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Recent Declines in Cod Species Stocks in the Northwest Atlantic

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Abstract

Several recent studies addressing issues of environmental conditions and the synchrony in production of cod species in the NAFO Convention Area have brought forward the question of appropriateness of statistical methods used. In this study trends were examined in stock state variables for 8 cod stocks described within the Canadian zone of the NAFO Convention Area, in an attempt to address the possible causes of the recent declines in biomass. Stocks assessment data from previous studies were obtained for cod stocks in Div. 2J+3KL, Div. 3NO, Subdiv. 3Ps, Subdiv. 3Pn and Div. 4RS, Div. 4T and Subdiv. 4Vn(J–A), Subdiv. 4Vs and Div. 4W, Div. 4X and Div. 5Zjm. The variables examined included spawning stock 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. The trends in stock state variable were compared using correlation analyses. The correlation were performed on natural log transformed, first differenced, and detrended series. It was observed that the decline of the Northwest Atlantic cod stocks in the late-1980s and early-1990s was initiated by poor recruitment of year-classes spawned in the 1980s and reduced growth rates. There were similarities in trends in recruitment and biomass of the northern stocks indicating that broad scaled environmental factors probably influenced the recruitment patterns. There appeared to be a discontinuity in the spatial scale of these effects between the southern stocks. Increases in fishing mortality during the period of decline exacerbated the uncertainties of general patterns.

Key words: Assessment, biomass, cod, environment, hydrography, recruitment, statistical analyses

Introduction

The groundfish industry in the NAFO area is currently in a deep crisis. Cod species fisheries in Subareas 2, 3 and Div. 4RSTVW are closed to directed fishing. Canadian cod quotas in Div. 4X and 5Z have been reduced. Groundfish fisheries off the northeast of USA are also in a state of crisis with cod, haddock and yellowtail flounder stocks at historic low levels (Anon., MS 1993). That so many fisheries are in trouble at the same time suggests 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 Convention Area, but there is some debate on appropriate statistical methods used. 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 auto-correlation. 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 consisted of constructing new series as the differences in adjacent observations. Their conclusion was that there are similarities among some stocks but at a much reduced spatial scale. They grouped cod stocks in Subarea 1, Div. 2J+3KL, Div. 3NO and Subdiv. 3Ps separately from cod in Div. 4T and Subdiv. 4Vn, Subdiv. 4Vs and 4W, Div. 4X and Div. 5Z. It should be noted that Koslow's analyses did not include the Div. 4T and Subdiv. 4Vn, Div. 4X and Div. 5Z stocks. Thompson and Page (1989) reanalysed the same cod and haddock recruitment series used by Koslow but after first differencing. They concluded that there was intra-specific synchrony in recruitment but that the cod and haddock trends were independent. They too concluded 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 be 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, the question arises: does it function independently of egg production? If so, reduced egg production would produce fewer recruits, all other things remaining equal.

In this study trends were examined in stock state variables for 8 cod stocks (Div. 2J+3KL, Div. 3NO, Subdiv. 3Ps, Subdiv. 3Pn and Div. 4RS, Div. 4T and Subdiv. 4Vn(N–A), Subdiv. 4Vs and Div. 4W, Div. 4X and Div. 5Zjm: *note*, these are referred to in the following text without reference to NAFO areas) within the Canadian zone of the NAFO Convention 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 8 cod stocks described in the Canadian zone of the NAFO Convention Area, those in 2J+3KL, 3NO, 3Ps, 3Pn4RS, 4TVn(N-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. The SSB estimates for most stocks were based on a knife-edged age of maturity determined from maturity data from research vessel surveys. Maturity ogives were used for 2J+3KL and 3NO cod (Shelton and Morgan, MS 1993; MS 1994). However, work is ongoing in other Canadian Department of Fisheries and Oceans (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 those of 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 the table of fishing mortalities was examined, 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. A multiplicative model was used 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 two trends were similar, however, the multiplicative estimates indicated a greater increase in F during the late-1980s and early-1990s 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 included both density dependent and density independent sources of mortality as well as any associated measurement error. With the exception of 2J+3KL 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 tended to be auto-correlated and some care was required in applying statistical tests of independence. Cohen *et al*. (1991) recommended detrending the time by calculating a new series based on the differences between successive observations (first differences). Thompson and Page (1989) noted, however, that such a transformation attenuates low frequency variations and may consequently remove important synchronous signals at this time scale. Both authors recommended the examination of log-transformed data to stabilize variance so that the data sets approximated the normal distribution. Myers *et al*. (1990) present a third transformation which removes any long-term linear trends in the series. In this study correlations will be presented of the natural log transformed, first differenced and detrended series. The latter two transformations are;

First Differences

$$\Delta \ln X_t = \ln X_{t+1} - \ln X_t$$

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.

