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Application of Some Index Methods to Georges Bank Yellowtail Flounder

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ABSTRACT

Simple graphical and empirical methods are used to examine the relationships between relative abundance and estimated catch of Georges Bank yellowtail flounder for three different synoptic surveys over the period 1963 to 2013. All three surveys reveal similar trends in abundance and relative fishing mortality. Kalman filtered estimates appear to be a useful way of summarizing trends and have strong similarities to model based estimates. Measures of relative fishing mortality increased steadily up through 1994, fell sharply in 1995 and have declined since then. Relative biomass increased rapidly for about 8 to 10 years after the decline in F , but has since declined, despite continued reductions in relative F . The simple model results suggest a change in underlying relationship between abundance and exploitation. While aggregated data used in this analysis are insufficient to identify the underlying cause, the large changes suggest that any model will have diagnostic problems unless an underlying mechanism for the change is incorporated into the model.

Introduction

Simple empirical and graphing approaches can be used to examine the expected relationship between biomass and harvest in exploited populations. In lightly exploited populations, one expects relatively little relationship because other processes play a greater role in governing inter-annual differences. In this exercise, we compare the responses of three synoptic surveys of relative biomass for Georges Bank yellowtail flounder to harvest. The findings of these analyses have implications for all modeling efforts for this resource, suggesting that external information about some underlying change in process is required to understand the dynamics of Georges Bank yellowtail flounder.

Methods

This paper is a simple examination of trends in catch and survey abundance over time. There are three primary synoptic surveys which have been used to assess Georges Bank yellowtail flounder. The NEFSC has conducted bottom trawl surveys on Georges Bank in the fall (generally early October) since 1963 and in the spring since 1968. The spring survey usually occurs in early to mid April. The Canadian Department of Fisheries and Oceans has conducted surveys in late winter (usually February) since 1987. Details on the design of each survey and changes over time are described in other working papers for this meeting. Estimates of total catch and swept area biomass estimates are summarized in Table 1. Catch for 2013 was assumed to be 500 mt.

To address the variability of the survey estimates and rates of change over time a maximum likelihood Kalman filter was used to smooth survey estimates. Unlike ARIMA or Lowess methods the Kalman filter explicitly incorporates the uncertainty of the annual observations into the smooth.

Define I_t as the relative abundance index at time t and C_t as the catch at time t . The simple relative fishing mortality rate at time t is defined as the ratio of C_t to I_t . This ratio can be noisy, owing to imprecision of survey estimates, and the variation can be damped by writing the relative F as a ratio of the catch to some average of the underlying indices. For the purpose of this report relative F is defined as the ratio of catch in year t as a lagged 3-yr average of the survey indices:

$$relF_t = \frac{C_t}{\left(\frac{I_t + I_{t-1} + I_{t-2}}{3} \right)} \quad (1)$$

The replacement ratio Ψ_t is defined as the ratio of current stock size to the average size of the parental stocks that produced it. Using a simple life history model, it can be shown that this ratio is proportional to a weighted-moving average of the spawning stock biomass in the previous A years. Empirically this can be approximated as the ratio of the current index to the simple average of the previous 5 years.

$$\Psi_t = \frac{I_t}{\sum_{j=1}^A I_{t-j} / A} \quad (2)$$

When rates of loss are dominated by removals by the fishery then Ψ_t and $\text{rel}F_t$ are expected to vary inversely.

To remove the effects of scale, the survey, catch and derived quantities were normalized by dividing the observations by their time series means.

Results from the most recent VPA model run were compared with the normalized survey and smoothed values. Spawning stock biomass estimates from the model were normalized. To properly compare the relative F for survey indices to an equivalent measure from the VPA model, catch was divided by the spawning stock biomass.

Results and Discussion

Normalized catches have been below the 1963-2013 average since 1983 (Fig. 1 top). Survey indices declined during this same period reaching lowest values in the late 1980s (Fig. 1 bottom). Survey indices remained low until about 1994 but increases rapidly to high values about 2003. The rapid increase coincided with the imposition of closed areas on Georges Bank and other management measures. Catches dropped sharply after 2004 and have declined since then. Survey abundance increase modestly after 2005 but has declined sharply since 2010.

The Kalman filtered estimates of abundance (Fig. 2) reveal a slightly different picture with less pronounced swings in abundance. High variance estimates, e.g. DFO 2008 and 2009 (Table 2) have less influence on overall trend. Nonetheless abundance estimates showed a consistent decline in the past 4 years (Fig. 3 top). Normalized Kalman estimates also agree well with VPA estimates until 2003 where in the model predictions drop sharply then reverse whereas all of the Kalman estimates suggest steady decline (Fig. 3 bottom).

Relative F estimates for each survey also have strong similarity with increasing rates from 1968 to 1994, followed by a sharp decline in 1995 (Fig. 4 top). Relative F estimates have continued to decline since then. Comparisons of normalized relative F for the survey with the normalized ratio of catch over the VPA estimate of SSB also reveal a strong similarity through 2000 (Fig. 4 bottom). After that, the estimates of relative F in the VPA increase at a faster rate until 2005. Since 2005 all of the measures of relative F decline.

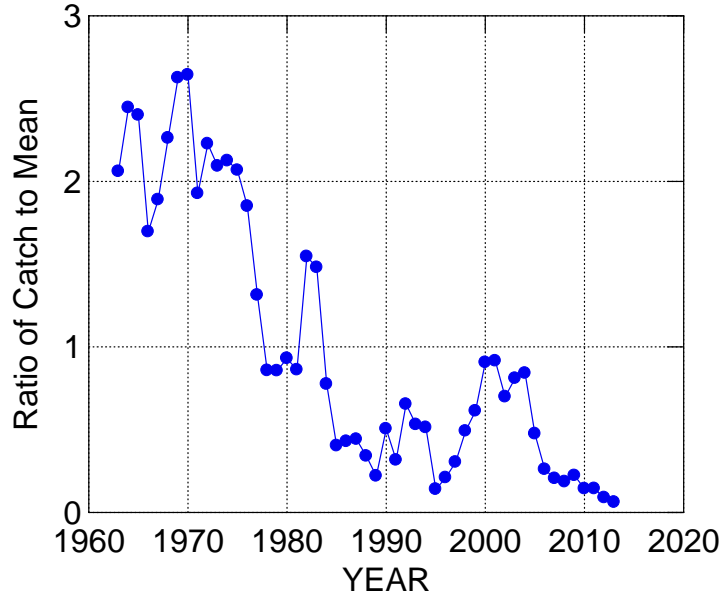
The six panel plots (Fig. 5-10) illustrate the inter-relationships among survey estimates of abundance, catch, functions of catch and relative abundance, and time. The two functions of catch and relative abundance considered are the replacement ratio (Eq. 2) and relative F (Eq. 1). Figures 5 to 7 examine the inter-relationships among variable for

the entire time series of each survey. Each survey suggests that the population was growing above replacement from about 1993 to about 2003 but has been below that since then. The relationship between the replacement ratio and fishing mortality (upper left panel of each figure) and relative F is weak. Some insight into the underlying causes for this pattern maybe gained by examining the isoclines plots (middle row, left column) of survey biomass and relative F for each survey. Each graph shows the expected decline in biomass as F increases up through 1994. The sharp reductions in F in 1995 and subsequent years however do not result in biomasses increases along the same isoclines. Instead the biomass increases slowly and then declines further with additional reductions in relative F (Fig. 5-7). In Figures 8 to 10 each survey is truncated at 1994. Each analysis reveals the problems of “one-way trips” and the relationship between the replacement ratio and relative F is insufficient to suggest a stable point where the replacement ratio is one.

Figures 11 to 13 further examine the bifurcation which occurs about 1995. The relationship between survey abundance and relative F is shown for stanzas up to 1994 and for 1995 and after. For the NEFSC fall and spring surveys, the confidence ellipse for the early period suggests good agreement with population theory about an isocline (Fig. 11 and 12). After 1994 the relationship becomes far more diffuse, with a near circular confidence interval s. For the DFO survey, the ranges of abundance before and after 1995 do not overlap as much. The DFO survey, which began in 1987 did not sample during the relatively high periods of abundance in the late sixties and early seventies. The estimated isoclines that would be estimated based on all the data is shown in the lower panels of Fig. 11 to 13. Each clearly reveals the heterogeneity of the population dynamics between these two time periods.

