Northwest Atlantic Fisheries Organization

Serial No. N4817 **NAFO SCR Doc. 03/11**

SCIENTIFIC COUNCIL MEETING – JUNE 2003

A Preliminary Examination of Variability in Condition of American Plaice in NAFO Divisions 3LNO

M. J. Morgan

Dept. of Fisheries and Oceans, PO Box 5667
St. John's, NL, A1C 5X1, Canada

Abstract

Spatial and temporal changes in condition were examined for American plaice (*Hippoglossoides platessoides*) in NAFO Div. 3L, 3N and 3O. Data were available from spring and fall Canadian research vessel surveys from 1993 to 2002 (2001 for fall). Data were available for males and females for both total body and liver weight. There was a clear seasonal difference in condition of American plaice with condition being higher in the fall. Relative body condition tended to be highest in Div. 3N in both spring and fall. Relative liver condition was highest in Div. 3L and lowest in Div. 3O in both seasons. There were no significant correlations between condition and abundance in a NAFO Division. There was significant annual variability in condition but no consistent pattern over time.

Key words: condition, liver, body, season, area.

Introduction

Measures of fish condition based on weight at a given length and liver size relative to body size, are thought to be reliable indicators of the energetic condition or energy reserves of fish (Lambert and Dutil, 1997a). Low condition is associated with poor feeding and/or environmental conditions and fish in poor condition may suffer increased natural mortality (Dutil and Lambert, 2000). Fish condition may vary annually as well as seasonally and can be related to changes in abundance and distribution (Lambert and Dutil, 1997b; Chouinard and Swain, 2002).

There have been large changes in the abundance and distribution of American plaice in Divi. 3LNO. The overall population has declined to low levels, at the same time as more of the population has been distributed in the southern area and in deeper waters (Morgan *et al.*, MS 2002; Morgan, 2001). These changes may be associated with spatial and temporal differences in condition. There is some indication that condition in American plaice changes seasonally (Maddock and Burton, 1999) but there has been little study of condition in this species.

The purpose of this study was to determine if there were spatial and temporal differences in condition in Div. 3LNO American plaice. Data were examined for differences between NAFO Divisions, across years and between spring and fall.

Materials and Methods

Data were available for males and females from Div. 3L, 3N and 3O. Surveys were conducted in the spring (mainly May to June) and fall (mainly October to December). Data were available from 1993 to 2002 (2001 for the fall) from stratified random research vessel surveys conducted by the Canadian Department of Fisheries and Oceans.

All weights were measured at sea using electronic balances. All weighed individuals had total body weight measured and a subset of individuals with body lengths of 30 cm or more also had liver weights measured. Because of the high variability of body weight measurements at small length, only fish greater than 12 cm in length were used in the analyses. The age of each individual was determined from otoliths and their total lengths were also measured.

Indices of condition were used to examine differences in both liver and body weight. For body weight the commonly used index of Fulton's K ($K=W/L^3$, where W is total body weight and L is length) showed an increasing trend with body length (Fig. 1), so an alternative index, relative K (K_r) was used. $K_r=W/\hat{W}$, where $\hat{W}$ is the predicted body weight from a length/weight relationship. The form of the length/weight relationship was $\log(W)=intercept + \log(L)$. This index removes the effect of length (Fig. 2). In this method a length/weight regression is carried out across each grouping or factor of interest. For instance, if seasonal differences for males are being examined by NAFO Division, a regression is conducted for each division using all spring and fall data together. To calculate K_r for an individual fish, its body weight was divided by the body weight predicted by the length/weight regression for a fish of that length, sex and, in this case, division. A similar index was calculated for liver condition, LK_r. As for K_r, LK_r was calculated using length/liver weight relationships calculated using data grouped over the appropriate factors.

To determine if there was a significant effect of season, division and year on LK_r or K_r, generalized linear models were used (McCullagh and Nelder, 1983). All models had an identity link function and a gamma error structure. All parameters were modelled as class variables. To examine the effect of abundance, correlations were conducted between the average K_r and LK_r for a division and year using spring data and the mean number per tow in the spring survey each year in that division.

Results and Discussion

There was a clear seasonal difference in condition of American plaice with condition being higher in the fall (Fig. 3, Table 1). Differences were significant both for body and liver condition, for all Divisions and for both sexes. There appeared to be less of a difference between the seasons in Div. 3O. Seasonal differences in condition are common and are thought to be related to differential allocation of energy to reproduction and somatic growth at different times of the year (Lambert and Dutil, 1997b; Maddock and Burton, 1999).

There were significant differences among Divisions in K_r in both spring and fall and for both sexes (Tables 2 and 3, Fig. 4 and 5). Although differences across divisions were not significant in all years, overall Div. 3N showed the highest condition in spring and to a lesser extent in fall as well. In fall both Div. 3N and 3L had higher K_r than Div. 3O.

There were also significant differences among Divisions and between sexes in LK_r in both spring and fall (Table 4 and 5, Fig. 4 and 5). However, the pattern across divisions was different for LK_r than for K_r. In both seasons LK_r was highest in Div. 3L and lowest in Div. 3O. It is not known why there would be a difference in spatial patterns between body condition and liver condition, although it may be related to differences in energy allocation, or in prey type.

There were no significant correlations between K_r and abundance in a division or between LK_r and abundance. It might be expected that fish in areas/years of low abundance would be in better condition because of higher food availability per individual. Alternatively it might be expected that fish condition would be better in areas of higher abundance because of higher survival and growth in areas of good environmental conditions. However neither of these hypotheses appeared to be the case as there were no significant negative or positive correlation between abundance and condition.

