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Temporal and Spatial Variation in Age and Length at Maturity in 2J3KL Cod

by

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Introduction

Significant year effects in age and length at maturity have been found for female cod in Div. 2J3KL for the period 1978-90 with a significant trend of declining length at maturity over that period (Xu et al. 1991). This paper extends this time period by 2 years including data from 1991-92 and also examines length and age at maturity for male cod in Div. 2J3KL over this 1978-92 time period.

Materials and Methods

Age, maturity and length frequency data collected from fall research vessel surveys were analyzed. One year was added to the ages in the fall surveys to produce ages on January 1 of the following year. For 2J and 3K, survey data were available from 1978-92. For 3L, the time period was 1981-92. In 3L, the fall survey from 1984 was not included since this survey ended 2 months before any fall survey in other years or areas began.

Otoliths were collected for ageing using a length stratified sampling scheme. A given age can straddle several length classes. The probability of being mature at a given age generally increases with length, with larger fish being more likely to be mature. This can result in inaccuracies in the estimation of proportion mature at age if length and catch at length are not taken into account. A formula developed by Hoenig and Morgan (in prep.) was used to correct for this length stratified sampling scheme.

$$\textit{Proportion mature at age}_a = \frac{\sum_{j=1}^{n} (C_j P_{aj} P_{ajm})}{\sum_{j=1}^{n} (C_j P_{aj})}$$

where: C_j = estimated population number at length j
P_{aj} = proportion of age a that is length j
P_{ajm} = proportion of age a at length j that is mature
n = number of length classes

The estimated population number at length (C_j) was calculated from research vessel survey length frequencies using Stratified Analysis Programs (Smith and Somerton, 1981) which weight the catch from a stratum by the size of the stratum.

Age and length at 50% maturity (A_{50} and L_{50}) were produced for each year, Division and sex with probit analysis, assuming a normal distribution (SAS Institute Inc., 1989). A_{50} and L_{50} were compared between males and females and for both sexes across Division. A year effect was examined by including data from all years in a

probit analysis for each Division and sex. Year was included as a class variable in the analyses to determine if year explained a significant amount of the variation in maturity at age and length. A_{50} and L_{50} were then examined across groups of years using either ANOVA or t-tests or their nonparametric equivalents. For 2J and 3K the data was divided into 3 five year time periods. For 3L the first 5 years was compared to the last 5 years.

Results

The A_{50} by year, Division and sex are shown in Table 1 and Figure 1. The L_{50} by year, Division and sex are shown in Table 2 and Figure 2. For all divisions the A_{50} and L_{50} for females was greater than for males (Table 3). A_{50} for females did not show a significant trend with division but the A_{50} for males did with the males maturing at a older age in the south than in the north (Table 4). L_{50} for both females and males showed significant geographical variation, maturing at a larger size in the south (Table 4).

For both sexes, in all divisions, year explained a significant amount of the variability in maturity at age (Table 5). Year also explained a significant amount of the variability in maturity at length for both sexes in all divisions (Table 6).

In all divisions the A_{50}s for both males and females in 1993 are the lowest in the time series (Table 1 and Figure 1). The L_{50}s in 1993 are also the lowest in the time series (Table 2 and Figure 2). However, for A_{50} this variation was not generally significant in a simple analyses across time period for any division for either males or females. Only males in 2J showed a significant difference in A_{50} across time (Table 7). However, in all divisions, both males and females showed a significant difference in L_{50} across time (Table 8). An examination of the Figures shows clearly that the trend across time is greater for length than age. Age at maturity does appear to be declining in recent years but the trend is not as great as for length.

Discussion

For all Divisions, females matured at a later age and larger size than males. Males matured at an older age in the south and both males and females matured at a larger size in the south.