Figures

Normalized Catch relative to Mean, 1963-2013



Normalized Survey Abundance Indices(X/mean)

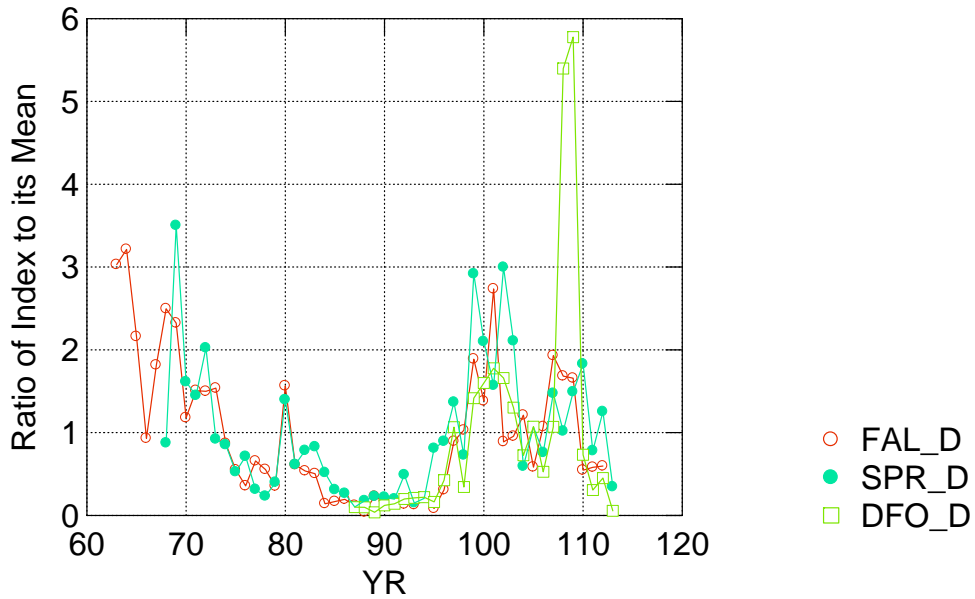


Figure 1. Normalized catch and survey information for 1963-2013. Values are expressed as the ratio of the respective means for each time series.

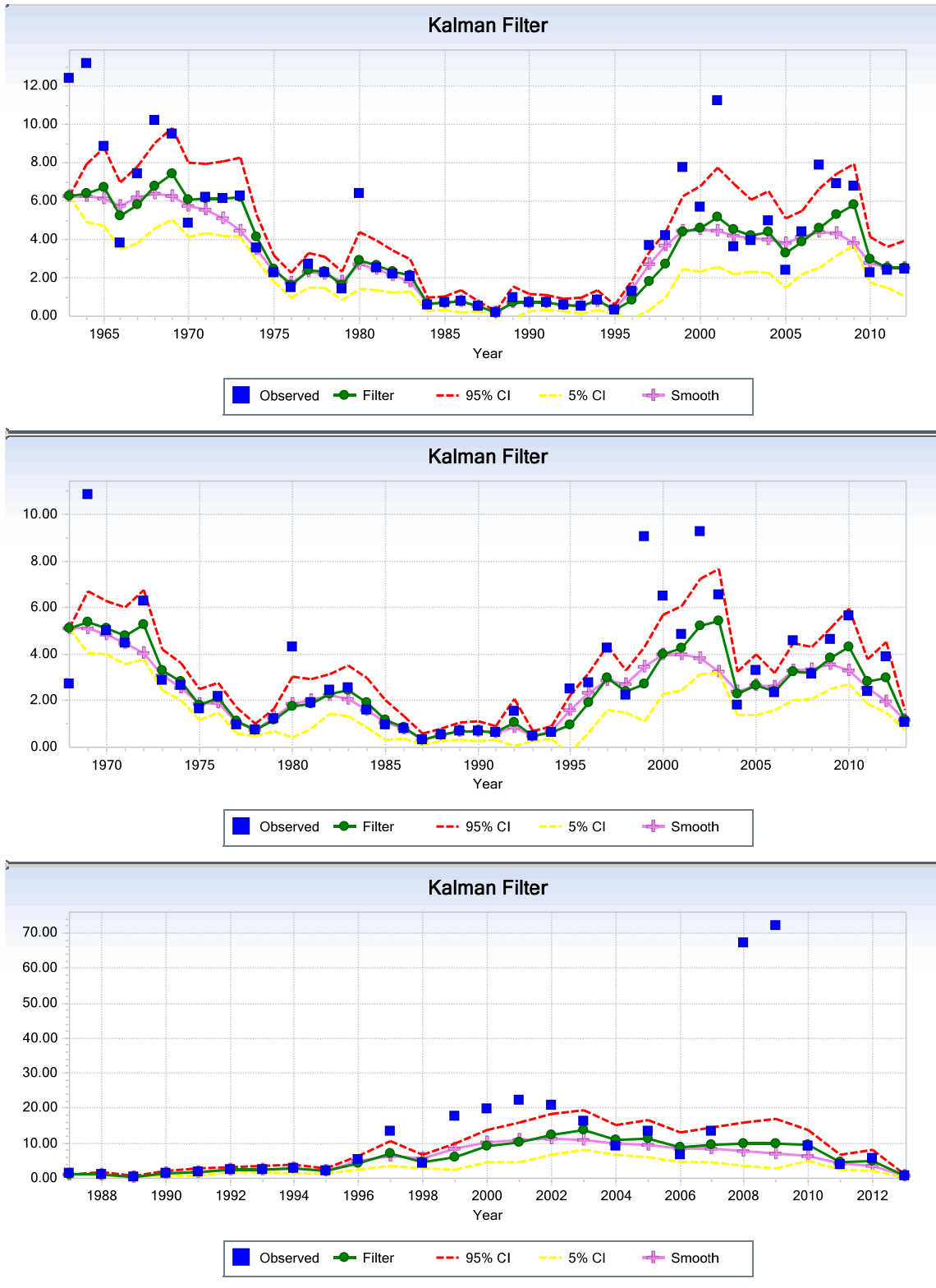
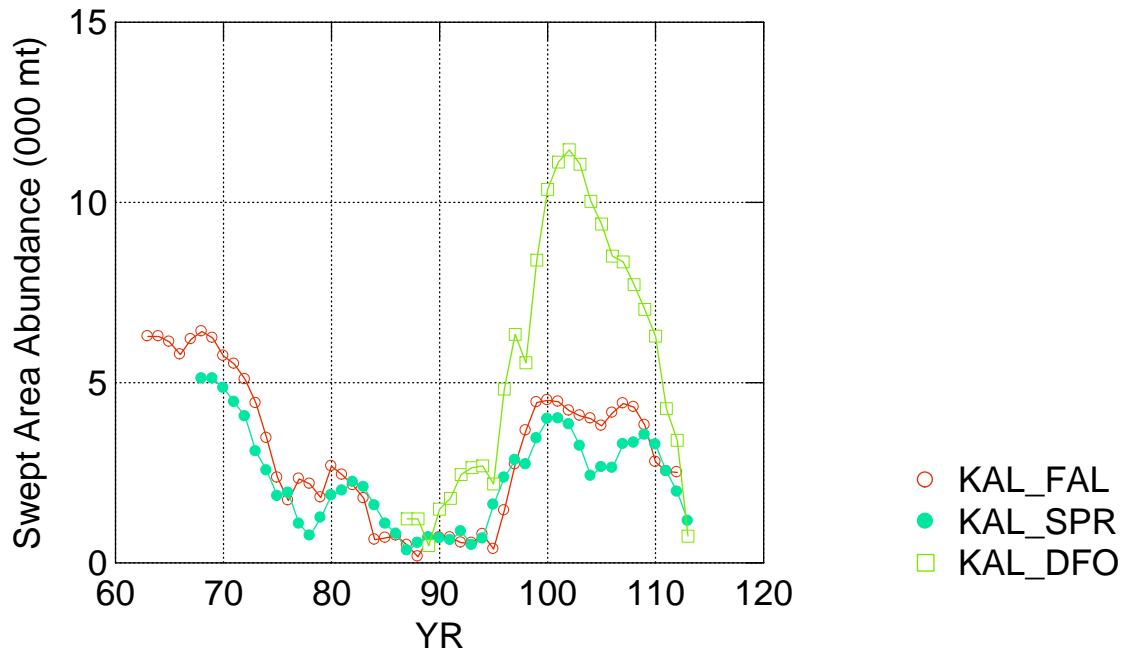


Figure 2. Summary of Kalman smoothed abundance estimate for NEFSC fall (top), NEFSC spring (middle), and DFO (bottom) trawls survey indices. Indices are expressed as swept area biomass estimates. Relative error estimates of each survey are presented in Table 1.

