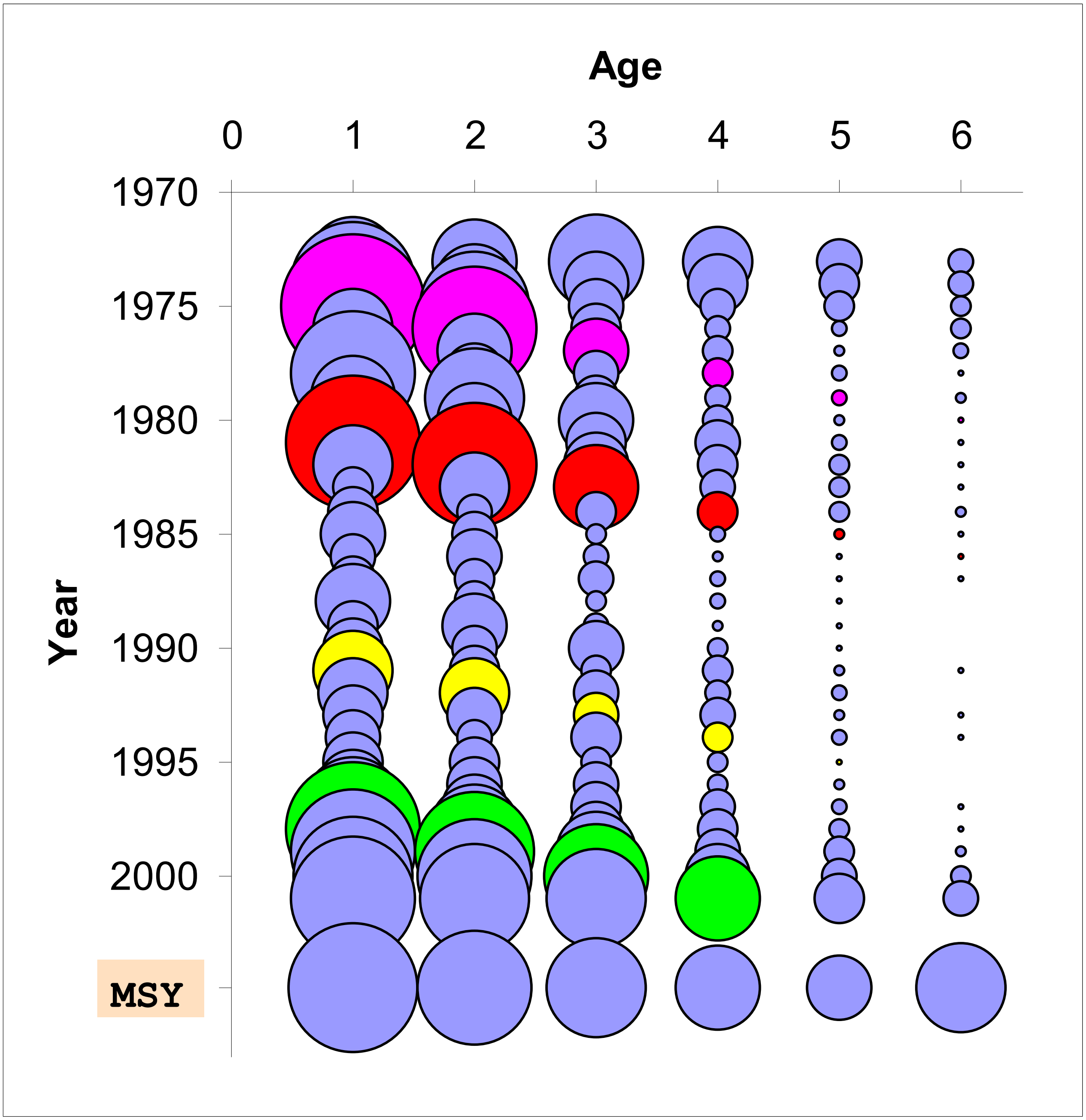
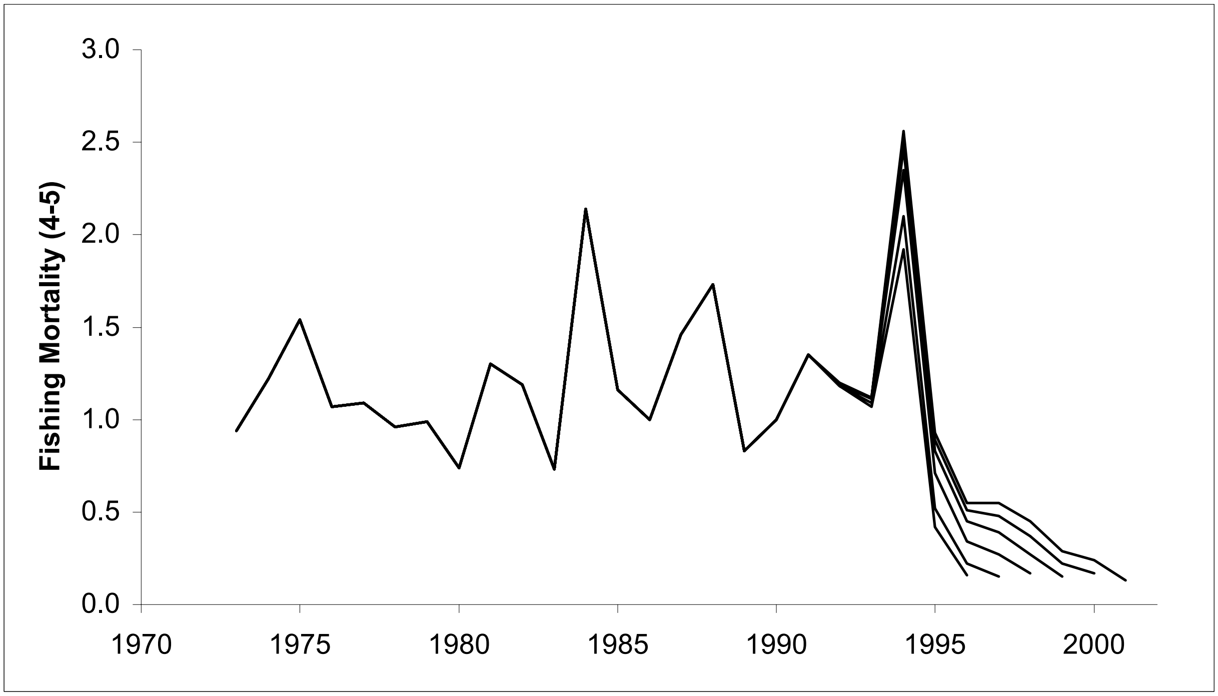


Figure C6. Retrospective patterns in Georges Bank yellowtail flounder VPA.



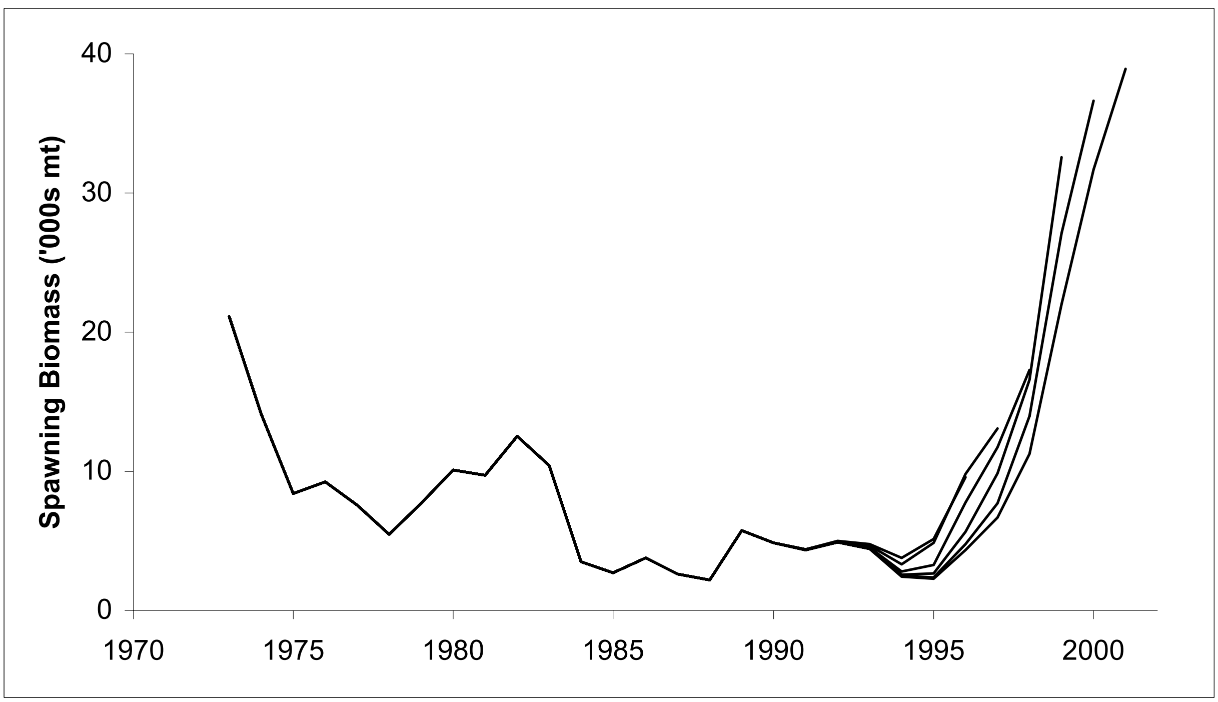



Figure C7. Point estimate (center symbol) and 80% confidence intervals (end symbols) for F and SSB in 2001 for the base run and three sensitivity analyses which increased the impacted survey catches.

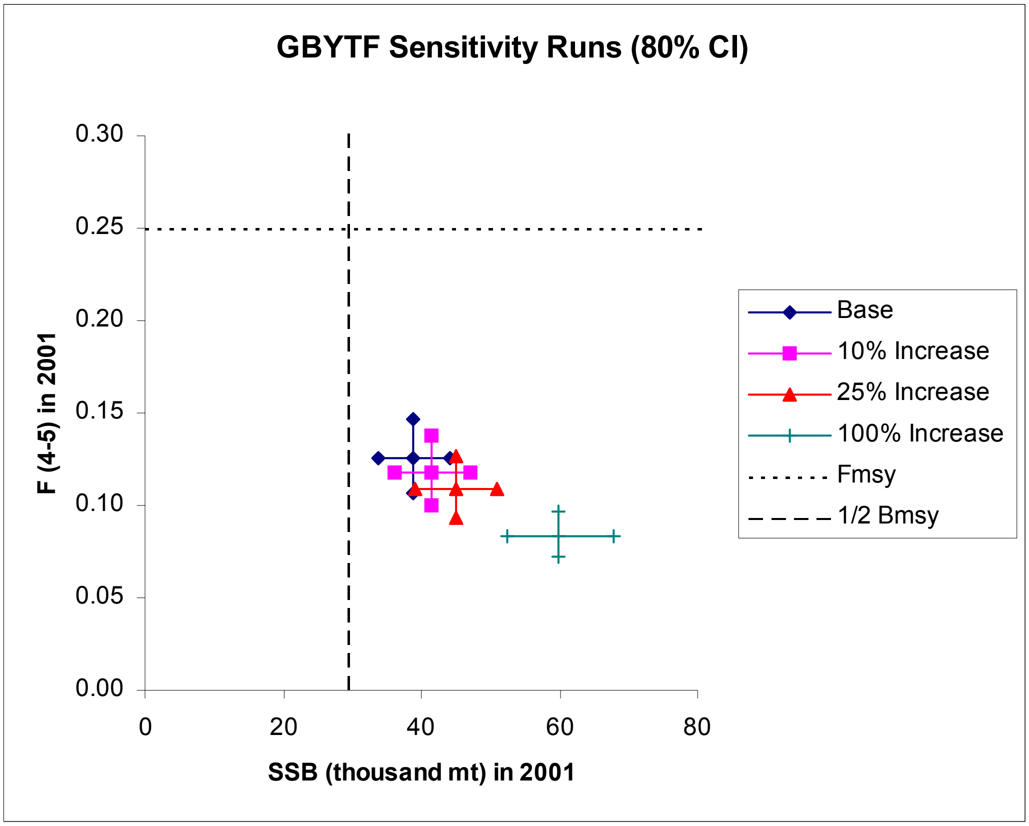


Figure C8. Projected spawning stock biomass under $F_{REBUILD}$=0.22 in years 2003 through 2009 to achieve a 50% probability of $B_{msy}$ in 2009.

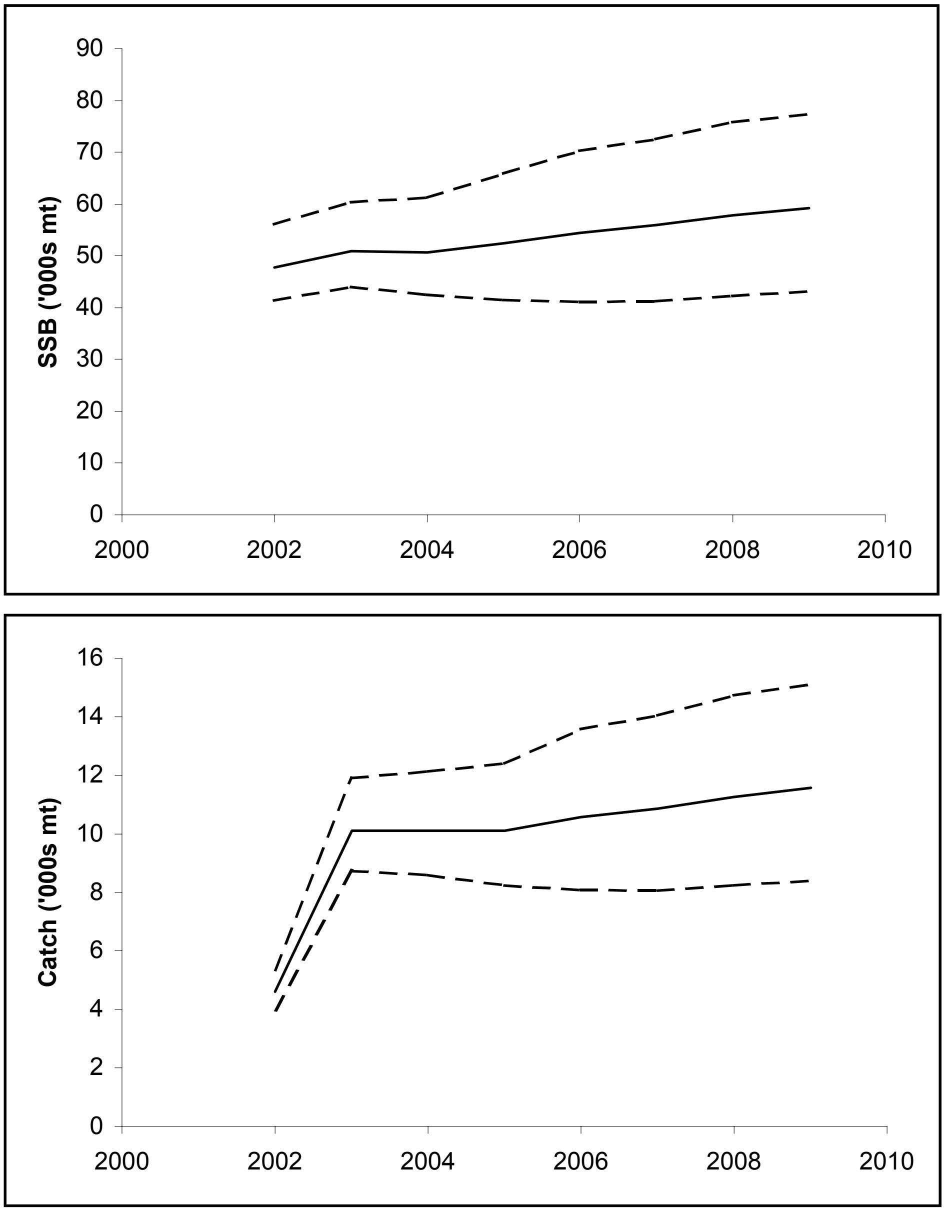
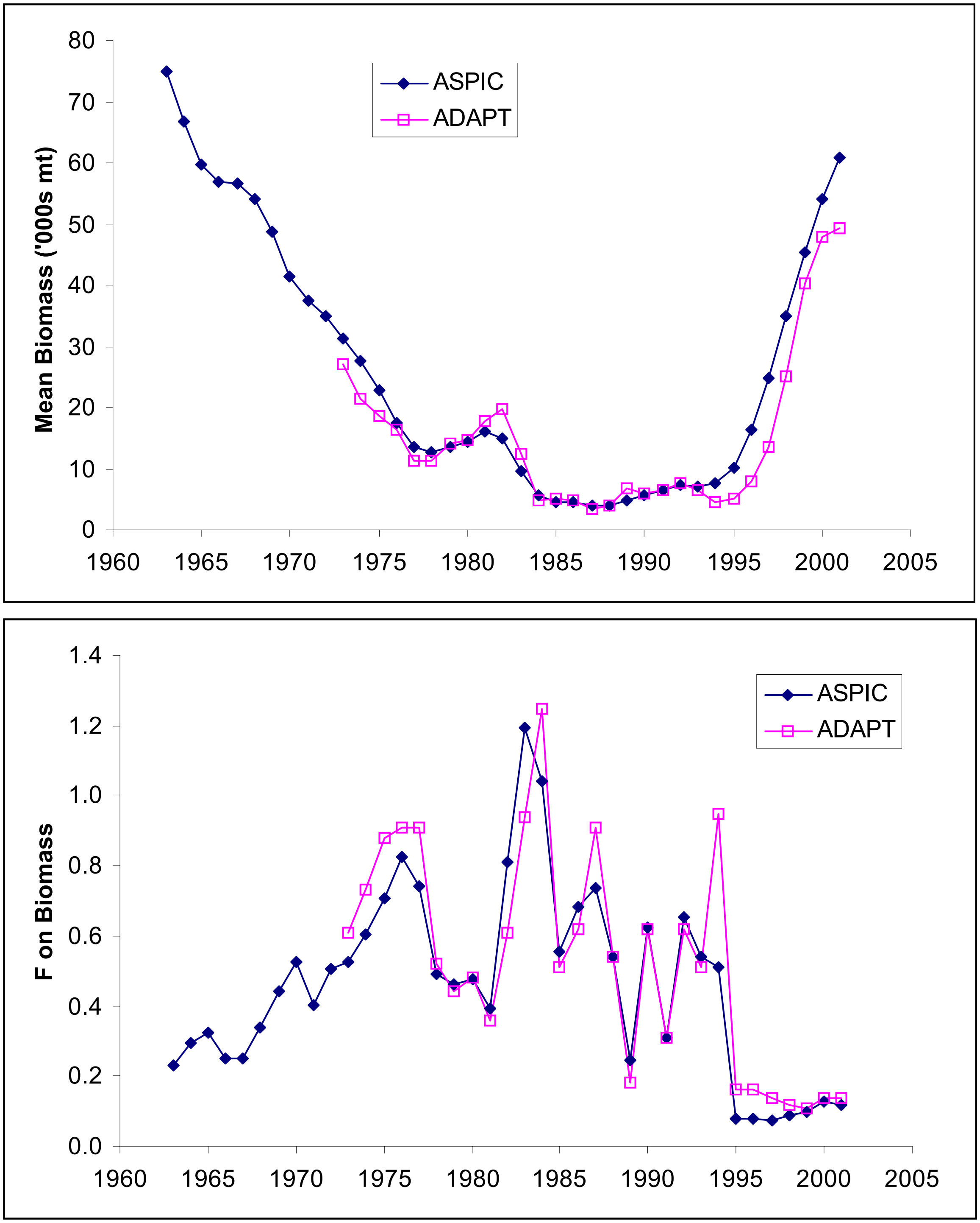


Figure C9. Mean biomass of Georges Bank yellowtail flounder and fishing mortality on biomass.



## D. Southern New England Yellowtail Flounder by S.X. Cadrin

### 1.0 Background

The southern New England yellowtail stock was at low biomass and relatively low F in 1999 (SSB was 5,400 mt and fully recruited F was 0.3; Cadrin 2001). This report updates catch and survey indices, and estimates 2001 fishing mortality and 2002 stock size. In August 2002, the Southern Demersal Working Group concluded that southern New England and Mid Atlantic yellowtail flounder should be assessed and managed as a single unit stock, and is concurrently preparing an assessment of the southern New England- Mid Atlantic yellowtail resource (Cadrin 2002). In September 2002, the Working Group reviewed input data, analyses and projections in this report.

### 2.0 2002 Assessment

2.1 2000-2001 Landings

U.S. landings were prorated as described in NEFSC (1998; Table D1; Figure D1). Landings from southern New England have steadily increased since 1999 (a 9% increase in 2000 and an 11% increase in 2001). Sampling in 2000 and 2001 improved from that in 1999 (Table D2). Although all classified market categories were sampled in each half-year period, the overall number of samples was low. Landings at length for 2001 and 2002 were estimated by half-year and market category. Landings at age for 1999 were revised by assuming the average age distribution for July to December in 1998, 2000 and 2001 for landings in the second half of 1999.

2.2 2000-2001 Discards

Discarded catch was estimated from logbook information on discard to kept ratios by half-year and gear (NEFSC 1998). Discards were 5% of landings by weight in 2000 and 2001. Discards at age were estimated from observer lengths and survey age-length keys, however length distribution of scallop dredge discards were only sampled in the second half of 2000. Those samples were used to characterize all 2000-2001 dredge discards. Total catch at age and mean weights at age are reported in Table D3.

2.3 2000-2002 Survey Indices

Survey abundance and biomass indices are reported in Table D4. Estimates are from valid tows in southern New England (offshore strata 5, 6, 9, 10; scallop strata 33, 34, 35, 46), standardized according to net, vessel, and door changes (NEFSC 1998). All survey indices of total abundance and total biomass remained low in recent years (Figure D2).

### 3.0 Assessment Results

3.1 Age-Based Analysis

Results of an updated VPA calibration of southern New England yellowtail are summarized in Table D5. This update uses existing stock definitions, i.e., Southern New England yellowtail flounder is a single stock. This analysis updates the assessment reported by Cadrin (2000) by including 1999-2001 landings and discards, 1999-2000 scallop and fall indices, and 2000-2002 winter and spring indices. Note that a VPA was updated in 2000, but was rejected because of inadequate sampling of catch at age in 1999 (see Cadrin 2000 for details). Results indicate that fishing mortality increased to 1.58 in 1999, and decreased to 0.54 and 0.46 in 2000 and 2001 (Figure D3). Spawning biomass increased from extremely low levels in the middle 1990s to 1,400 mt in 1999 and 2,000 mt in 2000, but slightly decreased to 1,900 mt in 2001. Retrospective analysis indicates a strong pattern of underestimating F, and overestimating SSB in recent years, but the estimates of 2000 F and SSB were much more consistent than those from 1994-1999 (Figure D4). Bootstrap analysis indicates that abundance was estimated with moderate precision (CV=38-47%). Sensitivity to recent NEFSC survey observations was evaluated by arbitrarily increasing recent NEFSC survey observations by 10%, 25%, and 100% (Figure D7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

Proxies for MSY reference points were derived from yield and SSB per recruit analyses and the assumption of constant recruitment (NEFSC 2002). Assuming that $F_{MSY}$ is approximately $F_{40\%}$ (0.27 on fully-recruited ages) and long-term average recruitment (40.7 million at age-1), MSY=9,000 mt and $SSB_{MSY}$=45,200 mt. Therefore, despite uncertainty in the assessment, the stock is clearly overfished (2001 SSB= 1,900mt, 4%$SSB_{MSY}$) and overfishing is occurring (2001 F=0.46, $=1.7 \cdot F_{MSY}$).

Stochastic projections that assume a 15% reduction in F from 2001 to 2002 and recruitment similar to that experienced in the last decade suggest that the stock cannot rebuild to $B_{MSY}$ by 2009 even if F in 2003-2010 is zero. If the same hindcast recruitment values used to derive the reference points (NEFSC 2002) are assumed for projections, therefore stock is expected to have approximately a 50% chance of rebuilding to $SSB_{MSY}$ by 2009 with an F of 0.10 (Figure D5, Table D6). However, long-term recruitment levels are not likely in the short-term, because SSB is extremely low, and retrospective patterns indicate that projections may be overly optimistic.

3.2 Biomass-Based Analysis

Due to continued low intensity of sampling and resulting problems estimating catch at age, a surplus production analysis (ASPIC) was updated to provide alternative perspectives on stock status. Biomass and F estimates are generally similar to the VPA, but biomass estimates in recent years are substantially greater than those from VPA (Figure D6). Despite the more optimistic perspective from ASPIC, stock biomass in 2001 remains only 15% of the ASPIC estimate of $B_{MSY}$. Therefore, ASPIC results also suggest that the stock is overfished. Stochastic projections at status quo F in 2002 and F=0 for 2003-2009 indicate a 25% probability of rebuilding to the ASPIC estimate of $B_{MSY}$ by 2009.

## 4.0 Sources of Uncertainty

- Estimates of recent catch at age may not be reliable due to poor sampling intensity. Therefore VPA and age-based projections may be misleading. Retrospective patterns may indicate inadequate sampling and mis-allocation of catch at age.
- Retrospective patterns indicate that VPA estimates of biomass and F may be overly optimistic. Updated VPAs may indicate that 2001 biomass levels were lower, and 2001 F greater than reported here.

- Although historical perspective from production models are valuable, current biomass levels may not be reliable, because recruitment is implicitly assumed to be a function of stock biomass.
- Inappropriate stock delineation may result in underestimated removals (e.g., from adjacent areas in the Mid Atlantic Bight).
- Estimates of prorated landings and discard ratios are based on preliminary logbook data and are subject to change.

**5.0 GARM Discussion**

The GARM noted that the Nantucket Lightship Closure does not appear to be helping recovery of this species. Abundance and size structure within the closed area does not appear to be significantly different from outside the area.

The question of what recruitment is appropriate for projections was raised. Using only the recent ten years of recruitment results in zero probability of rebuilding to $SSB_{MSY}$ because these recruitment values are so low. Using the entire time series of recruitment for projections does allow for rebuilding with F greater than zero. The GARM suggested that an interim rebuilding target may be derived from short-term recruitment (average=2.4 million) and 40% maximum SSB per recruit. The expected biomass at $F_{40\%}$ and short term recruitment is 2,700mt SSB, and current SSB is approximately 70% of the proposed interim target.

It was suggested that a jackknife approach be used to quantify the uncertainty in the generation of the catch at age.

**6.0 References**

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Table D1. Landings and catch of southern New England yellowtail flounder (thousand mt).

| | US Landings | US discards | Industrial landings | Foreign landings | total catch |
|---|---|---|---|---|---|
| 1960 | 7.8 | 3.2 | 0.5 | | 11.5 |
| 1961 | 11.6 | 4.7 | 0.7 | | 17.0 |
| 1962 | 13.1 | 5.3 | 0.2 | | 18.6 |
| 1963 | 22.0 | 5.9 | 0.3 | 0.2 | 27.9 |
| 1964 | 19.0 | 10.0 | 0.5 | | 29.0 |
| 1965 | 18.4 | 9.4 | 1.0 | 1.4 | 27.8 |
| 1966 | 14.9 | 8.7 | 2.7 | 0.7 | 23.6 |
| 1967 | 10.8 | 15.0 | 4.5 | 2.8 | 25.8 |
| 1968 | 14.3 | 13.7 | 3.9 | 3.5 | 28.0 |
| 1969 | 11.4 | 24.2 | 4.2 | 17.6 | 35.6 |
| 1970 | 13.1 | 9.3 | 2.1 | 2.5 | 22.4 |
| 1971 | 8.2 | 4.0 | 0.4 | 0.3 | 12.2 |
| 1972 | 8.2 | 5.0 | 0.3 | 3.0 | 13.2 |
| 1973 | 6.9 | 1.5 | 0.3 | 0.2 | 8.4 |
| 1974 | 6.4 | 8.7 | | 0.1 | 15.1 |
| 1975 | 3.2 | 1.9 | | | 5.1 |
| 1976 | 1.6 | 1.6 | | | 3.2 |
| 1977 | 2.8 | 1.9 | | | 4.7 |
| 1978 | 2.3 | 5.0 | | | 7.3 |
| 1979 | 5.3 | 4.4 | | | 9.7 |
| 1980 | 6.0 | 1.7 | | | 7.7 |
| 1981 | 4.7 | 1.2 | | | 5.9 |
| 1982 | 10.3 | 5.0 | | | 15.3 |
| 1983 | 17.0 | 3.5 | | | 20.5 |
| 1984 | 7.9 | 1.1 | | | 9.0 |
| 1985 | 2.7 | 1.2 | | | 3.9 |
| 1986 | 3.3 | 1.1 | | | 4.4 |
| 1987 | 1.6 | 0.9 | | | 2.5 |
| 1988 | 0.9 | 1.8 | | | 2.7 |
| 1989 | 2.5 | 5.5 | | | 8.0 |
| 1990 | 8.0 | 9.7 | | | 17.7 |
| 1991 | 3.9 | 2.3 | | | 6.2 |
| 1992 | 1.4 | 1.1 | | | 2.5 |
| 1993 | 0.5 | 0.1 | | | 0.6 |
| 1994 | 0.2 | 0.1 | | | 0.3 |
| 1995 | 0.2 | 0.1 | | | 0.2 |
| 1996 | 0.3 | 0.1 | | | 0.4 |
| 1997 | 0.2 | 0.0 | | | 0.3 |
| 1998 | 0.4 | 0.1 | | | 0.5 |
| 1999 | 0.7 | 0.1 | | | 0.8 |
| 2000 | 0.7 | 0.0 | | | 0.8 |
| 2001 | 0.8 | 0.0 | | | 0.9 |

Table D2. Samples of southern New England yellowtail flounder (italics indicate observer lengths).

Number of Fish Sampled

| year | half year | unclassified length | large lengths | small lengths | ages | # of observer trips |
|---|---|---|---|---|---|---|
| 1993 | 1 | 0 | 347 | 625 | 189 | 11 |
| | 2 | 0 | 72 | 234 | 73 | 3 |
| 1994 | 1 | 0 | 102 | 133 | 52 | 4 |
| | 2 | 0 | 252 | 254 | 143 | 6 |
| 1995 | 1 | 0 | 234 | 240 | 121 | 6 |
| | 2 | 0 | 94 | 146 | 50 | 3 |
| 1996 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 469 | 691 | 226 | 13 |
| 1997 | 1 | 0 | 813 | 803 | 317 | 18 |
| | 2 | 0 | 328 | 679 | 133 | 11 |
| 1998 | 1 | 49 | 283 | 596 | 202 | 8 |
| | 2 | 80 | 0 | 126 | 37 | 2 |
| 1999 | 1 | *154* | 272 | 408 | 333 | 9 |
| | 2 | *0* | 0 | 0 | 0 | 0 |
| 2000 | 1 | *170* | 304 | 103 | 621 | 11 |
| | 2 | *178* | 214 | 177 | 363 | 17 |
| 2001 | 1 | *249* | 191 | 263 | 710 | 9 |
| | 2 | *263* | 175 | 313 | 514 | 9 |

Table D3a. Catch at age (thousands) of southern New England yellowtail flounder.

| | age 1 | age 2 | age 3 | age 4 | age 5 | age 6 | age 7+ |
|---|---|---|---|---|---|---|---|
| 1973 | 188 | 5056 | 8299 | 4673 | 1716 | 1517 | 312 |
| 1974 | 858 | 28334 | 4715 | 5098 | 2500 | 950 | 1217 |
| 1975 | 8840 | 3779 | 1497 | 983 | 1257 | 549 | 471 |
| 1976 | 214 | 6599 | 912 | 245 | 337 | 391 | 355 |
| 1977 | 5442 | 4771 | 3973 | 392 | 205 | 253 | 283 |
| 1978 | 8698 | 13311 | 1495 | 1025 | 165 | 34 | 72 |
| 1979 | 204 | 19225 | 8371 | 1033 | 428 | 96 | 24 |
| 1980 | 988 | 9998 | 6342 | 3619 | 472 | 117 | 31 |
| 1981 | 38 | 6745 | 6737 | 2449 | 884 | 128 | 14 |
| 1982 | 169 | 35130 | 13693 | 1744 | 404 | 78 | 7 |
| 1983 | 2526 | 18430 | 38615 | 3364 | 376 | 129 | 42 |
| 1984 | 510 | 5731 | 14843 | 6661 | 740 | 244 | 21 |
| 1985 | 2230 | 7015 | 1516 | 1312 | 774 | 135 | 31 |
| 1986 | 462 | 9680 | 2921 | 561 | 324 | 119 | 22 |
| 1987 | 1590 | 3404 | 2033 | 803 | 139 | 47 | 9 |
| 1988 | 5899 | 2050 | 508 | 407 | 101 | 17 | 6 |
| 1989 | 24 | 19215 | 3103 | 411 | 47 | 3 | 0 |
| 1990 | 192 | 2048 | 42185 | 2025 | 79 | 5 | 0 |
| 1991 | 445 | 1607 | 5050 | 9489 | 93 | 1 | 17 |
| 1992 | 477 | 1453 | 1982 | 2347 | 279 | 11 | 3 |
| 1993 | 13 | 423 | 376 | 426 | 124 | 40 | 0 |
| 1994 | 9 | 150 | 222 | 165 | 132 | 49 | 1 |
| 1995 | 7 | 248 | 163 | 210 | 30 | 4 | 3 |
| 1996 | 21 | 305 | 496 | 151 | 29 | 13 | 6 |
| 1997 | 1 | 56 | 351 | 150 | 15 | 2 | 3 |
| 1998 | 0 | 388 | 478 | 179 | 34 | 5 | 1 |
| 1999 | 3 | 72 | 1446 | 180 | 56 | 13 | 5 |
| 2000 | 31 | 456 | 834 | 336 | 12 | 2 | 2 |
| 2001 | 1 | 235 | 1161 | 300 | 84 | 18 | 9 |

Table D3b. Mean weight at age (kg) of southern New England yellowtail flounder catch.

| | age 1 | age 2 | age 3 | age 4 | age 5 | age 6 | age 7+ |
|---|---|---|---|---|---|---|---|
| 1973 | 0.210 | 0.298 | 0.381 | 0.420 | 0.430 | 0.506 | 0.611 |
| 1974 | 0.203 | 0.308 | 0.359 | 0.429 | 0.477 | 0.476 | 0.518 |
| 1975 | 0.218 | 0.290 | 0.385 | 0.439 | 0.436 | 0.469 | 0.515 |
| 1976 | 0.228 | 0.303 | 0.427 | 0.528 | 0.533 | 0.568 | 0.603 |
| 1977 | 0.215 | 0.284 | 0.385 | 0.521 | 0.529 | 0.484 | 0.612 |
| 1978 | 0.234 | 0.296 | 0.402 | 0.543 | 0.710 | 0.791 | 0.677 |
| 1979 | 0.189 | 0.301 | 0.366 | 0.476 | 0.590 | 0.684 | 0.679 |
| 1980 | 0.206 | 0.281 | 0.384 | 0.499 | 0.690 | 0.891 | 1.182 |
| 1981 | 0.140 | 0.262 | 0.343 | 0.484 | 0.619 | 0.664 | 0.476 |
| 1982 | 0.226 | 0.263 | 0.354 | 0.502 | 0.661 | 0.821 | 0.956 |
| 1983 | 0.175 | 0.262 | 0.341 | 0.499 | 0.671 | 0.829 | 0.838 |
| 1984 | 0.182 | 0.239 | 0.298 | 0.388 | 0.497 | 0.652 | 0.724 |
| 1985 | 0.183 | 0.264 | 0.370 | 0.428 | 0.541 | 0.62 | 0.867 |
| 1986 | 0.186 | 0.285 | 0.335 | 0.470 | 0.598 | 0.617 | 0.804 |
| 1987 | 0.247 | 0.268 | 0.361 | 0.412 | 0.542 | 0.595 | 0.905 |
| 1988 | 0.270 | 0.293 | 0.398 | 0.501 | 0.664 | 0.936 | 0.937 |
| 1989 | 0.311 | 0.337 | 0.389 | 0.546 | 0.736 | 0.959 | 1.046 |
| 1990 | 0.301 | 0.327 | 0.378 | 0.461 | 0.800 | 0.884 | 0.781 |
| 1991 | 0.206 | 0.262 | 0.336 | 0.414 | 0.676 | 0.874 | 0.594 |
| 1992 | 0.167 | 0.316 | 0.367 | 0.430 | 0.597 | 0.779 | 1.409 |
| 1993 | 0.122 | 0.358 | 0.430 | 0.471 | 0.645 | 1.040 | 0.901 |
| 1994 | 0.108 | 0.320 | 0.349 | 0.416 | 0.556 | 0.717 | 0.949 |
| 1995 | 0.123 | 0.317 | 0.410 | 0.460 | 0.668 | 0.883 | 0.863 |
| 1996 | 0.147 | 0.374 | 0.409 | 0.466 | 0.585 | 0.665 | 0.804 |
| 1997 | 0.143 | 0.295 | 0.425 | 0.495 | 0.680 | 0.871 | 0.926 |
| 1998 | 0.130 | 0.284 | 0.399 | 0.528 | 0.694 | 0.790 | 0.707 |
| 1999 | 0.210 | 0.320 | 0.428 | 0.574 | 0.806 | 1.177 | 1.128 |
| 2000 | 0.020 | 0.367 | 0.493 | 0.587 | 0.774 | 0.860 | 0.904 |
| 2001 | 0.153 | 0.335 | 0.412 | 0.610 | 0.729 | 0.919 | 0.948 |

Table D4a. Survey indices of southern New England yellowtail abundance and biomass.

Mean Number per Tow at Age

| NEFSC Spring Survey | | | | Age | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | kg/tow |
| 1968 | 1.662 | 31.719 | 31.913 | 19.002 | 0.886 | 0.168 | 0.067 | 0.000 | 85.416 | 18.624 |
| 1969 | 5.102 | 19.866 | 27.261 | 14.675 | 2.540 | 0.285 | 0.000 | 0.000 | 69.730 | 13.340 |
| 1970 | 1.486 | 10.669 | 19.964 | 14.136 | 4.066 | 1.096 | 0.235 | 0.096 | 51.749 | 11.721 |
| 1971 | 1.066 | 11.323 | 8.519 | 23.664 | 6.065 | 0.967 | 0.011 | 0.011 | 51.627 | 10.693 |
| 1972 | 0.492 | 21.844 | 14.735 | 4.596 | 8.813 | 1.360 | 0.257 | 0.000 | 52.098 | 10.728 |
| 1973 | 1.301 | 7.270 | 12.713 | 6.276 | 4.261 | 6.595 | 0.820 | 0.456 | 39.693 | 14.678 |
| 1974 | 0.742 | 2.972 | 2.326 | 2.530 | 1.647 | 0.593 | 0.964 | 0.193 | 11.967 | 5.040 |
| 1975 | 0.561 | 1.556 | 0.500 | 0.769 | 0.810 | 0.471 | 0.033 | 0.146 | 4.845 | 1.984 |
| 1976 | 0.026 | 3.259 | 0.528 | 0.250 | 0.302 | 0.250 | 0.157 | 0.051 | 4.823 | 2.452 |
| 1977 | 0.205 | 1.251 | 1.556 | 0.166 | 0.173 | 0.080 | 0.024 | 0.103 | 3.557 | 1.993 |
| 1978 | 2.963 | 9.783 | 2.027 | 0.715 | 0.187 | 0.036 | 0.047 | 0.138 | 15.897 | 5.146 |
| 1979 | 1.542 | 3.357 | 1.741 | 0.354 | 0.110 | 0.000 | 0.000 | 0.008 | 7.112 | 2.147 |
| 1980 | 0.370 | 4.303 | 3.278 | 2.711 | 0.291 | 0.116 | 0.006 | 0.039 | 11.115 | 5.949 |
| 1981 | 0.203 | 8.622 | 3.089 | 1.279 | 0.464 | 0.047 | 0.000 | 0.000 | 13.704 | 6.846 |
| 1982 | 0.333 | 14.049 | 7.459 | 1.860 | 0.605 | 0.186 | 0.020 | 0.000 | 24.512 | 6.001 |
| 1983 | 0.090 | 3.900 | 12.916 | 1.059 | 0.312 | 0.000 | 0.000 | 0.000 | 18.278 | 4.641 |
| 1984 | 0.000 | 0.500 | 1.648 | 2.612 | 0.665 | 0.223 | 0.000 | 0.000 | 5.649 | 1.625 |
| 1985 | 0.561 | 0.744 | 0.417 | 0.201 | 0.454 | 0.093 | 0.000 | 0.000 | 2.470 | 0.666 |
| 1986 | 0.037 | 4.083 | 1.492 | 0.308 | 0.073 | 0.036 | 0.000 | 0.000 | 6.029 | 1.605 |
| 1987 | 0.000 | 0.198 | 0.919 | 0.144 | 0.000 | 0.000 | 0.000 | 0.000 | 1.261 | 0.402 |
| 1988 | 0.327 | 0.692 | 0.177 | 0.245 | 0.127 | 0.000 | 0.000 | 0.000 | 1.568 | 0.399 |
| 1989 | 0.151 | 10.308 | 0.604 | 0.066 | 0.000 | 0.000 | 0.000 | 0.000 | 11.129 | 2.433 |
| 1990 | 0.091 | 0.368 | 18.994 | 3.794 | 0.031 | 0.000 | 0.000 | 0.000 | 23.278 | 7.828 |
| 1991 | 0.438 | 0.340 | 1.573 | 4.484 | 0.510 | 0.111 | 0.000 | 0.000 | 7.455 | 2.786 |
| 1992 | 0.081 | 0.269 | 0.275 | 1.196 | 0.112 | 0.000 | 0.000 | 0.000 | 1.933 | 0.653 |
| 1993 | 0.037 | 0.533 | 0.221 | 0.517 | 0.097 | 0.000 | 0.000 | 0.000 | 1.405 | 0.506 |
| 1994 | 0.031 | 0.494 | 0.040 | 0.019 | 0.045 | 0.015 | 0.000 | 0.000 | 0.643 | 0.219 |
| 1995 | 0.054 | 0.944 | 0.284 | 0.072 | 0.030 | 0.011 | 0.018 | 0.000 | 1.413 | 0.360 |
| 1996 | 0.000 | 0.528 | 2.442 | 0.314 | 0.063 | 0.000 | 0.000 | 0.000 | 3.347 | 1.054 |
| 1997 | 0.119 | 1.816 | 1.735 | 0.274 | 0.081 | 0.000 | 0.000 | 0.000 | 4.025 | 1.183 |
| 1998 | 0.154 | 3.696 | 0.433 | 0.231 | 0.077 | 0.000 | 0.000 | 0.000 | 4.590 | 0.973 |
| 1999 | 0.037 | 1.426 | 3.265 | 0.243 | 0.036 | 0.000 | 0.000 | 0.000 | 5.006 | 1.763 |
| 2000 | 0.000 | 2.016 | 1.680 | 0.672 | 0.168 | 0.000 | 0.000 | 0.000 | 4.537 | 1.444 |
| 2001 | 0.000 | 0.109 | 2.535 | 0.471 | 0.077 | 0.000 | 0.000 | 0.000 | 3.192 | 1.267 |
| 2002 | 0.292 | 1.750 | 0.680 | 0.583 | 0.097 | 0.000 | 0.000 | 0.000 | 3.402 | 0.939 |
| mean | 0.587 | 5.330 | 5.427 | 3.157 | 0.979 | 0.364 | 0.076 | 0.035 | 15.956 | 4.288 |

Table D4b. Survey indices of southern New England yellowtail abundance and biomass.

Mean Number per Tow at Age

| **NEFSC Fall Survey** | | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | kg/tow |
| 1963 | 19.798 | 20.168 | 14.960 | 5.830 | 0.660 | 0.151 | 0.000 | 0.100 | 61.667 | 16.842 |
| 1964 | 22.529 | 31.952 | 5.861 | 8.701 | 3.983 | 1.108 | 0.000 | 0.000 | 74.133 | 19.03 |
| 1965 | 13.231 | 21.390 | 7.771 | 2.140 | 2.167 | 0.155 | 0.000 | 0.090 | 46.944 | 12.675 |
| 1966 | 43.305 | 13.066 | 2.375 | 1.247 | 0.231 | 0.000 | 0.000 | 0.000 | 60.224 | 9.431 |
| 1967 | 22.497 | 31.159 | 13.716 | 1.936 | 0.472 | 0.079 | 0.160 | 0.000 | 70.019 | 14.057 |
| 1968 | 11.285 | 13.352 | 22.860 | 1.443 | 0.115 | 0.000 | 0.000 | 0.000 | 49.055 | 10.062 |
| 1969 | 14.481 | 11.884 | 33.861 | 6.351 | 0.113 | 0.050 | 0.050 | 0.000 | 66.791 | 14.401 |
| 1970 | 5.157 | 6.736 | 19.936 | 12.961 | 3.067 | 0.520 | 0.089 | 0.000 | 48.466 | 10.965 |
| 1971 | 7.748 | 13.298 | 7.618 | 18.468 | 3.287 | 0.264 | 0.196 | 0.000 | 50.879 | 11.632 |
| 1972 | 5.135 | 20.125 | 24.054 | 22.993 | 14.991 | 2.050 | 0.054 | 0.000 | 89.402 | 20.114 |
| 1973 | 1.726 | 1.590 | 2.224 | 1.640 | 1.241 | 1.057 | 0.212 | 0.000 | 9.689 | 2.264 |
| 1974 | 1.216 | 2.047 | 0.676 | 2.776 | 1.166 | 0.489 | 0.238 | 0.093 | 8.701 | 2.141 |
| 1975 | 1.981 | 0.516 | 0.266 | 0.329 | 0.334 | 0.000 | 0.104 | 0.000 | 3.531 | 0.715 |
| 1976 | 3.632 | 7.331 | 0.877 | 0.088 | 0.139 | 0.361 | 0.423 | 0.189 | 13.041 | 2.962 |
| 1977 | 1.759 | 2.275 | 0.828 | 0.053 | 0.046 | 0.113 | 0.078 | 0.000 | 5.151 | 1.501 |
| 1978 | 3.247 | 7.599 | 0.450 | 0.392 | 0.043 | 0.009 | 0.079 | 0.032 | 11.851 | 3.057 |
| 1979 | 1.794 | 4.533 | 2.537 | 0.388 | 0.043 | 0.041 | 0.000 | 0.000 | 9.335 | 2.565 |
| 1980 | 1.463 | 4.506 | 1.202 | 0.426 | 0.000 | 0.000 | 0.000 | 0.000 | 7.597 | 1.957 |
| 1981 | 4.704 | 8.944 | 1.404 | 0.334 | 0.080 | 0.061 | 0.000 | 0.000 | 15.527 | 3.789 |
| 1982 | 2.610 | 29.372 | 8.673 | 1.025 | 0.409 | 0.000 | 0.000 | 0.000 | 42.088 | 8.126 |
| 1983 | 4.582 | 17.956 | 10.078 | 0.876 | 0.073 | 0.000 | 0.050 | 0.000 | 33.616 | 6.515 |
| 1984 | 0.719 | 2.217 | 2.400 | 0.659 | 0.000 | 0.000 | 0.000 | 0.000 | 5.994 | 1.365 |
| 1985 | 1.018 | 0.447 | 0.161 | 0.122 | 0.000 | 0.000 | 0.000 | 0.000 | 1.748 | 0.438 |
| 1986 | 0.826 | 1.685 | 0.365 | 0.088 | 0.000 | 0.000 | 0.000 | 0.000 | 2.963 | 0.883 |
| 1987 | 1.515 | 0.674 | 0.558 | 0.047 | 0.037 | 0.000 | 0.037 | 0.000 | 2.868 | 0.607 |
| 1988 | 1.261 | 0.388 | 0.173 | 0.195 | 0.048 | 0.000 | 0.000 | 0.000 | 2.065 | 0.496 |
| 1989 | 0.000 | 8.004 | 1.400 | 0.065 | 0.000 | 0.000 | 0.000 | 0.000 | 9.469 | 2.359 |
| 1990 | 0.000 | 0.097 | 2.395 | 0.270 | 0.000 | 0.000 | 0.000 | 0.000 | 2.763 | 0.974 |
| 1991 | 0.865 | 0.219 | 1.709 | 0.453 | 0.000 | 0.000 | 0.000 | 0.000 | 3.247 | 1.013 |
| 1992 | 0.261 | 0.062 | 0.180 | 0.337 | 0.012 | 0.000 | 0.000 | 0.000 | 0.852 | 0.229 |
| 1993 | 0.070 | 0.015 | 0.028 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.133 | 0.053 |
| 1994 | 0.754 | 0.553 | 0.198 | 0.192 | 0.085 | 0.011 | 0.000 | 0.000 | 1.793 | 0.374 |
| 1995 | 0.180 | 1.306 | 0.171 | 0.095 | 0.000 | 0.000 | 0.000 | 0.000 | 1.752 | 0.432 |
| 1996 | 0.653 | 0.290 | 0.258 | 0.025 | 0.000 | 0.000 | 0.000 | 0.000 | 1.226 | 0.266 |
| 1997 | 0.889 | 0.716 | 1.687 | 0.373 | 0.037 | 0.000 | 0.000 | 0.000 | 3.702 | 1.041 |
| 1998 | 1.384 | 2.141 | 0.188 | 0.076 | 0.000 | 0.036 | 0.000 | 0.000 | 3.824 | 0.899 |
| 1999 | 0.189 | 0.119 | 0.116 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.424 | 0.101 |
| 2000 | 0.223 | 1.675 | 0.670 | 0.335 | 0.000 | 0.000 | 0.112 | 0.000 | 3.015 | 0.988 |
| 2001 | 0.607 | 0.946 | 0.207 | 0.110 | 0.000 | 0.000 | 0.000 | 0.000 | 1.870 | 0.630 |
| mean | 5.264 | 7.471 | 5.002 | 2.407 | 0.843 | 0.168 | 0.048 | 0.013 | 21.216 | 4.819 |

Table D4c. Survey indices of southern New England yellowtail abundance and biomass.

Mean Number per Tow at Age

**NEFSC Winter Survey**

| | Age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | kg/tow |
| 1992 | 0.000 | 2.884 | 1.881 | 6.418 | 1.295 | 0.000 | 0.000 | 0.000 | 12.478 | 4.402 |
| 1993 | 1.349 | 3.853 | 0.711 | 1.841 | 0.306 | 0.000 | 0.000 | 0.000 | 8.060 | 1.968 |
| 1994 | 0.586 | 17.778 | 1.363 | 2.917 | 1.258 | 0.199 | 0.000 | 0.000 | 24.101 | 6.809 |
| 1995 | 0.368 | 7.615 | 4.474 | 1.317 | 0.493 | 0.123 | 0.036 | 0.000 | 14.426 | 4.059 |
| 1996 | 0.092 | 2.304 | 11.703 | 1.552 | 0.207 | 0.109 | 0.033 | 0.000 | 16.000 | 5.159 |
| 1997 | 0.301 | 3.976 | 9.141 | 2.625 | 0.508 | 0.000 | 0.000 | 0.000 | 16.551 | 5.831 |
| 1998 | 0.267 | 3.160 | 1.210 | 0.365 | 0.000 | 0.000 | 0.041 | 0.000 | 5.043 | 1.281 |
| 1999 | 0.550 | 10.699 | 14.210 | 0.528 | 0.176 | 0.000 | 0.000 | 0.000 | 26.163 | 8.874 |
| 2000 | 0.246 | 4.540 | 4.341 | 1.296 | 0.000 | 0.000 | 0.000 | 0.000 | 10.422 | 3.330 |
| 2001 | 0.026 | 1.963 | 14.025 | 2.848 | 0.370 | 0.160 | 0.027 | 0.000 | 19.418 | 7.944 |
| 2002 | 0.057 | 4.477 | 4.024 | 3.627 | 0.227 | 0.057 | 0.000 | 0.000 | 12.467 | 4.077 |
| mean | 0.349 | 5.750 | 6.098 | 2.303 | 0.440 | 0.059 | 0.013 | 0.000 | 15.012 | 4.885 |

**Scallop Survey**

Mean Number per Tow at Age

| Year | age-1 | all |
|---|---|---|
| 1982 | 0.406 | 8.129 |
| 1983 | 0.736 | 2.435 |
| 1984 | 0.193 | 0.612 |
| 1985 | 0.783 | 1.214 |
| 1986 | 0.020 | 0.581 |
| 1987 | 0.243 | 0.564 |
| 1988 | 6.133 | 6.613 |
| 1989 | 0.578 | 6.468 |
| 1990 | 0.077 | 0.647 |
| 1991 | 0.680 | 0.933 |
| 1992 | 0.456 | 0.653 |
| 1993 | 0.468 | 0.479 |
| 1994 | 1.020 | 1.664 |
| 1995 | 0.319 | 1.828 |
| 1996 | 0.213 | 1.570 |
| 1997 | 1.383 | 1.737 |
| 1998 | 1.121 | 2.383 |
| 1999 | 0.752 | 1.160 |
| 2000 | 0.360 | 1.855 |
| 2001 | 0.282 | 0.451 |
| 2002 | 0.088 | 0.605 |
| average | 0.760 | 1.939 |

Table D5a. Stock numbers from VPA for southern New England yellowtail flounder.

STOCK NUMBERS (Jan 1) in thousands -

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 42144 | 9234 | 28866 | 12910 | 47571 | 52422 | 30090 |
| 2 | 15230 | 34335 | 6784 | 15635 | 10376 | 34024 | 35049 |
| 3 | 19877 | 7894 | 2473 | 2135 | 6829 | 4179 | 15812 |
| 4 | 10100 | 8765 | 2197 | 670 | 922 | 1997 | 2068 |
| 5 | 3810 | 4041 | 2563 | 909 | 327 | 400 | 707 |
| 6 | 3446 | 1567 | 1046 | 961 | 439 | 82 | 179 |
| 7 | 700 | 1968 | 883 | 863 | 483 | 172 | 44 |
| 1+ | 95307 | 67803 | 44812 | 34082 | 66949 | 93276 | 83950 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 41943 | 126925 | 53147 | 14583 | 16730 | 19837 | 6969 |
| 2 | 24451 | 33446 | 103883 | 43360 | 9654 | 13236 | 14223 |
| 3 | 11300 | 10973 | 21280 | 53266 | 18824 | 2719 | 4489 |
| 4 | 5371 | 3513 | 2888 | 5033 | 8670 | 1982 | 854 |
| 5 | 759 | 1123 | 661 | 786 | 1077 | 1071 | 435 |
| 6 | 192 | 194 | 120 | 175 | 303 | 212 | 177 |
| 7 | 50 | 21 | 11 | 55 | 25 | 48 | 32 |
| 1+ | 84066 | 176195 | 181989 | 117259 | 55284 | 39104 | 27179 |

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 13987 | 121992 | 16399 | 6852 | 3535 | 1969 | 850 |
| 2 | 5287 | 10013 | 94541 | 13405 | 5436 | 2491 | 1180 |
| 3 | 2886 | 1249 | 6343 | 60017 | 9122 | 2997 | 725 |
| 4 | 1032 | 524 | 563 | 2385 | 10967 | 2899 | 660 |
| 5 | 192 | 119 | 60 | 89 | 121 | 393 | 250 |
| 6 | 63 | 31 | 06 | 07 | 01 | 15 | 69 |
| 7 | 12 | 11 | 00 | 00 | 22 | 04 | 00 |
| 1+ | 23459 | 133937 | 117911 | 82754 | 29203 | 10767 | 3735 |

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 1606 | 1509 | 1425 | 4145 | 3108 | 4887 | 2319 |
| 2 | 684 | 1306 | 1229 | 1148 | 3393 | 2545 | 3998 |
| 3 | 584 | 425 | 845 | 730 | 889 | 2427 | 2018 |
| 4 | 253 | 277 | 200 | 243 | 280 | 295 | 678 |
| 5 | 155 | 58 | 37 | 27 | 63 | 68 | 79 |
| 6 | 92 | 07 | 20 | 04 | 09 | 21 | 05 |
| 7 | 02 | 05 | 09 | 06 | 02 | 08 | 05 |
| 1+ | 3376 | 3588 | 3766 | 6303 | 7744 | 10250 | 9102 |

| | 2001 | 2002 |
|---|---|---|
| 1 | 2542 | 00 |
| 2 | 1871 | 2080 |
| 3 | 2861 | 1319 |
| 4 | 898 | 1292 |
| 5 | 251 | 464 |
| 6 | 54 | 130 |
| 7 | 27 | 42 |
| 1+ | 8503 | 5326 |

Table D5b. Fishing mortality estimates from VPA for southern New England yellowtail flounder.

FISHING MORTALITY -

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.11 | 0.41 | 0.02 | 0.14 | 0.20 | 0.01 |
| 2 | 0.46 | 2.43 | 0.96 | 0.63 | 0.71 | 0.57 | 0.93 |
| 3 | 0.62 | 1.08 | 1.11 | 0.64 | 1.03 | 0.50 | 0.88 |
| 4 | 0.72 | 1.03 | 0.68 | 0.52 | 0.63 | 0.84 | 0.80 |
| 5 | 0.69 | 1.15 | 0.78 | 0.53 | 1.18 | 0.61 | 1.11 |
| 6 | 0.67 | 1.11 | 0.87 | 0.60 | 1.01 | 0.61 | 0.90 |
| 7 | 0.67 | 1.11 | 0.87 | 0.60 | 1.01 | 0.61 | 0.90 |
| 4,6 | 0.69 | 1.10 | 0.78 | 0.55 | 0.94 | 0.69 | 0.94 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 0.03 | 0.00 | 0.00 | 0.21 | 0.03 | 0.13 | 0.08 |
| 2 | 0.60 | 0.25 | 0.47 | 0.63 | 1.07 | 0.88 | 1.39 |
| 3 | 0.97 | 1.13 | 1.24 | 1.62 | 2.05 | 0.96 | 1.27 |
| 4 | 1.36 | 1.47 | 1.10 | 1.34 | 1.89 | 1.32 | 1.29 |
| 5 | 1.16 | 2.04 | 1.13 | 0.75 | 1.43 | 1.60 | 1.73 |
| 6 | 1.12 | 1.30 | 1.27 | 1.68 | 2.19 | 1.22 | 1.36 |
| 7 | 1.12 | 1.30 | 1.27 | 1.68 | 2.19 | 1.22 | 1.36 |
| 4,6 | 1.22 | 1.61 | 1.17 | 1.26 | 1.84 | 1.38 | 1.46 |

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 0.13 | 0.05 | 0.00 | 0.03 | 0.15 | 0.31 | 0.02 |
| 2 | 1.24 | 0.26 | 0.25 | 0.18 | 0.40 | 1.03 | 0.50 |
| 3 | 1.51 | 0.60 | 0.78 | 1.50 | 0.95 | 1.31 | 0.85 |
| 4 | 1.96 | 1.96 | 1.64 | 2.78 | 3.13 | 2.25 | 1.25 |
| 5 | 1.62 | 2.82 | 1.97 | 3.99 | 1.91 | 1.53 | 0.80 |
| 6 | 1.73 | 0.93 | 0.85 | 1.63 | 1.73 | 1.79 | 1.01 |
| 7 | 1.73 | 0.93 | 0.85 | 1.63 | 1.73 | 1.79 | 1.01 |
| 4,6 | 1.77 | 1.90 | 1.49 | 2.80 | 2.26 | 1.86 | 1.02 |

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2 | 0.28 | 0.24 | 0.32 | 0.06 | 0.14 | 0.03 | 0.13 |
| 3 | 0.55 | 0.55 | 1.05 | 0.76 | 0.90 | 1.07 | 0.61 |
| 4 | 1.27 | 1.82 | 1.79 | 1.14 | 1.22 | 1.12 | 0.79 |
| 5 | 2.84 | 0.85 | 2.06 | 0.94 | 0.90 | 2.48 | 0.18 |
| 6 | 0.89 | 0.91 | 1.22 | 0.86 | 1.00 | 1.14 | 0.65 |
| 7 | 0.89 | 0.91 | 1.22 | 0.86 | 1.00 | 1.14 | 0.65 |
| 4,6 | 1.67 | 1.19 | 1.69 | 0.98 | 1.04 | 1.58 | 0.54 |

| | 2001 |
|---|---|
| 1 | 0.00 |
| 2 | 0.15 |
| 3 | 0.60 |
| 4 | 0.46 |
| 5 | 0.46 |
| 6 | 0.46 |
| 7 | 0.46 |
| 4,6 | 0.46 |

Table D5c. Spawning stock biomass estimates from VPA for southern New England yellowtail flounder.

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT) (using SSB mean weights)

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| 1 | 1056 | 214 | 634 | 349 | 1156 | 1348 | 678 |
| 2 | 2554 | 2615 | 899 | 2482 | 1493 | 5415 | 4871 |
| 3 | 5276 | 1630 | 542 | 630 | 1544 | 1228 | 3617 |
| 4 | 2896 | 2253 | 668 | 262 | 339 | 703 | 648 |
| 5 | 1131 | 1098 | 743 | 358 | 97 | 203 | 242 |
| 6 | 1215 | 432 | 315 | 392 | 128 | 46 | 77 |
| 7 | 298 | 591 | 292 | 373 | 178 | 83 | 19 |
| 1+ | 14427 | 8832 | 4091 | 4846 | 4936 | 9028 | 10152 |

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| 1 | 1022 | 2125 | 1435 | 279 | 359 | 411 | 150 |
| 2 | 3641 | 5371 | 15306 | 5938 | 1007 | 1648 | 1543 |
| 3 | 2613 | 2115 | 4048 | 8354 | 2152 | 608 | 799 |
| 4 | 1396 | 847 | 843 | 1321 | 1407 | 451 | 215 |
| 5 | 297 | 273 | 251 | 355 | 272 | 273 | 116 |
| 6 | 98 | 69 | 53 | 66 | 73 | 73 | 57 |
| 7 | 34 | 05 | 05 | 21 | 07 | 23 | 13 |
| 1+ | 9102 | 10806 | 21941 | 16334 | 5276 | 3487 | 2894 |

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 1 | 391 | 3850 | 610 | 243 | 82 | 35 | 12 |
| 2 | 575 | 1795 | 19510 | 2763 | 822 | 348 | 233 |
| 3 | 501 | 349 | 1609 | 10949 | 1863 | 574 | 197 |
| 4 | 173 | 107 | 142 | 317 | 1134 | 449 | 170 |
| 5 | 49 | 22 | 18 | 12 | 34 | 114 | 106 |
| 6 | 17 | 18 | 04 | 03 | 01 | 05 | 43 |
| 7 | 05 | 06 | 00 | 00 | 06 | 02 | 00 |
| 1+ | 1710 | 6148 | 21892 | 14288 | 3941 | 1526 | 762 |

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| 1 | 21 | 22 | 25 | 71 | 48 | 123 | 06 |
| 2 | 133 | 256 | 274 | 225 | 620 | 547 | 944 |
| 3 | 146 | 125 | 202 | 204 | 220 | 598 | 696 |
| 4 | 57 | 55 | 41 | 69 | 82 | 98 | 263 |
| 5 | 24 | 25 | 08 | 12 | 28 | 18 | 52 |
| 6 | 42 | 04 | 08 | 02 | 04 | 14 | 03 |
| 7 | 01 | 03 | 04 | 03 | 01 | 05 | 03 |
| 1+ | 424 | 490 | 561 | 586 | 1003 | 1403 | 1967 |

| | 2001 |
|---|---|
| 1 | 47 |
| 2 | 401 |
| 3 | 829 |
| 4 | 416 |
| 5 | 139 |
| 6 | 38 |
| 7 | 19 |
| 1+ | 1888 |

Table D6. Short-term projections of southern New England yellowtail flounder.

| Input Assumptions | age 1 | age 2 | age 3 | age 4 | age 5 | age 6 | age 7+ |
|---|---|---|---|---|---|---|---|
| stock weight (kg) | 0.129 | 0.327 | 0.416 | 0.517 | 0.685 | 0.852 | 0.887 |
| landed weight (kg) | 0.129 | 0.341 | 0.419 | 0.521 | 0.674 | 0.858 | 0.891 |
| discard weight (kg) | 0.037 | 0.309 | 0.375 | 0.511 | 0.667 | 0.840 | 0.891 |
| maturity | 0.130 | 0.740 | 0.980 | 1.000 | 1.000 | 1.000 | 1.000 |
| partial recruitment | 0.010 | 0.130 | 0.580 | 1.000 | 1.000 | 1.000 | 1.000 |
| proportion discarded | 1.000 | 0.330 | 0.180 | 0.180 | 0.180 | 0.180 | 0.180 |

Results

| Year | F | Landings (mt) | Discards (mt) | SSB (mt) |
|---|---|---|---|---|
| 2002 | 0.39 | 405 | 92 | 1931 |
| 2003 | 0.10* | 131 | 30 | 2647 |
| 2004 | 0.10* | 214 | 54 | 5482 |

* assumes long-term recruitment pattern

Figure D1. Total catch of southern New England yellowtail flounder.

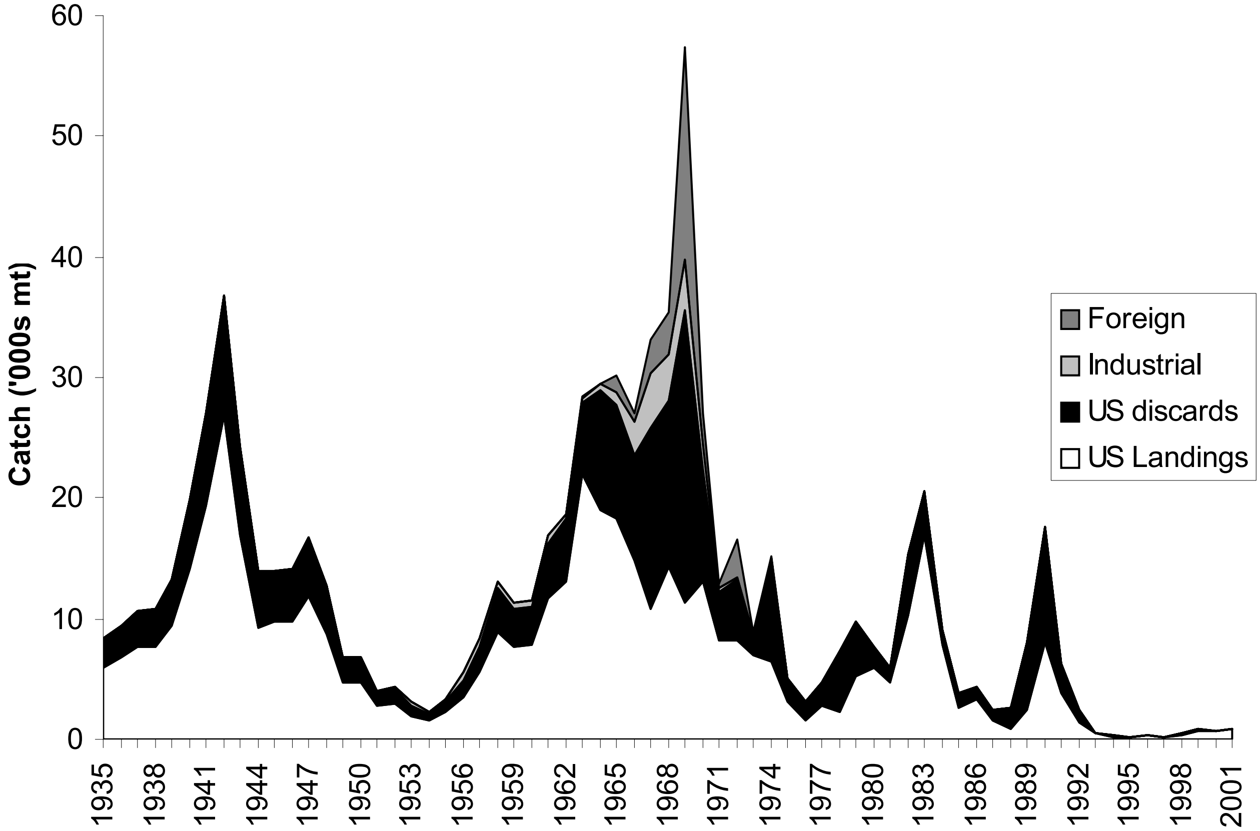



Figure D2. Survey indices of southern New England yellowtail flounder biomass.

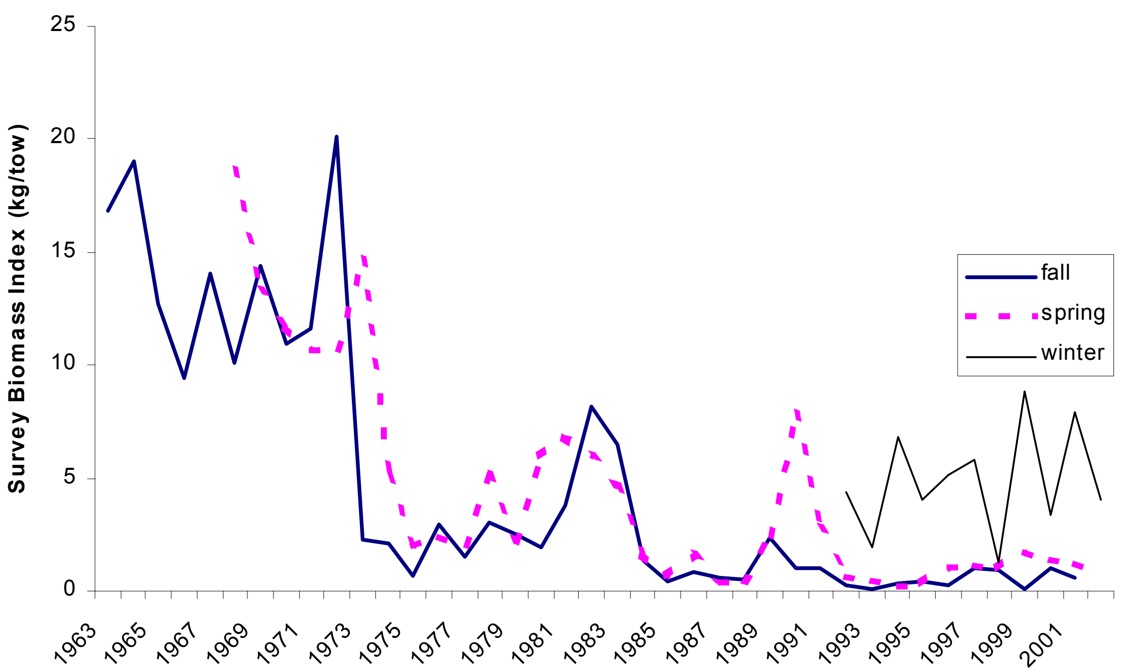


Figure D3a. Estimates of fishing mortality, recruitment and spawning stock biomass for southern New England yellowtail flounder from VPA.

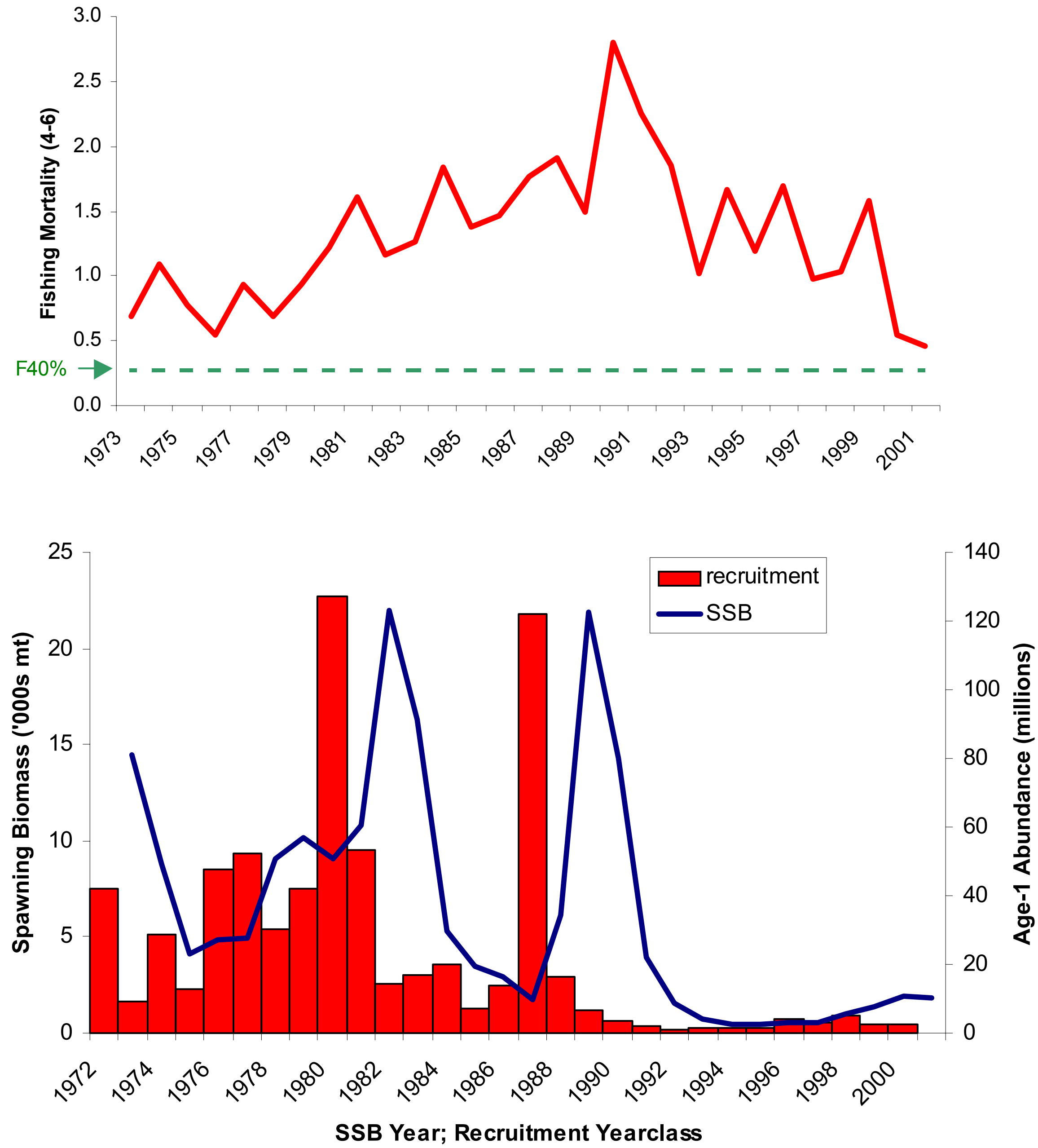


Figure D3b. Abundance at age of southern New England yellowtail flounder.

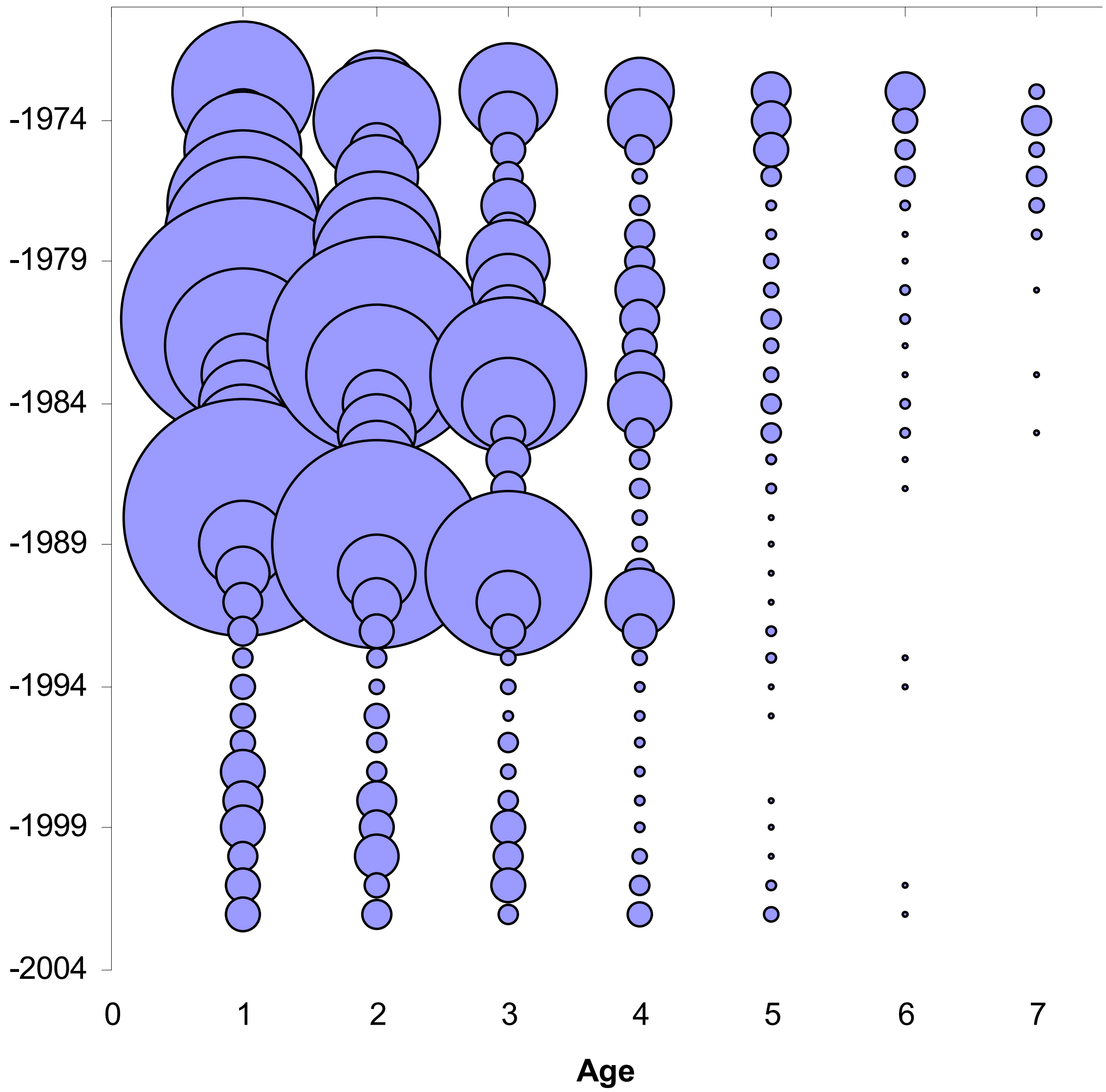


Figure D4.  Retrospective analysis of the southern New England yellowtail flounder VPA.

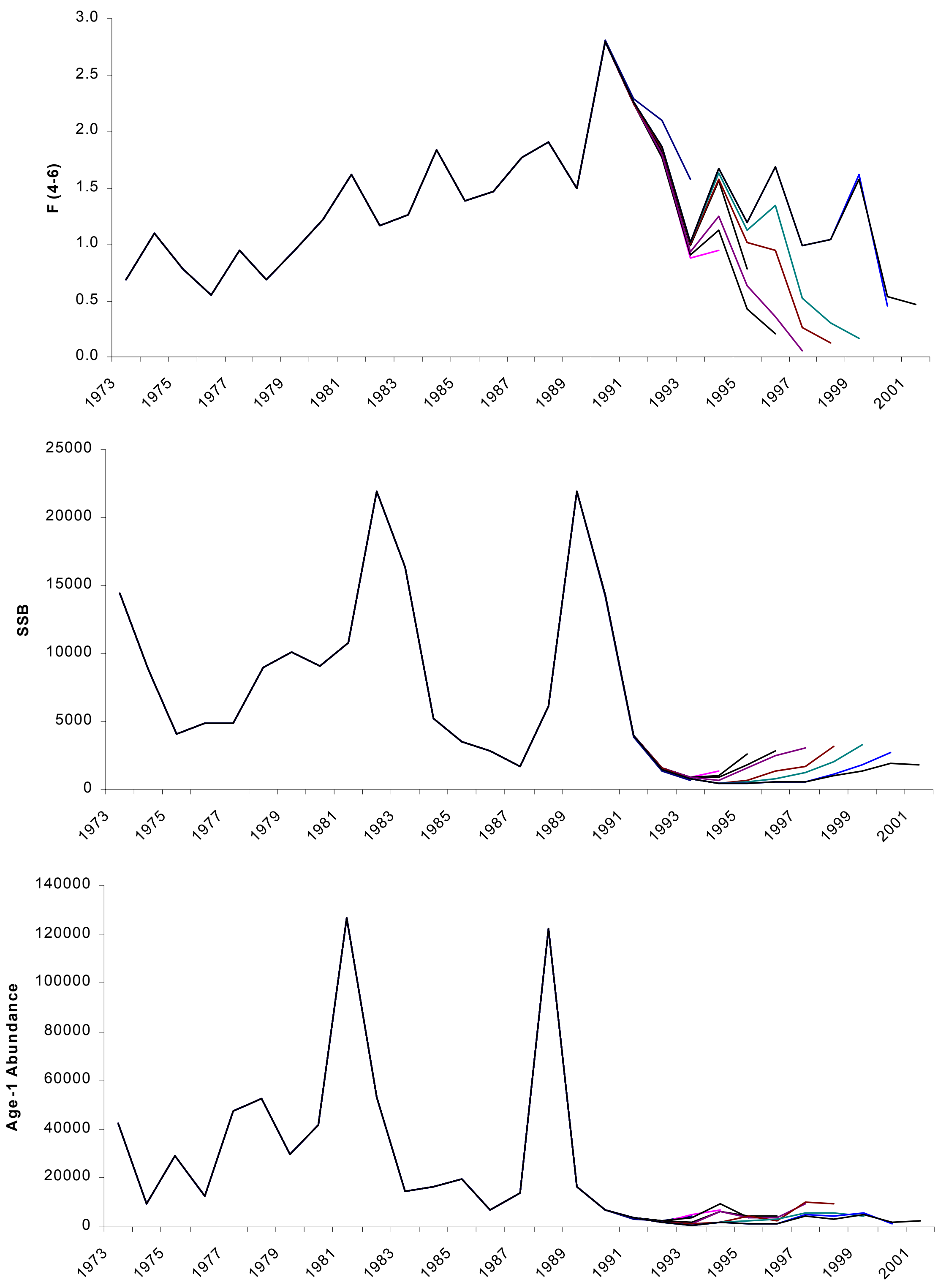


Figure D5. Stochastic projection of spawning biomass and total catch under two scenarios of recruitment and a constant F of $F_{rebuild} = 0.10$

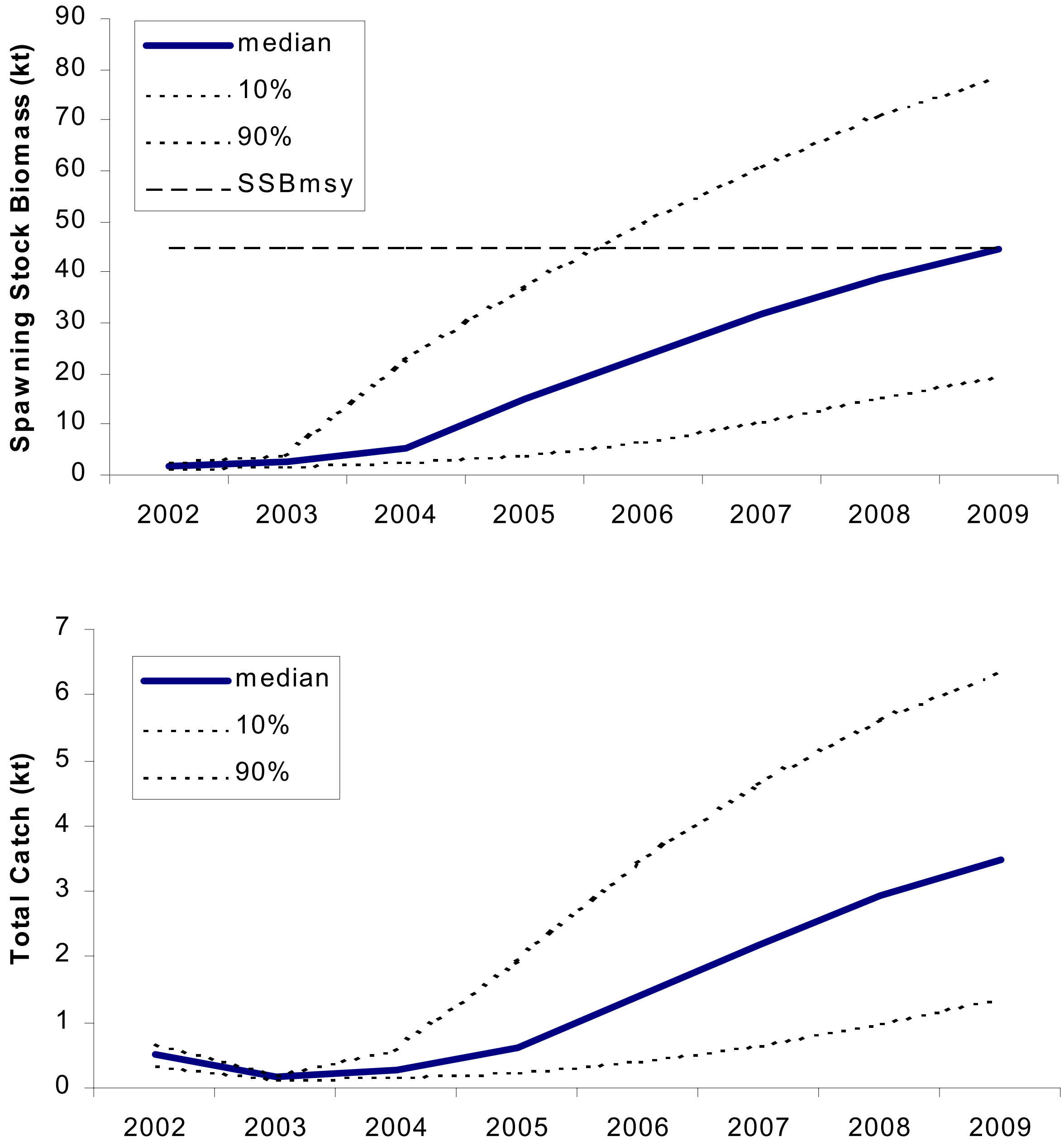


Figure D6. Mean biomass of southern New England yellowtail flounder and fishing mortality on biomass.

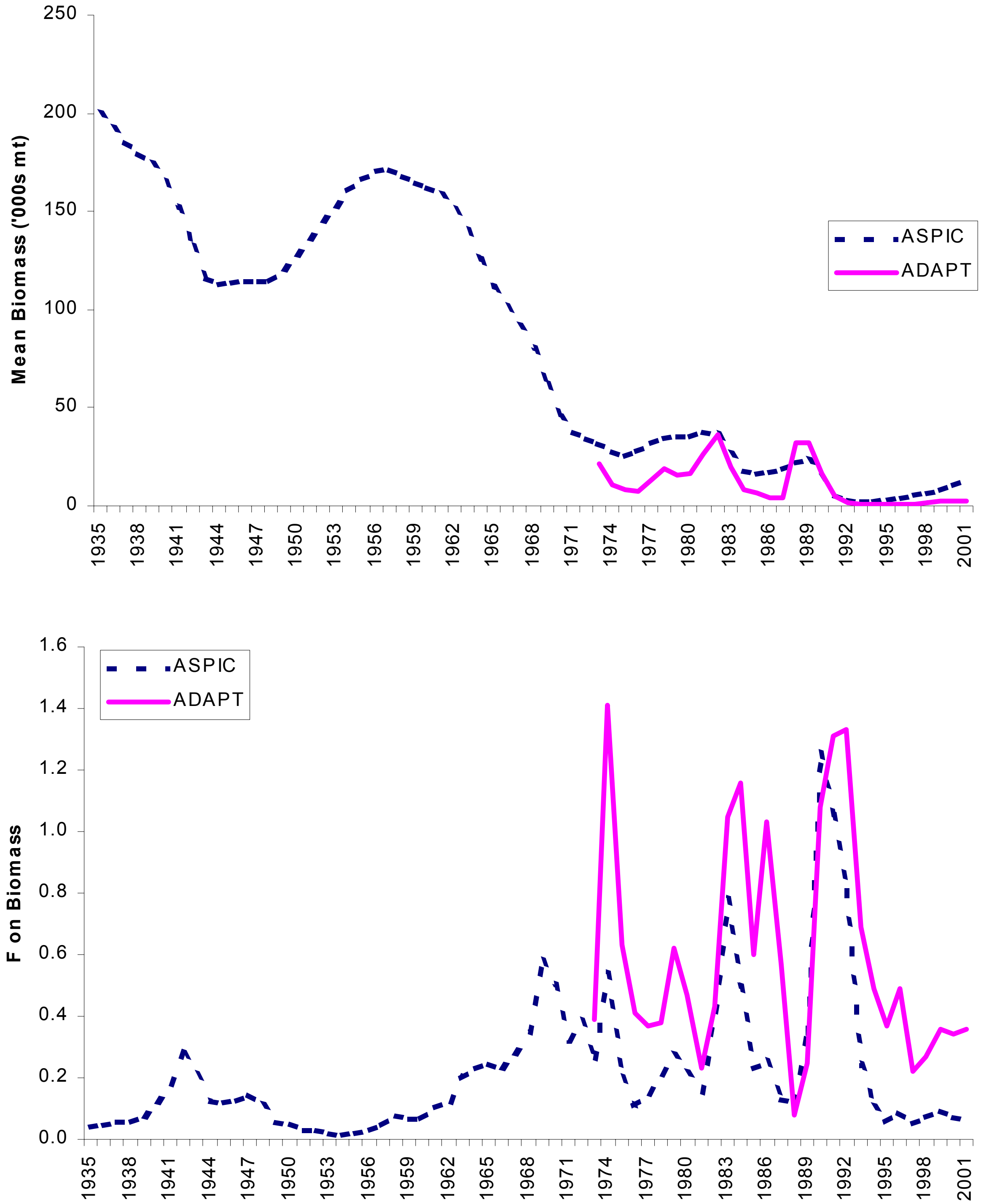
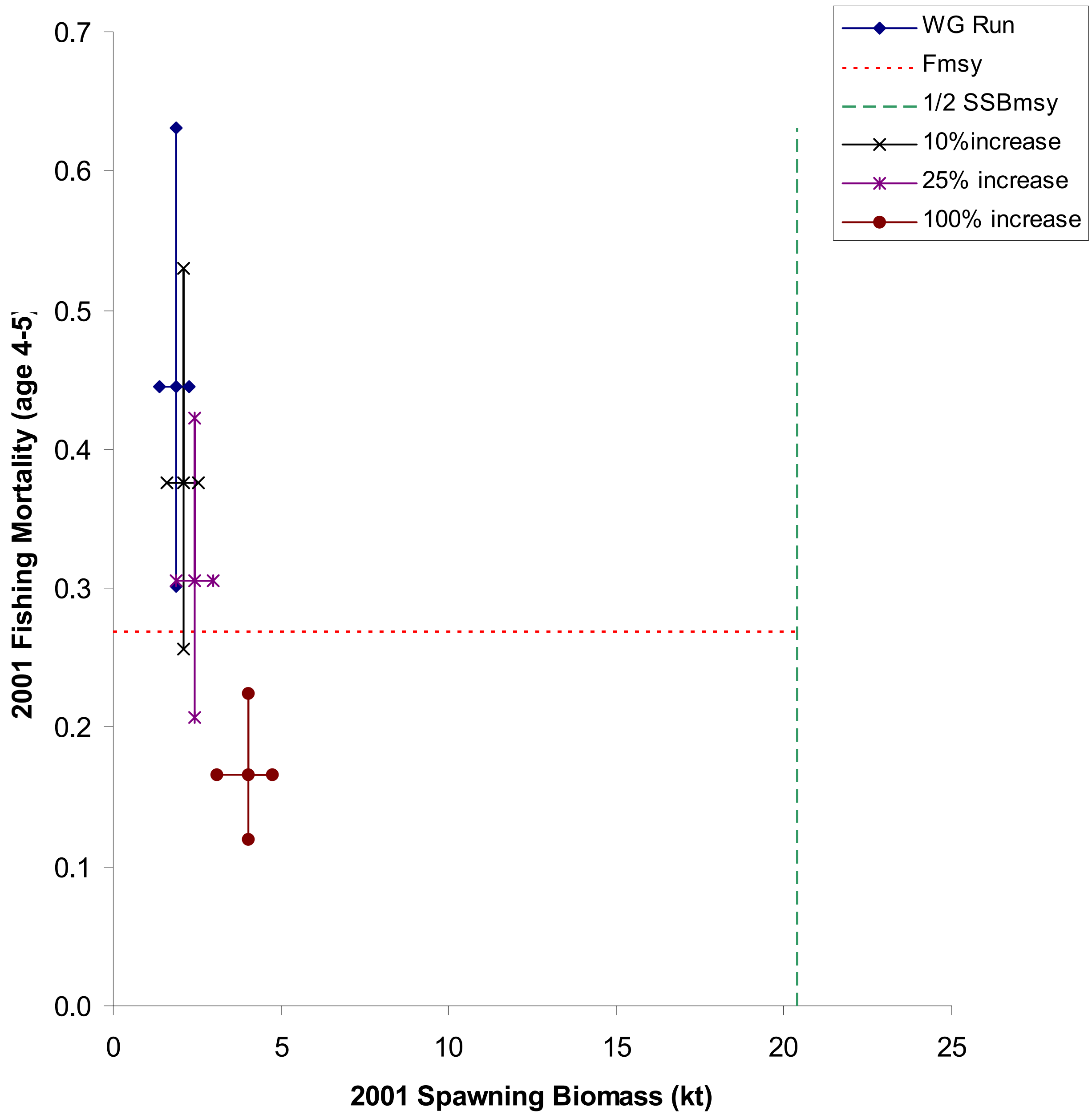


Figure D7. Sensitivity of results to increasing NEFSC indices since 2000 by 10%, 25% and 100% (with 80% confidence intervals). Results accepted by the working group ("WG Run") are shown for comparison.



**E. Cape Cod Yellowtail Flounder** by **S.X. Cadrin** and **J. King**

## 1.0 Background

The Cape Cod yellowtail flounder stock was at low biomass and was overexploited in 1999 (SSB was 1,900 mt and fully recruited F was 0.31; Cadrin and King 2001). This report updates catch and survey indices and estimates 2001 fishing mortality and 2002 stock size. In August 2002, the Southern Demersal Working Group concluded that Cape Cod and northern Gulf of Maine yellowtail flounder should be assessed and managed as a single unit stock, and is concurrently preparing an assessment of the Cape Cod - Gulf of Maine yellowtail resource (Cadrin and King 2002). In September 2002, the Working Group reviewed input data, analyses and projections in this report.

## 2.0 2002 Assessment

2.1 2000-2001 Landings

U.S. landings were prorated as described in Cadrin et al. (1999; Table E1; Figure E1). Landings from the Cape Cod stock increased from 1,100 mt in 1999 to 2,300 mt in 2000 and to 2,400 mt in 2001. Sampling intensity of landings in 2000 and 2001 improved from recent years. Although all classified market categories were sampled in each half-year period, the overall number of samples was low (Table E2).

2.2 2000-2001 Discards

Estimates of discarded catch for 1998-1999 were revised from those derived from logbook information (Cadrin and King 2001) using observer data by fishery as described by Cadrin et al. (1999). Estimates of 2000-2001 discards were also based on observer data. Discard rates varied between 7% and 19% of total catch for 1998-2001. Discards at age were estimated from sea-sampled lengths and survey age-length keys. Total catch at age and mean weights at age are reported in Table E3.

2.3 2000-2002 Survey Indices

Survey abundance and biomass indices are reported in Table E4. Estimates are from valid tows on the Cape Cod grounds (offshore strata 25, 26; inshore strata 56-66; Massachusetts strata 17-36) standardized according to net, vessel, and door changes (NEFSC 1998). Three of the four survey series indicate a substantial increase in biomass during 1999 and 2000, but only the Massachusetts spring survey remained high in 2001 and that index sharply decreased in 2002 (Figure E2).

## 3.0 Assessment Results

Results of an updated VPA calibration of Cape Cod yellowtail flounder (using the existing stock definition) are summarized in Table E5. This analysis updates the assessment reported in Cadrin and King (2001) by including 2000-2001 landings and discards, 2000 fall indices, all 2001 indices, and 2002 spring indices. The Working Group recommended a revised calibration configuration that includes all survey indices for older yellowtail to reduce the bias in estimates of age-5 abundance. Although parameter estimates in Cadrin et al. (1999) were not substantially biased, the positive bias in age-5 abundance increased in the updated assessments. The 2002 updated assessment initially had a 17% bias, when indices of older ages were excluded, but the bias decreased to 4% when the indices of older ages were included. Therefore, the revised calibration is used as the basis for this assessment. Results indicate that F increased to nearly 2.0 in 2000 and 2001, and SSB increased to 1,900mt in 2001 (Figure E3). Retrospective analysis indicates a tendency toward greatly underestimate F in the most recent years (Figure E4). Bootstrap analysis indicates that abundance was estimated with moderate to low precision (CV=33-43%). Sensitivity to recent NEFSC survey observations was evaluated using sensitivity analyses (Figure E6). Results are summarized in Section 5.2 (Summary of Assessment Advice).

Proxies for MSY reference points were derived from yield and SSB per recruit analyses and the assumption of constant recruitment (NEFSC 2002). Assuming that $F_{MSY}$ is approximately $F_{40\%}$ (0.21 on fully-recruited ages) and average recruitment (7.89 million at age-1), MSY=1,700 mt and $SSB_{MSY}$=8,400 mt. Therefore, despite uncertainty in the assessment, the stock is clearly overfished (2001 SSB= 1,900 mt=23%$SSB_{MSY}$) and overfishing is occurring (2001 F=2.0, = F>9 · $F_{MSY}$).

Stochastic projections at 85% of status quo F in 2002 and $F_{rebuild}$=0.12 for 2003-2009 indicate there is a 50% probability of rebuilding to $SSB_{MSY}$ by 2009 (Table E6, Figure E5). However, retrospective patterns indicate that projections may be overly optimistic.

**5.0 Sources of Uncertainty**

- Retrospective patterns indicate that VPA estimates of biomass and F may be overly optimistic. Updated VPAs may indicate that 2002 biomass levels were substantially lower, and 1999 F substantially greater than reported here. For example, previous assessments concluded that SSB rapidly increased in the late 1990s, but this updated assessment indicates much less rebuilding.
- Estimates of prorated landings and discard ratios are based on preliminary logbook data and are subject to change.
- The limited number of observer samples in small mesh and scallop dredge fisheries imposes considerable uncertainty in discard estimates.

**6.0 GARM Discussion**

The GARM noted that the high F seems inconsistent with level or increasing SSB and increasing survey indices. Discussion centered on how this could be possible, without the GARM reaching a consensus conclusion. The panel recommends that a cooperative tagging study be conducted to estimate F and evaluate the possibility of movement patterns out of the stock area that could be causing the estimates of F to be mis-representative.

It was suggested that the high F means that the tuning is actually only working on the oldest age group. The estimated catchabilities increase without reaching an asymptote with increasing age.

Ageing does not seem to be a problem with this stock, especially for the young ages in the catch. However, inadequate sampling of the catch could be causing a problem.

The short time series may not be sufficient to adequately estimate stock sizes. The time series is short due to extremely low sampling of catch prior to 1985 and because inshore strata were not sampled in the NEFSC surveys prior to 1979.

The possibility of contributions from the Georges Bank and/or Southern New England stocks of yellowtail flounder to the Cape Cod stock was discussed in terms of both adult movement and recruitment impacts. Given the relative sizes of the stocks, especially the Georges Bank and Cape Cod stocks, any transfer among stocks could overwhelm the signal from Cape Cod.

**7.0 References**

Cadrin, S.X. and J. King 2001. Cape Cod yellowtail flounder. In Assessment of 19 Northeast Groundfish Stocks through 2000. NEFSC Ref. Doc. 01-20: 67-79.

Cadrin, S.X. and J. King 2002. Stock Assessment of yellowtail flounder in the Cape Cod - Gulf of Maine area. SAW36 WPA7.

Cadrin, S.X., J. King, and L.E. Suslowicz. 1999. Status of the Cape Cod yellowtail flounder stock for 1998. NEFSC Ref. Doc. 99-04.

NEFSC (Northeast Fisheries Science Center). 2002. Final report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. 19 March, 2002.

Table E1. Landings of Cape Cod yellowtail flounder (mt).

| | Landings (mt) | Discards (mt) | Percent Discard | Total Catch (mt) |
|---|---|---|---|---|
| 1960 | 1,500 | 500 | 33 | 2,000 |
| 1961 | 1,800 | 600 | 33 | 2,400 |
| 1962 | 1,900 | 600 | 32 | 2,500 |
| 1963 | 3,600 | 1,000 | 28 | 4,600 |
| 1964 | 1,851 | 600 | 32 | 2,451 |
| 1965 | 1,498 | 500 | 33 | 1,998 |
| 1966 | 1,808 | 300 | 17 | 2,108 |
| 1967 | 1,542 | 800 | 52 | 2,342 |
| 1968 | 1,569 | 600 | 38 | 2,169 |
| 1969 | 1,346 | 300 | 22 | 1,646 |
| 1970 | 1,185 | 400 | 34 | 1,585 |
| 1971 | 1,662 | 700 | 42 | 2,362 |
| 1972 | 1,364 | 300 | 22 | 1,664 |
| 1973 | 1,662 | 0 | 0 | 1,662 |
| 1974 | 2,054 | 200 | 10 | 2,254 |
| 1975 | 2,027 | 0 | 0 | 2,027 |
| 1976 | 3,587 | 100 | 3 | 3,687 |
| 1977 | 3,469 | 0 | 0 | 3,469 |
| 1978 | 3,683 | 400 | 11 | 4,083 |
| 1979 | 4,163 | 500 | 12 | 4,663 |
| 1980 | 5,106 | 600 | 12 | 5,706 |
| 1981 | 3,149 | 600 | 19 | 3,749 |
| 1982 | 3,150 | 400 | 13 | 3,550 |
| 1983 | 1,884 | 300 | 16 | 2,184 |
| 1984 | 1,121 | 20 | 2 | 1,141 |
| 1985 | 967 | 77 | 8 | 1,044 |
| 1986 | 1,041 | 305 | 29 | 1,346 |
| 1987 | 1,159 | 198 | 17 | 1,357 |
| 1988 | 1,085 | 283 | 26 | 1,368 |
| 1989 | 909 | 390 | 43 | 1,299 |
| 1990 | 2,984 | 1,141 | 38 | 4,125 |
| 1991 | 1,472 | 405 | 28 | 1,877 |
| 1992 | 828 | 637 | 77 | 1,465 |
| 1993 | 628 | 90 | 14 | 718 |
| 1994 | 978 | 192 | 20 | 1,170 |
| 1995 | 1,207 | 233 | 19 | 1,440 |
| 1996 | 1,064 | 182 | 17 | 1,246 |
| 1997 | 1,040 | 257 | 25 | 1,297 |
| 1998 | 1,169 | 259 | 22 | 1,428 |
| 1999 | 1,089 | 107 | 10 | 1,196 |
| 2000 | 2,279 | 163 | 7 | 2,443 |
| 2001 | 2,362 | 447 | 19 | 2,810 |

Table E2. Samples of Cape Cod yellowtail flounder.

Number of Fish Sampled

| year | half year | trips | unclass. lengths | small lengths | large lengths | ages |
|---|---|---|---|---|---|---|
| 1985 | 1 | 5 | 109 | 304 | 196 | 292 |
| | 2 | 12 | 0 | 825 | 543 | 357 |
| 1986 | 1 | 4 | 0 | 608 | 206 | 217 |
| | 2 | 6 | 0 | 321 | 172 | 240 |
| 1987 | 1 | 6 | 0 | 300 | 352 | 353 |
| | 2 | 5 | 0 | 284 | 269 | 207 |
| 1988 | 1 | 6 | 0 | 477 | 267 | 286 |
| | 2 | 5 | 0 | 291 | 364 | 252 |
| 1989 | 1 | 6 | 10 | 261 | 314 | 305 |
| | 2 | 4 | 97 | 262 | 173 | 200 |
| 1990 | 1 | 8 | 536 | 532 | 374 | 339 |
| | 2 | 6 | 636 | 429 | 276 | 137 |
| 1991 | 1 | 8 | 811 | 501 | 332 | 610 |
| | 2 | 7 | 109 | 531 | 242 | 277 |
| 1992 | 1 | 4 | 707 | 126 | 254 | 339 |
| | 2 | 7 | 136 | 262 | 457 | 268 |
| 1993 | 1 | 3 | 170 | 145 | 182 | 177 |
| | 2 | 3 | 273 | 244 | 74 | 114 |
| 1994 | 1 | 4 | 100 | 261 | 170 | 273 |
| | 2 | 3 | 0 | 106 | 144 | 149 |
| 1995 | 1 | 4 | 39 | 276 | 201 | 196 |
| | 2 | 6 | 998 | 392 | 275 | 157 |
| 1996 | 1 | 1 | 2560 | 0 | 87 | 196 |
| | 2 | 12 | 118 | 495 | 640 | 485 |
| 1997 | 1 | 7 | 343 | 388 | 483 | 556 |
| | 2 | 17 | 317 | 996 | 869 | 634 |
| 1998 | 1 | 7 | 4781 | 0 | 508 | 195 |
| | 2 | 6 | 165 | 0 | 600 | 165 |
| 1999 | 1 | 4 | 2501 | 278 | 60 | 49 |
| | 2 | 4 | 1024 | 268 | 116 | 57 |
| 2000 | 1 | 46 | 521 | 723 | 2775 | 903 |
| | 2 | 15 | 0 | 566 | 1057 | 395 |
| 2001 | 1 | 8 | 3502 | 251 | 570 | 192 |
| | 2 | 16 | 1950 | 393 | 774 | 436 |

Table E3. Catch at age (above) and mean weights at age (below) of Cape Cod yellowtail flounder.

| Total catch at age (thousands) | | | | age | | |
|---|---|---|---|---|---|---|
| | age 1 | age 2 | age 3 | age 4 | age 5 | age 6+ |
| 1985 | 344 | 922 | 734 | 522 | 268 | 99 |
| 1986 | 79 | 3655 | 654 | 250 | 32 | 7 |
| 1987 | 14 | 1486 | 1954 | 268 | 100 | 46 |
| 1988 | 361 | 2130 | 1219 | 625 | 172 | 36 |
| 1989 | 114 | 2131 | 1385 | 233 | 31 | 8 |
| 1990 | 81 | 2738 | 8692 | 435 | 32 | 26 |
| 1991 | 460 | 1206 | 1464 | 1555 | 256 | 61 |
| 1992 | 1688 | 3881 | 1538 | 543 | 153 | 12 |
| 1993 | 138 | 349 | 857 | 602 | 91 | 46 |
| 1994 | 60 | 471 | 1301 | 699 | 240 | 113 |
| 1995 | 453 | 702 | 2382 | 858 | 154 | 83 |
| 1996 | 7 | 547 | 1425 | 892 | 298 | 18 |
| 1997 | 1 | 880 | 1437 | 819 | 182 | 14 |
| 1998 | 56 | 650 | 2101 | 518 | 151 | 44 |
| 1999 | 11 | 481 | 1321 | 668 | 109 | 48 |
| 2000 | 3 | 1024 | 2844 | 1228 | 153 | 38 |
| 2001 | 19 | 1644 | 3633 | 1083 | 155 | 39 |

| weight at age (kg) | | | | age | | |
|---|---|---|---|---|---|---|
| | age 1 | age 2 | age 3 | age 4 | age 5 | age 6+ |
| 1985 | 0.13 | 0.28 | 0.36 | 0.49 | 0.60 | 0.79 |
| 1986 | 0.10 | 0.25 | 0.43 | 0.53 | 0.73 | 0.99 |
| 1987 | 0.06 | 0.24 | 0.40 | 0.55 | 0.65 | 0.91 |
| 1988 | 0.12 | 0.21 | 0.34 | 0.53 | 0.70 | 0.85 |
| 1989 | 0.13 | 0.27 | 0.39 | 0.65 | 0.92 | 1.31 |
| 1990 | 0.08 | 0.26 | 0.37 | 0.55 | 0.82 | 0.96 |
| 1991 | 0.12 | 0.23 | 0.34 | 0.53 | 0.73 | 1.02 |
| 1992 | 0.05 | 0.13 | 0.32 | 0.52 | 0.61 | 1.15 |
| 1993 | 0.09 | 0.16 | 0.36 | 0.43 | 0.74 | 1.00 |
| 1994 | 0.08 | 0.22 | 0.36 | 0.49 | 0.62 | 0.83 |
| 1995 | 0.07 | 0.22 | 0.33 | 0.42 | 0.61 | 0.80 |
| 1996 | 0.04 | 0.19 | 0.39 | 0.49 | 0.53 | 1.02 |
| 1997 | 0.03 | 0.31 | 0.38 | 0.46 | 0.57 | 0.81 |
| 1998 | 0.03 | 0.27 | 0.40 | 0.53 | 0.62 | 1.04 |
| 1999 | 0.03 | 0.33 | 0.42 | 0.56 | 0.57 | 0.91 |
| 2000 | 0.03 | 0.37 | 0.44 | 0.56 | 0.61 | 0.87 |
| 2001 | 0.03 | 0.32 | 0.41 | 0.58 | 0.74 | 1.05 |

Table E4a. Survey indices of Cape Cod yellowtail abundance and biomass.
Mean Number per Tow at Age

| **MADMF Spring Survey** | | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | sum | kg/tow |
| 1978 | 2.71 | 20.69 | 11.82 | 1.60 | 0.63 | 0.54 | 0.10 | 0.13 | 38.22 | 10.16 |
| 1979 | 2.63 | 22.58 | 13.85 | 3.68 | 0.86 | 0.00 | 0.17 | 0.00 | 43.77 | 11.38 |
| 1980 | 2.68 | 17.62 | 10.10 | 2.30 | 0.15 | 0.00 | 0.00 | 0.00 | 32.85 | 10.03 |
| 1981 | 5.61 | 58.83 | 9.00 | 2.26 | 1.59 | 0.27 | 0.00 | 0.00 | 77.56 | 16.35 |
| 1982 | 0.69 | 17.06 | 17.04 | 4.45 | 0.94 | 0.06 | 0.04 | 0.00 | 40.28 | 12.85 |
| 1983 | 3.13 | 8.50 | 11.51 | 4.28 | 0.04 | 0.17 | 0.03 | 0.00 | 27.66 | 9.00 |
| 1984 | 0.43 | 18.13 | 7.56 | 2.29 | 0.85 | 0.00 | 0.00 | 0.00 | 29.26 | 7.37 |
| 1985 | 1.97 | 8.27 | 7.15 | 1.52 | 0.59 | 0.39 | 0.05 | 0.05 | 19.99 | 5.21 |
| 1986 | 1.73 | 15.39 | 1.74 | 0.24 | 0.21 | 0.04 | 0.00 | 0.00 | 19.36 | 4.52 |
| 1987 | 2.53 | 4.95 | 5.31 | 0.97 | 0.27 | 0.11 | 0.08 | 0.00 | 14.22 | 3.67 |
| 1988 | 3.10 | 14.46 | 2.52 | 0.60 | 0.05 | 0.02 | 0.00 | 0.00 | 20.74 | 3.83 |
| 1989 | 0.67 | 22.26 | 3.18 | 1.08 | 0.06 | 0.00 | 0.00 | 0.00 | 27.25 | 4.73 |
| 1990 | 0.63 | 11.77 | 15.57 | 0.63 | 0.14 | 0.01 | 0.02 | 0.01 | 28.77 | 6.60 |
| 1991 | 0.06 | 5.34 | 3.31 | 2.15 | 0.48 | 0.12 | 0.05 | 0.00 | 11.50 | 3.32 |
| 1992 | 1.30 | 11.03 | 9.71 | 2.38 | 1.45 | 0.03 | 0.03 | 0.00 | 25.94 | 6.54 |
| 1993 | 0.63 | 7.99 | 6.31 | 1.94 | 0.23 | 0.06 | 0.20 | 0.03 | 17.38 | 4.60 |
| 1994 | 2.67 | 24.02 | 7.53 | 1.49 | 0.33 | 0.12 | 0.00 | 0.00 | 36.15 | 6.23 |
| 1995 | 7.51 | 14.64 | 24.96 | 2.88 | 1.20 | 0.02 | 0.02 | 0.00 | 51.22 | 10.38 |
| 1996 | 1.17 | 18.03 | 14.70 | 6.78 | 1.74 | 0.00 | 0.04 | 0.00 | 42.46 | 9.25 |
| 1997 | 0.52 | 16.94 | 12.22 | 4.04 | 0.54 | 0.00 | 0.00 | 0.00 | 34.26 | 7.55 |
| 1998 | 0.55 | 4.96 | 13.50 | 1.25 | 0.19 | 0.02 | 0.00 | 0.00 | 20.46 | 5.17 |
| 1999 | 0.10 | 6.34 | 10.90 | 1.28 | 0.08 | 0.00 | 0.00 | 0.00 | 18.70 | 5.08 |
| 2000 | 0.83 | 21.92 | 33.29 | 11.28 | 1.30 | 0.52 | 0.00 | 0.00 | 69.14 | 20.37 |
| 2001 | 0.22 | 10.21 | 38.20 | 10.39 | 1.68 | 0.00 | 0.00 | 0.00 | 60.71 | 19.34 |
| 2002 | 0.36 | 1.29 | 13.84 | 5.34 | 0.26 | 0.17 | 0.00 | 0.00 | 21.27 | 7.43 |
| mean | 1.91 | 16.16 | 10.99 | 2.67 | 0.60 | 0.11 | 0.04 | 0.01 | 32.48 | 8.44 |

Table E4b. Survey indices of Cape Cod yellowtail abundance and biomass.

Mean Number per Tow at Age

| **MADMF Fall Survey** | | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | sum | kg/tow |
| 1978 | 0.04 | 7.13 | 7.74 | 1.45 | 0.11 | 0.00 | 0.01 | 0.00 | 0.00 | 16.48 | 2.80 |
| 1979 | 0.03 | 24.11 | 22.82 | 1.78 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 48.80 | 7.33 |
| 1980 | 0.03 | 26.54 | 12.38 | 2.70 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 42.00 | 5.90 |
| 1981 | 0.00 | 2.93 | 6.54 | 1.54 | 0.23 | 0.17 | 0.00 | 0.00 | 0.00 | 11.41 | 2.76 |
| 1982 | 0.00 | 9.58 | 3.36 | 5.54 | 0.30 | 0.08 | 0.00 | 0.00 | 0.00 | 18.86 | 4.20 |
| 1983 | 0.00 | 9.68 | 6.68 | 1.60 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 18.09 | 3.39 |
| 1984 | 0.04 | 1.91 | 3.00 | 0.86 | 0.39 | 0.10 | 0.02 | 0.00 | 0.04 | 6.37 | 1.18 |
| 1985 | 0.04 | 5.70 | 1.63 | 1.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 8.42 | 1.17 |
| 1986 | 0.01 | 2.60 | 4.95 | 0.20 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 7.80 | 1.36 |
| 1987 | 0.44 | 5.85 | 2.30 | 0.49 | 0.07 | 0.02 | 0.00 | 0.00 | 0.00 | 9.17 | 1.09 |
| 1988 | 0.00 | 8.96 | 11.24 | 2.27 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 22.62 | 3.71 |
| 1989 | 0.00 | 2.64 | 5.22 | 0.96 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 8.92 | 1.52 |
| 1990 | 0.00 | 5.20 | 11.93 | 4.84 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 21.98 | 4.16 |
| 1991 | 0.00 | 3.76 | 5.14 | 5.03 | 0.86 | 0.00 | 0.00 | 0.00 | 0.00 | 14.78 | 3.23 |
| 1992 | 0.20 | 7.18 | 3.62 | 2.08 | 0.47 | 0.20 | 0.00 | 0.00 | 0.00 | 13.75 | 2.00 |
| 1993 | 0.00 | 8.39 | 7.29 | 5.80 | 1.43 | 0.00 | 0.00 | 0.00 | 0.00 | 22.91 | 3.99 |
| 1994 | 0.00 | 2.36 | 11.79 | 1.79 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 16.09 | 3.27 |
| 1995 | 0.00 | 8.38 | 15.16 | 5.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29.40 | 5.75 |
| 1996 | 0.01 | 1.87 | 3.94 | 2.18 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 8.17 | 1.56 |
| 1997 | 0.00 | 1.01 | 7.38 | 1.14 | 0.16 | 0.10 | 0.00 | 0.00 | 0.00 | 9.79 | 2.10 |
| 1998 | 0.00 | 7.05 | 6.74 | 2.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16.05 | 2.68 |
| 1999 | 0.15 | 4.73 | 11.94 | 4.10 | 0.65 | 0.08 | 0.00 | 0.00 | 0.00 | 21.66 | 4.71 |
| 2000 | 0.00 | 1.36 | 8.25 | 3.53 | 0.22 | 0.10 | 0.00 | 0.03 | 0.00 | 13.48 | 3.46 |
| 2001 | 0.00 | 0.57 | 8.06 | 4.23 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 13.00 | 3.55 |
| mean | 0.04 | 6.65 | 7.88 | 2.63 | 0.26 | 0.04 | 0.00 | 0.00 | 0.00 | 17.50 | 3.20 |

Table E4c. Survey indices of Cape Cod yellowtail abundance and biomass.

Mean Number per Tow at Age

| **NEFSC Spring Survey** | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | sum | kg/tow |
| 1979 | 0.36 | 0.47 | 0.88 | 0.56 | 0.03 | 0.02 | 0.00 | 0.00 | 2.32 | 0.76 |
| 1980 | 0.00 | 4.76 | 2.72 | 0.95 | 0.19 | 0.00 | 0.00 | 0.00 | 8.62 | 3.11 |
| 1981 | 0.07 | 4.31 | 2.92 | 0.64 | 0.73 | 0.35 | 0.45 | 0.00 | 9.46 | 2.93 |
| 1982 | 0.05 | 1.86 | 4.82 | 2.47 | 0.67 | 0.38 | 0.42 | 0.11 | 10.78 | 4.57 |
| 1983 | 2.01 | 5.39 | 4.33 | 1.78 | 0.19 | 0.13 | 0.00 | 0.00 | 13.82 | 4.09 |
| 1984 | 0.06 | 1.72 | 1.02 | 0.66 | 0.43 | 0.04 | 0.05 | 0.12 | 4.10 | 1.37 |
| 1985 | 0.13 | 1.85 | 1.80 | 0.43 | 0.25 | 0.10 | 0.00 | 0.00 | 4.56 | 1.39 |
| 1986 | 0.03 | 2.99 | 0.26 | 0.07 | 0.17 | 0.00 | 0.00 | 0.00 | 3.51 | 0.68 |
| 1987 | 0.11 | 2.41 | 3.61 | 0.59 | 0.91 | 0.92 | 1.07 | 0.52 | 10.13 | 4.75 |
| 1988 | 1.48 | 6.31 | 1.30 | 0.85 | 0.33 | 0.12 | 0.06 | 0.00 | 10.43 | 1.68 |
| 1989 | 0.32 | 3.83 | 2.35 | 0.21 | 0.10 | 0.00 | 0.00 | 0.00 | 6.82 | 1.11 |
| 1990 | 0.00 | 3.66 | 8.87 | 0.23 | 0.00 | 0.16 | 0.00 | 0.00 | 12.93 | 2.78 |
| 1991 | 0.66 | 5.64 | 3.89 | 1.23 | 0.29 | 0.00 | 0.08 | 0.00 | 11.79 | 2.51 |
| 1992 | 0.25 | 1.50 | 2.34 | 0.65 | 0.03 | 0.00 | 0.00 | 0.00 | 4.77 | 1.06 |
| 1993 | 0.10 | 1.01 | 1.17 | 0.58 | 0.00 | 0.00 | 0.00 | 0.00 | 2.87 | 0.59 |
| 1994 | 0.54 | 3.81 | 1.57 | 0.61 | 0.22 | 0.13 | 0.00 | 0.00 | 6.88 | 1.15 |
| 1995 | 0.22 | 1.41 | 4.94 | 3.19 | 0.31 | 0.07 | 0.00 | 0.00 | 10.14 | 2.35 |
| 1996 | 0.02 | 0.57 | 0.79 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 1.81 | 0.40 |
| 1997 | 0.03 | 1.33 | 2.12 | 1.71 | 0.38 | 0.00 | 0.00 | 0.00 | 5.56 | 1.56 |
| 1998 | 0.00 | 1.14 | 3.35 | 1.22 | 0.28 | 0.00 | 0.00 | 0.00 | 5.99 | 1.47 |
| 1999 | 0.03 | 1.07 | 3.44 | 2.45 | 0.48 | 0.18 | 0.00 | 0.00 | 7.65 | 2.34 |
| 2000 | 0.48 | 5.56 | 21.74 | 7.49 | 1.21 | 1.45 | 0.00 | 0.00 | 37.93 | 12.39 |
| 2001 | 0.00 | 1.92 | 6.50 | 1.11 | 0.34 | 0.00 | 0.00 | 0.00 | 9.87 | 3.15 |
| 2002 | 0.02 | 2.66 | 8.15 | 3.60 | 0.28 | 0.04 | 0.00 | 0.04 | 14.80 | 4.58 |
| mean | 0.29 | 2.80 | 3.95 | 1.41 | 0.33 | 0.17 | 0.09 | 0.03 | 9.06 | 2.61 |

Table E4d. Survey indices of Cape Cod yellowtail abundance and biomass.

Mean Number per Tow at Age

| **NEFSC Fall Survey** | | | | | Age | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | sum | kg/tow |
| 1979 | 5.73 | 5.84 | 1.75 | 0.44 | 0.08 | 0.02 | 0.00 | 0.00 | 13.86 | 3.88 |
| 1980 | 14.13 | 12.04 | 5.46 | 2.08 | 0.46 | 0.00 | 0.05 | 0.00 | 34.21 | 8.95 |
| 1981 | 4.20 | 6.38 | 1.15 | 0.30 | 0.19 | 0.00 | 0.00 | 0.00 | 12.22 | 2.60 |
| 1982 | 0.77 | 3.67 | 3.53 | 0.43 | 0.48 | 0.04 | 0.00 | 0.00 | 8.92 | 2.84 |
| 1983 | 0.59 | 0.79 | 0.50 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.92 | 0.46 |
| 1984 | 0.43 | 1.50 | 0.69 | 0.87 | 0.62 | 0.20 | 0.10 | 0.10 | 4.51 | 1.77 |
| 1985 | 6.60 | 2.54 | 1.94 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 11.37 | 2.52 |
| 1986 | 1.73 | 4.71 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.83 | 1.25 |
| 1987 | 0.73 | 1.75 | 0.61 | 0.07 | 0.06 | 0.00 | 0.00 | 0.00 | 3.23 | 0.72 |
| 1988 | 4.13 | 6.04 | 0.60 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 10.88 | 1.49 |
| 1989 | 2.32 | 7.47 | 2.75 | 0.49 | 0.00 | 0.00 | 0.00 | 0.09 | 13.12 | 2.95 |
| 1990 | 4.67 | 7.93 | 3.72 | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 | 16.38 | 3.05 |
| 1991 | 2.39 | 2.23 | 1.93 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 6.95 | 1.49 |
| 1992 | 3.32 | 3.65 | 2.54 | 1.05 | 0.25 | 0.19 | 0.00 | 0.00 | 10.99 | 2.49 |
| 1993 | 5.86 | 5.75 | 0.68 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 12.39 | 1.38 |
| 1994 | 3.23 | 9.64 | 3.47 | 0.95 | 0.29 | 0.00 | 0.00 | 0.00 | 17.57 | 3.46 |
| 1995 | 0.79 | 1.09 | 1.05 | 0.23 | 0.05 | 0.00 | 0.00 | 0.00 | 3.21 | 0.93 |
| 1996 | 1.41 | 3.64 | 5.96 | 1.57 | 0.18 | 0.00 | 0.00 | 0.00 | 12.75 | 3.31 |
| 1997 | 1.39 | 3.23 | 3.67 | 1.66 | 0.90 | 0.15 | 0.00 | 0.00 | 11.00 | 2.96 |
| 1998 | 1.58 | 4.51 | 1.90 | 1.38 | 0.39 | 0.00 | 0.00 | 0.00 | 9.76 | 2.27 |
| 1999 | 5.27 | 10.55 | 6.88 | 2.12 | 0.94 | 0.04 | 0.00 | 0.00 | 25.80 | 7.64 |
| 2000 | 1.30 | 8.81 | 5.87 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 16.33 | 4.53 |
| 2001 | 0.29 | 4.93 | 2.92 | 0.12 | 0.03 | 0.03 | 0.00 | 0.00 | 8.31 | 2.47 |
| mean | 3.17 | 5.16 | 2.61 | 0.66 | 0.21 | 0.03 | 0.01 | 0.01 | 11.85 | 2.84 |

Table E5a. Stock numbers of Cape Cod yellowtail flounder from VPA.

STOCK NUMBERS (Jan 1) in thousands -

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| 1 | 9891 | 4712 | 6755 | 21229 | 7697 | 6279 | 9142 |
| 2 | 2702 | 7787 | 3786 | 5518 | 17054 | 6199 | 5067 |
| 3 | 1443 | 1378 | 3068 | 1756 | 2590 | 12034 | 2597 |
| 4 | 657 | 517 | 536 | 744 | 334 | 868 | 1988 |
| 5 | 326 | 65 | 197 | 196 | 43 | 63 | 317 |
| 6 | 116 | 14 | 89 | 39 | 11 | 50 | 73 |
| 1+ | 15133 | 14473 | 14432 | 29482 | 27730 | 25492 | 19184 |

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| 1 | 7149 | 7076 | 5495 | 4997 | 6435 | 5972 | 7932 |
| 2 | 7068 | 4326 | 5668 | 4445 | 3681 | 5262 | 4889 |
| 3 | 3057 | 2275 | 3226 | 4215 | 3004 | 2519 | 3512 |
| 4 | 802 | 1112 | 1088 | 1464 | 1295 | 1170 | 762 |
| 5 | 221 | 165 | 365 | 258 | 422 | 253 | 217 |
| 6 | 17 | 82 | 168 | 136 | 25 | 19 | 62 |
| 1+ | 18315 | 15036 | 16011 | 15514 | 14862 | 15195 | 17373 |

| | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|
| 1 | 11269 | 7444 | 1645 | 00 |
| 2 | 6444 | 9216 | 6092 | 1329 |
| 3 | 3414 | 4841 | 6619 | 3500 |
| 4 | 974 | 1600 | 1390 | 2132 |
| 5 | 155 | 193 | 199 | 158 |
| 6 | 67 | 46 | 48 | 28 |
| 1+ | 22323 | 23341 | 15993 | 7148 |

Table E5b. Fishing mortality estimates for Cape Cod yellowtail flounder from VPA.

FISHING MORTALITY -

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| 1 | 0.04 | 0.02 | 0.00 | 0.02 | 0.02 | 0.01 | 0.06 |
| 2 | 0.47 | 0.73 | 0.57 | 0.56 | 0.15 | 0.67 | 0.31 |
| 3 | 0.83 | 0.74 | 1.22 | 1.46 | 0.89 | 1.60 | 0.98 |
| 4 | 2.11 | 0.76 | 0.80 | 2.64 | 1.47 | 0.81 | 2.00 |
| 5 | 2.40 | 0.78 | 0.82 | 3.43 | 1.56 | 0.83 | 2.24 |
| 6 | 2.40 | 0.78 | 0.82 | 3.43 | 1.56 | 0.83 | 2.24 |
| 4,5 | 2.25 | 0.77 | 0.81 | 3.03 | 1.52 | 0.82 | 2.12 |

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| 1 | 0.30 | 0.02 | 0.01 | 0.11 | 0.00 | 0.00 | 0.01 |
| 2 | 0.93 | 0.09 | 0.10 | 0.19 | 0.18 | 0.20 | 0.16 |
| 3 | 0.81 | 0.54 | 0.59 | 0.98 | 0.74 | 1.00 | 1.08 |
| 4 | 1.38 | 0.91 | 1.24 | 1.04 | 1.43 | 1.49 | 1.39 |
| 5 | 1.45 | 0.94 | 1.29 | 1.08 | 1.51 | 1.58 | 1.47 |
| 6 | 1.45 | 0.94 | 1.29 | 1.08 | 1.51 | 1.58 | 1.47 |
| 4,5 | 1.42 | 0.93 | 1.27 | 1.06 | 1.47 | 1.53 | 1.43 |

| | 1999 | 2000 | 2001 |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.01 |
| 2 | 0.09 | 0.13 | 0.35 |
| 3 | 0.56 | 1.05 | 0.93 |
| 4 | 1.42 | 1.89 | 1.97 |
| 5 | 1.50 | 2.08 | 1.97 |
| 6 | 1.50 | 2.08 | 1.97 |
| 4,5 | 1.46 | 1.98 | 1.97 |

Table E5c. Spawning stock biomass estimates for Cape Cod yellowtail flounder from VPA.

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT)

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 46 | 106 | 53 | 68 | 319 | 90 | 76 |
| 3 | 274 | 324 | 551 | 242 | 519 | 1703 | 438 |
| 4 | 123 | 183 | 194 | 121 | 108 | 314 | 422 |
| 5 | 66 | 32 | 84 | 30 | 19 | 34 | 84 |
| 6 | 31 | 09 | 53 | 07 | 07 | 31 | 27 |
| 1+ | 540 | 654 | 934 | 468 | 972 | 2172 | 1046 |

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 46 | 49 | 88 | 66 | 48 | 110 | 91 |
| 3 | 520 | 488 | 677 | 689 | 641 | 471 | 667 |
| 4 | 216 | 301 | 293 | 366 | 322 | 267 | 208 |
| 5 | 68 | 76 | 122 | 92 | 110 | 69 | 67 |
| 6 | 10 | 51 | 75 | 64 | 12 | 07 | 32 |
| 1+ | 859 | 965 | 1254 | 1278 | 1132 | 924 | 1065 |

| | 1999 | 2000 | 2001 |
|---|---|---|---|
| 1 | 00 | 00 | 00 |
| 2 | 151 | 238 | 124 |
| 3 | 847 | 1026 | 1371 |
| 4 | 278 | 376 | 326 |
| 5 | 44 | 46 | 59 |
| 6 | 30 | 16 | 21 |
| 1+ | 1349 | 1700 | 1901 |

Table E6. Short term projections of Cape Cod yellowtail flounder.

| Input Assumptions | age 1 | age 2 | age 3 | age 4 | age 5 | age 6+ |
|---|---|---|---|---|---|---|
| stock weight (kg) | 0.04 | 0.28 | 0.39 | 0.51 | 0.61 | 0.92 |
| landed weight (kg) | 0.15 | 0.35 | 0.41 | 0.52 | 0.61 | 0.92 |
| discard weight (kg) | 0.15 | 0.22 | 0.30 | 0.41 | 0.53 | 0.75 |
| maturity | 0.00 | 0.08 | 0.81 | 1.00 | 1.00 | 1.00 |
| partial recruitment | 0.01 | 0.11 | 0.55 | 1.00 | 1.00 | 1.00 |
| proportion discarded | 1.00 | 0.52 | 0.20 | 0.07 | 0.05 | 0.04 |

Results

| Year | F | Landings (mt) | Discards (mt) | SSB (mt) |
|---|---|---|---|---|
| 2002 | 1.67 | 1651 | 224 | 1368 |
| 2003 | 0.12 | 117 | 17 | 1179 |
| 2004 | 0.12 | 217 | 31 | 2463 |

Figure E1. Total catch of Cape Cod yellowtail flounder.

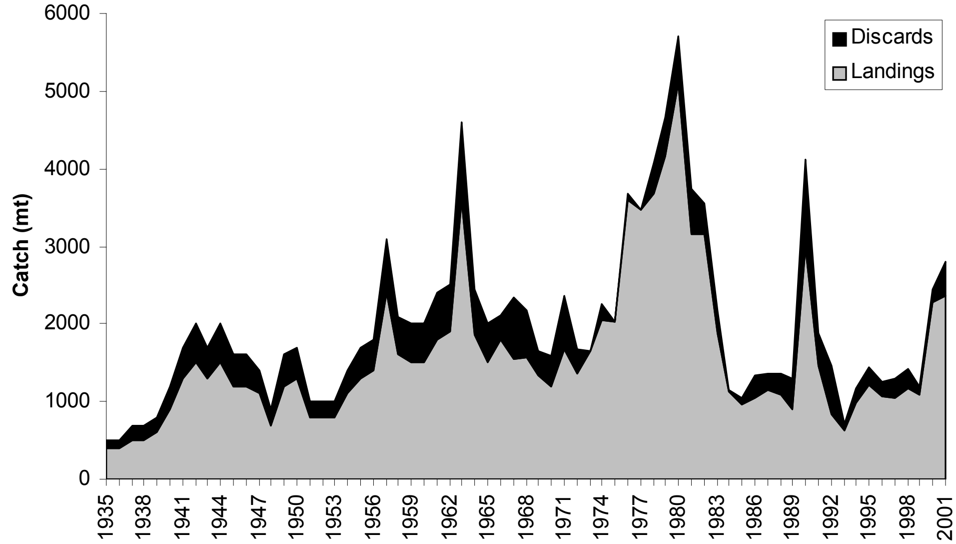



Figure E2. Survey indices of Cape Cod yellowtail flounder biomass.

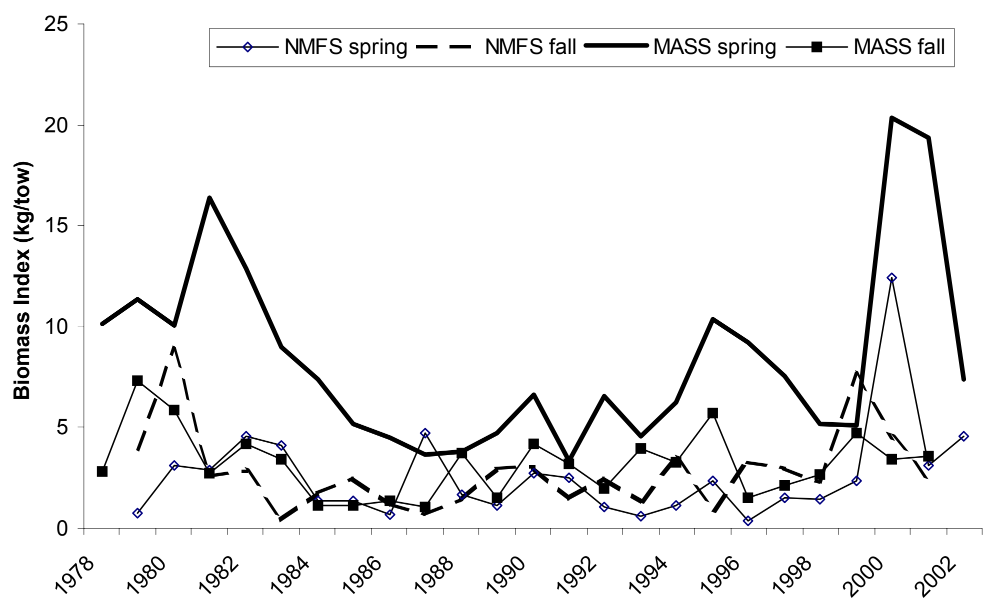
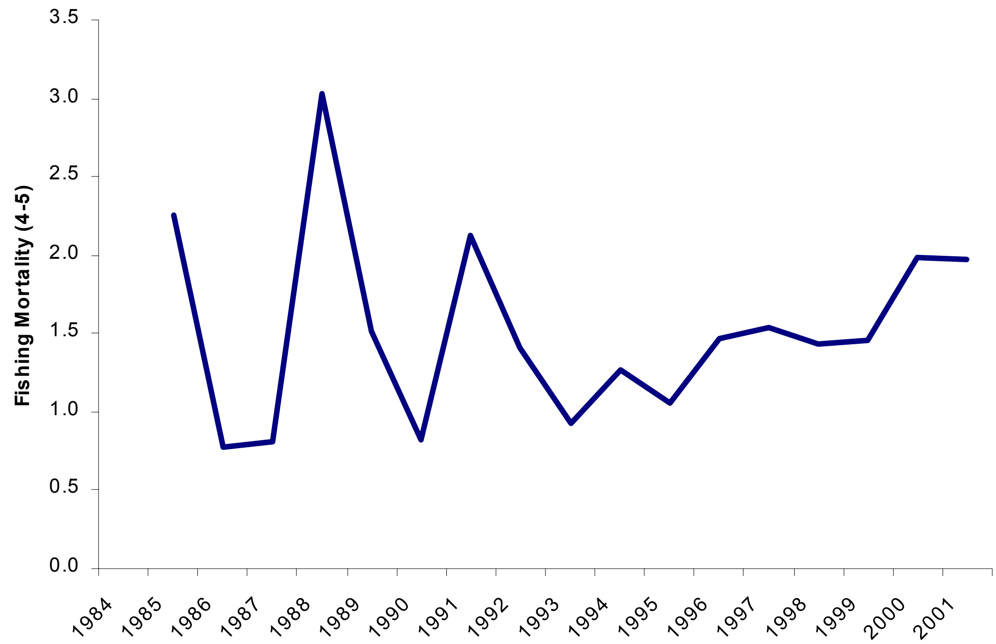


Figure E3. Cape Cod yellowtail flounder VPA results.



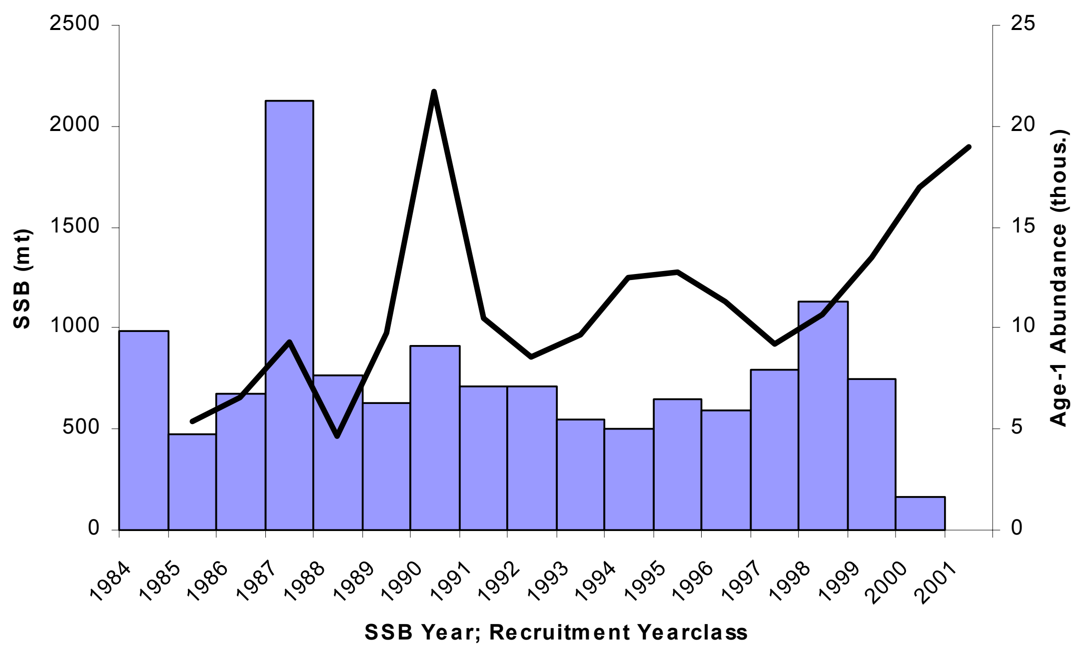



Figure E4.  Retrospective analysis of the Cape Cod yellowtail flounder VPA.

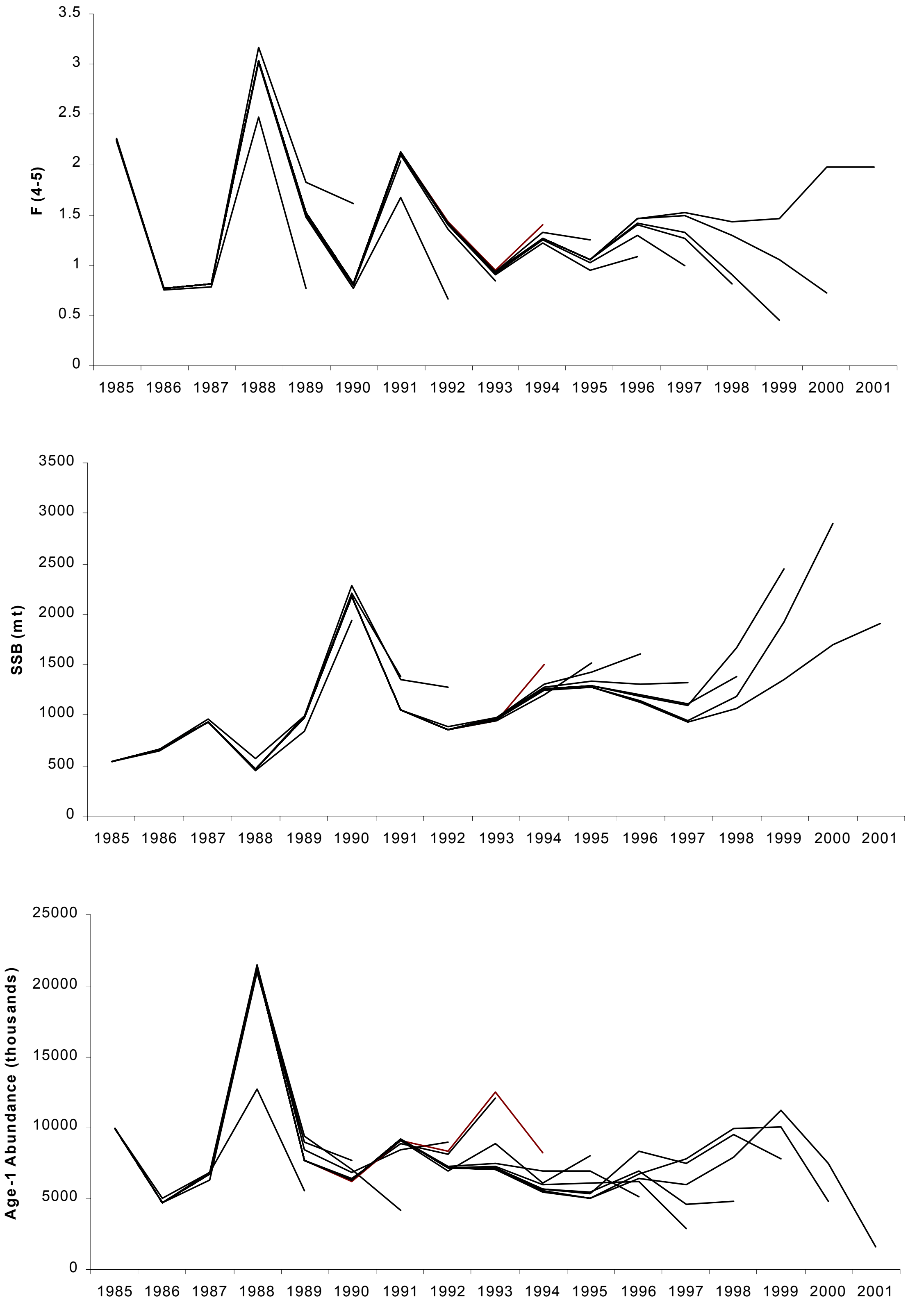
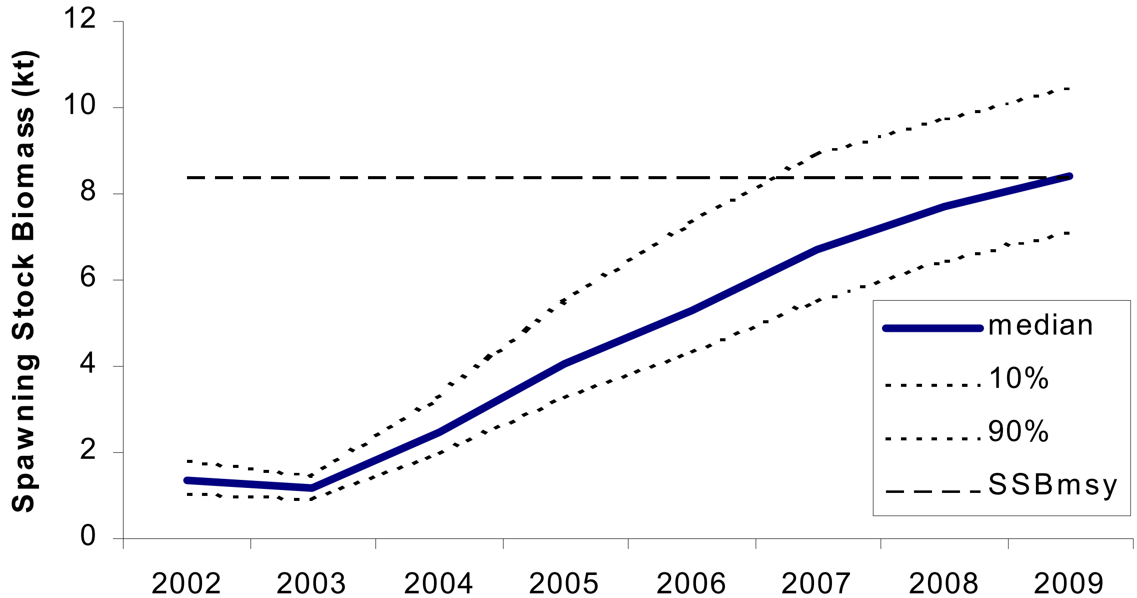


Figure E5. Stochastic projection of Cape Cod yellowtail flounder for $F_{REBUILD}$=0.12.



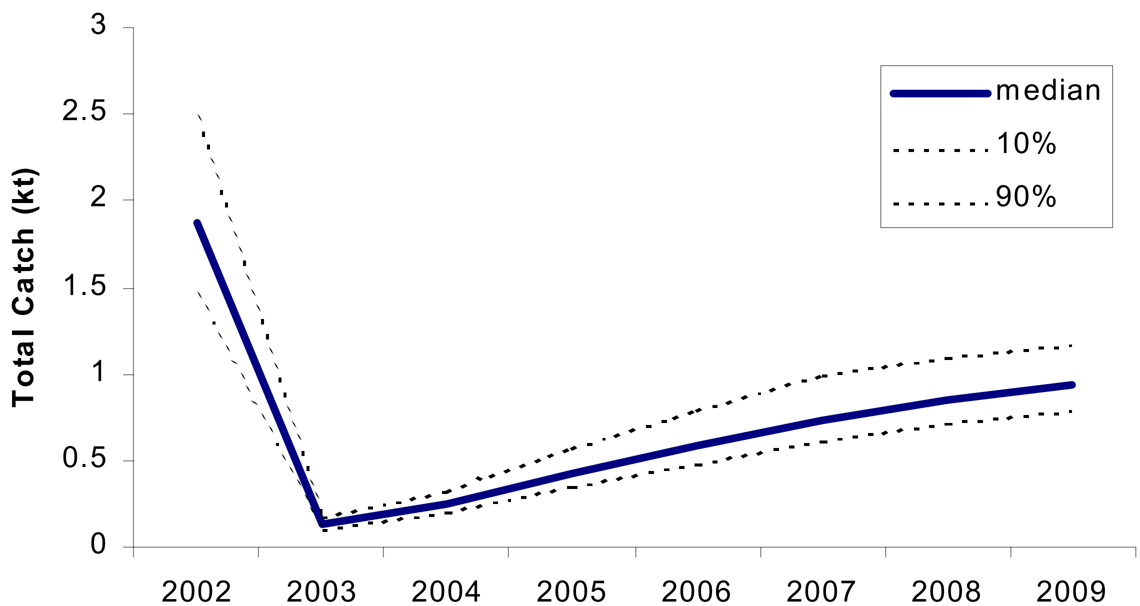
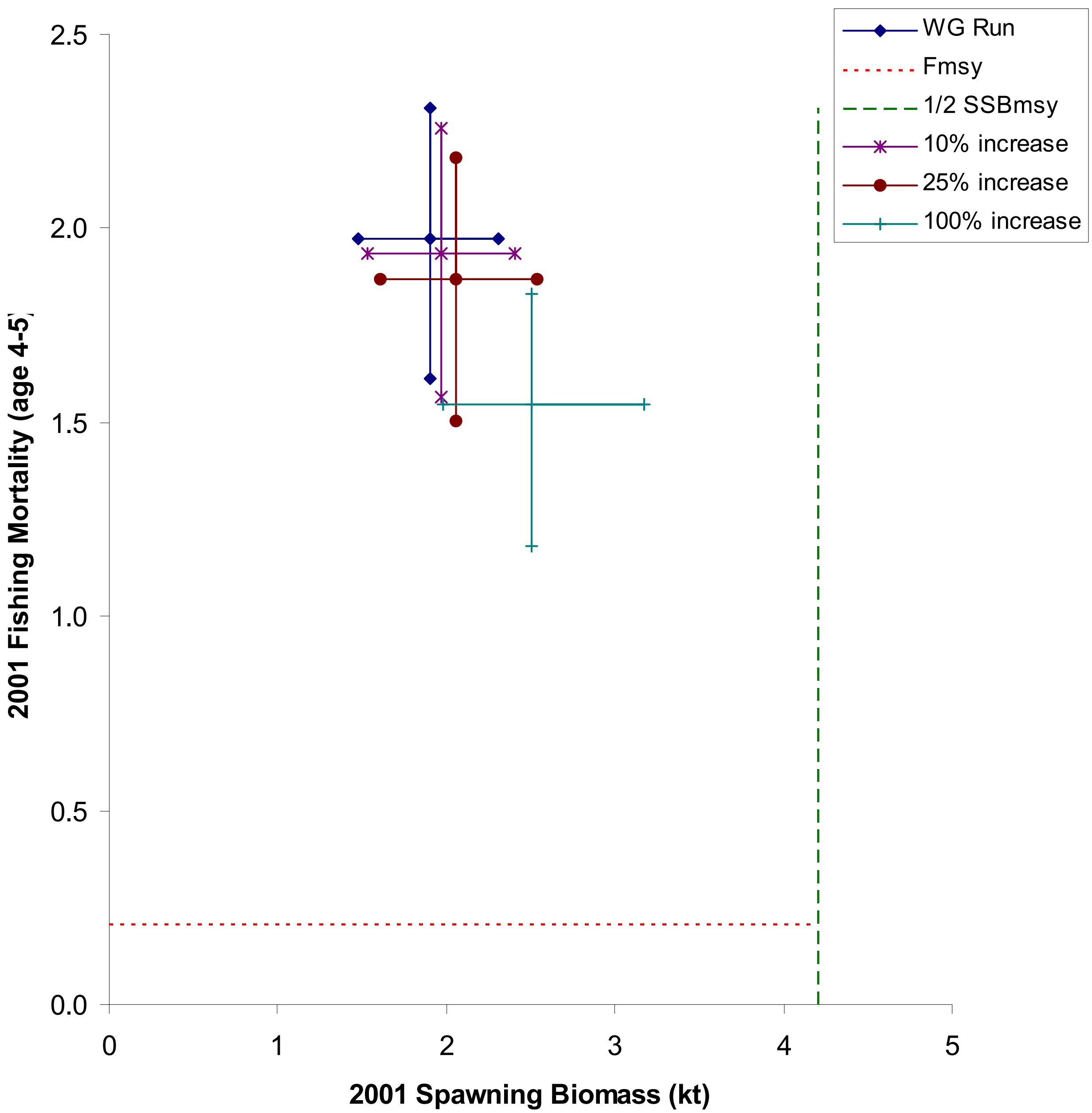



Figure E6. Sensitivity of results to excluding NEFSC survey indices and increasing NEFSC indices since 2000 by 10%, 25% and 100% (with 80% confidence intervals). Results accepted by the working group ("WG Run") are shown for comparison.



## F. Gulf of Maine Cod by R.K. Mayo and L. Col

### 1.0 Background

The Gulf of Maine Atlantic cod stock was last assessed in 2001 (Mayo *et al.* 2002; NEFSC 2001). All of the methodology applied in the present assessment is the same as in the 2001 assessment as described in Mayo *et al.* (2002). In the 2001 assessment, fully recruited fishing mortality (ages 4+) in 2000 was estimated to be 0.73, and the 1999 F was estimated to be 0.77. Spawning stock biomass was estimated to have declined to 11,100 mt in 1999, a decline from a recent high of 14,600 mt in 1995 and a series high of 24,200 mt in 1990. The strength of the most recent recruiting year classes was estimated to be very low. The 1993, 1994 and 1995 year classes continue to be estimated as the lowest in the VPA series dating back to 1982 (1981 year class). The recruit/SSB survival ratios for these most recent year classes were also estimated to be very low compared to previous year classes. NEFSC spring and autumn research vessel bottom trawl survey indices for Gulf of Maine cod had declined to record low levels in the mid-1990s; indices from both surveys fluctuated at relatively low levels but have been increasing in 2001 and 2002. The 1994-1996 year classes derived from the NEFSC and Commonwealth of Massachusetts surveys were also among the lowest in the respective series, but the Mass. DMF survey and the 2001 and 2002 NEFSC surveys indicate that the 1998 year class may be larger than the recent average.

### 2.0 The Fishery

Commercial landings of Gulf of Maine cod declined to 1,636 metric tons (mt) in 1999, a 61 % decline from 1998 (Table F1; Figure F1). Commercial landings have since increased to 3,730 mt in 2000 and 4,416 mt in 2001. Discard estimates have been derived on a gear-quarter basis from 1989 through 2001 based on NEFSC Observer Program data; these results indicate a substantial increase in the overall discard /kept ratio in 1999 compared to previous years. Ratios calculated for 2000 and 2001 are lower than the 1999 ratio, but substantially greater than the pre-1999 ratios. Discards estimated from the Observer Program data equaled 2,600, 1,200 and 1,600 mt in 1999, 2000 and 2001, respectively. Discards have also been estimated based on Vessel Trip Reports, filtered to exclude vessels which do not report discards. Discards based on these data have been estimated to be 2,800, 2,200 and 1,600 mt in 1999, 2000, and 2001, respectively.

During the review of the 2001 assessment at SAW33, it was agreed that the discard estimates from both Sea Sample and VTR data could be accepted with reservation. It was then concluded that only approximations of the actual estimates in 500 mt increments were considered. For the purposes of the present assessment, the procedure agreed at SAW33 was employed for the 2001 data. Full details are given in Mayo *et al.* (2002). Discards as derived in this manner are given below:

| Year | Landings | Discard Estimates SS | VTR | SARC 33 As Used | Commercial Catch |
|---|---|---|---|---|---|
| 1999 | 1,636 | 2,630 | 2,822 | 2,500 | 4,136 |
| 2000 | 3,730 | 1,170 | 2,246 | 1,000 | 4,730 |
| 2001 | 4,416 | 1,619 | 1,600 | 1,500* | 5,916 |

* SARC approach carried forward for 2001

The estimated recreational catch of Gulf of Maine cod (retained component only) remained the same in 1999 as in 1998 at approximately 822-824 mt, but increased to 1,100 mt in 2000 and 2,600 mt in 2001. For input to VPA, the landings at age were raised by the ratio of total catch (including discards) to landings under the assumption that high discarding in 1999-2001 was due to trip limits, resulting in discarding of all sizes in the same proportion as landings.

The number of commercial port samples for this stock declined from 78 in 1997 to 46 in 1998 to 15 in 1999. Port sampling has since improved, increasing to 61 samples in 2000 and 113 samples in 2001 (Table F2). Sampling was not well distributed among quarters and market categories in 1999 and 2000, as only 1 biological sample was taken in the 3rd and 4th quarter of 1999, requiring substantial pooling over quarter. In 1999 and 2000 samples from each market category were pooled on an annual basis, but improved sampling in 2001 allowed a return to the traditional quarterly pooling of samples within each market category. In 2001, sampling was approximately proportional to the distribution of the landings by market category (Table F3). As has generally been the case, the landings at age in 1999-2001 were dominated by age 3 and 4 cod (Table F4).

**3.0 Research Vessel Surveys**

NEFSC research vessel bottom trawl survey abundance and biomass indices for Gulf of Maine cod remained relatively low through autumn 1999 and spring 2000 (Table F5; Figure F2). The autumn 1999 indices increased slightly over 1998, while the spring 2000 indices decreased slightly from the 1999 values. However, biomass indices increased substantially in 2001 and spring 2002 over the 1999-2000 values.

Autumn biomass indices were also partitioned into inshore (strata 26 and 27; area 1,734 square miles) and offshore (strata 28-30, 36-40; 16,158 square miles) Gulf of Maine regions. When expressed in this manner, stratified mean weight per tow indices may be seen to represent comparative biomass density rather than indices of absolute biomass.

However, when appropriate weighting by area is applied to the respective inshore and offshore indices to allow comparison of absolute biomass between regions, the weighted indices provide a perspective on trends in absolute biomass. These results suggest that biomass has declined more precipitously in the offshore regions of the Gulf of Maine, while biomass in the inner region has declined at a lesser rate. Both inshore and offshore biomass indices have been increasing in recent years, consistent with an expansion of the population to the offshore area. Recruitment indices for the 1994-1997 year classes derived from the NEFSC and Mass. DMF bottom trawl surveys are among the lowest in the respective series, although indices for the 1998 and 1999 year classes appear to be above the recent average. The 2000 year class appears to be the extremely weak.

**4.0 Assessment**

Input Data and Analyses

The present assessment represents a one-year update to the previous assessment (Mayo *et al.* 2002; NEFSC 2001). The same VPA formulation used in the previous assessment was employed in the present update, except that current year (2002) spring survey data were available. Catch at age data were updated for 2001 with the inclusion of commercial discards (1,500 mt in 2001) and recreational catch at age. NEFSC and Mass. DMF survey abundance indices (stratified mean number per tow at age) were updated through spring 2002. As in recent VPAs, commercial CPUE indices were included only through 1993.

Precision of the 2001 spawning stock biomass and fully recruited fishing mortality was derived from 1,000 bootstrap replicates of the VPA based on resampling of survey residuals. A retrospective analysis of terminal year estimates of stock sizes, fully recruited fishing mortality and SSB were also carried out. Projections through 2009 were also completed.

Assessment Results

Fully recruited fishing mortality (ages 4+) in 2001 is estimated at 0.47 (Table F6; Figure F3), and spawning stock biomass is estimated to have increased to 22,000 mt in 2001 (Table F6; Figure F4). The 1998 year class is estimated to be equivalent to the 1992 year class (approximately 9-10 million fish), while all intervening year classes are below the long term geometric mean (5.9 million fish). The 1999 year class is slightly below average, the 2000 year class (< 1 million fish) is by far the poorest of those estimated by the VPA, and the 1993-1995 year classes are about ½ the long term average.

VPA Diagnostics

Based on the variability indicated by the survey residuals, the bootstrap analysis suggests that there is a 90% probability that 2001 fully recruited fishing mortality is greater than 0.38, and 2001 SSB is less than 25,600 mt. With the current VPA formulation, a retrospective pattern is evident in the estimates of terminal F whereby fully recruited F appears to have been overestimated in 1999 and 2000 and underestimated from 1994-1997 (Figure F5). The opposite pattern is evident for SSB, although to a lesser extent. Terminal year estimates of the strength of the 1994-1996 year classes in 1995-1997 were considerably lower than the retrospective estimates, but recent year classes appear to have been well estimated in the terminal year

VPA Sensitivity Runs

The sensitivity of the VPA calibration process to various assumptions of changes in survey catchability during 2000 to 2002 was examined. Specifically, the 2000-2002 NEFSC spring and autumn age-specific indices were arbitrarily raised by 10%, 25%, and 100%, and the VPA calibration process was repeated. Bootstrapping each of the VPAs provided a series of overlap plots based on the 80% confidence intervals (80% CI). These results suggest considerable overlap between the 10% and 25% adjustment VPAs and the base VPA, with the 100% adjustment VPA exhibiting considerable distance from all others (Figure F6). Further details are presented in section 4.2 of this report.

**5.0 Projections**

Catch and stock size projections were performed with $F_{2002}$ assumed equal to 85% of $F_{2001}$ (0.40), and $F_{2003\text{-}2009}$ determined by iterating a revised estimate of $F_{rebuild}$ until there was a 50% probability that SSB was equal to $SSB_{MSY}$ in 2009. The estimate of $F_{rebuild}$ based on the present VPA results is 0.114. Input data and projection results are given in Table F7 and Figure F7.

Medium term projections suggest that SSB will increase to SSBmsy (82,830 mt) by 2009 with at least a 50% probability if F is held at Frebuild (0.114) between 2003 and 2009 (Figure F7). Short term projections of catch for 2003 indicate that total catch (including commercial landings and discard, and recreational landings) should not exceed 2,479 mt if the revised estimate of $F_{rebuild}$ (0.114) is to be achieved in 2003.

**6.0 Biological Reference Points**

The following biological reference points were obtained from an age-structured production model (NEFSC 2002) performed on yield and SSB/recruit analyses and the VPA estimates of SSB and age 1 recruitment obtained from the 2001 assessment (Mayo *et al.* 2002):

| | |
|---|---|
| MSY | 16,600 mt |
| $SSB_{MSY}$ | 82,830 mt |
| $F_{MSY}$ | 0.225 (fully recruited) |

At that time, the fishing mortality required to rebuild SSB to $SSB_{MSY}$ by 2009 was determined to be 0.165, based on starting conditions in 2001. The fishing mortality to rebuild to the same $SSB_{MSY}$ was re-estimated from the results of the present assessment as 0.114, based on starting conditions in 2002. The differences are primarily due to the use of 85% of $F_{2001}$ (0.40) in 2002 in the present analysis versus an assumption of $F_{max}$ (0.258) in 2002 in the previous analysis, and the inclusion of the weak 2000 year class as part of the starting stock sizes in 2002 versus the geometric mean in the previous analysis. In addition the geometric mean recruitment applied in 2002 (5.9 million fish at age 1) is somewhat lower than the previous estimate (6.6 million) applied in 2001.

## 7.0 Conclusions

In 2001, SSB was less than ½ $SSB_{MSY}$ and fully recruited fishing mortality was about 2 times $F_{MSY}$. Therefore the stock is overfished and overfishing is occurring.

## 8.0 Summary

Fishing mortality appears to have declined considerably in 2001 compared to earlier years, and spawning biomass is continuing to increase. The SSB estimate for 2001 (22,000 mt) is close to the high values of 1982 and 1989-1991. However, the apparent improvement in the condition of the stock is dependent to a large extent on the incoming 1998 year class. The strength of subsequent year classes, however, is either just below average (1999 year class) or extremely low (2000 year class).

Although recent surveys have indicated a marked increase in biomass, especially spring 2001 and 2002 and autumn 2001, there appears to have been a catchability effect associated with the spring 2002 survey in which abundance indices at age for most cohorts increased over the previous year.

Overall, there is accumulating evidence that the biomass of Gulf of Maine cod has been increasing in 2001 and 2002. Further increases in biomass may occur if fishing mortality is reduced to maximize the contribution of the 1998 year class to the spawning stock. Based on the current maturity ogive, this year class will be fully mature at age 4 in 2002. However, given the expected relatively poor strength of the 1999 and 2000 year classes, rebuilding of the stock may plateau unless additional average or above average year classes recruit in the next several years.

## 9.0 GARM Panel Comments

The Panel commented that the stock distribution had collapsed into a small area within Massachusetts Bay; however, there is now some evidence that the stock is starting to expand towards the outer Gulf of Maine. The Panel observed that the 2000 year class was estimated to be the weakest in the time series but, at this time, it is premature to draw final conclusions regarding the strength of this year class given the retrospective pattern in recruitment estimates ( i.e. in future assessments, the 2000 year class may not be as low as currently estimated). The Panel noted that the 2000 fishing morality rate is lower than the estimate in the last assessment and this result is consistent with the retrospective pattern for fishing mortality which revealed a tendency to overestimate F in 2000.

Similarly, the Panel noted that the tuned 2001 F in the present assessment is considerably lower than the 2001 projected F (NEFSC 2002). This is due to several factors. The Projected 2001 F was based on stock conditions obtained from the 2001 VPA which was calibrated with research vessel survey data collected through autumn 2000. The present assessment utilizes 3 additional NEFSC surveys (2001 and 2002 spring and 2001 autumn), all of which indicated year over year increases in stock abundance, as well as corresponding Massachusetts surveys used to calibrate stock size estimates of recruiting ages.

**Sources of Uncertainty**

- Discard estimates included in the assessment in 1999-2001 based on the approach recommended by the 33rd SAW are likely to have underestimated the actual discards because they were rounded down to the nearest lower 500 ton bin.

- The estimate of the size of the incoming 2000 year class in 2001 is uncertain, but its influence on the projections is substantial. In the past, estimates of low recruitment were revised upward as data from the fishery were included, but the final estimates still indicated that they were lowest in the VPA series. Subsequent estimates of the strength of the 2000 year class may also increase.

## 10.0 Research Recommendations

- Explore a VPA formulation where autumn tuning indices are adjusted back to Jan 1, instead of shifted forward one year and one age.

- Explore the use of the state of Maine survey as a tuning indices.

- Given the overall truncation in the age composition, investigate possible trends in size/age composition of the inshore versus offshore areas.

- Request the Methods Working Group to investigate means of deriving an appropriate sampling intensity for commercial landings.

## 11.0 References

Mayo, R.K., E.M. Thunberg, S.E. Wigley and S.X. Cadrin. 2002. The 2001 Assessment of the Gulf of Maine Atlantic Cod Stock. NMFS/NEFSC, Woods Hole Laboratory Ref. Doc. 02-02.

NEFSC. 2001. 33rd Northeast Regional Stock Assessment Workshop (33rd SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NMFS/NEFSC, Reference Document 01-18.

NEFSC 2002. Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. NMFS/NEFSC, Reference Document 02-04, 254p.

Table F1. Commercial landings (metric tons, live) of Atlantic cod from the Gulf of Maine (NAFO Division 5Y), 1960 - 2001.[1]

| Year | Gulf of Maine USA | Canada | USSR | Other | Total |
|---|---|---|---|---|---|
| 1960 | 3448 | 129 | - | - | 3577 |
| 1961 | 3216 | 18 | - | - | 3234 |
| 1962 | 2989 | 83 | - | - | 3072 |
| 1963 | 2595 | 3 | 133 | - | 2731 |
| 1964 | 3226 | 25 | - | - | 3251 |
| 1965 | 3780 | 148 | - | - | 3928 |
| 1966 | 4008 | 384 | - | - | 4392 |
| 1967 | 5676 | 297 | - | - | 5973 |
| 1968 | 6360 | 61 | - | - | 6421 |
| 1969 | 8157 | 59 | - | 268 | 8484 |
| 1970 | 7812 | 26 | - | 423 | 8261 |
| 1971 | 7380 | 119 | - | 163 | 7662 |
| 1972 | 6776 | 53 | 11 | 77 | 6917 |
| 1973 | 6069 | 68 | - | 9 | 6146 |
| 1974 | 7639 | 120 | - | 5 | 7764 |
| 1975 | 8903 | 86 | - | 26 | 9015 |
| 1976 | 10172 | 16 | - | - | 10188 |
| 1977 | 12426 | - | - | - | 12426 |
| 1978 | 12426 | - | - | - | 12426 |
| 1979 | 11680 | - | - | - | 11680 |
| 1980 | 13528 | - | - | - | 13528 |
| 1981 | 12534 | - | - | - | 12534 |
| 1982 | 13582 | - | - | - | 13582 |
| 1983 | 13981 | - | - | - | 13981 |
| 1984 | 10806 | - | - | - | 10806 |
| 1985 | 10693 | - | - | - | 10693 |
| 1986 | 9664 | - | - | - | 9664 |
| 1987 | 7527 | - | - | - | 7527 |
| 1988 | 7958 | - | - | - | 7958 |
| 1989 | 10397 | - | - | - | 10397 |
| 1990 | 15154 | - | - | - | 15154 |
| 1991 | 17781 | - | - | - | 17781 |
| 1992 | 10891 | - | - | - | 10891 |
| 1993 | 8287 | - | - | - | 8287 |
| 1994* | 7877 | - | - | - | 7877 |
| 1995* | 6798 | - | - | - | 6798 |
| 1996* | 7194 | - | - | - | 7194 |
| 1997* | 5421 | - | - | - | 5421 |
| 1998* | 4156 | - | - | - | 4156 |
| 1999* | 1636 | - | - | - | 1636 |
| 2000* | 3730 | - | - | - | 3730 |
| 2001* | 4416 | - | - | - | 4416 |

* Provisional

[1] USA 1960-1993 landings from NMFS, NEFSC Detailed Weighout Files and Canvass data.
[2] USA 1994-2001 landings estimated by prorating NMFS, NEFSC Detailed Weighout data by Vessel Trip Reports.

Table F2. USA sampling of commercial Atlantic cod landings from the Gulf of Maine cod stock (NAFO Division 5Y), 1982 - 2001.

| | Number of Samples | | | | Number of Samples, by Market Category & Quarter | | | | | | | | | | | | | | | Annual Sampling Intensity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length Samples | | Age Samples | | Scrod | | | | | Market | | | | | Large | | | | | No. of Tons Landed/Sample | | | |
| Year | No. | No. Fish Measured | No. | No. Fish Aged | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Q1 | Q2 | Q3 | Q4 | ∑ | Scrod | Market | Large | ∑ |
| 1982 | 48 | 3848 | 48 | 866 | 6 | 7 | 6 | 6 | 25 | 4 | 3 | 7 | 4 | 18 | 0 | 2 | 1 | 2 | 5 | 134 | 348 | 792 | 266 |
| 1983 | 71 | 5241 | 67 | 1348 | 14 | 10 | 10 | 4 | 38 | 4 | 10 | 6 | 2 | 22 | 1 | 3 | 5 | 2 | 11 | 106 | 294 | 318 | 197 |
| 1984 | 55 | 3925 | 55 | 1224 | 7 | 5 | 6 | 7 | 25 | 4 | 3 | 5 | 6 | 18 | 1 | 6 | 3 | 2 | 12 | 85 | 319 | 245 | 193 |
| 1985 | 69 | 5426 | 66 | 1546 | 5 | 6 | 7 | 5 | 23 | 8 | 6 | 7 | 4 | 25 | 7 | 5 | 3 | 6 | 21 | 95 | 229 | 132 | 155 |
| 1986 | 53 | 3970 | 51 | 1160 | 5 | 5 | 6 | 3 | 19 | 5 | 6 | 8 | 2 | 21 | 1 | 5 | 4 | 3 | 13 | 124 | 242 | 170 | 182 |
| 1987 | 43 | 3184 | 42 | 939 | 4 | 4 | 3 | 4 | 15 | 5 | 5 | 3 | 5 | 18 | 4 | 2 | 3 | 1 | 10 | 83 | 224 | 225 | 175 |
| 1988 | 34 | 2669 | 33 | 741 | 4 | 3 | 4 | 4 | 15 | 1 | 5 | 3 | 5 | 14 | 1 | 2 | 2 | 0 | 5 | 147 | 271 | 391 | 234 |
| 1989 | 32 | 2668 | 32 | 714 | 3 | 3 | 3 | 3 | 12 | 4 | 1 | 5 | 4 | 14 | 2 | 2 | 1 | 1 | 6 | 209 | 430 | 311 | 325 |
| 1990 | 39 | 2982 | 38 | 789 | 3 | 7 | 3 | 5 | 18 | 4 | 7 | 4 | 3 | 18 | 0 | 2 | 1 | 0 | 3 | 300 | 378 | 966 | 387 |
| 1991 | 56 | 4519 | 56 | 1152 | 2 | 10 | 4 | 3 | 19 | 5 | 11 | 11 | 3 | 30 | 0 | 3 | 3 | 1 | 7 | 250 | 313 | 519 | 318 |
| 1992 | 51 | 4086 | 51 | 1002 | 2 | 8 | 6 | 3 | 19 | 6 | 7 | 7 | 3 | 23 | 3 | 1 | 1 | 4 | 9 | 104 | 232 | 375 | 214 |
| 1993 | 23 | 1753 | 23 | 447 | 3 | 3 | 3 | 1 | 10 | 1 | 2 | 4 | 1 | 8 | 1 | 1 | 2 | 1 | 5 | 177 | 453 | 527 | 360 |
| 1994 | 30 | 2696 | 33 | 665 | 0 | 2 | 2 | 4 | 8 | 1 | 4 | 4 | 6 | 15 | 0 | 2 | 3 | 2 | 7 | 180 | 284 | 272 | 263 |
| 1995 | 31 | 2568 | 32 | 662 | 4 | 2 | 2 | 4 | 12 | 2 | 7 | 1 | 2 | 12 | 0 | 5 | 0 | 2 | 7 | 133 | 300 | 202 | 219 |
| 1996 | 77 | 7027 | 71 | 1483 | 6 | 5 | 7 | 9 | 27 | 7 | 9 | 10 | 12 | 38 | 1 | 3 | 3 | 5 | 12 | 62 | 116 | 79 | 93 |
| 1997 | 78 | 6657 | 74 | 1521 | 7 | 10 | 3 | 9 | 29 | 11 | 9 | 9 | 7 | 36 | 1 | 8 | 2 | 2 | 13 | 37 | 91 | 71 | 69 |
| 1998 | 46 | 4205 | 46 | 912 | 4 | 7 | 0 | 3 | 14 | 8 | 9 | 9 | 3 | 29 | 0 | 0 | 2 | 1 | 3 | 53 | 81 | 321 | 90 |
| 1999 | 15 | 1305 | 16 | 350 | 6 | 0 | 1 | 0 | 7 | 4 | 2 | 0 | 0 | 6 | 2 | 0 | 0 | 0 | 2 | 36 | 144 | 245 | 109 |
| 2000 | 61 | 4687 | 57 | 1300 | 12 | 5 | 3 | 4 | 24 | 12 | 14 | 4 | 6 | 36 | 0 | 0 | 0 | 1 | 1 | 14 | 62 | 1131 | 61 |
| 2001 | 113 | 7326 | 105 | 2436 | 4 | 4 | 4 | 7 | 19 | 7 | 9 | 8 | 15 | 39 | 3 | 16 | 18 | 18 | 55 | 18 | 58 | 32 | 39 |

Source: 1982-1985 from Serchuk and Wigley (1986); 1986-2001 from NEFSC files.

