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Recent Declines in Cod Stocks in the Northwest Atlantic

by

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SYMPOSIUM ON ANOMALOUS OCEANOGRAPHIC CONDITIONS

Introduction

The groundfish industry in the NAFO area is currently in an deep crisis. Cod fisheries in Subareas 2,3 and Divisions 4RSTVW are closed to directed fishing. Canadian cod quotas in Divisions 4X and 5Z have been reduced. Groundfish fisheries off the northeast USA are also in a state of crisis with cod, haddock and yellowtail flounder stocks at historic low levels (Anon. 1993). That so many fisheries are in trouble at the same time suggests that there are large scale similarities in production among groundfish stocks in the northwest Atlantic. It is important to consider the relative importance of natural and human influences on these trends.

Several recent studies address the issue of environmental forcing and synchrony in production of cod and haddock stocks in the NAFO area but there is some debate on appropriate statistical methods. Koslow (1984) and Koslow et al. (1987) analyzed recruitment time series for several gadoid stocks in the NAFO area. When testing for independence of the recruitment time series, they adjusted the degrees of freedom to account for autocorrelation. They concluded that there were coherent, low-frequency patterns in year-class success of most cod and haddock stocks which resulted from environmental forcing independent of parent stock size. They were unable, however, to single out any particular environmental or biological variable. The analysis was repeated by Cohen et al. (1991) with some additional datasets and using first differencing to detrend the time series. This consists of constructing new series as the differences in adjacent observations. Their conclusion was that there similarities among some stocks but at a much reduced spatial scale. They grouped cod stocks in Subarea 1, Div. 2J3KL, 3NO, and 3Ps separately from cod in Div. 4TVn, 4VsW, 4X, and 5Z. It should be noted that Koslow's analyses did not include the Div. 4TVn, 4X, and 5Z stocks. Thompson and Page (1989) reanalyzed the same cod and haddock recruitment series used by Koslow but after first differencing. They concluded that there was intraspecific synchrony in recruitment but that the cod and haddock trends were independent. They too conclude that the recruitment patterns are independent of parent stock size. They note, however, that the technique of first differencing attenuates low-frequency signals in the data and may in fact mask important variations at this time scale.

It is clear that fishing will also affect stock trends. High fishing mortality (F) will reduce adult biomass and all cod stocks in the northwest Atlantic have been fished above the $F_{0.1}$ target level. The effects of high F on subsequent recruitment are less clear. Empirical relationships between spawning stock size and recruitment are generally poor suggesting that the two may be independent. On the other hand, several factors may mask the underlying relationships. The range of observed stock states may insufficient and the measurement process may not be precise enough to detect the true situation. If environmental forcing is the cause of the observed synchrony in recruitment, does it function independently of egg production? If so, then reduced egg production would produce fewer recruits, all other things remaining equal.

I will examine trends in stock state variables for 8 cod stocks within the Canadian portion of the NAFO area in an attempt to address the possible causes of the recent declines in biomass. The variables examined include biomass, recruitment, weights at age, fishing mortality, and pre-recruit survival rate. The last variable is the number of commercial aged recruits per unit spawning biomass. Serebryakov (1990) refers to this as the year-class survival rate.

Materials and Methods

Stock assessment data were obtained for eight cod stocks in the Canadian portion of the NAFO area, those in Div. 2J3KL, 3NO, 3Ps, 3Pn4RS, 4TVn(J-A), 4VsW, 4X, and 5Zjm. The variables of interest were spawning stock biomass (SSB), recruitment, and fishing mortality. Table 1 summarizes the sources of these data, the time periods covered, and the age relevant age groups. SSB estimates for most stocks are based on a knife-edged age of maturity determined from maturity data from research vessel surveys. Maturity ogives were used for Div. 2J3KL and 3NO cod (Shelton and Morgan 1993 Shelton and Morgan 1994). However, work is ongoing in other Canadian DFO laboratories to estimate annual maturity ogives for several other stocks. Consequently, the SSB data presented here will probably be modified in the near future. Recruitment estimates were taken from the first age in the respective sequential population analyses (SPA). This was age 3 for all stocks except 4VsW, 4X, and 5Zjm where age 1 estimates were available. Fishing mortalities (F) were calculated as the average over an age range considered to be fully recruited. An exception was made for 3NO cod. The assessment document used ages 7-10 as fully recruited. However, when I examined the table of fishing mortalities, the pattern was domed shaped with respect to age, and in the majority of years the F at ages 5 and 6 were higher than the age 7-10 average. I used a multiplicative model with age and year effects to re-estimate the trend in F. All ages were included (3-13) and the annual value was standardized to age 6. The 2 trends were similar, however the multiplicative estimates indicated a greater increase in F during the late 1980's and early 1990's than the age 7-10 average.

An index of pre-recruit survival was calculated as the ratio of recruits divided by SSB, much the same as Serebryakov (1990) . This index would include both density dependent and density independent sources of mortality as well as any associated measurement error. With the exception of Div. 2J3KL cod (Rice and Evans 1988), there are no strong relationships between stock and recruitment among these cod stocks. The survival index may thus represent variations in extrinsic effects on year-class size.

The trends in stock state variables were compared using correlation analysis. These time series tend to be autocorrelated and some care is required in applying statistical tests of independence. Cohen et al. 1991 recommend detrending the time by calculating a new series based on the differences between successive observations (first differences). Thompson and Page (1989) note, however, that such a transformation attenuates low frequency variations and may consequently remove important synchronous signals at this time scale. Both authors recommend examination of log-transformed data to stabilize variance and so that the data sets approximate the normal distribution. Myers et al. (1990) present a third transformation which removes any long term linear trends in the series. I will present correlations of the ln transformed, first differenced, and detrended series. The latter two transformations are;

First Differences $\nabla \ln X_t = \ln X_{t+1} - \ln X_t$

where X_t is the estimate of variable X (SSB, recruitment, or pre-recruit survival) in year t

Detrended $d \ln X_t = \ln X_t - a - bt$

where a and b are the intercept and slope of the linear relationship between variable X and year.

Results

Adult Biomass

Trends in adult biomass for the northern stocks (2J3KL, 3NO, 3Ps, 3Pn4RS, 4TVn, 4VsW) had several similar features (Figure 1). There was a gradual decline through the period up to 1970 followed by a rapid decline to a low point in the mid-1970's. There were rapid increases in the late 1970's followed by a period of relative stability. The biomass then began to decline in the late 1980's and in several cases continued to decline to an historic low in the most recent year (1992). The largest relative decline during the 1960's occurred for Div. 2J3KL cod.

The pattern for Div. 4X cod was different in that three cycle in biomass are evident with peaks in 1966, 1980, and 1990. The time series for 5Zjm cod is quite short but it corresponds well with that for Div. 4X. The amplitude of the variations in biomass for these southern stocks is less than that for the northern stocks.

The correlations among the biomass series indicate two groups of stocks, the six northern stocks and the two Gulf of Maine stocks (Figure 2). This pattern is most evident in the ln transformed and detrended series. The Div. 3Pn4S series is a weak member of the former group. Taking the first differences of the ln SSB removed the general downward trends in several series (e.g. Div. 2J3KL) while maintaining the decadal scale variations in the original time series.