Kalman Smoothed Abundance Estimates



Comparison of Kalman Filter with VPA Estimates (X/mean)

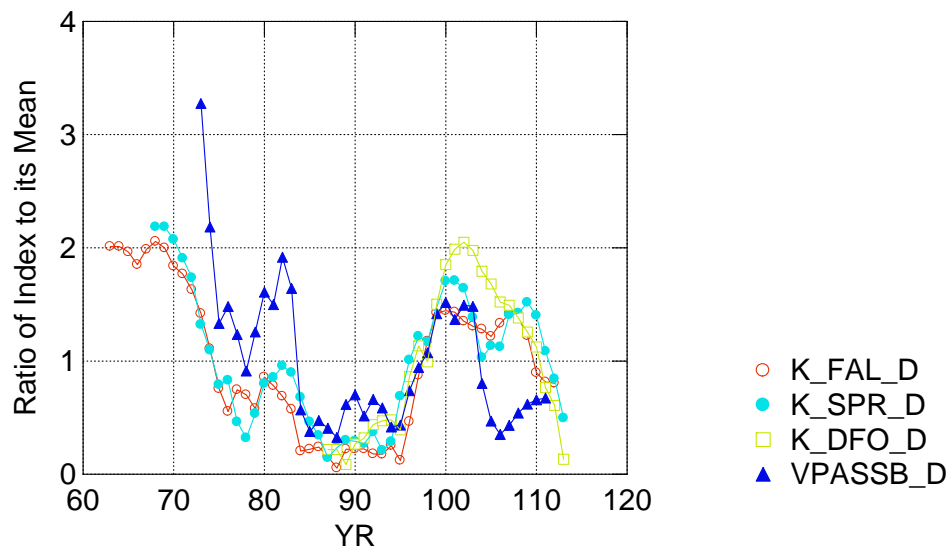
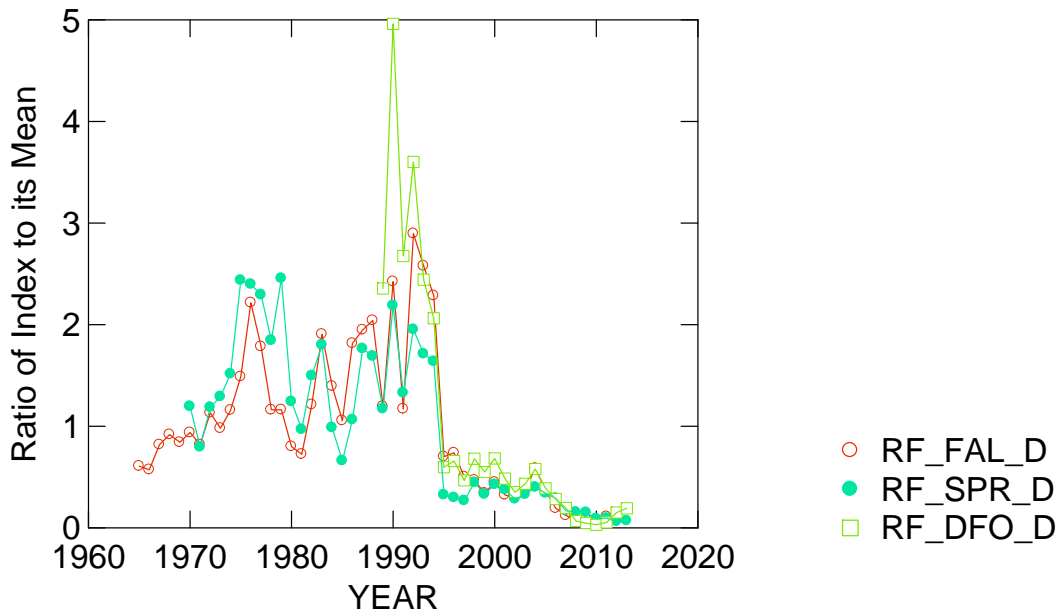


Figure 3. Summary of Kalman smoothed swept area abundance estimates (upper panel) for bottom trawl survey indices and comparison with VPA estimates of abundance (lower panel).

Normalized Relative F Indices (X/mean)



Comparison: Normalized Rel F to C/VPA_SSB (X/mean)

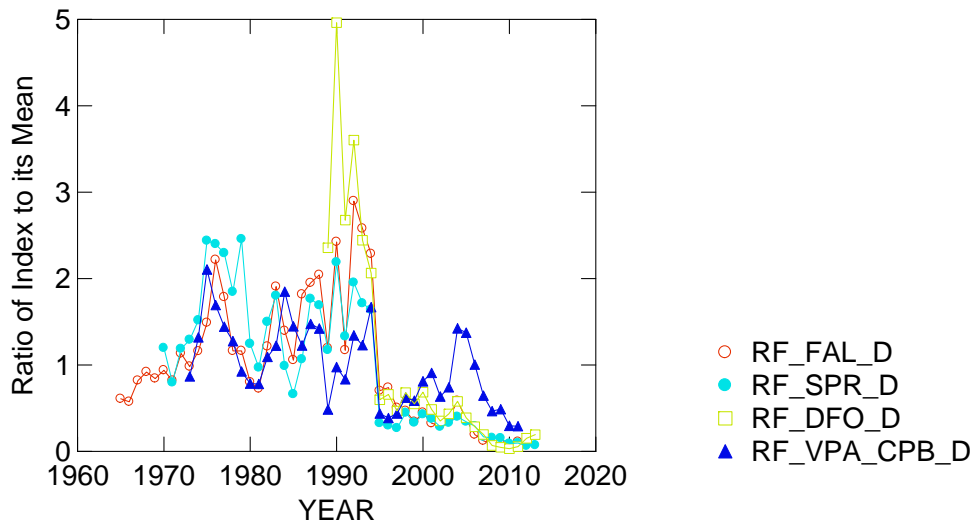


Figure 4. Comparison of relative F estimates based on the NEFSC fall and spring, and the DFO bottom trawls surveys (upper panel). All indices are normalized by dividing the observed value by the mean of the time series.

GB yellowtail Fall Survey, All Years

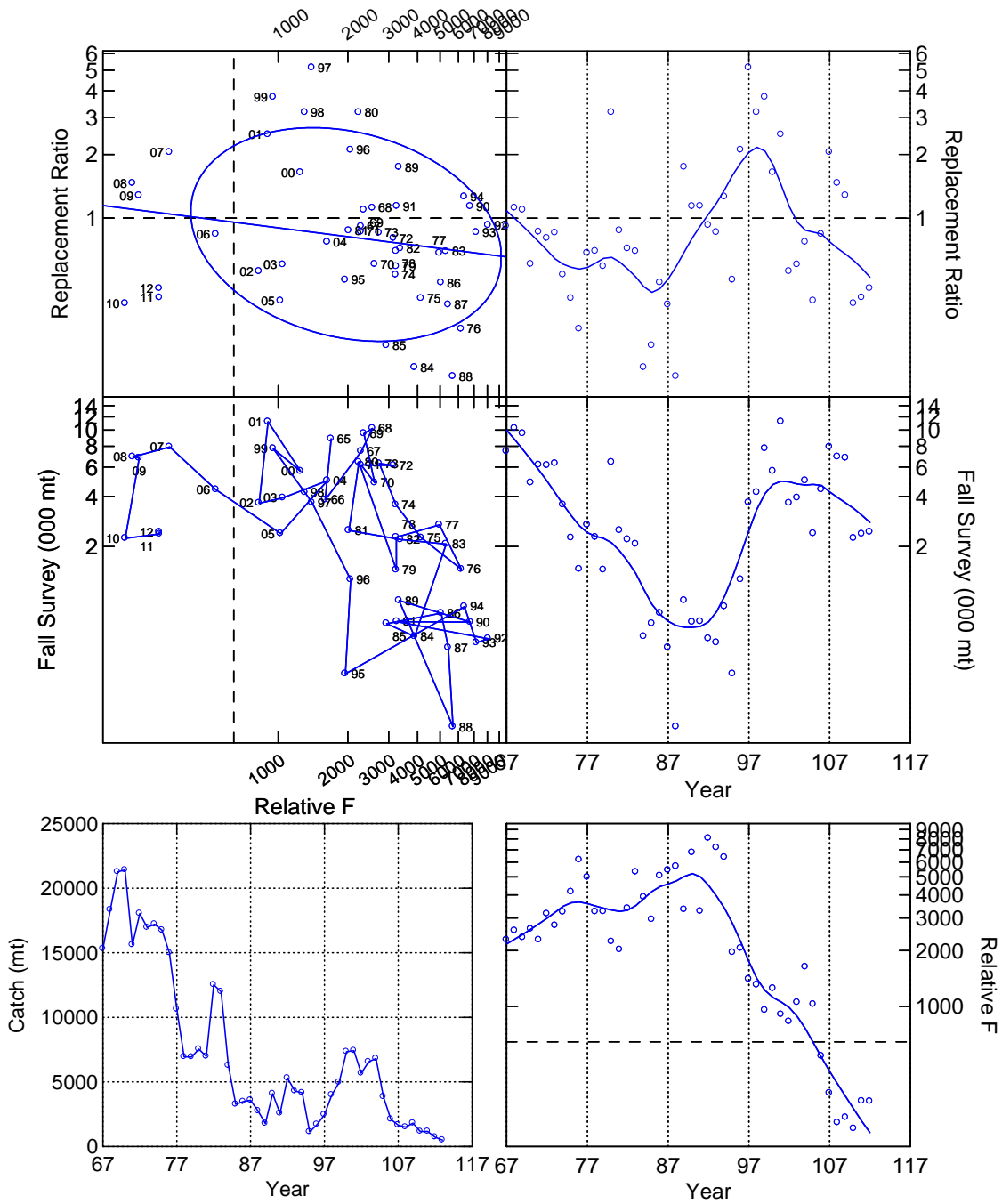


Figure 5. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the NEFSC fall bottom trawl survey, 1963-2012. Smooth lines in graphs on left side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