There was significant annual variability in both measures of condition for both sexes (Tables 2-5). Although there was some tendency for measures of condition to decline over time, this pattern was not consistent (Fig. 6-9)

References

CHOUINARD, G.A., and D.P. SWAIN. 2002. Depth-dependent variation in condition and length-at-age of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. **59**: 1451-1459.

DUTIL, J-D., and Y. LAMBERT. 2000. Natural mortality from poor condition in Atlantic cod (*Gadus morhua*). Can. J. Fish.Aquat. Sci., **57**: 826-836.

LAMBERT, Y., and J-D. DUTIL. 1997a. Can simple condition indices be used to monitor and quantify seasonal changes in the energy reserves of Atlantic cod (*Gadus morhua*)? Can. J. Fish. Aquat.Sci., **54(Suppl. 1):** 104-112.

LAMBERT, Y. and J-D. DUTIL. 1997b. Condition and energy reserves of Atlantic cod (*Gadus morhua*) during the collapse of the northern Gulf of St. Lawrence stock. Can. J. Fish. Aquat. Sci. 54: 2388-2400.

MADDOCK, D.M., and M.P.M. BURTON. 1999. Gross and histological observations of avarian development and related condition changes in American plaice. J. Fish Biol. **53:** 928-944.

MCCULLAGH, P., and J.A. NELDER. 1983. Generalized linear models. Chapman and Hall, London. 261 pp.

MORGAN, M.J. 2001. Time and location of spawning of American plaice in NAFO Divisions 3LNO. J. Northw. Atl. Fish. Sci. **29**: 41-49.

MORGAN, M.J., W.B. BRODIE, B.P. HEALEY, D. MADDOCK PARSONS, K.S. DWYER, and D. POWER. MS 2002. An assessment of American plaice in NAFO Div. 3LNO. NAFO SCR Doc. 02/70.

Table 1. Analyses of spring *vs.* fall data on relative body condition and relative liver condition. Results of generalized linear models are shown (χ^2 and p values).

	male		female	
Relative body condition				
3L	343.1	p<0.0001	824.5	p<0.0001
3N	657.9	p<0.0001	755.7	p<0.0001
3O	263.3	p<0.0001	340.7	p<0.0001
Relative liver condition				
3L	330.6	p<0.0001	762.6	p<0.0001
3N	356.9	p<0.0001	519.9	p<0.0001
3O	142.2	p<0.0001	392.6	p<0.0001

Table 2. Analyses of spring data on relative body condition. Results of generalized linear models are shown (χ^2 and p values) as well as the results of multiple contrast tests.

	male			female		
Effect of NAFO Division						
	81.4	p<0.0001	3L<3N, 3L=3O, 3N>3O	155.1	p<0.0001	3L<3N, 3L=3O, 3N>3O
Effect of NAFO Division by Year						
1993	97.5	p<0.0001	3L<3N, 3L=3O, 3N>3O	90.6	p<0.0001	3L<3N, 3L>3O, 3N>3O
1994	52.2	p<0.0001	3L<3N, 3L<3O, 3N>3O	55.6	p<0.0001	3L=3N, 3L>3O, 3N>3O
1995	58.6	p<0.0001	3L<3N, 3L=3O, 3N>3O	57.0	p<0.0001	3L<3N, 3L>3O, 3N>3O
1996	40.8	p<0.0001	3L<3N, 3L=3O, 3N>3O	59.3	p<0.0001	3L<3N, 3L=3O, 3N>3O
1997	17.4	p=0.002	3L>3N, 3L>3O, 3N=3O	5.6	NS	
1998	7.7	p=0.02	3L<3N, 3L<3O, 3N=3O	21.7	p<0.0001	3L<3N, 3L<3O, 3N=3O
1999	6.6	p=0.04	3L<3N, 3L=3O, 3N=3O	14.3	p=0.001	3L<3N, 3L=3O, 3N>3O
2000	4.5	NS		10.8	p=0.0046	3L<3N, 3L=3O, 3N>3O
2001	30.8	p<0.0001	3L<3N, 3L<3O, 3N=3O	22.4	p<0.0001	3L<3N, 3L<3O, 3N=3O
2002	6.6	p=0.04	3L<3N, 3L<3O, 3N=3O	0.5	NS	
Effect of Year by NAFO Division						
3L	133.1	p<0.0001		70.8	p<0.0001	
3N	97.5	p<0.0001		146.6	p<0.0001	
3O	67.6	p<0.0001		138.1	p<0.0001	

Table 3. Analyses of fall data on relative body condition. Results of generalized linear models are shown (χ^2 and p values) as well as the results of multiple contrast tests.

	male			female		
Effect of NAFO Division						
	133.9	p<0.0001	3L<3N, 3L>3O, 3N>3O	339.3	p<0.0001	3L<3N, 3L>3O, 3N>3O
Effect of NAFO Division by Year						
1993	96.2	p<0.0001	3L<3N, 3L=3O, 3N>3O	120.2	p<0.0001	3L<3N, 3L>3O, 3N>3O
1994	34.8	p<0.0001	3L<3N, 3L=3O, 3N>3O	74.9	p<0.0001	3L=3N, 3L>3O, 3N>3O
1995	59.7	p<0.0001	3L<3N, 3L<3O, 3N>3O	38.5	p<0.0001	3L<3N, 3L=3O, 3N>3O
1996	11.4	p=0.003	3L=3N, 3L>3O, 3N>3O	18.0	p<0.0001	3L=3N, 3L>3O, 3N>3O
1997	4.0	NS		39.4	p<0.0001	3L<3N, 3L>3O, 3N>3O
1998	29.8	p<0.0001	3L<3N, 3L>3O, 3N>3O	50.4	p<0.0001	3L=3N, 3L>3O, 3N>3O
1999	47.1	p<0.0001	3L=3N, 3L>3O, 3N>3O	72.4	p<0.0001	3L=3N, 3L>3O, 3N>3O
2000	8.5	p=0.01	3L<3N, 3L=3O, 3N>3O	8.5	p=0.01	3L<3N, 3L=3O, 3N=3O
2001	24.1	p<0.0001	3L>3N, 3L>3O, 3N>3O	41.3	p<0.0001	3L=3N, 3L>3O, 3N>3O
Effect of Year by Division						
3L	42.6	p<0.0001		56.3	p<0.0001	
3N	109.4	p<0.0001		91.3	p<0.0001	
3O	72.1	p<0.0001		35.4	p<0.0001	