There was significant yearly variation in both the maturity at length and age for both sexes. Both A_{50}s and L_{50}s in 1993 are the lowest in the time series. However, declines in length at maturity are much more distinct than declines in age at maturity. It is possible that inherent variability in age at maturity, as well as a greater variability in age measurement, make it difficult to detect trends in age at maturity over short periods. Also, changes in length at maturity may be the result of declines in growth.

The results of this analyses are very similar to those of Xu et al (1991). (To compare A_{50} and L_{50} between the papers one year must be added to the year in Table 2 and 6 of Xu et al to give them a time period of 1979-1991). Although the methods of analyses used in the two papers were different the A_{50} and L_{50} are very similar. Also, the trends from north to south, with fish generally maturing larger and older in the south are similar. As well the greater decline in size at maturity over time than in age at maturity found here is consistent with the patterns observed in Xu et al (1991).

References

SAS Institute Inc. 1989. SAS/STAT Users Guide Version 6, Fourth Edition. Vol. 2. SAS Institute Inc., Cary NC, 846 pp.

Smith, S.J. and G.D. Somerton. 1981. STRAP: A user-oriented computer analysis system for groundfish research trawl survey data. Can. Tech. Rep. Fish. Aquat. Sci. 1030: iv + 66 p.

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TABLE 1. AGE AT 50% MATURITY ON JANUARY 1						
YEAR	2J		3K		3L	
	FEMALES	MALES	FEMALES	MALES	FEMALES	MALES
1979	6.01	4.82	6.50	4.75	--	--
1980	5.60	4.30	5.50	4.36	--	--
1981	5.57	4.80	6.04	4.75	--	--
1982	6.36	4.94	6.00	4.47	6.30	5.18
1983	6.10	4.58	6.24	4.83	5.90	5.22
1984	6.20	4.49	5.99	4.56	6.32	5.30
1985	5.73	4.72	5.82	4.91	--	--
1986	6.04	4.69	5.91	4.53	6.53	5.39
1987	6.06	4.54	5.96	5.00	6.93	6.07
1988	5.92	4.53	6.10	4.75	6.53	5.33
1989	6.05	4.46	5.78	5.00	5.71	5.13
1990	5.81	4.36	5.84	4.64	5.93	5.06
1991	5.70	4.39	5.98	4.67	6.44	5.36
1992	5.64	3.73	5.37	3.97	6.86	4.85
1993	5.44	3.43	5.10	3.86	5.50	4.29

TABLE 2. LENGTH AT 50% MATURITY ON JANUARY 1						
YEAR	2J		3K		3L	
	FEMALES	MALES	FEMALES	MALES	FEMALES	MALES
1979	53.92	43.36	60.82	44.13	--	--
1980	52.47	40.82	53.56	44.24	--	--
1981	53.09	44.20	55.31	44.54	--	--
1982	55.52	44.88	54.93	45.76	54.58	46.64
1983	54.18	42.61	56.14	47.27	57.16	50.68
1984	54.67	42.16	55.90	44.19	58.73	49.24
1985	49.55	40.58	52.98	45.76	--	--
1986	48.08	37.92	51.28	41.85	54.96	46.84
1987	48.19	38.27	50.77	43.15	57.64	50.26
1988	47.84	40.01	51.81	42.62	56.62	46.31
1989	48.59	39.94	49.53	43.59	50.19	45.18
1990	48.44	38.61	50.34	41.63	50.80	44.56
1991	45.94	36.60	49.76	40.99	54.95	47.03
1992	42.90	31.15	45.07	35.94	55.72	43.66
1993	39.78	31.06	41.88	35.10	47.09	38.44