TABLE 1. Data sources used in this study indicating the years and age groups for spawning stock biomass (SSB), the year-classes and age for recruitment estimates (R), and the years fished and age range for averaging fishing mortalities (F). (Note: * indicates when estimates were based on maturity ogive, ** details given in text).

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

Results

Adult biomass

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

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

The correlations among the biomass series indicated two groups of stocks, the six northern stocks and the two Gulf of Maine stocks (Fig. 2). This pattern was most evident in the *ln* transformed and detrended series. The 3Pn4S series was 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. 2J+3KL) while maintaining the decadal scale variations in the original time series.

Recruitment

The recruitment time series showed more interannual variation than the SSB series (Table 3; Fig. 3). This is to be expected given that SSB is not independent from year to year. The series for the 2J+3KL and 3NO stocks showed an overall downward trend. The 4TVn and 4VsW series also declined during the 1980s. The 2J+3KL, 3NO, 3Ps and 4TVn series had 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 (Fig. 4). The two stocks from the Gulf of St. Lawrence (3Pn4RS and 4TVn) and Georges Bank (5Zjm) had weak correlations with the others. On the other hand, the 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 (2J+3KL, 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 was the high values for the mid- to late-1970 for the 6 northern stocks (Fig. 5). The year-classes from this period were above average in abundance and they were produced by very low

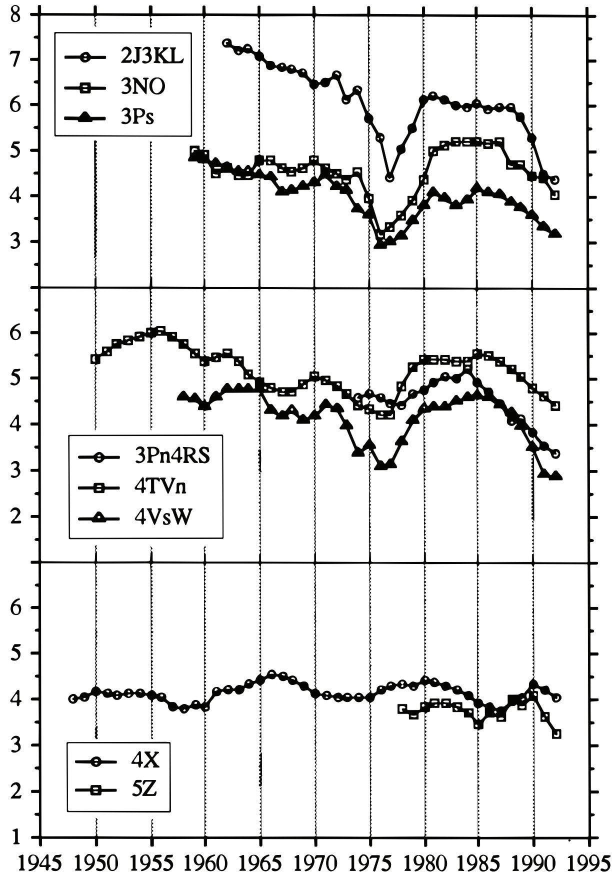

Fig. 1. Trends in spawning stock biomass for several Northwest Atlantic cod stocks.

SSB. Following these high values, the survival rates declined to minimal values in the mid-1980s. This was followed by a moderate fluctuation. The survival index for 3NO cod decreased drastically in the 1980s and was well below that of the other stocks. In contrast, the 4X stock had average survival rates during the 1970s with higher values in the mid-1980s 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 (Fig. 6). The spatial scale of the correlations was similar for the detrended series, except that 3Pn4RS series was not significantly correlated with the others. The 4X and 5Zjm series were significantly correlated. However, when the time series were differenced there were very few statistically significant correlations. This was likely a result of the attenuation of the low-frequency signals and amplification of the high frequency signals in these data.

Weight-at-age

Several of the cod stocks have experienced reduced growth rates during the 1980s (Fig. 7). There were significant negative trends in the weight-at-age 7 during the recent period 1978–92 for four stocks, 2J+3KL, 3Pn4RS, 4TVn and 4VsW. The 1992 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 (Table 4; Fig. 8). The trends in F were examined in relation to trends in SSB, in an attempt to identify in a qualitative sense the 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 was not consistent among the stocks. For 2J+3KL and 3NO cod, the trends suggested that increases in fishing mortality may have initiated the major declines in stock biomass. There was an increasing trend in the estimated F for 2J+3KL cod during the 1960s and at the same time SSB declined. The dramatic increase in estimated F in the mid-1970s 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 tons. There was another marked increase in estimated F in the late-1980s, which again appeared to precede the most recent decline in SSB. Estimates of F on 3NO fluctuated between 0.2 and 0.7 during the 1960s 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-1980s. At the same time, SSB increased substantially and attained a high level, almost twice that in the 1960s. 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 3NO cod stock was the only one where F was maintained close to the $F_{0.1}$ management target after the extension of fisheries jurisdiction and it was also the only stock where biomass in the 1980s exceeded that at the beginning of the 1960s.