Table 4. Analyses of spring data on relative liver condition. Results of generalized linear models are shown (χ^2 and p values) as well as the results of multiple contrast tests.

	male				female		
Effect of NAFO Division							
3.3	NS				49.6	3L>3N, 3L>3O, 3N>3O	
Effect of NAFO Division by Year							
1993	11.0	p=0.004	3L<3N, 3L=3O, 3N>3O		4.3	NS	
1994	0.8	NS			7.8	p=0.02	3L>3N, 3L>3O, 3N=3O
1995	1.0	NS			11.0	p=0.0009	3L>3O (no 3N data)
1996	2.2	NS			18.3	p=0.0001	3L=3N, 3L>3O, 3N>3O
1997	9.9	p=0.007	3L=3N, 3L>3O, 3N>3O		4.3	NS	
1998	1.9	NS			4.3	NS	
1999	0.2	NS			23.4	p<0.0001	3L>3N, 3L>3O, 3N>3O
2000	2.9	NS			11.7	p=0.66	3L>3N, 3L>3O, 3N=3O
2001	4.2	NS			5.6	NS	
2002	0.03	NS			2.0	NS	
Effect of Year by Division							
3L	20.4	p=0.02		28.7	p=0.0007		
3N	39.0	p<0.0001			23.4	p=0.0028	
3O	17.1	p=0.048			29.8	p=0.0005	

Table 5. Analyses of fall data on relative liver condition. Results of generalized linear models are shown (χ^2 and p values) as well as the results of multiple contrast tests.

	male			female		
Effect of NAFO Division						
75.6	p<0.0001	3L>3N, 3L>3O, 3N>3O	347.9	p<0.0001	3L>3N, 3L>3O, 3N>3O	
Effect of NAFO Division by Year						
1993	10.9	p=0.004	3L=3N, 3L>3O, 3N>3O	60.9	p<0.0001	3L>3N, 3L>3O, 3N>3O
1994	0.2	NS		23.3	p<0.0001	3L=3N, 3L>3O, 3N>3O
1995	2.0	NS		37.5	p<0.0001	3L>3N, 3L>3O, 3N>3O
1996	10.7	p=0.005	3L=3N, 3L=3O, 3N>3O	53.4	p<0.0001	3L=3N, 3L>3O, 3N>3O
1997	10.9	p=0.004	3L=3N, 3L>3O, 3N>3O	42.4	p<0.0001	3L>3N, 3L>3O, 3N>3O
1998	21.2	p<0.0001	3L>3N, 3L>3O, 3N=3O	48.8	p<0.0001	3L>3N, 3L>3O, 3N>3O
1999	39.2	p<0.0001	3L>3N, 3L>3O, 3N>3O	112.7	p<0.0001	3L>3N, 3L>3O, 3N>3O
2000	2.78	NS		27.0	p<0.0001	3L>3N, 3L>3O, 3N=3O
2001	20.4	p<0.0001	3L>3N, 3L>3O, 3N>3O	64.4	p<0.0001	3L>3N, 3L>3O, 3N>3O
Effect of Year by Division						
3L	31.3	p=0.0001		25.2	p=0.0015	
3N	37.3	p<0.0001		131.5	p<0.0001	
3O	36.7	p<0.0001		54.9	p<0.0001	