GB yellowtail Spring Survey, All Years

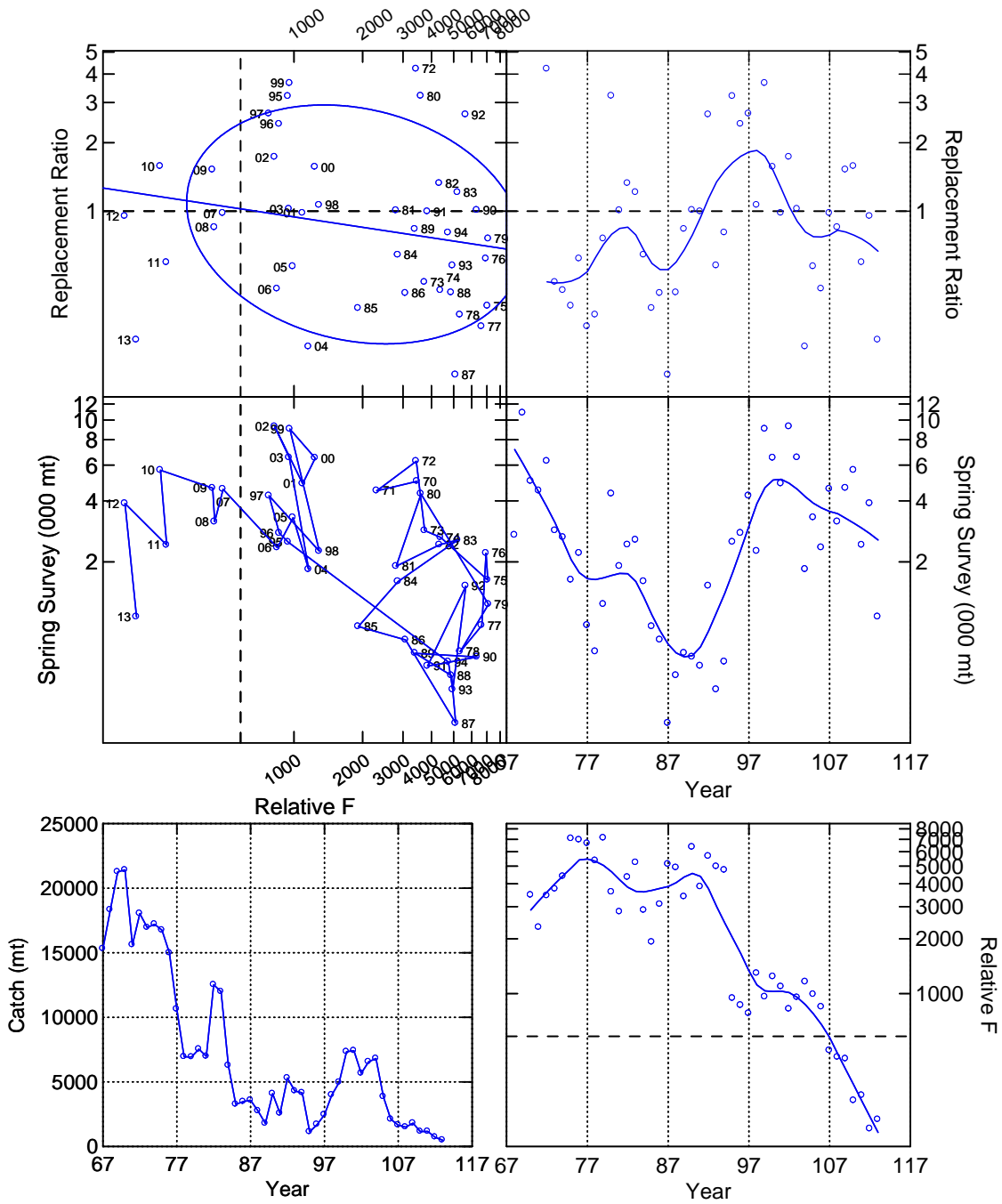


Figure 6. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the NEFSC spring bottom trawl survey, 1968-2013. Smooth lines in graphs on left side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

GB yellowtail DFO Survey, All Years

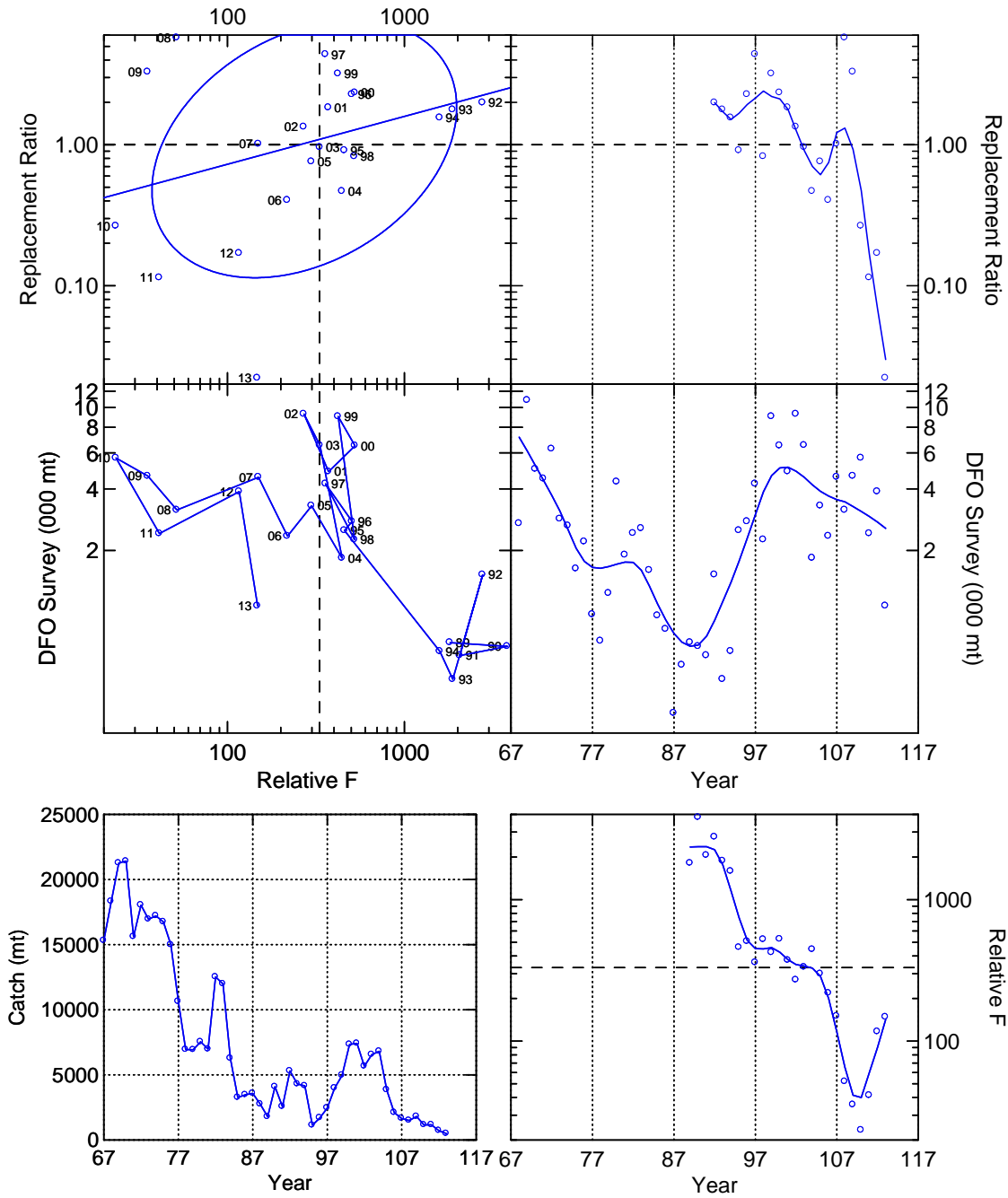


Figure 7. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the DFO bottom trawl survey, 1987-2013. Smooth lines in graphs on left side panels represent Lowess smoothes with tension = 0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