For the 4TVn, 4VsW, 3Ps, 3Pn4RS and 5Zjm stocks it appears that the large increases in fishing mortality occurred after the start of the decline in

TABLE 2. Spawning stock biomass estimates ('000 tons) for 8 cod stocks in the Northwest Atlantic. (See Table 1 for details on data sources.)

	Cod stocks							
Year	2J+3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
1948							54	
1949							58	
1950					228		66	
1951					261		62	
1952					312		58	
1953					341		62	
1954					365		62	
1955					402		60	
1956					427		58	
1957					364		45	
1958					311	97	45	
1959		147	123		257	93	48	
1960		135	119		216	80	46	
1961		91	111		236	97	65	
1962	1611	103	102		260	113	69	
1963	1379	88	94		216	118	67	
1964	1437	87	95		163	115	77	
1965	1196	120	85		135	114	83	
1966	971	121	81		118	74	95	
1967	912	102	58		110	66	90	
1968	886	94	62		112	72	82	
1969	814	102	68		133	59	73	
1970	630	122	74		154	64	62	
1971	672	102	85		143	82	60	
1972	783	90	68		127	75	56	
1973	464	79	61		105	52	57	
1974	560	94	40	96	83	29	56	
1975	301	51	36	106	75	34	58	
1976	197	23	18	99	69	22	67	
1977	84	28	20	87	68	23	72	
1978	157	36	23	84	125	38	77	45
1979	241	49	31	108	189	59	74	40
1980	458	78	44	114	229	78	82	47
1981	502	146	59	139	228	79	80	49
1982	466	169	51	152	226	80	72	50
1983	401	184	44	147	213	90	68	47
1984	386	184	51	182	215	96	59	41
1985	424	181	65	134	260	102	51	31
1986	367	179	60	111	249	100	46	41
1987	388	186	57	87	219	84	42	37
1988	381	112	49	59	181	71	53	54
1989	313	109	43	62	154	52	58	48
1990	196	88	36	47	121	33	75	58
1991	91	82	28	34	103	19	68	38
1992	80	58	24	29	83	18	56	26

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 was evident for 4VsW, 3Ps, 3Pn4RS and 5Zjm cod in the late-1980s.

There were no large spikes in the F estimates for 4X cod, yet three cycles were evident in the SSB time series. Thus, it appeared 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 4VsW and north. The patterns of SSB for the two Gulf of Maine stocks were significantly correlated but