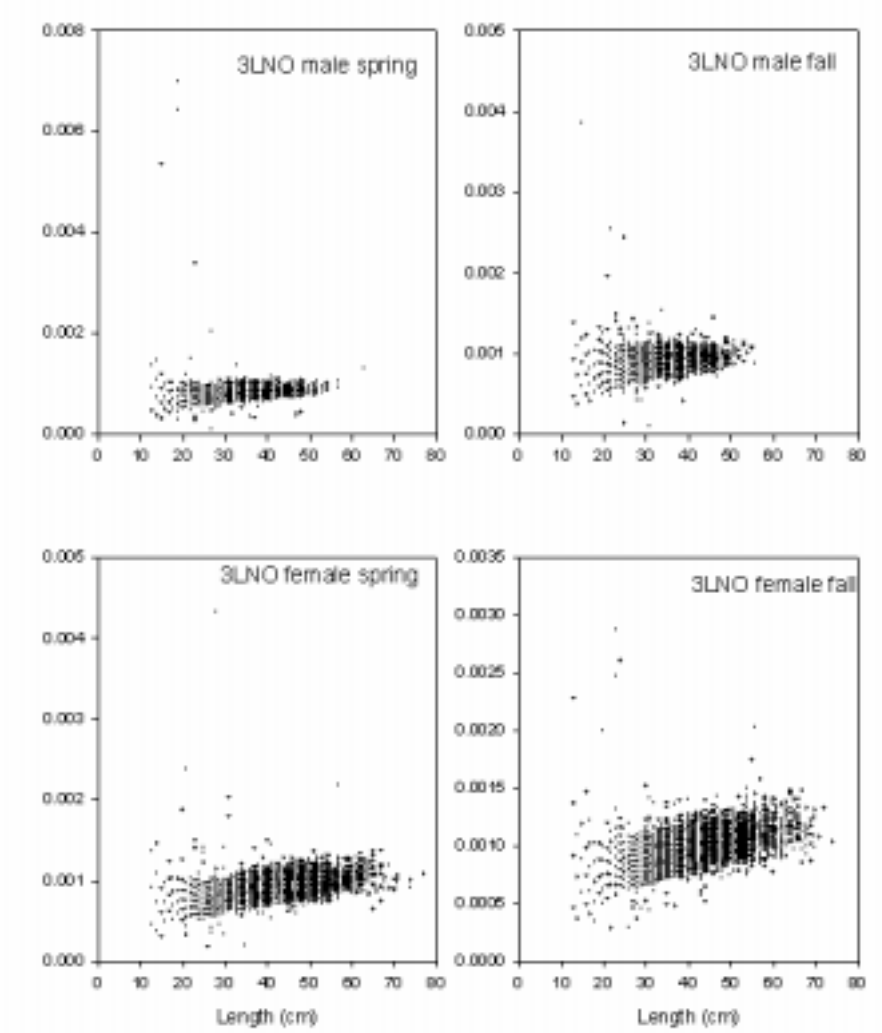

Fig. 1. Fulton's K for male and female American plaice in NAFO Div. 3LNO at different lengths. Data are from Canadian spring and fall surveys.

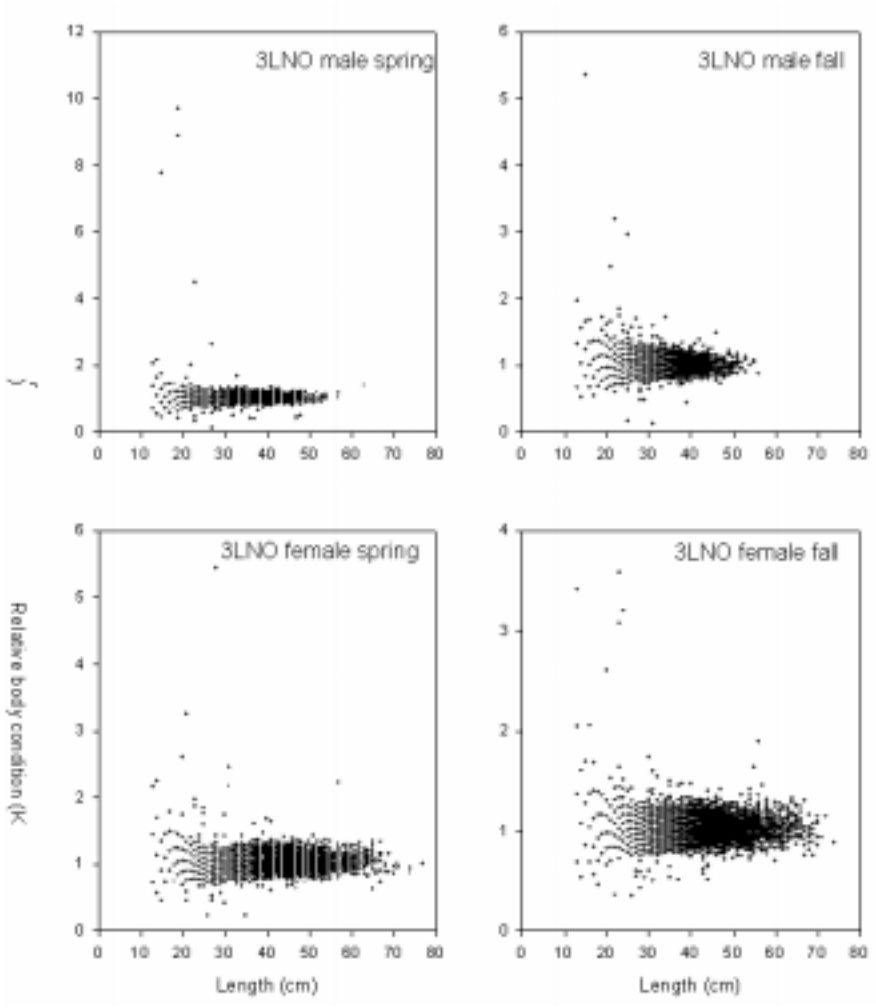

Fig. 2. Relative body condition (Kr) for male and female American plaice in NAFO Div. 3LNO at different lengths. Data are from Canadian spring and fall surveys.

