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Condition of Atlantic Cod in NAFO Div. 4X

Condition de la morue de la division 4X de l'OPANO

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Abstract

A measure of nutritional condition (Fulton's K, W/L^3) was examined for Atlantic cod collected during research vessel surveys conducted in NAFO Div. 4X from 1970 to 2001. Low values of this index have been associated with increased natural mortality, and lower fecundity in other Maritime cod stocks. The indices for cod in Div. 4X were compared with published values and cod caught on other parts of the Scotian Shelf. Using the reference of published studies from the Northern Gulf of St. Lawrence, current values of K in Div. 4X do not appear to be near the levels associated with death/morbidity, or with reduced reproductive success. However, critical levels of K are likely stock specific, and comparisons outside the stock area must be viewed with caution.

Résumé

On a examiné l'état nutritionnel (coefficient de condition K de Fulton, W/L3) de la morue capturée dans le cadre de relevés de navire de recherche effectués dans la division 4X de l'OPANO de 1970 à 2001. Chez d'autres stocks de morue des Maritimes, des faibles valeurs de ce coefficient étaient un signe de mortalité naturelle accrue et de fécondité réduite. On a comparé les coefficients pour la morue de 4X aux données publiées et aux coefficients pour les individus capturés ailleurs sur la plate-forme Scotian. Par rapport aux études publiées sur la morue du nord du golfe du Saint-Laurent, les coefficients de condition actuels de la morue de 4X ne semblent pas être proches des niveaux correspondant à la mort ou à un niveau réduit de succès de la reproduction. Mais comme chaque stock a probablement un niveau critique de K, les comparisons avec d'autres stocks doivent être considérées avec circonspection.

Introduction

Condition (or plumpness) of fish have several implications for the rational management of exploited populations. The plumpness of fish of a given length has direct implications for the yield from the fishery, which are well understood and generally accounted for in stock assessments. More recently, however, it has been shown that a fraction of post-spawning Northern Gulf of St. Lawrence cod had condition levels associated with mortality among unfed fish held in the laboratory (Lambert and Dutil 1997a). Dutil and Lambert (2000) further indicated that natural mortality from poor condition further decreased the productivity of the northern Gulf of St. Lawrence cod stock in the late 1980s and early 1990s. In addition to possible increases in natural mortality, there is evidence that in situations of decreasing available energy reserves, cod tend to reduce reproductive investment by reducing fecundity (Kjesbu et al. 1991, Lambert and Dutil 2000).

It is a relatively straightforward matter to monitor condition in marine fish populations. A commonly used metric is Fulton's K, which requires measurement of length and round weight ($K = W/L^3$). Fulton's K in Atlantic cod has been shown to well correlated with other commonly accepted measures of nutritional state, such as the hepatosomatic index (Lambert and Dutil 1997b). Given that individual measurements of length and weight have been available from the annual summer bottom trawl surveys conducted on the Scotian Shelf, there is an opportunity to describe and evaluate trends in condition for cod in Div. 4X, as part of the June 2002 "Framework" assessment for this stock.

Methods

We examined data from summer surveys conducted from 1970 to 2001. Following the convention in recent stock assessments, we considered that cod from Shelf strata (strata 470-483) should be treated separately from those taken in the Bay of Fundy strata (strata 484-495). This because the growth of the Bay of Fundy component is known to be faster than the Shelf component, which may also influence condition factor.

The number of individual measurements of length and weight for cod caught in 4X is shown in the text table below. To ensure an adequate sample size per time step, we elected to pool observations into four-year time periods. One way ANOVA was used to test for differences in Fulton's K between time periods for each area.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Scotian Shelf	315	133	182	133	159	153	170	176	126	140	142	135	65	179	141	97
Bay of Fundy	54	45	121	60	127	184	137	220	174	181	110	225	209	140	188	259
Total	369	178	303	193	286	337	307	396	300	321	252	360	274	319	329	356

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Scotian Shelf	101	56	193	162	264	227	198	91	102	169	237	163	122	137	85	53
Bay of Fundy	158	112	260	193	190	137	148	112	183	143	192	102	124	56	130	110
Total	259	168	453	355	454	364	346	203	285	312	429	265	246	193	215	163

It is known that K varies with length. Thus, it is necessary to select a range of lengths over which K is relatively invariant to assess interannual changes in condition. Without such a selection, changes in the length composition of the catch over the time series could bias the interpretation of changes in condition. The range of lengths used for the subsequent anaysis is based on visual inspection on Fulton's K at length for each area.