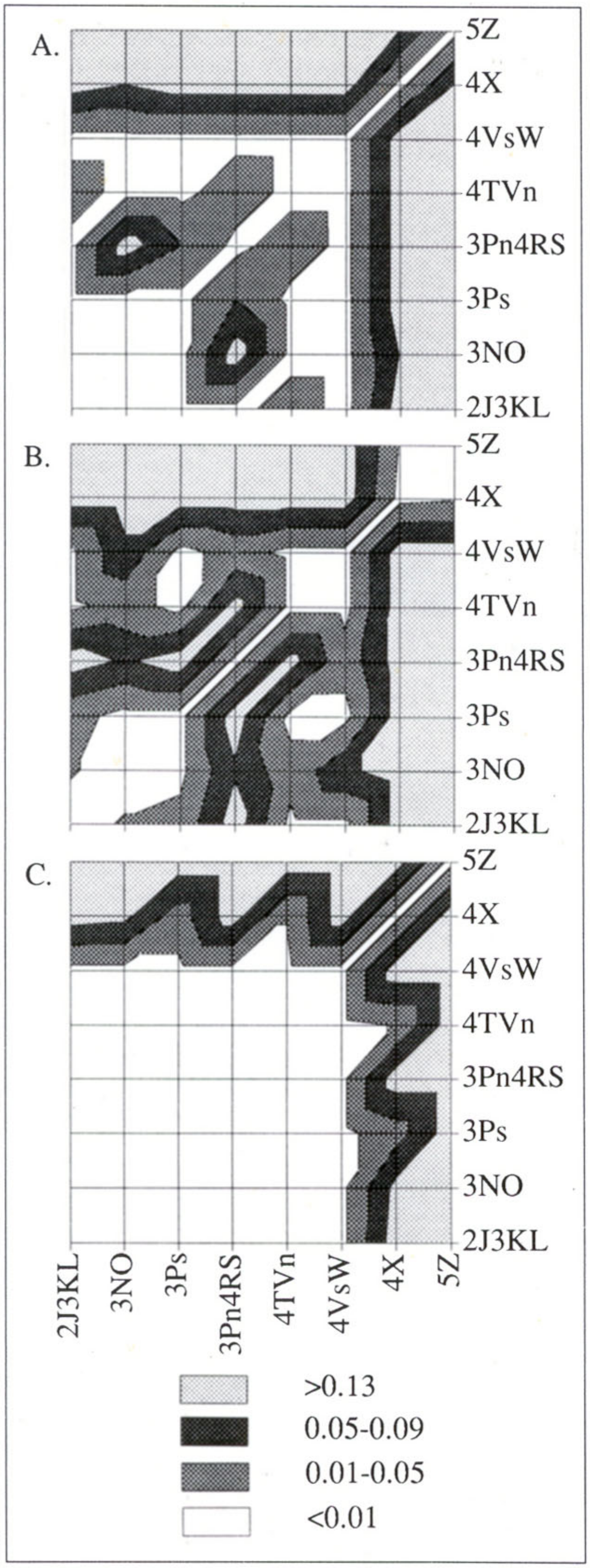

Fig. 2. Contour plots of significance of correlations in spawning stock biomass. (A) natural log transformed series, (B) first differences, (C) series detrended with linear regression.

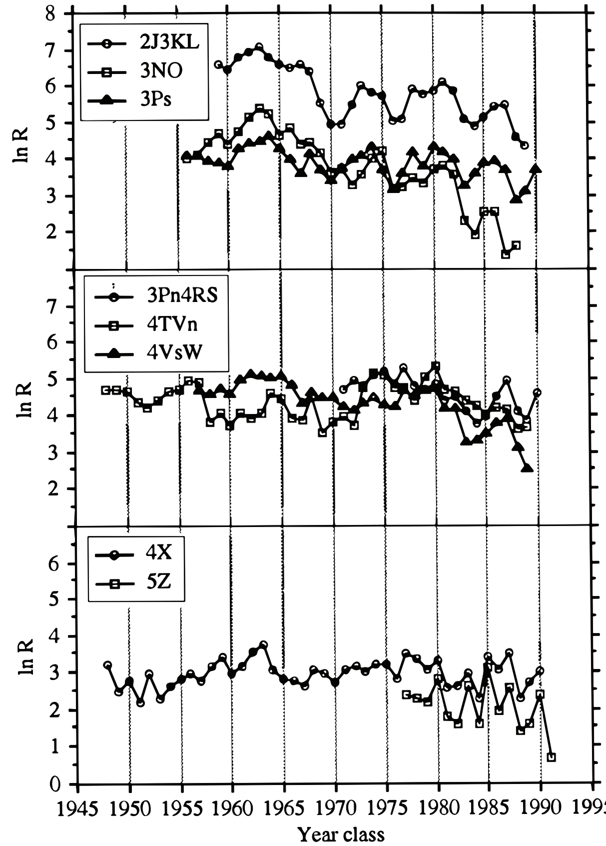

Fig. 3. Trends in recruitment for several Northwest Atlantic cod stocks

were different to 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 2J+3KL cod. This may be the result of the expansion of fishing on lightly exploited stock components in the offshore area during the 1960s. This was further supported by the stock recruitment data for this stock (Rice and Evans, 1988). The SSB and recruitment were the highest during the 1960s. 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 were 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 (2K+3KL and 3NO) stocks having more in common with the adjacent stocks than did the 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 differed from the others. It is highly unlikely that

