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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 graphical and empirical 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 presented at the Diagnostic and Empirical Approach Benchmark for Georges Bank Yellowtail Flounder. 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 autoregressive integrated moving average (ARIMA) or Lowess methods, the Kalman filter explicitly incorporates the uncertainty of the annual observations into the smooth.

The simple relative fishing mortality rate at time t ($relF_t$) is defined as the ratio of catch at time (C_t) to the relative abundance index at the same time (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:

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

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.

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

When rates of loss are dominated by removals by the fishery then Ψ_t and $relF_t$ 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 increased 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). However, the comparison between the VPA and Kalman estimates in recent years is confounded by the retrospective pattern in the VPA.

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 variables 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 relative F (upper left panel of each figure) is weak. Some insight into the underlying causes for this pattern may be 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 biomass 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 a problem 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. 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.

These simple model results, using only catch and survey data, suggest a change in underlying relationship between abundance and exploitation. While the 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.

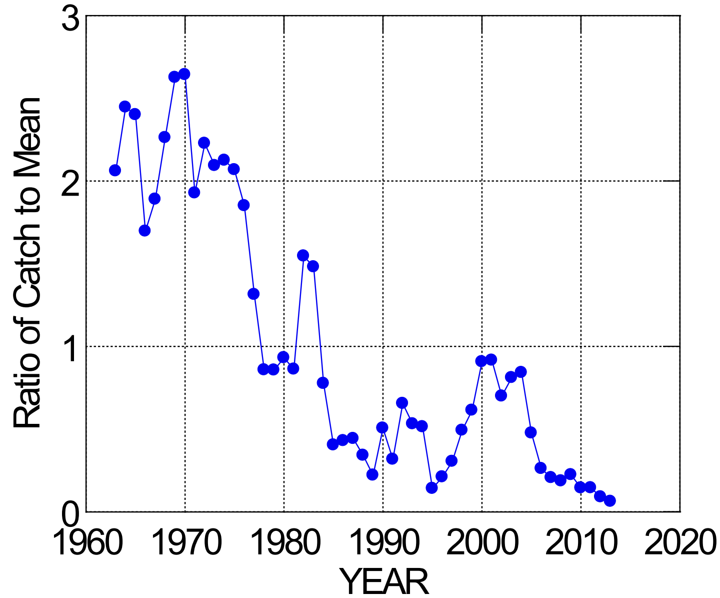
Table 1. Summary of catch, survey and Kalman-smoothed survey data for Georges Bank Yellowtail Flounder 1963-2013. Catch for 2013 assumed to be 500 mt.

		Swept Area Biomass Estimates (000 mt)						***Kalman Smoothed Biomass (000 mt)***		
Year	***Catch***	***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 year lagged moving average. Replacement ratio is current year biomass over average of previous 5 years.

	Relative F			*Replacement Ratio*		
Year	***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

Normalized Catch relative to Mean, 1963-2013



Normalized Survey Abundance Indices(X/mean)

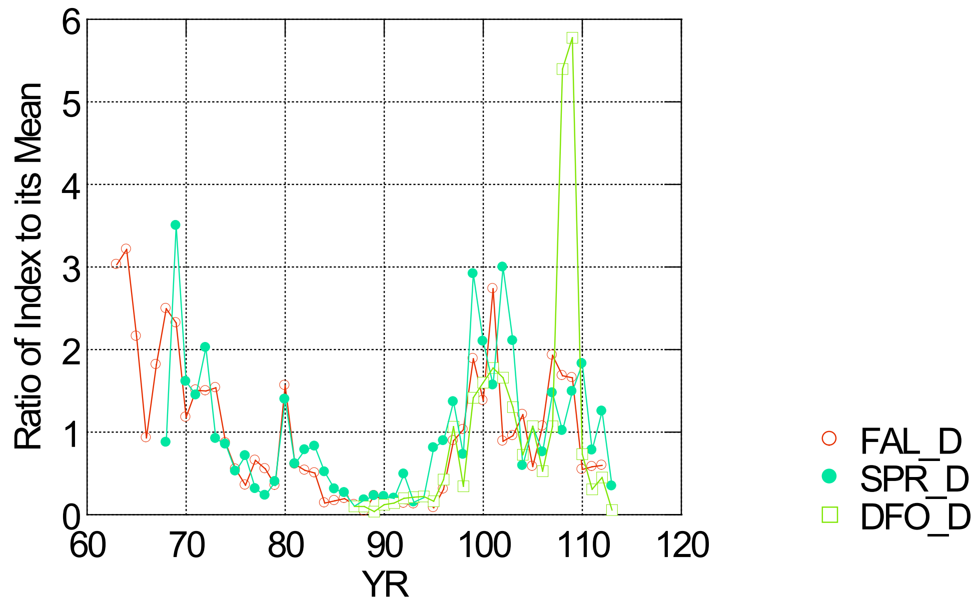


Figure 1. Normalized catch and survey information for 1963-2013. Values are expressed as the ratio of the respective means for each time series.