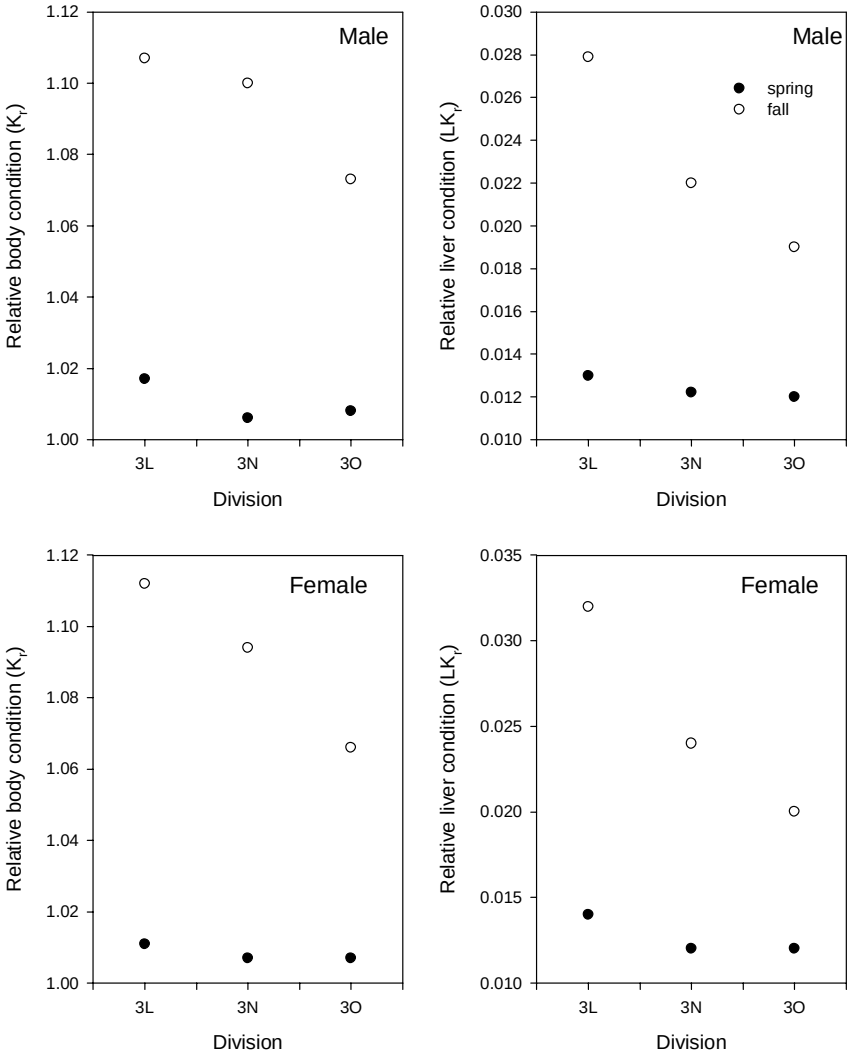

Fig. 3. Relative body condition (K_r) and relative liver condition (LK_r) for male and female American plaice in Div.3L, 3N and 3O. The open circles are spring and the closed circles fall.

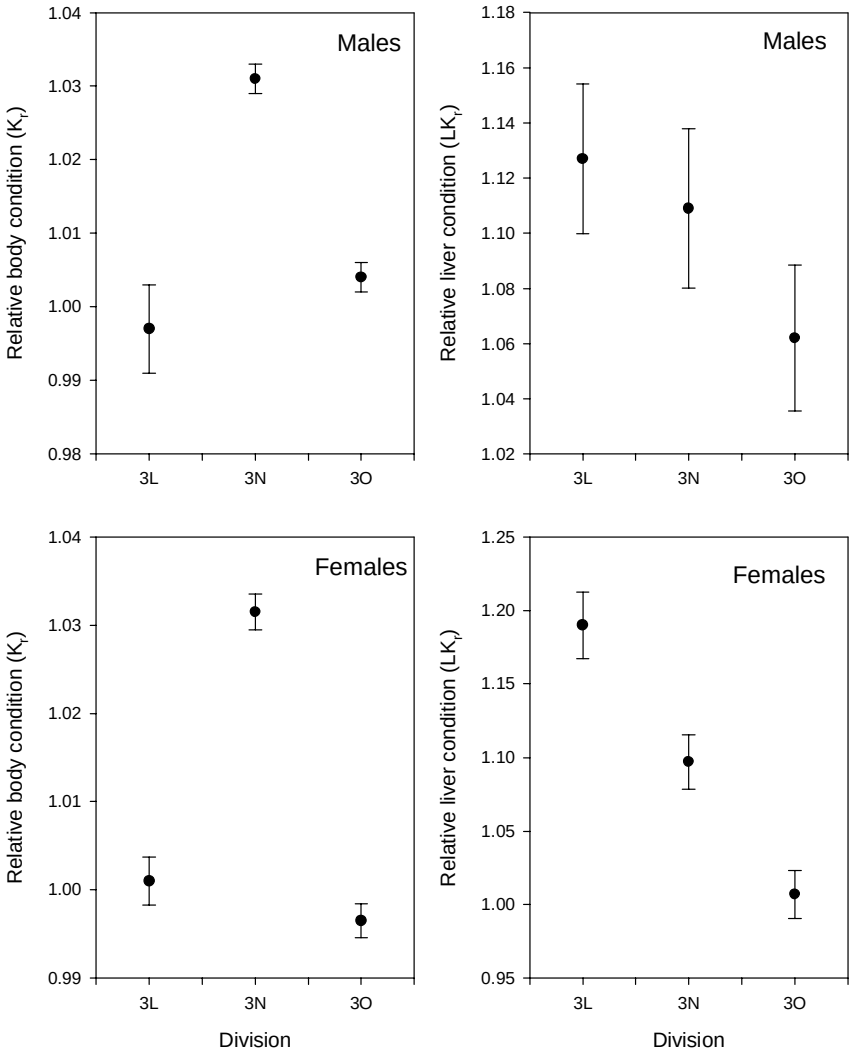

Fig. 4. Relative body condition (K_r) and relative liver condition (LK_r) for male and female American plaice in NAFO Div. 3L, 3N and 3O. Means $\pm$ 1 standard error are shown. Data are from Canadian spring surveys.