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

Year-class	2J+3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
1948					109		25	
1949					111		12	
1950					106		16	
1951					77		9	
1952					68		19	
1953					81		10	
1954					106		14	
1955					110		17	
1956		55	59		142		19	
1957		60	59		133	106	16	
1958		86	51		46	96	24	
1959	726	109	49		59	108	30	
1960	641	81	43		41	94	19	
1961	880	117	71		59	141	23	
1962	1040	166	81		51	159	34	
1963	1196	212	84		58	153	43	
1964	865	184	98		97	146	21	
1965	730	102	70		87	154	17	
1966	670	129	54		51	121	16	
1967	740	81	35		47	76	14	
1968	597	87	60		89	99	21	
1969	255	64	39		34	85	19	
1970	141	37	30		46	85	15	
1971	138	41	41	108	53	67	21	
1972	233	27	54	138	42	62	24	
1973	413	35	57	118	116	74	20	
1974	342	55	75	161	166	85	25	
1975	302	66	39	174	162	71	25	
1976	153	24	23	127	113	67	17	
1977	161	25	36	196	113	102	33	11
1978	361	32	64	122	83	90	29	10
1979	323	28	44	112	150	106	21	9
1980	352	42	73	126	205	112	27	17
1981	440	46	65	80	110	63	13	6
1982	353	36	52	90	103	63	14	5
1983	158	10	26	61	83	26	19	14
1984	130	7	36	43	71	27	10	5
1985	167	13	48	52	56	33	30	22
1986	223	13	51	88	66	43	21	7
1987	237	4	39	140	63	49	33	13
1988	100	5	17	62	38	22	10	4
1989	77		22	49	40	12	15	5
1990			39	101			20	11
1991								2

this similarity in survival index is due to density dependent pre-recruit mortality. Only 2J+3KL cod has a strong stock-recruitment relationship, but since the 1970s, the 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 2J+3KL, 3Pn4RS, 4TVn and 4VsW. If the current 4TVn weights-at-age were equal to the average for the 1970s, the SSB would be approximately 75% higher.

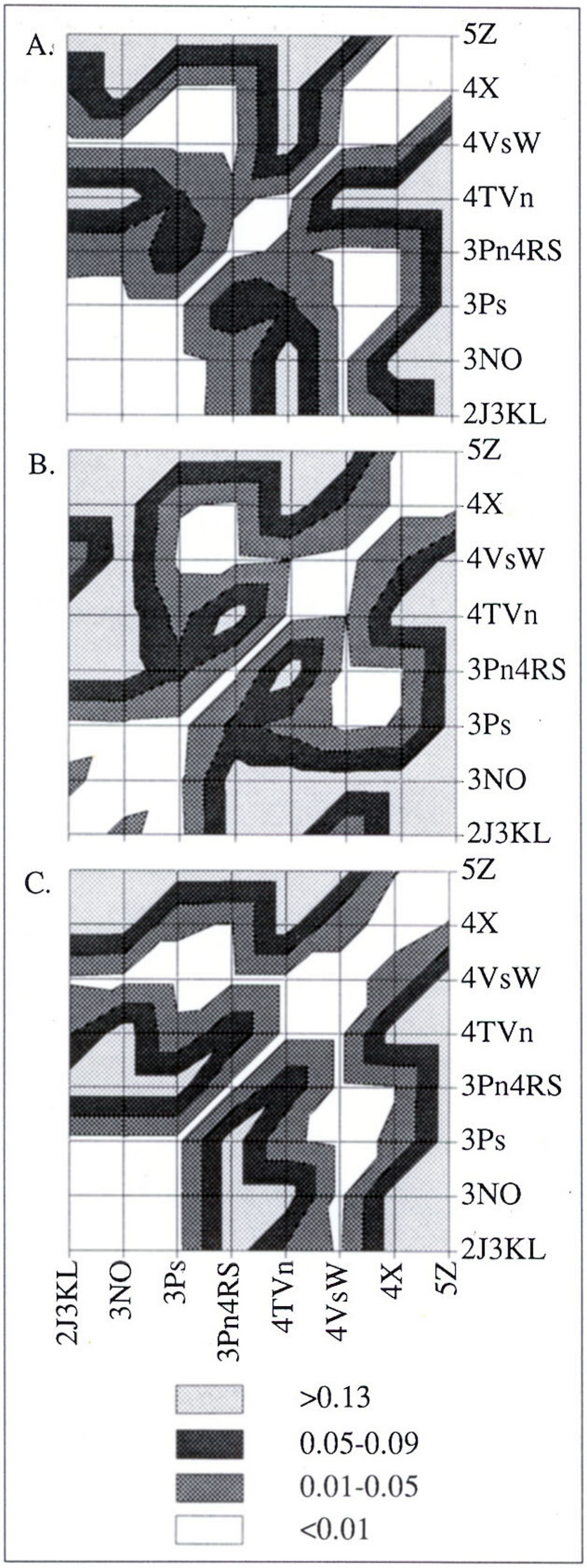

Fig. 4. Contour plots of significance of correlations in recruitment. (A) natural log transformed series, (B) first differences, (C) series detrended with linear regression.