Table F3. Percentage (by weight) of USA commercial Atlantic cod landings from the Gulf of Maine (NAFO Division 5Y), by market category, 1964 - 2001.

| | Gulf of Maine | | | |
|---|---|---|---|---|
| Year | Large | Market | Scrod | Total [a] |
| 1964 | 29 | 59 | 12 | 100 |
| 1965 | 39 | 54 | 7 | 100 |
| 1966 | 42 | 48 | 10 | 100 |
| 1967 | 41 | 41 | 17 | 100 |
| 1968 | 47 | 43 | 9 | 100 |
| 1969 | 35 | 55 | 9 | 100 |
| 1970 | 43 | 52 | 6 | 100 |
| 1971 | 52 | 42 | 6 | 100 |
| 1972 | 58 | 35 | 7 | 100 |
| 1973 | 52 | 36 | 11 | 100 |
| 1974 | 39 | 33 | 28 | 100 |
| 1975 | 32 | 42 | 26 | 100 |
| 1976 | 29 | 45 | 20 | 100 |
| 1977 | 33 | 42 | 22 | 100 |
| 1978 | 38 | 44 | 17 | 100 |
| 1979 | 37 | 49 | 14 | 100 |
| 1980 | 36 | 45 | 19 | 100 |
| 1981 | 29 | 45 | 22 | 100 |
| 1982 | 29 | 45 | 24 | 100 |
| 1983 | 25 | 45 | 28 | 100 |
| 1984 | 26 | 51 | 19 | 100 |
| 1985 | 25 | 51 | 20 | 100 |
| 1986 | 22 | 51 | 23 | 100 |
| 1987 | 29 | 52 | 16 | 100 |
| 1988 | 26 | 45 | 23 | 100 |
| 1989 | 17 | 55 | 23 | 100 |
| 1990 | 34 | 43 | 19 | 100 |
| 1991 | 26 | 51 | 20 | 100 |
| 1992 | 31 | 49 | 18 | 100 |
| 1993 | 32 | 44 | 21 | 100 |
| 1994 | 24 | 54 | 18 | 100 |
| 1995 | 21 | 53 | 23 | 100 |
| 1996 | 13 | 61 | 23 | 100 |
| 1997 | 17 | 60 | 20 | 100 |
| 1998 | 23 | 57 | 18 | 100 |
| 1999 | 29 | 53 | 16 | 100 |
| 2000 | 30 | 59 | 9 | 100 |
| 2001 | 40 | 51 | 8 | 100 |

[a] Includes landings of 'mixed' cod.

Table F4a. Total (commercial and recreational)landings at age (thousands of fish; metric tons) of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 2001. (Input data for Virtual Population Analysis)

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | Total |
| | | | **Total Landings at Age in Numbers (000's)** | | | | | |
| 1982 | 88 | 1995 | 2350 | 1386 | 717 | 75 | 242 | 6853 |
| 1983 | 14 | 1337 | 2896 | 1184 | 685 | 448 | 169 | 6733 |
| 1984 | 24 | 813 | 1572 | 1636 | 469 | 205 | 142 | 4861 |
| 1985 | 49 | 989 | 2111 | 1122 | 665 | 133 | 137 | 5206 |
| 1986 | 26 | 208 | 2750 | 929 | 275 | 197 | 190 | 4575 |
| 1987 | 41 | 907 | 1418 | 1525 | 330 | 79 | 97 | 4397 |
| 1988 | 6 | 520 | 2140 | 1149 | 434 | 51 | 34 | 4334 |
| 1989 | 5 | 530 | 2284 | 1698 | 485 | 91 | 61 | 5154 |
| 1990 | 7 | 294 | 4195 | 2373 | 488 | 167 | 105 | 7629 |
| 1991 | 5 | 447 | 1349 | 4948 | 946 | 151 | 85 | 7931 |
| 1992 | - | 350 | 600 | 526 | 2184 | 218 | 86 | 3962 |
| 1993 | 1 | 152 | 1998 | 787 | 140 | 481 | 39 | 3597 |
| 1994 | 1 | 57 | 1380 | 1228 | 315 | 74 | 88 | 3143 |
| 1995 | - | 279 | 1152 | 1324 | 204 | 14 | 34 | 3007 |
| 1996 | - | 86 | 688 | 1943 | 368 | 46 | 10 | 3141 |
| 1997 | - | 61 | 494 | 466 | 894 | 72 | 8 | 1995 |
| 1998 | - | 110 | 485 | 616 | 180 | 211 | 11 | 1614 |
| 1999[1] | 1 | 8 | 563 | 566 | 267 | 78 | 104 | 1586 |
| 2000[2] | - | 97 | 485 | 934 | 211 | 96 | 25 | 1849 |
| 2000[3] | - | 56 | 1000 | 666 | 370 | 104 | 87 | 2281 |
| | | | **Total Landings at Age in Weight (Tons)** | | | | | |
| 1982 | 50 | 2151 | 3735 | 3719 | 3392 | 494 | 2738 | 16279 |
| 1983 | 6 | 1421 | 4664 | 2891 | 2568 | 2691 | 1680 | 15921 |
| 1984 | 12 | 820 | 2551 | 4412 | 1710 | 1192 | 1462 | 12169 |
| 1985 | 18 | 1007 | 3442 | 3121 | 2929 | 725 | 1327 | 12549 |
| 1986 | 11 | 213 | 4946 | 2679 | 1252 | 1186 | 2225 | 12512 |
| 1987 | 13 | 917 | 2185 | 4752 | 1564 | 547 | 998 | 10976 |
| 1988 | 1 | 513 | 3764 | 2736 | 2204 | 321 | 363 | 9902 |
| 1989 | 3 | 628 | 3922 | 4979 | 1861 | 386 | 726 | 12575 |
| 1990 | 1 | 299 | 6941 | 5414 | 2046 | 1266 | 1424 | 17391 |
| 1991 | 1 | 507 | 2045 | 12204 | 3807 | 1093 | 944 | 20601 |
| 1992 | - | 536 | 1149 | 1432 | 6684 | 1080 | 911 | 11793 |
| 1993 | 1 | 172 | 3650 | 1903 | 594 | 2927 | 428 | 9675 |
| 1994 | - | 78 | 2568 | 3790 | 1047 | 449 | 868 | 8799 |
| 1995 | - | 452 | 2132 | 3531 | 1033 | 100 | 455 | 7703 |
| 1996 | - | 142 | 1440 | 4537 | 1321 | 340 | 109 | 7889 |
| 1997 | - | 105 | 1088 | 1382 | 2807 | 328 | 71 | 5781 |
| 1998 | - | 147 | 1023 | 1809 | 744 | 871 | 109 | 4701 |
| 1999[1] | - | 10 | 1036 | 1573 | 1093 | 449 | 801 | 4963 |
| 2000[2] | - | 156 | 1103 | 3090 | 905 | 559 | 181 | 5996 |
| 2000[3] | - | 104 | 2387 | 2143 | 1784 | 661 | 705 | 7780 |

1. Includes 2,500 mt of estimated discards.
2. Includes 1,000 mt of estimated discards.
3. Includes 1,500 mt of estimated disaards.

Table F4b. Mean weight (kg) and mean length (cm) at age of total landings (commercial and recreational) of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 2001. (Input data for Virtual Population Analysis)

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | Average |
| | **Total Landings Mean Weight (kg) at Age** | | | | | | | |
| 1982 | 0.568 | 1.078 | 1.589 | 2.683 | 4.731 | 6.587 | 11.314 | 2.375 |
| 1983 | 0.429 | 1.063 | 1.610 | 2.442 | 3.749 | 6.007 | 9.941 | 2.365 |
| 1984 | 0.500 | 1.009 | 1.623 | 2.697 | 3.646 | 5.815 | 10.296 | 2.503 |
| 1985 | 0.367 | 1.018 | 1.621 | 2.782 | 4.405 | 5.451 | 9.686 | 2.410 |
| 1986 | 0.423 | 1.024 | 1.799 | 2.884 | 4.553 | 6.020 | 11.711 | 2.735 |
| 1987 | 0.317 | 1.011 | 1.541 | 3.116 | 4.739 | 6.924 | 10.289 | 2.496 |
| 1988 | 0.167 | 0.987 | 1.759 | 2.381 | 5.078 | 6.294 | 10.676 | 2.285 |
| 1989 | 0.600 | 1.185 | 1.717 | 2.932 | 3.837 | 4.242 | 11.902 | 2.440 |
| 1990 | 0.143 | 1.017 | 1.655 | 2.282 | 4.193 | 7.581 | 13.562 | 2.280 |
| 1991 | 0.171 | 1.134 | 1.516 | 2.466 | 4.024 | 7.238 | 11.106 | 2.598 |
| 1992 | 0.468 | 1.531 | 1.915 | 2.722 | 3.060 | 5.000 | 10.593 | 2.977 |
| 1993 | 1.000 | 1.132 | 1.627 | 2.418 | 4.243 | 6.085 | 10.974 | 2.690 |
| 1994 | 0.418 | 1.368 | 1.861 | 3.086 | 3.324 | 6.068 | 9.864 | 2.800 |
| 1995 | 0.418 | 1.620 | 1.851 | 2.667 | 5.064 | 7.143 | 13.382 | 2.562 |
| 1996 | 0.418 | 1.651 | 2.093 | 2.335 | 3.590 | 7.391 | 10.900 | 2.512 |
| 1997 | 0.418 | 1.721 | 2.202 | 2.966 | 3.140 | 4.556 | 8.875 | 2.898 |
| 1998 | 0.466 | 1.336 | 2.109 | 2.937 | 4.133 | 4.128 | 9.909 | 2.913 |
| 1999 | 0.331 | 1.250 | 1.841 | 2.776 | 4.100 | 5.736 | 7.702 | 3.129 |
| 2000 | 0.418 | 1.600 | 2.274 | 3.310 | 4.291 | 5.811 | 7.307 | 3.243 |
| 2001 | 0.418 | 1.868 | 2.388 | 3.215 | 4.817 | 6.370 | 8.103 | 3.411 |
| | **Total Landings Mean Length (cm) at Age** | | | | | | | |
| 1982 | 37.1 | 46.6 | 52.7 | 62.6 | 76.5 | 85.6 | 101.4 | 57.4 |
| 1983 | 33.5 | 46.6 | 53.1 | 61.0 | 70.5 | 82.5 | 95.6 | 58.0 |
| 1984 | 28.5 | 45.5 | 53.3 | 63.1 | 69.5 | 81.2 | 98.1 | 59.3 |
| 1985 | 32.0 | 45.4 | 53.3 | 64.1 | 74.5 | 79.9 | 96.6 | 58.5 |
| 1986 | 33.7 | 45.1 | 55.3 | 64.6 | 75.0 | 82.4 | 105.9 | 61.1 |
| 1987 | 26.4 | 45.1 | 52.1 | 66.4 | 76.2 | 86.4 | 98.4 | 58.8 |
| 1988 | 26.2 | 45.0 | 54.7 | 60.6 | 78.1 | 83.2 | 100.5 | 58.1 |
| 1989 | 38.4 | 48.5 | 54.6 | 65.1 | 71.2 | 77.5 | 103.1 | 60.0 |
| 1990 | 23.7 | 46.2 | 54.1 | 60.0 | 73.2 | 89.7 | 108.9 | 58.3 |
| 1991 | 24.9 | 47.5 | 51.9 | 61.3 | 71.8 | 88.1 | 100.7 | 61.1 |
| 1992 | 31.3 | 52.9 | 56.4 | 62.9 | 65.5 | 76.9 | 100.1 | 64.1 |
| 1993 | 38.0 | 47.4 | 55.9 | 60.8 | 73.5 | 83.2 | 101.7 | 61.4 |
| 1994 | 26.3 | 50.3 | 56.1 | 66.0 | 67.2 | 82.4 | 97.5 | 62.8 |
| 1995 | 31.2 | 53.8 | 56.0 | 62.4 | 78.0 | 87.2 | 107.1 | 60.9 |
| 1996 | 31.2 | 54.0 | 58.3 | 60.3 | 68.9 | 88.9 | 103.5 | 61.2 |
| 1997 | 31.2 | 54.6 | 59.4 | 65.0 | 66.3 | 74.8 | 104.6 | 64.4 |
| 1998 | 35.0 | 50.7 | 58.4 | 64.8 | 72.4 | 72.1 | 95.1 | 63.9 |
| 1999 | 33.0 | 47.4 | 56.0 | 63.9 | 72.1 | 80.7 | 89.9 | 64.9 |
| 2000 | 31.2 | 53.4 | 59.4 | 65.6 | 73.7 | 82.3 | 88.1 | 66.4 |
| 2001 | 31.2 | 56.3 | 60.9 | 66.8 | 76.9 | 84.5 | 91.3 | 66.9 |

Table F5. Standardized stratified mean catch per tow in numbers and weight (kg) for Atlantic cod from NEFSC offshore spring and autumn research vessel bottom trawl surveys in the Gulf of Maine (Strata 26-30 and 36-40), 1963 - 2002 [a,b,c].

| | Spring | | Autumn | |
|---|---|---|---|---|
| Year | No/Tow | Wt/Tow | No/Tow | Wt/Tow |
| 1963 | - | - | 5.92 | 17.9 |
| 1964 | - | - | 4.00 | 22.8 |
| 1965 | - | - | 4.49 | 12.0 |
| 1966 | - | - | 3.78 | 12.9 |
| 1967 | - | - | 2.56 | 9.2 |
| 1968 | 5.44 | 17.9 | 4.39 | 19.4 |
| 1969 | 3.25 | 13.2 | 2.76 | 15.4 |
| 1970 | 2.21 | 11.1 | 4.90 | 16.4 |
| 1971 | 1.43 | 7.0 | 4.37 | 16.5 |
| 1972 | 2.06 | 8.0 | 9.31 | 13.0 |
| 1973 | 7.54 | 18.8 | 4.46 | 8.7 |
| 1974 | 2.91 | 7.4 | 4.33 | 9.0 |
| 1975 | 2.51 | 6.0 | 6.15 | 8.6 |
| 1976 | 2.78 | 7.6 | 2.15 | 6.7 |
| 1977 | 3.88 | 8.5 | 3.08 | 10.2 |
| 1978 | 2.06 | 7.7 | 5.75 | 12.9 |
| 1979 | 4.27 | 9.5 | 3.49 | 17.5 |
| 1980 | 2.15 | 6.2 | 7.04 | 14.2 |
| 1981 | 4.86 | 10.8 | 2.42 | 8.1 |
| 1982 | 3.75 | 8.6 | 7.77 | 16.1 |
| 1983 | 3.91 | 10.5 | 4.22 | 8.8 |
| 1984 | 3.40 | 5.8 | 2.42 | 8.8 |
| 1985 | 2.52 | 7.7 | 2.92 | 8.5 |
| 1986 | 1.96 | 3.6 | 1.95 | 5.1 |
| 1987 | 1.68 | 3.0 | 2.98 | 3.4 |
| 1988 | 3.13 | 3.3 | 5.90 | 6.6 |
| 1989 | 2.26 | 2.5 | 4.65 | 4.6 |
| 1990 | 2.36 | 3.1 | 2.99 | 4.9 |
| 1991 | 2.39 | 2.9 | 1.25 | 2.8 |
| 1992 | 2.41 | 8.7 | 1.43 | 2.4 |
| 1993 | 2.50 | 5.9 | 1.23 | 1.0 |
| 1994 | 1.27 | 2.4 | 2.14 | 2.7 |
| 1995 | 1.91 | 2.4 | 2.01 | 3.7 |
| 1996 | 2.46 | 5.4 | 1.32 | 2.4 |
| 1997 | 2.19 | 5.6 | 0.87 | 1.9 |
| 1998 | 1.71 | 4.2 | 0.84 | 1.5 |
| 1999 | 2.30 | 5.1 | 1.81 | 3.5 |
| 2000 | 3.08 | 3.2 | 2.60 | 4.7 |
| 2001 | 2.15 | 6.2 | 1.98 | 7.3 |
| 2002 | 3.72 | 10.9 | | |

[a] During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portugeuse polyvalent doors have been used in both surveys. Adjustments have been made to the 1963-1984 catch per tow data to standardize these data to polyvalent door equivalents. Conversion coefficients of 1.56 (numbers) and 1.62 (weight) were used in this standardization (NEFSC 1991).

[b] Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments have been made to the catch per tow data for these differences.

[c] In the Gulf of Maine, spring surveys during 1980-1982, 1989-1991 and 1994, and autumn surveys during 1977-1978, 1980, 1989-1991 and 1993 were accomplished with the R/V DELAWARE II; in all other years, the surveys were accomplished using the R/V ALBATROSS IV. Adjustments have been made to the R/V DELAWARE II catch per tow data to standardize these to R/V ALBTATROSS IV equivalents. Conversion coefficients 0.79 (number) and 0.67 (weight) were used in this standardization (NEFSC 1991).

Table F6. Final VPA Results for Gulf of Maine Cod, 1982-2002.

STOCK NUMBERS (Jan 1) in thousands -

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|
| 1 | 7769 | 7539 | 10464 | 7004 | 10161 | 12538 | 25198 |
| 2 | 10891 | 6281 | 6160 | 8545 | 5690 | 8296 | 10228 |
| 3 | 5359 | 7112 | 3933 | 4307 | 6101 | 4471 | 5971 |
| 4 | 3026 | 2262 | 3202 | 1797 | 1616 | 2507 | 2377 |
| 5 | 1796 | 1223 | 780 | 1142 | 456 | 483 | 673 |
| 6 | 170 | 822 | 382 | 214 | 333 | 125 | 97 |
| 7 | 541 | 305 | 260 | 216 | 315 | 150 | 63 |
| 1+ | 29552 | 25543 | 25180 | 23227 | 24674 | 28569 | 44607 |

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| 1 | 4302 | 4021 | 6994 | 6419 | 9373 | 3383 | 3457 |
| 2 | 20625 | 3518 | 3286 | 5721 | 5255 | 7673 | 2769 |
| 3 | 7903 | 16407 | 2614 | 2286 | 4368 | 4165 | 6231 |
| 4 | 2953 | 4404 | 9637 | 920 | 1328 | 1768 | 2161 |
| 5 | 907 | 881 | 1459 | 3413 | 277 | 376 | 336 |
| 6 | 158 | 303 | 280 | 338 | 818 | 100 | 22 |
| 7 | 104 | 188 | 155 | 132 | 65 | 116 | 53 |
| 1+ | 36952 | 29721 | 24423 | 19228 | 21485 | 17581 | 15030 |

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|
| 1 | 3377 | 5055 | 5183 | 10078 | 4564 | 566 | 00 |
| 2 | 2830 | 2765 | 4138 | 4243 | 8250 | 3737 | 463 |
| 3 | 2014 | 2239 | 2208 | 3289 | 3467 | 6667 | 3009 |
| 4 | 4059 | 1027 | 1386 | 1369 | 2183 | 2399 | 4554 |
| 5 | 572 | 1565 | 419 | 578 | 609 | 942 | 1362 |
| 6 | 91 | 135 | 473 | 180 | 231 | 308 | 437 |
| 7 | 19 | 15 | 24 | 237 | 60 | 255 | 289 |
| 1+ | 12962 | 12800 | 13832 | 19974 | 19364 | 14874 | 10113 |

FISHING MORTALITY -

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| 2 | 0.23 | 0.27 | 0.16 | 0.14 | 0.04 | 0.13 | 0.06 |
| 3 | 0.66 | 0.60 | 0.58 | 0.78 | 0.69 | 0.43 | 0.50 |
| 4 | 0.71 | 0.86 | 0.83 | 1.17 | 1.01 | 1.12 | 0.76 |
| 5 | 0.58 | 0.96 | 1.09 | 1.03 | 1.10 | 1.41 | 1.25 |
| 6 | 0.67 | 0.92 | 0.90 | 1.16 | 1.06 | 1.20 | 0.87 |
| 7 | 0.67 | 0.92 | 0.90 | 1.16 | 1.06 | 1.20 | 0.87 |
| 4-5,u | 0.64 | 0.91 | 0.96 | 1.10 | 1.05 | 1.26 | 1.01 |

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.03 | 0.10 | 0.16 | 0.07 | 0.03 | 0.01 | 0.12 |
| 3 | 0.38 | 0.33 | 0.84 | 0.34 | 0.70 | 0.46 | 0.23 |
| 4 | 1.01 | 0.91 | 0.84 | 1.00 | 1.06 | 1.46 | 1.13 |
| 5 | 0.89 | 0.95 | 1.26 | 1.23 | 0.82 | 2.62 | 1.11 |
| 6 | 1.01 | 0.94 | 0.91 | 1.22 | 1.05 | 1.70 | 1.17 |
| 7 | 1.01 | 0.94 | 0.91 | 1.22 | 1.05 | 1.70 | 1.17 |
| 4-5,u | 0.95 | 0.93 | 1.05 | 1.11 | 0.94 | 2.04 | 1.12 |

Table F6 (Continued).

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.03 | 0.02 | 0.03 | 0.00 | 0.01 | 0.02 |
| 3 | 0.47 | 0.28 | 0.28 | 0.21 | 0.17 | 0.18 |
| 4 | 0.75 | 0.70 | 0.68 | 0.61 | 0.64 | 0.37 |
| 5 | 1.24 | 1.00 | 0.64 | 0.71 | 0.48 | 0.57 |
| 6 | 0.82 | 0.89 | 0.68 | 0.65 | 0.61 | 0.47 |
| 7 | 0.82 | 0.89 | 0.68 | 0.65 | 0.61 | 0.47 |
| 4-5,u | 1.00 | 0.85 | 0.66 | 0.66 | 0.56 | 0.47 |

Jan 1 BIOMASS (using Jan 1 mean weights)

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|
| 1 | 3224 | 2111 | 3662 | 1541 | 2784 | 2257 | 1588 |
| 2 | 9606 | 4880 | 4053 | 6093 | 3488 | 5426 | 5717 |
| 3 | 6871 | 9367 | 5164 | 5509 | 8255 | 5615 | 7966 |
| 4 | 6869 | 4455 | 6674 | 3819 | 3495 | 5937 | 4552 |
| 5 | 7542 | 3880 | 2328 | 3935 | 1624 | 1785 | 2676 |
| 6 | 948 | 4381 | 1782 | 956 | 1715 | 701 | 528 |
| 7 | 6122 | 3030 | 2678 | 2097 | 3690 | 1543 | 678 |
| 1+ | 41181 | 32104 | 26341 | 23950 | 25051 | 23263 | 23705 |

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| 1 | 1983 | 205 | 399 | 1630 | 8014 | 717 | 726 |
| 2 | 9178 | 2747 | 1324 | 2929 | 3616 | 8978 | 2279 |
| 3 | 10290 | 22969 | 3247 | 3369 | 7303 | 6044 | 9913 |
| 4 | 6705 | 8716 | 19466 | 1868 | 2859 | 4197 | 4816 |
| 5 | 2741 | 3089 | 4420 | 9375 | 941 | 1065 | 1330 |
| 6 | 734 | 1636 | 1541 | 1517 | 3530 | 508 | 109 |
| 7 | 1238 | 2544 | 1720 | 1396 | 714 | 1141 | 714 |
| 1+ | 32869 | 41906 | 32116 | 22085 | 26976 | 22649 | 19887 |

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|
| 1 | 696 | 1183 | 1254 | 1522 | 1114 | 138 |
| 2 | 2352 | 2345 | 3091 | 3068 | 6006 | 2679 |
| 3 | 3708 | 4270 | 4207 | 5157 | 5845 | 11261 |
| 4 | 8439 | 2558 | 3526 | 3314 | 5390 | 5939 |
| 5 | 1769 | 4238 | 1467 | 2005 | 2102 | 3467 |
| 6 | 556 | 546 | 1701 | 877 | 1129 | 1565 |
| 7 | 212 | 131 | 241 | 1827 | 435 | 2066 |
| 1+ | 17731 | 15272 | 15487 | 17768 | 22021 | 27114 |

Table F6 (Continued).

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT) (using SSB mean weights)

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|
| 1 | 218 | 143 | 248 | 60 | 108 | 87 | 61 |
| 2 | 2326 | 1174 | 993 | 2765 | 1608 | 2465 | 2629 |
| 3 | 3630 | 5002 | 2764 | 4445 | 6762 | 4801 | 6729 |
| 4 | 5197 | 3283 | 4945 | 3039 | 2857 | 4768 | 3877 |
| 5 | 6421 | 3100 | 1821 | 3204 | 1308 | 1365 | 2102 |
| 6 | 820 | 3633 | 1483 | 763 | 1390 | 554 | 442 |
| 7 | 5296 | 2513 | 2229 | 1672 | 2991 | 1221 | 567 |
| 1+ | 23908 | 18848 | 14484 | 15947 | 17024 | 15262 | 16406 |

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| 1 | 77 | 22 | 42 | 173 | 853 | 28 | 28 |
| 2 | 4241 | 732 | 349 | 784 | 974 | 3295 | 821 |
| 3 | 8868 | 11771 | 1528 | 1724 | 3517 | 4822 | 8214 |
| 4 | 5481 | 5872 | 13262 | 1239 | 1876 | 3151 | 3820 |
| 5 | 2284 | 2372 | 3221 | 6871 | 739 | 666 | 1069 |
| 6 | 599 | 1327 | 1255 | 1173 | 2809 | 370 | 87 |
| 7 | 1012 | 2104 | 1430 | 1101 | 580 | 831 | 568 |
| 1+ | 22561 | 24200 | 21088 | 13065 | 11347 | 13163 | 14608 |

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|
| 1 | 27 | 46 | 49 | 59 | 43 | 05 |
| 2 | 859 | 858 | 1131 | 1127 | 2203 | 982 |
| 3 | 2950 | 3509 | 3458 | 4286 | 4892 | 9405 |
| 4 | 7127 | 2181 | 3016 | 2866 | 4639 | 5350 |
| 5 | 1391 | 3471 | 1274 | 1721 | 1875 | 3049 |
| 6 | 469 | 455 | 1469 | 761 | 986 | 1400 |
| 7 | 179 | 109 | 208 | 1585 | 380 | 1848 |
| 1+ | 13001 | 10630 | 10604 | 12405 | 15019 | 22040 |

Table F7a. Starting conditions and input data for short-term (2002-2004) stochastic stock biomass and catch projections for Gulf of Maine cod.

Input for Projections:

Number of Years: 3; Initial Year: 2002; Final Year: 2004
Number of Ages : 7; Age at Recruitment: 1; Last Age: 7
Natural Mortality is assumed Constant over time at: .200
Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Last age is a PLUS group;

Age-specific Input data for Projection # 1

| Age | Fish Mort Pattern | Nat Mort Pattern | Proportion Mature | Average Weights Catch | Average Weights Stock |
|---|---|---|---|---|---|
| 1 | .0010 | 1.0000 | .0400 | 0.441 | 0.283 |
| 2 | .0134 | 1.0000 | .3800 | 1.229 | 0.725 |
| 3 | .2867 | 1.0000 | .8900 | 1.782 | 1.466 |
| 4 | 1.0000 | 1.0000 | .9900 | 2.694 | 2.180 |
| 5 | 1.0000 | 1.0000 | 1.0000 | 4.089 | 3.343 |
| 6 | 1.0000 | 1.0000 | 1.0000 | 6.031 | 4.960 |
| 7+ | 1.0000 | 1.0000 | 1.0000 | 10.881 | 10.881 |

Table F7b. Results of short-term stochastic stock biomass and catch projections for Gulf of Maine cod.

Projections for 2002-2004;

F2002=0.40 Basis: 85% of Status quo 2001 point estimate.

Recruitment (age 1) 2002 and 2003 year classes derived from Beverton-Holts spawning stock-recruitment relationship based on 1981-1999 year classes.

SSB was estimated to be 22,000 mt in 2001.

| 2002 | | | 2003 | | | 2004 | |
|---|---|---|---|---|---|---|---|
| F | Catch | SSB | F | Catch | SSB | Catch | SSB |
| 0.40 | 7786 | 23616 | $F_{rebuild}$ =0.114 | 2479 | 22831 | 2916 | 31544 |

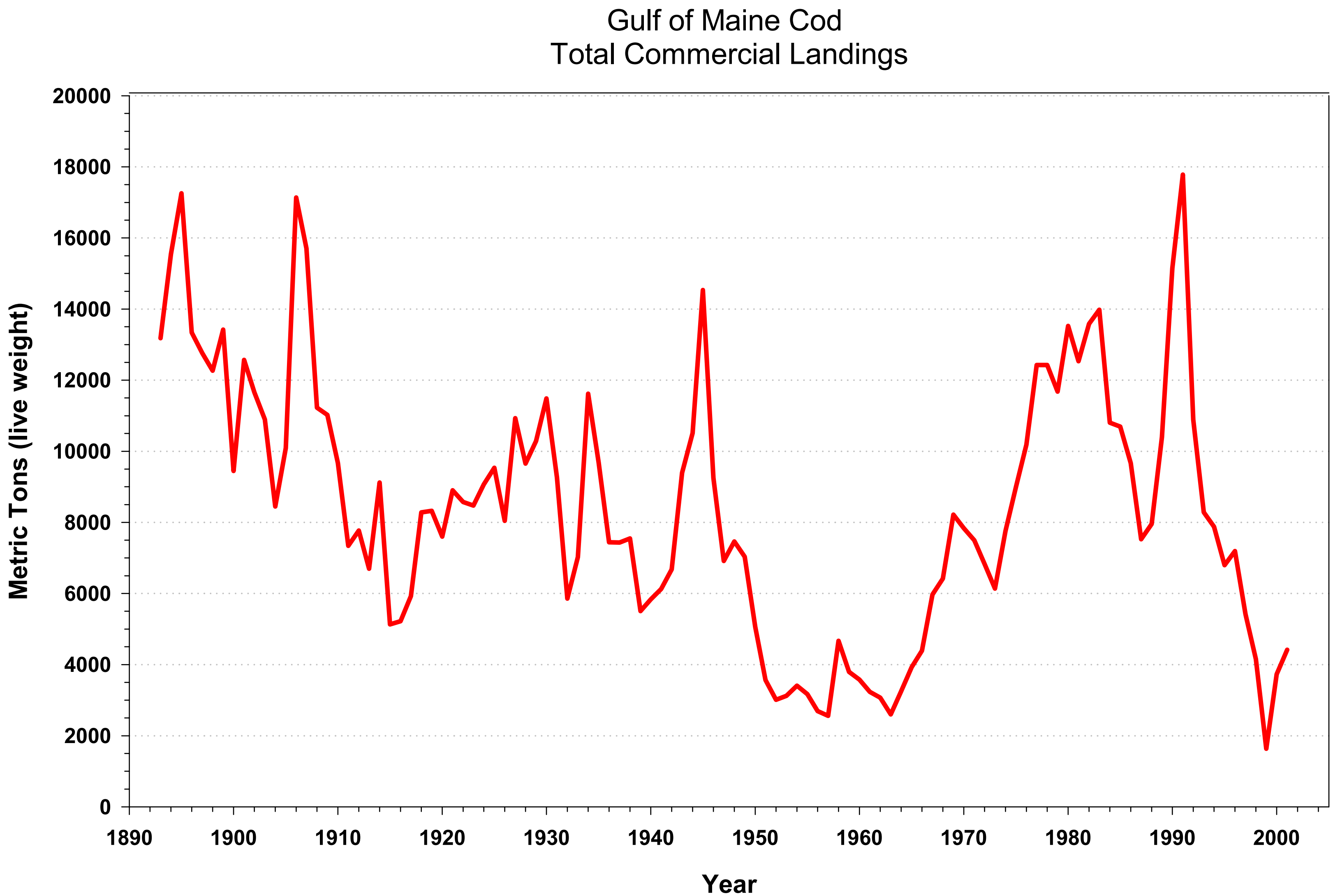



**Figure F1. Total commercial landings of Gulf of Maine cod (NAFO Div. 5Y), 1893-2001.**

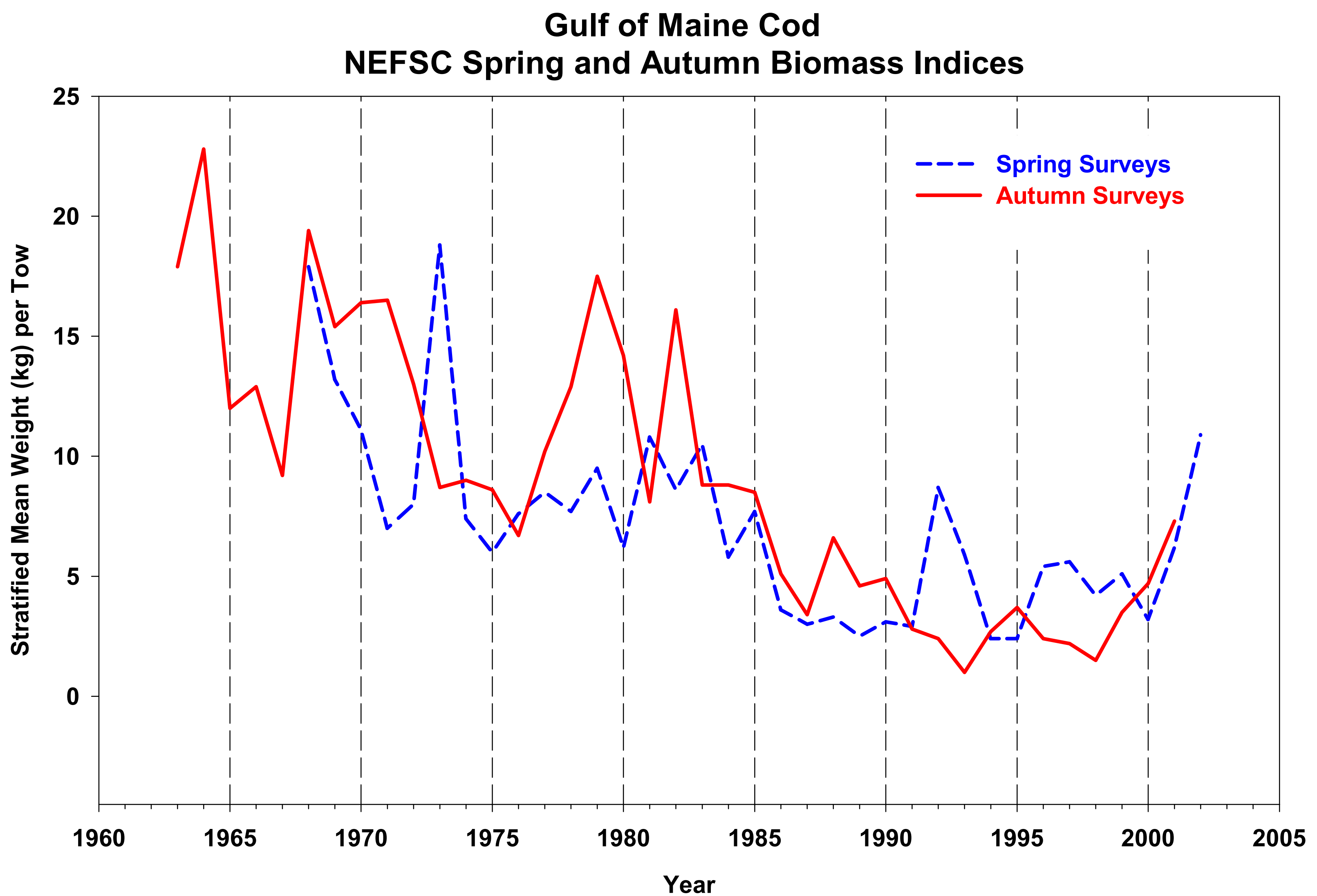



**Figure F2. Biomass indices (stratified mean weight per tow) for Gulf of Maine cod from NEFSC autumn bottom trawl surveys.**

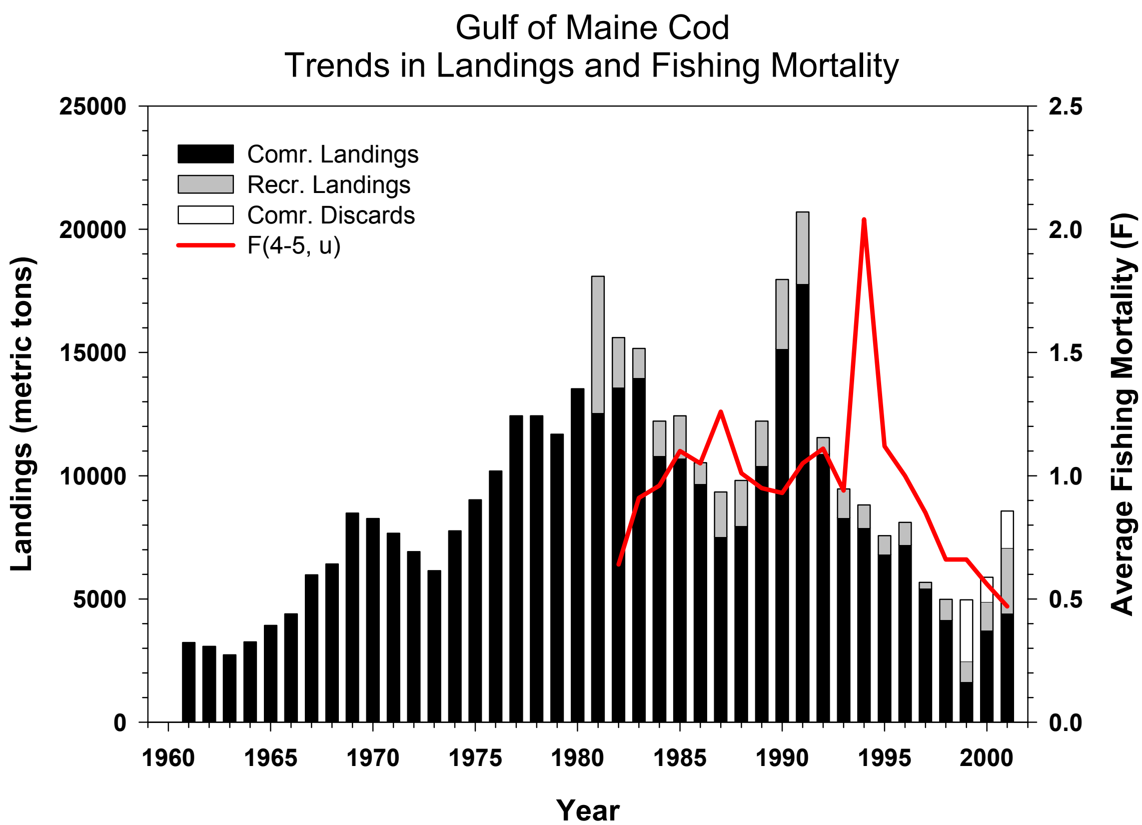



**Figure F3. Trends in landings and fishing mortality for Gulf of Maine cod.**

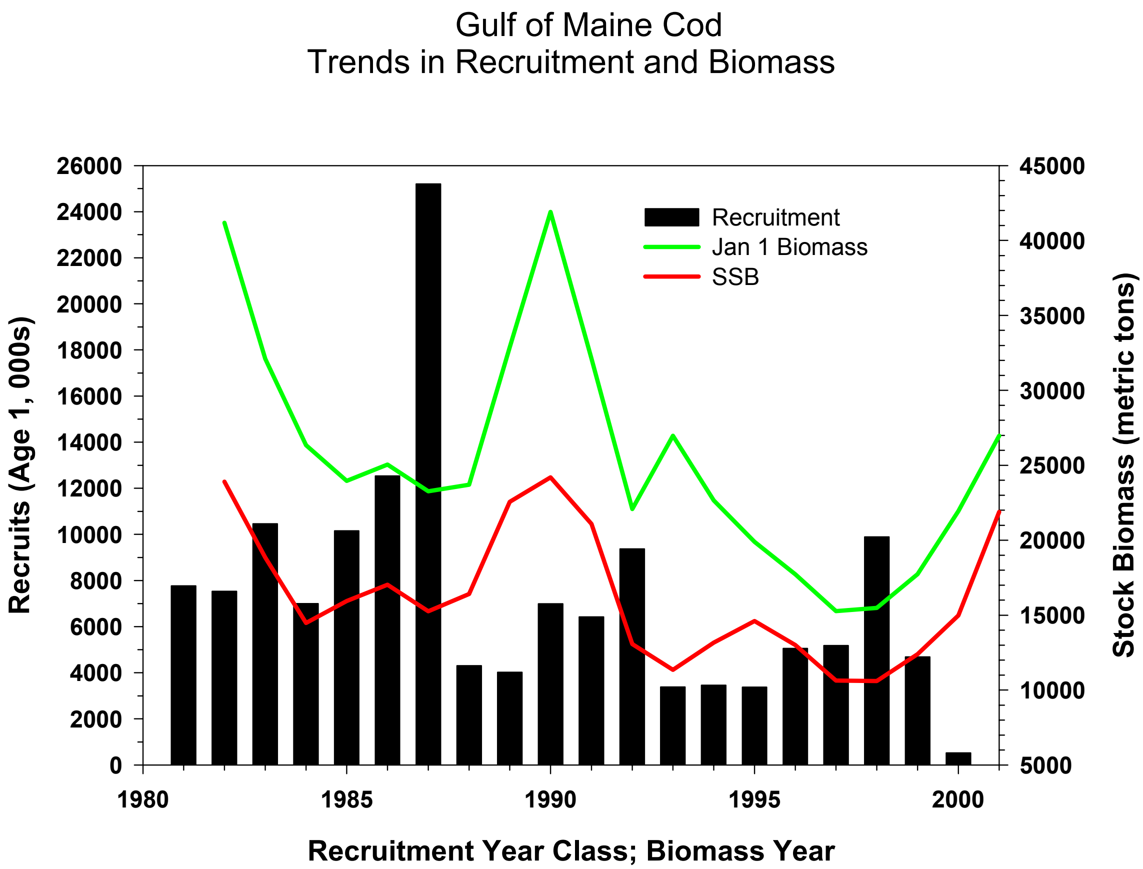
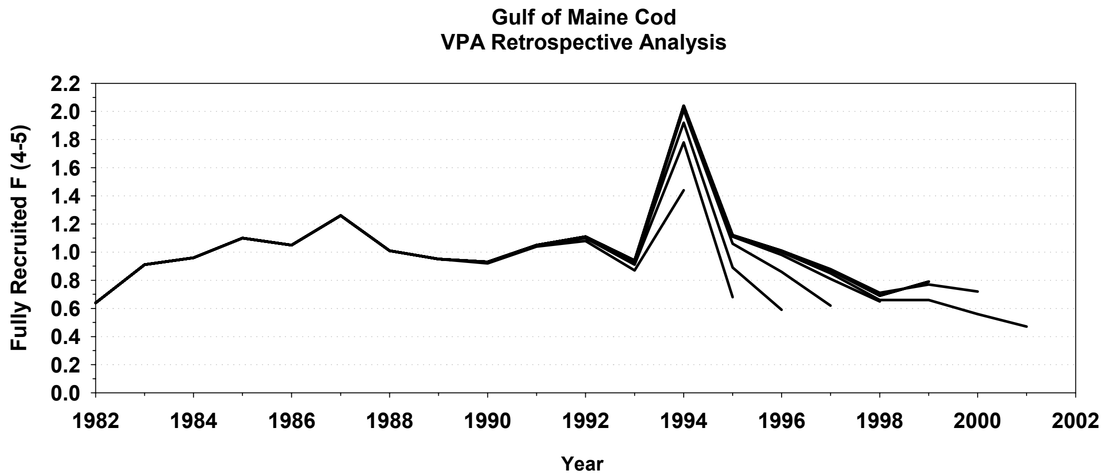
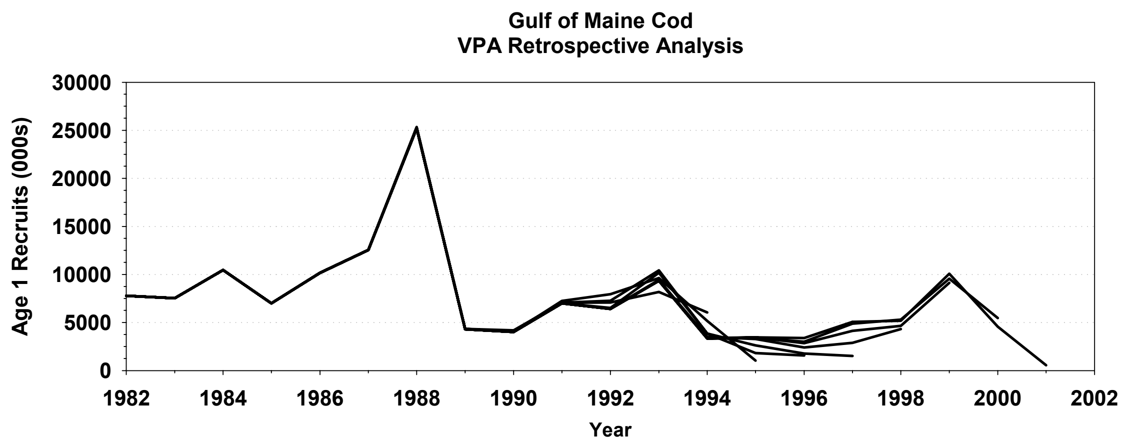



**Figure F4. Trends in recruitment (age 1) and biomass for Gulf of Maine cod.**



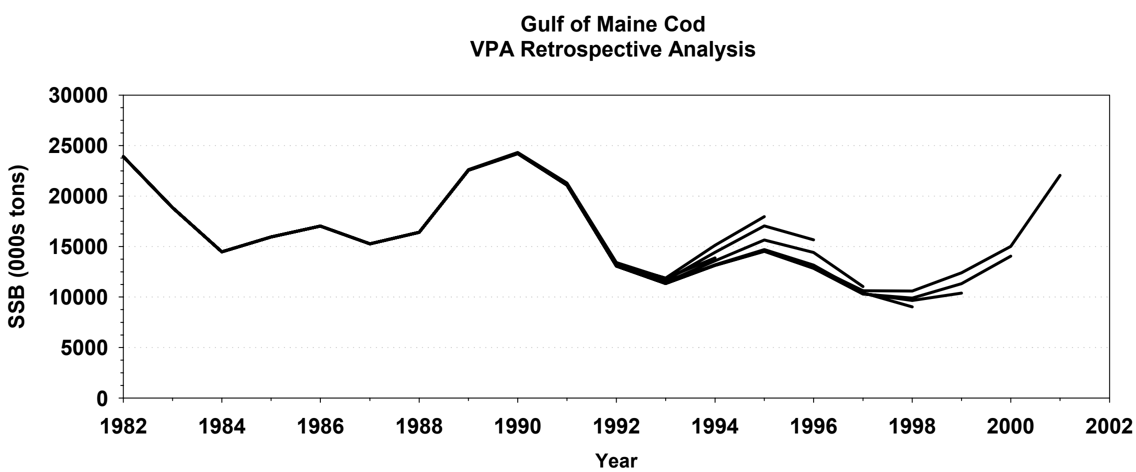




**Figure F5. Retrospective analysis of estimates of terminal year F, recruitment and SSB from the VPA for Gulf of Maine Cod.**

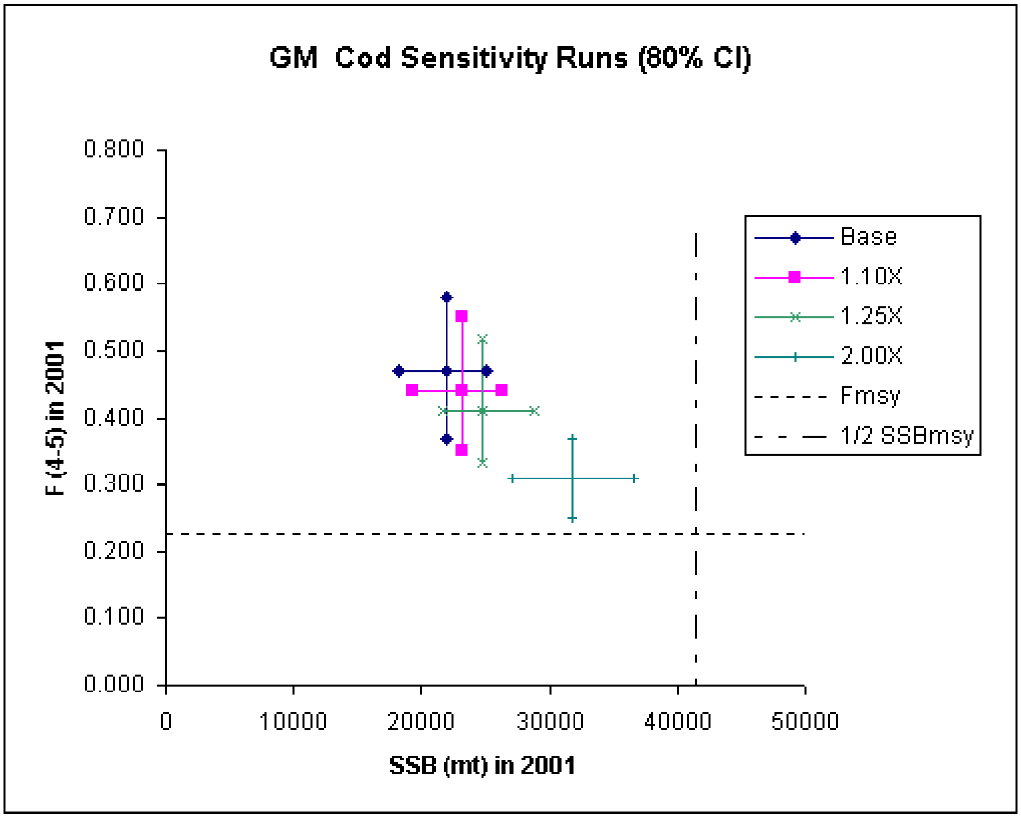
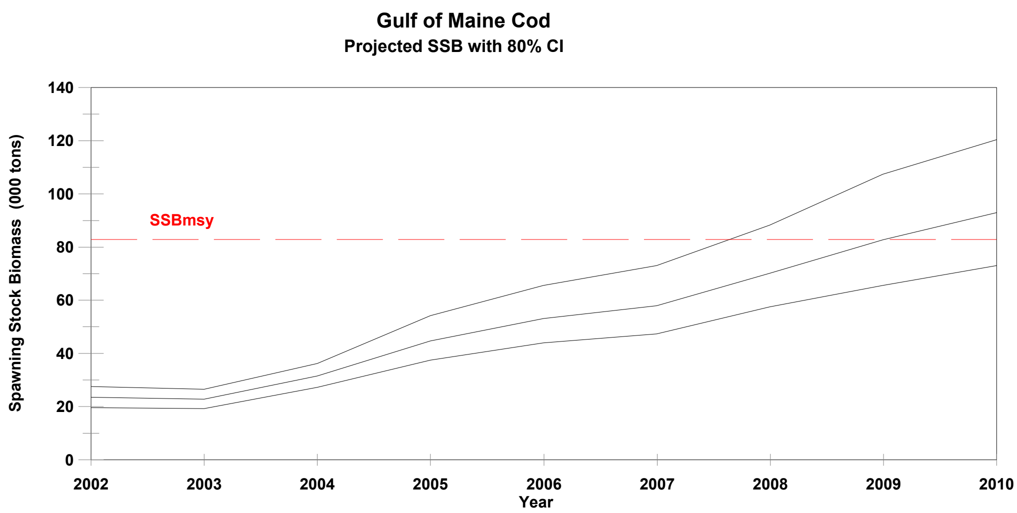
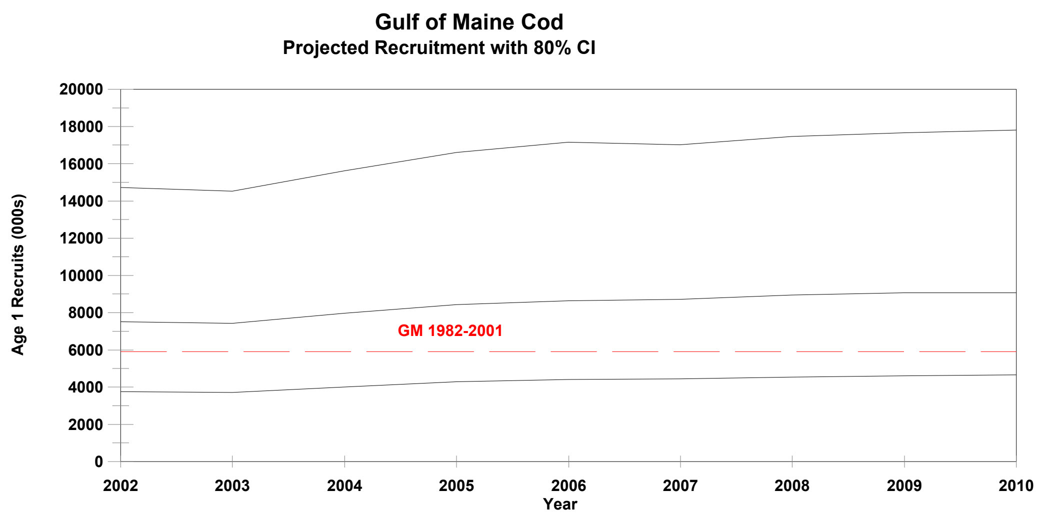



Figure F6. Sensitivity of VPA estimates of F and SSB in 2001 to presumed differences in survey catchability during 2000-2002 based on 1000 bootstrap replications (median and 80% CI) of the base VPA.



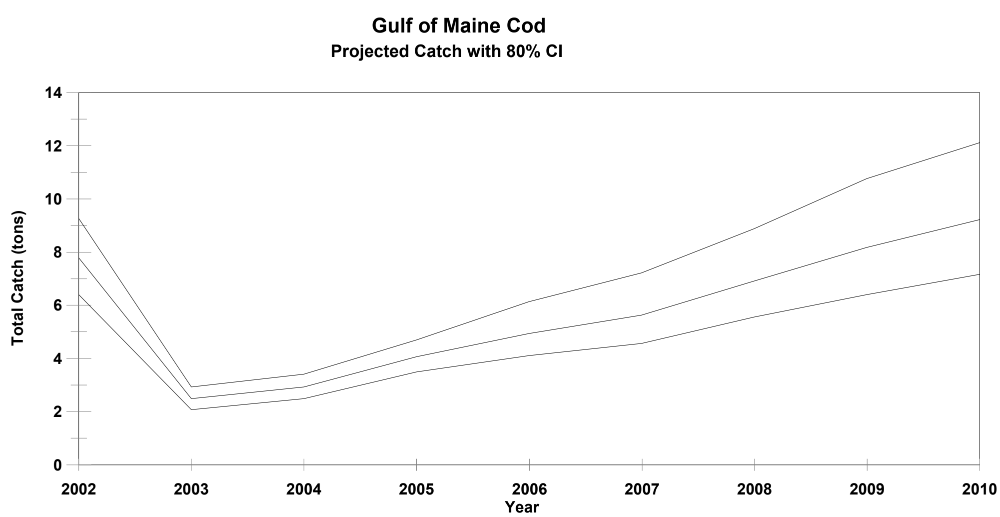




**Figure F7. Projected SSB, recruitment and catch for Gulf of Maine cod. $F_{rebuild}$=0.115.**

**G. Witch Flounder** by S. E. Wigley

## 1.0 Background

Witch flounder, *Glyptocephalus cynoglossus*, are assessed as a unit stock from the Gulf of Maine southward. An analytical assessment was last conducted for this species in 1999 (Wigley et al.1999) and reviewed at SAW 29 (NEFSC 1999). The SAW 29 assessment indicated average fishing mortality (ages 7-9, unweighted) increased from 0.21 in 1982 to 0.59 in 1985, declined to 0.24 in 1990, increased to 0.86 in 1996, then declined to 0.37 in 1998. Mean 3+ biomass declined steadily from 27,930 mt in 1982 to 7,742 mt in 1994, then sharply increased to 18,934 mt by 1998. Spawning stock biomass declined from 18,000 tons in 1982 to about 4,000 tons in 1993 and then increased sharply to 8,600 mt in 1998. Since 1982, recruitment at age 3 has ranged from approximately 3 million fish (1984 year class) to 38 million fish (1996 year class) with a mean of 14 million fish.

This report updates catch in 1999-2001, survey indices through spring 2002, estimates 2001 fishing mortality and 2002 spawning stock biomass, and provides projections of median landings and spawning stock biomass for two fishing mortality scenarios. Sensitivity analyses of assessment results were conducted to evaluate the impact of mis-marked survey trawl wires and the selection of survey tuning indices.

## 2.0 2002 Assessment

*The Fishery*

The U.S. nominal catch is taken from both the Georges Bank and Gulf of Maine regions. Canadian landings from both areas have been minor (not more than 68 mt annually). Landings for 1991-2000 averaged 2,200 mt annually but increased to over 3,000 mt in 2001 (Table G1 and Figure G1).

Sampling intensity of landings during 1999 and 2001 was comparable to that of the previous decade, i.e., an average of 43 samples annually. Sampling intensity in 2000 increased to 110 samples; however 100 of these were from the small market category (Table G2). As in previous years, it was necessary to pool some quarters for some market categories. To estimate landings at age and mean weights at age, quarter, semi-annual or annual age-length keys were applied to corresponding commercial landings length frequency data by market category. Landed weights-at-age in 1999-2001 continue to decline as observed in recent years (Table G2).

*Discard estimation*

Discards-at-age were updated using the same estimation methods used in the 1999 assessment. The estimation of large-mesh otter trawl discards is based upon a method which filters survey length frequency data through a commercial gear retention ogive and then through a culling ogive. A semi-annual ratio estimator of survey-filtered ‘kept’ index to semi-annual numbers landed was used to expand the estimated ‘discard’ survey index to numbers of fish discarded at length. Semi-annual numbers of fished discarded were apportioned to age using the corresponding seasonal NEFSC survey age/length key. Witch flounder discarded in the large mesh otter trawl fishery range in age from 0 to 6, with the majority at ages 4 to 5. Estimated numbers of fish discarded at sea in 2000-2001 comprised as much as 65% of witch flounder landed, similar to that estimated for 1996 (Figure G2).

Discards in the small mesh trawl fishery for northern shrimp during 1999-2001 were estimated from the relationship between age 3 fish in the autumn NEFSC survey and discard rate during 1993-1997. This method was used to estimate 1998 discards in the 1999 assessment due to lack of sea sampling in the shrimp fishery. For each year, the total discard weight was estimated by expanding the discard rates (mt/day fished) for 1998-2001 by the number of days fished estimated from the Vessel Trip Reports. Discarded numbers at age were derived by apportioning discard weight by the average age composition of discards in 1993-1997 and then dividing by the average 1993-1997 discard mean weights at age. Witch flounder discarded in the shrimp fishery range in age from 0 to 6, with the majority at ages 1-3. During 1999-2001, the number of fish discarded in the shrimp fishery averaged 8% of witch flounder landed (Figure G2).

The total catch at age is presented in Tables G3 and G4, and Figure G2 .

*Research Vessel Survey Indices*

NEFSC bottom trawl survey indices have increased since the late 1990's (Table G5, Figures G3a-b). Witch flounder abundance has reached near-record and record high levels in the spring and autumn surveys, respectively. The biomass indices have increased to levels observed in the mid-1980's. Survey age compositions are presented in Table G6. The survey mean weights and mean lengths at age show a similar decline as reported in the commercial landings. Survey maturity-at-age has decrease in 2000-2002.

**3.0 Assessment Results**

The VPA formulation is the same as the 1999 assessment and uses catch (landings plus discards) through 2001 and NEFSC spring and autumn survey indices through 2002 and 2001, respectively, to estimate stock sizes for ages 4 to 10. The VPA had a mean square residual of 0.76, the coefficients of variation (CVs) for estimated ages ranged between 32% and 45%, and the CVs for survey catchability coeffiecients (q) were consistent, ranging from 19% to 22%.

VPA results indicate average fishing mortality (ages 7-9, unweighted) increased from 0.21 in 1982 to 0.59 in 1985, declined to 0.24 in 1990, increased to 0.96 in 1996, then declined to 0.37 in 1999, and increased to 0.45 in 2001 (Table G7, Figure G4). Spawning stock biomass declined steadily from 18,000 mt in 1982 to 4,000 mt in 1995, and has increased to 11,300 mt in 2001 (Table G7, Figure G5). Since 1982, recruitment at age 3 has ranged from approximately 3 million fish (1984 year class) to 84 million fish (1997 year class) with a mean of 22 million fish (median of 14 million; Table G7, Figure G5). The addition of the 1995 to 1999 year classes to the stock-recruit data continued the negative trend observed in this relationship in the previous assessment.

The retrospective analysis indicates that average F was overestimated in the early to mid-1990's and underestimated in the late 1990s, but the 2000 F estimate was initially overestimated (Figure G6a). Spawning stock biomass was consistently overestimated since 1994 (Figure G6b). The retrospective analysis indicated a pattern of relatively consistent estimates of the number of age 3 recruits, with the notable exception of the 1992, 1993 and 1996 year classes, which were overestimated (Figure G6c).

Bootstrap results suggest that the estimates of F and spawning stock biomass are relatively precise with CVs of 19% and 13%, respectively. The 80% confidence interval for $F_{2001}$=0.45 was 0.38 and 0.59, and for $SSB_{2001}$ = 11,300 mt the 80% confidence interval was 9,784 mt and 13,584 mt (Figure G7).

*Biological Reference Points*

Based on yield and spawning stock biomass per recruit analyses and the arithmetic mean of the VPA age 3 recruitment (NEFSC 2002):

SSBmsy = 19,900 mt
Fmsy = F40% = 0.164
MSY = 2,990 mt.

In 2001, spawning stock biomass was slightly above ½ SSBmsy (9,950 mt), the overfished threshold, and fishing mortality (F = 0.45) was three times higher than Fmsy, the overfishing threshold; therefore, witch flounder was not overfished but overfishing was occurring in 2001 (Figure G7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

*Sensitivity Analyses*

NEFSC survey tuning indices from spring 2000-2002 and autumn 2000-2001 are arbitrarily adjusted by 1.1, 1.25, and 2.0 to evaluate the sensitivity of the VPA results to the potential gear effect of the differences in survey trawl wires during these years (Figure G7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

**4.0 Projections**

Since the stock is currently above the $SSB_{MSY}$ target, age-structured projections used Fmsy = F40% fishing mortality rate to evaluate the trajectories of spawning biomass and catch. The projection analyses used stock and landings mean weights at age and selectivity pattern from 1998-2001, the maturity at age from 2000-2002, and recruitment re-sampled from the cumulative distribution function based on the VPA age 3 recruitment from 1982 - 1998 year classes. Initial stock sizes in 2002 were derived from 1000 bootstrap iterations of the VPA. Fishing mortality in 2002 was set to fishing mortality in 2001 with a 15% reduction (e.g. $F_{2002} = F_{2001} * 0.85$). The fishing mortality in 2003 - 2009 was set to Fmsy = F40% = 0.164.

The median catch (median landings + median discards) in 2003 is projected to be 4,370 mt and 6,260 mt in 2004. The median SSB in 2003 is projected to be 25,410 mt and 34,700 mt in 2004 (Table G8) The projected median catch and SSB in 2009 under Fmsy are 5,764 mt and 36,807 mt, respectively (Figure G8).

**5.0 Panel Comments**

The GARM noted the block of positive residuals in the younger ages beginning in 1991, and suggested that the survey tuning series for the younger ages could be split into two series. The GARM noted that the SSB will reach SSBmsy within a year, yet current SSB is barely above ½ SSBmsy. A yield per recruit analysis with current mean weights, maturity ogive and partial recruitment was compared with the yield per recruit analysis used to estimate biological reference points. The results of this comparison indicated that the increase in mean recruitment was a contributing factor. The mean recruitment used to calculate the biological reference points was 12.42 million fish using the 1982 to 1994 year classes. However, with the assessment update, four additional year classes are estimated. The mean recruitment increases to 22.1 million fish (median 14.5 million) when the 1982-1998 year classes are used. The GARM pointed out that the recent above-average year classes may be poorly determined, and based on the retrospective pattern for recruitment, these year classes may be overestimated. The Panel concluded that the biological reference points are appropriate; however, the projections of SSB may be overly optimistic because future assessment updates may reveal that these year class are not as strong as they appear at this time.

## 6.0 Sources of Uncertainty

- Low frequency of samples across market category and quarter results in imprecise mean weights at age and estimates of numbers at age.
- Confounding of survey-based estimates of discards and use of same survey as tuning indices for VPA calibration may be a problem.
- Lack of data to support direct estimates of discards at age requires use of various surrogate survey-based methods.
- Retrospective patterns suggest that estimates of 2002 SSB may be overestimated (e.g. updated assessments may have lower estimated 2002 SSB).

## 7.0 Research recommendations for witch flounder

- Explore alternative VPA analyses with the survey tuning indices split into two series for the younger age groups.

## 8.0 References


Lange, A.M.T. and F.E. Lux. 1978. Review of the other flounder stocks (winter flounder, American plaice, witch flounder, and windowpane flounder) off the northeast United States. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 78-44, 53 pp.

Northern Demersal Working Group, Northeast Regional Stock Assessment Workshop. 2000. Assessment of 1 Northeast groundfish stocks through 1999: Report to the New England Fishery Management Council's Multispecies Monitoring Committee. Northeast Fish. Sci. Cent. Ref. Doc. 00-05; 175 p.

Northeast Fisheries Science Center. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. February 2002.

Northeast Fisheries Science Center. 1999. Report of the 29th Northeast Regional Stock Assessment Workshop (29th SAW), Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 99-14, 347 p.

Wigley, S.E., J. K.T. Brodziak, and S.X. Cadrin. 1999. Assessment of the witch flounder stock in Subareas 5 and 6 for 1999. Northeast Fish. Sci. Cent. Ref. Doc. 99-16, 153 p.

Table G1. Witch flounder landings, discards and catch (mt, live) from Subareas 5 and 6 1960-2001.

| | Landings | | | | | |
|---|---|---|---|---|---|---|
| Year | Canada | USA [2] | Other[1] | Total | Discard | Total USA Catch (used in VPA) |
| 1960 | - | 1255 | - | 1255 | | |
| 1961 | 2 | 1022 | - | 1024 | | |
| 1962 | 1 | 976 | - | 977 | | |
| 1963 | 27 | 1226 | 121 | 1374 | | |
| 1964 | 37 | 1381 | - | 1418 | | |
| 1965 | 22 | 2140 | 502 | 2664 | | |
| 1966 | 68 | 2935 | 311 | 3314 | | |
| 1967 | 63 | 3370 | 249 | 3682 | | |
| 1968 | 56 | 2807 | 191 | 3054 | | |
| 1969 | - | 2542 | 1310 | 3852 | | |
| 1970 | 19 | 3112 | 130 | 3261 | | |
| 1971 | 35 | 3220 | 2860 | 6115 | | |
| 1972 | 13 | 2934 | 2568 | 5515 | | |
| 1973 | 10 | 2523 | 629 | 3162 | | |
| 1974 | 9 | 1839 | 292 | 2140 | | |
| 1975 | 13 | 2127 | 217 | 2357 | | |
| 1976 | 5 | 1871 | 6 | 1882 | | |
| 1977 | 11 | 2469 | 13 | 2493 | | |
| 1978 | 18 | 3501 | 6 | 3525 | | |
| 1979 | 17 | 2878 | - | 2895 | | |
| 1980 | 18 | 3128 | 1 | 3147 | | |
| 1981 | 7 | 3422 | - | 3449 | | |
| 1982 | 9 | 4906 | - | 4915 | 48 | 4953 |
| 1983 | 45 | 6000 | - | 6045 | 162 | 6162 |
| 1984 | 15 | 6660 | - | 6675 | 100 | 6760 |
| 1985 | 46 | 6130 | - | 6431 | 61 | 6191 |
| 1986 | 67 | 4610 | - | 5216 | 25 | 4635 |
| 1987 | 23 | 3450 | - | 3819 | 47 | 3497 |
| 1988 | 45 | 3262 | - | 3665 | 60 | 3322 |
| 1989 | 13 | 2074 | - | 2384 | 133 | 2207 |
| 1990 | 12 | 1478 | - | 1492 | 184 | 1662 |
| 1991 | 7 | 1798 | - | 1805 | 95 | 1893 |
| 1992 | 7 | 2246 | - | 2253 | 171 | 2417 |
| 1993 | 10 | 2605 | - | 2615 | 376 | 2981 |
| 1994 | 34 | 2670 | - | 2704 | 422 | 3092 |
| 1995 | 11 | 2212 | - | 2223 | 265 | 2477 |
| 1996 | 10 | 2088 | - | 2098 | 454 | 2542 |
| 1997 | 7 | 1775 | - | 1782 | 393 | 2168 |
| 1998 | 10 | 1849 | - | 1859 | 335 | 2184 |
| 1999 | 19 | 2121 | - | 2140 | 354 | 2475 |
| 2000 | 53 | 2439 | - | 2492 | 547 | 2986 |
| 2001 | 32 | 3024 | - | 3047 | 705 | 3729 |

[1] Includes West Germany, East Germany, Poland, Spain, Japan, & the former USSR.
[2] excluding landings from Grand Banks (subarea 3).

Table G2. Summary of USA commercial witch flounder landings (mt), number of length samples(n), number of fish measured (len)and number of age samples (age) by market category and quarter for all gear types, 1981 - 2001. The sampling ratio represents the amount of landings per length sample.

| Year | | Quarter 1 Small | Quarter 1 Med. | Quarter 1 Large | Quarter 2 Small | Quarter 2 Med. | Quarter 2 Large | Quarter 3 Small | Quarter 3 Med. | Quarter 3 Large | Quarter 4 Small | Quarter 4 Med. | Quarter 4 Large | All | Sampling Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | mt | 260 | 7 | 517 | 269 | 32 | 694 | 242 | 13 | 607 | 230 | 0 | 453 | 3324 | |
| | n | . | . | . | . | 1 | 1 | . | 1 | . | 1 | . | 1 | 5 | |
| | len | . | . | . | . | 101 | 103 | . | 89 | . | 105 | . | 100 | 498 | |
| | age | . | . | . | . | . | 26 | . | 25 | . | 25 | . | 25 | 101 | |
| 1982 | mt | 348 | 1 | 726 | 342 | 73 | 886 | 287 | 170 | 739 | 278 | 201 | 669 | 4720 | |
| | n | 5 | 2 | 6 | 1 | 2 | 2 | 2 | 2 | 6 | 3 | 4 | 2 | 37 | 128 |
| | len | 527 | 194 | 626 | 126 | 209 | 216 | 189 | 210 | 514 | 307 | 393 | 189 | 3700 | |
| | age | 128 | 55 | 150 | 30 | 55 | 50 | 50 | 50 | 150 | 81 | 105 | 50 | 954 | |
| 1983 | mt | 475 | 250 | 910 | 471 | 286 | 1037 | 298 | 154 | 758 | 257 | 169 | 613 | 5678 | |
| | n | 5 | 2 | 3 | 5 | 1 | 5 | 8 | 3 | 8 | 6 | 3 | . | 49 | 116 |
| | len | 680 | 232 | 265 | 685 | 96 | 520 | 1008 | 123 | 981 | 677 | 344 | . | 5611 | |
| | age | 135 | 30 | 55 | 131 | 16 | 125 | 152 | 0 | 159 | 180 | 75 | . | 1058 | |
| 1984 | mt | 462 | 322 | 1036 | 513 | 393 | 1000 | 403 | 248 | 653 | 429 | 286 | 586 | 6331 | |
| | n | 5 | 9 | 4 | 7 | 1 | 7 | 8 | 1 | 2 | 4 | 2 | 1 | 51 | 124 |
| | len | 804 | 1112 | 400 | 970 | 117 | 775 | 1045 | 106 | 191 | 615 | 243 | 91 | 6469 | |
| | age | 154 | 250 | 76 | 186 | 25 | 180 | 210 | 28 | 53 | 105 | 44 | 25 | 1336 | |
| 1985 | mt | 465 | 377 | 613 | 697 | 453 | 850 | 526 | 291 | 553 | 433 | 310 | 408 | 5976 | |
| | n | 12 | 1 | 2 | 5 | 4 | 7 | 7 | 7 | 6 | 8 | 2 | 4 | 65 | 92 |
| | len | 1530 | 105 | 229 | 657 | 426 | 698 | 795 | 800 | 684 | 824 | 264 | 349 | 7361 | |
| | age | 319 | 29 | 50 | 106 | 77 | 153 | 97 | 138 | 113 | 161 | 25 | 29 | 1297 | |
| 1986 | mt | 384 | 309 | 356 | 654 | 421 | 595 | 375 | 238 | 354 | 312 | 212 | 238 | 4448 | |
| | n | 6 | 3 | 5 | 5 | 4 | 5 | 4 | 3 | 4 | 5 | 3 | 2 | 49 | 90 |
| | len | 662 | 307 | 515 | 558 | 410 | 413 | 302 | 364 | 406 | 416 | 337 | 233 | 4923 | |
| | age | 123 | 60 | 89 | 106 | 97 | 129 | 63 | 75 | 100 | 87 | 75 | 52 | 1056 | |
| 1987 | mt | 349 | 211 | 228 | 432 | 317 | 387 | 296 | 203 | 247 | 298 | 203 | 202 | 3373 | |
| | n | 1 | 1 | 2 | 4 | 2 | 3 | 5 | 5 | 4 | 2 | 3 | 2 | 34 | 69 |
| | len | 85 | 145 | 200 | 323 | 228 | 316 | 354 | 583 | 400 | 204 | 261 | 178 | 3277 | |
| | age | 25 | 25 | 50 | 77 | 47 | 76 | 78 | 113 | 95 | 48 | 64 | 51 | 749 | |

Table G2 continued.

| Year | | Quarter 1 Small | Med. | Large | Quarter 2 Small | Med. | Large | Quarter 3 Small | Med. | Large | Quarter 4 Small | Med. | Large | All | Sampling Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | mt | 424 | 304 | 271 | 436 | 393 | 389 | 184 | 176 | 208 | 140 | 140 | 131 | 3196 | |
| | n | 5 | 4 | 5 | 5 | 5 | 3 | 5 | 4 | 3 | 3 | 4 | 3 | 49 | 65 |
| | len | 335 | 407 | 465 | 344 | 544 | 429 | 396 | 359 | 295 | 229 | 402 | 356 | 4561 | |
| | age | 70 | 89 | 106 | 71 | 110 | 77 | 70 | 100 | 75 | 61 | 95 | 69 | 993 | |
| 1989 | mt | 230 | 174 | 148 | 255 | 264 | 251 | 98 | 145 | 156 | 85 | 107 | 103 | 2016 | |
| | n | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | . | 18 | 112 |
| | len | 94 | 201 | 222 | 230 | 236 | 27 | 150 | 206 | 100 | 125 | 202 | . | 1793 | |
| | age | 25 | 50 | 49 | 50 | 46 | 25 | 40 | 51 | 25 | 25 | 47 | . | 433 | |
| 1990 | mt | 113 | 125 | 107 | 147 | 168 | 147 | 100 | 119 | 129 | 84 | 79 | 85 | 1403 | |
| | n | 1 | 2 | 3 | 6 | 3 | 1 | 6 | 2 | 2 | 7 | 2 | . | 35 | 40 |
| | len | 134 | 199 | 199 | 335 | 296 | 100 | 349 | 247 | 145 | 381 | 201 | . | 2586 | |
| | age | 15 | 40 | 45 | 81 | 70 | 25 | 69 | 41 | 50 | 103 | 48 | . | 587 | |
| 1991 | mt | 71 | 56 | 58 | 219 | 151 | 167 | 192 | 142 | 184 | 168 | 108 | 121 | 1637 | |
| | n | 5 | 2 | 3 | 7 | 2 | 1 | 4 | 2 | 3 | 5 | 4 | 3 | 41 | 40 |
| | len | 262 | 224 | 401 | 537 | 239 | 125 | 212 | 165 | 249 | 300 | 410 | 274 | 3398 | |
| | age | 53 | 50 | 80 | 93 | 45 | 25 | 49 | 49 | 52 | 66 | 97 | 58 | 717 | |
| 1992 | mt | 180 | 86 | 82 | 466 | 163 | 174 | 205 | 115 | 138 | 212 | 97 | 116 | 2034 | |
| | n | 4 | 2 | 2 | 7 | 1 | 2 | 7 | 1 | 1 | 2 | . | 1 | 30 | 68 |
| | len | 259 | 241 | 185 | 501 | 125 | 235 | 477 | 121 | 117 | 129 | . | 46 | 2436 | |
| | age | 42 | 46 | 52 | 78 | 25 | 25 | 86 | 25 | 25 | 27 | . | 23 | 454 | |
| 1993 | mt | 350 | 112 | 110 | 442 | 192 | 161 | 263 | 122 | 150 | 331 | 96 | 106 | 2435 | |
| | n | 7 | 1 | . | 7 | 1 | 1 | 9 | 1 | 5 | . | . | . | 32 | 76 |
| | len | 830 | 100 | . | 741 | 107 | 100 | 728 | 85 | 499 | . | . | . | 3190 | |
| | age | 55 | 25 | . | 56 | 27 | 26 | 74 | . | 73 | . | . | . | 336 | |
| 1994 | mt | 403 | 143 | 98 | 505 | 183 | 154 | 390 | 122 | 117 | 383 | 91 | 80 | 2670 | |
| | n | . | . | . | 3 | 5 | 6 | 5 | 5 | 1 | 5 | 3 | 4 | 37 | 72 |
| | len | . | . | . | 560 | 532 | 749 | 356 | 648 | 105 | 342 | 368 | 407 | 4067 | |
| | age | . | . | . | 59 | 104 | 134 | 44 | 113 | 26 | 56 | 60 | 82 | 678 | |

Table G2 continued.

| Year | | Quarter 1 Small | Quarter 1 Med. | Quarter 1 Large | Quarter 2 Small | Quarter 2 Med. | Quarter 2 Large | Quarter 3 Small | Quarter 3 Med. | Quarter 3 Large | Quarter 4 Small | Quarter 4 Med. | Quarter 4 Large | All | Sampling Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | mt | 336 | 91 | 77 | 586 | 117 | 100 | 399 | 61 | 70 | 304 | 48 | 40 | 2212 | |
| | n | 3 | 3 | 3 | 6 | 3 | 5 | . | . | . | 2 | . | 1 | 26 | 85 |
| | len | 208 | 348 | 347 | 459 | 367 | 517 | . | . | . | 217 | . | 94 | 2557 | |
| | age | 53 | 84 | 89 | 81 | 75 | 135 | . | . | . | 27 | . | 25 | 569 | |
| 1996 | mt | 313 | 57 | 36 | 545 | 86 | 60 | 458 | 56 | 44 | 363 | 42 | 28 | 2088 | |
| | n | 5 | 2 | 3 | 5 | 2 | 1 | 5 | 4 | 4 | 5 | 3 | 3 | 42 | 50 |
| | len | 504 | 218 | 292 | 331 | 240 | 127 | 494 | 464 | 468 | 343 | 277 | 348 | 4106 | |
| | age | 59 | 45 | 78 | 53 | 50 | 26 | 59 | 86 | 101 | 60 | 70 | 69 | 756 | |
| 1997 | mt | 313 | 40 | 25 | 478 | 86 | 41 | 398 | 55 | 27 | 265 | 31 | 16 | 1775 | |
| | n | 6 | 3 | 3 | 9 | 4 | 3 | 9 | 3 | 1 | 9 | 1 | 1 | 52 | 34 |
| | len | 557 | 350 | 351 | 812 | 418 | 309 | 783 | 308 | 107 | 505 | 128 | 50 | 4678 | |
| | age | 77 | 68 | 70 | 108 | 73 | 77 | 98 | 81 | 20 | 73 | 18 | 23 | 786 | |
| 1998 | mt | 372 | 39 | 19 | 587 | 79 | 31 | 380 | 40 | 20 | 239 | 26 | 14 | 1849 | 80 |
| | n | 5 | 2 | 1 | 4 | 1 | 1 | 5 | 3 | 1 | . | . | . | 23 | |
| | len | 339 | 206 | 128 | 238 | 88 | 135 | 484 | 186 | 100 | . | . | . | 1904 | |
| | age | 45 | 50 | 19 | 30 | . | 29 | 47 | 22 | . | . | . | . | 242 | |
| 1999 | mt | 386 | 48 | 19 | 616 | 79 | 31 | 436 | 67 | 30 | 353 | 38 | 18 | 2121 | 51 |
| | n | 3 | . | . | 4 | . | . | 17 | 2 | 3 | 11 | 1 | . | 41 | |
| | len | 282 | . | . | 308 | . | . | 1110 | 201 | 306 | 775 | 109 | . | 3091 | |
| | age | 15 | . | . | 62 | . | . | 143 | . | 32 | 91 | 16 | . | 359 | |
| 2000 | mt | 477 | 53 | 17 | 583 | 93 | 27 | 555 | 89 | 28 | 451 | 50 | 16 | 2439 | 21 |
| | n | 31 | 2 | . | 47 | . | . | 17 | 1 | . | 5 | 5 | 2 | 110 | |
| | len | 2253 | 91 | . | 2445 | . | . | 994 | 105 | . | 308 | 558 | 217 | 6971 | |
| | age | 390 | 10 | . | 460 | . | . | 224 | 20 | . | 67 | 92 | 51 | 1314 | |
| 2001 | mt | 584 | 71 | 17 | 828 | 99 | 30 | 699 | 98 | 28 | 507 | 50 | 13 | 3024 | 70 |
| | n | 8 | 4 | 2 | 3 | 3 | 2 | 8 | 2 | 3 | 5 | 3 | . | 43 | |
| | len | 744 | 422 | 134 | 237 | 352 | 159 | 594 | 209 | 213 | 313 | 232 | . | 3609 | |
| | age | 125 | 63 | 42 | 47 | 48 | 64 | 126 | 34 | 46 | 61 | 48 | . | 704 | |

Table G3. Numbers ('000) at age of witch flounder in the total catch, 1982-2001.

| | | | | | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ | TOTAL |
| Total Catch in Numbers (1000's) at Age | | | | | | | | | | | | | |
| 1982 | 0.03 | 0.06 | 1.72 | 190.49 | 1064.47 | 1207.67 | 1475.40 | 665.20 | 656.00 | 399.50 | 239.40 | 1578.40 | 7478.4 |
| 1983 | 0.00 | 0.02 | 4.28 | 337.11 | 1346.17 | 1520.76 | 1575.12 | 1590.20 | 977.80 | 737.70 | 510.40 | 1675.50 | 10275.1 |
| 1984 | 0.00 | 0.33 | 0.88 | 146.61 | 1466.31 | 2002.70 | 1739.59 | 1486.50 | 1497.50 | 696.70 | 375.10 | 1718.80 | 11131.0 |
| 1985 | 0.00 | 0.34 | 3.47 | 123.58 | 1176.12 | 2118.21 | 1936.24 | 1524.90 | 1247.90 | 606.00 | 400.40 | 1359.20 | 10496.4 |
| 1986 | 0.00 | 0.53 | 3.86 | 22.95 | 377.07 | 1516.79 | 2775.35 | 1566.90 | 834.90 | 412.70 | 222.80 | 758.20 | 8492.1 |
| 1987 | 2.08 | 18.92 | 79.93 | 22.25 | 181.26 | 467.06 | 1280.06 | 1574.70 | 870.90 | 480.60 | 252.40 | 489.40 | 5719.6 |
| 1988 | 0.42 | 14.66 | 130.29 | 600.27 | 139.91 | 264.30 | 658.27 | 1382.70 | 1154.10 | 401.50 | 266.70 | 597.50 | 5610.6 |
| 1989 | 0.85 | 10.69 | 50.32 | 447.05 | 436.26 | 65.27 | 315.20 | 761.60 | 884.70 | 350.70 | 123.80 | 349.00 | 3795.4 |
| 1990 | 1.46 | 6.29 | 95.30 | 343.93 | 635.77 | 1108.23 | 257.90 | 276.30 | 475.30 | 336.90 | 82.10 | 179.10 | 3798.6 |
| 1991 | 3.06 | 17.90 | 23.26 | 441.77 | 407.92 | 872.56 | 581.70 | 238.60 | 247.50 | 295.60 | 317.30 | 260.80 | 3708.0 |
| 1992 | 2.84 | 44.35 | 159.43 | 399.46 | 1259.95 | 866.37 | 943.97 | 723.10 | 203.40 | 179.40 | 121.10 | 380.20 | 5283.6 |
| 1993 | 113.76 | 85.80 | 129.59 | 417.23 | 1807.93 | 1420.56 | 919.56 | 598.10 | 586.50 | 219.10 | 279.00 | 391.10 | 6968.2 |
| 1994 | 8.06 | 1368.48 | 496.44 | 41.97 | 1002.18 | 2762.60 | 1290.40 | 828.40 | 197.06 | 540.16 | 113.70 | 324.90 | 8974.4 |
| 1995 | 2.68 | 49.96 | 635.31 | 641.30 | 617.50 | 1197.11 | 1722.49 | 849.85 | 267.81 | 97.35 | 269.86 | 157.06 | 6508.3 |
| 1996 | 5.21 | 32.68 | 51.06 | 119.38 | 952.15 | 1978.27 | 1322.45 | 1431.51 | 263.42 | 215.63 | 57.09 | 113.69 | 6542.5 |
| 1997 | 8.68 | 74.92 | 104.10 | 104.87 | 1022.81 | 1467.20 | 1386.54 | 1016.31 | 592.64 | 83.33 | 49.90 | 70.24 | 5981.5 |
| 1998 | 49.78 | 391.45 | 268.05 | 219.73 | 619.38 | 1284.18 | 1483.99 | 1583.87 | 370.71 | 141.42 | 15.54 | 70.34 | 6498.4 |
| 1999 | 32.11 | 252.53 | 173.52 | 243.71 | 1079.28 | 1482.74 | 1395.00 | 1178.30 | 763.15 | 251.27 | 31.57 | 54.36 | 6937.6 |
| 2000 | 21.61 | 169.95 | 118.24 | 148.73 | 1395.59 | 1722.99 | 1187.30 | 1611.14 | 1027.62 | 623.71 | 94.82 | 212.81 | 8334.5 |
| 2001 | 12.33 | 96.96 | 65.98 | 160.66 | 1352.04 | 2348.48 | 1344.47 | 1671.77 | 1461.88 | 635.35 | 426.14 | 307.17 | 9883.2 |

Table G4. Mean weight (kg) at age of witch flounder in the total catch, 1982-2001.

| | Age | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ | Total |
| | | | | | | Total Catch Mean Weight (kg) at age | | | | | | | |
| 1982 | 0.000 | 0.002 | 0.038 | 0.152 | 0.242 | 0.329 | 0.421 | 0.550 | 0.727 | 0.886 | 0.983 | 1.406 | 0.662 |
| 1983 | - | 0.009 | 0.038 | 0.149 | 0.202 | 0.270 | 0.409 | 0.518 | 0.613 | 0.795 | 0.977 | 1.357 | 0.600 |
| 1984 | - | 0.017 | 0.040 | 0.151 | 0.229 | 0.328 | 0.421 | 0.539 | 0.664 | 0.817 | 0.922 | 1.339 | 0.607 |
| 1985 | - | 0.017 | 0.023 | 0.128 | 0.237 | 0.305 | 0.429 | 0.565 | 0.691 | 0.842 | 0.964 | 1.326 | 0.590 |
| 1986 | 0.000 | 0.017 | 0.026 | 0.089 | 0.206 | 0.299 | 0.408 | 0.533 | 0.676 | 0.853 | 0.975 | 1.321 | 0.546 |
| 1987 | 0.006 | 0.015 | 0.033 | 0.081 | 0.191 | 0.298 | 0.433 | 0.561 | 0.686 | 0.828 | 0.980 | 1.303 | 0.611 |
| 1988 | 0.004 | 0.006 | 0.017 | 0.045 | 0.203 | 0.311 | 0.434 | 0.538 | 0.668 | 0.819 | 0.980 | 1.326 | 0.592 |
| 1989 | 0.009 | 0.012 | 0.034 | 0.122 | 0.170 | 0.321 | 0.425 | 0.574 | 0.682 | 0.818 | 0.968 | 1.358 | 0.582 |
| 1990 | 0.004 | 0.012 | 0.029 | 0.062 | 0.187 | 0.257 | 0.438 | 0.586 | 0.688 | 0.849 | 1.049 | 1.454 | 0.438 |
| 1991 | 0.004 | 0.014 | 0.035 | 0.062 | 0.199 | 0.344 | 0.421 | 0.578 | 0.702 | 0.836 | 0.974 | 1.420 | 0.510 |
| 1992 | 0.003 | 0.007 | 0.026 | 0.103 | 0.230 | 0.379 | 0.459 | 0.614 | 0.739 | 0.822 | 0.882 | 1.243 | 0.458 |
| 1993 | 0.003 | 0.009 | 0.027 | 0.122 | 0.202 | 0.318 | 0.432 | 0.535 | 0.666 | 0.882 | 1.023 | 1.335 | 0.428 |
| 1994 | 0.005 | 0.004 | 0.019 | 0.070 | 0.202 | 0.280 | 0.430 | 0.534 | 0.691 | 0.832 | 0.909 | 1.266 | 0.345 |
| 1995 | 0.005 | 0.007 | 0.023 | 0.058 | 0.171 | 0.308 | 0.431 | 0.561 | 0.690 | 0.911 | 0.974 | 1.243 | 0.381 |
| 1996 | 0.004 | 0.019 | 0.031 | 0.061 | 0.155 | 0.234 | 0.425 | 0.554 | 0.708 | 0.856 | 0.974 | 1.232 | 0.389 |
| 1997 | 0.004 | 0.023 | 0.034 | 0.059 | 0.196 | 0.251 | 0.359 | 0.495 | 0.628 | 0.871 | 1.037 | 1.293 | 0.362 |
| 1998 | 0.003 | 0.006 | 0.023 | 0.065 | 0.169 | 0.249 | 0.349 | 0.492 | 0.585 | 0.871 | 0.978 | 1.206 | 0.339 |
| 1999 | 0.003 | 0.006 | 0.023 | 0.089 | 0.191 | 0.261 | 0.406 | 0.516 | 0.584 | 0.628 | 0.917 | 0.872 | 0.358 |
| 2000 | 0.003 | 0.006 | 0.024 | 0.083 | 0.185 | 0.207 | 0.359 | 0.450 | 0.533 | 0.633 | 0.677 | 0.925 | 0.359 |
| 2001 | 0.003 | 0.006 | 0.023 | 0.119 | 0.168 | 0.215 | 0.330 | 0.469 | 0.550 | 0.646 | 0.647 | 0.840 | 0.378 |
| mean | 0.004 | 0.011 | 0.028 | 0.094 | 0.197 | 0.288 | 0.411 | 0.538 | 0.659 | 0.815 | 0.940 | 1.253 | 0.477 |

Table G5. Stratified mean number per tow at age of witch flounder in NEFSC offshore spring and autumn bottom trawl surveys in Gulf of Maine-Georges Bank region (strata 22-30,36-40), 1963-2002.

| | SPRING | | AUTUMN | |
|---|---|---|---|---|
| Year | Number per tow | Weight per tow | Number per tow | Weight per tow |
| 1963 | - | - | 5.52 | 3.46 |
| 1964 | - | - | 2.89 | 2.00 |
| 1965 | - | - | 3.94 | 2.27 |
| 1966 | - | - | 7.80 | 4.56 |
| 1967 | - | - | 3.01 | 2.02 |
| 1968 | 4.83 | 3.35 | 4.82 | 3.49 |
| 1969 | 3.74 | 2.53 | 5.81 | 4.40 |
| 1970 | 6.39 | 4.49 | 4.89 | 3.71 |
| 1971 | 2.70 | 2.04 | 4.32 | 2.95 |
| 1972 | 5.35 | 4.01 | 3.24 | 2.42 |
| 1973 | 8.20 | 6.21 | 3.18 | 2.05 |
| 1974 | 6.23 | 3.62 | 2.38 | 1.58 |
| 1975 | 3.72 | 2.75 | 1.66 | 1.03 |
| 1976 | 5.50 | 3.70 | 1.34 | 0.94 |
| 1977 | 4.20 | 1.96 | 5.06 | 3.38 |
| 1978 | 3.87 | 2.56 | 4.04 | 2.94 |
| 1979 | 2.91 | 1.71 | 1.94 | 1.62 |
| 1980 | 8.46 | 3.89 | 2.62 | 2.04 |
| 1981 | 8.14 | 4.05 | 3.66 | 2.19 |
| 1982 | 3.64 | 1.87 | 0.99 | 0.83 |
| 1983 | 6.41 | 2.74 | 4.72 | 2.12 |
| 1984 | 3.00 | 1.66 | 4.37 | 2.34 |
| 1985 | 5.18 | 2.75 | 2.76 | 1.59 |
| 1986 | 2.07 | 1.35 | 1.59 | 1.09 |
| 1987 | 1.01 | 0.65 | 0.48 | 0.37 |
| 1988 | 1.43 | 0.85 | 1.38 | 0.57 |
| 1989 | 1.95 | 0.74 | 0.89 | 0.38 |
| 1990 | 0.63 | 0.24 | 2.00 | 0.40 |
| 1991 | 1.68 | 0.57 | 2.08 | 0.54 |
| 1992 | 1.26 | 0.48 | 0.94 | 0.24 |
| 1993 | 1.47 | 0.36 | 5.15 | 0.54 |
| 1994 | 3.13 | 0.53 | 2.21 | 0.42 |
| 1995 | 1.88 | 0.47 | 4.74 | 0.62 |
| 1996 | 1.36 | 0.28 | 5.38 | 1.02 |
| 1997 | 2.22 | 0.43 | 5.11 | 0.77 |
| 1998 | 4.27 | 0.77 | 3.70 | 0.47 |
| 1999 | 3.15 | 0.48 | 5.91 | 0.88 |
| 2000 | 3.45 | 0.52 | 6.63 | 1.11 |
| 2001 | 4.41 | 0.75 | 7.94 | 1.71 |
| 2002 | 8.10 | 1.62 | | |

Note: During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No significant differences in catchability were found for witch flounder, therefore no adjustments have been made (Byrne and Forrester, 1991). No significant differences were found between research vessels, and no adjustment have been made (Byrne and Forrester, 1991).

Spring surveys during 1973-1981 were accomplished with a 41 Yankee trawl; in all other years, a 36 Yankee trawl was used. No adjustments have been made.

Table G6. Stratified mean number per tow at age of witch flounder in NEFSC bottom trawl spring and autumn surveys (Strata 22-30, 36-40), 1980-2002.

| | AGE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ | Total |
| **Spring** | | | | | | | | | | | | | | | | |
| 1980 | 0.00 | 0.06 | 0.23 | 0.95 | 1.52 | 0.72 | 1.20 | 1.02 | 0.38 | 0.40 | 0.31 | 0.30 | 0.12 | 0.16 | 1.10 | 8.46 |
| 1981 | 0.00 | 0.00 | 0.05 | 0.82 | 0.93 | 2.00 | 1.02 | 0.76 | 0.67 | 0.42 | 0.13 | 0.20 | 0.24 | 0.22 | 0.90 | 8.40 |
| 1982 | 0.00 | 0.04 | 0.01 | 0.56 | 0.57 | 0.34 | 0.21 | 0.64 | 0.41 | 0.08 | 0.26 | 0.15 | 0.03 | 0.03 | 0.30 | 3.64 |
| 1983 | 0.00 | 0.00 | 0.03 | 0.58 | 1.25 | 1.33 | 0.55 | 0.64 | 0.67 | 0.48 | 0.20 | 0.09 | 0.08 | 0.11 | 0.41 | 6.41 |
| 1984 | 0.00 | 0.00 | 0.01 | 0.10 | 0.33 | 0.73 | 0.42 | 0.26 | 0.28 | 0.24 | 0.11 | 0.12 | 0.09 | 0.02 | 0.29 | 3.00 |
| 1985 | 0.00 | 0.00 | 0.00 | 0.02 | 0.43 | 1.11 | 1.19 | 0.86 | 0.45 | 0.13 | 0.06 | 0.14 | 0.09 | 0.04 | 0.67 | 5.18 |
| 1986 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.24 | 0.53 | 0.43 | 0.17 | 0.18 | 0.07 | 0.04 | 0.08 | 0.05 | 0.25 | 2.07 |
| 1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.12 | 0.12 | 0.26 | 0.17 | 0.03 | 0.06 | 0.03 | 0.00 | 0.00 | 0.15 | 1.01 |
| 1988 | 0.00 | 0.02 | 0.02 | 0.06 | 0.00 | 0.07 | 0.31 | 0.38 | 0.25 | 0.16 | 0.08 | 0.04 | 0.02 | 0.00 | 0.02 | 1.43 |
| 1989 | 0.00 | 0.02 | 0.01 | 0.04 | 0.98 | 0.12 | 0.07 | 0.10 | 0.31 | 0.07 | 0.03 | 0.05 | 0.05 | 0.02 | 0.06 | 1.95 |
| 1990 | 0.00 | 0.01 | 0.00 | 0.04 | 0.09 | 0.32 | 0.02 | 0.02 | 0.02 | 0.06 | 0.01 | 0.00 | 0.01 | 0.00 | 0.03 | 0.63 |
| 1991 | 0.00 | 0.04 | 0.00 | 0.78 | 0.11 | 0.11 | 0.19 | 0.02 | 0.09 | 0.10 | 0.14 | 0.02 | 0.02 | 0.00 | 0.07 | 1.68 |
| 1992 | 0.00 | 0.05 | 0.01 | 0.19 | 0.37 | 0.08 | 0.12 | 0.15 | 0.05 | 0.14 | 0.02 | 0.01 | 0.05 | 0.00 | 0.02 | 1.26 |
| 1993 | 0.00 | 0.15 | 0.11 | 0.14 | 0.46 | 0.33 | 0.06 | 0.08 | 0.00 | 0.02 | 0.02 | 0.00 | 0.06 | 0.00 | 0.04 | 1.47 |
| 1994 | 0.00 | 0.10 | 0.71 | 0.53 | 0.64 | 0.83 | 0.16 | 0.03 | 0.02 | 0.06 | 0.01 | 0.00 | 0.00 | 0.02 | 0.02 | 3.13 |
| 1995 | 0.00 | 0.04 | 0.12 | 0.58 | 0.32 | 0.18 | 0.31 | 0.11 | 0.12 | 0.04 | 0.00 | 0.04 | 0.03 | 0.00 | 0.00 | 1.88 |
| 1996 | 0.00 | 0.02 | 0.04 | 0.24 | 0.41 | 0.33 | 0.22 | 0.07 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 1.36 |
| 1997 | 0.00 | 0.07 | 0.07 | 0.15 | 0.71 | 0.58 | 0.46 | 0.08 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22 |
| 1998 | 0.00 | 0.11 | 1.06 | 0.73 | 0.41 | 0.79 | 0.70 | 0.21 | 0.15 | 0.08 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 4.27 |
| 1999 | 0.00 | 0.11 | 0.40 | 0.98 | 0.77 | 0.49 | 0.17 | 0.18 | 0.03 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 3.15 |
| 2000 | 0.00 | 0.01 | 0.27 | 1.17 | 0.70 | 0.67 | 0.24 | 0.25 | 0.11 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 3.45 |
| 2001 | 0.00 | 0.11 | 0.09 | 0.72 | 1.47 | 1.02 | 0.41 | 0.30 | 0.15 | 0.11 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 4.41 |
| 2002 | 0.00 | 0.02 | 0.06 | 0.87 | 2.69 | 2.23 | 0.81 | 0.70 | 0.35 | 0.20 | 0.10 | 0.02 | 0.00 | 0.03 | 0.04 | 8.10 |

Table G6 continued. Stratified mean number per tow at age of witch flounder in NEFSC bottom trawl spring and autumn surveys (Strata 22-30, 36-40), 1980-2002.

| | AGE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ | Total |
| **Autumn** | | | | | | | | | | | | | | | | |
| 1980 | 0.04 | 0.00 | 0.02 | 0.00 | 0.20 | 0.26 | 0.28 | 0.36 | 0.17 | 0.15 | 0.27 | 0.04 | 0.16 | 0.12 | 0.57 | 2.62 |
| 1981 | 0.03 | 0.07 | 0.03 | 0.24 | 0.44 | 0.61 | 0.46 | 0.27 | 0.26 | 0.18 | 0.21 | 0.17 | 0.04 | 0.13 | 0.48 | 3.66 |
| 1982 | 0.02 | 0.00 | 0.00 | 0.06 | 0.01 | 0.02 | 0.08 | 0.25 | 0.13 | 0.01 | 0.03 | 0.03 | 0.00 | 0.06 | 0.29 | 0.99 |
| 1983 | 0.00 | 0.01 | 0.01 | 0.49 | 1.60 | 0.78 | 0.51 | 0.47 | 0.11 | 0.10 | 0.12 | 0.09 | 0.02 | 0.00 | 0.42 | 4.72 |
| 1984 | 0.00 | 0.00 | 0.00 | 0.08 | 0.97 | 1.01 | 0.58 | 0.54 | 0.32 | 0.14 | 0.12 | 0.06 | 0.04 | 0.14 | 0.38 | 4.37 |
| 1985 | 0.00 | 0.00 | 0.01 | 0.07 | 0.06 | 0.60 | 0.62 | 0.58 | 0.24 | 0.13 | 0.09 | 0.01 | 0.03 | 0.10 | 0.22 | 2.76 |
| 1986 | 0.01 | 0.00 | 0.00 | 0.01 | 0.04 | 0.27 | 0.36 | 0.31 | 0.15 | 0.11 | 0.02 | 0.02 | 0.01 | 0.05 | 0.23 | 1.59 |
| 1987 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.02 | 0.05 | 0.18 | 0.07 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.08 | 0.48 |
| 1988 | 0.00 | 0.00 | 0.00 | 0.71 | 0.07 | 0.00 | 0.03 | 0.22 | 0.06 | 0.05 | 0.03 | 0.06 | 0.02 | 0.03 | 0.08 | 1.38 |
| 1989 | 0.17 | 0.02 | 0.02 | 0.08 | 0.30 | 0.01 | 0.02 | 0.04 | 0.05 | 0.09 | 0.01 | 0.00 | 0.03 | 0.00 | 0.04 | 0.89 |
| 1990 | 0.48 | 0.12 | 0.11 | 0.39 | 0.52 | 0.17 | 0.05 | 0.02 | 0.02 | 0.05 | 0.00 | 0.00 | 0.01 | 0.04 | 0.03 | 2.00 |
| 1991 | 0.22 | 0.02 | 0.17 | 0.67 | 0.35 | 0.27 | 0.15 | 0.09 | 0.06 | 0.02 | 0.04 | 0.03 | 0.00 | 0.00 | 0.00 | 2.08 |
| 1992 | 0.09 | 0.03 | 0.11 | 0.27 | 0.22 | 0.06 | 0.05 | 0.00 | 0.00 | 0.02 | 0.01 | 0.02 | 0.00 | 0.01 | 0.04 | 0.94 |
| 1993 | 2.54 | 0.67 | 0.11 | 0.55 | 0.76 | 0.23 | 0.06 | 0.03 | 0.08 | 0.00 | 0.02 | 0.04 | 0.00 | 0.01 | 0.01 | 5.15 |
| 1994 | 0.42 | 0.17 | 0.28 | 0.50 | 0.20 | 0.39 | 0.04 | 0.11 | 0.00 | 0.04 | 0.01 | 0.00 | 0.01 | 0.00 | 0.04 | 2.21 |
| 1995 | 0.51 | 0.21 | 0.80 | 1.57 | 0.86 | 0.49 | 0.22 | 0.00 | 0.00 | 0.01 | 0.05 | 0.00 | 0.00 | 0.00 | 0.01 | 4.74 |
| 1996 | 0.23 | 0.09 | 0.27 | 0.74 | 2.02 | 1.40 | 0.45 | 0.06 | 0.06 | 0.03 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 5.38 |
| 1997 | 0.89 | 0.34 | 1.00 | 0.53 | 0.86 | 0.77 | 0.40 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 5.10 |
| 1998 | 0.64 | 0.08 | 0.54 | 1.33 | 0.48 | 0.31 | 0.17 | 0.10 | 0.04 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.70 |
| 1999 | 0.32 | 0.53 | 1.17 | 1.51 | 1.06 | 0.58 | 0.36 | 0.28 | 0.06 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 5.91 |
| 2000 | 0.94 | 0.10 | 0.71 | 1.43 | 1.75 | 0.68 | 0.59 | 0.22 | 0.14 | 0.05 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 6.63 |
| 2001 | 0.00 | 0.04 | 0.21 | 0.92 | 3.13 | 1.93 | 0.81 | 0.62 | 0.16 | 0.06 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 7.94 |

Table G7. Estimates of beginning year stock size ('000 of fish), instantaneous fishing mortality (F) and spawning stock biomass (mt)for witch flounder estimated from virtual population analysis, 1982-2001.

Stock Size Jan 1 ('000)

| Age | **1982** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 15430 | 17856 | 15839 | 7315 | 4853 | 2936 | 9470 | 6322 | 6805 | 8941 |
| 4 | 12802 | 13104 | 15056 | 13497 | 6182 | 4155 | 2506 | 7594 | 5026 | 5538 |
| 5 | 9764 | 10032 | 10030 | 11598 | 10526 | 4971 | 3408 | 2028 | 6131 | 3736 |
| 6 | 7902 | 7284 | 7223 | 6775 | 8018 | 7652 | 3845 | 2688 | 1685 | 4249 |
| 7 | 4565 | 5433 | 4808 | 4603 | 4035 | 4326 | 5399 | 2699 | 2022 | 1211 |
| 8 | 2990 | 3312 | 3201 | 2759 | 2547 | 2019 | 2263 | 3364 | 1616 | 1484 |
| 9 | 2340 | 1965 | 1943 | 1365 | 1217 | 1418 | 930 | 877 | 2075 | 950 |
| 10 | 1372 | 1644 | 1007 | 1026 | 613 | 665 | 775 | 428 | 429 | 1473 |
| 11+ | 9013 | 5364 | 4580 | 3458 | 2071 | 1279 | 1724 | 1199 | 933 | 1206 |
| 3+ | 66178 | 65994 | 63687 | 52396 | 40062 | 29421 | 30320 | 27199 | 26722 | 28788 |

| | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 14538 | 10112 | 16169 | 15902 | 15982 | 18357 | 36749 | 51092 | 83904 | 67123 | 22643 |
| 4 | 7286 | 12142 | 8316 | 13878 | 13092 | 13645 | 15703 | 31427 | 43749 | 72079 | 57625 |
| 5 | 4388 | 5102 | 8774 | 6228 | 11372 | 10385 | 10795 | 12941 | 26048 | 36361 | 60784 |
| 6 | 2407 | 2973 | 3074 | 4988 | 4250 | 7953 | 7578 | 8100 | 9763 | 20821 | 29117 |
| 7 | 3118 | 1196 | 1706 | 1448 | 2696 | 2431 | 5559 | 5145 | 5678 | 7301 | 16673 |
| 8 | 821 | 2012 | 474 | 700 | 458 | 992 | 1150 | 3315 | 3335 | 3392 | 4733 |
| 9 | 1047 | 518 | 1188 | 225 | 354 | 150 | 304 | 646 | 2145 | 1917 | 1563 |
| 10 | 544 | 735 | 242 | 521 | 104 | 104 | 52 | 130 | 322 | 1268 | 1061 |
| 11+ | 1699 | 1023 | 686 | 300 | 204 | 145 | 233 | 224 | 720 | 908 | 1194 |
| 3+ | 35848 | 35813 | 40629 | 44190 | 48512 | 54162 | 78123 | 113020 | 175664 | 211170 | 195393 |

Table G7 continued.

Fishing Mortality

| Age | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.01 | 0 |
| 3 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.07 | 0.08 | 0.06 | 0.05 |
| 4 | 0.09 | 0.12 | 0.11 | 0.10 | 0.07 | 0.05 | 0.06 | 0.06 | 0.15 | 0.08 |
| 5 | 0.14 | 0.18 | 0.24 | 0.22 | 0.17 | 0.11 | 0.09 | 0.04 | 0.22 | 0.29 |
| 6 | 0.22 | 0.27 | 0.30 | 0.37 | 0.47 | 0.20 | 0.20 | 0.14 | 0.18 | 0.16 |
| 7 | 0.17 | 0.38 | 0.41 | 0.44 | 0.54 | 0.50 | 0.32 | 0.36 | 0.16 | 0.24 |
| 8 | 0.27 | 0.38 | 0.70 | 0.67 | 0.44 | 0.63 | 0.80 | 0.33 | 0.38 | 0.20 |
| 9 | 0.20 | 0.52 | 0.49 | 0.65 | 0.45 | 0.45 | 0.63 | 0.56 | 0.19 | 0.41 |
| 10 | 0.21 | 0.41 | 0.51 | 0.55 | 0.50 | 0.53 | 0.46 | 0.37 | 0.23 | 0.26 |
| 11+ | 0.21 | 0.41 | 0.51 | 0.55 | 0.50 | 0.53 | 0.46 | 0.37 | 0.23 | 0.26 |
| 7-9,u | 0.21 | 0.43 | 0.53 | 0.59 | 0.48 | 0.53 | 0.58 | 0.42 | 0.24 | 0.28 |

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| 2 | 0.01 | 0.01 | 0.03 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0.03 | 0.05 | 0.00 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0 |
| 4 | 0.21 | 0.17 | 0.14 | 0.05 | 0.08 | 0.08 | 0.04 | 0.04 | 0.03 | 0.02 |
| 5 | 0.24 | 0.36 | 0.41 | 0.23 | 0.21 | 0.17 | 0.14 | 0.13 | 0.07 | 0.07 |
| 6 | 0.55 | 0.41 | 0.60 | 0.47 | 0.41 | 0.21 | 0.24 | 0.21 | 0.14 | 0.07 |
| 7 | 0.29 | 0.77 | 0.74 | 1.00 | 0.85 | 0.60 | 0.37 | 0.28 | 0.37 | 0.28 |
| 8 | 0.31 | 0.38 | 0.59 | 0.53 | 0.97 | 1.03 | 0.43 | 0.29 | 0.40 | 0.62 |
| 9 | 0.20 | 0.61 | 0.67 | 0.63 | 1.07 | 0.91 | 0.70 | 0.54 | 0.38 | 0.44 |
| 10 | 0.27 | 0.53 | 0.70 | 0.82 | 0.90 | 0.72 | 0.39 | 0.30 | 0.38 | 0.45 |
| 11+ | 0.27 | 0.53 | 0.70 | 0.82 | 0.90 | 0.72 | 0.39 | 0.30 | 0.38 | 0.45 |
| 7-9,u | 0.27 | 0.59 | 0.67 | 0.72 | 0.96 | 0.85 | 0.50 | 0.37 | 0.38 | 0.45 |

Table G7 continued.

Spawning Stock biomass ('000 mt)

| Age | **1982** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 5 | 2 | 1 | 4 | 3 | 3 | 0 |
| 4 | 0 | 88 | 107 | 367 | 145 | 78 | 46 | 96 | 108 | 6 |
| 5 | 55 | 486 | 483 | 1871 | 1726 | 768 | 520 | 326 | 784 | 88 |
| 6 | 423 | 1297 | 1174 | 2237 | 2451 | 2495 | 1253 | 896 | 574 | 531 |
| 7 | 1105 | 1858 | 1648 | 2035 | 1718 | 1856 | 2410 | 1236 | 958 | 457 |
| 8 | 1589 | 1708 | 1578 | 1468 | 1428 | 1073 | 1182 | 1881 | 929 | 870 |
| 9 | 1806 | 1336 | 1237 | 894 | 845 | 959 | 613 | 575 | 1491 | 656 |
| 10 | 1206 | 1393 | 772 | 811 | 499 | 543 | 630 | 349 | 373 | 1250 |
| 11+ | 11938 | 6632 | 5491 | 4083 | 2457 | 1489 | 2063 | 1492 | 1273 | 1598 |
| 1+ | 18121 | 14798 | 12490 | 13772 | 11271 | 9263 | 8721 | 6854 | 6493 | 5456 |

| Age | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 69 |
| 4 | 8 | 17 | 87 | 102 | 84 | 100 | 106 | 237 | 489 | 744 |
| 5 | 113 | 127 | 893 | 684 | 1007 | 912 | 1069 | 1219 | 1248 | 1743 |
| 6 | 340 | 439 | 903 | 1406 | 1262 | 1955 | 1893 | 2185 | 1537 | 2828 |
| 7 | 1178 | 407 | 706 | 587 | 1116 | 985 | 2142 | 2030 | 1735 | 2172 |
| 8 | 482 | 1142 | 255 | 379 | 240 | 481 | 562 | 1652 | 1482 | 1378 |
| 9 | 750 | 368 | 770 | 157 | 222 | 99 | 195 | 348 | 1183 | 1010 |
| 10 | 435 | 602 | 188 | 399 | 82 | 85 | 44 | 108 | 192 | 734 |
| 11+ | 1968 | 1220 | 753 | 318 | 211 | 163 | 256 | 181 | 609 | 690 |
| 1+ | 5274 | 4321 | 4555 | 4032 | 4222 | 4779 | 6267 | 7960 | 8548 | 11368 |

Table G8. Summary of projection input and results for witch flounder. Projected median estimates of catch (median landings + median discards), landings, discards and spawning stock biomass are provided for fishing mortality with a 15% reduction in current F ($F_{2002} = F_{2001} * .85 = 0.38$).

Projection input:

| Age | Fish Mort. Pattern | Proportion Mature | Discard Fraction | Average Weights Landings | Stock | Discards |
|---|---|---|---|---|---|---|
| 3 | 0.0090 | 0.020 | 1.00 | 0.116 | 0.047 | 0.089 |
| 4 | 0.0960 | 0.090 | 0.93 | 0.293 | 0.114 | 0.168 |
| 5 | 0.2500 | 0.250 | 0.75 | 0.335 | 0.207 | 0.194 |
| 6 | 0.4150 | 0.540 | 0.15 | 0.387 | 0.295 | 0.219 |
| 7 | 1.0000 | 0.780 | 0.00 | 0.482 | 0.420 | 0.219 |
| 8 | 1.0000 | 0.930 | 0.00 | 0.563 | 0.524 | 0.219 |
| 9 | 1.0000 | 0.990 | 0.00 | 0.695 | 0.635 | 0.219 |
| 10 | 1.0000 | 1.000 | 0.00 | 0.805 | 0.777 | 0.219 |
| 11+ | 1.0000 | 1.000 | 0.00 | 0.961 | 0.961 | 0.219 |

Projection results (weight reported in '000 mt)

| Scenario | Year | F full | Median Catch | Median Landings | Median Discards | Median SSB |
|---|---|---|---|---|---|---|
| 85% of F2001 | 2002 | 0.38 | 7.11 | 5.96 | 1.15 | 18.31 |
| FMSY | 2003 | 0.164 | 4.37 | 3.98 | 0.39 | 25.41 |
| FMSY | 2004 | 0.164 | 6.26 | 6.06 | 0.20 | 34.70 |

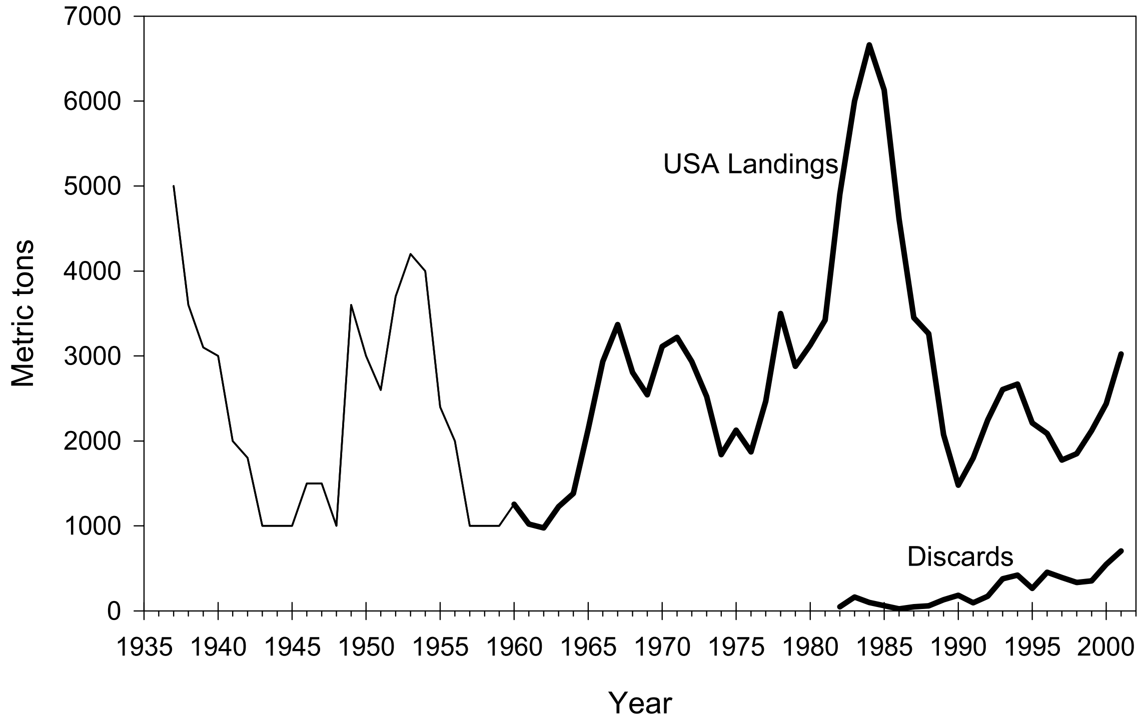



Figure G1. Historical USA witch flounder landings (mt), excluding USA landings from the Grand Banks in the mid-1980's. The thin line represents provisional landings data taken from Lange and Lux (1978). Discards are from the shrimp and large-mesh otter trawl fisheries.

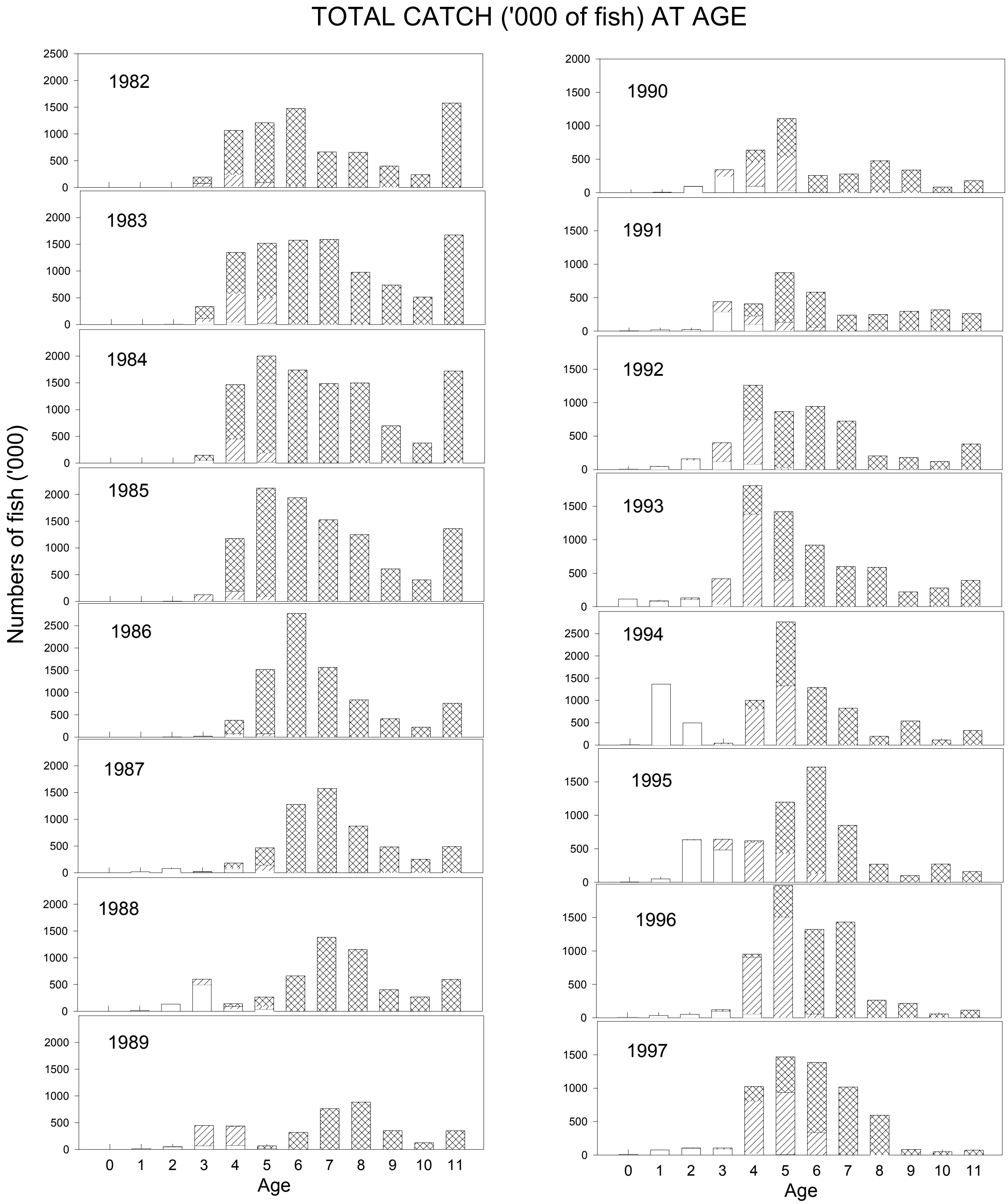



Figure G2. Number of witch flounder ('000 of fish) at age in the total catch, by fishery, 1982-2001. Open bar represents discards in the shrimp fishery, diagonal bar represents discards in large-mesh fishery and hatched bar represents landings.

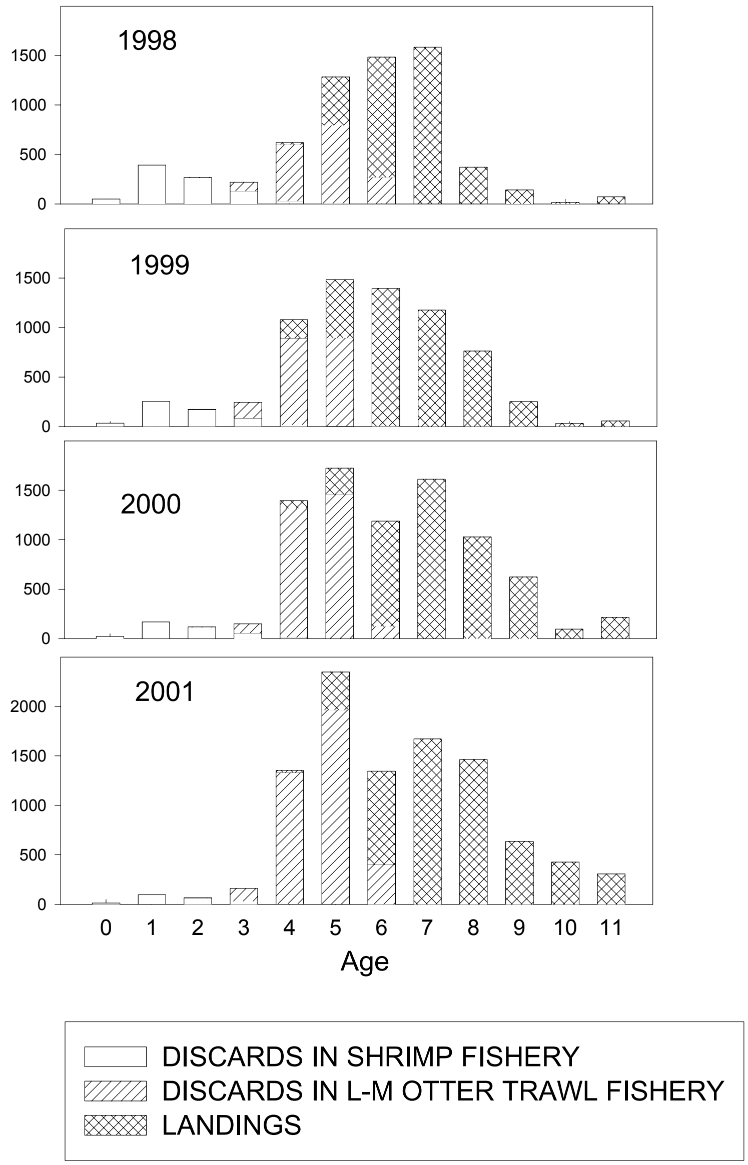



Figure G2 continued.

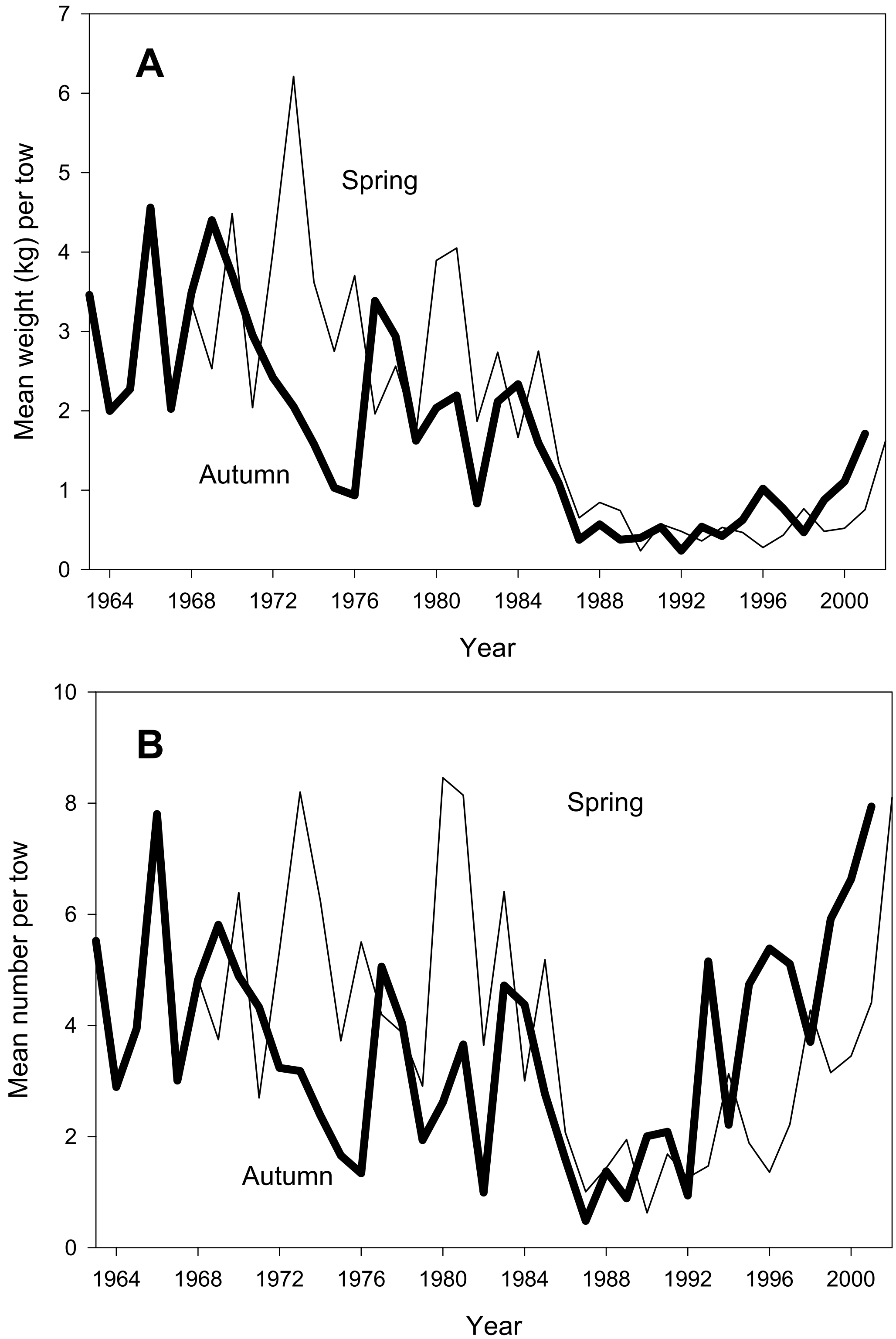



Figure G3. Stratified mean weight (kg) per tow (A) and mean number per tow (B) of witch flounder in the NEFSC spring and autumn bottom trawl surveys, 1963-2002.

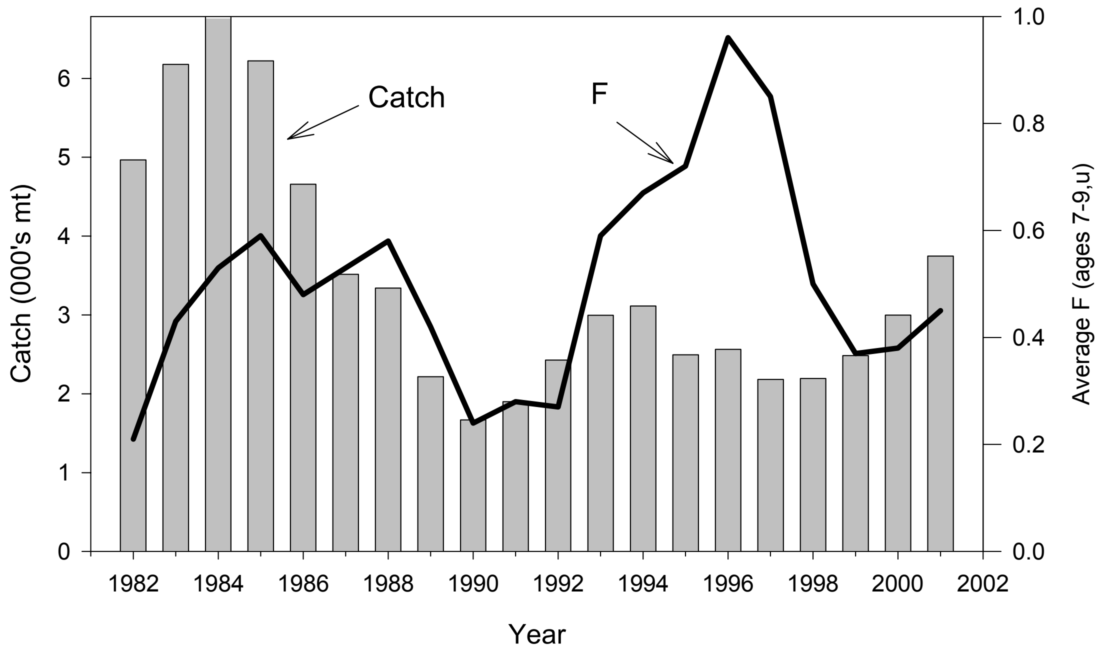



Figure G4. Trends in total catch and fishing mortality for witch flounder, 1982-2001.

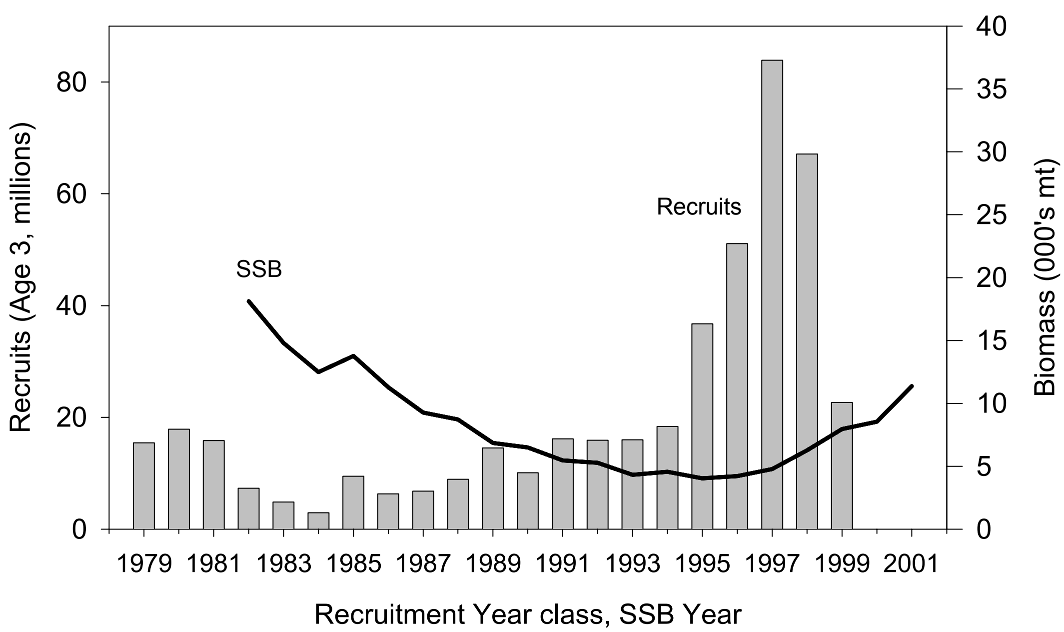



Figure G5. Trends in spawning stock biomass and recruitment (age 3) for witch flounder.

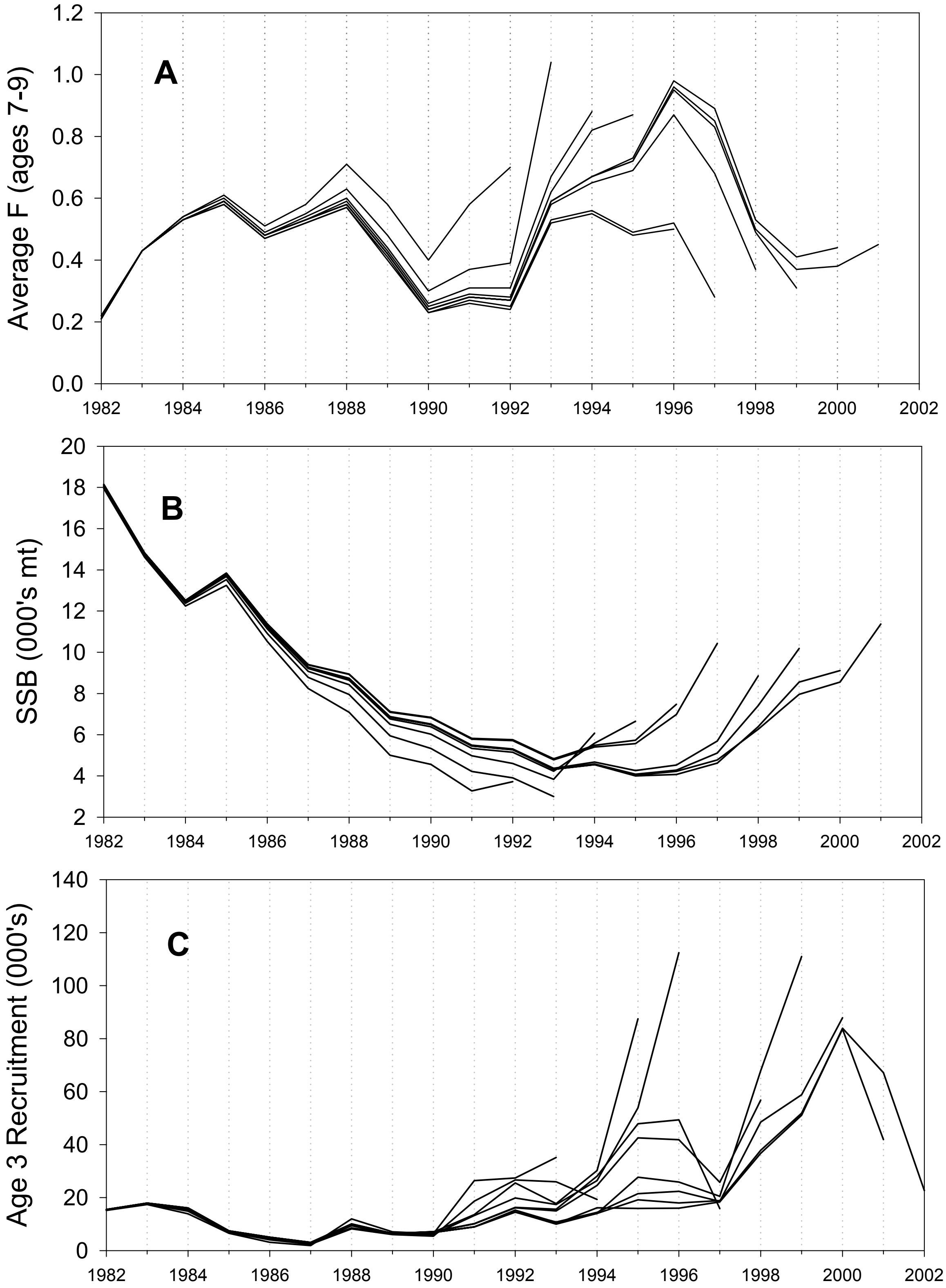



Figure G6. Retrospective analysis results of fishing mortality(A), spawning stock biomass (B), and age 3 recruitment(C).

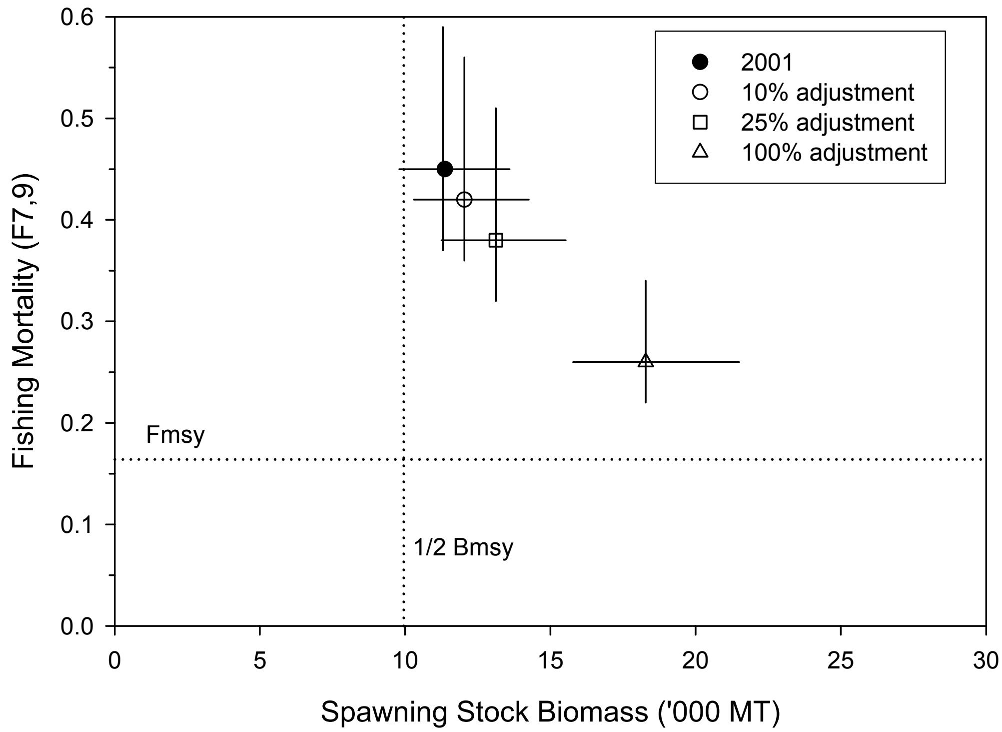



Figure G7. Stock status of witch flounder in 2001 (solid circle with 80% confidence intervals) and three sensitivity analyses: the open circle represents stock status when the 2000-2002 survey tuning indices were arbitrarily adjusted upward by 1.1; open square represents results when 2000-2002 survey tuning indices were arbitrarily adjusted by 1.25; open triangle represents results when 2002-2002 survey tuning indices were arbitrarily adjusted by 2.0.

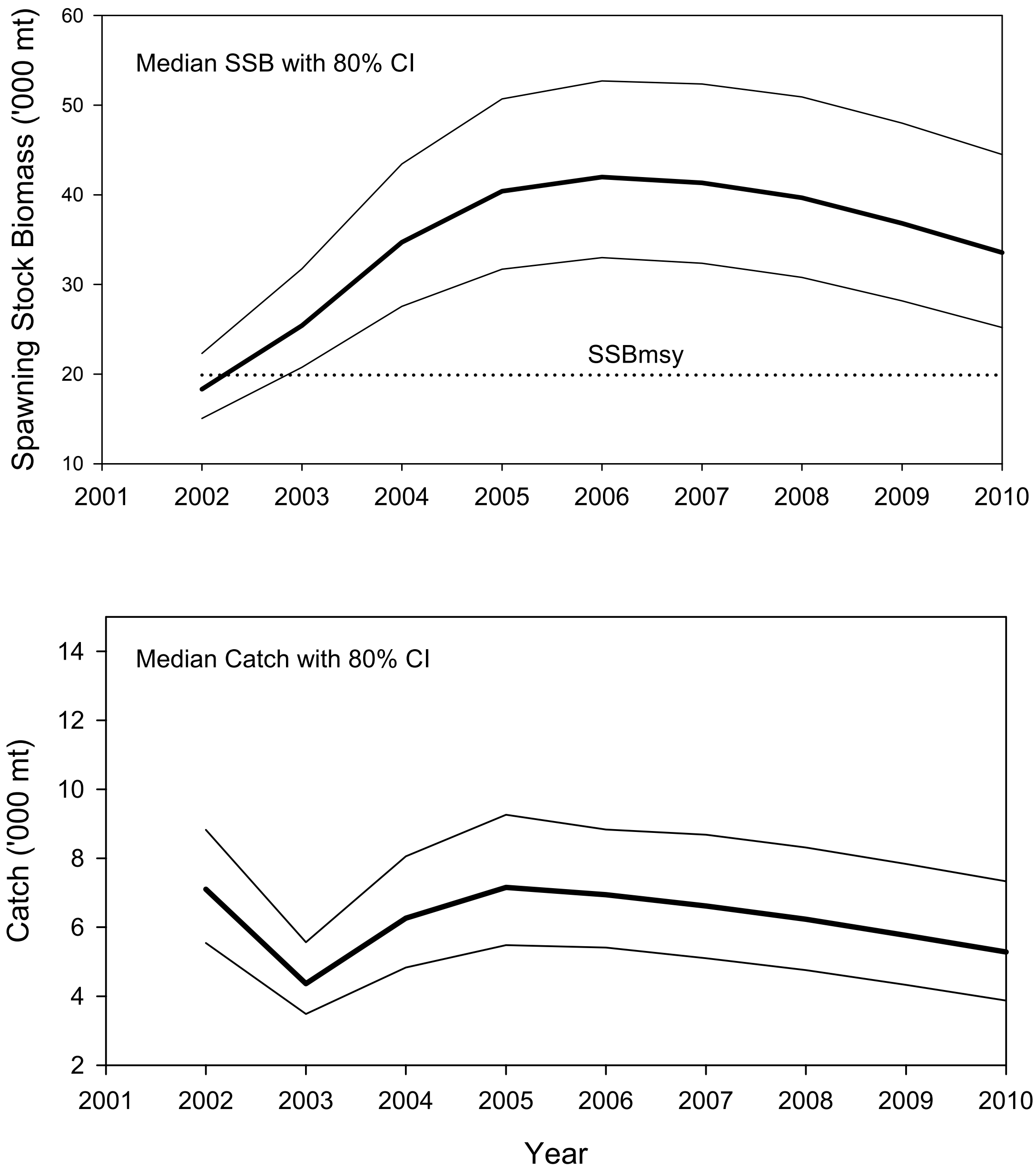



Figure G8. Projected median spawning stock biomass ('000 mt) and median catch ('000 mt) with 80% confidence intervals.

**H. Gulf of Maine-Georges Bank American Plaice** by L. O'Brien, C. Esteves, and L. Col

## 1.0 Background

This stock was last assessed in 2000 (O'Brien and Esteves 2001) and reviewed by the 32nd Northeast Regional SAW (NEFSC 2001). Fully recruited F (ages 5-8, unweighted average) in 1999 was estimated to be 0.27, a decrease of 10% from 1998. Spawning stock biomass was 14,056 mt in 1999, a decrease of 9% from 1998. The most recent strong recruitment since 1993 was the above- average 1998 year class with an average recruit/SSB survival ratio.

## 2.0 Fishery

Total commercial landings of Gulf of Maine-Georges Bank American plaice were 4,479 mt in 2001, a 3% increase from 2000 and a 38% increase from 1999 (Table H1, Figure H1). Canadian fisheries landed 46 mt in 2001, and 143 mt in 2000, accounting for about 1%-3% of the total landings. The otter trawl fleet accounts for more than 90% of the landings. The fishery is prosecuted primarily during the 2$^{nd}$ and 3$^{rd}$ calendar quarter of the year.

Discarding of small fish occurs in the northern shrimp fishery during the 1$^{st}$ and 4$^{th}$ calendar quarter, and year-round by the large mesh fishery. Discarded catch in the Northern shrimp fishery is estimated directly from sea-sampled trips (1989-1997) and indirectly using survey data (1980-1988,1998-2001). Discards in the large mesh fishery are also estimated based on survey data. Since 1998 discards in the shrimp fishery account for about 5% of the total catch (in numbers) and discards in the large mesh fishery account for about 20-30% of the total catch (in numbers) (Figure H2).

## 3.0 Research Surveys

The NEFSC survey indices of abundance and biomass have generally been increasing since 1988. The most recent spring and autumn indices, however, both indicate a decreasing trend (Table H2, Figure H3 and H4). Recruitment indices of age 1 fish from NEFSC autumn surveys indicate that both the 1997 and 1998 year classes are above average and similar in size to the 1992 year class (Table 3a). These same year classes in the autumn Massachusetts state survey are just below the time series average (Table 3b) .

## 4.0 Assessment

*Input data and Analyses*

The current assessment is an update and employs the same ADAPT formulation as in the 2000 assessment (O'Brien and Esteves 2001). Landings at age has been updated with total 2000 and 2001 landings, and discards have been estimated for the Northern shrimp fishery and the large mesh fishery. Number of samples obtained for characterizing the catch at age have improved since 1995 and samples were adequate for 2000-2001 (Table H4). The total catch at age includes estimates of discarded fish from both the Northern shrimp fishery and the large mesh fishery and landings from the commercial fishery (Table H5, Figure H2).

Research survey indices have been estimated for the spring NEFSC (ages 1-8) and MADMF (ages 1-5) surveys and the autumn NEFSC (ages1-6) and MADMF (ages 1-5) surveys for 2000-2001. The ADAPT calibration method (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to derive estimates of instantaneous fishing mortality and beginning year stock sizes in 2002. A conditional non-parametric bootstrap procedure (Efron 1982) was used to evaluate the precision of fishing mortality, spawning stock biomass, and mean biomass estimates. A retrospective analysis was performed for terminal year fishing mortality, spawning stock biomass, and age 1 recruitment.

*Assessment results*

Fully recruited fishing mortality (age 5-8) was estimated to be 0.43 in 2001 (Table H6, Figure H5). Spawning stock biomass in 2001 was estimated to be 13,822 mt, a 3% decrease from 2000 and a 5% decrease from 1999 (Table H6, Figure H6). Recruitment of the 2001 year class (39.3 million age 1 fish) is estimated to be similar to the above average 1998 year class (40 million age 1 fish) (Table H6, Figure H6).

*VPA Diagnostics*

Stock size estimates for ages 1-8 were well estimated with CVs ranging from 0.16 to 0.48. The distribution of F estimates from the bootstrap analysis ranged from 0.32 to 0.75 with an 80% probability that F in 2001 was between 0.37 and 0.50. The distribution of SSB estimates from the bootstrap analysis ranged from 10,500 mt to 18,500 mt with an 80% probability that SSB in 2000 was between 12,250 mt to 15,390 mt.

There is not a strong retrospective pattern in this model formulation (Figure H7). The terminal year estimates of fishing mortality exhibit a pattern of being more than the converged estimates prior to 1997. The SSB estimates do not have a retrospective pattern. The terminal year estimates of recruits are less than converged estimates from 1993. These patterns are similar to the previous assessment (O'Brien and Esteves 2001).

*Sensitivity Analyses*

Analyses were conducted to determine the sensitivity of fishing mortality and spawning stock biomass estimates to changes in the magnitude of the research survey indices used to calibrate the VPA. NEFSC spring and autumn survey indices for 2000-2002 were arbitrarily increased by 10%, 25% and 100% and used to re-calibrate the VPA (Figure H8). Results are summarized in Section 5.2 (Summary of Assessment Advice).

## 5.0 Projections

Long term forecasts of catch (landings plus discards) and SSB were conducted with $F_{2002}$= 0.85* $F_{2001}$. Input data and results for 2002-2004 are presented in Table H7. The $F_{rebuild}$ that would enable 50% probability of reaching SSBmsy by 2009 was 0.10. The current estimate of $F_{rebuild}$ is similar to the previous estimate of 0.13 (NEFSC 2002) which was based on the assessment results from 2000 (O'Brien and Esteves 2001). Landings are projected to be 1,336 mt in 2003 and 1,562 mt in 2004, and discards are projected to be 161 mt in 2003 and 128 mt in 2004 (Figure H9). SSB is projected to be 15,938 mt in 2003 and 17,038 mt in 2004 (Figure H9).

## 6.0 Biological Reference Points

Biological reference points were established for Gulf of Maine -Georges Bank American plaice based on yield per recruit analyses using $F_{40\%}$ as a proxy for $F_{MSY}$ (NEFSC 2002) as :

MSY= 4,900 mt
$SSB_{MSY}$ = 28,600 mt and
$F_{MSY}$= 0.166

In 2001, spawning stock biomass was estimated at 13,822 mt, about 48% of the target $SSB_{MSY}$. The stock is considered to be overfished, although the upper 80% confidence interval includes biomass >50% $SSB_{MSY}$ Overfishing is occurring on this stock because 2001 F= 0.43 > $F_{MSY}$ . The 80% confidence intervals about $F_{2001}$ were also above $F_{MSY}$.

## 7.0 Summary

American plaice in the Gulf of Maine-Georges Bank region are overfished and overfishing is occurring. Fishing mortality on this stock declined during 1996-1999, but then increased in 2000-2001 as the 1996 and 1997 year classes recruited to the fishery. Spawning stock biomass increased from 1995 to 1998 and has been decreasing since 1998. Spawning stock biomass was 13,822 mt in 2001. The 1998 and 2001 year classes appear to be above average, whereas the 2000 year class is the lowest on record. The survey biomass indices generally show an increasing trend during the last decade and the 1997 and 1998 year classes appear to be near or above average. The recent strong year classes represent an opportunity to rebuild the stock with lower fishing mortality rates.

## 8.0 Sources of Uncertainty

- Lack of direct estimates of discards from sea sampled trips for large mesh fishery and shrimp fishery.

- Projections of SSB are likely to be underestimated if recruits are underestimated as indicated by the strong retrospective pattern of age 1 recruits.

## 9.0 GARM Panel Comments

Discards are estimated with a method that uses survey indices for 2001-2002. The sensitivity analyses of the impact of the offset trawl warp on survey catches could also include the impact on discard estimates. The working group asked to see one year's discard estimates bumped up to reflect a 100% increase in survey catch in order to see the magnitude of discards.

The GARM concluded that it is inappropriate to use the MADMF indices in sensitivity analyses of the influence of a single survey series on estimates of F and SSB because of the limited geographic coverage of the survey.

Discards are an important part of the catch at age. Sea sampling of small mesh fisheries has been incomplete in recent years e.g., no sampling of the northern shrimp fishery since 1997. It was recommended that improved sea sampling for the northern shrimp fishery and other small mesh fisheries (e.g. the whiting fishery), and the scallop fishery be implemented (this is also a general recommendation since these fisheries generate discards for many stocks (e.g., Cape Cod yellowtail, SNE yellowtail, witch, American plaice).

The GARM noted a strong pattern in residuals for the age 1 survey index. This is most likely because the catch at age 1 consists solely of discards that were, in some periods, estimated using the same survey indices that have the residual pattern.

## 10. Research Recommendations

The GARM panel recommended that sensitivity analyses be conducted to evaluate effects of uncertainty in discard estimates on assessment results.