GB yellowtail Fall Survey, 1963-1994

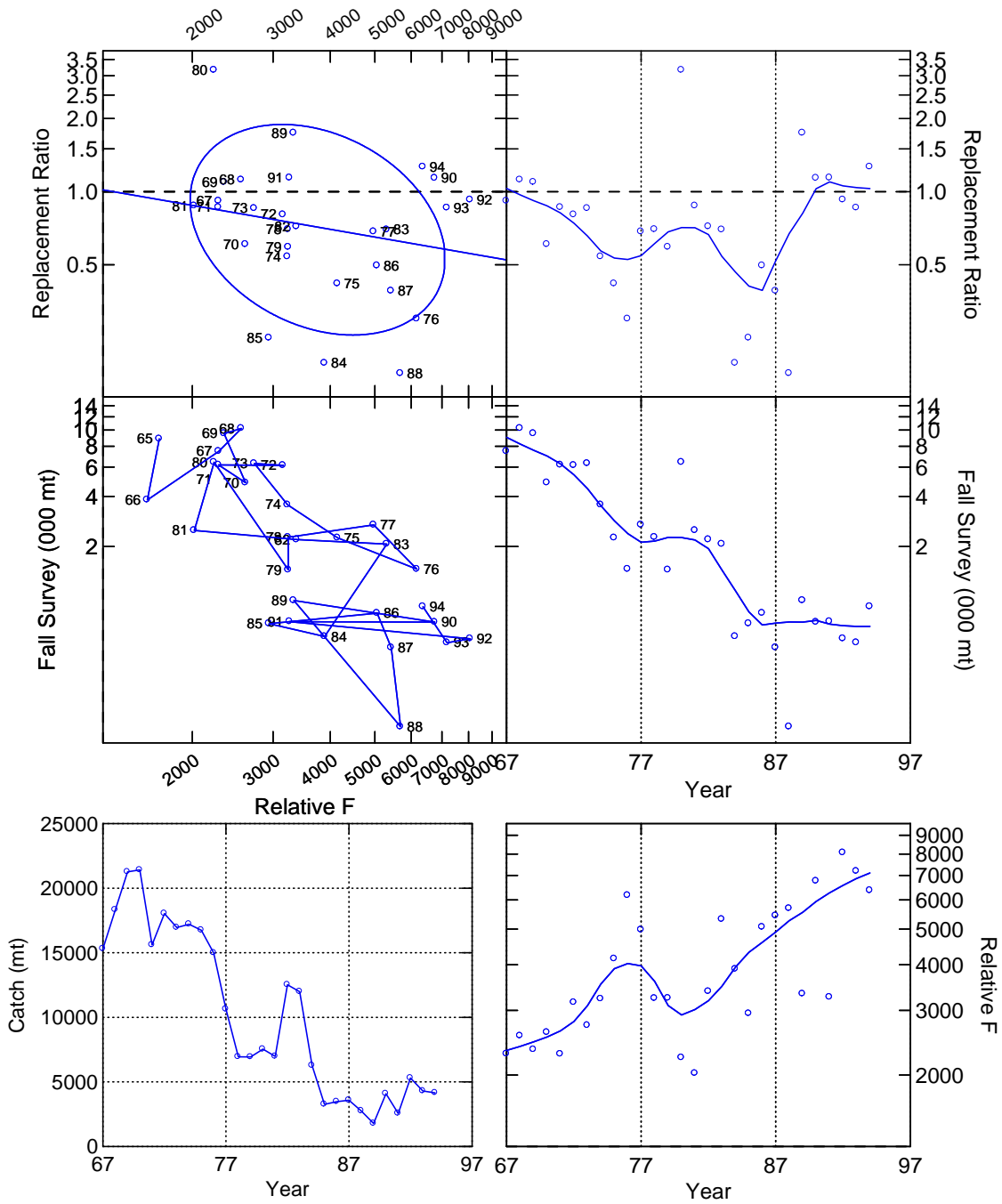


Figure 8. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the NEFSC fall bottom trawl survey, 1963-1994. Smooth lines in graphs on left side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

GB yellowtail Spring Survey, 1968-1994

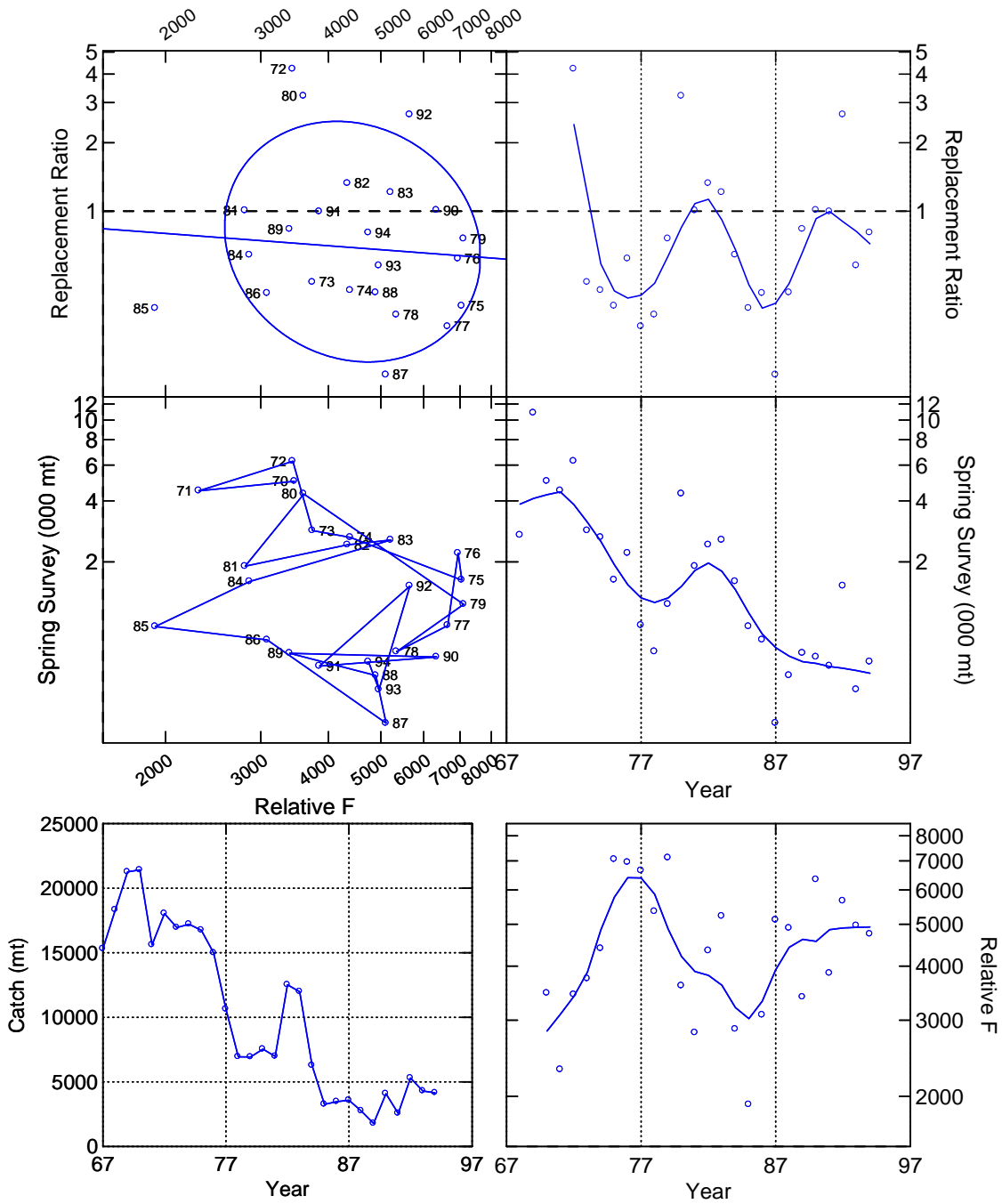


Figure 9. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the NEFSC spring bottom trawl survey, 1968-1994. Smooth lines in graphs on left side panels represent Lowess smoothes with tension = 0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