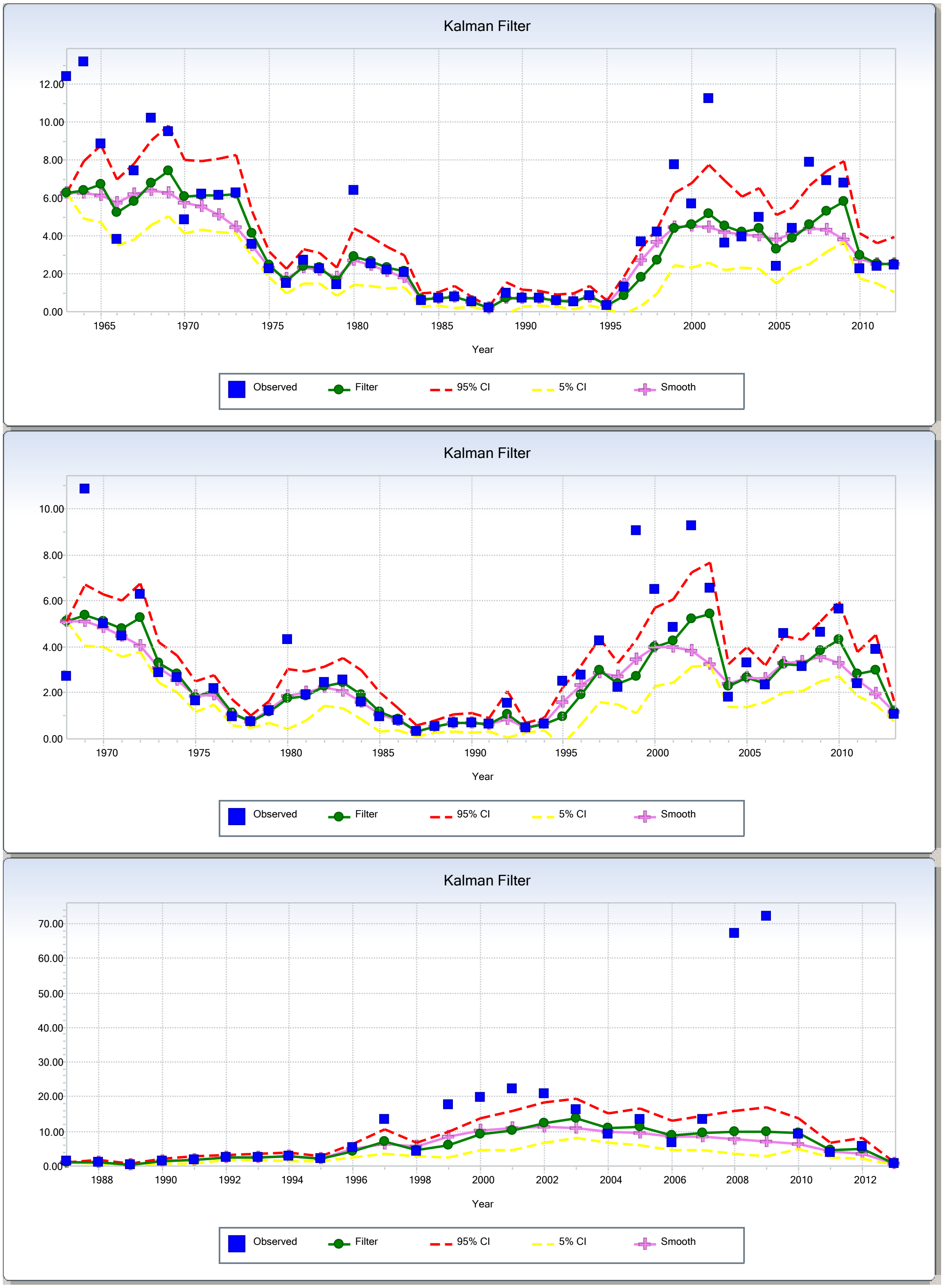
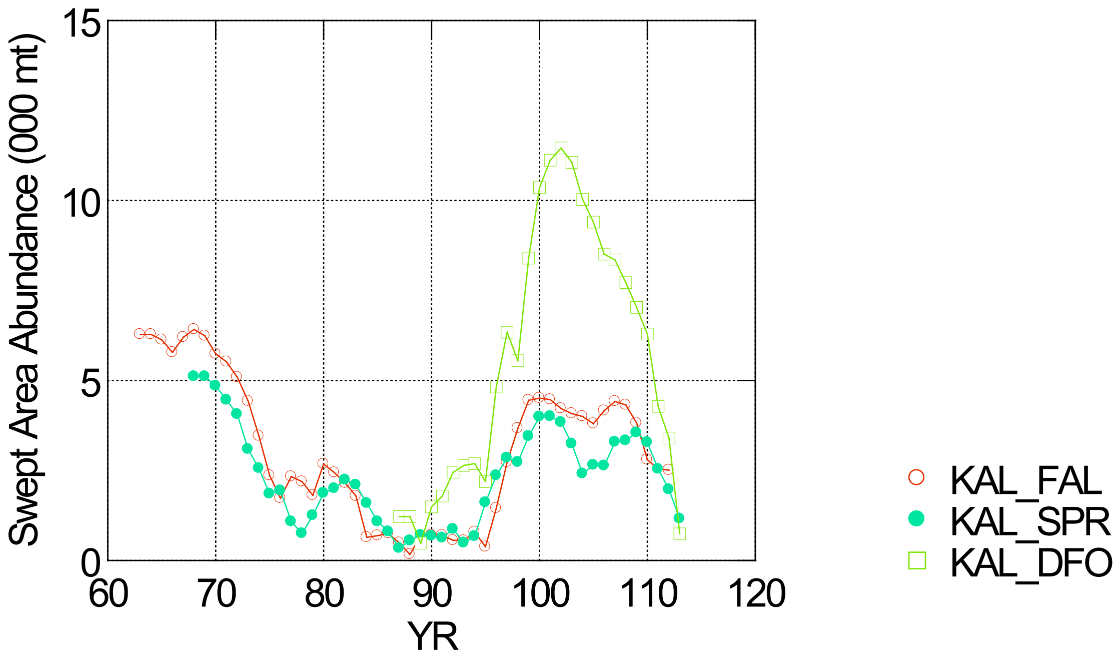


Figure 2. Summary of Kalman smoothed abundance estimate for NEFSC fall (top), NEFSC spring (middle), and DFO (bottom) trawls survey indices. Indices are expressed

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)