The survey time series could be split into two tuning indices based on time periods corresponding to changes in methods for estimating discards

## 11.0 References

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Table H1. Commercial landings (metric tons, live weight) of American plaice from the Gulf of Maine, Georges Bank, Southern New England and the Mid-Atlantic, 1960-2001.

| Year | Gulf of Maine | | | Georges Bank | | | | | Southern New England | | | | Mid - Atlantic | | | Grand Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | USA | Can | Total | USA | Can | USSR | Other | Total | USA | USSR | Other | Total | USA | Other | Total | USA | Other | Total |
| 1960 | 620 | 1 | 621 | 689 | - | - | - | 689 | - | - | - | 0 | - | - | 0 | 1309 | 1 | 1310 |
| 1961 | 692 | - | 692 | 830 | - | - | - | 830 | - | - | - | 0 | - | - | 0 | 1522 | 0 | 1522 |
| 1962 | 694 | - | 694 | 1233 | 44 | - | - | 1277 | - | - | - | 0 | - | - | 0 | 1927 | 44 | 1971 |
| 1963 | 693 | - | 693 | 1489 | 127 | 24 | - | 1640 | - | - | - | 0 | - | - | 0 | 2182 | 151 | 2333 |
| 1964 | 811 | - | 811 | 2800 | 177 | - | 11 | 2988 | - | - | - | 0 | - | - | 0 | 3611 | 188 | 3799 |
| 1965 | 967 | - | 967 | 2376 | 180 | 112 | - | 2668 | - | - | - | 0 | - | - | 0 | 3343 | 292 | 3635 |
| 1966 | 955 | 2 | 957 | 2388 | 242 | 279 | 1 | 2910 | - | - | - | 0 | - | - | 0 | 3343 | 524 | 3867 |
| 1967 | 1066 | 6 | 1072 | 2166 | 203 | 1018 | 10 | 3397 | - | - | - | 0 | 4 | - | 4 | 3236 | 1237 | 4473 |
| 1968 | 904 | 5 | 909 | 1695 | 173 | 193 | 5 | 2066 | 637 | 145 | - | 782 | 18 | 2 | 20 | 3254 | 523 | 3777 |
| 1969 | 1059 | 7 | 1066 | 1738 | 71 | 63 | 17 | 1889 | 505 | 349 | - | 854 | 130 | - | 130 | 3432 | 507 | 3939 |
| 1970 | 895 | - | 895 | 1603 | 92 | 927 | 658 | 3280 | 88 | 18 | 40 | 146 | 8 | - | 8 | 2594 | 1735 | 4329 |
| 1971 | 648 | 5 | 653 | 1511 | 38 | 228 | 296 | 2071 | 11 | 112 | 206 | 329 | 6 | 2 | 8 | 2176 | 887 | 3063 |
| 1972 | 569 | - | 569 | 1222 | 22 | 358 | - | 1602 | 3 | 71 | - | 74 | - | - | 0 | 1794 | 451 | 2245 |
| 1973 | 687 | - | 687 | 910 | 38 | 289 | - | 1237 | 5 | 158 | - | 163 | - | - | 0 | 1602 | 485 | 2087 |
| 1974 | 945 | 2 | 947 | 1039 | 27 | 16 | 2 | 1084 | 92 | 4 | - | 96 | - | - | 0 | 2076 | 51 | 2127 |
| 1975 | 1507 | - | 1507 | 913 | 25 | 148 | - | 1086 | 3 | - | - | 3 | - | - | 0 | 2423 | 173 | 2596 |
| 1976 | 2550 | - | 2550 | 948 | 24 | 3 | - | 975 | 10 | - | - | 10 | 1 | - | 1 | 3509 | 27 | 3536 |
| 1977 | 5647 | - | 5647 | 1408 | 35 | 50 | - | 1493 | 6 | 78 | - | 84 | 7 | - | 7 | 7068 | 163 | 7231 |
| 1978 | 7287 | 30 | 7317 | 2193 | 77 | - | - | 2270 | 15 | - | - | 15 | 8 | - | 8 | 9503 | 107 | 9610 |
| 1979 | 8835 | - | 8835 | 2478 | 23 | - | - | 2501 | 13 | - | 7 | 20 | 4 | - | 4 | 11330 | 30 | 11360 |
| 1980 | 11139 | - | 11139 | 2399 | 43 | - | 5 | 2447 | 10 | - | - | 10 | 1 | - | 1 | 13549 | 48 | 13597 |
| 1981 | 10327 | 1 | 10328 | 2482 | 15 | - | 2 | 2499 | 26 | - | 2 | 28 | 46 | - | 46 | 12881 | 20 | 12901 |
| 1982 | 11147 | - | 11147 | 3935 | 27 | - | 1 | 3963 | 35 | - | 2 | 37 | 9 | - | 9 | 15126 | 30 | 15156 |
| 1983 | 9142 | 7 | 9149 | 3955 | 30 | - | - | 3985 | 40 | - | - | 40 | 4 | - | 4 | 13141 | 37 | 13178 |
| 1984 | 6833 | 2 | 6835 | 3277 | 6 | - | - | 3283 | 17 | - | - | 17 | 7 | - | 7 | 10134 | 8 | 10142 |
| 1985 | 4766 | 1 | 4767 | 2249 | 40 | - | - | 2289 | 12 | - | - | 12 | 2 | - | 2 | 7029 | 41 | 7070 |
| 1986 | 3319 | - | 3319 | 1146 | 34 | - | - | 1180 | 4 | - | - | 4 | 3 | - | 3 | 4472 | 34 | 4506 |
| 1987 | 2766 | - | 2766 | 1032 | 48 | - | - | 1080 | 2 | - | - | 2 | 1 | - | 1 | 3801 | 48 | 3849 |
| 1988 | 2271 | - | 2271 | 1097 | 108 | - | - | 1205 | 13 | - | - | 13 | 1 | - | 1 | 3382 | 108 | 3490 |
| 1989 | 1646 | - | 1646 | 703 | 68 | - | - | 771 | 1 | - | - | 1 | 3 | - | 3 | 2353 | 68 | 2421 |
| 1990 | 1802 | - | 1802 | 639 | 52 | - | - | 690 | 2 | - | - | 2 | 2 | - | 2 | 2445 | 52 | 2497 |
| 1991 | 2936 | - | 2936 | 1310 | 26 | - | - | 1310 | 15 | - | - | 15 | 0 | - | 0 | 4261 | 26 | 4287 |
| 1992 | 4564 | - | 4566 | 1838 | 3 | - | - | 1838 | 10 | - | - | 10 | 4 | - | 4 | 6416 | 3 | 6419 |
| 1993 | 3865 | - | 3865 | 1838 | - | - | - | 1838 | 11 | - | - | 11 | 4 | - | 4 | 5718 | - | 5718 |
| 1994 | ***3357*** | - | 3431 | ***1683*** | 30 | - | - | 1562 | ***22*** | - | - | 22 | ***4*** | - | 4 | 5066 | 30 | 5096 |
| 1995 | ***3105*** | - | 3126 | ***1505*** | 2 | - | - | 1486 | ***15*** | - | - | 15 | ***20*** | - | 20 | 4645 | 2 | 4647 |
| 1996 | ***2912*** | - | 2922 | ***1430*** | 2 | - | - | 1423 | ***40*** | - | - | 40 | ***15*** | - | 15 | 4396 | 2 | 4398 |
| 1997 | ***2312*** | - | 2396 | ***1576*** | 65 | - | - | 1560 | ***23*** | - | - | 23 | ***26*** | - | 26 | 3937 | 65 | 4002 |
| 1998 | ***2234*** | - | 2234.4 | ***1385*** | 20 | - | - | 1405 | ***23*** | | | 23 | ***20*** | | 20 | 3663 | 20 | 3683 |
| 1999 | ***1718*** | - | 1717.7 | ***1384*** | 123 | - | - | 1507 | ***11*** | | | 11 | ***21*** | | 21 | 3134 | 123 | 3257 |
| 2000 | ***2497*** | - | 2497.5 | ***1687*** | 143 | - | - | 1830 | ***10*** | | | 10 | ***19*** | | 19 | 4213 | 143 | 4356 |
| 2001 | ***2602*** | - | 2601.7 | ***1814*** | 46 | - | - | 1860 | ***7*** | | | 7 | ***10*** | | 10 | 4433 | 46 | 4479 |

** 1994-2001 data are provisional and spatially distributed based on proportions of landings recorded by area in the VTR database

Table H2. Standardized stratified mean number and mean weight per tow (kg) of American plaice in NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine - Georges Bank area, 1963 -2002 (Offshore strata 26-30,36-40,13-25)

| | SPRING | | AUTUMN | |
|---|---|---|---|---|
| | Number | Weight | Number | Weight |
| 1963 | — | — | 14.17 | 5.87 |
| 1964 | — | — | 8.20 | 2.84 |
| 1965 | — | — | 11.95 | 3.80 |
| 1966 | — | — | 17.78 | 4.90 |
| 1967 | — | — | 11.05 | 2.69 |
| 1968 | 11.36 | 3.40 | 8.61 | 2.91 |
| 1969 | 8.59 | 2.68 | 7.51 | 2.36 |
| 1970 | 5.43 | 1.81 | 6.46 | 2.01 |
| 1971 | 3.80 | 1.26 | 7.47 | 1.96 |
| 1972 | 4.28 | 1.32 | 7.44 | 1.60 |
| 1973 | 7.18 | 1.85 | 6.19 | 1.94 |
| 1974 | 8.34 | 1.94 | 6.89 | 1.42 |
| 1975 | 5.78 | 1.72 | 8.12 | 2.43 |
| 1976 | 11.85 | 3.37 | 9.98 | 2.99 |
| 1977 | 14.57 | 5.11 | 11.80 | 3.52 |
| 1978 | 10.61 | 3.82 | 15.13 | 4.66 |
| 1979 | 9.23 | 3.62 | 9.96 | 4.00 |
| 1980 | 18.34 | 4.78 | 14.24 | 5.12 |
| 1981 | 18.75 | 5.88 | 13.04 | 5.62 |
| 1982 | 11.61 | 3.80 | 5.88 | 2.49 |
| 1983 | 16.94 | 4.60 | 9.34 | 3.45 |
| 1984 | 4.10 | 1.42 | 7.12 | 2.02 |
| 1985 | 4.94 | 1.88 | 6.95 | 2.00 |
| 1986 | 3.09 | 0.92 | 5.61 | 1.56 |
| 1987 | 3.50 | 0.81 | 4.38 | 1.09 |
| 1988 | 3.58 | 0.84 | 9.69 | 1.46 |
| 1989 | 4.81 | 0.75 | 9.21 | 1.17 |
| 1990 | 5.09 | 0.75 | 15.46 | 2.90 |
| 1991 | 5.91 | 1.05 | 7.71 | 1.56 |
| 1992 | 4.11 | 1.36 | 6.31 | 1.78 |
| 1993 | 5.29 | 1.39 | 11.89 | 2.39 |
| 1994 | 4.89 | 0.85 | 18.07 | 2.67 |
| 1995 | 9.43 | 1.94 | 11.84 | 2.58 |
| 1996 | 7.83 | 1.69 | 7.58 | 2.23 |
| 1997 | 7.62 | 1.62 | 6.27 | 1.94 |
| 1998 | 4.52 | 1.11 | 9.29 | 2.22 |
| 1999 | 4.18 | 1.20 | 11.03 | 2.57 |
| 2000 | 9.96 | 2.30 | 12.23 | 2.80 |
| 2001 | 10.65 | 2.19 | 10.40 | 2.63 |
| 2002 | 6.70 | 1.76 | | |

Table H3a . Standardized stratified mean number per tow by age and mean weight per tow (kg) of American plaice in NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine - Georges Bank[1] area, 1980-2002.

| | AGE GROUP | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | #/tow | kg/tow |
| Spring | | | | | | | | | | | | | | | | | |
| 1980 | 0.00 | 0.57 | 3.55 | 4.49 | 3.00 | 2.89 | 1.60 | 1.12 | 0.25 | 0.31 | 0.23 | 0.04 | 0.02 | 0.02 | 0.04 | 18.34 | 4.78 |
| 1981 | 0.00 | 0.13 | 3.49 | 4.31 | 3.55 | 2.67 | 1.74 | 1.45 | 0.79 | 0.41 | 0.34 | 0.07 | 0.09 | 0.07 | 0.09 | 18.75 | 5.88 |
| 1982 | 0.00 | 0.06 | 1.04 | 1.79 | 3.17 | 2.13 | 1.34 | 0.92 | 0.49 | 0.35 | 0.19 | 0.07 | 0.01 | 0.04 | 0.02 | 11.601 | 3.80 |
| 1983 | 0.00 | 0.20 | 3.68 | 3.33 | 4.48 | 2.64 | 1.18 | 0.58 | 0.32 | 0.15 | 0.15 | 0.11 | 0.05 | 0.02 | 0.04 | 16.94 | 4.60 |
| 1984 | 0.00 | 0.02 | 0.35 | 0.57 | 0.90 | 1.30 | 0.58 | 0.22 | 0.10 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 | 0.03 | 4.10 | 1.42 |
| 1985 | 0.00 | 0.03 | 0.32 | 0.98 | 0.86 | 0.73 | 0.86 | 0.46 | 0.42 | 0.12 | 0.07 | 0.04 | 0.02 | 0.02 | 0.02 | 4.94 | 1.88 |
| 1986 | 0.00 | 0.01 | 0.46 | 0.34 | 1.01 | 0.59 | 0.29 | 0.21 | 0.10 | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 3.09 | 0.92 |
| 1987 | 0.00 | 0.09 | 0.61 | 0.99 | 0.69 | 0.51 | 0.25 | 0.17 | 0.07 | 0.03 | 0.03 | 0.03 | 0.01 | 0.00 | 0.00 | 3.50 | 0.81 |
| 1988 | 0.00 | 0.20 | 0.99 | 0.84 | 0.76 | 0.31 | 0.23 | 0.12 | 0.01 | 0.09 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 3.58 | 0.84 |
| 1989 | 0.00 | 0.05 | 1.59 | 1.27 | 0.86 | 0.49 | 0.29 | 0.16 | 0.03 | 0.07 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 4.81 | 0.75 |
| 1990 | 0.00 | 0.00 | 0.57 | 2.65 | 1.02 | 0.54 | 0.17 | 0.06 | 0.04 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.09 | 0.75 |
| 1991 | 0.00 | 0.03 | 0.71 | 1.63 | 2.33 | 0.92 | 0.15 | 0.07 | 0.04 | 0.02 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 5.91 | 1.05 |
| 1992 | 0.00 | 0.06 | 0.34 | 1.15 | 0.88 | 1.07 | 0.43 | 0.11 | 0.04 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 4.11 | 1.36 |
| 1993 | 0.00 | 0.33 | 0.84 | 1.16 | 1.58 | 0.61 | 0.45 | 0.17 | 0.08 | 0.02 | 0.01 | 0.02 | 0.03 | 0.00 | 0.00 | 5.29 | 1.39 |
| 1994 | 0.00 | 0.03 | 1.43 | 1.14 | 1.12 | 0.75 | 0.23 | 0.10 | 0.03 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 4.88 | 0.85 |
| 1995 | 0.00 | 0.31 | 1.97 | 3.21 | 2.31 | 1.11 | 0.44 | 0.22 | 0.03 | 0.03 | 0.03 | 0.01 | 0.02 | 0.01 | 0.01 | 9.43 | 1.94 |
| 1996 | 0.00 | 0.02 | 0.47 | 1.94 | 3.30 | 1.31 | 0.53 | 0.20 | 0.05 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.83 | 1.69 |
| 1997 | 0.00 | 0.01 | 0.85 | 1.66 | 2.52 | 2.05 | 0.39 | 0.09 | 0.01 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 | 7.62 | 1.62 |
| 1998 | 0.00 | 0.06 | 0.19 | 1.02 | 1.12 | 1.22 | 0.68 | 0.16 | 0.06 | 0.01 | 0.01 | 0.003 | 0.01 | 0.00 | 0.00 | 4.52 | 1.11 |
| 1999 | 0.00 | 0.08 | 0.41 | 0.52 | 1.13 | 0.79 | 0.64 | 0.41 | 0.17 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 4.18 | 1.20 |
| 2000 | 0.00 | 0.03 | 1.91 | 2.48 | 2.22 | 1.60 | 0.86 | 0.60 | 0.15 | 0.07 | 0.02 | 0.003 | 0.01 | 0.00 | 0.00 | 9.96 | 2.30 |
| 2001 | 0.00 | 0.00 | 0.71 | 3.67 | 3.37 | 1.45 | 0.75 | 0.37 | 0.17 | 0.09 | 0.05 | 0.02 | 0.00 | 0.00 | 0.00 | 10.65 | 2.19 |
| 2002 | 0.00 | 0.10 | 0.35 | 0.98 | 2.35 | 1.66 | 0.51 | 0.33 | 0.20 | 0.14 | 0.07 | 0.01 | 0.00 | 0.00 | 0.00 | 6.70 | 1.76 |

Table H3a (continued). Standardized stratified mean number per tow by age and mean weight per tow (kg) of American plaice in NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine - Georges Bank[1] area, 1980-2002.

| | AGE GROUP | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | #/tow | kg/tow |
| **Autumn** | | | | | | | | | | | | | | | | | |
| 1980 | 0.00 | 1.58 | 2.22 | 2.72 | 2.85 | 1.53 | 1.03 | 0.93 | 0.57 | 0.31 | 0.20 | 0.11 | 0.04 | 0.07 | 0.08 | 14.24 | 5.12 |
| 1981 | 0.00 | 0.43 | 2.79 | 2.22 | 2.62 | 2.30 | 1.55 | 0.63 | 0.58 | 0.07 | 0.20 | 0.20 | 0.02 | 0.02 | 0.12 | 13.04 | 5.62 |
| 1982 | 0.00 | 0.20 | 0.91 | 1.65 | 1.27 | 0.57 | 0.48 | 0.30 | 0.17 | 0.19 | 0.08 | 0.03 | 0.00 | 0.00 | 0.02 | 5.88 | 2.49 |
| 1983 | 0.06 | 0.50 | 1.01 | 2.02 | 2.92 | 1.36 | 0.68 | 0.34 | 0.17 | 0.10 | 0.03 | 0.05 | 0.06 | 0.01 | 0.03 | 9.34 | 3.45 |
| 1984 | 0.02 | 0.22 | 2.24 | 1.56 | 1.21 | 1.07 | 0.51 | 0.12 | 0.10 | 0.00 | 0.03 | 0.01 | 0.02 | 0.00 | 0.01 | 7.12 | 2.02 |
| 1985 | 0.02 | 0.91 | 0.83 | 2.64 | 1.05 | 0.79 | 0.41 | 0.19 | 0.05 | 0.03 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 6.95 | 2.00 |
| 1986 | 0.10 | 0.51 | 1.48 | 0.89 | 1.45 | 0.47 | 0.43 | 0.16 | 0.12 | 0.04 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 5.61 | 1.56 |
| 1987 | 0.01 | 0.53 | 1.27 | 0.99 | 0.43 | 0.69 | 0.25 | 0.10 | 0.04 | 0.04 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 4.38 | 1.09 |
| 1988 | 0.00 | 2.84 | 2.97 | 2.39 | 0.78 | 0.47 | 0.10 | 0.07 | 0.00 | 0.03 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 9.69 | 1.46 |
| 1989 | 0.05 | 0.48 | 4.45 | 2.86 | 0.98 | 0.19 | 0.10 | 0.02 | 0.02 | 0.02 | 0.02 | 0.00 | 0.01 | 0.02 | 0.00 | 9.21 | 1.17 |
| 1990 | 0.01 | 1.52 | 2.26 | 7.49 | 2.89 | 0.59 | 0.25 | 0.11 | 0.07 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | 0.01 | 15.46 | 2.90 |
| 1991 | 0.02 | 0.47 | 2.48 | 2.03 | 1.59 | 0.73 | 0.30 | 0.04 | 0.07 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 7.71 | 1.56 |
| 1992 | 0.02 | 0.65 | 1.23 | 1.85 | 1.28 | 0.78 | 0.30 | 0.07 | 0.05 | 0.03 | 0.02 | 0.00 | 0.02 | 0.00 | 0.00 | 6.31 | 1.78 |
| 1993 | 0.01 | 1.71 | 2.35 | 3.47 | 2.28 | 1.05 | 0.80 | 0.11 | 0.04 | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 11.89 | 2.39 |
| 1994 | 0.04 | 3.83 | 7.53 | 2.81 | 1.71 | 1.30 | 0.04 | 0.25 | 0.13 | 0.01 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 18.07 | 2.67 |
| 1995 | 0.01 | 0.50 | 3.80 | 3.82 | 2.50 | 0.90 | 0.22 | 0.04 | 0.03 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 11.84 | 2.58 |
| 1996 | 0.01 | 0.54 | 0.81 | 2.00 | 2.74 | 0.93 | 0.39 | 0.07 | 0.04 | 0.03 | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 | 7.58 | 2.23 |
| 1997 | 0.01 | 0.36 | 1.06 | 1.55 | 1.86 | 1.04 | 0.32 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 6.27 | 1.94 |
| 1998 | 0.01 | 1.73 | 0.60 | 1.88 | 2.01 | 1.78 | 1.08 | 0.12 | 0.05 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 9.29 | 2.22 |
| 1999 | 0.02 | 2.00 | 2.20 | 2.05 | 2.13 | 1.60 | 0.81 | 0.20 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.03 | 2.57 |
| 2000 | 0.03 | 0.47 | 2.90 | 3.91 | 2.28 | 1.35 | 0.75 | 0.33 | 0.14 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 12.23 | 2.79 |
| 2001 | 0.02 | 0.40 | 1.22 | 3.31 | 2.64 | 1.46 | 0.53 | 0.41 | 0.20 | 0.17 | 0.02 | 0.00 | 0.01 | 0.00 | 0.00 | 10.40 | 2.63 |

[1] Offshore strata 13-30, 36-40

Table H3b. Stratified mean number per tow by age of American plaice in Massachusetts spring and autumn bottom trawl surveys in Massachusetts Bay and Cape Cod Bay (Regions 4+5), 1982-2002.

| Year | Age 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total #/tow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring | | | | | | | | | | | | | |
| 1982 | 0.00 | 7.18 | 49.25 | 33.35 | 17.14 | 5.00 | 2.42 | 1.12 | 0.26 | 0.15 | 0.03 | 0.07 | 115.97 |
| 1983 | 0.00 | 1.93 | 18.76 | 22.42 | 21.46 | 10.22 | 2.37 | 0.73 | 0.20 | 0.19 | 0.06 | 0.10 | 78.44 |
| 1984 | 0.00 | 2.15 | 27.44 | 21.32 | 10.57 | 4.64 | 1.21 | 0.18 | 0.09 | 0.01 | 0.03 | 0.07 | 67.71 |
| 1985 | 0.00 | 21.56 | 17.16 | 24.22 | 9.50 | 3.77 | 2.24 | 0.65 | 0.76 | 0.12 | 0.04 | 0.03 | 80.05 |
| 1986 | 0.00 | 27.06 | 110.27 | 26.91 | 14.43 | 2.84 | 0.61 | 0.05 | 0.08 | 0.06 | 0.00 | 0.16 | 182.47 |
| 1987 | 0.00 | 34.36 | 17.26 | 15.79 | 3.90 | 1.76 | 0.51 | 0.10 | 0.02 | 0.00 | 0.00 | 0.00 | 73.70 |
| 1988 | 0.00 | 81.47 | 63.57 | 17.85 | 8.72 | 1.54 | 0.47 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 173.71 |
| 1989 | 0.00 | 8.07 | 127.26 | 44.97 | 11.99 | 3.03 | 1.31 | 0.20 | 0.03 | 0.03 | 0.00 | 0.05 | 196.94 |
| 1990 | 0.00 | 7.73 | 25.37 | 56.71 | 16.48 | 3.43 | 0.53 | 0.11 | 0.10 | 0.13 | 0.00 | 0.00 | 110.59 |
| 1991 | 0.00 | 2.10 | 19.98 | 34.77 | 18.98 | 3.24 | 0.18 | 0.07 | 0.01 | 0.00 | 0.00 | 0.00 | 79.33 |
| 1992 | 0.00 | 8.20 | 11.06 | 33.98 | 14.99 | 7.42 | 1.11 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 77.21 |
| 1993 | 0.00 | 11.60 | 18.98 | 16.08 | 9.16 | 3.45 | 0.81 | 0.04 | 0.02 | 0.00 | 0.00 | 0.00 | 60.14 |
| 1994 | 0.00 | 11.60 | 52.57 | 22.12 | 7.13 | 3.88 | 1.03 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 98.64 |
| 1995 | 0.00 | 0.54 | 34.65 | 49.64 | 10.32 | 3.16 | 0.62 | 0.17 | 0.03 | 0.05 | 0.02 | 0.00 | 99.20 |
| 1996 | 0.00 | 2.29 | 4.14 | 14.92 | 31.39 | 6.33 | 1.01 | 0.77 | 0.01 | 0.00 | 0.00 | 0.00 | 60.86 |
| 1997 | 0.00 | 1.55 | 7.96 | 13.95 | 17.24 | 12.21 | 2.41 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 55.52 |
| 1998 | 0.00 | 2.83 | 4.33 | 11.45 | 7.53 | 8.93 | 3.95 | 0.49 | 0.00 | 0.03 | 0.00 | 0.00 | 39.54 |
| 1999 | 0.00 | 1.35 | 11.65 | 11.65 | 15.11 | 7.57 | 3.96 | 1.62 | 0.35 | 0.01 | 0.00 | 0.00 | 53.27 |
| 2000 | 0.00 | 3.45 | 56.51 | 34.86 | 19.98 | 13.29 | 4.95 | 3.64 | 0.17 | 0.03 | 0.00 | 0.00 | 136.88 |
| 2001 | 0.00 | 0.07 | 4.75 | 23.71 | 17.03 | 4.74 | 2.18 | 0.95 | 0.48 | 0.15 | 0.10 | 0.03 | 54.19 |
| 2002 | 0.00 | 6.26 | 4.15 | 10.77 | 18.59 | 5.93 | 1.49 | 0.78 | 0.38 | 0.21 | 0.07 | 0.00 | 48.63 |
| Autumn | | | | | | | | | | | | | |
| 1982 | 0.17 | 13.24 | 15.46 | 10.22 | 5.11 | 1.14 | 0.56 | 0.14 | 0.05 | 0.05 | 0.01 | 0.08 | 46.23 |
| 1983 | 1.29 | 52.17 | 18.98 | 10.02 | 8.30 | 1.39 | 0.32 | 0.15 | 0.05 | 0.06 | 0.00 | 0.01 | 92.74 |
| 1984 | 0.11 | 3.14 | 13.24 | 4.27 | 1.83 | 0.77 | 0.24 | 0.04 | 0.05 | 0.00 | 0.00 | 0.00 | 23.69 |
| 1985 | 0.00 | 60.97 | 9.45 | 14.21 | 1.56 | 0.14 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 86.38 |
| 1986 | 0.23 | 41.27 | 40.08 | 12.07 | 5.30 | 0.39 | 0.13 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 99.48 |
| 1987 | 0.24 | 46.36 | 14.60 | 3.00 | 0.52 | 0.23 | 0.07 | 0.01 | 0.04 | 0.00 | 0.00 | 0.00 | 65.07 |
| 1988 | 0.00 | 85.63 | 41.28 | 13.98 | 1.34 | 0.45 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 142.76 |
| 1989 | 0.03 | 57.56 | 122.25 | 31.03 | 2.33 | 0.13 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 213.35 |
| 1990 | 0.08 | 31.99 | 14.20 | 20.12 | 3.93 | 0.21 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 70.56 |
| 1991 | 0.04 | 24.07 | 90.36 | 40.05 | 11.51 | 1.17 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 167.34 |
| 1992 | 0.00 | 46.33 | 12.99 | 29.79 | 11.04 | 1.38 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 101.66 |
| 1993 | 0.00 | 76.21 | 36.80 | 17.59 | 6.85 | 1.71 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 139.84 |
| 1994 | 0.00 | 36.71 | 79.31 | 10.76 | 2.91 | 1.56 | 0.23 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 131.62 |
| 1995 | 0.00 | 11.84 | 44.22 | 24.93 | 4.21 | 0.91 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 86.19 |
| 1996 | 0.09 | 16.25 | 19.25 | 27.55 | 13.96 | 1.39 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 78.78 |
| 1997 | 0.00 | 13.61 | 28.08 | 17.91 | 10.29 | 1.46 | 0.19 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 71.55 |
| 1998 | 0.16 | 34.56 | 6.12 | 13.80 | 7.10 | 3.76 | 0.62 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 66.13 |
| 1999 | 0.00 | 29.23 | 32.57 | 20.61 | 10.58 | 2.85 | 1.2 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 97.45 |
| 2000 | 0.03 | 6.26 | 25.67 | 19.42 | 6.01 | 2.99 | 1.07 | 0.35 | 0.03 | 0.02 | 0.00 | 0.00 | 61.85 |
| 2001 | 0.00 | 3.01 | 14.71 | 30.81 | 9.07 | 2.67 | 0.26 | 0.36 | 0.15 | 0.02 | 0.00 | 0.00 | 61.06 |

Table H4. Sampling of commercial American plaice landings, by market category, for the Gulf of Maine and Georges Bank areas (NAFO Division 5Y and 5Z), 1985-2001.

| | | **Small** | | | | **Medium** | | | | **Large** | | | | Total Number Samples | Number of tons landed / sample | | | Total Lengths Measured | Total Numbers Aged |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | | Sm. | Med. | Lrg. | | |
| 1985 | GB | 2 | 4 | 14 | 3 | --- | 2 | 2 | 2 | --- | 3 | 7 | 1 | 40 | | | | 537 | 828 |
| | GM | 2 | 5 | 5 | 5 | 3 | 1 | 9 | 5 | 1 | 10 | 6 | 5 | 57 | | | | 1885 | 1321 |
| | total | 4 | 9 | 19 | 8 | 3 | 3 | 11 | 7 | 1 | 13 | 13 | 6 | 97 | 49 | 55 | 116 | 2422 | 2149 |
| 1986 | GB | 3 | 6 | 5 | 3 | 2 | 4 | 3 | 2 | 1 | 4 | 3 | 2 | 38 | | | | 908 | 716 |
| | GM | 9 | 5 | 3 | 5 | 3 | 4 | 5 | 1 | 10 | 10 | 7 | 4 | 66 | | | | 1199 | 1420 |
| | total | 12 | 11 | 8 | 8 | 5 | 8 | 8 | 3 | 11 | 14 | 10 | 6 | 104 | 33 | 35 | 56 | 2107 | 2136 |
| 1987 | GB | 4 | 5 | 5 | 1 | --- | 2 | 3 | 2 | 2 | 4 | 4 | 1 | 33 | | | | 715 | 633 |
| | GM | 2 | 6 | 5 | 3 | 1 | 5 | 2 | 3 | 3 | 3 | 6 | 5 | 44 | | | | 1226 | 885 |
| | total | 6 | 11 | 10 | 4 | 1 | 7 | 5 | 5 | 5 | 7 | 10 | 6 | 77 | 39 | 40 | 63 | 1941 | 1518 |
| 1988 | GB | 3 | 7 | 4 | 2 | 1 | 3 | 4 | 2 | 4 | 5 | 2 | 4 | 41 | | | | 1023 | 505 |
| | GM | 4 | 7 | 4 | 5 | 6 | 6 | 4 | 3 | 6 | 5 | 3 | 2 | 55 | | | | 2166 | 803 |
| | total | 7 | 14 | 8 | 7 | 7 | 9 | 8 | 5 | 10 | 10 | 5 | 6 | 96 | 34 | 21 | 40 | 3189 | 1308 |
| 1989 | GB | 2 | 5 | 5 | --- | 1 | 1 | 6 | 1 | 5 | 3 | 3 | --- | 32 | | | | 869 | 600 |
| | GM | 1 | 3 | 3 | 3 | 1 | --- | 4 | 3 | 2 | 1 | --- | 1 | 22 | | | | 863 | 432 |
| | total | 3 | 8 | 8 | 3 | 2 | 1 | 10 | 4 | 7 | 4 | 3 | 1 | 54 | 35 | 29 | 63 | 1732 | 1032 |
| 1990 | GB | --- | 5 | 6 | --- | 2 | 1 | 2 | 2 | --- | 2 | 5 | --- | 25 | | | | 698 | 494 |
| | GM | 5 | 5 | 3 | 3 | 1 | 6 | 3 | 5 | 1 | 5 | 3 | 5 | 45 | | | | 1558 | 938 |
| | total | 5 | 10 | 9 | 3 | 3 | 7 | 5 | 7 | 1 | 7 | 8 | 5 | 70 | 33 | 26 | 42 | 2256 | 1432 |
| 1991 | GB | --- | 3 | 1 | --- | 3 | 1 | 1 | --- | 3 | 3 | 2 | --- | 17 | | | | 494 | 123 |
| | GM | 5 | 3 | 7 | 6 | 3 | 1 | 4 | 3 | --- | 1 | 5 | 2 | 40 | | | | 1211 | 736 |
| | total | 5 | 6 | 8 | 6 | 6 | 2 | 5 | 3 | 3 | 4 | 7 | 2 | 57 | 78 | 67 | 67 | 1705 | 859 |
| 1992 | GB | --- | 4 | 1 | --- | --- | 1 | 1 | --- | --- | 2 | 2 | 1 | 12 | | | | 200 | 158 |
| | GM | 1 | 5 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 2 | 3 | 2 | 29 | | | | 1148 | 684 |
| | total | 1 | 9 | 3 | 2 | 1 | 5 | 4 | 2 | 2 | 4 | 5 | 3 | 41 | 168 | 143 | 155 | 1348 | 842 |
| 1993 | GB | --- | 2 | 1 | 1 | --- | 1 | --- | --- | --- | 3 | 2 | 1 | 11 | | | | 69 | 190 |
| | GM | 2 | 4 | 4 | 1 | --- | 2 | 2 | --- | --- | 1 | 2 | --- | 18 | | | | 445 | 251 |
| | total | 2 | 6 | 5 | 2 | 0 | 3 | 2 | 0 | 0 | 4 | 4 | 1 | 29 | 133 | 260 | 253 | 514 | 441 |
| 1994 | GB | --- | --- | --- | --- | --- | --- | 1 | 1 | --- | 1 | --- | 1 | 4 | | | | 204 | 52 |
| | GM | --- | 2 | 5 | 3 | --- | 4 | 3 | 3 | --- | 2 | 3 | 3 | 28 | | | | 1307 | 458 |
| | total | 0 | 2 | 5 | 3 | 0 | 4 | 4 | 4 | 0 | 3 | 3 | 4 | 32 | 205 | 97 | 181 | 1511 | 510 |
| 1995 | GB | 1 | --- | --- | --- | 1 | --- | --- | --- | 1 | --- | --- | --- | 3 | | | | 149 | 44 |
| | GM | 1 | 3 | --- | 2 | --- | 2 | --- | --- | --- | 2 | --- | 1 | 11 | | | | 276 | 149 |
| | total | 2 | 3 | 0 | 2 | 1 | 2 | 0 | 0 | 1 | 2 | 0 | 1 | 14 | 323 | 336 | 332 | 425 | 193 |
| 1996 | GB | --- | 2 | 2 | 1 | --- | 1 | 4 | --- | --- | 2 | 1 | 1 | 14 | | | | 852 | 222 |
| | GM | 2 | 3 | 2 | 1 | 2 | 1 | 3 | 5 | 3 | 1 | 4 | 2 | 29 | | | | 1582 | 435 |
| | total | 2 | 5 | 4 | 2 | 2 | 2 | 7 | 5 | 3 | 3 | 5 | 3 | 43 | 189 | 53 | 75 | 2434 | 657 |
| 1997 | GB | 2 | 4 | 2 | 3 | --- | 2 | 3 | 1 | --- | 2 | --- | --- | 19 | | | | 460 | 231 |
| | GM | 4 | 4 | 3 | 1 | 2 | 3 | 3 | --- | 1 | 5 | 3 | 2 | 31 | | | | 1138 | 489 |
| | total | 6 | 8 | 5 | 4 | 2 | 5 | 6 | 1 | 1 | 7 | 3 | 2 | 50 | 82 | 77 | 69 | 1598 | 720 |
| 1998 | GB | 1 | 4 | 1 | --- | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | | | | 1440 | 247 |
| | GM | 2 | 3 | 1 | 1 | 6 | 3 | 7 | 7 | 2 | 2 | 2 | 2 | 38 | | | | 3994 | 577 |
| | total | 3 | 7 | 2 | 1 | 8 | 4 | 8 | 8 | 3 | 3 | 3 | 3 | 53 | 111 | 41 | 87 | 5434 | 824 |
| 1999 | GB | 4 | 4 | --- | 1 | 5 | 2 | 1 | --- | --- | 4 | 1 | --- | 22 | | | | 2356 | 308 |
| | GM | 6 | 8 | 6 | 9 | 7 | 4 | 5 | 7 | 1 | 6 | 3 | 2 | 64 | | | | 6428 | 967 |
| | total | 10 | 12 | 6 | 10 | 12 | 6 | 6 | 7 | 1 | 10 | 4 | 2 | 86 | 31 | 29 | 61 | 8784 | 1275 |
| 2000 | GB | 14 | 11 | 3 | 1 | 1 | 2 | --- | 1 | 2 | 2 | 2 | 2 | 41 | | | | 2546 | 412 |
| | GM | 14 | 28 | 4 | 1 | 2 | 7 | 3 | --- | --- | 4 | 1 | 3 | 67 | | | | 4567 | 743 |
| | total | 28 | 39 | 7 | 2 | 3 | 9 | 3 | 1 | 2 | 6 | 3 | 5 | 108 | 22 | 79 | 78 | 7113 | 1155 |
| 2001 | GB | 4 | 2 | 1 | 2 | --- | 2 | 2 | 3 | --- | 3 | 2 | 1 | 22 | | | | 2143 | 228 |
| | GM | 4 | 3 | 4 | --- | 3 | 2 | 2 | 2 | 4 | 2 | 1 | 4 | 31 | | | | 3089 | 435 |
| | total | 8 | 5 | 5 | 2 | 3 | 4 | 4 | 5 | 4 | 5 | 3 | 5 | 53 | 87 | 79 | 81 | 5232 | 663 |

Table H5. Catch at age (thousands of fish; metric tons) and mean weight (kg), of commercial landings, large mesh and northern shrimp fishery discards of American plaice, ages 1-9+, from Gulf of Maine - Georges Bank, and South, 1980-2001.

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Catch in Numbers (000's) at Age | | | | | | |
| 1980 | 0 | 5 | 99 | 1072 | 2672 | 3939 | 3933 | 3632 | 1185 | 3369 | 19906 |
| 1981 | 0 | 5 | 982 | 2192 | 5055 | 5337 | 3648 | 2401 | 1582 | 1706 | 22907 |
| 1982 | 0 | 10 | 603 | 3348 | 4574 | 4503 | 3599 | 3297 | 2038 | 2710 | 24681 |
| 1983 | 0 | 15 | 663 | 1478 | 5177 | 4918 | 3913 | 2270 | 1272 | 2062 | 21768 |
| 1984 | 0 | 3 | 370 | 991 | 2422 | 6031 | 3244 | 1936 | 580 | 1350 | 16927 |
| 1985 | 0 | 65 | 158 | 1217 | 1336 | 2405 | 2872 | 2228 | 1081 | 887 | 12250 |
| 1986 | 0 | 59 | 639 | 738 | 2284 | 1700 | 1476 | 1307 | 631 | 460 | 9295 |
| 1987 | 0 | 38 | 590 | 1840 | 1439 | 2282 | 1337 | 895 | 543 | 309 | 9274 |
| 1988 | 0 | 314 | 786 | 1840 | 1833 | 1597 | 1444 | 553 | 270 | 321 | 8957 |
| 1989 | 0 | 132 | 1653 | 1831 | 1125 | 829 | 536 | 753 | 471 | 411 | 7740 |
| 1990 | 0 | 68 | 676 | 3389 | 2664 | 1369 | 531 | 291 | 349 | 450 | 9787 |
| 1991 | 0 | 13 | 323 | 1001 | 4410 | 3403 | 1123 | 321 | 164 | 402 | 11161 |
| 1992 | 0 | 37 | 231 | 1083 | 2222 | 6810 | 2724 | 819 | 198 | 342 | 14467 |
| 1993 | 0 | 107 | 426 | 2032 | 4141 | 3583 | 3139 | 1403 | 265 | 563 | 15658 |
| 1994 | 1 | 288 | 506 | 623 | 2627 | 4459 | 1703 | 1288 | 608 | 688 | 12791 |
| 1995 | 1 | 518 | 1488 | 2285 | 6503 | 4826 | 2001 | 654 | 584 | 315 | 19174 |
| 1996 | 0 | 195 | 936 | 1418 | 4443 | 2958 | 1471 | 549 | 250 | 224 | 12444 |
| 1997 | 0 | 158 | 1375 | 803 | 2739 | 3919 | 1701 | 718 | 230 | 335 | 11978 |
| 1998 | 0 | 37 | 63 | 281 | 883 | 2607 | 2476 | 1044 | 320 | 272 | 7983 |
| 1999 | 0 | 4 | 202 | 205 | 985 | 1713 | 2073 | 1273 | 463 | 261 | 7180 |
| 2000 | 0 | 3 | 320 | 744 | 1229 | 1838 | 2354 | 1676 | 560 | 220 | 8944 |
| 2001 | 0 | 0 | 85 | 520 | 1322 | 2470 | 2063 | 1649 | 935 | 439 | 9485 |

Table H5. (continued) Catch at age (thousands of fish; metric tons) and mean weight (kg), of commercial landings, large mesh and northern shrimp fishery
continued discards of American plaice, ages 1-9+, from Gulf of Maine - Georges Bank, and South, 1980-2001.

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean Weight at age (kg) | | | | | |
| 1980 | 0.000 | 0.030 | 0.076 | 0.154 | 0.267 | 0.409 | 0.653 | 0.829 | 1.039 | 1.523 | 0.725 |
| 1981 | 0.000 | 0.032 | 0.108 | 0.168 | 0.316 | 0.442 | 0.778 | 0.885 | 0.978 | 1.315 | 0.576 |
| 1982 | 0.000 | 0.018 | 0.115 | 0.230 | 0.290 | 0.418 | 0.564 | 0.960 | 1.138 | 1.479 | 0.631 |
| 1983 | 0.002 | 0.013 | 0.033 | 0.185 | 0.378 | 0.530 | 0.670 | 0.823 | 1.042 | 1.479 | 0.630 |
| 1984 | 0.000 | 0.004 | 0.045 | 0.161 | 0.303 | 0.524 | 0.630 | 0.888 | 1.187 | 1.657 | 0.636 |
| 1985 | 0.000 | 0.018 | 0.058 | 0.084 | 0.209 | 0.331 | 0.534 | 0.847 | 1.167 | 1.618 | 0.596 |
| 1986 | 0.001 | 0.016 | 0.042 | 0.138 | 0.229 | 0.384 | 0.587 | 0.842 | 1.174 | 1.702 | 0.516 |
| 1987 | 0.000 | 0.013 | 0.046 | 0.131 | 0.234 | 0.409 | 0.609 | 0.892 | 1.173 | 1.688 | 0.465 |
| 1988 | 0.000 | 0.016 | 0.046 | 0.159 | 0.284 | 0.449 | 0.641 | 0.880 | 1.231 | 1.630 | 0.429 |
| 1989 | 0.000 | 0.012 | 0.041 | 0.135 | 0.275 | 0.446 | 0.566 | 0.736 | 0.857 | 1.537 | 0.373 |
| 1990 | 0.000 | 0.021 | 0.058 | 0.138 | 0.265 | 0.455 | 0.639 | 0.824 | 0.968 | 1.352 | 0.344 |
| 1991 | 0.000 | 0.015 | 0.053 | 0.120 | 0.330 | 0.498 | 0.710 | 0.960 | 1.161 | 1.479 | 0.464 |
| 1992 | 0.000 | 0.028 | 0.065 | 0.159 | 0.315 | 0.485 | 0.717 | 0.948 | 1.202 | 1.617 | 0.533 |
| 1993 | 0.000 | 0.016 | 0.078 | 0.212 | 0.304 | 0.434 | 0.590 | 0.936 | 1.234 | 1.647 | 0.492 |
| 1994 | 0.001 | 0.014 | 0.028 | 0.194 | 0.328 | 0.418 | 0.564 | 0.763 | 1.083 | 1.807 | 0.525 |
| 1995 | 0.001 | 0.012 | 0.027 | 0.203 | 0.322 | 0.453 | 0.646 | 0.909 | 1.166 | 1.399 | 0.407 |
| 1996 | 0.000 | 0.014 | 0.038 | 0.110 | 0.338 | 0.474 | 0.637 | 0.902 | 1.172 | 1.657 | 0.418 |
| 1997 | 0.000 | 0.014 | 0.021 | 0.111 | 0.316 | 0.402 | 0.605 | 0.746 | 0.951 | 1.565 | 0.407 |
| 1998 | 0.001 | 0.013 | 0.030 | 0.165 | 0.281 | 0.371 | 0.518 | 0.805 | 1.031 | 2.482 | 0.550 |
| 1999 | 0.000 | 0.008 | 0.018 | 0.198 | 0.324 | 0.417 | 0.535 | 0.702 | 0.879 | 1.401 | 0.537 |
| 2000 | 0.000 | 0.013 | 0.031 | 0.221 | 0.314 | 0.436 | 0.538 | 0.732 | 1.002 | 1.234 | 0.524 |
| 2001 | 0.000 | 0.000 | 0.018 | 0.131 | 0.297 | 0.418 | 0.518 | 0.681 | 0.823 | 1.130 | 0.522 |
| 1980-2001 | 0.001 | 0.016 | 0.049 | 0.159 | 0.296 | 0.437 | 0.611 | 0.841 | 1.075 | 1.564 | 0.514 |
| 1997-2001 | 0.001 | 0.012 | 0.024 | 0.165 | 0.306 | 0.409 | 0.543 | 0.733 | 0.937 | 1.562 | 0.508 |

Table H6. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F) and spawning stock biomass (mt) of Gulf of Maine-Georges Bank American plaice, estimated from virtual population analysis (VPA) and calibrated using the commercial catch at age ADAPT formulation, 1980-2001.

**Stock Numbers (Jan 1 ) in thousands**

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 52640 | 25117 | 21944 | 25115 | 13179 | 14379 | 18433 | 36791 | 53241 | 27075 | 33006 | 33292 | 40176 | 44722 | 40917 | 31176 | 29111 | 21210 | 34525 | 39965 | 14071 | 4015 | 39260 |
| 2 | 42215 | 43094 | 20559 | 17957 | 20548 | 10787 | 11714 | 15038 | 30088 | 43306 | 22048 | 26961 | 27245 | 32860 | 36518 | 33240 | 25056 | 23658 | 17223 | 28233 | 32717 | 11517 | 3287 |
| 3 | 35914 | 34473 | 34394 | 16287 | 14102 | 16489 | 8689 | 9012 | 11778 | 23923 | 33961 | 17440 | 21782 | 22097 | 26518 | 29441 | 25868 | 19667 | 18125 | 14044 | 22932 | 26497 | 9353 |
| 4 | 24231 | 28434 | 26241 | 25130 | 11997 | 10649 | 12399 | 6446 | 5714 | 7978 | 17929 | 24738 | 13373 | 16853 | 16253 | 21148 | 22037 | 19896 | 15376 | 14585 | 11313 | 18102 | 21223 |
| 5 | 21550 | 17421 | 18706 | 17345 | 15890 | 7631 | 7510 | 8085 | 3976 | 3020 | 5514 | 12269 | 16263 | 8938 | 10052 | 10930 | 11430 | 14022 | 13811 | 11790 | 11050 | 8150 | 13625 |
| 6 | 17203 | 14080 | 9434 | 11240 | 9751 | 7553 | 4072 | 4610 | 4554 | 1810 | 1722 | 3276 | 6966 | 7153 | 4076 | 4195 | 4582 | 6682 | 7934 | 8949 | 8102 | 7384 | 4438 |
| 7 | 11092 | 10526 | 8227 | 4467 | 5662 | 5048 | 3585 | 1998 | 2565 | 2422 | 997 | 929 | 1666 | 3238 | 3016 | 1796 | 1624 | 2420 | 3931 | 4255 | 5451 | 4504 | 4179 |
| 8 | 5101 | 5795 | 6445 | 3752 | 1603 | 2884 | 2117 | 1752 | 826 | 1600 | 1302 | 553 | 471 | 623 | 1382 | 1304 | 879 | 833 | 1332 | 2274 | 2332 | 2946 | 2195 |
| 9+ | 14407 | 6202 | 8496 | 6025 | 3694 | 2342 | 1531 | 989 | 973 | 1384 | 1666 | 1344 | 803 | 1307 | 1544 | 694 | 781 | 1204 | 1125 | 1274 | 910 | 1371 | 2295 |
| 1 + | 224352 | 185140 | 154444 | 127318 | 96428 | 77763 | 70049 | 84722 | 113716 | 112518 | 118145 | 120802 | 128745 | 137793 | 140277 | 133924 | 121368 | 109592 | 113381 | 125369 | 108878 | 84486 | 99854 |

**Fishing Mortality**

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.01 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | 0.06 | 0.04 | 0.03 | 0.04 | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.04 | 0.07 | 0 | 0.01 | 0.01 | 0.01 |
| 3 | 0.03 | 0.07 | 0.11 | 0.11 | 0.08 | 0.09 | 0.1 | 0.26 | 0.19 | 0.09 | 0.12 | 0.07 | 0.06 | 0.11 | 0.03 | 0.09 | 0.06 | 0.05 | 0.02 | 0.02 | 0.04 | 0.02 |
| 4 | 0.13 | 0.22 | 0.21 | 0.26 | 0.25 | 0.15 | 0.23 | 0.28 | 0.44 | 0.17 | 0.18 | 0.22 | 0.2 | 0.32 | 0.2 | 0.42 | 0.25 | 0.17 | 0.07 | 0.08 | 0.13 | 0.08 |
| 5 | 0.23 | 0.41 | 0.31 | 0.38 | 0.54 | 0.43 | 0.29 | 0.37 | 0.59 | 0.36 | 0.32 | 0.37 | 0.62 | 0.59 | 0.67 | 0.67 | 0.34 | 0.37 | 0.23 | 0.18 | 0.2 | 0.41 |
| 6 | 0.29 | 0.34 | 0.55 | 0.49 | 0.46 | 0.55 | 0.51 | 0.39 | 0.43 | 0.4 | 0.42 | 0.48 | 0.57 | 0.66 | 0.62 | 0.75 | 0.44 | 0.33 | 0.42 | 0.3 | 0.39 | 0.37 |
| 7 | 0.45 | 0.29 | 0.59 | 0.82 | 0.47 | 0.67 | 0.52 | 0.68 | 0.27 | 0.42 | 0.39 | 0.48 | 0.78 | 0.65 | 0.64 | 0.51 | 0.47 | 0.4 | 0.35 | 0.4 | 0.42 | 0.52 |
| 8 | 0.3 | 0.36 | 0.43 | 0.47 | 0.51 | 0.53 | 0.4 | 0.42 | 0.45 | 0.39 | 0.35 | 0.4 | 0.63 | 0.64 | 0.67 | 0.68 | 0.38 | 0.36 | 0.31 | 0.25 | 0.31 | 0.43 |
| 9+ | 0.3 | 0.36 | 0.43 | 0.47 | 0.51 | 0.53 | 0.4 | 0.42 | 0.45 | 0.39 | 0.35 | 0.4 | 0.63 | 0.64 | 0.67 | 0.68 | 0.38 | 0.36 | 0.31 | 0.25 | 0.31 | 0.43 |
| mn 5-8,u | 0.32 | 0.35 | 0.47 | 0.54 | 0.50 | 0.55 | 0.43 | 0.47 | 0.44 | 0.39 | 0.37 | 0.43 | 0.65 | 0.64 | 0.65 | 0.65 | 0.41 | 0.37 | 0.33 | 0.28 | 0.33 | 0.43 |

Table H6 continued.

**SSB at the start of the spawning season - males and females (mt)**

| age | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | 12 | 8 | 5 | 0 | 5 | 11 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 164 | 186 | 95 | 32 | 37 | 12 | 71 | 92 | 14 | 21 | 11 | 17 | 16 | 15 | 7 | 6 | 5 | 4 | 10 | 12 | 15 | 5 |
| 3 | 878 | 873 | 1206 | 529 | 230 | 225 | 395 | 327 | 156 | 299 | 400 | 230 | 320 | 287 | 370 | 246 | 157 | 144 | 182 | 184 | 245 | 289 |
| 4 | 2413 | 2943 | 2719 | 3438 | 1320 | 929 | 1285 | 853 | 611 | 988 | 2003 | 3084 | 1525 | 1955 | 2331 | 2720 | 3094 | 2027 | 1553 | 1917 | 1583 | 2633 |
| 5 | 4546 | 4061 | 4723 | 4651 | 4638 | 1633 | 1787 | 2036 | 995 | 878 | 1611 | 3634 | 4980 | 2555 | 2704 | 3183 | 3673 | 4218 | 3899 | 3377 | 3456 | 2332 |
| 6 | 7938 | 6457 | 3632 | 4659 | 4446 | 3084 | 1488 | 1908 | 1971 | 778 | 780 | 1556 | 3405 | 3053 | 1627 | 1703 | 2077 | 3105 | 3065 | 3491 | 3283 | 3012 |
| 7 | 7051 | 6935 | 5724 | 2308 | 3614 | 2906 | 2011 | 1160 | 1668 | 1425 | 588 | 614 | 1068 | 2144 | 1641 | 1076 | 1048 | 1436 | 2393 | 2208 | 2926 | 2277 |
| 8 | 4181 | 4535 | 5528 | 3174 | 1326 | 2443 | 1817 | 1492 | 736 | 1197 | 957 | 466 | 411 | 547 | 1121 | 986 | 785 | 670 | 1029 | 1707 | 1723 | 1952 |
| 9+ | 19379 | 7092 | 10734 | 7538 | 5125 | 3153 | 2243 | 1430 | 1349 | 1834 | 1962 | 1712 | 1056 | 1748 | 2247 | 779 | 1120 | 1636 | 2458 | 1593 | 989 | 1323 |
| Total | 46575 | 33094 | 34369 | 26333 | 20739 | 14391 | 11108 | 9315 | 7501 | 7420 | 8312 | 11313 | 12781 | 12303 | 12048 | 10699 | 11960 | 13240 | 14589 | 14490 | 14220 | 13822 |

**Percent Mature (females)**

| age | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3 | 3 | 3 | 3 | 3 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 8 | 8 | 8 | 8 | 8 | 8 | 24 | 24 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 |
| 3 | 24 | 24 | 24 | 24 | 24 | 24 | 55 | 55 | 17 | 17 | 17 | 17 | 17 | 12 | 12 | 12 | 12 | 12 | 18 | 18 | 18 | 18 |
| 4 | 52 | 52 | 52 | 52 | 52 | 52 | 83 | 83 | 65 | 65 | 65 | 65 | 65 | 60 | 60 | 60 | 60 | 60 | 61 | 61 | 61 | 61 |
| 5 | 79 | 79 | 79 | 79 | 79 | 79 | 95 | 95 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 92 | 92 | 92 | 92 |
| 6 | 93 | 93 | 93 | 93 | 93 | 93 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| 7 | 98 | 98 | 98 | 98 | 98 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 8 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Table H7. Input parameters and results of stochastic projection analysis using an empirical resampling model for Gulf of Maine-Georges Bank American plaice for 2002-2009 for $F_{2002} = 0.85F_{2001}$.

**Input for Projections**:

| Age | Fishing Mortality(PR) | Discard Fraction | % Mature | Average Weight Stock | Average Weight Landed | Average Weight Discarded |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 1.00 | 0.00 | 0.001 | 0.009 | 0.011 |
| 2 | 0.03 | 1.00 | 0.03 | 0.172 | 0.015 | 0.022 |
| 3 | 0.07 | 0.92 | 0.18 | 0.391 | 0.068 | 0.165 |
| 4 | 0.28 | 0.70 | 0.61 | 0.432 | 0.246 | 0.260 |
| 5 | 0.72 | 0.29 | 0.92 | 0.478 | 0.360 | 0.287 |
| 6 | 1.00 | 0.14 | 0.99 | 0.568 | 0.465 | 0.297 |
| 7 | 1.00 | 0.07 | 1.00 | 0.735 | 0.612 | 0.297 |
| 8 | 1.00 | 0.03 | 1.00 | 0.919 | 0.819 | 0.334 |
| 9 | 1.00 | 0.02 | 1.00 | 1.268 | 1.255 | 0.415 |

**Projection results for 2002-2004**

| Year | Recruitment (000 fish) | | F | Median Landings (000 mt) | Median Discards (000 mt) | Median SSB (000 mt) |
|---|---|---|---|---|---|---|
| F2002= 0.85 F2001 | | | | | | |
| 2002 | 30174 | | 0.37 | 4.030 | 0.711 | 15.269 |
| 2003 | 30121 | $F_{rebuild}$ | 0.10 | 1.336 | 0.161 | 15.938 |
| 2004 | 30101 | | 0.10 | 1.562 | 0.128 | 17.038 |

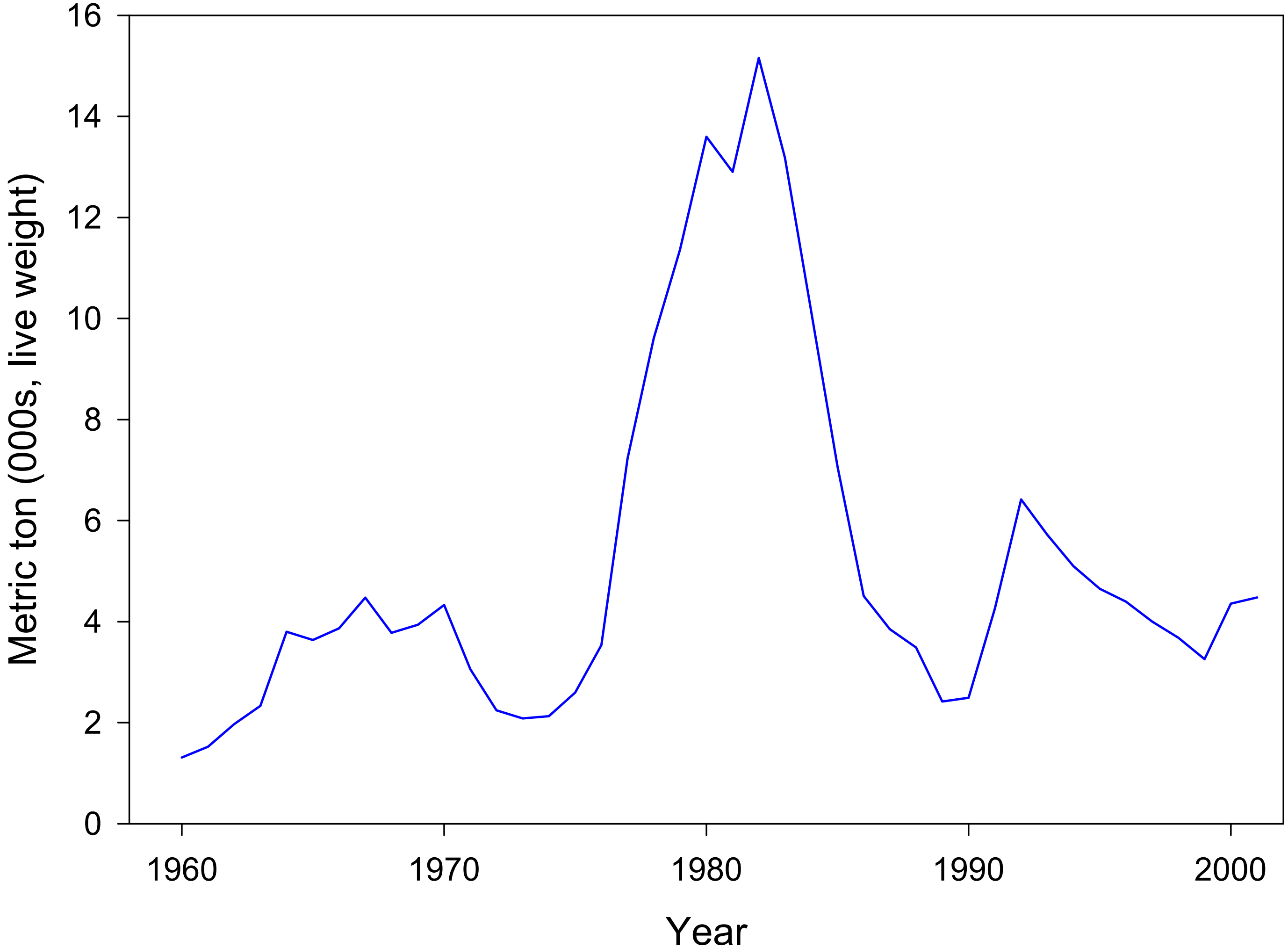


Figure H1. Total commercial landings of Gulf of Maine-Georges Bank American plaice (Division 5Z and 6), 1960-2001.

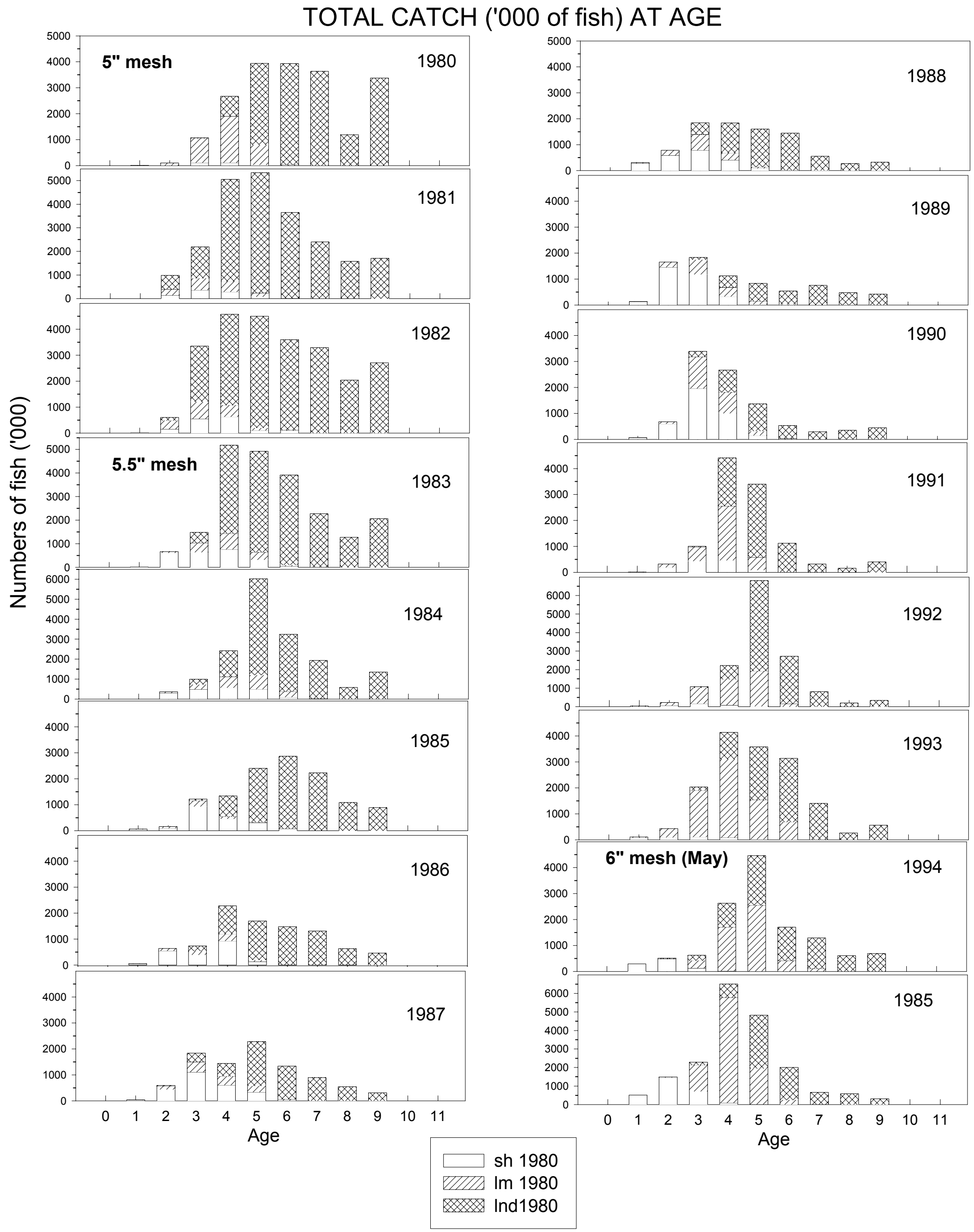


Figure H2. Number of American plaice ('000 of fish) at age in the total catch (discards from shrimp and large mesh fisheries, and landings), 1980 - 2001.

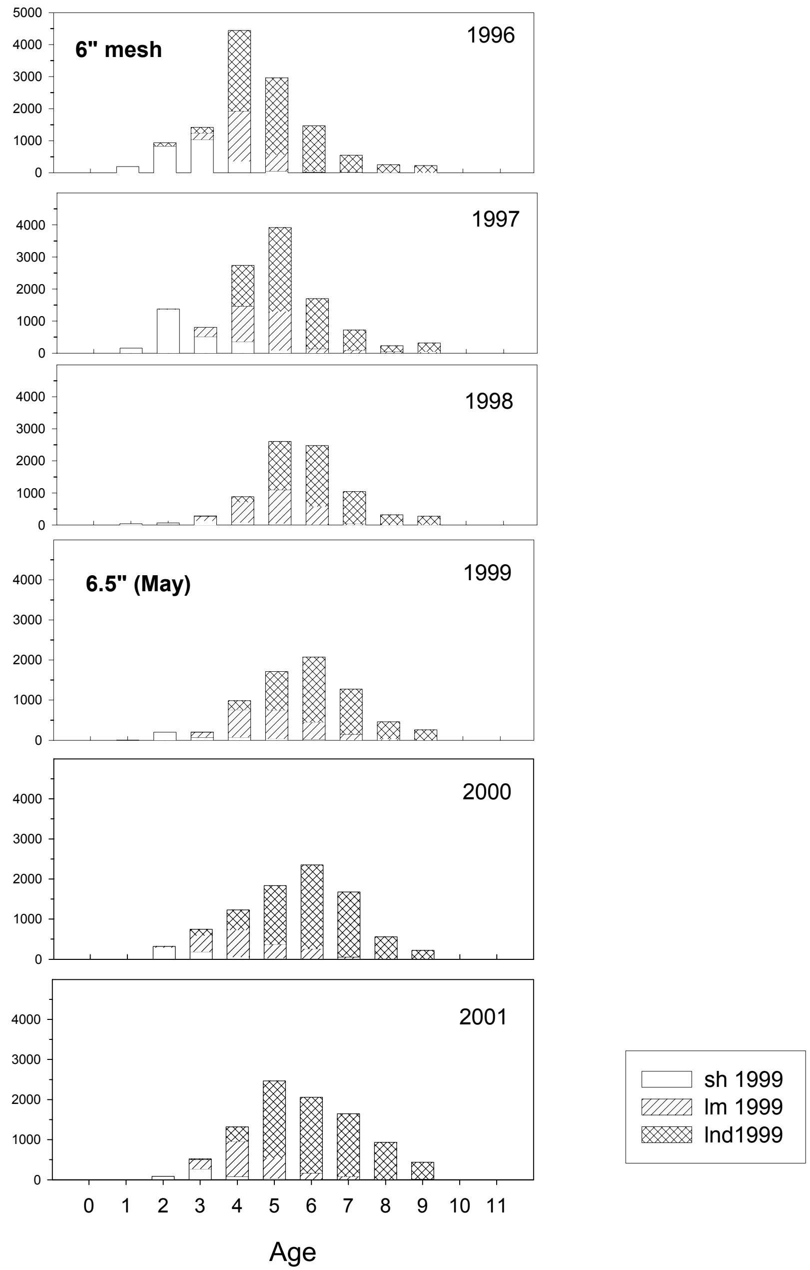


Figure H2 continued.

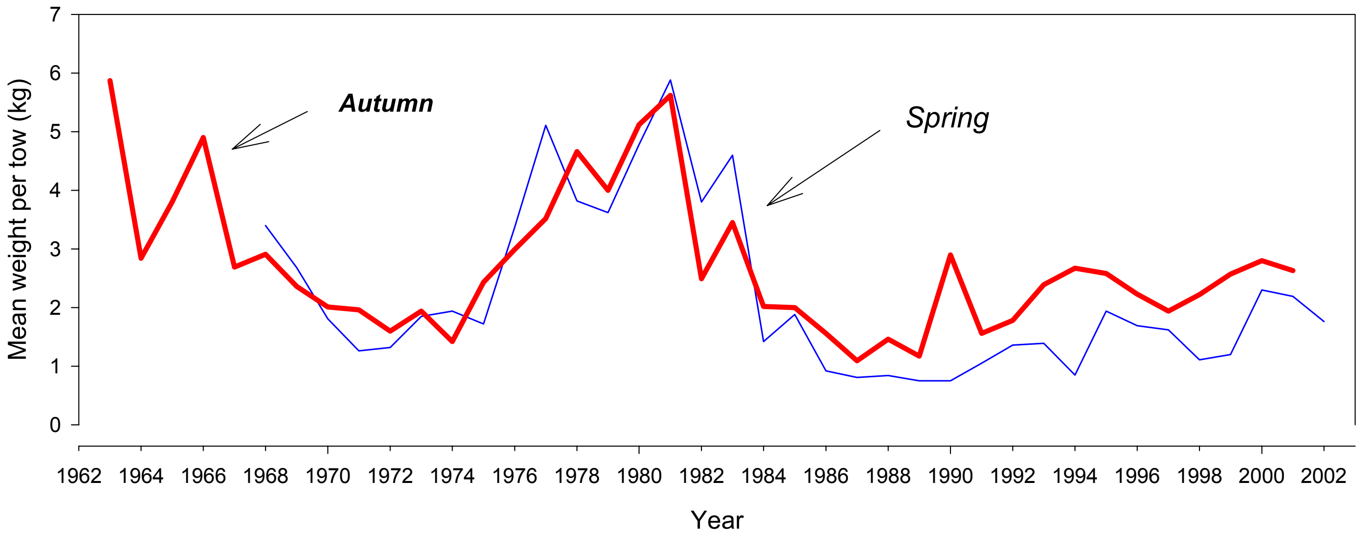


Figure H3. Standardized stratified mean weight per tow (kg) of American plaice in NEFSC spring and autumn research vessel bottom trawl survey in the Gulf of Maine-Georges Bank region, 1963-2002.

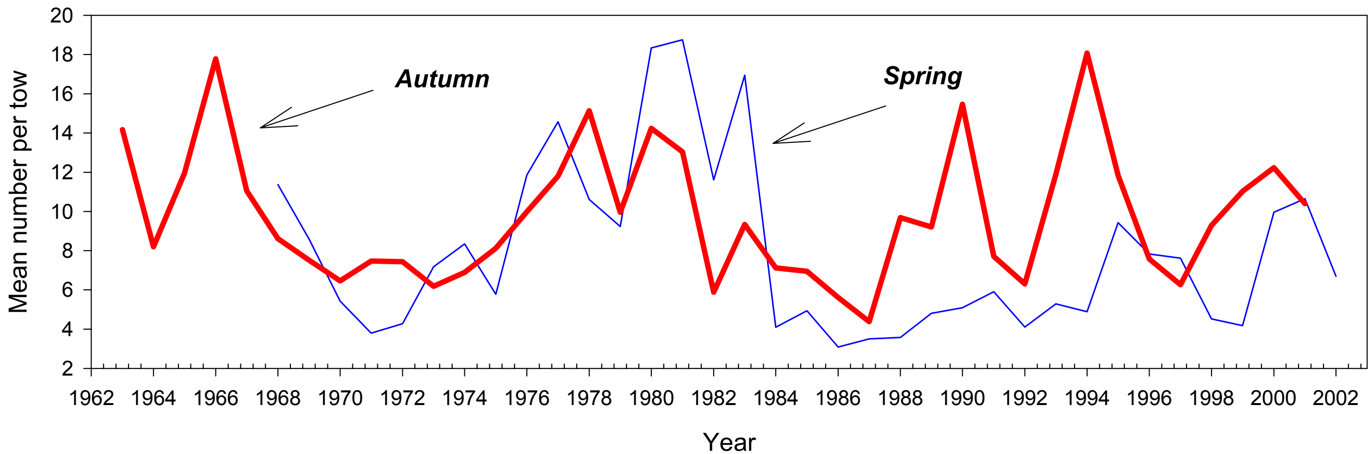


Figure H4. Standardized stratified mean number per tow of American plaice in NEFSC spring and autumn research vessel bottom trawl survey in the Gulf of Maine-Georges Bank region, 1963-2002.

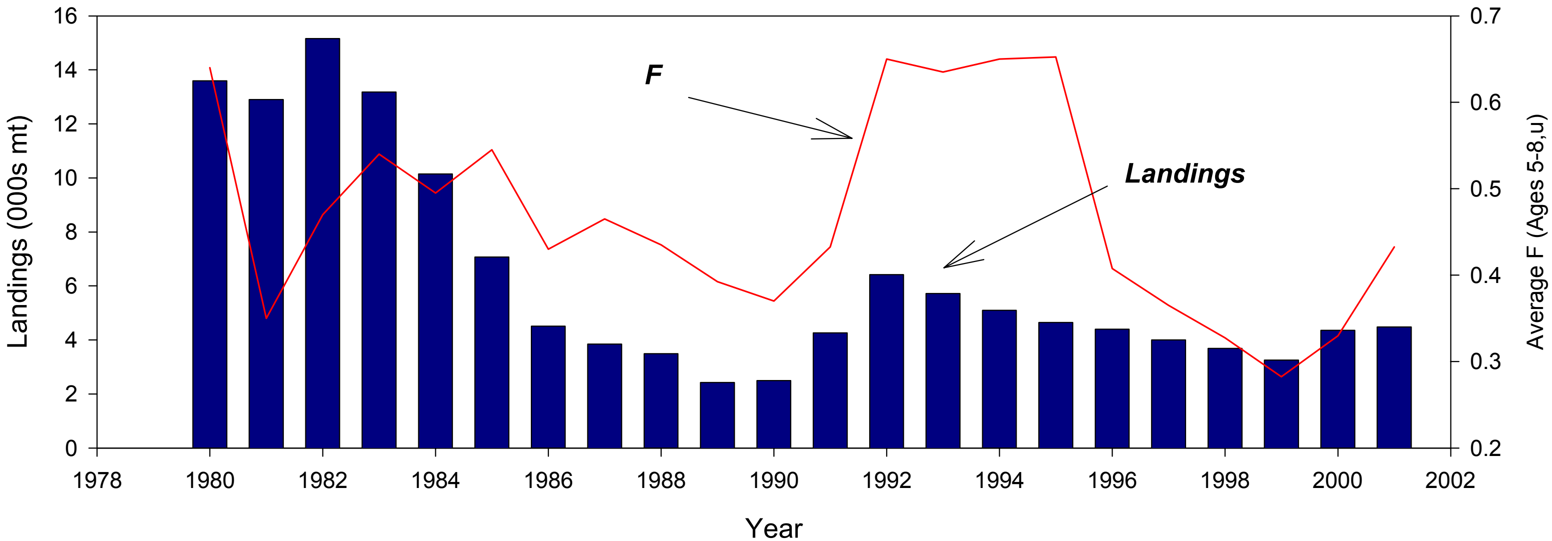


Figure H5. Trends in total commercial landings and fishing mortality for Gulf of Maine-Georges Bank American plaice, 1980-2001.

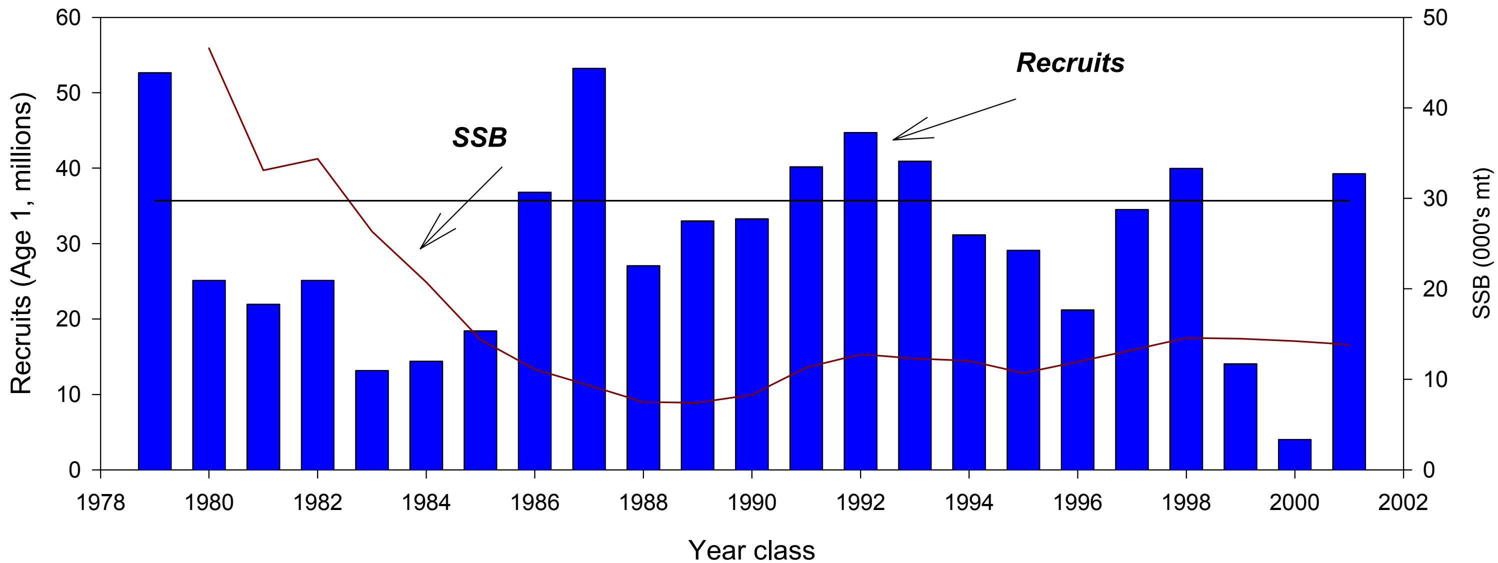


Figure H6. Trends in recruitment and spawning stock biomass for Gulf of Maine-Georges Bank American plaice, 1980-2001.

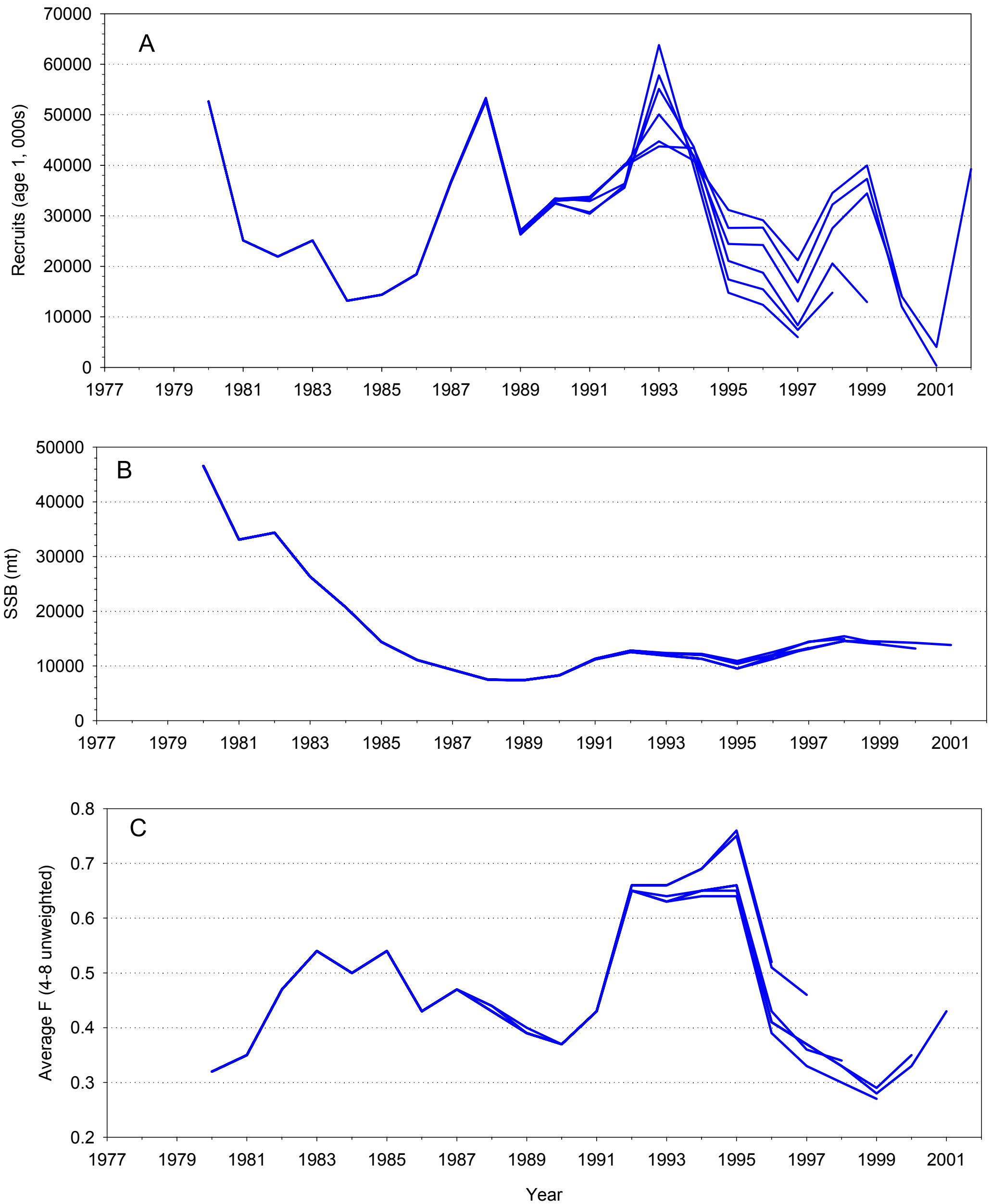


Figure H7. Retrospective analysis of Gulf of Maine-Georges Bank American plaice recruits at age 1(A), spawning stock biomass (B), and fishing mortality (C) (average F, aged 5-8, unweighted), based on the final ADAPT VPA formulation, 2001-1996.

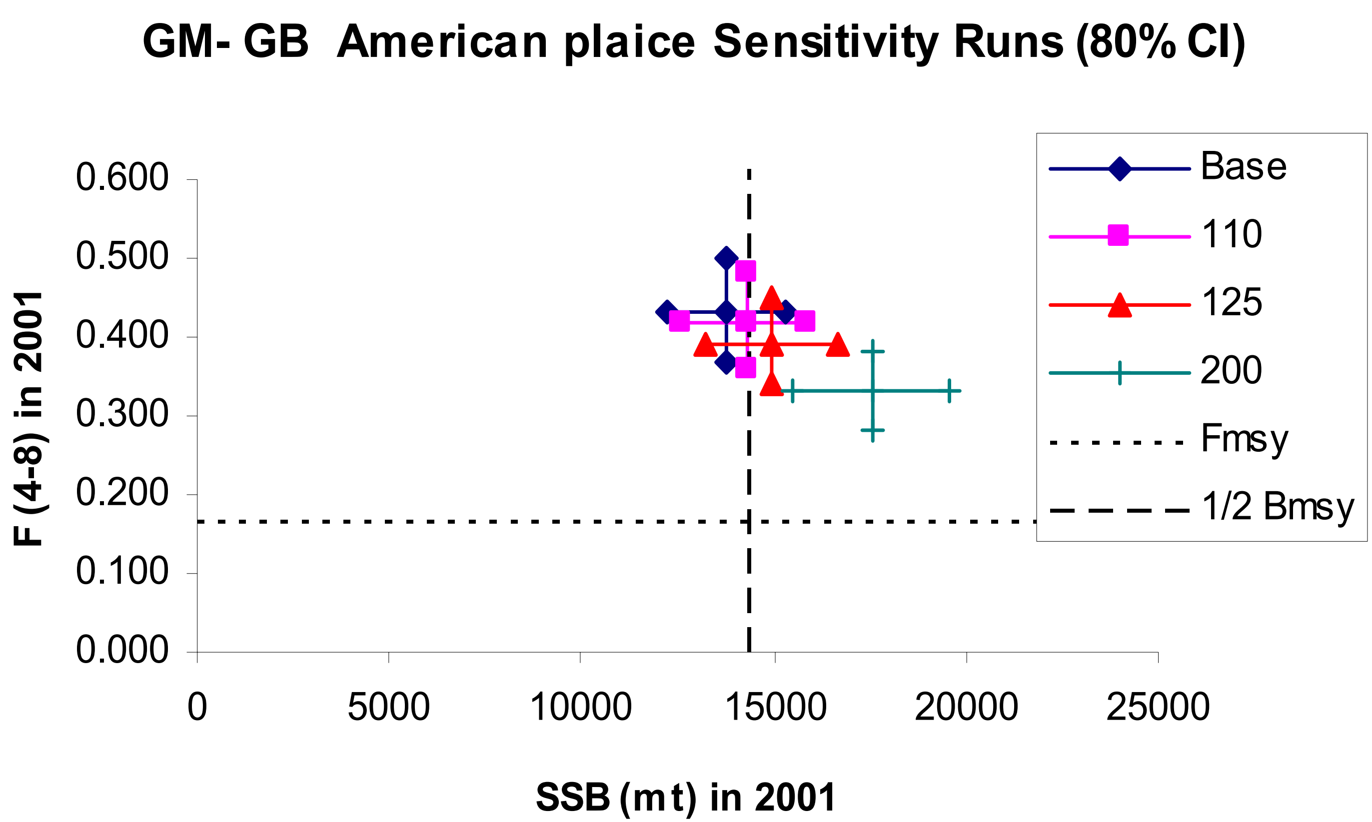


Figure H8. Fishing mortality and spawning stock biomass estimates from VPA calibrated using survey indices increased by 0% (base), 10% (110), 25% (125), and 100 %(200).

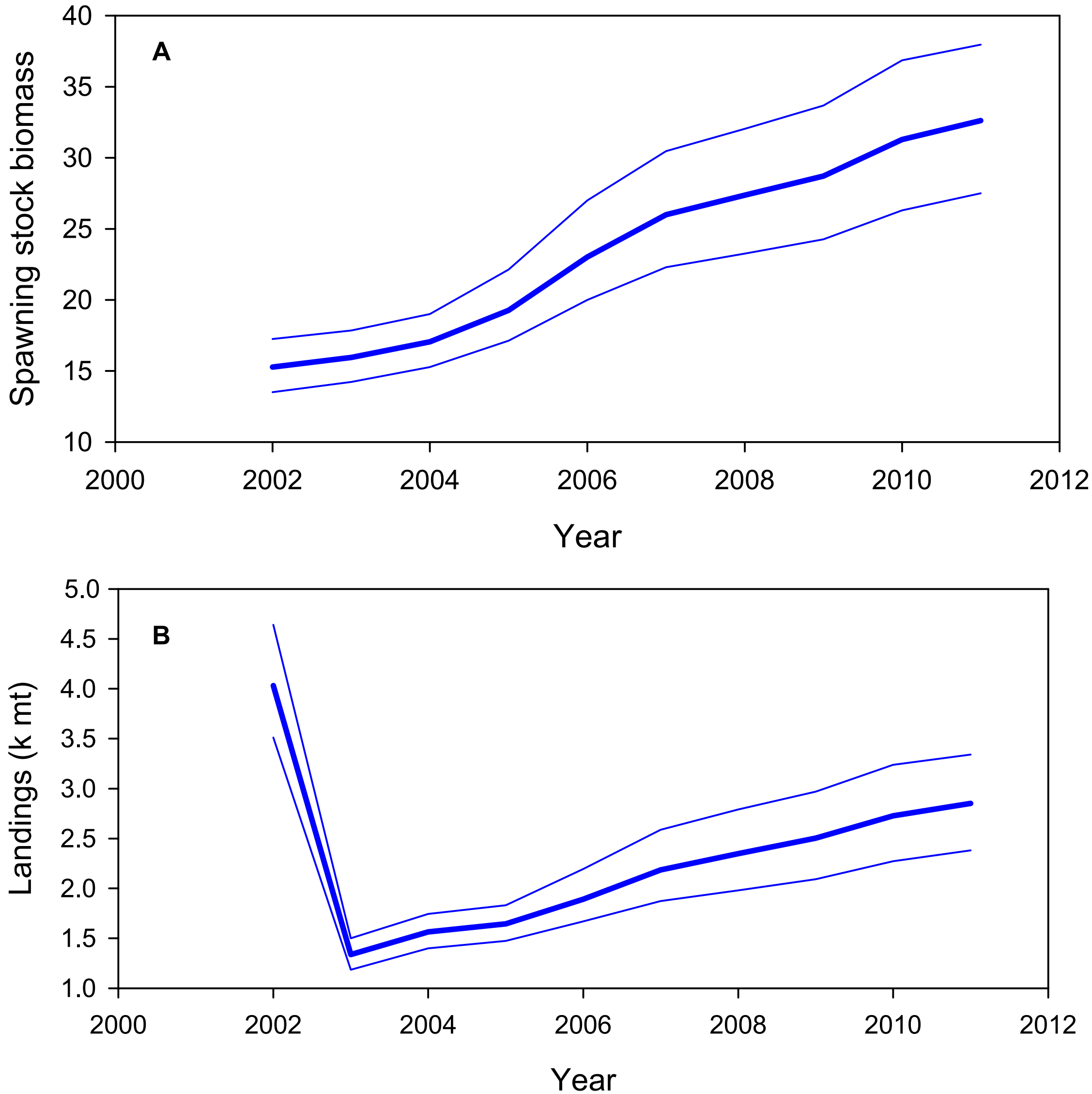


Figure H9. Median and 80% confidence intervals of predicted spawning stock biomass (panel A) and predicted landings (panel B) for American plaice under $F_{rebuild}$ = 0.10.

## I. Georges Bank Winter Flounder by Lisa Hendrickson

### 1.0 Background

The Georges Bank winter flounder stock was last assessed in November, 2001 at SAW/SARC 34 (NEFSC 2002a). The assessment was based on a biomass dynamics model (ASPIC) (Prager 1995) which incorporated catch (1964-2000) and biomass indices from the NEFSC autumn (1963-2000) and spring (1968-2001) bottom trawl surveys. Model results indicated a reasonable fit to the input data and that yield has been below surplus production since 1994. Relative estimates of mean biomass ($B_t/B_{MSY}$) declined sharply during 1977-1994, then increased to $B_{MSY}$ in 2000. Relative fishing mortality rates ($F_t/F_{MSY}$) have been at or below $F_{MSY}$ since 1994. During 2000, the stock was not overfished and overfishing was not occurring.

In 2002, the biological reference points adopted at SAW34 were re-examined and use of the absolute estimates of $F_{MSY}$ and $B_{MSY}$, rather than survey-based equivalents, were recommended (NEFSC 2002b). In addition, medium term stochastic projections (Prager 1995) were generated for 2002-2008 using bootstrap distributions of stock biomass in 2001 generated from the SAW 34 ASPIC model and assuming $F_{2002}=F_{2001}$ and $F_{2003\text{-}2008}=F_{MSY}$. Projected biomass was maintained at $B_{MSY}$ throughout the projected time series with high probability. Projected catch increased to 3,000 mt and was also maintained throughout the projected time series.

### 2.0 Assessment Results

Stock status was assessed from the results of an updated run of the SAW 34 ASPIC model. Data updates included the addition of NEFSC survey biomass indices from autumn of 2001 and spring of 2002, as well as total landings in 2001.

The sensitivity of catch rate underestimation, due to trawl warp length offsets, during NEFSC surveys conducted between the spring of 2000 and 2002 was also assessed.

#### 2.1 <u>The Fishery</u>

Total commercial landings of Georges Bank winter flounder are predominately from the U.S., but prior to 1977 also included landings from Canadian and distant water fleets. Since 1994, the Canadian proportion of total landings has increased to 5-10%. Total landings peaked at 4,500 mt in 1972 then declined between 1984 and 1995 from 3,900 mt to 800 mt, respectively (Table I1 and Figure I1). Landings have been increasing since 1995 and reached 2,500 mt in 2001.

Discarding of winter flounder occurs in the multi-species otter trawl fishery and the scallop dredge fishery. However, existing data are insufficient to produce reliable estimates of the magnitude or size and age composition of these discards (NEFSC 2002a).

## 2.2 Research Survey Indices

Relative biomass (stratified mean kg per tow) and abundance (stratified mean number per tow) indices from the NEFSC spring (April 1968-2002) and autumn (October 1963-2001) bottom trawl surveys, as well the Canadian spring bottom trawl surveys (March 1987-2002) are presented in Table I2. Biomass indices from all three surveys are presented in Figure I2. Canadian survey indices were not included in the current assessment because not all winter flounder habitat on Georges Bank is sampled during that survey (NEFSC 2001). Despite considerable variability, both NEFSC series of biomass indices indicate a declining trend during the 1980s and an increasing trend since the early 1990s. The Canadian biomass indices also indicate an increasing trend since 1992. In 2001, biomass indices from all three surveys were above their time series averages.

## 2.3 Biological Reference Points

The biological reference points for Georges Bank winter flounder are the absolute estimates of $F_{MSY}$ and $B_{MSY}$ from the SAW 34 ASPIC model (NEFSC 2002b). A maximum sustainable yield of 3,020 mt was estimated to be produced by a biomass ($B_{MSY}$) of 9,355 mt at a $F_{MSY}$ value of 0.32. Threshold F is defined as $F_{MSY}$ (= 0.32) when biomass is greater than $B_{MSY}$ (= 9,355 mt) then declines linearly to zero at 1/2 $B_{MSY}$ (= 4,677 mt). The target fishing mortality rate is defined as 75% of $F_{MSY}$ (= 0.24) when biomass is greater than 9,355 mt then declines linearly to zero at a threshold biomass of 4,677 mt.

## 2.4 ASPIC Model Results and Stock Status

Fishing mortality rates declined sharply during 1993 and 1999, from 0.71 to 0.14, (Table I3 and Figure I3) and were at or below $F_{MSY}$ (= 0.32) during 1995-2001. Average total biomass has been increasing since 1994 and was slightly above $B_{MSY}$ during 2001 (Figure I4). There was no retrospective pattern in the ASPIC-derived estimates of fishing mortality rates or total biomass (Figure I5). The 2001 fishing mortality rate estimate is 0.25 and the 2001 total biomass estimate is 9,805 mt. Therefore, in 2001 the stock was not overfished and overfishing was not occurring.

## 2.5 Sensitivity Analyses

Autumn and spring survey biomass indices from 2000-2002 were increased by 10%, 25% and 100% and included in a sensitivity analysis using the updated ASPIC model configuration (Table I4). Relative total biomass and fishing mortality rate point estimates for 2001 and their respective 80% confidence intervals, generated from 1,000 bootstrap iterations, are shown for the nominal run and the three sets of increased survey indices (Figure I6). The ASPIC model produces new reference point estimates with each run, so a solid line is used in Figure I6 to indicate a ratio of the current $F_{MSY}$ and $B_{MSY}$ reference points in relation to those re-estimated for comparison of the sensitivity analysis results (dashed line). Relative fishing mortality rates decreased and relative total biomass increased with increases in the survey biomass indices. However, overlapping confidence intervals indicate there was no significant difference between the nominal run and the three runs that incorporated increased survey biomass indices.

## 3.0 Projections

Short-term (2002-2005) and long-term (2002-2010) stochastic projections (Figure I7) were performed under a scenario where $F_{2002}$=15% reduction in $F_{2001}$ and fishing mortality rates for the following years were set at $F_{MSY}$ (= 0.32). Biomass levels above $B_{MSY}$ were projected for 2003-2005 and yields of about 3,000 mt (MSY) were projected for the same time period (Table I5).

## 4.0 Sources of Uncertainty

1. Exclusion of the discards from the U.S. otter trawl and scallop dredge fisheries results in an underestimation of fishery removals of the younger age classes (ages 0 to 3).

2. Current biomass levels estimated from the ASPIC model may not be reliable because recruitment is implicitly assumed to be a function of stock biomass.

3. U.S. landings are based on prorations of preliminary logbook data which are subject to change.

4. There is some uncertainty about the accuracy of reported Canadian landings because of the non-targeted nature of the Canadian fishery and the tendency to report landings of some flatfish species, including winter flounder, as unclassified flounders.

## 5.0 Literature Cited


Northeast Fisheries Science Center. 2002a. Report of the 34th Northeast Regional Stock Assessment Workshop (34th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 02-06; 346 p.

Northeast Fisheries Science Center. 2002b. Final report of the working group on re-evaluation of biological reference points for New England groundfish. 231 p.

Prager, M.H. 1995. User's manual for ASPIC: a stock production model incorporating covariates. SEFSC Lab. Doc. MIA

Table I1. Landings (mt) of Georges Bank winter flounder, by statistical area and country, during 1964-2001.

| YEAR | 522-525 561-562 USA[1] | 5Ze[2] (521-526 and 541-562) CANADA | USSR | 5Z (521-562) CANADA | USSR | TOTAL |
|---|---|---|---|---|---|---|
| 1964 | 1,371 | | | 146 | | 1,517 |
| 1965 | 1,176 | | | 199 | 312 | 1,687 |
| 1966 | 1,877 | | | 164 | 156 | 2,197 |
| 1967 | 1,917 | | | 83 | 349 | 2,349 |
| 1968 | 1,570 | 57 | 372 | | | 1,999 |
| 1969 | 2,167 | 116 | 235 | | | 2,518 |
| 1970 | 2,615 | 61 | 40 | | | 2,716 |
| 1971 | 3,092 | 62 | 1,029 | | | 4,183 |
| 1972 | 2,805 | 8 | 1,699 | | | 4,512 |
| 1973 | 2,269 | 14 | 693 | | | 2,976 |
| 1974 | 2,124 | 12 | 82 | | | 2,218 |
| 1975 | 2,409 | 13 | 515 | | | 2,937 |
| 1976 | 1,877 | 15 | 1 | | | 1,893 |
| 1977 | 3,572 | 15 | 7 | | | 3,594 |
| 1978 | 3,185 | 65 | | | | 3,250 |
| 1979 | 3,045 | 19 | | | | 3,064 |
| 1980 | 3,931 | 44 | | | | 3,975 |
| 1981 | 3,993 | 19 | | | | 4,012 |
| 1982 | 2,961 | 19 | | | | 2,980 |
| 1983 | 3,894 | 14 | | | | 3,908 |
| 1984 | 3,927 | 4 | | | | 3,931 |
| 1985 | 2,151 | 12 | | | | 2,163 |
| 1986 | 1,762 | 25 | | | | 1,787 |
| 1987 | 2,637 | 32 | | | | 2,669 |
| 1988 | 2,804 | 55 | | | | 2,859 |
| 1989 | 1,880 | 11 | | | | 1,891 |
| 1990 | 1,898 | 55 | | | | 1,953 |
| 1991 | 1,814 | 14 | | | | 1,828 |
| 1992 | 1,822 | 27 | | | | 1,849 |
| 1993 | 1,662 | 21 | | | | 1,683 |
| 1994 | 907 | 65 | | | | 972 |
| 1995 | 706 | 54 | | | | 760 |
| 1996 | 1,265 | 71 | | | | 1,336 |
| 1997 | 1,287 | 143 | | | | 1,430 |
| 1998 | 1,243 | 93 | | | | 1,336 |
| 1999 | 938 | 104 | | | | 1,042 |
| 2000 | 1,677 | 161 | | | | 1,838 |
| 2001 | 1,945 | 529 | | | | 2,474 |

[1] USA landings prior to 1985 include those from Statistical Areas 551 and 552 and landings during 1994-2001 were prorated from Vessel Trip Reports based on gear, month and state.
[2] Includes landings from statistical areas 521 and 526; outside of the Georges Bank winter flounder stock area.

Table I2. Standardized, stratified abundance (numbers) and biomass (weight) indices for Georges Bank winter flounder from the U.S. NEFSC spring and autumn, and Canadian spring research vessel bottom trawl surveys. U.S. offshore survey strata 13-22; Canadian survey strata (5Z1-5Z4). Trawl door standardization coefficients of 1.46 (numbers) and 1.39 (weight) were applied to indices from U.S. survey indices conducted prior to 1985 to account for differences in catchability between survey doors.

| | **U.S. Spring Survey** | | **U.S. Autumn Survey** | | **Canada Spring Survey** | |
|---|---|---|---|---|---|---|
| | Number/tow | kg/tow | Number/tow | kg/tow | Number/tow | kg/tow |
| 1963 | | | 1.20 | 1.82 | | |
| 1964 | | | 1.30 | 1.82 | | |
| 1965 | | | 2.15 | 2.05 | | |
| 1966 | | | 5.16 | 5.66 | | |
| 1967 | *Spring Survey initiated in 1968* | | 1.79 | 2.07 | | |
| 1968 | 2.70 | 3.11 | 1.31 | 1.07 | | |
| 1969 | 3.14 | 4.29 | 2.37 | 2.39 | | |
| 1970 | 1.86 | 2.29 | 5.62 | 6.49 | | |
| 1971 | 1.84 | 2.17 | 1.32 | 1.26 | | |
| 1972 | 4.95 | 5.32 | 1.26 | 1.58 | | |
| 1973 | 2.95 | 3.51 | 1.22 | 1.20 | | |
| 1974 | 6.05 | 5.78 | 1.19 | 1.46 | | |
| 1975 | 1.96 | 1.41 | 3.79 | 2.06 | | |
| 1976 | 4.67 | 3.01 | 5.99 | 3.93 | | |
| 1977 | 3.79 | 1.58 | 4.86 | 3.99 | | |
| 1978 | 7.07 | 5.06 | 4.06 | 3.10 | | |
| 1979 | 1.74 | 2.21 | 5.07 | 3.83 | | |
| 1980 | 3.22 | 2.80 | 1.66 | 1.87 | | |
| 1981 | 3.73 | 3.75 | 3.83 | 2.43 | | |
| 1982 | 2.30 | 1.52 | 5.30 | 2.69 | | |
| 1983 | 8.41 | 7.11 | 2.73 | 2.36 | | |
| 1984 | 5.53 | 5.60 | 3.93 | 2.45 | | |
| 1985 | 3.84 | 2.65 | 1.98 | 1.12 | | |
| 1986 | 2.00 | 1.21 | 3.58 | 2.18 | *Iinitiated in 1987* | |
| 1987 | 2.80 | 1.25 | 0.76 | 0.89 | 1.24 | 1.74 |
| 1988 | 2.93 | 1.65 | 4.08 | 1.27 | 4.31 | 2.75 |
| 1989 | 1.30 | 0.76 | 1.56 | 1.05 | 4.05 | 1.95 |
| 1990 | 2.80 | 1.57 | 0.50 | 0.35 | 4.93 | 2.64 |
| 1991 | 2.40 | 1.32 | 0.27 | 0.14 | 1.98 | 1.38 |
| 1992 | 1.42 | 0.90 | 0.68 | 0.38 | 0.51 | 0.59 |
| 1993 | 1.02 | 0.57 | 1.17 | 0.66 | 3.53 | 1.76 |
| 1994 | 1.29 | 0.58 | 0.87 | 0.58 | 5.10 | 2.01 |
| 1995 | 2.61 | 1.49 | 2.36 | 1.34 | 5.63 | 1.96 |
| 1996 | 2.31 | 1.50 | 1.54 | 1.76 | 4.12 | 2.30 |
| 1997 | 1.61 | 1.19 | 1.74 | 1.53 | 4.58 | 3.09 |
| 1998 | 0.76 | 0.72 | 1.78 | 1.57 | 1.14 | 1.21 |
| 1999 | 3.83 | 3.48 | 1.54 | 1.76 | 1.25 | 1.89 |
| 2000 | 4.42 | 3.69 | 2.16 | 2.66 | 1.48 | 2.22 |
| 2001 | 1.29 | 1.22 | 2.45 | 2.51 | 2.28 | 2.54 |
| 2002 | 5.05 | 5.16 | | | 3.17 | 3.85 |

Table I3. Fishing mortality rates and average total biomass (mt) estimates for Georges Bank winter flounder during 1964-2001.

| Year | Fishing Mortality | Total Biomass (mt) |
|---|---|---|
| 1964 | 0.26 | 5,752 |
| 1965 | 0.25 | 6,883 |
| 1966 | 0.28 | 7,850 |
| 1967 | 0.27 | 8,569 |
| 1968 | 0.21 | 9,420 |
| 1969 | 0.25 | 10,160 |
| 1970 | 0.26 | 10,510 |
| 1971 | 0.42 | 9,978 |
| 1972 | 0.52 | 8,622 |
| 1973 | 0.38 | 7,933 |
| 1974 | 0.27 | 8,340 |
| 1975 | 0.34 | 8,765 |
| 1976 | 0.20 | 9,393 |
| 1977 | 0.37 | 9,630 |
| 1978 | 0.35 | 9,243 |
| 1979 | 0.34 | 9,120 |
| 1980 | 0.46 | 8,589 |
| 1981 | 0.53 | 7,567 |
| 1982 | 0.43 | 7,007 |
| 1983 | 0.62 | 6,327 |
| 1984 | 0.80 | 4,945 |
| 1985 | 0.51 | 4,232 |
| 1986 | 0.40 | 4,454 |
| 1987 | 0.60 | 4,446 |
| 1988 | 0.76 | 3,771 |
| 1989 | 0.57 | 3,313 |
| 1990 | 0.62 | 3,154 |
| 1991 | 0.62 | 2,949 |
| 1992 | 0.69 | 2,688 |
| 1993 | 0.71 | 2,365 |
| 1994 | 0.40 | 2,420 |
| 1995 | 0.25 | 3,089 |
| 1996 | 0.34 | 3,927 |
| 1997 | 0.30 | 4,730 |
| 1998 | 0.23 | 5,823 |
| 1999 | 0.14 | 7,407 |
| 2000 | 0.21 | 8,950 |
| 2001 | 0.25 | 9,805 |

Table I4. Summary of results from a sensitivity analysis of increases in survey biomass indices using an ASPIC biomass dynamics model for the assessment of Georges Bank winter flounder.

| Input Data | U.S. autumn survey, 1964-2001<br>U.S. spring survey, 1968-2002<br>Total landings, 1964-2001<br>(Nominal run) | Nominal run with 10% increase in 2000-2002 survey indices | Nominal run with 25% increase in 2000-2002 survey indices | Nominal run with 100% increase in 2000-2002 survey indices |
|---|---|---|---|---|
| Total Objective Function | 1.959 | 1.954 | 1.956 | 2.055 |
| | | | | |
| B coverage | 0.923 | 0.938 | 0.945 | 1.130 |
| B nearness | 1.000 | 1.000 | 1.000 | 1.000 |
| | | | | |
| $R^2$ in CPUE | | | | |
| U.S. Autumn Survey | 0.34 | 0.35 | 0.36 | 0.41 |
| U.S. Spring Survey | 0.23 | 0.24 | 0.25 | 0.29 |
| | | | | |
| B1 Ratio | 0.57 | 0.56 | 0.54 | 0.47 |
| r | 0.66 | 0.69 | 0.72 | 0.86 |
| | | | | |
| $F_{msy}$ | 0.33 | 0.35 | 0.36 | 0.43 |
| $B_{msy}$ (mt) | 9,119 | 8,742 | 8,429 | 7,193 |
| MSY (mt) | 3,028 | 3,036 | 3,047 | 3,097 |
| | | | | |
| $B_{2002}/B_{MSY}$ | 1.10 | 1.16 | 1.22 | 1.38 |
| $F_{2001}/F_{MSY}$ | 0.76 | 0.72 | 0.68 | 0.58 |

Table I5. Short-term stochastic projections of yield (mt) and total biomass (mt), during 2002-2005, for Georges Bank winter flounder assuming F2002=15% reduction in F2001 and F2003-2005 = FMSY.

| Year | Yield (mt) | Total Biomass (mt) |
|---|---|---|
| 2002 | 2,250 | 10,250 |
| 2003 | 3,433 | 11,020 |
| 2004 | 3,323 | 10,590 |
| 2005 | 3,253 | 10,310 |

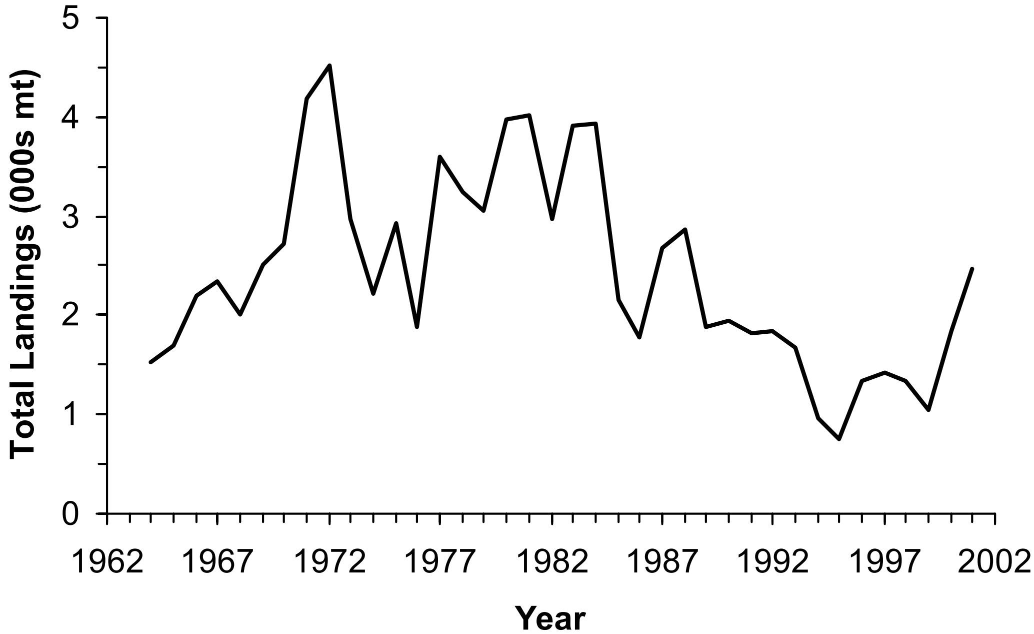


Figure I1. Total commercial landings of Georges Bank winter flounder during 1964-2001.

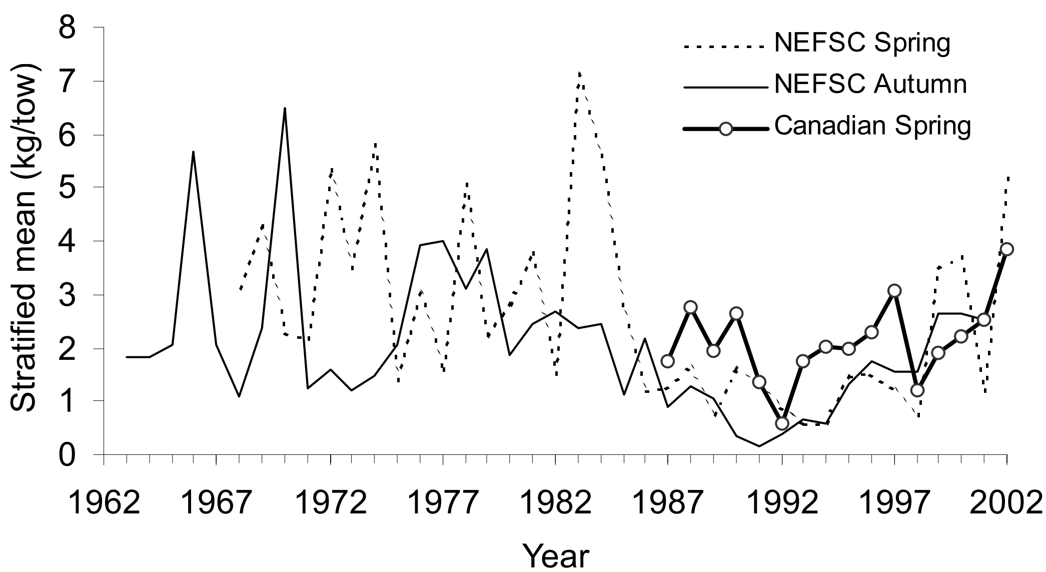


Figure I2. Relative biomass indices (stratified mean kg per tow) of Georges Bank winter flounder from NEFSC spring (1968-2002) and autumn (1963-2001) bottom trawl surveys and the Canadian spring (1987-2002) bottom trawl survey.

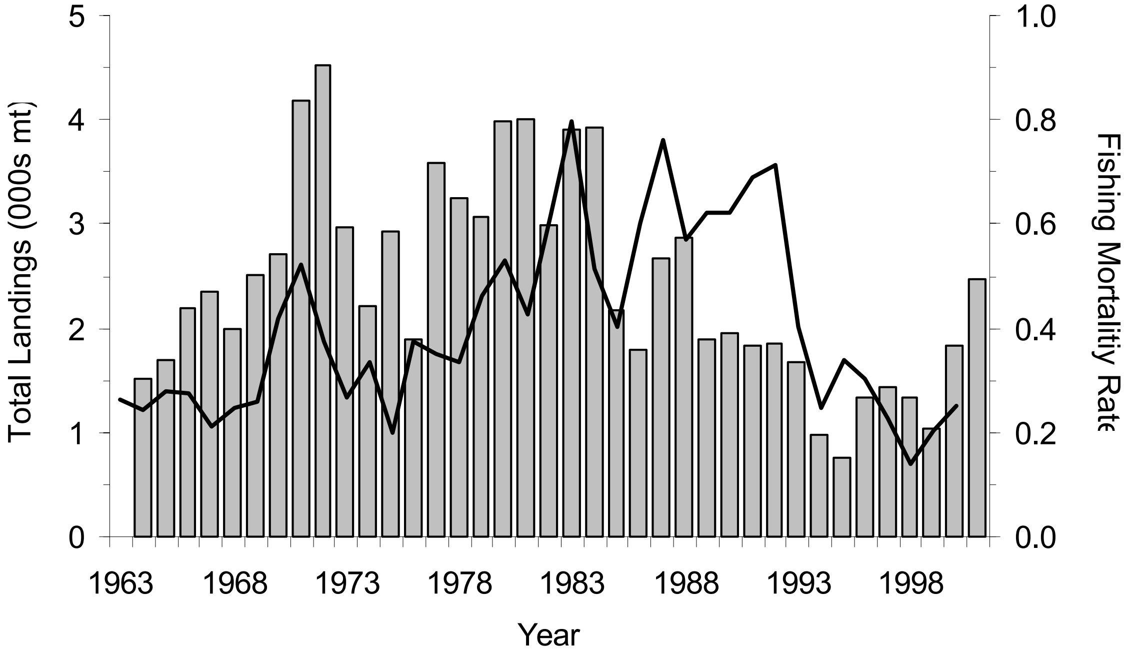


Figure I3. Trends in total landings and fishing mortality rates for Georges Bank winter flounder during 1964-2001.

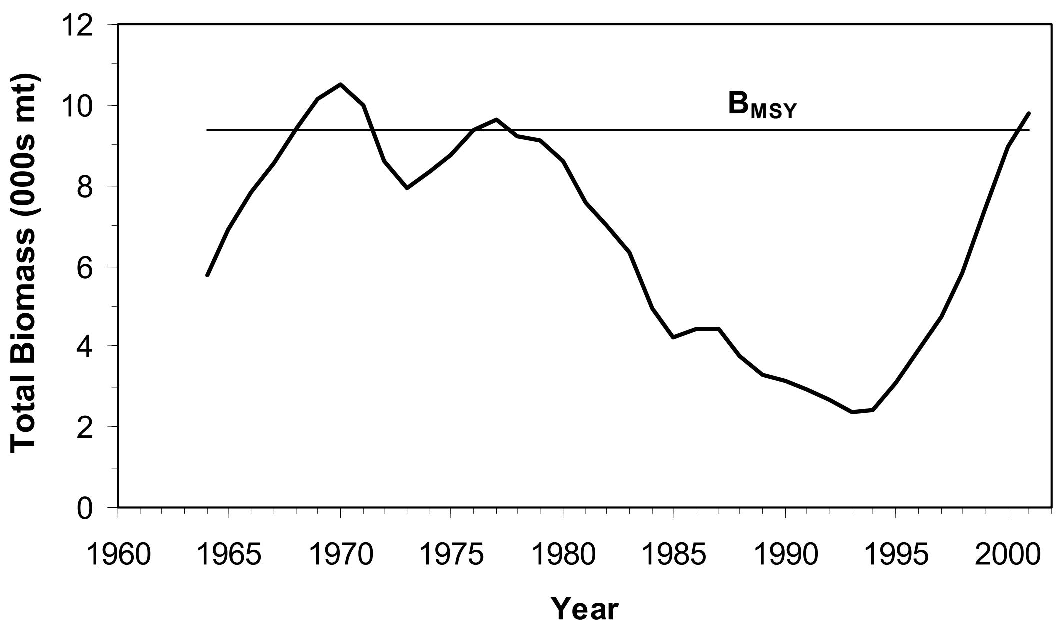


Figure I4. Trends in Georges Bank winter flounder total biomass, estimated from an ASPIC biomass dynamics model, during 1964-2001 in relation to $B_{MSY}$ (9,355 mt).

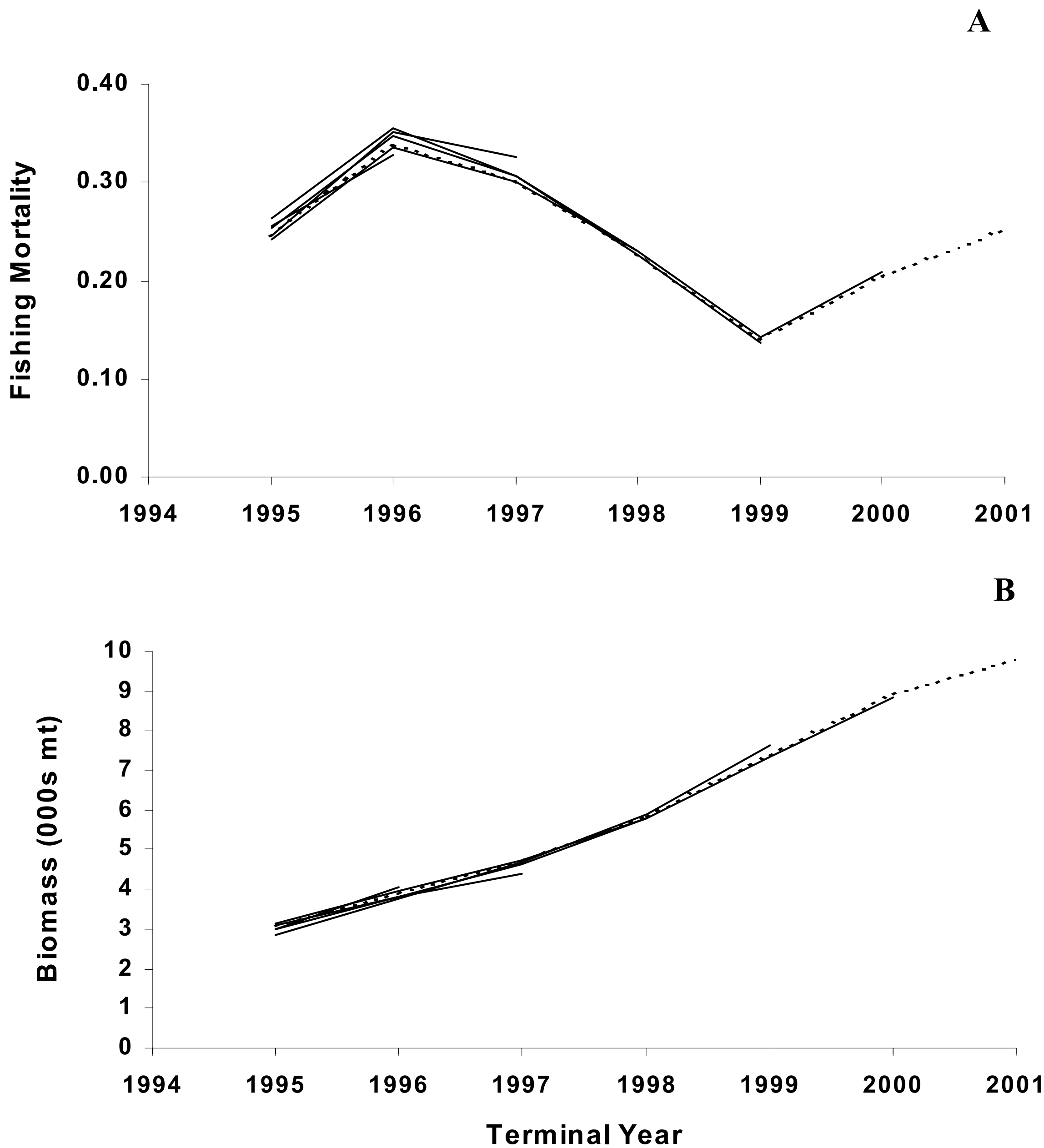


Figure I5. Retrospective analysis of ASPIC-derived estimates of (A) fishing mortality rates and (B) total biomass for Georges Bank winter flounder during 1995-2001.

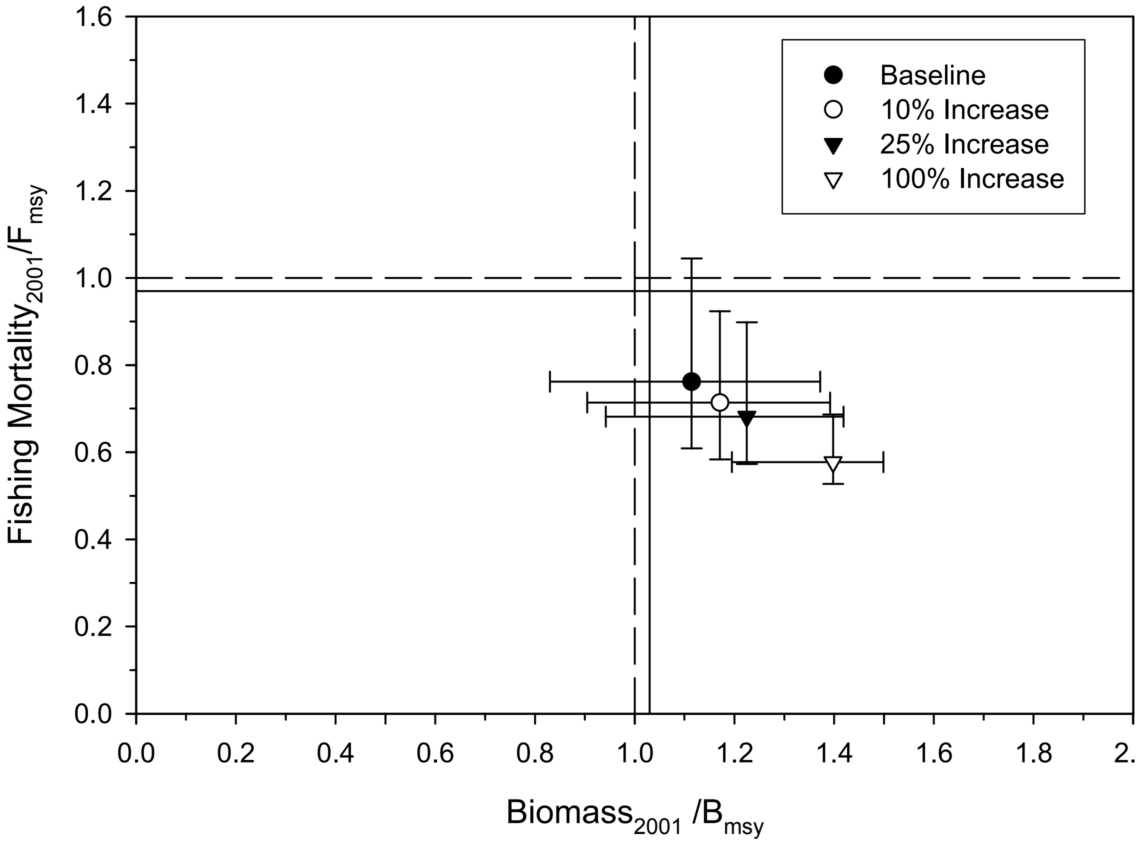


Figure I6. Point estimates and 80% confidence intervals of relative total biomass and fishing mortality rates during 2001 generated from a bootstrapped nominal run of an ASPIC biomass dynamics model and three sensitivity runs, including increased NEFSC survey biomass indices during spring 2000-2002, for the Georges Bank winter flounder stock. Solid lines represent ratios of the current $B_{MSY}$ and $F_{MSY}$ reference points in relation to those re-estimated from the sensitivity analysis (dashed line).

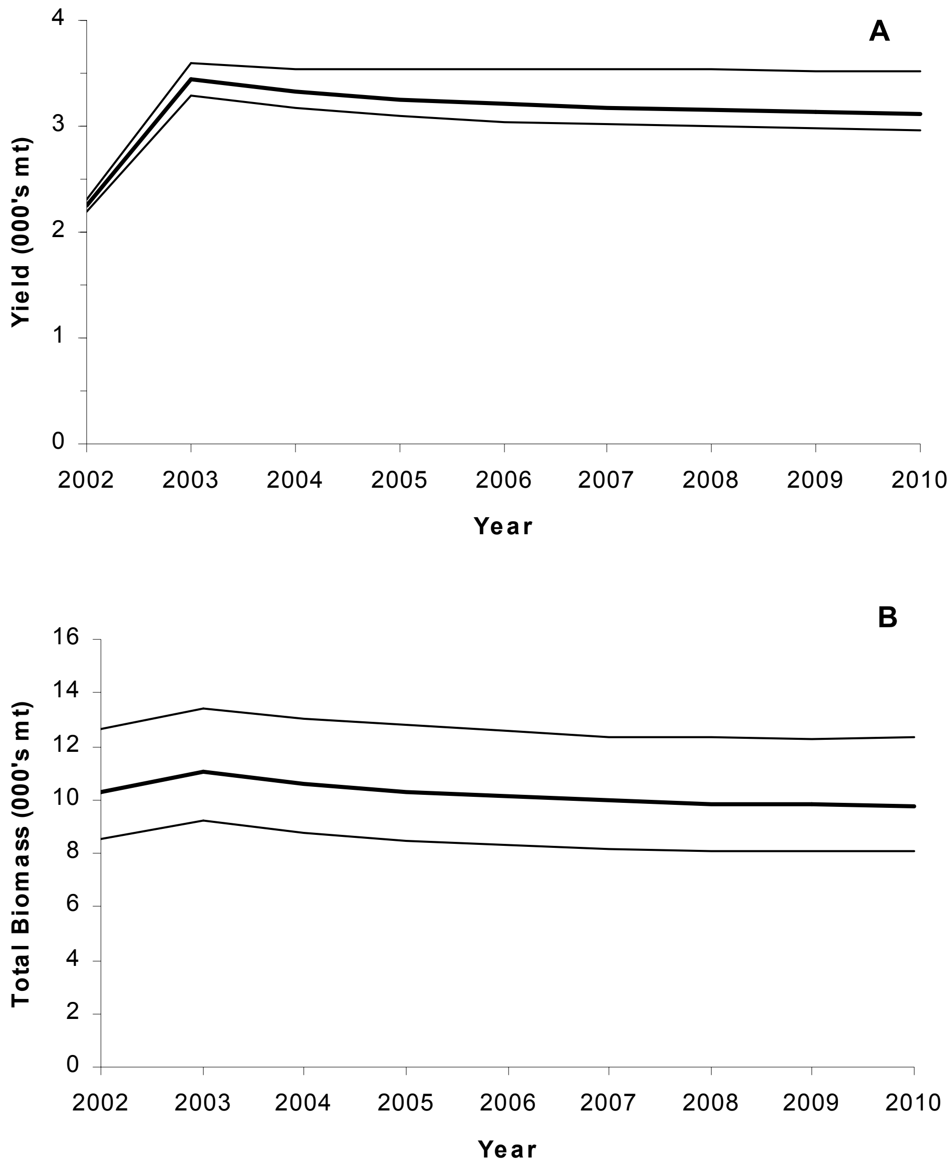


Figure I7. Median and 80% confidence intervals of projected (A) yield (mt) and (B) total biomass (mt) of Georges Bank winter flounder under $F_{MSY}$ fishing mortality rates (F=0.32) during 2003-2010 and assuming $F_{2002}$=15% reduction in $F_{2001}$.

## J. Southern New England/Mid-Atlantic (SNE/MA) winter flounder by Mark Terceiro

### 1.0 Background

The current assessment of the SNE/MA stock complex of winter flounder is an update of the previous assessments completed in 1998 at SARC 28 (NEFSC 1999). The SARC 28 assessment included catch through 1997, research survey abundance indices through 1998, catch-at-age analyzed by virtual population analysis (VPA) for 1981-1997, and biological reference points based on a production model conditioned on VPA results. The SARC 28 assessment concluded that the stock complex was fully exploited and at a medium level of biomass. Total biomass in 1997 was estimated to be 17,900 mt, spawning stock biomass was estimated to be 8,600 mt, and the fully recruited fishing mortality rate was estimated to be F = 0.31 Subsequent to the SARC 28 assessment, the status of SNE/MA winter flounder has been evaluated annually by projection methods to provide advice to the New England Fishery Management Council (NEFMC). The last such status update was provided in 2001, and projected total biomass to be 25,300 mt, spawning stock biomass to be 13,800 mt, and fully recruited F = 0.29, in 1999 (NEFSC 2001). The current assessment, conducted by the ASMFC Winter Flounder Technical Committee in September 2002, updates landings and discard estimates, research survey abundance indices, and assessment models through 2001-2002, as applicable.

### 2.0 2002 Assessment

*The Fishery*

After reaching an historical peak of 11,977 metric tons (mt) in 1966, then declining through the 1970s, total U.S. commercial landings of winter flounder again peaked at 11,176 mt in 1981, and then steadily declined to a record low of 2,159 mt in 1994. Landings have increased since 1994 to 4,448 mt in 2001 (Table J1, Figure J1). The primary gear in the fishery is the otter trawl which accounts for an average of 95% of landings since 1989. Scallop dredges account for 4%, with such gears as handlines, pound nets, fyke nets, and gill nets each accounting for about 1% of total landings.

Recreational landings reached a peak in 1984 of 5,772 mt but declined substantially thereafter (Table J2, Figure J1). Recreational landings have been less than 1,000 mt since 1991, with the lowest estimated landings in 1998 of 290 mt. Recreational landings in 2001 from the Southern New England/Mid Atlantic stock complex were 552 mt. The principal mode of fishing is private/rental boats, with most recreational landings occurring during January to June.

*Input data and analyses*

Length samples of winter flounder are available from both the commercial and recreational landings. In the commercial fishery, annual sampling intensity varied from 59 to 264 mt landed per 100 lengths measured during 1981-2001 (Table J3). Since 1997, port sampling has been adequate to develop the commercial fishery landings at age on a half-year, market category basis across all statistical areas.

In the recreational fishery, annual sampling intensity varied from 36 to 231 mt landed per 100 lengths measured during 1981-1997. Ages were determined using NEFSC survey spring and fall age-length keys.

Since 1995, the ASMFC Winter Flounder Technical Committee has considered NEFSC Fishery Observer data (OB), and NER vessel trip report (VTR) data as sources of information to use in the estimation of commercial fishery discards. The Committee concluded that the VTR mean discard to landed ratio aggregated over all trips in annual half-year season strata provided the most reliable data from which to estimate commercial fishery discards. VTR trawl gear fishery discards to landings ratios on a half-year basis were applied to corresponding commercial fishery landings to estimate discards in weight (Table J4, Figure J1). The Fishery Observer length frequency samples were judged adequate to directly characterize the proportion discarded at length. A discard mortality rate of 50% (Howell et al., 1992) was applied to trawl discards to produce the number of fish discarded dead at length. For 1998, discard estimates at length were made by half-year; for 1999-2001, sample lengths were applied on an annual basis due to low sample sizes. Ages were determined using NEFSC survey spring and fall age-length keys.

A discard mortality of 15% was assumed for recreational discards (B2 category from MRFSS data), as assumed in Howell et al. (1992). Discard losses peaked in 1984-1985 at 0.7 million fish. Discards have since declined, reaching a low in 1999 of 62,000 fish. In 2001, 81,000 fish were estimated to have been discarded (Table J4, Figure J1). Since 1997, irregular sampling of the recreational fisheries by state fisheries agencies has indicated that the discard is usually of fish below the minimum landing size of 12 inches (30 cm). For 1998-2001, the recreational discard has been assumed to have the same length frequency as the landed portion of the catch below 12 inches, and so is predominantly ages 1, 2, and 3 fish. The recreational discard for 1998-2001 is aged using NEFSC survey spring and fall age-length keys.

The virtual population analysis (VPA) was calibrated using the NEFSC Woods Hole Fisheries Assessment Compilation Toolbox (FACT) version 1.50 of the ADAPT VPA (Conser and Powers 1990). Abundance indices at age were available from several research surveys: NEFSC spring bottom trawl ages 1-7+, NEFSC fall ages 1-5 (advanced to tune January 1 abundance of ages 2-6), NEFSC winter ages 1-5, Massachusetts spring ages 1-7+, Rhode Island fall age 0 (advanced to tune age-1), Rhode Island spring ages 1-7+, Connecticut spring ages 1-7+, New York age 0 (advanced to tune age-1) and age-1, Massachusetts summer seine index of age-0 (advanced to tune age-1), Delaware juvenile trawl survey age-0 (advanced to tune age-1), New Jersey Ocean trawl survey ages 1-7+, and New Jersey River trawl survey ages 1-7+. Survey indices were selected for inclusion in VPA tuning based on consideration of the partial variance in a VPA trial run including all indices, residual error patterns from the trial runs, and on the significance of the correlation among indices and with VPA abundance estimates from the trial run including all indices. A conditional non-parametric bootstrap procedure (Efron 1982) was used to evaluate the precision of fishing mortality and spawning stock biomass. A retrospective analysis was performed for terminal year fishing mortality, spawning stock biomass, and age 1 recruitment.

## 3.0 Assessment results

*Research surveys*

Mean weight per tow and number per tow indices for the NEFSC spring, fall, and winter time series are presented in Table J5. Indices dropped from the beginning of the time series in the 1960s to a low point in the early to mid- 1970s, then rose to a peak by the early 1980s. Following several years of high indices, abundance once again declined to below the low levels of the 1970s. NEFSC survey indices reached near- or record low levels for the time series in the late 1980s- 1990s. Indices from the three survey series generally increased during 1993-1998/1999, but have since declined (Figure J2).

Several state survey indices were available to characterize abundance of winter flounder. The Massachusetts Division of Marine Fisheries (MADMF) spring and fall survey (1978-2001), Rhode Island Division of Fish and Wildlife (RIDFW) spring and fall survey (1979-2001), Connecticut Department of Environmental Protection (CTDEP), Long Island Sound Trawl Survey (1984-2001), and the New Jersey Division of Fish, Game and Wildlife (NJDFW) ocean survey trends are summarized in Table J6 and Figure J2. The numerous state recruitment surveys (MADMF, RIDFW, CTDEP, New York Department of Environmental Conservation (NYDEP), NJDFW, Delaware Division of Fish and Game (DEDFG)) are summarized in Table J7 and Figure J3.

*Virtual Population Analysis*

During 1981-1993, fishing mortality (fully recruited F, ages 4-5) varied between 0.4 (1982) and 1.4 (1988), and was as high as 1.2 as recently as 1997. Fishing mortality has been in the range of 0.5-0.6 during 1999-2001 ($F_{2001} = 0.51$; Table J8, Figure J4). SSB declined from 14,800 mt in 1983 to a record low of 2,700 mt in 1994. SSB has increased since 1994 to 7,600 mt in 2001 (Table J8, Figure J5). Recruitment declined continuously from 62.9 million age-1 fish in 1981 to 7.8 million in 1992. Recruitment then averaged 14.7 million fish during 1993-2001, below the VPA time series average of 23.9 million. The 2002 year class is estimated to be the smallest on record, at only 5.7 million fish (Table J8, Figure J5).

*VPA diagnostics*

The Technical Committee considered six different configurations of tuning indices. In general, tuning indices were excluded if they exhibited high partial variance (indicating a lack of fit within the VPA model) and low correlation with other indices with similar spatial and temporal characteristics and with the VPA estimates of 2002 stock size. Run W36ALL was the initial trial including all indices. Run W36_1 excluded eight indices with high partial variance within the VPA and low correlation with other indices and/or the VPA estimates of stock size, resulting in improvements both in overall fit (mean square residual (MSR) reduced by 14%) and in the precision of the stock size estimates. Run W36_2 dropped an additional seven indices from the W36_1 configuration, resulting in further improvements in fit (21% improvement over run W36_1) and precision. This was the run adopted as final by the Technical Committee, and is the basis for all further analyses.

The precision of the 2002 stock size, fishing mortality at age in 2001, and SSB estimates from VPA was evaluated using bootstrap techniques (Efron 1982). Five hundred bootstrap iterations were realized in which errors (differences between predicted and observed survey values) were resampled. Bootstrap estimates of stock size at age indicate low bias (<6%) for ages 2-7+ and bootstrap standard errors provide stock size CVs ranging from 18% at age 3 to 34% at age 1. Bootstrapped estimates of spawning stock biomass indicate a CV of 9%, with low bias (bootstrap mean estimate of spawning stock biomass of 7,705 mt compared with VPA estimate of 7,643 mt). There is an 80% probability that spawning stock in 2001 was between 6,800 mt and 8,400 mt. The bootstrap estimates of standard error associated with fishing mortality rates at age indicate good precision. Coefficients of variation for F estimates ranged from 16% at age 3 to 21% at ages 1, 6 and 7+. There is an 80% probability that fully recruited F for ages 4-5 in 2001 was between 0.44 and 0.58.

A retrospective analysis of the VPA was conducted back to a terminal catch year of 1997 ( Figure J6). The SNE/MA winter flounder VPA exhibits a severe retrospective pattern of underestimation of F and overestimation of SSB during the late 1990s. The most likely cause of this pattern is the underestimation of the total catch. The analysis indicated a tendency for the significant underestimation of fully recruited F for the terminal years 1993-1999. In that period, underestimation of F ranged from 232% for 1997 to 14% for 1993. The pattern reversed for 2000 (i.e., F was overestimated), indicating that survey variability may also contribute to the retrospective pattern of the SNE/MA winter flounder VPA. Fishing mortality appears to have been overestimated for 2000 by 7%. The retrospective pattern for spawning stock biomass has been a tendency for overestimation since 1991. The overestimation of SSB was most severe for the 1997 and 1998 terminal years (115% and 198% overestimation). The retrospective estimation of age-1 recruits indicated a tendency for overestimation during 1993-2000, with recruitment apparently underestimated for 2001 (2000 year class).

*Sensitivity of VPA estimates to hypothetical NEFSC survey adjustments*

Sensitivity analyses of the VPA results to hypothetical changes in the recent NEFSC spring and fall survey values were conducted (Figure J7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

## 4.0 Biological reference points

The Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (RPWG; NEFSC 2002) re-estimated the biological reference points for SNE/MA winter flounder in 2002 using yield and SSB per recruit (Thompson and Bell 1936) and Beverton-Holt stock-recruitment models (Beverton and Holt 1957, Brodziak et al. 2001, Mace and Doonan 1988) based on the SARC 28 assessment (NEFSC 1999). The yield and SSB per recruit analyses indicate that $F_{40\%}$ = 0.21 and $F_{0.1}$ = 0.25. The stock-recruitment model indicated that MSY = 10,600 mt, $F_{msy}$ = 0.32, and $B_{msy}$ = 30,100 mt.

Biological reference points estimated by the RPWG (NEFSC 2002) were updated by the Technical Committee with partial recruitment pattern and mean weights at age for 1998-2000 (the 2001 estimates were not included in the averages due to the retrospective variability of the partial recruitment pattern in the terminal year of the VPA). Given the stability of the input data to these analyses and the consistency of the results with the previous work, the Technical Committee elected to retain the RPWG (NEFSC 2002) estimates of biological reference points for this assessment. The assessment indicates that the stock complex is overfished and overfishing is occurring.

**5.0 GARM comments**

The discussion focused on 2 major issues. The first involved the research vessel surveys, and the apparent lack of consistency between the total biomass and young-of-the-year indices derived from the individual state and NEFSC time series. Several reasons for the inconsistency were discussed, however the major issue is spatial and temporal discontinuity. Each of the surveys covers different portions of the population and they are not conducted concurrently. Each of the state surveys samples a relatively small portion of the inshore range of the species while the NEFSC survey samples the broad offshore area. Due to the migratory behavior of the species, environmental variability in the inshore waters may have a strong influence on the species availability to the survey gear. The GARM recommended that the subcommittee explore methods to weight the surveys based on their area of coverage of the population.

The second major issue discussed at the GARM was the problematic retrospective pattern of underestimation of F and overestimation of SSB during the late 1990s exhibited in the VPA. The pattern in the late 1990s may have been due to a low level of samples from the commercial fishery. The GARM agreed that the VPA provides information on stock status, i.e. the stock complex is overfished and overfishing is occurring, however projections based on the current VPA should not be conducted for this assessment.

**6.0 Sources of uncertainty**

1) Landings data for 1994 and later years are derived by proration and are considered provisional.

2) Length frequency sampling intensity of the recreational fishery landings has been low in some recent years.

3) Length frequency sampling intensity of the commercial fishery discards has been low in some recent years.

4) Commercial fishery discard estimates are based on rates provided by fishermen in the vessel trip reports, due to inadequate fishery observer sampling.

5) The SNE/MA winter flounder VPA exhibits a severe retrospective pattern of underestimation of F and overestimation of SSB during the late 1990s.

**7.0 Summary**

The Southern New England/Mid-Atlantic winter flounder stock complex is overfished and overfishing is occurring. Fully recruited fishing mortality in 2001 was 0.51 (exploitation rate = 37%), about 60% above the RPWG (NEFSC 2002) re-estimate of Fmsy = 0.32. There is an 80% chance that the 2001 F was between 0.44 and 0.58. Spawning stock biomass was estimated to be 7,600 mt in 2001, about 25% of the re-estimate of Bmsy = 30,100 mt. There is an 80% chance that the spawning stock biomass was between 6,800 mt and 8,400 mt in 2001.

Spawning stock biomass declined substantially from 13,000-14,000 mt during the early 1980s to only 2,700 mt during 1994-1996, but has increased since the mid 1990s to about 7,600 mt in 2001 due to reduced fishing mortality rates since 1997. The arithmetic average recruitment from 1981 to 2001 is 23.9 million age-1 fish, with a median of 18.9 million fish. Recent recruitment to the stock has been below average since 1989. The 2001 year class, at only 5.6 million fish, is the smallest in the 22-year time series.

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Table J1. Winter flounder commercial landings (metric tons) for southern New England/Mid-Atlantic stock complex area (U.S. statistical reporting areas 521, 526, divisions 53, 61-63) as reported by NEFSC weighout, state bulletin and general canvass data.

| Year | Metric Tons |
|---|---|
| 1964 | 7,474 |
| 1965 | 8,678 |
| 1966 | 11,977 |
| 1967 | 9,478 |
| 1968 | 7,070 |
| 1969 | 8,107 |
| 1970 | 8,603 |
| 1971 | 7,367 |
| 1972 | 5,190 |
| 1973 | 5,573 |
| 1974 | 4,259 |
| 1975 | 3,982 |
| 1976 | 3,265 |
| 1977 | 4,413 |
| 1978 | 6,327 |
| 1979 | 6,543 |
| 1980 | 10,627 |
| 1981 | 11,176 |
| 1982 | 9,438 |
| 1983 | 8,659 |
| 1984 | 8,882 |
| 1985 | 7,052 |
| 1986 | 4,929 |
| 1987 | 5,172 |
| 1988 | 4,312 |
| 1989 | 3,670 |
| 1990 | 4,232 |
| 1991 | 4,823 |
| 1992 | 3,816 |
| 1993 | 3,010 |
| 1994 | 2,159 |
| 1995 | 2,634 |
| 1996 | 2,781 |
| 1997 | 3,441 |
| 1998 | 3,208 |
| 1999 | 3,444 |
| 2000 | 3,783 |
| 2001 | 4,448 |

Table J2. Estimated number (000's) and weight (mt) of winter flounder caught, landed, and discarded in the recreational fishery, Southern New England/Mid-Atlantic stock complex.

| | Number (000's) | | | | Metric tons |
|---|---|---|---|---|---|
| | Catch A+B1+B2 | Landed A+B1 | Released B2 | 15% Release Mortality | Landed A+B1 |
| 1981 | 11006 | 8089 | 2916 | 437 | 3050 |
| 1982 | 10665 | 8392 | 2273 | 341 | 2457 |
| 1983 | 11010 | 8365 | 2645 | 397 | 2524 |
| 1984 | 17723 | 12756 | 4967 | 745 | 5772 |
| 1985 | 18056 | 13297 | 4759 | 714 | 5198 |
| 1986 | 9368 | 6995 | 2374 | 356 | 2940 |
| 1987 | 9213 | 6900 | 2313 | 347 | 3141 |
| 1988 | 10134 | 7358 | 2775 | 416 | 3423 |
| 1989 | 5919 | 3682 | 2236 | 335 | 1802 |
| 1990 | 3827 | 2486 | 1340 | 201 | 1063 |
| 1991 | 4325 | 2795 | 1530 | 230 | 1214 |
| 1992 | 1360 | 806 | 555 | 83 | 393 |
| 1993 | 2211 | 1180 | 1031 | 155 | 543 |
| 1994 | 1829 | 1209 | 620 | 93 | 598 |
| 1995 | 1850 | 1390 | 461 | 69 | 661 |
| 1996 | 2679 | 1554 | 1125 | 169 | 689 |
| 1997 | 1901 | 1207 | 694 | 104 | 621 |
| 1998 | 1008 | 584 | 425 | 64 | 290 |
| 1999 | 1071 | 658 | 412 | 62 | 320 |
| 2000 | 2043 | 1346 | 697 | 105 | 831 |
| 2001 | 1441 | 901 | 540 | 81 | 552 |

Table J3. The total number of commercial lengths sampled by market category for Southern New England/Mid-Atlantic winter flounder. The landing (mt) and metric tons per 100 lengths are also shown.

| year | number of lengths | | | | | landing (mt) | mt/100 lengths |
|---|---|---|---|---|---|---|---|
| | unclass | small | medium | large | total | | |
| 1981 | 1,904 | 1,542 | - | 784 | 4,230 | 11,176 | 264 |
| 1982 | 513 | 2,425 | 657 | 2,201 | 5,796 | 9,438 | 163 |
| 1983 | 927 | 1,790 | 1,044 | 1,840 | 5,601 | 8,659 | 155 |
| 1984 | 551 | 1,171 | 637 | 1,338 | 3,697 | 8,882 | 240 |
| 1985 | 716 | 2,632 | 1,663 | 1,396 | 6,407 | 7,052 | 110 |
| 1986 | 799 | 2,206 | 1,024 | 1,091 | 5,120 | 4,929 | 96 |
| 1987 | 99 | 2,524 | 670 | 1,978 | 5,271 | 5,172 | 98 |
| 1988 | 269 | 1,731 | 958 | 1,250 | 4,208 | 4,312 | 102 |
| 1989 | 106 | 1,224 | 1,220 | 975 | 3,525 | 3,670 | 104 |
| 1990 | 102 | 1,473 | 1,180 | 1,333 | 4,088 | 4,232 | 104 |
| 1991 | - | 1,220 | 921 | 917 | 3,058 | 4,823 | 158 |
| 1992 | 402 | 1,343 | 1,259 | 1,159 | 4,163 | 3,816 | 92 |
| 1993 | 62 | 1,249 | 401 | 642 | 2,354 | 3,010 | 128 |
| 1994 | 142 | 1,092 | 816 | 543 | 2,593 | 2,159 | 83 |
| 1995 | 79 | 1,182 | 290 | 325 | 1,876 | 2,634 | 140 |
| 1996 | 480 | 854 | 521 | 109 | 1,964 | 2,781 | 142 |
| 1997 | 201 | 1,327 | 1,176 | 1,301 | 4,005 | 3,441 | 86 |
| 1998 | 942 | 899 | 1,325 | 415 | 3,581 | 3,208 | 90 |
| 1999 | 2,381 | 798 | 607 | 821 | 4,607 | 3,444 | 75 |
| 2000 | 1,653 | 942 | 2,893 | 965 | 6,453 | 3,783 | 59 |
| 2001 | 760 | 897 | 2,301 | 2,297 | 6,255 | 4,448 | 71 |

Table J4. Total winter flounder recreational and commercial catch for the Southern New England/Mid-Atlantic stock complex in weight (mt) and numbers (000s).

| Year | Commercial Landings | | Commercial Discards | | Recreational Landings | | Recreational Discards | | Total Catch | | % Discards/Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mt | 000s | mt | 000s | mt | 000s | mt | 000s | mt | 000s | mt | 000s |
| 1981 | 11,176 | 20,705 | 1,343 | 5,123 | 3,050 | 8,089 | 88 | 437 | 15,657 | 34,354 | 9.1 | 16.2 |
| 1982 | 9,438 | 19,016 | 1,149 | 4,271 | 2,457 | 8,392 | 66 | 341 | 13,110 | 32,020 | 9.3 | 14.4 |
| 1983 | 8,659 | 16,312 | 1,311 | 5,251 | 2,524 | 8,365 | 125 | 399 | 12,619 | 30,327 | 11.4 | 18.6 |
| 1984 | 8,882 | 17,116 | 986 | 3,936 | 5,772 | 12,756 | 148 | 745 | 15,788 | 34,553 | 7.2 | 13.5 |
| 1985 | 7,052 | 14,211 | 1,534 | 4,531 | 5,198 | 13,297 | 230 | 714 | 14,014 | 32,753 | 12.6 | 16.0 |
| 1986 | 4,929 | 9,460 | 1,273 | 4,902 | 2,940 | 6,994 | 66 | 356 | 9,208 | 21,712 | 14.5 | 24.2 |
| 1987 | 5,172 | 10,524 | 950 | 3,545 | 3,141 | 6,899 | 61 | 347 | 9,324 | 21,315 | 10.8 | 18.3 |
| 1988 | 4,312 | 8,377 | 904 | 3,728 | 3,423 | 7,359 | 69 | 416 | 8,708 | 19,880 | 11.2 | 20.8 |
| 1989 | 3,670 | 7,888 | 1,404 | 5,761 | 1,802 | 3,684 | 49 | 335 | 6,925 | 17,668 | 21.0 | 34.5 |
| 1990 | 4,232 | 7,202 | 673 | 2,567 | 1,063 | 2,485 | 31 | 201 | 5,999 | 12,455 | 11.7 | 22.2 |
| 1991 | 4,823 | 9,063 | 784 | 2,701 | 1,214 | 2,794 | 51 | 230 | 6,872 | 14,788 | 12.2 | 19.8 |
| 1992 | 3,816 | 6,759 | 511 | 1,811 | 393 | 802 | 15 | 83 | 4,735 | 9,455 | 11.1 | 20.0 |
| 1993 | 3,010 | 5,336 | 457 | 1,580 | 543 | 1,180 | 31 | 155 | 4,041 | 8,251 | 12.1 | 21.0 |
| 1994 | 2,159 | 1,948 | 304 | 344 | 598 | 1,210 | 34 | 93 | 3,095 | 3,595 | 10.9 | 12.2 |
| 1995 | 2,634 | 2,321 | 121 | 107 | 661 | 1,390 | 23 | 69 | 3,439 | 3,887 | 4.2 | 4.5 |
| 1996 | 2,781 | 2,372 | 173 | 149 | 689 | 1,555 | 64 | 168 | 3,707 | 4,244 | 6.4 | 7.5 |
| 1997 | 3,441 | 5,834 | 267 | 1,200 | 618 | 1,204 | 26 | 85 | 4,352 | 8,323 | 6.7 | 15.4 |
| 1998 | 3,208 | 6,224 | 456 | 1,503 | 290 | 584 | 13 | 64 | 3,967 | 8,375 | 11.8 | 18.7 |
| 1999 | 3,444 | 7,356 | 329 | 1,074 | 320 | 658 | 14 | 62 | 4,107 | 9,150 | 8.4 | 12.4 |
| 2000 | 3,783 | 6,590 | 148 | 534 | 831 | 1,346 | 30 | 105 | 4,792 | 8,575 | 3.7 | 7.5 |
| 2001 | 4,448 | 7,690 | 83 | 285 | 552 | 901 | 19 | 81 | 5,102 | 8,957 | 2.0 | 4.1 |

Table J5. Winter flounder NEFSC survey index stratified mean number and mean weight (kg) per tow for the Southern New England- Mid-Atlantic stock complex. Spring and fall strata set (offshore 1-12, 25, 69-76 ; inshore 1-29, 45-56); winter strata set (offshore 1-2, 5-6,9-10,69,73).

| | Spring | | | | Fall | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Number | N(CV) | Weight | W(CV) | Number | N(CV) | Weight | W(CV) |
| 1963 | | | | | 8.554 | 33.2 | 3.284 | 41.4 |
| 1964 | | | | | 13.673 | 22.1 | 4.894 | 19.4 |
| 1965 | | | | | 15.537 | 32.5 | 4.435 | 28.7 |
| 1966 | | | | | 9.843 | 31.5 | 3.275 | 27.3 |
| 1967 | | | | | 9.109 | 20.6 | 2.745 | 18.7 |
| 1968 | 2.444 | 26.7 | 0.734 | 37.2 | 8.105 | 21.0 | 2.190 | 18.7 |
| 1969 | 5.640 | 34.3 | 3.414 | 53.7 | 6.841 | 34.9 | 1.939 | 29.7 |
| 1970 | 2.729 | 30.9 | 1.326 | 35.6 | 5.110 | 36.1 | 2.375 | 47.8 |
| 1971 | 2.035 | 32.9 | 0.756 | 36.2 | 3.861 | 17.5 | 1.231 | 19.1 |
| 1972 | 1.865 | 28.1 | 0.656 | 32.1 | 7.687 | 39.4 | 3.053 | 44.6 |
| 1973 | 7.458 | 19.9 | 2.013 | 20.6 | 2.691 | 26.9 | 0.775 | 25.8 |
| 1974 | 3.362 | 21.9 | 1.043 | 19.3 | 2.032 | 31.1 | 0.822 | 29.4 |
| 1975 | 1.135 | 22.6 | 0.354 | 20.8 | 2.196 | 20.3 | 0.688 | 22.1 |
| 1976 | 3.085 | 16.3 | 0.804 | 17.2 | 2.376 | 32.2 | 1.251 | 42.9 |
| 1977 | 4.209 | 17.2 | 1.189 | 18.6 | 4.722 | 22.5 | 1.735 | 25.2 |
| 1978 | 6.695 | 11.1 | 1.758 | 13.3 | 3.743 | 17.6 | 1.430 | 22.6 |
| 1979 | 2.966 | 16.8 | 1.069 | 25.0 | 10.058 | 18.4 | 2.606 | 15.4 |
| 1980 | 15.250 | 17.5 | 3.551 | 13.6 | 9.964 | 31.0 | 3.216 | 29.5 |
| 1981 | 18.234 | 20.9 | 4.762 | 16.9 | 10.206 | 20.3 | 3.110 | 19.9 |
| 1982 | 6.986 | 20.1 | 1.918 | 15.8 | 4.927 | 22.8 | 1.683 | 25.9 |
| 1983 | 6.262 | 18.4 | 2.469 | 28.0 | 8.757 | 37.6 | 2.690 | 31.7 |
| 1984 | 5.524 | 19.0 | 2.072 | 28.4 | 2.681 | 21.1 | 0.887 | 21.0 |
| 1985 | 5.360 | 17.4 | 1.983 | 16.5 | 2.727 | 21.5 | 0.991 | 21.5 |
| 1986 | 2.266 | 23.9 | 0.766 | 23.4 | 1.538 | 21.9 | 0.487 | 19.1 |
| 1987 | 1.763 | 21.3 | 0.568 | 17.9 | 1.167 | 28.9 | 0.419 | 37.8 |
| 1988 | 2.126 | 19.6 | 0.730 | 19.3 | 1.246 | 22.4 | 0.530 | 27.5 |
| 1989 | 2.485 | 33.5 | 0.582 | 29.6 | 1.435 | 40.7 | 0.341 | 30.4 |
| 1990 | 1.992 | 36.8 | 0.472 | 33.1 | 1.979 | 29.6 | 0.546 | 25.8 |
| 1991 | 2.473 | 15.6 | 0.692 | 14.7 | 1.950 | 23.6 | 0.708 | 25.6 |

Table J5 continued.

| | Spring | | | | Fall | | | | Winter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Number | N(CV) | Weight | W(CV) | Number | N(CV) | Weight | W(CV) | Number | N(CV) | Weight | W(CV) |
| 1992 | 1.579 | 23.4 | 0.435 | 22.1 | 2.963 | 32.4 | 0.829 | 31.8 | 3.680 | 27.3 | 0.928 | 26.0 |
| 1993 | 0.961 | 19.1 | 0.219 | 14.8 | 1.382 | 25.0 | 0.392 | 25.9 | 2.590 | 29.4 | 0.456 | 21.5 |
| 1994 | 1.510 | 26.4 | 0.329 | 21.9 | 4.134 | 24.8 | 1.482 | 27.3 | 3.797 | 30.8 | 1.183 | 35.5 |
| 1995 | 2.097 | 23.4 | 0.592 | 19.1 | 2.253 | 20.7 | 0.626 | 17.3 | 2.221 | 26.1 | 0.697 | 29.1 |
| 1996 | 1.517 | 14.3 | 0.428 | 15.2 | 3.186 | 39.8 | 1.063 | 45.3 | 3.778 | 28.4 | 0.734 | 25.2 |
| 1997 | 1.436 | 22.1 | 0.399 | 20.0 | 7.893 | 32.6 | 2.583 | 26.7 | 3.906 | 19.7 | 1.043 | 21.6 |
| 1998 | 2.774 | 20.6 | 0.845 | 22.1 | 6.597 | 13.6 | 2.232 | 9.9 | 7.169 | 21.6 | 1.830 | 24.1 |
| 1999 | 4.171 | 16.2 | 1.245 | 16.4 | 3.596 | 17.0 | 1.549 | 16.5 | 10.328 | 31.8 | 3.100 | 32.3 |
| 2000 | 3.172 | 26.6 | 1.123 | 31.9 | 6.168 | 25.5 | 2.143 | 26.2 | 5.571 | 32.9 | 1.525 | 29.5 |
| 2001 | 1.568 | 14.3 | 0.581 | 13.3 | 4.877 | 28.1 | 2.030 | 28.5 | 3.096 | 31.6 | 0.873 | 29.0 |
| 2002 | 2.043 | 15.7 | 0.782 | 16.3 | | | | | 2.901 | 27.7 | 1.188 | 38.3 |

NOTE: 1968-1972 spring index does not include inshore strata ; 1963-1971 fall index does not include inshore strata. All indices calculated with trawl door conversion factors where appropriate. Winter trawl survey began in 1992.

Table J6. SNE/MA winter flounder mean weight per tow for annual state surveys.

| Year | MADMF spring | RIDFW spring | RIDFW fall | CTDEP | NJDFW Ocean (April) |
|---|---|---|---|---|---|
| 1978 | 18.12 | | | | |
| 1979 | 18.17 | 7.72 | 7.24 | | |
| 1980 | 15.18 | 13.57 | 4.88 | | |
| 1981 | 15.77 | 12.13 | 2.12 | | |
| 1982 | 14.82 | 5.23 | 1.30 | | |
| 1983 | 19.67 | 9.52 | 2.28 | | |
| 1984 | 14.68 | 8.43 | 3.38 | 15.68 | |
| 1985 | 11.60 | 5.93 | 3.01 | 13.82 | |
| 1986 | 10.36 | 6.47 | 3.12 | 10.33 | |
| 1987 | 9.57 | 8.14 | 2.25 | 11.76 | |
| 1988 | 6.64 | 6.02 | 1.45 | 18.29 | |
| 1989 | 8.46 | 3.09 | 0.79 | 22.62 | 5.86 |
| 1990 | 5.38 | 3.07 | 0.71 | 29.02 | 4.78 |
| 1991 | 2.91 | 7.38 | 0.18 | 24.59 | 5.32 |
| 1992 | 7.99 | 0.95 | 0.42 | 12.29 | 2.48 |
| 1993 | 8.16 | 0.22 | 0.50 | 10.26 | 3.87 |
| 1994 | 12.59 | 1.67 | 0.33 | 12.20 | 3.25 |
| 1995 | 7.98 | 6.04 | 0.89 | 7.72 | 8.06 |
| 1996 | 9.78 | 4.45 | 0.91 | 20.41 | 3.73 |
| 1997 | 10.02 | 4.57 | 0.64 | 15.53 | 6.52 |
| 1998 | 7.99 | 5.00 | 0.32 | 14.66 | 4.17 |
| 1999 | 4.44 | 3.66 | 0.57 | 10.29 | 6.83 |
| 2000 | 6.52 | 4.52 | 0.56 | 12.63 | 5.24 |
| 2001 | 3.73 | 3.56 | 0.28 | 14.02 | 6.36 |
| 2002 | | | | 10.90 | 8.80 |

Table J7. State survey indices (stratified mean number per tow or haul) for young-of-year winter flounder in Southern New England/Mid-Atlantic stock complex.

| Year | CTDEP | RIDFW | DEDFG | MADMF | NYDEC |
|---|---|---|---|---|---|
| 1975 | | | | 0.30 | |
| 1976 | | | | 0.32 | |
| 1977 | | | | 0.60 | |
| 1978 | | | | 0.34 | |
| 1979 | | | | 0.49 | |
| 1980 | | | | 0.40 | |
| 1981 | | | | 0.32 | |
| 1982 | | | | 0.37 | |
| 1983 | | | | 0.23 | |
| 1984 | | | | 0.32 | |
| 1985 | | | | 0.34 | 0.75 |
| 1986 | | 29.00 | 0.17 | 0.32 | |
| 1987 | | 11.60 | 0.09 | 0.27 | 0.97 |
| 1988 | 15.50 | 8.90 | 0.02 | 0.18 | 0.69 |
| 1989 | 1.90 | 18.90 | 0.29 | 0.42 | 1.67 |
| 1990 | 3.10 | 22.10 | 0.63 | 0.33 | 2.71 |
| 1991 | 5.80 | 12.00 | 0.03 | 0.27 | 2.57 |
| 1992 | 13.70 | 33.20 | 0.27 | 0.29 | 11.49 |
| 1993 | 6.00 | 5.50 | 0.04 | 0.07 | 4.73 |
| 1994 | 16.60 | 2.60 | 0.31 | 0.15 | 2.44 |
| 1995 | 12.50 | 5.30 | 0.10 | 0.16 | 0.91 |
| 1996 | 19.20 | 2.80 | 0.04 | 0.22 | 3.80 |
| 1997 | 7.47 | 4.40 | | 0.39 | 4.42 |
| 1998 | 9.38 | 2.50 | | 0.16 | 3.11 |
| 1999 | 8.70 | 14.60 | | 0.19 | 7.49 |
| 2000 | 4.30 | 52.90 | | 0.33 | 0.90 |
| 2001 | 1.30 | 12.90 | | 0.21 | 2.31 |
| 2002 | | | | 0.10 | |

Table J8. Virtual Population Analysis for SNE/MA winter flounder, 1981-2001.

STOCK NUMBERS (Jan 1) in thousands

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| 1 | 62859 | 52020 | 56503 | 35617 | 34615 | 32795 | 25973 |
| 2 | 52566 | 50232 | 42060 | 45703 | 28708 | 28090 | 26656 |
| 3 | 27768 | 30289 | 28226 | 27884 | 26945 | 16839 | 17273 |
| 4 | 7146 | 9748 | 13560 | 11068 | 10077 | 10446 | 5551 |
| 5 | 1468 | 2600 | 4606 | 5559 | 4603 | 2773 | 4738 |
| 6 | 363 | 600 | 1577 | 2148 | 2944 | 1096 | 1317 |
| 7 | 218 | 564 | 1219 | 1949 | 2228 | 876 | 730 |
| 1+ | 152388 | 146054 | 147751 | 129927 | 110120 | 92914 | 82238 |

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|
| 1 | 26726 | 23113 | 17366 | 11355 | 7808 | 8844 | 8315 |
| 2 | 21199 | 21806 | 18504 | 14185 | 9249 | 6370 | 6993 |
| 3 | 17057 | 13790 | 13106 | 13242 | 8875 | 6212 | 3350 |
| 4 | 6000 | 5458 | 4798 | 5053 | 4381 | 3233 | 2074 |
| 5 | 1748 | 1325 | 1299 | 1276 | 1111 | 1251 | 1084 |
| 6 | 1433 | 339 | 317 | 369 | 268 | 300 | 495 |
| 7 | 433 | 312 | 223 | 165 | 86 | 218 | 300 |
| 1+ | 74596 | 66142 | 55613 | 45645 | 31778 | 26429 | 22611 |

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| 1 | 12647 | 17632 | 21154 | 18793 | 13372 | 12710 | 19011 |
| 2 | 6753 | 10333 | 14407 | 16971 | 15341 | 10889 | 10343 |
| 3 | 4733 | 5352 | 7658 | 9864 | 11966 | 10076 | 7610 |
| 4 | 1700 | 2190 | 3070 | 3284 | 4761 | 6170 | 5082 |
| 5 | 1053 | 588 | 791 | 875 | 1063 | 2320 | 2830 |
| 6 | 606 | 487 | 171 | 159 | 254 | 456 | 1120 |
| 7 | 433 | 312 | 73 | 228 | 83 | 168 | 512 |
| 1+ | 27925 | 36893 | 47324 | 50174 | 46840 | 42788 | 46509 |

| | 2002 |
|---|---|
| 1 | 5665 |
| 2 | 15553 |
| 3 | 6671 |
| 4 | 2912 |
| 5 | 2179 |
| 6 | 1602 |
| 7 | 1057 |
| 1+ | 35639 |

Table J8 continued.

FISHING MORTALITY

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 |
| 2 | 0.35 | 0.38 | 0.21 | 0.33 | 0.33 | 0.29 | 0.25 |
| 3 | 0.85 | 0.60 | 0.74 | 0.82 | 0.75 | 0.91 | 0.86 |
| 4 | 0.81 | 0.55 | 0.69 | 0.68 | 1.09 | 0.59 | 0.96 |
| 5 | 0.69 | 0.30 | 0.56 | 0.44 | 1.23 | 0.54 | 1.00 |
| 6 | 0.81 | 0.50 | 0.67 | 0.60 | 1.18 | 0.59 | 1.00 |
| 7 | 0.81 | 0.50 | 0.67 | 0.60 | 1.18 | 0.59 | 1.00 |

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.02 | 0.00 | 0.01 | 0.00 | 0.03 | 0.01 |
| 2 | 0.23 | 0.31 | 0.13 | 0.27 | 0.20 | 0.44 | 0.19 |
| 3 | 0.94 | 0.86 | 0.75 | 0.91 | 0.81 | 0.90 | 0.48 |
| 4 | 1.31 | 1.24 | 1.12 | 1.31 | 1.05 | 0.89 | 0.48 |
| 5 | 1.44 | 1.23 | 1.06 | 1.36 | 1.11 | 0.73 | 0.38 |
| 6 | 1.41 | 1.29 | 1.15 | 1.39 | 1.10 | 0.86 | 0.45 |
| 7 | 1.41 | 1.29 | 1.15 | 1.39 | 1.10 | 0.86 | 0.45 |

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 |
| 2 | 0.03 | 0.10 | 0.18 | 0.15 | 0.22 | 0.16 | 0.24 |
| 3 | 0.57 | 0.36 | 0.65 | 0.53 | 0.46 | 0.48 | 0.76 |
| 4 | 0.86 | 0.82 | 1.06 | 0.93 | 0.52 | 0.58 | 0.65 |
| 5 | 0.57 | 1.04 | 1.40 | 1.04 | 0.65 | 0.53 | 0.37 |
| 6 | 0.76 | 0.88 | 1.16 | 0.98 | 0.55 | 0.57 | 0.23 |
| 7 | 0.76 | 0.88 | 1.16 | 0.98 | 0.55 | 0.57 | 0.23 |

Average F for 4,5

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| 4,5 | 0.75 | 0.42 | 0.63 | 0.56 | 1.16 | 0.57 | 0.98 |

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|
| 4,5 | 1.38 | 1.23 | 1.09 | 1.34 | 1.08 | 0.81 | 0.43 |

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| 4,5 | 0.72 | 0.93 | 1.23 | 0.98 | 0.58 | 0.55 | 0.51 |

Table J8 continued.

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT) (using SSB mean weights)

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 3 | 4739 | 4757 | 3771 | 3557 | 3615 | 2395 | 2482 |
| 4 | 3893 | 4592 | 5119 | 3855 | 3106 | 3541 | 1958 |
| 5 | 1205 | 2157 | 2899 | 2927 | 1838 | 1374 | 1779 |
| 6 | 341 | 603 | 1387 | 1540 | 1272 | 634 | 644 |
| 7 | 214 | 900 | 1590 | 2129 | 1037 | 718 | 489 |
| 1+ | 10393 | 13009 | 14766 | 14008 | 10869 | 8662 | 7353 |

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 3 | 2282 | 1923 | 1831 | 1980 | 1414 | 960 | 600 |
| 4 | 1863 | 1642 | 1556 | 1627 | 1626 | 1242 | 902 |
| 5 | 744 | 576 | 590 | 526 | 559 | 667 | 639 |
| 6 | 516 | 169 | 177 | 200 | 156 | 203 | 300 |
| 7 | 260 | 248 | 169 | 140 | 93 | 206 | 215 |
| 1+ | 5663 | 4559 | 4323 | 4474 | 3848 | 3278 | 2656 |

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| 1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 3 | 849 | 1028 | 1563 | 1817 | 2128 | 1756 | 2579 |
| 4 | 665 | 857 | 1311 | 1354 | 1990 | 2548 | 2103 |
| 5 | 589 | 293 | 389 | 452 | 563 | 1251 | 1692 |
| 6 | 376 | 301 | 113 | 107 | 170 | 296 | 715 |
| 7 | 279 | 214 | 84 | 224 | 73 | 169 | 553 |
| 1+ | 2759 | 2693 | 3459 | 3954 | 4923 | 6021 | 7643 |

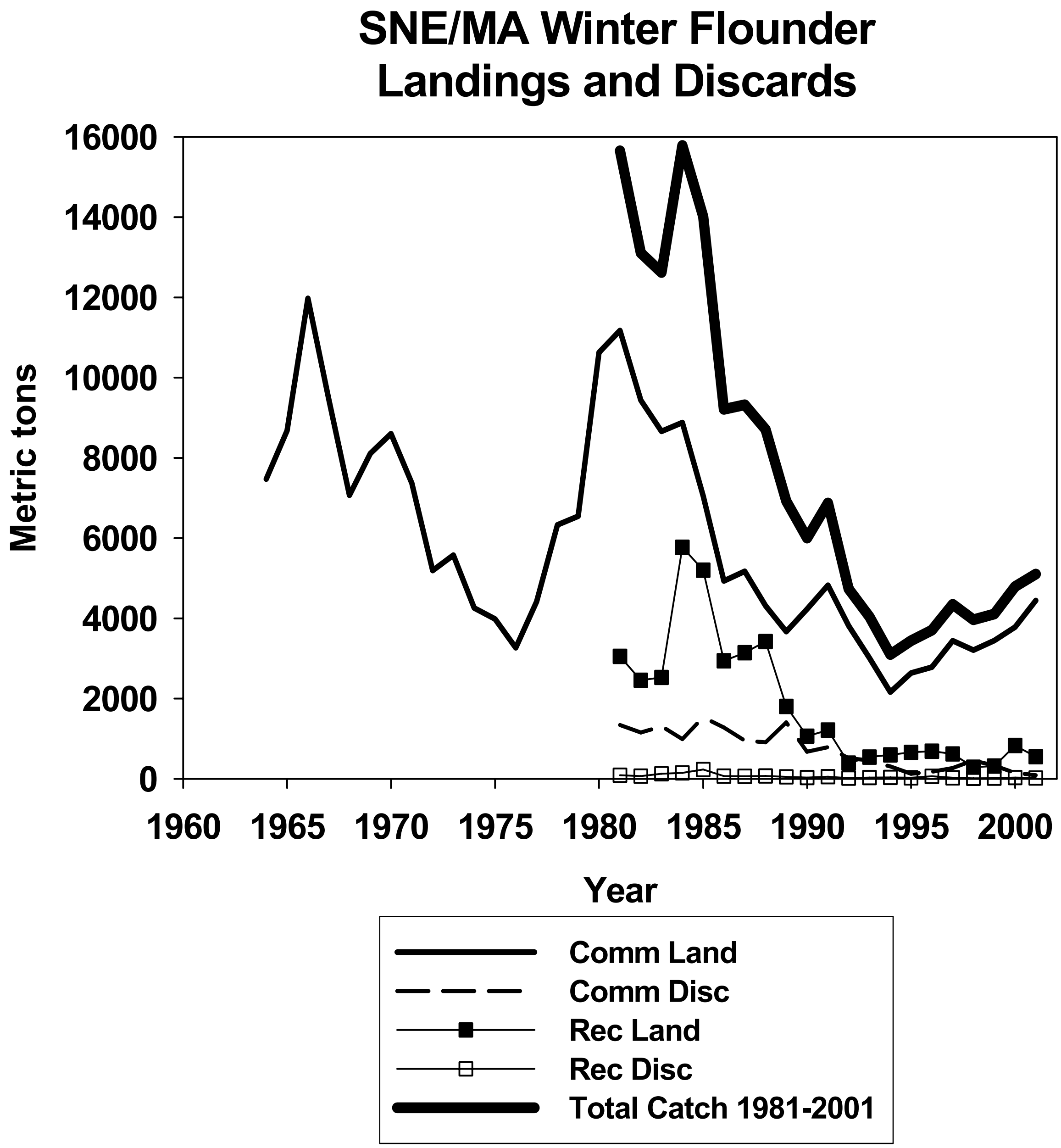


Figure J1. Commercial landings (1964-2001), commercial discards (1981-2001) recreational landings (1981-2001), recreational discards (1981-2001) and total fishery catch (198-2001) for the SNE/MA winter flounder stock complex.

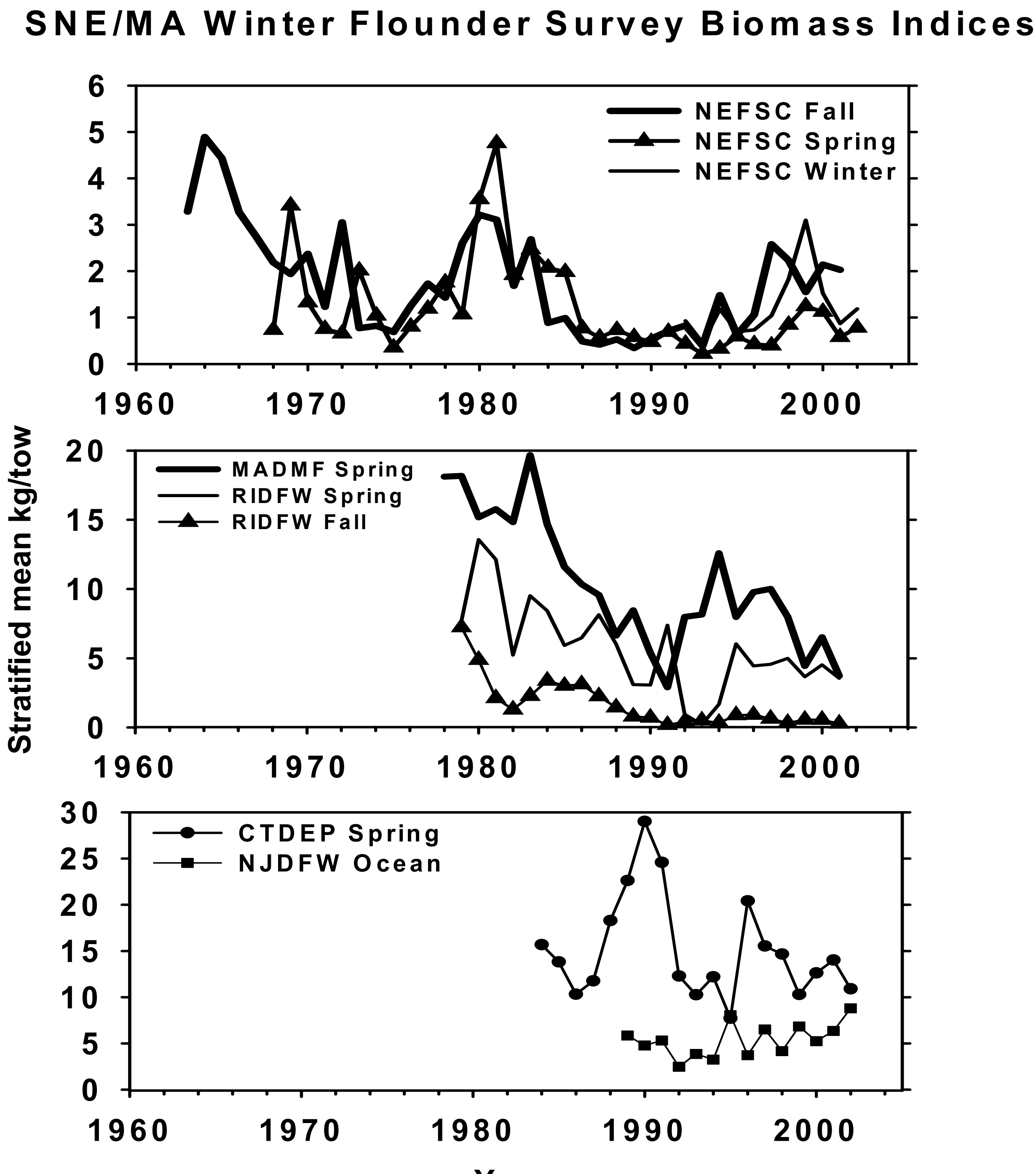


Figure J2. Trends in research survey biomass indices for SNE/MA winter flounder.

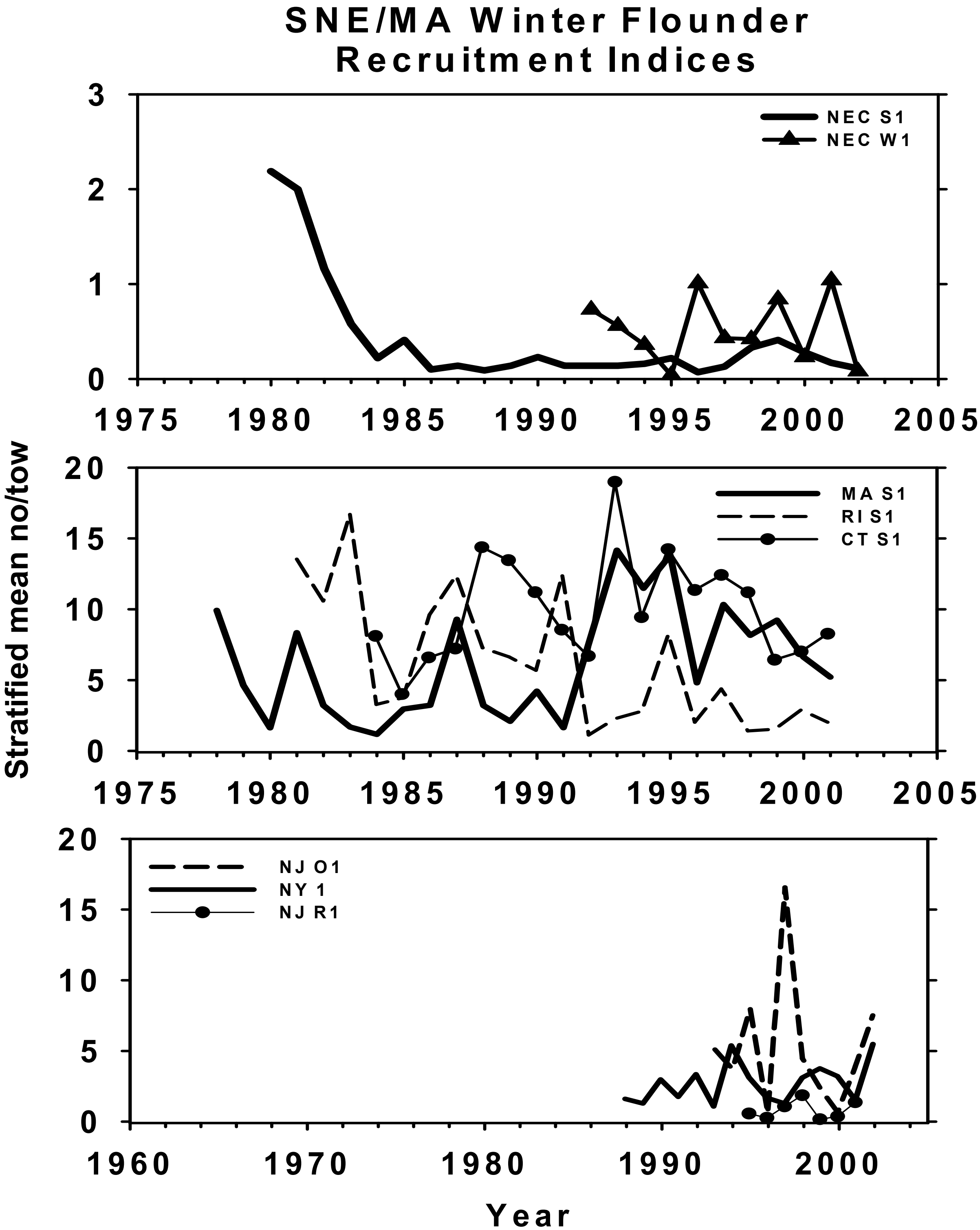


Figure J3. Trends in research survey recruitment indices for SNE/MA winter flounder. Includes spring survey age-1 indices and fall YOY indices advanced one year

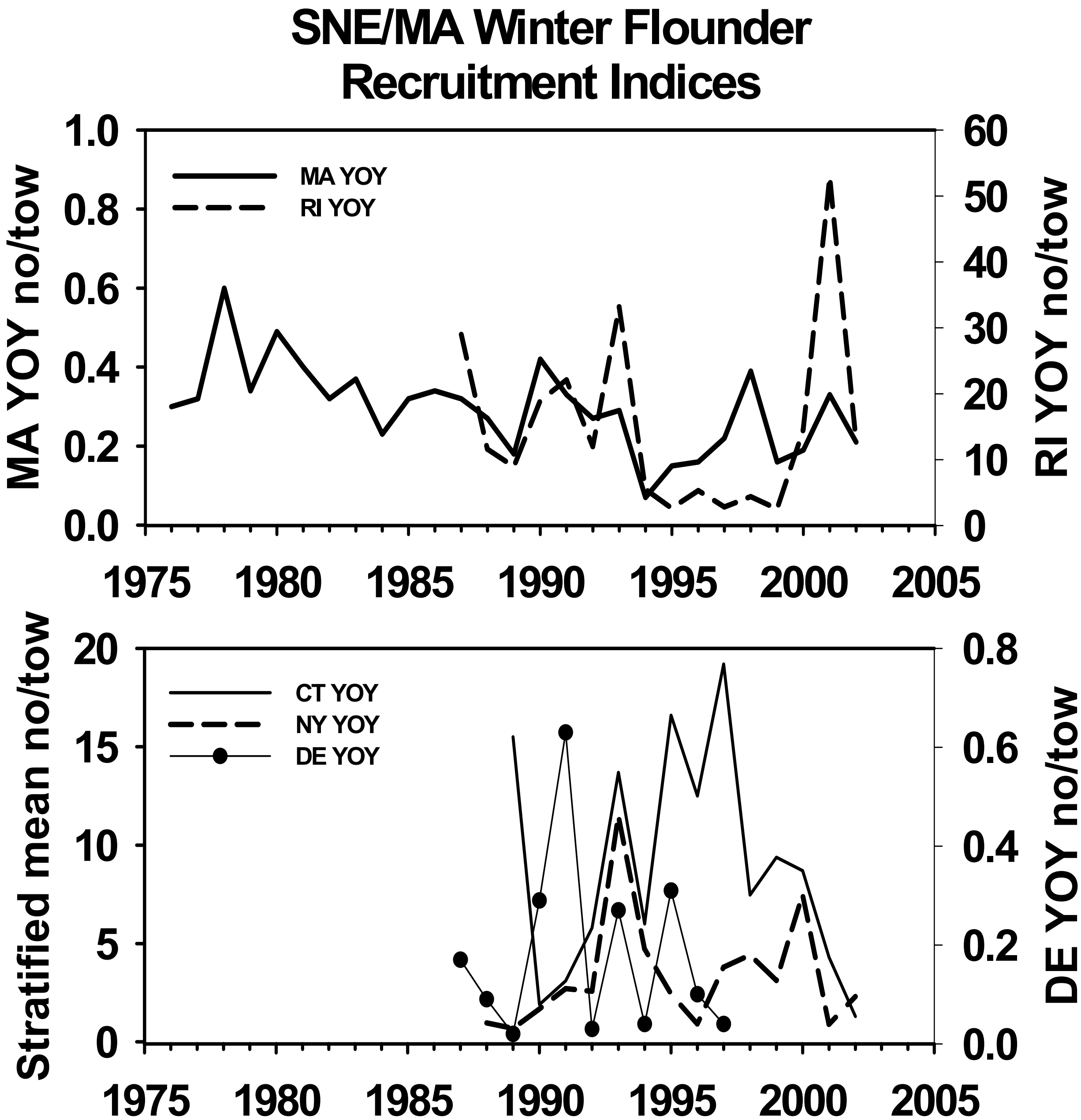


Figure J3 continued.

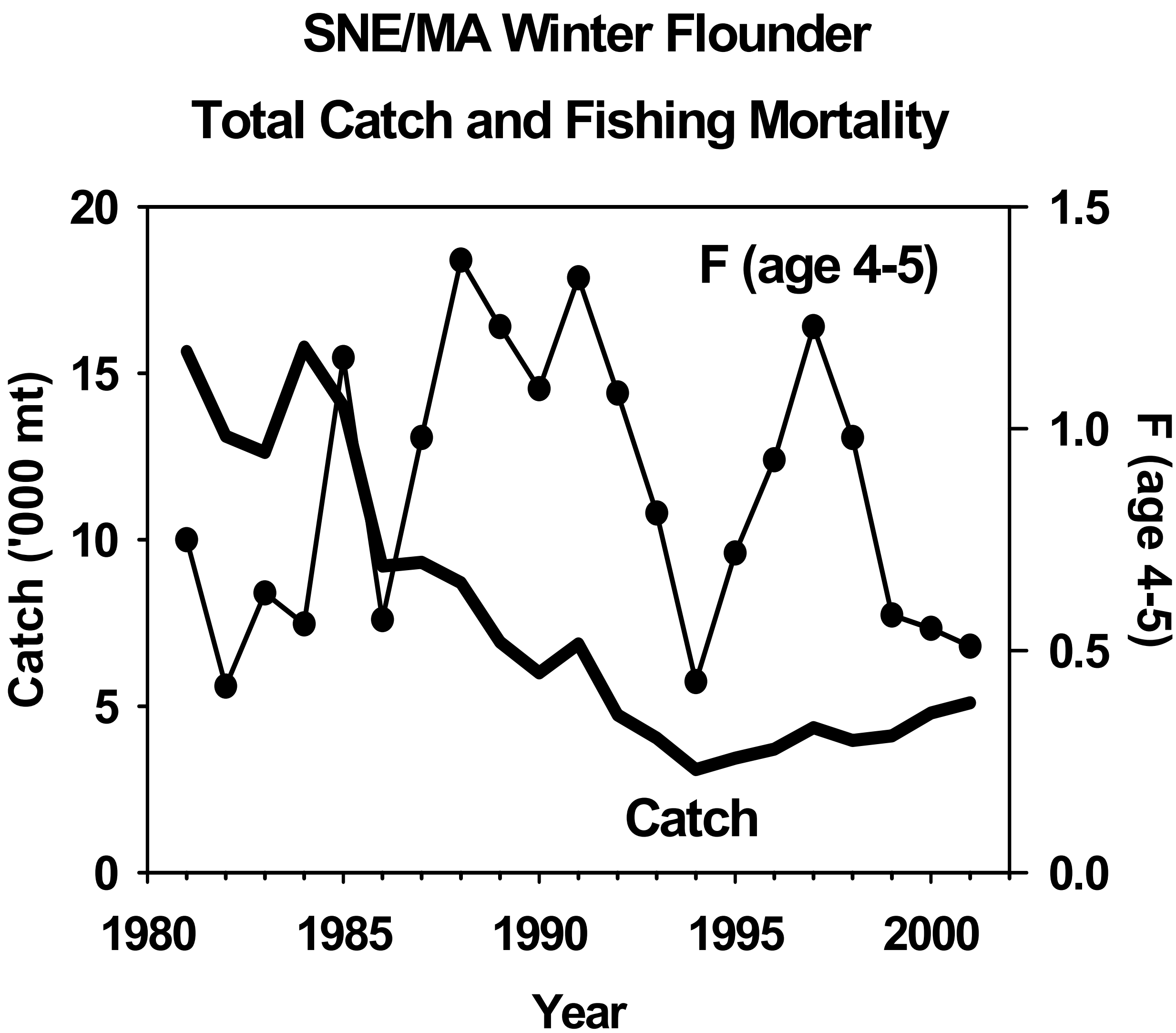


Figure J4. Total catch (landings and discards, thousands of metric tons) and fishing mortality rate (F, ages 4-5, unweighted) for SNE/MA winter flounder.