Recruitment

The recruitment time series show more interannual variation than the SSB series (Figure 3). This is to be expected given that spawning biomass is not independent from year to year. The series for the Div. 2J3KL and 3NO stocks shows an overall downward trend. The Div. 4TVn and 4VsW series also declined during the 1980's. The Div. 2J3KL, 3NO, 3Ps, and 4TVn series have relatively high recruitment around 1975, 1980, and 1986. The main effect of differencing was to remove the dominant downward trends and accentuate the interannual variation.

The correlations among the ln transformed recruitment series were weaker than among the SSB series (Figure 4). The two stocks from the Gulf of St. Lawrence (Div. 3Pn4RS and 4TVn) and Georges Bank (Div. 5Zjm) had weak correlations with the others. On the other hand, the Div.

4X series was significantly correlated with the 3Ps, 3Pn4RS, and 4VsW series. When the data were differenced, there were several significant correlations on a more local spatial scale. The 3 northern series (2J3KL, 3NO, and 3Ps) were significantly correlated ($p<0.05$) as were 3Ps, 4VsW, and 4X series. The results of the correlation analysis of the detrended series was similar to those of the ln transformed series.

Pre-recruit Survival

The most striking feature of the pre-recruit survival data is the high values for the mid- to late-1970 for the 6 northern stocks (Figure 5). The year-classes from this period were above average in abundance and they were produced by very low SSB. Following these high values, the survival rates declined to minimal values in the mid-1980's. This was followed by a moderate fluctuation. The survival index for Div. 3NO cod decreased drastically in the 1980's and was well below that of the other stocks. In contrast, the Div. 4X stock had average survival rates during the 1970's with higher values in the mid-1980's and around 1960. The survival index for the two Gulf of Maine stocks was generally lower than for the more northerly stocks even though the recruitment estimates for the Gulf of Maine stocks were at age 1.

The correlations of the ln transformed survival rates indicated a very strong spatial pattern with significant correlations among almost all of the northern stocks and weak correlations among these stocks and the 2 from the Gulf of Maine (Figure 6). The spatial scale of the correlations was similar for the detrended series, except that Div. 3Pn4RS series was not significantly correlated with the others. The Div. 4X and 5Zjm series were significantly correlated. However, when the time series were differenced there were very few statistically significant correlations.

This is likely a result of the attenuation of the low-frequency amplification of the high frequency signals in these data.

Weight at Age

Several of the cod stocks have experienced reduced growth rates during the 1980's (Figure 7). There were significant negative trends in the weight at age 7 during the recent period 1978-92 for four stocks, 2J3KL, 3Pn4RS, 4TVn, and 4VsW. The 1992 in weights at age 7 were between 52% - 70% those in 1978. For the other stocks there were no apparent trends.

Fishing Mortality and Biomass

There have been large variations in fishing mortality exerted on these stocks over the past 30 years (Figure 8). I have examined trends in F in relation to trends in SSB in an attempt to identify in a qualitative sense possible causal relationships between the two, i.e. were the fluctuations initiated by increased F or were increases in F initiated by reduced biomass.

The pattern is not consistent among the stocks. For Div. 2J3KL and 3NO cod, the trends suggest that increases in fishing mortality may have initiated the major declines in stock biomass. There was an increasing trend in the estimated F for Div. 2J3KL cod during the 1960's and at the same time SSB declined. The dramatic increase in estimated F in the mid-1970's preceded the final drop in SSB in that decade. F was reduced in 1977 and remained relatively stable between 0.4 and 0.6. SSB recovered somewhat and was stable at around 400,000 t. There was another marked increase in estimated F in the late 1980's which again appeared to precede the most recent decline in SSB. Estimates of F on Div. 3NO fluctuated between 0.2 and 0.7 during the 1960's but the SSB remained relatively stable. There was a large increase in F in 1974-75 which was followed by a large decline in SSB. F declined afterwards and was estimated to be in the range of 0.2 during the early 1980's. At the same time, SSB increased substantially and attained a high level, almost twice that in the 1960's. F began to increase in 1986 and continued to increase until 1992. There was a substantial decrease in the estimated SSB in 1988 and the decline continued until 1992. It is interesting to note that the Div. 3NO cod stock is the only one where F was maintained close to the $F_{0.1}$ management target after the extension of fisheries jurisdiction and it is also the only stock where biomass in the 1980's exceeded that at the beginning of the 1960's.

For the Div. 4TVn, 4VsW, 3Ps, 3Pn4RS, and 5Zjm stocks it appears that the large increases in fishing mortality occurred after the start of the decline in SSB. For 4TVn cod the SSB began to decline in 1971, fishing mortality estimates declined slightly until 1973 but then increased sharply in 1974-75. Similarly, the SSB declined again beginning in 1986 but F did not increase substantially until 1988. This pattern is evident for Div. 4VsW, 3Ps, 3Pn4RS, and 5Zjm cod in the late 1980's.

There were no large spikes in the F estimates for Div. 4X cod yet three cycles are evident in the SSB time series. Thus, it would appear that stock size can vary even if F is relatively constant.

Discussion

There are strong similarities in trends in SSB among these northwest Atlantic cod stocks. There was a high degree of synchrony among the stocks from Div. 4VsW and north. The patterns of SSB for the two Gulf of Maine stocks were significantly correlated but different than the northern stocks. The range of values was greater for the northern stocks than for those on Georges Bank. The largest proportional decline occurred for Div. 2J3KL cod. This may be the result of the expansion of fishing on lightly exploited stock components in the offshore area during the 1960's. This is further supported by the stock recruitment data for this stock (Rice and Evans 1988). SSB and recruitment were the highest during the 1960's. This may be the only stock of the eight examined where the time series include periods of low exploitation and high SSB thus increasing the contrast in the data.

There are strong similarities in the recruitment time series which suggest relatively large scale environmental forcing. The spatial scale of the similarities was reduced with the Gulf of St. Lawrence and Newfoundland (Div. 2K3KL and 3NO) stocks having more in common with the adjacent stocks than did the Div. 4VsW and 3Ps stocks. The analysis of the pre-recruit survival indices indicated similarities on a spatial scale similar to the SSB analysis. The northern stocks were highly correlated while the two Gulf of Maine stocks were similar between themselves but different that the others. It is highly unlikely that this similarity in survival index is due to density dependent pre-recruit mortality. Only Div. 2J3KL cod has a strong stock-recruitment relationship, but since the 1970's SSB levels have been much below the level where density dependent mortality would have an important effect. While there is some debate over the spatial scale of synchrony in the cod recruitment series, these results are in agreement with previous studies (Koslow 1984, Koslow et al. 1987, Thompson and Page 1989, Cohen et al. 1991) in suggesting that within the area occupied by these cod stocks, recruitment patterns are probably driven by environmental processes.