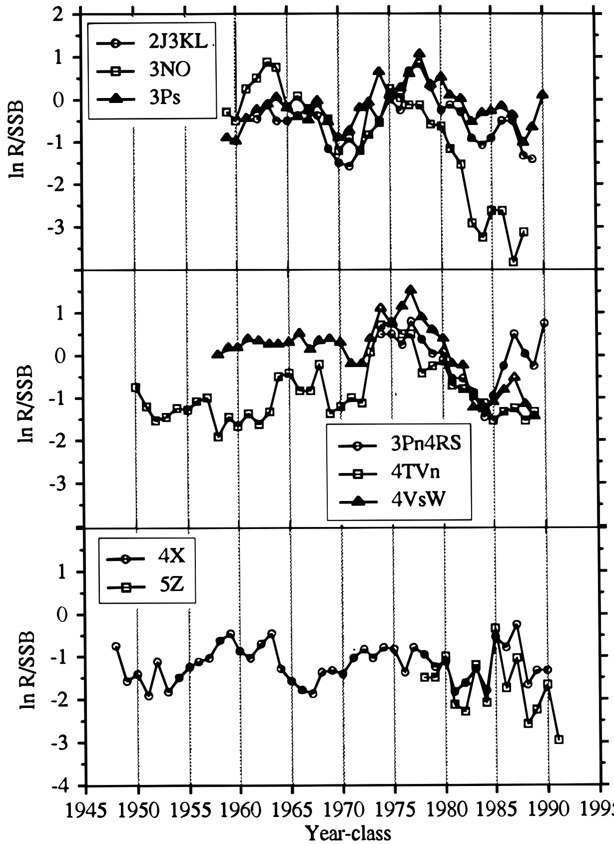

Fig. 5. Trends in ln pre-recruit survival index for cod stocks in different geographic areas.

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 TACs which were set above target fishing mortalities. In the case of 2J+3KL 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 4X cod.

In summary, the decline of the Northwest Atlantic cod stocks in the late-1980s and early-1990s was initiated by poor recruitment of year-classes spawned in the 1980s and reduced growth rates. There were similarities in trends in recruitment and biomass of the northerly stocks, 2J+3KL, 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 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 of

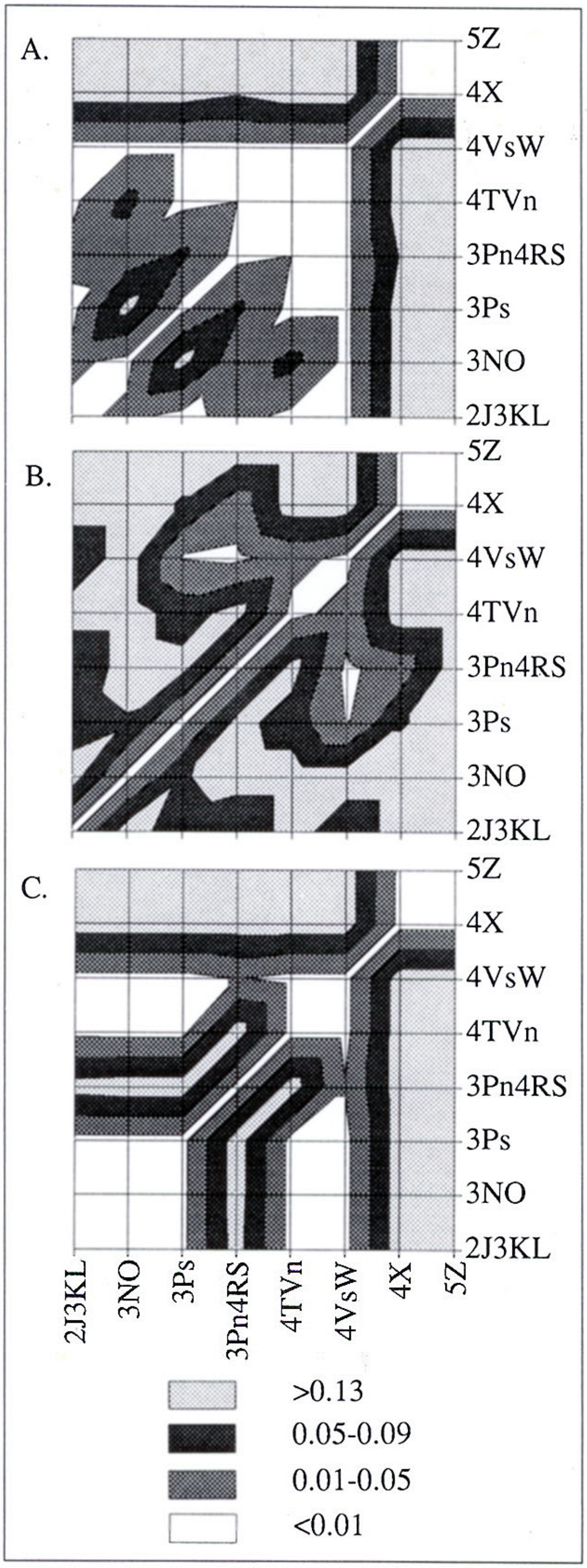

Fig. 6. Contour plots of significance of correlations in pre-recruit survival. (A) natural log transformed series, (B) first differences, (C) for the series detrended with linear regression.