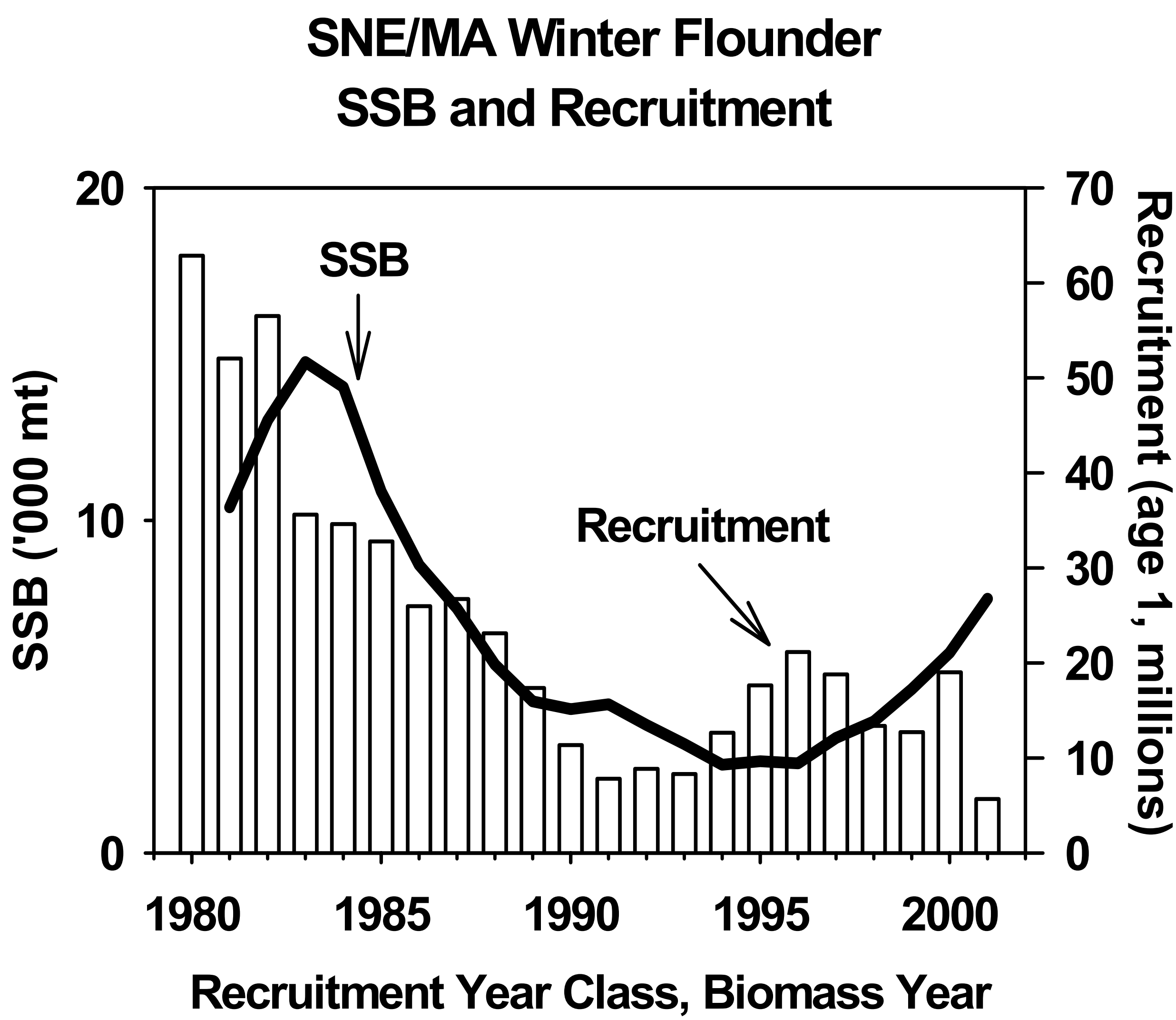


Figure J5. Spawning stock biomass (SSB, ages 3-7+, '000 mt) and recruitment (millions of fish at age-1) for SNE/MA winter flounder.

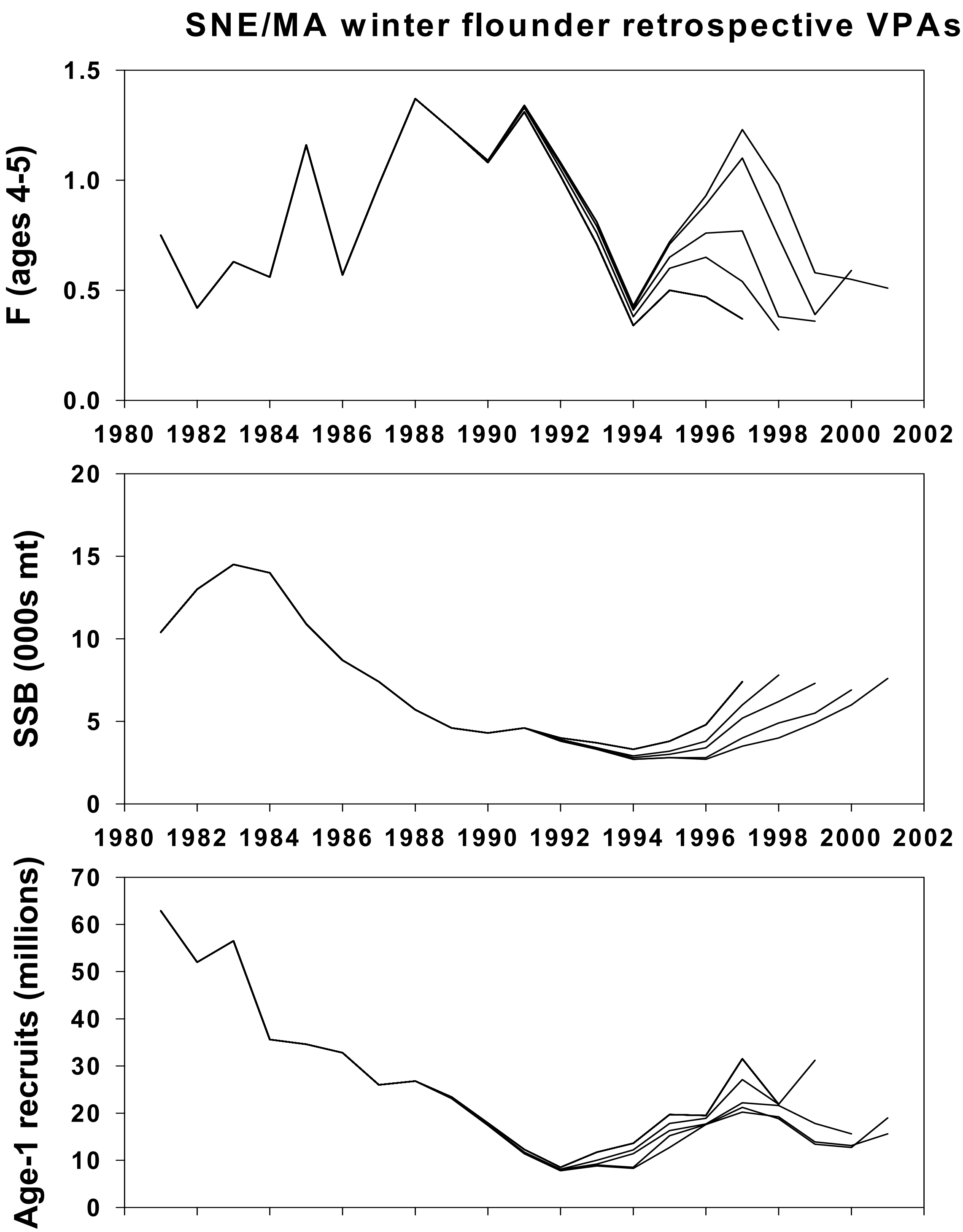


Figure J6. Retrospective VPAs for SNE/MA winter flounder.

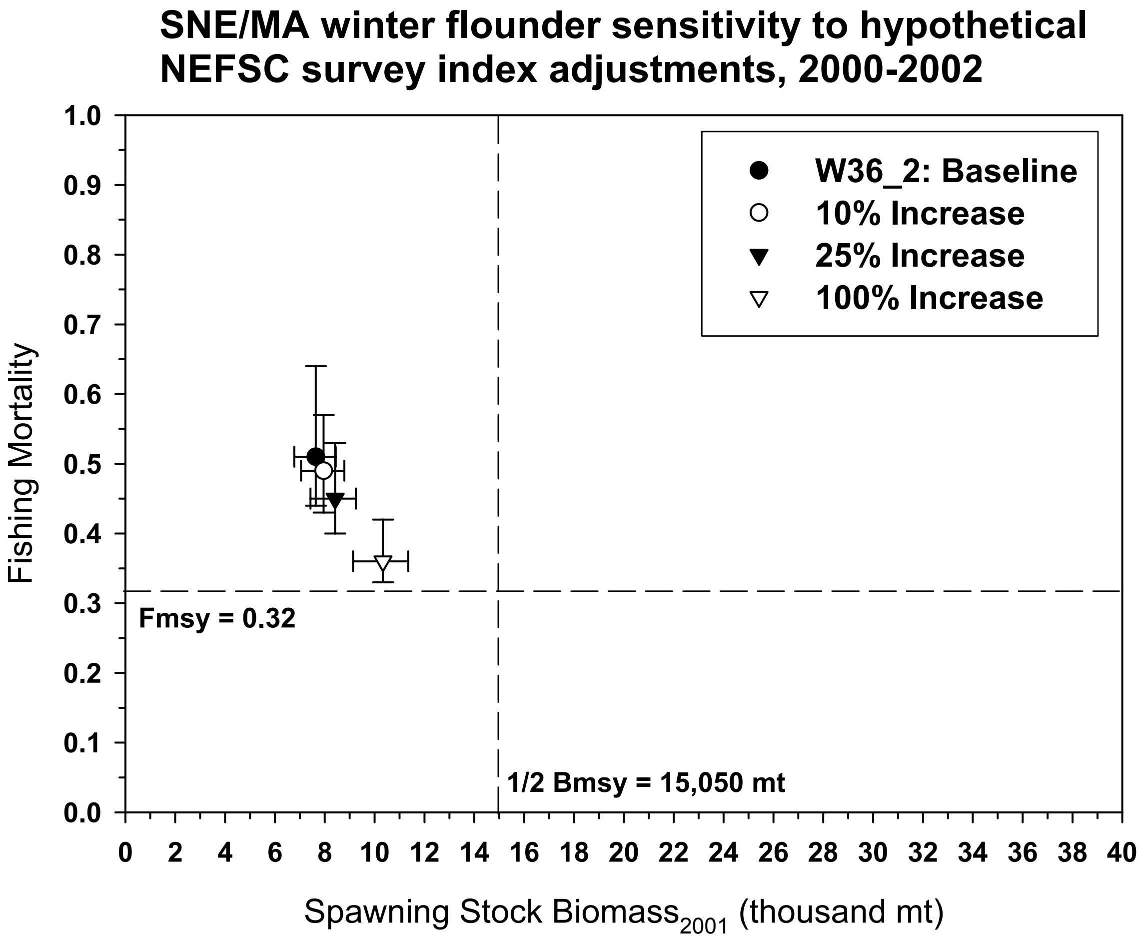


Figure J7. SNE/MA winter flounder VPA sensitivity to hypothetical NEFSC winter, spring, and fall survey index adjustments.

**K. Georges Bank/Gulf of Maine White Hake** by K.A. Sosebee

**1.0 Background**

This stock was last assessed in 2001 and reviewed at SAW 33. An ASPIC model was used to estimate stock sizes and fishing mortality. Only fish > 60 cm were included to eliminate species identification as a source of uncertainty. Landings and discards were used in the model, which was tuned with spring and autumn survey biomass indices. Fishing mortality in 2000 was estimated to be more than twice the value for $F_{msy}$. Biomass estimates were less than 1/4 $B_{msy}$. NEFSC spring and autumn research vessel bottom trawl survey indices had declined to near record low levels in 1999 but increased in 2000.

**2.0 The Fishery**

United States commercial landings of white hake increased to 3,364 metric tons (mt) in 2001, a 16% increase from 2000 (Table K1; Figure K1). Canadian landings declined to 228 mt (9% decline). Discard estimates were derived for 2001 using the same method as in the previous assessment. Discards increased 38% to 439 mt overall (Figure K1). Only otter trawl discards are used in the assessment. Such discards increased to 334 mt (34%).

**3.0 2002 Assessment**

Landings-at-length were estimated using port samples collected in 2001. The sampling intensity (Table K2) and coverage were adequate, except for the unclassified market category. As in the previous assessment, unclassified landings were low and were raised with the total at the end.

Discards-at-length were estimated using length samples from 2000 and 2001. The otter trawl sampling in the observer program was very low (one sample in the first half) in 2001 so pooling was necessary (Table K3). The possible mis-identification of species is a problem, particularly for estimation of discards. The length compositions of both the landings and discards were broken out into fish <= 60 cm and fish > 60 cm (Table K4, Figure K2). This length cutoff ensures that most of the fish > 60 cm are white hake since red hake do not reach this size. For years prior to 1985, an average proportion of fish > 60 cm for 1985-2000 was used to split the landings into two parts (75% > 60 cm). All discards prior to 1989 were assumed to be <= 60 cm. The NEFSC surveys were also split into two parts as in the commercial length compositions (Figure K2, Table K6). The rate of decline for the > 60 cm portion of the stock is apparently greater than that for the stock as a whole.

The ASPIC model from the previous assessment using catch of white hake greater than 60 cm was updated .

## 4.0 Assessment Results

NEFSC research vessel bottom trawl survey abundance and biomass indices for white hake remained relatively low through autumn 1999 (Table K5, Figure K3). Autumn indices increased sharply in 2000 and 2001.

Estimates of $F_{msy}$ and $B_{msy}$ from the > 60 cm ASPIC model changed significantly with the addition of one year of data. The estimated value for r, the intrinsic rate of increase, also changed (from 0.58 to 0.73). This value of r appears to be implausibly high for a gadid species which lives to be 20 years old. Therefore, the GARM did not accept the ASPIC model results.

Since the ASPIC model was not accepted, an alternative was developed. An index of relative exploitation (catch/survey biomass index) corresponding to a replacement ratio of 1.0, as described in NEFSC (2002) was developed for biomass indices and catches of white hake > 60 cm. Autumn NEFSC survey biomass indices from 1963 through 2001 (Figure K2) were used to calculate the replacement ratios, defined as the biomass index in the current year divided by the average biomass indices from the previous 5 years. The biomass indices and total catch (Figure K2) were used to compute the relative exploitation rates, defined as the catch in the current year divided by the 3 year average survey biomass index for the previous 2 years and the current year (Figure K4). These relative exploitation rates (or relative F) may be considered a proxy for F for white hake.

Prior to the 1980s, a high proportion of the replacement ratios equaled or exceeded 1.0 (Figure K4). During the 1980s and early 1990s, most of the replacement ratios were less than 1.0, with ratios greater than 1.0 appearing sporadically. The values for the last two years were greater than 1.0 due to the large increase in the survey biomass index in the last two years.

The relationship between replacement ratios and relative F was evaluated by a linear regression of the $\log_e$ replacement ratio on $\log_e$ relative F (NEFSC 2002) and the results were used to derive an estimate of relative F corresponding to a replacement ratio of 1.0 (Figure K4). Results for white hake were highly significant (NEFSC 2002). The regression indicates that, on average, when the relative F is greater than 0.55, the stock is not likely to replace itself.

The GARM decided to use the value of MSY estimated from the last accepted ASPIC model run at SAW 33. In evaluating this number, the GARM also looked at the relationship between the catches and survey indices. It appears that when catches exceeded 4,200 mt, the survey indices of biomass declined, and when catches dropped below this value, the indices either stabilized or increased. The value of 4,234 mt can then be used to derive $B_{MSY}$ by dividing it by $F_{MSY}$. This gives a value of 7.70 kg/tow for $B_{msy}$.

The current value for biomass of 2.35 kg/tow is below that of ½ $B_{msy}$ and indicates that this stock is overfished. Likewise, the relative F value of 1.36 is above $F_{msy}$ indicating that overfishing is occurring.

## 5.0 Biological Reference Points

The following biological reference point proxies were obtained from an index-based model of replacement ratios (NEFSC 2002) derived from indices of relative exploitation:

| | |
|---|---|
| MSY | 4,234 mt |
| $B_{MSY}$ | 7.70 kg/tow |
| $F_{MSY}$ | 0.55 (Relative F) |

## 6.0 Trawl Warp Analyses

Analyses were conducted to determine the effects of increasing the survey biomass indices for 2000 and 2001 to account for possible trawl warp problems. Results are summarized in section 5.2 (Summary of Assessment Advice).

## 7.0 GARM comments

The GARM reviewed the ASPIC results for white hake and noted a significant change in the estimate of r from the last assessment. The GARM concluded that the ASPIC model does not provide reliable results for determining stock status and that stock status should be determined directly from the surveys.

## 8.0 Sources of Uncertainty

- Catch at age and length are not well characterized due to possible mis-identification of species in the commercial and sea sampling data, low sampling of commercial landings, and sparse discard data.

- Catchability of older ages and larger fish in the survey may be low.

## 9.0 References


NEFSC. 2001. 33rd Northeast Regional Stock Assessment Workshop (33rd SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NMFS/NEFSC, Woods Hole Laboratory Ref. Doc. 01-18.

NEFSC. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. NMFS/NEFSC, Woods Hole Laboratory Ref. Doc. 02-04.

Table K1. Total Landings (mt,live) of white hake by country from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6), 1964-2001.

| | Canada | USA | Other | Grand Total |
|---|---|---|---|---|
| 1964 | 29 | 3016 | 0 | 3045 |
| 1965 | 0 | 2617 | 0 | 2617 |
| 1966 | 0 | 1563 | 0 | 1563 |
| 1967 | 16 | 1126 | 0 | 1142 |
| 1968 | 85 | 1210 | 0 | 1295 |
| 1969 | 34 | 1343 | 6 | 1383 |
| 1970 | 46 | 1807 | 280 | 2133 |
| 1971 | 100 | 2583 | 214 | 2897 |
| 1972 | 40 | 2946 | 159 | 3145 |
| 1973 | 117 | 3279 | 5 | 3401 |
| 1974 | 232 | 3773 | 0 | 4005 |
| 1975 | 146 | 3672 | 0 | 3818 |
| 1976 | 195 | 4104 | 0 | 4299 |
| 1977 | 170 | 4976 | 338 | 5484 |
| 1978 | 155 | 4869 | 29 | 5053 |
| 1979 | 251 | 4044 | 4 | 4299 |
| 1980 | 305 | 4746 | 2 | 5053 |
| 1981 | 454 | 5969 | 0 | 6423 |
| 1982 | 764 | 6179 | 2 | 6945 |
| 1983 | 810 | 6408 | 0 | 7218 |
| 1984 | 1013 | 6757 | 0 | 7770 |
| 1985 | 953 | 7353 | 0 | 8306 |
| 1986 | 956 | 6109 | 0 | 7065 |
| 1987 | 555 | 5818 | 0 | 6373 |
| 1988 | 534 | 4783 | 0 | 5317 |
| 1989 | 583 | 4548 | 0 | 5131 |
| 1990 | 547 | 4927 | 0 | 5474 |
| 1991 | 552 | 5607 | 0 | 6159 |
| 1992 | 1138 | 8444 | 0 | 9582 |
| 1993 | 1681 | 7466 | 0 | 9147 |
| 1994 | 955 | 4737 | 0 | 5692 |
| 1995 | 481 | 4333 | 0 | 4814 |
| 1996 | 372 | 3287 | 0 | 3659 |
| 1997 | 290 | 2225 | 0 | 2515 |
| 1998 | 228 | 2364 | 0 | 2592 |
| 1999 | 174 | 2624 | 0 | 2798 |
| 2000 | 224 | 2990 | 0 | 3214 |
| 2001 | 203 | 3482 | 0 | 3685 |

Table K2. Summary of US commercial white hake landings (mt), number of length samples (n), and number of fish measured(len) by market category and quarter from the Gulf of Maine to the Mid-Atlantic (SA 464,465, 511-515,521-526,533-539,611-626) for all gear types, 1985-2001.

| | | small | | | | | medium | | | | | large | | | | | unclassified | | | | | All | Sampling Intensity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | Q1 | Q2 | Q3 | Q4 | sum | Q1 | Q2 | Q3 | Q4 | sum | Q1 | Q2 | Q3 | Q4 | sum | Q1 | Q2 | Q3 | Q4 | sum | Total | mt/ sample |
| 1985 | mt | 129 | 162 | 235 | 167 | 694 | 63 | 78 | 181 | 124 | 446 | 237 | 433 | 1135 | 623 | 2428 | 367 | 737 | 1690 | 988 | 3782 | 7349 | 272 |
| | N | - | 2 | 4 | 3 | 9 | - | - | - | - | - | - | 5 | 5 | 3 | 13 | - | 1 | 3 | 1 | 5 | 27 | |
| | #fish | - | 233 | 323 | 317 | 873 | - | - | - | - | - | - | 632 | 519 | 271 | 1422 | - | 101 | 293 | 104 | 498 | 2793 | |
| 1986 | mt | 59 | 134 | 105 | 100 | 398 | 86 | 89 | 55 | 54 | 284 | 274 | 422 | 835 | 417 | 1948 | 455 | 752 | 1578 | 694 | 3478 | 6107 | 235 |
| | N | 1 | 3 | 2 | 1 | 7 | 1 | 1 | - | 2 | 4 | 1 | 3 | 2 | 1 | 7 | 2 | 2 | 3 | 1 | 8 | 26 | |
| | #fish | 102 | 263 | 215 | 101 | 681 | 94 | 122 | - | 229 | 445 | 122 | 315 | 248 | 96 | 781 | 215 | 206 | 292 | 106 | 819 | 2726 | |
| 1987 | mt | 98 | 300 | 641 | 576 | 1616 | 13 | 49 | 122 | 123 | 306 | 171 | 326 | 943 | 372 | 1813 | 262 | 482 | 1035 | 301 | 2080 | 5814 | 194 |
| | N | - | 2 | 4 | 5 | 11 | - | 2 | 1 | 1 | 4 | - | 1 | 6 | 3 | 10 | 2 | 1 | 1 | 1 | 5 | 30 | |
| | #fish | - | 240 | 291 | 507 | 1038 | - | 203 | 91 | 109 | 403 | - | 111 | 518 | 236 | 865 | 218 | 140 | 112 | 125 | 595 | 2901 | |
| 1988 | mt | 181 | 549 | 893 | 397 | 2020 | 26 | 82 | 262 | 120 | 489 | 136 | 330 | 695 | 325 | 1486 | 73 | 137 | 437 | 134 | 782 | 4776 | 165 |
| | N | 5 | 6 | 3 | 5 | 19 | 1 | 1 | 1 | - | 3 | 1 | 1 | 2 | 1 | 5 | - | 1 | - | 1 | 2 | 29 | |
| | #fish | 558 | 764 | 240 | 478 | 2040 | 100 | 92 | 105 | - | 297 | 112 | 121 | 214 | 85 | 532 | - | 100 | - | 41 | 141 | 3010 | |
| 1989 | mt | 149 | 221 | 404 | 358 | 1132 | 41 | 54 | 124 | 68 | 287 | 188 | 473 | 904 | 470 | 2035 | 33 | 190 | 774 | 96 | 1092 | 4547 | 350 |
| | N | 1 | 1 | 2 | 2 | 6 | - | - | 1 | - | 1 | - | - | 2 | 2 | 4 | 1 | - | 1 | - | 2 | 13 | |
| | #fish | 91 | 94 | 213 | 195 | 593 | - | - | 103 | - | 103 | - | - | 206 | 204 | 410 | 100 | - | 106 | - | 206 | 1312 | |
| 1990 | mt | 207 | 411 | 885 | 450 | 1953 | 43 | 108 | 303 | 171 | 625 | 167 | 300 | 596 | 320 | 1382 | 24 | 182 | 580 | 176 | 962 | 4922 | 234 |
| | N | 3 | 4 | 4 | 2 | 13 | - | - | 2 | 1 | 3 | 2 | - | 1 | 1 | 4 | - | - | - | 1 | 1 | 21 | |
| | #fish | 309 | 408 | 399 | 151 | 1267 | - | - | 302 | 99 | 401 | 214 | - | 101 | 103 | 418 | - | - | - | 101 | 101 | 2087 | |
| 1991 | mt | 150 | 366 | 1215 | 612 | 2342 | 88 | 160 | 381 | 129 | 758 | 126 | 241 | 533 | 338 | 1238 | 52 | 358 | 714 | 138 | 1262 | 5601 | 156 |
| | N | 2 | 5 | 6 | 4 | 17 | 1 | 1 | 3 | 1 | 6 | 4 | 1 | 1 | 4 | 10 | - | 2 | 1 | - | 3 | 36 | |
| | #fish | 151 | 471 | 485 | 244 | 1351 | 103 | 100 | 382 | 100 | 685 | 375 | 99 | 96 | 539 | 1109 | - | 207 | 94 | - | 301 | 3446 | |
| 1992 | mt | 424 | 626 | 1735 | 848 | 3633 | 102 | 202 | 766 | 358 | 1428 | 231 | 351 | 699 | 371 | 1651 | 60 | 280 | 1246 | 141 | 1727 | 8439 | 211 |
| | N | 4 | 4 | 8 | 3 | 19 | 1 | 4 | 3 | 3 | 11 | - | 2 | 3 | 2 | 7 | 1 | - | 2 | - | 3 | 40 | |
| | #fish | 329 | 432 | 655 | 240 | 1656 | 80 | 388 | 266 | 317 | 1051 | - | 194 | 325 | 297 | 816 | 97 | - | 237 | - | 334 | 3857 | |
| 1993 | mt | 331 | 502 | 453 | 214 | 1500 | 161 | 397 | 1117 | 461 | 2136 | 173 | 476 | 795 | 416 | 1860 | 94 | 463 | 975 | 433 | 1965 | 7462 | 191 |
| | N | 2 | 5 | 4 | 1 | 12 | 2 | 3 | 2 | 1 | 8 | 2 | 3 | 7 | 2 | 14 | - | 2 | 2 | 1 | 5 | 39 | |
| | #fish | 150 | 504 | 275 | 50 | 979 | 184 | 309 | 196 | 95 | 784 | 199 | 262 | 676 | 175 | 1312 | - | 214 | 196 | 97 | 507 | 3582 | |
| 1994 | mt | 63 | 82 | 116 | 56 | 317 | 154 | 374 | 593 | 265 | 1386 | 206 | 481 | 687 | 407 | 1782 | 193 | 352 | 457 | 251 | 1252 | 4737 | 144 |
| | N | - | 2 | 4 | 1 | 7 | - | 2 | 3 | 3 | 8 | - | 3 | 4 | 2 | 9 | - | 2 | 4 | 3 | 9 | 33 | |
| | #fish | - | 167 | 386 | 100 | 653 | - | 230 | 305 | 272 | 807 | - | 303 | 363 | 304 | 970 | - | 236 | 431 | 372 | 1039 | 3469 | |

Table K2 cont.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | mt | 39 | 43 | 98 | 56 | 245 | 140 | 238 | 616 | 399 | 1393 | 197 | 398 | 595 | 374 | 1564 | 134 | 225 | 504 | 268 | 1130 | 4333 | 361 |
| | N | - | 1 | 1 | 1 | 3 | - | 2 | 2 | 1 | 5 | - | 2 | - | 1 | 3 | - | 1 | - | - | 1 | 12 | |
| | #fish | - | 107 | 97 | 105 | 309 | - | 191 | 222 | 111 | 524 | - | 221 | - | 103 | 324 | - | 100 | - | - | 100 | 1257 | |
| 1996 | mt | 23 | 34 | 80 | 43 | 181 | 96 | 207 | 531 | 269 | 1103 | 208 | 331 | 416 | 280 | 1234 | 110 | 152 | 339 | 169 | 769 | 3287 | 122 |
| | N | - | - | - | - | - | 1 | - | 4 | 4 | 9 | - | 2 | 4 | 5 | 11 | 1 | 1 | 3 | 2 | 7 | 27 | |
| | #fish | - | - | - | - | - | 101 | - | 435 | 541 | 1077 | - | 202 | 451 | 759 | 1412 | 127 | 72 | 326 | 220 | 745 | 3234 | |
| 1997 | mt | 31 | 58 | 124 | 83 | 295 | 76 | 113 | 369 | 193 | 751 | 146 | 146 | 438 | 335 | 1065 | 34 | 28 | 26 | 26 | 113 | 2225 | 32 |
| | N | 4 | 2 | 4 | 2 | 12 | 3 | 7 | 6 | 13 | 29 | 5 | 7 | 7 | 9 | 28 | - | - | - | 1 | 1 | 70 | |
| | #fish | 458 | 206 | 430 | 261 | 1355 | 276 | 694 | 564 | 1200 | 2734 | 541 | 720 | 678 | 896 | 2835 | - | - | - | 58 | 58 | 6982 | |
| 1998 | mt | 31 | 54 | 128 | 105 | 318 | 55 | 77 | 218 | 152 | 502 | 159 | 311 | 571 | 407 | 1449 | 28 | 23 | 34 | 14 | 100 | 2370 | 74 |
| | N | 1 | 2 | 1 | 1 | 5 | 3 | - | 3 | 2 | 8 | 7 | 2 | 8 | 1 | 18 | - | - | 1 | - | 1 | 32 | |
| | #fish | 53 | 220 | 120 | 59 | 452 | 327 | - | 402 | 305 | 1034 | 684 | 213 | 1311 | 110 | 2318 | - | - | 118 | - | 118 | 3922 | |
| 1999 | mt | 50 | 76 | 103 | 87 | 317 | 85 | 110 | 236 | 149 | 580 | 303 | 468 | 633 | 257 | 1661 | 11 | 14 | 25 | 16 | 66 | 2624 | 119 |
| | N | - | - | 1 | - | 1 | 1 | 1 | 3 | 4 | 9 | 1 | 6 | 2 | 3 | 12 | - | - | - | - | - | 22 | |
| | #fish | - | - | 119 | - | 119 | 111 | 102 | 315 | 313 | 841 | 166 | 665 | 202 | 327 | 1360 | - | - | - | - | - | 2320 | |
| 2000 | mt | 55 | 70 | 81 | 81 | 286 | 118 | 202 | 289 | 201 | 811 | 293 | 497 | 596 | 446 | 1833 | 14 | 15 | 20 | 12 | 60 | 2990 | 120 |
| | N | 4 | - | - | 1 | 5 | 5 | 1 | 5 | 4 | 15 | 1 | 1 | - | 3 | 5 | - | - | - | - | - | 25 | |
| | #fish | 428 | - | - | 123 | 551 | 527 | 106 | 573 | 450 | 1656 | 103 | 126 | - | 336 | 565 | - | - | - | - | - | 2772 | |
| 2001 | mt | 59 | 122 | 167 | 177 | 525 | 131 | 155 | 219 | 310 | 815 | 413 | 497 | 697 | 434 | 2041 | 10 | 22 | 57 | 12 | 101 | 3482 | 97 |
| | N | 2 | 3 | 2 | 2 | 9 | 2 | 1 | 2 | 2 | 7 | 3 | 4 | 7 | 6 | 20 | - | - | - | - | - | 36 | |
| | # fish | 231 | 329 | 213 | 224 | 997 | 221 | 100 | 235 | 215 | 771 | 328 | 456 | 797 | 660 | 2241 | - | - | - | - | - | 4009 | |

Table K3. Summary of Domestic Observer number of number of trips (trips) and number of age samples taken (age) by gear type, half year, and catch disposition, 1989-2001.

| | | Sink Gill Net | | | | | | Otter Trawl | | | | | | Grand Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Half 1 | | Half 2 | | Total | | Half 1 | | Half 2 | | Total | | | |
| | | Kept | Disc | Kept | Disc | Kept | Disc | Kept | Disc | Kept | Disc | Kept | Disc | Kept | Disc |
| 1989 | trips | | | 14 | 1 | 14 | 1 | 4 | 10 | 3 | 19 | 7 | 29 | 21 | 30 |
| | len | | | 512 | 2 | 512 | 2 | 123 | 916 | 154 | 1734 | 277 | 2650 | 789 | 2652 |
| 1990 | trips | 6 | | 8 | 1 | 14 | 1 | 3 | 4 | 1 | 5 | 4 | 9 | 18 | 10 |
| | len | 206 | | 1197 | 32 | 1403 | 32 | 69 | 53 | 138 | 312 | 207 | 365 | 1610 | 397 |
| 1991 | trips | 20 | 1 | 89 | 7 | 109 | 8 | 2 | 1 | 3 | 2 | 5 | 3 | 114 | 11 |
| | len | 2526 | 135 | 9973 | 30 | 12499 | 165 | 53 | 180 | 413 | 45 | 466 | 225 | 12965 | 390 |
| 1992 | trips | 34 | 1 | 182 | 4 | 216 | 5 | 7 | 6 | 2 | 4 | 9 | 10 | 225 | 15 |
| | len | 1620 | 1 | 8473 | 4 | 10093 | 5 | 265 | 17 | 59 | 144 | 324 | 161 | 10417 | 166 |
| 1993 | trips | 26 | 1 | 129 | 10 | 155 | 11 | 8 | 20 | 5 | 2 | 13 | 22 | 168 | 33 |
| | len | 1276 | 1 | 4001 | 13 | 5277 | 14 | 681 | 333 | 658 | 44 | 1339 | 377 | 6616 | 391 |
| 1994 | trips | 10 | | 81 | 3 | 91 | 3 | 12 | 37 | 8 | 7 | 20 | 44 | 111 | 47 |
| | len | 44 | | 1835 | 12 | 1879 | 12 | 247 | 570 | 489 | 294 | 736 | 864 | 2615 | 876 |
| 1995 | trips | 9 | 1 | 117 | 7 | 126 | 8 | 12 | 49 | 9 | 10 | 21 | 59 | 147 | 67 |
| | len | 167 | 1 | 2638 | 30 | 2805 | 31 | 1111 | 1375 | 697 | 372 | 1808 | 1747 | 4613 | 1778 |
| 1996 | trips | 11 | 2 | 78 | 2 | 89 | 4 | 8 | 16 | 6 | 13 | 14 | 29 | 103 | 33 |
| | len | 70 | 13 | 826 | 3 | 896 | 16 | 284 | 526 | 331 | 381 | 615 | 907 | 1511 | 923 |
| 1997 | trips | 8 | | 24 | 2 | 32 | 2 | 5 | 9 | 6 | 6 | 11 | 15 | 43 | 17 |
| | len | 85 | | 427 | 4 | 512 | 4 | 117 | 93 | 110 | 64 | 227 | 157 | 739 | 161 |
| 1998 | trips | 8 | | 31 | 1 | 39 | 1 | 3 | 2 | 1 | 1 | 4 | 3 | 43 | 4 |
| | len | 36 | | 411 | 1 | 447 | 1 | 39 | 17 | 12 | 2 | 51 | 19 | 498 | 20 |
| 1999 | trips | 6 | | 17 | 3 | 23 | 3 | 1 | | 7 | 17 | 8 | 17 | 31 | 20 |
| | len | 79 | | 218 | 20 | 297 | 20 | 23 | | 113 | 287 | 136 | 287 | 433 | 307 |
| 2000 | trips | 7 | 2 | 5 | | 12 | 2 | 7 | 5 | 15 | 10 | 22 | 15 | 34 | 17 |
| | len | 47 | 9 | 143 | | 190 | 9 | 421 | 119 | 475 | 76 | 896 | 195 | 1086 | 204 |
| 2001 | trips | 1 | 1 | 6 | 1 | 7 | 2 | 1 | 1 | 4 | | 5 | 1 | 12 | 3 |
| | len | 15 | 3 | 4501 | 2 | 4516 | 5 | 46 | 43 | 2217 | | 2263 | 43 | 6779 | 48 |

Table K4. Commercial catch of white hake by size group.

| | > 60 cm | | | <= 60 cm | | |
|---|---|---|---|---|---|---|
| Year | Landings | Discards | Total | Landings | Discards | Total |
| 1964 | 2284 | 0 | 2284 | 761 | 664 | 1425 |
| 1965 | 1963 | 0 | 1963 | 654 | 408 | 1062 |
| 1966 | 1173 | 0 | 1173 | 391 | 298 | 689 |
| 1967 | 857 | 0 | 857 | 286 | 288 | 574 |
| 1968 | 971 | 0 | 971 | 324 | 325 | 649 |
| 1969 | 1037 | 0 | 1037 | 346 | 370 | 716 |
| 1970 | 1600 | 0 | 1600 | 533 | 582 | 1115 |
| 1971 | 2173 | 0 | 2173 | 724 | 760 | 1484 |
| 1972 | 2359 | 0 | 2359 | 786 | 678 | 1464 |
| 1973 | 2551 | 0 | 2551 | 850 | 767 | 1617 |
| 1974 | 3004 | 0 | 3004 | 1001 | 731 | 1732 |
| 1975 | 2864 | 0 | 2864 | 954 | 536 | 1490 |
| 1976 | 3224 | 0 | 3224 | 1075 | 634 | 1709 |
| 1977 | 4113 | 0 | 4113 | 1371 | 914 | 2285 |
| 1978 | 3790 | 0 | 3790 | 1263 | 862 | 2125 |
| 1979 | 3224 | 0 | 3224 | 1075 | 813 | 1888 |
| 1980 | 3790 | 0 | 3790 | 1263 | 1049 | 2312 |
| 1981 | 4817 | 0 | 4817 | 1606 | 1372 | 2978 |
| 1982 | 5209 | 0 | 5209 | 1736 | 1525 | 3261 |
| 1983 | 5414 | 0 | 5414 | 1805 | 1923 | 3728 |
| 1984 | 5828 | 0 | 5828 | 1943 | 2037 | 3980 |
| 1985 | 6306 | 0 | 6306 | 1987 | 2176 | 4163 |
| 1986 | 6405 | 0 | 6405 | 654 | 1845 | 2499 |
| 1987 | 5025 | 0 | 5025 | 1353 | 1895 | 3248 |
| 1988 | 3295 | 0 | 3295 | 2041 | 1444 | 3485 |
| 1989 | 3944 | 0 | 3944 | 1186 | 2050 | 3236 |
| 1990 | 3156 | 0 | 3156 | 2330 | 4297 | 6627 |
| 1991 | 3824 | 0 | 3824 | 2347 | 1350 | 3697 |
| 1992 | 6147 | 0 | 6147 | 3434 | 715 | 4149 |
| 1993 | 5576 | 0 | 5576 | 3583 | 603 | 4186 |
| 1994 | 3985 | 55 | 4040 | 1706 | 177 | 1883 |
| 1995 | 2185 | 2 | 2187 | 2625 | 133 | 2758 |
| 1996 | 2850 | 0 | 2850 | 806 | 517 | 1323 |
| 1997 | 2248 | 75 | 2323 | 270 | 147 | 417 |
| 1998 | 2421 | 78 | 2499 | 173 | 160 | 333 |
| 1999 | 2530 | 565 | 3095 | 269 | 1509 | 1778 |
| 2000 | 2999 | 17 | 3016 | 215 | 263 | 478 |
| 2001 | 3093 | 107 | 3200 | 593 | 264 | 857 |

Table K5. Stratified mean catch per tow in numbers and weight (kg) for white hake from NEFSC offshore spring and autumn research vessel bottom trawl surveys (strata 21-30,33-40), 1963-2002.

| | Spring | | | Autumn | | |
|---|---|---|---|---|---|---|
| Year | No/Tow | Wt/Tow | Length | No/Tow | Wt/Tow | Length |
| 1963 | | | | 5.00 | 6.31 | 46.2 |
| 1964 | | | | 1.77 | 4.14 | 56.3 |
| 1965 | | | | 4.39 | 6.86 | 50.4 |
| 1966 | | | | 6.79 | 7.67 | 45.1 |
| 1967 | | | | 3.92 | 3.64 | 42.6 |
| 1968 | 1.60 | 1.74 | 44.1 | 4.24 | 4.54 | 44.9 |
| 1969 | 3.76 | 5.09 | 46.3 | 9.24 | 13.09 | 46.8 |
| 1970 | 5.84 | 11.86 | 52.9 | 8.05 | 12.82 | 51.3 |
| 1971 | 3.31 | 5.14 | 51.3 | 10.38 | 12.10 | 43.6 |
| 1972 | 10.18 | 12.66 | 47.3 | 12.52 | 13.10 | 45.2 |
| 1973 | 9.24 | 12.22 | 49.9 | 9.05 | 13.46 | 51.7 |
| 1974 | 8.08 | 13.99 | 55.0 | 5.35 | 11.00 | 54.5 |
| 1975 | 9.32 | 11.22 | 44.7 | 5.28 | 7.23 | 48.5 |
| 1976 | 9.98 | 17.01 | 52.7 | 6.04 | 10.56 | 54.7 |
| 1977 | 6.13 | 11.01 | 55.5 | 9.78 | 13.74 | 47.8 |
| 1978 | 3.22 | 6.14 | 51.8 | 7.87 | 12.54 | 50.2 |
| 1979 | 5.26 | 4.97 | 43.0 | 5.62 | 10.31 | 53.1 |
| 1980 | 10.38 | 13.96 | 49.7 | 10.86 | 16.66 | 48.8 |
| 1981 | 17.09 | 19.92 | 45.9 | 8.70 | 12.16 | 49.9 |
| 1982 | 6.06 | 8.91 | 51.0 | 1.96 | 2.11 | 46.7 |
| 1983 | 3.23 | 3.12 | 43.7 | 8.22 | 10.79 | 48.8 |
| 1984 | 2.75 | 4.17 | 51.4 | 5.32 | 8.23 | 51.9 |
| 1985 | 4.33 | 5.38 | 48.5 | 9.37 | 9.74 | 42.9 |
| 1986 | 8.24 | 5.61 | 40.0 | 14.42 | 11.56 | 41.9 |
| 1987 | 7.15 | 6.44 | 45.3 | 7.59 | 9.62 | 49.2 |
| 1988 | 4.52 | 3.69 | 41.9 | 8.12 | 9.88 | 46.1 |
| 1989 | 3.65 | 3.22 | 43.0 | 11.76 | 9.23 | 40.5 |
| 1990 | 11.11 | 18.37 | 53.3 | 13.09 | 10.58 | 41.5 |
| 1991 | 8.42 | 6.14 | 41.6 | 13.22 | 12.20 | 44.6 |
| 1992 | 7.59 | 7.11 | 45.1 | 10.16 | 11.24 | 47.7 |
| 1993 | 7.93 | 6.84 | 45.1 | 11.35 | 11.66 | 45.2 |
| 1994 | 4.59 | 3.17 | 40.1 | 8.44 | 7.02 | 42.3 |
| 1995 | 4.38 | 4.02 | 44.1 | 9.54 | 8.20 | 40.8 |
| 1996 | 2.87 | 3.07 | 45.9 | 4.52 | 6.35 | 51.2 |
| 1997 | 1.88 | 0.89 | 38.4 | 4.69 | 4.55 | 41.5 |
| 1998 | 2.25 | 1.09 | 37.7 | 4.41 | 4.27 | 44.5 |
| 1999 | 3.32 | 2.97 | 44.6 | 5.68 | 3.44 | 36.3 |
| 2000 | 5.19 | 3.33 | 40.4 | 7.57 | 6.72 | 43.8 |
| 2001 | 4.81 | 5.18 | 48.4 | 5.74 | 7.97 | 52.7 |
| 2002 | 5.13 | 6.32 | 49.0 | | | |

Table K6. NEFSC autumn and spring survey indices by size group.

| | Autumn | | Spring | |
|---|---|---|---|---|
| Year | > 60 | <= 60 | > 60 | <= 60 |
| 1964 | 3.25 | 0.89 | | |
| 1965 | 4.60 | 2.26 | | |
| 1966 | 4.00 | 3.67 | | |
| 1967 | 1.77 | 1.85 | | |
| 1968 | 2.20 | 2.34 | 0.98 | 0.76 |
| 1969 | 8.38 | 4.71 | 3.58 | 1.52 |
| 1970 | 7.76 | 5.07 | 9.12 | 2.74 |
| 1971 | 8.00 | 4.10 | 3.62 | 1.52 |
| 1972 | 7.04 | 6.05 | 8.95 | 3.71 |
| 1973 | 8.22 | 5.23 | 7.01 | 5.21 |
| 1974 | 8.19 | 2.80 | 10.34 | 3.65 |
| 1975 | 4.46 | 2.77 | 7.48 | 3.74 |
| 1976 | 6.83 | 3.73 | 12.90 | 4.10 |
| 1977 | 9.07 | 4.67 | 7.97 | 3.04 |
| 1978 | 8.46 | 4.08 | 4.97 | 1.17 |
| 1979 | 6.97 | 3.34 | 2.83 | 2.14 |
| 1980 | 11.60 | 5.06 | 8.73 | 5.23 |
| 1981 | 8.44 | 3.72 | 13.47 | 6.45 |
| 1982 | | | 6.15 | 2.76 |
| 1983 | 6.06 | 4.73 | 1.54 | 1.58 |
| 1984 | 5.05 | 3.18 | 2.68 | 1.49 |
| 1985 | 5.49 | 4.24 | 3.06 | 2.32 |
| 1986 | 4.38 | 7.18 | 2.29 | 3.32 |
| 1987 | 4.56 | 5.06 | 2.56 | 3.88 |
| 1988 | 5.41 | 4.48 | 1.90 | 1.80 |
| 1989 | 3.84 | 5.39 | 1.80 | 1.42 |
| 1990 | 3.79 | 6.79 | 12.14 | 6.22 |
| 1991 | 4.83 | 7.37 | 2.76 | 3.38 |
| 1992 | 4.14 | 7.10 | 2.30 | 4.81 |
| 1993 | 4.90 | 6.76 | 2.68 | 4.16 |
| 1994 | 2.46 | 4.56 | 1.23 | 1.94 |
| 1995 | 2.96 | 5.23 | 1.96 | 2.06 |
| 1996 | 3.34 | 3.01 | 1.77 | 1.30 |
| 1997 | 2.60 | 1.95 | 0.14 | 0.75 |
| 1998 | 1.64 | 2.64 | 0.26 | 0.84 |
| 1999 | 1.26 | 2.17 | 1.43 | 1.53 |
| 2000 | 2.91 | 3.81 | 1.08 | 2.26 |
| 2001 | 2.89 | 5.08 | 2.16 | 3.02 |
| 2002 | | | 3.44 | 1.73 |

Table K7. Three-year moving average of the NEFSC autumn survey index and the relative F values used in the index-based model of replacement ratios.

| Year | Survey Index | Relative F |
|---|---|---|
| 1965 | 3.92 | 0.50 |
| 1966 | 3.95 | 0.30 |
| 1967 | 3.46 | 0.25 |
| 1968 | 2.66 | 0.36 |
| 1969 | 4.12 | 0.25 |
| 1970 | 6.11 | 0.26 |
| 1971 | 8.05 | 0.27 |
| 1972 | 7.60 | 0.31 |
| 1973 | 7.75 | 0.33 |
| 1974 | 7.82 | 0.38 |
| 1975 | 6.96 | 0.41 |
| 1976 | 6.49 | 0.50 |
| 1977 | 6.79 | 0.61 |
| 1978 | 8.12 | 0.47 |
| 1979 | 8.17 | 0.39 |
| 1980 | 9.01 | 0.42 |
| 1981 | 9.00 | 0.54 |
| 1982 | 9.09 | 0.57 |
| 1983 | 7.25 | 0.75 |
| 1984 | 6.12 | 0.95 |
| 1985 | 5.53 | 1.14 |
| 1986 | 4.97 | 1.29 |
| 1987 | 4.81 | 1.04 |
| 1988 | 4.78 | 0.69 |
| 1989 | 4.60 | 0.86 |
| 1990 | 4.35 | 0.73 |
| 1991 | 4.15 | 0.92 |
| 1992 | 4.25 | 1.44 |
| 1993 | 4.63 | 1.21 |
| 1994 | 3.84 | 1.05 |
| 1995 | 3.44 | 0.64 |
| 1996 | 2.92 | 0.98 |
| 1997 | 2.97 | 0.78 |
| 1998 | 2.52 | 0.99 |
| 1999 | 1.83 | 1.69 |
| 2000 | 1.94 | 1.56 |
| 2001 | 2.35 | 1.36 |

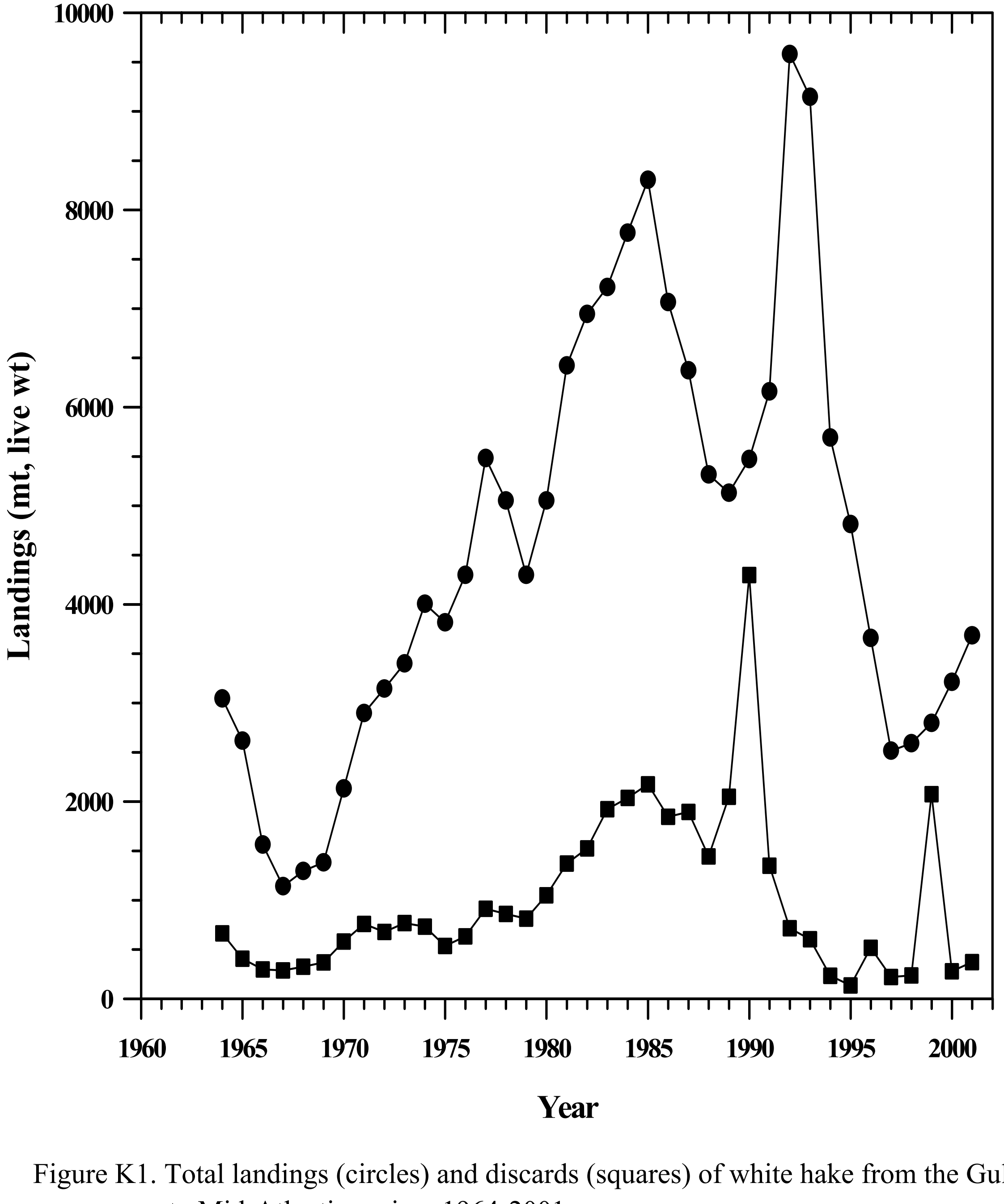


Figure K1. Total landings (circles) and discards (squares) of white hake from the Gulf of Maine to Mid-Atlantic region, 1964-2001.

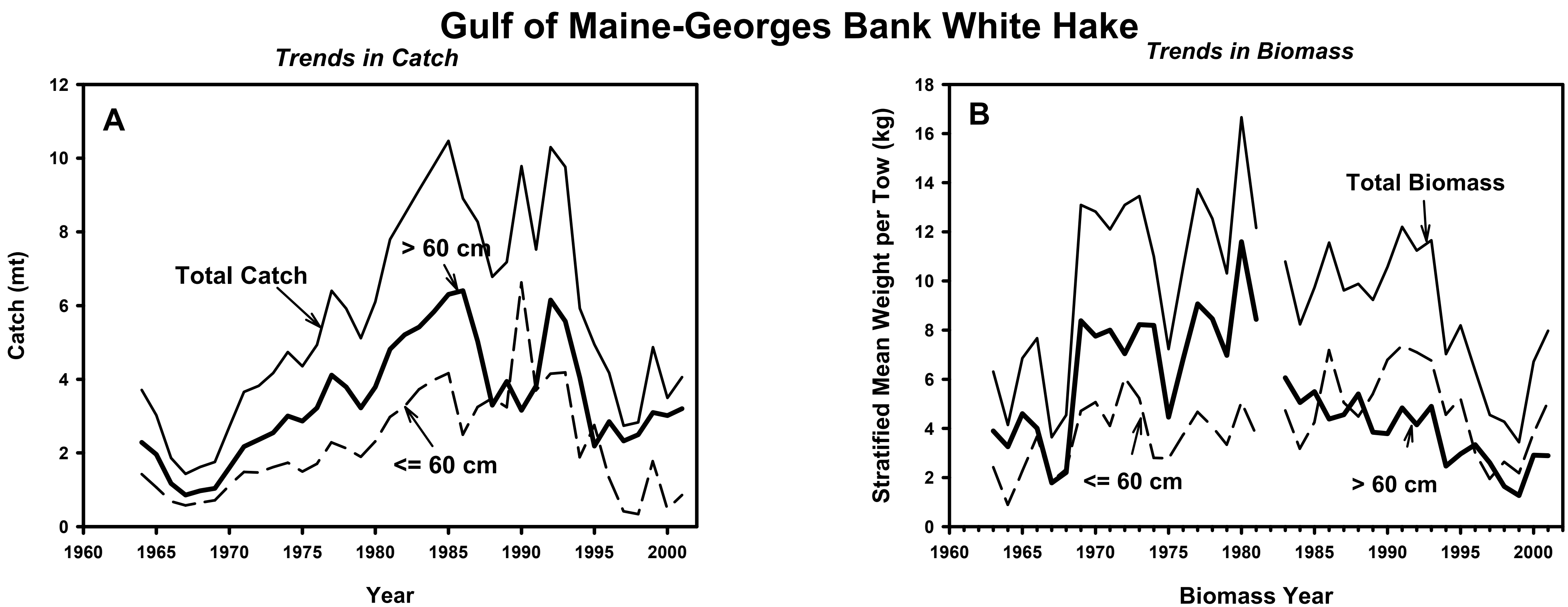


Figure K2. Trends in catch (Panel A) and survey indices of biomass (Panel B) by size class.

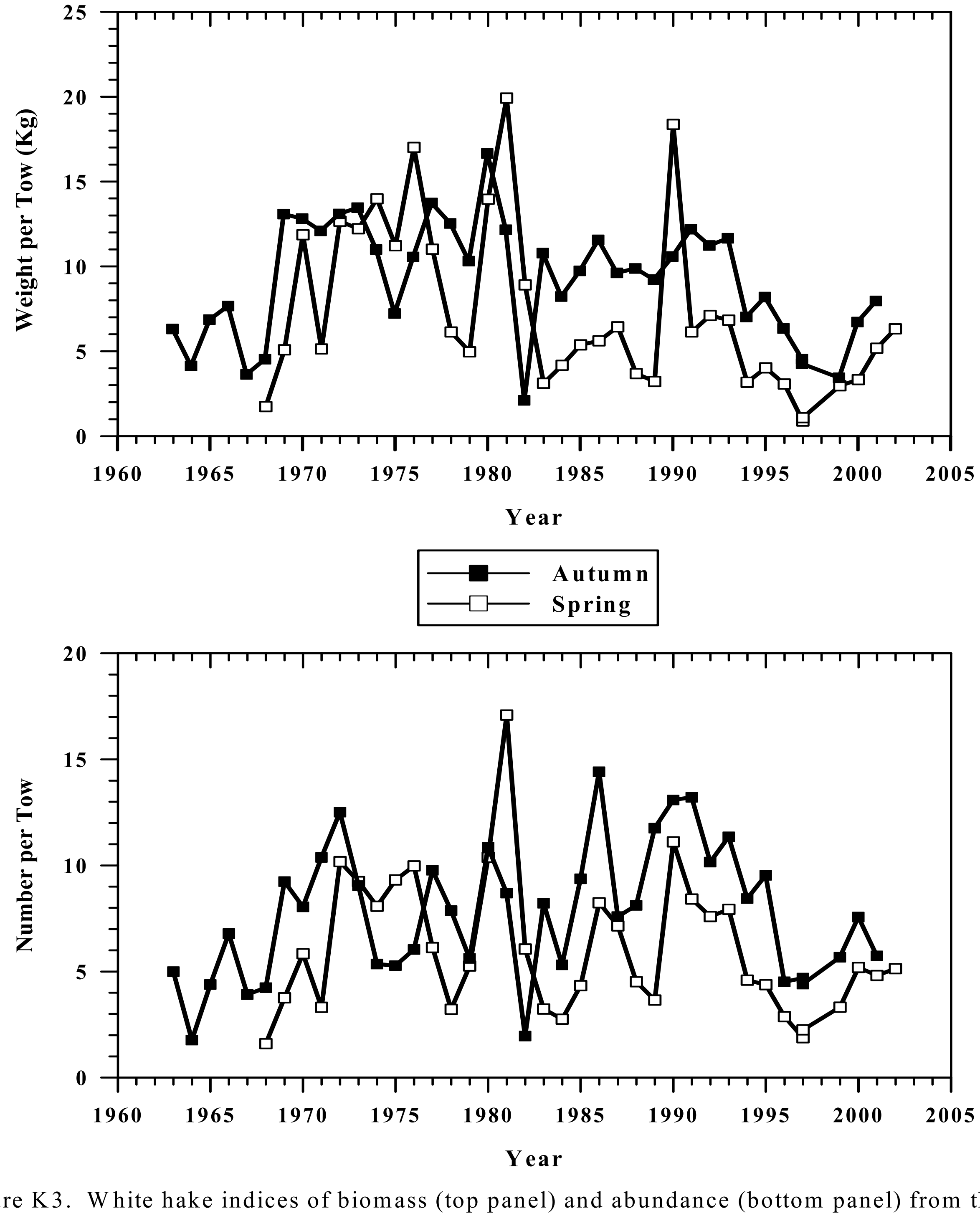


Figure K3. White hake indices of biomass (top panel) and abundance (bottom panel) from the NEFSC bottom trawl spring (solid line) and autumn (dashed line) surveys in the Gulf of Maine to Northern Georges Bank region (offshore strata 21-30, 33-40), 1963-2002.

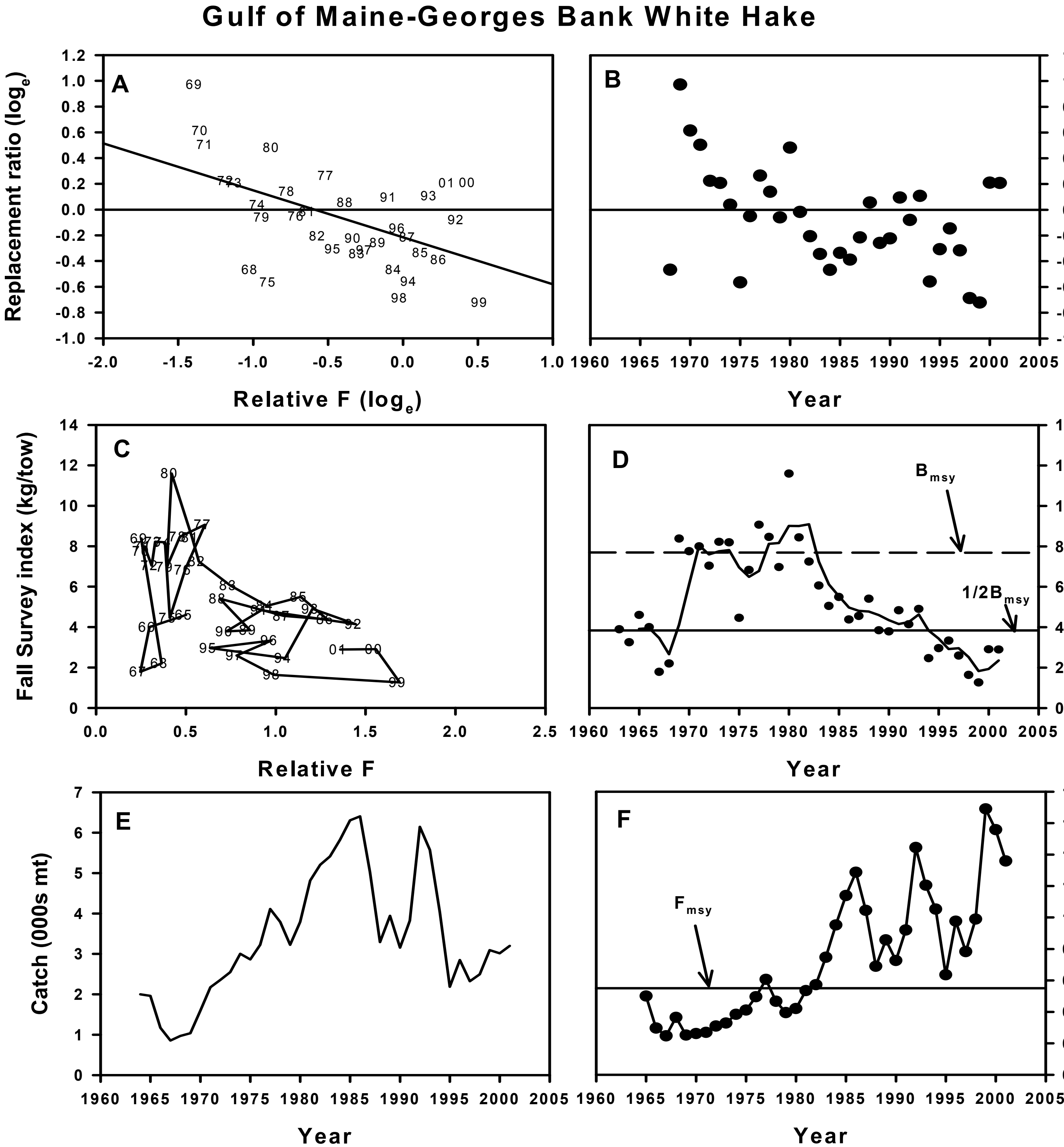


Figure K4. Six-panel plot depicting relatioship between relative F and replacement ratio (A), trend in replacement ratio (B), relationship between biomass and relative F (C), trend in biomass (D), trend in catch (E), and trend in relative F (F).

## L. Scotian Shelf-Georges Bank-Gulf of Maine Pollock by R.K. Mayo and L. Col

### 1.0 Background

Pollock, *Pollachius virens* (L.) Are assessed as a unit stock from the eastern Scotian Shelf (NAFO Division 4V) to Georges Bank, the Gulf of Maine and portions of the Mid-Atlantic region (Subareas 5 and 6). This stock was last assessed over its range via VPA at SAW 16 in 1993 (Mayo and Figuerido 1993, NEFSC 1993a, 1993b). At that time, spawning stock biomass had been declining since the mid-1980s, and was expected to reach its long-term average (144,000 mt). Fishing mortality was estimated to be 0.72 in 1992, above $F_{20\%}$ (0.65) and well above Fmed (0.47). The stock was then considered to be fully exploited and at a medium biomass level.

The state of this stock was most recently evaluated in 2000 via index assessment (Mayo 2001). At that time, it was noted that biomass indices for the Gulf of Maine-Georges Bank portion of the stock, derived from NEFSC autumn bottom trawl surveys, had increased during the mid-1970s, declined sharply during the 1980s, but have been generally increasing since the mid-1990s. Indices derived from Canadian bottom trawl surveys, conducted on the Scotian Shelf, increased during the 1980s, but declined sharply during the early 1990s. The index assessment provided no basis with which to evaluate the state of the stock relative to the control rule as determined by the Overfishing Definition Review Panel (Anon. 1998).

An assessment of this stock over the major portion of its range (NAFO Divisions 4VWX and Subdivision 5Zc) has been conducted by Canada since 1989. The most recent full stock assessment was conducted in 1999 (Neilson et al. 1999) and the most recent update was performed in 2001. In 1999, it was noted that age 5+ population biomass reached a maximum in 1985 and then declined steadily to a minimum in 1995. Biomass had increased slightly after 1995 due to recruitment from the 1992 year class. Recent recruitment has been declining, and it was concluded that most indicators of stock status suggest that the resource remains depleted. The 2001 update indicated a further decline in the relative biomass indices and a reduction in the size structure of the population.

### 2.0 The Fishery

### 2.1 Divisions 4VWX and Subareas 5&6

Nominal commercial catches from the Scotian Shelf, Gulf of Maine, and Georges Bank region increased from an annual average of 38,200 mt during 1972-76 to 68,800 mt in 1986 (Table L1, Figure L1). Canadian landings increased steadily from 24,700 mt in 1977 to an annual average of 43,900 mt during 1985-87, while U.S. landings increased from an average of 9,700 mt during 1973-77 to more than 19,000 mt annually from 1985-1987, peaking at 24,500 mt in 1986. Landings by distant-water fleets declined from an annual average of 9,800 mt during 1970-73 to less than 1,100 mt per year during 1981-88. Distant-water fleet landings increased to 3,300 mt in 1991, but have since declined to negligible levels. Over time, most of the distant water fleet catch has been taken by the USSR/Russian fleet on the Scotian Shelf (Table L1).

By 1996, USA and Canadian landings had declined to 2,963 mt and 9,145 mt, respectively, the lowest landings by either country in over 3 decades. Landings by distant water fleets fishing on the Scotian Shelf remained almost negligible. Since 1996, USA and Canadian landings have increased slightly but remain low relative to past levels. From 1999 to 2001, USA landings fluctuated between 4,111 and 4,600 mt, and Canadian landings ranged from 5,700 to 7,700 mt (Table L1).

Since 1984, the USA fishery has been restricted to areas of the Gulf of Maine and Georges Bank west of the line delimiting the USA and Canadian fishery zones. The Canadian fishery occurs primarily on the Scotian Shelf and additional landings are obtained from Georges Bank east of the line delimiting the USA and Canadian fishery zones. This fishery on the Scotian Shelf has shifted westward over time, and the contribution to the total catch from larger, mobile gear vessels has steadily diminished since 1981.

### 2.2 Subareas 5&6

The commercial fishery in Subareas 5&6 is dominated by United States landings with additional catches taken by some distant water fleets primarily during the 1970s and by Canada. The total landings increased steadily from less than 10,000 mt during the 1960s to a maximum of over 26,000 mt in 1986 (Figure L2). Landings declined sharply during the late 1980s and have remained below 10,000 mt throughout most of the 1990s. Landings since 1999 have fluctuated between 5,000 and 6,000 mt.

## 3.0 Research Survey Indices

Indices of relative biomass (ln re-transformed), derived from NEFSC autumn bottom trawl surveys have varied considerably since 1963 (Table L2, Figure L2). Indices generally fluctuated between 2 and 5 kg per tow throughout most of the 1960s and 1970s, peaking at over 5-7 kg per tow during the mid-to-late 1970s, reflecting recruitment of several moderate-to strong year classes from the early 1970s. Strong year classes were also produced in 1979 and 1980, after which recruitment began to diminish.

Biomass indices declined rapidly during the early 1980s, and continued to decline steadily through the early 1990s, remaining below 1 kg per tow and reaching a minimum in 1994. Since 1994, biomass indices from the Gulf of Maine-Georges Bank region have generally increased, reaching 1.5 kg per tow in 1999 and 2.45 kg/tow in 2001 (Table L2, Figure L2). On the Scotian Shelf, Canadian biomass indices, derived from commercial fishery catch rates, declined rapidly after 1985, following the recruitment of the 1979 year class. After increasing slightly from 1994 to 1996, catch rate indices have continued to decline (Neilson et al. 1999).

## 4.0 Assessment Results

### 4.1 Divisions 4VWX and Subareas 5&6

As evident from recent trends in total landings from the entire stock and NEFSC autumn biomass indices calculated for the Gulf of Maine-Georges Bank region, exploitation ratios (total landings/NEFSC autumn biomass index) peaked in the mid-to-late 1980s after which they steadily declined (Table L3, Figure L3). Biomass indices from the Gulf of Maine-Georges Bank region have been increasing since the late 1990s, and now indicate that biomass may have returned to levels evident during the early 1980s. Measures of stock biomass on the Scotian Shelf, however, remain extremely low relative to past levels.

### 4.2 Subareas 5&6

As evident from recent trends in total landings from Subareas 5 and 6 and NEFSC autumn biomass indices calculated for the Gulf of Maine-Georges Bank region, exploitation ratios (Subarea 5&6 landings/NEFSC autumn biomass index) peaked in the mid-to-late 1980s after which they steadily declined (Table L3, Figure L4). Biomass indices from the Gulf of Maine-Georges Bank region have been increasing during the late 1990s and now indicate that biomass may have returned to levels evident during the early 1980s.

### Relative Exploitation Rate Analyses

An index of relative exploitation (catch/survey biomass index) corresponding to a replacement ratio of 1.0, as described in NEFSC (2002) was developed for the portion of the unit stock of pollock within the USA EEZ (NAFO Subareas 5&6). Autumn NEFSC survey biomass indices from the Gulf of Maine and Georges Bank region from 1963 through 2001 (Figure L5) were used to calculate the replacement ratios, defined as the biomass index in the current year divided by the average biomass indices from the previous 5 years. The biomass indices and total landings (Figure L6) from the same region were used to compute the relative exploitation rates, defined as the catch in the current year divided by the 3 year average survey biomass index for the current year and the previous 2 years (Figure L7). These relative exploitation rates (or relative F) may be considered a proxy for F for that portion of the pollock stock considered in this analysis.

Prior to the 1980s, a high proportion of the replacement ratios equaled or exceeded 1.0 (Figure L8). During the 1980s and early 1990s, most of the replacement ratios were less than 1.0, with ratios greater than 1.0 appearing again by the late 1990s as the biomass indices began to gradually increase from the very low levels of the mid-1990s.

The relationship between replacement ratios and relative F was evaluated by a linear regression of the $Log_e$ replacement ratio on $Log_e$ relative F (NEFSC 2002) and the results were used to derive an estimate of relative F corresponding to a replacement ratio of 1.0 (Figure L9). Results for pollock were highly significant (NEFSC 2002), and the estimate of the relative replacement F (F rel rep) has a low standard error compared to the point estimate (5.88). The regression indicates that, on average, when the relative F is greater than 5.88, the stock is not likely to replace itself in the long-term.

The data displayed in Figures L5, L8 and L10 also provide a means to derive a biomass index which relates to the replacement ratios. In this case, it is evident that most of the replacement ratios below 1.0 occurred during the 1980s when the biomass index was less than about 3.0. This index may be considered as the biomass proxy for Bmsy that corresponds to the relative F proxy for Fmsy.

**5.0 Biological Reference Points**

Since the relative F relates the catch directly to survey biomass, the catch corresponding to the Bmsy proxy can be estimated from the relative F and the biomass index of Bmsy. For pollock, this computes to 3.0 * 5.88 = 17.64, or 17,640 mt as a proxy for MSY.

The following biological reference point proxies were obtained from an index-based model of replacement ratios (NEFSC 2002) derived from indices of relative exploitation (Table L3):

| | |
|---|---|
| MSY | 17,640 mt |
| $B_{MSY}$ | 3.00 kg/tow |
| $F_{MSY}$ | 5.88 (Relative F) |

Since the mid-1990s, the NEFSC autumn survey biomass has been increasing towards the 3.0 kg/tow Bmsy proxy, and the replacement ratio has remained at or above 1.0. Since 1999 the relative F has remained below the 5.88 Fmsy proxy.

Short term projections indicate total commercial landings (including Canadian) of 5,500 mt from Subareas 5&6 in 2003 based on a relative F which will allow the biomass to increase by 10% annually.

**6.0 Sensitivity Analysis**

Clearly, analyses that are directly linked to survey indices will be more sensitive to changes in survey catchability than model-based analyses such as VPA. The sensitivity of estimates of relative F and replacement ratios to presumed changes in survey catchability during autumn 2000 and 2001 were evaluated and the results are presented in Section 4.2. Results are summarized in Section 5.2 (Summary of Assessment Advice).

**7.0 Summary**

In 2001, the 3-year average biomass index for pollock was 1.60, approximately 58% of the 3.00 Bmsy proxy. Thus, current biomass is estimated to be between ½ Bmsy and Bmsy. In 2001, the 3-year average relative F was 3.55, approximately 60% of the 5.88 Fmsy proxy. Thus, current F is estimated to be below Fmsy. Accordingly, in 2001 the stock was not overfished and overfishing was not occurring.

## 8.0 GARM Panel Comments

After the survey proxy reference point analyses were described, the GARM panel suggested that performance of the method should be verified by comparing results from the proxy method with estimates of absolute values of the same reference points derived from VPA-based results.

The projections of catch based on a 10% growth in biomass should be updated in the present analysis using 2001 starting conditions.

The survey biomass indices which form the basis of the estimates of the biomass and F proxy reference points are based on a set of survey strata that have been incompletely sampled over the 1963-2001 time period. The Panel recommends that the survey data be re-evaluated with a goal of achieving a consistent strata set over the entire time period.

## 9.0 Sources of Uncertainty

- Survey indices for pollock exhibit considerable inter-annual variability

- Movement of pollock among the NAFO Divisions comprising the stock unit is likely to vary over time, contributing to the year effects noted in the surveys

## 10.0 References

Anon. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report. Overfishing Definition Review Panel. June 17, 1998.

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NEFSC 1993b. Report of the 16th Northeast Regional Stock Assessment Workshop (16th SAW). The Plenary. NMFS, Northeast Fisheries Science Center Reference Document 93-19, 57p.

Neilson, J., P. Perley and C. Nelson. 1999. The 1999 Assessment of Pollock (*Pollachius virens*) in NAFO Divisions 4VWX and Subdivision 5Zc. DFO Can. Stock Assess. Sec. Res. Doc. 99/160.

NEFSC 2002. Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish, . NMFS/NEFSC, Reference Document 02-04, 254p.

Table L1. Pollock landings (metric tons, live) from Divisions 4VWX and Subareas 5 and 6 by country, 1960-2001.

| Year | Canada | USA | FRG | GDR | Japan | Spain | USSR | Cuba | Others | Total DWF | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | 29470 | 10132 | 0 | 0 | 0 | 783 | 0 | 0 | 1 | 784 | 40386 |
| 1961 | 26323 | 10265 | 0 | 0 | 0 | 982 | 0 | 0 | 1 | 983 | 37571 |
| 1962 | 31721 | 7391 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39112 |
| 1963 | 28999 | 6650 | 126 | 0 | 0 | 0 | 793 | 0 | 28 | 947 | 36596 |
| 1964 | 30007 | 6006 | 208 | 0 | 0 | 0 | 4603 | 0 | 429 | 5240 | 41253 |
| 1965 | 27316 | 5303 | 71 | 0 | 0 | 1361 | 2667 | 0 | 11 | 4110 | 36729 |
| 1966 | 18271 | 3791 | 0 | 0 | 0 | 2384 | 9865 | 0 | 12 | 12261 | 34323 |
| 1967 | 17567 | 3312 | 0 | 0 | 0 | 1779 | 644 | 0 | 15 | 2438 | 23317 |
| 1968 | 18062 | 3276 | 0 | 0 | 0 | 1128 | 372 | 0 | 7 | 1507 | 22845 |
| 1969 | 15968 | 3943 | 1188 | 2195 | 0 | 1515 | 227 | 0 | 7 | 5132 | 25043 |
| 1970 | 10753 | 3976 | 3233 | 4710 | 40 | 532 | 527 | 0 | 0 | 9042 | 23771 |
| 1971 | 11757 | 4890 | 633 | 6849 | 15 | 912 | 2216 | 0 | 3 | 10628 | 27275 |
| 1972 | 18022 | 5729 | 475 | 4816 | 8 | 616 | 3495 | 0 | 58 | 9468 | 33219 |
| 1973 | 26990 | 6303 | 1124 | 948 | 1570 | 3113 | 3092 | 0 | 36 | 9883 | 43176 |
| 1974 | 24975 | 8726 | 149 | 2 | 40 | 1500 | 2301 | 0 | 62 | 4054 | 37755 |
| 1975 | 26548 | 9318 | 236 | 95 | 0 | 708 | 2004 | 0 | 124 | 3167 | 39033 |
| 1976 | 23568 | 10863 | 994 | 24 | 0 | 303 | 1466 | 0 | 390 | 3177 | 37608 |
| 1977 | 24654 | 13056 | 368 | 0 | 1 | 2 | 182 | 0 | 53 | 606 | 38316 |
| 1978 | 26801 | 17714 | 0 | 0 | 110 | 0 | 502 | 141 | 39 | 792 | 45307 |
| 1979 | 29967 | 15541 | 7 | 0 | 19 | 0 | 1025 | 50 | 23 | 1124 | 46632 |
| 1980 | 35986 | 18280 | 0 | 0 | 81 | 0 | 950 | 32 | 99 | 1162 | 55428 |
| 1981 | 40270 | 18171 | 0 | 0 | 15 | 0 | 358 | 0 | 90 | 463 | 58904 |
| 1982 | 38029 | 14357 | 0 | 0 | 3 | 0 | 297 | 84 | 44 | 428 | 52814 |
| 1983 | 32749 | 13967 | 0 | 0 | 6 | 0 | 226 | 261 | 22 | 515 | 47231 |
| 1984 | 33465 | 17903 | 0 | 1 | 1 | 0 | 97 | 123 | 46 | 268 | 51636 |
| 1985 | 43300 | 19457 | 0 | 0 | 17 | 0 | 336 | 66 | 77 | 496 | 63253 |
| 1986 | 42845 | 24542 | 0 | 0 | 51 | 0 | 564 | 387 | 81 | 1083 | 68470 |
| 1987 | 45407 | 20353 | 0 | 0 | 82 | 0 | 314 | 343 | 28 | 767 | 66527 |
| 1988 | 41690 | 14960 | 0 | 0 | 1 | 0 | 1054 | 225 | 0 | 1280 | 57930 |
| 1989 | 41093 | 10553 | 0 | 0 | 1 | 0 | 1782 | 99 | 478 | 2360 | 54006 |
| 1990 | 36178 | 9645 | 0 | 0 | 0 | 0 | 1040 | 261 | 3 | 1304 | 47127 |
| 1991 | 37931 | 7950 | 0 | 0 | 38 | 0 | 1117 | 459 | 167 | 1781 | 47662 |
| 1992 | 32002 | 7183 | 0 | 0 | 72 | 0 | 1006 | 1015 | 9 | 2102 | 41287 |
| 1993 | 20253 | 5629 | 0 | 0 | 0 | 0 | 176 | 644 | 0 | 820 | 26702 |
| 1994 | 15240 | 3768 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 19018 |
| 1995 | 9781 | 3358 | 0 | 0 | 0 | 0 | 0 | 58 | 0 | 58 | 13197 |
| 1996 | 9145 | 2963 | 0 | 0 | 0 | 0 | 6 | 129 | 0 | 135 | 12243 |
| 1997 | 11927 | 4267 | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 64 | 16258 |
| 1998 | 14371 | 5583 | 0 | 0 | 0 | 0 | 1 | 9 | 0 | 10 | 19964 |
| 1999 | 7737 | 4594 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 12337 |
| 2000 | 5676 | 4043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9719 |
| 2001 | 6306 | 4111 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10417 |

1996-1999 Canadian Data Preliminary
1994-2001 USA Data Preliminary
1999 DWF Data Preliminary

Table L2. Stratified mean catch per tow in numbers and weight (kg) for Scotian Shelf, Gulf of Maine, and Georges Bank pollock in **NEFSC offshore spring[1], summer[2], and autumn[1] bottom trawl surveys**, 1963-2001.

| | Spring[3] | | | | Summer | | | | Autumn | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight | | Numbers | | Weight | | Numbers | | Weight | | Numbers | |
| Year | Linear | Retrans-formed | Linear | Retrans-formed | Linear | Retrans-formed | Linear | Retrans-formed | Linear | Retrans-formed | Linear | Retrans-formed |
| 1963 | - | - | - | - | 10.28 | 3.45 | 2.31 | 1.07 | 5.79 | 4.96 | 1.46 | 1.32 |
| 1964 | - | - | - | - | 5.27 | 2.32 | 2.06 | 0.96 | 4.35 | 2.42 | 1.63 | 1.04 |
| 1965 | - | - | - | - | 2.56 | 1.05 | 1.72 | 0.63 | 2.75 | 2.12 | 0.83 | 0.77 |
| 1966 | - | - | - | - | - | - | - | - | 2.35 | 1.61 | 0.97 | 0.58 |
| 1967 | - | - | - | - | - | - | - | - | 1.80 | 1.16 | 0.52 | 0.44 |
| 1968 | 4.50 | 2.90 | 1.10 | 0.93 | - | - | - | - | 3.17 | 2.30 | 0.69 | 0.62 |
| 1969 | 2.66 | 2.53 | 1.12 | 0.99 | 1.75 | 1.19 | 0.70 | 0.47 | 6.59 | 3.01 | 1.31 | 0.85 |
| 1970 | 4.91 | 3.53 | 1.67 | 1.47 | - | - | - | - | 2.59 | 2.00 | 0.64 | 0.62 |
| 1971 | 4.39 | 3.30 | 1.18 | 1.05 | - | - | - | - | 3.96 | 1.90 | 1.09 | 0.69 |
| 1972 | 5.67 | 4.07 | 4.43 | 2.62 | - | - | - | - | 4.37 | 3.13 | 1.41 | 1.16 |
| 1973 | 4.82 | 3.77 | 4.00 | 1.61 | - | - | - | - | 4.71 | 4.04 | 1.64 | 1.25 |
| 1974 | 4.10 | 4.43 | 1.39 | 1.24 | - | - | - | - | 3.18 | 1.52 | 0.90 | 0.56 |
| 1975 | 5.90 | 5.37 | 1.67 | 1.32 | - | - | - | - | 2.04 | 1.50 | 0.70 | 0.50 |
| 1976 | 6.84 | 7.02 | 1.59 | 1.48 | - | - | - | - | 16.66 | 7.32 | 3.69 | 1.70 |
| 1977 | 3.38 | 3.04 | 1.61 | 1.23 | 9.98 | 8.35 | 2.07 | 1.67 | 8.78 | 5.26 | 2.14 | 1.25 |
| 1978 | 6.56 | 3.71 | 2.48 | 1.06 | 4.05 | 3.80 | 1.29 | 0.92 | 5.83 | 3.56 | 0.98 | 0.67 |
| 1979 | 4.75 | 4.07 | 1.06 | 0.97 | 17.57 | 4.14 | 2.96 | 1.19 | 5.81 | 4.67 | 1.28 | 0.91 |
| 1980 | 4.40 | 3.92 | 1.52 | 1.17 | 9.83 | 6.61 | 12.21 | 2.25 | 4.63 | 3.32 | 0.83 | 0.68 |
| 1981 | 6.17 | 5.42 | 1.95 | 1.40 | - | - | - | - | 7.75 | 1.56 | 5.24 | 0.63 |
| 1982 | 6.62 | 3.68 | 3.98 | 2.02 | - | - | - | - | 3.14 | 1.63 | 1.40 | 0.78 |
| 1983 | 1.83 | 1.20 | 0.90 | 0.69 | - | - | - | - | 3.03 | 1.41 | 0.98 | 0.61 |
| 1984 | 2.87 | 2.06 | 1.00 | 0.84 | - | - | - | - | 1.10 | 0.70 | 0.43 | 0.38 |
| 1985 | 26.81 | 7.85 | 13.70 | 3.05 | - | - | - | - | 2.43 | 1.97 | 1.12 | 0.77 |
| 1986 | 7.69 | 4.10 | 1.84 | 1.25 | - | - | - | - | 1.83 | 1.20 | 0.88 | 0.58 |
| 1987 | 13.17 | 2.50 | 6.94 | 1.14 | - | - | - | - | 2.01 | 1.20 | 0.60 | 0.51 |
| 1988 | 1.98 | 1.36 | 0.89 | 0.74 | - | - | - | - | 12.83 | 1.75 | 3.71 | 0.86 |
| 1989 | 5.17 | 2.18 | 1.98 | 1.02 | - | - | - | - | 1.20 | 0.61 | 1.86 | 0.76 |
| 1990 | 1.79 | 1.14 | 0.75 | 0.55 | - | - | - | - | 2.11 | 1.05 | 0.83 | 0.60 |
| 1991 | 5.14 | 2.96 | 2.32 | 1.44 | - | - | - | - | 1.04 | 0.64 | 0.72 | 0.54 |
| 1992 | 3.35 | 2.17 | 1.79 | 1.24 | - | - | - | - | 1.69 | 0.92 | 1.05 | 0.65 |
| 1993 | 1.63 | 1.29 | 1.64 | 1.16 | - | - | - | - | 0.76 | 0.56 | 1.03 | 0.56 |
| 1994 | 1.17 | 0.94 | 0.59 | 0.54 | - | - | - | - | 0.72 | 0.41 | 0.50 | 0.37 |
| 1995 | 3.89 | 1.48 | 3.46 | 0.89 | - | - | - | - | 1.38 | 0.67 | 0.93 | 0.54 |
| 1996 | 1.07 | 0.75 | 0.65 | 0.51 | - | - | - | - | 1.10 | 0.70 | 1.02 | 0.69 |
| 1997 | 4.51 | 2.01 | 3.33 | 1.78 | - | - | - | - | 1.49 | 0.98 | 1.74 | 0.90 |
| 1998 | 2.69 | 1.65 | 2.64 | 1.56 | - | - | - | - | 1.29 | 0.76 | 2.07 | 0.74 |
| 1999 | 1.07 | 0.86 | 2.16 | 1.02 | - | - | - | - | 3.07 | 1.52 | 2.40 | 1.40 |
| 2000 | 1.35 | 0.98 | 1.49 | 0.98 | - | - | - | - | 1.42 | 0.83 | 2.74 | 1.33 |
| 2001 | 2.03 | 1.28 | 1.69 | 1.27 | - | - | - | - | 3.57 | 2.45 | 2.38 | 1.81 |

[1] Strata 13-40 (See Figure 3).
[2] Strata 21-28 and 37-40 (See Figure 3).
[3] The "36 Yankee" trawl was used from 1968-1972, and 1982-1999; the "41 Yankee" trawl was used from 1973-1981. No gear conversion factors are available to adjust for differences in fishing power.

Table L3. Total commercial landings (mt), NEFSC autumn survey biomass index (kg/tow,Ln, retransformed), replacement index and exploitation ratio for pollock in NAFO Subareas 5&6.

| Year | Total Landings (mt) | NEFSC Autumn Survey Biomass Index (kg/tow) Annual | NEFSC Autumn Survey Biomass Index (kg/tow) 3-yr Avg | Relative F Ratio Annual | Relative F Ratio 3-yr Avg | Replacement Ratio 5-yr Avg |
|---|---|---|---|---|---|---|
| 1963 | 6241 | 4.960 | | 1.258 | | |
| 1964 | 9008 | 2.420 | | 3.722 | | |
| 1965 | 9000 | 2.120 | 3.167 | 4.245 | 2.842 | |
| 1966 | 9847 | 1.610 | 2.050 | 6.116 | 4.803 | |
| 1967 | 8534 | 1.160 | 1.630 | 7.357 | 5.236 | |
| 1968 | 5222 | 2.300 | 1.690 | 2.270 | 3.090 | 0.937 |
| 1969 | 9822 | 3.010 | 2.157 | 3.263 | 4.554 | 1.566 |
| 1970 | 11976 | 2.000 | 2.437 | 5.988 | 4.915 | 0.980 |
| 1971 | 15203 | 1.900 | 2.303 | 8.002 | 6.600 | 0.942 |
| 1972 | 13013 | 3.130 | 2.343 | 4.158 | 5.553 | 1.509 |
| 1973 | 13076 | 4.040 | 3.023 | 3.237 | 4.325 | 1.637 |
| 1974 | 12393 | 1.520 | 2.897 | 8.153 | 4.278 | 0.540 |
| 1975 | 13871 | 1.500 | 2.353 | 9.247 | 5.894 | 0.596 |
| 1976 | 13382 | 7.320 | 3.447 | 1.828 | 3.883 | 3.027 |
| 1977 | 16273 | 5.260 | 4.693 | 3.094 | 3.467 | 1.502 |
| 1978 | 22305 | 3.560 | 5.380 | 6.265 | 4.146 | 0.906 |
| 1979 | 18452 | 4.670 | 4.497 | 3.951 | 4.103 | 1.219 |
| 1980 | 23539 | 3.320 | 3.850 | 7.090 | 6.114 | 0.744 |
| 1981 | 22068 | 1.560 | 3.183 | 14.146 | 6.932 | 0.323 |
| 1982 | 19466 | 1.629 | 2.170 | 11.950 | 8.972 | 0.443 |
| 1983 | 17816 | 1.414 | 1.534 | 12.600 | 11.612 | 0.480 |
| 1984 | 20633 | 0.700 | 1.248 | 29.476 | 16.537 | 0.278 |
| 1985 | 21069 | 1.967 | 1.360 | 10.711 | 15.488 | 1.141 |
| 1986 | 26507 | 1.205 | 1.291 | 21.998 | 20.537 | 0.829 |
| 1987 | 22347 | 1.202 | 1.458 | 18.592 | 15.327 | 0.869 |
| 1988 | 17304 | 1.753 | 1.387 | 9.871 | 12.479 | 1.351 |
| 1989 | 11903 | 0.608 | 1.188 | 19.577 | 10.022 | 0.445 |
| 1990 | 11201 | 1.054 | 1.138 | 10.627 | 9.840 | 0.782 |
| 1991 | 9600 | 0.640 | 0.767 | 15.000 | 12.511 | 0.550 |
| 1992 | 10225 | 0.920 | 0.871 | 11.114 | 11.735 | 0.875 |
| 1993 | 9873 | 0.496 | 0.685 | 19.905 | 14.406 | 0.498 |
| 1994 | 7099 | 0.409 | 0.608 | 17.357 | 11.670 | 0.550 |
| 1995 | 4362 | 0.667 | 0.524 | 6.540 | 8.324 | 0.948 |
| 1996 | 4164 | 0.704 | 0.593 | 5.915 | 7.018 | 1.124 |
| 1997 | 5483 | 0.984 | 0.785 | 5.572 | 6.985 | 1.539 |
| 1998 | 7441 | 0.758 | 0.815 | 9.817 | 9.126 | 1.163 |
| 1999 | 5591 | 1.522 | 1.088 | 3.673 | 5.139 | 2.161 |
| 2000 | 5240 | 0.833 | 1.038 | 6.291 | 5.050 | 0.899 |
| 2001 | 5680 | 2.448 | 1.601 | 2.320 | 3.548 | 2.549 |

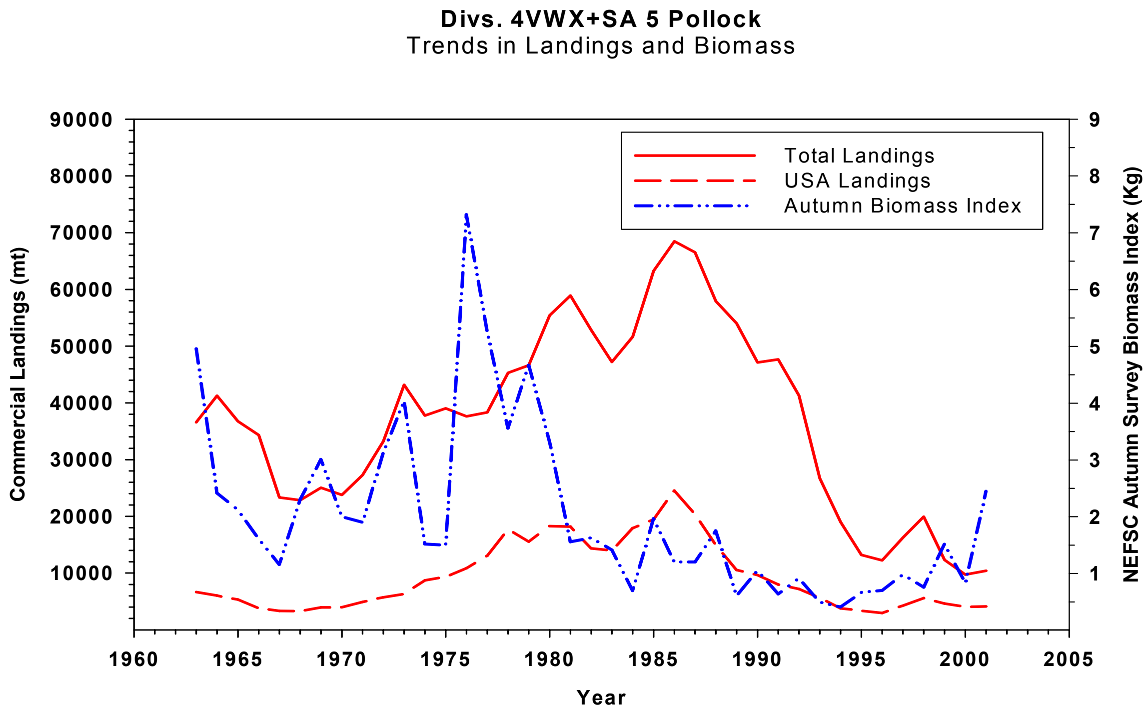


Figure L1. Trends in total and USA landings of pollock from Divisions 4VWX and Subareas 5 and 6, and NEFSC autumn survey biomass index (kg/tow), 1963-2001.

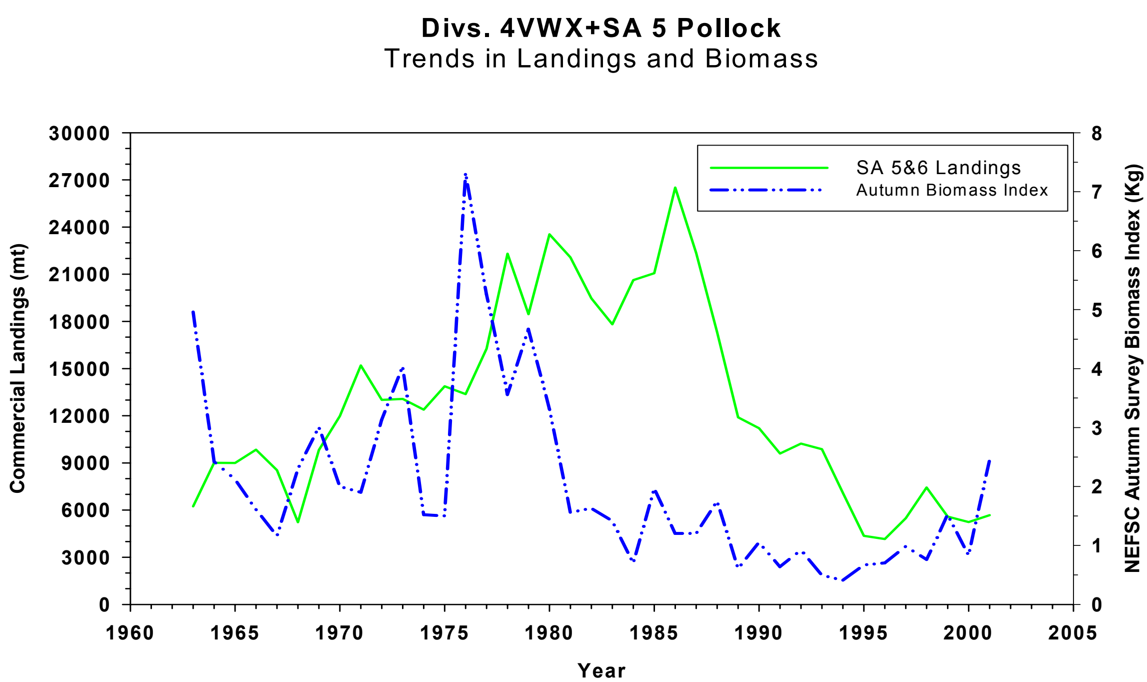


Figure L2. Trends in total landings of pollock from Divisions 4VWX and from Subareas 5 and 6, and NEFSC autumn survey biomass index (kg/tow), 1963-2001.

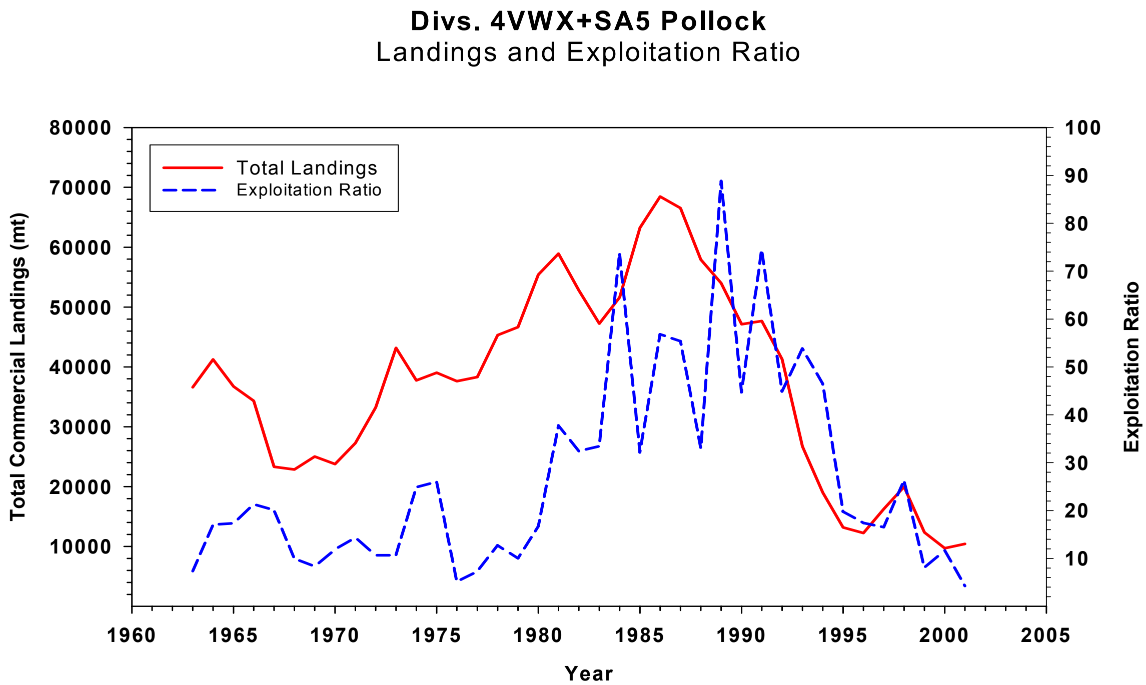


**Figure L3. Trends in total landings of pollock from Divisions 4VWX and Subareas 5 and 6, and indices of relative exploitation (landings/survey biomass), 1963-2001.**

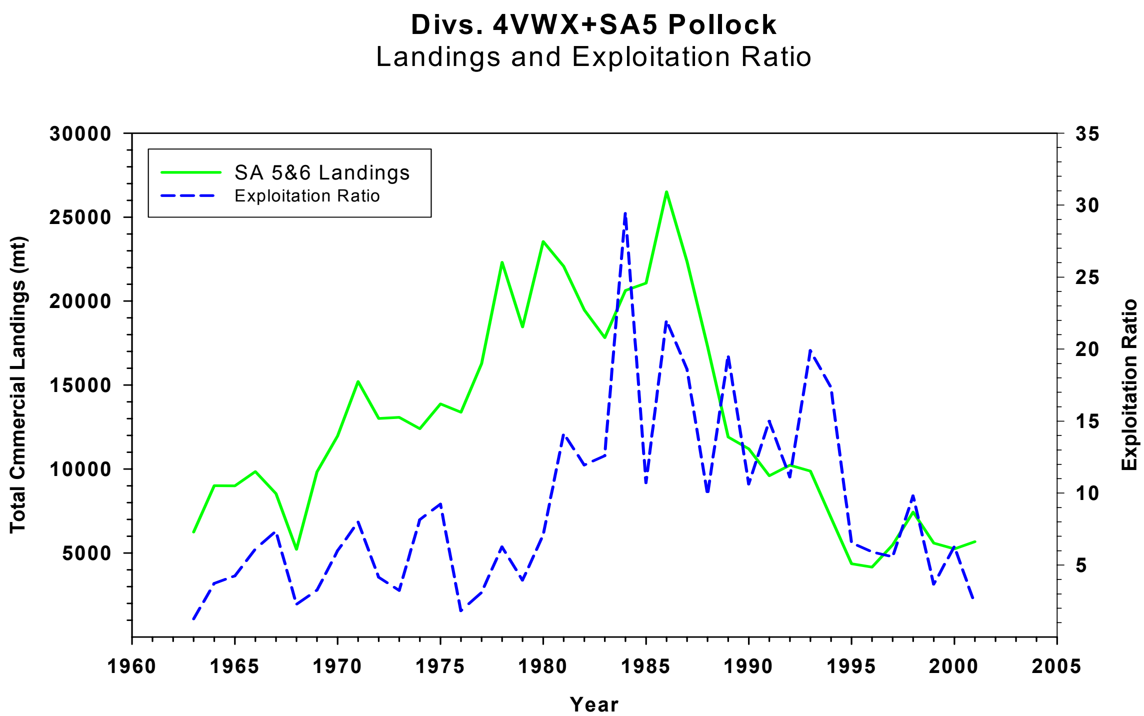


**Figure L4. Trends in total landings of pollock from Subareas 5 and 6, and indices of relative exploitation (landings/survey biomass), 1963-2001.**

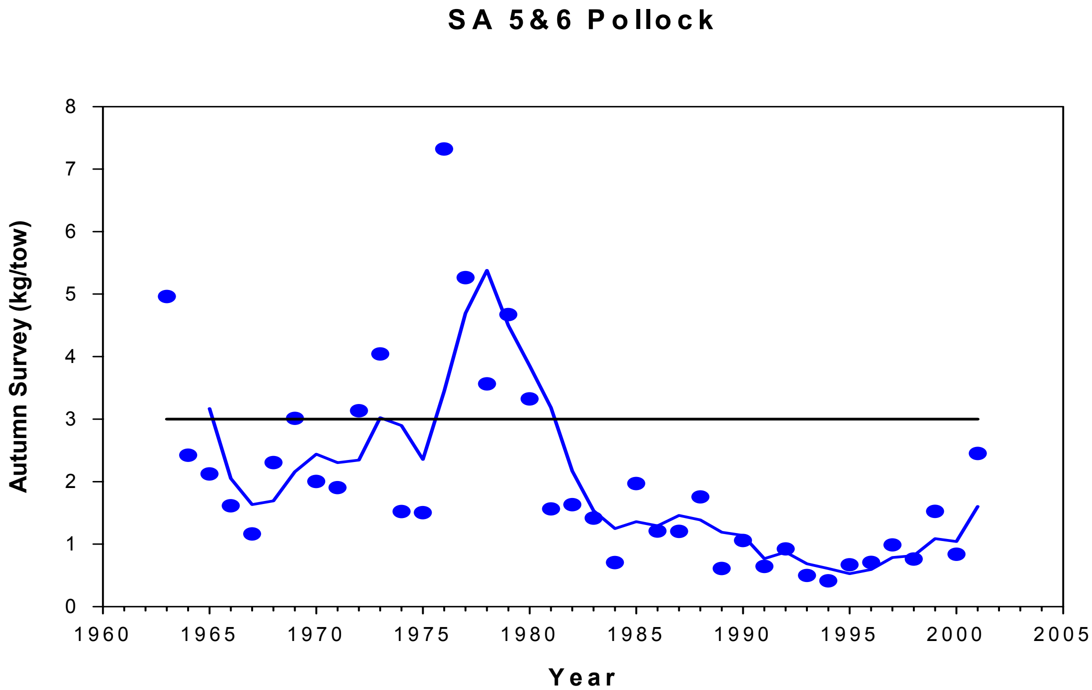


Figure L5. Trends in the NEFSC autumn survey biomass index for pollock from Subareas 5 and 6, 1963-2001.

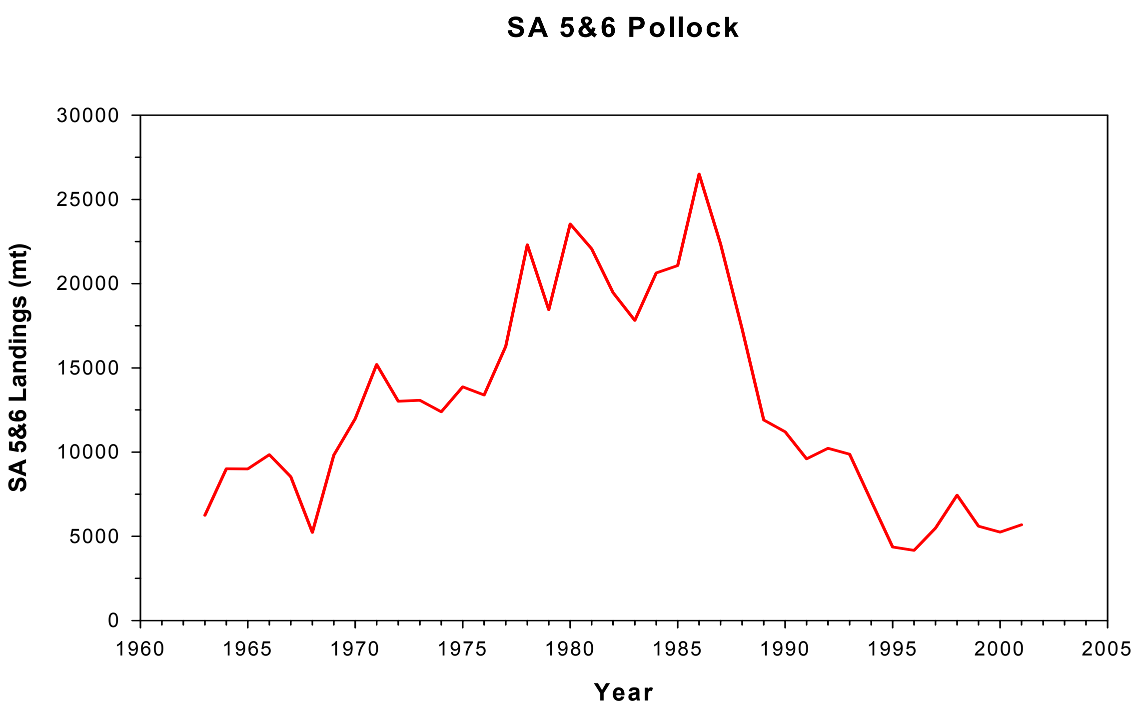


Figure L6. Trends in total landings of pollock from Subareas 5 and 6, 1963-2001.

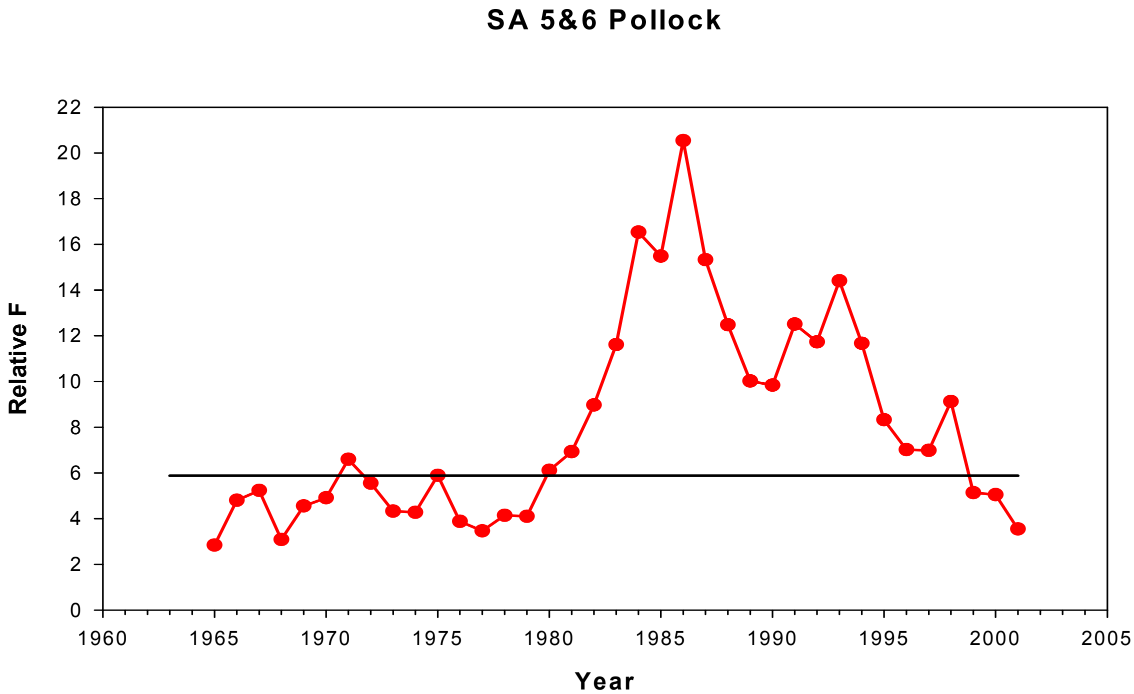


Figure L7. Trends in relative F for pollock in Subareas 5 and 6, 1963-2001.

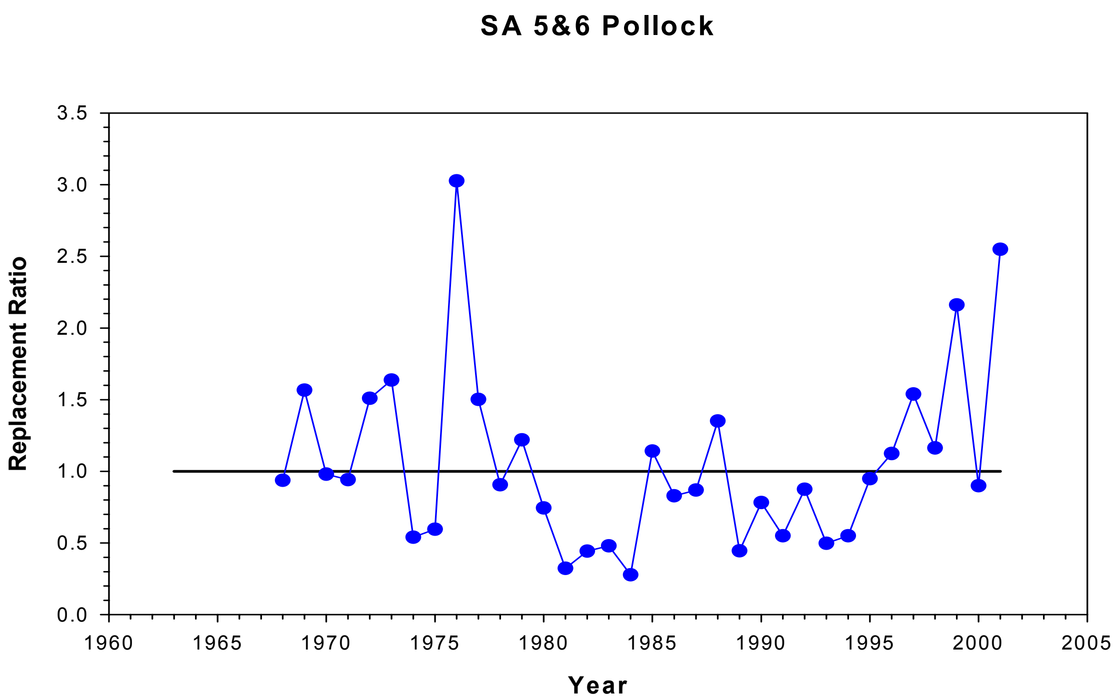


Figure L8. Trends in replacement ratio for pollock in Subareas 5 and 6, 1963-2001.

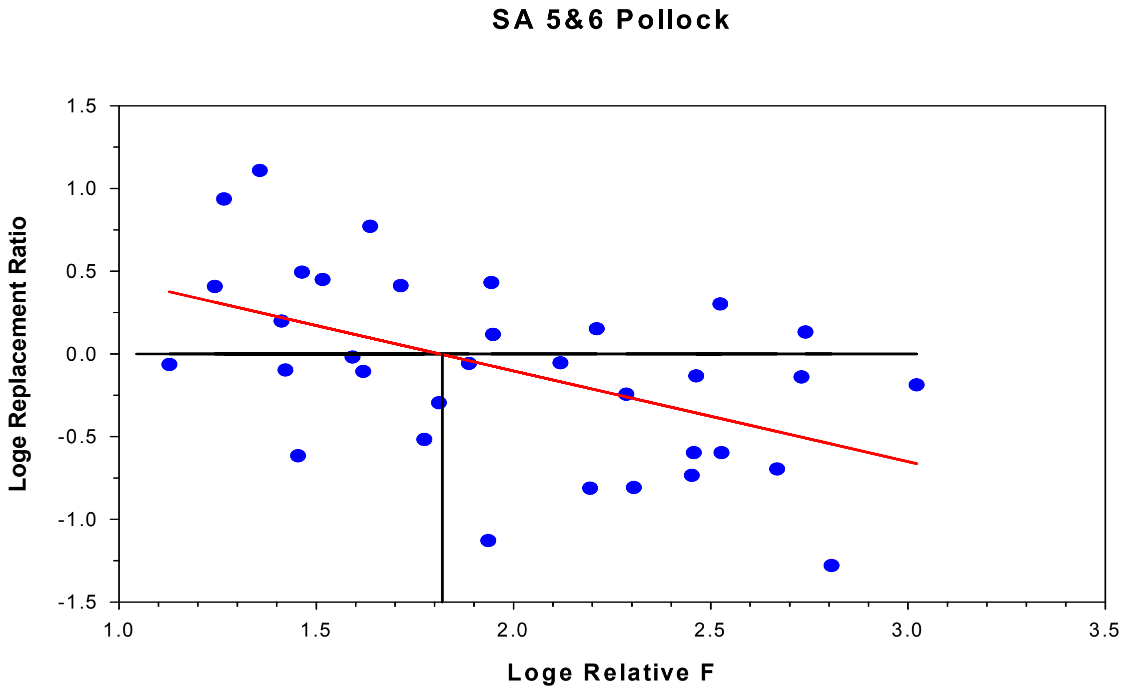


**Figure L9. Relationship between the replacement ratio and relative F for pollock in Subareas 5 and 6, 1963-2001.**

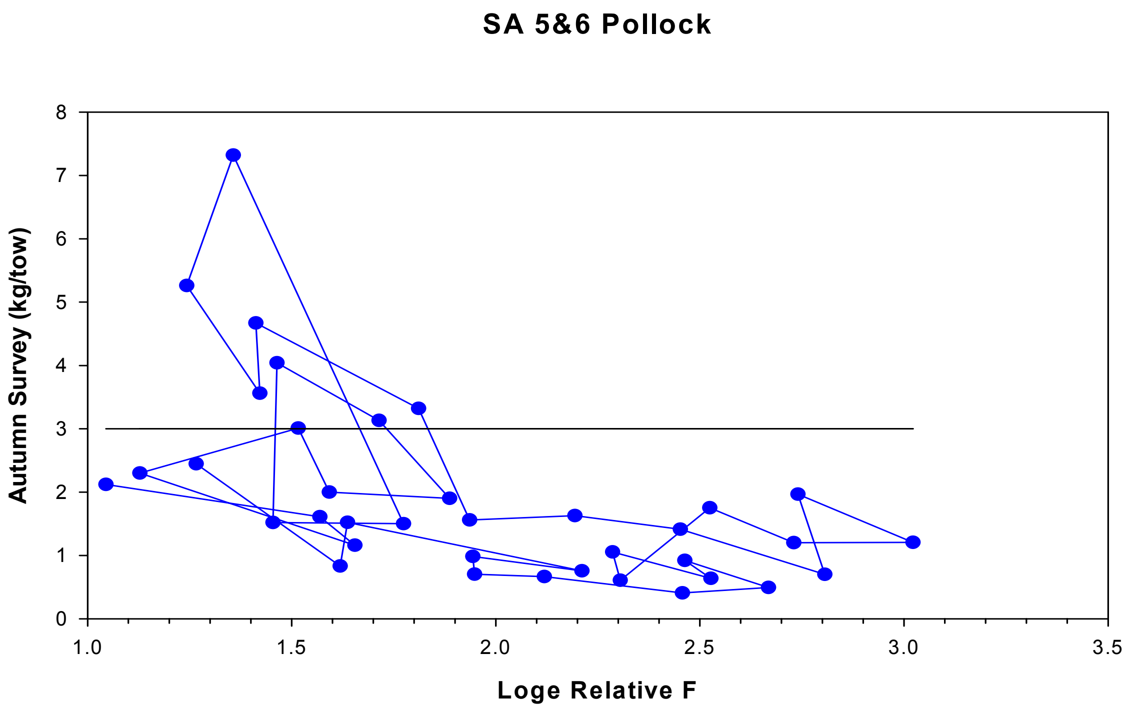


**Figure L10. Relationship between the NEFSC autumn survey biomass index and relative F for pollock in Subareas 5 and 6, 1963-2001.**

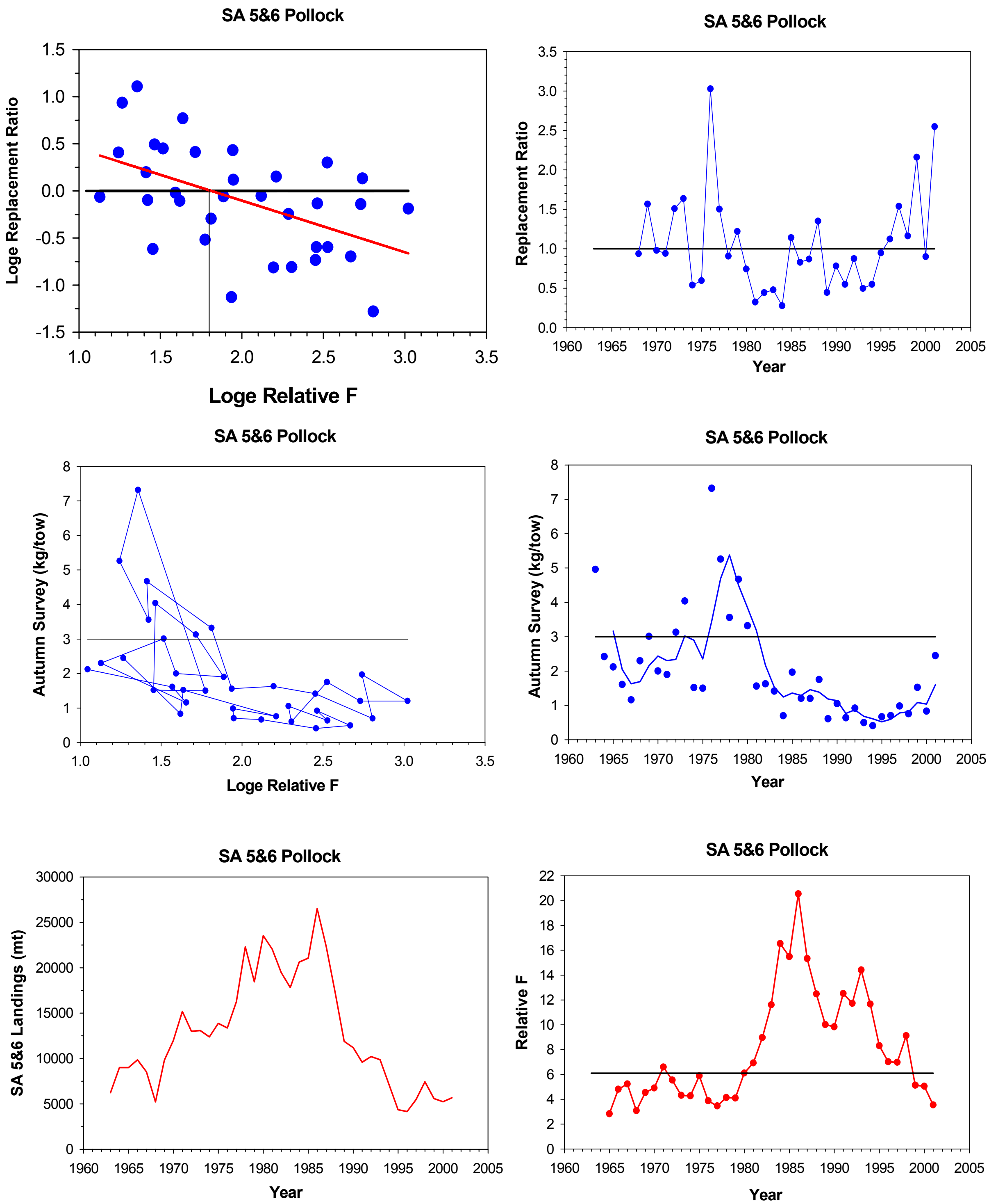


**Figure L11. Six-panel plot illustrating relationships between landings, survey biomass indices, relative F, and replacement ratios for pollock in Subareas 5 and 6, 1963-2001.**

## M. Gulf of Maine-Georges Bank Acadian Redfish by R.K. Mayo and L. Col

### 1.0 Background

The most recent stock assessment of Acadian redfish in Subarea 5 was completed in 2001 (Mayo *et al.* 2002), and the results were reviewed at the 33rd Northeast Regional Stock Assessment Workshop in June, 2001 (NEFSC 2001a, 2001b). The assessment was based on several analyses including trends in catch/survey biomass exploitation ratios; a yield and biomass per recruit analysis; an age-structured dynamics model which incorporates information on the age composition of the landings, size and age composition of the population, and trends in relative abundance derived from commercial CPUE and research vessel survey biomass indices; and an age-aggregated biomass dynamics model. Surplus production estimates were derived from the age-structured dynamics model, and information on current biomass and fishing mortality relative to MSY-based reference points were also provided by the biomass dynamics model.

At that time, the NEFSC autumn survey biomass index had increased substantially during the mid-1990s and had remained relatively high through 2000. The rapid increase in abundance and biomass was attributed to recruitment and growth of the 1992 and other early-1990s year classes. The assessment conducted in 2001 provided no basis with which to evaluate the state of the stock relative to the control rule as determined by the Overfishing Definition Review Panel (Anon. 1998).

### 2.0 The Fishery

During the early development phase of the Gulf of Maine redfish fishery, USA landings increased rapidly to a peak level of about 56,000 mt in 1942 followed by a steep decline through the early 1950s (Table M1; Figure M1). Nominal catches then declined at a more gradual rate to less than 10,000 mt during the 1960s. During the 1970s, USA landings increased again, peaking at 16,000 mt in 1971 and again at 15,000 mt in 1979. During the 1970s, additional catches by Canadian and distant water fleets increased the total redfish catch to a maximum of about 17,000 to 20,000 mt per year from 1970 through 1973; catches of redfish by these fleets declined to negligible levels after 1976. Landings of redfish declined steadily throughout the1980s, remaining below 1,000 mt per year since 1989, and at less than 500 mt per year since 1994. Total redfish landings in 2001 were 360 mt compared to 319 mt in 2000.

### 3.0 Research Survey Indices

Indices of relative biomass, derived from NEFSC autumn research vessel bottom trawl surveys, although variable, exhibited a steady decline between 1963 and 1982 (Table M2, Figure M2). On average, the biomass index appears to have declined by about 90% over a 20 year period. During this time, only 2 year classes of any significance were produced, 1971 and 1978. Between 1983 and 1993, the biomass index approximately doubled, reflecting the relatively low rate of removals by the fishery and the very slow growth rate of the species. No substantial year classes were detected by research vessel surveys in the inshore survey strata traditionally used to monitor recruitment until autumn 1995 when a substantial number of fish in the 15-19 cm range were noted, suggesting the possibility of above average reproduction in 1990 and/or 1991. This was followed by a very large increase in the index in the offshore strata in the autumn of 1996. The autumn biomass index has fluctuated between 20 and 30 kg per tow since then, a magnitude comparable to the period between 1963 and the mid-1970s.

During the earlier periods, however, redfish were generally first detected in the inshore strata at relatively small sizes ( ~ 10 cm or less, age 1 or 2), only to appear in the offshore strata after about 5 or six years (Mayo 1993). During the 1990s recruitment event, the year class was not detected until fish were close to 20 cm, or about ages 4 or 5, and the numbers appeared to be present in both inshore and offshore strata. The autumn biomass index increased 4-5 fold between the early 1990s and the mid-1990s, a rate that is inconsistent with the dynamics of this species. The spring index, however, suggests only a very modest change in biomass since the mid-1990s.

## 4.0 Assessment Results

Since the assessment reviewed at SAW 33 was completed, no additional aging data have become available to allow an assessment update. Landings remained very low in 2001 and the 2001 NEFSC autumn survey biomass index remained similar to that of 2000, indicating no appreciable change in the exploitation rate since 2000. Therefore, the results from the 2001 assessment serve as the basis for the present assessment report.

Exploitation ratios (catch/survey biomass) suggest that fishing mortality has been very low since the mid-1980s compared to previous periods (Table M3; Figure M3). Estimates of fishing mortality derived from the age-structured dynamics model and the age-aggregated biomass model were similar (Mayo *et al.* 2002), both indicating that current fishing mortality is low relative to past decades and less than 5% of $F_{MSY}$. Spawning stock biomass has increased since the mid-1990s, and was estimated to be 119,600 mt in 2000 (Mayo *et al*. 2002) due, in large part, to strong recruitment from the early 1990s. When measured against the estimates of $F_{MSY}$ and $SSB_{MSY}$ provided in NEFSC (2002), the stock is not overfished, and overfishing is not occurring.

Given the continued extremely low landings of redfish relative to the recent increase in biomass, exploitation is now extremely low compared to the 1960s and 1970s (Table M3; Figure M3). However, in contrast to this earlier period, where a substantial proportion of the stock persisted in the 30-40 cm range (Mayo, 1993), during the 1990s, almost all of the redfish were less than 25 cm, and almost none are greater than 30 cm. This suggests that, given the present demographics of the stock, only a small fraction of the biomass would be considered exploitable.

## 5.0 Biological Reference Points

Estimates of recruitment obtained from the age-structured biomass dynamics model reviewed at the 33rd SAW were used to imply the probable recruitment that could be produced by a rebuilt stock as described in NEFSC (2002). Recruitment estimates derived by the model from the

1952-1999 yearclasses served as the basis for evaluating trends and patterns in recruitment. The stock-recruitment data suggest an increase in the frequency of larger year classes (> 50 million fish) at higher biomass levels. Therefore, recruitment estimates corresponding to the upper quartile of the SSB range served as the basis for deriving mean and median recruitment estimates. In accordance with the recommendation of the Stock Assessment Review Committee of the 33rd SAW, the estimate of $F_{50\%}$ (0.04) is taken as a proxy for $F_{MSY}$. This fishing mortality rate produces 4.1073 kg of spawning stock biomass per recruit and 0.1429 kg of yield per recruit. The resulting mean recruitment of 57.63 million fish results in an $SSB_{MSY}$ estimate of 236, 700 mt when multiplied by the SSB per recruit, and an MSY estimate of 8,235 mt when multiplied by the yield per recruit.

Reference points derived from the non parametric approach are:

| | |
|---|---|
| MSY | 8,235mt |
| $B_{MSY}$ | 236,700 mt |
| $F_{MSY}$ | 0.04 = $F_{50\%}$ MSP |

It was determined (NEFSC 2002) that the stock could not be rebuilt to $B_{MSY}$ by 2009 even at F=0.0. Therefore, the rebuilding scenario invoked a 20 year plus 1 mean generation time (31 years for Acadian redfish) to achieve rebuilding. This results in an $F_{rebuild}$ = 0.01.

**6.0 GARM Panel Comments**

A question was raised as to why the catches have not followed the increase in the survey biomass. The current mesh size is too large for the size of the fish which make up the bulk of the biomass. The fishery for redfish from the 1950s to the 1980s used a smaller mesh size for redfish trips (3"). Some fishers claim to be discarding but there do not appear to be any large discarding events in the data. There is no evidence of targeting at present. The market was lost when the stock declined.

The change in mesh size used in the fishery was a concern in the interpretation of exploitation ratios. Ratios of catch to total biomass indices may not be comparable under different mesh regimes because the change in the amount of exploitable biomass would produce different q's. This is probably not a direct concern because exploitation ratios are not the basis for the assessment and the overall conclusion would not change. For species in which larger fish make up the major portion of the catch, this may not be a problem, but it may be for smaller-sized species such as redfish.

There was a question as to whether the year classes from the 1990s may have been inshore of the survey at younger ages. This had not been the case in the past for other large year classes. The Massachusetts survey does occasionally catch small redfish.

**Recommendations**

- Compute survey biomass indices of exploitable biomass and utilize these for calculating exploitation ratios.
- Perform a more systematic analysis of the  data to determine discard rates.

## 7.0 Sources of Uncertainty

- The sharp increase in the survey biomass index in 1996 is inconsistent with the life history characteristics of this species.
- Given the pelagic diurnal movement and general distribution of redfish, swept area estimates of stock biomass derived from bottom trawl survey data will tend to under-estimate absolute stock size.

## 8.0 References

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Table M1 Nominal redfish catches (metric tons), actual and standardized catch per unit effort, and calculated standardized USA and total effort for the Gulf of Maine-Georges Bank redfish fishery.

| | Nominal Catch (Metric tons) | | | USA Catch per Unit Effort (tons/day) | | Calculated Standard Effort (days fished) | |
|---|---|---|---|---|---|---|---|
| Year | USA | Others | Total | Actual | Standard | USA | Total |
| 1934 | 519 | | 519 | | | | |
| 1935 | 7549 | | 7549 | | | | |
| 1936 | 23162 | | 23162 | | | | |
| 1937 | 14823 | | 14823 | | | | |
| 1938 | 20640 | | 20640 | | | | |
| 1939 | 25406 | | 25406 | | | | |
| 1940 | 26762 | | 26762 | | | | |
| 1941 | 50796 | | 50796 | | | | |
| 1942 | 55892 | | 55892 | 6.9 | 6.9 | 8100 | 8100 |
| 1943 | 48348 | | 48348 | 6.7 | 6.7 | 7216 | 7216 |
| 1944 | 50439 | | 50439 | 5.4 | 5.4 | 9341 | 9341 |
| 1945 | 37912 | | 37912 | 4.5 | 4.5 | 8425 | 8425 |
| 1946 | 42423 | | 42423 | 4.7 | 4.7 | 9026 | 9026 |
| 1947 | 40160 | | 40160 | 4.9 | 4.9 | 8196 | 8196 |
| 1948 | 43631 | | 43631 | 5.4 | 5.4 | 8080 | 8080 |
| 1949 | 30743 | | 30743 | 3.3 | 3.3 | 9316 | 9316 |
| 1950 | 34307 | | 34307 | 4.1 | 4.1 | 8368 | 8368 |
| 1951 | 30077 | | 30077 | 4.1 | 4.1 | 7336 | 7336 |
| 1952 | 21377 | | 21377 | 3.5 | 3.4 | 6287 | 6287 |
| 1953 | 16791 | | 16791 | 3.8 | 3.6 | 4664 | 4664 |
| 1954 | 12988 | | 12988 | 3.4 | 3.1 | 4190 | 4190 |
| 1955 | 13914 | | 13914 | 4.5 | 4.0 | 3479 | 3479 |
| 1956 | 14388 | | 14388 | 4.4 | 3.8 | 3786 | 3786 |
| 1957 | 18490 | | 18490 | 4.3 | 3.6 | 5136 | 5136 |
| 1958 | 16043 | 4 | 16047 | 4.4 | 3.6 | 4456 | 4458 |
| 1959 | 15521 | | 15521 | 4.3 | 3.5 | 4435 | 4435 |
| 1960 | 11373 | 2 | 11375 | 3.8 | 3.0 | 3791 | 3792 |
| 1961 | 14040 | 61 | 14101 | 4.6 | 3.5 | 4011 | 4029 |
| 1962 | 12541 | 1593 | 14134 | 5.4 | 4.0 | 3135 | 3534 |
| 1963 | 8871 | 1175 | 10046 | 4.1 | 3.0 | 2957 | 3349 |
| 1964 | 7812 | 501 | 8313 | 4.3 | 2.9 | 2694 | 2867 |
| 1965 | 6986 | 1071 | 8057 | 7.0 | 4.4 | 1588 | 1831 |
| 1966 | 7204 | 1365 | 8569 | 11.7 | 6.4 | 1126 | 1339 |
| 1967 | 10442 | 422 | 10864 | 12.4 | 5.6 | 1865 | 1940 |
| 1968 | 6578 | 199 | 6777 | 14.7 | 6.1 | 1078 | 1111 |
| 1969 | 12041 | 414 | 12455 | 11.4 | 4.9 | 2457 | 2542 |
| 1970 | 15534 | 1207 | 16741 | 9.0 | 4.0 | 3884 | 4185 |
| 1971 | 16267 | 3767 | 20034 | 7.0 | 3.2 | 5083 | 6261 |
| 1972 | 13157 | 5938 | 19095 | 5.7 | 2.9 | 4537 | 6584 |
| 1973 | 11954 | 5406 | 17360 | 5.3 | 2.9 | 4122 | 5986 |
| 1974 | 8677 | 1794 | 10471 | 5.0 | 2.6 | 3337 | 4027 |
| 1975 | 9075 | 1497 | 10572 | 4.0 | 2.2 | 4125 | 4805 |
| 1976 | 10131 | 565 | 10696 | 4.6 | 2.3 | 4405 | 4650 |
| 1977 | 13012 | 211 | 13223 | 4.9 | 2.5 | 5205 | 5289 |
| 1978 | 13991 | 92 | 14083 | 4.8 | 2.4 | 5830 | 5868 |
| 1979 | 14722 | 33 | 14755 | 3.6 | 1.9 | 7748 | 7766 |
| 1980 | 10085 | 98 | 10183 | 3.2 | 1.6 | 6303 | 6364 |
| 1981 | 7896 | 19 | 7915 | 2.7 | 1.4 | 5640 | 5654 |
| 1982 | 6735 | 168 | 6903 | 2.7 | 1.5 | 4490 | 4602 |
| 1983 | 5215 | 113 | 5328 | 2.1 | 1.2 | 4346 | 4440 |
| 1984 | 4722 | 71 | 4793 | 1.9 | 1.1 | 4293 | 4357 |
| 1985 | 4164 | 118 | 4282 | 1.4 | 0.9 | 4627 | 4758 |
| 1986 | 2790 | 139 | 2929 | 1.0 | 0.6 | 4650 | 4882 |
| 1987 | 1859 | 35 | 1894 | 1.1 | 0.7 | 2656 | 2706 |
| 1988 | 1076 | 101 | 1177 | 0.9 | 0.5 | 2152 | 2354 |
| 1989 | 628 | 9 | 637 | 1.1 | 0.6 | 1047 | 1062 |
| 1990 | 588 | 13 | 601 | | | | |
| 1991 | 525 | | 525 | | | | |
| 1992 | 849 | | 849 | | | | |
| 1993 | 800 | | 800 | | | | |
| 1994* | 440 | | 440 | | | | |
| 1995* | 440 | | 440 | | | | |
| 1996* | 322 | | 322 | | | | |
| 1997* | 251 | | 251 | | | | |
| 1998* | 320 | | 320 | | | | |
| 1999* | 353 | | 353 | | | | |
| 2000* | 319 | | 319 | | | | |
| 2001* | 360 | | 360 | | | | |

* Preliminary
CPUE and effort not calculated after 1989 due to sharp reduction in directed redfish trips .

Table M2 Autumn NEFSC bottom trawl survey stratified mean catch per tow indices, average weights and average lengths of redfish in the Gulf of Maine - Georges Bank region.

| Year | INSHORE 1 Stratified Mean Catch per Tow Number | INSHORE 1 Stratified Mean Catch per Tow kg | INSHORE 1 Avg. Wgt. (kg) | INSHORE 1 Avg. Length (cm) | OFFSHORE 2 Stratified Mean Catch per Tow Number | OFFSHORE 2 Stratified Mean Catch per Tow (kg) | OFFSHORE 2 Avg. Wgt. (kg) | OFFSHORE 2 Avg. Length (cm) | COMBINED 3 Stratified Mean Catch per Tow Number | COMBINED 3 Stratified Mean Catch per Tow kg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 86.3 | 7.6 | 0.088 | 17.4 | 87.5 | 27.0 | 0.309 | 26.4 | 87.3 | 24.1 |
| 1964 | 81.3 | 13.5 | 0.166 | 20.2 | 122.3 | 61.8 | 0.505 | 30.8 | 116.3 | 54.6 |
| 1965 | 189.5 | 22.3 | 0.118 | 17.7 | 33.9 | 11.5 | 0.339 | 25.3 | 57.0 | 13.1 |
| 1966 | 172.8 | 17.0 | 0.098 | 16.2 | 77.8 | 31.2 | 0.401 | 27.4 | 91.9 | 29.1 |
| 1967 | 62.9 | 5.3 | 0.084 | 17.7 | 107.1 | 27.6 | 0.258 | 23.6 | 100.5 | 24.3 |
| 1968 | 41.1 | 4.7 | 0.114 | 18.3 | 161.3 | 46.6 | 0.289 | 25.1 | 143.4 | 40.4 |
| 1969 | 105.9 | 16.0 | 0.151 | 20.7 | 65.2 | 24.8 | 0.380 | 27.4 | 71.2 | 23.5 |
| 1970 | 18.2 | 2.8 | 0.154 | 20.3 | 107.2 | 38.2 | 0.356 | 26.3 | 94.0 | 32.9 |
| 1971 | 20.7 | 4.7 | 0.227 | 21.8 | 52.8 | 26.7 | 0.506 | 29.7 | 48.0 | 23.4 |
| 1972 | 36.4 | 6.6 | 0.181 | 20.8 | 58.9 | 27.8 | 0.472 | 29.2 | 55.6 | 24.6 |
| 1973 | 26.2 | 2.1 | 0.080 | 15.6 | 41.4 | 19.7 | 0.476 | 29.7 | 39.2 | 17.0 |
| 1974 | 44.4 | 4.7 | 0.106 | 18.0 | 49.0 | 27.6 | 0.563 | 30.1 | 48.3 | 24.2 |
| 1975 | 45.7 | 6.0 | 0.131 | 19.6 | 79.9 | 45.9 | 0.574 | 30.6 | 74.8 | 39.9 |
| 1976 | 11.6 | 2.5 | 0.216 | 22.6 | 31.9 | 17.5 | 0.549 | 30.2 | 28.9 | 15.3 |
| 1977 | 54.6 | 12.3 | 0.225 | 23.4 | 37.9 | 18.1 | 0.478 | 28.5 | 40.4 | 17.3 |
| 1978 | 20.4 | 5.5 | 0.270 | 24.6 | 49.5 | 23.4 | 0.473 | 29.0 | 45.2 | 20.7 |
| 1979 | 6.2 | 2.1 | 0.339 | 26.5 | 32.8 | 18.4 | 0.561 | 30.5 | 28.9 | 16.0 |
| 1980 | 20.6 | 6.2 | 0.301 | 24.6 | 20.6 | 13.8 | 0.670 | 31.8 | 20.6 | 12.6 |
| 1981 | 6.8 | 1.9 | 0.279 | 24.9 | 22.7 | 14.0 | 0.617 | 31.8 | 20.4 | 12.2 |
| 1982 | 28.2 | 4.6 | 0.163 | 21.2 | 5.6 | 3.2 | 0.571 | 31.5 | 9.0 | 3.4 |
| 1983 | 30.2 | 8.7 | 0.288 | 24.8 | 6.5 | 3.3 | 0.508 | 29.1 | 10.0 | 4.1 |
| 1984 | 7.7 | 3.2 | 0.416 | 27.9 | 7.8 | 4.1 | 0.526 | 29.0 | 7.8 | 3.9 |
| 1985 | 7.2 | 2.1 | 0.292 | 24.8 | 14.0 | 6.3 | 0.450 | 28.0 | 13.0 | 5.7 |
| 1986 | 67.6 | 15.3 | 0.226 | 23.3 | 18.8 | 6.7 | 0.356 | 26.1 | 26.1 | 8.0 |
| 1987 | 26.5 | 4.8 | 0.181 | 21.9 | 11.5 | 5.6 | 0.487 | 29.2 | 13.7 | 5.5 |
| 1988 | 18.5 | 5.1 | 0.276 | 21.9 | 11.4 | 6.5 | 0.570 | 29.1 | 12.4 | 6.3 |
| 1989 | 14.0 | 2.9 | 0.207 | 22.6 | 21.3 | 7.5 | 0.352 | 25.9 | 20.3 | 6.8 |
| 1990 | 57.6 | 14.5 | 0.252 | 23.8 | 31.7 | 11.7 | 0.369 | 26.7 | 35.5 | 12.2 |
| 1991 | 7.2 | 1.1 | 0.153 | 20.4 | 21.1 | 9.6 | 0.455 | 28.5 | 19.1 | 8.4 |
| 1992 | 7.8 | 1.2 | 0.147 | 20.0 | 24.9 | 9.3 | 0.374 | 27.3 | 22.4 | 8.1 |
| 1993 | 53.7 | 7.4 | 0.137 | 20.0 | 32.5 | 11.9 | 0.366 | 26.3 | 35.6 | 11.2 |
| 1994 | 31.5 | 5.4 | 0.171 | 21.7 | 19.0 | 6.0 | 0.317 | 25.0 | 20.9 | 5.9 |
| 1995 | 109.7 | 11.1 | 0.102 | 18.5 | 19.9 | 3.5 | 0.177 | 21.3 | 33.2 | 4.7 |
| 1996 | 53.8 | 9.1 | 0.169 | 21.5 | 189.9 | 34.4 | 0.181 | 21.9 | 169.6 | 30.6 |
| 1997 | 105.6 | 15.7 | 0.149 | 20.3 | 57.9 | 19.5 | 0.337 | 26.0 | 65.0 | 18.9 |
| 1998 | 48.7 | 10.7 | 0.219 | 20.4 | 128.9 | 35.4 | 0.275 | 23.6 | 117.0 | 31.7 |
| 1999 | 164.2 | 35.1 | 0.214 | 23.2 | 68.2 | 20.7 | 0.304 | 25.6 | 82.5 | 22.9 |
| 2000 | 133.3 | 21.8 | 0.164 | 21.6 | 99.4 | 26.9 | 0.271 | 24.8 | 104.4 | 26.2 |
| 2001 | 144.4 | 28.9 | 0.200 | 22.8 | 80.2 | 28.0 | 0.349 | 27.3 | 89.8 | 28.2 |

1. Strata Set: 26, 27, 39, 40
2. Strata Set: 24, 28-30, 36-38
3. Strata Set: 24, 26-30, 36-40

Table M3. Commercial landings (mt), NEFSC autumn survey biomass index (kg/tow), and index of exploitation for Gulf of Maine redfish.

| Year | Commercial landings (mt) | Biomass Index | Exploitation Ratio |
|---|---|---|---|
| 1963 | 10046 | 24.1 | 0.4168 |
| 1964 | 8313 | 54.6 | 0.1523 |
| 1965 | 8057 | 13.1 | 0.6150 |
| 1966 | 8569 | 29.1 | 0.2945 |
| 1967 | 10864 | 24.3 | 0.4471 |
| 1968 | 6777 | 40.4 | 0.1677 |
| 1969 | 12455 | 23.5 | 0.5300 |
| 1970 | 16741 | 32.9 | 0.5088 |
| 1971 | 20034 | 23.4 | 0.8562 |
| 1972 | 19095 | 24.6 | 0.7762 |
| 1973 | 17360 | 17.0 | 1.0212 |
| 1974 | 10471 | 24.2 | 0.4327 |
| 1975 | 10572 | 39.9 | 0.2650 |
| 1976 | 10696 | 15.3 | 0.6991 |
| 1977 | 13223 | 17.3 | 0.7643 |
| 1978 | 14083 | 20.7 | 0.6803 |
| 1979 | 14755 | 16.0 | 0.9222 |
| 1980 | 10183 | 12.6 | 0.8082 |
| 1981 | 7915 | 12.2 | 0.6488 |
| 1982 | 6903 | 3.4 | 2.0303 |
| 1983 | 5328 | 4.1 | 1.2995 |
| 1984 | 4793 | 3.9 | 1.2290 |
| 1985 | 4282 | 5.7 | 0.7512 |
| 1986 | 2929 | 8.0 | 0.3661 |
| 1987 | 1894 | 5.5 | 0.3444 |
| 1988 | 1177 | 6.3 | 0.1868 |
| 1989 | 637 | 6.8 | 0.0937 |
| 1990 | 601 | 12.2 | 0.0493 |
| 1991 | 525 | 8.4 | 0.0625 |
| 1992 | 849 | 8.1 | 0.1049 |
| 1993 | 800 | 11.2 | 0.0714 |
| 1994 | 440 | 5.9 | 0.0741 |
| 1995 | 440 | 4.7 | 0.0946 |
| 1996 | 322 | 30.6 | 0.0105 |
| 1997 | 251 | 18.9 | 0.0133 |
| 1998 | 320 | 31.7 | 0.0101 |
| 1999 | 353 | 22.9 | 0.0154 |
| 2000 | 319 | 26.2 | 0.0122 |
| 2001 | 360 | 28.2 | 0.0128 |

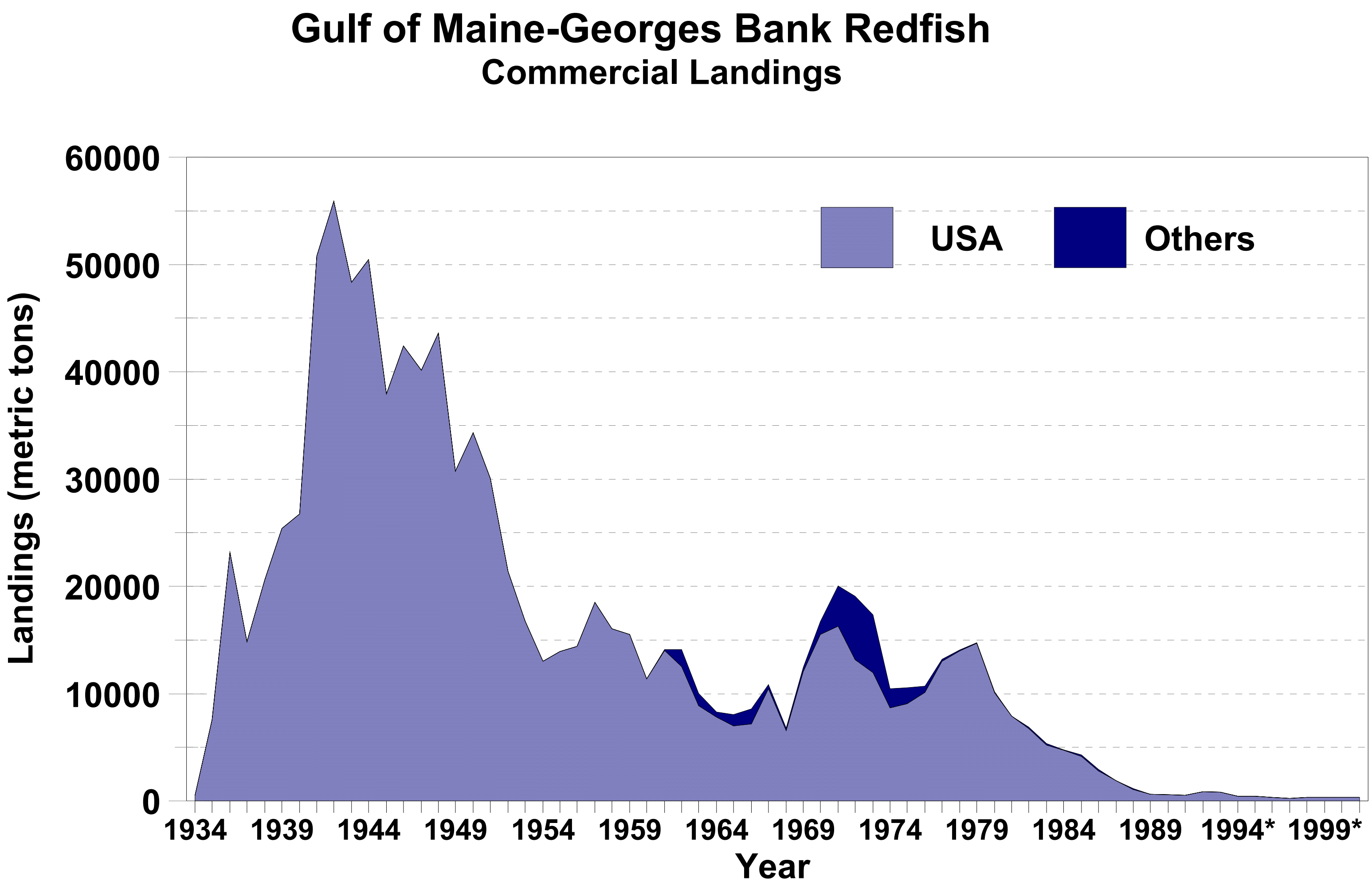


**Figure M1. Total commercial landings of Acadian redfish from the Gulf of Maine-Georges Bank region, 1934-2001**

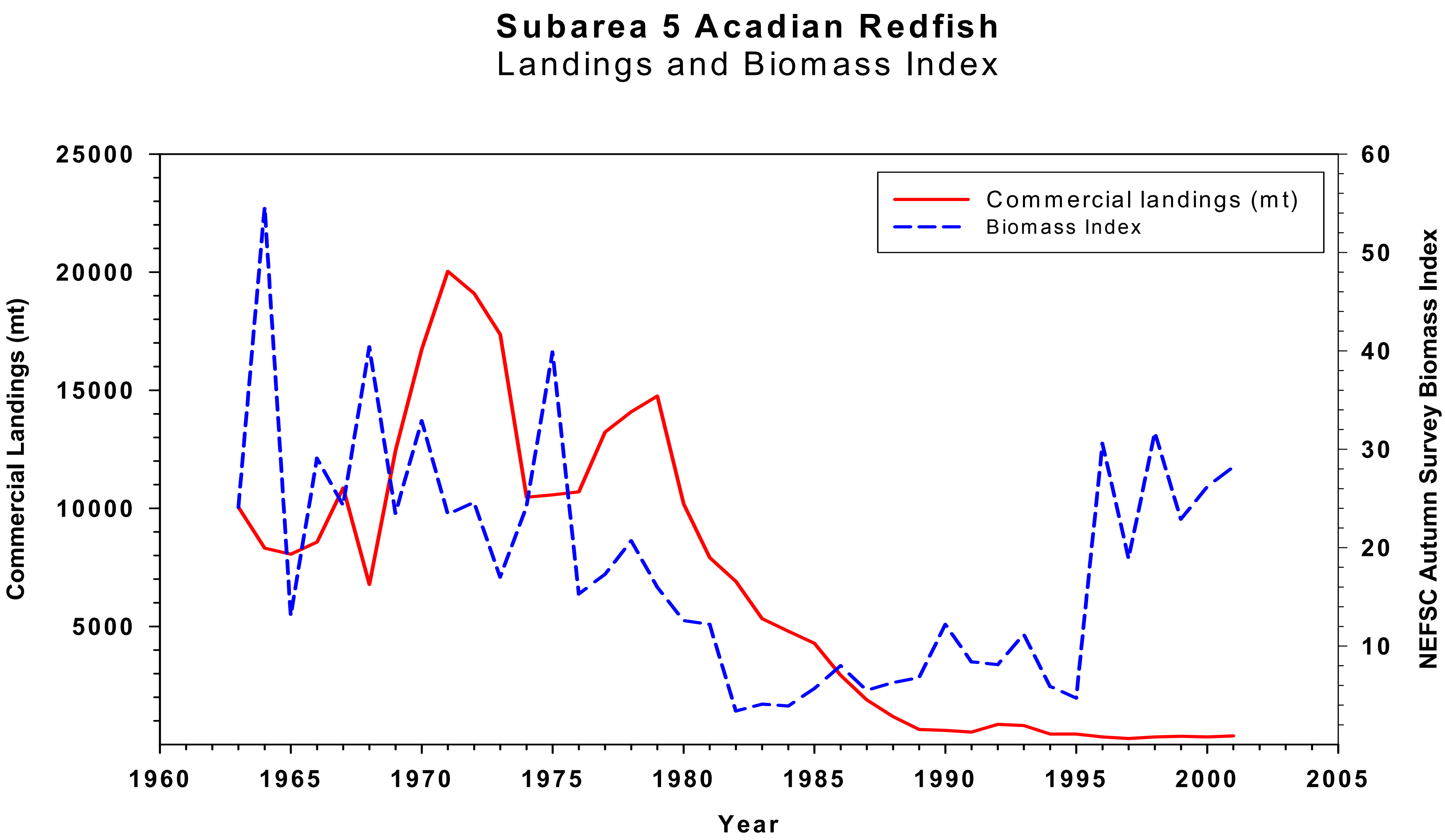


**Figure M2. Commercial landings and biomass index derived from NEFSC autumn survey biomass indices for Acadian redfish, 1963-2001.**

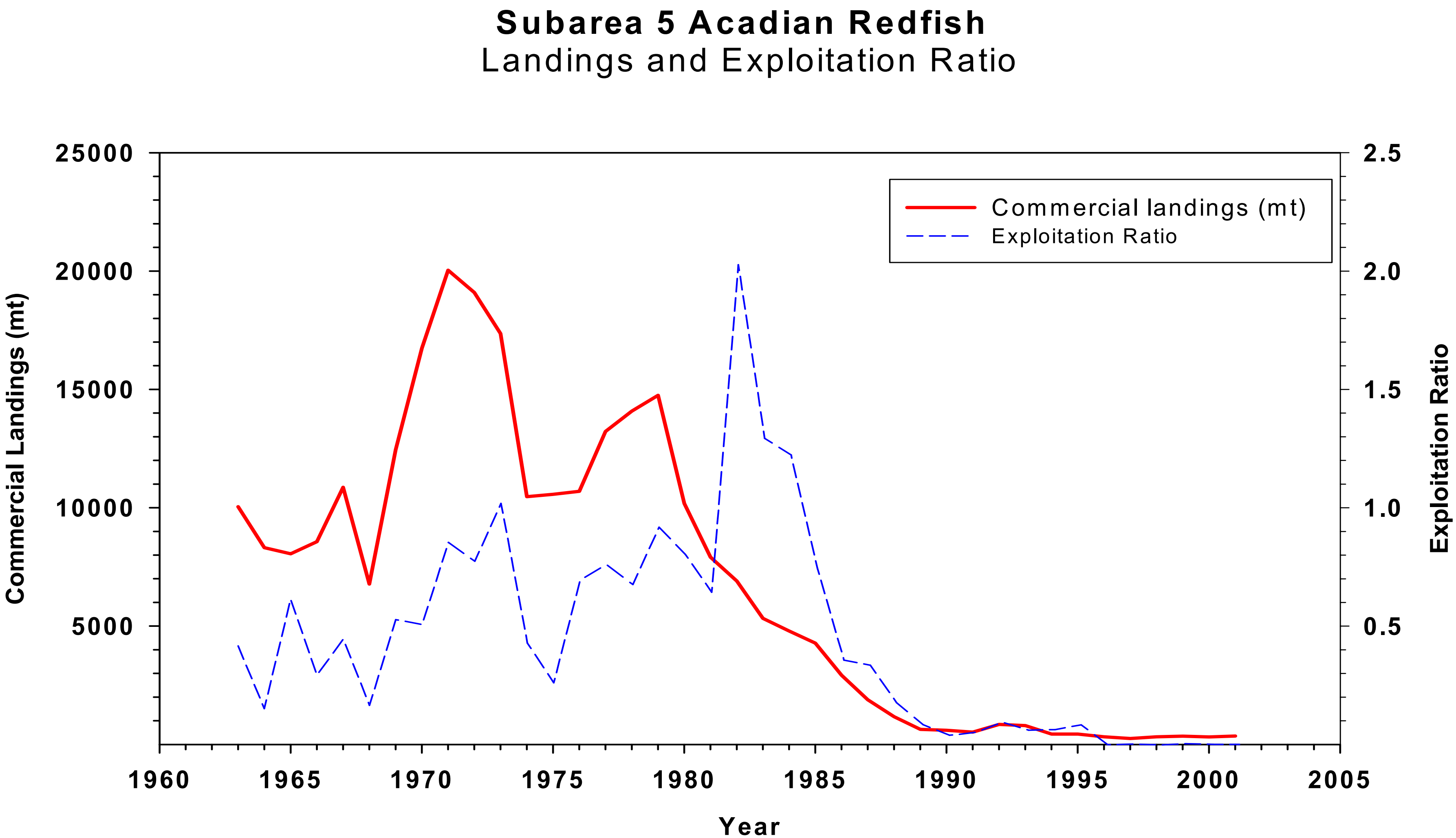


**Figure M3. Commercial landings and exploitation ratios derived from NEFSC autumn survey biomass indices for Acadian redfish.**

## N. Ocean Pout by S.E. Wigley

### 1.0 Background

Ocean pout, *Macrozoarces americanus*, are assessed as a unit stock from Cape Cod Bay south to Delaware. An index assessment for this species was last reviewed at SAW 11 in 1990 (NEFSC 1990). The status of this stock was most recently evaluated in 2000 (NEFSC 2001). At that time, the three year average spring biomass index (1997-1999 average = 1.98 kg/tow) was approximately 40% of the current $B_{msy}$ proxy (1980-1991 median = 4.9 kg/tow) and below the biomass threshold (½ Bmsy = 2.4 kg/tow). Ocean pout are included in the New England Fishery Management Council's Multispecies Fishery Management Plan under the "nonregulated multispecies" category.

### 2.0 The Fishery

From 1964 to 1974, an industrial fishery developed for ocean pout, and nominal catches by the U.S. fleet averaged 4,700 mt. Distant-water fleets began harvesting ocean pout in large quantities in 1966, and total nominal catches peaked at 27,000 mt in 1969. Foreign catches declined substantially afterward, and none have been reported since 1974 (Table N1, Figure N1). United States landings declined to an average of 600 mt annually during 1975 to 1983. Catches increased in 1984 and 1985 to 1,300 mt and 1,500 mt respectively, due to the development of a small directed fishery in Cape Cod Bay supplying the fresh fillet market. Landings have declined more or less continually since 1987. In recent years, landings from the southern New England/Mid-Atlantic area have continued to dominate the catch, reversing landing patterns observed in 1986-1987, when the Cape Cod Bay fishery was dominant. The shift in landings is attributed to the changes in management (gear/mesh) regulations. Total landings in 2001 were only 18 mt, a near-record low in the time series (Table N1, Figure N1).

### 3.0 Research Survey Indices

Commercial landings and the NEFSC spring research vessel survey biomass index followed similar trends during 1968 to 1975 (encompassing peak levels of foreign fishing and the domestic industrial fishery); both declined from very high values in 1968-1969 to lows of 300 mt and 1.3 kg per tow, respectively, in 1975. Between 1975 and 1985, survey indices increased to record high levels, peaking in 1981 and 1985. Since 1985, survey catch per tow indices have generally declined, and are presently below than the long-term survey average (3.5 kg per tow); the 2001 spring survey index was 2.8 kg per tow (Table N2, Figure N1). Both NEFSC winter survey and the Massachusetts Division of Marine Fisheries inshore research vessel surveys confirm the declining trend observed in the NEFSC spring survey.

### 4.0 Exploitation Indices

Annual relative exploitation ratios (landings/NEFSC spring survey biomass index) have declined sharply from a peak in 1973 to low levels in the early 1980s then increased slightly in the late-1980s, after which they declined to record low levels (Table N3, Figure N2). The 2001 exploitation index (0.007) was the lowest in the time series and well below the Fmsy proxy (0.31), derived as the MSY proxy (1,500 mt) divided by the Bmsy proxy. Since discards have not been estimated, and landings, not total catch, were used to derive exploitation ratios, the exploitation ratios may be under estimated.

## 5.0 Assessment Results

The index assessment presented above reveals that landings, survey and exploitation ratios trends have remained stable. No substantial change in stock status has occurred since the last assessment.

For ocean pout, the replacement ratio and relative F analyses were not sufficiently informative for estimating Bmsy, Fmsy, and MSY (NEFSC 2002). Thus, the biological reference points for ocean pout remain based upon research vessel survey biomass trends and the exploitation history (Applegate et al. 1998). MSY was chosen to be 1,500 mt and the Bmsy proxy was determined as the median survey index from 1980-1991 (4.9 kg/tow). The minimum biomass threshold is ½ of the Bmsy proxy (2.4 kg/tow). Given these proxies, the threshold Fmsy is 0.31 (1.5/4.9).

To evaluate stock conditions, the three year average of NEFSC spring survey indices and the exploitation ratio (2001 landings/ average of 1999, 2000, 2001 spring survey biomass indices) were used as proxies for biomass and fishing mortality, respectively. In 2001, the three year average survey index (2.46 kg/tow) indicates that biomass is slightly above 1/2Bmsy and the exploitation ratio (0.007) indicates F is below the F threshold (Figure N3). Thus, the ocean pout population was not overfished and overfishing did not occur in 2001.

Since the ocean pout fishery occurs primarily in the spring it is possible to evaluate the stock condition for 2002. Using the NEFSC 2002 spring survey (2.026 kg/tow), the 3 year average spring biomass index (2.28 kg/tow) is below ½ Bmsy. Using preliminary 2002 landings (9 mt), the 2002 exploitation ratio (0.004) remains below the F threshold. Thus, the preliminary evaluation for 2002 is that the ocean pout population is overfished and overfishing is not occurring.

*Sensitivity analyses*

Sensitivity analyses were conducted by deriving exploitation ratios from NEFSC spring biomass indices which were arbitrarily increased by 10%, 25% and 100% (Figure N3). Results are summarized in Section 5.2 (Summary of Assessment Advice).

## 6.0 GARM Comments

The discussion centered around the conclusion that the stock was defined as overfished despite minimal landings for two decades. Although landings have been low perhaps due to mesh size regulations, the possibility exists that significant numbers are discarded in other fisheries. The panel noted that the landings to survey ratio has not accounted for the changes in commercial catchability which has occurred over time due to changes in mesh regulation. Declining trends in the NEFSC spring biomass correspond with the declining biomass trends observed in the Massachusetts inshore survey. It was noted that any inflation of the NEFSC index to account for potential gear problems would only create a mis-match between these series.

A preliminary examination of length frequency data from the NEFSC spring survey series revealed little change in the minimum and maximum size over time. The GARM suggested further exploration of the size distribution for evidence of changing stock demographics given the stock decline over time.

## 7.0 Sources of Uncertainty

- The size composition of the commercial landings could not be characterized, due to the lack of commercial length samples.
- Discards have not been estimated, only landings were used to derive exploitation ratios instead of total catch. Therefore, exploitation ratios may be underestimated.

## Research Recommendations

- Explore various data sources to estimate the magnitude of discarding in fisheries which may impact the ocean pout population (e.g. scallop fishery).
- Explore computing survey biomass indices of exploitable biomass and utilize these for calculating exploitation ratios.
- Examine demographic data for changes over time.
- Initiate biological studies to update basic life history information.

## 8.0 References

Applegate, A., S.X. Cadrin, J. Hoenig, C. Moore, S. Murawski, and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. New England Fishery Management Council Report.

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Northeast Fisheries Science Center. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.

Wigley, S.E. 2000. Ocean Pout. In: Clark, S.H. (Ed.) Status of the Fishery Resources off the Northeastern United States. NOAA Tech. Mem. NMFS-NE-115. Electronic document. http://www.nefsc.nmfs.gov/sos/spsyn/og/pout.html

Table N1. Commercial landings (mt, live) of ocean pout from the Gulf of Maine-Mid-Atlantic region (NAFO Subarea 5 and 6), 1962-2002.

| | USA | | | | |
|---|---|---|---|---|---|
| Year | 5 | 6 | Total | Other | Total |
| 1962 | 0 | 0 | 0 | 0 | 0 |
| 1963 | 20 | 0 | 20 | 0 | 20 |
| 1964 | 2123 | 0 | 2123 | 0 | 2123 |
| 1965 | 877 | 0 | 877 | 0 | 877 |
| 1966 | 7149 | 0 | 7149 | 6231 | 13380 |
| 1967 | 7090 | 0 | 7090 | 271 | 7361 |
| 1968 | 8373 | 364 | 8737 | 4324 | 13061 |
| 1969 | 5571 | 966 | 6537 | 20435 | 26972 |
| 1970 | 5851 | 426 | 6277 | 895 | 7172 |
| 1971 | 2678 | 1448 | 4126 | 1784 | 5910 |
| 1972 | 1927 | 358 | 2285 | 1066 | 3351 |
| 1973 | 2810 | 285 | 3095 | 2275 | 5370 |
| 1974 | 2790 | 459 | 3249 | 483 | 3732 |
| 1975 | 209 | 65 | 274 | 3 | 277 |
| 1976 | 341 | 337 | 678 | 0 | 678 |
| 1977 | 809 | 250 | 1059 | 0 | 1059 |
| 1978 | 715 | 320 | 1035 | 0 | 1035 |
| 1979 | 658 | 14 | 672 | 0 | 672 |
| 1980 | 339 | 11 | 350 | 0 | 350 |
| 1981 | 234 | 17 | 251 | 0 | 251 |
| 1982 | 317 | 4 | 321 | 0 | 321 |
| 1983 | 408 | 0 | 408 | 0 | 408 |
| 1984 | 1324 | 0 | 1324 | 0 | 1324 |
| 1985 | 1450 | 54 | 1504 | 0 | 1504 |
| 1986 | 801 | 1 | 802 | 0 | 802 |
| 1987 | 2111 | 74 | 2185 | 0 | 2185 |
| 1988 | 1765 | 46 | 1811 | 0 | 1811 |
| 1989 | 1308 | 6 | 1314 | 0 | 1314 |
| 1990 | 1299 | 13 | 1312 | 0 | 1312 |
| 1991 | 1361 | 63 | 1424 | 0 | 1424 |
| 1992 | 406 | 68 | 474 | 0 | 474 |
| 1993 | 217 | 15 | 232 | 0 | 232 |
| 1994 | 137 | 59 | 196 | 0 | 196 |
| 1995 | 51 | 14 | 65 | 0 | 65 |
| 1996 | 22 | 29 | 51 | 0 | 51 |
| 1997 | 8 | 25 | 33 | 0 | 33 |
| 1998 | 8 | 9 | 17 | 0 | 17 |
| 1999 | 8 | 10 | 18 | 0 | 18 |
| 2000 | 8 | 11 | 19 | 0 | 19 |
| 2001 | 9 | 9 | 18 | 0 | 18 |
| 2002* | 2 | 7 | 9 | 0 | 9 |

1994-1999 spatial patterns are based upon Vessel Trip Report data.
* preliminary.

Table N2. Stratified mean catch per tow in weight and numbers, mean length and individual average fish weight of ocean pout in NEFSC spring surveys, in the Gulf of Maine-Mid-Atlantic region (strata 1-26,73-76), 1968-2002.

| Year | Mean weight (kg) per tow | Mean number per tow | Mean Length (cm) | Individual average weight (kg) |
|---|---|---|---|---|
| 1968 | 5.366 | 6.766 | 51.1 | 0.793 |
| 1969 | 6.154 | 8.629 | 49.3 | 0.713 |
| 1970 | 5.180 | 6.133 | 51.9 | 0.845 |
| 1971 | 2.183 | 3.135 | 50.2 | 0.696 |
| 1972 | 4.453 | 5.090 | 51.6 | 0.875 |
| 1973 | 3.373 | 4.591 | 48.8 | 0.735 |
| 1974 | 1.479 | 2.310 | 47.0 | 0.640 |
| 1975 | 1.293 | 1.358 | 53.4 | 0.952 |
| 1976 | 1.400 | 2.440 | 46.5 | 0.574 |
| 1977 | 3.605 | 6.366 | 44.8 | 0.566 |
| 1978 | 3.371 | 11.831 | 31.6 | 0.285 |
| 1979 | 1.493 | 5.197 | 34.7 | 0.287 |
| 1980 | 5.729 | 11.837 | 42.6 | 0.484 |
| 1981 | 7.605 | 14.131 | 42.7 | 0.538 |
| 1982 | 4.743 | 8.690 | 44.0 | 0.546 |
| 1983 | 4.236 | 5.076 | 50.5 | 0.835 |
| 1984 | 5.540 | 7.275 | 50.0 | 0.762 |
| 1985 | 6.494 | 9.011 | 48.7 | 0.721 |
| 1986 | 6.345 | 6.995 | 53.0 | 0.907 |
| 1987 | 2.705 | 3.076 | 51.7 | 0.879 |
| 1988 | 3.244 | 5.405 | 45.0 | 0.600 |
| 1989 | 2.792 | 5.323 | 44.0 | 0.525 |
| 1990 | 5.074 | 6.369 | 50.3 | 0.797 |
| 1991 | 3.783 | 5.596 | 49.7 | 0.676 |
| 1992 | 2.257 | 2.639 | 52.9 | 0.855 |
| 1993 | 3.084 | 3.546 | 53.4 | 0.870 |
| 1994 | 2.309 | 2.639 | 54.3 | 0.875 |
| 1995 | 1.916 | 2.525 | 50.5 | 0.759 |
| 1996 | 2.058 | 3.127 | 47.6 | 0.658 |
| 1997 | 1.632 | 2.069 | 52.4 | 0.789 |
| 1998 | 1.733 | 2.957 | 46.1 | 0.586 |
| 1999 | 2.561 | 3.340 | 50.2 | 0.767 |
| 2000 | 2.016 | 3.113 | 48.2 | 0.648 |
| 2001 | 2.801 | 3.748 | 51.6 | 0.747 |
| 2002 | 2.026 | 2.809 | 51.3 | 0.721 |

Table N3. Annual relative exploitation ratios (annual landings /spring survey biomass indices) and relative exploitation ratios used in stock status (annual landings/ 3year average spring biomass indices) for ocean pout, 1968-2002.

| Year | Annual relative exploitation rate (landings/spring index) | Relative exploitation ratio (landings/ 3 yr avg spring index) |
|---|---|---|
| 1968 | 2.434 | |
| 1969 | 4.383 | |
| 1970 | 1.385 | 1.2884 |
| 1971 | 2.249 | 1.0897 |
| 1972 | 0.753 | 0.8508 |
| 1973 | 1.592 | 1.6096 |
| 1974 | 2.523 | 1.2032 |
| 1975 | 0.214 | 0.1352 |
| 1976 | 0.484 | 0.4875 |
| 1977 | 0.294 | 0.5044 |
| 1978 | 0.307 | 0.3707 |
| 1979 | 0.450 | 0.2380 |
| 1980 | 0.061 | 0.0991 |
| 1981 | 0.033 | 0.0508 |
| 1982 | 0.068 | 0.0533 |
| 1983 | 0.096 | 0.0738 |
| 1984 | 0.239 | 0.2736 |
| 1985 | 0.232 | 0.2773 |
| 1986 | 0.126 | 0.1309 |
| 1987 | 0.808 | 0.4217 |
| 1988 | 0.558 | 0.4419 |
| 1989 | 0.468 | 0.4482 |
| 1990 | 0.259 | 0.3543 |
| 1991 | 0.376 | 0.3667 |
| 1992 | 0.210 | 0.1280 |
| 1993 | 0.075 | 0.0763 |
| 1994 | 0.085 | 0.0770 |
| 1995 | 0.034 | 0.0268 |
| 1996 | 0.025 | 0.0244 |
| 1997 | 0.021 | 0.0180 |
| 1998 | 0.010 | 0.0097 |
| 1999 | 0.007 | 0.0086 |
| 2000 | 0.009 | 0.0089 |
| 2001 | 0.006 | 0.0071 |
| 2002 | 0.004 | 0.0039 |

Note: preliminary 2002 landings used.