Table 3. Comparison of A_{50} and L_{50} Between Males and Females by Division			
A_{50}	Mean	Std Dev	Test Result
2J Female	5.88	0.26	t=3.17 df=28 p<0.001
2J Male	4.45	0.40	
3K Female	5.88	0.34	t=3.26 df=28 p<0.001
3K Male	4.60	0.33	
3L Female	6.27	0.46	t=5.66 df=20 p<0.001
3L Male	5.20	0.43	
L_{50}			
2J Female	49.54	4.51	t=6.36 df=28 p<0.001
2J Male	39.48	4.14	
3K Female	52.00	4.62	t=6.28 df=28 p<0.001
3K Male	42.72	3.37	
3L Female	54.18	3.70	t=4.85 df=18 p<0.001
3L Male	46.25	3.61	

Table 4. Comparison of A_{50} and L_{50} Across Division H's are from Kruskal-Wallis ANOVA by Ranks F's are from ANOVA			
A_{50} Males	Mean	Std Dev	Test Result
2J	4.45	0.40	H=16.77 df=2 p<0.001
3K	4.60	0.33	
3L	5.20	0.43	
A_{50} Females			
2J	5.88	0.26	F=4.90 df=2,40 p<0.05
3K	5.88	0.34	
3L	6.27	0.46	
L_{50} Males			
2J	39.48	4.14	H=15.57 df=2 p<0.001
3K	42.72	3.37	
3L	46.25	3.61	
L_{50} Females			
2J	49.54	4.51	F=3.46 df=2,39 p<0.05
3K	52.00	4.62	
3L	54.18	3.70	

TABLE 5. RESULTS OF PROBIT ANALYSIS ON EFFECT OF YEAR ON MATURITY AT AGE BY DIVISION		
2J	FEMALES	X^2=1943.8 DF=14 P<0.001
	MALES	X^2=1724.4 DF=14 P<0.001
3K	FEMALES	X^2=2524.7 DF=14 P<0.001
	MALES	X^2=2171.3 DF=14 P<0.001
3L	FEMALES	X^2=2219.6 DF=10 P<0.001
	MALES	X^2=2095.2 DF=10 P<0.001

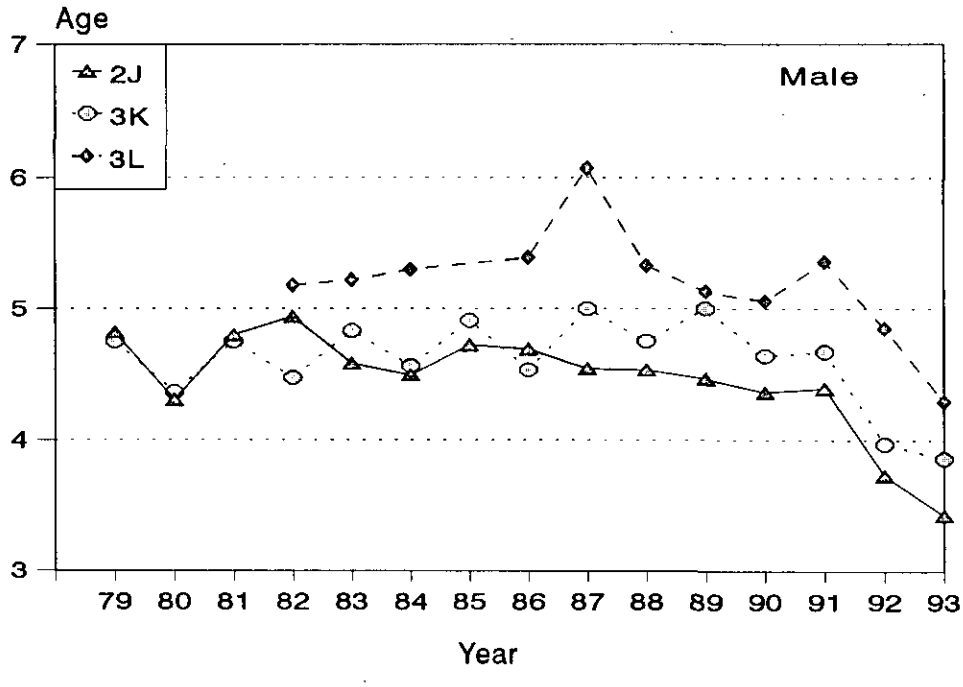
TABLE 6. RESULTS OF PROBIT ANALYSES ON EFFECT OF YEAR ON MATURITY AT LENGTH BY DIVISION		
2J	FEMALES	X^2=384.7 DF=14 P<0.001
	MALES	X^2=497.5 DF=14 P<0.001
3K	FEMALES	X^2=435.7 DF=14 P<0.001
	MALES	X^2=263.6 DF=14 P<0.001
3L	FEMALES	X^2=169.8 DF=10 P<0.001
	MALES	X^2=145.2 DF=10 P<0.001