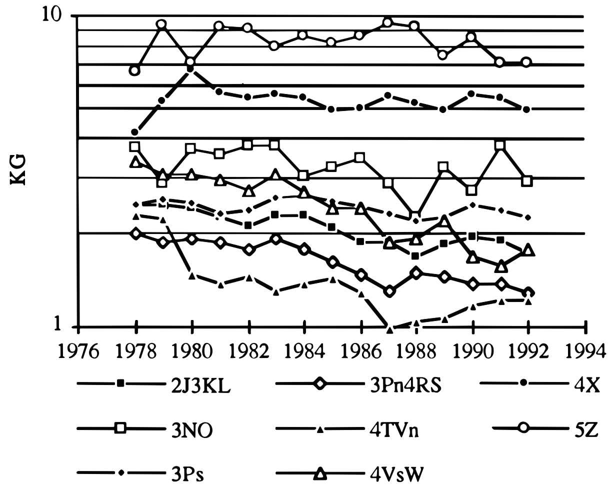

Fig. 7. Trends in weights-at-age 7 of cod in different stock areas.

considerable uncertainty, at least in part, 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 grading 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 TACs (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, MS 1993). While it became clear in the mid-1980s that fishing mortality 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 TACs and such interim measures as the 50% rule and multi-year TACs were introduced (Anon., MS 1989; MS 1990). However, these were not successful at reducing F. Only in the past 2–3 years has it become apparent that Fs 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

TABLE 4. Fishing mortality estimates for 8 cod stocks in the Northwest Atlantic. (See Table 1 for details on data sources.)

Year-class	2J+3KL	3NO	3Ps	3Pn4RS	4TVn	4VsW	4X	5Z
1948							0.58	
1949							0.27	
1950					0.42		0.29	
1951					0.28		0.29	
1952					0.32		0.33	
1953					0.38		0.27	
1954					0.52		0.35	
1955					0.41		0.28	
1956					0.52		0.40	
1957					0.49		0.55	
1958					0.81	0.49	0.32	
1959		0.45	0.41		1.39	0.54	0.53	
1960		0.45	0.48		0.55	0.42	0.47	
1961		0.32	0.67		0.66	0.65	0.31	
1962	0.32	0.28	0.39		0.35	0.69	0.32	
1963	0.30	0.45	0.37		0.50	0.39	0.45	
1964	0.41	0.43	0.55		0.48	0.32	0.75	
1965	0.55	0.63	0.55		0.71	0.75	0.46	
1966	0.40	0.74	0.73		0.62	0.55	0.57	
1967	0.43	0.71	0.43		0.48	0.51	0.44	
1968	0.60	0.72	0.42		0.67	0.86	0.63	
1969	0.81	0.57	0.56		0.51	0.43	0.57	
1970	0.58	0.51	0.50		0.81	0.32	0.36	
1971	0.48	0.54	0.63		0.59	0.58	0.39	
1972	0.51	0.39	0.64		0.53	0.42	0.48	
1973	0.50	0.69	0.78		0.52	1.23	0.45	
1974	0.80	1.35	1.16	0.42	0.70	0.45	0.55	
1975	0.98	1.20	0.91	0.36	0.84	1.06	0.44	
1976	1.17	0.34	0.36	0.47	0.53	0.60	0.30	
1977	0.52	0.34	0.49	0.57	0.38	0.29	0.29	
1978	0.53	0.15	0.53	0.42	0.46	0.27	0.42	0.45
1979	0.47	0.14	0.43	0.49	0.71	0.22	0.50	0.39
1980	0.32	0.11	0.62	0.50	0.49	0.45	0.43	0.34
1981	0.35	0.16	0.54	0.41	0.84	0.44	0.49	0.39
1982	0.47	0.21	0.48	0.53	0.58	0.46	0.60	0.57
1983	0.46	0.17	0.44	0.37	0.47	0.35	0.50	0.56
1984	0.51	0.14	0.33	0.54	0.73	0.40	0.47	0.47
1985	0.55	0.21	0.49	0.49	0.56	0.64	0.58	0.59
1986	0.52	0.27	0.55	0.69	0.66	0.44	0.55	0.48
1987	0.56	0.33	0.66	0.86	0.48	0.53	0.49	0.41
1988	0.72	0.39	0.59	0.53	0.61	0.66	0.58	0.50
1989	0.91	0.47	0.46	0.69	0.84	0.55	0.40	0.34
1990	0.96	0.63	0.58	0.69	0.97	1.31	0.45	0.52
1991	0.68	0.75	0.70	0.57	0.95	0.73	0.48	0.79
1992		0.92	0.70	0.51	0.87	1.56	0.60	0.81

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.