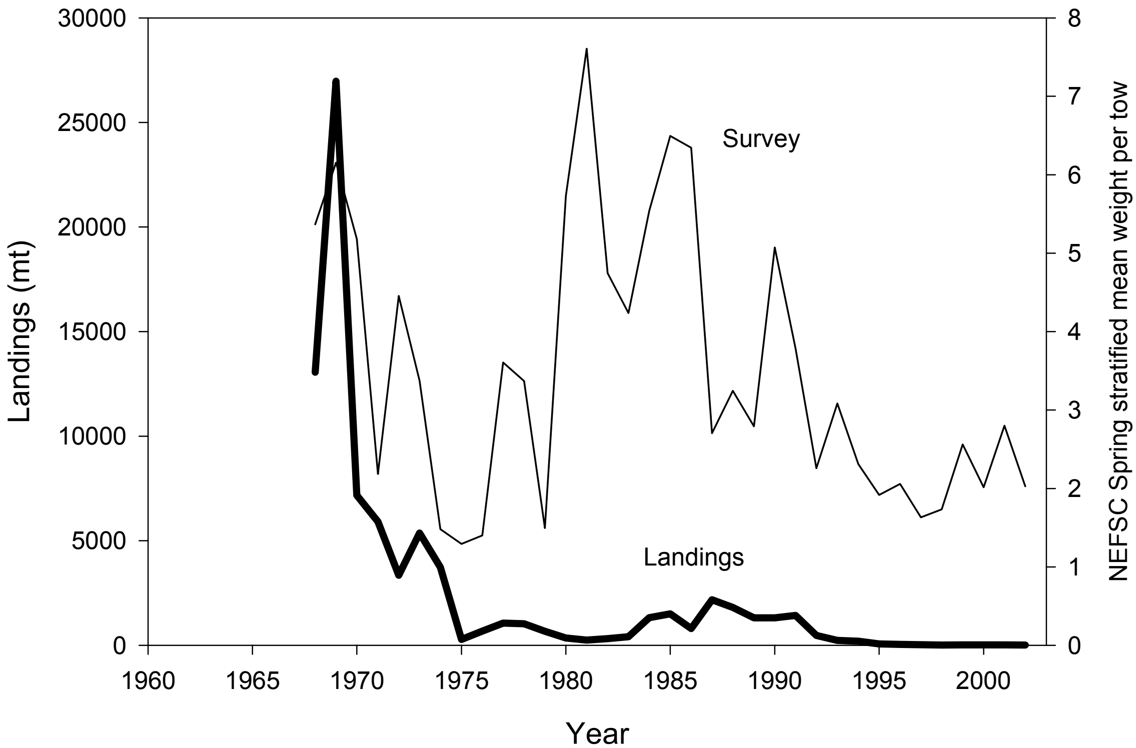


Figure N1. Trends in landings (mt) and NEFSC spring survey biomass (kg/tow) for ocean pout, 1968 - 2002.

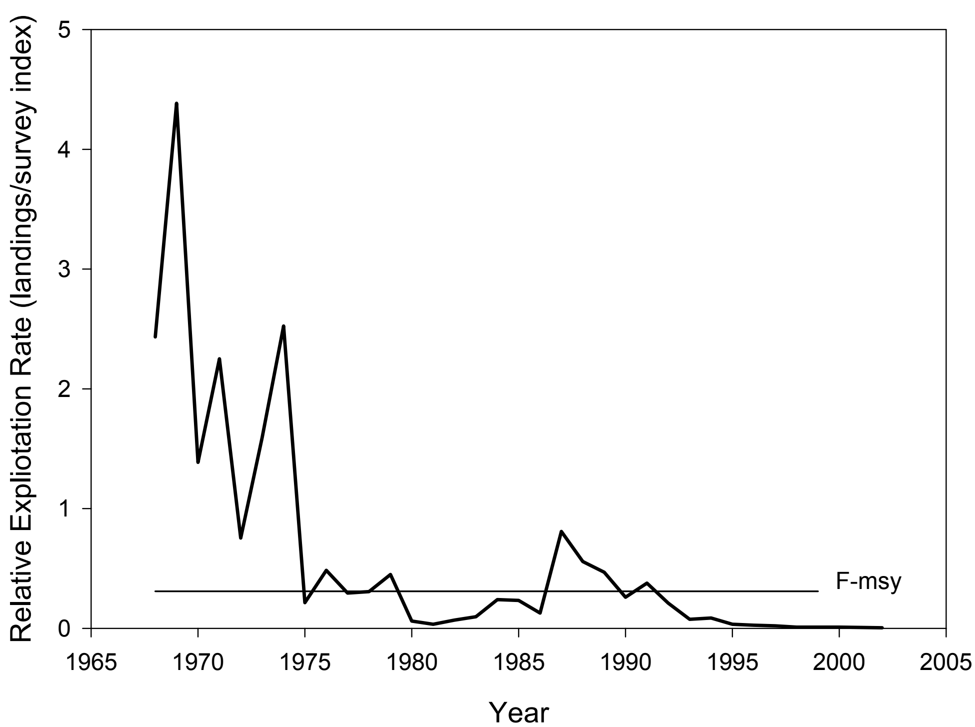


Figure N2.
Exploitation indices (landings/spring biomass index) for ocean pout, 1970 - 2002.

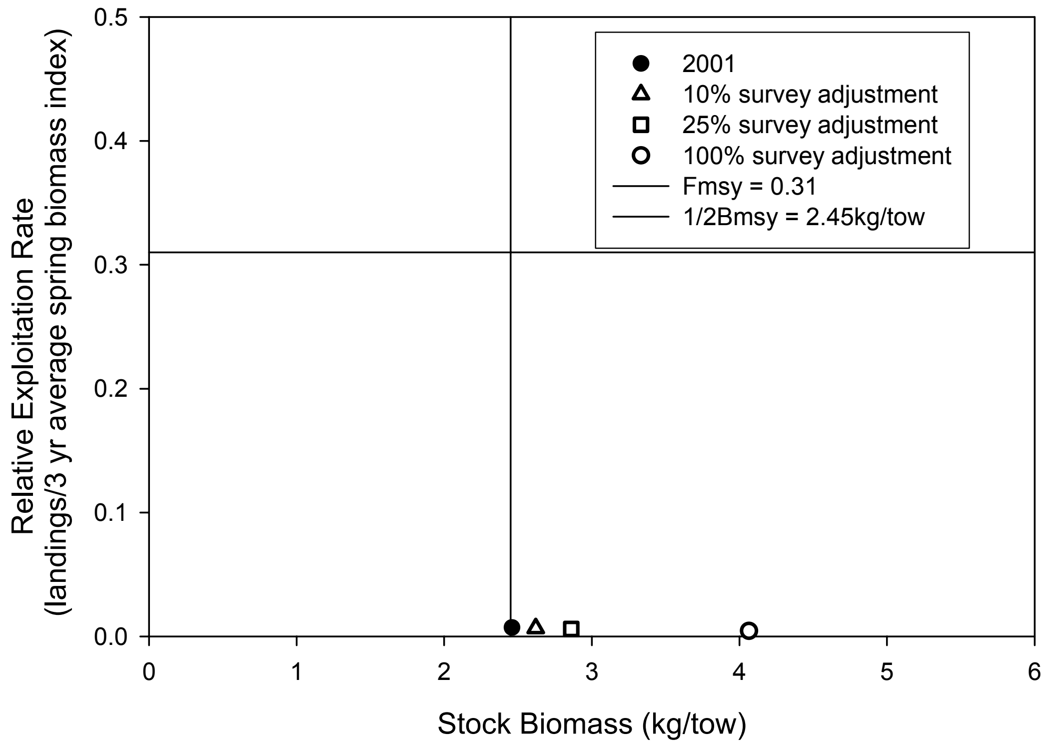


Figure N3. Ocean pout stock status in 2001 and three sensitivity analyses in which NEFSC spring survey biomass was arbitrarily adjusted by 10%, 25% and 100%.

**O. Windowpane Flounder (Gulf of Maine-Georges Bank)** by Lisa Hendrickson

## 1.0 Background

No stock structure information is available for windowpane flounder. However, the assessment assumes two stock areas (Georges Bank and Southern New England) based on apparent differences in growth, sexual maturity, and abundance trends. Landings from the Gulf of Maine are low, so that area is combined with Georges Bank.

The northern windowpane flounder stock, which includes the Gulf of Maine and Georges Bank regions (GOM-GB), has never been formally assessed as part of the SAW/SARC process. The following index-based assessment is an update of the last report on stock status (NEFSC 2001) and a re-evaluation of the overfishing definition (NEFSC 2002).

## 2.0 Assessment Results

### 2.1 The Fishery

Windowpane landings were first recorded in 1975. During most years, the GOM-GB stock has comprised a higher proportion of the total landings than the SNE-MAB stock. Following a 1991 record high of 2,900 mt, landings declined sharply to 300 mt in 1994 (Table O1 and Figure O1). High landings during the early 1990s probably reflected an expansion of the fishery to offshore areas, as well as the targeting of windowpane flounder as an alternative to depleted groundfish stocks. Landings declined from 700 mt in 1996 to a record low of 44 mt in 2001.

Discarding of windowpane has not been quantified, so discards were not included in the calculation of exploitation indices.

### 2.2 Research Survey Indices

Biomass indices of GOM-GB windowpane flounder from the NEFSC autumn bottom trawl surveys (1963-2001) are presented in Table O1 and Figure O2. Survey biomass indices are highly variable, but indicate a declining trend following a time series peak in 1984 and an increasing trend after 1991. The large increase in the 1998 survey index is primarily attributable to a large catch of windowpane at one station.

### 2.3 Biological Reference Points

Biological reference points for GOM-GB windowpane flounder were derived from survey-based proxies of biomass and exploitation rates and are based on an ASPIC-based MSY estimate of 1,000 mt. The threshold F is defined as an $F_{MSY}$ proxy (= 1.11) when the NEFSC autumn survey index is greater than 0.94 kg/tow (equal to a $B_{MSY}$ proxy) and declines linearly to zero at 50% of the $B_{MSY}$ proxy (= 0.47 kg/tow). The target exploitation index is defined as 60% of the $F_{MSY}$ proxy (= 0.67) when the autumn survey index is greater than 0.94 kg/tow and declines linearly to zero at 0.47 kg/tow.

## 2.4 Relative Exploitation Rates and Stock Status

Relative exploitation rates (landings/NEFSC autumn survey biomass index) have been declining since reaching a peak in 1991 (Table O1 and Figure O3) and were below the $F_{MSY}$ proxy (=1.11) during 1997-2001. The 1999-2001 autumn survey mean biomass index equals 0.79 kg/tow and the 1999-2001 mean exploitation index (landings/NEFSC autumn survey biomass index) equals 0.10 (Table O3 and Figure O2). Overfishing was not occurring and the stock was not overfished in 2001.

## 3.0 Sources of Uncertainty

* Stock structure is uncertain.

* Discarding is not quantified and may represent a sizable fraction of the multi-species catches given recent groundfish retention restrictions.

* Vessel trip reports have been used to prorate the landings since 1995, and a fraction of the landings from Southern New England may have been reported as Georges Bank landings or vice versa.

## 4.0 Literature Cited

NEFSC (Northeast Fisheries Science Center). 2002. Final report of the working group on reevaluation of biological reference points for New England groundfish. 231 p.

NEFSC (Northeast Fisheries Science Center). 2001. Assessment of 19 Northeast groundfish stocks through 2000; a report to the New England Fishery Management Council's Multi-species Monitoring Committee. Northern and Southern Demersal Working Groups, Northeast Stock Assessment Workshop. *Northeast Fish. Sci. Cent. Ref. Doc.* 01-20;
217 p.

Table O1. Landings (mt), NEFSC autumn survey biomass indices (stratified mean kg per tow, offshore strata 13-29 and 37-40), and exploitation indices (landings/autumn survey biomass index) for Gulf of Maine-Georges Bank windowpane flounder during 1963-2001. Landings include Statistical Areas beginning with 51 and 52, with the exception of 526, 530-539 and 541.

| Year | Landings[1] (mt) | Biomass Indices (kg per tow) | Exploitation Indices (landings/biomass index) |
|---|---|---|---|
| 1963 | | 0.24 | |
| 1964 | | 0.10 | |
| 1965 | | 0.17 | |
| 1966 | | 0.48 | |
| 1967 | | 0.52 | |
| 1968 | | 0.26 | |
| 1969 | | 0.64 | |
| 1970 | | 0.19 | |
| 1971 | | 0.16 | |
| 1972 | | 0.57 | |
| 1973 | | 1.53 | |
| 1974 | | 0.82 | |
| 1975 | 1,300 | 0.39 | 3.38 |
| 1976 | 1,516 | 1.17 | 1.30 |
| 1977 | 1,099 | 1.56 | 0.71 |
| 1978 | 923 | 1.15 | 0.80 |
| 1979 | 856 | 0.73 | 1.18 |
| 1980 | 408 | 0.63 | 0.65 |
| 1981 | 413 | 0.79 | 0.52 |
| 1982 | 411 | 0.49 | 0.83 |
| 1983 | 460 | 0.55 | 0.84 |
| 1984 | 743 | 2.14 | 0.35 |
| 1985 | 2,141 | 0.94 | 2.29 |
| 1986 | 1,842 | 1.11 | 1.67 |
| 1987 | 1,396 | 0.65 | 2.16 |
| 1988 | 1,377 | 0.65 | 2.12 |
| 1989 | 1,577 | 0.41 | 3.81 |
| 1990 | 1,078 | 1.13 | 0.96 |
| 1991 | 2,862 | 0.17 | 16.74 |
| 1992 | 1,519 | 0.38 | 4.01 |
| 1993 | 1,212 | 0.62 | 1.96 |
| 1994 | 300 | 0.31 | 0.97 |
| 1995 | 700 | 0.80 | 0.87 |
| 1996 | 700 | 0.50 | 1.40 |
| 1997 | 418 | 0.43 | 0.96 |
| 1998 | 396 | 1.66 | 0.24 |
| 1999 | 46 | 0.73 | 0.06 |
| 2000 | 142 | 0.73 | 0.20 |
| 2001 | 44 | 0.92 | 0.05 |

[1] Landings from 1995-2001were prorated based on Vessel Trip Reports.

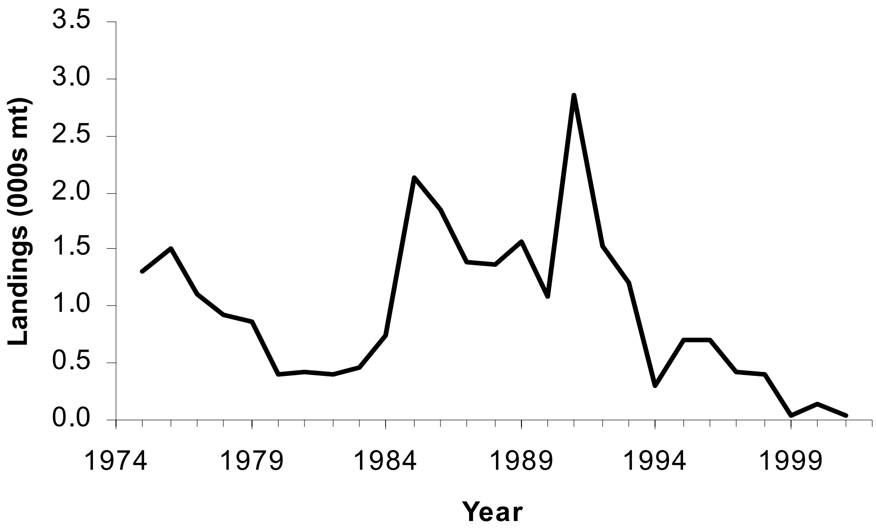


Figure O1. Commercial landings of Gulf of Maine-Georges Bank windowpane flounder during 1975-2001.

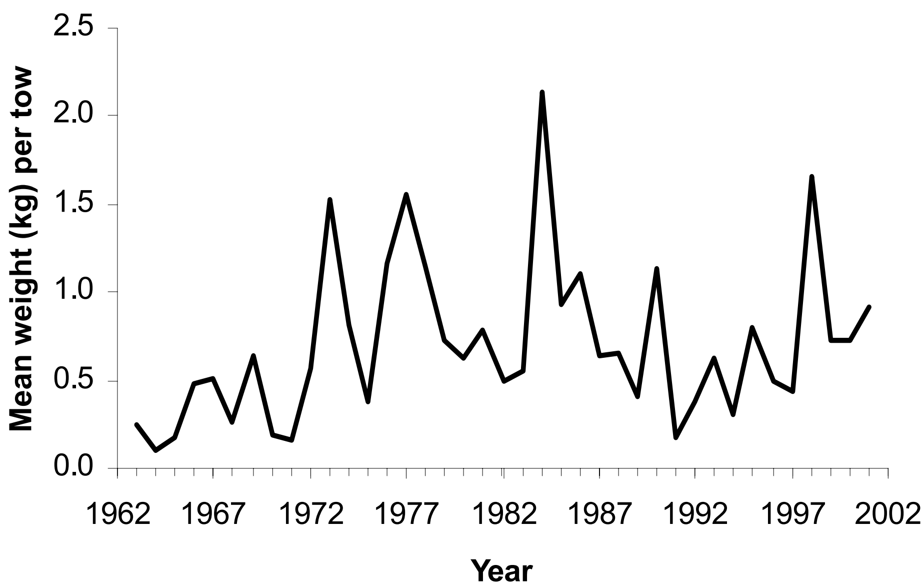


Figure O2. Relative biomass indices (stratified mean kg per tow) for Gulf of Maine-Georges Bank windowpane flounder from the NEFSC autumn bottom trawl surveys during 1963-2001.

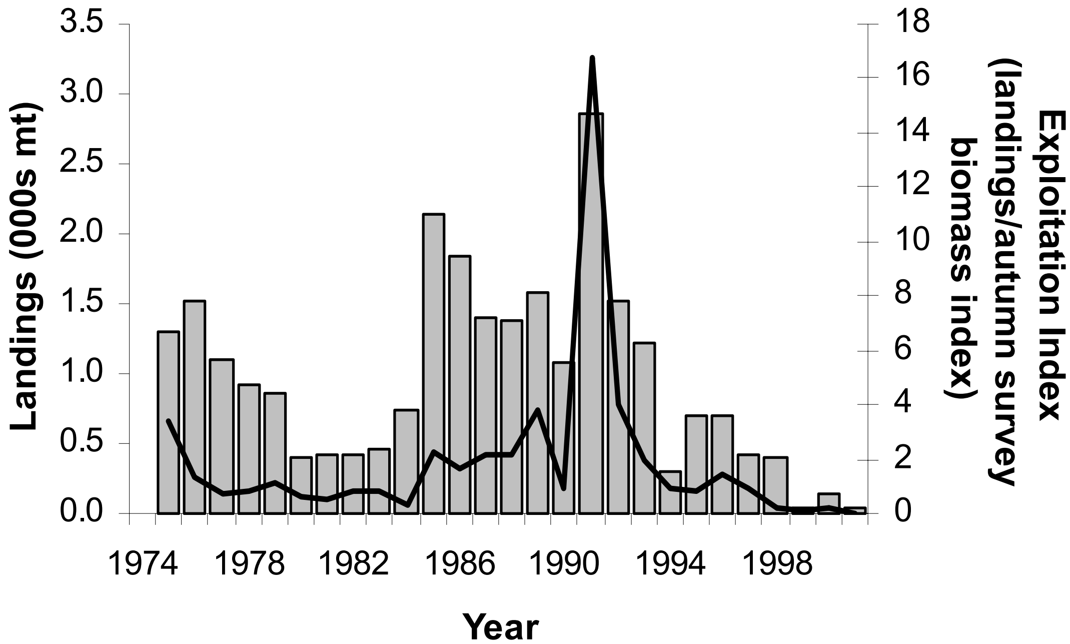


Figure O3. Relative exploitation indices (landings/autumn survey biomass indices) and landings (mt) of Gulf of Maine-Georges Bank windowpane flounder during 1975-2001.

**P. Windowpane Flounder (Southern New England-Mid-Atlantic Bight)**
by Lisa Hendrickson

## 1.0 Background

No stock structure information is available. Therefore, a provisional arrangement has been adopted that recognizes two stock areas based on apparent differences in growth, sexual maturity, and abundance trends between fish from Georges Bank and from Southern New England. The proportion of total landings contributed by the Mid-Atlantic area is low, so data from that area are combined with those from Southern New England.

The southern windowpane flounder stock, which includes the southern New England and Mid-Atlantic Bight regions (SNE-MAB), has never been formally assessed as part of the SAW/SARC process. The following index-based assessment is an update of the last report on stock status (NEFSC 2001) and a re-evaluation of the overfishing definition (NEFSC 2002).

## 2.0 Assessment Results

### 2.1 The Fishery

Windowpane landings were first recorded in 1975. During most years, the GOM-GB stock has comprised a higher proportion of the total landings than the SNE-MAB stock. However, SNE-MAB landings exceeded those from the Gulf of Maine-Georges Bank stock during 1980-1984, 1999 and 2001 (Table P1 and Figure P1). Landings declined rapidly during 1985-1995, from a peak of 2,100 mt to a record low of 100 mt, respectively. During 1996-2000, landings stabilized at the lowest levels observed in the time series, ranging between 100 mt and 200 mt. Landings in 2001 were 112 mt.

Discarding of windowpane has not been quantified, so discards were not included in the calculation of exploitation indices.

### 2.2 Research Survey Indices

Relative biomass indices, stratified mean weight (kg) per tow, of SNE-MAB windowpane flounder from the NEFSC autumn (1963-2001) bottom trawl surveys are presented in Table P1 and Figure P2. Biomass indices are highly variable, but indicate a declining trend during 1982-1993 followed by stable, but low biomass levels during 1994-2000 and a slight increase in 2001.

### 2.3 Biological Reference Points

Biological reference points for SNE-MAB windowpane flounder that were adopted in Amendment 9 were derived from survey-based proxies of biomass and exploitation and based on an ASPIC-based MSY estimate of 900 mt. The overfishing definition was subsequently revised based on a stock replacement ratio analysis, but target reference points were not revised (NEFSC 2002). The threshold F is defined as an $F_{MSY}$ proxy (= 0.98) when the NEFSC autumn survey index is greater than 0.92 kg/tow (equal to a $B_{MSY}$ proxy) and declines linearly to zero at 50% of the $B_{MSY}$ proxy (= 0.46 kg/tow).

2.4 Relative Exploitation Rates and Stock Status

Relative exploitation rates (landings/NEFSC autumn survey biomass index) declined sharply after reaching a peak in 1993 (Table P1 and Figure P3) and were below the $F_{MSY}$ proxy (= 0.98) during 1994-2001. The 1999-2001 autumn survey mean biomass index equals 0.21 kg/tow and the 1999-2001 mean exploitation index (landings/NEFSC autumn survey biomass index) equals 0.69. Based on the biological reference points, overfishing is not occurring, but the stock is overfished. However, exploitation rates are based only on landings, and if unaccounted discarding is substantial, then the 1999-2001 average exploitation rate is underestimated.

## 3.0 Sources of Uncertainty

3.1 Stock structure is uncertain.

3.2 Discarding is not quantified and may represent a sizable fraction of the multi-species and sea scallop catches.

3.3 Vessel trip reports have been used to prorate the landings, since 1995, and a fraction of the landings from Southern New England may have been reported as Georges Bank landings or visa versa.

## 4.0 Literature Cited

Northeast Fisheries Science Center. 2002. Final report of the working group on re-evaluation of biological reference points for New England groundfish. 231 p.

Northeast Fisheries Science Center. 2001. Assessment of 19 Northeast groundfish stocks through 2000; a report to the New England Fishery Management Council's Multi-species Monitoring Committee. Northern and Southern Demersal Working Groups, Northeast Stock Assessment Workshop. *Northeast Fish. Sci. Cent. Ref. Doc.* 01-20; 217 p.

Table P1. Landings (mt), NEFSC autumn survey biomass indices (stratified mean kg per tow, offshore strata 1-12 and 61-76), and exploitation indices (landings/autumn survey biomass index) for Southern New England-Mid-Atlantic Bight windowpane flounder during 1963-2001. Landings include Statistical Areas beginning with 6, 526, 530-539 and 541.

| Year | Landings[1] (mt) | Biomass Indices (kg per tow) | Exploitation Indices (landings/biomass index) |
|---|---|---|---|
| 1963 | | 1.99 | |
| 1964 | | 0.87 | |
| 1965 | | 0.78 | |
| 1966 | | 1.11 | |
| 1967 | | 0.81 | |
| 1968 | | 0.90 | |
| 1969 | | 0.37 | |
| 1970 | | 0.31 | |
| 1971 | | 0.40 | |
| 1972 | | 0.57 | |
| 1973 | | 0.58 | |
| 1974 | | 0.26 | |
| 1975 | 681 | 0.14 | 4.76 |
| 1976 | 568 | 0.36 | 1.58 |
| 1977 | 647 | 0.54 | 1.21 |
| 1978 | 898 | 0.54 | 1.67 |
| 1979 | 633 | 0.76 | 0.83 |
| 1980 | 532 | 0.26 | 2.08 |
| 1981 | 883 | 0.52 | 1.70 |
| 1982 | 651 | 0.87 | 0.75 |
| 1983 | 798 | 0.37 | 2.17 |
| 1984 | 1,088 | 0.25 | 4.40 |
| 1985 | 2,065 | 0.62 | 3.34 |
| 1986 | 1,381 | 0.56 | 2.45 |
| 1987 | 887 | 0.44 | 2.02 |
| 1988 | 1,172 | 0.42 | 2.76 |
| 1989 | 1,121 | 0.09 | 12.18 |
| 1990 | 890 | 0.18 | 4.92 |
| 1991 | 817 | 0.41 | 2.02 |
| 1992 | 584 | 0.18 | 3.24 |
| 1993 | 469 | 0.03 | 15.14 |
| 1994 | 200 | 0.23 | 0.89 |
| 1995 | 100 | 0.20 | 0.50 |
| 1996 | 200 | 0.26 | 0.76 |
| 1997 | 7,107 | 0.13 | 0.84 |
| 1998 | 123 | 0.18 | 0.68 |
| 1999 | 116 | 0.12 | 1.00 |
| 2000 | 126 | 0.17 | 0.75 |
| 2001 | 112 | 0.34 | 0.33 |

[1] Landings from 1995-2001were prorated based on Vessel Trip Reports.

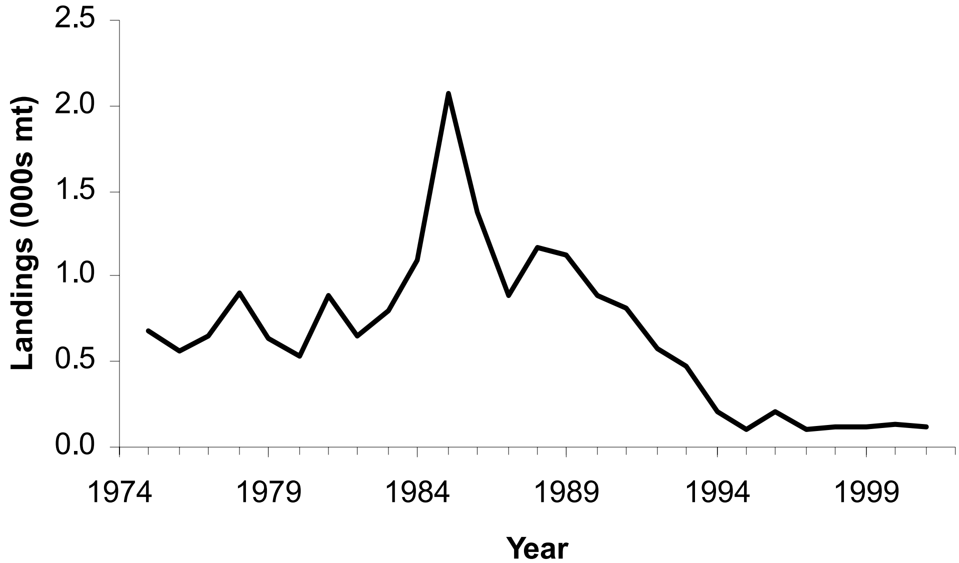


Figure P1. Landings of Southern New England-Mid-Atlantic Bight windowpane flounder during 1963-2001.

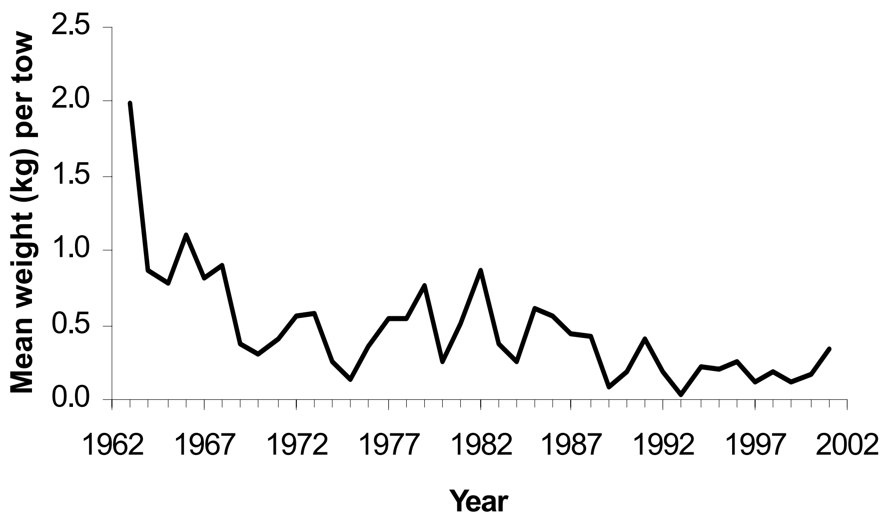


Figure P2. Relative biomass indices (stratified mean kg per tow) for Southern New England-Mid-Atlantic Bight windowpane flounder from the NEFSC autumn research vessel bottom trawl surveys (offshore strata 1-12 and 61-76) during 1963-2001.

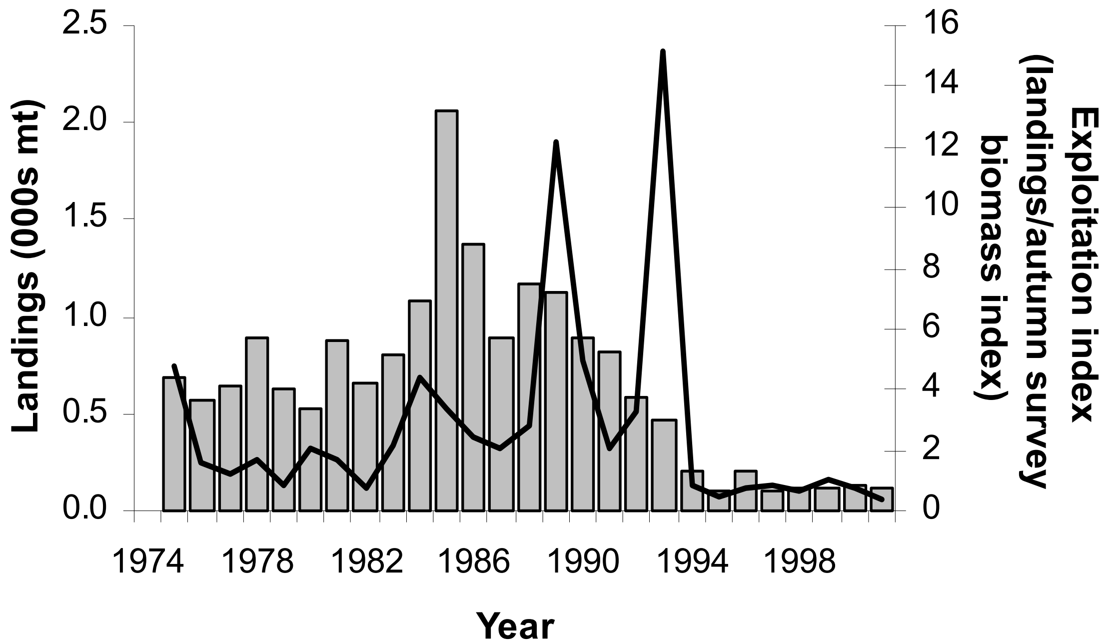


Figure P3. Relative exploitation indices (landings/autumn survey biomass indices) and landings (mt) of Southern New England-Mid-Atlantic Bight windowpane flounder during 1975-2001.

**Q. MID ATLANTIC YELLOWTAIL FLOUNDER** by Steve Cadrin

**1.0 Background**

The stock has been at relatively low abundance in recent years (Overholtz and Cadrin 1999, Cadrin 2001). This report updates catch through 2001 and survey indices through 2002. In August 2002, the Southern Demersal Working Group concluded that southern New England and Mid Atlantic yellowtail flounder should be assessed and managed as a single unit stock, and is concurrently preparing an assessment of the southern New England- Mid Atlantic yellowtail resource (SAW36 WP A6). In September 2002, the Working Group reviewed input data, analyses and projections in this report.

**2.0 2002 Assessment**

2.1 2000-2001 Landings
Recent landings (1994-1999) were prorated as described in the Georges Bank assessment (Cadrin et al. 1998; Table Q1; Figure Q1). Landings from Mid Atlantic yellowtail in 2001 (230 mt) was similar to landings in 2000.

2.3 1999-2002 Survey Indices
Survey abundance and biomass indices are reported in Table Q1. Estimates are from valid tows in the Mid-Atlantic area (offshore strata 1, 2, 69, 70, 73, 74), standardized according to net, vessel, and door changes (Cadrin et al. 1998). All survey indices of total biomass remained low (Figure Q2).

**3.0 Assessment Results**

The average fall biomass index for the last three years (1999-2001 average=0.21 kg/tow) is 2% of the $B_{MSY}$ proxy (12.91 kg/tow) and well below the biomass threshold ($B_{MSY}/2$=6.46 kg/tow). The average exploitation index (landings/fall survey biomass index) for the last three years (2.17) is almost seven times greater than the $F_{MSY}$ proxy (0.33).

Sensitivity to recent NEFSC survey observations was evaluated by increasing recent NEFSC survey observations by 10%, 25%, and 100% (Figure Q3). Results are summarized in Section 5.2 (Summary of Assessment Advice).

**4.0 Sources of Uncertainty**

- Estimates of prorated landings and discard ratios are based on preliminary logbook data and are subject to change.
- The Mid Atlantic yellowtail resource may not be self-sustaining and may be an extension of the southern New England stock.

## 5.0 GARM Discussion

The GARM agreed that the stock appears to be more overfished than the Southern New England stock. Results from combining the two stocks gives the same impression as the two parts separately.

The GARM recommends that ichthyoplankton surveys be processed. This data could be used in meta-population analysis with movement of recruits among stocks.

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Table Q1. Survey indices, landings and exploitation indices of Mid-Atlantic yellowtail flounder.

| | NEFSC fall | | NEFSC spring | | NEFSC winter | | Landings | Exploitation |
|---|---|---|---|---|---|---|---|---|
| | #/tow | kg/tow | #/tow | kg/tow | #/tow | kg/tow | (k mt) | Index |
| 1963* | 35.17 | 11.45 | | | | | | |
| 1964* | 20.01 | 6.22 | | | | | 1.80 | 0.29 |
| 1965* | 59.84 | 7.45 | | | | | 2.10 | 0.28 |
| 1966* | 58.89 | 11.33 | | | | | 2.40 | 0.21 |
| 1967 | 67.81 | 11.93 | | | | | 5.30 | 0.44 |
| 1968 | 99.21 | 17.26 | 106.06 | 21.78 | | | 3.30 | 0.19 |
| 1969 | 55.33 | 12.61 | 83.69 | 17.67 | | | 4.60 | 0.36 |
| 1970 | 55.16 | 13.20 | 58.05 | 14.41 | | | 4.20 | 0.32 |
| 1971 | 32.91 | 4.84 | 44.54 | 10.10 | | | 7.90 | 1.63 |
| 1972 | 105.21 | 26.82 | 46.71 | 12.69 | | | 8.90 | 0.33 |
| 1973 | 10.05 | 2.40 | 39.16 | 11.76 | | | 5.10 | 2.13 |
| 1974 | 0.80 | 0.24 | 16.33 | 5.62 | | | 1.90 | 7.85 |
| 1975 | 1.06 | 0.21 | 2.20 | 0.90 | | | 0.70 | 3.41 |
| 1976 | 0.46 | 0.08 | 5.22 | 1.22 | | | 0.30 | 3.80 |
| 1977 | 1.75 | 0.23 | 8.91 | 2.26 | | | 0.60 | 2.58 |
| 1978 | 1.45 | 0.29 | 12.12 | 2.59 | | | 0.40 | 1.39 |
| 1979 | 1.27 | 0.26 | 2.94 | 0.77 | | | 0.50 | 1.95 |
| 1980 | 0.97 | 0.19 | 14.53 | 4.60 | | | 0.30 | 1.55 |
| 1981 | 22.81 | 3.04 | 34.13 | 8.16 | | | 0.70 | 0.23 |
| 1982 | 12.47 | 2.18 | 29.23 | 6.71 | | | 0.43 | 0.20 |
| 1983 | 2.31 | 0.47 | 16.56 | 4.27 | | | 0.59 | 1.26 |
| 1984 | 2.05 | 0.23 | 4.13 | 1.22 | | | 1.04 | 4.48 |
| 1985 | 1.71 | 0.19 | 5.06 | 1.37 | | | 0.15 | 0.79 |
| 1986 | 0.97 | 0.21 | 2.51 | 0.56 | | | 0.25 | 1.18 |
| 1987 | 0.15 | 0.01 | 0.65 | 0.23 | | | 0.17 | 11.52 |
| 1988 | 3.93 | 0.23 | 0.93 | 0.33 | | | 0.09 | 0.42 |
| 1989 | 7.16 | 1.16 | 10.18 | 1.65 | | | 0.40 | 0.34 |
| 1990 | 4.23 | 0.81 | 9.94 | 2.62 | | | 0.24 | 0.29 |
| 1991 | 0.37 | 0.13 | 6.90 | 2.08 | | | 0.21 | 1.67 |
| 1992 | 0.00 | 0.00 | 2.29 | 0.83 | 12.86 | 4.96 | 0.24 | --- |
| 1993 | 0.58 | 0.09 | 0.45 | 0.19 | 4.19 | 1.87 | 0.17 | 1.90 |
| 1994 | 2.26 | 0.23 | 0.09 | 0.06 | 3.45 | 1.42 | 0.24 | 1.02 |
| 1995 | 0.08 | 0.03 | 1.30 | 0.28 | 13.50 | 2.73 | 0.02 | 0.71 |
| 1996 | 0.25 | 0.06 | 1.40 | 0.46 | 5.84 | 1.74 | 0.15 | 2.77 |
| 1997 | 0.83 | 0.21 | 1.14 | 0.43 | 12.26 | 4.52 | 0.54 | 2.59 |
| 1998 | 0.30 | 0.09 | 2.71 | 0.68 | 14.06 | 3.61 | 0.22 | 2.50 |
| 1999 | 2.03 | 0.50 | 1.39 | 0.59 | 1.75 | 3.74 | 0.47 | 0.95 |
| 2000 | 0.37 | 0.11 | 1.42 | 0.57 | 7.76 | 2.53 | 0.22 | 1.94 |
| 2001 | 0.07 | 0.02 | 0.26 | 0.16 | 4.72 | 2.08 | 0.23 | 14.64 |
| Mean | 17.24 | 3.51 | 16.86 | 4.11 | 8.04 | 2.92 | 1.50 | 2.17 |
| 3y mean | | 0.21 | | 0.44 | | 2.78 | | 5.84 |

* not all strata sampled.

Figure Q1. Landings and exploitation index of Mid Atlantic yellowtail flounder.

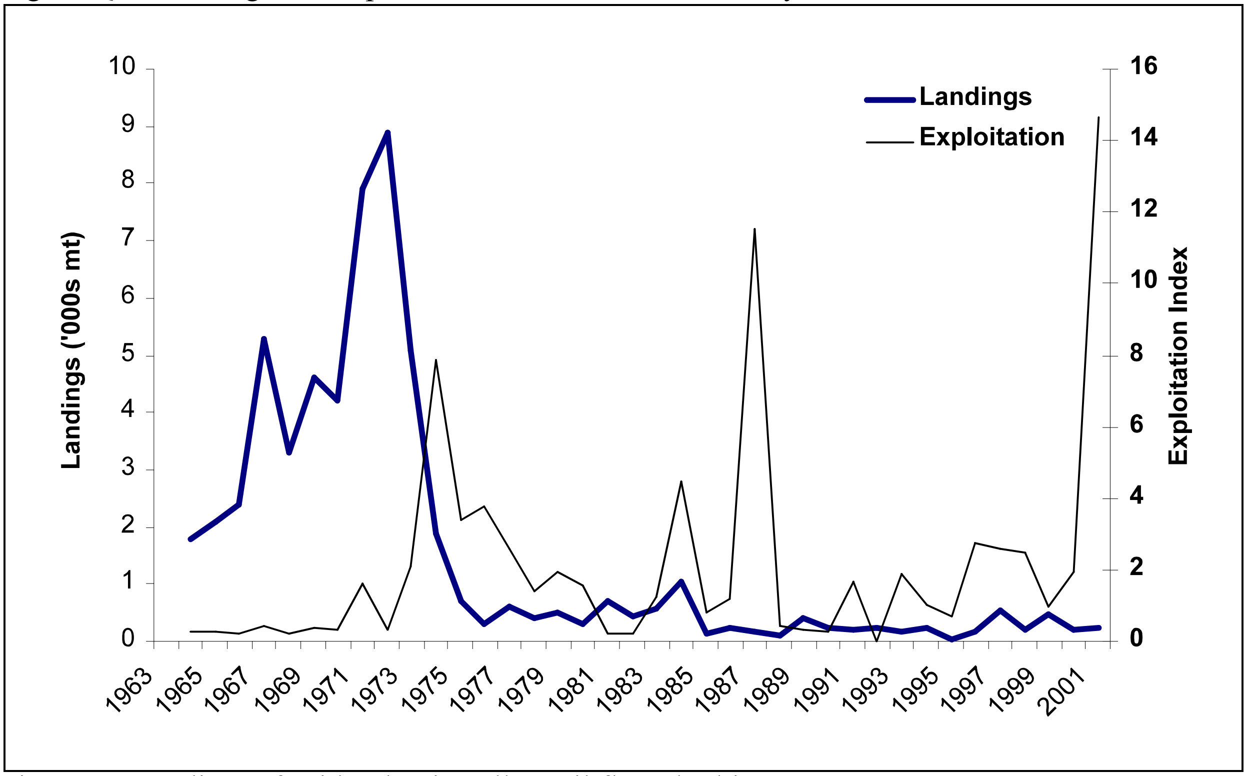



Figure Q2. Indices of Mid Atlantic yellowtail flounder biomass.

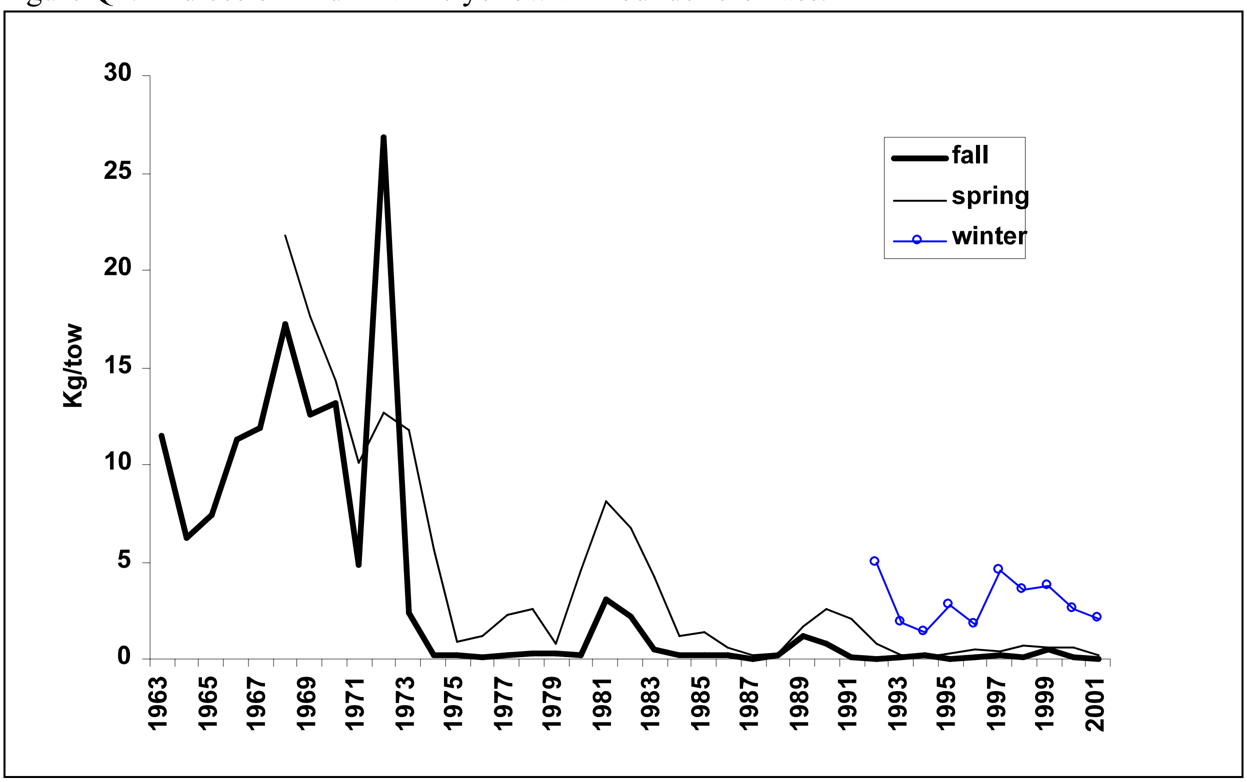
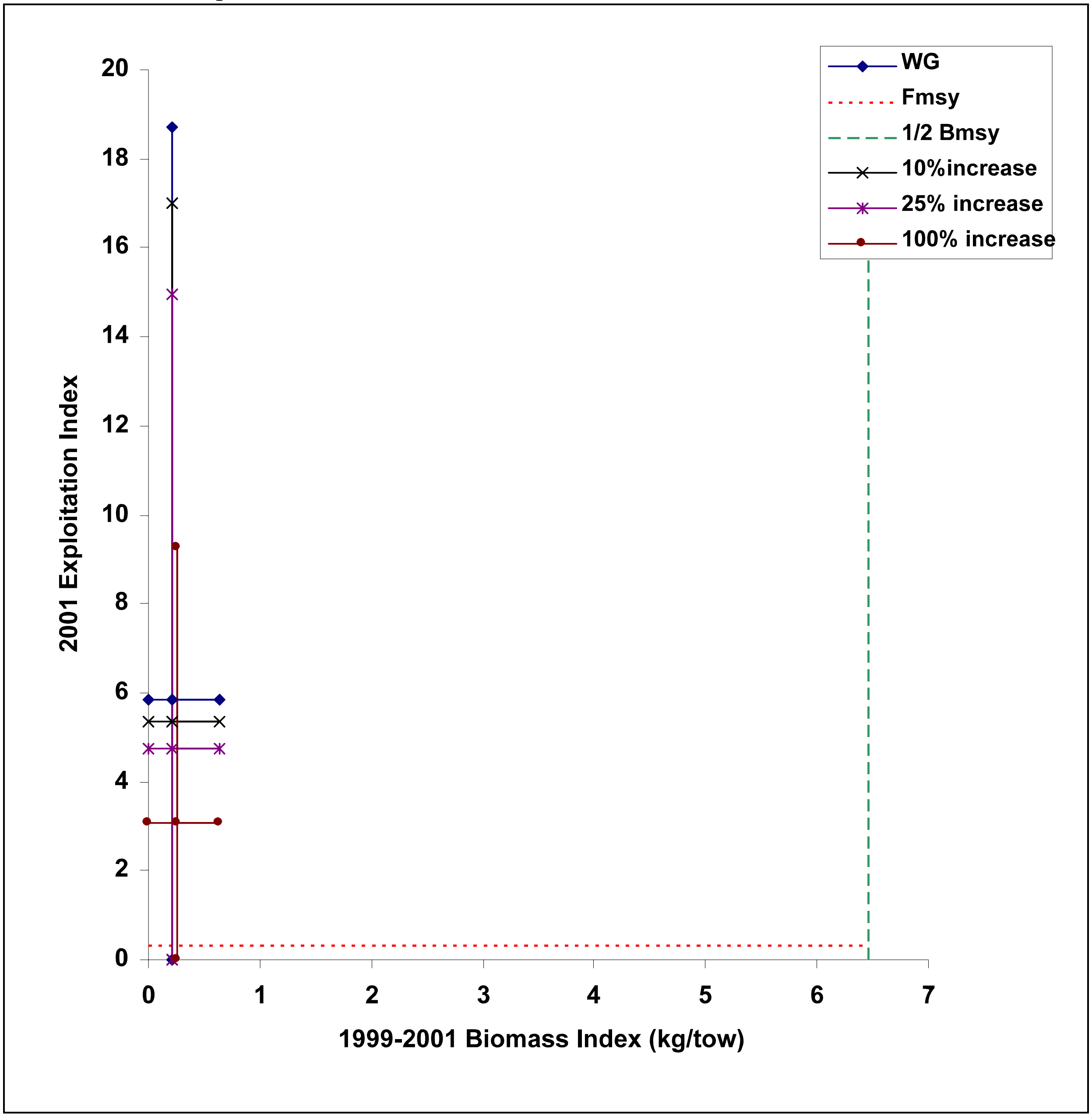


Figure Q3. Sensitivity of results to increasing NEFSC indices since 2000 by 10%, 25% and 100% (with 80% confidence intervals). Results accepted by the working group ("WG") are shown for comparison.



**R. Gulf of Maine Haddock** by Jon Brodziak and Michele Thompson

## 1.0 Background

The Gulf of Maine haddock stock was last assessed in 2001 by the Northern Demersal Working Group (NEFSC 2001). Research survey indices indicated that stock biomass was increasing. In this report, we update the Gulf of Maine haddock assessment using fishery data for 2001 and available survey data for 2001-2002. Updated survey biomass and exploitation rate indices are used for stock status determination.

## 2.0 Assessment for 2002

### 2.1 2001 Landings

US haddock landings were prorated into Georges Bank and Gulf of Maine stock components using a standard algorithm. US Gulf of Maine haddock commercial fishery landings totaled 1,190 mt in 2001, a 72% increase over 2000 (Table R1, Figure R1) and over 2.5 times the 1992-2000 average (451 mt). Despite the substantial increase, commercial landings in 2001 were still less than half of average landings during 1982-1991 (2,564 mt).

Provisional US recreational landings of Gulf of Maine haddock were extracted from MRFSS databases in 2001 (Scott Steinback, NEFSC, personal communication). Recreational landings totaled 203 mt in 2001, a 7% increase over 2000 landings and over three times average recreational landings since 1992 (Figure R1).

### 2.2 Survey Indices

US spring survey indices were computed for 2001-2002 (Table B2, Figure B2) and US autumn survey indices were computed for 2001 (Table B2, Figure B2) using standardized data.

## 3.0 Assessment Results

### 3.1 Index-Based Results

An updated index-based assessment was conducted. The 3-year average of the NEFSC autumn survey biomass constituted the stock biomass index, except for 1963-1964 where one- and two-year averages were used (Table R3). Commercial fishery landings were used as the catch (Table R3). Observed exploitation rate indices were computed as the catch divided by the observed survey biomass index in each year. Smoothed exploitation rate indices used for stock status determination were computed as the catch divided by the 3-year average stock biomass index (Table R3, Figure R3). The smoothed exploitation rate index in 2001 was 0.115, an increase of roughly 20% over the 2000 index (0.095) and one-half of the $F_{MSY}$ proxy (0.23).

### 3.2 Sensitivity to Potential Trawl Warp Inconsistencies during 2000-2002

Measurements of NEFSC survey trawl warps in autumn 2002 suggested that right and left warps may have been offset by up to several feet during winter 2000 through spring 2002 surveys. To evaluate the sensitivity of index-based results to potential undercapture of fish, NEFSC autumn survey indices were arbitrarily adjusted upwards by 10%, 25%, and 100% for autumn 2000 and 2001. Results are summarized in Section 5.2 (Summary of Assessment Advice).

## 4.0 Sources of Uncertainty

- Recruitment dynamics of the Gulf of Maine and Georges Bank haddock stocks may be linked. The amount of interchange between stocks is a source of uncertainty.

## 5.0 Summary Stock Status

Biological Reference Points
For Gulf of Maine haddock, the stock biomass index ($B_{MSY}$) and the proxy exploitation rate index ($F_{MSY}$) to produce MSY are $B_{MSY}$ = 22.17 kg/tow and $F_{MSY}$ = 0.23 (NEFSC 2002). The overfished threshold ($B_{THRESHOLD}$) for Gulf of Maine haddock is $B_{THRESHOLD}$ = ½ $B_{MSY}$ = 11.08 kg/tow. The overfishing threshold ($F_{THRESHOLD}$) for Gulf of Maine haddock is $F_{THRESHOLD}$ = $F_{MSY}$ = 0.23.

Stock Status in 2001
In 2001, the stock biomass index was 10.31 kg/tow (93% of $B_{THRESHOLD}$ and 47% of $B_{MSY}$) with a standard error of 4.08 kg/tow. Based on the point estimate of the biomass index, the Gulf of Maine haddock stock was overfished in 2001. In 2001, the exploitation rate index was 0.115 (50% of $F_{THRESHOLD}$). Therefore, overfishing was not occurring on the Gulf of Maine haddock stock in 2001.

Projections
Projected catches to rebuild the Gulf of Maine stock were evaluated in spring 2002 (NEFSC 2002, Table 4.1.2). Projected catches for 2002-2009 were updated assuming a 10% annual increase in biomass from 2001 onwards with a constant exploitation rate index. Projected catches (rounded to the nearest 100 mt) were: 1,500 mt in 2002 and 2003; 1,700 mt in 2004; 1,800 mt in 2005; 2,000 mt in 2006; 2,200 mt in 2007; 2,500 mt in 2008; and 2,700 mt in 2009.

## 6.0 References

Northeast Fisheries Science Center. 2001. Assessment of 19 Northeast groundfish stocks through 2000. NEFSC Reference Document 01-20, Woods Hole, MA, 02543.

Northeast Fisheries Science Center. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. NEFSC Reference Document 02-04, Woods Hole, MA, 02543.

Table R1. Commercial landings (mt, live weight) of haddock from the Gulf of Maine (NAFO Division 5Y; U.S. statistical areas 511-515) from 1956-2001.

| Year | United States | Canada | USSR | Other | Total |
|---|---|---|---|---|---|
| 1956 | 7278 | 29 | -- | -- | 7307 |
| 1957 | 6141 | 25 | -- | -- | 6166 |
| 1958 | 7082 | 285 | -- | -- | 7367 |
| 1959 | 4497 | 163 | -- | -- | 4660 |
| 1960 | 4541 | 383 | -- | -- | 4924 |
| 1961 | 5297 | 112 | -- | -- | 5409 |
| 1962 | 5003 | 107 | -- | -- | 5110 |
| 1963 | 4742 | 3 | 44 | -- | 4789 |
| 1964 | 5383 | 70 | -- | -- | 5453 |
| 1965 | 4204 | 159 | -- | -- | 4363 |
| 1966 | 4579 | 1125 | -- | -- | 5704 |
| 1967 | 4907 | 589 | -- | – | 5496 |
| 1968 | 3437 | 120 | -- | -- | 3557 |
| 1969 | 2423 | 59 | -- | 231 | 2713 |
| 1970 | 1457 | 38 | -- | 67 | 1562 |
| 1971 | 1194 | 85 | -- | 27 | 1306 |
| 1972 | 909 | 23 | 4 | -- | 936 |
| 1973 | 509 | 49 | -- | -- | 558 |
| 1974 | 622 | 198 | -- | 9 | 829 |
| 1975 | 1180 | 79 | -- | 4 | 1263 |
| 1976 | 1865 | 91 | -- | -- | 1956 |
| 1977 | 3296 | 26 | -- | -- | 3322 |
| 1978 | 4538 | 641 | -- | -- | 5179 |
| 1979 | 4622 | 257 | -- | -- | 4879 |
| 1980 | 7270 | 203 | -- | -- | 7473 |
| 1981 | 5726 | 513 | -- | -- | 6239 |
| 1982 | 5645 | 1278 | -- | -- | 6923 |
| 1983 | 5594 | 2003 | -- | -- | 7597 |
| 1984 | 2793 | 1245 | -- | -- | 4038 |
| 1985 | 2234 | 781 | -- | -- | 3015 |
| 1986 | 1443 | 225 | -- | -- | 1668 |
| 1987 | 829 | -- | -- | -- | 829 |
| 1988 | 436 | -- | -- | -- | 436 |
| 1989 | 264 | -- | -- | -- | 264 |
| 1990 | 433 | -- | -- | -- | 433 |
| 1991 | 431 | -- | -- | -- | 431 |
| 1992 | 312 | -- | -- | -- | 312 |
| 1993 | 193 | -- | -- | -- | 193 |
| 1994 [1] | 112 | -- | -- | -- | 112 |
| 1995 [1] | 192 | -- | -- | -- | 192 |
| 1996 [1] | 257 | -- | -- | -- | 257 |
| 1997 [1] | 616 | -- | -- | -- | 616 |
| 1998 [1] | 1018 | -- | -- | -- | 1018 |
| 1999 [1] | 668 | -- | -- | -- | 668 |
| 2000 [1] | 691 | – | – | – | 691 |
| 2001 [1] | 1190 | – | – | – | 1190 |

[1] U.S. landings from 1994-2001 are provisional.

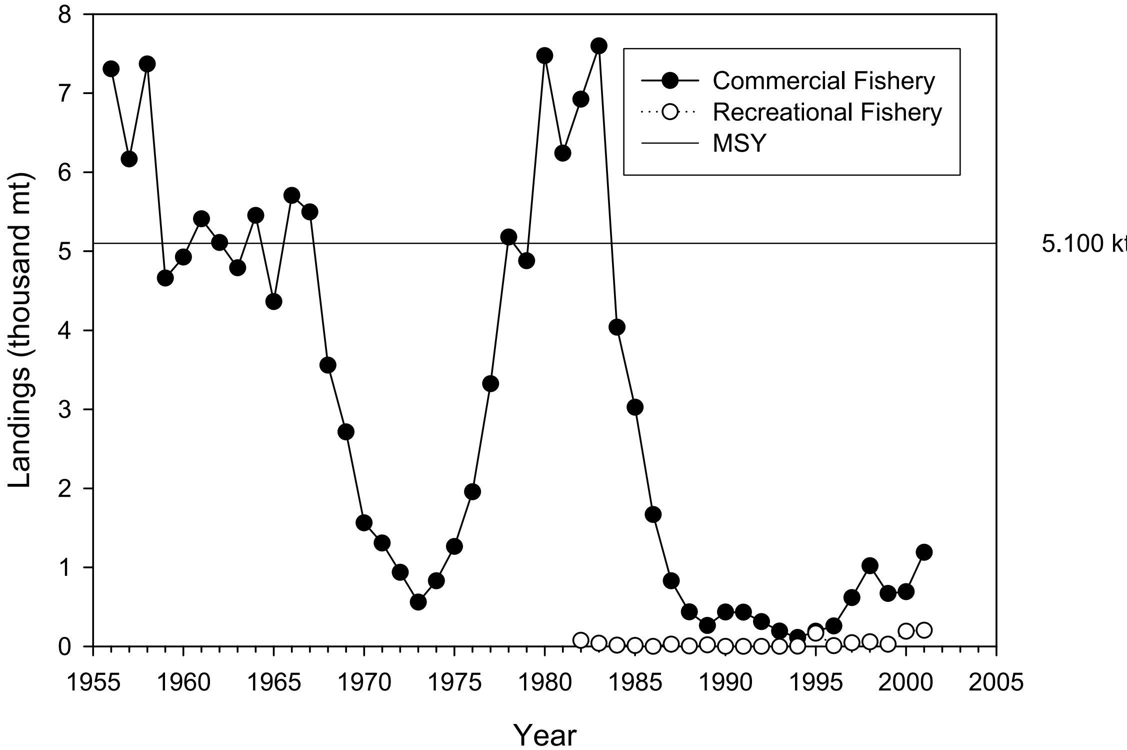
Table R2. Stratified mean catch number and weight (kg) per tow for haddock in NEFSC offshore spring and autumn research vessel bottom trawl surveys in the Gulf of Maine (Strata 01260-01280, 01360-01400), 1963-2002.

| Year | Spring Number per Tow | Spring Weight per Tow | | Autumn Number per Tow | Autumn Weight per Tow |
|---|---|---|---|---|---|
| 1963 | | | | 69.549 | 50.697 |
| 1964 | | | | 14.176 | 18.829 |
| 1965 | | | | 17.434 | 17.644 |
| 1966 | | | | 11.652 | 13.859 |
| 1967 | | | | 12.186 | 16.853 |
| 1968 | 6.008 | 7.887 | | 7.648 | 15.484 |
| 1969 | 3.783 | 7.376 | | 5.451 | 12.854 |
| 1970 | 0.906 | 1.725 | | 2.918 | 7.354 |
| 1971 | 0.878 | 2.523 | | 2.879 | 8.137 |
| 1972 | 0.862 | 0.867 | | 1.984 | 3.036 |
| 1973 | 1.204 | 1.578 | | 4.165 | 8.583 |
| 1974 | 1.437 | 1.059 | | 2.687 | 3.347 |
| 1975 | 2.770 | 3.482 | | 5.533 | 8.616 |
| 1976 | 8.326 | 6.350 | | 6.035 | 8.040 |
| 1977 | 6.799 | 6.725 | | 8.296 | 8.752 |
| 1978 | 1.356 | 1.434 | | 9.163 | 20.932 |
| 1979 | 3.330 | 4.633 | | 5.528 | 13.723 |
| 1980 | 2.697 | 3.383 | | 7.152 | 9.835 |
| 1981 | 4.405 | 4.488 | | 3.869 | 9.344 |
| 1982 | 2.047 | 2.555 | | 2.627 | 4.164 |
| 1983 | 3.678 | 3.567 | | 2.598 | 5.219 |
| 1984 | 1.095 | 1.144 | | 1.696 | 3.893 |
| 1985 | 1.773 | 1.882 | | 4.079 | 6.149 |
| 1986 | 0.707 | 1.284 | | 0.623 | 1.392 |
| 1987 | 0.092 | 0.062 | | 1.035 | 2.645 |
| 1988 | 0.187 | 0.301 | | 0.335 | 1.476 |
| 1989 | 0.083 | 0.124 | | 0.283 | 0.631 |
| 1990 | 0.024 | 0.000 | | 0.145 | 0.432 |
| 1991 | 0.074 | 0.066 | | 0.142 | 0.120 |
| 1992 | 0.193 | 0.271 | | 0.211 | 0.091 |
| 1993 | 0.450 | 0.200 | | 0.866 | 0.472 |
| 1994 | 0.402 | 0.253 | | 0.325 | 0.217 |
| 1995 | 0.806 | 0.350 | | 0.977 | 1.099 |
| 1996 | 0.305 | 0.338 | | 2.407 | 3.543 |
| 1997 | 1.935 | 1.222 | | 2.688 | 2.424 |
| 1998 | 0.197 | 0.112 | | 3.130 | 2.917 |
| 1999 | 4.267 | 1.108 | | 6.730 | 4.910 |
| 2000 | 3.610 | 1.815 | | 16.589 | 14.032 |
| 2001 | 2.364 | 3.215 | | 9.960 | 11.983 |
| 2002 | 5.704 | 2.794 | | | |

Table R3. Exploitation rate index for Gulf of Maine haddock based on autumn NEFSC survey biomass index and (3-year average, except for 1963-1964) and annual commercial landings, 1963-2001.

| Year | Landings | Survey Index | 3-Year Average Survey Index | Annual Exploitation Rate Index Based on 3-Year Survey Index |
|---|---|---|---|---|
| 1963 | 4.789 | 50.697 | 50.697 | 0.094 |
| 1964 | 5.453 | 18.829 | 34.763 | 0.157 |
| 1965 | 4.363 | 17.644 | 29.057 | 0.150 |
| 1966 | 5.704 | 13.859 | 16.777 | 0.340 |
| 1967 | 5.496 | 16.853 | 16.119 | 0.341 |
| 1968 | 3.557 | 15.484 | 15.399 | 0.231 |
| 1969 | 2.713 | 12.854 | 15.064 | 0.180 |
| 1970 | 1.562 | 7.354 | 11.897 | 0.131 |
| 1971 | 1.306 | 8.137 | 9.448 | 0.138 |
| 1972 | 0.936 | 3.036 | 6.176 | 0.152 |
| 1973 | 0.558 | 8.583 | 6.585 | 0.085 |
| 1974 | 0.829 | 3.347 | 4.989 | 0.166 |
| 1975 | 1.263 | 8.616 | 6.849 | 0.184 |
| 1976 | 1.956 | 8.04 | 6.668 | 0.293 |
| 1977 | 3.322 | 8.752 | 8.469 | 0.392 |
| 1978 | 5.179 | 20.932 | 12.575 | 0.412 |
| 1979 | 4.879 | 13.723 | 14.469 | 0.337 |
| 1980 | 7.473 | 9.835 | 14.830 | 0.504 |
| 1981 | 6.239 | 9.344 | 10.967 | 0.569 |
| 1982 | 6.923 | 4.164 | 7.781 | 0.890 |
| 1983 | 7.597 | 5.219 | 6.242 | 1.217 |
| 1984 | 4.038 | 3.893 | 4.425 | 0.912 |
| 1985 | 3.025 | 6.149 | 5.087 | 0.595 |
| 1986 | 1.668 | 1.392 | 3.811 | 0.438 |
| 1987 | 0.829 | 2.645 | 3.395 | 0.244 |
| 1988 | 0.436 | 1.476 | 1.838 | 0.237 |
| 1989 | 0.264 | 0.631 | 1.584 | 0.167 |
| 1990 | 0.433 | 0.432 | 0.846 | 0.512 |
| 1991 | 0.431 | 0.12 | 0.394 | 1.093 |
| 1992 | 0.312 | 0.091 | 0.214 | 1.456 |
| 1993 | 0.193 | 0.472 | 0.228 | 0.848 |
| 1994 | 0.112 | 0.217 | 0.260 | 0.431 |
| 1995 | 0.192 | 1.099 | 0.596 | 0.322 |
| 1996 | 0.257 | 3.543 | 1.620 | 0.159 |
| 1997 | 0.616 | 2.424 | 2.355 | 0.262 |
| 1998 | 1.018 | 2.917 | 2.961 | 0.344 |
| 1999 | 0.668 | 4.910 | 3.417 | 0.195 |
| 2000 | 0.691 | 14.032 | 7.286 | 0.095 |
| 2001 | 1.190 | 11.983 | 10.308 | 0.115 |
| | | | | |
| Average 1963-2001 | 2.525 | 8.301 | 9.140 | 0.395 |

Figure R1. Gulf of Maine haddock commercial landings during 1956-2001 and provisional recreational landings during 1982-2001.



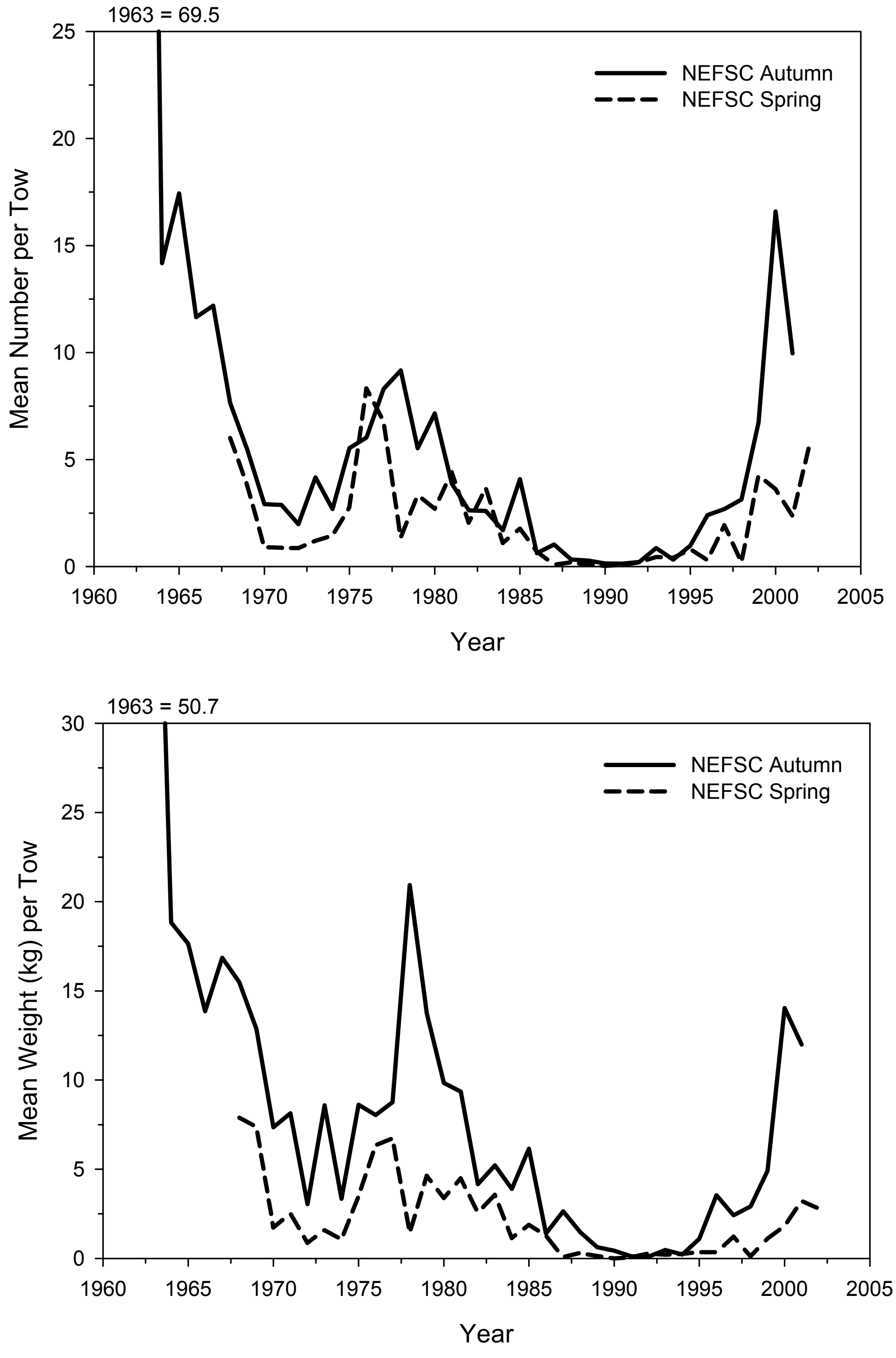
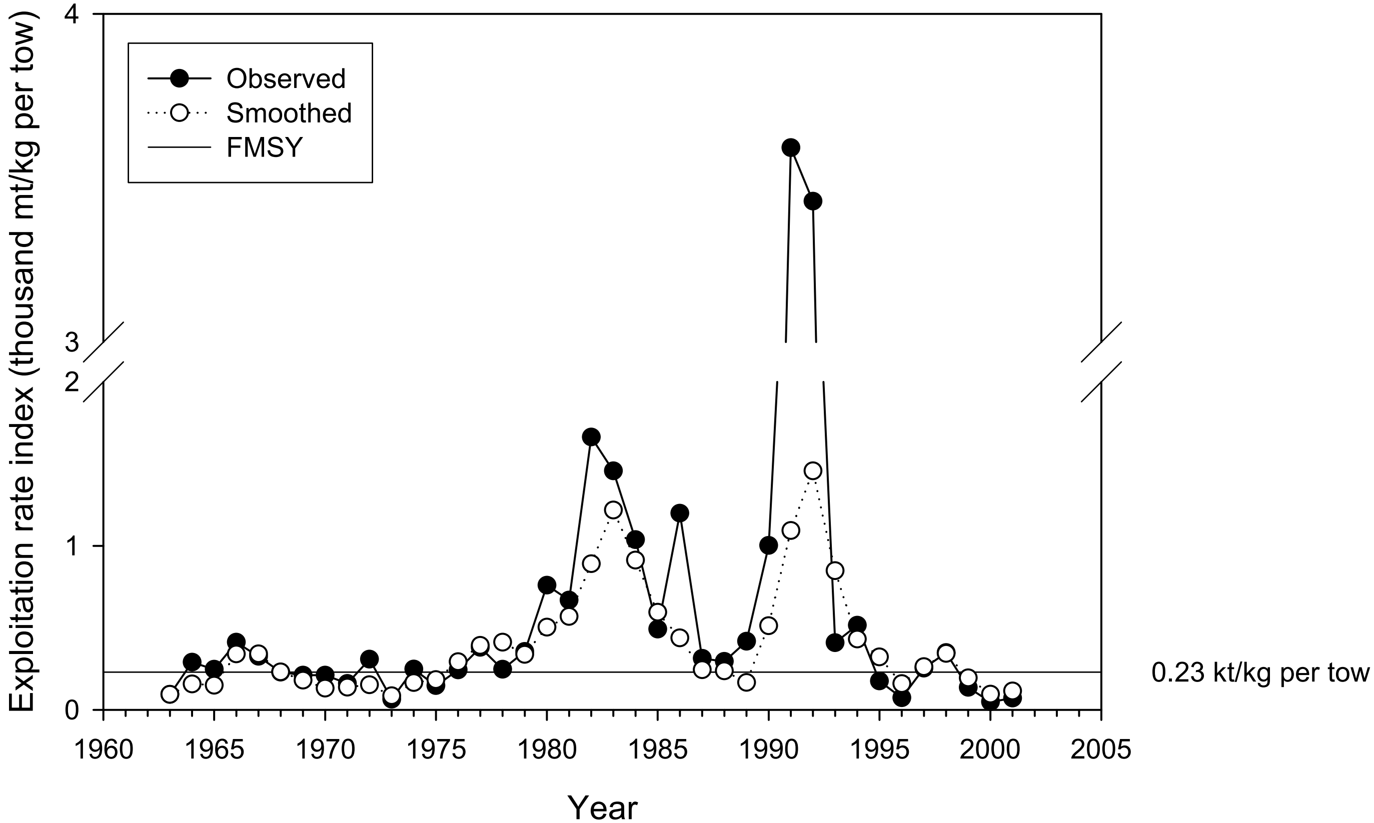



Figure R2. Northeast Fisheries Science Center research standardized and stratified survey abundance (mean number per tow; top panel) and biomass (kg per tow; bottom panel) indices for Gulf of Maine haddock from 1963-2002. U.S. survey includes strata 01260-01280 and 01360-01400.

Figure R3. Observed and smoothed exploitation rate indices for Gulf of Maine haddock, 1963-2001.



**S. Atlantic Halibut** by Jon Brodziak

## 1.0 Background

The Atlantic halibut (*Hippoglossus hippoglossus*) is distributed from Labrador to southern New England in the northwest Atlantic (Bigelow and Schroeder 1953). The Atlantic halibut stock within Gulf of Maine-Georges Bank waters (NAFO Subarea 5) has been exploited since the 1830s. The Gulf of Maine-Georges Bank Atlantic halibut stock was last assessed in 2001 by the Northern Demersal Working Group (NEFSC 2001). The stock was overfished based on research survey indices and is not expected to rebuild in the near future. In this report, we update the Atlantic halibut assessment using fishery data for 2001 and available survey data for 2001-2002. Updated survey biomass indices are used for stock status determination.

## 2.0 Assessment for 2002

### 2.1 2001 Landings

Records of Atlantic halibut landings from the Gulf of Maine and Georges Bank begin in 1893 (Table S1, Figure S1). Substantial landings occurred prior to this, however, as the halibut fishery declined in the late 1800s (Hennemuth and Rockwell 1987). Landings have decreased since the 1890s as components of the resource have been sequentially depleted. Annual landings averaged 662 mt during 1893-1940 and declined to an average of 144 mt during 1941-1976. During 1977-2000, landings have averaged 89 $mt \cdot yr^{-1}$. Reported landings in 2001 were 22 mt. Of these, 11 mt (50%) were landed by domestic fishermen with the remainder landed by Canadian fishermen (Division 5Zc).

### 2.2 Survey Indices

The Northeast Fisheries Science Center spring and autumn bottom trawl surveys provide measures of the relative abundance of Atlantic halibut within the Gulf of Maine and Georges Bank region (offshore survey strata 13-30 and 36-40, Table S2). Both indices have high inter-annual variability since relatively few halibut are captured during these surveys; in some years, no halibut are caught. The survey indices suggest that relative abundance increased during the 1970s to early 1980s and subsequently declined in the 1990s. It is unknown whether abundance trends in the Gulf of Maine and Georges Bank region have been influenced by changes in the seasonal distribution and availability of Atlantic halibut, however. US spring survey indices were computed for 2001-2002 (Table S2, Figure S2) and US autumn survey indices were computed for 2001 (Table S2, Figure S2) using standardized data.

## 3.0 Assessment Results

Based on updated spring and autumn survey data, Atlantic halibut biomass within the Gulf of Maine and Georges Bank region remains low. Swept-area biomass indices in spring 2001 and 2002 were 544 and 425 mt with a 5-year average of 312 mt in 2001 (Figure S3). Autumn swept-area biomass in 2000 was 123 mt with a 5-year average of 232 mt in 2001 (Figure S3). Thus, stock biomass, as indexed by the 5-year moving average of autumn swept-area biomass, was below the biomass threshold of 2,700 mt (Figure S3). Although no estimates of fishing mortality are available, exploitation rate indices (annual landings/5-year moving average of survey index) suggest that exploitation rates have probably been stable since the 1970s, and may have declined during the 1990s (Figure 4). Thus, the Atlantic halibut stock in the Gulf of Maine and Georges Bank region remains depleted and exploitation rates do not appear to have increased since the 1970s.

## 4.0 Sources of Uncertainty

- Fishery-dependent information on the size and age composition of Atlantic halibut landings is limited, although an experimental fishery in the Gulf of Maine during 2000-2002 has provided some valuable fishery-dependent data (Sigourney 2002).

- Stock structure of Atlantic halibut within the Gulf of Maine and Georges Bank region is uncertain. Wise and Jensen (1959) documented movements of tagged Atlantic halibut between Georges Bank and Browns Bank, but it is difficult to draw any definite conclusions about movement rates from their study. Recently, one halibut released near Stonington, Maine in April 2000 during the Gulf of Maine experimental fishery was recaptured off Port au Basque, Newfoundland in May 2002 after growing from 32 to 40 inches in total length (Kohl Kanwit, Maine DMF, personal communication). To date, preliminary data indicate three recaptures of fish tagged in the experimental fishery during 2000-2002 within Canadian waters.

- The portion of the Atlantic halibut population within Gulf of Maine and Georges Bank region is a transboundary stock. Conservation measures for both USA and Canadian fisheries may be needed to rebuild this stock.

## 5.0 Summary Stock Status

Biological Reference Points
For Gulf of Maine-Georges Bank Atlantic halibut, the stock biomass index ($B_{MSY}$) and the proxy exploitation rate index ($F_{MSY}$) to produce MSY are $B_{MSY}$ = 5,400 mt and $F_{MSY}$ = 0.06 (NEFMC 1998, NEFSC 2002). The overfished threshold ($B_{THRESHOLD}$) for Atlantic halibut is $B_{THRESHOLD}$ = ½ $B_{MSY}$ = 2,700 mt. The overfishing threshold ($F_{THRESHOLD}$) for Atlantic halibut is $F_{THRESHOLD}$ = $F_{MSY}$ = 0.06.

Stock Status in 2001
In 2001, the stock biomass index was 232 mt (9% of $B_{THRESHOLD}$ and 4% of $B_{MSY}$) with a standard error of 50 mt. Based on the point estimate of the biomass index, the Gulf of Maine-Georges Bank Atlantic halibut stock was overfished in 2001. In 2001, no estimate of fishing mortality was available and overfishing status was unknown.

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| Table Sl. Reported landings (mt) of Atlantic halibut from the Gulf of Maine and Georges Bank, 1893-2001. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | USA | Canada | Other | Total | Year | USA | Canada | Other | Total |
| 1893 | 634 | 0 | 0 | 634 | 1947 | 196 | 0 | 0 | 196 |
| 1894 | 843 | 0 | 0 | 843 | 1948 | 156 | 0 | 0 | 156 |
| 1895 | 4200 | 0 | 0 | 4200 | 1949 | 157 | 0 | 0 | 157 |
| 1896 | 4908 | 0 | 0 | 4908 | 1950 | 116 | 0 | 0 | 116 |
| 1897 | 733 | 0 | 0 | 733 | 1951 | 154 | 0 | 0 | 154 |
| 1898 | 564 | 0 | 0 | 564 | 1952 | 123 | 0 | 0 | 123 |
| 1899 | 407 | 0 | 0 | 407 | 1953 | 104 | 0 | 0 | 104 |
| 1900 | 311 | 0 | 0 | 311 | 1954 | 125 | 0 | 0 | 125 |
| 1901 | 287 | 0 | 0 | 287 | 1955 | 74 | 0 | 0 | 74 |
| 1902 | 367 | 0 | 0 | 367 | 1956 | 62 | 0 | 0 | 62 |
| 1903 | 502 | 0 | 0 | 502 | 1957 | 80 | 0 | 0 | 80 |
| 1904 | 332 | 0 | 0 | 332 | 1958 | 73 | 0 | 0 | 73 |
| 1905 | 580 | 0 | 0 | 580 | 1959 | 59 | 0 | 0 | 59 |
| 1906 | 542 | 0 | 0 | 542 | 1960 | 63 | 0 | 0 | 63 |
| 1907 | 447 | 0 | 0 | 447 | 1961 | 79 | 5 | 0 | 84 |
| 1908 | 891 | 0 | 0 | 891 | 1962 | 86 | 35 | 25 | 146 |
| 1909 | 193 | 0 | 0 | 193 | 1963 | 94 | 88 | 1 | 183 |
| 1910 | 329 | 0 | 0 | 329 | 1964 | 115 | 120 | 1 | 236 |
| 1911 | 389 | 0 | 0 | 389 | 1965 | 128 | 153 | 18 | 299 |
| 1912 | 460 | 0 | 0 | 460 | 1966 | 110 | 110 | 62 | 282 |
| 1913 | 402 | 0 | 0 | 402 | 1967 | 102 | 386 | 26 | 514 |
| 1914 | 329 | 0 | 0 | 329 | 1968 | 74 | 193 | 3 | 270 |
| 1915 | 336 | 0 | 0 | 336 | 1969 | 63 | 96 | 9 | 168 |
| 1916 | 478 | 0 | 0 | 478 | 1970 | 52 | 67 | 19 | 138 |
| 1917 | 293 | 0 | 0 | 293 | 1971 | 81 | 38 | 0 | 119 |
| 1918 | 375 | 0 | 0 | 375 | 1972 | 63 | 37 | 8 | 108 |
| 1919 | 496 | 0 | 0 | 496 | 1973 | 51 | 38 | 0 | 89 |
| 1920 | 896 | 0 | 0 | 896 | 1974 | 46 | 29 | 1 | 76 |
| 1921 | 689 | 0 | 0 | 689 | 1975 | 70 | 36 | 0 | 106 |
| 1922 | 694 | 0 | 0 | 694 | 1976 | 58 | 33 | 0 | 91 |
| 1923 | 508 | 0 | 0 | 508 | 1977 | 50 | 31 | 0 | 81 |
| 1924 | 616 | 0 | 0 | 616 | 1978 | 84 | 50 | 0 | 134 |
| 1925 | 843 | 0 | 0 | 843 | 1979 | 125 | 29 | 0 | 154 |
| 1926 | 944 | 0 | 0 | 944 | 1980 | 80 | 88 | 0 | 168 |
| 1927 | 831 | 0 | 0 | 831 | 1981 | 80 | 118 | 0 | 198 |
| 1928 | 781 | 0 | 0 | 781 | 1982 | 85 | 116 | 0 | 201 |
| 1929 | 570 | 0 | 0 | 570 | 1983 | 72 | 131 | 0 | 203 |
| 1930 | 716 | 0 | 0 | 716 | 1984 | 75 | 62 | 0 | 137 |
| 1931 | 511 | 0 | 0 | 511 | 1985 | 61 | 57 | 0 | 118 |
| 1932 | 443 | 0 | 0 | 443 | 1986 | 44 | 32 | 0 | 76 |
| 1933 | 279 | 0 | 0 | 279 | 1987 | 27 | 23 | 0 | 50 |
| 1934 | 192 | 0 | 0 | 192 | 1988 | 47 | 81 | 0 | 128 |
| 1935 | 292 | 0 | 0 | 292 | 1989 | 13 | 65 | 0 | 78 |
| 1936 | 374 | 0 | 0 | 374 | 1990 | 16 | 58 | 0 | 74 |
| 1937 | 187 | 0 | 0 | 187 | 1991 | 30 | 58 | 0 | 88 |
| 1938 | 146 | 0 | 0 | 146 | 1992 | 22 | 47 | 0 | 69 |
| 1939 | 124 | 0 | 0 | 124 | 1993 | 15 | 50 | 0 | 65 |
| 1940 | 497 | 0 | 0 | 497 | 1994 | 22 | 24 | 0 | 46 |
| 1941 | 145 | 0 | 0 | 145 | 1995 | 11 | 8 | 0 | 19 |
| 1942 | 250 | 0 | 0 | 250 | 1996 | 13 | 12 | 0 | 25 |
| 1943 | 76 | 0 | 0 | 76 | 1997 | 14 | 14 | 0 | 28 |
| 1944 | 77 | 0 | 0 | 77 | 1998 | 8 | 9 | 0 | 17 |
| 1945 | 55 | 0 | 0 | 55 | 1999 | 12 | 8 | 0 | 20 |
| 1946 | 124 | 0 | 0 | 124 | 2000 | 11 | 6 | 0 | 17 |
| | | | | | 2001 | 11 | 11 | 0 | 22 |

Table S2. Stratified mean weight (kg) per tow of Atlantic halibut from NEFSC spring[1] and autumn surveys (offshore strata 13-30, 36-40) and exploitation rate indices calculated as annual landings divided by the 5-year moving average of swept-area biomass indices.

| Year | Spring Survey Index | Autumn Survey Index | Spring Explotiation Rate Index | Autumn Explotiation Rate Index | | |
|---|---|---|---|---|---|---|
| 1963 | | 0.085 | | | | |
| 1964 | | 0.067 | | | | |
| 1965 | | 0.032 | | | | |
| 1966 | | 0.004 | | | | |
| 1967 | | 0.009 | | 3.93 | | |
| 1968 | 0.129 | 0.000 | | 3.63 | | |
| 1969 | 0.236 | 0.494 | | 0.47 | | |
| 1970 | 0.105 | 0.000 | | 0.41 | | |
| 1971 | 0.033 | 0.091 | | 0.30 | | |
| 1972 | 0.005 | 0.018 | 0.32 | 0.27 | | |
| 1973 | 0.113 | 0.131 | 0.27 | 0.18 | | |
| 1974 | 0.112 | 0.014 | 0.31 | 0.45 | | |
| 1975 | 0.000 | 0.095 | 0.61 | 0.46 | | |
| 1976 | 0.644 | 0.378 | 0.16 | 0.22 | | |
| 1977 | 0.142 | 0.059 | 0.12 | 0.18 | | |
| 1978 | 0.163 | 0.294 | 0.19 | 0.24 | | |
| 1979 | 0.357 | 0.040 | 0.18 | 0.27 | | |
| 1980 | 0.563 | 0.010 | 0.14 | 0.32 | | |
| 1981 | 0.066 | 0.321 | 0.23 | 0.41 | | |
| 1982 | 0.082 | 0.115 | 0.25 | 0.39 | | |
| 1983 | 0.611 | 0.000 | 0.18 | 0.63 | | |
| 1984 | 0.022 | 0.124 | 0.15 | 0.36 | | |
| 1985 | 0.063 | 0.106 | 0.21 | 0.27 | | |
| 1986 | 0.000 | 0.313 | 0.15 | 0.17 | | |
| 1987 | 0.287 | 0.033 | 0.08 | 0.13 | | |
| 1988 | 0.023 | 0.004 | 0.49 | 0.33 | | |
| 1989 | 0.000 | 0.066 | 0.32 | 0.23 | | |
| 1990 | 0.064 | 0.060 | 0.30 | 0.23 | | |
| 1991 | 0.062 | 0.243 | 0.30 | 0.33 | | |
| 1992 | 0.037 | 0.201 | 0.56 | 0.18 | | |
| 1993 | 0.006 | 0.046 | 0.58 | 0.16 | | |
| 1994 | 0.017 | 0.000 | 0.37 | 0.13 | | |
| 1995 | 0.005 | 0.066 | 0.23 | 0.05 | | |
| 1996 | 0.013 | 0.053 | 0.48 | 0.10 | | |
| 1997 | 0.063 | 0.174 | 0.41 | 0.12 | | |
| 1998 | 0.017 | 0.103 | 0.22 | 0.06 | | |
| 1999 | 0.239 | 0.015 | 0.09 | 0.07 | | |
| 2000 | 0.000 | 0.021 | 0.08 | 0.07 | | |
| 2001 | 0.164 | 0.037 | 0.07 | 0.09 | | |
| 2002 | 0.128 | | | | | |

Figure S1. Atlantic halibut landings from the Gulf of Maine-Georges Bank region during 1893-2001.

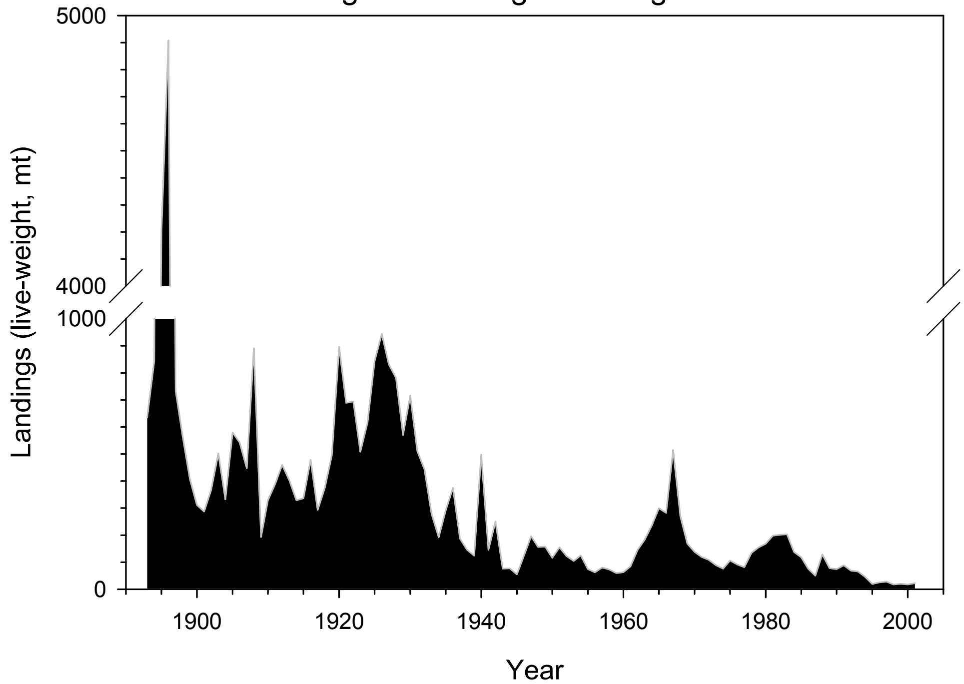



Figure S2. Trends in swept-area biomass indices (mt) of Atlantic halibut from NEFSC spring and autumn bottom trawl surveys.

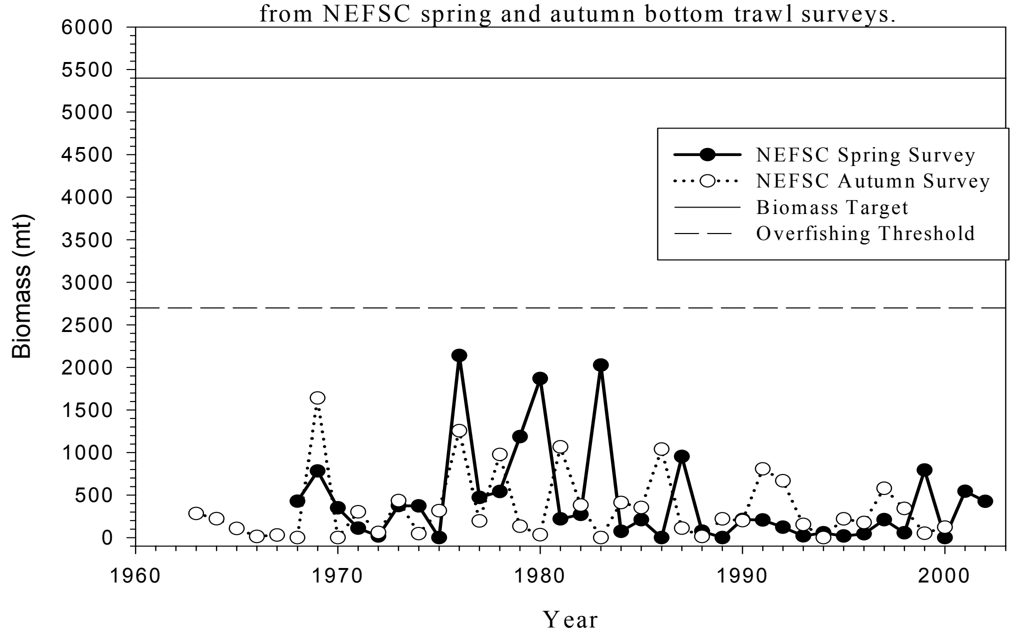


Figure S3. Trends in Atlantic halibut landings from the Gulf of Maine and Georges Bank in comparison to 5-year moving averages of spring and autumn survey indices, 1967-2001.

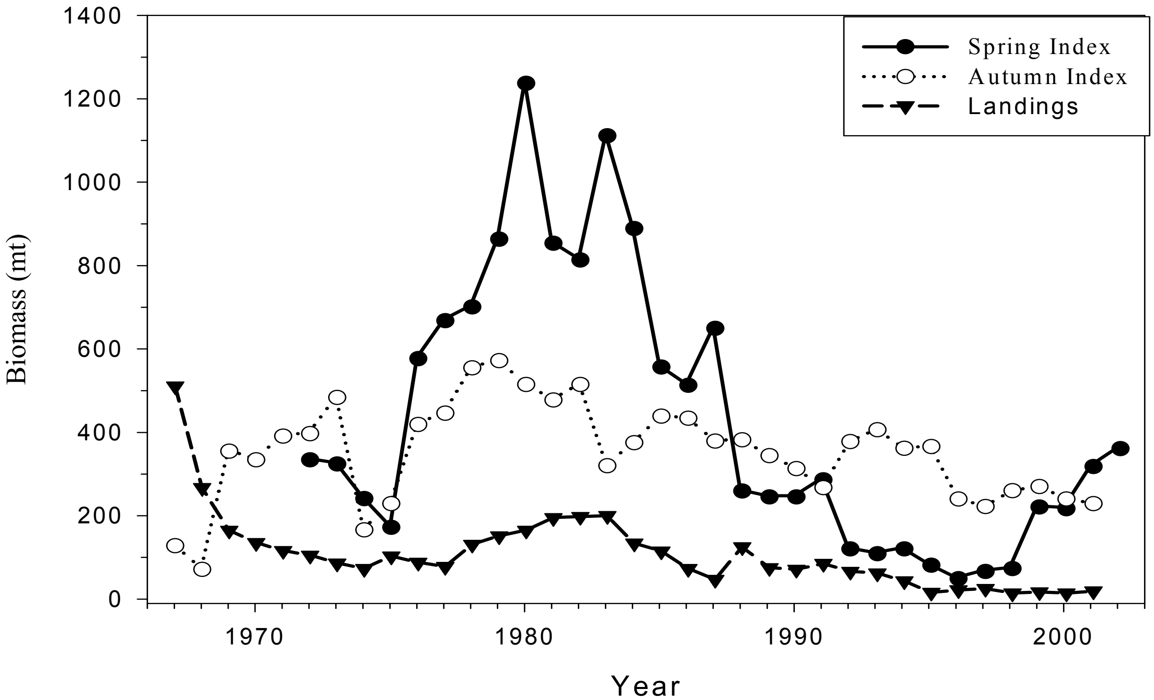
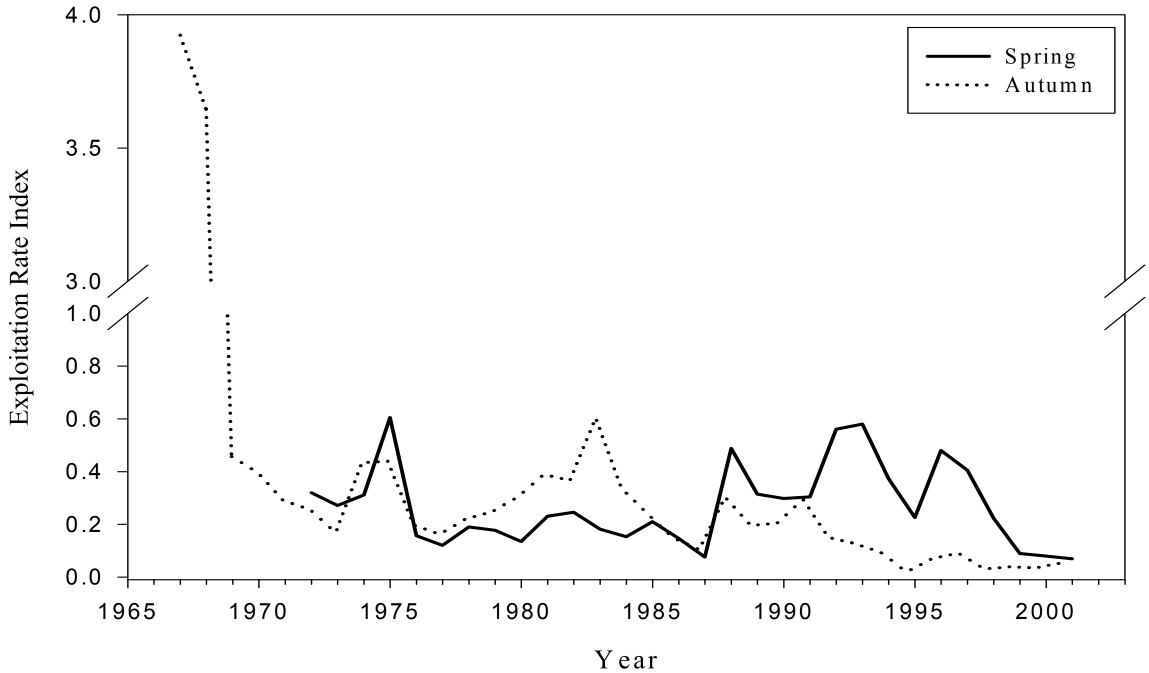


Figure S4. Trends in exploitation rate indices for Atlantic halibut from the Gulf of Maine and Georges Bank based on 5-year moving averages of NEFSC spring and autumn survey indices, 1967-2001



**T. Gulf of Maine (GM) winter flounder** by Paul Nitschke

## 1.0 Background

The last assessment for Gulf of Maine winter flounder was an index-based assessment reviewed at SARC 21 (NEFSC 1996). Low indices and the absence of large fish in the survey led SARC 21 to conclude that the stock was overexploited in the mid 1990s. The ASMFC Winter Flounder Technical Committee has constructed a benchmark virtual population analysis (VPA) in September 2002 which will be reviewed at SARC 36 (December 2002). Since this is a new benchmark assessment, full VPA output is not included here, but will be available in draft form to the council.

## 2.0 Fishery

Commercial landings were near 1,000 mt from 1964 to the mid 1970s. Thereafter commercial landings increased to a peak of 2,793 mt in 1982, and then steadily declined to a record low of 253 mt in 1999. Landings have remained near 500 mt since 1999 (Table T1, Figure T1). Otter trawl was the primary gear used during 1964-1985 (>95% of the landings). Since 1985 the proportion of landings coming from gill nets has increased, and has averaged 25% since1990.

Recreational landings reached a peak in 1981 ( 2,554 mt) but declined substantially thereafter (Table T2, Figure T2). Landings have been less than 1000 mt since 1995, with the lowest estimated landings in 1998 (30 mt). Landings in 2001 for Gulf of Maine winter flounder were 43 mt.

In the commercial fishery, annual sampling intensity varied during 1982-2001 from 4 to 310 mt landed per sample. Overall sampling intensity was adequate, however temporal and market category coverage in some years was poor (Table T3). Samples were pooled by halfyear when possible. Lengths of kept fish from observer data were used to supplement length data of unclassified fish. Lengths taken from gillnet trips in the observer data were used to characterize the gillnet proportion of the landings.

Discards were estimated for the large mesh trawl (1982-2001), gillnet (1986-2001), and northern shrimp fishery (1982-2001). The survey method was used in estimating both the discard and discard length composition for the large mesh trawl fishery from 1982-1993 (Mayo et al. 1992). VTR large mesh otter trawl discards to landings ratios were applied to corresponding commercial fishery landings to estimate discards in weight from 1994 to 2001. Fishery observer discard-to-landings ratios were used for estimating gillnet discard rates. Observer discard-to-days fished ratios were used for the northern shrimp fishery since landing of winter flounder in the shrimp fishery is prohibited. The observer length frequency data for gillnet and the northern shrimp fishery were used to characterize the proportion discarded at length. The sample proportion at length, converted to weight, was used to convert the discard estimate in weight to numbers at length. As for the southern New England stock (NEFSC 1999), a 50% mortality rate was applied to all commercial discard data (Howell et al., 1992). Numbers at ages were determined using NEFSC/MDMF spring and NEFSC fall survey age-length keys (Table T5).

A discard mortality of 15% was assumed for recreational discards (B2 category from MRFSS data), as assumed in Howell et al. (1992). Discard losses peaked at 140,000 fish in 1982. Discards have since declined reaching a low of 7,000 fish in 1999. In 2001, 15,000 fish were estimated to have been discarded (Table T2, Figure T2). Since 1997, irregular sampling of recreational fisheries has indicated that discards are usually fish below the minimum landing size of 12 inches (30 cm). For 1982-2001, the recreational discard has been assumed to have the same length frequency as the catch in the MDMF survey below the legal size and above an assumed hookable fish size (13 cm). The recreational discard for 1982-2001 is aged using NEFSC/MDMF spring and NEFSC fall survey age-length keys.

**3.0 Research Surveys**

Mean number per tow indices for the NEFSC and the Massachusetts Division of Marine Fisheries (MDMF) spring and fall time series are presented in Table T4 and Figures T3 through T6. All of the indices generally show a decrease in the population in the late 1980s from a high in the early 1980s with low abundance remaining through the early 1990s. All of the indices show signs of increased abundance starting in 1998 and 1999.

The Seabrook Nuclear Power Plant in New Hampshire has conducted a monthly bottom trawl survey since 1985. This survey also shows an increase in the number of fish in the late 1990s (Figure T7).

**4.0 2001 Assessment**

The VPA for Gulf of Maine winter flounder will be reviewed at SARC 36 (December 2002), therefore, results are not presented here. Estimates of Bmsy and Fmsy are not currently available.

**5.0 Sources of uncertainty**

* Landings data for 1994 and later years are derived by proration and are considered provisional.

* The lack of survey coverage in inshore New Hampshire and Maine where winter flounder are abundant is a source of uncertainty. Low number of tows taken per strata in inshore Massachusetts strata in the NEFSC survey is a source of variability in the index.

* Length frequency sampling coverage of the commercial fishery has been poor in some years.

* Observer sampling intensity of the commercial large mesh fishery has been low. Shrimp fishery discard sampling has been dropped in recent years. Commercial fishery discard

estimates are based on rates provided by fishermen in the vessel trip reports, due to inadequate fishery observer sampling.

## 6.0 GARM comments

The benchmark VPA assessment for Gulf of Maine winter flounder was presented to the GARM. However the GARM did not comment on the VPA assessment since a review has not been made on this assessment and a formal review will be conducted in the upcoming SARC. VPA results will be verbally presented to the council. The GARM also noted that all the surveys showed similar trends.

## 7.0 Summary

Stock summary information will be finalized at SARC 36.

## References

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Mayo, R.K., L. O'Brien, and N. Buxton. 1992. Discard estimates of American plaice, *Hippoglossoides platessoides*, in the Gulf of Maine northern shrimp fishery and the Gulf of Maine-Georges Bank large-mesh otter trawl fishery. SAW 14 Res. Doc. 14/3. 40 pp.

NEFSC. 1996. Report of the 21$^{th}$ Northeast Regional Stock Assessment Workshop (21st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. [By Northeast Regional Stock Assessment Workshop No. 21.] June 1996.

Table T1. Winter flounder commercial landings (metric tons) for Gulf of Maine stock (U.S. statistical reporting areas 512 to 515).

| Year | metric tons |
|---|---|
| 1964 | 1,081 |
| 1965 | 665 |
| 1966 | 785 |
| 1967 | 803 |
| 1968 | 864 |
| 1969 | 975 |
| 1970 | 1,092 |
| 1971 | 1,113 |
| 1972 | 1,085 |
| 1973 | 1,080 |
| 1974 | 885 |
| 1975 | 1,181 |
| 1976 | 1,465 |
| 1977 | 2,161 |
| 1978 | 2,194 |
| 1979 | 2,021 |
| 1980 | 2,437 |
| 1981 | 2,406 |
| 1982 | 2,793 |
| 1983 | 2,096 |
| 1984 | 1,699 |
| 1985 | 1,582 |
| 1986 | 1,188 |
| 1987 | 1,140 |
| 1988 | 1,250 |
| 1989 | 1,253 |
| 1990 | 1,116 |
| 1991 | 1,008 |
| 1992 | 825 |
| 1993 | 611 |
| 1994 | 552 |
| 1995 | 796 |
| 1996 | 600 |
| 1997 | 618 |
| 1998 | 637 |
| 1999 | 253 |
| 2000 | 382 |
| 2001 | 571 |

Table T2. Estimated number (000's) and weight (mt) of winter flounder caught, landed, and discarded in the recreational fishery, Gulf of Maine stock.

| | Number (000's) | | | | Metric tons |
|---|---|---|---|---|---|
| | Catch A+B1+B2 | Landed A+B1 | Released B2 | 15% Release Mortality | Landed A+B1 |
| 1981 | 6,200 | 5,433 | 767 | 115 | 2,554 |
| 1982 | 8,207 | 7,274 | 933 | 140 | 1,876 |
| 1983 | 2,169 | 1,988 | 181 | 27 | 868 |
| 1984 | 2,477 | 2,285 | 191 | 29 | 1,300 |
| 1985 | 3,694 | 3,220 | 474 | 71 | 1,896 |
| 1986 | 946 | 691 | 255 | 38 | 523 |
| 1987 | 3,070 | 2,391 | 679 | 102 | 1,809 |
| 1988 | 953 | 841 | 111 | 17 | 345 |
| 1989 | 1,971 | 1,678 | 294 | 44 | 620 |
| 1990 | 786 | 652 | 134 | 20 | 370 |
| 1991 | 213 | 154 | 59 | 9 | 91 |
| 1992 | 186 | 137 | 48 | 7 | 90 |
| 1993 | 396 | 249 | 147 | 22 | 140 |
| 1994 | 232 | 145 | 87 | 13 | 83 |
| 1995 | 150 | 82 | 68 | 10 | 39 |
| 1996 | 184 | 98 | 86 | 13 | 56 |
| 1997 | 192 | 64 | 129 | 19 | 43 |
| 1998 | 109 | 65 | 44 | 7 | 30 |
| 1999 | 115 | 67 | 48 | 7 | 34 |
| 2000 | 177 | 75 | 102 | 15 | 42 |
| 2001 | 172 | 72 | 100 | 15 | 43 |

Table T3. Number of samples, lengths, ages, and sampling intensity for Gulf of Maine winter flounder. Number of samples and calculations of metric tons per sample is done on a halfyear basis and does not include observer data or gillnet landings from 1990-2001. Lengths in bold font are from observer trawl data.

| | | Number of lengths | | | | | Ages | Number of samples | | | | | mt/samples | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | qtr | lg | sm | md | un | total | total | lg | sm | md | un | total | lg | sm | md | un | total |
| 1982 | 1 | - | - | - | 296 | | | - | - | - | 3 | | | | | | |
| | 2 | 102 | 101 | - | 159 | | | 1 | 1 | - | 1 | | 838 | 453 | - | 46 | |
| | 3 | 84 | 81 | - | 106 | | | 1 | 1 | - | 1 | | | | | | |
| | 4 | - | - | - | - | 929 | 483 | - | - | - | - | 9 | 396 | 691 | - | 231 | 310 |
| 1983 | 1 | 80 | - | 99 | - | | | 1 | - | 1 | - | | | | | | |
| | 2 | 300 | 100 | - | 407 | | | 3 | 1 | - | 4 | | 120 | 510 | - | 53 | |
| | 3 | 108 | 388 | - | - | | | 1 | 3 | - | - | | | | | | |
| | 4 | 107 | 956 | - | 106 | 2651 | 1182 | 1 | 8 | - | 1 | 24 | 125 | 44 | 64 | 95 | 87 |
| 1984 | 1 | 201 | 209 | - | - | | | 2 | 2 | - | - | | | | | | |
| | 2 | 237 | 294 | - | 221 | | | 3 | 2 | - | 2 | | 74 | 95 | - | - | |
| | 3 | - | 123 | - | - | | | - | 1 | - | - | | | | | | |
| | 4 | 126 | 690 | 100 | - | 2201 | 908 | 1 | 5 | 1 | - | 19 | 189 | 67 | 114 | 124 | 89 |
| 1985 | 1 | 273 | 565 | - | - | | | 3 | 3 | - | - | | | | | | |
| | 2 | 392 | 170 | - | - | | | 3 | 2 | - | - | | 54 | - | - | - | |
| | 3 | 105 | - | - | - | | | 1 | - | - | - | | | | | | |
| | 4 | 116 | - | - | 80 | 1701 | 318 | 1 | - | - | 1 | 14 | 87 | - | 182 | 176 | 113 |
| 1986 | 1 | - | - | - | 266 | | | - | - | - | 3 | | | | | | |
| | 2 | 237 | 109 | 109 | - | | | 3 | 1 | 1 | - | | - | 242 | 126 | 48 | |
| | 3 | - | 111 | 86 | - | | | - | 1 | 1 | - | | | | | | |
| | 4 | - | 389 | 107 | 89 | 1503 | 344 | - | 5 | 1 | 1 | 17 | 113 | 37 | 31 | 56 | 70 |
| 1987 | 1 | - | - | - | 113 | | | - | - | - | 1 | | | | | | |
| | 2 | - | - | - | - | | | - | - | - | - | | - | - | - | - | |
| | 3 | - | 95 | - | - | | | - | 1 | - | - | | | | | | |
| | 4 | 47 | 156 | 272 | - | 683 | 130 | 1 | 2 | 3 | - | 8 | 257 | 137 | 75 | 249 | 143 |
| 1988 | 1 | - | 258 | 311 | - | | | - | 3 | 3 | - | | | | | | |
| | 2 | 102 | - | 395 | - | | | 1 | - | 4 | - | | - | 108 | 23 | - | |
| | 3 | - | - | - | - | | | - | - | - | - | | | | | | |
| | 4 | - | 169 | 107 | - | 1342 | 249 | - | 2 | 1 | - | 14 | 340 | 164 | 96 | - | 89 |
| 1989 | 1 | - | - | - | 100 | | | - | - | - | 1 | | | | | | |
| | 2 | 113 | - | 91 | **134** | | | 1 | - | 1 | - | | - | - | 168 | - | |
| | 3 | - | 95 | 120 | **32** | | | - | 1 | 1 | - | | | | | | |
| | 4 | - | - | 100 | - | 785 | 148 | - | - | 1 | - | 6 | 313 | 435 | 42 | 254 | 209 |
| 1990 | 1 | 328 | 301 | - | - | | | 3 | 4 | - | - | | | | | | |
| | 2 | - | - | - | 102 | | | - | - | - | 1 | | 64 | 48 | - | - | |
| | 3 | - | - | - | - | | | - | - | - | - | | | | | | |
| | 4 | 117 | 197 | 97 | - | 1142 | 241 | 1 | 2 | 1 | - | 12 | 83 | 90 | 138 | 118 | 75 |

Table T3.  Continued.

| year | qtr | Number of lengths lg | sm | md | un | total | Ages total | Number of samples lg | sm | md | un | total | mt/samples lg | sm | md | un | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 1 | 100 | 51 | 105 | 101 | | | 1 | 1 | 1 | 1 | | | | | | |
| | 2 | 88 | 203 | 100 | **42** | | | 1 | 2 | 1 | - | | 92 | 72 | - | - | |
| | 3 | - | 95 | - | - | | | - | 1 | - | - | | | | | | |
| | 4 | 236 | 254 | - | - | 1375 | 262 | 3 | 3 | - | - | 15 | 32 | 47 | 95 | 115 | 65 |
| 1992 | 1 | 110 | - | - | **107** | | | 1 | - | - | - | | | | | | |
| | 2 | 136 | 100 | 93 | - | | | 2 | 1 | 1 | - | | 47 | 119 | 84 | - | |
| | 3 | - | - | - | - | | | - | - | - | - | | | | | | |
| | 4 | 57 | 74 | 253 | - | 930 | 270 | 1 | 1 | 3 | - | 10 | 75 | 134 | 19 | - | 67 |
| 1993 | 1 | 100 | - | - | - | | | 1 | - | - | - | | | | | | |
| | 2 | - | - | 288 | - | | | - | - | 3 | - | | 83 | - | 16 | - | |
| | 3 | - | 55 | - | **91** | | | - | 1 | - | - | | | | | | |
| | 4 | 80 | - | 157 | **51** | 822 | 183 | 1 | - | 2 | - | 8 | 47 | 177 | 30 | - | 59 |
| 1994 | 1 | - | - | - | - | | | - | - | - | - | | | | | | |
| | 2 | - | 71 | 92 | 102 | | | - | 1 | 1 | 1 | | - | - | 75 | - | |
| | 3 | - | - | - | - | | | - | - | - | - | | | | | | |
| | 4 | 94 | - | 235 | - | 594 | 139 | 1 | - | 3 | - | 7 | 112 | 143 | 15 | 60 | 62 |
| 1995 | 1 | 101 | - | 175 | **63** | | | 1 | - | 2 | - | | | | | | |
| | 2 | - | - | 299 | - | | | - | - | 3 | - | | - | - | 37 | - | |
| | 3 | - | - | 414 | - | | | - | - | 4 | - | | | | | | |
| | 4 | - | - | - | **609** | 1661 | 248 | - | - | - | - | 10 | 134 | - | 42 | - | 55 |
| 1996 | 1 | - | 77 | - | - | | | - | 1 | - | - | | | | | | |
| | 2 | - | 231 | - | - | | | - | 2 | - | - | | - | 44 | - | - | |
| | 3 | - | 355 | 252 | - | | | - | 2 | 3 | - | | | | | | |
| | 4 | 84 | 440 | 86 | **112** | 1637 | 246 | 1 | 5 | 1 | - | 15 | 80 | 16 | 18 | | 29 |
| 1997 | 1 | - | 204 | - | - | | | - | 2 | - | - | | | | | | |
| | 2 | - | 127 | 75 | - | | | - | 2 | 1 | - | | - | 28 | 66 | - | |
| | 3 | - | 220 | 218 | - | | | - | 2 | 3 | - | | | | | | |
| | 4 | 307 | 502 | 56 | - | 1709 | 295 | 4 | 8 | 1 | - | 23 | 25 | 11 | 14 | - | 19 |
| 1998 | 1 | - | 148 | 79 | - | | | - | 2 | 1 | - | | | | | | |
| | 2 | - | 151 | 201 | - | | | - | 3 | 2 | - | | - | 34 | 29 | - | |
| | 3 | - | 583 | - | - | | | - | 7 | | - | | | | | | |
| | 4 | 69 | 163 | 110 | - | 1504 | 341 | 1 | 2 | 1 | - | 19 | 65 | 14 | 30 | - | 25 |
| 1999 | 1 | - | 173 | 104 | - | | | - | 2 | 1 | - | | | | | | |
| | 2 | - | | 171 | - | | | - | - | 2 | - | | - | 17 | - | - | |
| | 3 | - | 28 | - | - | | | - | 1 | - | - | | | | | | |
| | 4 | - | 152 | - | **408** | 1036 | 149 | - | 3 | - | - | 9 | - | 5 | 10 | - | 19 |
| 2000 | 1 | - | 866 | 143 | **480** | | | - | 12 | 2 | - | | | | | | |
| | 2 | - | 3441 | 51 | **554** | | | - | 45 | 1 | - | | - | 1 | - | - | |
| | 3 | - | 102 | - | **50** | | | - | 2 | - | - | | | | | | |
| | 4 | - | 114 | - | **26** | 5827 | 883 | - | 2 | - | - | 64 | - | 12 | 13 | - | 4 |
| 2001 | 1 | - | - | 187 | **172** | | | - | - | 2 | - | | | | | | |
| | 2 | 99 | 157 | 189 | **630** | | | 1 | 2 | 3 | - | | - | 37 | 10 | - | |
| | 3 | - | 100 | 52 | **399** | | | - | 1 | 1 | - | | | | | | |
| | 4 | - | 154 | 198 | **1307** | 3644 | 246 | - | 2 | 2 | - | 14 | 26 | 21 | 24 | - | 32 |

Table T4. NEFSC and MA DMF survey indices of abundance for Gulf of Maine winter flounder. Indices are stratified mean number and mean weight (kg) per tow. NEFSC indices are for inshore strata (58,59,60,61,65,66) and offshore strata (26,27,38,39,40). NEFSC indices are calculated with trawl door conversion factors where appropriate. MA DMF uses strata 25-36.

| | NEFSC spring | | NEFSC fall | | MDMF spring | | MDMF fall | |
|---|---|---|---|---|---|---|---|---|
| year | number | weight | number | weight | number | weight | number | weight |
| 1978 | | | | | 86.805 | 18.373 | 43.360 | 9.887 |
| 1979 | 9.063 | 3.218 | 6.003 | 2.602 | 64.952 | 14.407 | 119.506 | 28.978 |
| 1980 | 11.284 | 4.447 | 13.141 | 6.553 | 66.231 | 17.494 | 74.684 | 15.940 |
| 1981 | 13.051 | 3.946 | 4.179 | 3.029 | 100.569 | 28.370 | 47.342 | 13.228 |
| 1982 | 7.670 | 3.022 | 4.201 | 1.924 | 60.719 | 14.687 | 106.053 | 23.635 |
| 1983 | 12.367 | 5.653 | 10.304 | 3.519 | 108.508 | 27.233 | 88.143 | 15.772 |
| 1984 | 5.155 | 1.979 | 7.732 | 3.106 | 66.271 | 15.977 | 35.956 | 10.817 |
| 1985 | 3.469 | 1.418 | 7.638 | 2.324 | 48.651 | 13.594 | 44.564 | 7.381 |
| 1986 | 2.343 | 0.998 | 2.502 | 0.938 | 62.356 | 14.724 | 41.914 | 6.603 |
| 1987 | 5.609 | 1.503 | 1.605 | 0.488 | 83.171 | 17.648 | 50.426 | 7.227 |
| 1988 | 6.897 | 1.649 | 3.000 | 1.031 | 52.733 | 10.617 | 33.063 | 7.173 |
| 1989 | 3.717 | 1.316 | 6.402 | 2.013 | 63.595 | 13.317 | 33.983 | 7.462 |
| 1990 | 5.415 | 2.252 | 3.527 | 1.177 | 74.131 | 12.966 | 67.874 | 13.452 |
| 1991 | 4.517 | 1.436 | 7.035 | 1.467 | 49.265 | 11.587 | 88.777 | 15.473 |
| 1992 | 3.933 | 1.160 | 10.447 | 3.096 | 74.146 | 13.938 | 77.350 | 13.471 |
| 1993 | 1.556 | 0.353 | 7.559 | 1.859 | 80.133 | 12.390 | 92.476 | 14.996 |
| 1994 | 3.481 | 0.891 | 4.870 | 1.319 | 71.710 | 10.036 | 67.351 | 13.560 |
| 1995 | 12.185 | 3.149 | 4.765 | 1.446 | 87.848 | 14.560 | 84.768 | 17.250 |
| 1996 | 2.736 | 0.732 | 10.099 | 3.116 | 77.249 | 12.823 | 74.295 | 13.031 |
| 1997 | 2.806 | 0.664 | 10.008 | 2.950 | 95.918 | 14.796 | 74.347 | 14.316 |
| 1998 | 2.001 | 0.528 | 3.218 | 0.987 | 91.466 | 15.756 | 93.889 | 14.934 |
| 1999 | 6.510 | 1.982 | 10.921 | 3.269 | 77.941 | 14.198 | 117.648 | 22.672 |
| 2000 | 10.383 | 2.885 | 12.705 | 5.065 | 169.291 | 35.453 | 101.633 | 25.693 |
| 2001 | 5.242 | 1.666 | 8.845 | 3.143 | 90.153 | 23.891 | 80.978 | 18.367 |
| 2002 | 12.066 | 3.693 | | | 87.376 | 21.404 | | |

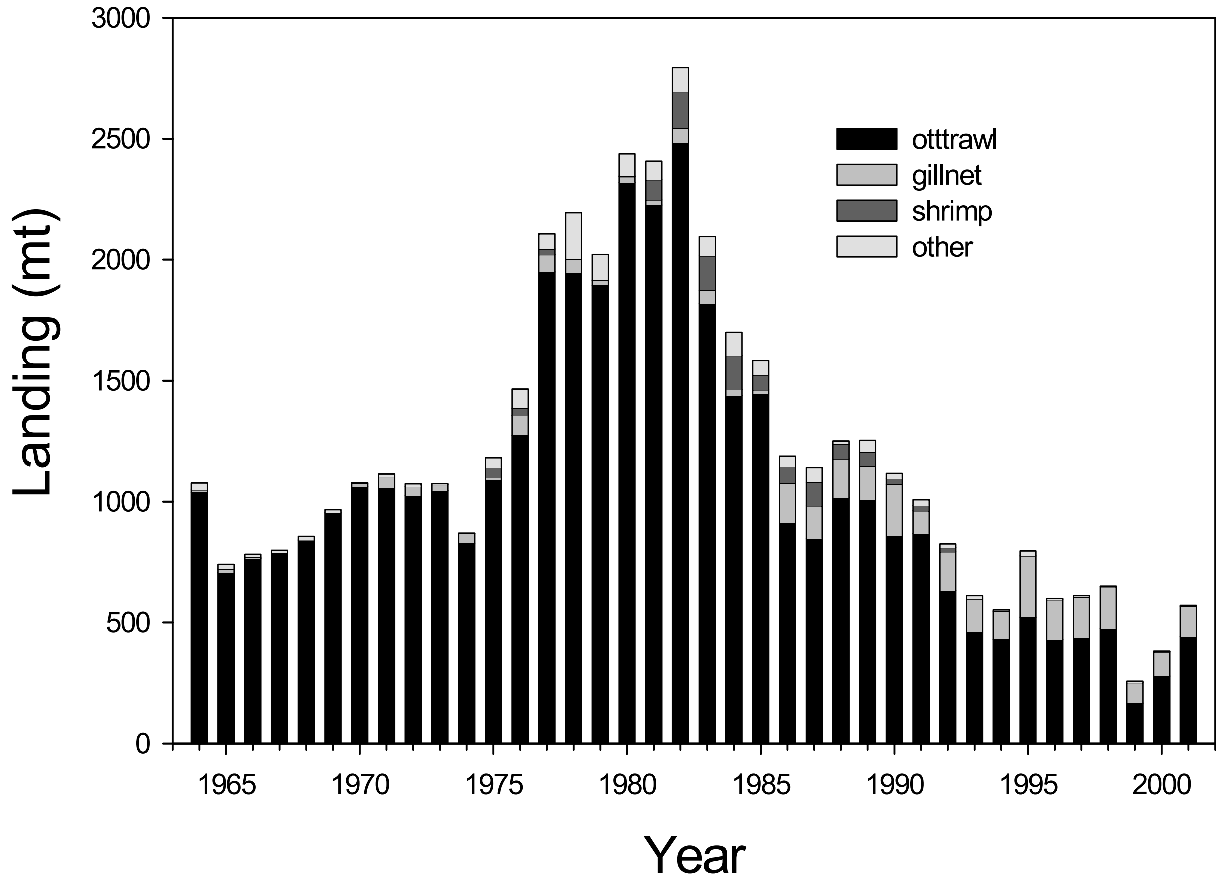



Figure T1. Gulf of Maine winter flounder landings (mt) by gear.

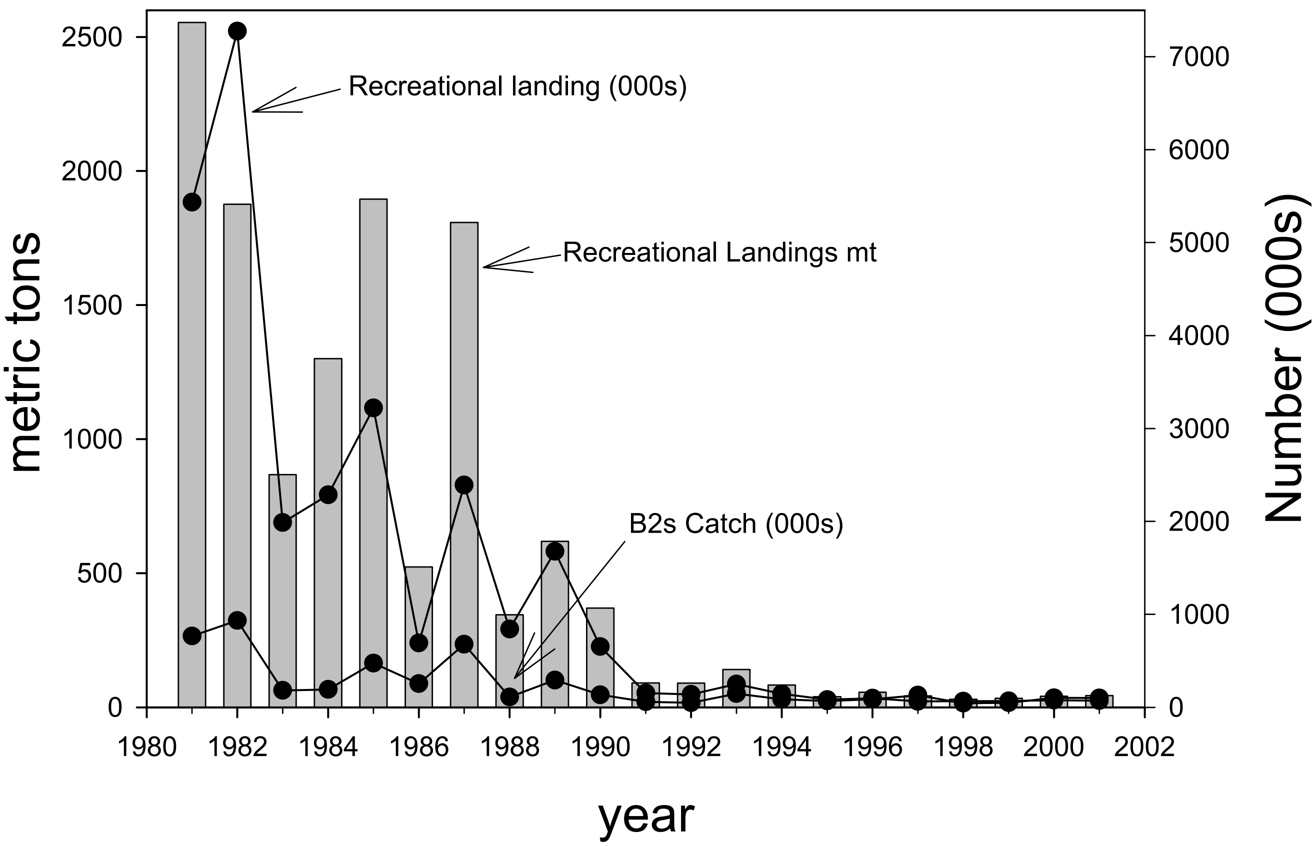



Figure T2. Recreational landings in numbers and metric tons for Gulf of Maine winter flounder. B2 catch is fished released alive.

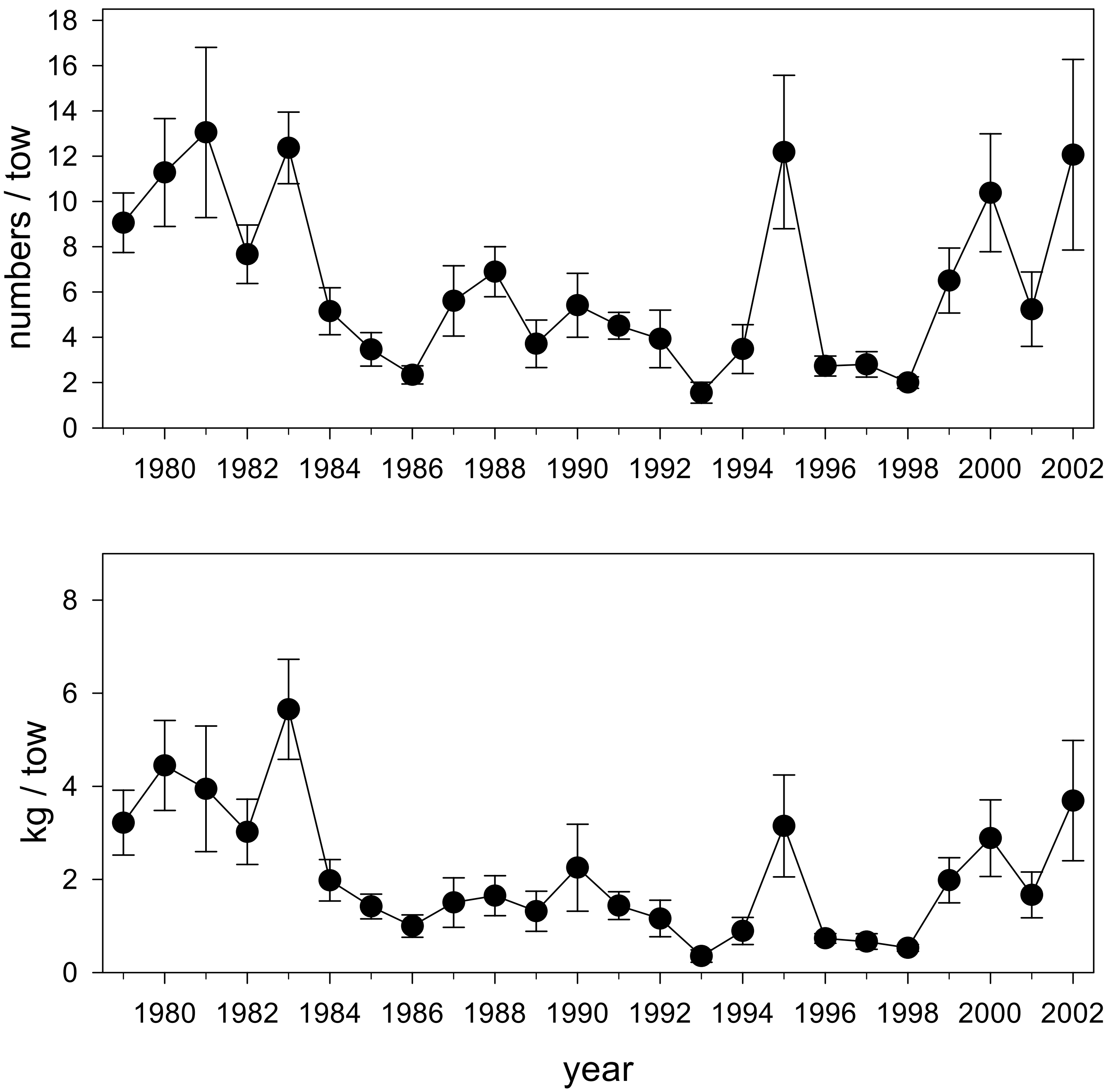



Figure T3. NEFSC Spring survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder. Trawl door conversion factors are used where appropriate.

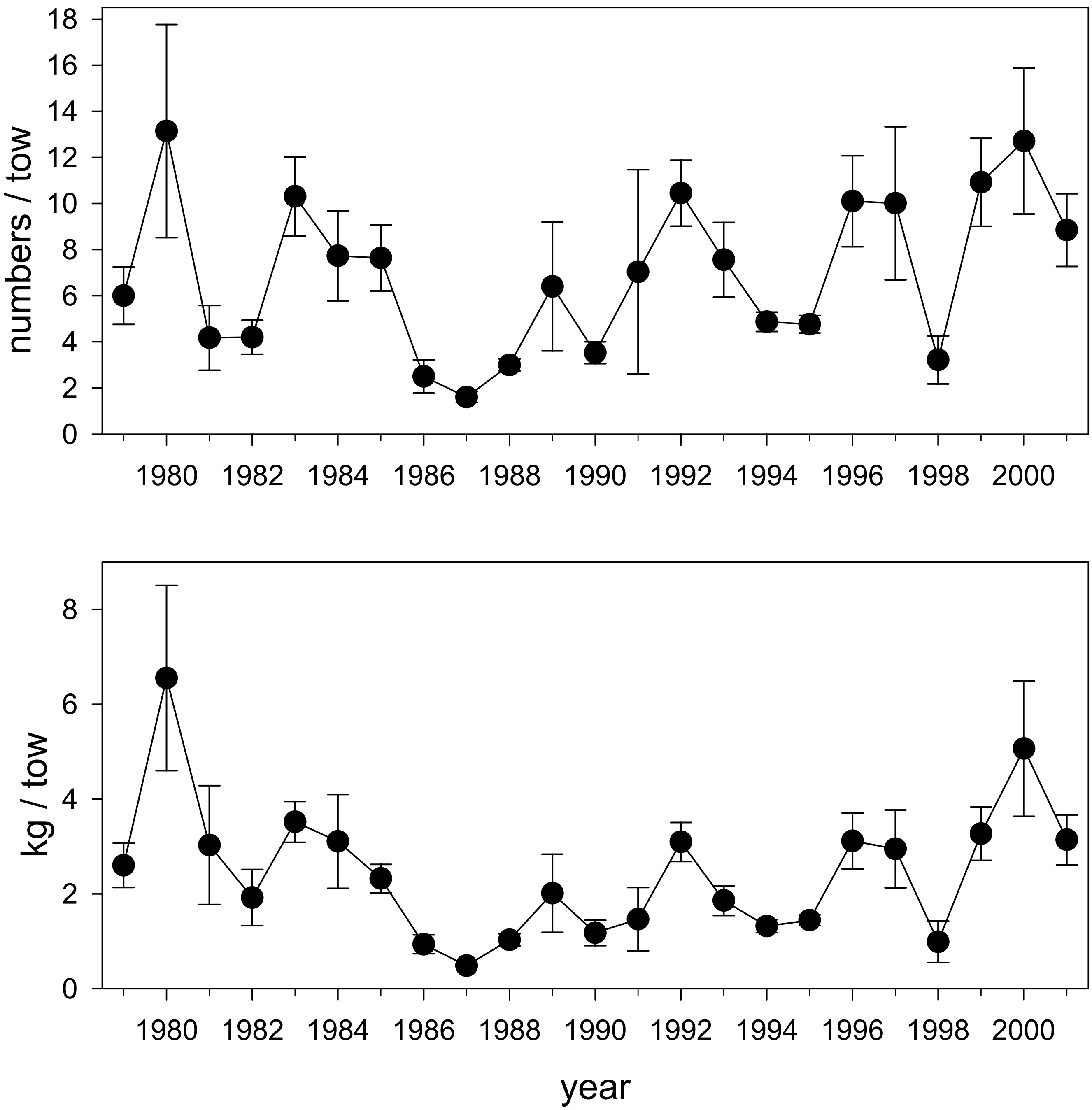



Figure T4. NEFSC Fall survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder. Trawl door conversion factors are used where appropriate.

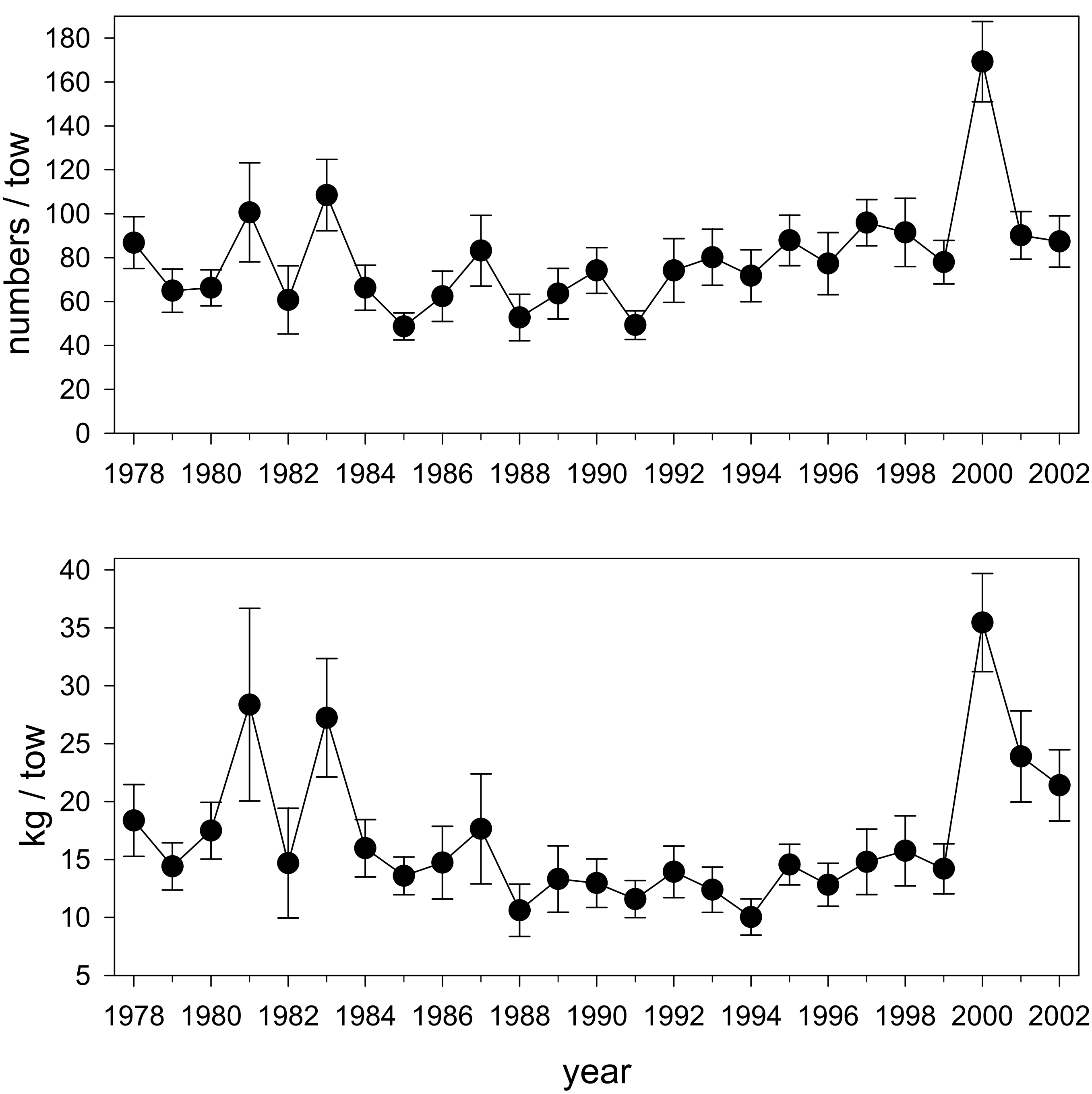



Figure T5. Massachusetts Division of Marine Fisheries (MA DMF) spring survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder.

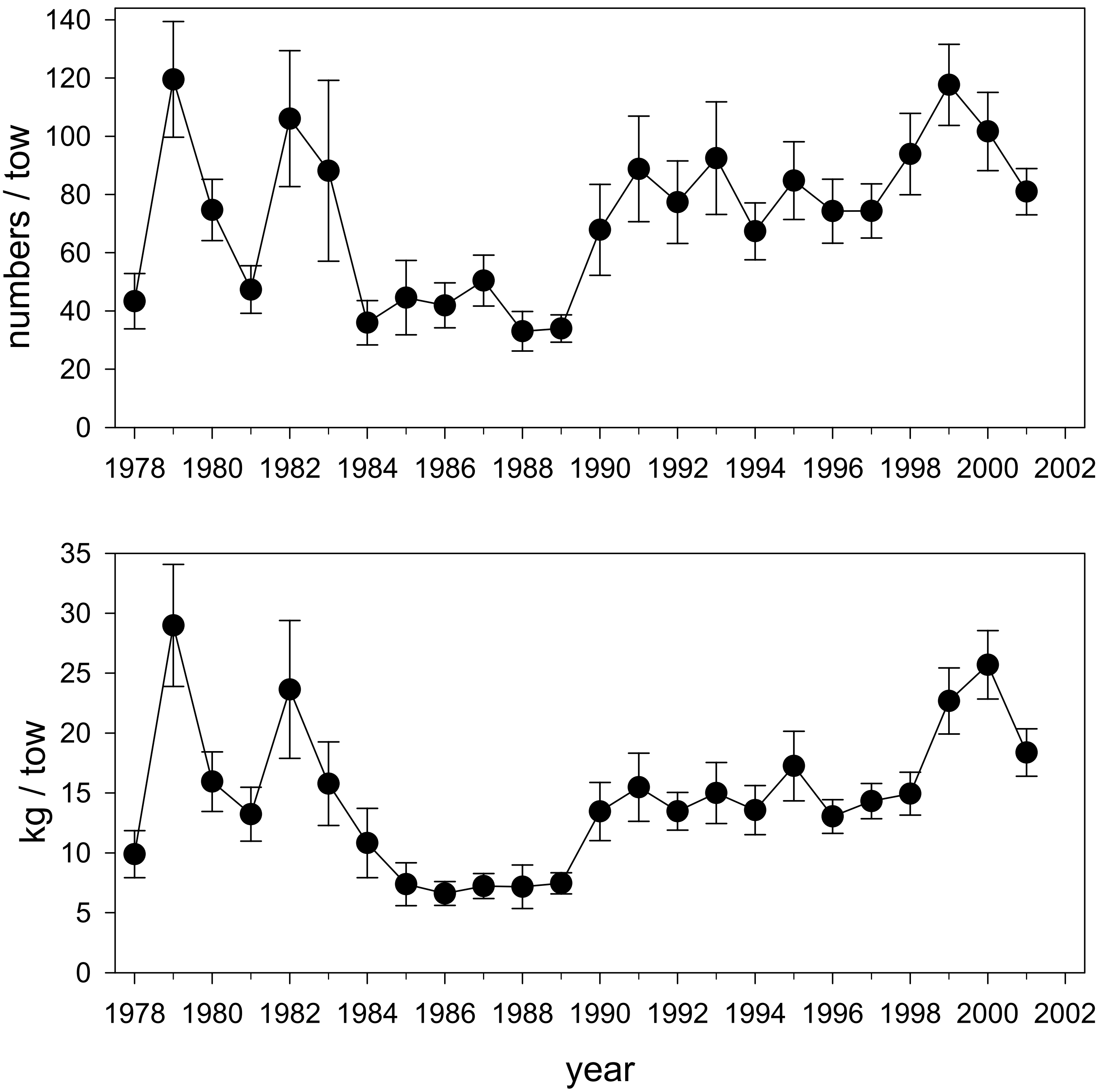



Figure T6. Massachusetts Division of Marine Fisheries (MA DMF) Fall survey stratified mean numbers and mean weight (kg) per tow for Gulf of Maine winter flounder.

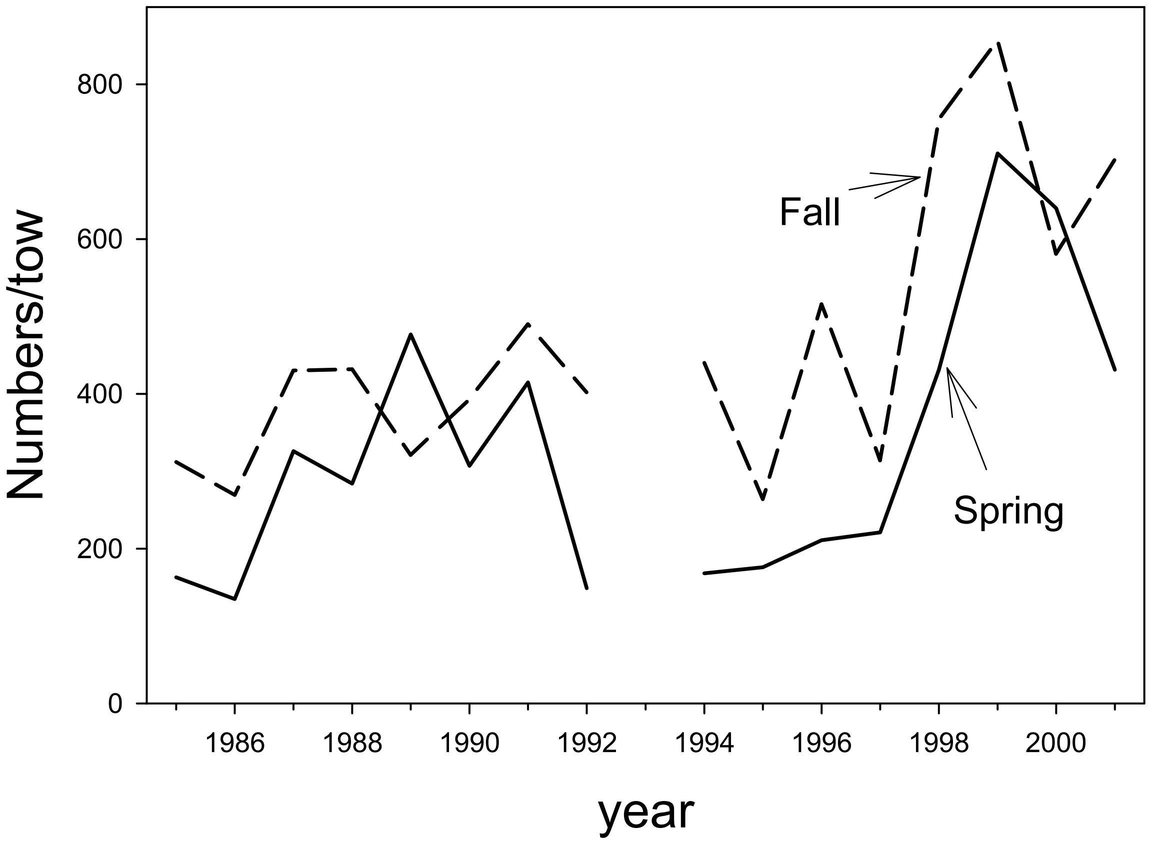



Figure T7. Seabrook Nuclear Power Plant in (New Hampshire) spring and fall survey mean numbers per tow for Gulf of Maine winter flounder. No survey was done in 1993.

## Section 3. Examination of Possible Effects of Trawl Survey Time-Series Interventions Beginning in 2000

### 3.1 Description of the Warp Offset Problem

The objectives of this section are to evaluate the potential effects of mismarked trawl cables on the catches of groundfish species in NEFSC R/V trawl surveys conducted since 2000. Eight surveys were affected (Spring 2000-2002, Winter 2000-2002, and Fall 2000-2001) but the magnitude of the potential changes is unknown. First principles suggest that the likely changes should be negative (i.e., lower catches in 2000-2002). Trawls are bilaterally symmetric and offset cables will induce asymmetry in the trawl's alignment. Departures from symmetry could upset the balance of dynamic forces that govern performance of the net. Catastrophic changes are relatively infrequent and readily detected in standard surveys. More subtle features such as vibrations, variability in bottom contact, reduced net width, and decreased height of the head rope are more difficult to detect. Moreover, the effects of such changes interact with contagiously-distributed fish populations whose variations in abundance and catchability may overwhelm issues of gear performance.

While pilot studies to test the effects of offset trawl cables were conducted in fall 2002, comprehensive experiments have yet to be completed. Analysis of historical data from the NEFSC time series and comparisons with other data sets, are however, instructive for gauging the magnitude of likely effects. We have pursued three basic approaches to see if effects of the trawl warp offsets are evident in the data. The first approach is descriptive. We examined the basic properties of the catch data and performed various tests to determine if changes had occurred since 1999. These analyses rely primarily on the historical data serving as a temporal control. The second approach relies on comparisons between the NEFSC time series and contemporaneous samples from other surveys. We consider comparisons between the NEFSC trawl data and similar surveys conducted by Department of Fisheries and Ocean (DFO) Canada. In addition, vessel comparison studies (R/V *Albatross IV* versus R/V *Delaware II*) conducted before and after 2000 fortuitously allow for an estimate of the relative effect of warp offsets on catches.

Finally, we used models to evaluate the consequences of hypothesized levels of bias on the relative indices for assessment of resource status. Each potential level of bias has implications for relative efficiency of capture at depth. We used simple models to predict the reduction in capture efficiency that would have led to underestimation of abundance at the hypothesized levels.

Table 3.1.1. Measured differences in trawl warp lengths at varying fishing depths.

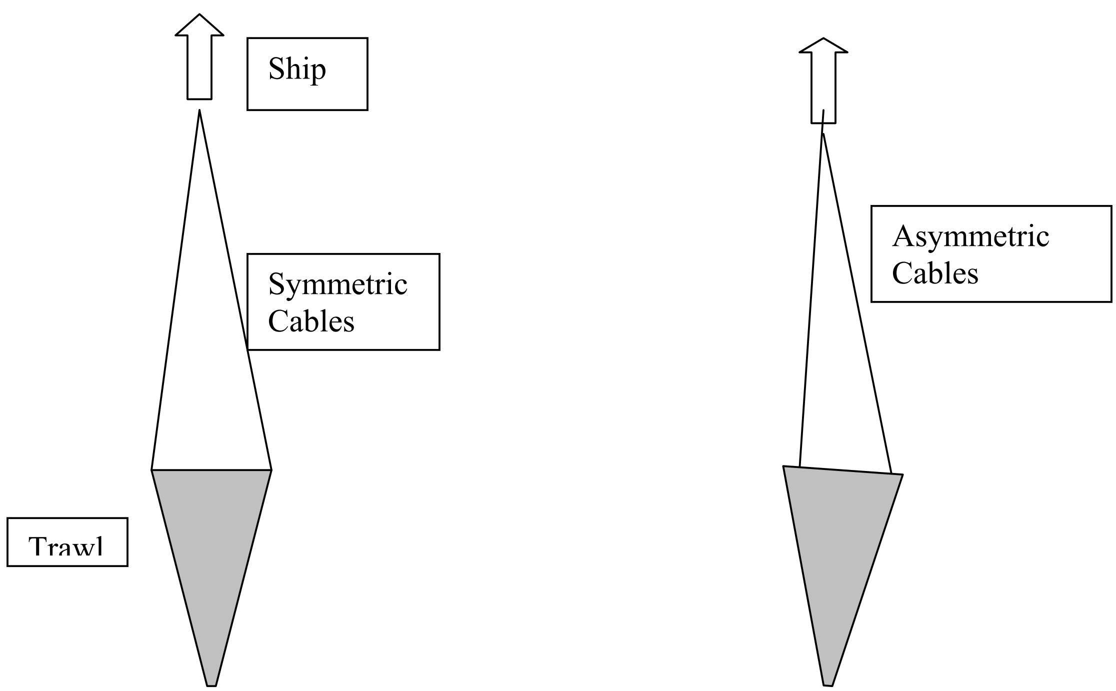
**Differences in Warp length between port and starboard marks.**

| ***Warp(m)*** | ***Depth(m)*** | ***Difference (inches)*** | ***Difference (m)*** | ***Difference (ft)*** |
|---|---|---|---|---|
| 0 | 0 | 0 | 0.00 | 0.0 |
| 50 | 17 | 16 | 0.41 | 1.3 |
| 100 | 33 | 1 | 0.03 | 0.1 |
| 150 | 50 | 24 | 0.61 | 2.0 |
| 200 | 67 | 39 | 0.99 | 3.3 |
| 250 | 83 | 49 | 1.24 | 4.1 |
| 300 | 100 | 67 | 1.70 | 5.6 |
| 350 | 117 | 69 | 1.75 | 5.8 |
| 400 | 133 | 81 | 2.06 | 6.8 |
| 450 | 150 | 94 | 2.39 | 7.8 |
| 500 | 200 | 107 | 2.72 | 8.9 |
| 550 | 220 | 124 | 3.15 | 10.3 |
| 600 | 240 | 131 | 3.33 | 10.9 |
| 650 | 260 | 117 | 2.97 | 9.8 |
| 700 | 280 | 150 | 3.81 | 12.5 |
| 750 | 300 | 158 | 4.01 | 13.2 |
| 800 | 320 | 164 | 4.17 | 13.7 |
| 850 | 340 | 172 | 4.37 | 14.3 |
| 900 | 360 | 188 | 4.78 | 15.7 |
| 950 | 380 | 214 | 5.44 | 17.8 |
| 1000 | 400 | 200 | 5.08 | 16.7 |

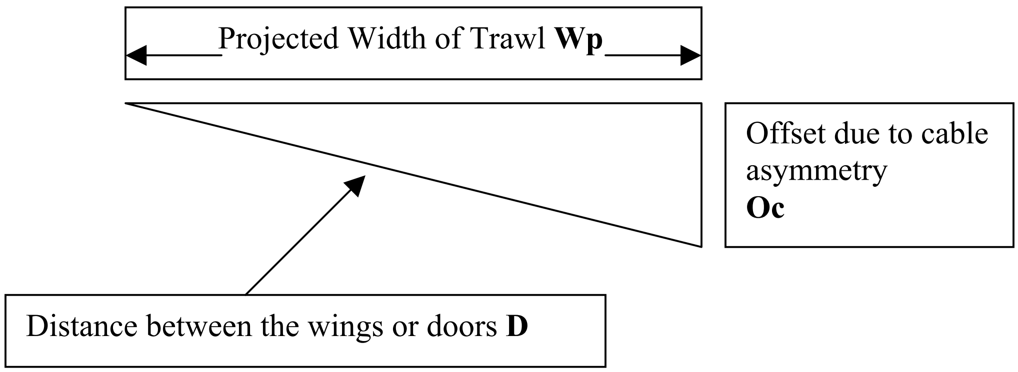
### 3.1.1 Trawl Geometry and Its Potential Implications for Catch Rates

The measured differences between the port and starboard cables are listed in Table 3.1.1. The ratio of the wire deployed to water depth is defined as the scope ratio. NEFSC uses a 3:1 scope for tows conducted at depths less than 150 m. At depths greater than 150 m the scope is set at 2.5:1. The difference between the cable lengths increases with the length of cable such that the differences between cables increases with fishing depth. The relationship between the warp offset and depth is linear (Fig. 3.1.1).

Basic geometric principles can be used to evaluate the potential effects of the asymmetric warp lengths on the area swept by the trawl. When the cables are of equal length, the distance between the trawl doors can be considered as the base of an isosceles triangle. A line drawn between the doors will be tangential to the direction of the ship. This distance between the wings of the net defines the measure of area swept for species which do not actively avoid the moving net. For finfish species that avoid both the net and the silt plume generated by the trawl doors, the effective area swept can be considered as the distance between the trawl doors. The minimal estimate total area swept can thus be estimated as the distance towed times the distance between the wings.



As a first approximation, the effects of asymmetric doors can be addressed with respect to the implied decrease in the distance between doors. If the Euclidean distance between the doors remains constant, then the reduction in area swept can be estimated as the base of a right-angled triangle using the Pythagorean theorem.




When the cables are symmetric then Wp=D. When the cables are asymmetric, by a distance of approximately Oc, the projected width of the trawl tangential to the axis of the ship's direction is

$$W_p = \sqrt{D^2 - Oc^2}$$

The fractional reduction in area swept per unit of towing distance can then be expressed as **$(D-W_p)/D$.** This approximation relies on the rather strong assumption that the trawl behaves like a rigid body. In reality the conformation of the trawl will depend upon the balance of forces acting on it. Detailed description of changes in net configuration and performance await the results of physical model tests, numerical model simulations, and field experiments with video observations.

The simple geometry of this example however, suggests that the consequences for changes in area swept are very small (Fig 3.1.2). At fishing depths below 300 m the difference in the area swept between the wings will less than 2%. The differences in the width swept by the doors would be about 7%. More than 90% of the NEFSC survey stations are at depths less than 200 m; at these depths, the reductions in either door width or net width would be less than 3%. Thus changes in catchability derived from considerations of simple geometry are likely to be small. Effects of the warp offset on catchability, if they exist, must manifest themselves as significant changes in net configuration or performance. Such changes could include reduced tendency to hold bottom, decreased headrope height, or excessive vibrations or pressure waves. Each of these factors should be subject to experimental confirmation through video studies and comparative fishing experiments.

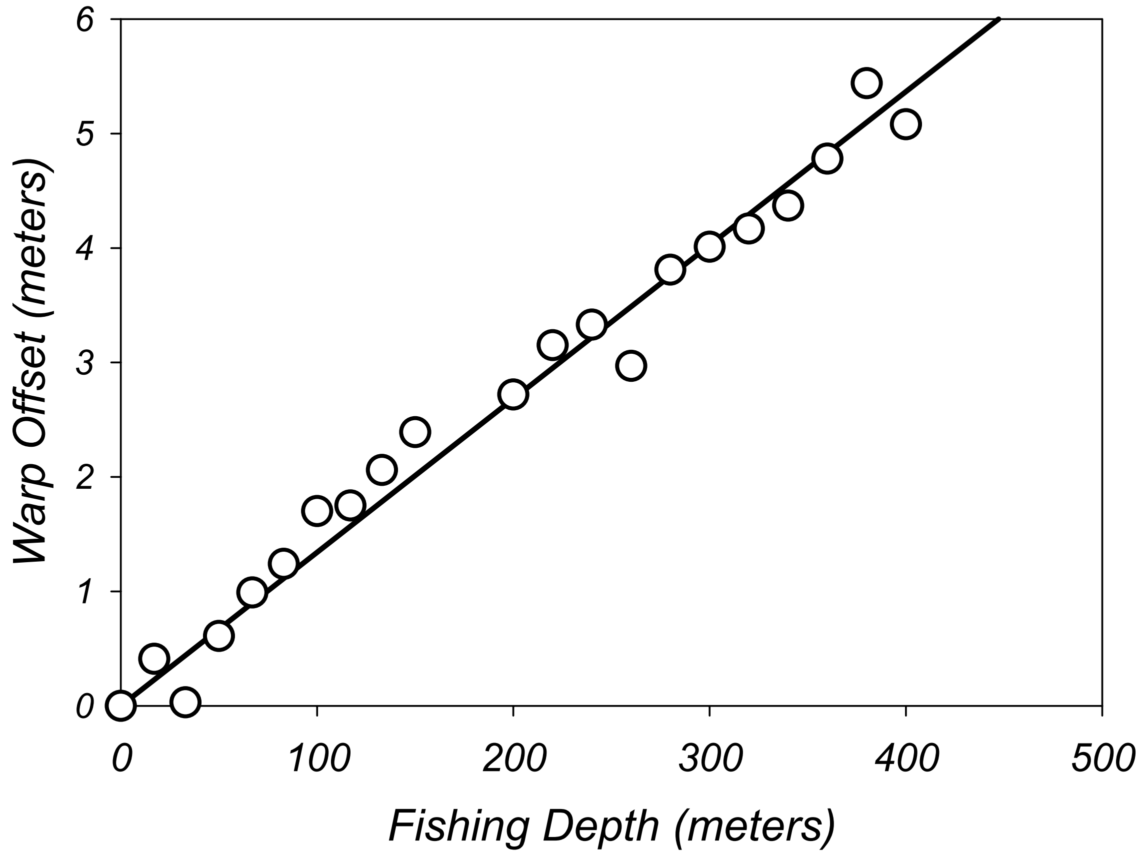
The deductive conclusions from trawl geometry provide a basis for examination of existing data. If the reductions in trawl width are greater than predicted by the static rigid-body analysis, then all species analyzed should be affected by a similar magnitude. Other modifications of trawl performance, however, are likely to have differential effects on the mix of species caught. If the warp offset causes the footrope to lose contact with the bottom, flatfish species should experience greater reductions in catches than other groundfish. Conversely, reductions in the height of the headrope should leave catch rates of flatfish unaffected but decrease catches of free-swimming species. Changes in net vibrations or increases in the net's pressure wave will tend to enhance the avoidance response of faster moving species and individuals within species. Under this hypothesis, the size composition of the catches should shift toward smaller individuals. In aggregate, these factors would be expected to increase the frequency of faulty trawl deployments, differentially reduce species-specific catch rates, and show an increasing effect with towing depth.

The following sections attempt to test these hypotheses in a variety of ways. Each section follows a general pattern of hypothesis formulation, description of the data, presentation of mathematical or statistical theory, and the results of the analyses. We attempt to inter-relate models with the observed data. In most instances, this is done in the conventional fashion of comparing statistical models with observations. In other instances, the models are used to illustrate the plausibility of hypotheses. The following table provides a guide to these hypotheses and test procedures.

| Hypothesis | Test Procedure | Section |
|---|---|---|
| Warp offset effects should lead to an increase in frequency of gear problems during 2000-2002 compared to pre 2000 surveys. Increases between treatment and control periods should be more pronounced with increasing depth. | Examined frequency of tows with gear problems by year for the spring (1985-2002), winter (1992-2002) and fall (1985-2001) surveys for the period 1985-2002. Used generalized additive models to estimate year and depth effects. | 3.2 |
| Larger individuals should be less vulnerable to capture by an asymmetric trawl. | Compared size frequency distributions of cod, haddock, yellowtail flounder, and monkfish caught in Albatross surveys with Canadian DFO surveys, fishing power surveys on the R/V Delaware, and a special commercial survey for monkfish. | 3.3 |
| Warp offset should decrease efficiency of net leading to decreases in average abundance and higher variation in catch. | Computed variance and mean of each strata within year for fall (1963-2001), spring (1968-2002), and winter (1992-2002) surveys for 22 species-stocks. Compared 90% confidence ellipses for pre and post treatment period. | 3.6 |
| Reductions in capture efficiency at depth should shift the loci of species abundance to shallower | Computed catch (numbers/tow)-weighted and biomass (kg/tow)-weighted average depths for each year and survey type (as above) for 22 species-stocks. For selected species, compared | 3.7 |

| | | |
|---|---|---|
| depths during the 2000-2002 period. | the cumulative catch distributions vs. depth by year. | |
| Reductions in catch rates should be more pronounced with increases in depth. | Regressed standardized pre –post treatment differences in average catch (num/tow) vs. depth (20 m intervals) and biomass (kg/tow) vs. depth (20 m intervals) for spring (1997-1999 vs. 2000-02), winter (1997-99 vs. 2000-02) and fall (1998-99 vs. 2000-01). For statistically significant changes, estimated depth dependent function to describe loss of efficiency with depth. Computed expected magnitude of underestimation for 2000-2002 indices. | 3.7 |
| Hypothesized increases in average number caught in 2000 to 2002 surveys have implication for the reductions in depth-related catch efficiency. | Estimated magnitude of depth-related decreases in efficiency for putative increases in abundance of 10%, 25% and 100% for cod, haddock, and yellowtail stocks. | 3.7 |
| Trawl surveys conducted by Canada and NEFSC scallop surveys are unaffected by warp offset. Comparisons of abundance estimates derived from these surveys with NEFSC trawl surveys should allow estimation of warp-related effects. | For annual composite abundance estimates, compared standardized log catch ratios for NEFSC trawl surveys with DFO trawl and NEFSC scallop dredge surveys for 20 species. Generalized linear model used to test for intervention effect. | 3.9 |
| Experiments to compare catch rates between the *Albatross* and *Delaware* in 1980s and 2002 provide an indirect measure of warp offset effect. | Reanalyze the vessel comparison experiments to estimate the likely magnitude of the trawl cable offset effect. | 3.11 |
| Warp offset effects may have reduced 2000-2002 indices used in assessment models. Hypothesized effect levels were 10, 25 and 100%. | Each assessment model was run with four assumed levels of warp-offset effect: 0% change, +10%, +25% and +100% for indices in 2000-02. Bootstrap estimates of biomass and full F were computed for each model run and confidence intervals were compared for terminal year estimates. | 5.2 |

Figure 3.1.1. Difference between port and starboard warp marks vs. fishing depth



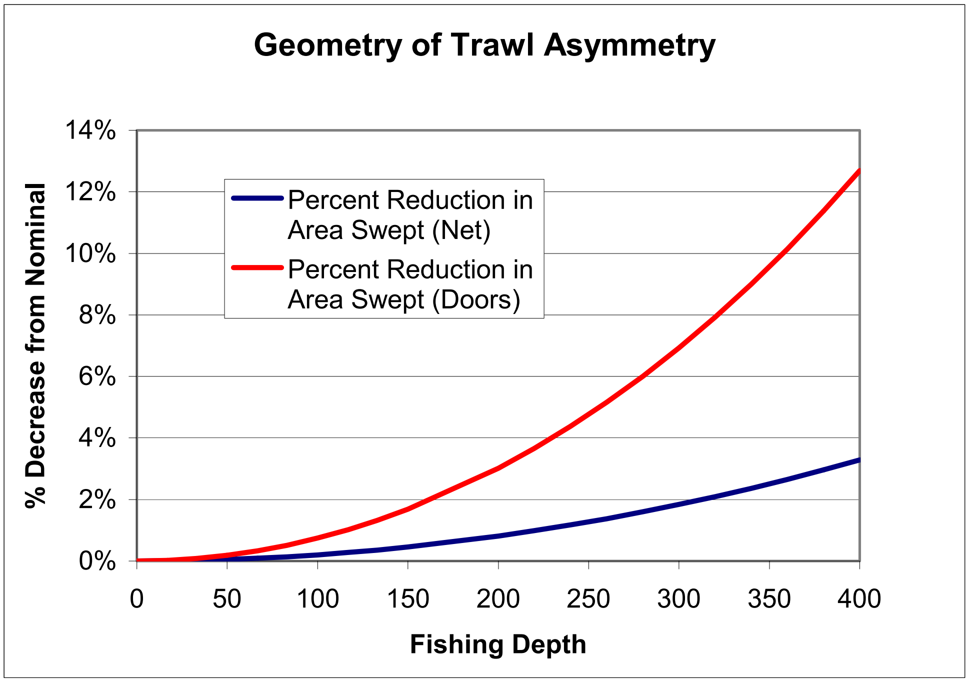



Figure 3.1.2 Predicted effect of trawl offset on reduction in area swept for fishing depths from 0 to 400 m.

## 3.2 Frequency of Damaged Bottom Trawl Gear in NEFSC Surveys

Summary

1) Analysis of tow records for NEFSC spring, fall and winter bottom trawl surveys by the R/V *Albatross IV* using the Yankee No. 36 bottom trawl during 1982-2002 shows that the frequency of tows with damage to survey bottom trawls varied randomly during 1983-2002, with relatively little variation during recent years.
2) Of eight surveys during 2002-2002 with mis-marked warps, two surveys had more than average levels of any gear damage while six surveys had average or less than average levels of any gear damage.
3) Simple graphical analyses and GAM model results suggest that mis-marked warps had little or no effect on the probability of gear damage.
4) Frequency of gear damage increases with depth. However, the frequency of major damage (i.e. severe enough to preclude use of the tow in stock assessment calculations) is not appreciable at depths routinely surveyed and for tows used in most stock assessments.

Introduction

Gear damage may have increased or decreased during recent surveys if mis-marked warps affected operating characteristics of the NEFSC survey bottom trawls. Gear damage data provide evidence about possible changes in net operating characteristics. However, gear damage data probably provide no information about changes in the fishing efficiency of NEFSC bottom trawls. Gear damage and fishing power are not directly linked because their relationship is unknown (a net prone to damage may catch more or less fish than a net not prone to damage), and because survey tows with major damage are routinely excluded from NEFSC stock assessment calculations.

We examined trends in survey tow records to determine if mis-marked warps changed the frequency of survey tows with gear damage. The information used was qualitative gear condition data recorded by the watch chief or chief scientist routinely following all bottom trawl survey tows. Although the data are qualitative, they were collected and recorded based on consistently applied and specific criteria that are available to all watch chiefs and chief scientists.

Tows included in the analysis were from all randomly allocated survey tows (STATYPE=1) by the NOAA Research Vessel *Albatross IV* using the Yankee No. 36 trawl during spring, fall and winter survey cruises beginning in 1983 (Table 3.2.1). Spring and fall surveys cover the same grounds and the all tows since 1983 used the same type of net. Winter surveys have consistently used a different net (with roller gear in place of a ground cable) and cover a smaller area that excludes rocky grounds (mainly on the northern half of Georges Bank) where gear damage may be more likely to occur.

Data used in this analysis were for tows at depths ≤ 620 m. The maximum depth of survey strata for tows used in stock assessments varies but is near 200 fathoms (366 m). Tows with STATYPE=1 at depths greater than 366 m were included (n=23, 0.2% of the total) because they provide useful information about gear damage at relatively extreme depths. However, tows deeper than 366 m are generally not used in stock assessment work because they are not "random" in the same way as tows randomly allocated to survey strata.

Gear damage was evaluated in in three main categories: i) "any" damage, including slight damage that does not prevent use of data from a survey tow in stock assessment work, ii) "major" damage that is severe enough to prevent use of stock assessment data from a tow, and iii) "minor" damage. The frequency of minor damage is of interest because most tows classified as minor for this analysis would also be used in stock assessments (the definitions of useful tows for stock assessment work and tows with minor damage for this assessment correspond approximately). Tows with minor damage were computed by subtraction (i.e. minor = any-major).

Survey bottom trawl tows with gear damage were identified in the NEFSC survey database using the GEARCOND variable, which is part of the data collected by the survey watch chief at the end of each tow. GEARCOND records the physical condition of the trawl on deck at the end of the tow, as judged by the watch chief or chief scientist based on specific criteria. For this analysis, tows with any gear damage were defined as tows with GEARCOND = 2 or larger. Tows with a major damage were defined as tows with GEARCOND=7 or larger.

GEARCOND=6 is used for tows that are obstructed by debris encountered during the tow. The probability of picking up debris is related to tow location and unlikely to be affected by mis-marked warps. Therefore, tows with GEARCOND=6 were excluded. Thus, the analysis dealt with the probability of gear damage in tows that were not significantly obstructed by debris.

A total of 11,402 tows were used in the analysis. In total, 1,102 tows (9.7%) had any gear damage (as defined above), 173 tows (1.5%) had major gear damage and 1102-173=929 tows (8.1%) had minor damage (Table 1 and Figures 3.2.1 to 3.2.3). Proportions for fall, spring and winter surveys were similar (see below).

| | N Tows | Proportion tows with "any" gear problems (GEARCOND ≥2 ) | Proportion tows with "major" gear problems (GEARCOND ≥7 ) | Proportion tows with "minor" gear problems (GEARCOND ≥7 ) |
|---|---|---|---|---|
| FALL | 4696 | 0.0945 | 0.0132 | 0.0813 |
| SPRING | 5402 | 0.0950 | 0.0139 | 0.0811 |
| WINTER | 1304 | 0.1112 | 0.0276 | 0.0836 |
| All | 11402 | 0.0966 | 0.0152 | 0.0815 |

There is no evidence that mis-marked warps increased the probability of gear damage based on trends in frequencies of damaged gear (Table 3.2.1 and Figure 3.2.3). Frequencies of damaged bottom trawls in surveys during 2002-2003 with mis-marked warps were generally lower than average. In particular, six out of eight surveys (75%) during 2000-2002 had lower than average levels of any gear damage. Four out of eight surveys (50%) during 2000-2002 had below average levels of major gear damage. Gear damage was more variable for the fall survey prior to 1988 and for the winter survey prior to 1996. Trends in gear damage for recent surveys with mis-marked warps were similar to trends in prior years.