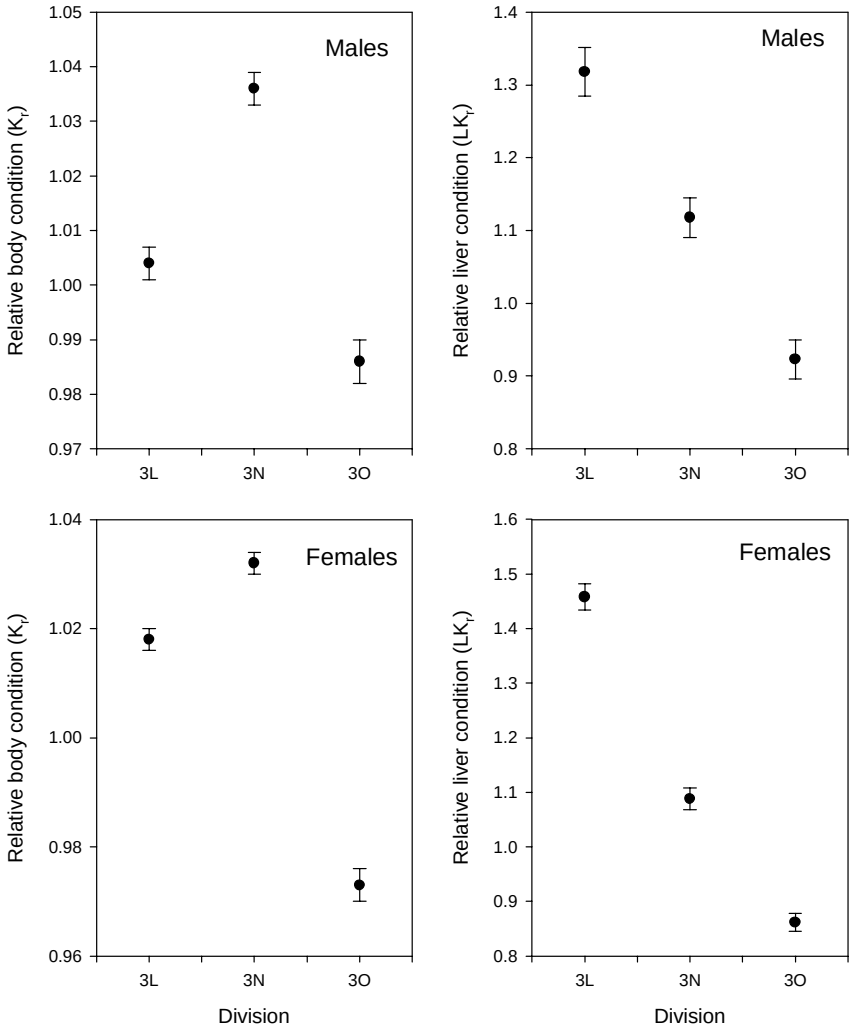

Fig. 5. Relative body condition (K_r) and relative liver condition (LK_r) for male and female American plaice in NAFO Div. 3L, 3N and 3O. Means $\pm$ 1 standard error are shown. Data are from Canadian fall surveys.

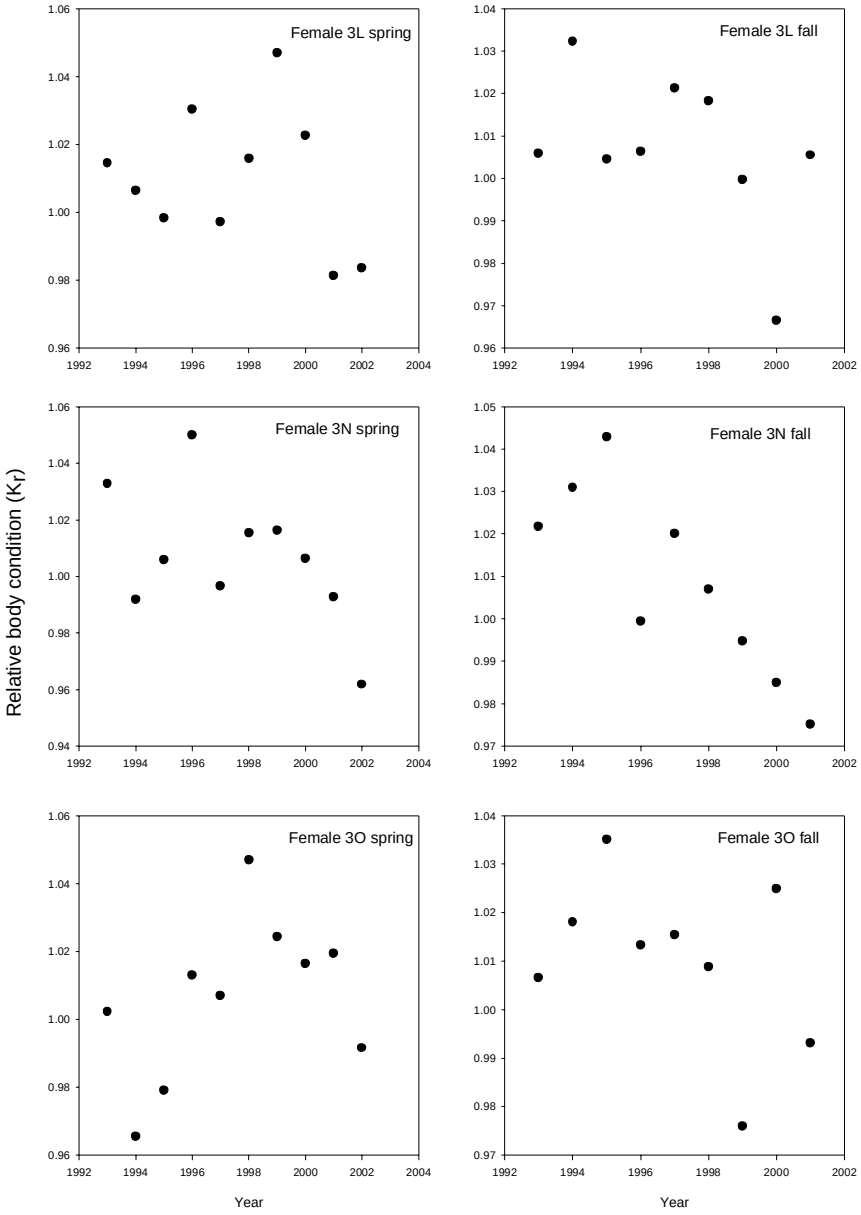

Fig. 6. Mean relative body condition (K_r) for female American plaice in NAFO Div. 3L, 3N and 3O for each year in spring and fall.