GB yellowtail DFO Survey 1987-1994

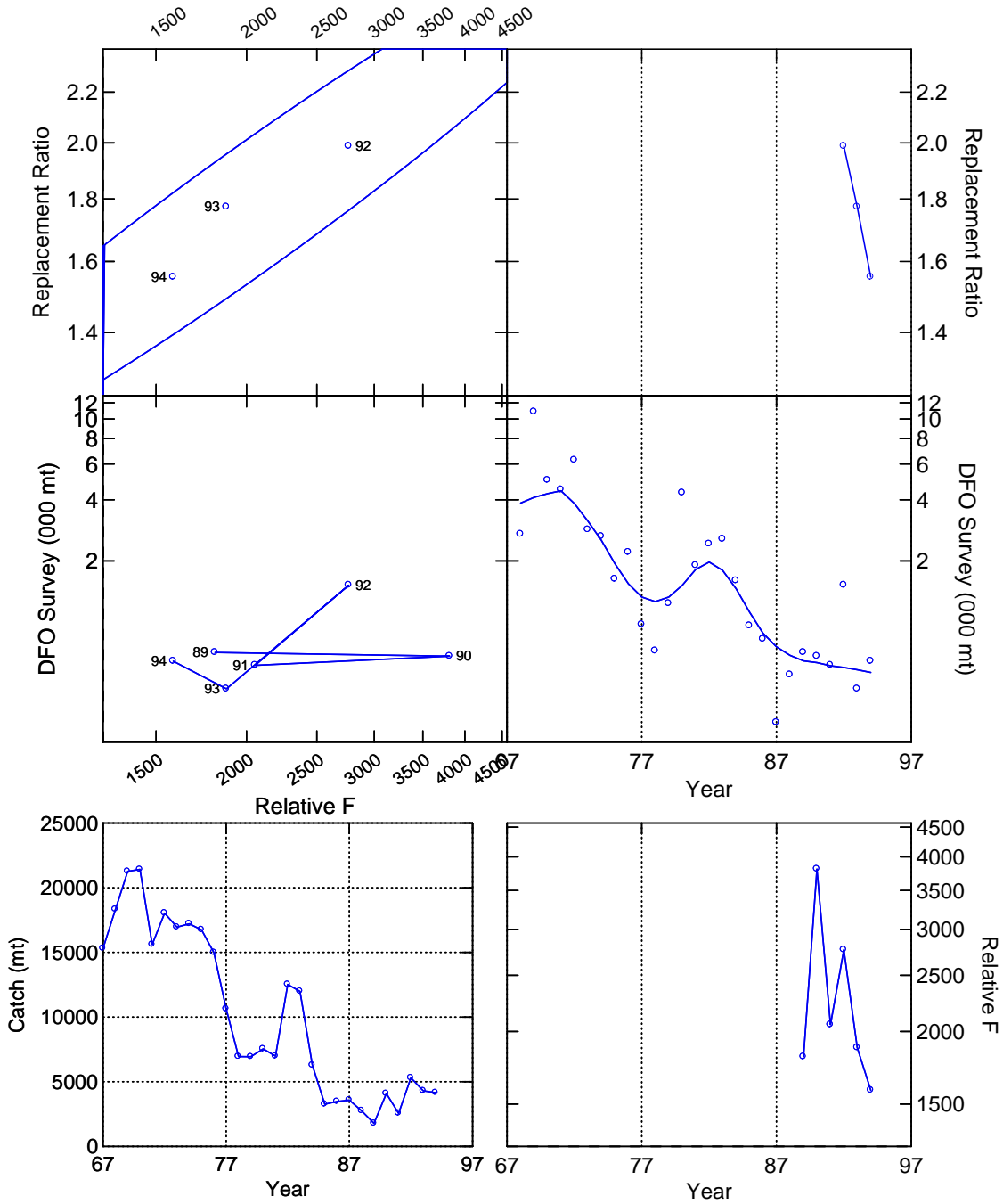
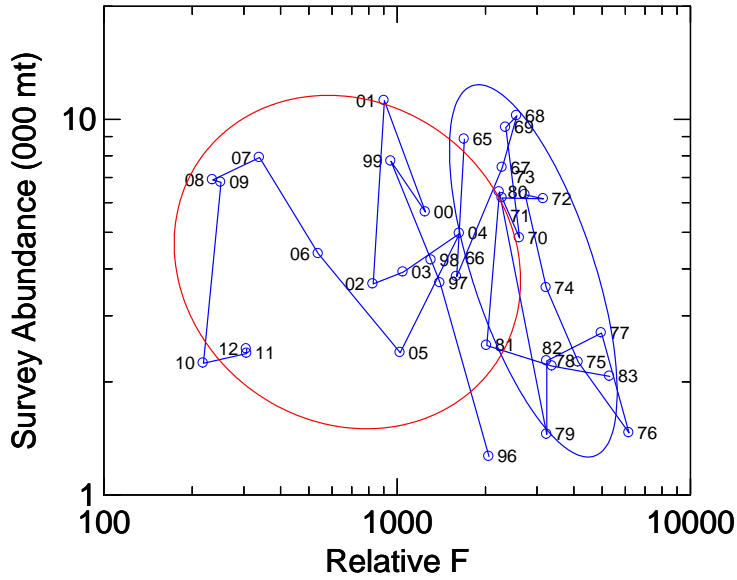


Figure 10. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank yellowtail flounder based on the DFO bottom trawl survey, 1987-1994. Smooth lines in graphs on left side panels represent Lowess smoothes with tension = 0.5. Relative F is defined as current catch over the 3-yr moving average index value. Replacement ratio is defined as current abundance index over the average index of preceding 5 years.

Fall Survey



Fall Survey

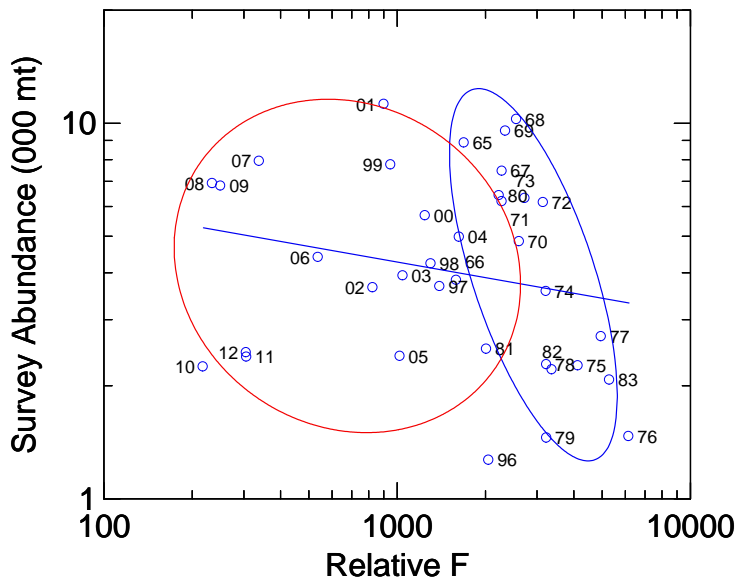
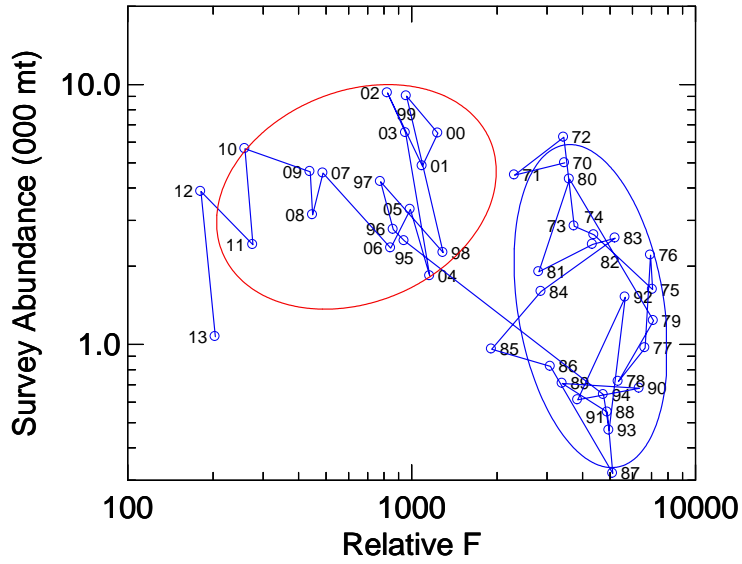


Figure 11. Isocline plots for relative biomass indices vs relative F for NEFSC fall bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1963-1994 and 1995-2012. Bottom panel shows the average isocline that would be estimated from a regression based on both stanzas.