Modeling

Generalized additive models (GAMs) were used to refine estimates of probability for gear damage during each cruise. Separate GAM models for major and minor gear damage were fit to tow-by-tow survey data by maximum likelihood assuming that the occurrence of gear damage followed a binomial distribution (i.e. as in logistic regression). Cruise id number, season (fall, spring or winter) and mis-marked warps were treated as categorical variables. Treating cruise id numbers as a categorical variable is, in effect, the same as including statistical interactions between all categorical variables that change from survey to survey (i.e. year, season, vessel and type of trawl) and makes season almost redundant. Average tow depth and swell height were included in models as covariates. The relationship between frequency of gear damage and covariates was modeled using loess scatter plot smoothers. The loess term for depth, for example, was a smooth line that allowed estimates of depth effects on gear damage to change continuously with depth.

Swell height was missing in 762 out of 11,402 tows (6.7% of the total) but was not significant in preliminary model runs using the subset of tow records that included swell height data. Therefore, swell height was omitted from further GAM modeling.

Final GAM models were identified using F-tests to measure goodness of fit. A stepwise procedure identified the best final model by eliminating variables with insignificant effect on model fit. However, mis-marked warp effects were always included in final models because they are of special interest. The best model for any damage included warps, cruise, and depth effects. The best model for major damage included only warp and depth effects.

Based on GAM model results, there was no evidence of increased probability of any or major gear damage in cruises with mis-marked warps. Warp effect estimates were very small and statistically insignificant in final models (Figure 3.2.4). Depth had a much stronger effect on the probability of gear damage than any other variable. The probability of any or major damage increases steadily with depth and loess terms for depth were highly significant ($p < 0.0000001$) in both models.

To describe the effects of depth in simple terms, predicted percent tows with any damage and with major damage were calculated from GAM models fit to data for years with and without potential warp effects. The probability of gear damage during cruises with mis-marked warps fell within the range for cruises without the potential problem (Figure 3.2.5). The probability of major gear damage during cruises with and without mis-marked warps was similar at depths < 360 m (Figure 3.2.5). Results for major damage at depths greater than 360 m were erratic for mis-marked warps due to scarcity of tows in deep water during 2000-2002.

The probability of any gear damage averages about 10% at depths less than 220 m and increases to about 25% at 360 m.  The probability of major gear damage increases with depth and is less than 6% at all depths less than 360 m. For data collected at depths < 360 m and routinely used in stock assessments, almost all gear damage was minor.

Table 3.2.1. Gear damage and summary information for bottom trawl survey cruises by the *R/V Albatross IV* during 1983-2002. The proportion tows with "any" gear damage is the proportion tows with GEARCOND ≥2. The proportion tows with "major" gear damage is the proportion tows with GEARCOND≥7. Proportion tows with "minor" gear problems was computed by subtraction (any-major). Obstructed tows (GEARCOND=6) were excluded Eight surveys during 2000-2002 had mis-marked warps.

| Cruise | Year | Season | N Tows | Proportion tows with "any" gear problems (GEARCOND ≥2 ) | Proportion tows with "major" gear problems (GEARCOND ≥7 ) | Proportion tows with "minor" gear problems (GEARCOND ≥7 ) |
|---|---|---|---|---|---|---|
| 198306 | 1983 | Fall | 410 | 0.059 | 0.010 | 0.049 |
| 198405 | 1984 | Fall | 347 | 0.115 | 0.009 | 0.107 |
| 198508 | 1985 | Fall | 148 | 0.122 | 0.027 | 0.095 |
| 198606 | 1986 | Fall | 251 | 0.187 | 0.012 | 0.175 |
| 198705 | 1987 | Fall | 319 | 0.053 | 0.016 | 0.038 |
| 198803 | 1988 | Fall | 305 | 0.079 | 0.013 | 0.066 |
| 199206 | 1992 | Fall | 332 | 0.123 | 0.018 | 0.105 |
| 199406 | 1994 | Fall | 332 | 0.120 | 0.018 | 0.102 |
| 199507 | 1995 | Fall | 329 | 0.067 | 0.006 | 0.061 |
| 199604 | 1996 | Fall | 315 | 0.137 | 0.022 | 0.114 |
| 199706 | 1997 | Fall | 318 | 0.072 | 0.006 | 0.066 |
| 199804 | 1998 | Fall | 322 | 0.084 | 0.012 | 0.071 |
| 199908 | 1999 | Fall | 326 | 0.077 | 0.015 | 0.061 |
| 200005 | 2000 | Fall | 317 | 0.060 | 0.003 | 0.057 |
| 200109 | 2001 | Fall | 325 | 0.105 | 0.018 | 0.086 |
| 198303 | 1983 | Spring | 410 | 0.132 | 0.015 | 0.117 |
| 198402 | 1984 | Spring | 400 | 0.098 | 0.013 | 0.085 |
| 198502 | 1985 | Spring | 371 | 0.078 | 0.016 | 0.062 |
| 198603 | 1986 | Spring | 362 | 0.088 | 0.006 | 0.083 |
| 198702 | 1987 | Spring | 281 | 0.121 | 0.007 | 0.114 |
| 198801 | 1988 | Spring | 315 | 0.067 | 0.010 | 0.057 |
| 199202 | 1992 | Spring | 316 | 0.095 | 0.013 | 0.082 |
| 199302 | 1993 | Spring | 319 | 0.103 | 0.013 | 0.091 |
| 199503 | 1995 | Spring | 325 | 0.055 | 0.012 | 0.043 |
| 199602 | 1996 | Spring | 344 | 0.142 | 0.026 | 0.116 |
| 199702 | 1997 | Spring | 326 | 0.077 | 0.012 | 0.064 |
| 199802 | 1998 | Spring | 360 | 0.097 | 0.017 | 0.081 |
| 199902 | 1999 | Spring | 317 | 0.066 | 0.016 | 0.050 |
| 200002 | 2000 | Spring | 325 | 0.095 | 0.015 | 0.080 |
| 200102 | 2001 | Spring | 315 | 0.095 | 0.016 | 0.079 |
| 200202 | 2002 | Spring | 316 | 0.101 | 0.016 | 0.085 |
| 199201 | 1992 | Winter | 62 | 0.048 | 0.032 | 0.016 |
| 199301 | 1993 | Winter | 116 | 0.043 | 0.000 | 0.043 |
| 199502 | 1995 | Winter | 151 | 0.179 | 0.040 | 0.139 |
| 199601 | 1996 | Winter | 134 | 0.112 | 0.037 | 0.075 |
| 199701 | 1997 | Winter | 124 | 0.121 | 0.032 | 0.089 |
| 199801 | 1998 | Winter | 133 | 0.128 | 0.023 | 0.105 |
| 199901 | 1999 | Winter | 139 | 0.122 | 0.036 | 0.086 |
| 200001 | 2000 | Winter | 124 | 0.105 | 0.032 | 0.073 |
| 200101 | 2001 | Winter | 167 | 0.114 | 0.018 | 0.096 |
| 200201 | 2002 | Winter | 154 | 0.091 | 0.026 | 0.065 |

Figure 3.2.1. Location of tows by the *R/V Albatross IV* with "any" damage in NEFSC fall, spring and winter surveys during 1983-2002.

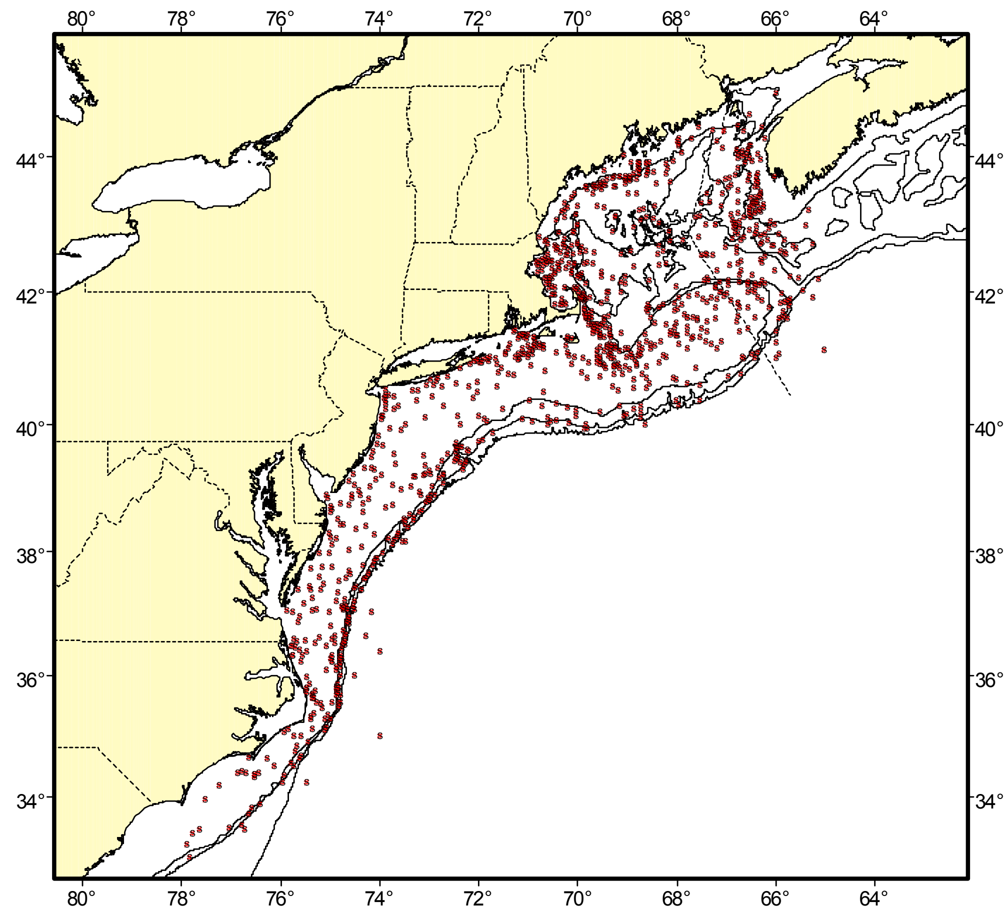


Figure 3.2.2. Location of tows by the *R/V Albatross IV* with "major" damage in NEFSC fall, spring and winter surveys during 1983-2002.

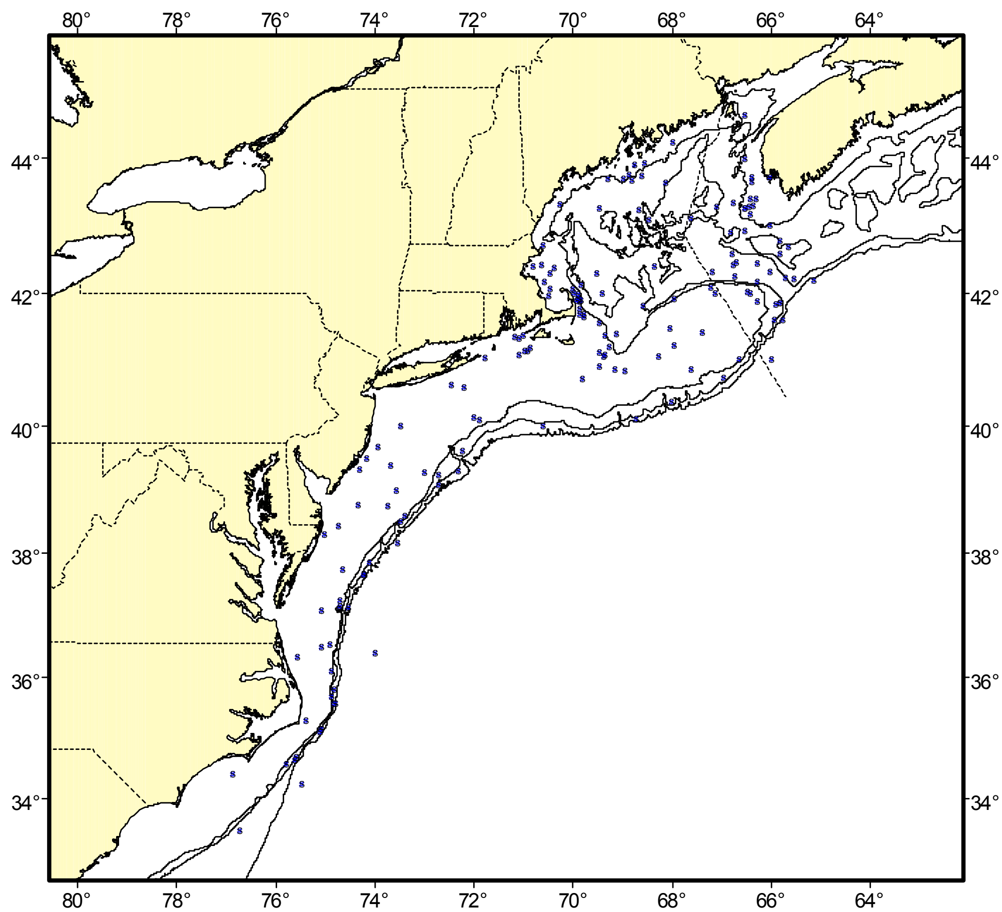


Figure 3.2.3. Proportion of tows with any, minor and major damage in NEFSC fall, spring and winter surveys during 1983-2002. The vertical line in each plot separates tows with and without mis-marked warps. The horizontal line in each plot shows the average proportion of tows in each survey with any gear damage.

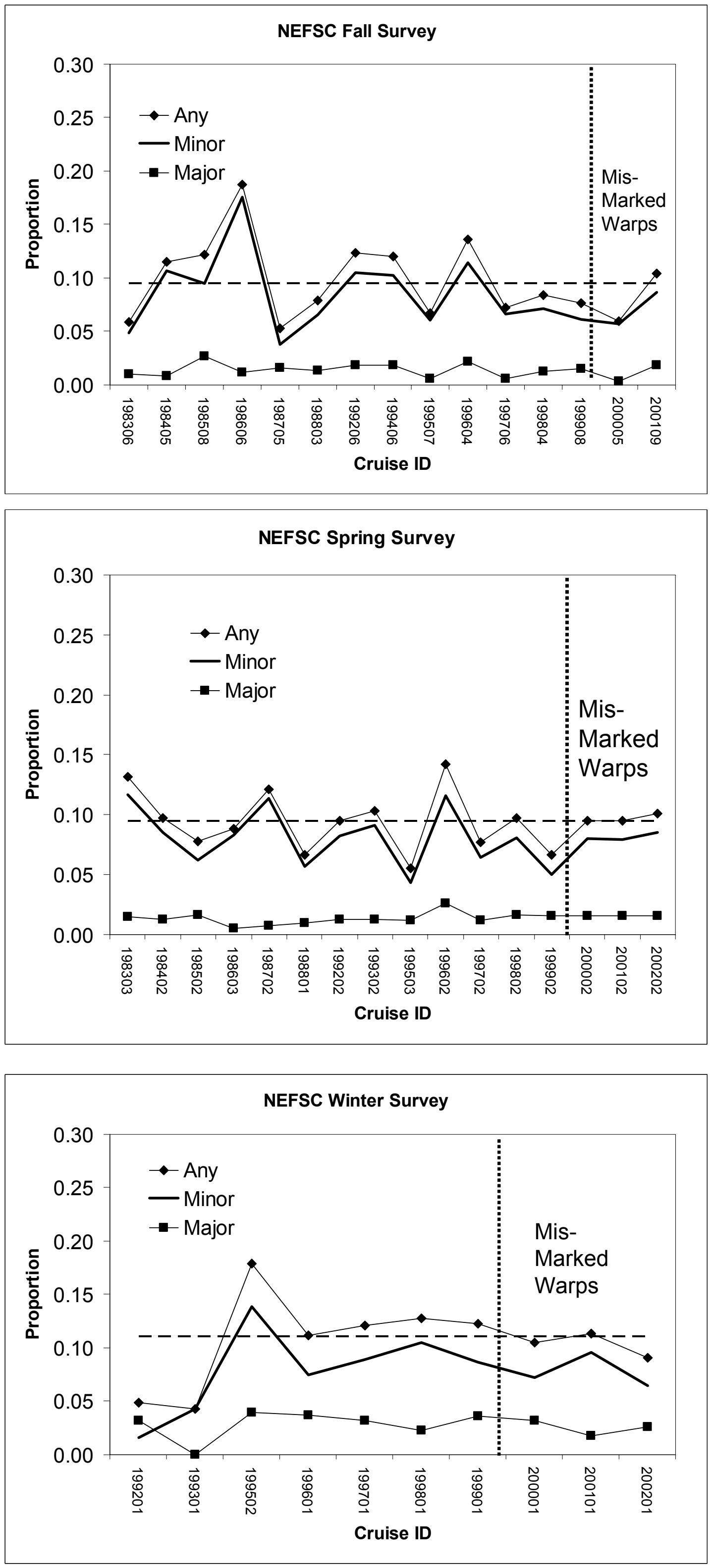


Figure 3.2.4. Estimated warp effects in the final GAM model for the frequency of any damage during NEFSC survey tows. The dotted lines are 95% confidence intervals for the parameter estimates. Results from models for major damage were similar.

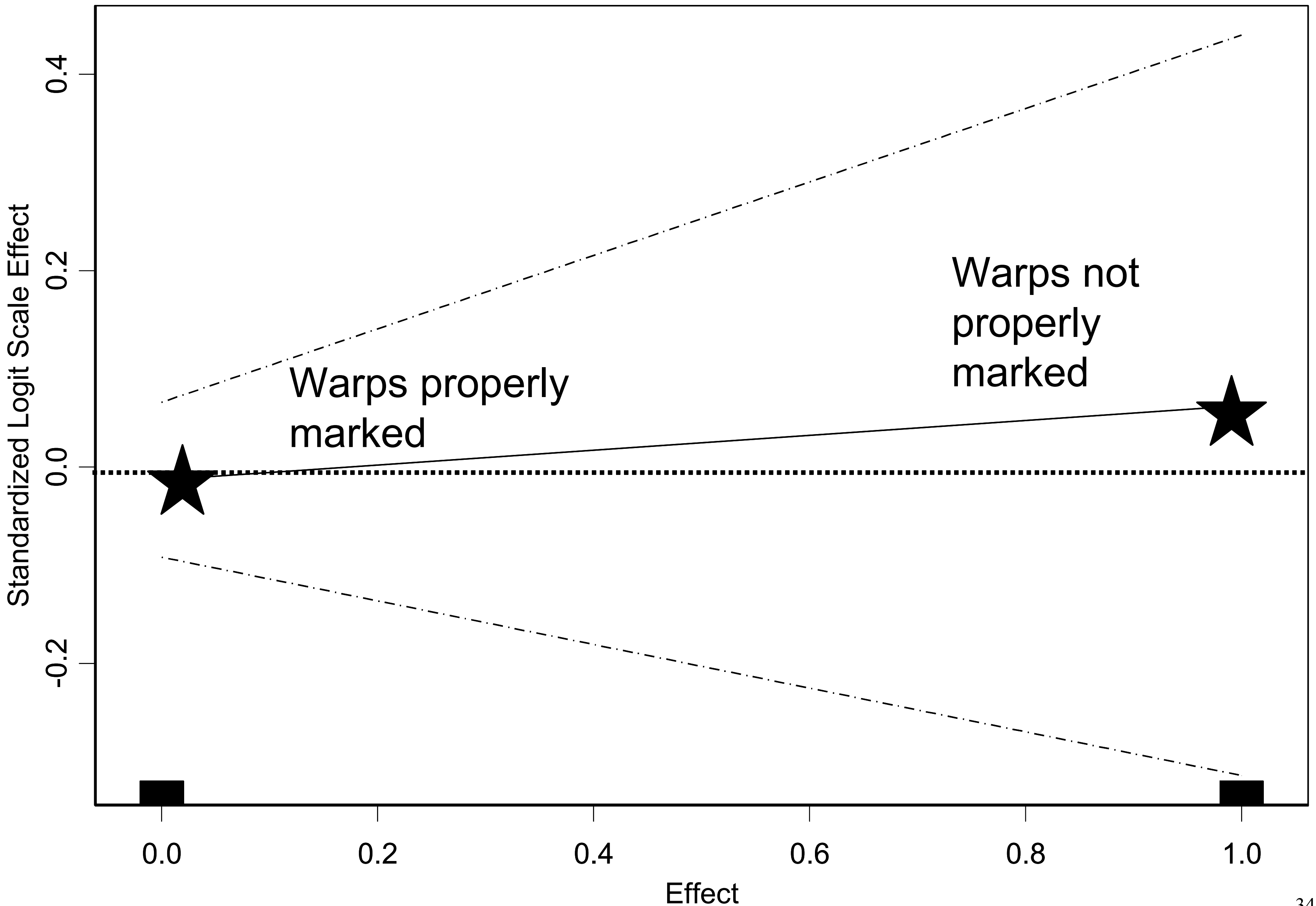
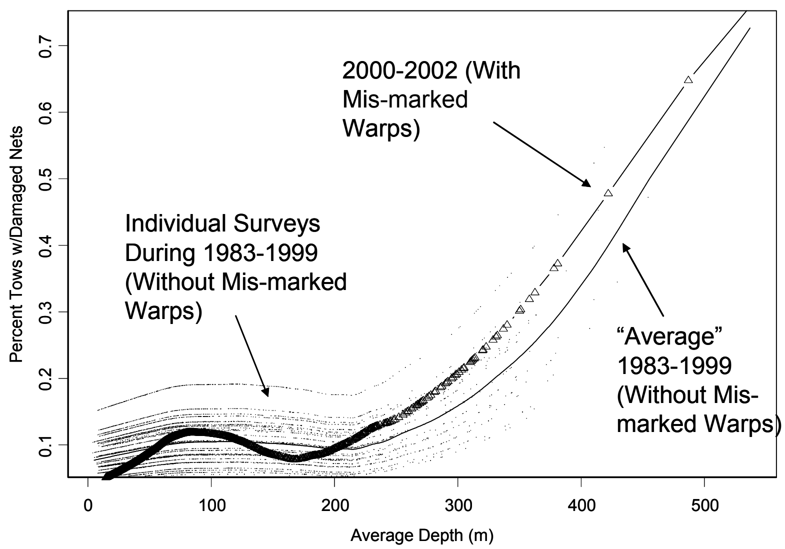
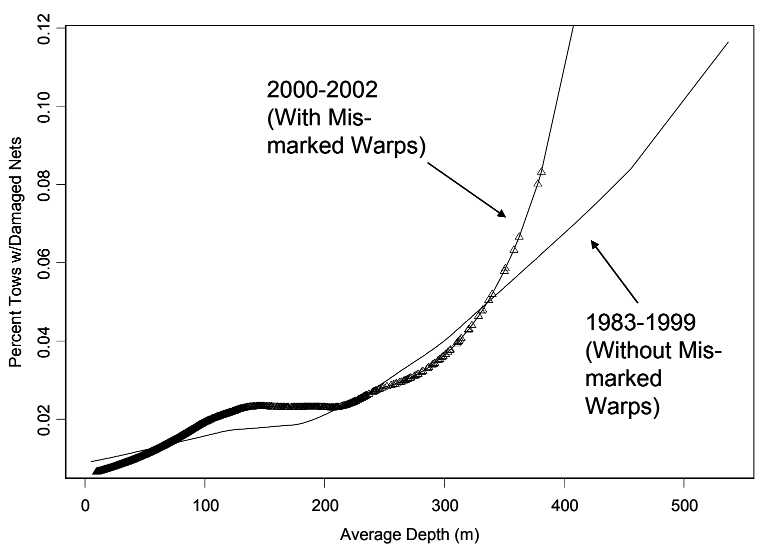


Figure 3.2.5. Predicted frequency of tows with any (top) and major (bottom) gear damage as a function of tow depth, based on separate GAM models for surveys during 2000-2002 with mis-marked warps and surveys during 1983-2001 without mis-marked warps. The GAM model for any damage with warp effects includes depth only. The best GAM model for any damage included cruise effects and predictions for each cruise are plotted ".". In addition, "average" results for any damage from a simplified model with cruise effects omitted are also shown.



### 3.3 Evaluation of Fish Size in Relation to Offsets


Summary and Conclusions

There is no evidence that mis-marked warps affected length composition of cod, haddock or yellowtail flounder taken by the *R/V Albatross IV*. Mis-marked warps did not appear to reduce or increase, on a proportional basis, the catch of large or small fish.


Introduction

In this analysis, survey length composition data from NEFSC survey bottom trawls with mis-marked warps were compared to length composition data from other bottom trawl surveys and from commercial bottom trawls. The purpose of the analysis was to test the hypothesis that mis-marked warps affected the catch of small or large fish in NEFSC survey bottom trawls during 2000-2002. The analysis focused on three key species (cod, haddock and yellowtail flounder) and there were three groups of comparisons (see below).

The first group of analyses (Figures 3.3.1 to 3.3.3) used data from NEFSC and DFO (Department of Fisheries and Oceans Canada) spring surveys over the Canadian portion of Georges Bank during 1997-1999 ("pre-warps") and 2000-2002 ("post warps"). Both spring bottom trawl surveys cover the same area on Georges Bank at about the same time of year. The Canadian portion of Georges Bank (DFO bottom trawl strata 5Za-5Zb; NEFSC offshore survey strata 16-18 and 21-22) was selected for analysis because fish abundance is relatively high on the Canadian side and intensity of DFO sampling is reduced in US portions of Georges Bank. Data were for depths less than 100 fathoms (183 m) because the DFO survey does not sample deeper water near Georges Bank.

The second group of analyses involved monkfish length composition data for the Georges Bank and Mid-Atlantic Bight areas from the 2001 NEFSC winter bottom trawl survey (with mis-marked warps) and length composition data collected by commercial vessels (6 inch mesh codends with no liner) during the 2001 cooperative monkfish survey.

The third group of analyses involved length composition data for paired tows in a fishing power experiment during the 2001 NEFSC spring bottom trawl survey. For the fishing power experiment, the *R/V Delaware II* (no mis-marked warps) towed the same type of net beside the track towed by the *R/V Albatross I* (with mis-marked warps) at the same time or approximately the same time. The purpose of the experiment was to calibrate catches by the vessels. Problems with mis-marked warps on the *R/V Albatross IV* were unknown at the time. Fishing power of the two vessels differs for some species but length composition data depend primarily on the type and configuration of the trawl. Thus, length composition data from the two vessels should differ if mis-marked warps affected the length composition of catches by the *R/V Albatross IV*.

Average length composition data for each time period were used in most comparisons. Averages were computed by expressing the length composition for each survey (or tow) as proportions and then averaging the proportions for each survey.

Results

Length composition data for cod and yellowtail flounder from the Canadian portion of Georges Bank were similar in the two spring surveys and in the pre-and post warp periods (Figures 3.3.1 to 3.3.3). The DFO survey took more large haddock and less small haddock, on a proportional basis, than the NEFSC survey during both periods. Length composition data for haddock in the NEFSC survey appear more variable than for the DFO survey, probably because the sample size (number of tows, see below) is lower in the NEFSC survey for the Canadian side of Georges Bank. Given the sample size for NEFSC surveys, the wide range of sizes, and natural variability in haddock, the differences in length composition data for haddock in the pre- and post-warp periods are best attributed to random variability in the data.

| Survey | Number Pre-Warp Tows (1997-1999) | Number Post warp Tows (2000-2002) |
|---|---|---|
| NEFSC Spring | 67 | 65 |
| DFO | 127 | 131 |

Length composition data from the 2001 NEFSC bottom trawl survey and commercial vessels in the Cooperative Monkfish Survey show that NEFSC survey bottom trawls took proportionally more small monkfish due to the small mesh liner in survey bottom trawls (< 25 cm, Figure 3.3.4). However, length composition data for larger monkfish (> 25 cm) were similar suggesting that mis-marked warps had little effect on size composition of monkfish in the NEFSC survey.

Length composition data from paired tows by the R/V *Albatross IV* (with mis-marked warps) and R/V Delaware II (without mis-marked warps) during the 2002 spring survey fishing power experiment were virtually identical for cod, haddock and yellowtail flounder (Figure 3.3.5).

Fig. 3.3.1. Length composition data for cod on Georges Bank in spring surveys.

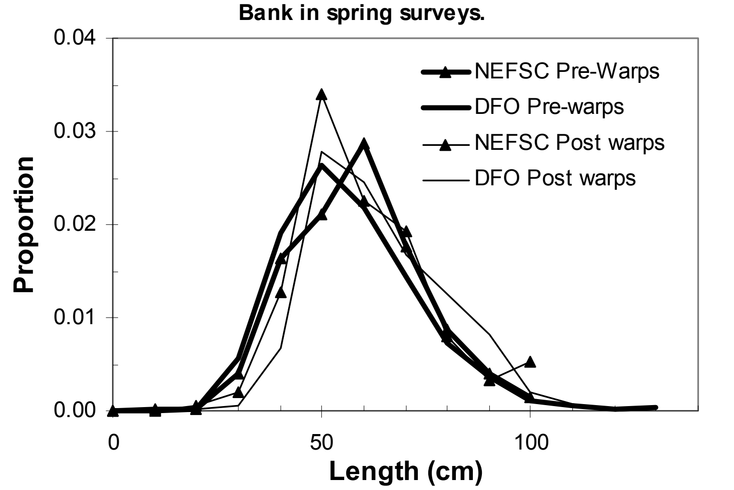



Fig. 3.3.2. Length composition data for haddock on Georges Bank in spring surveys.

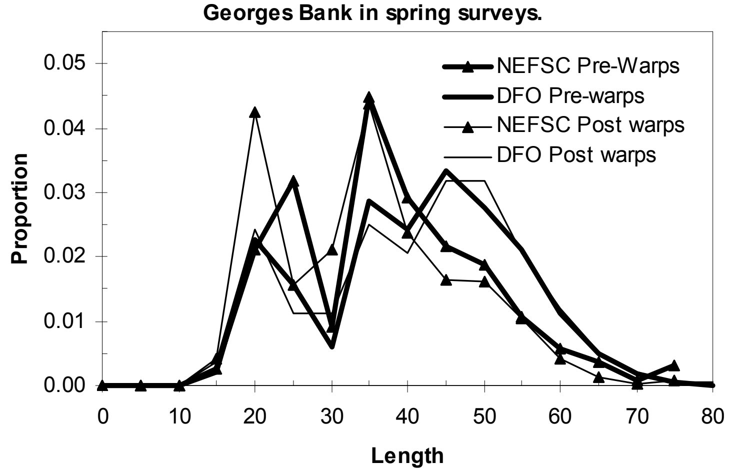



Fig. 3.3.3. Length composition data for yellowtail flounder on Georges Bank in spring surveys.

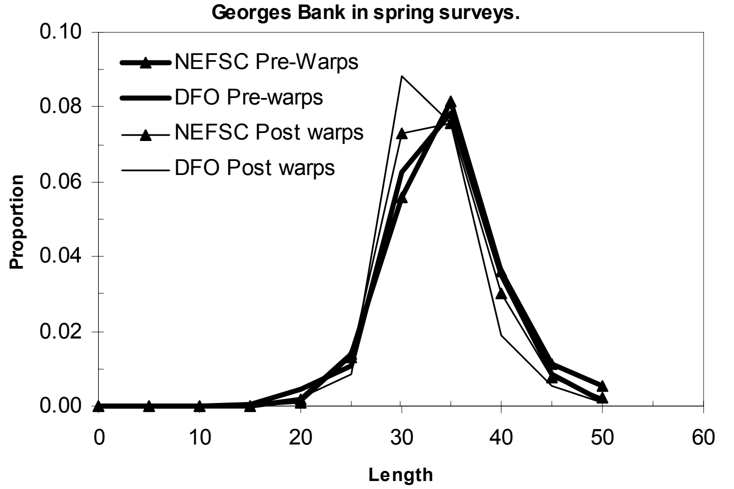


Figure 3.3.4. Length composition data for monkfish during 2001 in the NEFSC winter survey (northern and southern areas) and commercial vessels in the Cooperative Monkfish Survey (southern area).

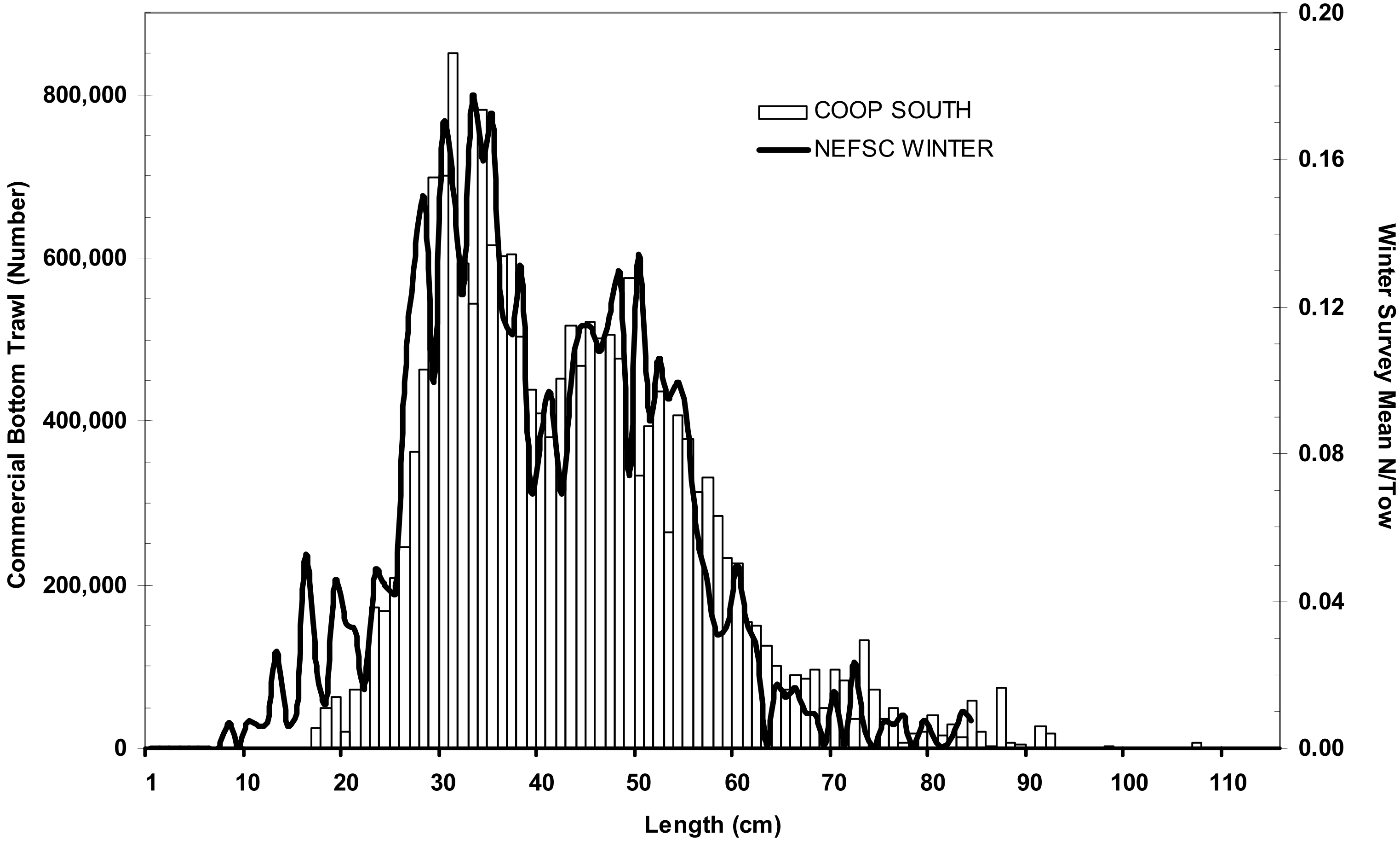
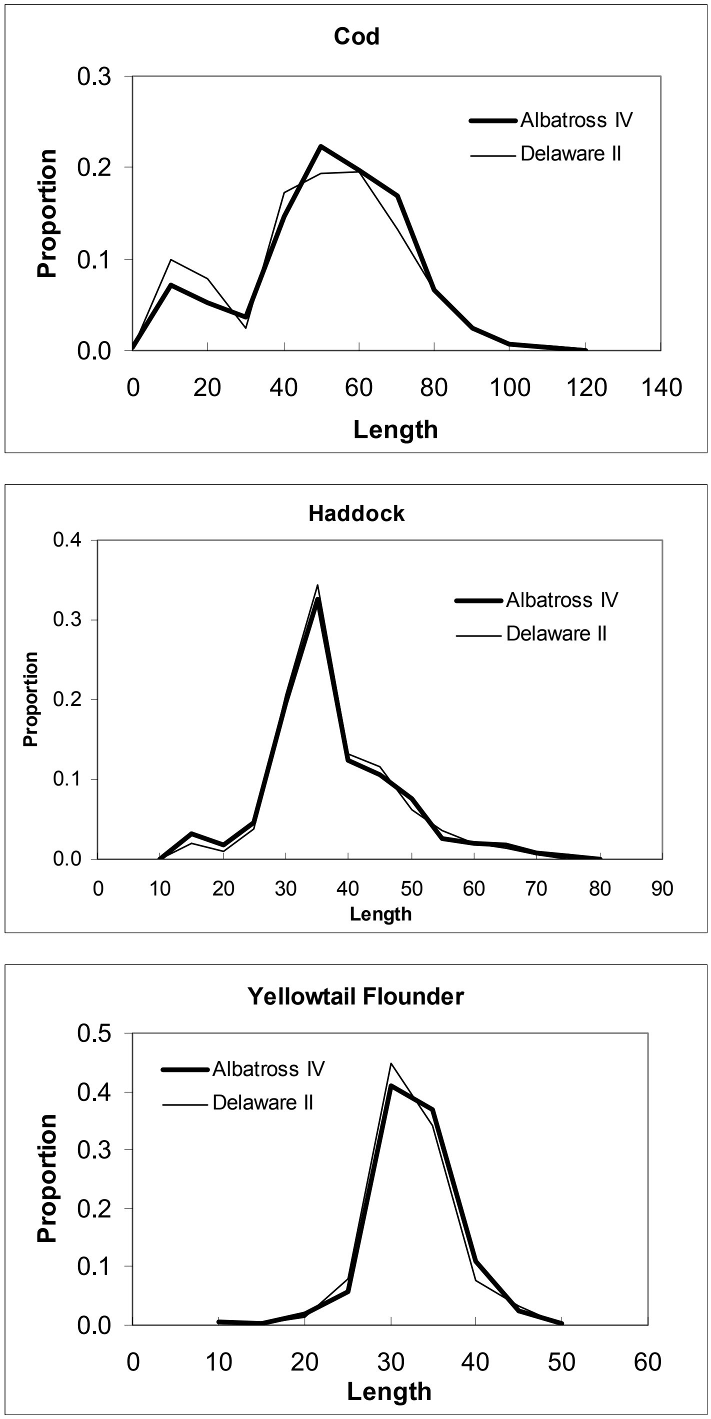


Figure 3.3.5. Length composition data for cod, haddock and yellowtail flounder in paired tows for a fishing power experiment during the spring of 2002.



## 3.4 Evaluation of Gear Mensuration Data from the R/V *Albatross IV* Trawl Warp Offset Experiment

The effects of trawl warp length offsets on the gear performance of the R/V *Albatross* were assessed during a controlled experiment, conducted on September 25-26, 2002, at six stations ranging in depth from 46-91 m (Figure 3.4.1). During each tow, gear performance was assessed through videotaping and logging of gear mensuration data from Simrad sensors mounted on the doors and the trawl wing ends and headrope of a Yankee 36 net. In addition, several other variables logged by the Simrad ITI system, such as speed over ground, vessel location and water depth were evaluated.

During each tow, warp length offsets of 0 ft. (equal port and starboard warp lengths), 2 ft., 4 ft., 6 ft., and 12 ft. were paid out from the starboard side of the vessel, followed by the port side of the vessel. An additional offset of 18 ft. was fished at the deepest station sampled (station 907). At each station, the trawl winches were locked and the trawl was allowed to reach the bottom and stabilize before beginning the experiment. During each tow, the trawl remained in the water throughout all offset changes, and after consistent sensor readings were observed, was allowed to fish for variable periods of time.

Changes in trawl geometry were evaluated graphically and statistically. Wing spread and headrope height readings from each station were graphed over time, between the winch lock and re-engage period, and each warp offset change was denoted. No headrope height readings were obtained at station 904. Door spread was not evaluated because the door sensors did not operate consistently. However, door spread is geometrically related to wing spread and wing spread data were evaluated.

In summary, graphs of headrope height and wingspread were similar across warp offset treatments (horizontal trend) and there was no indication of a change in this trend across stations (depths; Figure 3.4.2).

Headrope height and wingspread data, for port and starboard offsets were also evaluated statistically. At each station, the means and standard deviations of headrope height and wingspread were calculated separately, for port and starboard offsets, for each warp offset time interval (Figure 3.4.3). Headrope height and wingspread data collected at stations 904 and 905 represent single readings, so no statistical evaluation of these data was conducted. Means and standard deviations of headrope height and wingspread for the combined stations (stations 906, 907, 908 and 909) were also computed.

In summary, port and starboard wingspread means for each warp offset treatment were similar. The same was true for headrope height means. In addition, there was no significant difference detected between wingspread means for warp length offsets of 0-6 ft. at depths of 49-91 m. The same was true for headrope height means. Differences between headrope height means for even warps and warp length offsets of 12 ft. varied in significance between stations. The same was true for wingspread means. There was no significant difference detected between wingspread means, for all stations combined, for warp length offsets of 0-12 ft. at depths of 49-91 m. The same was true for headrope height means for all stations combined (Figure 3.4.4). At the deepest station (91 m), there was no significant difference between headrope height means of warp length offsets of 0-18 ft. The same was true for wingspread means for the starboard side.

These data indicate that even at warp offsets greater than depths where groundfish stocks are typically found (Figure 3.7.31), the net remains spread and open, with mensuration readings very similar to the no-offset condition. While this does not prove that warp offsets on catch rates are negligible, had net dimensions changed dramatically, survey catches would most likely have been affected.

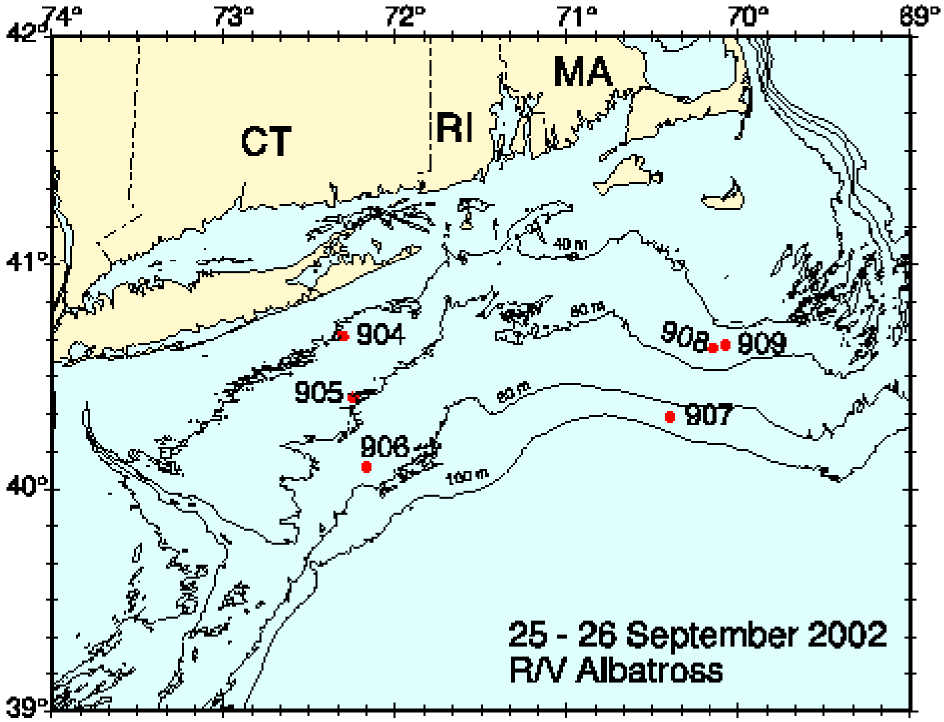



Figure 3.4.1. Locations of stations where video and trawl sensor data were collected to assess the effects of warp length offsets on the trawl performance (Yankee 36 net) of the R/V *Albatross IV* during 25-26 September, 2002.

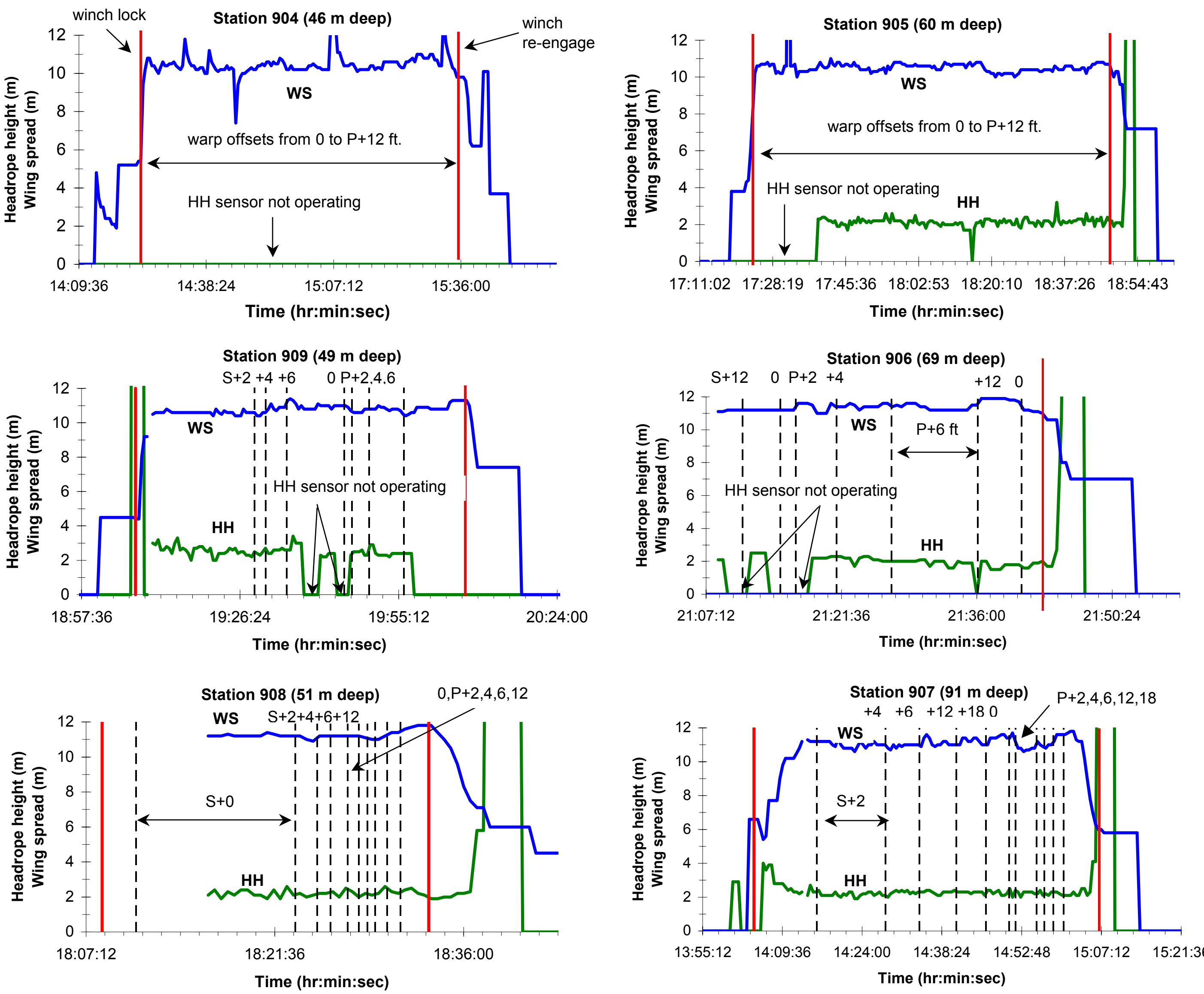
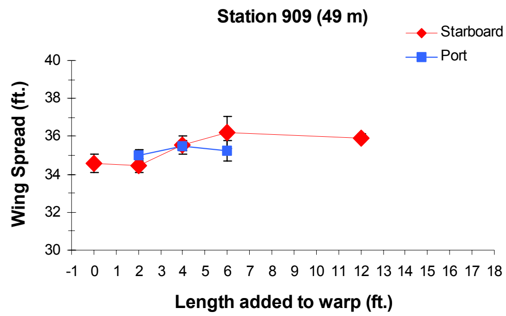
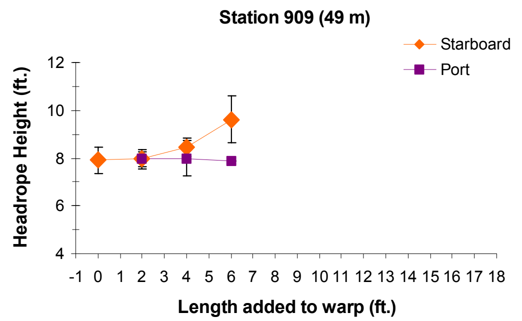
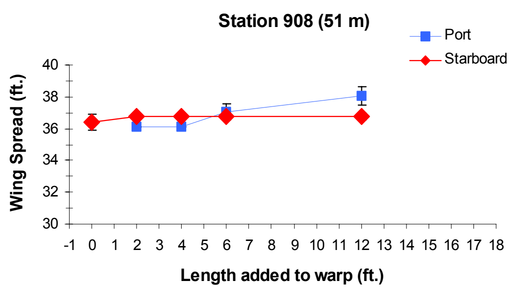
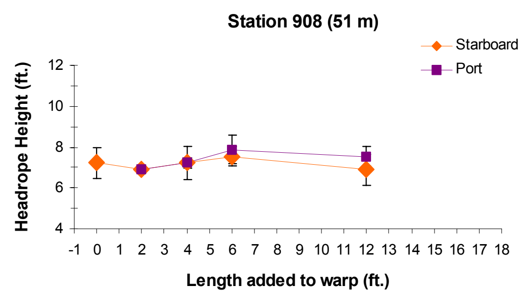


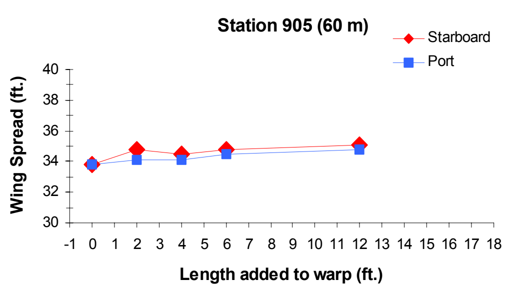

Figure 3.4.2. Yankee 36 headrope height (ft.) and wing spread (ft.) measurements recorded by the Simrad ITI system of the R/V *Albatross IV* at stations sampled during a 25-26 September, 2002 warp length offset experiment. Dashed lines represent starboard (S) and port (P) trawl warp length offsets of 0 ft., 2 ft., 4 ft., 6 ft., 12 ft. and 18 ft.

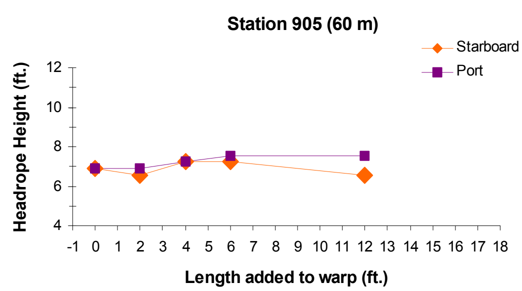

Station 909 (49 m)
Starboard
Port
Wing Spread (ft.)
Length added to warp (ft.)

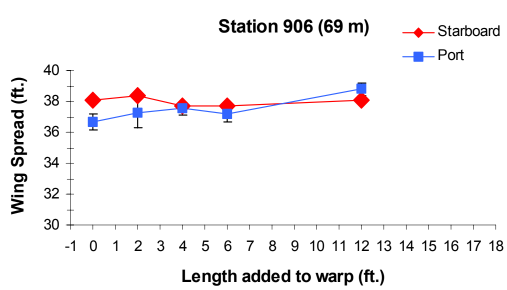

Station 909 (49 m)
Starboard
Port
Headrope Height (ft.)
Length added to warp (ft.)

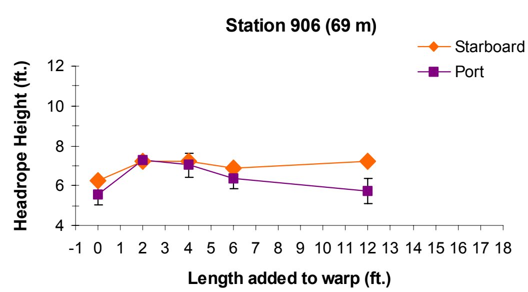

Station 908 (51 m)
Port
Starboard
Wing Spread (ft.)
Length added to warp (ft.)

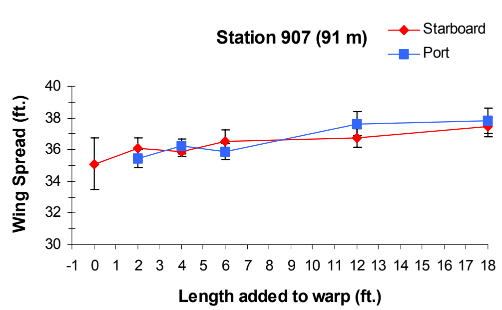

Station 908 (51 m)
Starboard
Port
Headrope Height (ft.)
Length added to warp (ft.)

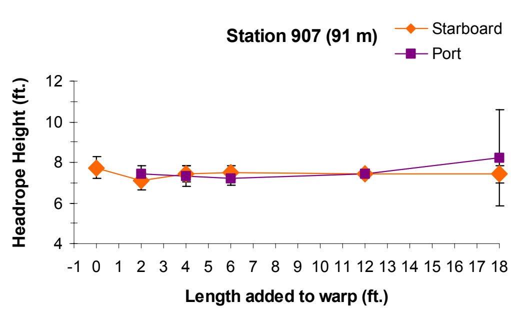

Station 905 (60 m)
Starboard
Port
Wing Spread (ft.)
Length added to warp (ft.)

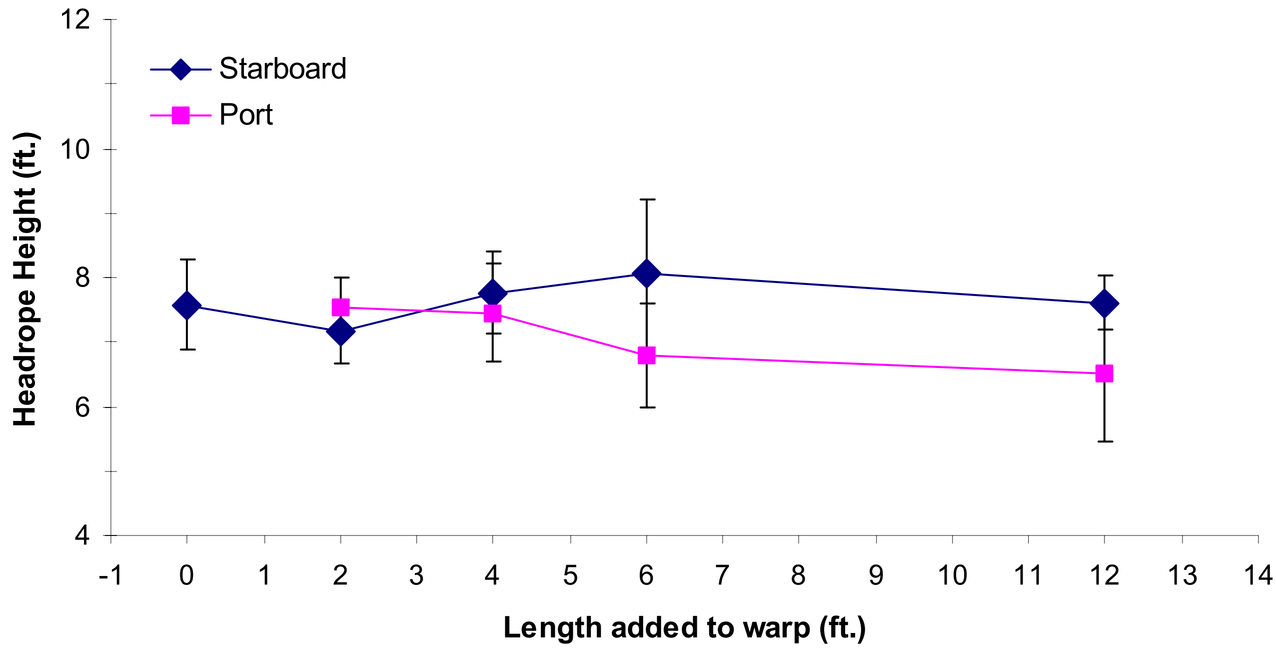

Station 905 (60 m)
Starboard
Port
Headrope Height (ft.)
Length added to warp (ft.)


Station 906 (69 m)
Starboard
Port
Wing Spread (ft.)
Length added to warp (ft.)


Station 906 (69 m)
Starboard
Port
Headrope Height (ft.)
Length added to warp (ft.)


Station 907 (91 m)
Starboard
Port
Wing Spread (ft.)
Length added to warp (ft.)


Station 907 (91 m)
Starboard
Port
Headrope Height (ft.)
Length added to warp (ft.)



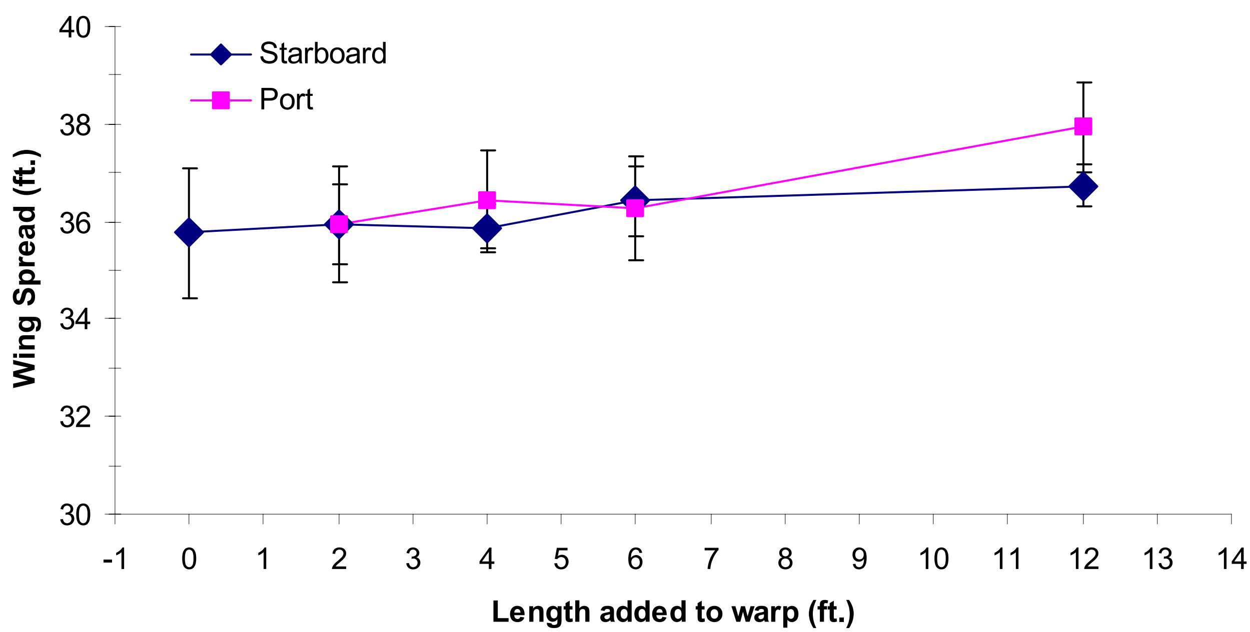




Figure 3.4.4. Means and standard deviations of headrope height (ft.) and wing spread (ft.) measurements of the Yankee 36 net of the R/V *Albatross IV,* at starboard and port trawl warp length offsets of 0 ft., 2 ft., 4 ft., 6 ft., 12 ft., for stations 906, 907,908 and 909 combined. Starboard warp offsets of 0-6 ft. do not include station 906 because these data were not obtained.

### 3.5 Models to Evaluate Changes in Relative Efficiency

The nature of the mismarked cables (i.e., discrepancies increasing with wire length) and the basic geometry of asymmetry suggest that the catchability bias should increase monotonically with depth. A variety of simple models were examined to explain potential effects of reduced catchability. A basic derivation of the alternative models is presented below.

Regression analysis of warp difference vs. fishing depth (Fig. 3.1.1) suggests a highly significant regression ($R^2$=0.98) in which the warp difference ***dW*** is proportional to depth ***D***.

$$dW = 0.0134\,D \qquad (1)$$

Since the NEFSC trawl surveys began in 1963, 99.9% of the tows have been conducted at depths of less than 390 m. This suggests that the maximum value of dW should be about 5.55 m. If the reduction in relative efficiency dE is proportional to the ratio of the ***dW*** to $dW_{max}$ then one can write

$$dE = \left(\frac{dW}{dW_{\max}}\right) H_{effect} \qquad (2)$$

where $H_{effect}$ is an assumed level of reduction in efficiency at the maximum depth. For example, if 99% of the fish would have been captured at shallower depths were not captured at depth $D_{max}$ then $H_{effect}$ = 0.99. The revised estimate of catch can then be written as

$$C_{rev} = \frac{C_{obs}}{1 - dE} = \frac{C_{obs}}{1 - \left(\frac{0.0134\,D}{W_{\max}}\right) H_{effect}} \qquad (3)$$

Equation 3 can be used to explore the consequences of varying levels of reductions in catch efficiency. For example, the ability to the model to explain a 2X increase in abundance (e.g., if the survey estimates in 2002 were actually 100% higher than estimated) can be tested by summing overall depths and catches in a survey.

$$\sum_j C_{j\,rev} = 2\sum_j C_{j,obs} = \sum_j \left( \frac{C_{j,obs}}{1-\left(\frac{0.0134 D_j}{W_{\max}}\right) H_{effect}} \right) \quad (4)$$

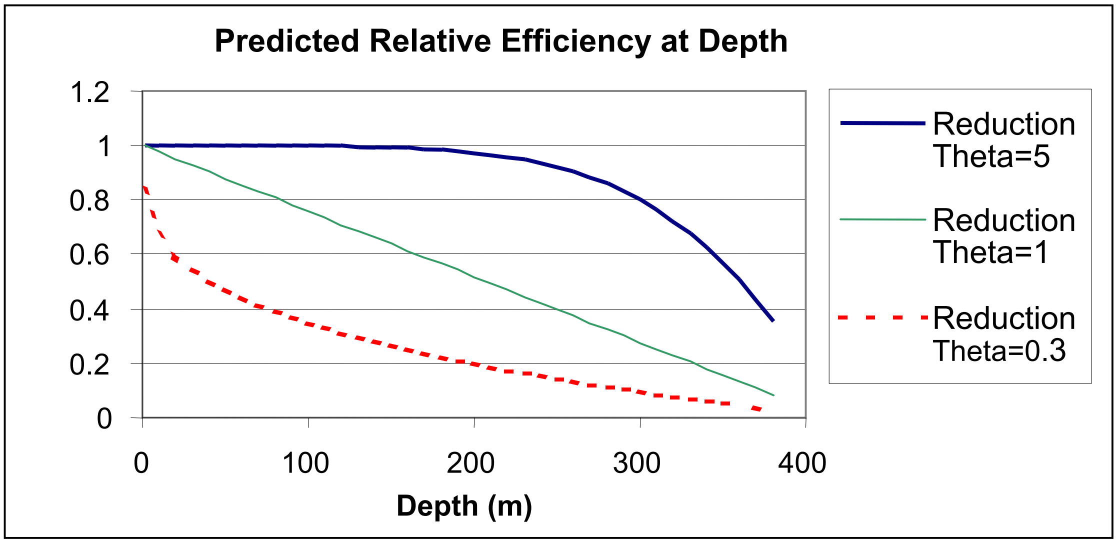
Initial tests with this model however, suggested that it was inadequate to explain increases in catch as high as 50%. This occurs because $H_{effect}$ must be less than 1.0. This simple model deduction suggested that the warp offset effect, if it exists, must be nonlinear. Another simple model that allows for more complicated behavior is to define ***dE(D)*** as

$$dE = \left( \frac{dW}{dW_{\max}} \right)^{\theta} = \left( \frac{0.0134 D}{dW_{\max}} \right)^{\theta} \quad (5)$$

where θ can vary from 0 to infinity. When θ exceeds 1 dE will become smaller. As dE approaches zero, dE will approach 1. Substituting Eq. 5 into Eq. 3 leads to Model 2, which is defined as:

$$C_{rev} = \frac{C_{obs}}{1-dE} = \frac{C_{obs}}{1-\left( \frac{0.0134\, D}{W_{\max}} \right)^{\theta}} \quad (6)$$

Model 2 (Eq. 6) allows for changes in relative efficiency that are linear when θ is 1, convex when θ <1 concave when θ >1. Note that the expression $dW/dW_{max}$ will always be less than one. Model 2 assumes that the reduction in efficiency will approach 1 as depth approaches Dmax when θ is less than one. Under these conditions, the rescaled catch will be much higher than the observed, and the hypothesized effect of a small warp offset is large even at the most shallow depths. In contrast, the reduction in efficiency will stay near zero at nearly all depths when θ >>1, and relatively little difference in catch rates should be evident. The basic premise of the model is that the effect of the warp offset on gear performance should be a monotonically increasing function of warp offset (Fig. 3.5.1). Since the magnitude of warp offset increases with fishing depth, reductions in catch should be more evident at deeper stations.



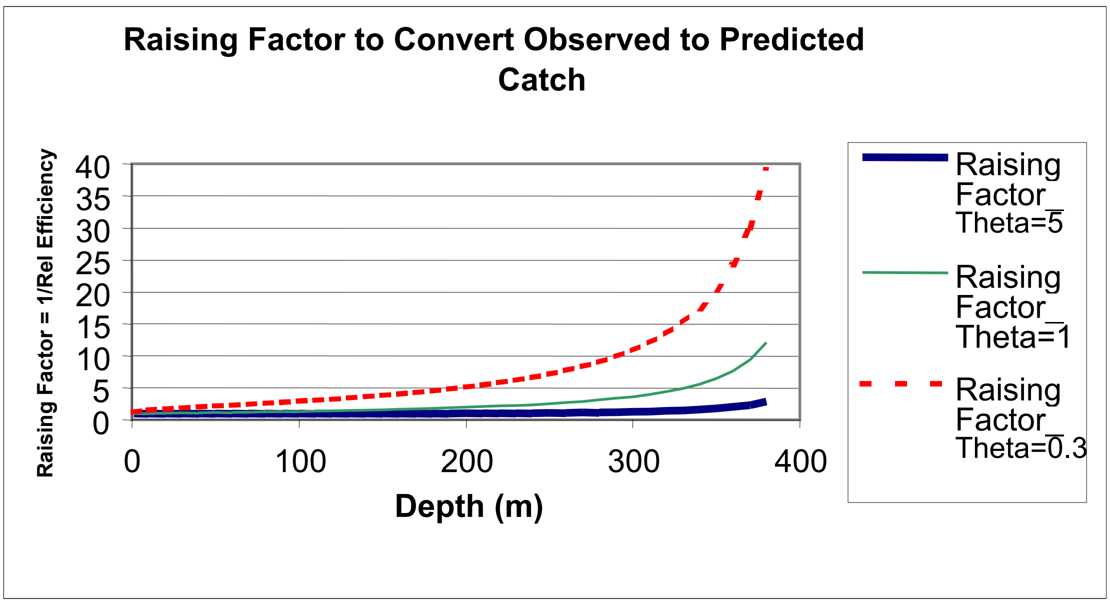




Fig. 3.5.1. Example behavior of Model 2 (Eq. 6) for varying levels of $\theta$. Top panel shows predicted decline in relative efficiency. Bottom panel illustrates raising factor that would be applied to convert observed catch to predicted catch without the warp offset effect.

### 3.6. Variance vs. Mean Relationships

We hypothesized that potential reductions in gear efficiency owing to asymmetric trawl warps may lead to decreases in average catch rates and increases in variance of estimates. To test this hypothesis, we examined survey data from the NEFSC database for the fall, spring, and winter surveys for the period 1963 to 2002. A database of 28,734 tows for 22 species-stocks was used. Total catch in numbers and total weight per tow were the primary response variables; no age or length information was used. Survey catches were subsequently processed to compute statum means and variances (Section 3.6) as well as catch-weighted average depths (Section 3.7). Where appropriate, defined management-based stocks were treated separately. The species (stocks) were—cod(GB,GOM), haddock(GB, GOM), yellowtail flounder(GB, SNE, CC), American plaice, witch flounder, redfish, pollock, halibut, white hake, winter flounder (GB, SNE), windowpane flounder (Northern, Southern), ocean pout, summer flounder, spiny dogfish, fourspot flounder, and longhorn sculpin. Several non-groundfish species were added to evaluate changes in stocks that are ubiquitous (spiny dogfish), lightly fished (fourspot flounder) or unfished (longhorn sculpin).

Coefficients of variation (CV) for catch in numbers and total weight for each stratum were computed as the ratio of the standard error of the mean divided by the stratum mean. It can be shown that this form of the CV has an upper bound of 1.0 for nonnegative random variables. The upper bound of 1.0 arises when all but one of the observations in a set is zero. The distribution of stratum specific CVs was characterized by a box plot which illustrate the median CV as a horizontal center line, and the interquartile range as lower and upper bounds of a box. Time series of the CVs were plotted for each species, stock and survey in Fig. 3.6.1-3.6.20. Halibut catches were considered too infrequent to permit meaningful estimates of stratum specific variances.

If the underlying pattern of catches in the trawls were adversely affected by the trawl offset one would expect to see an increase in the relative variation of catches in the affected survey years (2000-2002). Visual inspection of the 60 time-series plots revealed no apparent change in the magnitude of the CV during the affected period. The interquartile range of CVs since 2000 agreed well (i.e., overlapped) with the trendless pattern of CVs for each species and survey prior to 2000. The absence of change in either the median CV or the interquartile range of the CVs reaffirms the general principle that variation in catches increases with the mean, that this property holds across all of the species examined, and that the potential effects of the trawl warp offset, if any, are small relative to the usual variation in catches. These properties appear to apply to exploited as well as unexploited stocks.

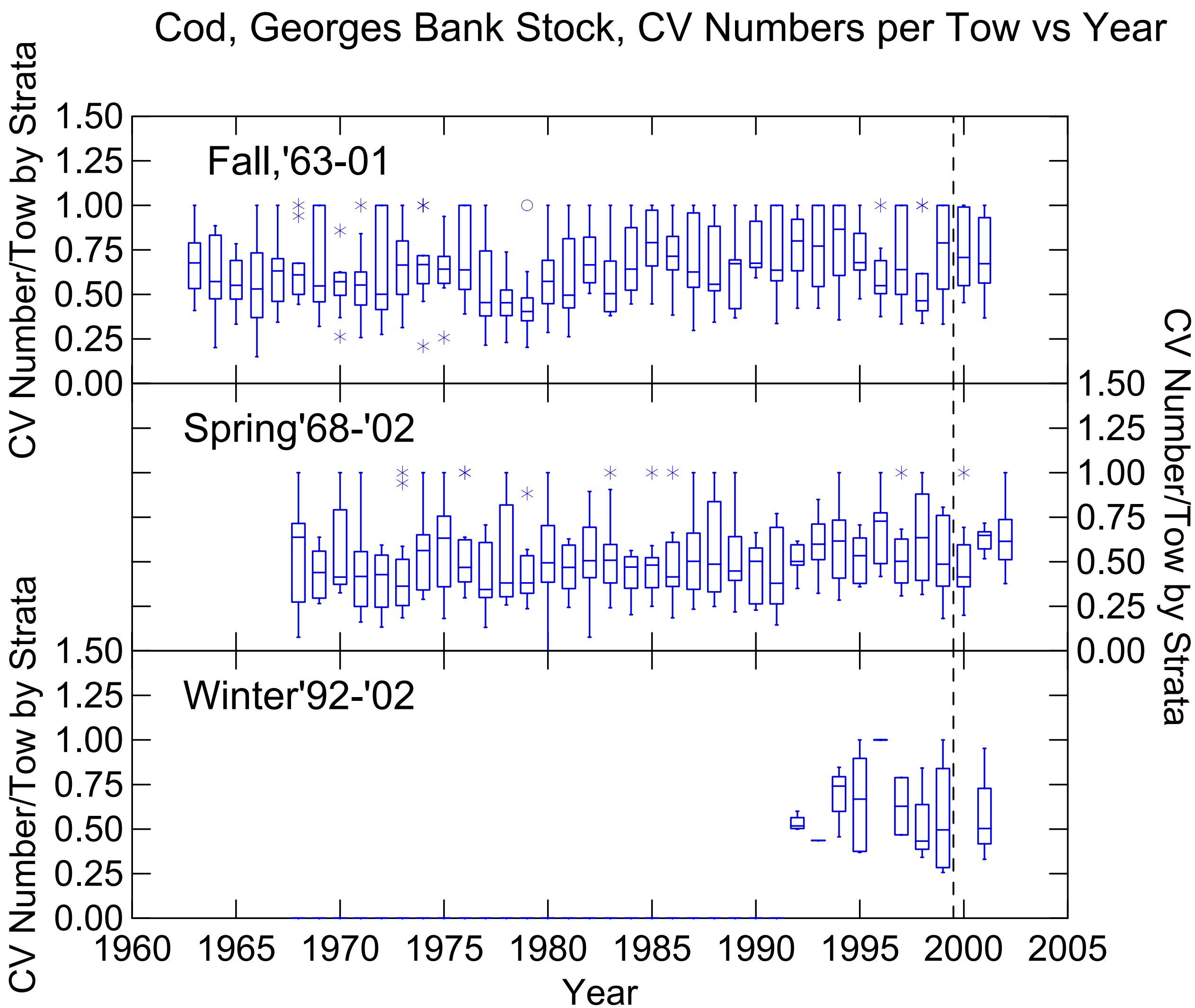



Fig. 3.6.1. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of cod for fall, spring , and winter NEFSC trawl surveys.

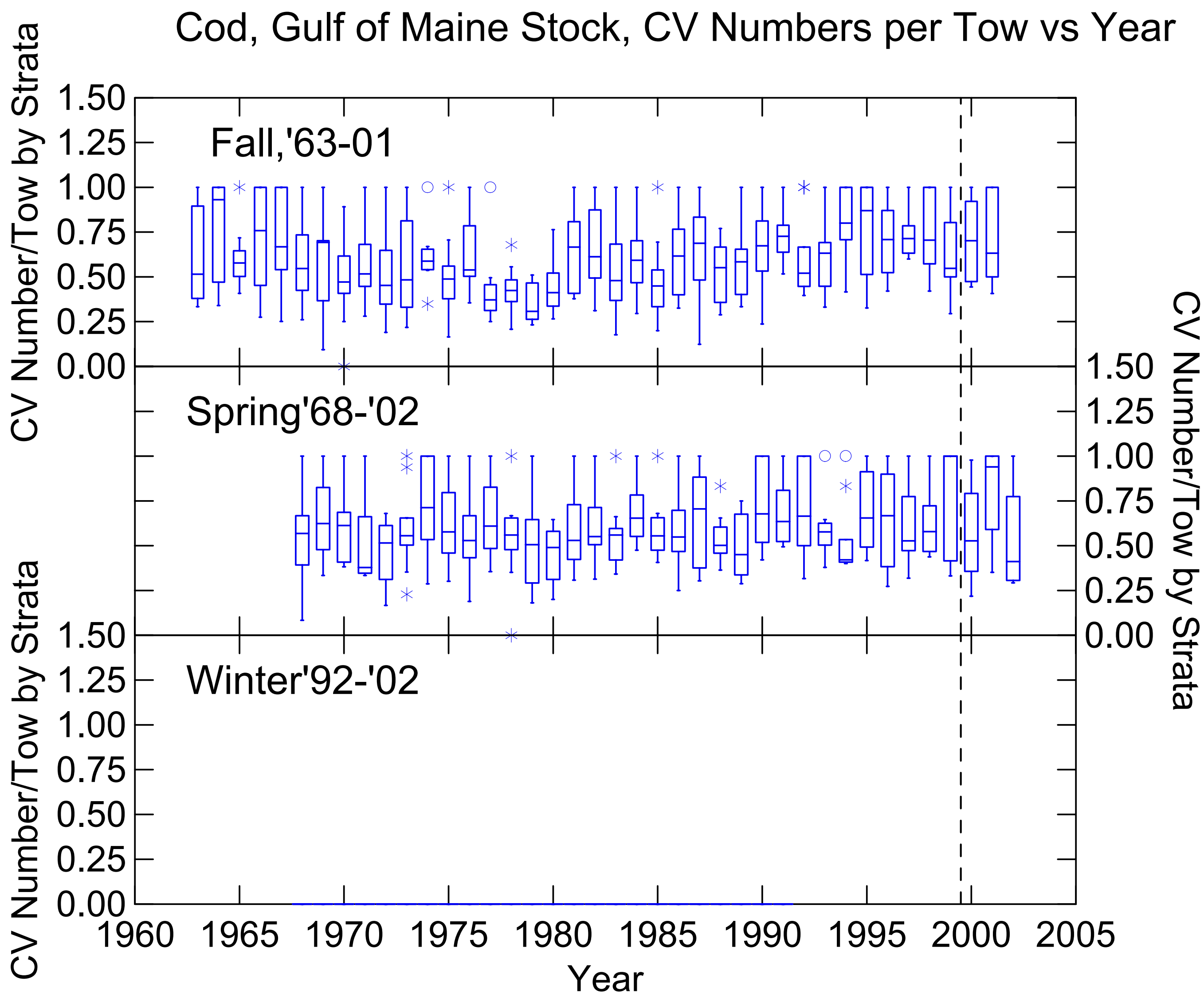



Fig. 3.6.2. Box plots of stratum-specific coefficients of catch (numbers/tow) for Gulf of Maine stock of cod for fall, spring , and winter NEFSC trawl surveys.

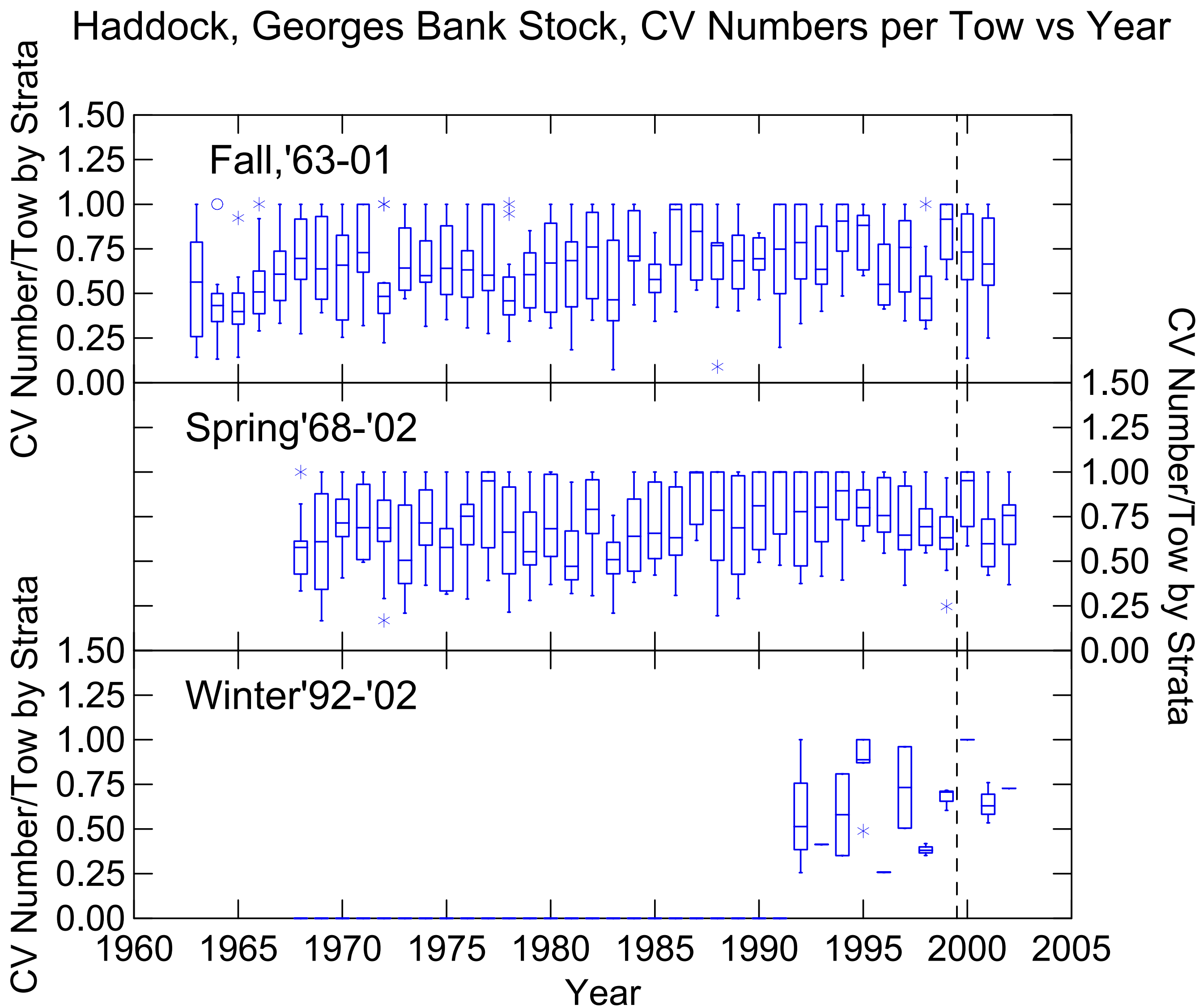



Fig. 3.6.3. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of haddock for fall, spring , and winter NEFSC trawl surveys.

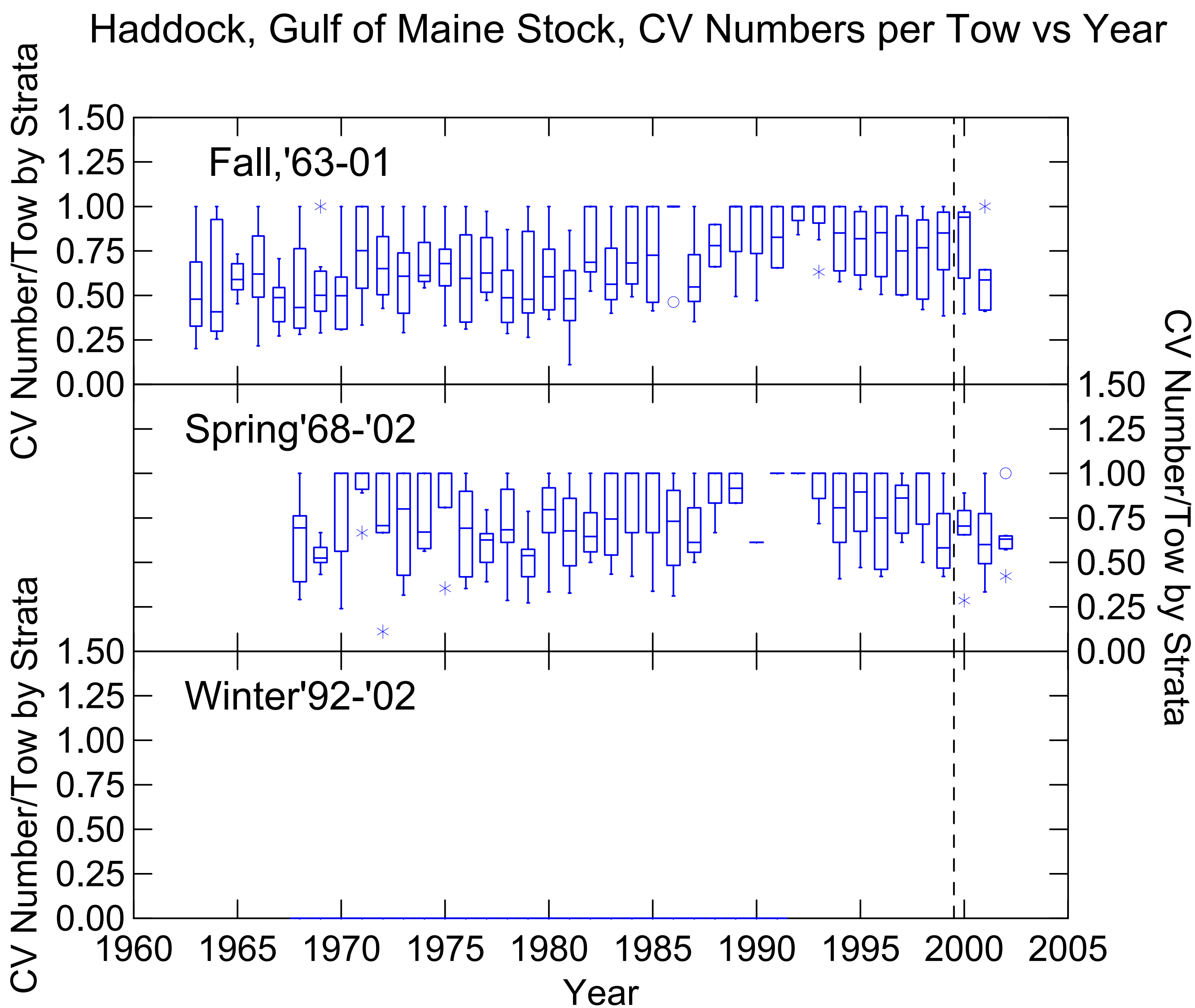



Fig. 3.6.4. Box plots of stratum-specific coefficients of catch (numbers/tow) for Gulf of Maine stock of haddock for fall, spring , and winter NEFSC trawl surveys.

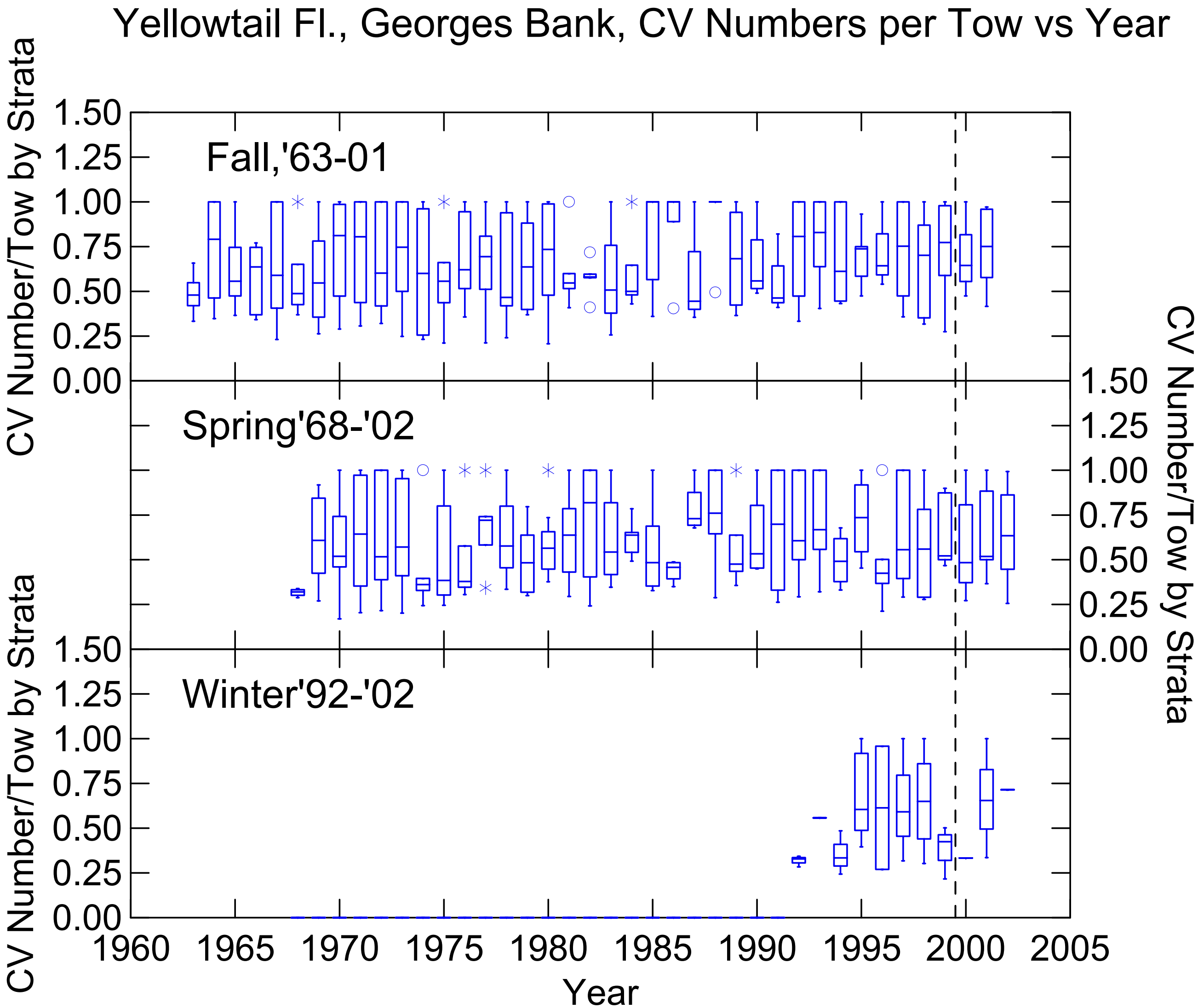



Fig. 3.6.5. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

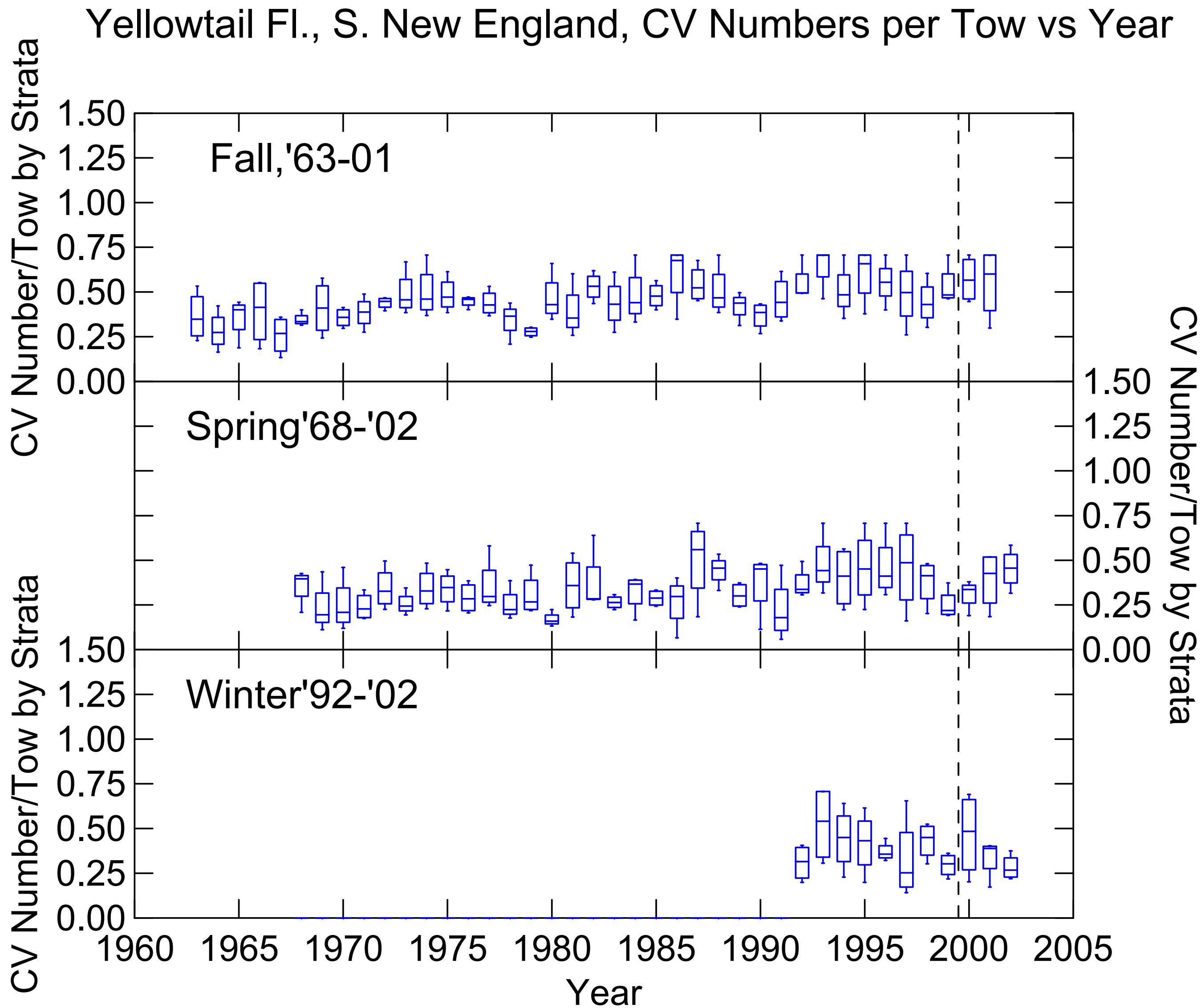



Fig. 3.6.6. Box plots of stratum-specific coefficients of catch (numbers/tow) for Southern New England stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

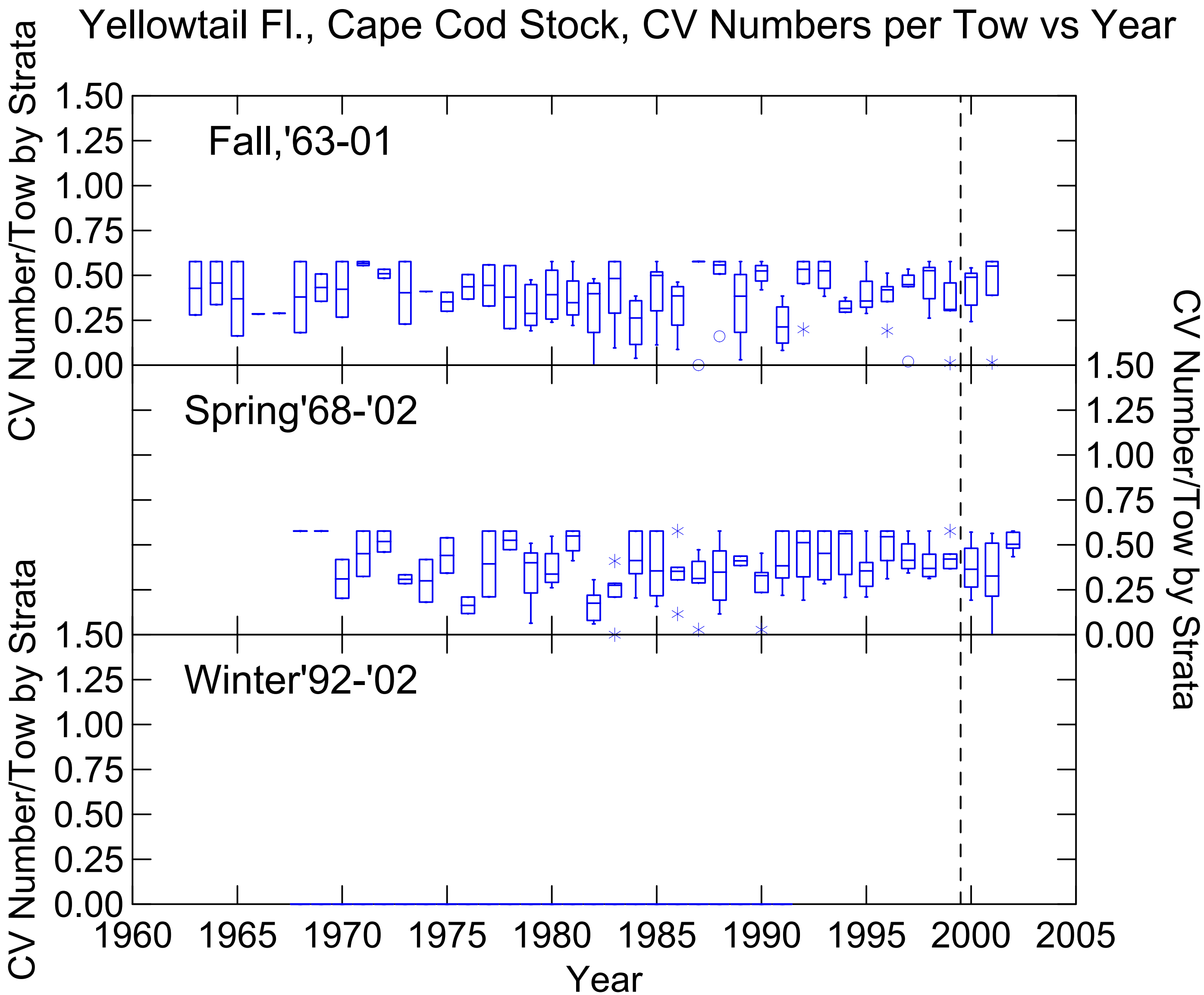



Fig. 3.6.7. Box plots of stratum-specific coefficients of catch (numbers/tow) for Cape Cod stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

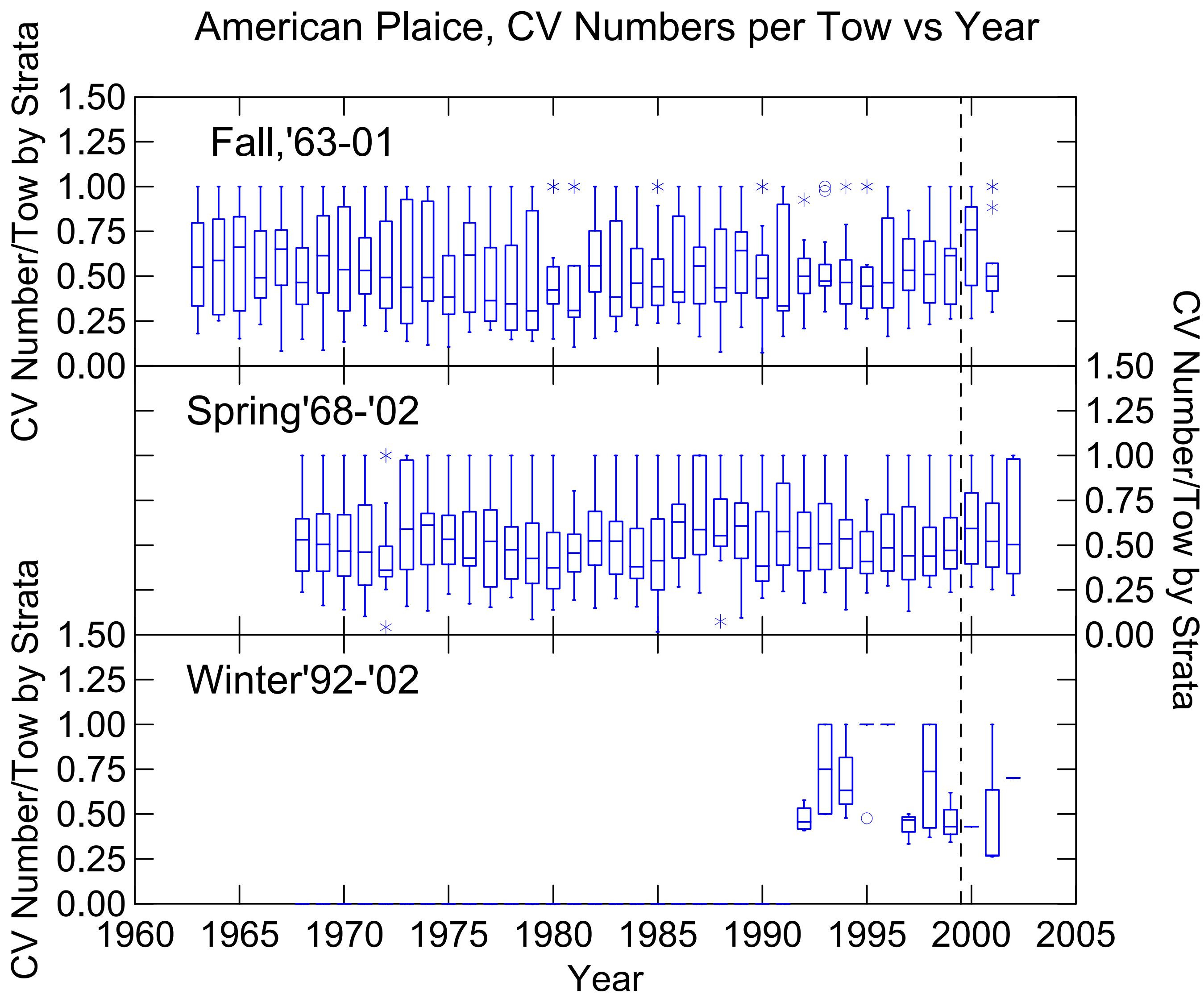



Fig. 3.6.8. Box plots of stratum-specific coefficients of catch (numbers/tow) for American plaice for fall, spring , and winter NEFSC trawl surveys.

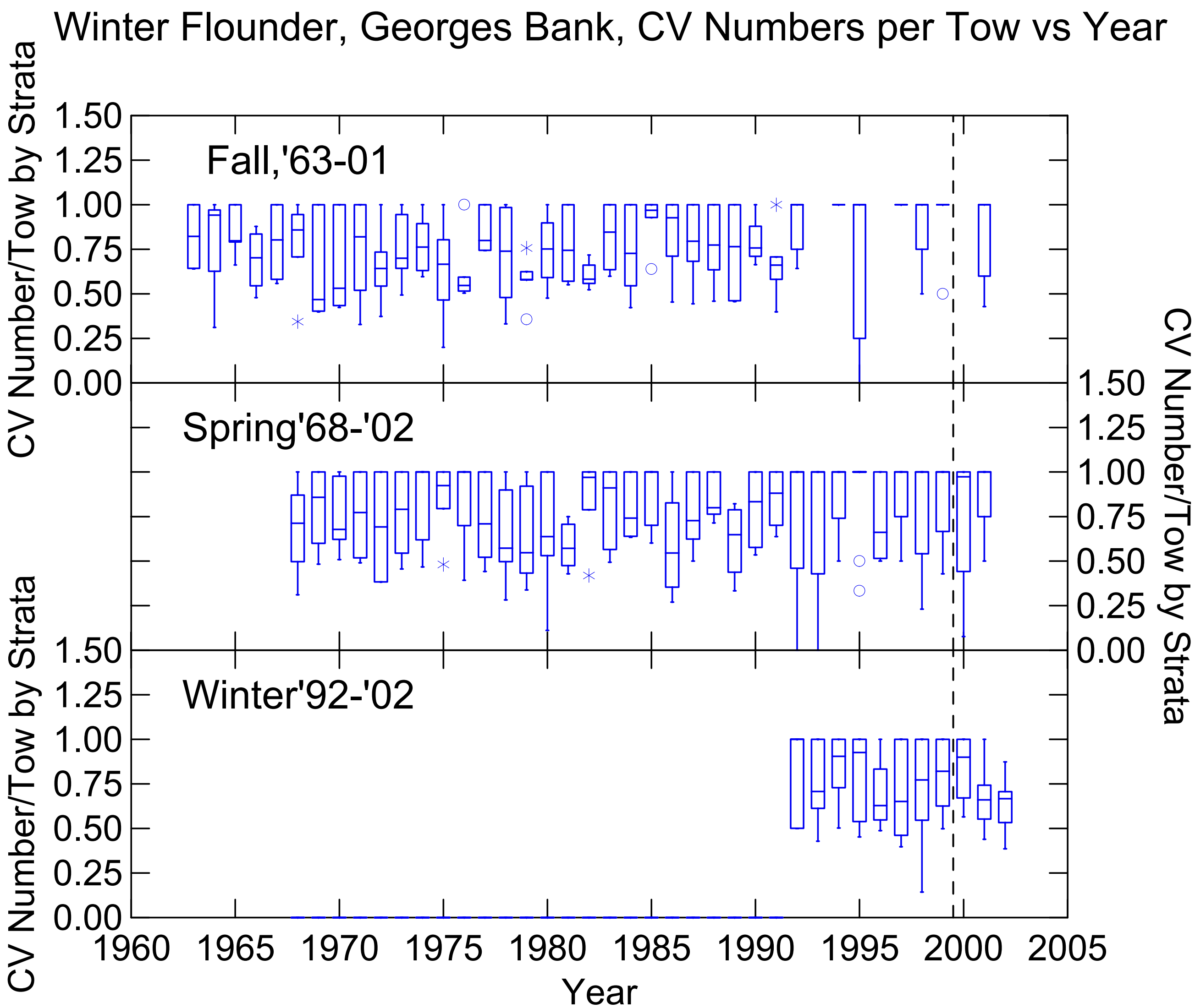



Fig. 3.6.9. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of winter flounder for fall, spring , and winter NEFSC trawl surveys.

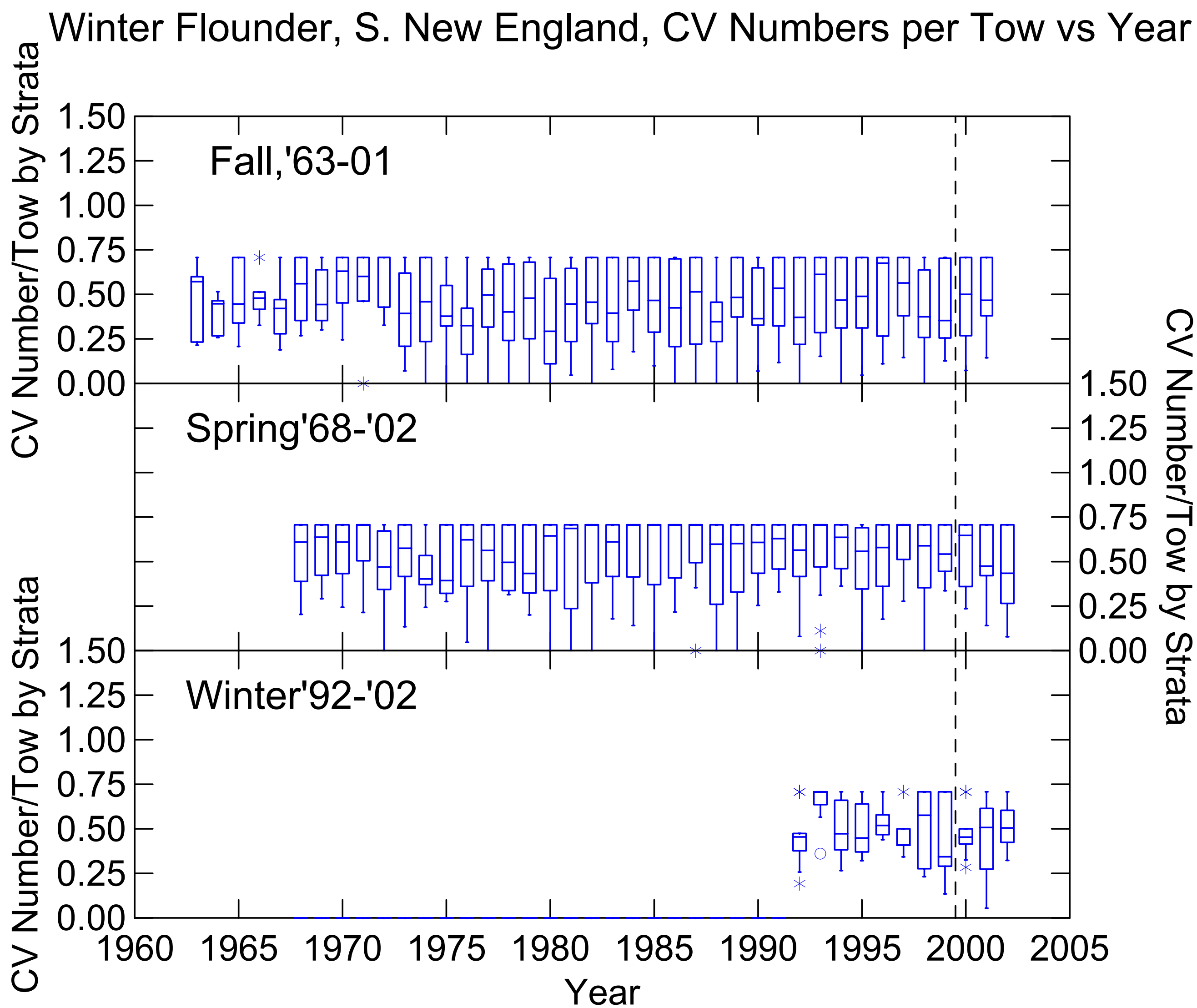



Fig. 3.6.10. Box plots of stratum-specific coefficients of catch (numbers/tow) for Southern New England stock of winter flounder for fall, spring , and winter NEFSC trawl surveys.

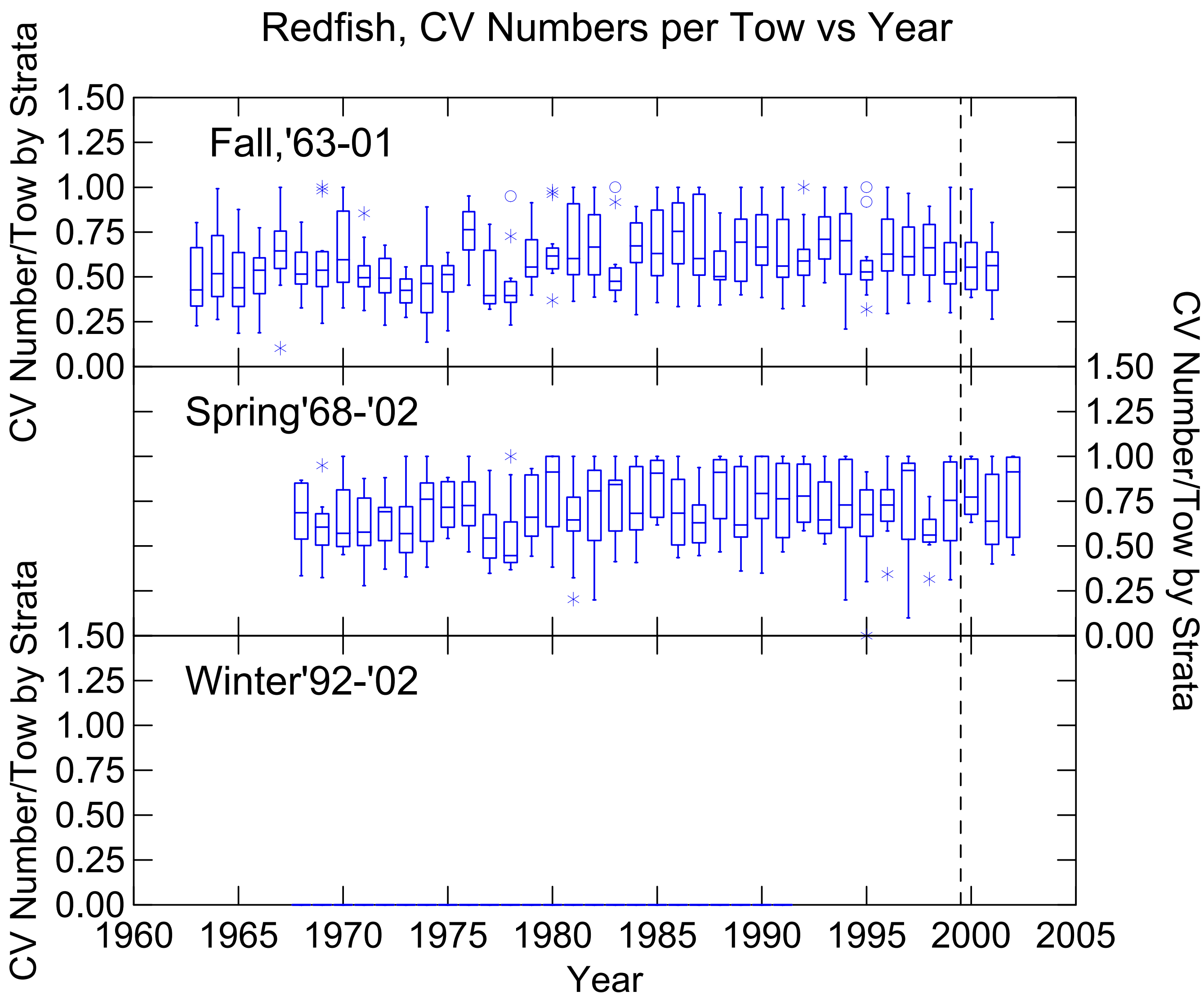



Fig. 3.6.11. Box plots of stratum-specific coefficients of catch (numbers/tow) for Acadian redfish for fall, spring , and winter NEFSC trawl surveys.

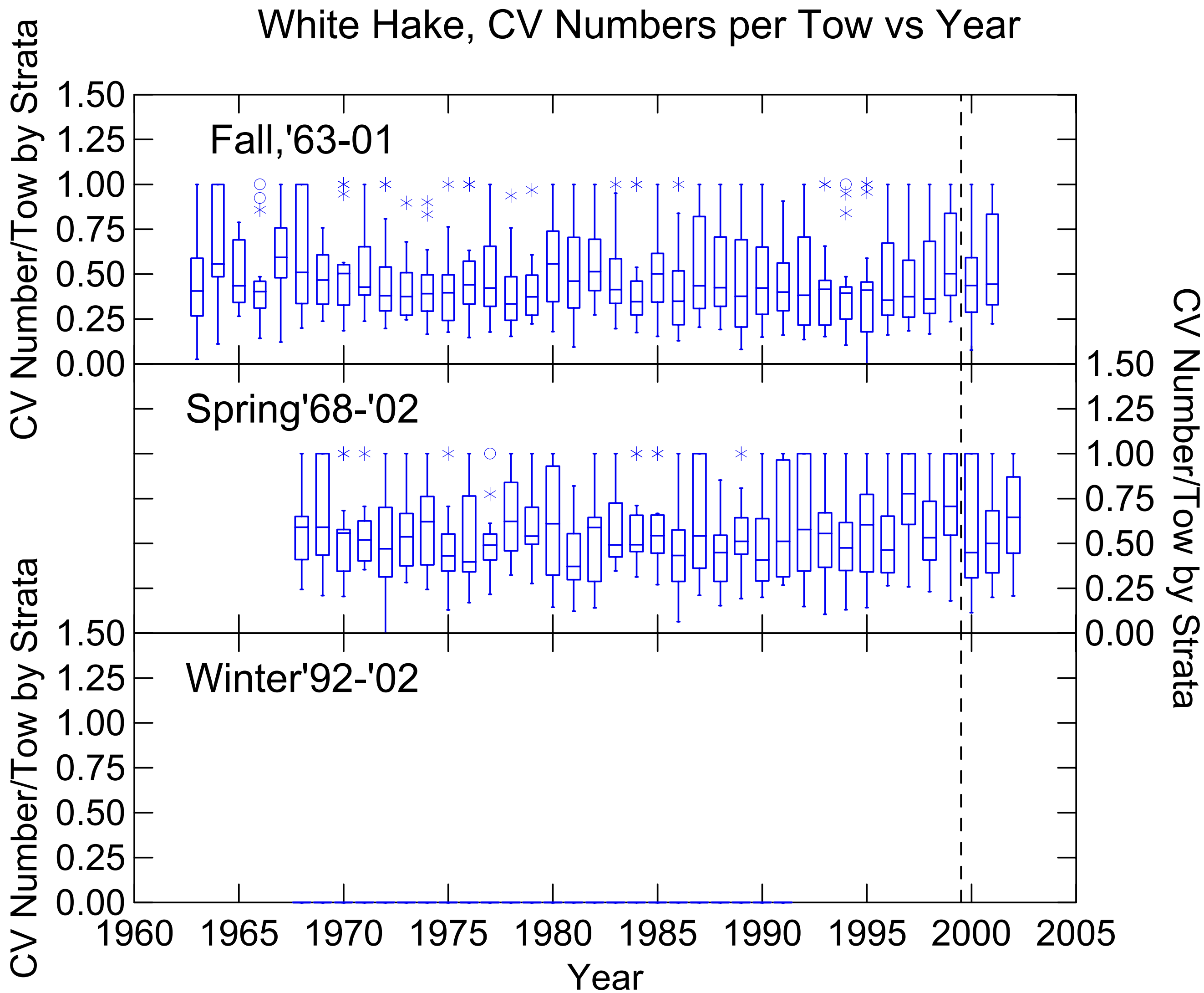



Fig. 3.6.12. Box plots of stratum-specific coefficients of catch (numbers/tow) for white hake for fall, spring , and winter NEFSC trawl surveys.

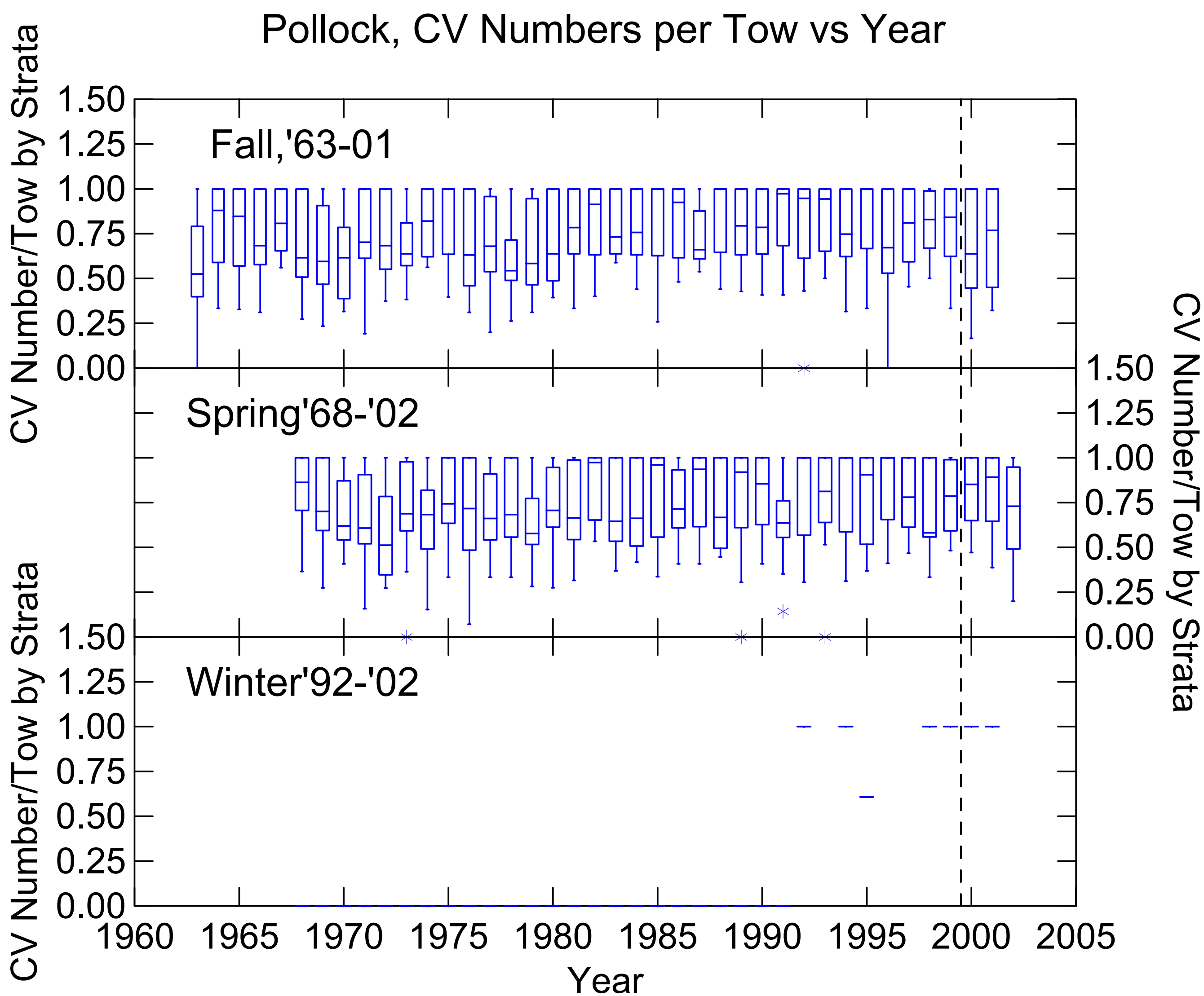



Fig. 3.6.13. Box plots of stratum-specific coefficients of catch (numbers/tow) for pollock for fall, spring , and winter NEFSC trawl surveys.

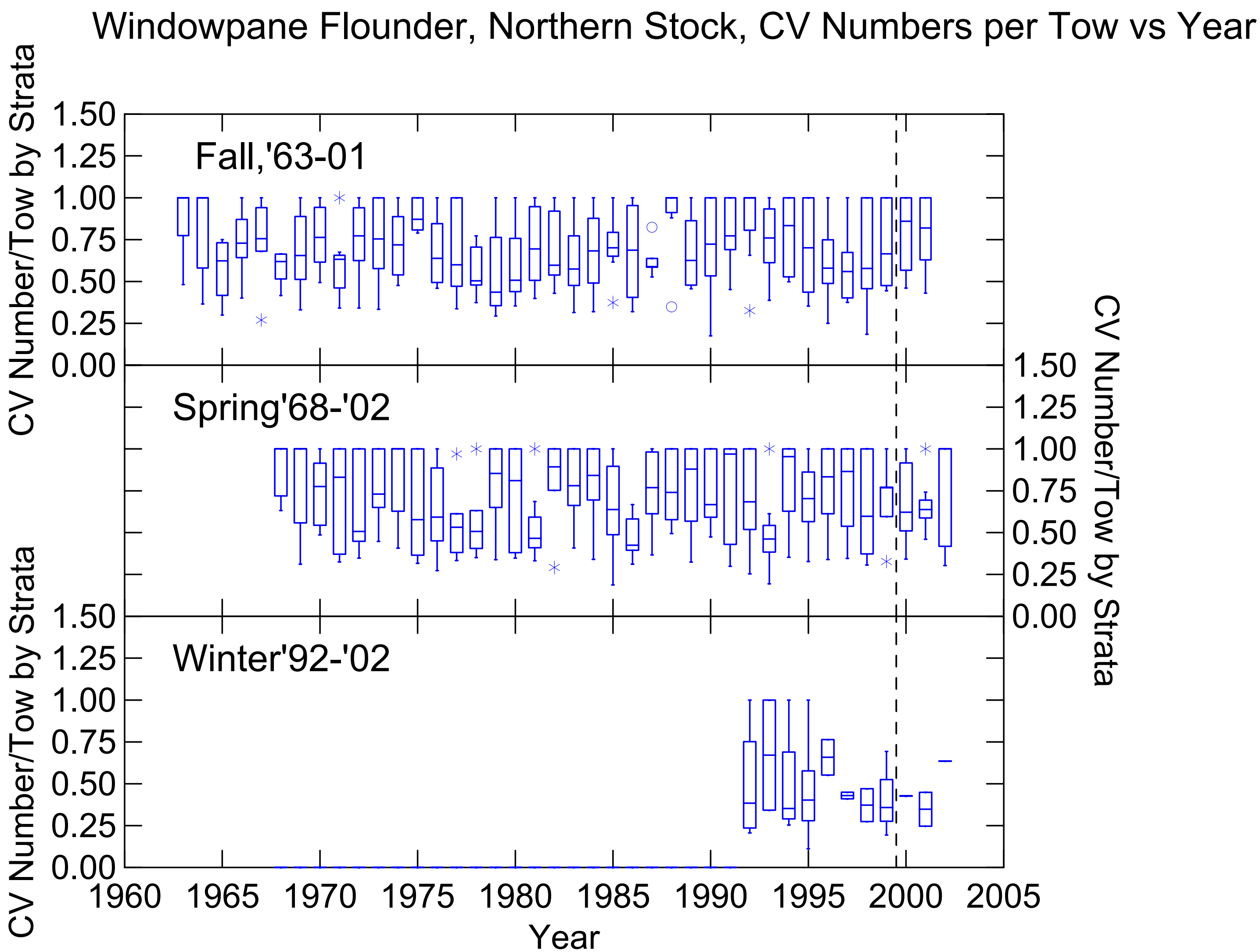



Fig. 3.6.14. Box plots of stratum-specific coefficients of catch (numbers/tow) for northern stock of windowpane flounder for fall, spring , and winter NEFSC trawl surveys.

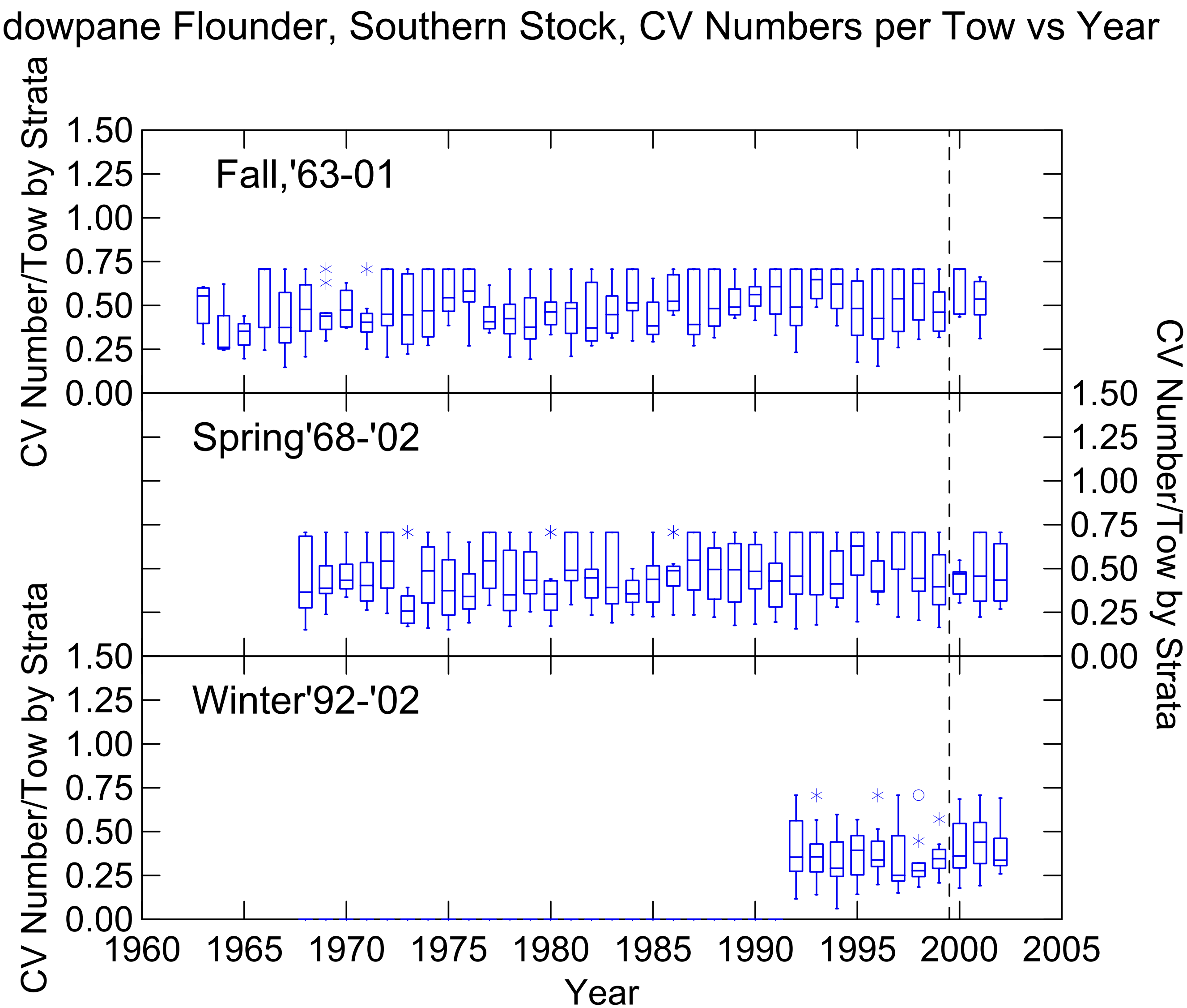



Fig. 3.6.15. Box plots of stratum-specific coefficients of catch (numbers/tow) for southern stock of windowpane flounder for fall, spring , and winter NEFSC trawl surveys.

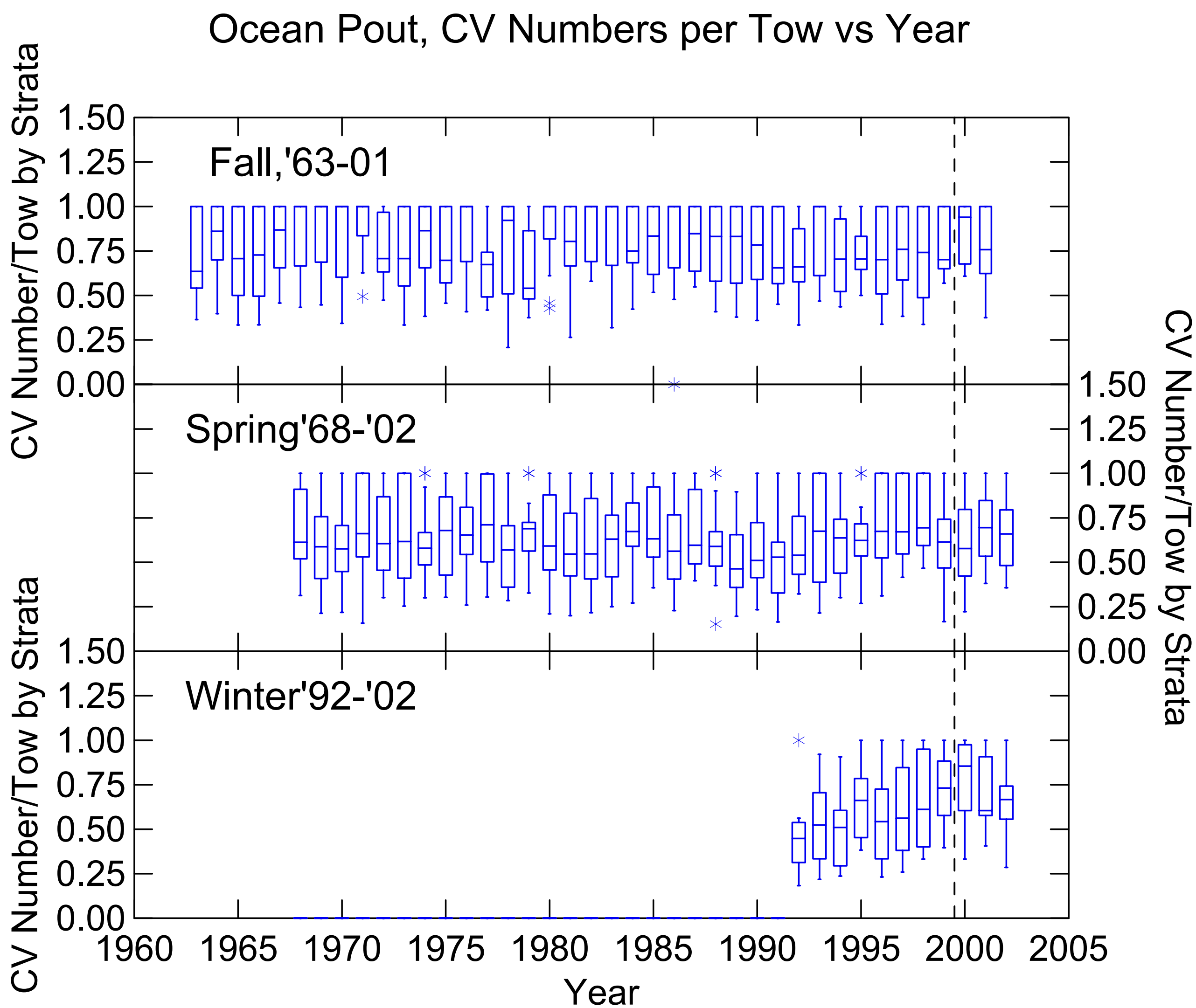



Fig. 3.6.16. Box plots of stratum-specific coefficients of catch (numbers/tow) for ocean pout for fall, spring , and winter NEFSC trawl surveys.

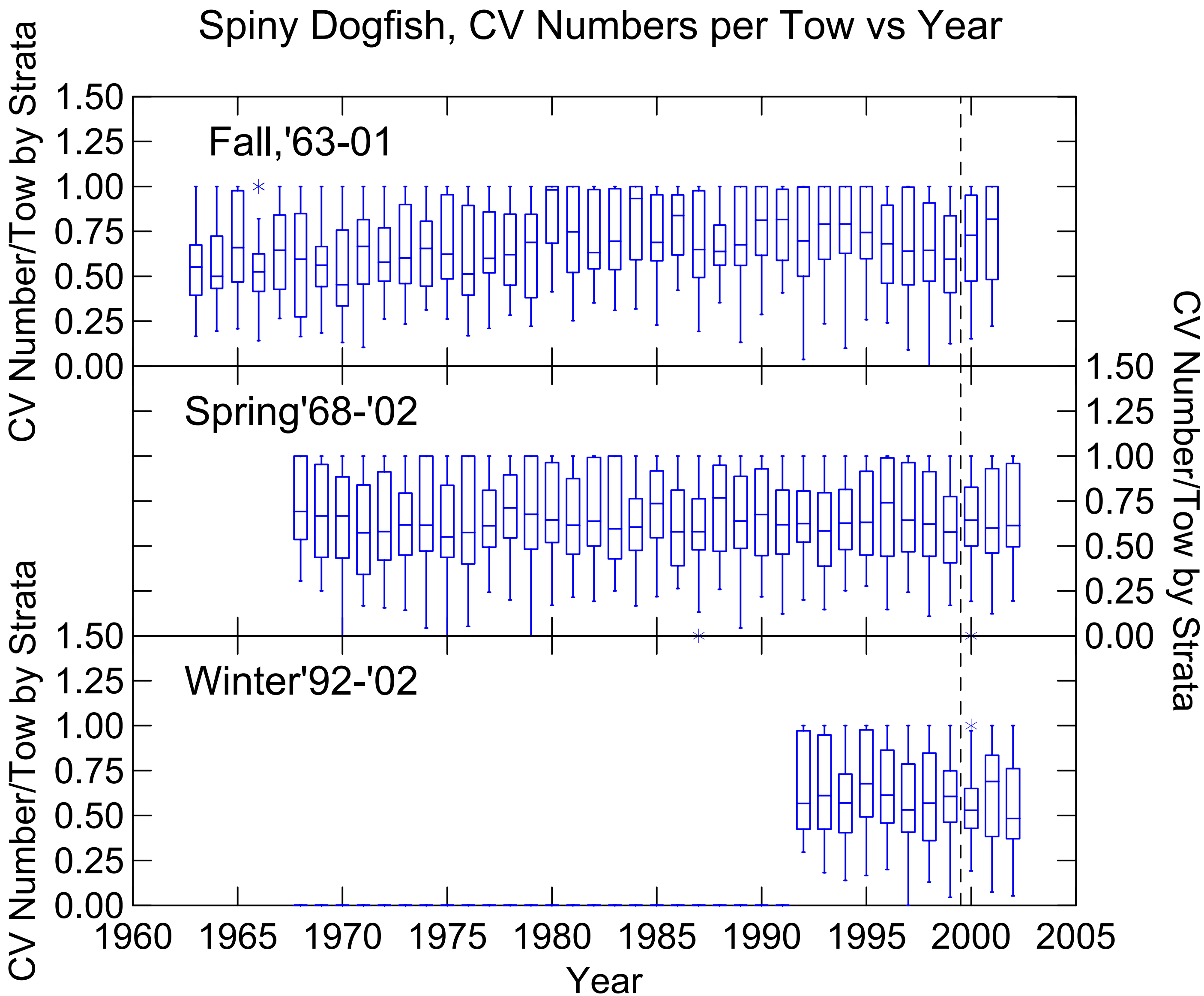



Fig. 3.6.17. Box plots of stratum-specific coefficients of catch (numbers/tow) for spiny dogfish for fall, spring , and winter NEFSC trawl surveys.

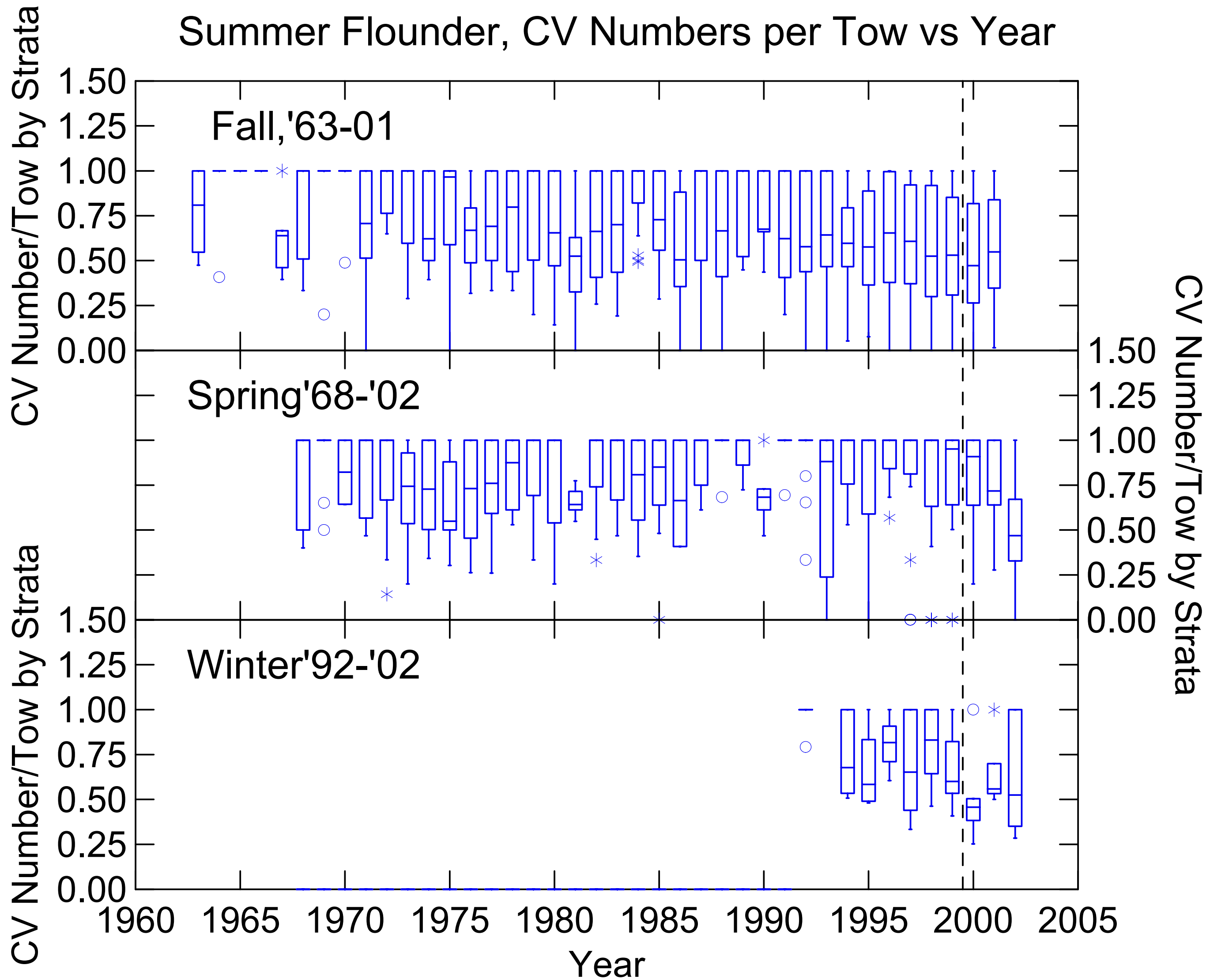



Fig. 3.6.18. Box plots of stratum-specific coefficients of catch (numbers/tow) for summer flounder for fall, spring , and winter NEFSC trawl surveys.

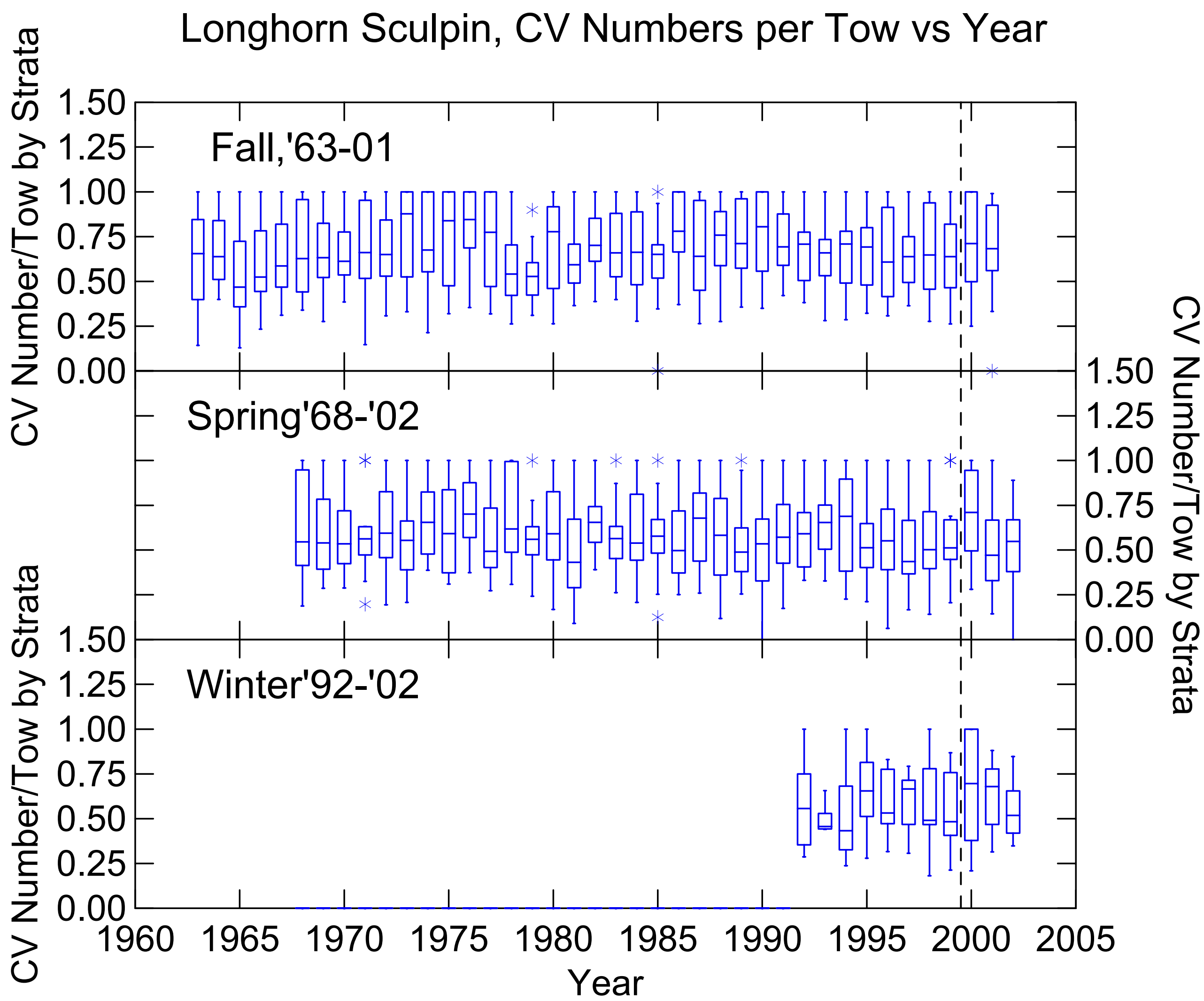



Fig. 3.6.19. Box plots of stratum-specific coefficients of catch (numbers/tow) for longhorn sculpins for fall, spring , and winter NEFSC trawl surveys.

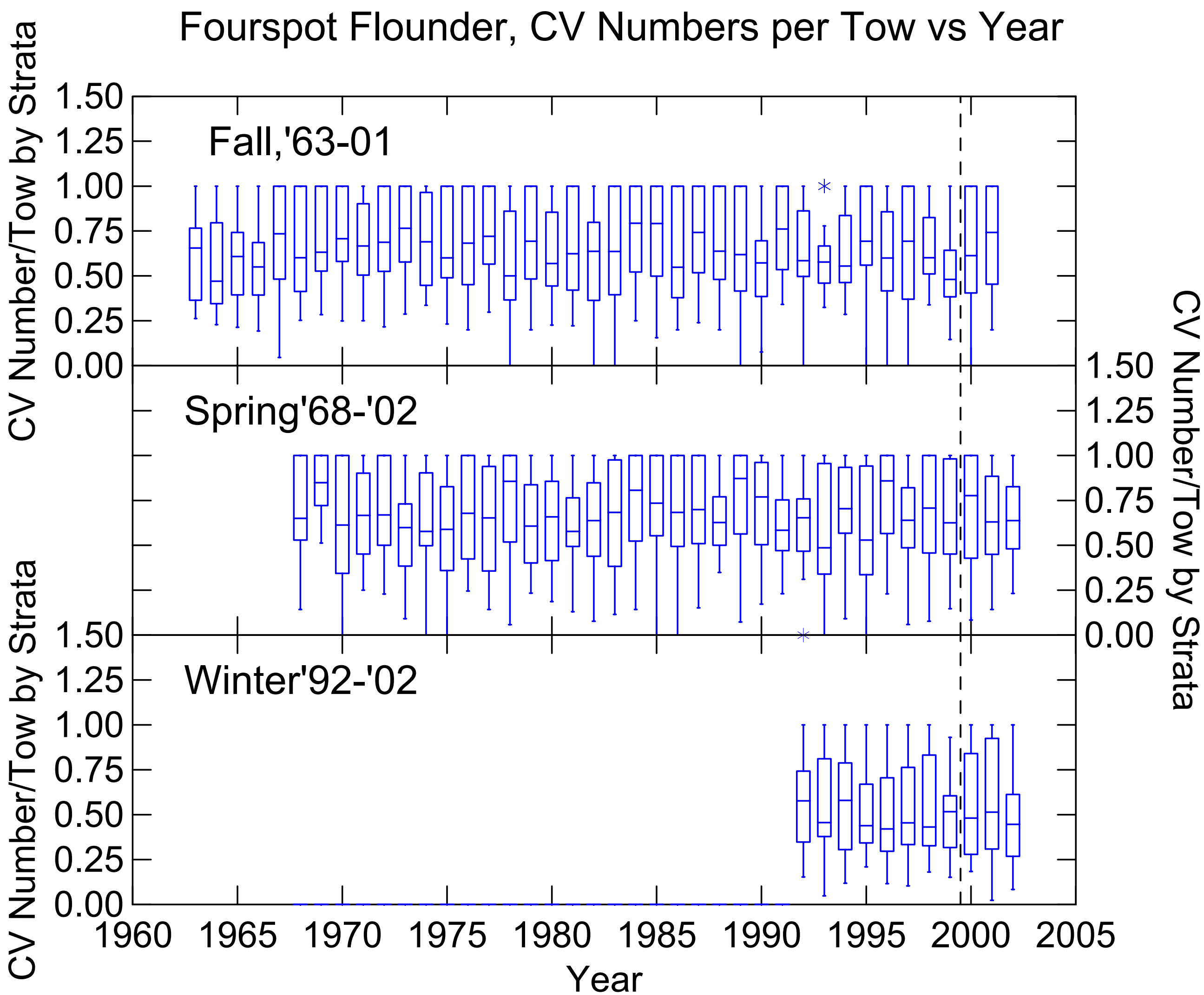



Fig. 3.6.20. Box plots of stratum-specific coefficients of catch (numbers/tow) for fourspot flounders for fall, spring , and winter NEFSC trawl surveys.

## 3.7. Changes in Observed Depth Distribution

The geometric arguments in Section 3.1 suggest that the efficiency of the trawl should decrease with increasing depth. Under this hypothesis, one would expect a greater fraction of the population to be caught at shallower depths. The loci of population abundance, as measured by a catch-weighted average depth, should be lower in the affected years (2000-2002) than in the base period. The long-term time series of trawl survey data allows the characterization of the seasonal and annual shifts in abundance for each species. Many species have distinct seasonal changes in average depth, coinciding with temperature changes, spawning events, feeding migrations and so forth. The timing of these events is likely to change with environmental conditions and to a lesser extent, with variations in the timing of the NEFSC surveys. The historical pattern of catches can thus serve as a sampling distribution of the catch-weighted average depth. If the warp offset factor caused a severe decline in capture rates at depth, one would expect the mean depth at capture to lie outside the range of historical values.

### *3.7.1. Catch-Weighted Average Depth*

The time series of depth distribution patterns was examined in several different ways. At the aggregate level, the mean and variance of catch-weighted average depths were computed for each species, stock, survey, and year. Both numbers per tow and weight (kg) per tow were used to weight the depth at capture. The stratum area information associated with the survey tows was not incorporated into the estimates. The following estimators were used:

$$\overline{D}_{C,t} = \frac{\sum_{k=1}^{n_t} D_{k,t} C_{k,t}}{\sum_{k=1}^{n_t} C_{k,t}} \qquad (7)$$

where $D_{k,t}$ is the depth of tow k, $n_t$ is the total number of tows in year t, and $C_{k,t}$ is the catch in either numbers or weight in tow k and year t. The variance of the catch-weighted depth was estimated as

$$V(\overline{D}_{C,t}) = \frac{\sum_{k=1}^{n_t} D_{k,t}^2 C_{k,t} - \left( \sum_{k=1}^{n_t} D_{k,t} C_{k,t} \right)^2}{\sum_{k=1}^{n_t} C_{k,t} \left( \sum_{k=1}^{n_t} C_{k,t} - 1 \right)} \qquad (8)$$

The standard error of the $D_{C,t}$ was estimated as

$$SE(\overline{D}_{C,t}) = \frac{\sqrt{V(\overline{D}_{c,t})}}{n_t} \qquad (9)$$

The time series of these values are plotted in Fig. 3.7.1 to 3.7.22 for each species. Lowess smooths were used to identify any apparent trends in average depth. These plots show that in nearly every instance, the average depths in 2000-2002 were within the range of historical variation.

The distribution of average depths before and after 2000 were compared using both parametric and nonparametric statistical tests (Table 3.7.1). Parametric t-tests were used to test whether the mean of the average or mean of the standard deviation of catch-weighted depths during the 2000-2002 period were significantly different from the earlier values. T-tests were computed in two way—with a pooled estimate of a common variance, and with separate variances for each group. Of the 88 tests conducted with each method, 10 (11%) were significant at the 5% level. If the Bonferroni adjustment factor for multiple tests is applied, the Type 1 error rate becomes 0.05/(2*88). At this level of statistical significance, only one of the tests was significant.

The t-test was applied to a pooled set of observations of annual means for all survey types combined. To look at finer scale patterns with respect to each survey (i.e. fall,winter, spring) we used a Kruskall-Wallis test. Under this partitioning of the data, a reliable estimate of the variance for the treatment group was not possible (2-3 observations). Of the 232 tests conducted, 15 (6.5%) were significant at the 5% level. The Bonferroni criterion is quite stringent (0.05/(2*232)) and none of the tests suggested that the catch-weighted average depth during the post treatment period was significantly different from the pre-treatment means.

In summary, there is no compelling evidence of statistically significant changes in the average depth distribution of the 22 stocks examined. Significant tests, when they arose, were usually associated with a difference in the mean of the standard errors of the catch weighted average depth. The low number of statistically significant tests, and the absence of any apparent pattern in the tests suggest that the effects of warp offset factors, if any, are minor.

Analysis of the cumulative frequency distribution of catches with respect to depth may be found in Appendix 2.

### *3.7.2 Comparisons of Catch Rates at Depth: 1997-1999 vs. 2000-2002*

The analyses of gear problem rate, mean-variance relationships and catch weighted average depth all fail to provide evidence of a significant effect of the mismarked cables on trawl performance. No consistent pattern emerges with respect to species groupings (e.g., round groundfish vs. flatfish) or geographical region, especially in the Gulf of Maine. Given its greater average depth one would expect a greater frequency of gear problems since 1999, a tendency to catch less fish in deeper strata, or more variation among tows. None of these features is readily discernible.

In an attempt to conduct more direct tests of potential depth effects on gear performance, it was hypothesized that average catch rates would decline with depth. Moreover, differences in catch rates between a baseline period and the 2000-2002 period should increase with depth. We tested this hypothesis by comparing average catch rates between the pre and post-treatment periods. Average catch rates in both number and weight per tow, were computed for each species, stock and season over 20 m depth intervals. Twenty m depth intervals were used to ensure that sufficient numbers of observations were available to obtain a reliable estimate of the mean. For the spring and winter surveys, we compared catch rates at depth in 2000-2002 with similar quantities for 1997-1999. For the fall survey, we compared 1998-1999 with 2000-2001. This approach ensured that the numbers of observations contributing to each mean would be roughly equal. The general equation for computing these quantities can be expressed as:

$$\overline{C}_{D_k,\tau} = \sum_{D_j \in D_k} \frac{C_{j,\tau}}{n\{D_j \in D_k\}} \quad \forall_j \qquad (10)$$

Where $C_{j,\tau}$= tow j within period $\tau$ whose average depth $D_j$ is with the interval of depths defined by $D_k$. The expression n{.} denotes a counting operator that counts the number of tows within the set. Differences between the "control" and "treatment" periods this experiment were computed on the arithmetic scale, and standardized by the estimated standard deviation of the differences for a given comparison. The standardized difference can be written as

$$Z_k = \frac{\overline{C}_{D_k,\tau=1} - \overline{C}_{D_k,\tau=2}}{\hat{\sigma}} \qquad (11)$$

where $\tau=1$ is the control period and $\tau=2$ denotes the years in the treatment period. A simple regression model of the form

$$Z_k = \alpha + \beta D_k \qquad (12)$$

was used to test for effects of depth. When $\beta \sim 0$, $\alpha$ should equal ~zero. If $\beta > 0$ it implies that the average catch rate in the control period exceeded that in the treatment period and would imply some influence of the warp offset on the catch rates. Conversely, $\beta < 0$ implies that catches in the treatment period exceeded those in the control period.

Equation 12 provides a useful test for trend in catch rates with depth but it is not sufficient to isolate the influence decreasing efficiency with depth. This arises because Eq. 12 is linear and allows for changes in efficiency at shallow depths as well. These post hoc analyses cannot distinguish between true changes in abundance (which would lead to +/- variations) and effects induced by the trawl warp. However, the use of 3 surveys should help to distinguish changes that are real (e.g., all three indices increase with depth) versus artifacts of random variation. Two separate analyses of the standardized difference were conducted. First, plots of $Z_k$ versus depth were constructed for all combinations of 21 species-stock combinations and 3 surveys (Fall, Spring, Winter). For each combination, two response variables (average numbers/tow, average weight/tow) were examined. A linear regression was computed for each combination and response variable to test for statistically significant values of $\alpha$ and $\beta$.

Results of the statistical tests are summarized in Table 3.7.1. Of the 112 individual tests conducted, 8 had probability levels less than 0.05. Of these, six had positive and two had negative slopes. The slope was positive for Gulf of Maine cod numbers per tow for both the spring and fall surveys. Similarly, longhorn sculpins had positive slopes for the spring survey regressions. The total number of significant tests is about that expected due to chance alone, but the association of significant tests for Gulf of Maine cod in both the spring and fall surveys merits some attention. The positive trend in the slope of the standardized difference with respect to depth is induced by a few large tows in shallow depth strata during the 2000-2002 interval rather than any general trend toward decreasing average catch rates in deeper strata.

None of the other Gulf of Maine species, notably haddock, pollock, and white hake demonstrated any trend with depth. Moreover, deeper water species, such as redfish and witch flounder did not demonstrate any significant trends of differences with depth. Had the reduced capture rate at depth been a general function of decreasing efficiency, one would have expected some of these comparisons to be significant.

A set of omnibus tests (Table 3.7. 3) in which all species were pooled, suggested no significant slopes for the differences of average numbers or weights per tow or for standardized log ratios of numbers or weights. For the fall survey, the standardized log ratio of numbers and weight in the fall survey was significantly correlated with depth—the slope however, was negative, suggesting higher overall catch rates in the post treatment period.

The second analysis considered the effects of depth on catch differences as a statistical control process. The standardization approach (Eq. 12) ensures that most differences will be between ± 3.5 standard deviations units. Moreover, 80% of the values should lie between ±1.28 SD, and 95% between ±1.96 SD units. Standardization of the differences also allows for pooling across species to permit testing of more general hypotheses. In particular, we examined general tests for gadoid species, flatfish species, species with median depths less than 100 m and those greater than 100 m. If general reductions in catch rates were evident with increasing depth, one would expect a general increase in positive residuals in deeper strata.

Figure 3.7.23 to 3.7.27 suggested no patterns associated with decreased relative efficiency with depth. On the contrary, the plots suggested less than expected variation in the standardized differences as depth increased. This pattern held for gadoid species, flatfish species, shallow versus deep-water species, as well as for all species combined.

A comparison of the observed and expected number of standardized differences suggested that the distribution was leptokurtotic (more peaked) compared to the expected normal distribution with mean zero and unary variance (Table 3.7.4).

In summary, the comparative tests of differences in catch rates versus depth interval did not suggest any significant trend in catch differences with depth. Increases in overall abundance during the 2000-2002 period would potentially cancel out the effects of depth related changes, but one has to postulate an awkward assumption that the increases at depth would have been greater in the deeper waters for 21 species-stocks x 3 surveys. Moreover, the likelihood that such increases would be exactly sufficient to offset the depth related decreases in efficiency, for all of these tests, seems implausible.

### *3.7.3 Implications of VPA Sensitivity Analyses for Relative Efficiency*

Stock assessment models for the GARM investigated the implications of arbitrary increases in the 2000 to 2002 survey indices by factors of 10, 25 and 100%. These potential increases cannot be divorced from their implications for depth relative to efficiency. For example, one cannot simply postulate that the net was 25% less efficient at all fishing depths unless one also postulates that any amount of asymmetry in cable lengths leads to equal degrees of reduced efficiency. This not only denies the fact that increases in asymmetry can reduce efficiency but also asserts that unrealized differences in cable length (i.e., cable still on the winch) influence catch rates at shallower depths.

The 10, 25 and 100% raising factors also do not address the differences in depth distributions among species. By applying the same factors to both deep-water species (eg. Redfish) and shallow-water species (e.g., yellowtail flounder), one implies that the reduction in capture efficiency varies significantly among species.

These implications of these assertions were investigated by substituting Eq. 6 into Eq. 4. to obtain:

$$\sum_j C_{j\,rev} = (1+\delta)\sum_j C_{j,obs} = \sum_j \left( \frac{C_{j,obs}}{1-\left(\frac{0.0134D_j}{W_{\max}}\right)^{\theta}} \right) \qquad (13)$$

Eq. 13 can now be used to find the value of θ necessary to obtain an increase of magnitude δ when integrating over the entire depth range of a species. To illustrate this property, Eq. 13 was solved for hypothetical increases of 10%, 25% and 100% for cod, haddock, and yellowtail flounder for the 2000-2002 spring surveys, and 2000-2001 fall surveys. Model results, summarized in Fig. 3.7.28 to 3.7.30, suggest that efficiency reductions of about 50% would occur at depths of 100 m for cod and haddock if a 100% increase in the survey indices were true. For yellowtail flounder, an increase of 100% in the indices implies a rapid drop in trawl efficiency with decreases of 50% at 50 m. An important aspect of each of the analyses is that the reduction in efficiency is a concave function (i.e., θ >1). This model suggest that sharp declines in efficiency are necessary even when the asymmetry of the trawl is relatively minor.

Eq. 13 predicts the necessary decline in relative efficiency if the δ value is true. Using the data sets described in Section 3.7.2 (Eq. 10) , one can also estimate the magnitude of the expected decline supported by comparison of data in pre and post-warp offset periods. In other words, it is possible to evaluate the potential magnitude of the relative efficiency reduction if the pre- and post –periods are not unduly compromised by large changes in abundance. Results in Fig. 3.7.28-30, labeled as "Actual Data" suggest no reductions for yellowtail flounder or cod at depths less than 300 m. For haddock, (Fig. 3.7.29) the model suggests a reduction of up to 10% at 200m in the fall survey. It is important to note however, that even this magnitude of effect is insufficient to achieve even a 10% increase in the average abundance estimate. These results have important implications for the ascertaining the feasibility of certain raising factors. **On the basis of these analyses, there is no support for even the 10% level of hypothesized increase in survey abundances for cod, haddock or yellowtail flounder.**

### 3.7.4 Comparisons of Catch-Weighted Depth at Capture

Differences in catch-weighted depth at capture are summarized in Figures 3.7.31 and 3.7.32. Data are organized by species average depths at capture, and are divided for each into pre- and post-warp offset periods. The entire (1963-1999) pre-warp period is included in Figure 3.7.31, and, because of potential time trends of depth at capture, only the period 1997-1999 is included as the pre warp period in Figure 3.7.32. These analyses clearly demonstrate that the average depths of capture are not significantly different pre- and post-warp offset, and that there are no progressive differences between depths at capture among the periods as a function of species depth ranges. Virtually all of the catches of groundfish species included in the GARM updates are made in depths where the offsets were about 9 feet or less.