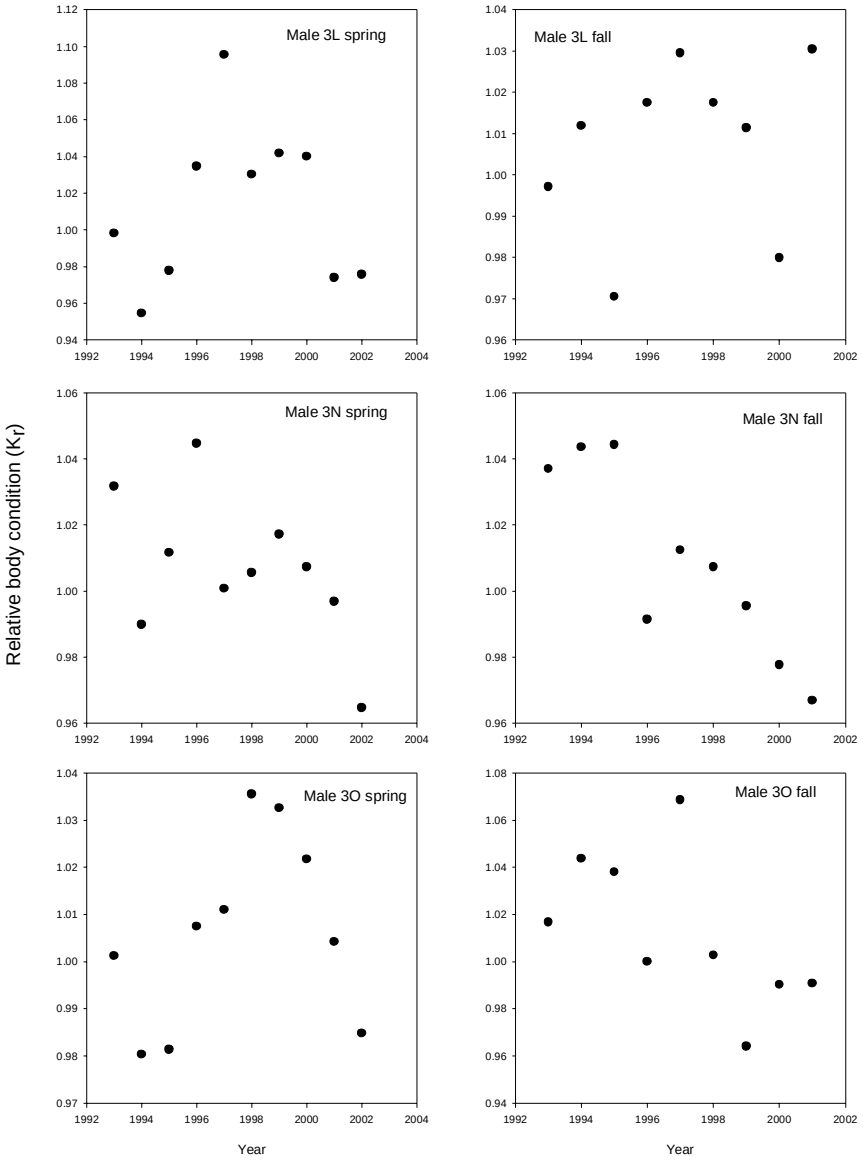

Fig. 7. Mean relative body condition (K_r) for male American plaice in NAFO Div. 3L, 3N and 3O for each year in spring and fall.