Spring Survey



Spring Survey

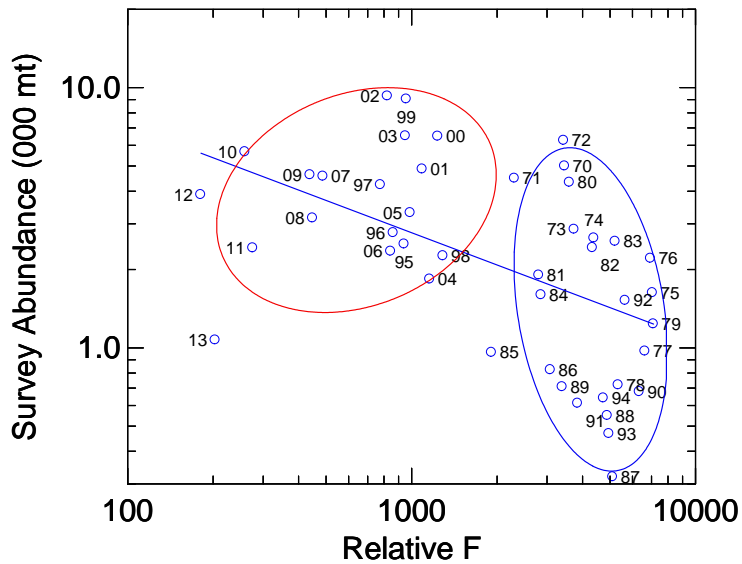
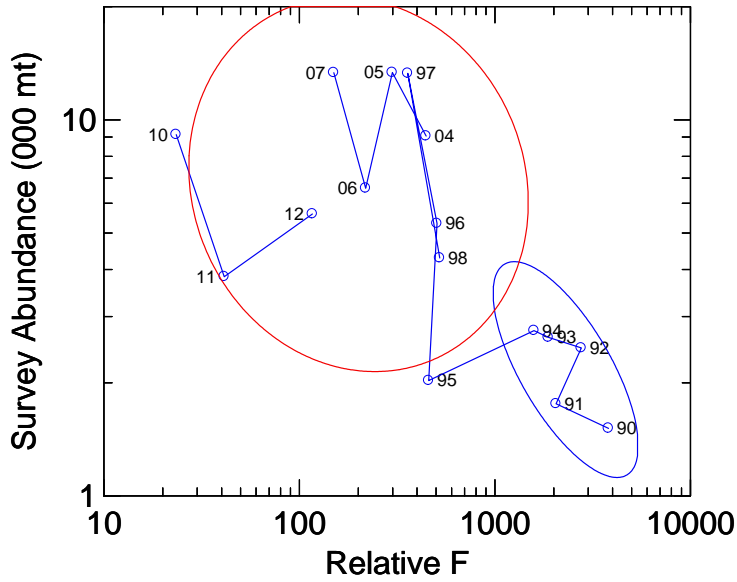


Figure 12. Isocline plots for relative biomass indices vs relative F for NEFSC spring bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1968-1994 and 1995-2013. Bottom panel shows the average isocline that would be estimated from a regression based on both stanzas.

DFO Survey



DFO Survey

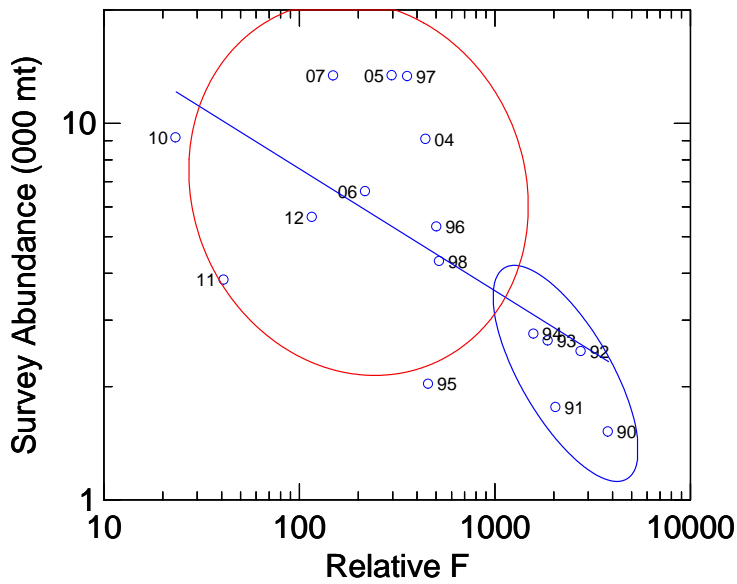


Figure 13. Isocline plots for relative biomass indices vs relative F for DFO bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1987-1994 and 1995-2013. Bottom panel shows the average isocline that would be estimated from a regression based on both stanzas.

Table 1. Summary of Catch, survey and Kalman-smoothed survey data for Georges Bank Yellowtail Flounder 1963-2013