In the absence of controlled feeding/starvation studies to determine critical values of K for this stock, we used values for the Northern Gulf of St. Lawrence cod population derived from both field and laboratory observations (Lambert and Dutil 1997a). To provide further context to the results from Div. 4X, we also include observations from the eastern Scotian Shelf (Divs. 4W and 4V).

To evaluate the possibility that condition affects reproductive success, we compared the annual residuals from the R/SSB relationship for this stock with an aggregate measure of condition for the 4X cod stock. The aggregate measure is a weighted average of the condition observed for the Bay of Fundy and Scotian Shelf components of 4X cod. The weighting factor was the ratio of age 3+ survey abundance in each component divided by the total abundance in Div. 4X.

Results

After inspecting the relationship between length and condition factor (Fig. 1), we concluded that condition was unaffected by fish length between a range of 40 and 94 cm, and 40 to 100 cm, for the Scotian Shelf and Bay of Fundy components, respectively. The time series of observations of condition for the two components are shown in Fig. 2. For the Bay of Fundy component, condition has followed a generally increasing trend. For the Shelf component, condition declined in the mid-1980s, and has recovered recently. Analysis of variance and multiple range tests indicate that the changes in condition observed for the Scotian Shelf and Bay of Fundy components described above were significant (see Table 1 and 2 for Scotian Shelf and Bay of Fundy components respectively).

The same trends in condition shown in Fig. 2 are presented in Fig. 3, along with data from the eastern Scotian Shelf. The condition of cod from the eastern Scotian Shelf has been declining since the late 1970s, with a slight improvement recently. In general, the condition of cod in 4X is higher than that observed in 4W or 4V.

A comparison of annual condition (aggregated for both components of 4X cod, as described above) and the measure of reproductive output after correcting for the effect of spawning stock biomass (residuals from the R/SSB relationship) is shown in Fig. 4. We found little evidence of concurrence of unusually strong R/SSB values with high condition values. From the mid 1990s to the present, however, both series have been increasing indicating improving condition and survival of recruits.

Discussion

The condition data available for the two components of 4X cod are compared with levels associated with mortality or impaired recruitment in other stocks in Fig. 5. While it appears that present levels of condition are considerably higher than those associated with elevated mortality or reduced recruitment in the Northern Gulf of St. Lawrence (Lambert and Dutil 2000), it is likely that the critical values are stock-specific, since cod exhibit interpopulation differences in growth rates and food conversion efficiencies (Purchase and Brown 2000). The values of K reported for Lambert and Dutil's investigation included total weight less gonad weight, further reducing the comparability with our results, which are based on total weight.

It is also important to note that condition varies seasonally, with the lowest values expected immediately after spawning. Fish would be most at risk of increased natural mortality during that period. The data reported here are from summer surveys, a period considerably after spawning. Observations by Lambert and Dutil (2000) indicated that the pre-spawning fish with K =0.9 might lose condition to the extent that K would equal about 0.7 immediately after spawning. Such fish were reported to be at increased risk of postspawning mortality and were associated with lower fecundity during spawning. However, in the absence of knowledge of the seasonal cycle of condition for 4X cod, it is difficult to apply the Gulf of St. Lawrence results with any confidence.

To better appreciate seasonal cycles of condition in Div. 4X, it could be possible to sample the fishery for individual lengths and weight when fish are landed in a round condition. Stock specific feeding/starvation trials could also help elucidate critical levels of condition for 4X cod.

Fulton's K is one of many methods that have been suggested to reflect fish condition. Another commonly-used approach is to use least squares regressions of weight and length to provide an estimate of predicted weight at a given length. We summarize the results of a comparison of the two approaches in Fig. 6. It can be seen that the two methods provide very comparable results. Cone (1989) noted K can provide a useful measure of condition, as long as K is not confounded with length. By selecting ranges of lengths over which K was stable, we have avoided that particular concern.

In summary, current condition levels in Div. 4X cod are at high levels relative to previous observations in the 31 year long series. It is unlikely that these levels are resulting in significant additional natural mortality or impairment of recruitment.

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Table 1. Analysis of variance and multiple range tests for condition factor of Atlantic cod, Scotian Shelf, 1970-2001 (years are coded into four year long blocks).