The lack of strong stock/recruitment relationships for these stocks does not necessarily mean that recruitment is independent of stock size. Whatever the extrinsic mechanism is that affects pre-recruit survival, it may affect the early life history stages proportionally. If this is the case, higher SSB will produce larger year-classes, all other things remaining equal.

Reduced weight at age had an important effect on the SSB of several stocks, namely Div. 2J3KL, 3Pn4RS, 4TVs, and 4VsW. If the current Div. 4TVn weights at age were equal to the average for the 1970's, the SSB would be approximately 75% higher.

Variations in fishing mortality have exacerbated the trends in SSB. For many of the stocks, F increased after the biomass began to decline, possibly in order to achieve TAC's which were set above target fishing mortalities. In the case of Div. 2J3KL and 3NO cod, F appears to have increased before the recent decline in SSB, and may have initiated the declines. The stock which had the least variation in SSB also had the least variation in F, namely Div. 4X cod.

In summary, the decline of northwest Atlantic cod stocks in the late 1980's and early 1990's was initiated by poor recruitment of year-classes spawned in the 1980's and reduced growth rates. There were similarities in trends in recruitment and biomass of the northerly stocks, Div. 2J3KL, 3NO, 3Ps, 3Pn4RS, 4TVn and 4VsW indicating that broad scale environmental factors probably influenced the recruitment patterns. There appears to be a discontinuity in the spatial scale of these effects between the Div. 4VsW and 4X cod stocks.

Fishing mortality (F) increased during the period of decline, thus exacerbating its extent. That F could increase to such an extent was the result, at least in part, of considerable uncertainty about management measures. It is difficult to generalize about the causes for these uncertainties, but here are some common features. A comprehensive review of the management of groundfish fisheries in the DFO Scotia-Fundy Region is given by Angel et al. (1994). Annual stock assessments tended to overestimate stock size (Sinclair et al. 1991). The accuracy of the fisheries data which formed the basis of these assessments, was questioned and probably contributed to the problem. There was extensive wastage of catches through discarding small fish and hygrading catches to keep only the most valuable individuals. Catch misreporting also occurred . The precision of stock size estimates proved to be less than anticipated. The quota allocation system was sensitive to 10% changes in advised TAC's (see Basic Principles of DFO Groundfish Management Plans) but the coefficient of variation of advised catches from stock assessments was in the range of 25% (Gavaris 1993). While it became clear in the mid-1980's that fishing mortality (F) was in excess of the $F_{0.1}$ targets for these cod stocks, the stock biomasses were high and there was uncertainty about the necessity to reduce F at the time. In the face of these uncertainties there was considerable resistance to reduce TAC's and such interim measures as the 50% rule and multi-year TAC's were introduced (Anon. 1989, Anon., 1990). However, these were not successful at reducing F. Only in the past 2-3 years has it become apparent that F's around $F_{0.1}$ for cod make sense from both a recruitment and growth point of view (Maguire and Mace 1993).

The environmental mechanisms that have been influencing cod recruitment are unclear. Research into these mechanisms will be costly, lengthy, difficult and may not prove successful. One must ask what would be done with the results as we will never be in a position to influence the environmental mechanisms let alone predict them into the future.

On the other hand, the fishery impacts on the stocks are better understood and there is a better chance to control these. It is clear that F must be reduced to prevent both recruitment and growth overfishing. Fleet overcapacity is extensive with only a fraction of the licensed vessels active and the active fleet generates fishing mortality 3-4 times the management target. Overcapacity results in competition for limited resources leading to overcapitalization and it fosters catch misreporting and wastage, thus deteriorating the fisheries database needed for stock assessment and management.

More emphasis should be placed on fisheries management science. Improved methods are needed for establishing and achieving fleet capacity targets. New management strategies and tactics that are robust to inevitable fluctuations in resource abundance and uncertainties about the future are required. The accuracy of the basic fisheries statistics must be improved.

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Table 1: Data sources used in this study. The years and age groups are indicated for spawning stock biomass (SSB). If no ages are given, then the estimates were based on a maturity ogive. The year-classes and age of recruitment are indicated for recruitment estimates (R). The annual fishing mortalities (F) and the age range used for averaging are indicated in the last column. * see the methods section for details on how the average F for 3NO cod was obtained. Data are presented in Tables 1-3.

Stock	Source	SSB (year)	R (year-class)	F (year)
2J3KL				
	Bishop et al. (1993b)	1962-70, 7+	1959-89, 3	1962-91, 7-9
	Shelton and Morgan, unpublished data	1971-92		
3NO				
	Davis et al. (1993)	1959-71, 7+	1956-88, 3	1959-92, *
	Shelton and Morgan (1994)	1972-92		
3Ps				
	Bishop et al. (1993a)	1959-92, 7+	1956-90, 3	1959-92, 6+
3Pn4RS				
	Fréchet and Gagnon (1993)	1974-92, 7+	1971-90, 3	1974-92, 7-9
4TVn(J-A)				
	Chouinard et al. (1994)	1950-92, 5+	1947-89, 3	1950-92, 9-12
4VsW				
	Fanning and MacEachern (1990)	1958-70, 6+	1957-69, 1	1958-70, 7-9
	Mohn and MacEachern (1993)	1971-92, 6+	1970-91 1	1971-92, 7-9
4X				
	Gavaris (1993)	1948-92, 3+	1947-90 1	1948-92, 4-6
5Zjm				
	Hunt and Buzeta (1993)	1978-92, 3+	1977-91 1	1978-92, 3+

Table 2: Spawning stock biomass estimates ('000 t) for 8 cod stocks in the northwest Atlantic. See Table 1 for details on data sources.

Year	2J3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
48							54	
49							58	
50					228		66	
51					261		62	
52					312		58	
53					341		62	
54					365		62	
55					402		60	
56					427		58	
57					364		45	
58					311	97	45	
59		147	123		257	93	48	
60		135	119		216	80	46	
61		91	111		236	97	65	
62	1611	103	102		260	113	69	
63	1379	88	94		216	118	67	
64	1437	87	95		163	115	77	
65	1196	120	85		135	114	83	
66	971	121	81		118	74	95	
67	912	102	58		110	66	90	
68	886	94	62		112	72	82	
69	814	102	68		133	59	73	
70	630	122	74		154	64	62	
71	672	102	85		143	82	60	
72	783	90	68		127	75	56	
73	464	79	61		105	52	57	
74	560	94	40	96	83	29	56	
75	301	51	36	106	75	34	58	
76	197	23	18	99	69	22	67	
77	84	28	20	87	68	23	72	
78	157	36	23	84	125	38	77	45
79	241	49	31	108	189	59	74	40
80	458	78	44	114	229	78	82	47
81	502	146	59	139	228	79	80	49
82	466	169	51	152	226	80	72	50
83	401	184	44	147	213	90	68	47
84	386	184	51	182	215	96	59	41
85	424	181	65	134	260	102	51	31
86	367	179	60	111	249	100	46	41
87	388	186	57	87	219	84	42	37
88	381	112	49	59	181	71	53	54
89	313	109	43	62	154	52	58	48
90	196	88	36	47	121	33	75	58
91	91	82	28	34	103	19	68	38
92	80	58	24	29	83	18	56	26

Table 3: Recruitment estimates (millions) for 8 cod stocks in the northwest Atlantic. See Table 1 for details on data sources.