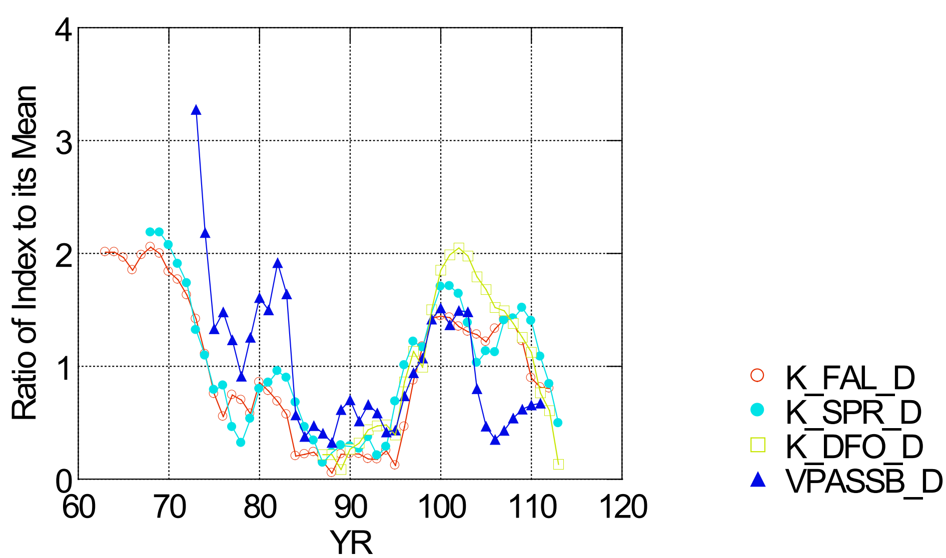
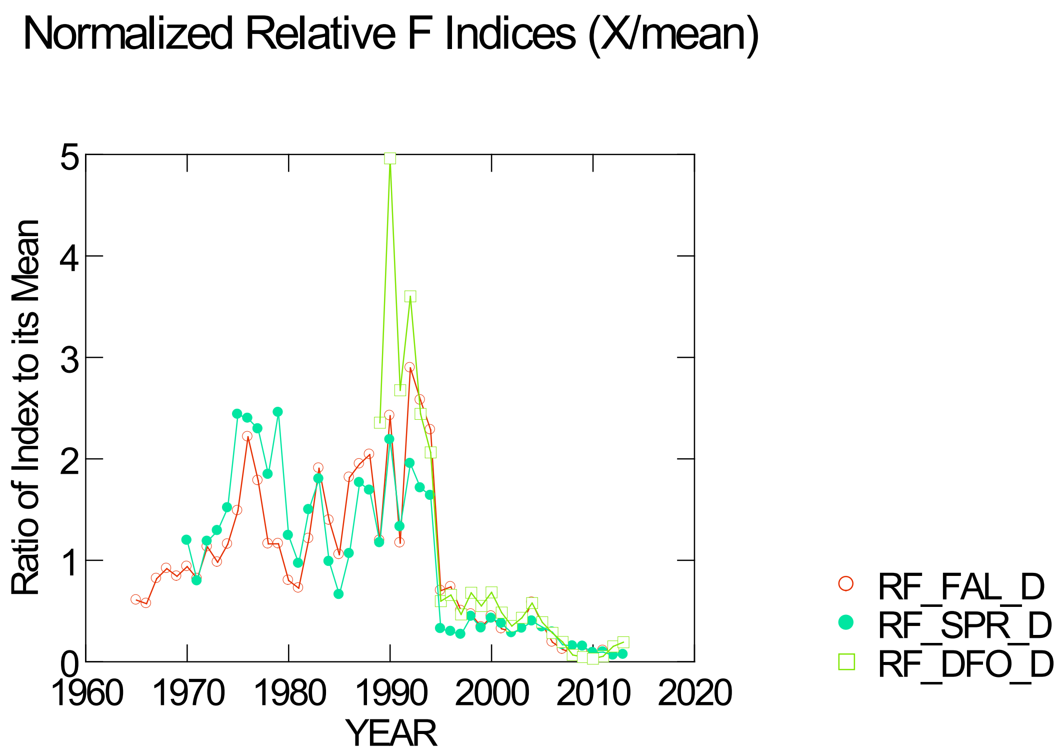


Figure 3. Summary of Kalman smoothed swept area abundance estimates (upper panel) for bottom trawl survey indices and comparison with VPA estimates of abundance (lower panel). Note that years are found by adding 1900 to YR values (e.g., YR 60 equals year 1960).



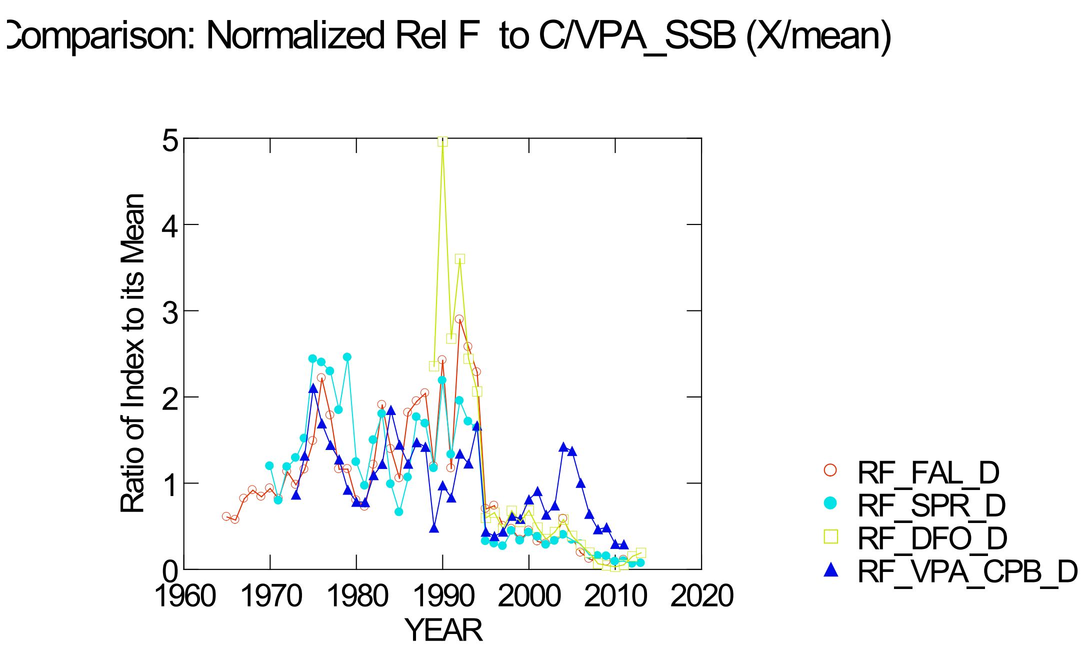


Figure 4. Comparison of relative F estimates based on the NEFSC fall and spring, and the DFO bottom trawls surveys (upper panel) and VPA estimates (catch/SSB; bottom panel). All indices are normalized by dividing the observed value by the mean of the time series.