Table 3.7.1. Summary of statistical tests to evaluate the likelihood that the catch-weighted average depth and variance of catch-weighted depth had changed in response to warp offset factors in 2000 to 2002
Catch weighted average depths are based on either numbers/tow [N] or weight (kg)/tow [W].
Numbers of samples for the tests depends on the number of years and seasons considered.
The number of pre- and post-intervention cases for spring only comparisons is 32 vs 3, for fall only, 37 vs 2 and for winter only, 8 vs 3.
When all seasons are combined the number of cases for the pre- and post intervention period is 77 vs 8.

| | | | | | Significance levels for t-test comparisons using alternative variance estimators | | Significance levels for Nonparametric |
|---|---|---|---|---|---|---|---|
| **species** | **stock** | **season** | **Response Variable** | **Weighting Factor: N=num/tow, W=kg/tow** | ***p*: sep var t-test** | ***p*: pooled var t-test** | ***p*: Kruskal Wallis test** |
| Haddock | Georges Bank | all | SD | W | 0.289862 | 0.433023 | |
| Haddock | Georges Bank | all | SD | W | 0.14826 | 0.163566 | |
| Haddock | Georges Bank | all | SD | W | 0.052296 | 0.266823 | |
| Haddock | Georges Bank | all | SD | W | 0.105207 | 0.139573 | |
| Haddock | Georges Bank | fall | SD | W | | | 0.798966 |
| Haddock | Georges Bank | fall | SD | W | | | 0.524311 |
| Haddock | Georges Bank | fall | SD | W | | | 0.339541 |
| Haddock | Georges Bank | fall | SD | W | | | 0.279068 |
| Haddock | Georges Bank | spring | SD | W | | | 0.859684 |
| Haddock | Georges Bank | spring | SD | W | | | 0.859684 |
| Haddock | Georges Bank | spring | SD | W | | | 0.723674 |
| Haddock | Georges Bank | spring | SD | W | | | 0.679988 |
| Haddock | Georges Bank | winter | SD | W | | | 0.794003 |
| Haddock | Georges Bank | winter | SD | W | | | 0.29627 |
| Haddock | Georges Bank | winter | SD | W | | | 0.601508 |
| Haddock | Georges Bank | winter | SD | W | | | 0.794003 |
| Cod | Georges Bank | all | SD | W | 0.904804 | 0.90178 | |
| Cod | Georges Bank | all | SD | W | 0.640815 | 0.684401 | |
| Cod | Georges Bank | all | SD | W | 0.906653 | 0.908996 | |
| Cod | Georges Bank | all | SD | W | 0.64553 | 0.706991 | |
| Cod | Georges Bank | fall | SD | W | | | 0.610492 |
| Cod | Georges Bank | fall | SD | W | | | 0.949232 |
| Cod | Georges Bank | fall | SD | W | | | 0.444833 |
| Cod | Georges Bank | fall | SD | W | | | 0.949232 |
| Cod | Georges Bank | spring | SD | W | | | 0.953011 |
| Cod | Georges Bank | spring | SD | W | | | 0.637352 |
| Cod | Georges Bank | spring | SD | W | | | 0.637352 |
| Cod | Georges Bank | spring | SD | W | | | 0.288844 |
| Cod | Georges Bank | winter | SD | W | | | 0.245278 |
| Cod | Georges Bank | winter | SD | W | | | 0.121335 |
| Cod | Georges Bank | winter | SD | W | | | 0.698535 |
| Cod | Georges Bank | winter | SD | W | | | 0.438578 |
| Yellowtail | Georges Bank | all | SD | W | 0.996997 | 0.995838 | |
| Yellowtail | Georges Bank | all | SD | W | 0.000071 | 0.02002 | |
| Yellowtail | Georges Bank | all | SD | W | 0.784343 | 0.709294 | |
| Yellowtail | Georges Bank | all | SD | W | 0.00437 | 0.019447 | |
| Yellowtail | Georges Bank | fall | SD | W | | | 0.048403 |
| Yellowtail | Georges Bank | fall | SD | W | | | 0.226372 |
| Yellowtail | Georges Bank | fall | SD | W | | | 0.085591 |
| Yellowtail | Georges Bank | fall | SD | W | | | 0.074619 |
| Yellowtail | Georges Bank | spring | SD | W | | | 0.813664 |
| Yellowtail | Georges Bank | spring | SD | W | | | 0.025145 |
| Yellowtail | Georges Bank | spring | SD | W | | | 0.595883 |
| Yellowtail | Georges Bank | spring | SD | W | | | 0.015694 |
| Yellowtail | Georges Bank | winter | SD | W | | | 0.414216 |
| Yellowtail | Georges Bank | winter | SD | W | | | 0.153042 |
| Yellowtail | Georges Bank | winter | SD | W | | | 0.540291 |
| Yellowtail | Georges Bank | winter | SD | W | | | 0.414216 |

Table 3.7.1 (continued).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| American Plaice | Georges Bank | all | SD | W | 0.437437 | 0.325598 | |
| American Plaice | Georges Bank | all | SD | W | 0.062179 | 0.000586 | |
| American Plaice | Georges Bank | all | SD | W | 0.322863 | 0.194199 | |
| American Plaice | Georges Bank | all | SD | W | 0.06563 | 0.000953 | |
| American Plaice | Georges Bank | fall | SD | W | | | 0.566616 |
| American Plaice | Georges Bank | fall | SD | W | | | 0.70244 |
| American Plaice | Georges Bank | fall | SD | W | | | 0.70244 |
| American Plaice | Georges Bank | fall | SD | W | | | 0.898669 |
| American Plaice | Georges Bank | spring | SD | W | | | 0.443657 |
| American Plaice | Georges Bank | spring | SD | W | | | 0.0771 |
| American Plaice | Georges Bank | spring | SD | W | | | 0.238593 |
| American Plaice | Georges Bank | spring | SD | W | | | 0.013328 |
| American Plaice | Georges Bank | winter | SD | W | | | 0.305059 |
| American Plaice | Georges Bank | winter | SD | W | | | 0.030368 |
| American Plaice | Georges Bank | winter | SD | W | | | 0.21 |
| American Plaice | Georges Bank | winter | SD | W | | | 0.052705 |
| Witch Flounder | Georges Bank | all | SD | W | 0.124172 | 0.200626 | |
| Witch Flounder | Georges Bank | all | SD | W | 0.543153 | 0.617123 | |
| Witch Flounder | Georges Bank | all | SD | W | 0.351447 | 0.269114 | |
| Witch Flounder | Georges Bank | all | SD | W | 0.923525 | 0.930964 | |
| Witch Flounder | Georges Bank | fall | SD | W | | | 0.444833 |
| Witch Flounder | Georges Bank | fall | SD | W | | | 0.524311 |
| Witch Flounder | Georges Bank | fall | SD | W | | | 0.655814 |
| Witch Flounder | Georges Bank | fall | SD | W | | | 0.566616 |
| Witch Flounder | Georges Bank | spring | SD | W | | | 0.443657 |
| Witch Flounder | Georges Bank | spring | SD | W | | | 0.859684 |
| Witch Flounder | Georges Bank | spring | SD | W | | | 0.215925 |
| Witch Flounder | Georges Bank | spring | SD | W | | | 0.4795 |
| Acadian Redfish | Georges Bank | all | SD | W | 0.573568 | 0.76492 | |
| Acadian Redfish | Georges Bank | all | SD | W | 0.010728 | 0.001963 | |
| Acadian Redfish | Georges Bank | all | SD | W | 0.174974 | 0.584986 | |
| Acadian Redfish | Georges Bank | all | SD | W | 0.034491 | 0.023123 | |
| Acadian Redfish | Georges Bank | fall | SD | W | | | 0.798966 |
| Acadian Redfish | Georges Bank | fall | SD | W | | | 0.111433 |
| Acadian Redfish | Georges Bank | fall | SD | W | | | 0.655814 |
| Acadian Redfish | Georges Bank | fall | SD | W | | | 0.444833 |
| Acadian Redfish | Georges Bank | spring | SD | W | | | 0.516868 |
| Acadian Redfish | Georges Bank | spring | SD | W | | | 0.006717 |
| Acadian Redfish | Georges Bank | spring | SD | W | | | 0.443657 |
| Acadian Redfish | Georges Bank | spring | SD | W | | | 0.015694 |
| White Hake | Georges Bank | all | SD | W | 0.172133 | 0.093167 | |
| White Hake | Georges Bank | all | SD | W | 0.658388 | 0.724624 | |
| White Hake | Georges Bank | all | SD | W | 0.333881 | 0.263352 | |
| White Hake | Georges Bank | all | SD | W | 0.001484 | 0.155635 | |
| White Hake | Georges Bank | fall | SD | W | | | 0.126484 |
| White Hake | Georges Bank | fall | SD | W | | | 0.111433 |
| White Hake | Georges Bank | fall | SD | W | | | 0.444833 |
| White Hake | Georges Bank | fall | SD | W | | | 0.202866 |
| White Hake | Georges Bank | spring | SD | W | | | 0.238593 |
| White Hake | Georges Bank | spring | SD | W | | | 0.637352 |
| White Hake | Georges Bank | spring | SD | W | | | 0.316472 |
| White Hake | Georges Bank | spring | SD | W | | | 0.288844 |
| Pollock | Georges Bank | all | SD | W | 0.956284 | 0.94036 | |
| Pollock | Georges Bank | all | SD | W | 0.235266 | 0.183857 | |
| Pollock | Georges Bank | all | SD | W | 0.232096 | 0.085014 | |
| Pollock | Georges Bank | all | SD | W | 0.897456 | 0.906902 | |
| Pollock | Georges Bank | fall | SD | W | | | 0.848514 |
| Pollock | Georges Bank | fall | SD | W | | | 0.566616 |
| Pollock | Georges Bank | fall | SD | W | | | 0.339541 |
| Pollock | Georges Bank | fall | SD | W | | | 0.750214 |
| Pollock | Georges Bank | spring | SD | W | | | 0.768278 |
| Pollock | Georges Bank | spring | SD | W | | | 0.029239 |
| Pollock | Georges Bank | spring | SD | W | | | 0.03917 |
| Pollock | Georges Bank | spring | SD | W | | | 0.723674 |

Table 3.7.1 (continued).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ocean Pout | Georges Bank | all | SD | W | 0.67499 | 0.58049 | |
| Ocean Pout | Georges Bank | all | SD | W | 0.987109 | 0.987866 | |
| Ocean Pout | Georges Bank | all | SD | W | 0.80934 | 0.758454 | |
| Ocean Pout | Georges Bank | all | SD | W | 0.838922 | 0.872914 | |
| Ocean Pout | Georges Bank | fall | SD | W | | | 0.048403 |
| Ocean Pout | Georges Bank | fall | SD | W | | | 0.161282 |
| Ocean Pout | Georges Bank | fall | SD | W | | | 0.041601 |
| Ocean Pout | Georges Bank | fall | SD | W | | | 0.407824 |
| Ocean Pout | Georges Bank | spring | SD | W | | | 0.140714 |
| Ocean Pout | Georges Bank | spring | SD | W | | | 0.111612 |
| Ocean Pout | Georges Bank | spring | SD | W | | | 0.175326 |
| Ocean Pout | Georges Bank | spring | SD | W | | | 0.08748 |
| Ocean Pout | Georges Bank | winter | SD | W | | | 0.683091 |
| Ocean Pout | Georges Bank | winter | SD | W | | | 0.540291 |
| Ocean Pout | Georges Bank | winter | SD | W | | | 0.307434 |
| Ocean Pout | Georges Bank | winter | SD | W | | | 0.683091 |
| Windowpane | Northern | all | SD | W | 0.673309 | 0.634325 | |
| Windowpane | Northern | all | SD | W | 0.114477 | 0.219954 | |
| Windowpane | Northern | all | SD | W | 0.537566 | 0.437876 | |
| Windowpane | Northern | all | SD | W | 0.08611 | 0.195187 | |
| Windowpane | Northern | fall | SD | W | | | 0.339541 |
| Windowpane | Northern | fall | SD | W | | | 0.339541 |
| Windowpane | Northern | fall | SD | W | | | 0.655814 |
| Windowpane | Northern | fall | SD | W | | | 0.202866 |
| Windowpane | Northern | spring | SD | W | | | 0.194851 |
| Windowpane | Northern | spring | SD | W | | | 0.316472 |
| Windowpane | Northern | spring | SD | W | | | 0.26289 |
| Windowpane | Northern | spring | SD | W | | | 0.859684 |
| Windowpane | Northern | winter | SD | W | | | 0.838256 |
| Windowpane | Northern | winter | SD | W | | | 0.414216 |
| Windowpane | Northern | winter | SD | W | | | 0.683091 |
| Windowpane | Northern | winter | SD | W | | | 0.220671 |
| Halibut | Georges Bank | all | SD | W | 0.777323 | 0.648636 | |
| Halibut | Georges Bank | all | SD | W | 0.296723 | 0.356407 | |
| Halibut | Georges Bank | all | SD | W | 0.734529 | 0.67077 | |
| Halibut | Georges Bank | all | SD | W | 0.116645 | 0.081905 | |
| Halibut | Georges Bank | fall | SD | W | | | 0.898664 |
| Halibut | Georges Bank | fall | SD | W | | | 0.898669 |
| Halibut | Georges Bank | fall | SD | W | | | 1 |
| Halibut | Georges Bank | fall | SD | W | | | 0.949232 |
| Halibut | Georges Bank | spring | SD | W | | | 0.634226 |
| Halibut | Georges Bank | spring | SD | W | | | 0.078983 |
| Halibut | Georges Bank | spring | SD | W | | | 0.906186 |
| Halibut | Georges Bank | spring | SD | W | | | 0.021556 |
| Dogfish | Georges Bank | all | SD | W | 0.657296 | 0.766204 | |
| Dogfish | Georges Bank | all | SD | W | 0.268458 | 0.221025 | |
| Dogfish | Georges Bank | all | SD | W | 0.725488 | 0.800442 | |
| Dogfish | Georges Bank | all | SD | W | 0.311377 | 0.247918 | |
| Dogfish | Georges Bank | fall | SD | W | | | 0.308325 |
| Dogfish | Georges Bank | fall | SD | W | | | 0.161282 |
| Dogfish | Georges Bank | fall | SD | W | | | 0.226372 |
| Dogfish | Georges Bank | fall | SD | W | | | 0.226372 |
| Dogfish | Georges Bank | spring | SD | W | | | 0.175326 |
| Dogfish | Georges Bank | spring | SD | W | | | 0.345779 |
| Dogfish | Georges Bank | spring | SD | W | | | 0.516868 |
| Dogfish | Georges Bank | spring | SD | W | | | 0.376759 |
| Dogfish | Georges Bank | winter | SD | W | | | 0.414216 |
| Dogfish | Georges Bank | winter | SD | W | | | 0.307434 |
| Dogfish | Georges Bank | winter | SD | W | | | 0.307434 |
| Dogfish | Georges Bank | winter | SD | W | | | 0.414216 |

Table 3.7.1 (continued).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fourspot Flounder | Georges Bank | all | SD | W | 0.468537 | 0.520394 | |
| Fourspot Flounder | Georges Bank | all | SD | W | 0.782591 | 0.818612 | |
| Fourspot Flounder | Georges Bank | all | SD | W | 0.674166 | 0.73479 | |
| Fourspot Flounder | Georges Bank | all | SD | W | 0.636316 | 0.732836 | |
| Fourspot Flounder | Georges Bank | fall | SD | W | | | 0.610492 |
| Fourspot Flounder | Georges Bank | fall | SD | W | | | 0.111433 |
| Fourspot Flounder | Georges Bank | fall | SD | W | | | 0.750214 |
| Fourspot Flounder | Georges Bank | fall | SD | W | | | 0.70244 |
| Fourspot Flounder | Georges Bank | spring | SD | W | | | 0.03917 |
| Fourspot Flounder | Georges Bank | spring | SD | W | | | 0.09896 |
| Fourspot Flounder | Georges Bank | spring | SD | W | | | 0.033895 |
| Fourspot Flounder | Georges Bank | spring | SD | W | | | 0.09896 |
| Fourspot Flounder | Georges Bank | winter | SD | W | | | 0.066193 |
| Fourspot Flounder | Georges Bank | winter | SD | W | | | 0.066193 |
| Fourspot Flounder | Georges Bank | winter | SD | W | | | 0.066193 |
| Fourspot Flounder | Georges Bank | winter | SD | W | | | 0.066193 |
| Longhorn Sculpin | Georges Bank | all | SD | W | 0.180463 | 0.110084 | |
| Longhorn Sculpin | Georges Bank | all | SD | W | 0.353837 | 0.205575 | |
| Longhorn Sculpin | Georges Bank | all | SD | W | 0.140948 | 0.107944 | |
| Longhorn Sculpin | Georges Bank | all | SD | W | 0.209937 | 0.107135 | |
| Longhorn Sculpin | Georges Bank | fall | SD | W | | | 0.407824 |
| Longhorn Sculpin | Georges Bank | fall | SD | W | | | 0.655814 |
| Longhorn Sculpin | Georges Bank | fall | SD | W | | | 0.483686 |
| Longhorn Sculpin | Georges Bank | fall | SD | W | | | 0.610492 |
| Longhorn Sculpin | Georges Bank | spring | SD | W | | | 0.316472 |
| Longhorn Sculpin | Georges Bank | spring | SD | W | | | 0.4795 |
| Longhorn Sculpin | Georges Bank | spring | SD | W | | | 0.288844 |
| Longhorn Sculpin | Georges Bank | spring | SD | W | | | 0.316472 |
| Longhorn Sculpin | Georges Bank | winter | SD | W | | | 0.220671 |
| Longhorn Sculpin | Georges Bank | winter | SD | W | | | 0.414216 |
| Longhorn Sculpin | Georges Bank | winter | SD | W | | | 0.307434 |
| Longhorn Sculpin | Georges Bank | winter | SD | W | | | 0.414216 |
| Winter Flounder | Georges Bank | all | SD | W | 0.483801 | 0.440467 | |
| Winter Flounder | Georges Bank | all | SD | W | 0.363302 | 0.4133 | |
| Winter Flounder | Georges Bank | all | SD | W | 0.468608 | 0.411567 | |
| Winter Flounder | Georges Bank | all | SD | W | 0.302825 | 0.352209 | |
| Winter Flounder | Georges Bank | fall | SD | W | | | 0.135682 |
| Winter Flounder | Georges Bank | fall | SD | W | | | 0.193759 |
| Winter Flounder | Georges Bank | fall | SD | W | | | 0.135682 |
| Winter Flounder | Georges Bank | fall | SD | W | | | 0.193759 |
| Winter Flounder | Georges Bank | spring | SD | W | | | 0.143235 |
| Winter Flounder | Georges Bank | spring | SD | W | | | 0.305507 |
| Winter Flounder | Georges Bank | spring | SD | W | | | 0.124283 |
| Winter Flounder | Georges Bank | spring | SD | W | | | 0.213399 |
| Winter Flounder | Georges Bank | winter | SD | W | | | 0.10247 |
| Winter Flounder | Georges Bank | winter | SD | W | | | 0.414216 |
| Winter Flounder | Georges Bank | winter | SD | W | | | 0.10247 |
| Winter Flounder | Georges Bank | winter | SD | W | | | 0.414216 |
| Summer Flounder | Georges Bank | all | SD | W | 0.605129 | 0.699592 | |
| Summer Flounder | Georges Bank | all | SD | W | 0.820766 | 0.879866 | |
| Summer Flounder | Georges Bank | all | SD | W | 0.699944 | 0.751436 | |
| Summer Flounder | Georges Bank | all | SD | W | 0.473265 | 0.653004 | |
| Summer Flounder | Georges Bank | fall | SD | W | | | 0.150382 |
| Summer Flounder | Georges Bank | fall | SD | W | | | 0.3268 |
| Summer Flounder | Georges Bank | fall | SD | W | | | 0.191063 |
| Summer Flounder | Georges Bank | fall | SD | W | | | 0.214211 |
| Summer Flounder | Georges Bank | spring | SD | W | | | 0.906186 |
| Summer Flounder | Georges Bank | spring | SD | W | | | 0.4795 |
| Summer Flounder | Georges Bank | spring | SD | W | | | 0.813664 |
| Summer Flounder | Georges Bank | spring | SD | W | | | 0.443657 |
| Summer Flounder | Georges Bank | winter | SD | W | | | 0.21 |
| Summer Flounder | Georges Bank | winter | SD | W | | | 0.73244 |
| Summer Flounder | Georges Bank | winter | SD | W | | | 0.21 |
| Summer Flounder | Georges Bank | winter | SD | W | | | 0.305059 |

Table 3.7.1 (continued).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Haddock | Gulf of Maine | all | SD | W | 0.870036 | 0.905378 | |
| Haddock | Gulf of Maine | all | SD | W | 0.031405 | 0.058599 | |
| Haddock | Gulf of Maine | all | SD | W | 0.132005 | 0.270298 | |
| Haddock | Gulf of Maine | all | SD | W | 0.106911 | 0.178393 | |
| Haddock | Gulf of Maine | fall | SD | W | | | 1 |
| Haddock | Gulf of Maine | fall | SD | W | | | 0.097832 |
| Haddock | Gulf of Maine | fall | SD | W | | | 0.143073 |
| Haddock | Gulf of Maine | fall | SD | W | | | 0.202866 |
| Haddock | Gulf of Maine | spring | SD | W | | | 0.859684 |
| Haddock | Gulf of Maine | spring | SD | W | | | 0.157299 |
| Haddock | Gulf of Maine | spring | SD | W | | | 0.927432 |
| Haddock | Gulf of Maine | spring | SD | W | | | 0.236415 |
| Cod | Gulf of Maine | all | SD | W | 0.530754 | 0.584534 | |
| Cod | Gulf of Maine | all | SD | W | 0.393274 | 0.450724 | |
| Cod | Gulf of Maine | all | SD | W | 0.183749 | 0.398397 | |
| Cod | Gulf of Maine | all | SD | W | 0.047991 | 0.094618 | |
| Cod | Gulf of Maine | fall | SD | W | | | 1 |
| Cod | Gulf of Maine | fall | SD | W | | | 0.111433 |
| Cod | Gulf of Maine | fall | SD | W | | | 0.524311 |
| Cod | Gulf of Maine | fall | SD | W | | | 0.161282 |
| Cod | Gulf of Maine | spring | SD | W | | | 0.316472 |
| Cod | Gulf of Maine | spring | SD | W | | | 0.953011 |
| Cod | Gulf of Maine | spring | SD | W | | | 0.345779 |
| Cod | Gulf of Maine | spring | SD | W | | | 0.288844 |
| Yellowtail | S. New England | all | SD | W | 0.702098 | 0.801407 | |
| Yellowtail | S. New England | all | SD | W | 0.046119 | 0.031408 | |
| Yellowtail | S. New England | all | SD | W | 0.949283 | 0.957267 | |
| Yellowtail | S. New England | all | SD | W | 0.04699 | 0.045465 | |
| Yellowtail | S. New England | fall | SD | W | | | 0.566616 |
| Yellowtail | S. New England | fall | SD | W | | | 0.226372 |
| Yellowtail | S. New England | fall | SD | W | | | 0.251759 |
| Yellowtail | S. New England | fall | SD | W | | | 0.251759 |
| Yellowtail | S. New England | spring | SD | W | | | 0.859684 |
| Yellowtail | S. New England | spring | SD | W | | | 0.345779 |
| Yellowtail | S. New England | spring | SD | W | | | 0.768278 |
| Yellowtail | S. New England | spring | SD | W | | | 0.26289 |
| Yellowtail | S. New England | winter | SD | W | | | 0.683091 |
| Yellowtail | S. New England | winter | SD | W | | | 0.10247 |
| Yellowtail | S. New England | winter | SD | W | | | 1 |
| Yellowtail | S. New England | winter | SD | W | | | 0.041227 |
| Windowpane | Southern | all | SD | W | 0.673705 | 0.664883 | |
| Windowpane | Southern | all | SD | W | 0.769474 | 0.791003 | |
| Windowpane | Southern | all | SD | W | 0.715402 | 0.71455 | |
| Windowpane | Southern | all | SD | W | 0.59928 | 0.632188 | |
| Windowpane | Southern | fall | SD | W | | | 0.226372 |
| Windowpane | Southern | fall | SD | W | | | 0.566616 |
| Windowpane | Southern | fall | SD | W | | | 0.279068 |
| Windowpane | Southern | fall | SD | W | | | 0.898669 |
| Windowpane | Southern | spring | SD | W | | | 0.953011 |
| Windowpane | Southern | spring | SD | W | | | 0.4795 |
| Windowpane | Southern | spring | SD | W | | | 0.813664 |
| Windowpane | Southern | spring | SD | W | | | 0.637352 |
| Windowpane | Southern | winter | SD | W | | | 0.838256 |
| Windowpane | Southern | winter | SD | W | | | 0.540291 |
| Windowpane | Southern | winter | SD | W | | | 0.838256 |
| Windowpane | Southern | winter | SD | W | | | 0.414216 |

Table 3.7.1 (continued).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Winter Flounder | S. New England | all | SD | W | 0.032823 | 0.003262 | |
| Winter Flounder | S. New England | all | SD | W | 0.125266 | 0.135732 | |
| Winter Flounder | S. New England | all | SD | W | 0.054484 | 0.009231 | |
| Winter Flounder | S. New England | all | SD | W | 0.138046 | 0.123636 | |
| Winter Flounder | S. New England | fall | SD | W | | | 0.143073 |
| Winter Flounder | S. New England | fall | SD | W | | | 0.339541 |
| Winter Flounder | S. New England | fall | SD | W | | | 0.161282 |
| Winter Flounder | S. New England | fall | SD | W | | | 0.483686 |
| Winter Flounder | S. New England | spring | SD | W | | | 0.26289 |
| Winter Flounder | S. New England | spring | SD | W | | | 0.768278 |
| Winter Flounder | S. New England | spring | SD | W | | | 0.345779 |
| Winter Flounder | S. New England | spring | SD | W | | | 0.516868 |
| Winter Flounder | S. New England | winter | SD | W | | | 0.220671 |
| Winter Flounder | S. New England | winter | SD | W | | | 0.307434 |
| Winter Flounder | S. New England | winter | SD | W | | | 0.10247 |
| Winter Flounder | S. New England | winter | SD | W | | | 0.307434 |
| Yellowtail | Cape Cod | all | SD | W | 0.348209 | 0.247442 | |
| Yellowtail | Cape Cod | all | SD | W | 0.499274 | 0.654831 | |
| Yellowtail | Cape Cod | all | SD | W | 0.347324 | 0.253839 | |
| Yellowtail | Cape Cod | all | SD | W | 0.368072 | 0.562796 | |
| Yellowtail | Cape Cod | fall | SD | W | | | 0.898669 |
| Yellowtail | Cape Cod | fall | SD | W | | | 0.949232 |
| Yellowtail | Cape Cod | fall | SD | W | | | 0.949232 |
| Yellowtail | Cape Cod | fall | SD | W | | | 1 |
| Yellowtail | Cape Cod | spring | SD | W | | | 0.194819 |
| Yellowtail | Cape Cod | spring | SD | W | | | 0.443657 |
| Yellowtail | Cape Cod | spring | SD | W | | | 0.236415 |
| Yellowtail | Cape Cod | spring | SD | W | | | 0.378639 |
| | | | | Total Tests | 88 | 88 | 232 |
| | Num P levels less than 0.05 | | | | 0 | 0 | 0 |
| | Fraction pf tests with less than 0.05 | | | | 0.000 | 0.000 | 0.000 |
| | Bonferroni P level for multiple tests, each with 5% Type I errors | | | | 0.000284091 | 0.000284091 | 0.000107759 |
| | Number of tests that with probability levels less than Bonferroni limit | | | | 0 | 0 | 0 |

Table 3.7.2. Summary of statistical test of regression model for standardized difference of pre-post treatment catch rates versus depth for numbers per tow, and biomass (kg) per tow. Model type refers to response variable: num/tow= Nd_stan, weight per tow=Wd_stan.

| model type | Species | Stock | Season | Effect: Constant | Effect: DepthMid | Adj $R^2$ | p-value |
|---|---|---|---|---|---|---|---|
| Nd_stan | Acadian Redfish | all | fall | 0.473255 | -0.002754 | 0 | 0.573 |
| Wd_stan | Acadian Redfish | 1 | fall | 0.699839 | -0.004073 | 0 | 0.399 |
| Nd_stan | Acadian Redfish | all | spring | 0.203443 | -0.001017 | 0 | 0.772 |
| Wd_stan | Acadian Redfish | all | spring | 0.005724 | -0.000029 | 0 | 0.994 |
| Nd_stan | American Plaice | all | fall | 0.707636 | -0.00467 | 0.063654 | 0.205 |
| Wd_stan | American Plaice | all | fall | 0.709069 | -0.004679 | 0.06428 | 0.204 |
| Nd_stan | American Plaice | all | spring | -0.379685 | 0.002109 | 0 | 0.456 |
| Wd_stan | American Plaice | all | spring | -0.336627 | 0.00187 | 0 | 0.509 |
| Nd_stan | American Plaice | all | winter | 2.350554 | -0.019588 | 0.421454 | 0.097 |
| Wd_stan | American Plaice | all | winter | 2.748405 | -0.022903 | 0.667988 | 0.029 |
| Nd_stan | cod | GB | fall | -0.113871 | 0.000949 | 0 | 0.875 |
| Wd_stan | Cod | GB | fall | -0.400822 | 0.00334 | 0 | 0.575 |
| Nd_stan | cod | GB | spring | 0.00633 | -0.000053 | 0 | 0.993 |
| Wd_stan | Cod | GB | spring | -0.055814 | 0.000465 | 0 | 0.938 |
| Nd_stan | cod | GB | winter | 0.270265 | -0.002252 | 0 | 0.874 |
| Wd_stan | Cod | GB | winter | -0.739223 | 0.00616 | 0 | 0.660 |
| Nd_stan | cod | GM | fall | -1.586011 | 0.009231 | 0.346768 | 0.033 |
| Wd_stan | Cod | GM | fall | -1.368388 | 0.007964 | 0.229734 | 0.077 |
| Nd_stan | cod | GM | spring | -1.774249 | 0.008871 | 0.513467 | 0.002 |
| Wd_stan | Cod | GM | spring | -0.646247 | 0.003231 | 0 | 0.350 |
| Nd_stan | Dogfish | all | fall | -0.236035 | 0.001475 | 0 | 0.674 |
| Wd_stan | Dogfish | all | fall | -0.018783 | 0.000117 | 0 | 0.973 |
| Nd_stan | Dogfish | all | spring | 0.333086 | -0.00185 | 0 | 0.514 |
| Wd_stan | Dogfish | all | spring | 0.348654 | -0.001937 | 0 | 0.494 |
| Nd_stan | Dogfish | all | winter | 0.511442 | -0.003086 | 0.005047 | 0.322 |
| Wd_stan | Dogfish | all | winter | 0.773519 | -0.004668 | 0.118831 | 0.123 |
| Nd_stan | Fluke | all | fall | -0.22145 | 0.001845 | 0 | 0.680 |
| Wd_stan | Fluke | all | fall | -0.290864 | 0.002424 | 0 | 0.587 |
| Nd_stan | Fluke | all | spring | -0.880215 | 0.007335 | 0.207759 | 0.077 |
| Wd_stan | Fluke | all | spring | -0.960853 | 0.008007 | 0.266731 | 0.049 |
| Nd_stan | Fluke | all | winter | -0.783761 | 0.009797 | 0 | 0.475 |
| Wd_stan | Fluke | all | winter | -0.10594 | 0.001324 | 0 | 0.926 |
| Nd_stan | Fourspot Flounder | all | fall | -0.595604 | 0.004803 | 0 | 0.367 |
| Wd_stan | Fourspot Flounder | all | fall | -0.517414 | 0.004173 | 0 | 0.436 |
| Nd_stan | Fourspot Flounder | all | spring | -0.807506 | 0.005383 | 0.10089 | 0.154 |
| Wd_stan | Fourspot Flounder | all | spring | -0.878435 | 0.005856 | 0.136065 | 0.117 |
| Nd_stan | Fourspot Flounder | all | winter | -0.26492 | 0.001599 | 0 | 0.614 |
| Wd_stan | Fourspot Flounder | all | winter | -0.355459 | 0.002145 | 0 | 0.496 |
| Nd_stan | haddock | GB | fall | -0.084348 | 0.000588 | 0 | 0.887 |
| Wd_stan | Haddock | GB | fall | -0.19594 | 0.001367 | 0 | 0.741 |
| Nd_stan | haddock | GB | spring | -0.41692 | 0.002396 | 0 | 0.413 |
| Wd_stan | Haddock | GB | spring | -0.070542 | 0.000405 | 0 | 0.891 |
| Nd_stan | haddock | GB | winter | -1.413863 | 0.011782 | 0 | 0.382 |
| Wd_stan | Haddock | GB | winter | -1.154848 | 0.009624 | 0 | 0.483 |
| Nd_stan | haddock | GOM | fall | -0.197185 | 0.001232 | 0 | 0.838 |
| Wd_stan | Haddock | GOM | fall | -0.537264 | 0.003358 | 0 | 0.573 |
| Nd_stan | haddock | GOM | spring | -0.115982 | 0.000725 | 0 | 0.904 |
| Wd_stan | Haddock | GOM | spring | -0.513181 | 0.003207 | 0 | 0.591 |
| Nd_stan | Longhorn Sculpin | all | fall | 0.568906 | -0.004741 | 0 | 0.421 |
| Wd_stan | Longhorn Sculpin | all | fall | 0.687844 | -0.005732 | 0.010532 | 0.326 |
| Nd_stan | Longhorn Sculpin | all | spring | -1.668872 | 0.013907 | 0.672825 | 0.002 |
| Wd_stan | Longhorn Sculpin | all | spring | -1.580484 | 0.013171 | 0.590553 | 0.006 |
| Nd_stan | Longhorn Sculpin | all | winter | -1.382063 | 0.017276 | 0.272292 | 0.165 |
| Wd_stan | Longhorn Sculpin | all | winter | -1.354093 | 0.016926 | 0.251366 | 0.177 |
| Nd_stan | Ocean Pout | all | fall | 0.629009 | -0.004839 | 0.003345 | 0.336 |
| Wd_stan | Ocean Pout | all | fall | 0.587859 | -0.004522 | 0 | 0.370 |
| Nd_stan | Ocean Pout | all | spring | -0.288995 | 0.002223 | 0 | 0.665 |
| Wd_stan | Ocean Pout | all | spring | -0.217109 | 0.00167 | 0 | 0.746 |
| Nd_stan | Ocean Pout | all | winter | 0.080832 | -0.000652 | 0 | 0.905 |
| Wd_stan | Ocean Pout | all | winter | 0.3447 | -0.00278 | 0 | 0.608 |

Table 3.7.2 (continued).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nd_stan | Pollock | all | fall | 0.665613 | -0.004392 | 0.045841 | 0.235 | |
| Wd_stan | Pollock | all | fall | 0.49967 | -0.003297 | 0 | 0.380 | |
| Nd_stan | Pollock | all | spring | 0.165327 | -0.000918 | 0 | 0.747 | |
| Wd_stan | Pollock | all | spring | 0.704614 | -0.003915 | 0.077428 | 0.155 | |
| Nd_stan | White Hake | all | fall | 0.74412 | -0.00491 | 0.080002 | 0.181 | |
| Wd_stan | White Hake | all | fall | 0.973632 | -0.006425 | 0.201691 | 0.070 | |
| Nd_stan | White Hake | all | spring | 1.250393 | -0.006947 | 0.39734 | 0.005 | |
| Wd_stan | White Hake | all | spring | 1.299752 | -0.007221 | 0.43508 | 0.003 | |
| Nd_stan | Windowpane | North | fall | 0.811478 | -0.005796 | 0.092174 | 0.176 | |
| Wd_stan | Windowpane | North | fall | 0.972239 | -0.006945 | 0.175858 | 0.097 | |
| Nd_stan | Windowpane | North | spring | -1.1458 | 0.007161 | 0.305566 | 0.024 | |
| Wd_stan | Windowpane | North | spring | -1.178886 | 0.007368 | 0.32835 | 0.019 | |
| Nd_stan | Windowpane | North | winter | -2.544398 | 0.021203 | 0.536766 | 0.060 | |
| Wd_stan | Windowpane | North | winter | -2.444078 | 0.020367 | 0.475948 | 0.078 | |
| Nd_stan | Windowpane | South | fall | -0.472428 | 0.004395 | 0 | 0.502 | |
| Wd_stan | Windowpane | South | fall | -0.652119 | 0.006066 | 0.007209 | 0.345 | |
| Nd_stan | Windowpane | South | spring | -0.411368 | 0.002904 | 0 | 0.496 | |
| Wd_stan | Windowpane | South | spring | -0.134864 | 0.000952 | 0 | 0.825 | |
| Nd_stan | Windowpane | South | winter | -0.340323 | 0.002054 | 0 | 0.515 | |
| Wd_stan | Windowpane | South | winter | -0.509875 | 0.003077 | 0.004506 | 0.324 | |
| Nd_stan | Winter Flounder | GB | fall | 1.414214 | -0.070711 | n/a | n/a | |
| Wd_stan | Winter Flounder | GB | fall | 1.414214 | -0.070711 | n/a | n/a | |
| Nd_stan | Winter Flounder | GB | spring | -1.358549 | 0.045285 | 0.640582 | 0.279 | |
| Wd_stan | Winter Flounder | GB | spring | -1.424703 | 0.04749 | 0.804248 | 0.203 | |
| Nd_stan | Winter Flounder | GB | winter | 0.829594 | -0.007392 | 0.072265 | 0.243 | |
| Wd_stan | Winter Flounder | GB | winter | 0.874185 | -0.00779 | 0.096012 | 0.216 | |
| Nd_stan | Winter Flounder | SNE | fall | -0.387029 | 0.002908 | 0 | 0.423 | |
| Wd_stan | Winter Flounder | SNE | fall | -0.375643 | 0.002823 | 0 | 0.438 | |
| Nd_stan | Winter Flounder | SNE | spring | 0.386662 | -0.002379 | 0 | 0.378 | |
| Wd_stan | Winter Flounder | SNE | spring | 0.487718 | -0.003001 | 0.023735 | 0.262 | |
| Nd_stan | Winter Flounder | SNE | winter | -0.533972 | 0.006675 | 0 | 0.456 | |
| Wd_stan | Winter Flounder | SNE | winter | -1.248604 | 0.015608 | 0.241034 | 0.060 | |
| Nd_stan | Witch Flouder | all | fall | 0.197154 | -0.001301 | 0 | 0.733 | |
| Wd_stan | Witch Flouder | all | fall | -0.084724 | 0.000559 | 0 | 0.884 | |
| Nd_stan | Witch Flouder | all | spring | 0.229952 | -0.001278 | 0 | 0.654 | |
| Wd_stan | Witch Flouder | all | spring | 0.663112 | -0.003684 | 0.060409 | 0.183 | |
| Nd_stan | Yellowtail | GB | fall | -0.525323 | 0.005837 | 0 | 0.585 | |
| Wd_stan | Yellowtail | GB | fall | -0.524222 | 0.005825 | 0 | 0.586 | |
| Nd_stan | Yellowtail | GB | spring | -0.266372 | 0.00333 | 0 | 0.814 | |
| Wd_stan | Yellowtail | GB | spring | -0.280611 | 0.003508 | 0 | 0.804 | |
| Nd_stan | Yellowtail | GB | winter | -2.389447 | 0.019912 | 0.443857 | 0.089 | |
| Wd_stan | Yellowtail | GB | winter | -2.266207 | 0.018885 | 0.37413 | 0.116 | |
| Nd_stan | Yellowtail | SNE | fall | -0.622878 | 0.010381 | 0 | 0.732 | |
| Wd_stan | Yellowtail | SNE | fall | -2.005485 | 0.033425 | 0.617214 | 0.137 | |
| Nd_stan | Yellowtail | SNE | spring | -0.787223 | 0.011246 | 0 | 0.557 | |
| Wd_stan | Yellowtail | SNE | spring | -1.35803 | 0.0194 | 0.168502 | 0.271 | |
| Nd_stan | Yellowtail | SNE | winter | 0.387471 | -0.005535 | 0 | 0.778 | |
| Wd_stan | Yellowtail | SNE | winter | -0.132346 | 0.001891 | 0 | 0.924 | |
| Nd_stan | Yellowtail | CC | fall | 0.694145 | -0.013883 | 0 | 0.460 | |
| Wd_stan | Yellowtail | CC | fall | 0.67586 | -0.013517 | 0 | 0.473 | |
| Nd_stan | Yellowtail | CC | spring | 0.313874 | -0.005231 | 0 | 0.710 | |
| Wd_stan | Yellowtail | CC | spring | 0.228901 | -0.003815 | 0 | 0.787 | |

Table 3.7.3. Summary of statistical tests of regression model for standardized difference of pre-post treatment catch rates versus deoth for numbers per tow, and biomass (kg) per tow. Model type refers to response variable: num/tow= Nd_stan, weight per tow=Wd_stan. For these analyses, all species are pooled; the depth effect coefficient represents the change in the standardized difference. Positive values imply that the pre-treatment catch rates exceeded the post-treatment catch rates.

| **Model Type** | **Difference** | **Season** | **Constant** | **Depthmid** | **Adj. R^2** | **p-value** |
|---|---|---|---|---|---|---|
| Wd stan | Weight | spring | -0.018886 | 0.000121 | 0 | 0.8621 |
| Nd_stan | Number | spring | -0.142906 | 0.000914 | 0.002964 | 0.1879 |
| lnWd_stan | ln W | spring | 0.023038 | -0.000147 | 0 | 0.8322 |
| lnNd_stan | ln N | spring | 0.081126 | -0.000519 | 0 | 0.4553 |
| Wd stan | Weight | fall | 0.066983 | -0.000492 | 0 | 0.5780 |
| Nd_stan | Number | fall | 0.075799 | -0.000556 | 0 | 0.5289 |
| lnWd_stan | ln W | fall | 0.358677 | -0.002632 | 0.037413 | 0.0026 |
| lnNd_stan | ln N | fall | 0.416881 | -0.003059 | 0.052196 | 0.0004 |
| Wd stan | Weight | winter | -0.065415 | 0.000521 | 0 | 0.6700 |
| Nd_stan | Number | winter | -0.064781 | 0.000515 | 0 | 0.6730 |
| lnWd_stan | ln W | winter | -0.085622 | 0.000681 | 0 | 0.5769 |
| lnNd_stan | ln N | winter | 0.002906 | -0.000023 | 0 | 0.9849 |

Table 3.7.4. Summary of frequencies of standardized residuals of average catch (number/tow) vs Depth for all species combined.

Expected frequencies are based on assumption that standardized residuals are normally distributed.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 80%CI | | | | 80% CI | | | | |
| 90% CI | | | 90% CI | | | | | |
| 95% CI | | 95% CI | | | | | | |

| min Stan Dif | <-1.96 | -1.96 | -1.645 | -1.282 | 0 | 1.282 | 1.645 | |
|---|---|---|---|---|---|---|---|---|
| max Stan Dif | | -1.645 | -1.282 | 0 | 1.282 | 1.645 | 1.96 | >1.96 |

| Depth Interval (m) | <0.025 | (0.025-0.05) | (0.05-0.10) | (0.10-0.50) | (0.50-0.90) | (0.90-0.95) | (0.95-0.975) | >0.975 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 8 |
| 30 | 3 | 1 | 0 | 17 | 23 | 0 | 0 | 2 | 46 |
| 50 | 3 | 0 | 1 | 16 | 18 | 4 | 2 | 1 | 45 |
| 70 | 4 | 4 | 4 | 16 | 21 | 2 | 2 | 2 | 55 |
| 90 | 4 | 1 | 2 | 24 | 20 | 1 | 2 | 1 | 55 |
| 110 | 4 | 0 | 1 | 21 | 23 | 2 | 2 | 0 | 53 |
| 130 | 0 | 1 | 2 | 17 | 24 | 3 | 2 | 1 | 50 |
| 150 | 4 | 0 | 2 | 11 | 22 | 1 | 1 | 4 | 45 |
| 170 | 2 | 0 | 0 | 15 | 24 | 1 | 0 | 1 | 43 |
| 190 | 1 | 2 | 0 | 17 | 15 | 0 | 0 | 0 | 35 |
| 210 | 2 | 0 | 0 | 12 | 20 | 1 | 1 | 2 | 38 |
| 230 | 0 | 0 | 0 | 15 | 17 | 2 | 0 | 0 | 34 |
| 250 | 0 | 0 | 0 | 5 | 15 | 1 | 0 | 0 | 21 |
| 270 | 1 | 0 | 0 | 6 | 8 | 0 | 0 | 0 | 15 |
| 290 | 0 | 0 | 1 | 7 | 13 | 0 | 0 | 0 | 21 |
| 310 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 9 |
| 330 | 1 | 0 | 1 | 4 | 6 | 0 | 0 | 0 | 12 |
| Total | 29 | 9 | 14 | 212 | 277 | 18 | 12 | 14 | 585 |
| Percent | 0.050 | 0.015 | 0.024 | 0.362 | 0.474 | 0.031 | 0.021 | 0.024 | |
| | | | | | | | | | |
| Expected% | 0.025 | 0.025 | 0.05 | 0.34135 | 0.34135 | 0.05 | 0.025 | 0.025 | |
| Expected # | 14.6 | 14.6 | 29.3 | 199.7 | 199.7 | 29.3 | 14.6 | 14.6 | |

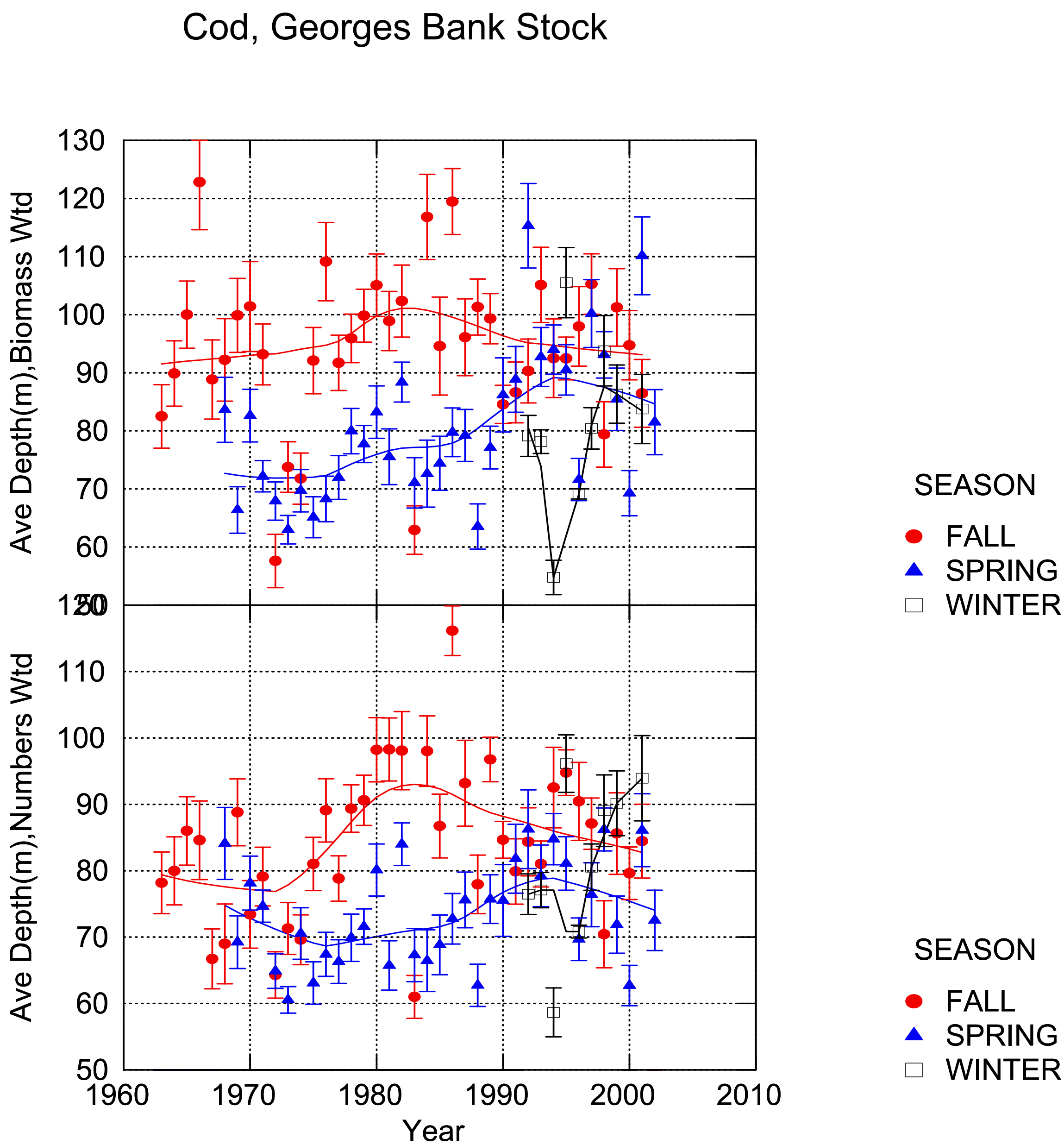



Fig. 3.7.1. Temporal trends in catch weighted average depth for Georges Bank Cod stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

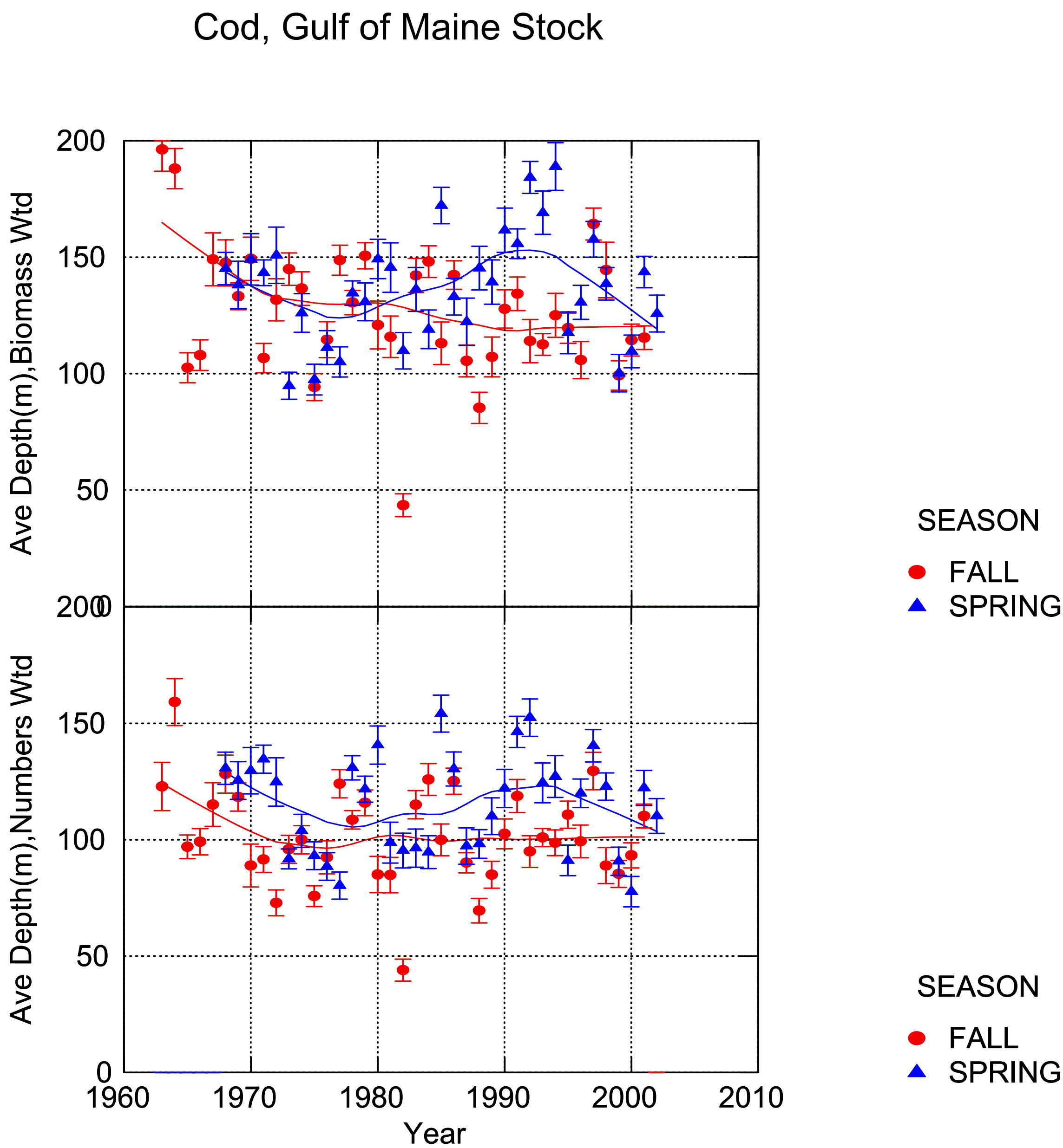



Fig. 3.7.2. Temporal trends in catch weighted average depth for Gulf of Maine Cod stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

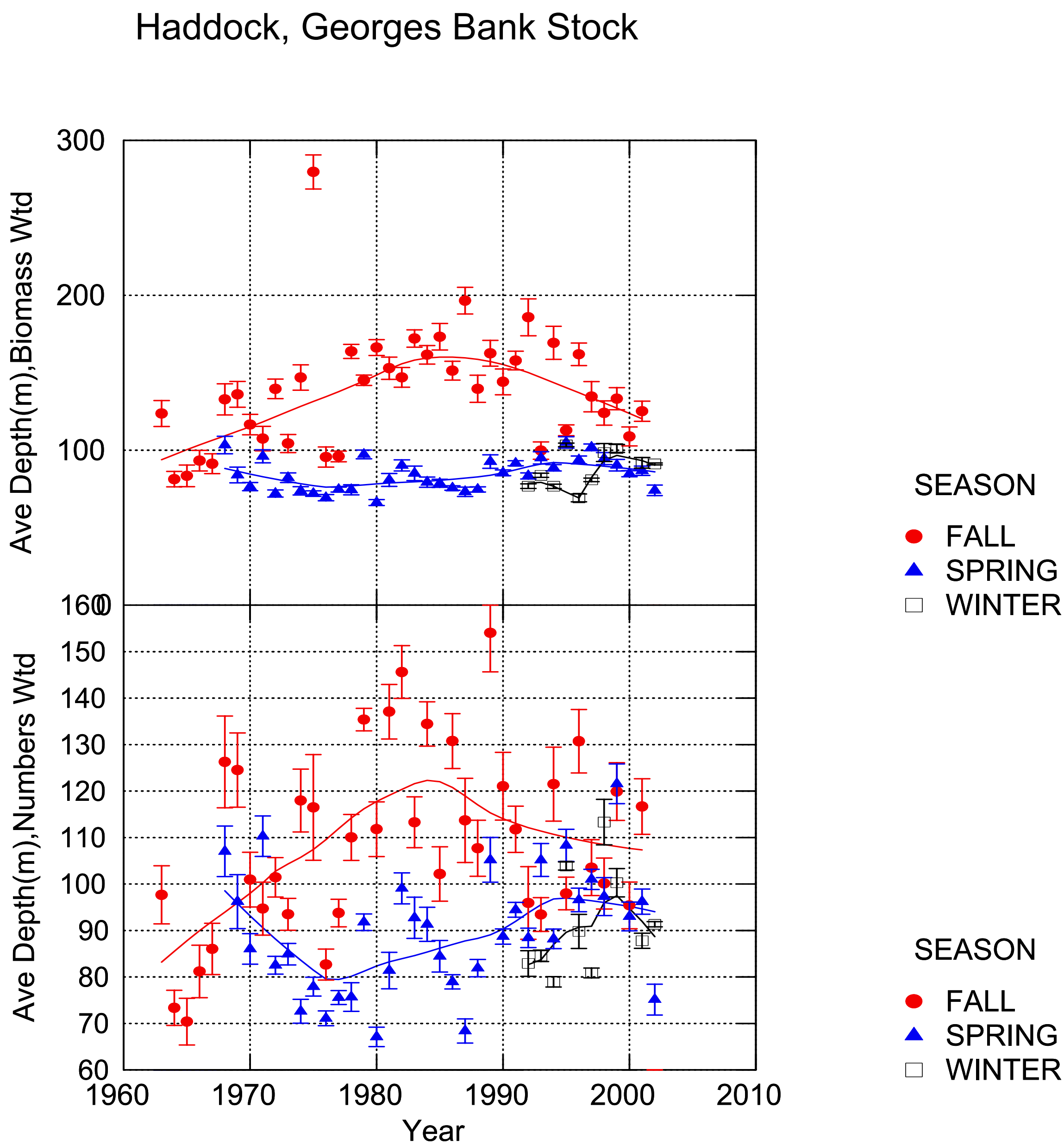



Fig. 3.7.3. Temporal trends in catch weighted average depth for Georges Bank Haddock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

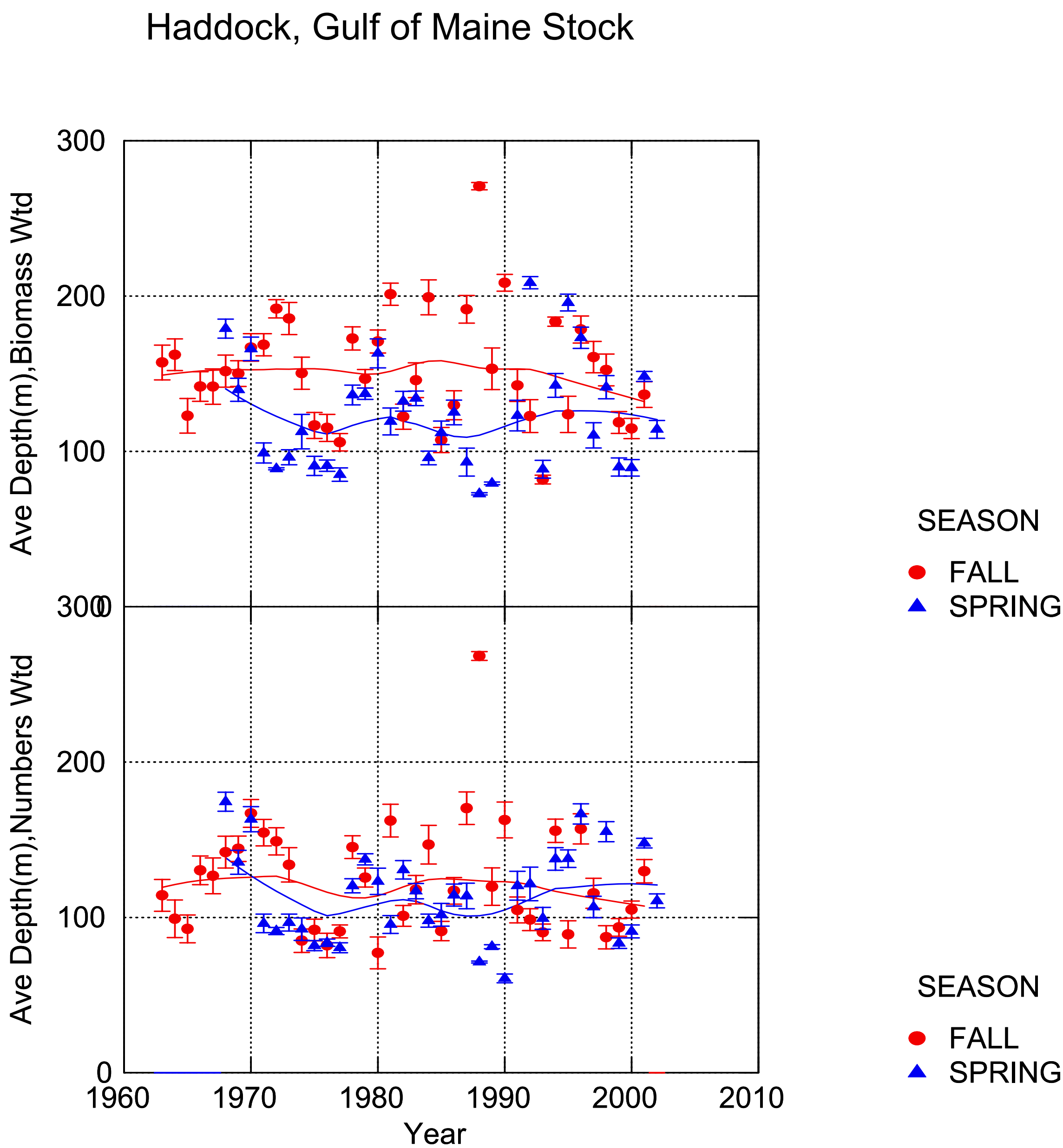



Fig. 3.7.4. Temporal trends in catch weighted average depth for Gulf of Maine Haddock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

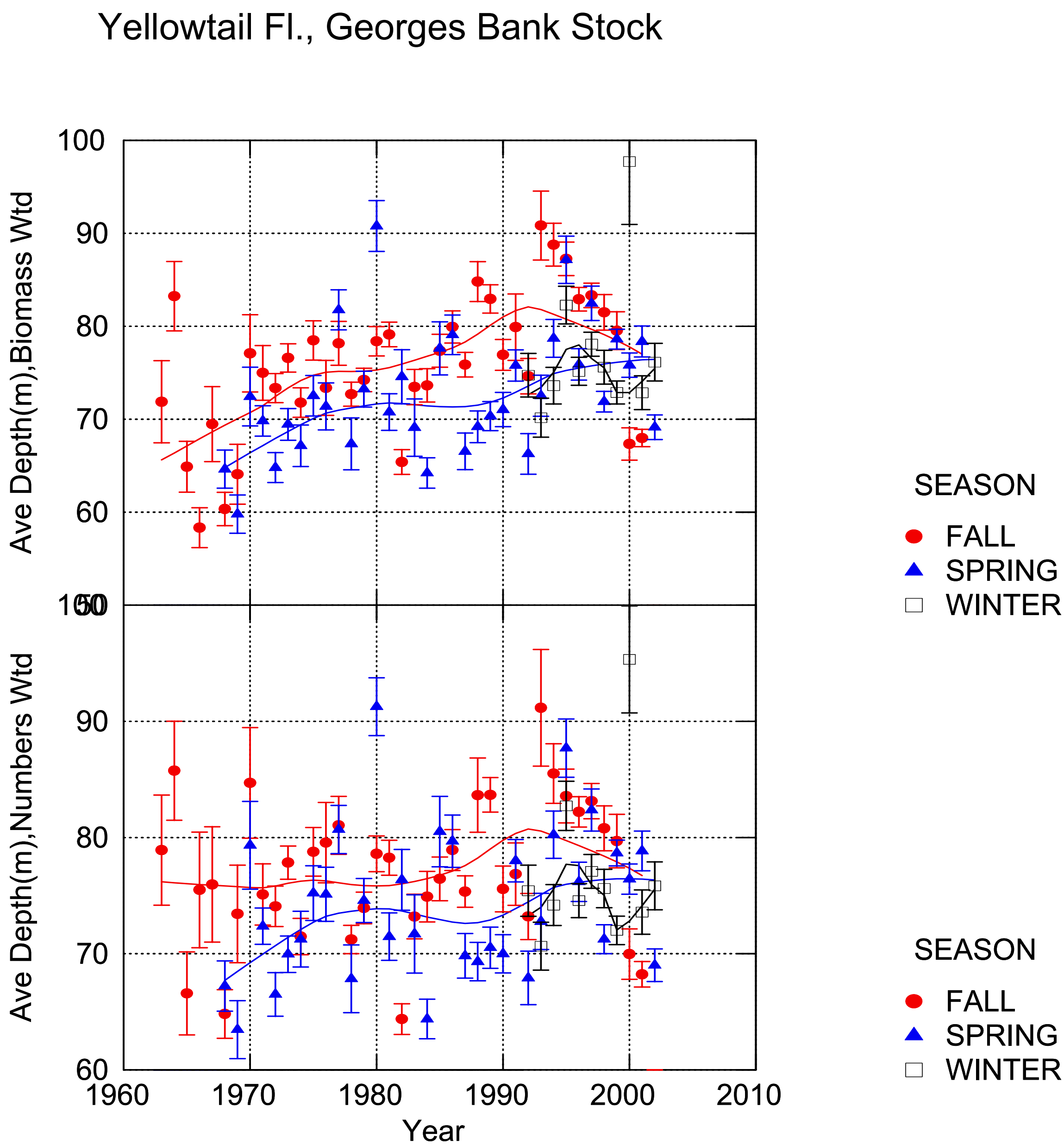



Fig. 3.7.5. Temporal trends in catch weighted average depth for Georges Bank Yellowtail stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Yellowtail Fl. , SNE Stock

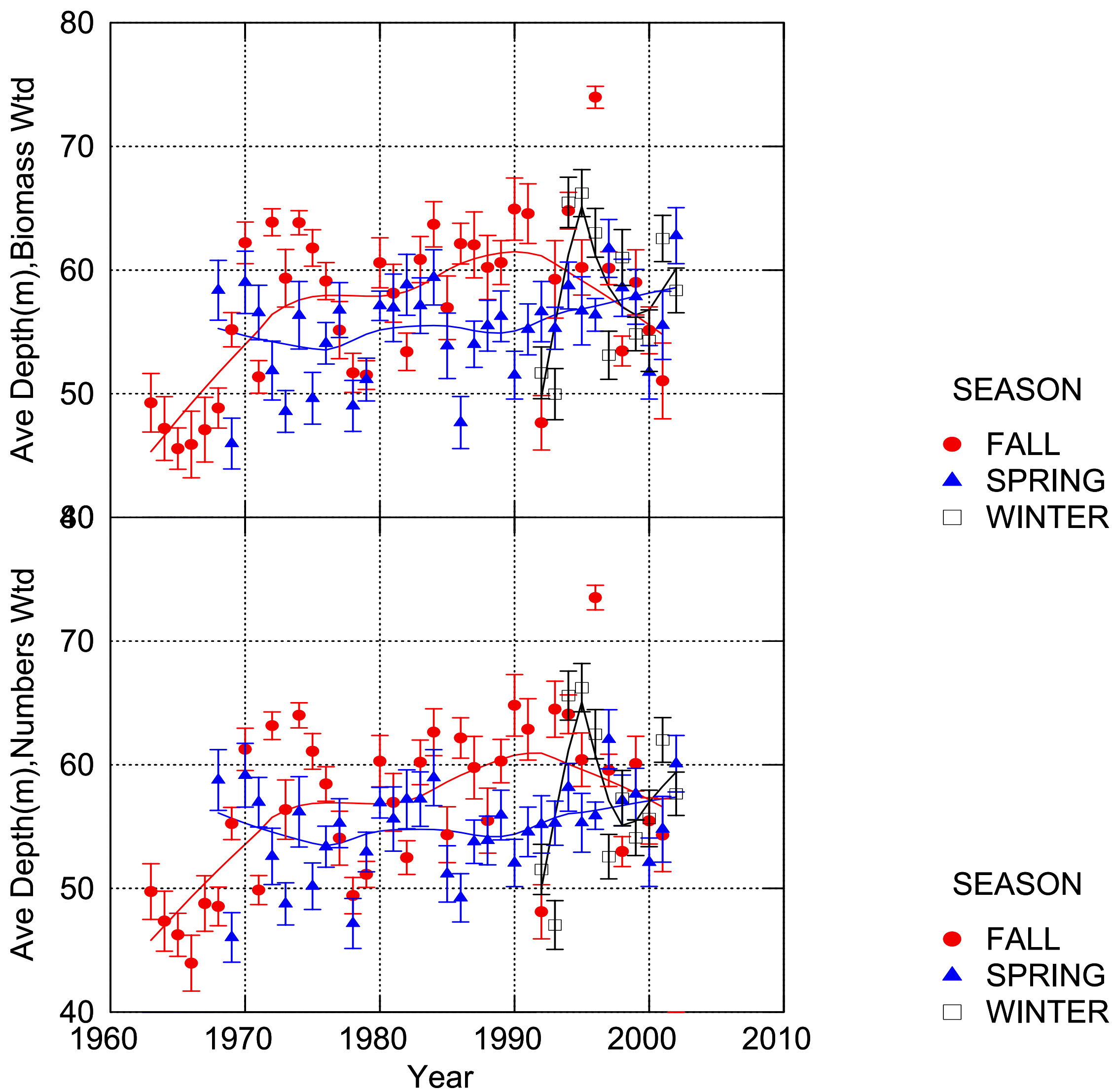



Fig. 3.7.6. Temporal trends in catch weighted average depth for Southern New England Yellowtail stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

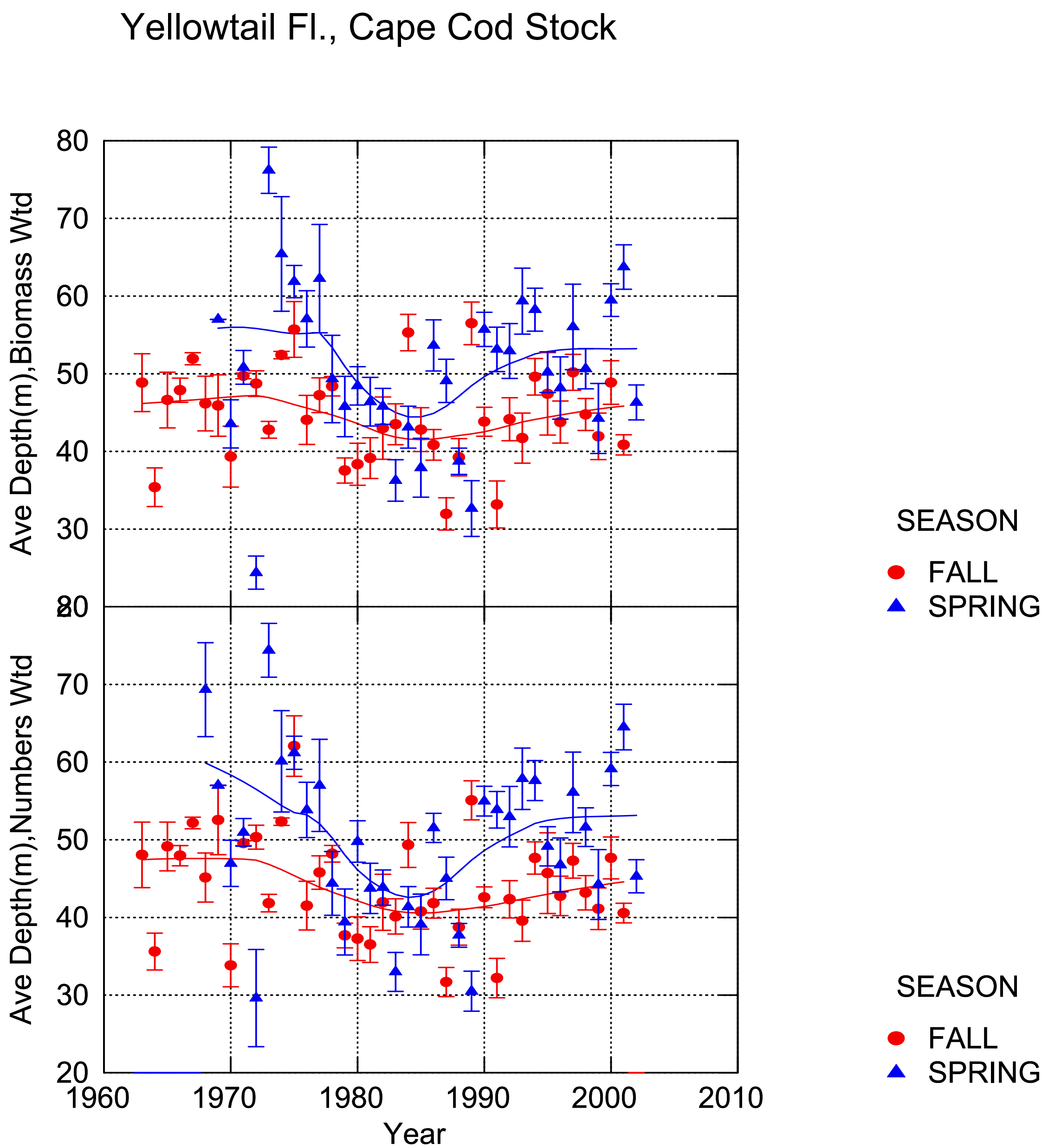



Fig. 3.7.7. Temporal trends in catch weighted average depth for Cape Cod Yellowtail Flounder  stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

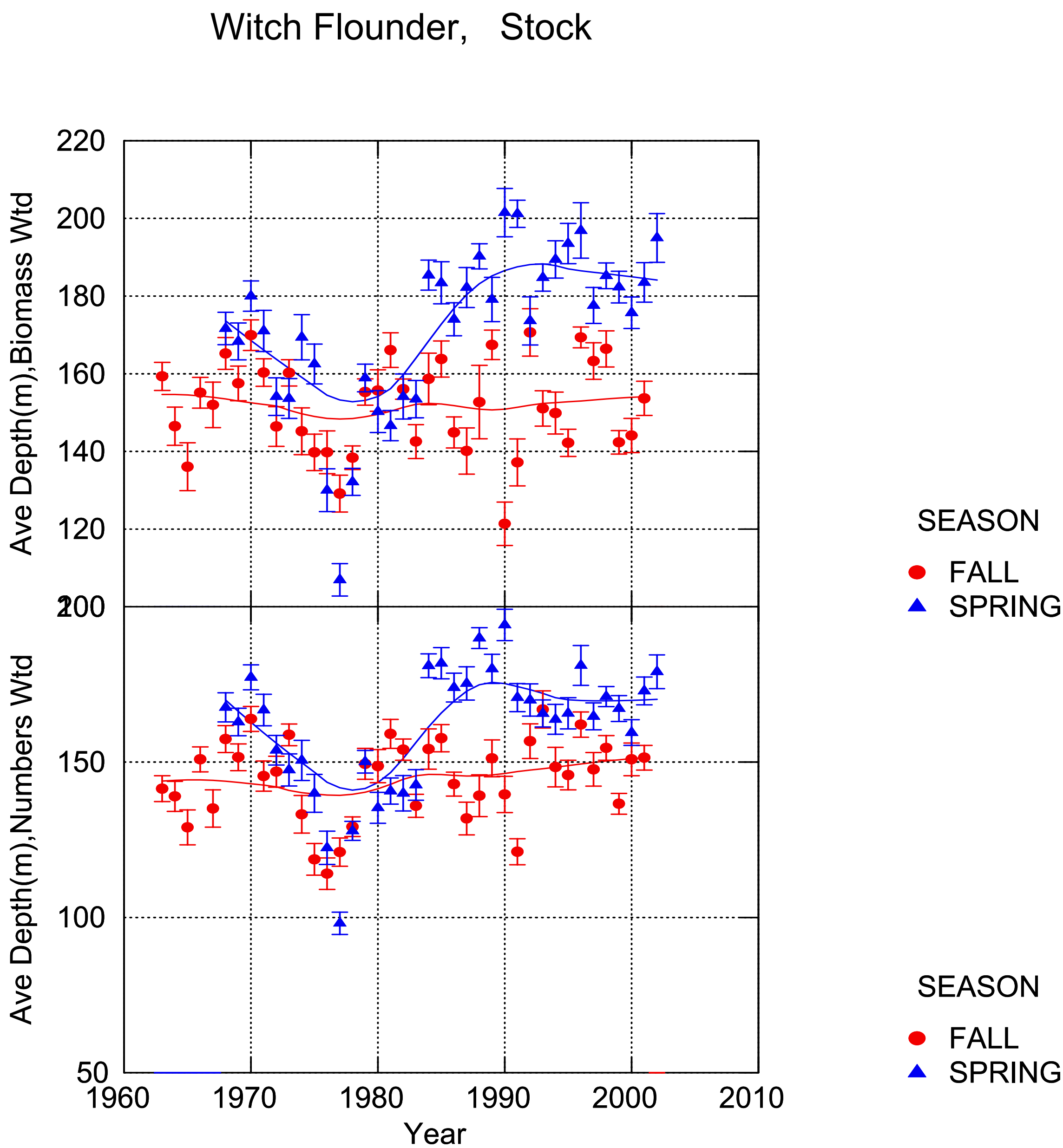



Fig. 3.7.8. Temporal trends in catch weighted average depth for Witch Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

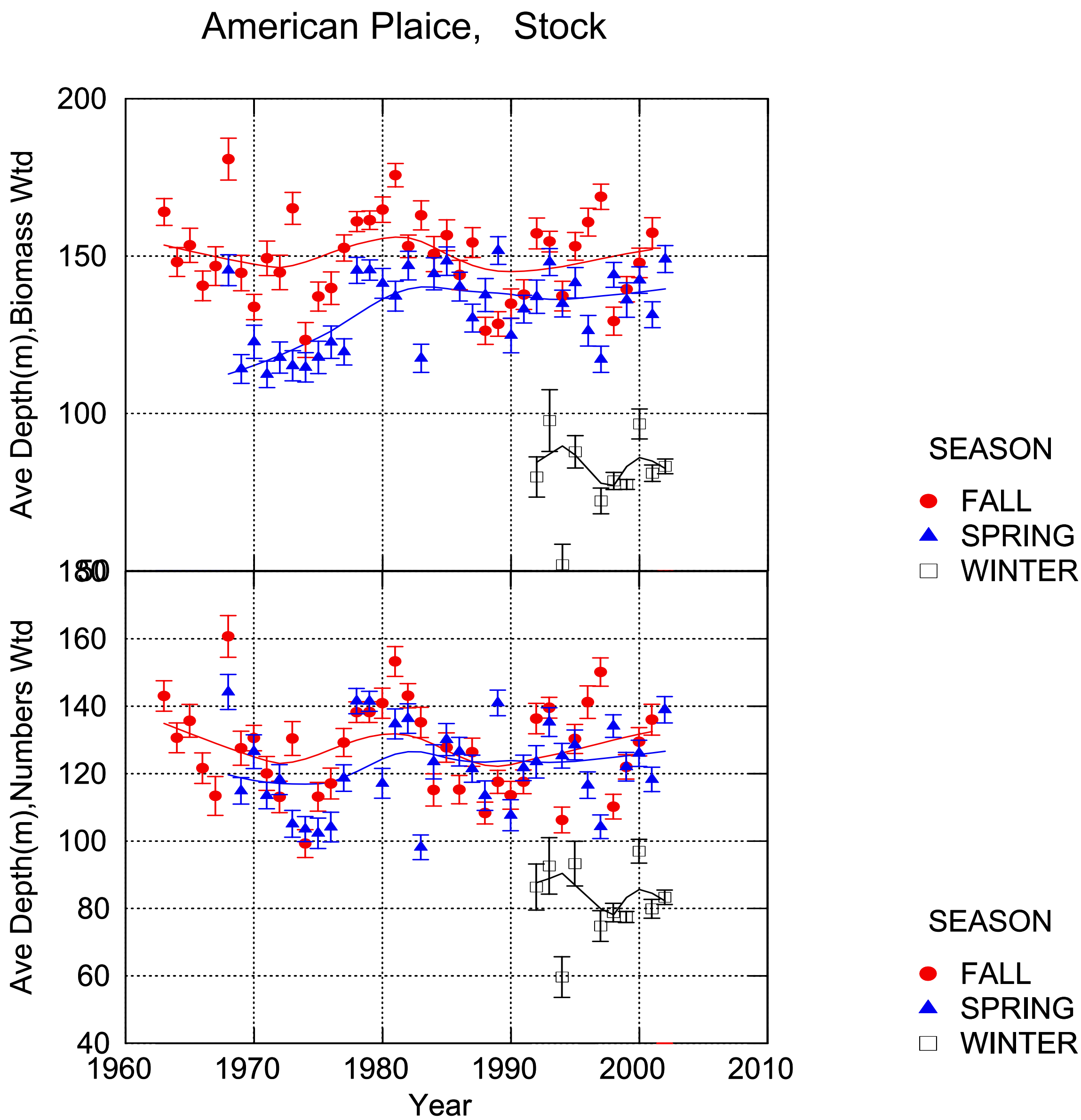



Fig. 3.7.9. Temporal trends in catch weighted average depth for American Plaice stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

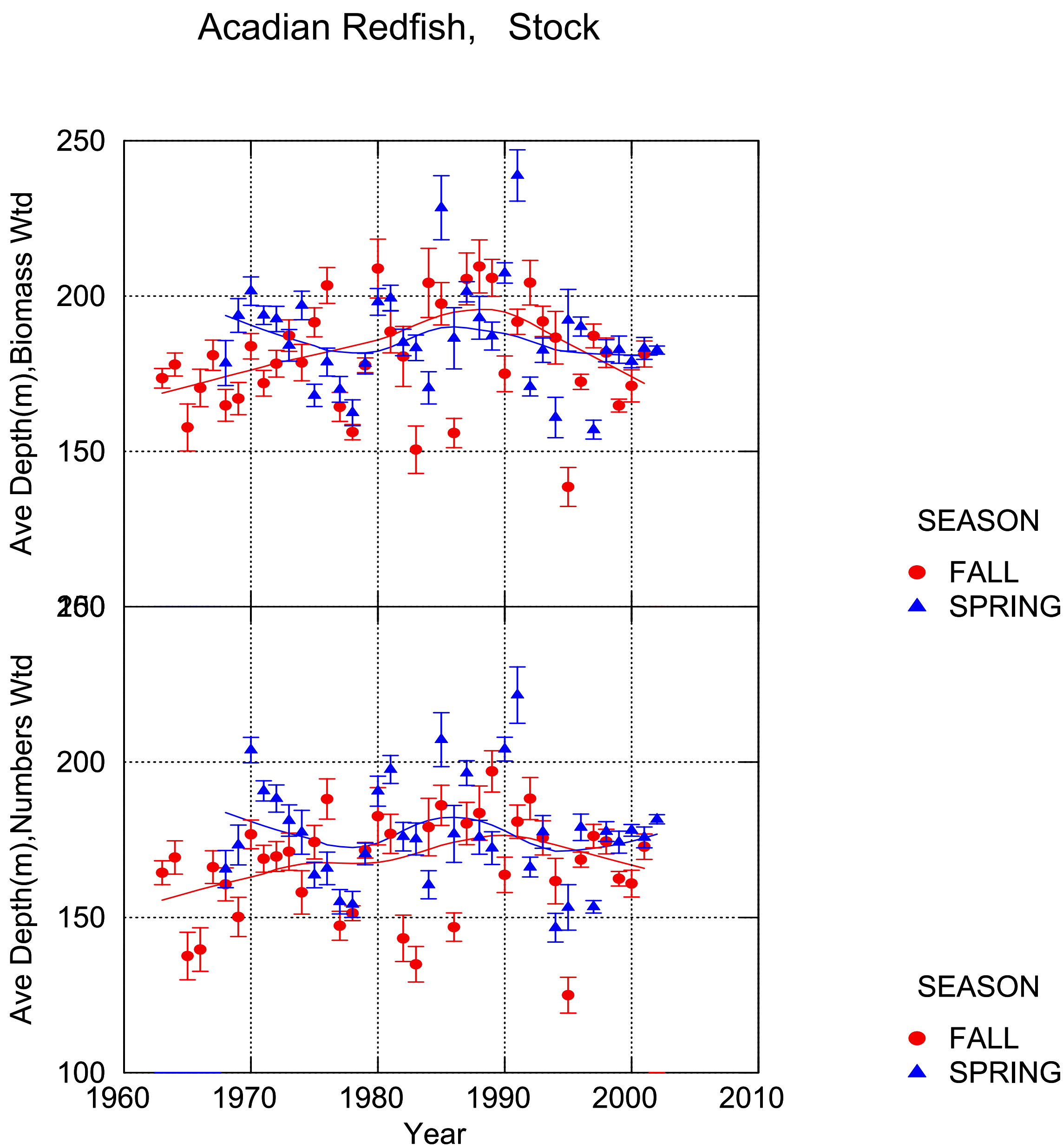



Fig. 3.7.10. Temporal trends in catch weighted average depth for Acadian Redfish stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

White Hake,   Stock

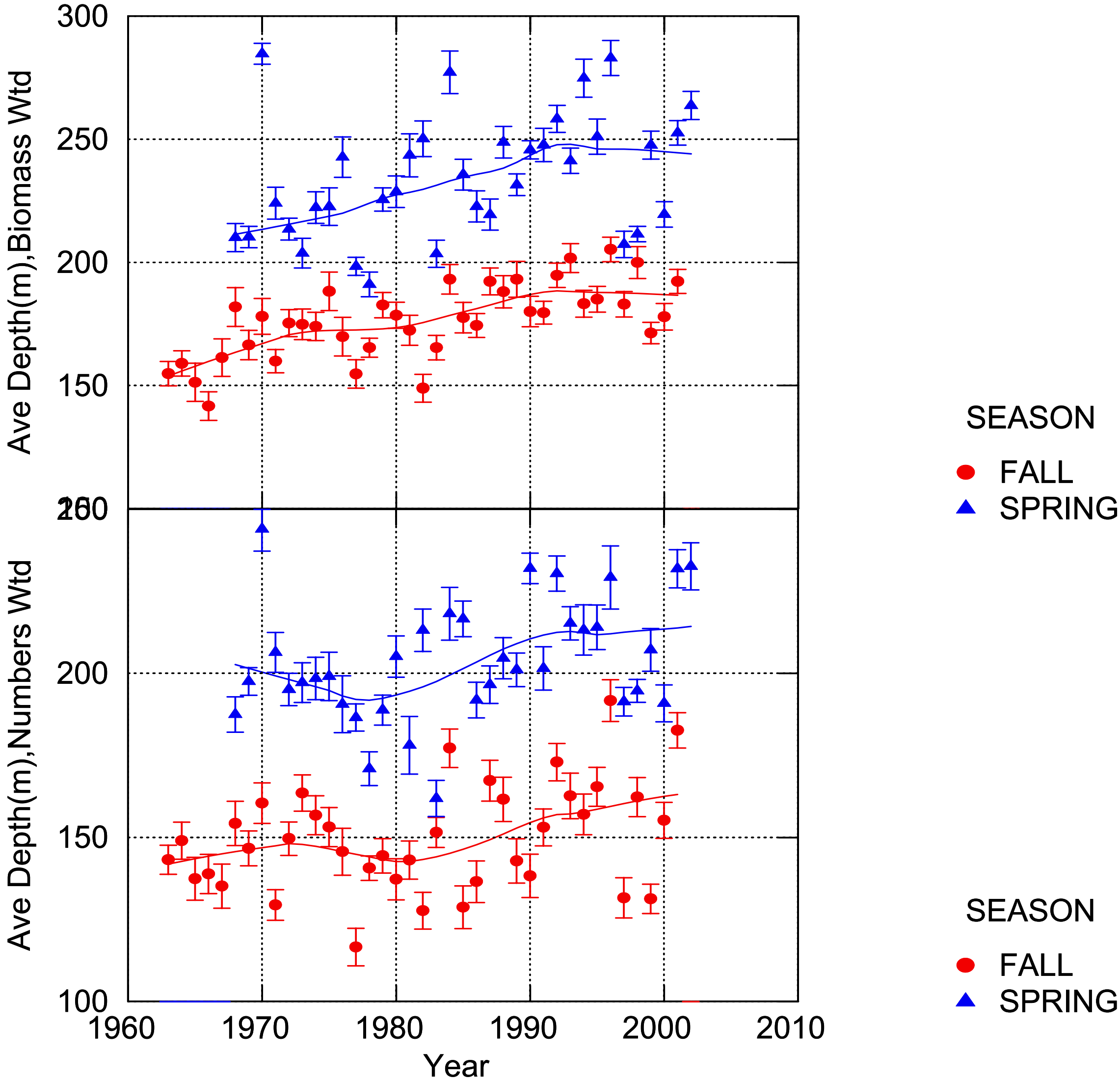



Fig. 3.7.11. Temporal trends in catch weighted average depth for White Hake stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

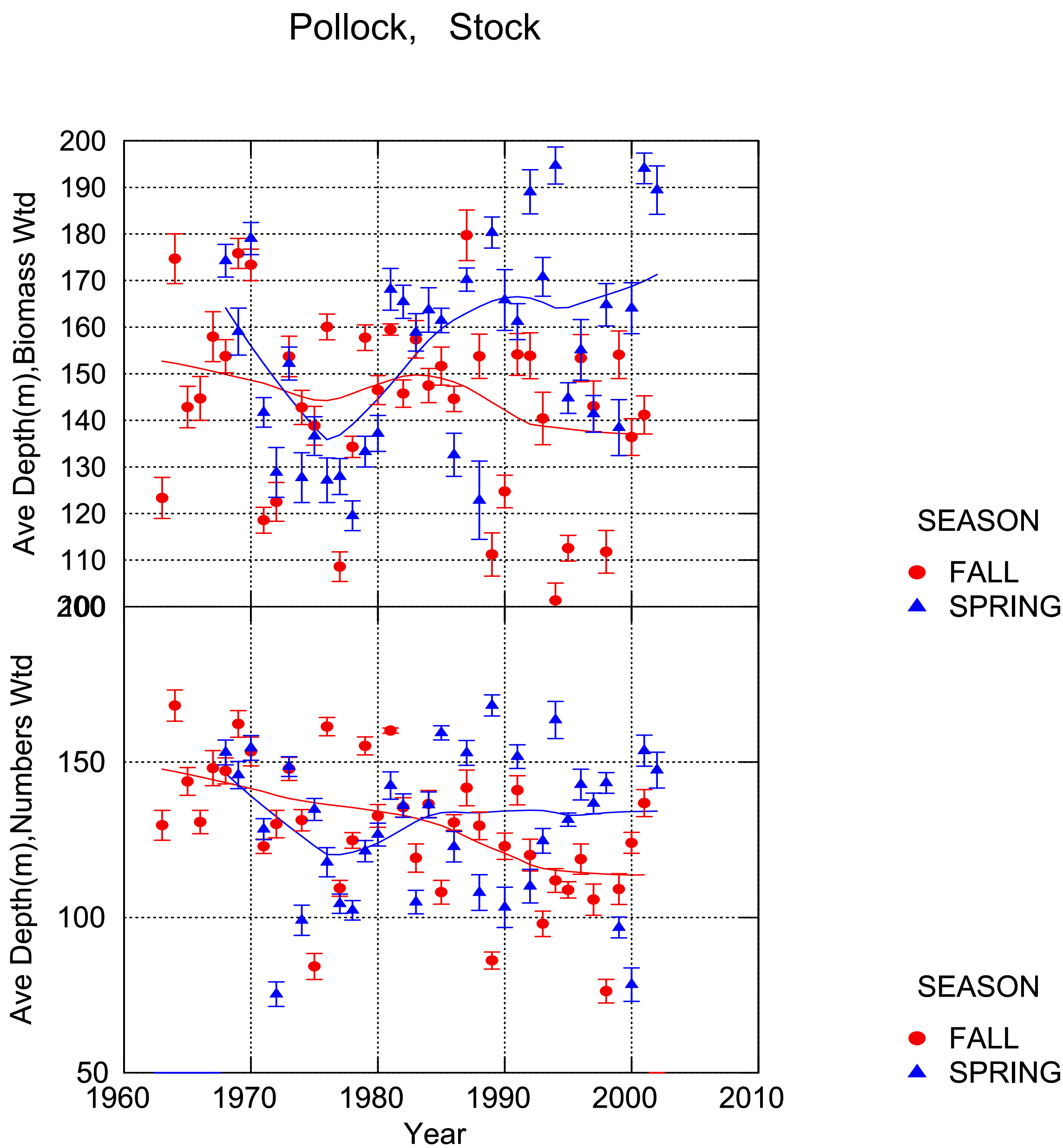



Fig. 3.7.12. Temporal trends in catch weighted average depth for Pollock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

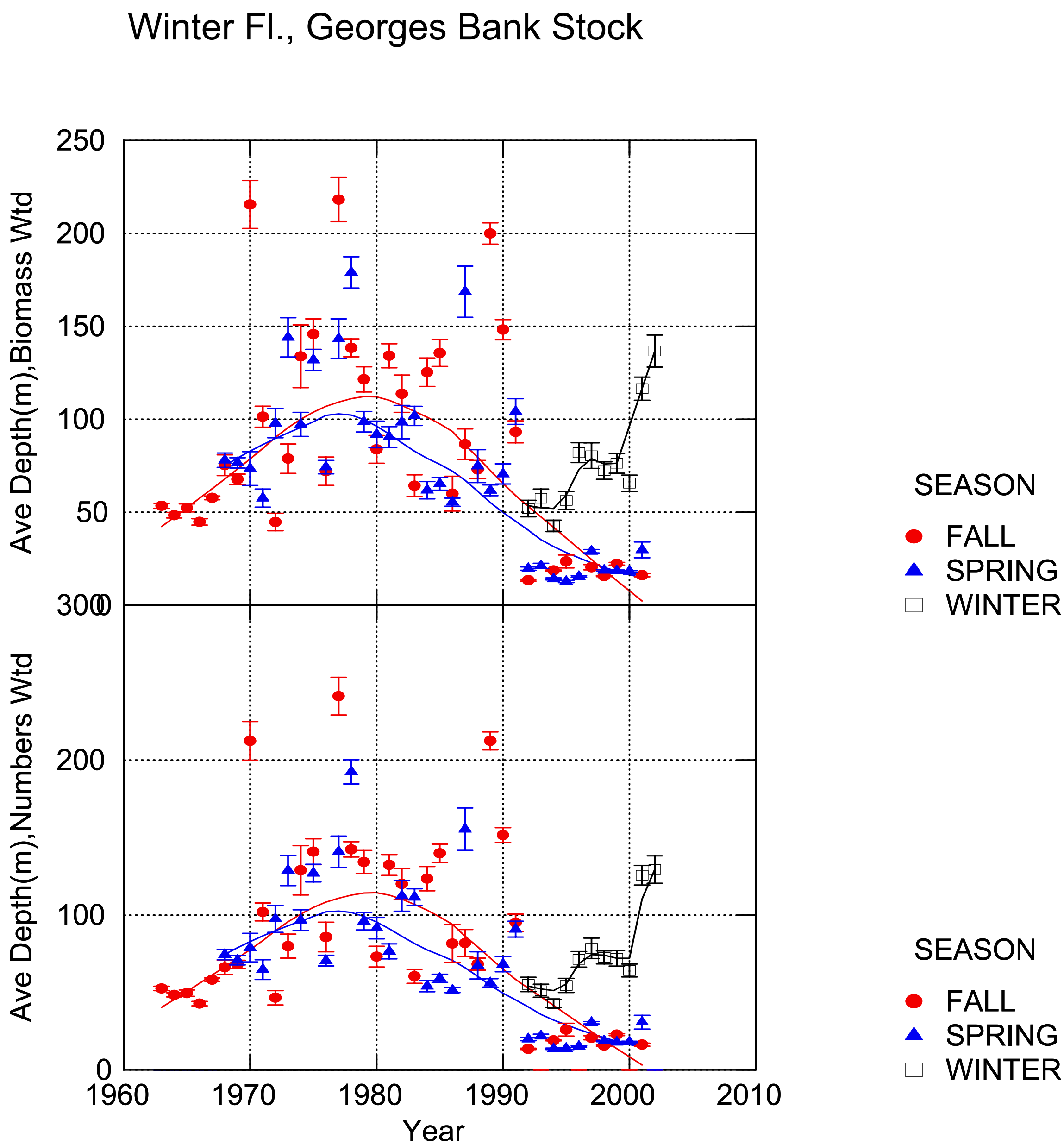



Fig. 3.7.13. Temporal trends in catch weighted average depth for Georges Bank Winter Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

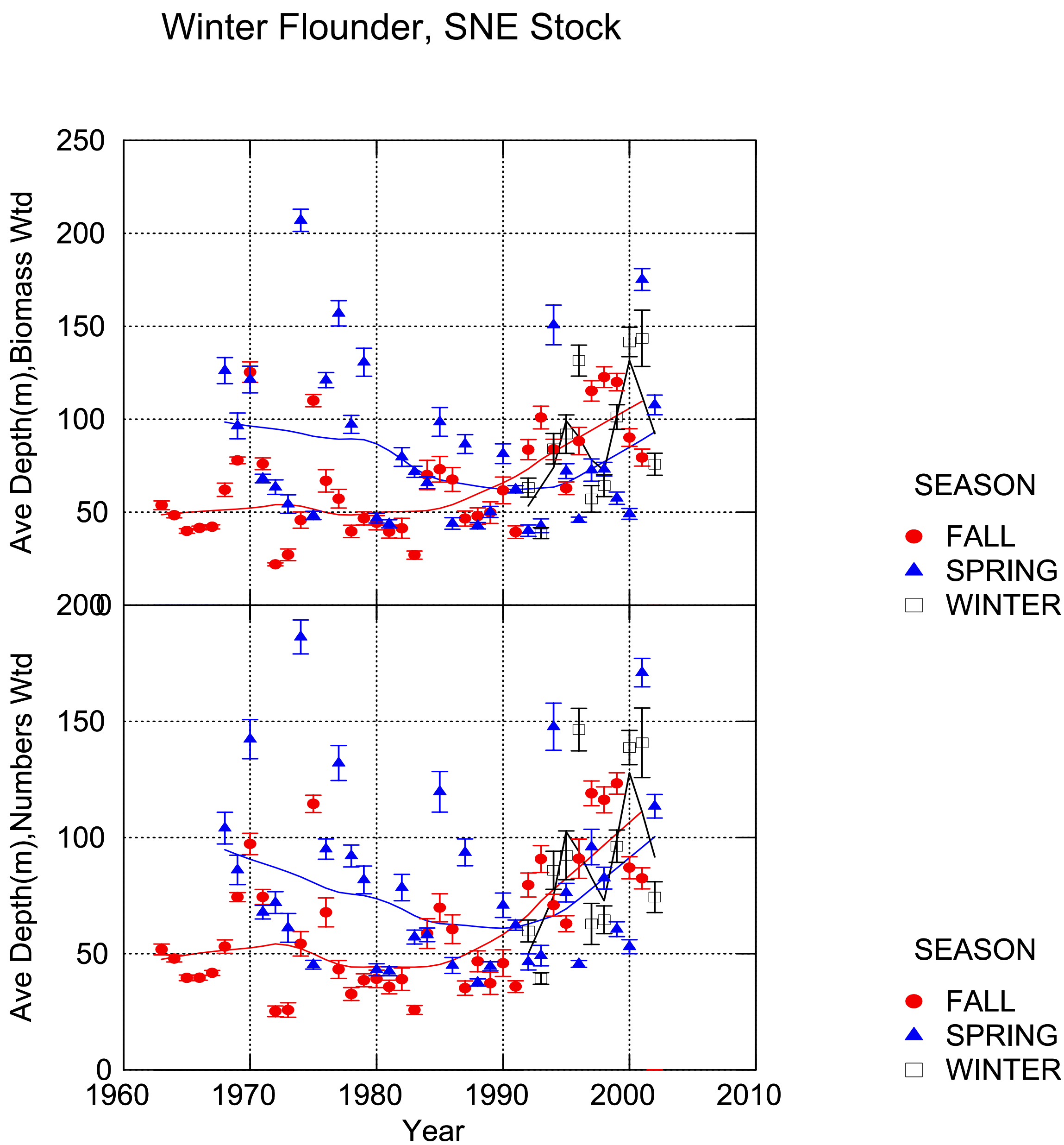



Fig. 3.7.14. Temporal trends in catch weighted average depth for Southern New England Winter Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Windowpane Fl., Northern Stock

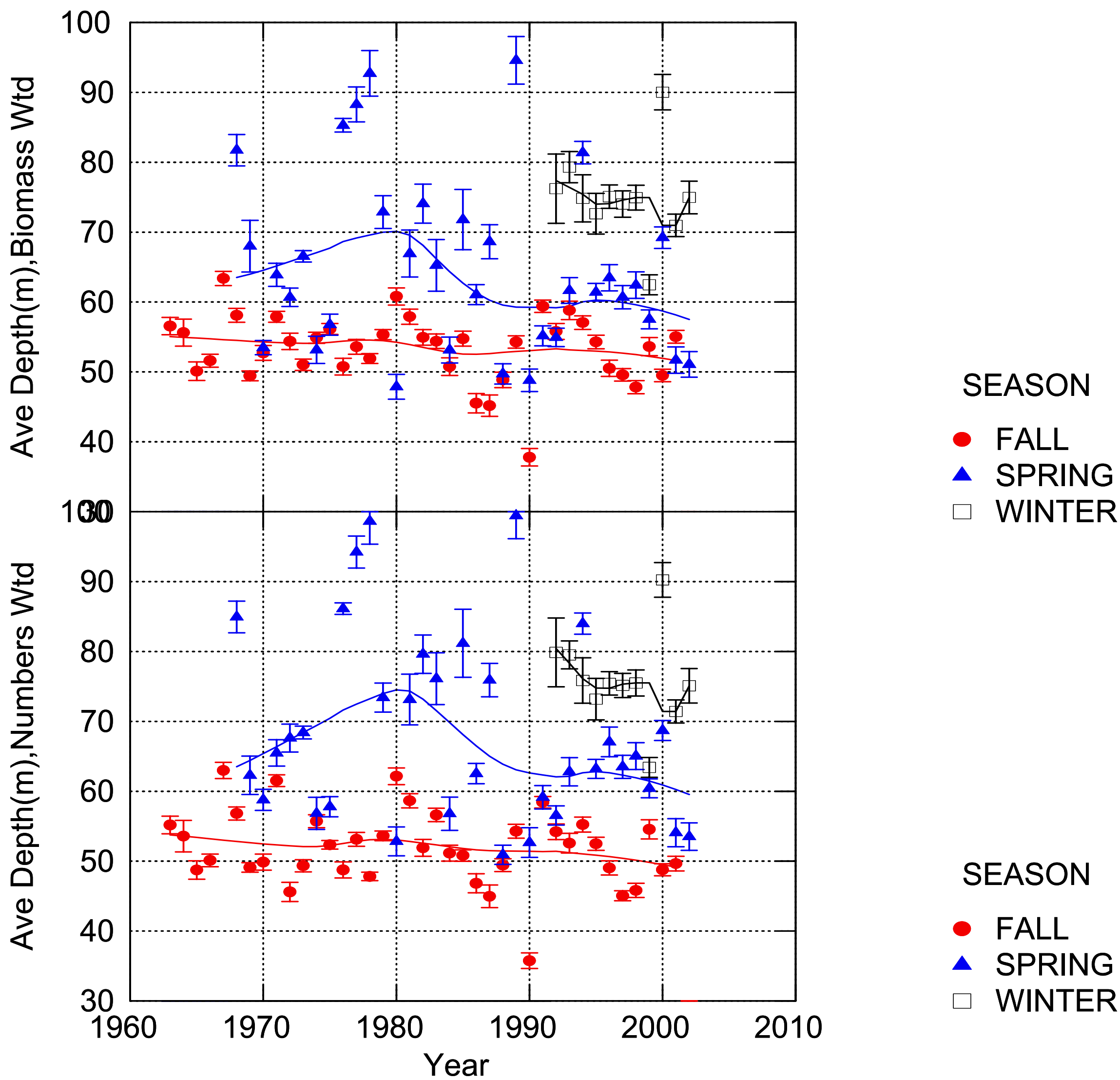



Fig. 3.7.15. Temporal trends in catch weighted average depth for Northern Windowpane Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

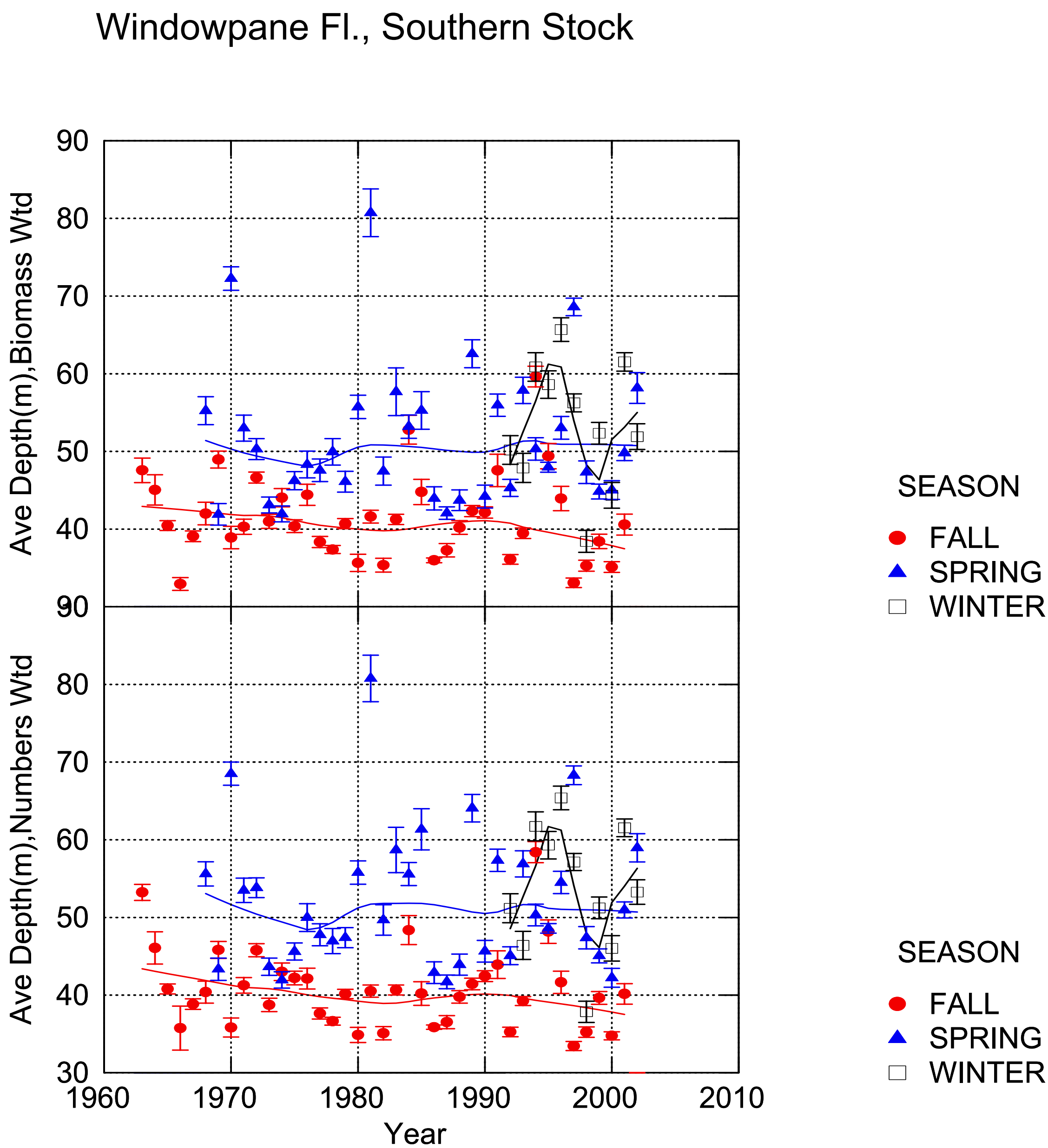



Fig. 3.7.16. Temporal trends in catch weighted average depth for Windowpane Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

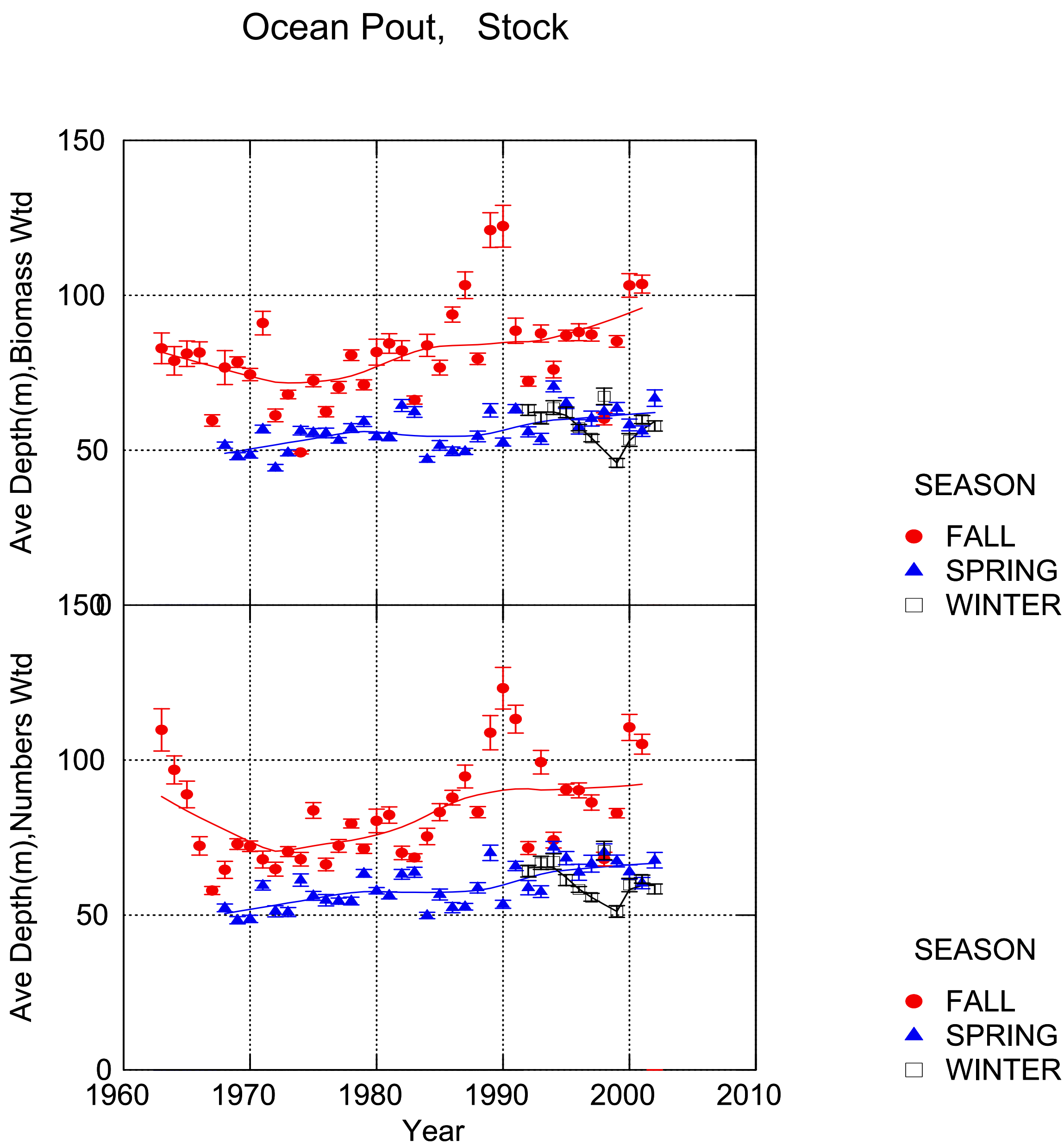



Fig. 3.7.17. Temporal trends in catch weighted average depth for Ocean Pout stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

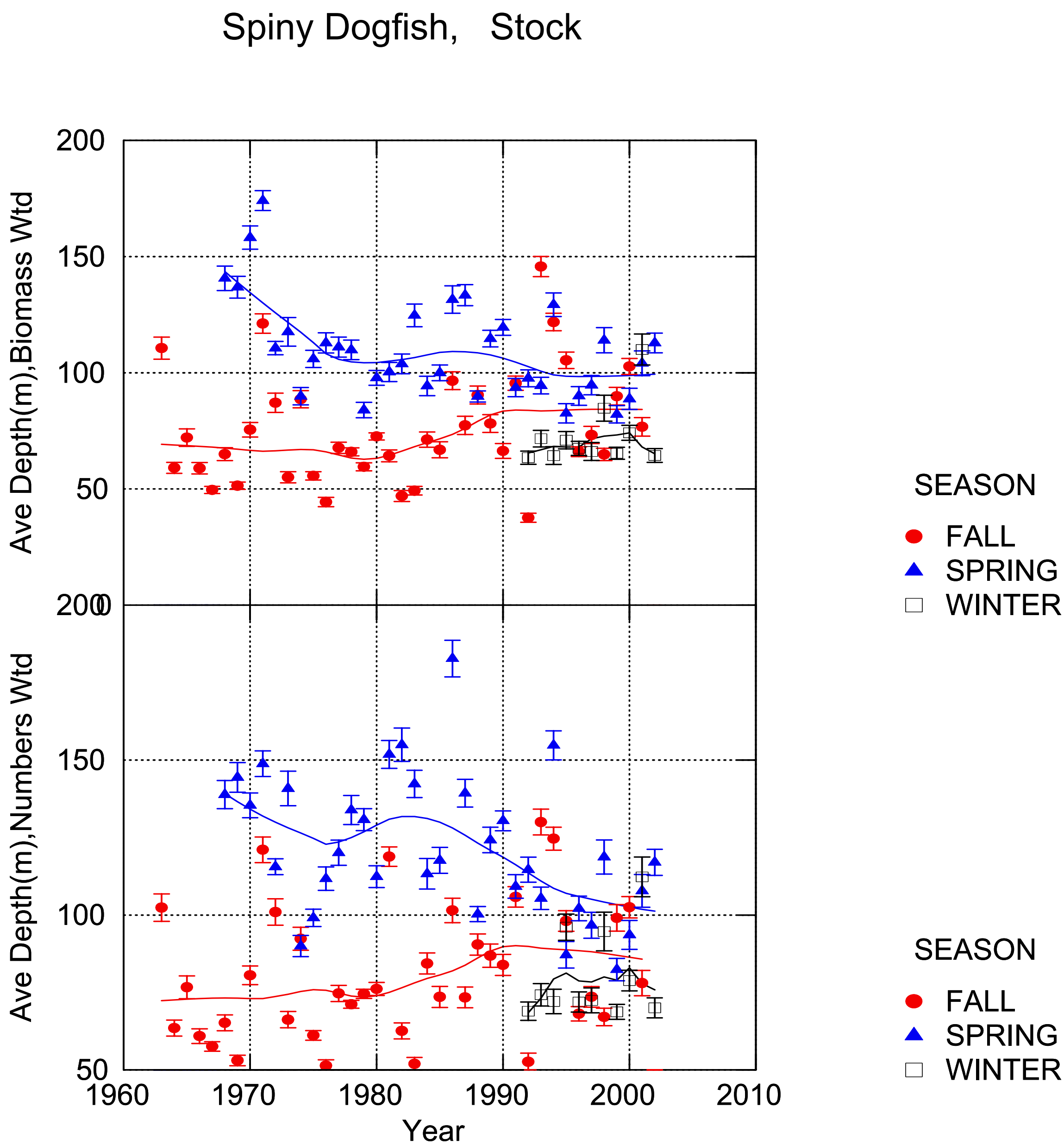



Fig. 3.7.18. Temporal trends in catch weighted average depth for Spiny Dogfish stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Summer Flounder, Stock

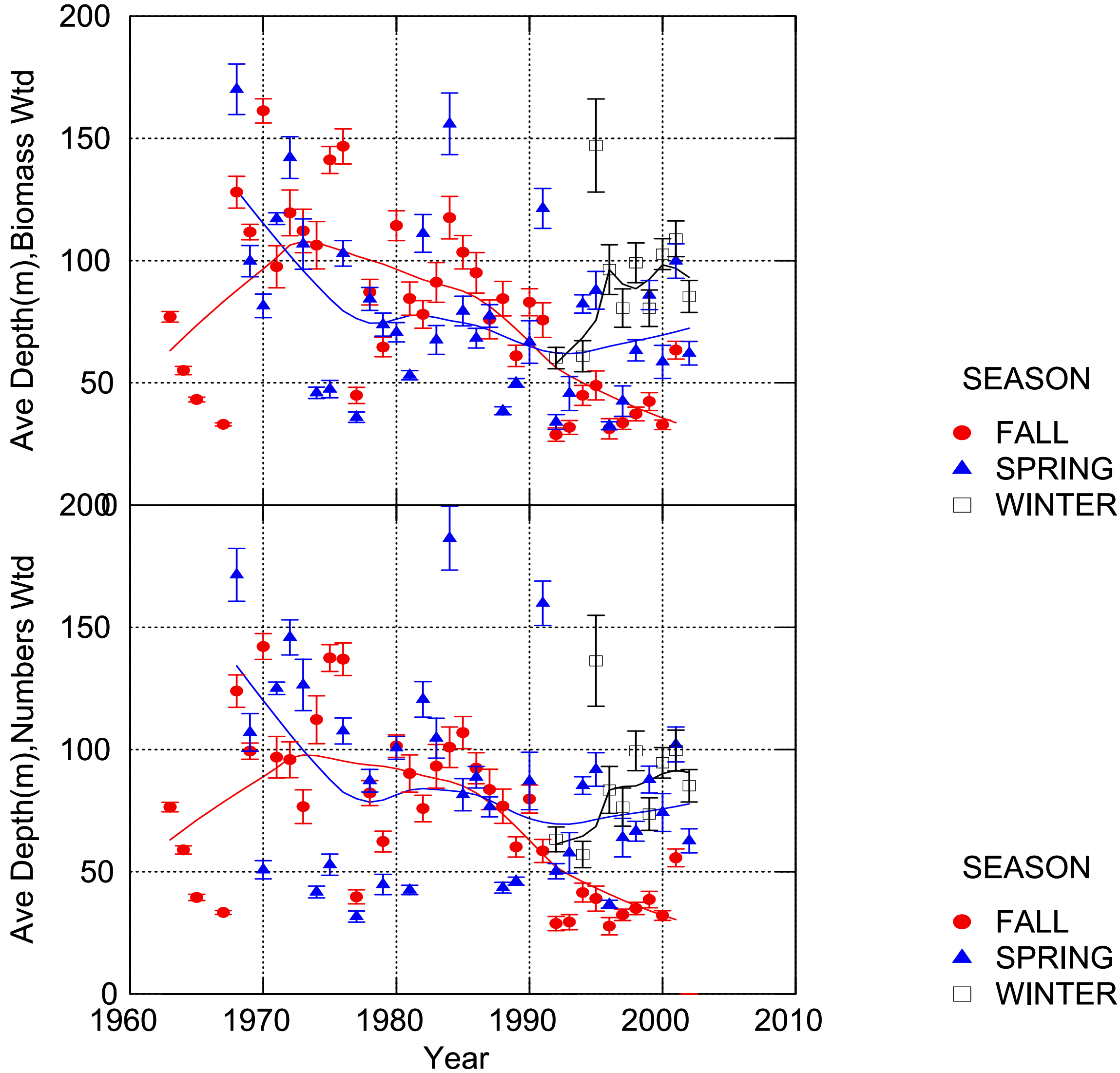



Fig. 3.7.19. Temporal trends in catch weighted average depth for Summer Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

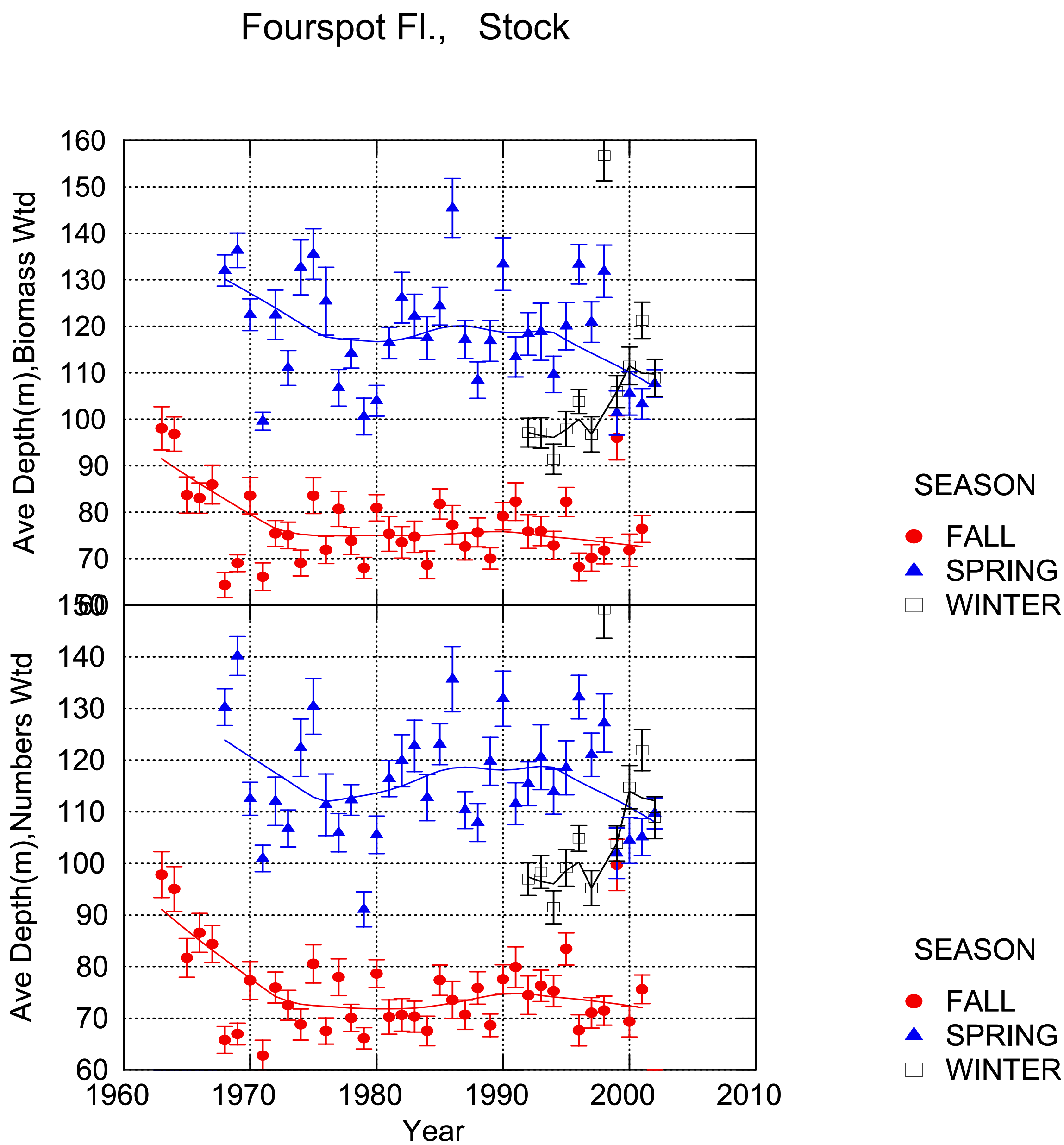



Fig. 3.7.20. Temporal trends in catch weighted average depth for Fourspot Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Longhorn Sculpin,   Stock

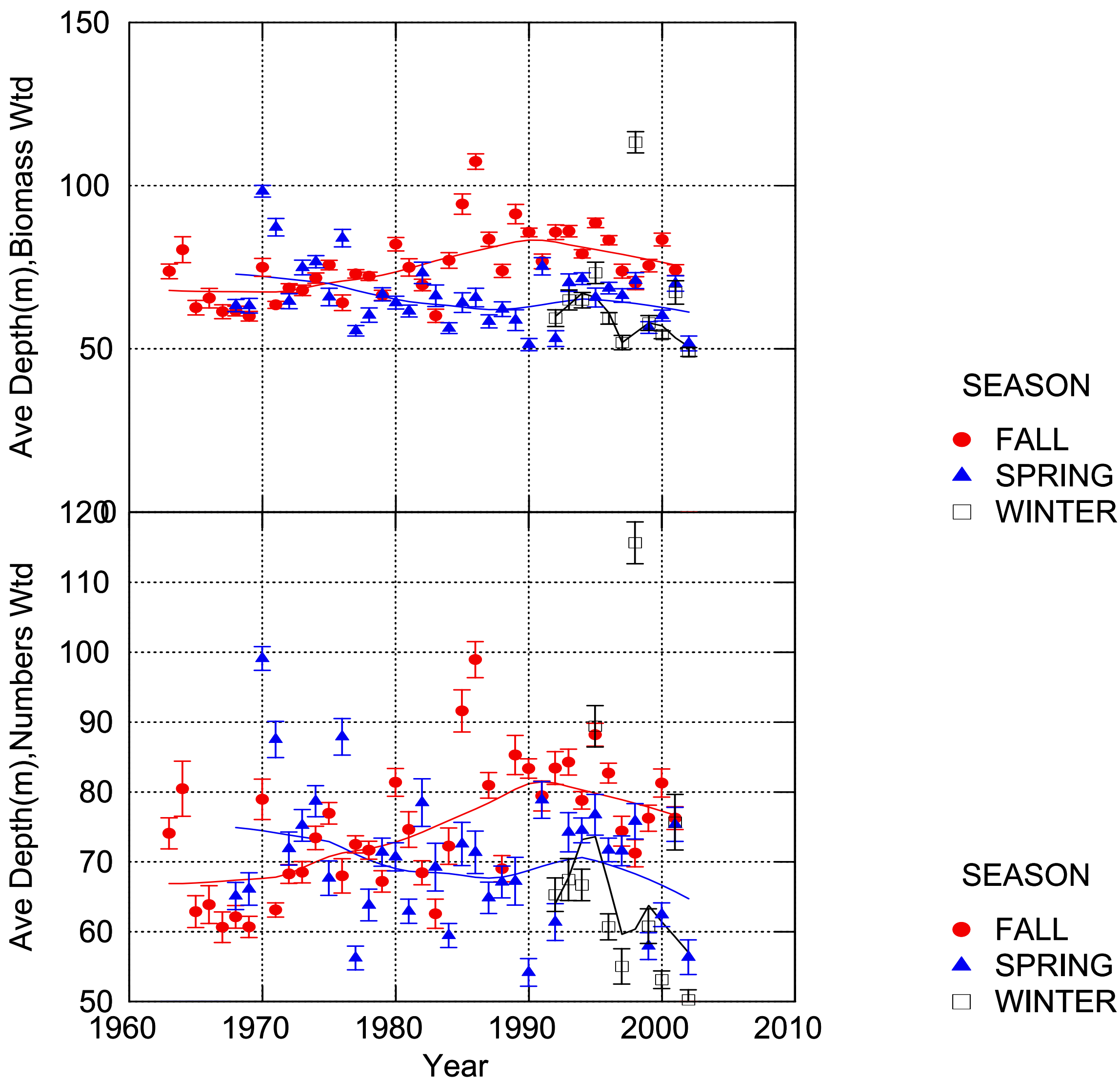



Fig. 3.7.21. Temporal trends in catch weighted average depth for Longhorn Sculpin stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

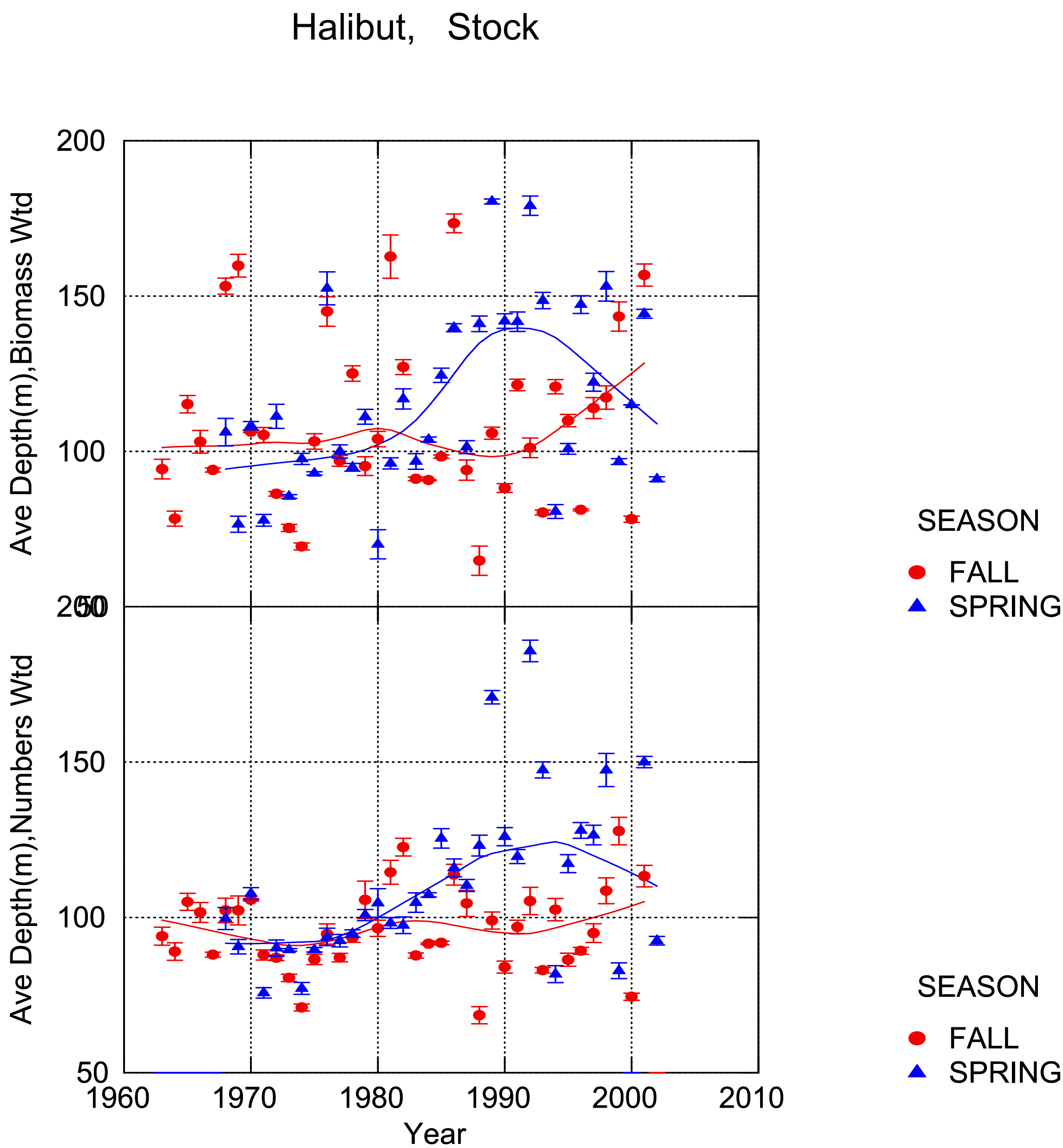



Fig. 3.7.22. Temporal trends in catch weighted average depth for Halibut stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

## All Species Combined

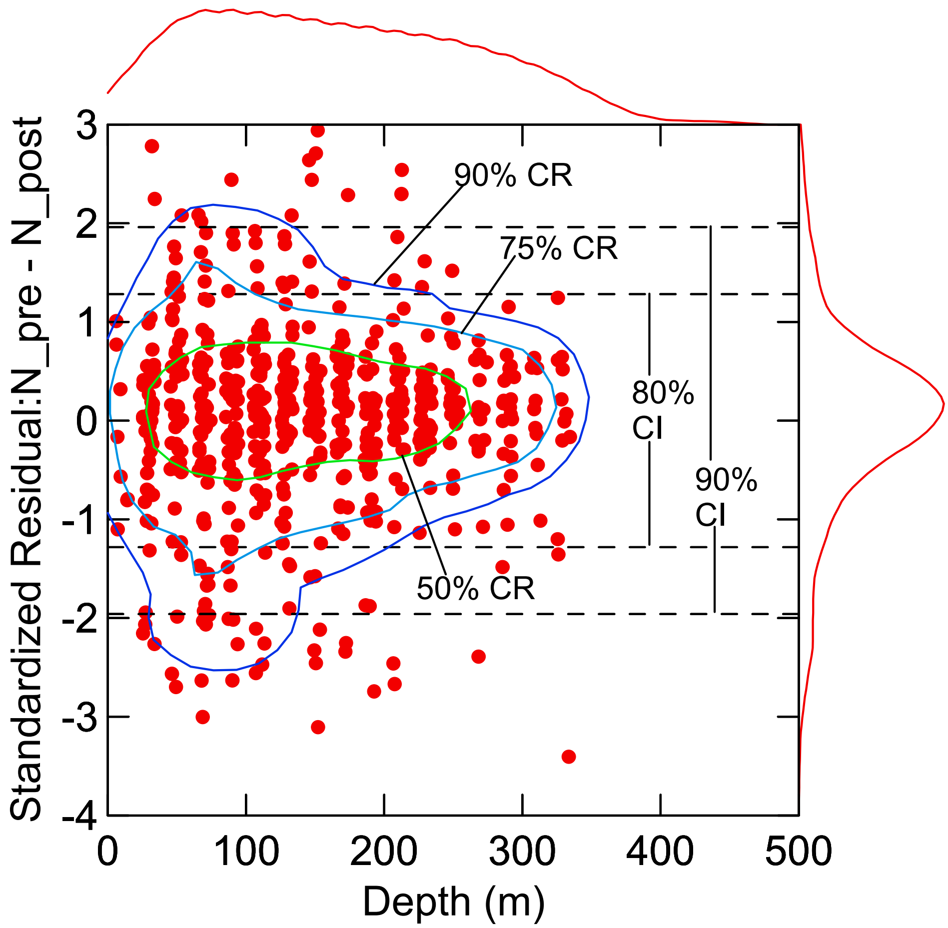



Fig. 3.7.23. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for all species combined. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

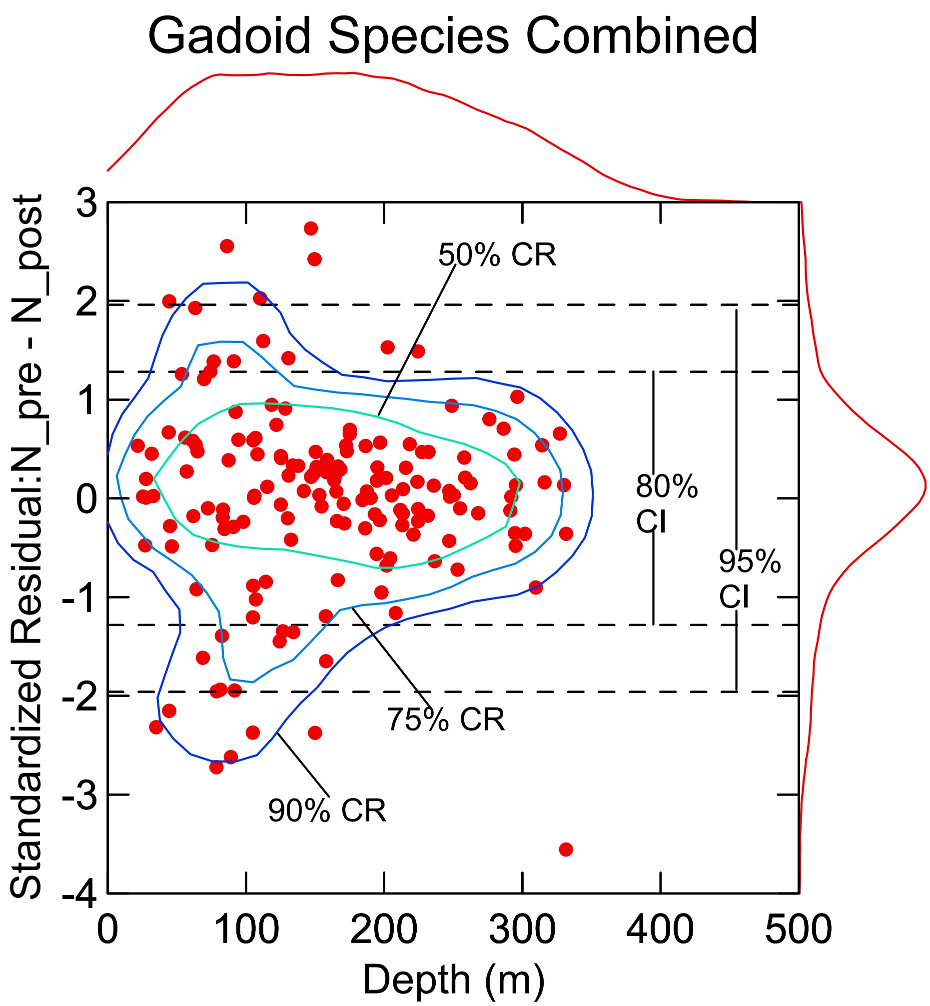



Fig. 3.7.24. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for gadoid species (GB cod, GOM cod, GB haddock, GOM haddock, white hake, and pollock. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

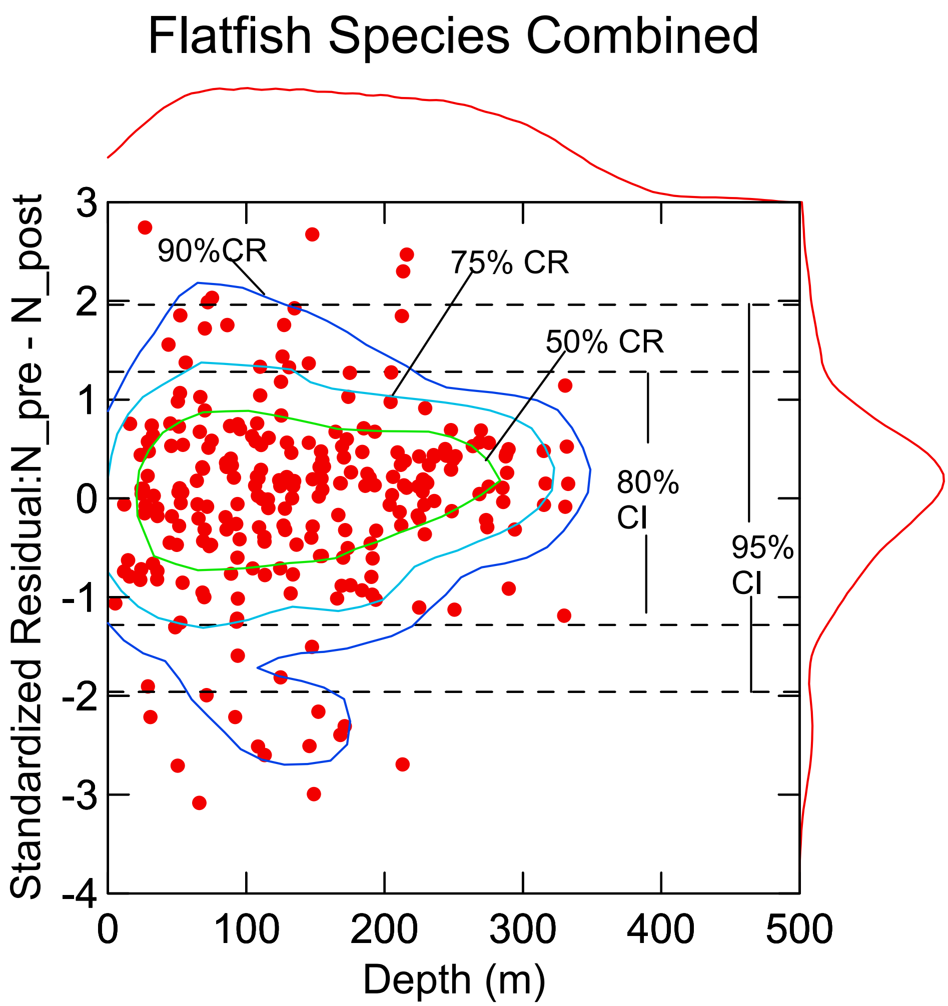



Fig. 3.7.25. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB yellowtail, SNE yellowtail, Cape Cod yellowtail, American plaice, witch flounder, windowpane (Northern and Southern), GB winter flounder SNE winter flounder, summer flounder, and fourspot flounder. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines.
The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

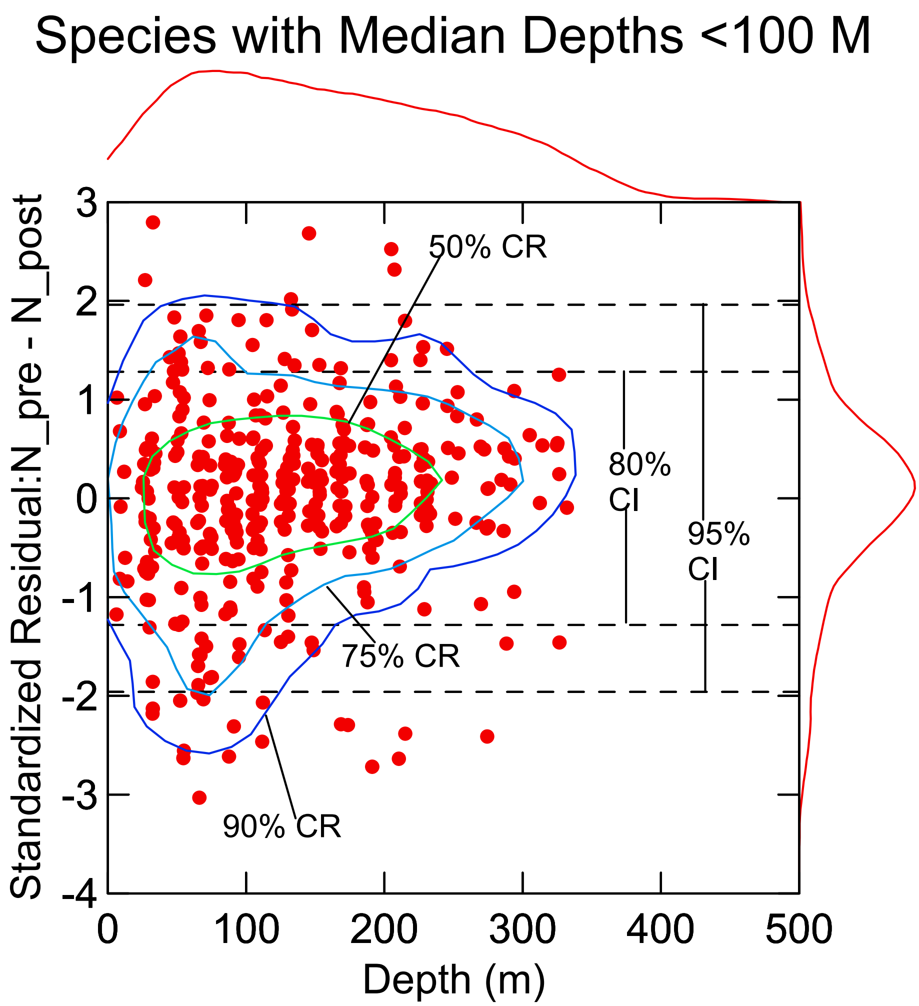



Fig. 3.7.26. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB yellowtail, SNE yellowtail, Cape Cod yellowtail, windowpane flounder (Northern and Southern), GB winter flounder, GB cod, GOM cod, SNE winter flounder, summer flounder, fourspot flounder, ocean pout, longhorn sculpin, spiny dogfish. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

Species with Median Depths >100 M

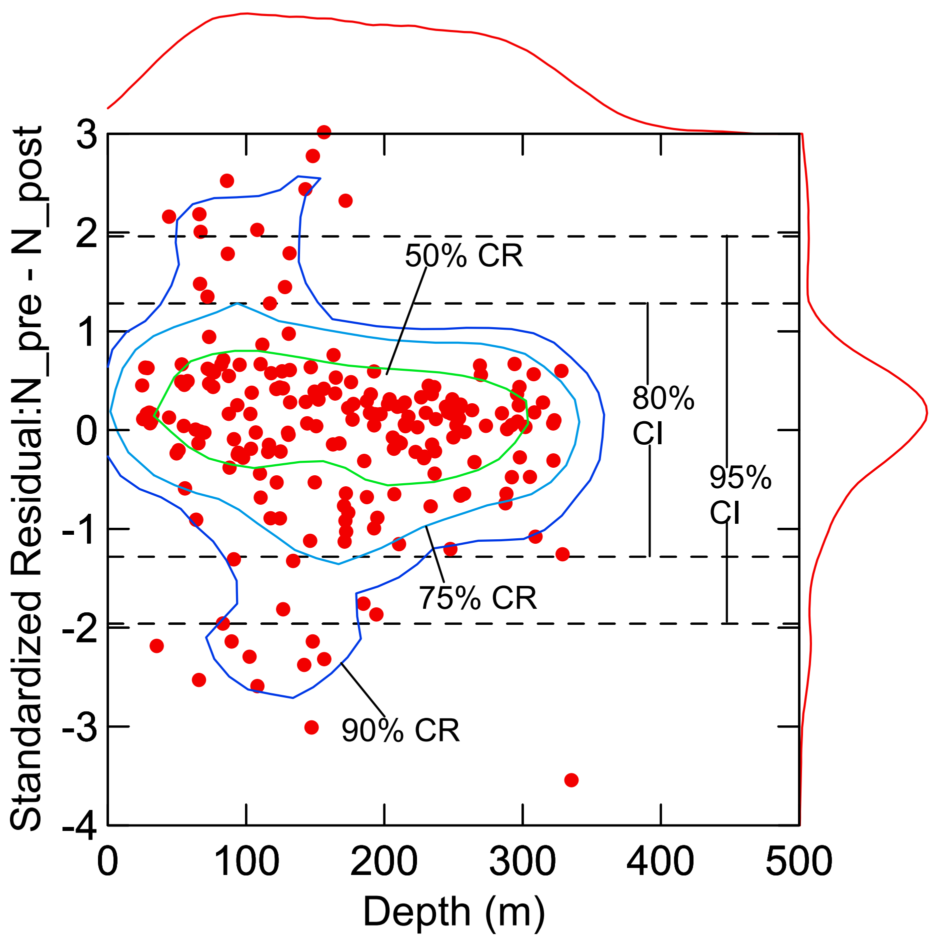
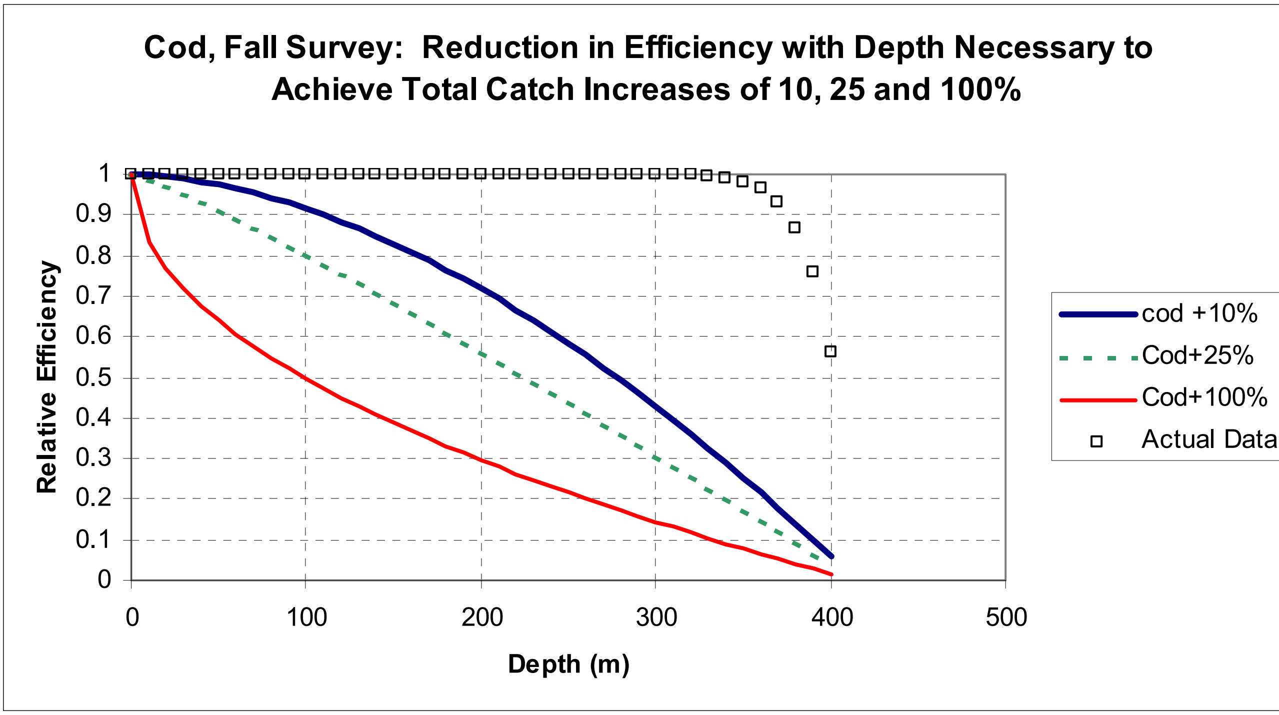



Fig. 3.7.27. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB haddock, GOM haddock, white hake, pollock, American plaice, witch flounder, and Acadian redfish. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.



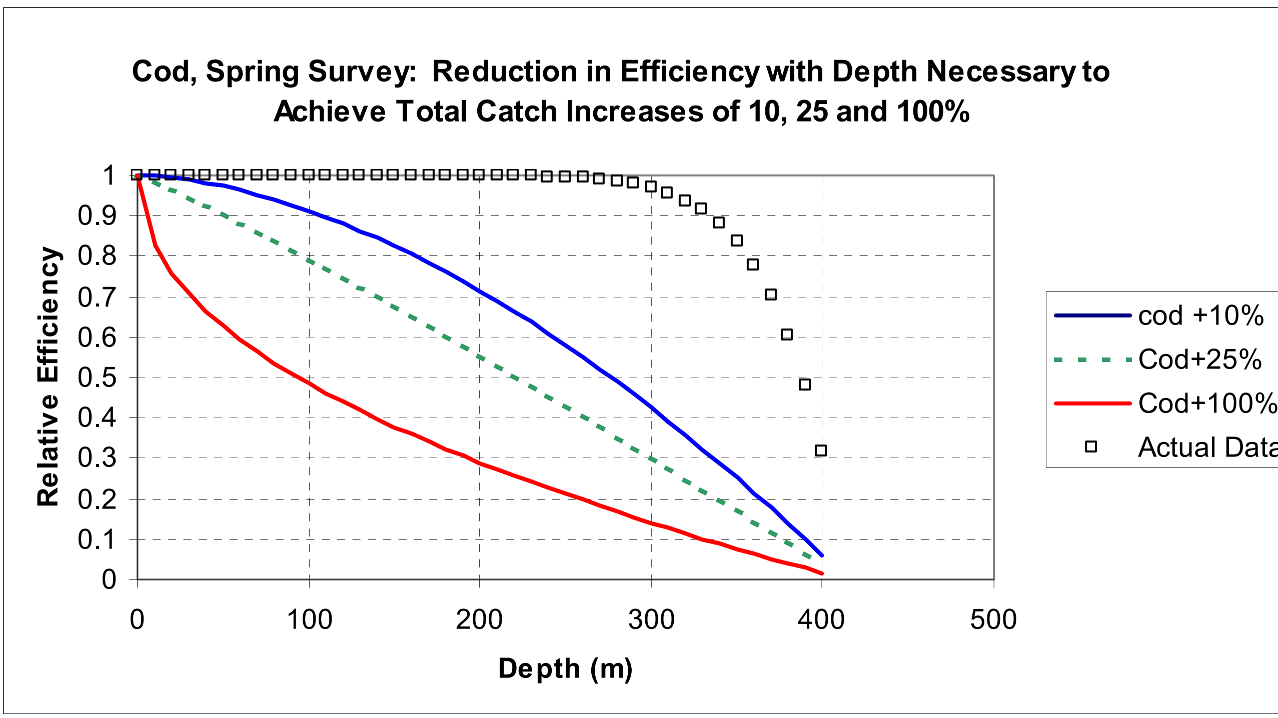
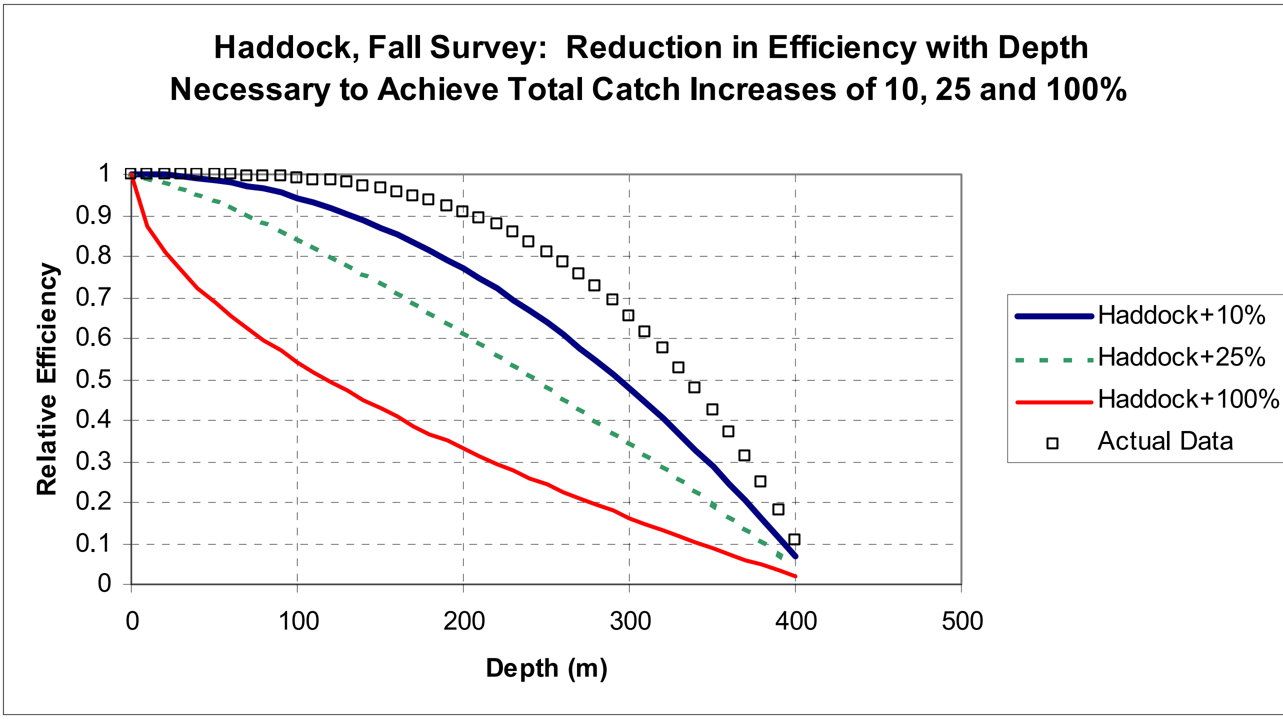




Fig. 3.7.28. Predicted reductions in relative efficiency of capture for cod in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. "Actual data" plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.



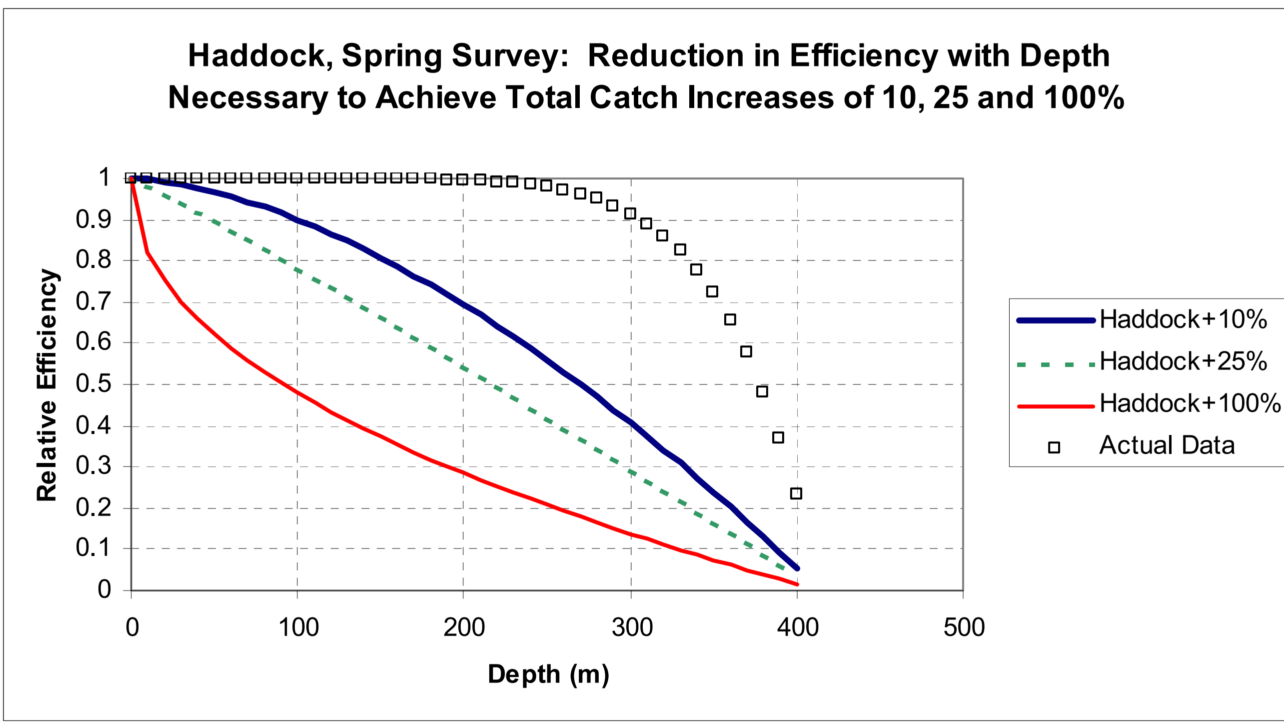
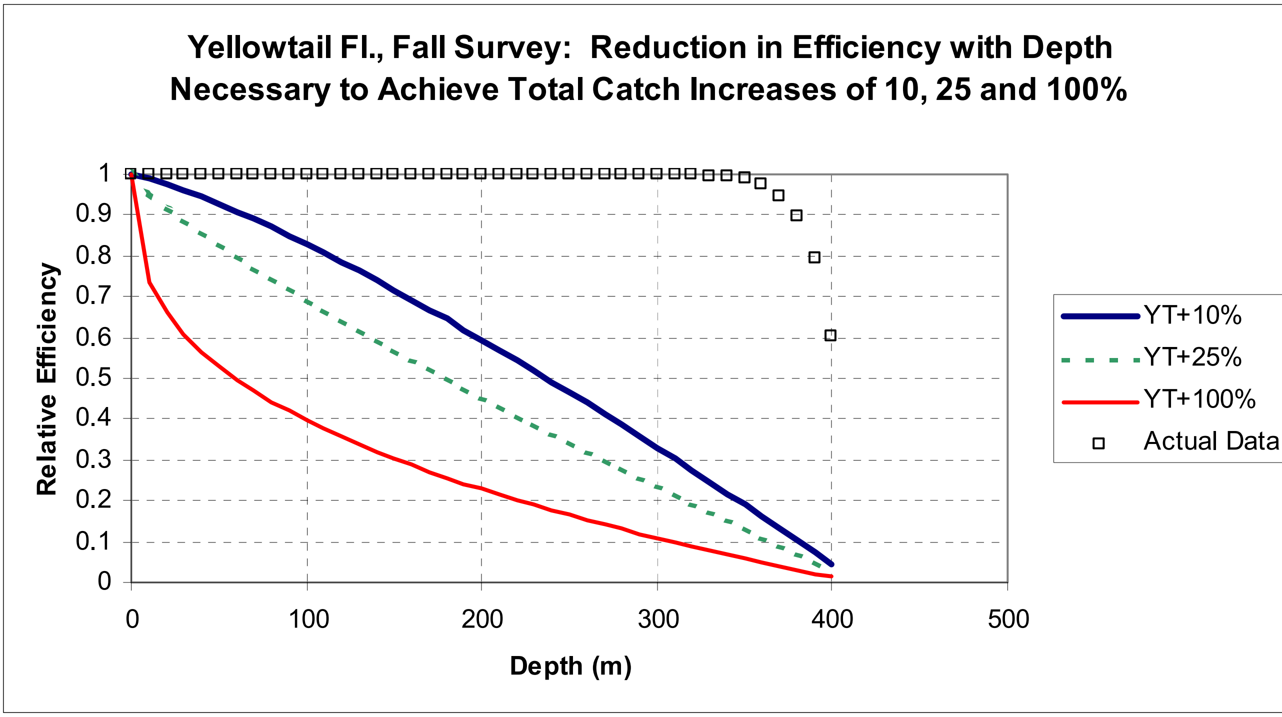




Fig. 3.7.29. Predicted reductions in relative efficiency of capture for haddock in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. "Actual data" plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.



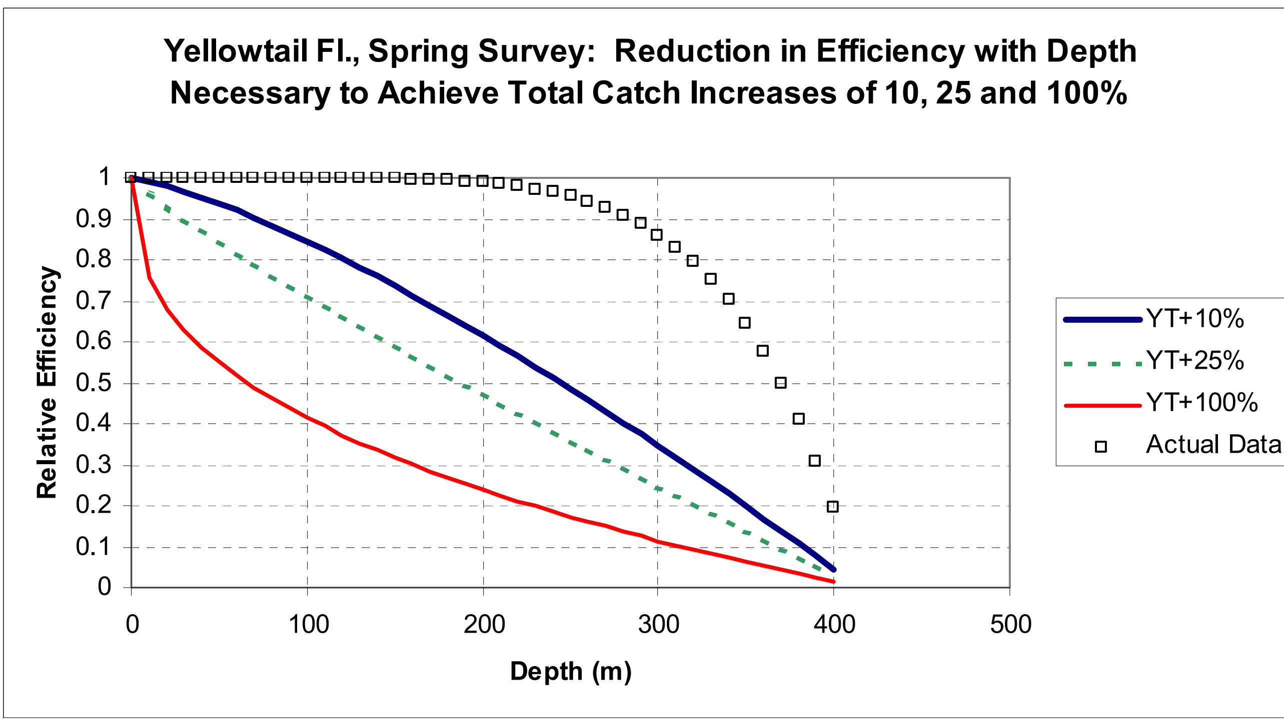




Fig. 3.7.30. Predicted reductions in relative efficiency of capture for yellowtail flounder in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. “Actual data” plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.

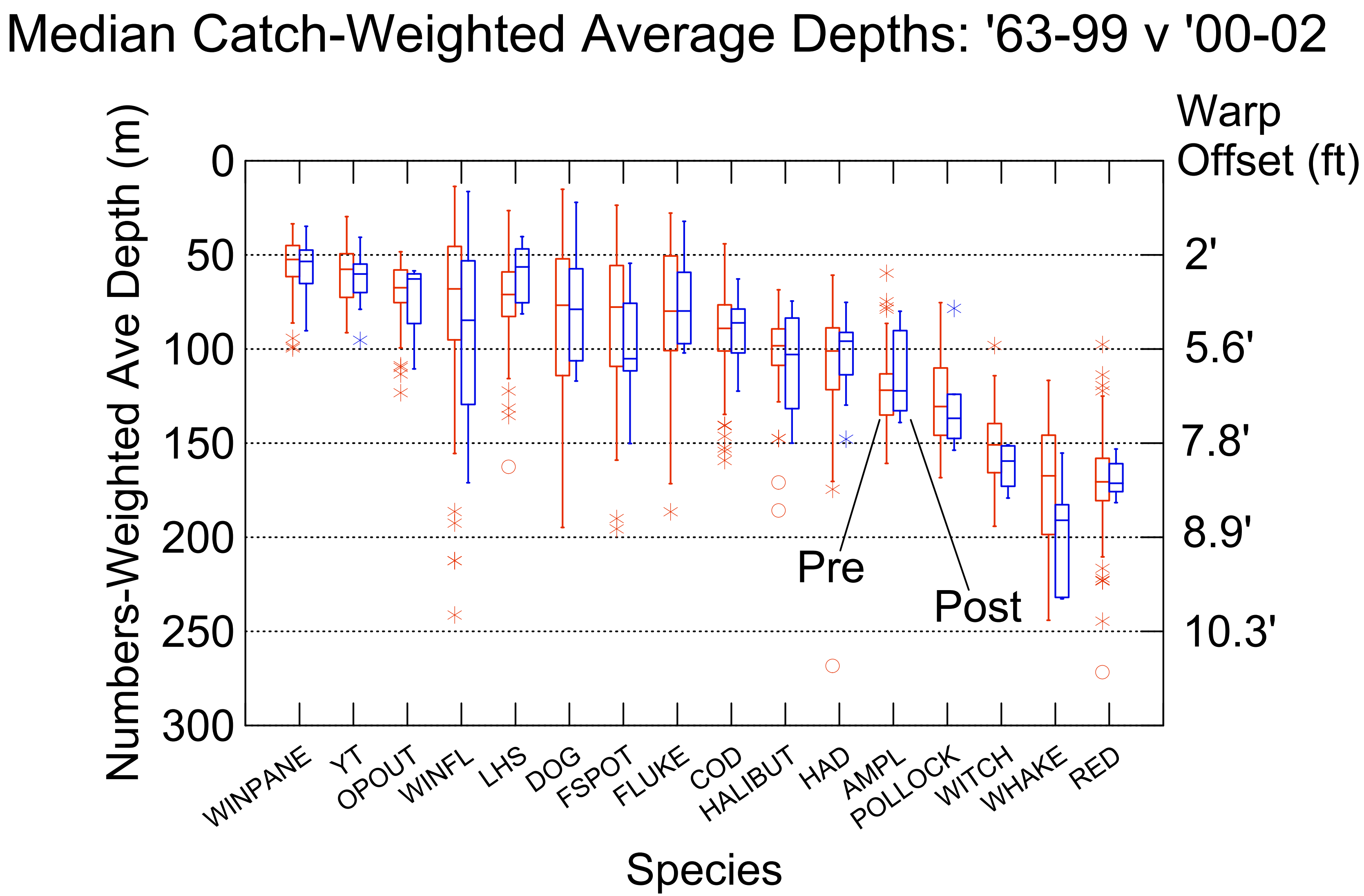



Figure 3.7.31. Catch weighted average depths at capture for 16 species of groundfish taken in NEFSC bottom trawl surveys. Data are presented for pre- and post trawl warp offset periods. The pre-warp period includes all data from 1963 onward until 1999.

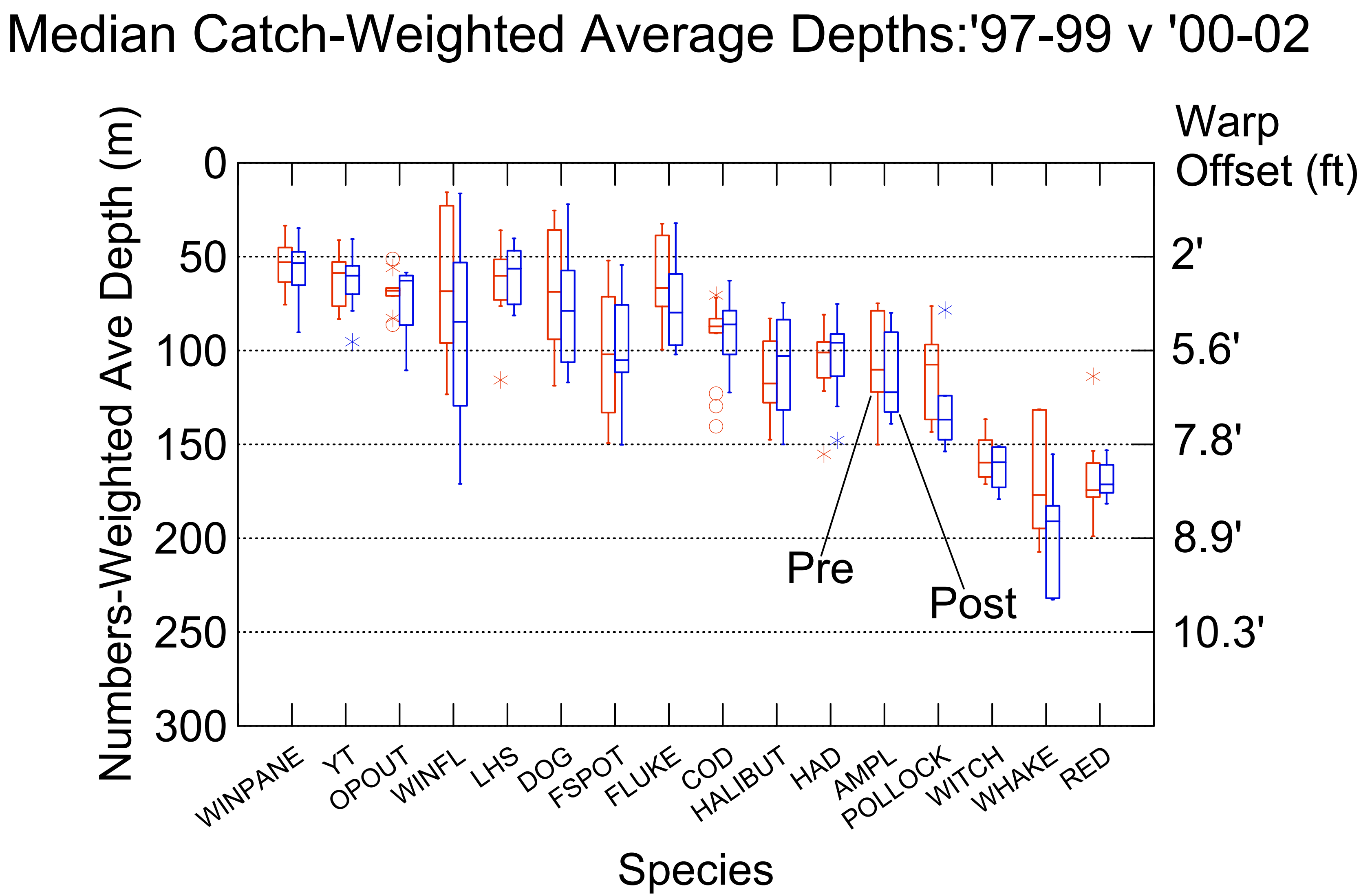



Figure 3.7.32. Catch weighted average depths at capture for 16 species of groundfish taken in NEFSC bottom trawl surveys. Data are presented for pre- and post trawl warp offset periods. The pre-warp period includes all data from 1997-1999.

### 3.8 Changes in Abundance Indices Pre- and Post Warp Intervention

Various abundance indices using the *Albatross IV* survey vessel are available for all 20 of the stocks assessed in section 2 of this document. Surveys potentially influenced by the warp offsets include the winter, spring and autumn bottom trawl time series. Overall there are 39 trawl survey series that are used in the assessments of the 20 stocks (Table 3.8). This analysis considers patterns in the directional change (positive, negative or the same) for each stock and survey series in pairs of adjacent years (e.g., 1998 to 1999, 1999 to 2000, etc.) to determine whether there are patterns in proportions of stocks increasing, decreasing or remaining the same associated with the warp offset intervention. The absolute abundance change from one year to the next is confounded by the underlying abundance changes in the stocks under consideration. The directional analysis, however, is likely more robust to the confounding influences of stock size changes in looking for potential interventions in the data series.

The directional changes for each stock and survey series (+, - or no change) are compiled in Table 3.8. Overall there were 25 series showing positive changes in stock abundance indices from 1998 to 1999, and 14 stocks showing stock declines. The potential intervention due to trawl warp offsets would have been manifested in the directional changes between 1999 and 2000. In that pair of years, the proportion of stocks showing positive changes was nearly identical to that in the previous year (23 of 39 stocks), with 15 showing a decline and one unchanged (Figure 3.8). For the years 2000-2001 and 2001-2002 the intervention would have been included in both years, so there would be no expected decline in the proportion of increasing/declining stocks due to the potential effects of the warp offsets. Interestingly, in 2000/2001, the proportion of declining versus increasing stocks reversed from the previous years, suggesting a year effect in these data. In 2001-2002 (winter and spring indices only), increasing stocks again dominated the total (12/17).

The overall patterns of increasing/declining stocks in the "intervention" year was thus very similar to the year previous, suggesting no systematic pattern of reduced catch efficiency that would be great enough to be discerned in such analyses. Based on the degree of warp offset by fishing depth, if such an intervention were to influence abundance indices, the effect would likely be most pronounced for the deepest dwelling species (i.e., where the warp offset was greatest). The deepest-dwelling of the groundfish stocks considered (based on catch-weighted median depths at capture, section 3.7) are American plaice, pollock, witch flounder, white hake, and redfish. There are nine survey series used in the assessments of these five stocks (Table 3.8). Data from the intervention year (i.e., 1999-2000) indicate that in 8 of these 9 series, the direction of change in abundance indices was actually positive (pollock in the autumn survey was the only negative change for the five stocks). Thus, analysis does not suggest a strong year effect coincident with a trawl warp offset intervention.

Table 3.8. Directional change in abundance (numbers per tow) of various species/stocks for pairs of years. For each stock all tuning indices used in the assessment that were influenced by the warp offsets in 2000-2002 are included. Positive (+) changes between years indicates the index increased. The warp change on Albatross occurred between 1999 and 2000.

| **Stock/Species** | **Surveys Series** | **1998-1999** | **1999-2000** | **2000-2001** | **2001-2002** |
|---|---|---|---|---|---|
| GB Cod | Spring | - | + | - | + |
| | Fall | - | + | - | |
| GB Haddock | Spring | + | - | + | + |
| | Fall | + | - | + | |
| GB Yellowtail | Spring | + | - | - | + |
| | Fall | + | - | + | |
| SNE Yellowtail | Spring | + | - | - | + |
| | Fall | - | + | - | |
| | Winter | + | - | + | - |
| CC Yellowtail | Spring | + | + | - | + |
| | Fall | + | - | - | |
| GM Cod | Spring | + | + | - | + |
| | Fall | + | + | - | |
| Witch | Spring | - | + | + | + |
| | Fall | + | + | + | |
| Plaice | Spring | - | + | + | - |
| | Fall | + | + | - | |
| GB Winter Flounder | Spring | + | + | - | + |
| | Fall | - | + | + | |
| SNE Winter Flounder | Spring | + | - | - | + |
| | Fall | - | + | - | |
| | Winter | + | - | - | - |
| White hake | Spring | + | + | - | + |
| | Fall | + | + | - | |
| Pollock | Spring | - | + | + | |
| | Fall | + | - | + | |
| Redfish | Fall | - | + | - | |
| Ocean Pout | Spring | + | - | + | - |
| N Windowpane | Fall | - | o | + | |
| S Windowpane | Fall | - | + | + | |
| MAB Yellowtail | Spring | + | - | - | |
| | Fall | - | + | - | |
| | Winter | - | + | - | |
| GM Haddock | Spring | + | - | - | + |
| | Fall | + | + | - | |
| Atlantic Halibut | Spring | + | - | + | - |
| | Fall | - | - | - | |
| GM Winter Flounder | Spring | + | + | - | + |
| | Fall | + | + | - | |
| | Sum Increases (+) | 25 | 23 | 14 | 12 |
| | Sum Decreases (-) | 14 | 15 | 25 | 5 |
| | Sum No Change (o) | 0 | 1 | 0 | 0 |

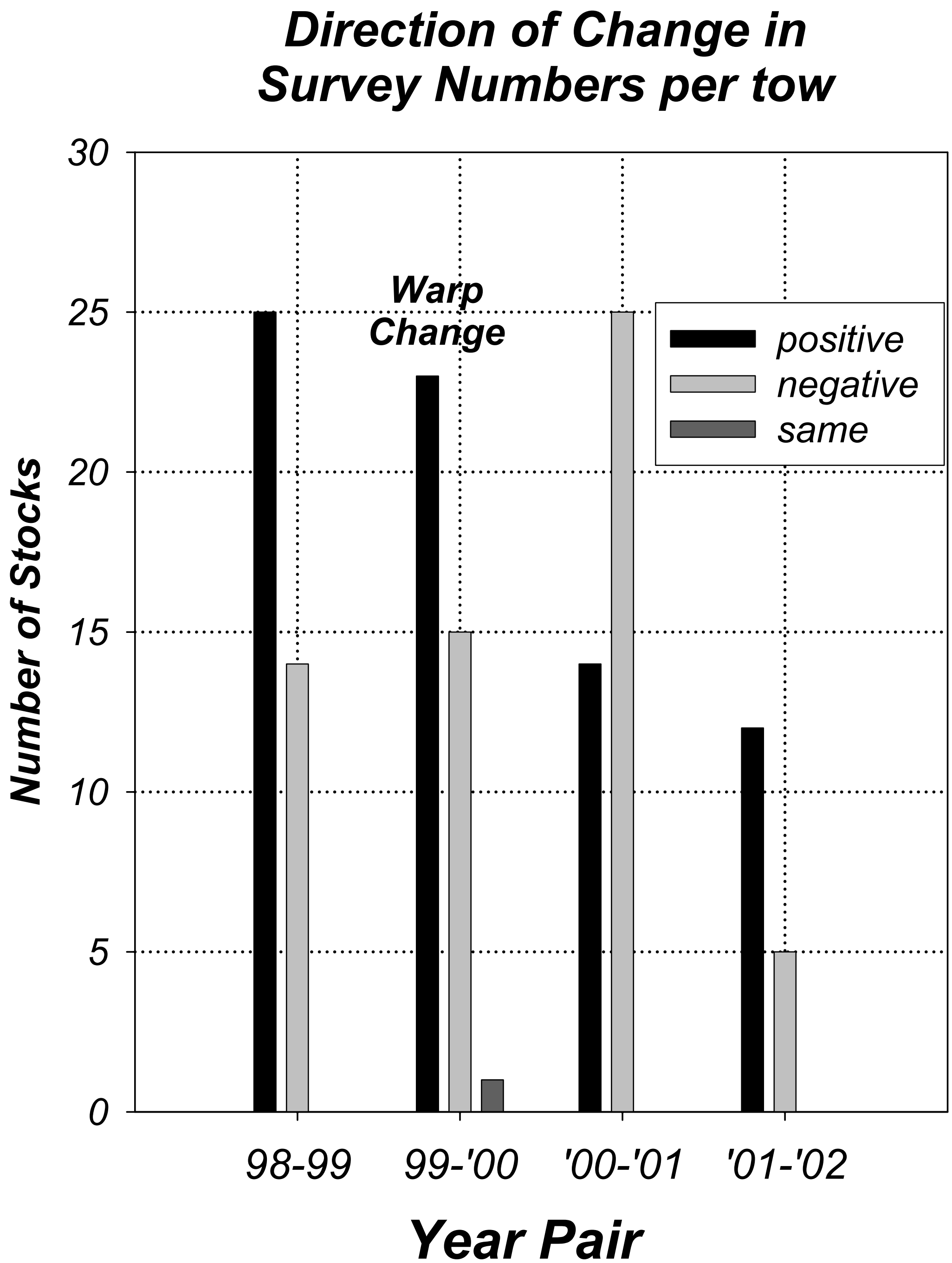



Figure 3.8. Directional change in abundance (numbers per tow) of various species/stocks for pairs of years. For each stock all tuning indices used in the assessment that were influenced by the warp offsets in 2000-2002 are included. Positive changes between years indicates the index increased. The warp change on *Albatross* occurred between 1999 and 2000.

## 3.9 Trends in Relative Fishing Power for NEFSC Bottom Trawl Surveys during 2000-2002

Summary and Conclusions

1) Trends in relative fishing power of bottom trawls used in NEFSC surveys were characterized using an index calculated from NEFSC bottom trawl, DFO bottom trawl and NEFSC sea scallop survey data. Index trends were examined to determine if relative fishing power of NEFSC bottom trawls declined during 2000-2002 while mis-marked warps were used.
2) Twenty species were included in the analysis: American plaice, Atlantic mackerel, cod, spiny dogfish, fourspot flounder, goosefish, haddock, herring, little skate, ocean pout, Pollock, red hake, redfish, sea scallop, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder.
3) Catch rates for NEFSC bottom trawl and other surveys had similar trends.
4) There were a total of 323 index values in 22 comparisons. Of these, 63 (20%) were for years when NEFSC bottom trawls had mis-marked warps.
5) Results suggest that relative fishing power varies to some extent over time in all species and surveys. For all species as a group, relative fishing power in NEFSC bottom trawl surveys was somewhat above average during 2000-2002 while warps were mis-marked.
6) Based on these data, there is no evidence that mis-marked warps systematically reduced the fishing power of NEFSC bottom trawls during 2000-2002 for all species.

Introduction

Indices of relative fishing power were computed using survey data (number caught per standard tow) from NEFSC bottom trawl, DFO (Department of Fisheries and Oceans Canada)[1] bottom trawl, and NEFSC sea scallop surveys. Indices of relative fishing power for each species were examined qualitatively and statistically to determine if relative fishing power of NEFSC bottom trawls declined during 2000-2002 with mis-marked warps. Most of the comparisons involved NEFSC and DFO spring bottom trawl surveys but NEFSC winter bottom trawl, fall bottom trawl and scallop surveys were used as well. Species examined include American plaice, Atlantic mackerel, cod, spiny dogfish, fourspot flounder, goosefish, haddock, herring, little skate, ocean pout, pollock, red hake, redfish, sea scallop, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder. The data used in comparisons were similar in terms of area surveyed and survey timing.

As many species-survey comparisons as possible were included in the analysis and the statistical approaches used to analyze index trends accommodated all comparisons simultaneously because it would be difficult to detect a small or moderate size change in fishing power for any single species.

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[1] Dr. J. Hunt, Fisheries and Oceans Canada, Marine Fish Division, Gulf of Maine Section, 531 Brandy Cove Rd., St. Andrews, New Brunswick, E5B 2L9, CANADA

## Materials and Methods

NEFSC bottom trawl survey data were either spring, fall or winter survey catch rates (mean number per standard tow) in "successful" tows (database SHG values ≤ 136) in NEFSC offshore survey strata. Bottom trawl survey and scallop survey data were tabulated by combining strata that made the area covered by both surveys as similar as possible. In particular, DFO spring survey data used in comparisons for Georges Bank (GBK) were for DFO bottom trawl strata 5Za-5Zh. NEFSC bottom trawl survey data used in comparisons with DFO or scallop survey data for GBK were from NEFSC offshore bottom trawl survey strata 9-11, 13-14, 16-17 and 19-25. NEFSC offshore strata for GBK exclude the deepest NEFSC strata that are not sampled in the DFO survey. NEFSC bottom trawl survey data used in comparisons with scallop survey data for the Mid-Atlantic Bight (MAB) area were from NEFSC offshore bottom trawl survey strata 1, 2, 65-66, 69-70, and 73-74 and were chosen to maximize overlap with the MAB area assumed in sea scallop assessments. Scallop survey data used in comparisons were for NEFSC shellfish strata 46-47, 49-55, 58-63, 65-66, 71-72 and 74 (the GBK stock area used in sea scallop stock assessments) or 6-7, 10-11, 14-15, 18-19, 22-31 and 33-35 (the MAB stock area used in sea scallop assessments).