Year-class	2J3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
48					109		25	
49					111		12	
50					106		16	
51					77		9	
52					68		19	
53					81		10	
54					106		14	
55					110		17	
56		55	59		142		19	
57		60	59		133	106	16	
58		86	51		46	96	24	
59	726	109	49		59	108	30	
60	641	81	43		41	94	19	
61	880	117	71		59	141	23	
62	1040	166	81		51	159	34	
63	1196	212	84		58	153	43	
64	865	184	98		97	146	21	
65	730	102	70		87	154	17	
66	670	129	54		51	121	16	
67	740	81	35		47	76	14	
68	597	87	60		89	99	21	
69	255	64	39		34	85	19	
70	141	37	30		46	85	15	
71	138	41	41	108	53	67	21	
72	233	27	54	138	42	62	24	
73	413	35	57	118	116	74	20	
74	342	55	75	161	166	85	25	
75	302	66	39	174	162	71	25	
76	153	24	23	127	113	67	17	
77	161	25	36	196	113	102	33	11
78	361	32	64	122	83	90	29	10
79	323	28	44	112	150	106	21	9
80	352	42	73	126	205	112	27	17
81	440	46	65	80	110	63	13	6
82	353	36	52	90	103	63	14	5
83	158	10	26	61	83	26	19	14
84	130	7	36	43	71	27	10	5
85	167	13	48	52	56	33	30	22
86	223	13	51	88	66	43	21	7
87	237	4	39	140	63	49	33	13
88	100	5	17	62	38	22	10	4
89	77		22	49	40	12	15	5
90			39	101			20	11
91								2

Table 4: Fishing mortality estimates for 8 cod stocks in the northwest Atlantic. See Table 1 for details on data sources.

Year	2J3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
48							0.58	
49							0.27	
50					0.42		0.29	
51					0.28		0.29	
52					0.32		0.33	
53					0.38		0.27	
54					0.52		0.35	
55					0.41		0.28	
56					0.52		0.40	
57					0.49		0.55	
58					0.81	0.49	0.32	
59		0.45	0.41		1.39	0.54	0.53	
60		0.45	0.48		0.55	0.42	0.47	
61		0.32	0.67		0.66	0.65	0.31	
62	0.32	0.28	0.39		0.35	0.69	0.32	
63	0.30	0.45	0.37		0.50	0.39	0.45	
64	0.41	0.43	0.55		0.48	0.32	0.76	
65	0.55	0.63	0.55		0.71	0.76	0.46	
66	0.40	0.74	0.73		0.62	0.55	0.57	
67	0.43	0.71	0.43		0.48	0.51	0.44	
68	0.60	0.72	0.42		0.67	0.86	0.63	
69	0.81	0.57	0.56		0.51	0.43	0.57	
70	0.58	0.51	0.50		0.81	0.32	0.36	
71	0.48	0.54	0.63		0.59	0.58	0.39	
72	0.51	0.39	0.64		0.53	0.42	0.48	
73	0.50	0.69	0.78		0.52	1.23	0.45	
74	0.80	1.35	1.16	0.42	0.70	0.45	0.55	
75	0.98	1.20	0.91	0.36	0.84	1.06	0.44	
76	1.17	0.34	0.36	0.47	0.53	0.60	0.30	
77	0.52	0.34	0.49	0.57	0.38	0.29	0.29	
78	0.53	0.15	0.53	0.42	0.46	0.27	0.42	0.45
79	0.47	0.14	0.43	0.49	0.71	0.22	0.50	0.39
80	0.32	0.11	0.62	0.50	0.49	0.45	0.43	0.34
81	0.35	0.16	0.54	0.41	0.84	0.44	0.49	0.39
82	0.47	0.21	0.48	0.53	0.58	0.46	0.60	0.57
83	0.46	0.17	0.44	0.37	0.47	0.35	0.50	0.56
84	0.51	0.14	0.33	0.54	0.73	0.40	0.47	0.47
85	0.55	0.21	0.49	0.49	0.56	0.64	0.58	0.59
86	0.52	0.27	0.55	0.69	0.66	0.44	0.55	0.48
87	0.56	0.33	0.66	0.86	0.48	0.53	0.49	0.41
88	0.72	0.39	0.59	0.53	0.61	0.66	0.58	0.50
89	0.91	0.47	0.46	0.69	0.84	0.55	0.40	0.34
90	0.96	0.63	0.58	0.69	0.97	1.31	0.45	0.52
91	0.68	0.75	0.70	0.57	0.95	0.73	0.48	0.79
92		0.92	0.70	0.51	0.87	1.56	0.60	0.81