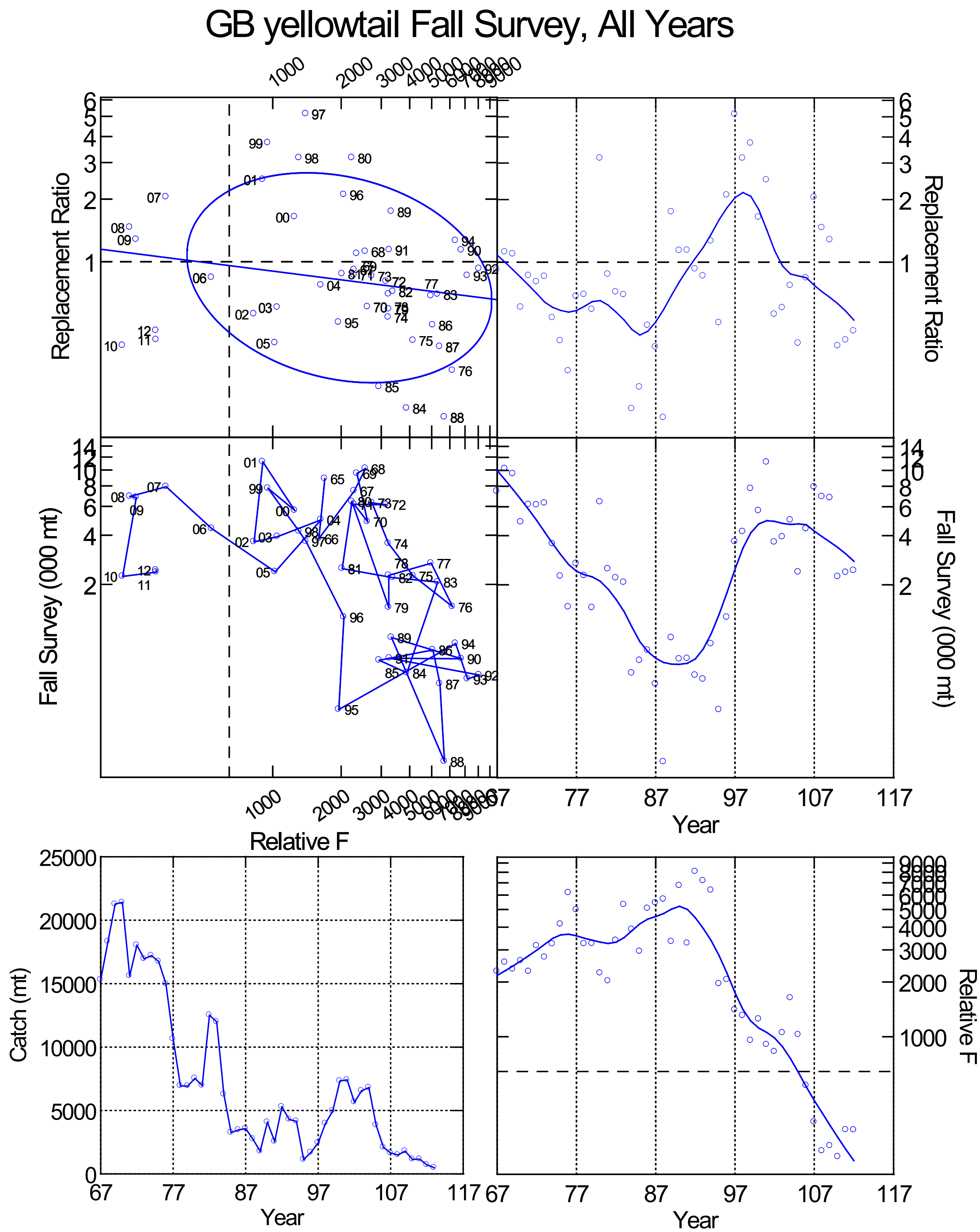


Figure 5. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the NEFSC fall bottom trawl survey, 1963-2012. Upper left panel shows linear regression and 75% confidence ellipse. Smooth lines in graphs on right side panels represent Lowess 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.

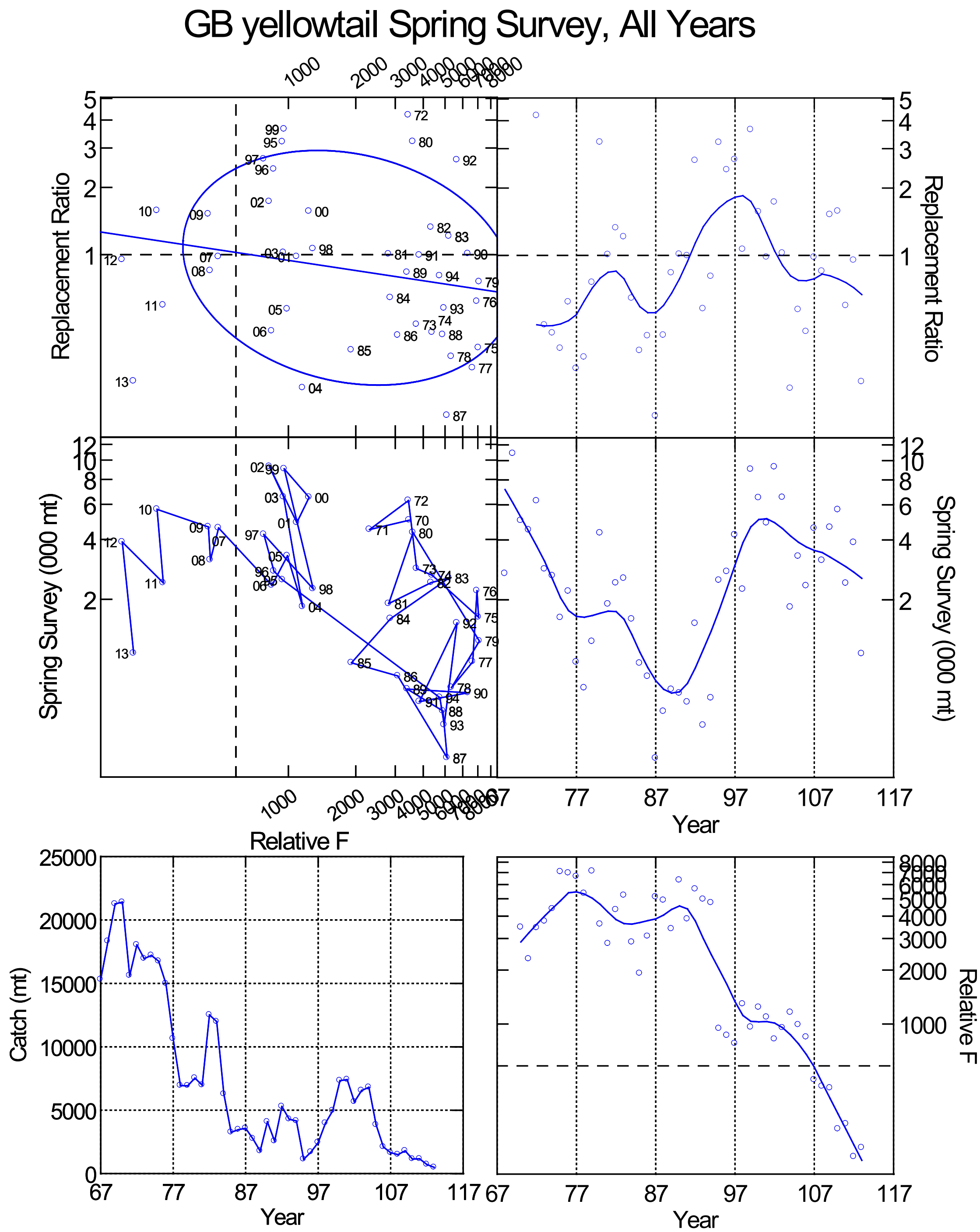


Figure 6. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the NEFSC spring bottom trawl survey, 1968-2013. Upper left panel shows linear regression and 75% confidence ellipse. Smooth lines in graphs on right side panels represent Lowess 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.