Table 7. Comparison of A_{50} Across Time Period by Division and Sex

2J Males	Mean	Std Dev	Test Result
1979-83	4.69	0.25	F=5.65 df=2,14 p<0.05
1984-88	4.59	0.10	
1989-93	4.07	0.46	
3K Males			
1979-83	4.63	0.20	F=1.22 df=2,14 p=0.33
1984-88	4.75	0.21	
1989-93	4.43	0.49	
3L Males			
1982-87	5.43	0.36	t=2.02 df=8 p=0.08
1989-93	4.94	0.40	
2J Females			
1979-83	5.93	0.34	F=1.43 df=2,14 p=0.28
1984-88	5.99	0.18	
1989-93	5.73	0.22	
3K Females			
1979-83	6.06	0.37	F=2.87 df=2,14 p=0.10
1984-88	5.96	0.10	
1989-93	5.61	0.37	
3L Females			
1982-87	6.40	0.38	t=1.03 df=8 p=0.33
1989-93	6.09	0.56	

Table 8. Comparison of L_{50} Across Time Period by Division by Sex. F's are from ANOVA, H's are from Kruskal-Wallis ANOVA by ranks, and t's from t-tests

2J Females	Mean	Std Dev	Test Result
1979-83	53.84	1.16	F=11.89 df=2,14 p<0.001
1984-88	49.67	2.88	
1989-93	45.13	3.78	
3K Females			
1979-83	56.15	2.77	F=11.61 df=2,14 p<0.002
1984-88	52.54	2.04	
1989-93	47.32	3.70	
3L Females			
1982-87	56.61	1.78	t=2.72 df=8 p<0.05
1989-93	51.75	3.57	
2J Males			
1979-83	43.17	1.57	H=10.26 df=2 p<0.01
1984-88	39.88	1.65	
1989-93	35.47	4.16	
2K Males			
1979-83	45.19	1.33	F=7.28 df=2,14 p<0.01
1984-88	43.51	1.52	
1989-93	39.45	3.72	
3L Males			
1982-87	48.73	1.90	t=2.96 df=8 p<0.05
1989-93	43.77	3.23	