ANOVA

KFACTOR

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		1.190	7	.170	15.300	.000
	Linear Term	Unweighted	.073	1	.073	6.588	.010
		Weighted	.214	1	.214	19.214	.000
		Deviation	.977	6	.163	14.648	.000
Within Groups			53.316	4797	.011		
Total			54.506	4804			

KFACTOR

	YEAR	N	Subset for alpha = .05				
			1	2	3	4	5
Tukey HSD[a,b]	4	482	.95380879				
	6	780	.95967216				
	7	671	.97068767	.97068767			
	5	512		.98064773	.98064773		
	2	658		.98809377	.98809377		
	1	762			.99452756		
	3	543			.99652858		
	8	397			.99792154		
	Sig.		.121	.097	.103		
Duncan[a,b]	4	482	.95380879				
	6	780	.95967216	.95967216			
	7	671		.97068767	.97068767		
	5	512			.98064773	.98064773	
	2	658				.98809377	.98809377
	1	762					.99452756
	3	543					.99652858
	8	397					.99792154
	Sig.		.347	.077	.110	.232	.153

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 571.723.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 2. Analysis of variance and multiple range tests for condition factor of Atlantic cod, Bay of Fundy, 1970-2001 (years are coded into four year long blocks).

ANOVA

KFACTOR

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		.703	7	.100	9.428	.000
	Linear Term	Unweighted	.158	1	.158	14.814	.000
		Weighted	.221	1	.221	20.736	.000
		Deviation	.482	6	.080	7.543	.000
Within Groups			50.845	4776	.011		
Total			51.548	4783			

KFACTOR

	YEAR	N	Subset for alpha = .05			
			1	2	3	4
Tukey HSD[a,b]	2	668	.987369556			
	1	280	1.00300960	1.00300960		
	3	690	1.00551686	1.00551686		
	7	620		1.00684346		
	6	587		1.00915395		
	4	796		1.01130956	1.0113096	
	8	420		1.02082930	1.0208293	
	5	723			1.0295885	
	Sig.		.076	.087	.071	
Duncan[a,b]	2	668	.987369556			
	1	280		1.00300960		
	3	690		1.00551686		
	7	620		1.00684346		
	6	587		1.00915395	1.0091540	
	4	796		1.01130956	1.0113096	
	8	420			1.0208293	1.0208293
	5	723				1.0295885
	Sig.		1.000	.247	.079	.164

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 538.556.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