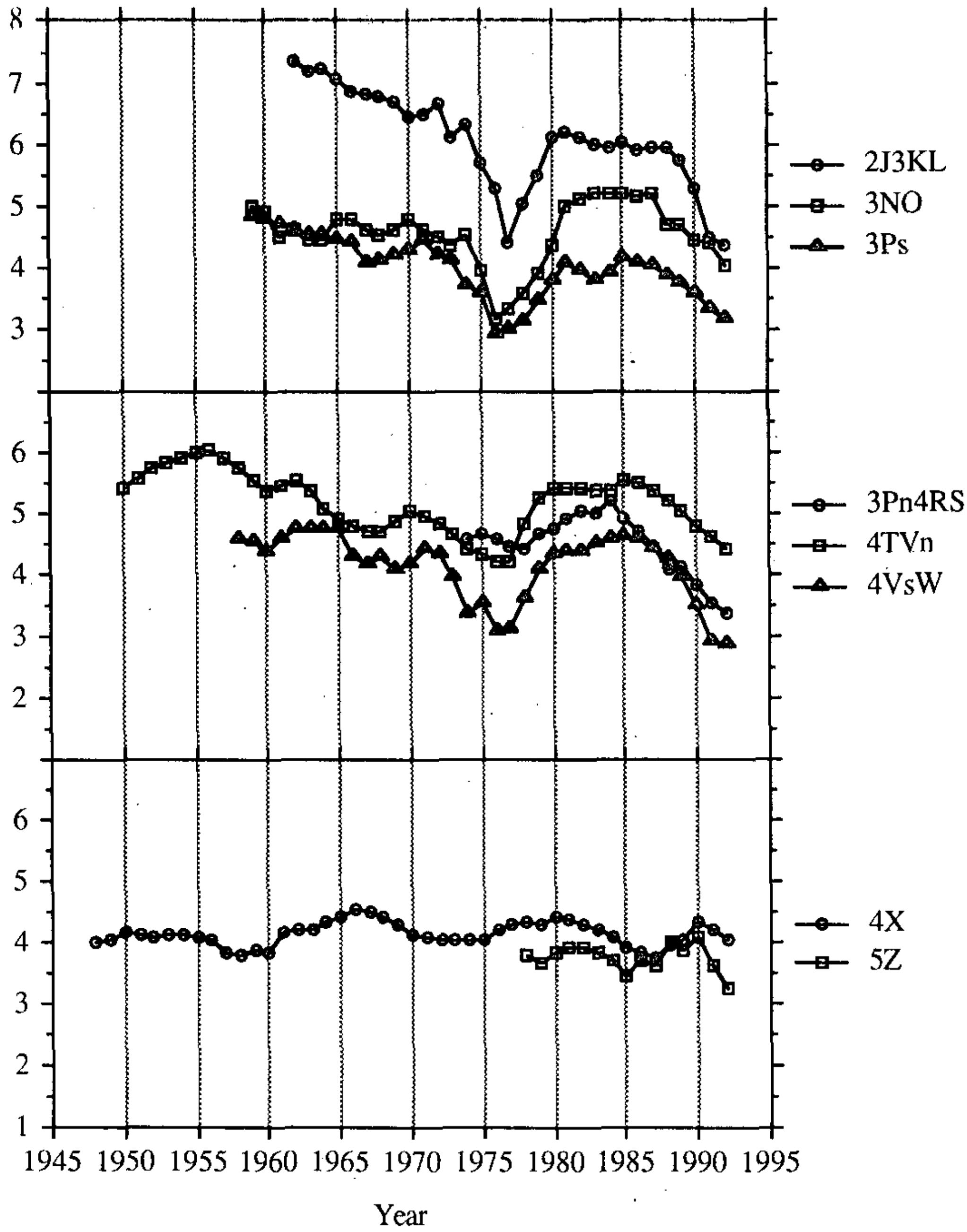

Figure 1: Trends in ln (spawning stock biomass '000 t) for several northwest Atlantic cod stocks.

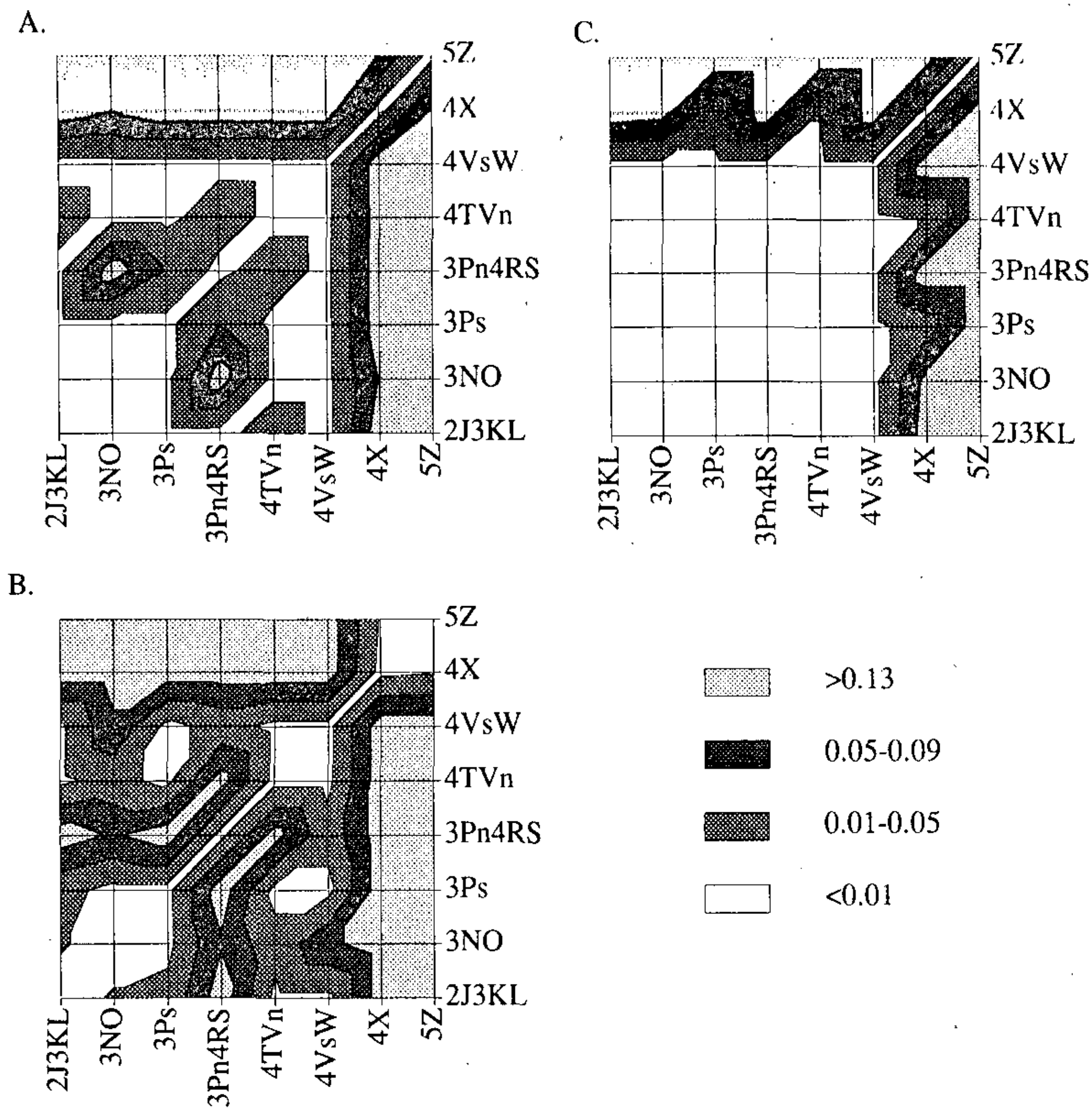

Figure 2: Contour plots of the significance of correlations in SSB. Panel A. is for ln transformed series, B. for the first differences, and C. for the series detrended with linear regression.