During the years included in this analysis (beginning in either 1979, 1982 or 1987, depending on the species and surveys), NEFSC spring and fall surveys used two vessels (*R/V Albatross IV* and *R/V Delaware II*), two types of bottom trawls (Yankee No. 41 in the spring survey during 1979-1981; Yankee No. 36 otherwise and in all years for the fall survey), and two types of trawl doors (BMV doors prior to 1985, polyvalent doors afterwards). The NEFSC winter survey began in 1992 and used both vessels with the standard 60-80 bottom trawl. Based on standard NEFSC procedures, vessel, trawl and door correction factors were applied where available to make catch rates on all surveys comparable to the Yankee No. 41 trawl with polyvalent doors fished by the *R/V Albatross IV*. Correction factors are probably imprecise but, fortunately, the majority of comparisons involved the NEFSC and DFO bottom trawl surveys beginning in 1987. Different vessels were used in the spring survey after 1986 in some years. However, only one type of bottom trawl and one type of trawl door was used after that date.

DFO spring bottom trawl data were compared to NEFSC spring bottom trawl survey data for GBK (see below). DFO data were survey catch rates (mean number per standard tow, adjusted for distance towed based on standard DFO procedures) for "good, random survey tows" in DFO ground fish strata 5Za-5Zh (at depths < 100 fathoms) during 1987-1992 and 1995-2002. There was no DFO survey over Georges Bank during 1993 and coverage was incomplete during 1994. Therefore, catch rates during 1993-1994 were excluded from comparisons. DFO survey data for Georges Bank used in this analysis were collected by a single vessel (*R/V Alfred Needler*) and one type of bottom trawl gear (Western 2A bottom trawl). Sea scallop was excluded from comparisons for GBK because trawls are relatively inefficient for sea scallop on rough grounds found across much of GBK.

| Georges Bank Species | Years Comparing NEFSC and DFO Spring Surveys |
|---|---|
| American plaice | 14 |
| Atlantic mackerel | 12 |
| Cod | 14 |
| Spiny dogfish | 14 |
| Fourspot | 14 |
| Haddock | 14 |
| Herring | 14 |
| Little skate | 14 |
| Ocean pout | 14 |
| Pollock | 14 |
| Red hake | 13 |
| Redfish | 14 |
| Silver hake | 14 |
| White hake | 14 |
| Windowpane flounder | 14 |
| Winter flounder | 14 |
| Witch flounder | 14 |
| Yellowtail flounder | 14 |
| Total | 249 |

Catch rates for fish and sea scallops in annual NEFSC sea scallop surveys were compared to NEFSC survey bottom trawl catch rates (see below). The scallop survey during 2000-2002 was not affected by mis-marked warps on the *R/V Albatross IV* because the survey scallop dredge is towed by a single wire. Comparisons with scallop survey catches are potentially important because the scallop survey takes species on the bottom that might be missed by the bottom trawl if mis-marked warps reduced trawl bottom contact during 2000-2002. The scallop survey is conducted annually in the summer using a standard 8’ New Bedford style scallop dredge with 2” rings and a 1.75” plastic liner. However, in accord with standard procedures for scallop assessments, empty strata in some years were filled by borrowing catches from the same strata in the preceding and following year.

Scallop survey catch data used in this analysis were limited to sea scallops, goosefish and yellowtail flounder per standard tow because scallop survey catches have not been fully computerized for most fish species. Scallop survey data (mean number per standard tow) for the GBK and MAB regions were compared to the average of spring and fall NEFSC survey data during the same year because the scallop survey is carried out in the summer after the spring survey and before the fall survey. Comparisons involving average spring and fall survey data excluded 2002 because only the spring survey had mis-marked warps during 2002. In addition, catch rates for goosefish in MAB from the scallop survey were compared to NEFSC winter bottom trawl catch rate, because the winter survey takes substantial numbers of goosefish.

Goosefish were the only case of a comparison involving NEFSC winter survey and scallop survey data.

Catch rates used in species-comparisons were for all sizes with several exceptions. Data for GBK yellowtail < 20 cm TL in the scallop survey were excluded because survey bottom trawls are not efficient for yellowtail < 20 cm TL. Goosefish data for MAB from the scallop survey were for individuals 20-59 cm TL because survey bottom trawls are not efficient for goosefish smaller than 20 cm and scallop dredges are not efficient for goosefish larger than 60 cm. Comparisons of scallop catch rates were for scallops with shell heights of 9-13.9 cm because bottom trawls and scallop dredges both catch considerable numbers of scallops in this size range and because scallop dredges and commercial bottom trawls sample large (9-13.9 cm) and small (< 9 cm) scallops with different efficiency. Goosefish and yellowtail flounder comparisons began in 1982 because the scallop survey did not cover all of the Georges Bank strata in earlier years and because goosefish catches had not been recorded earlier.

MAB yellowtail and GBK goosefish were not used for comparisons because catch rates in NEFSC scallop, spring and fall surveys were too low and variable. The winter NEFSC winter survey takes substantial numbers of goosefish but does not cover the entire GBK region.

| Mid-Atlantic Bight Species | Years Comparing GBK Scallop and Average NEFSC Spring & Fall | Years Comparing MAB Scallop and Average NEFSC Spring & Fall | Years Comparing MAB Scallop and NEFSC Winter | Total |
|---|---|---|---|---|
| Goosefish | -- | 20 | 11 | 31 |
| Sea scallop | -- | 23 | -- | 23 |
| Yellowtail flounder | 20 | -- | -- | 20 |
| Total | 20 | 43 | 11 | 74 |

Catch rates for NEFSC bottom trawl and other surveys followed similar trends in most cases (Figure 3.9-1). Correspondence in trends for scallops in the scallop, spring and fall surveys was surprisingly strong.

*Standardized log catch rate ratios*

The ratio of mean catch rates in two surveys during the same year is a measure of the relative fishing power of the two surveys. For each species in the analysis, we computed annual values of log survey catch ratios:

$$X_y = \ln\left(\frac{I_y}{K_y}\right)$$

where $I_y$ is the catch rate (number per standard tow) during year $y$ for the NEFSC bottom trawl survey, and $K_y$ is the catch rate for the same species in the DFO or scallop survey. Log catch ratios have better statistical properties (i.e. symmetrical statistical distributions and constant variance) than the original values.

For ease in analysis and plotting, standardized log survey catch ratios for each species were standardized (Tables 3.9.1 and Figure 3.9.2):

$$\chi_y = \frac{(X_y - \bar{X})}{\sigma}$$

where $\chi_y$ is the standardized log survey catch rate SLSCR index of relative fishing power, $\bar{X}$ is the average of $X_y$ values prior to 2000 and $\sigma$ is the standard deviation of $X_y$ values prior to 2000. Means and standard deviations used in standardization calculations were for years prior to 2000 so that the mean SLSCR for years prior to 2000 would average zero and the standard deviation for years prior to 2000 would be one. This convention facilitated analyses but had no effect on results.

NEFSC spring, fall or winter catch rates were always in the numerator of ratios used to compute SLSCR index values. This is important because increases in ratios indicate possible increases in relative fishing power for bottom trawls used in NEFSC spring fall or winter surveys, and vice-versa. If mis-marked warps reduced the fishing power of bottom trawls used in the NEFSC spring survey relative to the DFO spring survey, for example, then SLSCR values for 2000-2002 in the comparison should tend to be small or negative. In addition, an abrupt change in index values may be evident in the index values for 1999-2000.

There were 22 species comparisons in the final data set with a total of 323 SLSCR index values. Of the total, 63 (20%) were for surveys with mis-marked warps during 2000-2002.

*Interpretation of SLSCR index values*

In theory, both the direction and magnitude of SLSCR index values have meaning. An index value of zero means no apparent change in relative fishing power, positive indices indicate above average relative fishing power, negative values indicate below average relative fishing power, and larger changes in index values suggest larger changes in relative fishing power. However, theory aside, there are a number of important issues to keep in mind while interpreting SLSCR index values (see below). In view of these issues, it is prudent to focus on results for groups of species and groups of years. In comparing index values for a single or few species over a short period of time, it is prudent to focus on the sign (positive or negative) of SLSCR values.

Changes in relative fishing power of both surveys in a comparison are confounded in SLSCR values. For example, increases in SLSCR could be due to values and increased relative fishing power in NEFSC bottom trawl surveys could be due to changes in either the numerator (NEFSC bottom trawl catch rates) or the denominator (DFO or scallop survey catch rates). This is an important because, in theory, variation in SLSCR values in a particular comparison could be due entirely to variability in fishing power of either the NEFSC bottom trawl (in the numerator) or the survey (DFO or scallop) used for comparison in the denominator.

Environmental factors likely influence both surveys in a comparison so that there is a covariance between catch rates and fishing power for both surveys. Further, trends in abundance will affect catch rates in both surveys so that catch rates are correlated. SLSCR was calculated using ratios, however, so that environmental "year effects" and "abundance" effects should cancel out.

SLSCR index values measure relative fishing power ***but can not be interpreted as percentage or proportional changes***. For example, if the SLSCR for a species was 0.0 for 1997, 0.1 for 1998, and -0.5 in 1999, one could conclude that relative fishing power was near average in 1997, apparently increased slightly in 1998 and apparently declined substantially in 1999. However, it would be incorrect to conclude that relative fishing power increased by 10% of the average value in 1998 and then declined by 60% of the average value during 1999.

The variance of SLSCR index values has not been measured and both the direction and magnitude of changes in the index may be largely random. Variance and statistical properties were not calculated in this analysis due to lack of time. Variance is likely considerable and the possibility of bias or autocorrelation in index values has not been fully explored. Survey catch rate data are intrinsically variable and there may be covariances between catches in two different surveys during the same year that do not cancel. Covariances may exist between SLSCR values for one species in adjacent years (autocorrelation) and among species in the same year. These types of correlations almost certainly increase uncertainty in SLSCR index values by reducing information about relative fishing power in the survey data. Therefore, patterns in these indices were evaluated for overall trends rather than for individual species/stocks in specific surveys.

Results

SLSCR index values indicate that relative fishing power for all species taken together was slightly above average (0.06) during 1999 and increased a small amount to 0.09 in 2000, the first year with mis-marked warps (Table 3.9.1). The average SLSCR value for all species taken together during 2000-2002 was 0.14, indicating that average fishing power for NEFSC bottom trawls was above average during 2000-2002 while warps were mis-marked. There was no obvious relationship between mean depth for each species and SLSCR values during 2000-2001 (Table 3.9.1). Depth is of interest because of hypotheses that effects of mis-marked warps increased with depth.

The sign of SLSCR values (i.e. positive for increased fishing power, negative for decreased fishing power; Table 3.9.2) also indicate about average overall fishing power for NEFSC bottom trawls with mis-marked warps during 2000-2002. SLSCR values were positive in 11 out of 22 (50%) comparisons for 1999 and 12 out of 22 (55%) comparisons for 2000. Considering all comparisons during 2000-2002, SLSCR values were positive in 34 out of 63 (54%) of cases, compared to 33 out of 66 (50%) during 1997-1999. Thus, the number of species for which fishing power of NEFSC survey bottom trawls was above average was about 50% before and after the introduction of mis-marked warps. There was no obvious relationship between species mean depth and the sign of SLSCR values during 2000-2001 (Table 3.9.2). There are a number of other such comparisons (e.g. between NMFS fall surveys and Canadian surveys) that could be pursued. However, results presented in section 3.8 indicate similar conclusions regarding the lack of a detectable intervention due to the warp offset issue.

Table 3.9.1. Standardized SLSCR indices of relative fishing power for NEFSC bottom trawls during 1991-2002. Positive values mean that the NEFSC bottom trawl survey had above average relative fishing power, and vice versa. Index values do not measure percentage or proportional changes in relative fishing power. For example, a value 0f 0.1 does not imply a 10% increase. Species are sorted roughly in order of average depth in spring NEFSC survey catches during 1968-2002 (shallow depths at the top). Few indices are available for 1993-1994 because DFO surveys were not carried out or were incomplete on Georges Bank.

| **Species** | **Surveys** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **1997-1999** | **2000-2002** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Skate | Spring-DFO | 0.93 | 2.16 | | | -0.71 | 0.56 | -1.31 | -0.26 | 0.02 | -0.59 | 0.31 | 0.92 | -0.51 | 0.21 |
| Windowpane | Spring-DFO | 1.23 | -0.23 | | | -0.86 | -0.96 | -0.44 | -1.09 | -0.67 | 0.62 | 0.57 | -0.17 | -0.73 | 0.34 |
| Winter Flounder | Spring-DFO | 0.90 | -0.28 | | | -0.29 | -0.26 | -0.71 | -0.18 | 2.41 | 1.69 | 0.29 | 1.30 | 0.51 | 1.09 |
| Yellowtail | Spring-DFO | 0.62 | -0.66 | | | 0.67 | -0.24 | -0.89 | 0.66 | -0.22 | -0.47 | -1.58 | 0.16 | -0.15 | -0.63 |
| Yellowtail | Spr&Fall-Scallop | -1.04 | 0.37 | -1.76 | -0.55 | -0.94 | -1.23 | -0.73 | -0.64 | 0.29 | -0.16 | 1.25 | | -0.36 | 0.55 |
| Ocean Pout | Spring-DFO | 0.63 | -1.60 | | | 0.71 | 0.16 | 0.73 | 0.15 | 0.84 | 1.93 | 1.87 | 3.92 | 0.57 | 2.57 |
| Mackerel | Spring-DFO | -1.60 | -0.33 | | | -0.14 | 0.24 | 0.84 | -1.42 | 0.49 | 0.92 | -0.69 | -0.47 | -0.03 | -0.08 |
| Herring | Spring-DFO | -0.84 | 0.66 | | | 0.03 | 0.08 | -0.54 | 1.47 | -0.86 | -0.88 | -0.89 | 0.94 | 0.02 | -0.28 |
| Scallop | Spr&Fall-Scallop | 0.17 | 0.70 | -0.08 | 0.75 | -0.02 | -1.32 | 0.31 | 0.96 | 0.63 | 0.70 | -0.37 | | 0.63 | 0.17 |
| Cod | Spring-DFO | 0.07 | -1.26 | | | 0.73 | -1.73 | -0.31 | 2.05 | -0.37 | -0.96 | -0.30 | -0.88 | 0.46 | -0.71 |
| Haddock | Spring-DFO | -0.32 | -1.97 | | | 0.13 | 1.34 | 1.27 | -0.69 | -0.68 | -1.83 | -0.54 | -0.10 | -0.03 | -0.82 |
| Red Hake | Spring-DFO | 1.17 | | | | 0.70 | -2.01 | -0.01 | 1.45 | -0.03 | 0.53 | -0.18 | 0.84 | 0.47 | 0.40 |
| Fourspot | Spring-DFO | -0.35 | -0.83 | | | 0.41 | 1.86 | -0.32 | 0.29 | -1.96 | 1.32 | -0.81 | 0.45 | -0.67 | 0.32 |
| Dogfish | Spring-DFO | 0.04 | -1.59 | | | -1.09 | 0.06 | 0.62 | 1.69 | 1.41 | 0.05 | 0.14 | 0.91 | 1.24 | 0.37 |
| Goosefish | Spr&Fall-Scallop | 0.88 | -0.91 | -0.33 | -0.06 | -0.47 | -0.94 | -0.50 | -0.26 | -0.15 | 0.69 | -0.25 | | -0.31 | 0.22 |
| Goosefish | Winter-Scallop | | -0.31 | 0.88 | -0.96 | 0.05 | 1.83 | -0.50 | 0.26 | -1.25 | 0.16 | 1.27 | 1.75 | -0.49 | 1.06 |
| Plaice | Spring-DFO | 0.14 | -2.25 | | | 0.56 | 0.63 | -0.73 | 0.74 | -0.79 | 0.49 | 0.14 | -0.11 | -0.26 | 0.17 |
| Pollock | Spring-DFO | 0.44 | -1.58 | | | 1.86 | -0.21 | 0.26 | 0.82 | 0.45 | -0.39 | 0.16 | -3.05 | 0.51 | -1.09 |
| Silver hake | Spring-DFO | -0.33 | -1.32 | | | -0.66 | -1.19 | -0.13 | 1.31 | 0.10 | -1.44 | -0.24 | 1.31 | 0.43 | -0.12 |
| Witch Flounder | Spring-DFO | 0.29 | -0.66 | | | -0.29 | 0.22 | -2.16 | 1.88 | -0.35 | -1.14 | -0.79 | 0.01 | -0.21 | -0.64 |
| Redfish | Spring-DFO | -1.54 | 1.76 | | | -0.37 | 0.18 | 0.50 | 0.68 | 0.51 | 1.50 | 1.28 | -0.29 | 0.57 | 0.83 |
| White hake | Spring-DFO | -0.21 | -1.13 | | | -0.63 | -0.10 | -0.85 | 0.87 | 1.41 | -0.66 | -1.59 | 0.06 | 0.48 | -0.73 |
| **Count All** | | 21 | 21 | 4 | 4 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 19 | 66 | 63 |
| **Average All** | | 0.06 | -0.54 | | | -0.03 | -0.14 | -0.25 | 0.49 | 0.06 | 0.09 | -0.04 | 0.39 | 0.10 | 0.14 |

Table 3.9.2. The sign ("+" for above and "–" for below average) of SLSCR relative fishing power indices during 1991-2002. Species are sorted roughly in order of average depth in spring NEFSC survey catches during 1968-2002 (shallow depths at the top). Few indices are available for 1993-1994 because DFO surveys were not carried out or were incomplete on Georges Bank.

| Species | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 1997-1999 | 2000-2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Skate | + | + | | | - | + | - | - | + | - | + | + | 0.33 | 67% |
| Windowpane | + | - | | | - | - | - | - | - | + | + | - | 0.00 | 67% |
| Winter Flounder | + | - | | | - | - | - | - | + | + | + | + | 0.33 | 100% |
| Yellowtail | + | - | | | + | - | - | + | - | - | - | + | 0.33 | 33% |
| Yellowtail | - | + | - | - | - | - | - | - | + | - | + | | 0.33 | 50% |
| Ocean Pout | + | - | | | + | + | + | + | + | + | + | + | 1.00 | 100% |
| Mackerel | - | - | | | - | + | + | - | + | + | - | - | 0.67 | 33% |
| Herring | - | + | | | + | + | - | + | - | - | - | + | 0.33 | 33% |
| Scallop | + | + | - | + | - | - | + | + | + | + | - | | 1.00 | 50% |
| Cod | + | - | | | + | - | - | + | - | - | - | - | 0.33 | 0% |
| Haddock | - | - | | | + | + | + | - | - | - | - | - | 0.33 | 0% |
| Red Hake | + | | | | + | - | - | + | - | + | - | + | 0.33 | 67% |
| Fourspot | - | - | | | + | + | - | + | - | + | - | + | 0.33 | 67% |
| Dogfish | + | - | | | - | + | + | + | + | + | + | + | 1.00 | 100% |
| Goosefish | + | - | - | - | - | - | - | - | - | + | - | | 0.00 | 50% |
| Goosefish | | - | + | - | + | + | - | + | - | + | + | + | 0.33 | 100% |
| Plaice | + | - | | | + | + | - | + | - | + | + | - | 0.33 | 67% |
| Pollock | + | - | | | + | - | + | + | + | - | + | - | 1.00 | 33% |
| Silver hake | - | - | | | - | - | - | + | + | - | - | + | 0.67 | 33% |
| Witch Flounder | + | - | | | - | + | - | + | - | - | - | + | 0.33 | 33% |
| Redfish | - | + | | | - | + | + | + | + | + | + | - | 1.00 | 67% |
| White hake | - | - | | | - | - | - | + | + | - | - | + | 0.67 | 33% |
| **Count All** | 21 | 21 | 4 | 4 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 19 | 66 | 63 |
| **Count (+) All** | 13 | 5 | 1 | 1 | 10 | 11 | 7 | 15 | 11 | 12 | 10 | 12 | 33 | 34 |
| **Percent (+) All** | 62% | 24% | | | 45% | 50% | 32% | 68% | 50% | 55% | 45% | 63% | 50% | 54% |

Figure 3.9.1. Time series of survey catch rates for all species comparisons in this analysis. Original catch rates were rescaled for ease in plotting to a mean value of zero and a standard deviation of one.

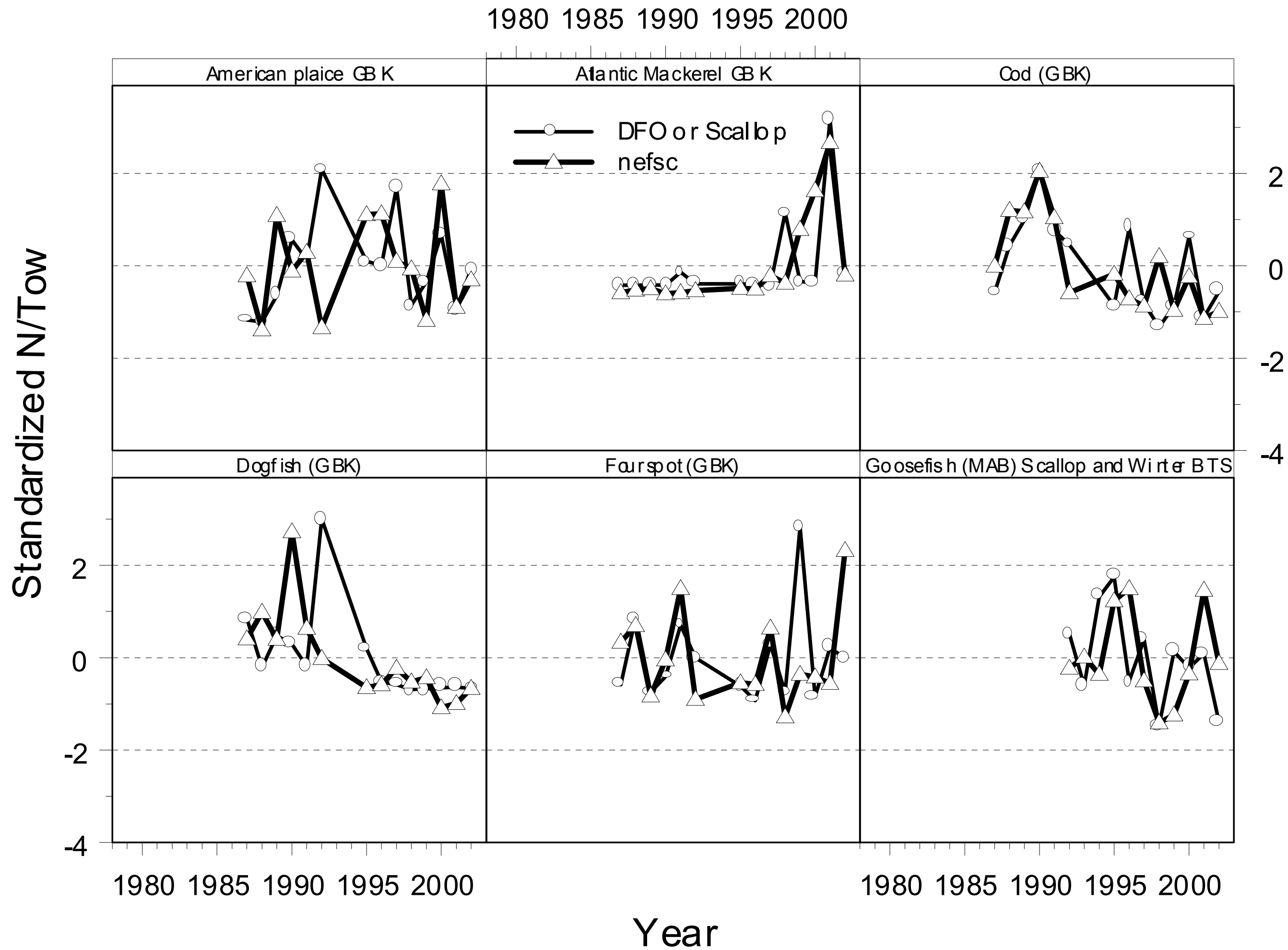


Figure 3.9.1. (cont.)

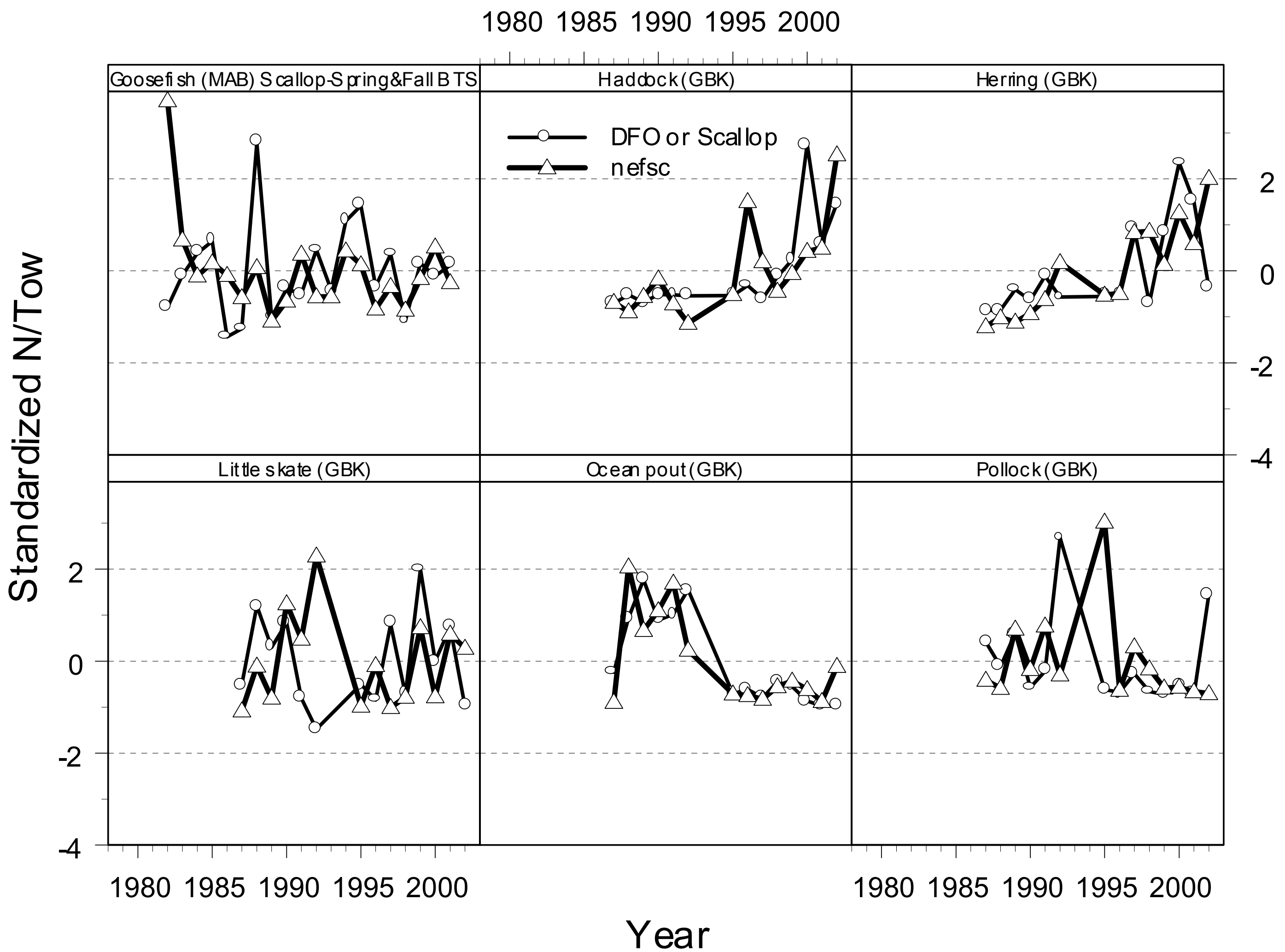


Figure 3.9-1. (cont.)

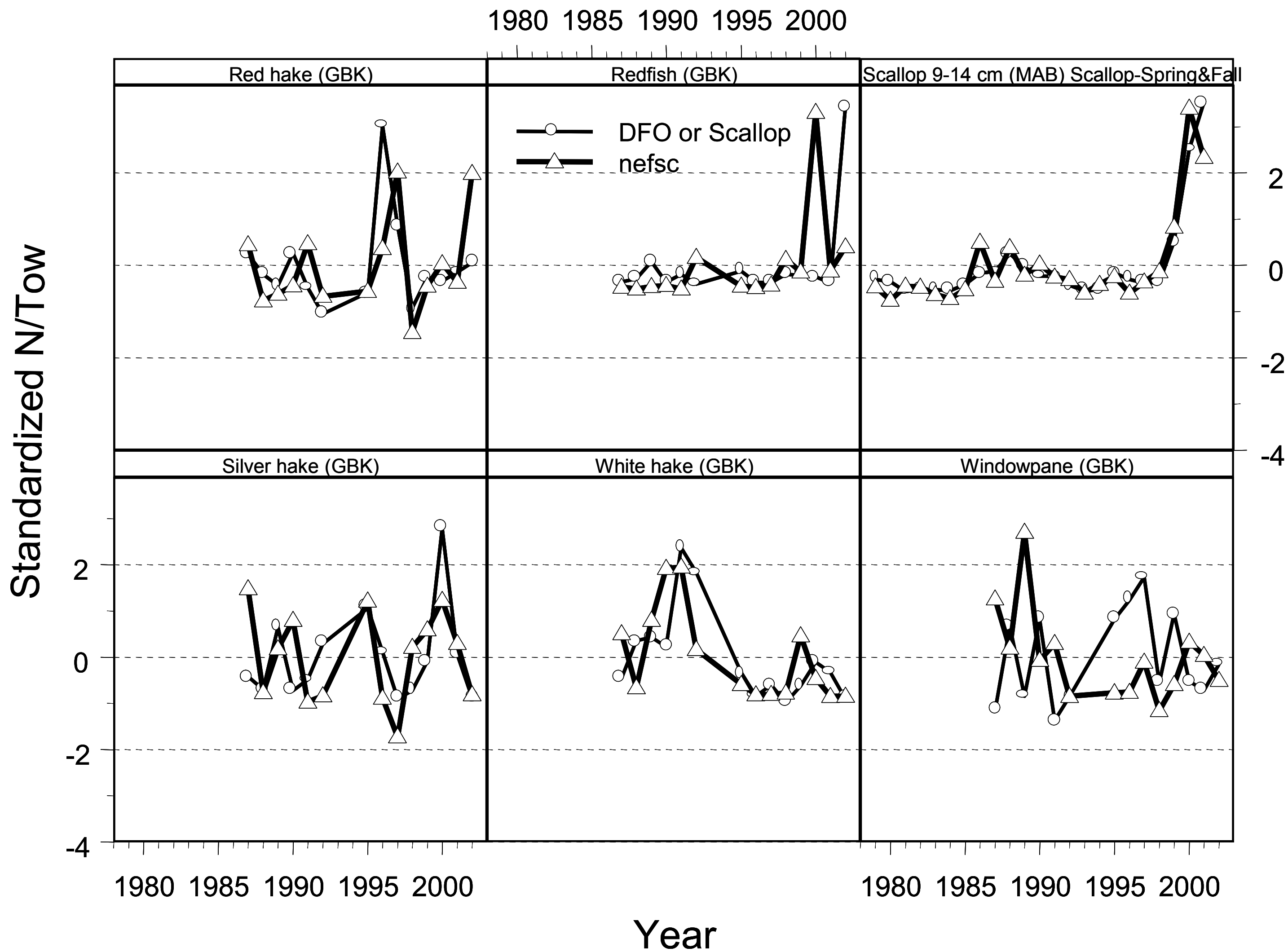


Figure 3.9.1. (cont.)

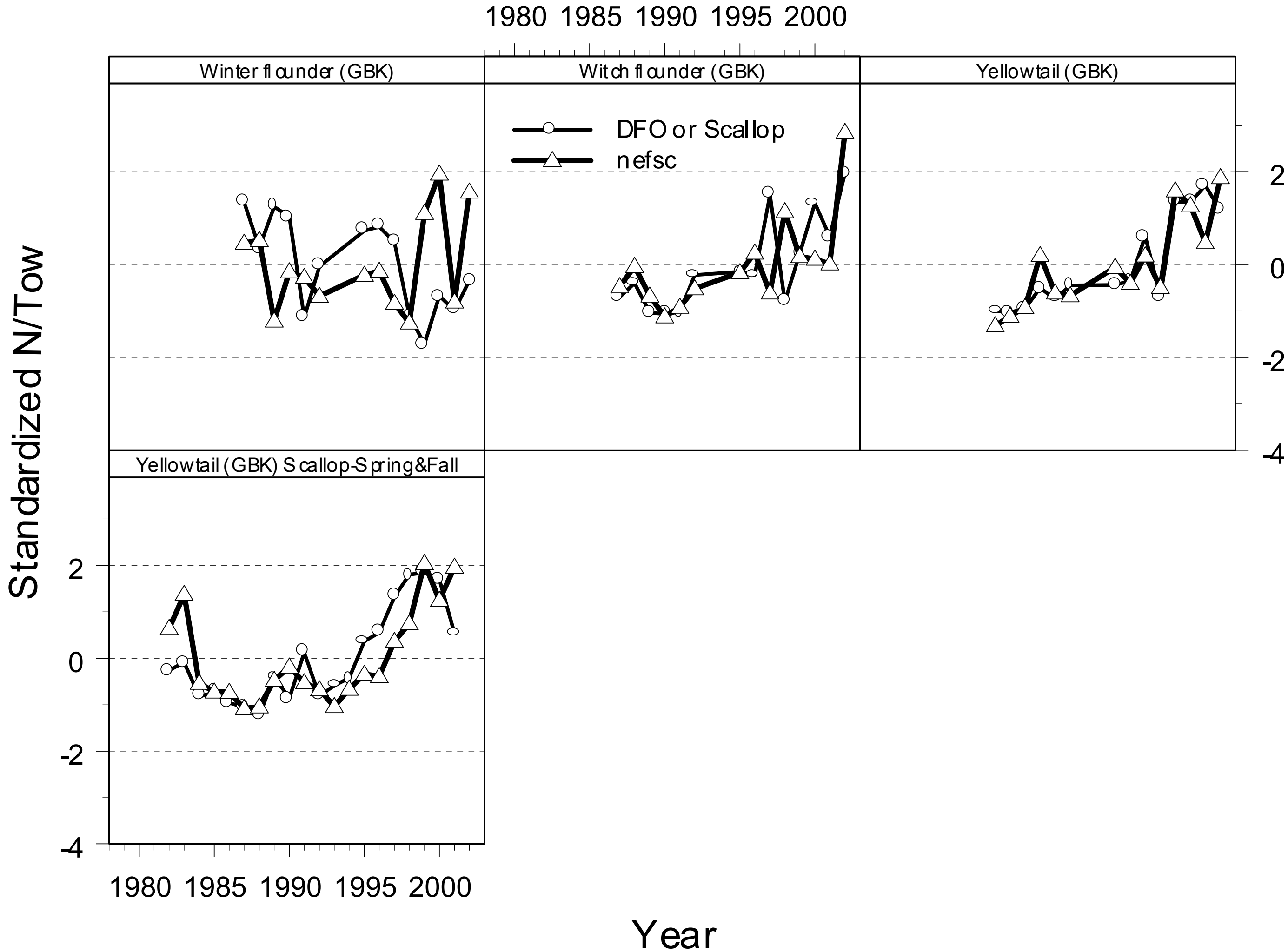


Figure 3.9.2. Time series of SLSCR indices of relative fishing power for all species comparisons in this analysis.

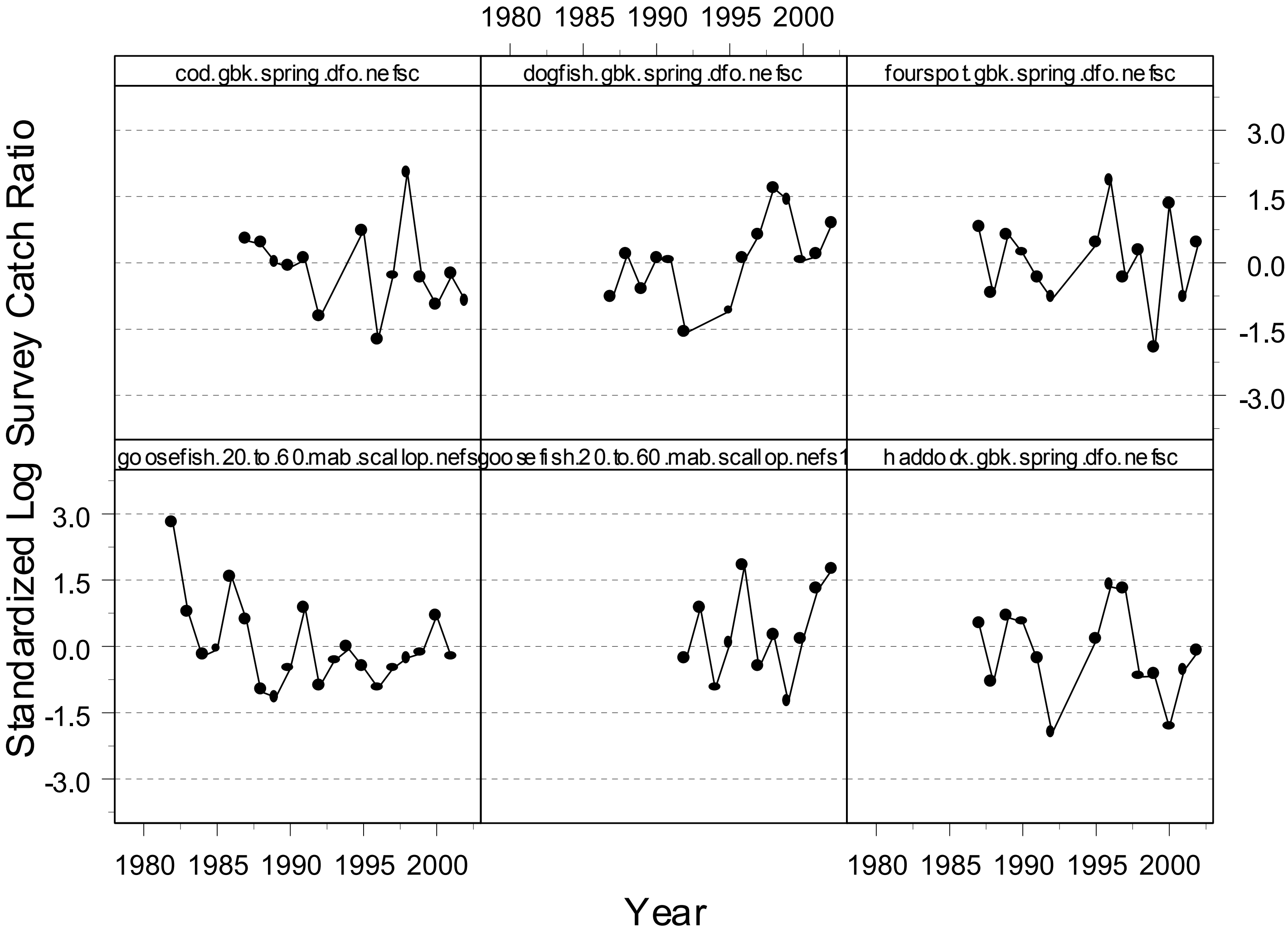


Figure 3.9.2. (cont.)

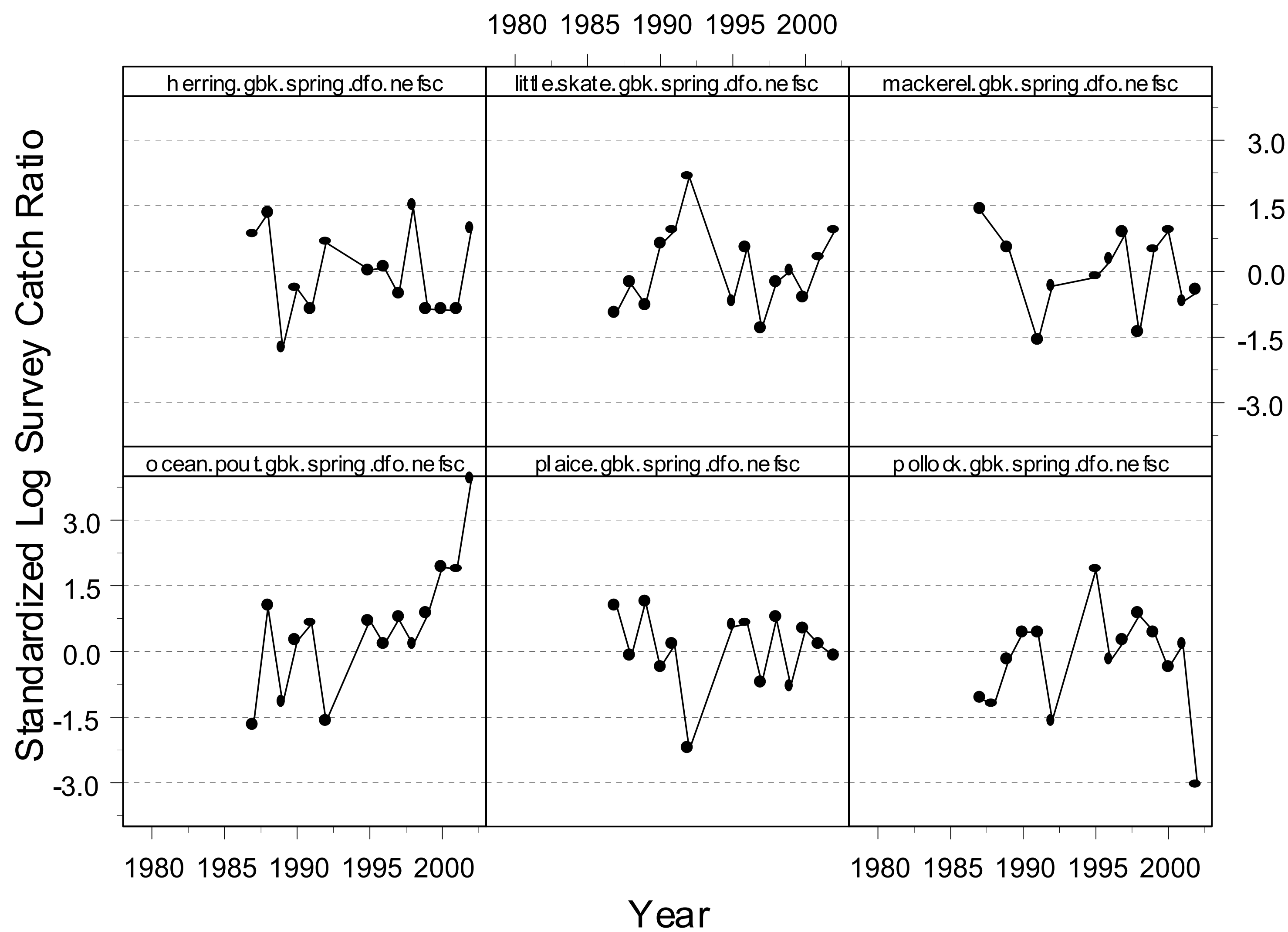


Figure 3.9.2. (cont.)

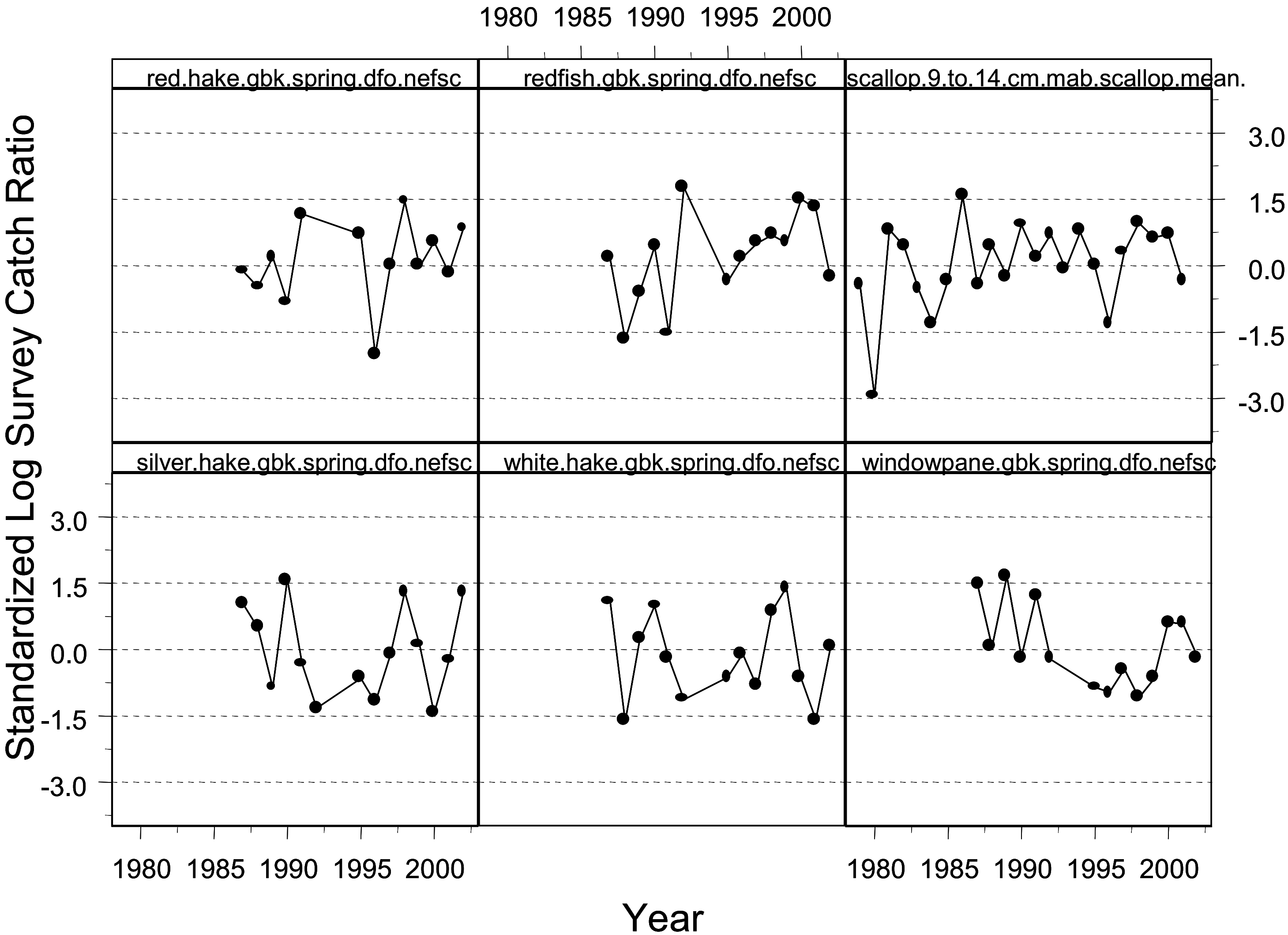
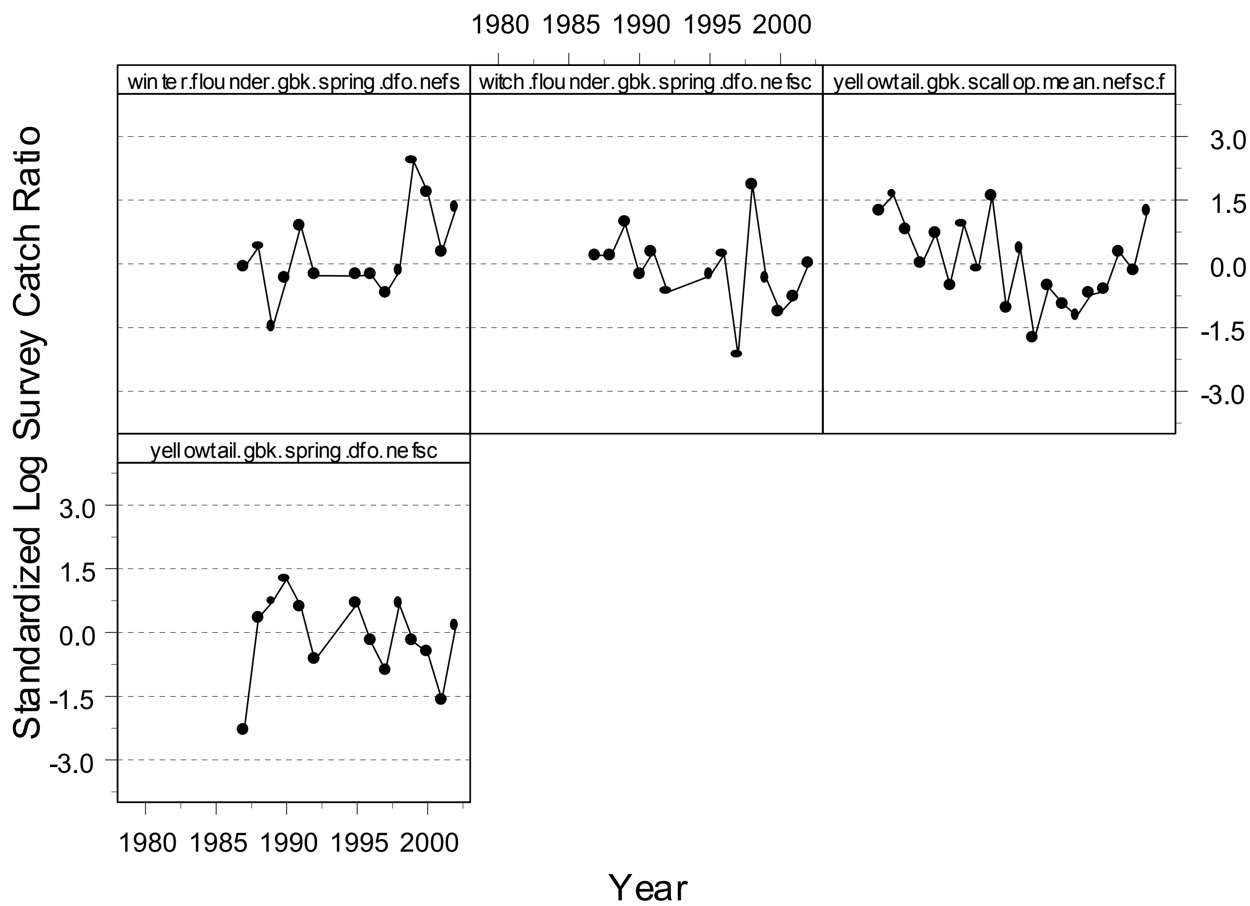


Figure 3.9-2. (cont.)



### 3.10 VPA Performance

The virtual population analysis results under the sensitivity runs (increasing the warp-impacted surveys by arbitrary levels of 10%, 25% and 100%) were examined for signs of improved fit relative to the base run. If in fact the warp-impacted surveys were catching fewer fish than expected, an improved fit and decrease of residuals would be expected under the sensitivity runs. However, of eight stocks examined, five decreased in fit, one remain unchanged, and two improved (Table 3.10.1). On average, the fit remain unchanged for the 10% run, decreased by 1% for the 25% run, and decreased by 4% for the 100% run. The overall fits of the virtual population analyses do not indicate a loss of fish in the warp impacted surveys.

The VPA performance was further examined by comparing the survey and year specific residuals from the sensitivity runs with the base case for each stock. These changes in residual were plotted so that positive values denote an improvement in fit while negative values denote a decrease in fit. Note that due to the backward convergence of VPA these changes will decrease for earlier years. If in fact the warp impacted surveys catch fewer fish than expected, trends in the residuals should be seen, viz., more positive changes than negative ones, especially for the impacted surveys. However, examination of these changes in residuals resulted in either random patterns or sets of decreased fits that were not balanced by associated increased fits. As the warp impacted surveys were increased, the magnitude of change in the residuals increased, as expected, but did not produce more positive changes than negative ones for either all indices or the warp-impacted survey indices taken alone. The changes in residuals from the sensitivity VPA runs do not indicate a loss of fish in the impacted surveys.

Retrospective patterns are common in VPA results and were seen for many of these stocks. If the warp impacted surveys were catching fewer fish than expected, a decrease in retrospective pattern would be expected under the sensitivity runs. However, the sensitivity runs had similar retrospective patterns to the base case for those stocks examined. The changes in retrospective patterns do not indicate a loss of fish in the impacted surveys.

Table 3.10.1 Mean square residual and change in mean square residual relative to the base run (positive values denote an improved fit) from eight stocks assessed with VPA. The three sensitivity analyses correspond to increasing the warp impacted surveys by 10%, 25% and 100%.

| | Mean Square Residual | | | |
|---|---|---|---|---|
| | base | x1.10 | x1.25 | x2.00 |
| GBCod | 0.58880 | 0.58822 | 0.58839 | 0.59875 |
| GBHaddock | 0.69544 | 0.69435 | 0.69402 | 0.70135 |
| GBYTF | 0.71389 | 0.71046 | 0.70664 | 0.70068 |
| SNEYTF | 1.07064 | 1.07141 | 1.07089 | 1.07124 |
| CCYTF | 0.82761 | 0.83632 | 0.84960 | 0.90921 |
| GOMCod | 0.44121 | 0.44242 | 0.44498 | 0.46370 |
| Witch | 0.76730 | 0.76576 | 0.76248 | 0.75622 |
| Plaice | 0.38929 | 0.39456 | 0.40283 | 0.44496 |

| | Relative Change in Mean Square Residual | | |
|---|---|---|---|
| | x1.10 | x1.25 | x2.00 |
| GBCod | 0% | 0% | -2% |
| GBHaddock | 0% | 0% | -1% |
| GBYTF | 0% | 1% | 2% |
| SNEYTF | 0% | 0% | 0% |
| CCYTF | -1% | -3% | -10% |
| GOMCod | 0% | -1% | -5% |
| Witch | 0% | 1% | 1% |
| Plaice | -1% | -3% | -14% |
| | | | |
| average | 0% | -1% | -4% |

## 3.11 Results from Comparative Fishing Power Studies Between *Albatross IV* and *Delaware II*

Fishing power studies (calibration experiments) are necessary if significant changes are made to elements of the trawl survey system over the time series. Such studies have been conducted in the past for the NEFSC bottom trawl surveys when elements such as survey ships and trawl doors have been changed (Sissenwine and Bowman, 1978; Byrne and Forrester, 1991; Forrester unpublished ms). These studies rely on side-by-side or repeat towing, with tows taken by one vessel serving as control, and the element of change (e.g., doors or ships) as the primary factor under investigation. Other variables such as the order of tows in repeat towing or the orientation of side-by-side towing (port vs. starboard) are usually randomized.

A one-time change in the trawl gear that affected the catching efficiency and, hence, the survey series was made in the 1980s as the doors were upgraded from a BMV wood and metal door to an all-metal oval polyvalent door (Byrne and Forrester 1991). To appropriately adjust the time series, conversion factors were estimated from replicated towing experiments to maintain the integrity of the time series, as the new doors generally improved the catch efficiency of the survey tows. Similarly, while the *Albatross IV* has been the primary survey vessel used in the bottom trawl time series, because of various scheduled and unscheduled maintenance and repair issues, the *Delaware II* has periodically been substituted as the survey ship. Therefore, a series of side-by-side comparison tows have been made since the early 1980s to estimate the relative efficiency of the two ships, by species, for use in calibration (Byrne and Forrester 1991). Following calibration, data from the two vessels are comparable. Since the *Albatross* will enter the shipyard for extensive repairs in late 2002, it was anticipated that the *Delaware II* would be used as the bottom trawl survey ship for the winter 2003 and spring 2003 surveys. Therefore, additional side-by-side tows were conducted in conjunction with the spring 2002 bottom trawl survey.

Unbeknownst to the NEFSC at the time, the spring 2002 side-by-side towing between *Albatross* and *Delaware* essentially compared one vessel with systematic and progressive trawl warps offset (*Albatross*) against a ship with small but non-biased warp measurement differences (*Delaware* warp offsets averaged 18”, varying randomly between port and starboard sides). Since there are differences in fishing power by ship (Byrne and Forrester 1991), the side-by-side towing results in 2002 cannot be compared directly to measure effects of the warp offset on *Albatross*. However, the results of the hundreds of side-by-side tows made between 1982 and 1988 can be compared to 2002 results to see if the ratio of *Albatross* to *Delaware* catches (by species) have changed (catch rates cannot be compared directly between the two time periods since underlying abundances have changed). Thus, the *Delaware* effectively serves as control, because its operating procedure was constant before and after the warp offset on *Albatross*.

If the warp offsets on *Albatross* had a significant impact on trawl catch efficiency then this would be manifested as a difference in the ratio of *Albatross* to *Delaware* catches between time periods. Information on the mean ratio of catches (A/D) and their 95% confidence intervals are presented for the two time periods in Table 3.11 and Figure 3.11.1, for 10 species where there were sufficient pairs of data to provide meaningful and reliable information for analysis. Sample sizes were 484 pairs of tows in the 1980s and 132 pairs in 2002. Over the 10 stocks considered, the mean ratio of *Albatross* to *Delaware* catch in the 1980s was 0.88, and in 2002 was 0.91. For the 10 species investigated, five had higher mean ratios in 2002 versus the 1980s, and 5 the opposite trend. Of the 10 species investigated, there were no statistically significant changes in the ratio of *Albatross* to *Delaware* catches in nine; the one significant difference was for yellowtail flounder, which indicated an apparent increase in fishing power of the *Albatross* relative to the *Delaware* in 2002. Because the experimental units are the trawl hauls, the results for the 10 species are not independent, and thus the most robust measure of change is based on the composite of species. The apparent increase in catching efficiency for yellowtail flounder could be spurious (one false positive out of ten is not unlikely; on average this occurs in one out of 20 times in tests at the 5% significance level).

In order to discern the ability of this test to detect differences in relative fishing power between ships and time periods, the 2002 data were subjected to a power analysis. Information presented is the percent difference in the ratio of *Albatross* to *Delaware* catches, by species, that can be detected at the 5% significance level in a two-sided test. For all species the average difference in catch ratios that could be detected was 21.4%, varying from 12.2% (haddock) to 34.6% (winter flounder; Table 3.11; Figure 3.11.2).

Estimates of fishing power coefficients (ratio of *Albatross* to *Delaware* catches) were thus similar between vessels in experiments before and after the warp change on *Albatross IV*. There was only one statistically significant change in this ratio after the warp change in the 10 species examined (and this result could be spurious). These paired comparison tests (although not intended for the purpose when they were conducted) provide robust data to test the warp effects (and include any other systematic changes in the fishing system since 1988 such as the new method for lashing the net to the traveler wire). Based on information from 2002, the catch ratio test can detect differences of between 12% and 35%, with 95% probability, depending on species. Therefore, large (greater than 40%-50%) reductions in catchability of the *Albatross* survey during the period of the warp offset are highly unlikely as they should have been detected.

**References**

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Forrester, J.R.S. (m.s.). A trawl survey conversion coefficient suitable for lognormal data. National Marine Fisheries Service, Woods Hole laboratory 17 pp (mimeo)

Sissenwine, M.P. and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. ICNAF Research Bulletin 13: 81-87.

Table 3.11. Estimated relative fishing power coefficients (ratio of *Albatross* to *Delaware*) for side-by-side trawling studies done between 1982 and 1988 and in spring 2002. Data are given for 10 species for which sufficient numbers of catch pairs (Albatross and Delaware) are available to support the analysis. The percent of difference in fishing power that is detectable at the 0.05 level of significance (two-tailed test), based on 2002 data is also presented. Means over species and experiments are given.

| Species | 1982-1988 Ratio | 1982-1988 SE | 1982-1988 L-95% CI | 1982-1988 U-95% CI | 2002 Ratio | 2002 SE | 2002 L-95% CI | 2002 U-95% CI | 2002 % Detectable Difference |
|---|---|---|---|---|---|---|---|---|---|
| Yellowtail Flounder | 0.7390 | 0.0512 | 0.6386 | 0.8394 | 1.1087 | 0.1118 | 0.8896 | 1.3278 | 19.8 |
| Winter Skate | 0.8450 | 0.1036 | 0.6419 | 1.0481 | 0.7750 | 0.0874 | 0.6037 | 0.9463 | 22.1 |
| Winter Flounder | 0.9745 | 0.0892 | 0.7997 | 1.1493 | 0.8781 | 0.1548 | 0.5747 | 1.1815 | 34.6 |
| Four Spot Flounder | 0.8396 | 0.0405 | 0.7602 | 0.9190 | 1.0530 | 0.1019 | 0.8533 | 1.2527 | 19.0 |
| Cod | 0.7190 | 0.1007 | 0.5216 | 0.9164 | 0.8780 | 0.1520 | 0.5801 | 1.1759 | 33.9 |
| Haddock | 1.1056 | 0.2069 | 0.7001 | 1.5111 | 0.8096 | 0.0506 | 0.7104 | 0.9088 | 12.2 |
| Red Hake | 0.8965 | 0.1073 | 0.6863 | 1.0167 | 0.8096 | 0.0507 | 0.7102 | 0.9090 | 12.3 |
| Silver Hake | 1.1040 | 0.2740 | 0.5670 | 1.6410 | 0.8620 | 0.0740 | 0.7170 | 1.0070 | 16.8 |
| American Plaice | 0.7802 | 0.0670 | 0.6489 | 0.9115 | 0.8975 | 0.0851 | 0.7307 | 1.0643 | 18.6 |
| White Hake | 0.7818 | 0.0949 | 0.5958 | 0.9678 | 1.0620 | 0.1320 | 0.8033 | 1.3207 | 24.4 |
| Mean | 0.8785 | 0.1135 | 0.6560 | 1.1010 | 0.9134 | 0.1000 | 0.7173 | 1.1094 | 21.4 |

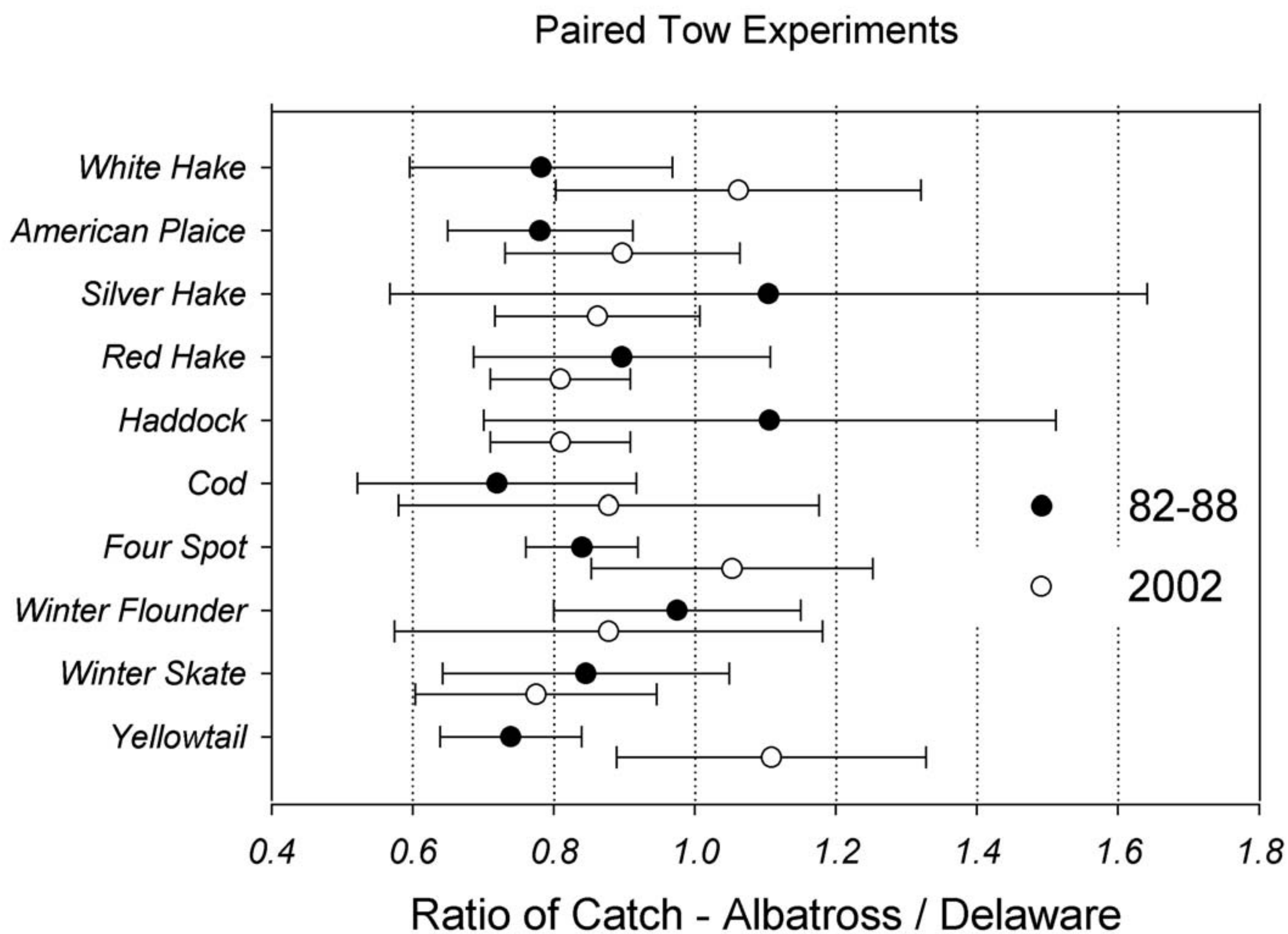


Figure 3.11.1. Results of fishing power calibration studies for NOAA R/Vs *Albatross IV* and *Delaware II* during two time periods. Data are the mean ratio of catch by species (A/D) and the 95% confidence intervals

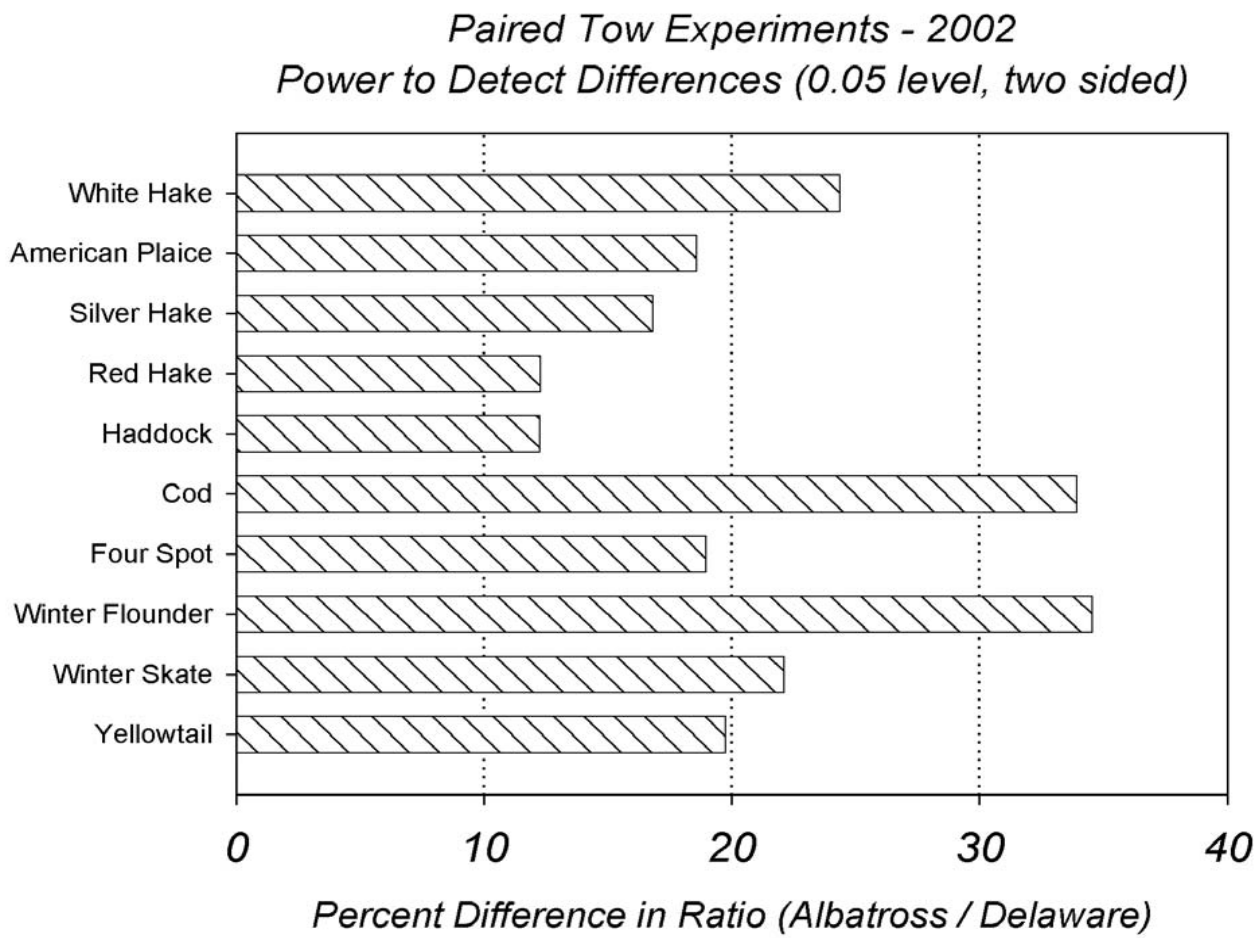


Figure 3.11.2. Calculated ratios of *Albatross* to *Delaware* surveys that can be detected at the 0.05 level of significance, using a two-tailed test. Analyses are based on 2002 side-by-side trawling experiments

## Section 4 GARM Summary Comments on Evidence for Interventions in Trawl Survey Data Beginning in 2000

This section summarizes a variety of investigations on the potential effects of mismarked cables on the Northeast Fisheries Science Center trawl survey abundance indices for 2000 to 2002. There were eight affected surveys (winter 2000, 2001 and 2002; spring 2000, 2001 and 2002; and fall 2000 and 2001). Information collected from dockside warp measurements indicated that the warp mis-calibration was related to the initial biased marking of the 50 meter intervals on one warp and was not due to progressive wire stretch. Therefore, the degree of intervention was thought to be approximately equal in all surveys since winter 2000.

These indices serve as fishery-independent measures of relative population size and are integral components of mathematical models used to estimate absolute population size. The indices of average numbers and weight per tow are derived from a stratified random survey design and the precision of the estimates can be derived using well-known statistical methods. Every method of sampling has limitations that introduce bias into the estimates. If the various factors that introduce bias are constant over time, the ability to detect population trends is not compromised. However, if bias factors change over time, true changes in abundance are confounded with unestimated bias. The relative precision of the survey estimates has important implications for the ability to detect bias changes. In the case of potential bias induced by asymmetric trawl cables, the effect (or signal) must exceed the normal range of variability (or noise) in the survey estimates.

The potential effects of warp offset can be addressed with a combination of deductive and inductive approaches. The magnitude of the difference of marks between the port and starboard cables increases with the amount of cable deployed. Geometric principles suggest that the maximum difference in the area swept per tow at 250 m would be less than 5%; over 96% of the stations sampled in a typical survey occur at depths less than 250 m. If significantly greater reductions in catchability are postulated, they must be attributable to major changes in the performance of the doors such that a) the net does not open as wide, b) the net loses contact with the bottom, c) the headrope height decreases, or d) mechanical vibrations or changes in pressure waves enhance the avoidance behavior of fish. If a) is true, then all species should experience a common rate of decline. If b) is true, bottom tending fish, especially flounders should show greater reductions than round groundfish. Factor c) would reduce the volume of water filtered, and have a similar effect to reduction in area swept. Finally if d) is true, then abundance faster-swimming species and larger-sized individuals would have show greater reductions in abundance than their more sluggish counterparts. These deductions can be used in the interpretation of comparisons across species and can also guide the analysis of trawl mensuration data.

The GARM reviewed the results of a series of 10 different studies to evaluate evidence for an intervention in the NMFS trawl survey data associated with the use of mis-calibrated trawl warps (the wire ropes attaching the trawl doors to the vessel).

Information on the potential effects of the warp offset on trawl survey performance evaluated by the GARM included studies of rates of gear damage over time, calculations of trawl geometry as a function of the warp offsets, by depth, patterns in mean/variance relationships in trawl survey catch data by stock, and depth-at-capture information from pre- and post-warp misaligned cruises. Additionally, the GARM evaluated trends (directional changes from year-to-year) in abundance measures before and after the warp mis-marking. The results from side-by-side trawling experiments conducted by the *Albatross* and *Delaware* vessels to estimate their relative fishing power, conducted before and after the warp mis-marking on the *Albatross* were also considered. Standardized catch-rates from surveys conducted with mis-matched warps were compared to survey CPUEs from surveys with comparable spatial and temporal coverage, and unaffected by the problem (e.g., Canadian trawl surveys and USA sea scallop surveys). The GARM also examined evidence for differences in length distributions from survey catches pre- and post warp offset by evaluating the relative size composition in Canadian and USA spring surveys in overlapping survey areas (e.g. Eastern Georges Bank). Monkfish size composition data collected on industry-based surveys and the winter 2001 *Albatross* survey were also compared, as were length compositions obtained in side-by-side trawling between *Albatross* and *Delaware* in spring 2002.

The GARM examined information on wing-spread and headrope height measurements from experimental warp offsets as presented at the Trawl Warp Workshop conducted during October 2-3, 2002. Using data collected during the September 25-27 warp experiment. Additionally, The GARM examined video information collected in the same warp-offset experiments.

It was postulated by gear experts at the Trawl Warp Workshop that the warp offset would induce changes in gear efficiency resulting from the "long" trawl wing being more prone to damage (as it would be potentially more susceptible to hang-ups). The GARM found no significant change in the frequency of trawl tows experiencing minor or major damage associated with the warp offset as compared to previous surveys with correct warp markings.

It was postulated at the Trawl Warp Workshop that one effect of misaligned warps might be the differential loss of large fish in survey catches. Based on examinations of size distributions of cod and haddock, not only was there little difference in the proportions of large fish but there was little apparent difference in the entire size frequency, by survey series, of these stocks pre- and post warp offset time period in both USA and Canadian series in areas of overlap (northeast Georges Bank). The small relative differences in USA mean length distributions of cod and haddock for the three years before and three years after the warp offset were similar to the differences in the Canadian series in pre- and post warp periods. Differences in the size composition of large monkfish between industry and *Albatross* winter surveys were minimal. Size compositions from *Albatross-Delaware* paired towing experiments in spring 2002 also indicated no loss of large fish due to the *Albatross* warp mis-marking.

Trawl mensuration data indicate that wing spread and head rope height did not vary appreciably with offsets that occurred in depths where groundfish typically occur (e.g. warp offset up to about 9 feet), and the net remained open with warp offsets up to 18 feet. Consistent trawl performance within this range of warp offsets is supported by the absence of detectible effects as indicated by the other information reported herein. The GARM noted that catching efficiency might be related to other factors such as bottom contact by the foot rope and vibrations associated with the offset gear. Video information on the former was equivocal (as concluded at the Trawl Warp Workshop where some participants thought the foot rope contact changed with offsets while others did not). Measurements on vibrations and pressure waves in relation to warp offsets were not made.

Calculations based on geometry of the trawl in the offset condition (a worst-case scenario) and the postulated increase in the potential problem in relation to species catches-at-depth indicate that reductions on the order of 50% or larger in trawl survey catches are implausible.

It was postulated by the GARM that if there was a trawl warp effect, more variable catches might result from a misaligned net, influencing the relationship between the variance and the mean. Empirical plots of catch data indicated no apparent differences in the variance compared to mean relationships for the species examined, and plots of the coefficient of variation (standard deviation divided by the mean) of catches in numbers by survey stratum over time showed no obvious differences pre- and post warp offsets.

Since the warp offset increased proportionally with depth, it was postulated that if the catch efficiency of the trawl decreased accordingly, a shallower apparent depth of capture for the deeper-dwelling species in the post-offset period as compared with the pre-offset surveys would be observed. There were no detectable differences in the catch-weighted depth of capture of any species examined relative to the warp offset.

There was no evidence for a trend in the direction of abundance index changes associated with the warp offset, when comparing pairs of adjacent years. For each pair of years (e.g., 1998 versus 1999, 1999 versus 2000, etc.), the direction of the abundance index change was evaluated. While the evaluation of the changes in abundance indices are potentially confounded by underlying changes in resource abundance, the number of stock/index combinations showing positive increases in abundance was virtually identical between 1998-1999 and 1999-2000 (when the intervention was made). The abundance indices for the deepest dwelling stocks did not show differential reductions between years pre and post-warp offsets.

*Albatross* trawl survey data were compared to independent surveys conducted by other vessels (e.g. Canadian trawl survey and sea scallop dredge surveys aboard *Albatross* but using a single warp*)*. The frequency of species showing positive relative changes in abundance in *Albatross* surveys was nearly the same in the three years before (50%) and the three years after (54%) the warp change. For all species, the relative fishing power of

*Albatross* post warp change was slightly but not statistically greater than the comparison vessels.

In examining the various stock assessments, there was no obvious improvement in VPA residual patterns (e.g., reduced serial correlation) or tightness of the fit when trawl survey catches were arbitrarily increased by 10%, 25% and 100%. In fact, VPA model fits showed, on average, a 4% decrease in model fit when survey indices in 2000-2002 were arbitrarily increased by 100%. Similarly, retrospective patterns that occur in some VPA models persisted even with the arbitrarily increased survey catches. The stock assessment models integrate catch-at-age information and the full time series from the surveys, thereby damping the influence of variation in recent survey indices.

Fishing power studies were conducted between *Albatross IV* and *Delaware II* in 2002 (after the warp change on the *Albatross*) and in 1982, 1983, and 1988. Estimates of fishing power coefficients (ratio of *Albatross* to *Delaware* catches) were similar between vessels in experiments before and after the warp change on *Albatross IV*. There was only one statistically significant change in this ratio after the warp change in 10 species examined. In this one case, the ratio of *Albatross* to *Delaware* catch of yellowtail flounder increased between the 1980s and 2002. These paired comparison tests (although not intended for that purpose at the time) provide robust data to test the warp effects (and include any other systematic changes in the fishing system since 1988). Specifically, because these paired trawl studies were conducted simultaneously before and after the warp offset they are not confounded by underlying changes in the abundance of the groundfish stocks. Based on information from 2002, the catch ratio test can detect differences of between 12 and 35%, depending on species. Therefore large (greater than 40-50%) reductions in catchability of the *Albatross* survey during the period of the warp offset are highly unlikely. For all species combined, the ratio of *Albatross-Delaware* catches was 0.88 before the warp offset and 0.91 after, suggesting negligible change.

**Based on the evidence cited above, there is no indication of a systematic reduction in trawl survey fish catch efficiency due to the trawl warp offsets.**

## Section 5 Summary of Assessment Advice and Management Implications

### 5.1 Summary of Assessments

The 20 assessment updates indicate improved biomass and landings and generally lower fishing mortality rates since the mid-1990s (Table 5.1; Figures 5.1.1-5.1.3). The biomass of eight of the stocks was at or above ½ B-MSY in 2001, while 12 stocks were below the threshold. Stock biomasses have improved in 19 of the 20 stocks since 1995 (Figure 5.1.2; the exception being Mid-Atlantic yellowtail), with a median percent increase in biomass for all stocks of 177% (range: -33 to 2430 percent). Fishing mortality (F) rates declined for 15 of 19 stocks between 1994 and 2001 (Figure 5.1.3). In the case of Georges Bank yellowtail flounder, F has declined by about 90% since the mid-1990s. Numerous other stocks have experienced reductions in F of 20-50%, including Georges Bank and Gulf of Maine cod, Georges Bank haddock, witch flounder and American plaice. For several of the stocks where harvest rates are measured by landings to survey biomass ratios (exploitation index methods), relative Fs have been reduced by 50% or more (e.g., Gulf of Maine haddock, pollock and windowpane flounder). The four stocks showing increases in F since 1994 were Cape Cod and Mid-Atlantic yellowtail, white hake and Southern New England/Mid-Atlantic winter flounder. Of the 19 stocks for which 2001 fishing mortality (or its proxy) can be estimated, 10 were fished below F-MSY in 2001, and 9 above (Table 5.1; Figure 5.1.1).

Overall landings for the 20 stocks (USA and Canada combined) increased from 49,700 mt in 1995 to 69,400 mt in 2001 (a 40% increase). The primary stocks contributing to increased groundfish landings were Georges Bank haddock, Georges Bank yellowtail flounder, Georges Bank cod, and Georges Bank winter flounder. Together, these four stocks accounted for a combined increase in landings of 21,700 mt; greater than the cumulative 20 stock total increase of 19,700 mt between 1995 and 2001. Stocks declining in landings since 1995 were primarily pollock, Gulf of Maine cod and white hake.

Trends in biomasses for the various stocks since 1990 are summarized in Figure 5.1.2. The various stocks are grouped by assessment area, based on where the stock distributions and landings are predominant (since some stocks occur in more than one of the areas). Biomasses generally declined in all regions from 1990 to 1995. Increases since have been most rapid on Georges Bank and the Gulf of Maine, with biomass increases for four of the five Southern New England-Mid-Atlantic stocks more modest.

Two stocks continue to have extremely high fishing mortality rates - Mid-Atlantic yellowtail flounder and Cape Cod yellowtail flounder (Figure 5.1.1). In the former case, assessment scientists will present analyses to SARC 36 recommending that the Mid-Atlantic and Southern New England yellowtail resources be combined. The case of Cape Cod yellowtail remains enigmatic, in that the apparent mortality rates on the stock remain exceptionally high despite the reductions in F seen in co-occurring stocks (e.g., Gulf of Maine cod, and winter flounder). The GARM recommended additional biological studies, including tagging, to better understand the relationships between Cape Cod yellowtail and adjacent stocks of the same species.

For the remaining seven stocks where fishing mortality exceeded F-MSY, the average reduction necessary to reach that level was 52% (range: 37% for Southern New England/Mid-Atlantic winter flounder to 64%, witch flounder).

In order to achieve biomass targets by appropriate dates, F-rebuild was computed for each stock using stochastic medium-term projection methodologies.  The F reductions required to achieve the biomass goals by the target dates are greater than the F reductions required to achieve F-MSY on a stock-by-stock basis (Table 5.1).

Table 5.1. Summary of fishing mortality rate and biomass status for 20 Northeast groundfish stocks in 2001. Projections of maximum F to achieve B-MSY (F-Rebuild) assume F in 2002 = 0.85 * F in 2001, and stocks should be rebuilt by 2009, unless otherwise noted.

| Species | Stock | F-MSY | F-2001 | % F Reduction to achieve F-MSY | F-Rebuild | % F Reduction to achieve F-Rebuild | B-MSY ('000 mt) | B-2001 ('000 mt) | B-2001 % of B-MSY |
|---|---|---|---|---|---|---|---|---|---|
| Cod | GM | 0.23 | 0.47 | 51 | 0.11 | 76 | 82.8 | 22.0 | 27 |
| | GB | 0.18 | 0.38 | 53 | 0.15* | 61 | 216.8 | 29.2 | 14 |
| Haddock | GM | 0.23+ | 0.12 | none | 0.20 | none | 22.17# | 10.31 | 47 |
| | GB | 0.26 | 0.22 | none | 0.20 | 10 | 250.3 | 74.4 | 30 |
| Yellowtail | CC | 0.21 | 1.97 | 89 | 0.12 | 94 | 8.4 | 1.9 | 23 |
| | GB | 0.25 | 0.13 | none | 0.22 | none | 58.8 | 38.9 | 66 |
| | SNE | 0.27 | 0.46 | 41 | 0.10** | 78 | 45.2 | 1.9 | 4 |
| | MA | 0.33+ | 2.17 | 85 | 0.30 | 86 | 12.91# | 0.21 | 2 |
| Witch Flounder | | 0.16 | 0.45 | 64 | - | none | 19.9 | 11.3 | 57 |
| American Plaice | | 0.17 | 0.43 | 60 | 0.10 | 77 | 28.6 | 13.8 | 48 |
| Winter Flounder | GM | 0.26 | 0.14 | none | - | none | 5.4 | 5.37 | 99 |
| | GB | 0.32 | 0.25 | none | - | none | 9.4 | 9.8 | 104 |
| | SNE-MA | 0.32 | 0.51 | 37 | 0.12 | 76 | 30.1 | 7.6 | 25 |
| White Hake | | 0.55+ | 1.36 | 60 | 0.50 | 63 | 7.70# | 2.35 | 31 |
| Pollock | | 5.88+ | 3.55 | none | 4.83 | none | 3.0# | 1.60 | 53 |
| Redfish | | 0.04 | 0.01 | none | 0.01*** | none | 236.7 | 119.6 | 51 |
| Ocean Pout | | 0.31+ | 0.007 | none | n/a | n/a | 4.90# | 2.46 | 50 |
| Windowpane | Northern | 1.11+ | 0.1 | none | - | none | 0.94# | 0.79 | 84 |
| | Southern | 0.98+ | 0.69 | none | 0.73 | none | 0.92# | 0.21 | 23 |
| Atlantic Halibut | | 0.06 | unknown | unknown | unknown | unknown | 5.4 | 0.2 | 4 |

+ = fishing mortality rate proxy is catch divided by the survey abundance index
# = biomass target based on survey abundance index
* = rebuilding period is 2019 for GB cod
** = the SNE YT stock cannot be rebuilt to long-term biomass target by 2009 even if F=0.0 (using recruitment from last 10 years)
*** = rebuilding period is 2041 for redfish

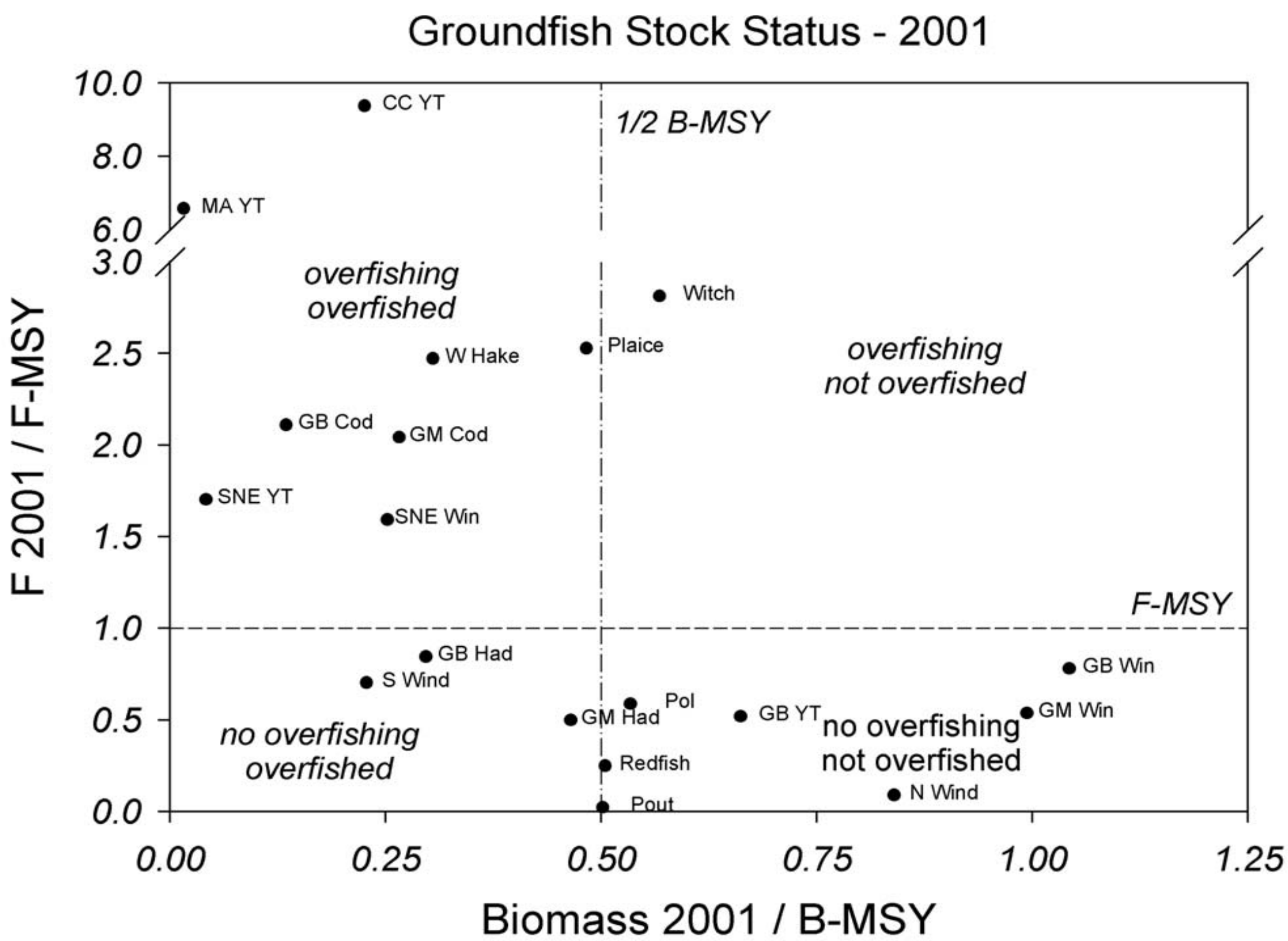


Figure 5.1.1. Status of 19 Northeast groundfish stocks relative to status determination criteria of fishing mortality and stock biomass. The data are expressed as ratios of the 2001 F and biomass to the F-MSY and B-MSY values for each stock. Halibut status not plotted

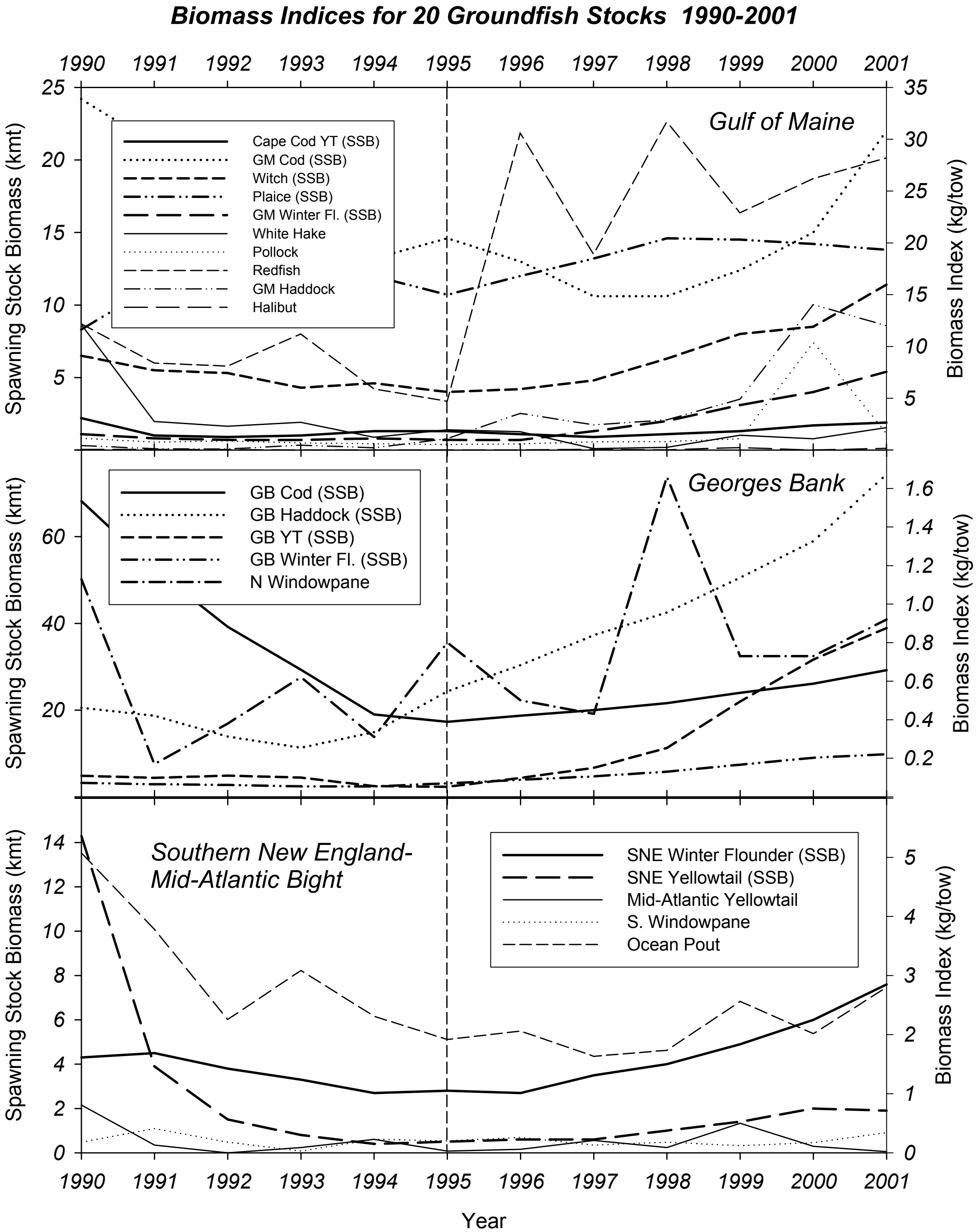


Figure 5.1.2. Changes in stock biomass (spawning biomass or total biomass survey index) for 20 Northeast groundfish stocks, 1990-2001. The biomass index plotted for each stock is noted. Stocks are grouped by the area of predominant concentration (Gulf of Maine, Georges Bank, Southern New England – Mid-Atlantic Bight).

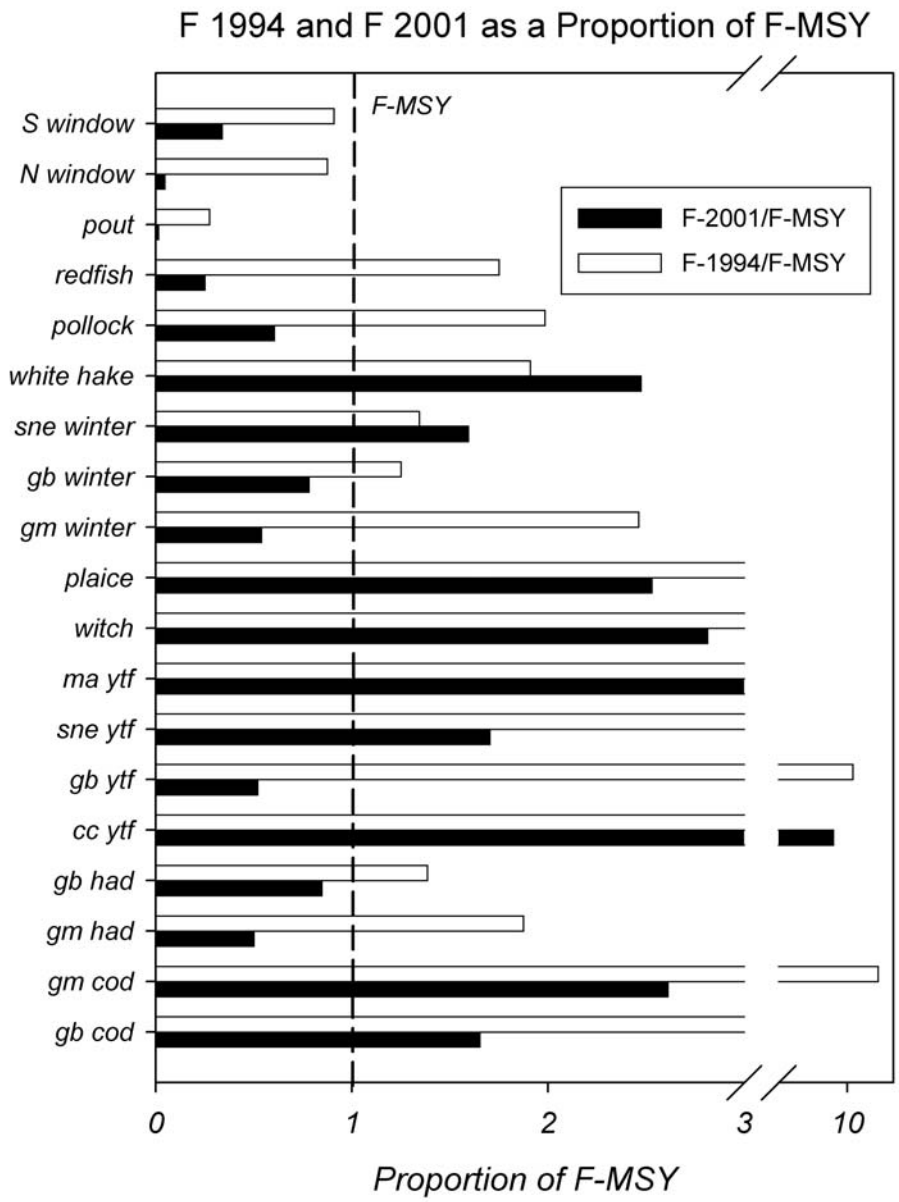


Figure 5.1.3. Changes in fishing mortality rate or exploitation rate indices for 19 stocks of Northeast groundfish between 1994 and 2001. The fishing mortality rate in each year is expressed as a ratio of the F-MSY value for each stock (a ratio of 1 means the stock is fished at F-MSY).

## 5.2 Sensitivity of Stock Assessment Calculations to Potential Warp Offsets

Given the absence of measurable intervention effects associated with the warp offsets, the GARM endorsed the nominal assessment calculations as the basis for management decision-making. However, in order to examine the robustness of the management advice to potential variations in the survey catches, the GARM carried out a series of sensitivity analyses. These analyses are reflected in each of the stock assessments presented in section 2 of this report, and specifically as the "cross" plots of sensitivity of assessment calculations to arbitrary increases in survey indices in years influenced by the warp offsets.

Sensitivity runs conducted for the various assessments included arbitrary increases in trawl survey catches for affected surveys of 10%, 25% and 100%. The first two scenarios consider decreases in survey catch rates that are at or below the limits of detection of the analyses of offset effects carried out at the GARM. The 100% increase is not supported by analyses carried out at the meeting, the increase is only included for illustrative purposes. An effect of this magnitude would likely have been detectable in the various exploratory data analyses. It should be noted that these arbitrary increases in survey catches were used in assessment calculations across all species, including those found in shallow depths (and thus less likely to be negatively influenced by warp offsets, e.g., yellowtail flounder, winter flounder, windowpane).

The confidence intervals from the +10% and +25% sensitivity runs overlapped the nominal assessment results for all stocks therefore changes of this magnitude have no significant impact on estimates of F and SSB (Table 5.2). The stock assessment models integrate unaffected catch information from commercial and recreational fisheries and the full time series from the research vessel surveys, reducing the influence of variations in recent survey indices.

In only three of 20 stocks did the qualitative status determination for overfished (e.g., <1/2 BMSY) change by adding arbitrary increases in survey abundance indices (Table 5.2). In two cases (American plaice, and Gulf of Maine haddock), the stocks were near ½ BMSY based on nominal assessment results. In these cases the 10% increases in surveys were sufficient to change biomass status determination. Of the 18 other cases, arbitrary increases in recent surveys of 100% changed only the biomass status for white hake.

In only one case (Southern New England yellowtail flounder) did the status determination regarding the overfishing criterion (fishing mortality rate) change with arbitrary increases in survey catches up to 100%.

**The overall management advice is robust to variations in recent survey catch rates.**

Table 5.2. Summary of status determinations for 20 New England groundfish stocks. Sensitivity of status determination to arbitrary increases in trawl survey abundance indices for 2000 to spring 2002 are given for three levels of increase (+10%, +25% and +100%). Overfishing refers to the current fishing mortality rate relative to F-MSY. Overfished refers to the current biomass relative to B-MSY. Asterisks (*) indicate cases where the 80% bootstrap confidence interval for a particular criterion does not overlap that from the nominal assessment run. Shaded cells are where status determination changes from the nominal assessment when survey catch data are increased. SSB is spawning stock biomass, TSB is total stock biomass.

| Species | Stock | Status Criterion | Nominal Status | Status +10% | Status +25% | Status +100% |
|---|---|---|---|---|---|---|
| Atlantic Cod | Gulf of Maine | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | overfished * |
| | Georges Bank | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| Haddock | Gulf of Maine | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | overfished | not overfished | not overfished | not overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | overfished | overfished | overfished | overfished * |
| Yellowtail Flounder | Cape Cod | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing * |
| | | SSB | not overfished | not overfished | not overfished | not overfished * |
| | S. New England | F | overfishing | overfishing | overfishing | no overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| | Mid-Atlantic | F | overfishing | overfishing | overfishing | overfishing |
| | | TSB | overfished | overfished | overfished | overfished |
| Witch Flounder | | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | not overfished | not overfished | not overfished | not overfished * |
| American Plaice | | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | not overfished | not overfished | not overfished * |

Table 5.2 (continued).

| Species | Stock | Criterion | Nominal | +10% | +25% | +100% |
|---|---|---|---|---|---|---|
| Winter Flounder | Gulf of Maine | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | not overfished | not overfished | not overfished | not overfished |
| | Georges Bank | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| | S. New England-Mid-Atlantic | F | overfishing | overfishing | overfishing | overfishing * |
| | | SSB | overfished | overfished | overfished | overfished * |
| White Hake | | F | overfishing | overfishing | overfishing | overfishing |
| | | SSB | overfished | overfished | overfished | not overfished |
| Pollock | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| Acadian Redfish+ | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | SSB | not overfished | not overfished | not overfished | not overfished |
| Ocean Pout | | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | Not overfished | not overfished | not overfished | not overfished |
| Windowpane Flounder | Northern | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | not overfished | not overfished | not overfished | not overfished |
| | Southern | F | no overfishing | no overfishing | no overfishing | no overfishing |
| | | TSB | overfished | overfished | overfished | overfished |
| Atlantic Halibut | | F | unknown | unknown | unknown | unknown |
| | | SSB | overfished | overfished | overfished | overfished |

+ = Assessment models were not updated for Acadian redfish
unknown = estimates of F or proxy are not available for Atlantic halibut

## 5.3 Consistency of NMFS Bottom Trawl Survey Data

Evidence for a postulated decrease in catch efficiency due to trawl warp offsets during 2000 – 2002 spring NMFS bottom trawl surveys is reviewed and summarized in sections 3 and 4 of this report. Given the interest in this topic and other issues that were raised concerning the catch efficiency of the fishing system in recent years (NEFSC 2002), it is useful to consider long term trends in the indices and how they relate to other measures of abundance. The total, multispecies abundance index (kg/tow, all species combined) was computed for all offshore survey strata consistently sampled in the NMFS fall survey during 1963-2001 (Figure 5.3a). This series showed initial high abundance of all species, followed by a precipitous decline in the mid-1960s to a low in the mid-1970s. The index increased in the late 1970s-early 1980s, then declined to a time series low in the early 1990s. Recent indices have increased steadily to a level similar to those in the early 1980s. The 2001 index was 141 kg/tow - about 67% of the time series high in 1964 (209 kg/tow).

The second index is that from the Massachusetts Division of Marine Fisheries, fall bottom trawl survey (Figure 5.3b). This series uses a different vessel and trawl gear and fishes at generally shallower depths (primarily within 3 miles of the Massachusetts coastline) than the NMFS survey. This series began in 1978, and its all time high value (311 kg/tow) occurred in that year. The 2001 fall Massachusetts index was 257 kg, or 83% of the 1978 value. The series also shows a declining trend in the early 1990s, followed by an increase in the past several years.

The third survey series (Figure 5.3c) is a subset of the NMFS fall trawl series only for those offshore survey strata near the Massachusetts coast. The NMFS survey generally samples deeper waters than the Massachusetts survey, but the species mix of the reduced NMFS survey set is more similar to that sampled inshore than the NMFS survey as a whole. This series shows trends in abundance similar to the NMFS series and the Massachusetts Division of Marine Fisheries Series. The time-series high index was in 1983 at 301 kg/tow, and the 2001 index was 215 kg/tow, or 71% of the maximum.

The fourth series displayed (Figure 5.3d) is the “principal groundfish and flounders” index computed from the fall survey series. The index includes 12 groundfish and flatfish species, and all offshore survey strata, and is smoothed with an autoregressive moving average model. This index peaked in 1963 at 72 kg/tow, and the 2001 value was 36 kg/tow (50% of the maximum).

The overall trends in these indices and the general comportment of the NMFS and Mass-DMF surveys do not support the hypothesis of highly reduced catch efficiency in the NMFS surveys during the period of warp offsets or in the recent past (as compared with earlier periods of the time series). The Massachusetts and NMFS series do not necessarily index the same things (i.e., the MA-DMF inshore survey catches a higher proportion of juvenile fish than does the offshore NMFS survey), but the trends and scale of indices in these series are comparable. If the NMFS survey has become $1/10^{th}$ as efficient as it used to be (as was proposed at the Trawl Warp Workshop, NEFSC 2002), then the 2001 index for the full NMFS trawl survey would be 1.41 metric tons per tow, roughly 6.8 times the maximum (1964) value. Even if the recent catch efficiency were reduced by a factor of two as compared with earlier years, this would generate indices inconsistent with the trends in other survey series, and at levels that are inconsistent with population sizes of fished resources or landings patterns. For example, the 1964 survey index for all species was 209 kg. The maximum groundfish catch ever taken off the Northeast USA was in 1965 (766,000 metric tons), and the index declined steeply by the fall of 1965 (Figure 5.3a). By comparison, landings of groundfish in 2001 were about 80,000 metric tons, and the index of abundance increased modestly from 2000. Doubling of the 2001 trawl survey catch would produce an value equivalent to the highest value ever seen in the principal groundfish and flounders index (1963), and 36% higher than the maximum value of the fall survey series for all species (Figure 5.3a).

Information from the NEFSC, Massachusetts DMF, and other applicable fishery-independent surveys are consistent in that they show a strong and continuing recovery of the groundfish complex in recent years, roughly to levels last seen in the early 1980s.

**Reference**

NEFSC 2002. Report of the Workshop on Trawl Warp Effects on Fishing Gear Performance, 2-3 October, 2002, Woods Hole, MA. Northeast Fisheries Science Center Reference Document 00-15. 80 pp.

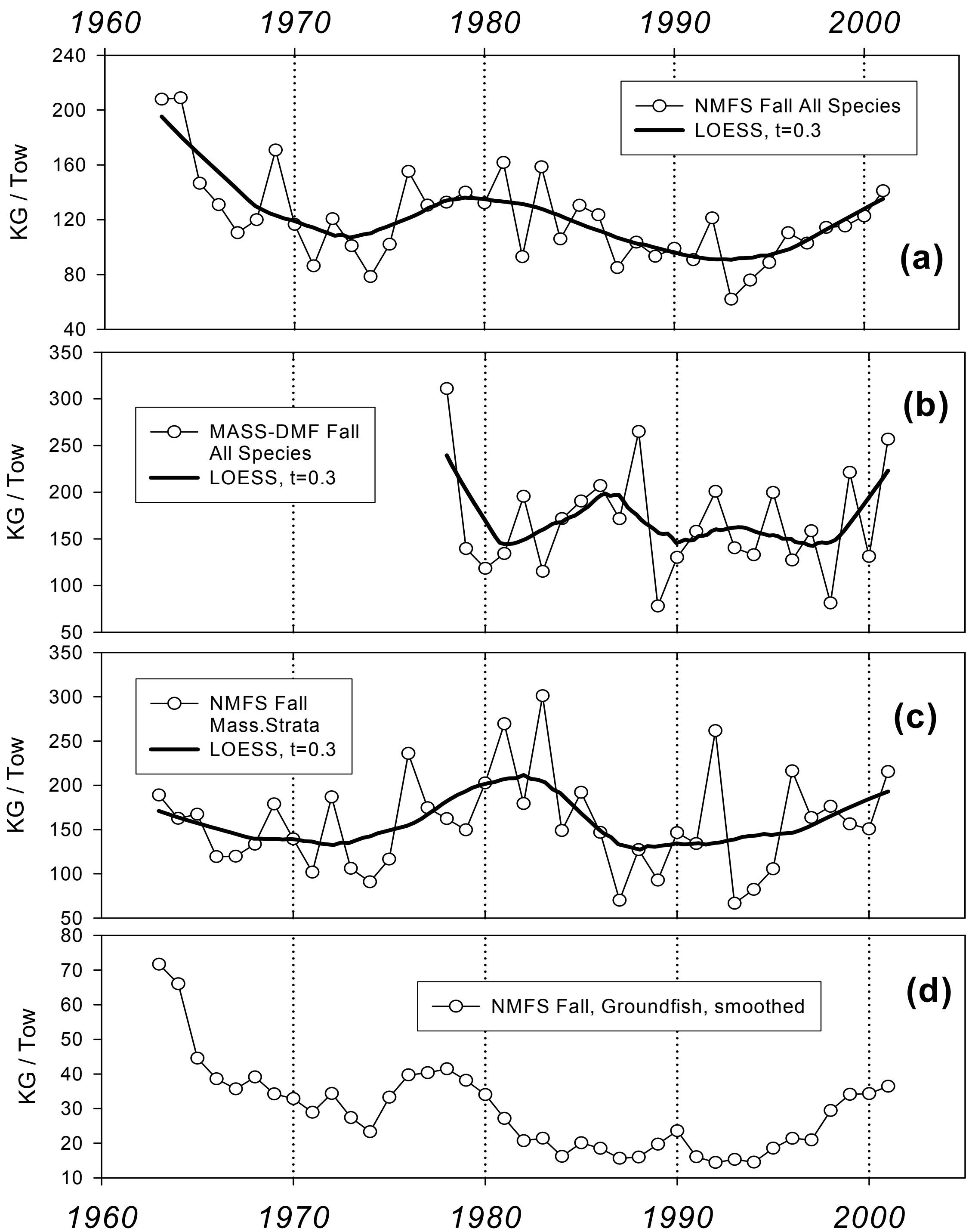


Figure 5.3. Trends in bottom trawl survey abundance indices, 1963-2001. The panels display observed and smoothed (bold lines) indices for: (a) the NMFS Fall survey (kg/tow) for all species, (b) the Massachusetts Division of Marine Fisheries Fall, (c) the NMFS Fall offshore survey for strata near the Massachusetts coast, and (d) the principal groundfish and flounders abundance index for the NMFS fall bottom trawl survey (smoothed series).

## Section 6 Comments and Recommendations

This section summarizes various generic discussion items at the GARM meeting, and provides additional recommendations.

### 6.1 Projections

Medium-term projections for assessments were conducted for years 2002-2009, with the exception of Georges Bank cod which had a 2002-2019 time horizon. The index assessments were projected assuming a 10% growth rate in stock size each year to determine the expected catch under this condition. The ASPIC assessment of Georges Bank winter flounder was projected assuming the r and K estimates from each bootstrap of the tuning indices. This projection used the F needed to achieve Bmsy in 2009 with 50% probability over all the bootstraps. The two sources of uncertainty included in the age-based projections were initial stock abundance at age in 2001 and future recruitment. Other potential sources of variability, such as implementation uncertainty and changes in weight-at-age, maturity-at-age, selectivity-at-age, or natural mortality, were not included. Therefore, the confidence intervals presented in the assessment projections are minimal estimates of future uncertainty.

More importantly, the lack of inclusion of other sources of uncertainty in the projections could bias the estimated probability of achieving a biomass target. If unmodeled uncertainties were symmetrically distributed about the median, then the probability of achieving a biomass target would remain unchanged. However, if unmodeled uncertainties were not symmetrically distributed about the median, the probability of achieving a biomass target would either decrease or increase. For example, although many of the age-based assessments exhibited retrospective patterns, no corrections were made to the 2001 population abundances. Since many of the retrospective patterns showed an overestimation of SSB in the terminal year, the projections may be biased upwards in terms of the initial stock abundance and produce overly optimistic rebuilding trajectories. A recent examination of stock assessment projections using a wide range stocks found that unmodeled uncertainties were not symmetrically distributed in general (Patterson *et al.*, 2001). In particular, Patterson *et al.* reported a substantial bias towards being overly optimistic in estimating the probability of achieving biomass targets. They recommended using multiple model structures and assumptions combined with model-averaging methods, decision tables, or management procedure simulations to more accurately reflect inherent uncertainties in management advice. Time constraints have not allowed their approach to be used in this report. As a result, it is recommended that projection results be viewed with caution since they may overstate the true probability of achieving biomass targets.

### Reference

Patterson, K., R. Cook, C. Darby, S. Gavaris, L. Kell, P. Lewy, B. Mesnil, A. Punt, V. Restrepo, D.W. Skagen, and G. Stefánsson. 2001. Estimating uncertainty in fish stock assessment and forecasting. Fish and Fisheries. 2: 125-157.

## 6.2 Use of Exploitation Ratios

For stocks where instantaneous rates of fishing mortality cannot be calculated (e.g., age or length data are not sufficient for age- or length-based analytical assessment), proxies for the exploitation rate have been used for reference point determination and status evaluation (NEFSC 2002). These proxies for exploitation rate involve dividing the landings by an annual biomass index determined from trawl survey data. Generally, a three-year moving average of the survey data were used as the annual index to smooth variability from survey sampling. In most cases the indices used in such analyses were the total catch per tow of all size groups combined. This index was used as the denominator of the relative exploitation ratio, with the numerator the catch in weight (usually only the landings are known for the stocks having incomplete age- or length-based data).

Application of this technique should allow a relatively robust evaluation of the *relative* rate of exploitation over time. However, there is a potential mis-match in these ratios since a portion of the biomass index (in the denominator) comprises sizes not contributing to the catch (e.g., juvenile fish). The effect of the use of the total biomass index for all sizes may not be substantial as juvenile fish are likely to have a disproportionately lower influence on the total biomass index owing to their lower average individual weights. For the various stocks so assessed, only the white hake assessment uses catch and survey indices comprising the same size groups (e.g., fish > 60 cm). It is recommended that when calculating such indices in the future, that only size groups likely to be included in the catches (landings and discards) be used to develop indices of exploitation.

**Reference**

NEFSC 2002. Final report of the Working Group on re-evaluation of biological reference points for New England groundfish. Northeast Fisheries Science Center Reference Document 02-04. 123 p.

## 6.3. Quality of Catch-at-Age Sampling

Estimates of the age composition of the catch are a primary requisite for age-structured assessment techniques such as virtual population analysis (VPA). Of the 20 groundfish stocks reassessed herein, 10 stocks use age-based assessments (section 2). In order to estimate the catch-at-age, age composition estimates are derived from port sampling of landings, and sea sampling of discards (if sufficient sampling exists). Length and age samples are obtained at the port of landing by sampling at dealer's businesses, fish houses and auctions. The sampling is stratified by market category since increased sampling of large (old) fish is usually the goal, because ages at length are more variable for larger fish.

Port sampling performance is summarized in appropriate tables included in the various species sections. Sampling information for 9 of the 10 stocks is summarized for the past four years (1998-2001) by the number of samples obtained (e.g., number of individual samples aggregated over market categories by species), the number of fish lengths measured, and the number of age structures (e.g., scales or otoliths) aged for the species (Table 6.3; Figure 6.3). One measure of sampling intensity is the number of metric tons of landings per sample obtained. With this metric, more intensive sampling is indicated by a relatively low number (fewer tons represented by each sample).

Overall sampling increased substantially between 1998-1999 and 2000-2001 (Table 6.3; Figure 6.3). The total numbers of samples and ages more than doubled from 1998-1999 to 2000-2001 and the number of lengths increased by over 60%. The sampling increase was most apparent in 2000, but 2001 sampling, particularly for ages, was much higher than in 1998 and 1999. Sampling intensity increased from 75 mt/sample to 41 mt/sample in 2000 and decreased to 69 mt/sample in 2001. Overall landings increased 61% for the nine stocks summarized, thus rates of sampling have more than kept pace with the landings increases. Sampling intensity varied by stock; improved sampling in recent years is most apparent for Gulf of Maine cod, Georges Bank haddock, and Georges Bank yellowtail (although the number of t/sample for Georges Bank yellowtail is higher than for most stocks).

The GARM considered the port sampling issues in the larger context of the overall level of sampling required to characterize catch-at-age with acceptable levels of precision for use in age-based assessments. This information is particularly important since the overall level of landings of these stocks is expected to increase significantly in the next few years. The GARM recommended that a statistical bootstrapping technique be applied to the landings-at-age data to estimate the variance in landings-at-age and to investigate the stability of such estimates given various sampling rates. The GARM noted that, because of cluster sampling issues, increasing the numbers of different vessel trips sampled, rather than just the total lengths and ages obtained would likely have the most positive impact on the quality of landings-at-age estimates.

Table 6.3. Summary of commercial catch-at-age sampling for VPA stocks, 1998-2001.

| stock | year | samples | lengths | ages | Landings (mt) | mt/samp |
|---|---|---|---|---|---|---|
| gb cod | 1998 | 80 | 7076 | 1545 | 6959 | 87 |
| | 1999 | 68 | 5987 | 1503 | 8061 | 119 |
| | 2000 | 155 | 12219 | 2951 | 7617 | 49 |
| | 2001 | 108 | 8389 | 2389 | 10635 | 98 |
| gb had | 1998 | 24 | 1692 | 686 | 1841 | 77 |
| | 1999 | 28 | 2268 | 595 | 2775 | 99 |
| | 2000 | 51 | 3699 | 1256 | 3366 | 66 |
| | 2001 | 72 | 5276 | 1985 | 4637 | 64 |
| gb yt | 1998 | 9 | 1426 | 293 | 1823 | 203 |
| | 1999 | 11 | 1542 | 300 | 2066 | 188 |
| | 2000 | 11 | 2762 | 605 | 3678 | 334 |
| | 2001 | 30 | 3400 | 814 | 3768 | 126 |
| sne yt | 1998 | 10 | 1134 | 239 | 400 | 40 |
| | 1999 | 9 | 1167 | 333 | 700 | 78 |
| | 2000 | 28 | 1146 | 984 | 700 | 25 |
| | 2001 | 18 | 1454 | 1224 | 800 | 44 |
| ccyt | 1998 | 13 | 6054 | 195 | 1169 | 90 |
| | 1999 | 8 | 4247 | 106 | 1089 | 136 |
| | 2000 | 61 | 11696 | 1298 | 2279 | 37 |
| | 2001 | 24 | 7440 | 628 | 2362 | 98 |
| gm cod | 1998 | 46 | 4205 | 912 | 4156 | 90 |
| | 1999 | 15 | 1305 | 350 | 1636 | 109 |
| | 2000 | 61 | 4687 | 1300 | 3730 | 61 |
| | 2001 | 113 | 7326 | 2436 | 4416 | 39 |
| witch | 1998 | 23 | 1904 | 242 | 1849 | 80 |
| | 1999 | 41 | 3091 | 359 | 2121 | 52 |
| | 2000 | 110 | 2439 | 1314 | 2439 | 22 |
| | 2001 | 43 | 3609 | 704 | 3024 | 70 |
| plaice | 1998 | 53 | 5434 | 824 | 2234 | 42 |
| | 1999 | 86 | 8784 | 1275 | 1718 | 20 |
| | 2000 | 108 | 7113 | 1155 | 2497 | 23 |
| | 2001 | 53 | 5232 | 663 | 2602 | 49 |
| gm wf | 1998 | 19 | 1504 | 341 | 637 | 34 |
| | 1999 | 9 | 1036 | 149 | 253 | 28 |
| | 2000 | 64 | 5827 | 883 | 382 | 6 |
| | 2001 | 14 | 3644 | 246 | 571 | 41 |
| total | 1998 | 277 | 30429 | 5277 | 21068 | 76 |
| | 1999 | 275 | 29427 | 4970 | 20419 | 74 |
| | 2000 | 649 | 51588 | 11746 | 26688 | 41 |
| | 2001 | 475 | 45770 | 11089 | 32815 | 69 |

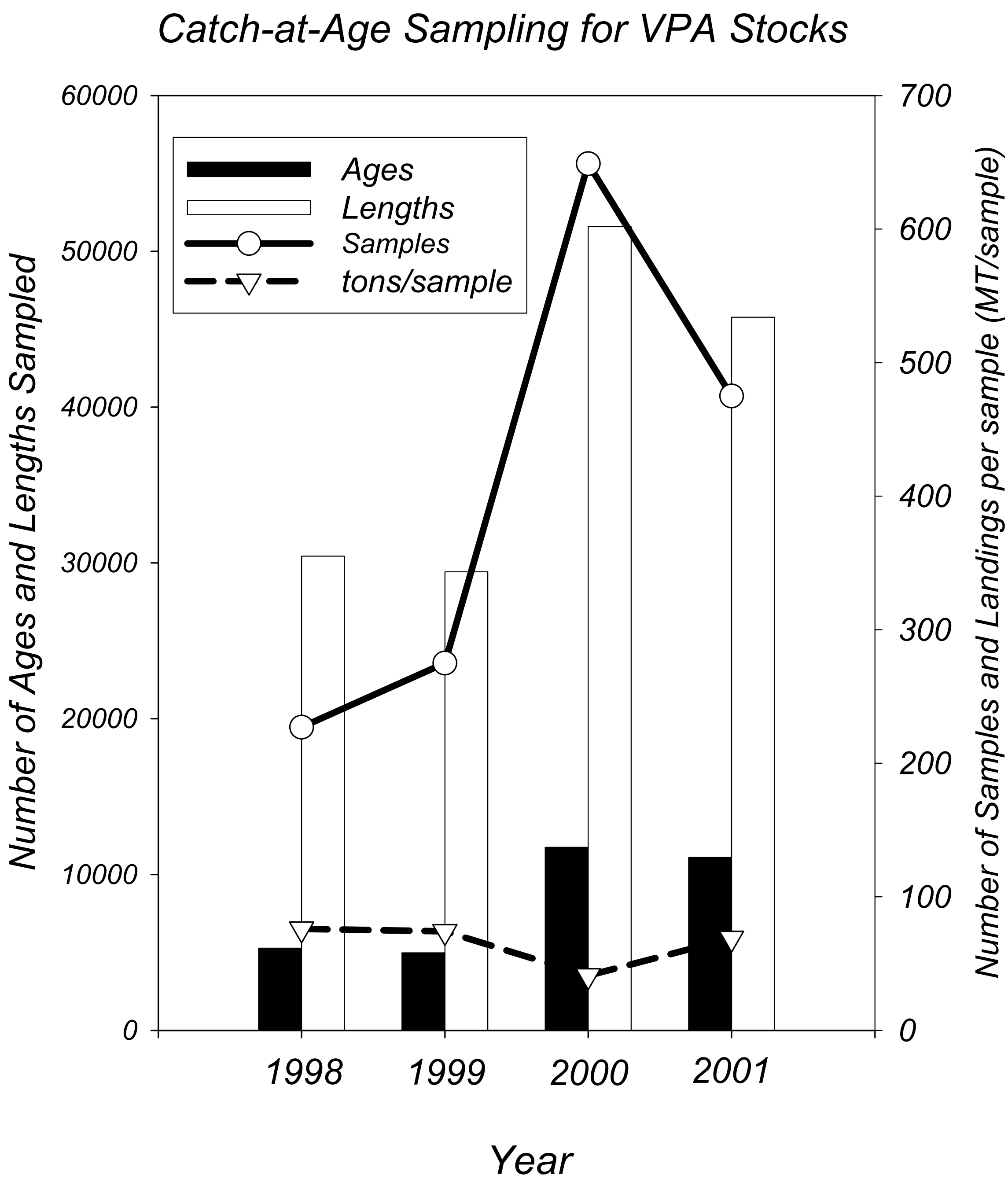


Figure 6.3. Summary of biological sampling for catch-at-age estimation, 1998-2001. Data are the number of samples, number of individual length frequency samples, numbers of fish aged and the sampling intensity (metric tons of landings per sample).

## 6.4 Recommendations

Research recommendations appropriate to individual stocks are summarized in appropriate chapters in section 2 of this report. Listed below are research recommendations of a more generic nature:

- Based on considerations outlined in section 6.1, a retrospective evaluation of the performance of stock projections used in support of management is recommended. Such an analysis could shed light on the utility of various recruitment assumptions and other sources of uncertainty in stock and landings projection approaches.

- Index methods for biomass and fishing mortality status determination are used for a number of the groundfish stocks for which age- or length-based catch and abundance information are lacking. The performance of these indices should be evaluated and uncertainty measures routinely incorporated in the determination of stock status.

- Port sampling for estimating landings-at-age is an important component of stock assessment. The overall levels of port sampling have increased since 1998, as landings have increased. Maintenance, and in some cases, improvement in the rates of sampling are required to ensure adequate levels of sampling for estimating the catch-at-age. Further, a simulation (re-sampling) study is recommended to evaluate the reliability of catch-at-age estimates in relation to the rates of sampling.

- Estimation of fishery discards remains problematic for these stocks, as the overall level of sea sampling prior to 2002 was low and variable by fishery type. Increased rates of sea sampling coverage (occurring in 2002 and beyond) should allow a statistical evaluation of the reliability of discard estimates, and the development of target sampling rates in order to reliably estimate discard mortalities at age for inclusion in assessments.

- Some stocks might have sufficient age and length-based information to upgrade the assessment type from an index basis to an age structured assessment (e.g., Gulf of Maine haddock). Age-structured modeling, even with partial information, may improve the basis for status determination for these stocks, and these improvements should be investigated.

- The GARM considered a variety of studies, including comparative fishing experiments developed to evaluate ship effects, to better understand the potential effects on survey indices due to the warp offset issue. The GARM notes that in order to evaluate the warp offset issue more directly, appropriately designed experimentation with warp offset and warp aligned tows is considered the most direct method.

**Appendix 1.**

# Centre for Independent Experts
# University of Miami

## Independent Experts Report of the Groundfish Assessment Review Meeting
## Woods Hole 8 – 11 October 2002

Dr C. D. Darby

The Centre for Environment Fisheries & Aquacultre Science (C.E.F.A.S.)
Methods and Multispecies Modelling Group
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### Executive summary

The Groundfish Assessment Review Meeting (GARM) took place in Woods Hole on the 8 – 11 October 2002. The meeting peer reviewed stock assessments for 20 Northeast USA groundfish species.

The GARM meeting was competently chaired, organised, and supported by NEFSC staff. All of its terms of reference were addressed within the limited time available. Assessment co-ordinators were prepared for the meeting and presentations of data and model results were well structured. The ability, attitude, and team-work demonstrated by the meeting participants was of a comparable, high standard to the better quality assessment meetings that I have attended within the International Commission for the Exploration o the Sea (ICES), Canada, and the North Atlantic Fisheries Organisation (NAFO).

The procedures adopted for the assessment reviews follow similar protocols and standards to those used within ICES and NAFO. Each assessment was reviewed in detail, and suggestions and criticism were readily accepted and incorporated into the assessment models or taken forward within research recommendations.

The meeting was the most optimistic assessment meeting that I have attended. For the majority of stocks, fishing mortality has gradually been reduced and in response spawning stock biomass (SSB) is rebuilding.

Unfortunately, the trawl offset issue clouded what would otherwise have been a relatively straightforward assessment review. The attitude of the NEFSC staff to the data analysis required for resolving this issue was open-minded and thorough. The conclusion that there were limited or no effects of the offset on survey catch rates was robust to the type of analysis and the data sets used. Sensitivity tests of the assessments revealed that even if a substantial warp effect had not been detected by the statistical analysis, the conclusions that the stocks are currently being over-fished would not change.

**Conduct of the meeting**

*Review*

The meeting presentations and discussions were open and balanced, and sufficient time was allowed for each issue. It is unfortunate that the invitation to attend was not taken up by the fishing industry; this would have provided a useful opportunity for the industry to contribute to the process and add its experience on the state of the stocks.

The GARM meeting was well chaired and organised by Dr. Steve Murawski who, given the limited time available for the review of 20 stocks, kept the meeting on track and discussions relevant.

The GARM had high-quality background support from the NEFSC staff, prior to and during the meeting. Without this support, the meeting would have been considerably more difficult. The Web site and LAN set up for the meeting allowed rapid dissemination of information and results and both were extremely successful.

At the meeting, the assessment co-ordinators were well prepared. Suggestions and criticism were readily accepted and most of the additional work required by the GARM was completed during the evenings, after the meetings, in time for review the next day. The ability, attitude, and team-work demonstrated by the meeting participants was of a comparable, high, standard to the better quality assessment meetings that I have attended within ICES, Canada, and at NAFO.

The NEFSC Modelling Group provided invaluable support to the meeting on the issue of the trawl warp offset. The extraction and statistical analysis of the data used in the resolution of this issue required a substantial amount of effort by that group in a very short time period. Their input was much appreciated by the GARM and the external reviewers.

*Recommendations*

I have two minor criticisms that apply to the review procedure and logistics.

- I could have achieved more if I had earlier notice that the meeting was to take place. Reading of the papers and supporting documentation was carried out at short notice and more time to assimilate and link together the information would have been a distinct advantage.

- Although some of the important background documents were available on the Web site, many were not. Electronic versions of all the major texts referred to in the report should be accessible. This issue was raised during the meeting and will be addressed for the current report.

**Data**

*Review*

During recent years, there has been an increased pressure on the fishery to reduce fishing mortality. In general, this has led to high-grading and dumping when trip limits are exceeded. In some fisheries, the reduction in commercial landings has also led to the recreational fishery becoming a major proportion of the catch.

Data on the number of samples for length and age were presented at the meeting for each stock. The stock co-ordinators were aware that the level of sampling has been very low, and that this has created problems in the collation of assessment data sets. In recent years, the situation has improved as the level of sampling of the commercial catch has increased.

*Recommendations*

- The level of sampling of the commercial landings has increased in recent years and is described within the assessment texts as currently being "adequate". The magnitude of the error resulting from sampling should be enumerated annually.

- Calculations for the levels of random error associated with sampling for length and age distributions are routinely submitted to ICES Working Groups as part of a report on the quality and sources of the data being used for the assessment. This should be a routine part of the preparation of assessment data for the stocks examined by the GARM.

- In many cases, catch data are prorated from logbook information. If not currently available (there was no obvious reference in the stock assessment texts), a study of the levels of uncertainty that this raising procedure introduces to the catch data should be considered.

- The intensity of sampling of the discards and recreational landings does not appear to have been increased in line with their magnitude; consequently, increasing levels of uncertainty are associated with the assessment results.

- The retrospective patterns shown by the majority of the assessments, over-estimation of SSB, and under-estimation of F could be a direct result of under estimation of discard mortality.

**The Review and Updating of Stock Assessments**

*Review*

All of the assessment Terms of Reference for the GARM were covered. Assessment models were fitted to the updated survey and catch data and stock status determined for each of the stocks. The fitting procedures, model diagnostics, and results were discussed in detail, and the conclusions drawn about the stock dynamics are consistent with the model estimates and associated uncertainties.

Assessment co-ordinators were well prepared and organised. The presentations of data and model results were well structured. The procedures adopted for the assessment reviews follow similar protocols and standards to those used within ICES and NAFO. Each assessment was reviewed in detail and suggestions and criticism were readily accepted and incorporated into the assessment models or taken forward within research recommendations.

The age-based models that were applied to assess the recent stock dynamics are standard methods that are routinely used within other fisheries management institutions, and the review protocol adopted by the meeting was appropriate for those methods. The index based assessment methodology approach to the estimation stock status and reference points, that is being developed at the NEFSC, is more advanced than methods applied at other North Atlantic research and management organisations.

The potential influence of the trawl warp offset on model estimates was examined and discussed at all stages of the assessment process. Within each stock, the sensitivity of the assessments to the trawl warp issue was thoroughly explored in a consistent approach to the problem. The approach was discussed and developed prior to the meeting, which was a useful time saver.

*Recommendations*

- Single calibration series assessments were used by the GARM to examine the agreement between stock estimates derived from independent survey series. Caution is needed when applying this approach, in that the series should cover the whole age range and spatial distribution of the exploited fraction of the stock used in the assessment model. Discussions within the GARM showed that this issue was being addressed in the current approach and in the research recommendations.

- In only a limited number of cases were alternative model structures used to examine the robustness of the results to model structural uncertainty (e.g. VPA vs. ASPIC). Recent studies have shown that this uncertainty can be as significant as random errors about the assumed model. Given the uncertainty introduced to the assessment by the low levels of sampling in recent years, I would recommend a comparison with models that allow for uncertainty in the catch at age data.

- It was surprising that age based stock assessments were not being carried out for Gulf of Maine haddock and pollock. Ageing of these species is relatively straightforward. It should therefore be possible to construct age-based assessments even if only for recent short periods of time. Such models could be used to evaluate growth over-fishing reference points for comparison with the index based analyses presented at the GARM.

- The level of mortality estimated for the Yellowtail stocks is very high for a flatfish species. This is especially the case for the Cape Cod stock, which is increasing under severe fishing pressure. A co-operative tagging study, carried out with the fishing industry, could provide valuable information on growth rates, ageing and stock identity. This information could help resolve this apparent anomaly.

- The bootstrap procedures used to derive confidence limits for F and SSB do not include all of the uncertainty in the assessment process. They are model conditioned and do not include errors in the catch data or retrospective bias. They are therefore under-estimates of the uncertainty in F and SSB. This problem is not unique to the GARM/Working Group models. It is a research area within fisheries science that is currently being actively explored. The GARM was up to date with the most recent thinking on these issues and its advice was given with regard to them.

- Further development of the index based assessment methodology should be encouraged, especially with regard to the estimation of the uncertainty associated with stock and reference point parameters.

**Management Advice and Reference Points**

*Review*

The GARM did not update any of the reference points established by the *Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.* For each stock, the recent dynamic history of the population and the fishery were discussed in detail in relation to the biomass and fishing mortality benchmark reference points. The sensitivity, of the stock status relative to reference point benchmarks, to the trawl warp issue was continually raised within the meeting and addressed using sensitivity analyses. The conclusion that the status of the stocks relative to management reference points is robust to the relatively minor changes in catchability that would have resulted from the trawl warp offset.

*Recommendations*

- At least two of the stocks for which the GARM provides management advice (pollock and Atlantic halibut) are not "closed" entities but are part of a much larger population complex. The units are not true stocks with negligible immigration and emigration, as required for a full understanding of the population and fishery dynamics. Whilst management of these stocks using reference points derived from the index method provides an indication of the relative exploitation status of the stock sub-unit, the stock dynamics could be controlled by events taking place outside of the management area, e.g. recruitment. As such, spawning stock and recruitment analyses and reference points for these stocks could be highly ambiguous. The GARM was aware of the problem and is monitoring the situation. It is strongly recommended that the assessment and management of such stocks be addressed in spatial units that equate to the scale of their system dynamics.

- In some texts, $B_{msy}$ is quoted when SSB values have been used for the determination of the reference point. Although the authors are aware of their meaning and glossaries are sometimes provided at the beginning of reports, if the reader is not aware of the potential for error or the text is extracted in isolation, this will lead to confusion and mistakes. It is strongly recommended that a common nomenclature is adopted for the SSB and biomass based reference points. This issue was discussed within the GARM and will be addressed.

- The majority of the stocks examined by the GARM are taken in mixed species fisheries. Changes in effort or TAC directed towards target species will influence the dynamics of other species. It was therefore surprising that the management advice was provided on a single stock basis without discussion of mixed fishery issues. F rebuild resulting in the recovery of one stock within the designated time frame may impose an indirect bycatch or discard mortality, on a second stock, that is too high for it to recover.

**The Trawl Warp Issue**

*Review*

The GARM was unanimous in its conclusion that that the magnitude of the trawl warp offset effect on survey catchability is relatively small relative to the natural and sampling variation inherent in all survey time series. Assessment results and the advice as to the state of the stock were shown to be robust to under-estimation bias at the level of the expected effects.

In my opinion, a level-headed and rigorous scientific analysis was applied to the trawl warp offset problem. Although the "gut feeling" of the participants was that there should be little or no effect, this was not allowed to influence the analysis or the interpretation of the results.

Numerous diverse data sets and methodologies were analysed in order to find an indication that the mis-marked trawl warps had had an effect on the catch rates from the surveys. These included trawl monitoring measurements, trawl damage indices, catch rates of species by depth, between and within survey series. In each case, the results of the analysis pointed to the conclusion that a reduction in survey catchability could not be detected during the period when the offset was present. This was not unexpected given the video evidence that the net was still fishing at the expected range of trawl offsets and that such offsets will fall within the natural variation induced by currents, wind and wave action, fishing on slopes, etc.

Sensitivity tests applied to the assessments revealed that even if a substantial (x2) effect were to be missed by the statistical data analysis, the conclusions that the stocks are being over-fished would not change.

*Recommendations*

- Although current statistical analysis have established that the trawl warp offset does not appear to have had a significant impact on the catchability of the survey series, this issue should not be closed after this GARM. It is my understanding that there are a series of experiments that will be conducted by the NEFSC and the fishing industry to examine the problem in more detail. The issue should therefore be placed on the agenda for next year's Working Groups and GARM.

- The detailed data analysis required for the resolution of the trawl warp offset issue has highlighted the importance of comparative towing calibration exercises when planning gear and ship alterations.

**Documents reviewed**

***Historic***

Brodziak, J., P. Rago, and R. Conser. 1998. A general approach for making short-term stochastic projections from an age-structured fisheries assessment model. In F. Funk, T. Quinn II, J. Heifetz, J. Ianelli, J. Powers, J. Schweigert, P. Sullivan, and C.-I. Zhang (Eds.), *Proceedings of the International Symposium on Fishery Stock Assessment Models for the 21st Century*. Alaska Sea Grant College Program, Univ. of Alaska, Fairbanks.

Mayo, R.K., E. Thunberg, S.E. Wigley and S.X. Cadrin. 2002. The 2001 Assessment of the Gulf of Maine cod stock. Northeast Fish. Sci. Cent. Ref. Doc. 02-02

NEFSC 2002. Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish, . NMFS/NEFSC, Reference Document 02-04, 254p.

NEFSC (Northeast Fisheries Science Center). 2001. Assessment of 19 Northeast Groundfish Stocks through 2000. Northern Demersal and Southern Demersal Working Groups, Northeast Regional Stock Assessment Workshop. Northeast Fish. Sci. Cent. Ref. Doc. 01-20, 217p.

O'Brien, L. and N. J. Munroe 2001. Assessment of the Georges Bank cod stock for 2001. *Northeast Fish. Sci. Cent. Ref. Doc* 01-10, 126 p.

Stone, H. H Stock assessment of Georges Bank (5Zjmnh) Yellowtail Flounder for 2002 CSAS Research Document 2002/057

## *APPENDIX I*

### *GARM Working documents*

A O'Brien L., N. J. Munroe, and L. Col. Georges Bank Cod.

B Brodziak, J., M. Thompson, R. Brown, and N. Munroe. Georges Bank Haddock.

C1 Legault, C. Georges Bank Yellowtail Flounder.

C2 Legault, C. Georges Bank Yellowtail Flounder Sensitivities.

D Cadrin, S. Southern New England Yellowtail Flounder.

E Cadrin, S and J King. Cape Cod Yellowtail Flounder.

F Mayo, R.K. and L. Col. Gulf of Maine Atlantic Cod Stock.

G Wigley, S. E. Witch Flounder.

H O'Brien, L., C.Esteves, and L. Col Amercian Plaice in the Gulf of Maine/Georges Bank Region.

I Hendrickson, L. Georges Bank Winter Flounder

J Terceiro, M. Southern New England/Mid-Atlantic Winter Flounder

K Sosebee, K.A. Georges Bank/Gulf of Maine White Hake.

L Mayo and L. Col. R.K. The 2002 Status of Pollock, *Pollachius virens* (L.) in NAFO Divisions 4VWX and Subareas 5 and 6.

M Mayo R.K. and L. Col. The 2002 Status of Acadian Redfish, *Sebastes fasciatus* Storer in the Gulf of Maine-Georges Bank Region.

N Wigley S. Ocean Pout

O Hendrickson, L. Windowpane Flounder (Gulf of Maine-Georges Bank)

P Hendrickson, L. Windowpane Flounder (Southern New England-Mid-Atlantic Bight)

Q Cadrin, S. Mid Atlantic Yellowtail Flounder.

R Brodziak, J. and M.Thompson Gulf of Maine Haddock.

S Brodziak, J. Atlantic Halibut

T Nitschke, P. Gulf of Maine Winter Flounder

U Report of the NEFSC Methods Working Group. Evaluation of the potential effects of asymmetric trawl cables on R/V Albatross survey indices from 2000 to 2002.

*APPENDIX II*

## STATEMENT OF WORK

**Subcontract between the University of Miami and CEFAS (Dr. Chris Darby)**

### Groundfish Assessment Review Meeting

The purpose of requesting outside peer reviewers from the Center of Independent Experts (CIE) is to provide input to the Groundfish Assessment Review Meeting (GARM) for northeast USA stocks. The Northeast Multispecies Fishery Management Plan (Multispecies Plan) includes 20 groundfish stocks. The GARM meeting (scheduled for 8-11 October, 2002, in Woods Hole, Massachusetts), will provide scientific review of assessment information and ancillary analyses. The CIE reviewers are requested to provide input on assessment results and forecasts, and to help construct the final report of the meeting.

The GARM meeting is a regional process for updating stock assessments using existing models, VPA formulations, and other assessment approaches. Specifically, the GARM will:

A. Provide updated catch information (landings and discards, where appropriate) for the 20 stocks to be assessed (see list below), catch-at-age data (estimated based on port sampling, where applicable);

| | |
|---|---|
| Cod | Gulf of Maine |
| | Georges Bank |
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| Yellowtail flounder | Georges Bank |
| | Cape Cod |
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| | Mid-Atlantic |
| Winter flounder | Gulf of Maine |
| | Georges Bank |
| | Southern New England |
| Acadian redfish | |
| American plaice | |
| Witch flounder | |
| Pollock | |
| Windowpane flounder | Northern |
| | Southern |
| White hake | |
| Ocean pout | |
| Atlantic halibut | |

B. Provide updated research vessel survey indices (through spring 2002) for all appropriate survey series, including NMFS spring and autumn series, Canadian series, and state surveys (as appropriate);

C. Estimate fishing mortality rates (or appropriate proxies) for all 20 stocks (through 2001), and provide estimates of terminal year stock sizes;

D. Evaluate stock status relative to applicable biological reference points (FMSY and BMSY) as provided in the Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0204/);

E. Provide updated estimates of F-Rebuild (the fishing mortality rate required to rebuild biomasses to BMSY by 2009) for all applicable stocks; and

F. Comment on the potential sensitivity of assessment results to trawl warp marking discrepancies that occurred in surveys between spring 2000 and spring 2002.

**Specific Responsibilities of the CIE Reviewer**

The scientific expertise required is in the area of stock assessment and population dynamics.

The CIE reviewer's duties shall occupy no longer than 10 days: Several days prior to the GARM meeting for document review; four days to participate in the GARM meeting; one day following the GARM meeting to review the draft final workshop report; and several days to complete the report to be submitted to the CIE. No consensus opinion between the two CIE reviewers is sought.

Specific tasks and the schedule are itemized below.

1. Prepare for the GARM meeting by reviewing documents posted on the web prior to 8 October 2002.

2. Serve as active participant in the GARM meeting from 8-11 October 2002, providing input, comment, and scientific overview of analyses, and actively participate in drafting the final report and conclusions of the GARM.

3. Review the draft GARM report during the week of 14-18 October 2002, so that the NEFSC can meet the deadline for completion of the final document by 21 October 2002. The review comments should be provided to the Northeast Fisheries Science Center via Dr. Steven Murawski (508-495-2303, smurawsk@whsun1.wh.whoi.edu) no later than October 18, 2002.

4. No later than October 25, 2002, submit the written report[1] (see Annex I) addressed to the "University of Miami Independent System for Peer Review," and sent to

[1] The written report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the written report that will be submitted to NMFS and the consultant.

Dr. David Die, via email to ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu.  This report shall include the comments provided under task 3 above.

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings, and conclusions/recommendations.

3. The report shall also include as separate appendices the bibliography of materials reviewed for the GARM and a copy of the statement of work.

**Review Report on the 2002 Groundfish Assessment Review Meeting (GARM) and its findings and recommendations**

By

Jon Helge Vølstad[1], Ph.D.
Versar, Inc.
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USA

[1]Representing the Center of Independent Experts, at the Rosenstiel School of Marine and Atmospheric Science, University of Miami.

October 29, 2002

## Executive Summary

Assessments (through 2001) of the 20 stocks under the Northeast fisheries management plan updated and reviewed by GARM are of consistent high quality, based on models that are suitable for the available data for each stock. The GARM review meeting was competently chaired, and conducted in a spirit of cooperation and teamwork. The assessments, conducted by experienced stock assessment biologists, were subject to a rigorous and very open peer review process that identified the most likely sources of uncertainty and, in some cases, inconsistencies were discovered. In response to requests by GARM, inconsistencies were usually corrected in time for review the next day. In-accurate information on catch-at-age, resulting from limited spatial and temporal sampling coverage of landings and limited, if any, information on discard was identified as a major source of uncertainty in some age-based assessments. Systematic patterns in the residuals of many VPA model fits (e.g., multiple years in a row with negative or positive residuals) strongly indicates bias in the catch-at-age data, for example resulting from significant discards not accounted for, or from biased catch sampling. The control of fishing mortality through trip limits, which has been implemented for some stocks in recent years, might increase the level of discards and, worse, cause a shift in the time series of catch-at-age that is difficult to correct for in stock assessments.

GARM conducted a rigorous and very thorough evaluation of potential effects of a trawl warp offset recently discovered on the NOAA research vessel *Albatross IV*. The offset, which applied to surveys conducted from winter and spring 2000-2002, and fall 2000 and 2001, could potentially affect recent stock assessments. A suite of studies related to gear configuration, fishing power, and survey indices of abundance and size composition over time strongly suggested that any change in trawling efficiency as a result of the offset was minor. Results from previous controlled fishing power experiments conduced with *Albatross IV* trawling alongside another vessel (*Delaware II*) showed very similar catching efficiencies for *Albatross IV* relative to *Delaware II* before and after the warp offset, thus precluding a major drop in trawl catching efficiency caused by the offset. Analyses of the series of *Albatross IV* survey indices of abundance (and size composition) alone, or compared to Canadian independent surveys for some species, did not reveal a substantial shift related to drop in fishing power after the warp offset. An additional sensitivity analysis conducted by GARM using hypothetical increases of 10%, 25%, and 100% in survey abundances (corresponding to reductions in catching efficiency well beyond what is supported by available data) would not have sufficient impact on stock assessments to change the determination of status with respect to overfishing (fishing mortality rates) for 19 of the 20 species under the Northeast FMP. American plaice, which had a biomass close to the target of ½ B-MSY in 2001, changed status from 'overfishing' to 'no overfishing" in the (unlikely) event of a 50% reduction in fishing power caused by the warp offset (corresponding to a 100% upward adjustment of the abundance index). The qualitative status based on the comparison of estimated biomass to the reference (½ B-MSY) changed for two species (American Plaice and Gulf of Maine haddock) with a hypothetical 10% (or higher) increase in abundance because their estimated biomass were close to the threshold. Clearly, when the point estimate of biomass is close to the threshold, even insignificant changes in catching efficiency (i.e., within the natural variability caused by weather conditions, variations in the vertical distribution of fish, and other factors) could change the qualitative status. Based on these considerations, I believe that it was demonstrated beyond a reasonable doubt that the offset of trawl warps on *Albatross IV* has not invalidated the stock assessments and the determination of fishing status with respect to overfishing.

## 1. Background

The Northeast Fisheries Science Center (NEFSC) conducts assessments of 20 major groundfish stocks (A-T, Appendix A) under the Northeast Multispecies Fishery Management Plan (FMP). These stock assessments are based on methods that use abundance indices from fisheries independent trawl surveys (conducted since 1963), either directly or indirectly. For stocks where sufficient information is available on catch at age over time (e.g., from port sampling, logbooks and other sources), the assessments are based on VPA (Virtual Population or Cohort Analysis) (A-G) or ADAPT (H). Independent survey indices of abundance (or biomass) are used for the tuning (calibration) of these age-based or integrated models. The assessments of nine stocks (L-T) are based directly on the fisheries independent survey indices of abundance (or biomass) and the estimated population characteristics of the stocks (e.g., size and age distribution), along with information on catch. Due to limitations in basic catch-at-age data, the assessment of two stocks (I, J) was based on a stock production model incorporating covariates (ASPIC), with spring and autumn survey indices of biomass used for tuning; while one stock (K) was assessed by a biomass dynamic model, using survey indices of biomass.

Abundance indices and estimates of population characteristics from fisheries independent surveys provide essential information for the assessments of the groundfish stocks under the Northeast FMP. The NOAA research vessel *Albatross IV* has been used by NEFSC to conduct stratified random surveys for the assessment and monitoring of groundfish stocks since 1963, representing an unparalleled continuous time series for tracking the status and trends of major stocks under the Northeast FMP. The normal operating area for *Albatross IV* is the Gulf of Maine, Georges Bank, and the continental shelf and slope from Southern New England to Cape Hatteras, NC. Concerns have been raised that the reliability of the surveys conducted by Alba*tross IV* has been jeopardized in the most recent years because of an un-intended change in the sampling gear configuration in

2000, thus potentially compromising stock assessments for recent years. Measurements of NEFSC survey trawl warps in autumn 2002 suggested that right and left warps (the wires that attach the trawl gear to the vessel) may have been offset by up to several feet on the NOAA Ship *Albatross IV* during surveys conducted from winter 2000 through spring 2002. The offset was caused by biased measurements of the 50 m intervals for one warp, and as a result of these miss-markings, the offset increased proportionally with the length of cable deployed. The fishing industry and other constituents have postulated that the offset may have substantially reduced the trawl catching efficiency because of reduced bottom contact and lesser opening of the trawl. The possibility of the trawl collapsing at greater depths, which would result in zero catches, was also raised. A considerable reduction in trawling efficiency would introduce bias and reduce the reliability of the survey indices of abundance and estimates of population characteristics (e.g., length and age compositions) of groundfish species under the FMP.

These concerns were addressed in the Groundfish Assessment Review Meeting (GARM) from October 8-11, 2002 in Woods Hole, MA. GARM conducted a scientific review of assessment information and ancillary analyses including multiple studies to assess if the warp offset significantly affected trawling efficiency. GARM also assessed the potential implications of warp offset on stock assessment and resulting determination for overfished status (e.g., <1/2 BMSY) for the 20 species under the Northeast FMP, based on hypothesized reductions in the catching efficiency of the trawl in a series of sensitivity analyses.

## 2. Review of the GARM Activities and Findings

Dr. Steve Murawski chaired the GARM meeting, held at the Northeast Fisheries Science Center (NEFSC) in Woods Hole from October 8-11, 2002, in an organized and effective manner. The meeting was conducted in a spirit of cooperation and teamwork. Draft documents of most updated stock assessments were made available for review a few days before the meeting. During the GARM meeting, the responsible assessment expert presented each stock assessment update, and the panel of experts reviewed it. The group of regional stock assessment scientists (both NMFS and non-NMFS people) and external experts conducted the review. The team of scientists was very diligent in the search for inconsistencies in the methods and results, and everyone was very open to critique from the panel of reviewers.

## 2.1. Updating of Stock Assessments

Most stock assessments reviewed at the GARM were routine updates of assessments previously reviewed in the SAW or elsewhere. All the assessments specified in the Terms of Reference for the GARM were covered. Estimates of fishing mortality rates (or proxies thereof) and biomasses in 2001, relative to management reference points 2001 fishing mortality (or its proxy), were provided for 19 stocks. For one stock (T), the assessment presented was developed for the first time (by the ASMFC Technical Committee), and has not yet been subject to standard peer review. Accordingly, the details of the analytical stock assessment modeling are not incorporated in the GARM report, pending that “benchmark” review to be conducted at SAW-36 in December 2002.

Quality of the input data, and the suitability of the VPA model specifications were evaluated through inspection of residual plots. Alternative model structures (e.g., ASPIC) were used in a few cases to examine the robustness of the VPA results. The two primary sources of uncertainty included in the projections (for 2002 and onwards) based on VPA assessments are: (1) the initial estimated stock abundance at age in year 2001, which is driven by the fisheries-independent survey indices used for tuning, and (2) future recruitment to the stock. The tuning minimized the differences between predicted numbers at age from the VPA and the fisheries-independent indices of abundance through parameter adjustments, and has most influence on estimates for recent years. The VPA is a recursive procedure that converges to yield robust estimates of number at age back in time (under certain assumptions) provided that the input catch statistics are reliable over time.

Inaccuracy in catch-at-age for commercial (and recreational) fisheries resulting from limited spatial and temporal sampling coverage of landings, and limited, if any, information on discard, was recognized by the whole panel as a problem. The non-random residual pattern in the VPA model fits observed for many stocks, with residuals being negative or positive for a series of years, strongly indicates that substantial components of the catch are unaccounted for. The strong retrospective patterns of under-estimation of F also could results from discard unaccounted for. The recent implementation of trip limits to reduce fishing pressure for some stocks is likely to increase discard of target species (e.g., through high-grading), and could introduce significant bias in stock assessments.

## 2.2. Management Advice and Reference Points

The GARM maintained the reference points established in "The Report of the Working Group on Re-evaluation of Biological Reference Points for New England groundfish". Sensitivity analyses were conducted to evaluate hypothetical effects of trawl warp offset on the status determination for each stock. Their analyses demonstrated that the determination of the status of stocks, relative to biological reference points set by management, was robust to small (10%), and moderate (25%) changes in the catching efficiency of the trawl used for tracking relative abundance over time. I agree with these findings.

Sampling variability in survey indices of abundance, and the variability in VPA estimates related to uncertainty in catch-at-age, is generally not taken into account in the determination of overfishing status. In my opinion, this introduces a risk, since true abundance could be substantially lower, or higher, than the value used in the determination of overfishing status. Effects of errors in catch-at-age, for example resulting from poor information about discard, are likely to be of greater importance in the determination of fishing status than the minor change in trawl catching efficiency resulting from the warp offset on *Albatross IV*.

## 2.3. Trawling performance related to warp offset

The GARM reviewed the results of a series of 10 different studies to evaluate evidence of a reduction in trawl catch efficiency associated with the use of miss-calibrated trawl warps on *Albatross IV*. There were eight affected surveys (winter and spring 2000-2002; and fall 2000 and 2001). These studies covered three broad categories:

a. Trawl geometry and performance in relation to the warp offsets as function of depth - direct observations of bottom contact and trawl configuration (wing-spread and headrope height measurements), as well as data on rates of gear damage from the *Albatross IV* surveys;

b. Shifts in the time series of survey indices of abundance and estimated population characteristics (e.g., size distributions) resulting from reduced trawling efficiency;

c. Fishing power studies - paired trawling conducted by *Albatross IV* alongside the *Delaware II* vessel before and after spring 2000.

I was very impressed by the thorough scientific analysis that had been conducted by NEFSC staff, using all available relevant data, to reveal any shift in trawl catching efficiency caused by the warp offset on *Albatross IV*. The analysts and methods experts, at the request of myself and other GARM members, conducted multiple additional analyses during the meeting. The results did not reveal any significant effects on the catching efficiency of the trawl related to the offset of the warps for depths where groundfish typically occur (warp offset up to about nine feet). In particular, a large number of parallel trawl hauls conducted by *Albatross IV* alongside *Delaware II* before and after the warp offset showed virtually no change in relative fishing power between the vessels. The analyses were restricted to ten species (including cod, haddock, and yellowtail flounder) that had sufficient sampling coverage for a valid comparison of fishing power between vessels. The almost identical relative catch rates for flatfish before and after the warp offset clearly indicate that the trawl maintained good bottom contact despite the warp offset. In effect, this fishing power study can be considered a controlled experiment (although not intended at the time) to detect effects of the warp offset. The *Delaware II* served as a control because it used a fixed gear and trawling procedure for both time periods (before and after the warp offset on the *Albatross IV* gear). Thus, an appreciable reduction in catching efficiency for *Albatross IV* after the warp offset, as postulated by some, would have resulted in a change in the ratio of mean catches for the two vessels. This did not happen. Any substantial changes in the underlying fish abundance pre and post warp offset, which could be a confounding factor in the evaluation of *Albatross IV* survey indices alone, are essentially accounted for because of the parallel trawling (in space and time) with another vessel.

## 3. Conclusions and Recommendations

Assessments through 2001 of the 20 stocks under the Northeast fisheries management are of consistently high quality, based on models that are suitable for the available data for each stock. The assessments and updates, conducted by experienced stock assessment biologists, were subject to a rigorous review process. The potential effects of the warp offset on *Albatross IV* in recent years were thoroughly evaluated. Based on all available results, I firmly believe that the warp offset has had minimal effects on the stock assessments conducted in recent years. Because the reduction of trawl catching efficiency resulting from warp offsets appear to be very small in depths where groundfish typically occur (warp offset up to about 9 feet), an intensive and well designed parallel trawling experiment involving *Albatross IV* along with a control vessel (e.g., the *Delaware II* or an industrial fishing vessel) would be required to detect and calibrate such effects. Such an experiment could also provide additional information on the fishing power in deep waters, with warps offsets up to 18 feet. Although recent trawl experiment studies showed that the net remained open at the maximum offset of 18 feet, the actual fishing power in this case can only be determined from further experimental trawling. It is my understanding that such an experiment is being planned by NEFSC in cooperation with the fishing industry. Depending on the results from such an experiment, additional evaluations of the effects of the warp offset on stock assessments might be warranted.

Age-based assessments (VPA or ADAPT) with appropriate tuning are generally considered to be robust, when assumptions about natural mortality and recruitment are reasonable. However, such age-based assessments are particularly sensitive to inaccurate information on catches at age, for example related limited sampling coverage (spatially and temporally) of landings, and unreported discards. I recommend that the variability in VPA (and ADAPT) assessments caused by sampling variability in estimated landings in number by age be evaluated, for example by applying boot-strapping to port sampling data in connection with the model runs. Also, biased assessments (of unknown magnitude) could occur when multiple survey indices used for tuning of VPA are assigned equal weights, regardless of spatial coverage and precision. Such bias can be severe when some surveys only cover a limited fraction of the distribution area of a species. One way to reduce or eliminate such bias is to combine the respective survey estimates by using a composite estimator with appropriate weighting of each series, before the series is applied in tuning of VPA models. Additional post-stratification might be appropriate when surveys overlap in a sub-area.

I also noted that index based methods for determining fishing status do not incorporate measures of uncertainty in relative fishing mortality rate in the determination of overfished status. Reference points are based on estimated relative F that support replacement of the stock, or a specified growth rate. In the index-based assessments, the relative fishing mortality rate of a species is estimated as the ratio of catch (or harvest for some species) to the relative estimate of abundance from the research trawl surveys. Uncertainty in this ratio estimate is due to sampling variability in the survey indices, as well as in the estimated total catches. Also, bias would be introduced if the total catches were poorly estimated, for example due to unreliable or no estimates of discard. It is important that the precision and accuracy of the estimated fishing mortality (F) be quantified, so that risk of stock depletion (or of setting too harsh limits on catch size) under current management regimes can be evaluated. The research trawl surveys conducted by NEFSC are probability-based, and thus have the great advantage that precision in the survey estimates of abundance can be quantified. In fact, to my knowledge, the survey series started by NEFSC in 1963 (using *Albatross IV*) was the first example (worldwide) of applying stratified random sampling to trawl surveys. I recommend that NEFSC move towards using a more precautionary approach to determine status relative to reference points, for example based on confidence limits of the abundance estimates. Although the relative standard errors might be fairly large because the estimates are based on moderate sample sizes, it would be more in line with the pre-cautionary approach to take such uncertainty into account. This can be illustrated through an example: If a point estimate of F for a species is just below the overfishing threshold, but with an upper confidence interval that extends well above the threshold, this would clearly indicate that the risk of overfishing occurring is high. By contrast, an estimated F just above the threshold, but with tight confidence limits, suggest a lower risk of severe overfishing than in the former example. The comparison of sampling variability in survey indices of abundance to variability in estimates of catch-at-age can also be useful when planning allocation of resources among fisheries dependent and fisheries in-dependent sampling programs.

## 4. References

The Report of the Working Group on Re-evaluation of Biological Reference Points for New England groundfish Improving Fish Stock Assessments. National Academy Press, Washington DC, 1998. 177 p.

Improving Fish Stock Assessments. National Academy Press. Washington, DC, 1998. 176 pp.

Improving the Collection, Management, and Use of Marine Fisheries Data, 2000. Ocean Studies Board, National Research Council, 236 pp.

## Appendix A

Bibliography of materials reviewed:

- Report of the Groundfish Assessment Review Meeting (GARM) Assessment of 20 Northeast Groundfish Stocks through 2001. (By the Northern Demersal Working Group; Southern Demersal Working Group; Assessment Methods Working Group).

The above report includes updated stock assessments for 20 groundfish species (Documents posted on www.nefsc.noaa.gov/garm):

A. Georges Bank cod (Loretta O'Brien)
B. Georges Bank Haddock (Jon Brodziak)
C. Georges Bank Yellowtail Flounder (Chris Legault/Steve Cadrin)
D. So. New England Yellowtail Flounder (Steve Cadrin/Chris Legault)
E. Cape Cod Yellowtail Flounder (Steve Cadrin/Chris Legault)
F. Gulf of Maine Cod (Ralph Mayo)
G. Witch Flounder (Sue Wigley)
H. American Plaice (Loretta O'Brien)
I. Georges Bank Winter Flounder (Lisa Hendrickson)
J. So. New England/Mid Atlantic Winter Flounder (Steve C/Mark)
K. White Hake (Kathy Sosebee)
L. Pollock (Ralph Mayo)
M. Acadian Redfish (Ralph Mayo)
N. Ocean Pout (Sue Wigley)
O. Gulf of Maine/Georges Bank Windowpane (Lisa Hendrickson)
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Q. Mid-Atlantic Yellowtail Flounder (Steve Cadrin/Chris Legault)
R. Gulf of Maine Haddock (Jon Brodziak)
S. Atlantic Halibut (Jon Brodziak)
T. Gulf of Maine Winter Flounder (Paul Nitschke)

Results from the Methods Working Group Report on Examination of Possible Trawl Survey Time- Series Interventions beginning in 2000 were presented in power-point with additional hand-outs. The following issues were covered:

- Description of warp offset problem, and how it relates to fishing depth (Paul Rago)
- Gear Damage Studies (Larry Jacobson)
- Evaluation of Fish Size in Relation to Warp Offsets (Larry Jacobson w/ Anne Richards)
- Warp Experiment Information (Data provided by Lisa Hendrickson)
- Trawl Geometry and Related Issues (Paul Rago/Steve Cadrin)
- Mean/Variance Relationships in Fish Catch (Paul Rago)
- Catch-at-Depth Relationships (Paul Rago /Steve Cadrin )
- Changes in Abundance Indices Pre- and Post Warp Intervention (Steve Cadrin)
- Log Catch Ratios Between Affected and Unaffected Surveys (Larry/Steve)
- VPA Performance (Residuals, Retrospective Patterns) (Chris Legault)
- Evaluation of Fishing Power Experiments, 1980s vs. 2002 (Mike Fogarty/Steve Cadrin)

## APPENDIX B: STATEMENT OF WORK

**Subcontract between the University of Miami and Versar, Inc. (Dr. Jon Helge Vølstad)**

### Groundfish Assessment Review Meeting

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The GARM meeting is a regional process for updating stock assessments using existing models, VPA formulations, and other assessment approaches. Specifically, the GARM will:

A. Provide updated catch information (landings and discards, where appropriate) for the 20 stocks to be assessed (see list below), catch-at-age data (estimated based on port sampling, where applicable);

| | |
|---|---|
| Cod | Gulf of Maine |
| | Georges Bank |
| Haddock | Gulf of Maine |
| | Georges Bank |
| Yellowtail flounder | Georges Bank |
| | Cape Cod |
| | Southern New England |
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| Winter flounder | Gulf of Maine |
| | Georges Bank |
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| American plaice | |
| Witch flounder | |
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| Windowpane flounder | Northern |
| | Southern |
| White hake | |
| Ocean pout | |

Atlantic halibut

B. Provide updated research vessel survey indices (through spring 2002) for all appropriate survey series, including NMFS spring and autumn series, Canadian series, and state surveys (as appropriate);

C. Estimate fishing mortality rates (or appropriate proxies) for all 20 stocks (through 2001), and provide estimates of terminal year stock sizes;

D. Evaluate stock status relative to applicable biological reference points (FMSY and BMSY) as provided in the Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0204/);

E. Provide updated estimates of F-Rebuild (the fishing mortality rate required to rebuild biomasses to BMSY by 2009) for all applicable stocks; and

F. Comment on the potential sensitivity of assessment results to trawl warp-marking discrepancies that occurred in surveys between spring 2000 and spring 2002.

**Specific Responsibilities of the CIE Reviewer**

The scientific expertise required is in the area of stock assessment and population dynamics.

The CIE reviewer's duties shall occupy no longer than 10 days: Several days prior to the GARM meeting for document review; four days to participate in the GARM meeting; one day following the GARM meeting to review the draft final workshop report; and several days to complete the report to be submitted to the CIE. No consensus opinion between the two CIE reviewers is sought.

Specific tasks and the schedule are itemized below.

1. Prepare for the GARM meeting by reviewing documents posted on the web prior to 8 October 2002. This web site is http://www.nefsc.noaa.gov/garm/. The login is "garm"; the password is "kingfish". Additional scientific information will be presented during the GARM meeting.

2. Serve as active participant in the GARM meeting from 8-11 October 2002, providing input, comment, and scientific overview of analyses, and actively participate in drafting the final report and conclusions of the GARM.

3. Review the draft GARM report during the week of 14-18 October 2002, so that the NEFSC can meet the deadline for completion of the final document by 21 October 2002. The review comments should be provided to the Northeast Fisheries Science

Center via Dr. Steven Murawski (508-495-2303, smurawsk@whsun1.wh.whoi.edu) no later than October 18, 2002.

4. No later than October 25, 2002, submit the written report[1] (see Annex I) addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via email to ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu. This report shall include the comments provided under task 3 above.

Signed________________________________ Date_______________

[1] The written report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the written report that will be submitted to NMFS and the consultant.

ANNEX I:  REPORT GENERATION AND PROCEDURAL ITEMS

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings, and conclusions/recommendations.

3. The report shall also include as separate appendices the bibliography of materials reviewed for the GARM and a copy of the statement of work.

**Appendix 2 Supplemental Information from Section 3.7.**

## Cumulative Distribution Plots

More subtle changes in the depth distribution might be ascertained by considering the cumulative distribution of catch at depth by year and survey type. The general idea here is that the historical pattern of catches at depth constitute an "envelope" of historical variation. Under the hypothesis that the efficiency of capture decreases with increasing depth, the expected pattern during the post treatment period should be a CDF lying to the left of the envelope. The basic intuitive properties of this approach are summarized in Fig. H.23 using a hypothetical example. Suppose that the indices of abundance for species X in the 2000-2002 surveys were low and should actually have been 25%, 100%, or even 1000% higher. Equation 6 can be substituted into Eq.4 and value of theta can be solved using nonlinear optimization of the equation:

$$\sum_j C_{j\,rev} = (1+\delta)\sum_j C_{j,obs} = \sum_j \left( \frac{C_{j,obs}}{1-\left(\frac{0.0134 D_j}{W_{\max}}\right)^{\theta}} \right) \quad (13)$$

Fig. H23 illustrates the expected behavior of the CDF for values of delta =0.1, 1.0, and 10.0. The respective values of theta were 1.725, 0.721, and 0.109

Examination of these plots was conducted for the two stocks of cod (Fig. H.24-25), two haddock stocks (Fig. H.26-27), three yellowtail flounder stocks (Fig. H.28-30), witch flounder (Fig. H.31), spiny dogfish (Fig. H.32), and longhorn sculpin (Fig. H.33). There was some suggestion that one of the spring surveys for spiny dogfish and longhorn scalping "fit" this expected pattern. For all other species, stock, and surveys, the 2000-2002 Cuffs lay within the historical range. (Fig. H24-H33).

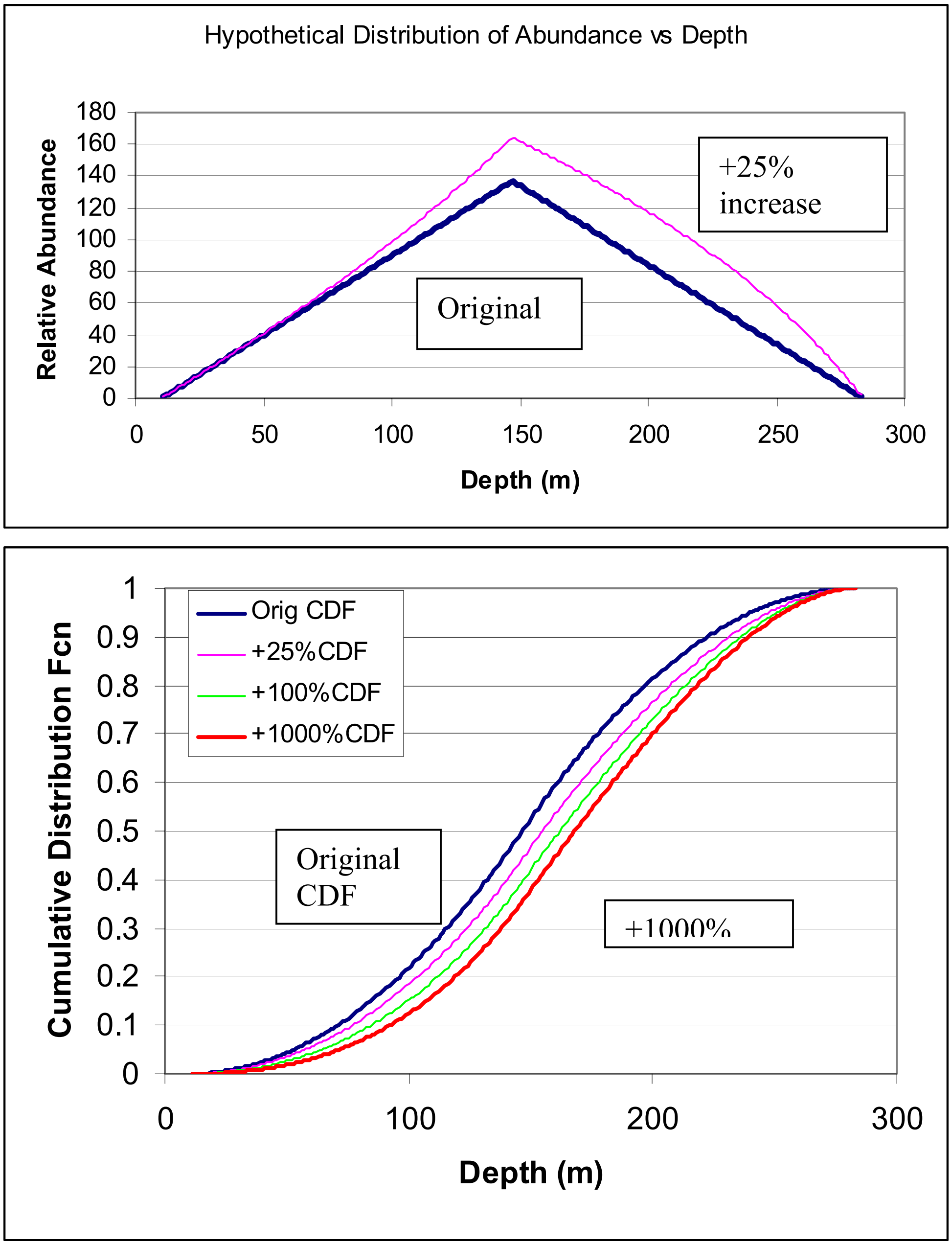


Fig. H23. Predicted shift in shift in average depth distribution for population distribution at depth for varying levels of underestimation of abundance. In the above example the theta parameter of the depth dependent relative efficiency function is modified to attain the target increase in biomass.

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