| Catch for 2013 assumed to be 500 mt. | | | | | | | | | | |
|--------------------------------------|-------|---------------------------------------|-----|--------|-----|--------|-----|----------------------------------|--------|-------|
| Year | Catch | Swept Area Biomass Estimates (000 mt) | | | | | | Kalman Smoothed Biomass (000 mt) | | |
| | | Fall | CV% | Spring | CV% | DFO | CV% | Fall | Spring | DFO |
| 1963 | 16690 | 12.413 | 19% | | | | | 6.28 | | |
| 1964 | 19814 | 13.168 | 40% | | | | | 6.28 | | |
| 1965 | 19448 | 8.852 | 32% | | | | | 6.13 | | |
| 1966 | 13741 | 3.813 | 32% | | | | | 5.78 | | |
| 1967 | 15307 | 7.445 | 26% | | | | | 6.20 | | |
| 1968 | 18321 | 10.227 | 23% | 2.709 | 23% | | | 6.42 | 5.11 | |
| 1969 | 21271 | 9.519 | 26% | 10.842 | 29% | | | 6.24 | 5.11 | |
| 1970 | 21410 | 4.833 | 28% | 4.994 | 15% | | | 5.74 | 4.85 | |
| 1971 | 15610 | 6.178 | 21% | 4.483 | 19% | | | 5.52 | 4.46 | |
| 1972 | 18039 | 6.142 | 28% | 6.266 | 21% | | | 5.09 | 4.06 | |
| 1973 | 16953 | 6.299 | 30% | 2.852 | 17% | | | 4.43 | 3.09 | |
| 1974 | 17211 | 3.561 | 19% | 2.64 | 18% | | | 3.46 | 2.56 | |
| 1975 | 16750 | 2.257 | 16% | 1.626 | 22% | | | 2.36 | 1.85 | |
| 1976 | 14988 | 1.463 | 25% | 2.206 | 17% | | | 1.73 | 1.94 | |
| 1977 | 10639 | 2.699 | 20% | 0.97 | 31% | | | 2.33 | 1.08 | |
| 1978 | 6944 | 2.274 | 20% | 0.72 | 19% | | | 2.19 | 0.75 | |
| 1979 | 6935 | 1.45 | 29% | 1.234 | 21% | | | 1.81 | 1.25 | |
| 1980 | 7539 | 6.412 | 22% | 4.325 | 35% | | | 2.68 | 1.87 | |
| 1981 | 6979 | 2.5 | 32% | 1.903 | 33% | | | 2.44 | 2.00 | |
| 1982 | 12520 | 2.203 | 30% | 2.426 | 20% | | | 2.15 | 2.24 | |
| 1983 | 11989 | 2.068 | 22% | 2.564 | 30% | | | 1.79 | 2.10 | |
| 1984 | 6280 | 0.576 | 31% | 1.598 | 43% | | | 0.64 | 1.59 | |
| 1985 | 3267 | 0.688 | 26% | 0.959 | 51% | | | 0.69 | 1.08 | |
| 1986 | 3474 | 0.796 | 37% | 0.823 | 31% | | | 0.75 | 0.80 | |
| 1987 | 3580 | 0.494 | 28% | 0.319 | 37% | 1.25 | 27% | 0.49 | 0.34 | 1.22 |
| 1988 | 2759 | 0.165 | 32% | 0.549 | 26% | 1.235 | 22% | 0.17 | 0.55 | 1.22 |
| 1989 | 1783 | 0.948 | 58% | 0.708 | 26% | 0.471 | 26% | 0.69 | 0.70 | 0.48 |
| 1990 | 4089 | 0.703 | 33% | 0.678 | 32% | 1.513 | 22% | 0.70 | 0.68 | 1.49 |
| 1991 | 2564 | 0.708 | 29% | 0.612 | 25% | 1.758 | 33% | 0.70 | 0.63 | 1.79 |
| 1992 | 5299 | 0.559 | 30% | 1.52 | 46% | 2.475 | 16% | 0.56 | 0.87 | 2.45 |
| 1993 | 4300 | 0.529 | 42% | 0.468 | 26% | 2.642 | 15% | 0.55 | 0.49 | 2.64 |
| 1994 | 4158 | 0.871 | 32% | 0.641 | 22% | 2.753 | 23% | 0.79 | 0.67 | 2.69 |
| 1995 | 1135 | 0.344 | 35% | 2.504 | 60% | 2.027 | 20% | 0.38 | 1.61 | 2.19 |
| 1996 | 1700 | 1.265 | 58% | 2.769 | 31% | 5.303 | 22% | 1.45 | 2.36 | 4.82 |
| 1997 | 2464 | 3.67 | 35% | 4.231 | 24% | 13.293 | 23% | 2.73 | 2.85 | 6.34 |
| 1998 | 3985 | 4.22 | 34% | 2.256 | 22% | 4.293 | 24% | 3.67 | 2.73 | 5.55 |
| 1999 | 4963 | 7.738 | 21% | 9.033 | 42% | 17.666 | 32% | 4.45 | 3.45 | 8.40 |
| 2000 | 7341 | 5.666 | 49% | 6.499 | 23% | 19.949 | 25% | 4.51 | 3.99 | 10.36 |
| 2001 | 7419 | 11.213 | 40% | 4.859 | 33% | 22.158 | 42% | 4.47 | 4.00 | 11.12 |
| 2002 | 5663 | 3.644 | 51% | 9.282 | 26% | 20.699 | 31% | 4.22 | 3.84 | 11.46 |
| 2003 | 6562 | 3.919 | 33% | 6.524 | 40% | 16.249 | 32% | 4.08 | 3.24 | 11.06 |
| 2004 | 6815 | 4.966 | 46% | 1.835 | 27% | 9.054 | 31% | 4.00 | 2.41 | 10.03 |
| 2005 | 3851 | 2.391 | 52% | 3.307 | 33% | 13.357 | 53% | 3.80 | 2.65 | 9.40 |
| 2006 | 2109 | 4.388 | 27% | 2.349 | 19% | 6.579 | 44% | 4.16 | 2.63 | 8.51 |
| 2007 | 1662 | 7.912 | 31% | 4.563 | 22% | 13.344 | 43% | 4.42 | 3.29 | 8.35 |
| 2008 | 1504 | 6.9 | 28% | 3.152 | 22% | 67.319 | 94% | 4.32 | 3.33 | 7.72 |
| 2009 | 1806 | 6.797 | 27% | 4.619 | 22% | 72.044 | 79% | 3.82 | 3.55 | 7.03 |
| 2010 | 1160 | 2.242 | 30% | 5.662 | 27% | 9.138 | 29% | 2.80 | 3.28 | 6.29 |
| 2011 | 1169 | 2.38 | 26% | 2.419 | 23% | 3.83 | 29% | 2.54 | 2.54 | 4.28 |
| 2012 | 722 | 2.446 | 47% | 3.878 | 49% | 5.62 | 36% | 2.51 | 1.97 | 3.40 |
| 2013 | 500 | | | 1.071 | 21% | 0.698 | 33% | | 1.16 | 0.74 |

Table 2. Relative F and Replacement ratios for Georges Bank Yellowtail Flounder, 1963-2013

| Relative F is based on a 3 yr lagged moving average. | | | | | | |
|--|------------|--------|--------|-------------------|--------|-------|
| Replacement ratio is current year biomass over average of previous 5 years | | | | | | |
| Year | Relative F | | | Replacement Ratio | | |
| | Fall | Spring | DFO | Fall | Spring | DFO |
| 1963 | | | | | | |
| 1964 | | | | | | |
| 1965 | 1694.4 | | | | | |
| 1966 | 1595.7 | | | | | |
| 1967 | 2283.5 | | | | | |
| 1968 | 2558.2 | | | 1.119 | | |
| 1969 | 2346.8 | | | 1.094 | | |
| 1970 | 2613.2 | 3463.5 | | 0.606 | | |
| 1971 | 2281.1 | 2304.7 | | 0.862 | | |
| 1972 | 3155.0 | 3437.5 | | 0.804 | | |
| 1973 | 2731.6 | 3739.4 | | 0.854 | 0.487 | |
| 1974 | 3226.7 | 4391.3 | | 0.540 | 0.448 | |
| 1975 | 4147.1 | 7059.6 | | 0.418 | 0.383 | |
| 1976 | 6175.5 | 6947.5 | | 0.299 | 0.617 | |
| 1977 | 4972.3 | 6646.6 | | 0.684 | 0.311 | |
| 1978 | 3236.8 | 5347.0 | | 0.698 | 0.350 | |
| 1979 | 3239.1 | 7115.3 | | 0.592 | 0.756 | |
| 1980 | 2231.4 | 3602.0 | | 3.161 | 3.201 | |
| 1981 | 2020.6 | 2805.8 | | 0.874 | 1.006 | |
| 1982 | 3379.2 | 4340.2 | | 0.718 | 1.325 | |
| 1983 | 5311.9 | 5217.9 | | 0.697 | 1.209 | |
| 1984 | 3886.9 | 2859.7 | | 0.197 | 0.642 | |
| 1985 | 2941.5 | 1913.9 | | 0.250 | 0.374 | |
| 1986 | 5059.2 | 3083.4 | | 0.495 | 0.435 | |
| 1987 | 5429.7 | 5111.9 | | 0.390 | 0.191 | |
| 1988 | 5688.7 | 4894.7 | | 0.178 | 0.438 | |
| 1989 | 3328.6 | 3394.0 | 1809.5 | 1.743 | 0.833 | |
| 1990 | 6755.0 | 6339.5 | 3810.8 | 1.137 | 1.010 | |
| 1991 | 3260.7 | 3849.8 | 2055.6 | 1.140 | 0.994 | |
| 1992 | 8069.5 | 5657.3 | 2766.6 | 0.926 | 2.652 | 1.987 |
| 1993 | 7182.6 | 4961.5 | 1876.4 | 0.858 | 0.575 | 1.773 |
| 1994 | 6367.5 | 4744.8 | 1585.0 | 1.263 | 0.804 | 1.554 |
| 1995 | 1952.4 | 942.4 | 458.8 | 0.510 | 3.195 | 0.910 |
| 1996 | 2056.5 | 862.4 | 505.8 | 2.101 | 2.410 | 2.275 |
| 1997 | 1400.3 | 777.8 | 358.4 | 5.143 | 2.677 | 4.373 |
| 1998 | 1305.8 | 1291.6 | 522.3 | 3.159 | 1.063 | 0.825 |
| 1999 | 952.7 | 959.3 | 422.4 | 3.731 | 3.642 | 3.192 |
| 2000 | 1249.6 | 1238.1 | 525.5 | 1.644 | 1.563 | 2.342 |
| 2001 | 904.1 | 1091.5 | 372.4 | 2.485 | 0.980 | 1.831 |
| 2002 | 827.8 | 823.1 | 270.5 | 0.560 | 1.727 | 1.338 |
| 2003 | 1048.5 | 952.6 | 333.1 | 0.603 | 1.022 | 0.958 |
| 2004 | 1631.8 | 1158.9 | 444.4 | 0.772 | 0.253 | 0.468 |
| 2005 | 1024.6 | 990.3 | 298.8 | 0.407 | 0.570 | 0.758 |
| 2006 | 538.7 | 844.6 | 218.2 | 0.840 | 0.455 | 0.404 |
| 2007 | 339.4 | 487.9 | 149.8 | 2.049 | 0.979 | 1.012 |
| 2008 | 235.0 | 448.3 | 51.7 | 1.463 | 0.848 | 5.746 |
| 2009 | 250.7 | 439.3 | 35.5 | 1.280 | 1.519 | 3.285 |
| 2010 | 218.3 | 259.1 | 23.4 | 0.395 | 1.574 | 0.265 |
| 2011 | 307.1 | 276.1 | 41.3 | 0.421 | 0.594 | 0.114 |
| 2012 | 306.5 | 181.1 | 116.5 | 0.466 | 0.950 | 0.170 |
| 2013 | | 203.6 | 147.8 | | 0.271 | 0.022 |