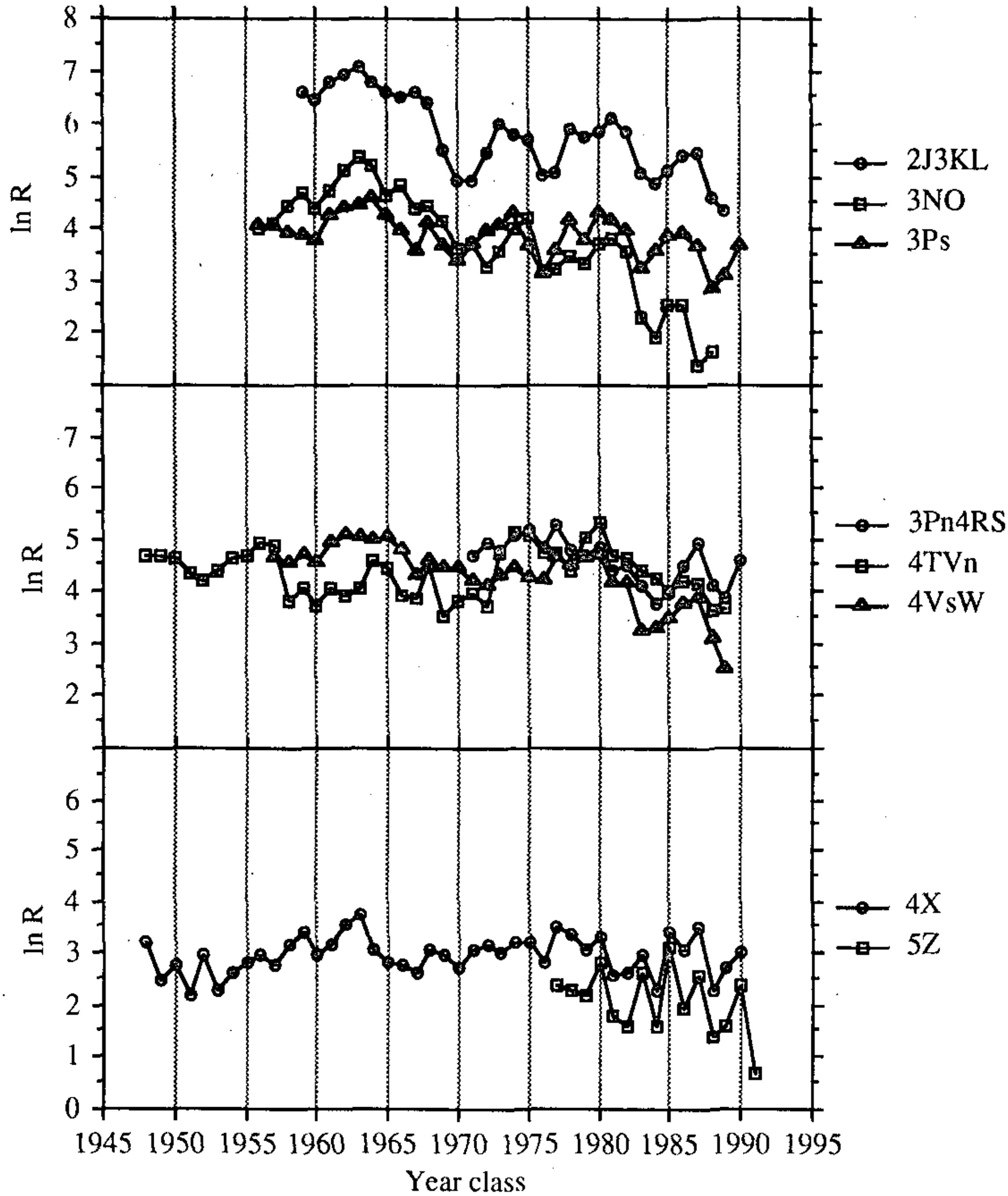

Figure 3: Trends in ln (recruitment $*10^{-6}$) for several northwest Atlantic cod stocks

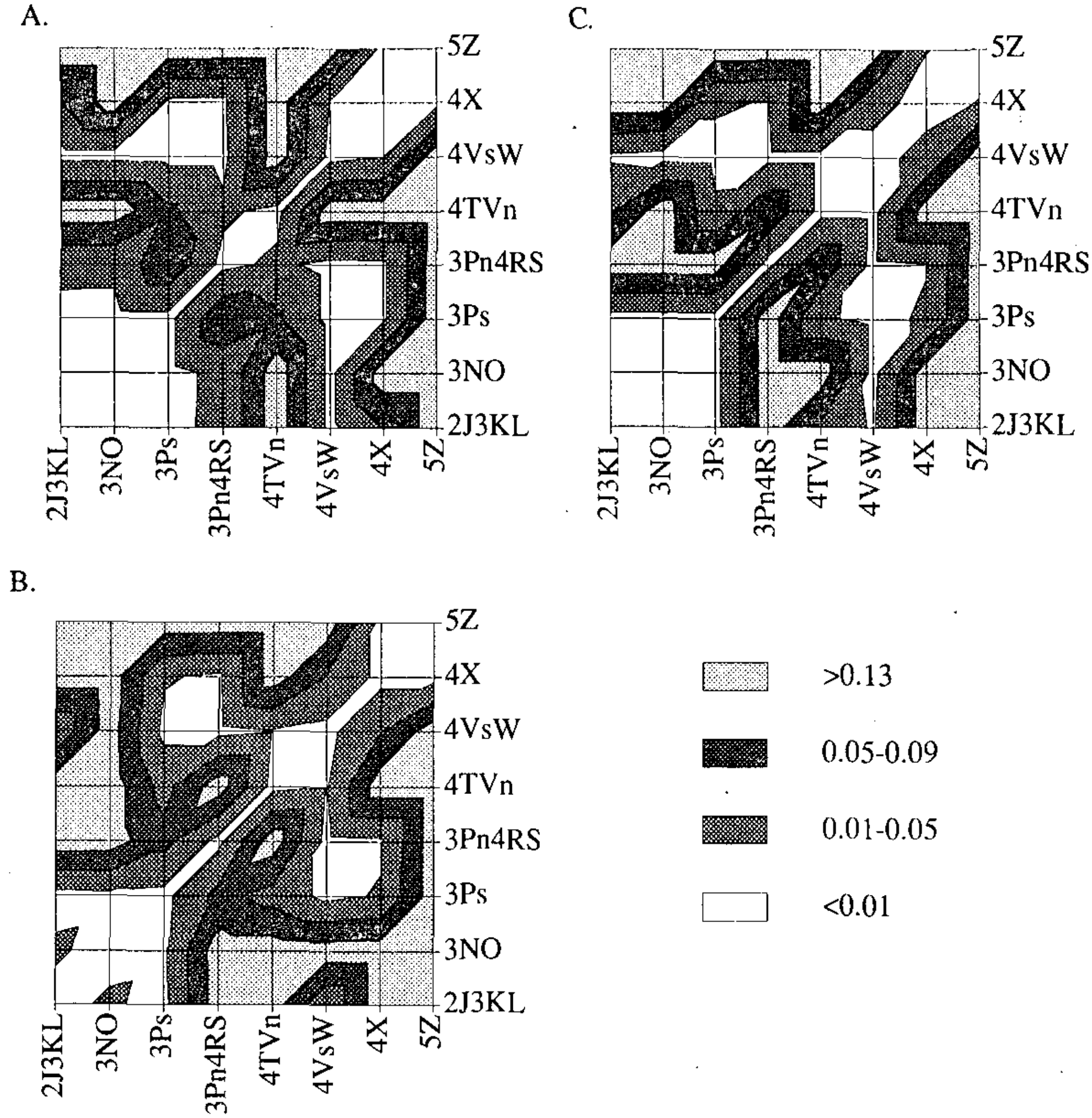

Figure 4: Contour plots of the significance of correlations in recruitment. Panel A. is for ln transformed series, B. for the first differences, and C. for the series detrended with linear regression.