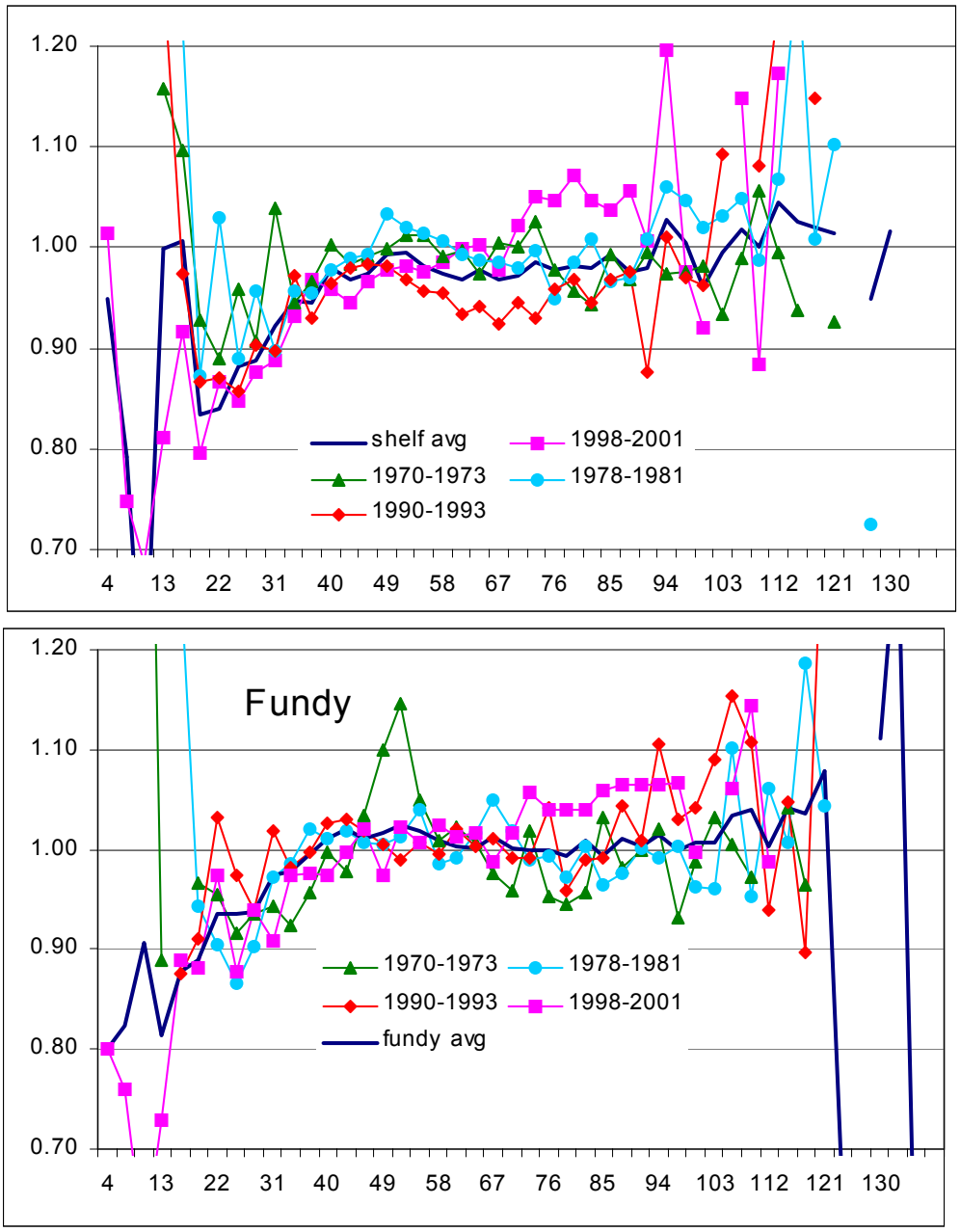

Fig. 1. Relationship between Fulton's K and fork length of Atlantic cod. The data are grouped into four year long series, and only some representative periods are shown. The top panel represents the Scotian Shelf component and the bottom panel contains the information from the Bay of Fundy component.