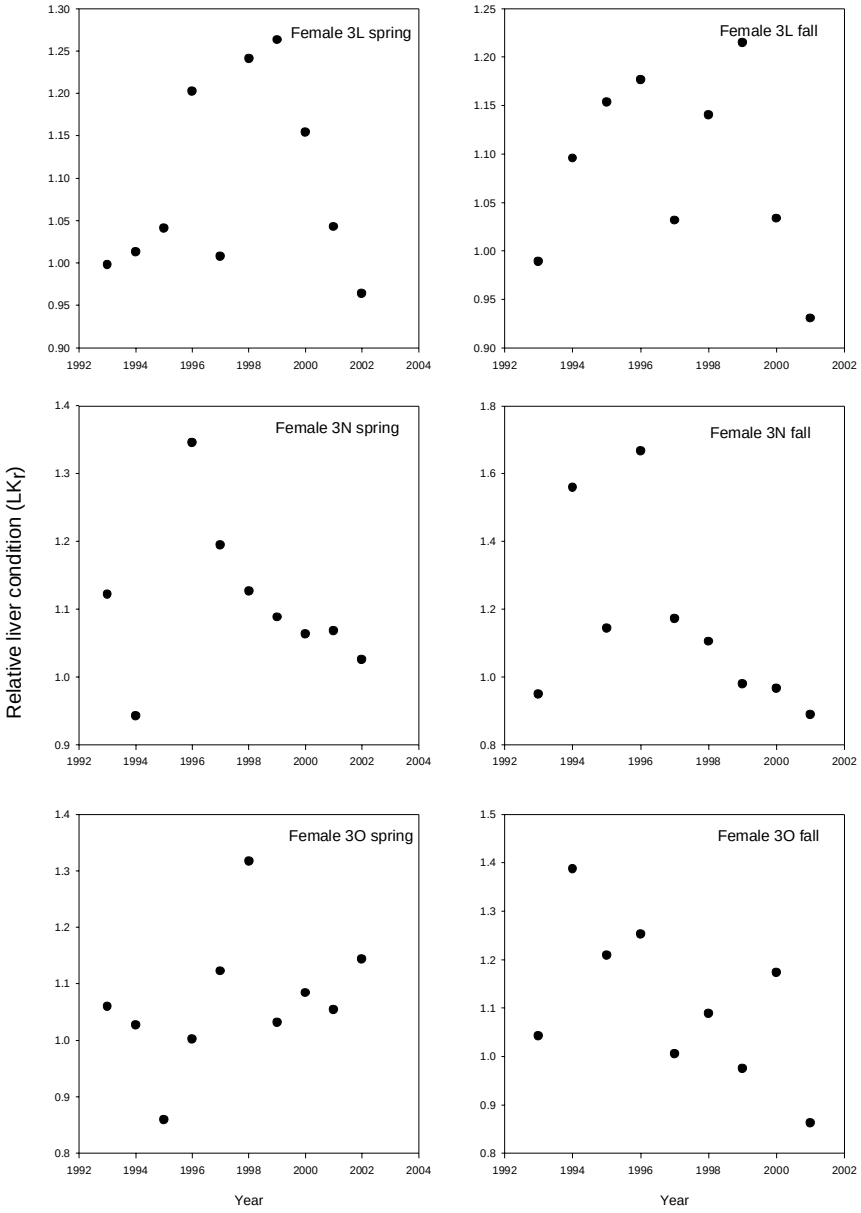

Fig. 8. Mean relative liver condition (LK_r) for female American plaice in NAFO Div. 3L, 3N and 3O for each year in spring and fall.

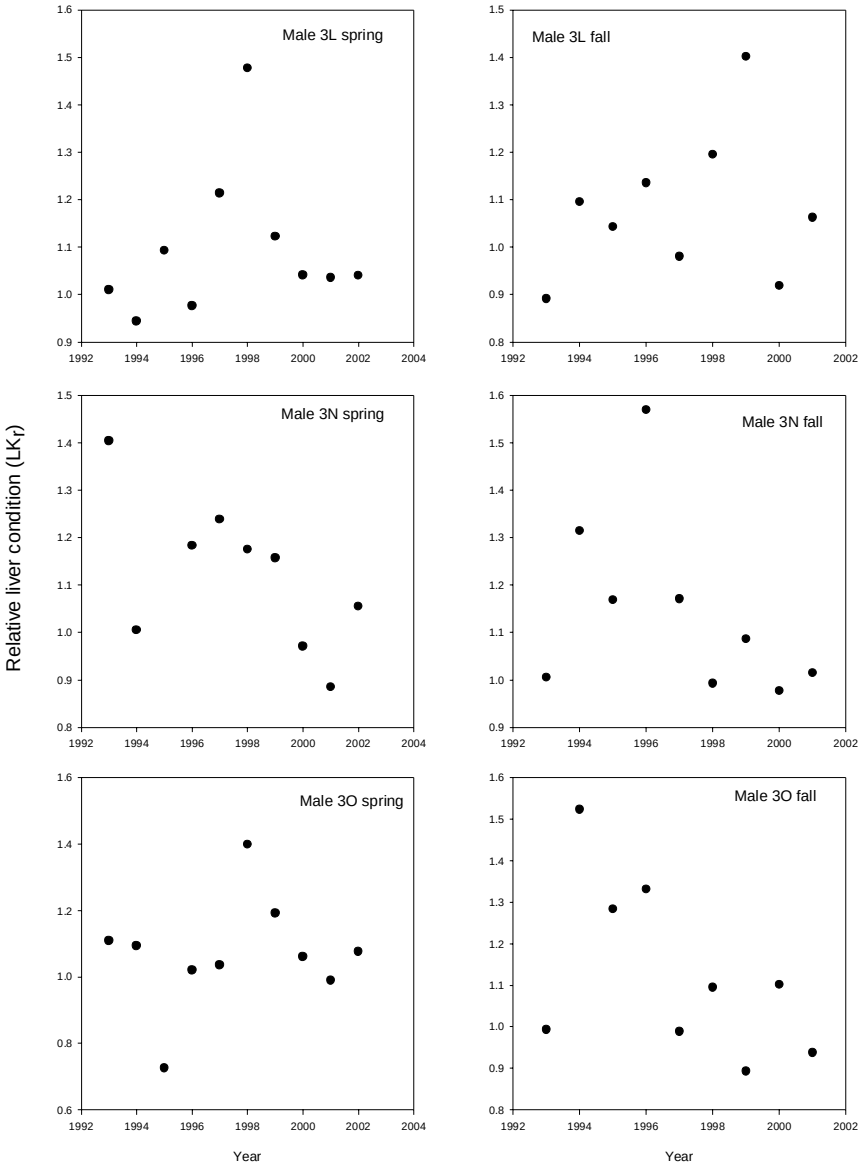

Fig. 9. Mean relative liver condition (LK_r) for male American plaice in NAFO Div. 3L, 3N and 3O for each year in spring and fall.