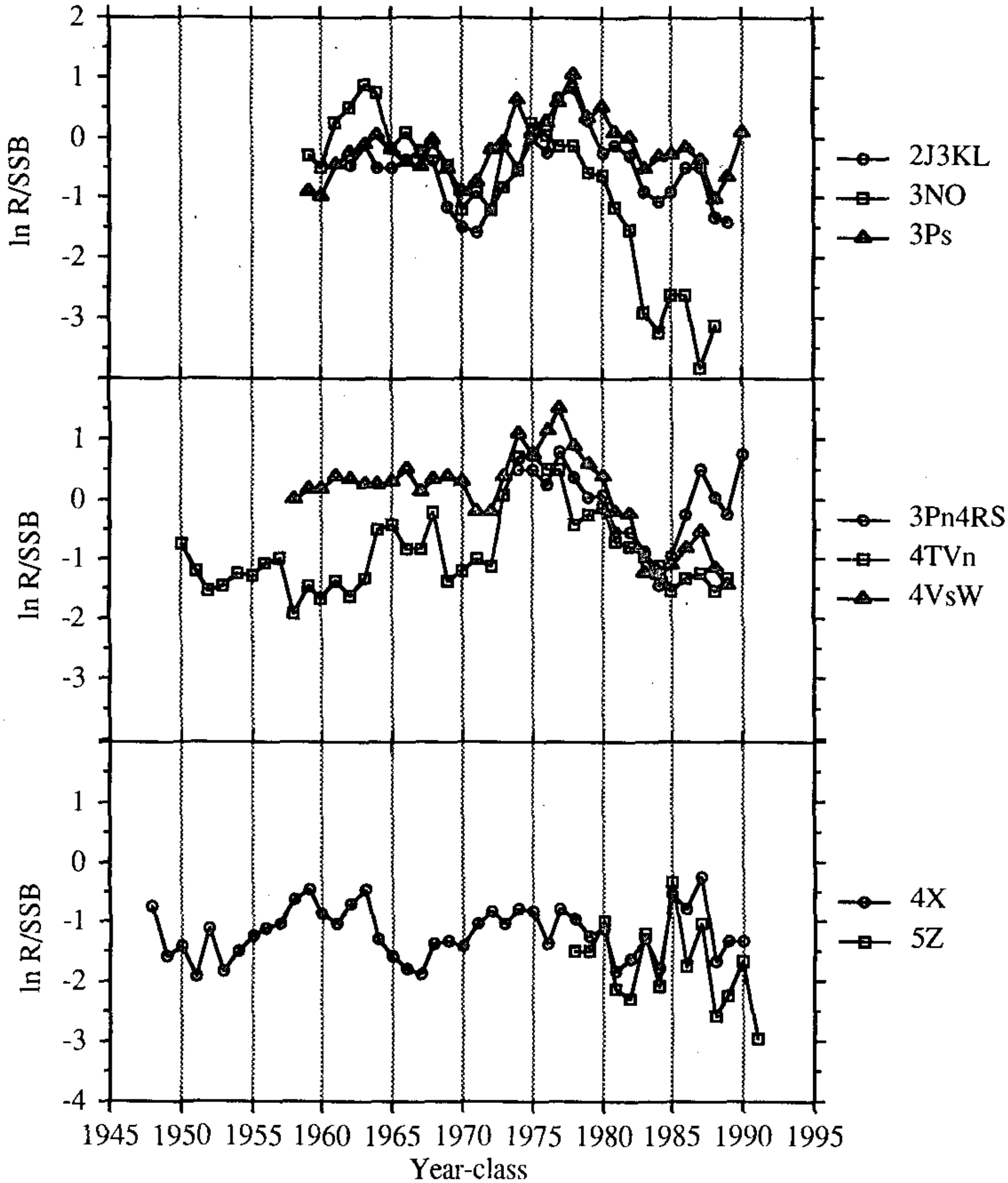

Figure 5: Trends in ln pre-recruit survival index for northern (upper panel), Gulf and eastern Scotian Shelf (middle panel), and Gulf of Maine (lower panel) cod stocks.

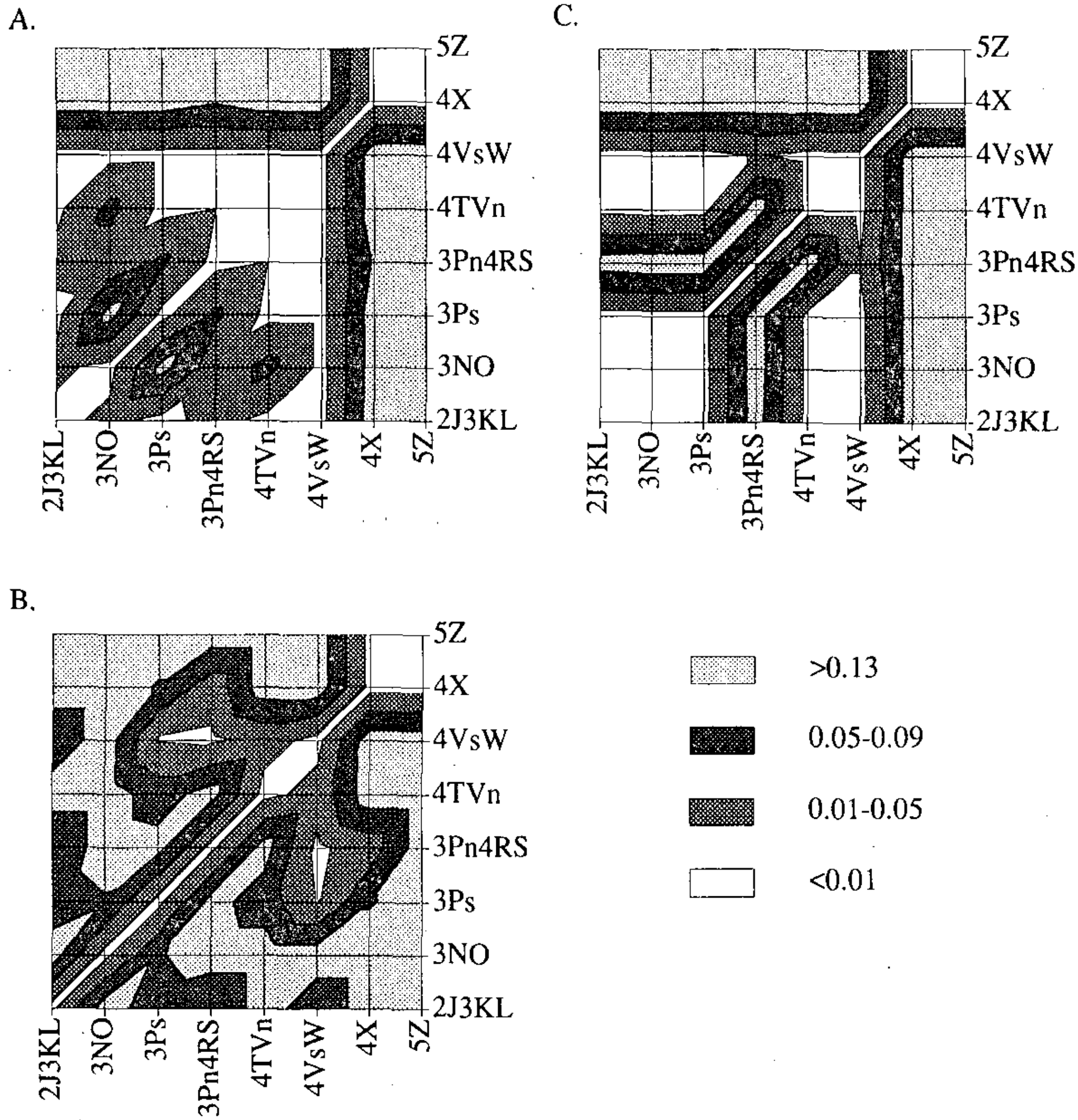

Figure 6: Contour plots of the significance of correlations in pre-recruit survival. Panel A. is for ln transformed series, B. for the first differences, and C. for the series detrended with linear regression.