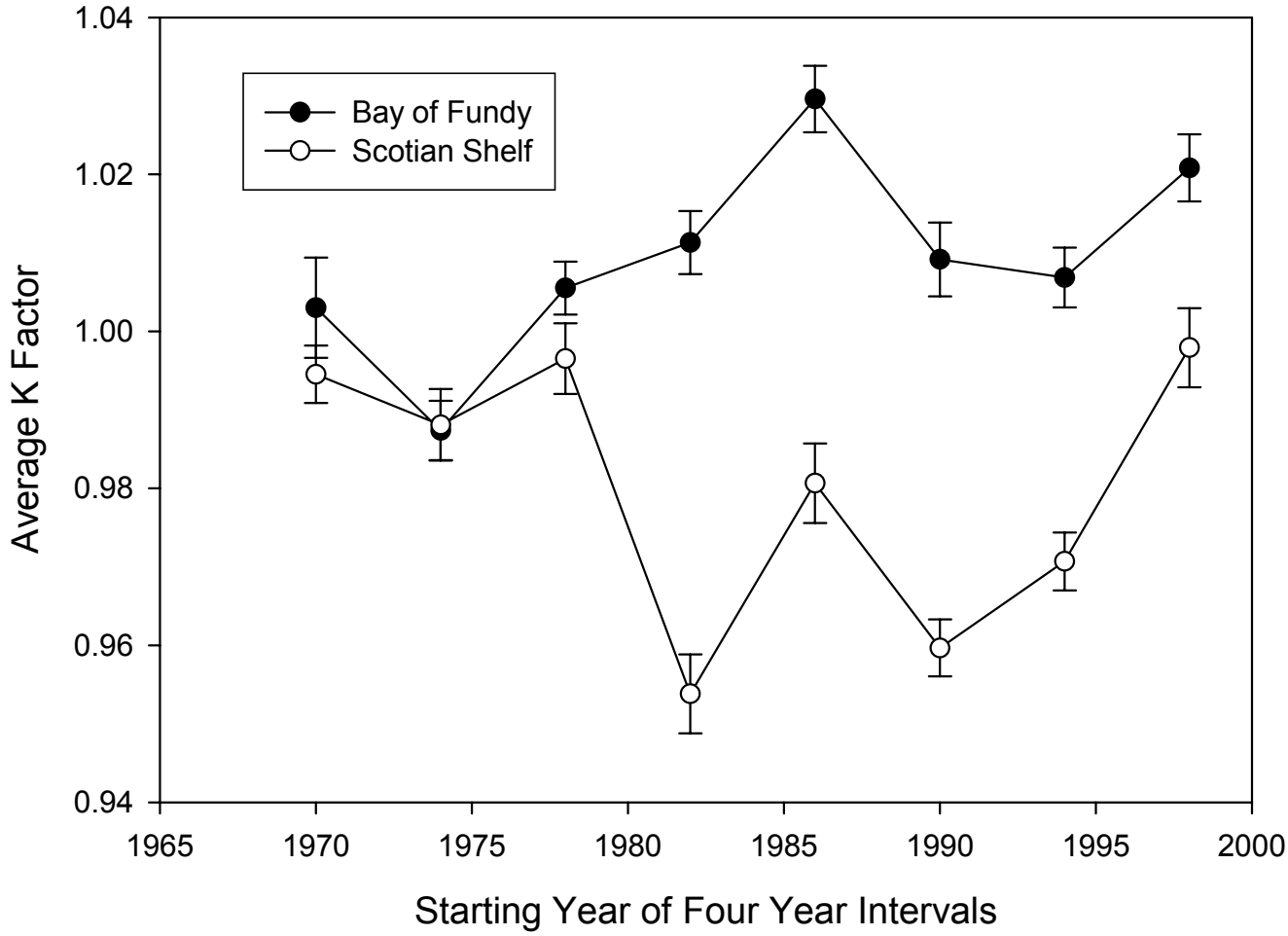

Fig. 2. Trends in average (plus/minus 1 SE) Fulton's K for NAFO Div. 4X Atlantic cod, as obtained from summer bottom trawl surveys, 1970 – 2001. Observations are split into the Bay of Fundy and Scotian Shelf components following the convention in the stock assessment.