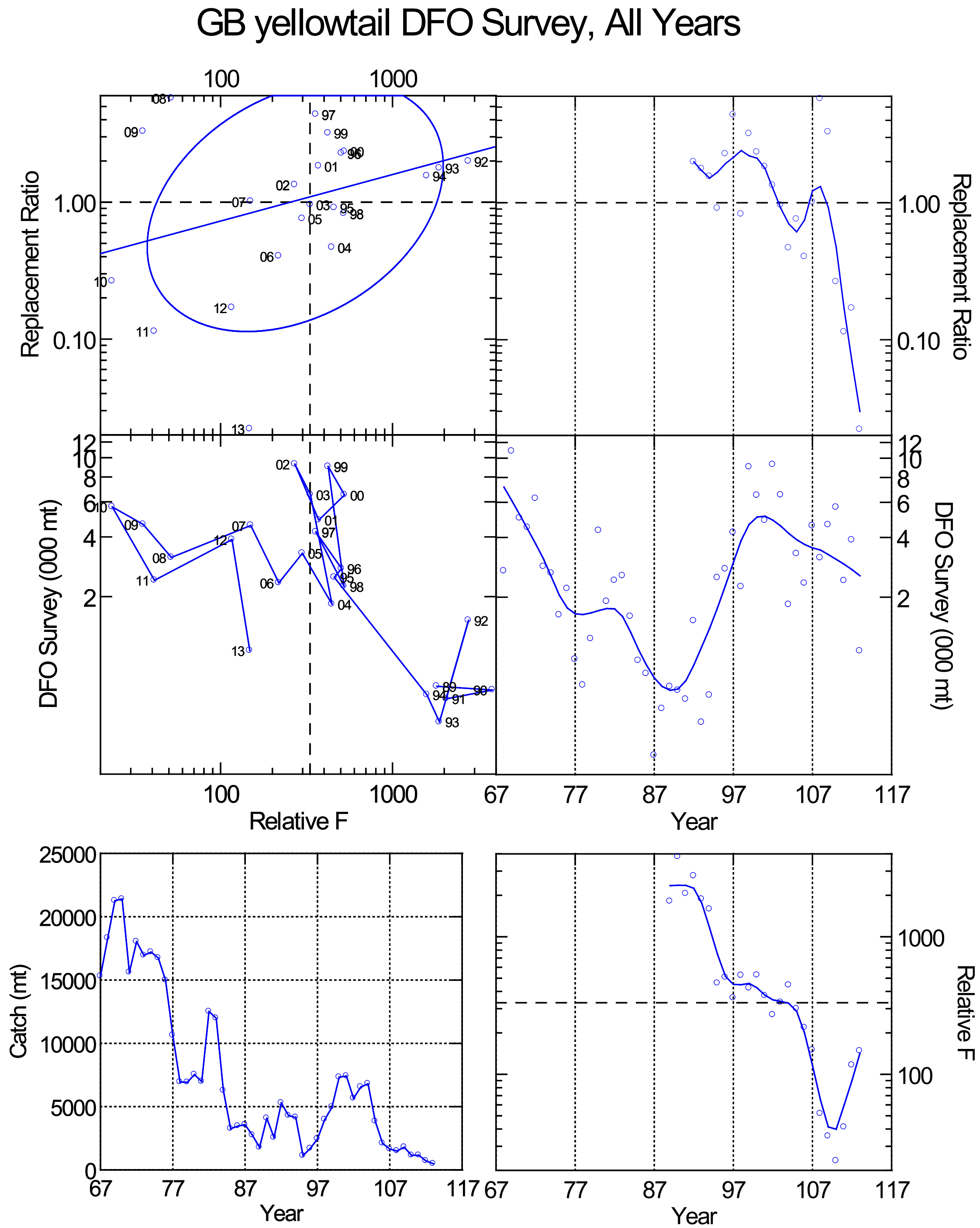


Figure 7. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the DFO bottom trawl survey, 1987-2013. Upper left panel shows linear regression and 75% confidence ellipse. Smooth lines in graphs on right side panels represent Lowess smoothes 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.