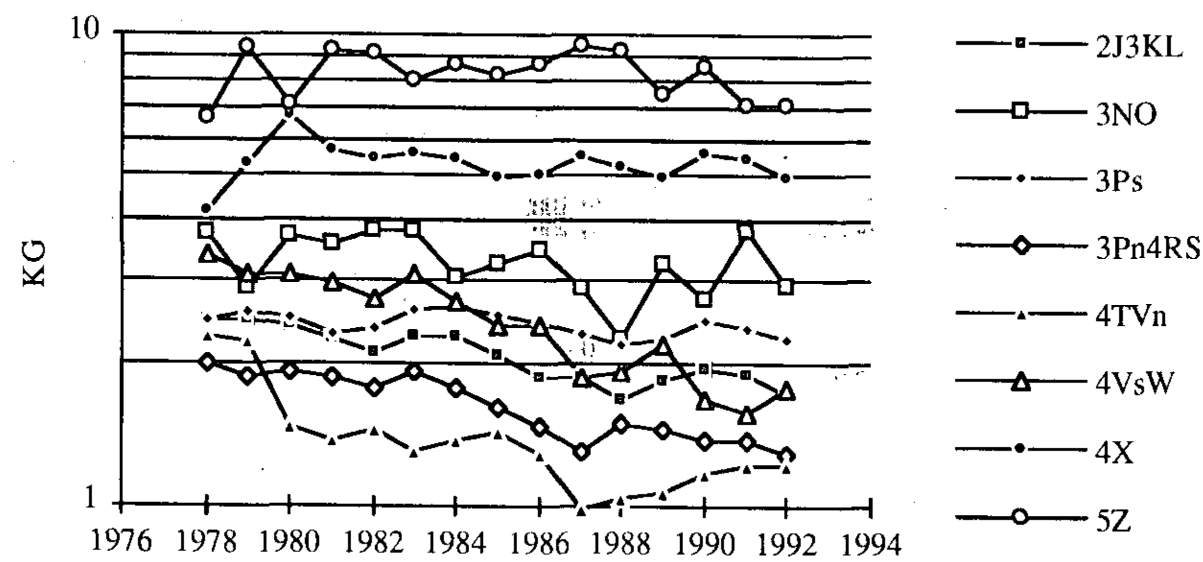

Figure 7: Trends in weights at age 7.

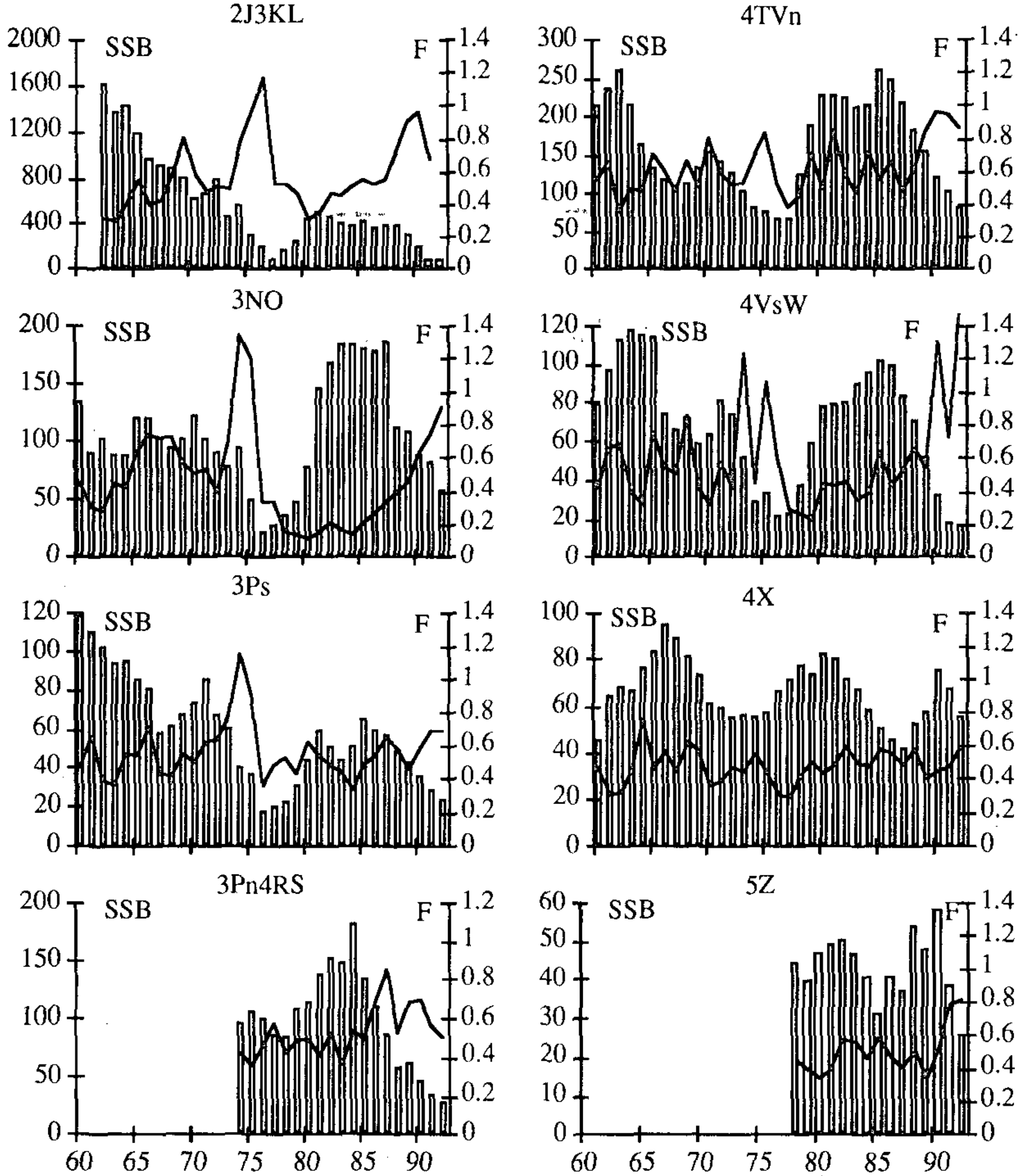

Figure 8: Trends in spawning stock biomass (bars) and fishing mortality (lines) for several northwest Atlantic cod stocks.