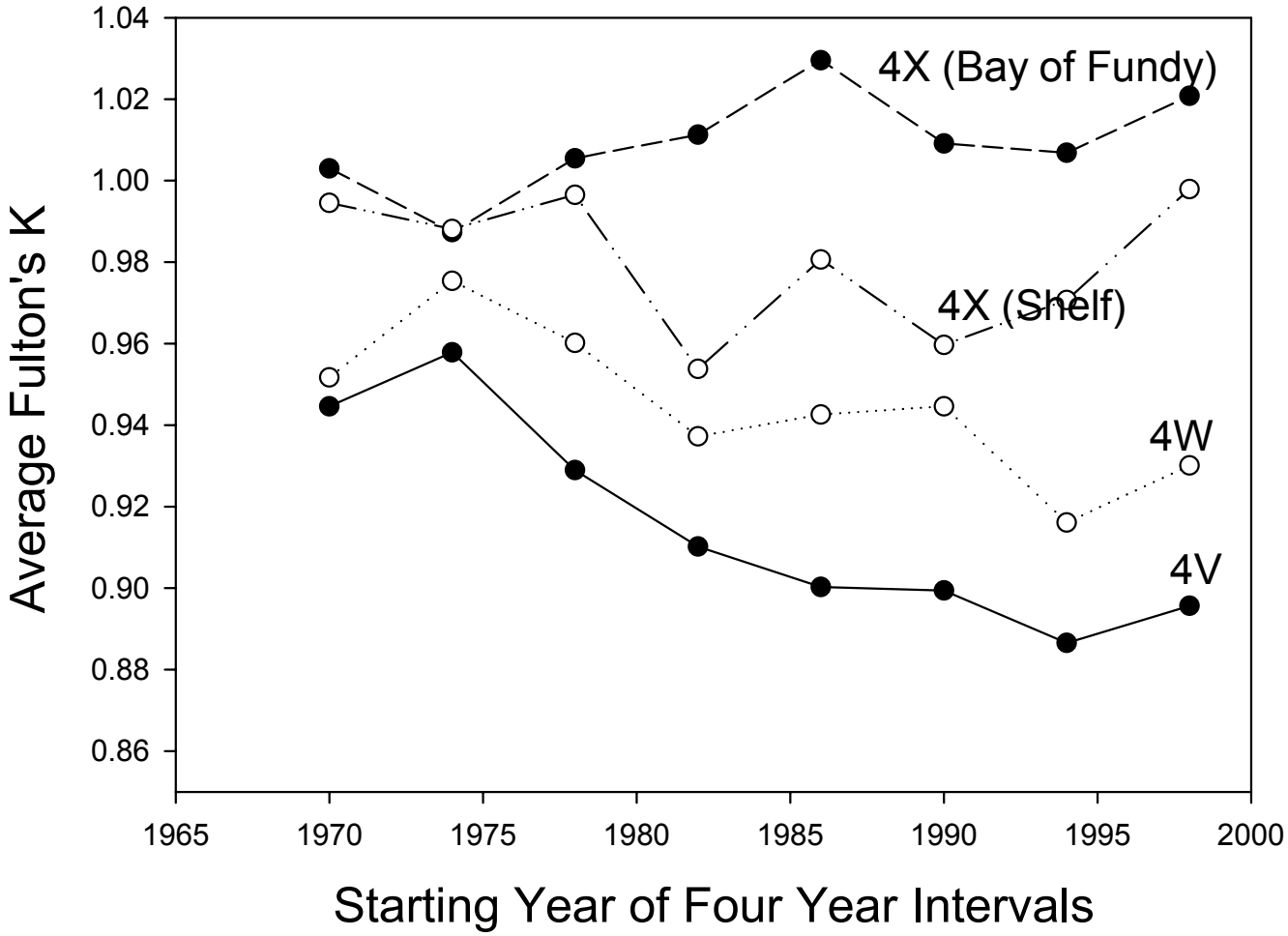

Fig. 3. Trends in average Fulton's K for NAFO Div. 4X Atlantic cod shown in Fig. 2 compared with cod from 4W and 4V, 1970-2001. All data are from summer groundfish surveys.