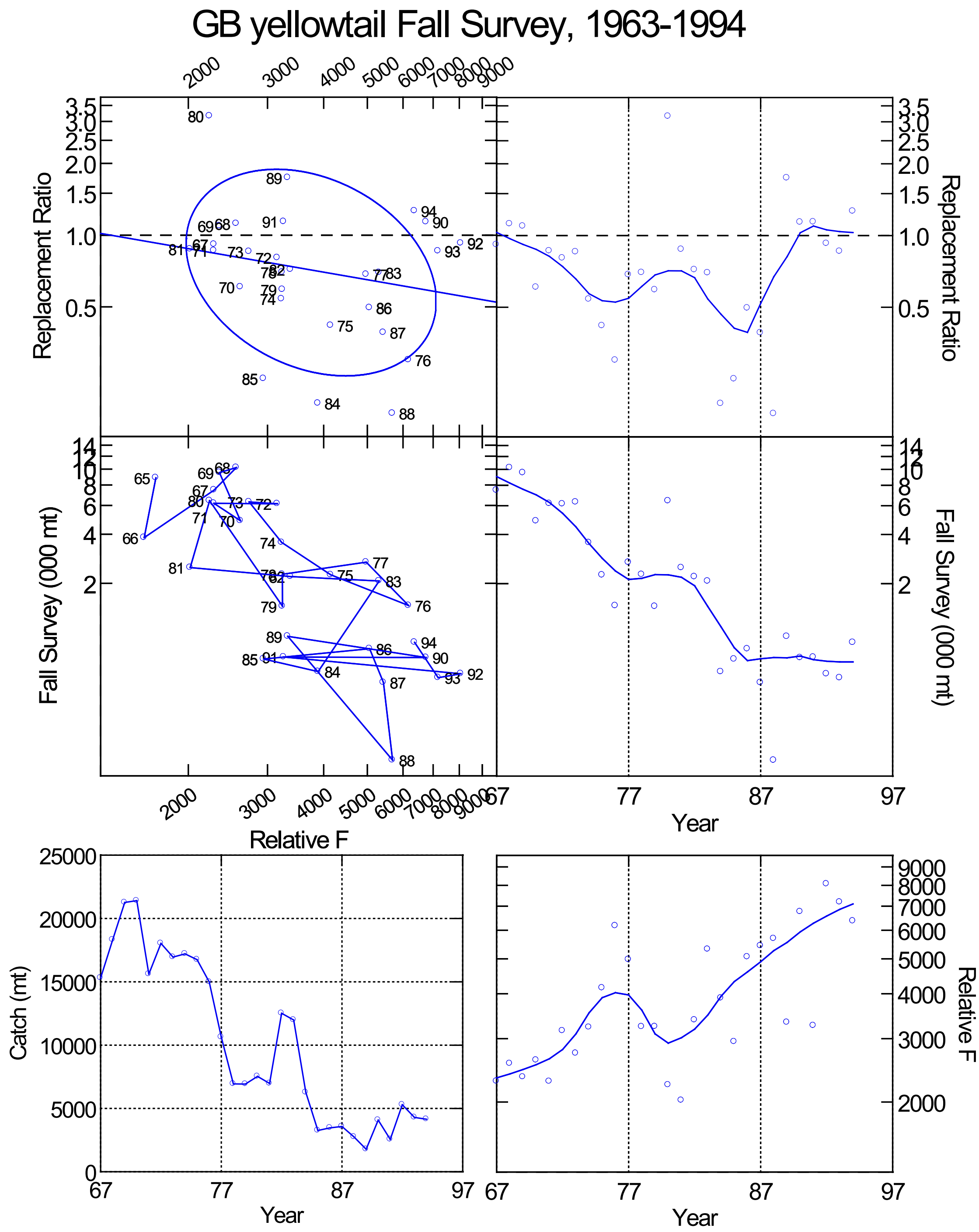


Figure 8. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the NEFSC fall bottom trawl survey, 1963-1994. Smooth lines in graphs on right side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch over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

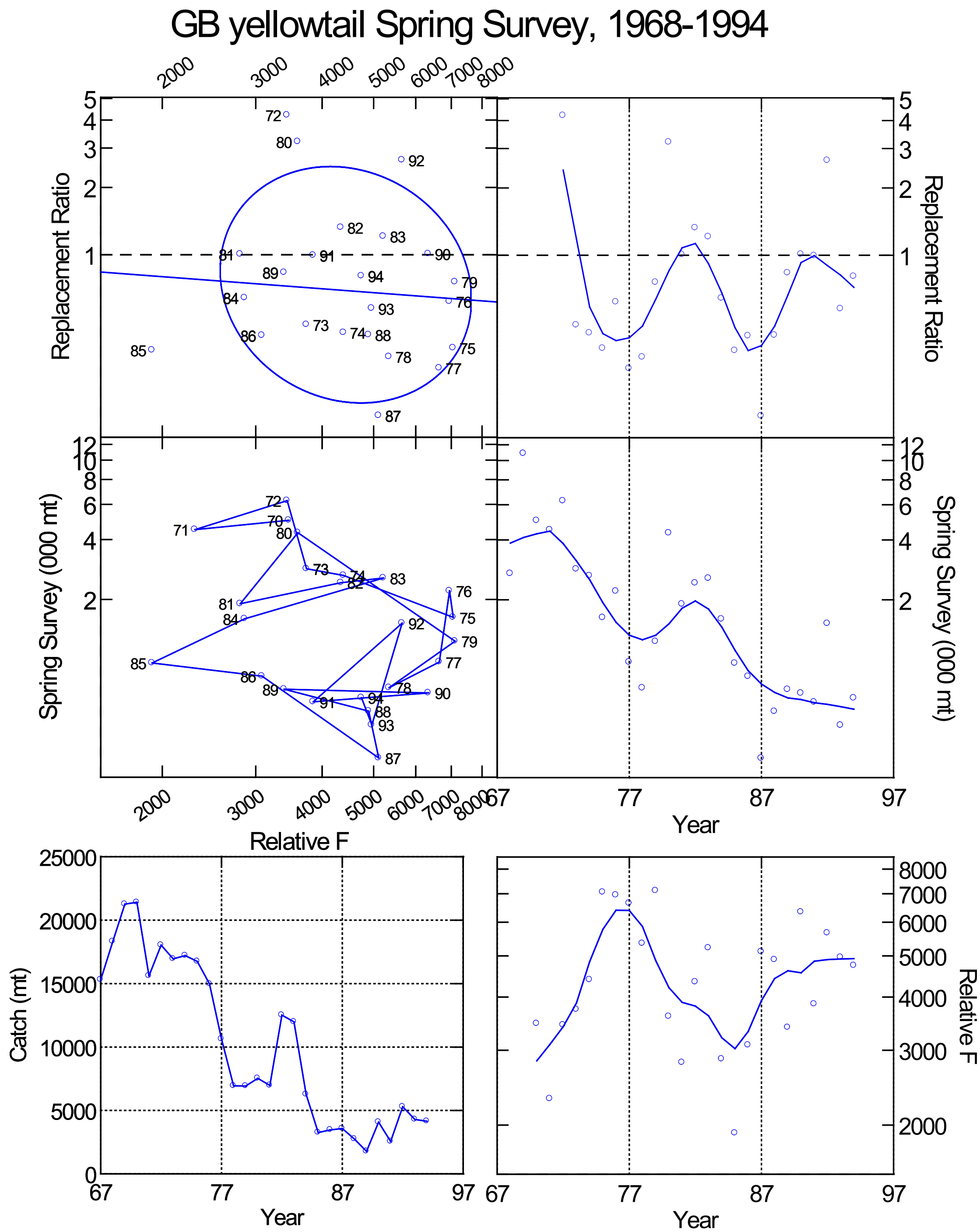


Figure 9. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the NEFSC spring bottom trawl survey, 1968-1994. Smooth lines in graphs on right side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch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