In conclusion, it could be stated that 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 accommodate the inevitable fluctuations in resource abundance and uncertainties about the future, are required. The accuracy of the basic fisheries statistics must be improved.

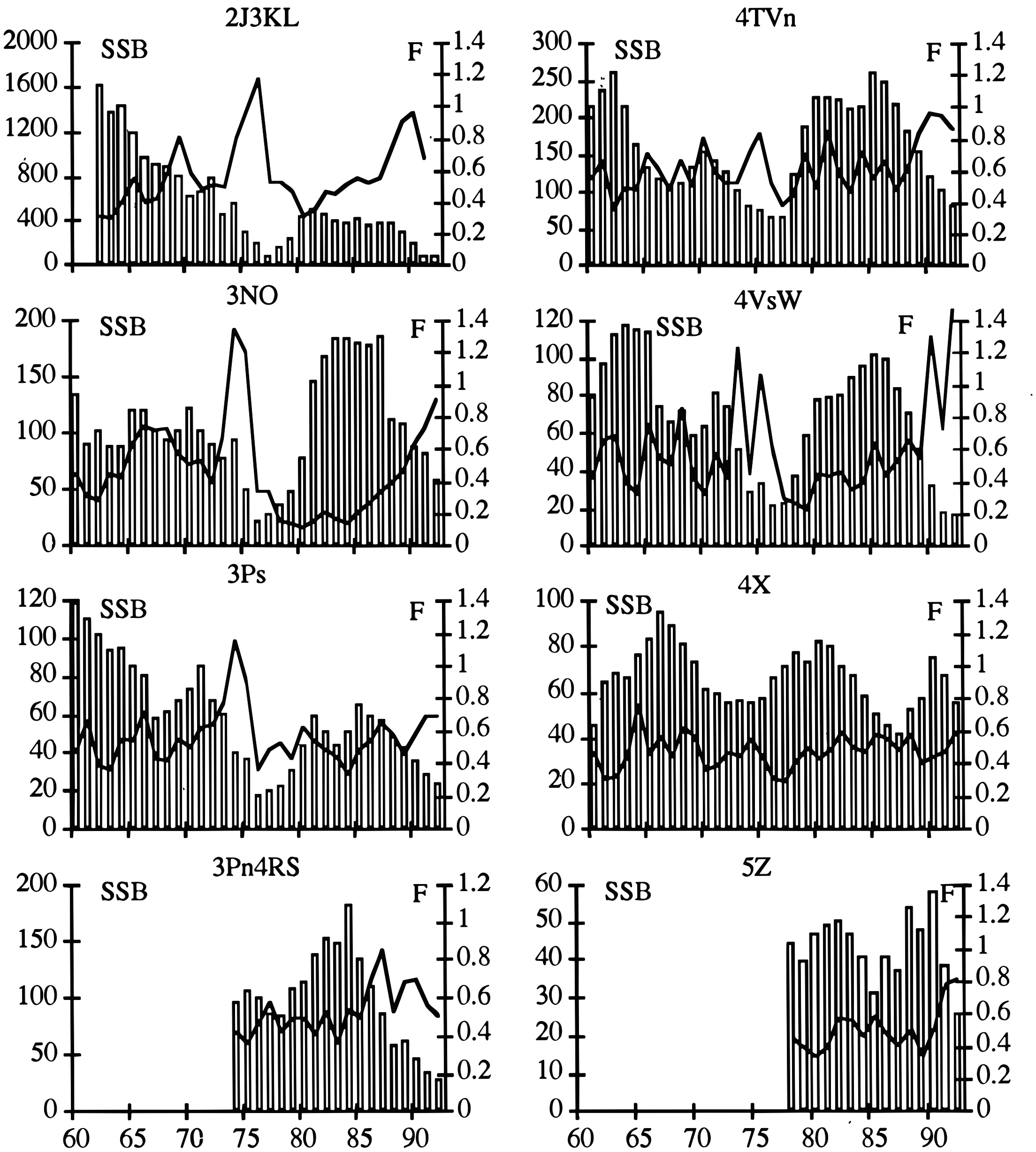

Fig. 8. Trends in spawning stock biomass (bars) and fishing mortality (lines) for several Northwest Atlantic cod stocks.

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