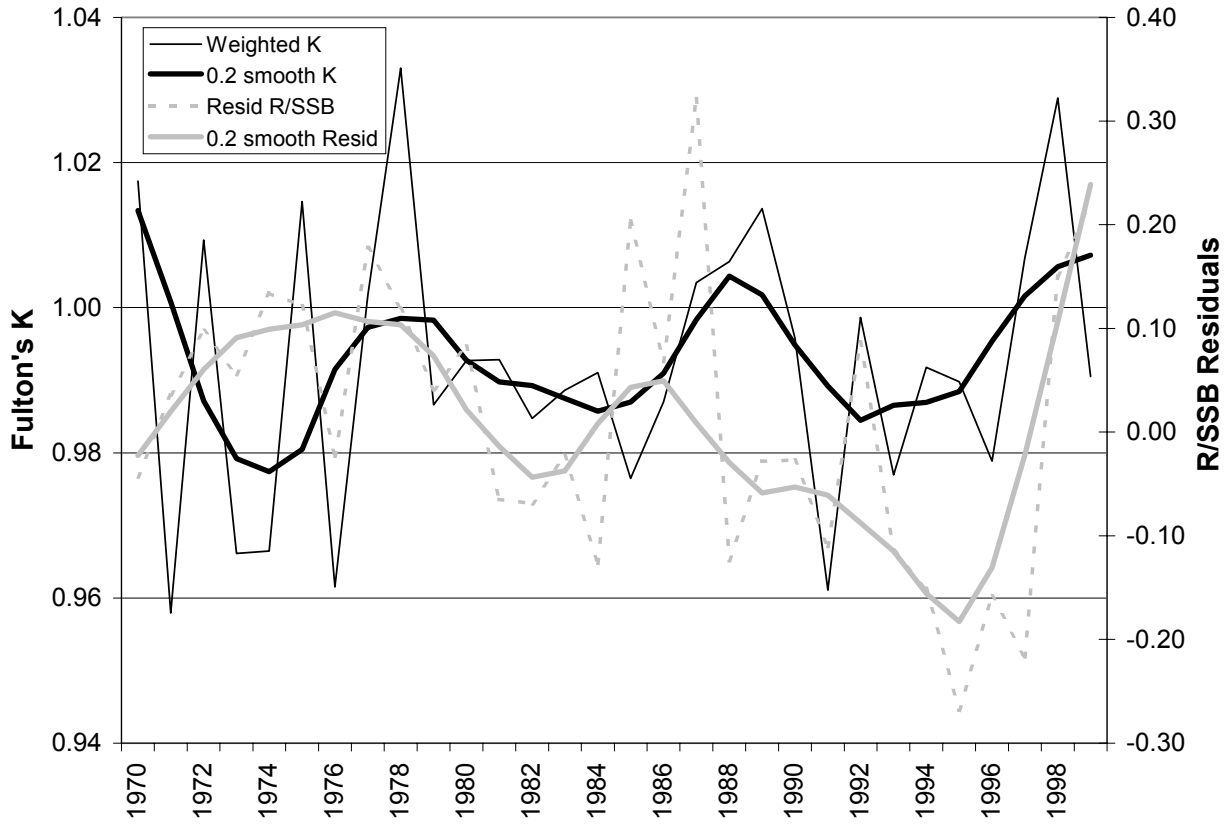

Fig. 4. LOESS smoothed series of Fulton's cod for Atlantic Cod in Div. 4X, compared with the LOESS smoothed series of residuals from the stock recruitment relationship for that stock. The smoothed series appear as thick lines (K is black, and R/SSB is grey), and the raw data series are shown as thinner lines.

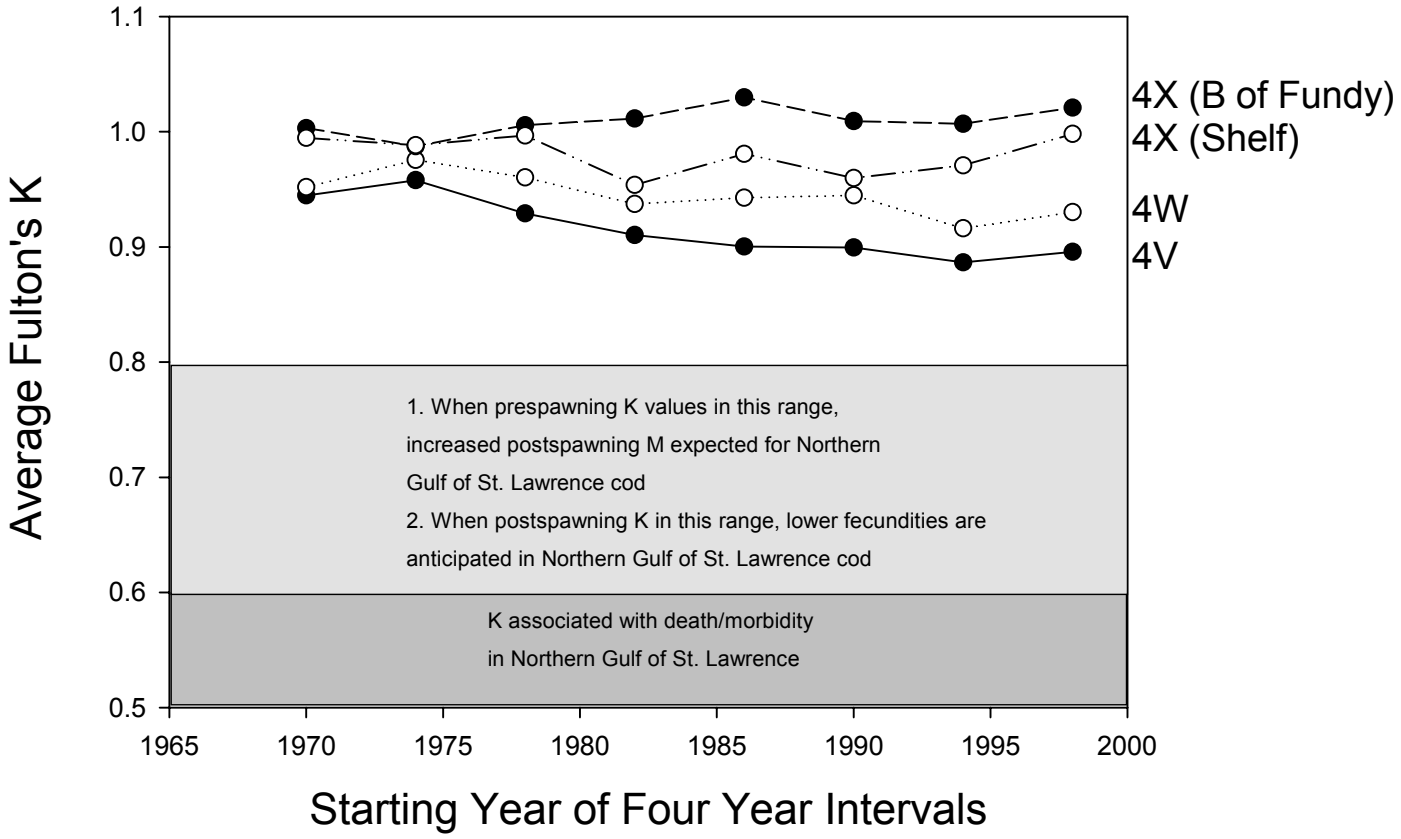

Fig. 5. Trends in condition of Scotian Shelf Atlantic cod in relation to published critical values for the Northern Gulf of St. Lawrence (Lambert and Dutil, 2000). The K values for the Northern Gulf of St. Lawrence were based on total weight less gonad weight, whereas the Scotian Shelf data include total weight.