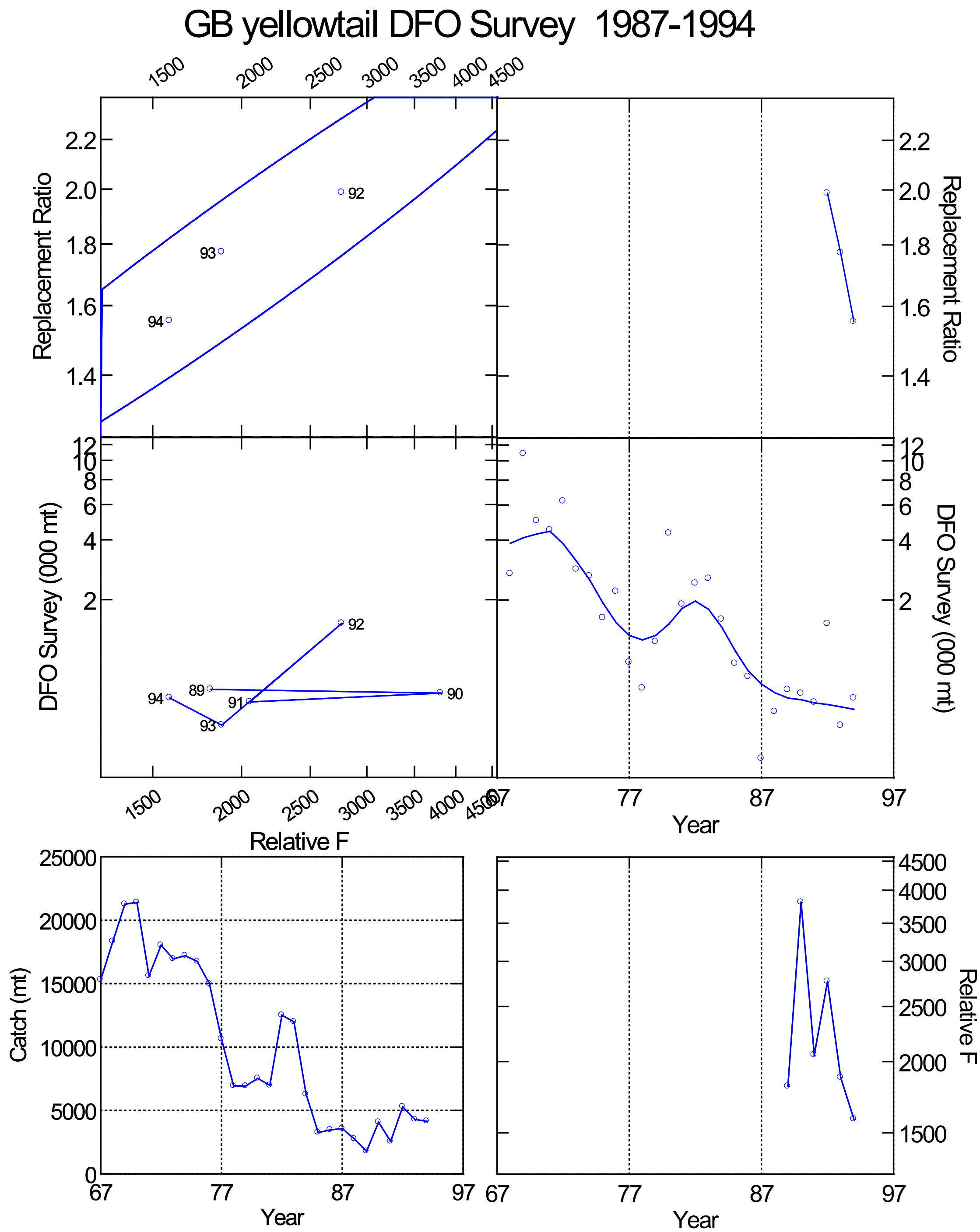


Figure 10. Trends in relative biomass, catch, relative F and replacement ratio for Georges Bank Yellowtail Flounder based on the DFO bottom trawl survey, 1987-1994. Smooth lines in graphs on right side panels represent Lowess smoothes with tension =0.5. Relative F is defined as current catch over the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

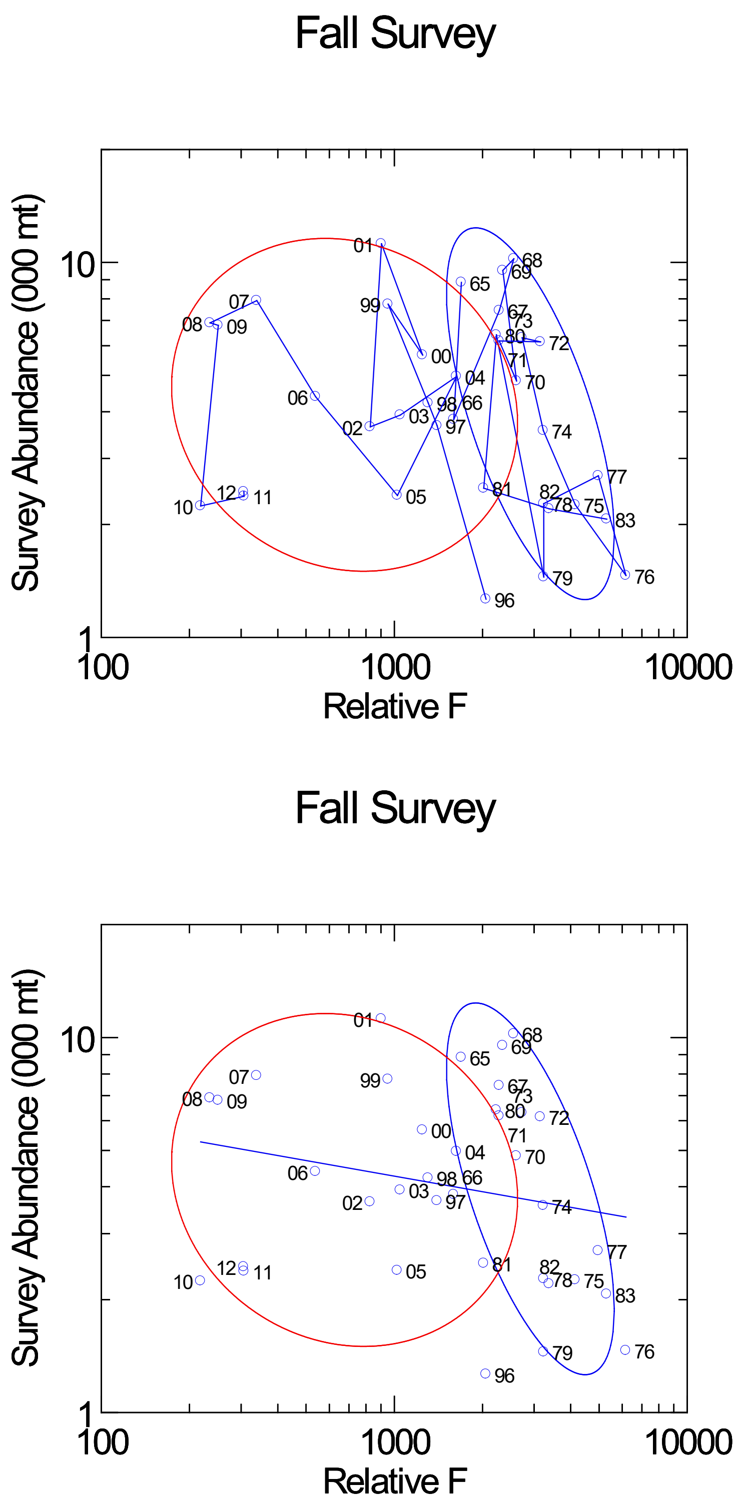
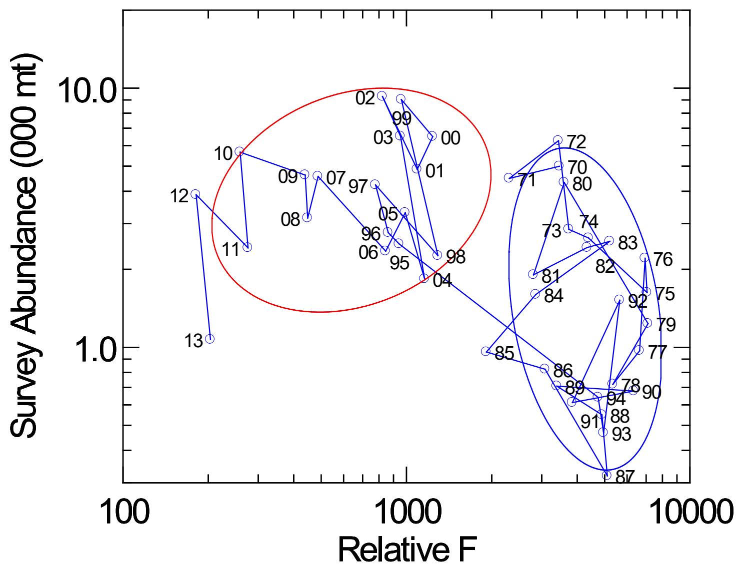


Figure 11. Isocline plots for relative biomass indices vs relative F for NEFSC fall bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1963-1994 and 1995-2012. Bottom panel shows the average isocline that would be estimated from a regression based on both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

Spring Survey



Spring Survey

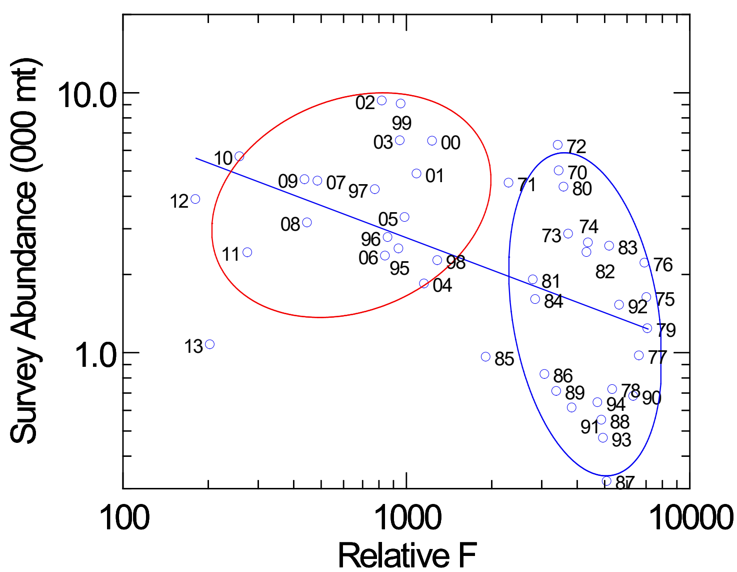
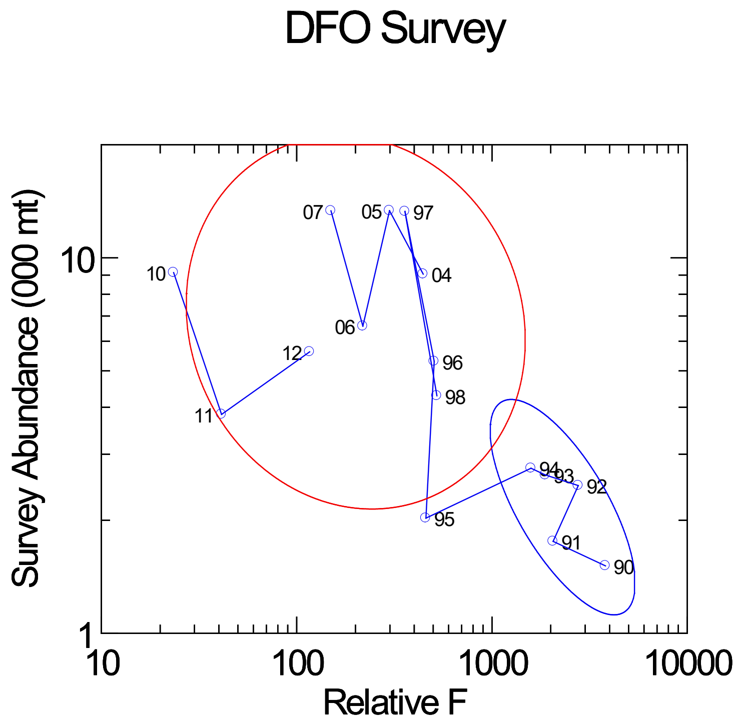


Figure 12. Isocline plots for relative biomass indices vs relative F for NEFSC spring bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1968-1994 and 1995-2013. Bottom panel shows the average isocline that would be estimated from a regression based on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



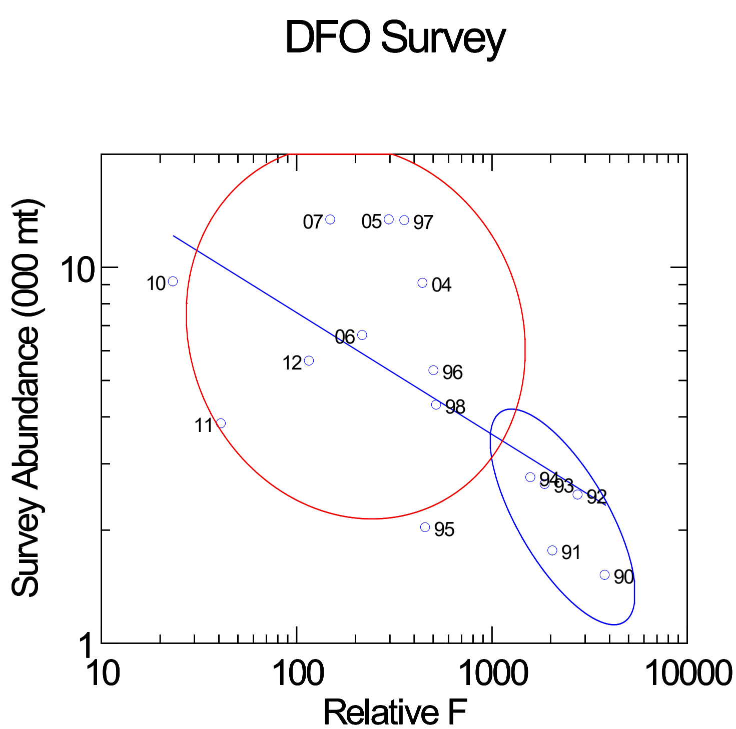


Figure 13. Isocline plots for relative biomass indices vs relative F for DFO bottom trawl survey. Top panel shows time series of values and the 75% confidence ellipse represent 1987-1994 and 1995-2013. Bottom panel shows the average isocline that would be estimated from a regression based on both stanzas.