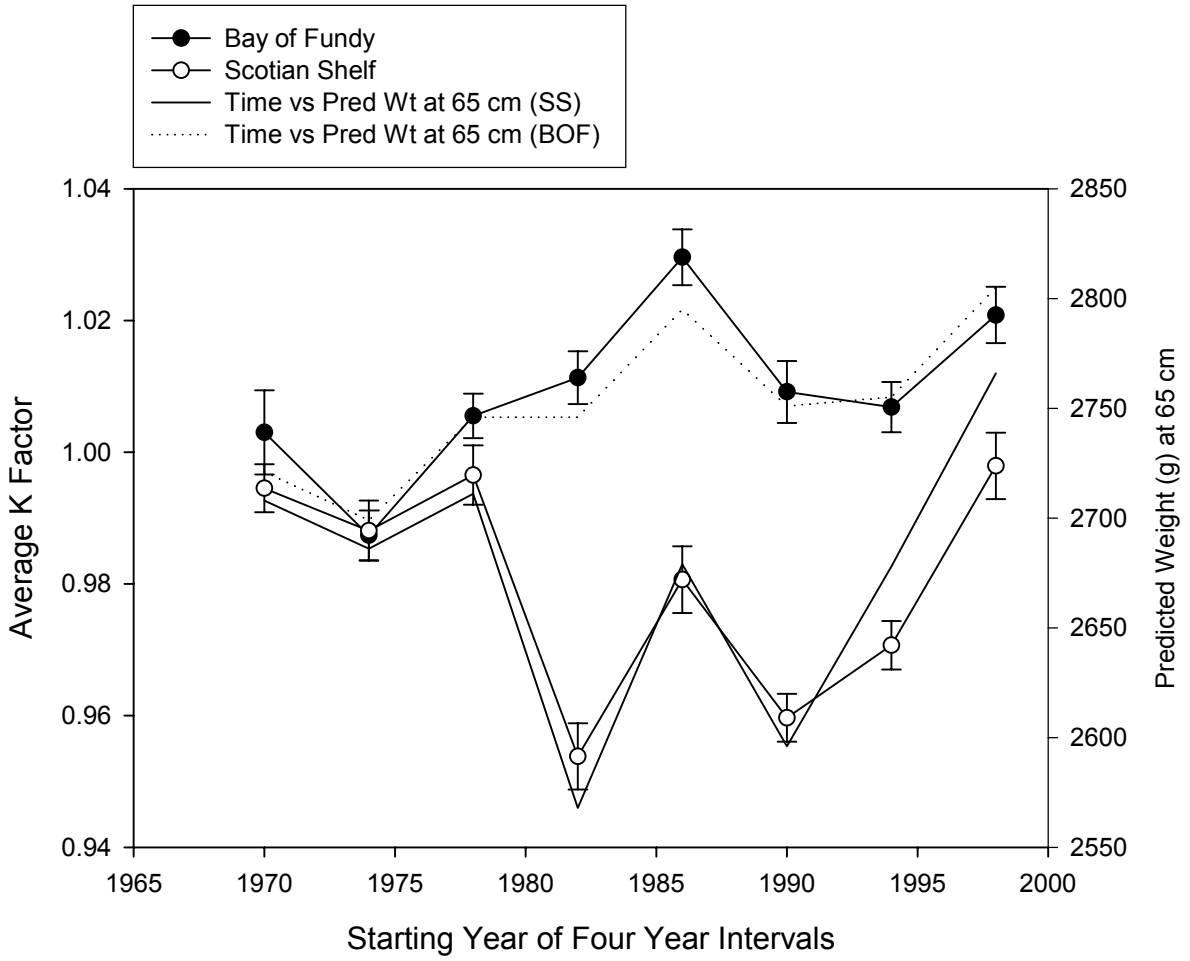

Fig. 6. Comparison of trends in condition of 4X Atlantic cod using Fulton's K, and a regression approach that provides the predicted weight at 65 cm.