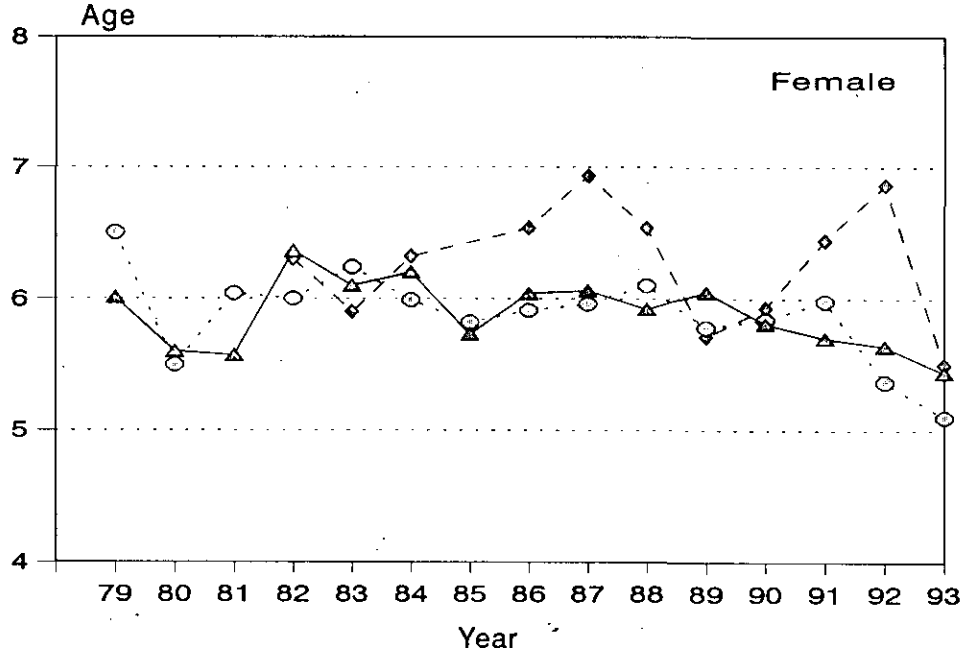
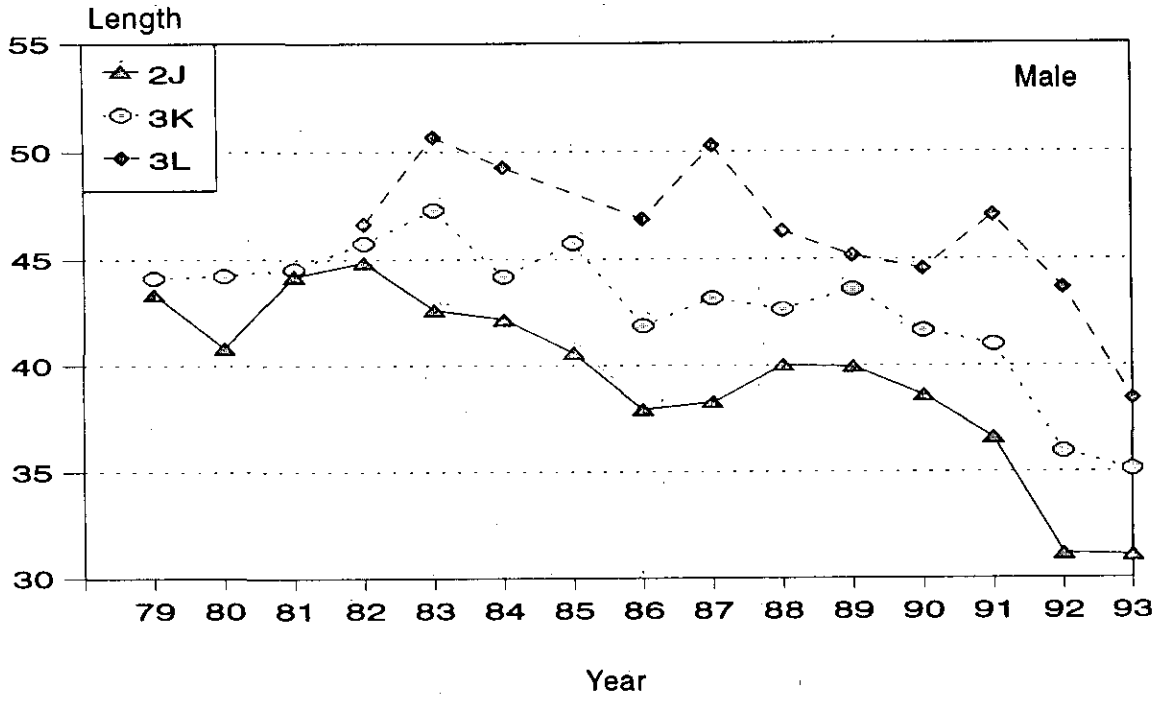


Fig. 1 Age at 50% maturity (Jan. 1) for Cod in Div. 2J3KL.



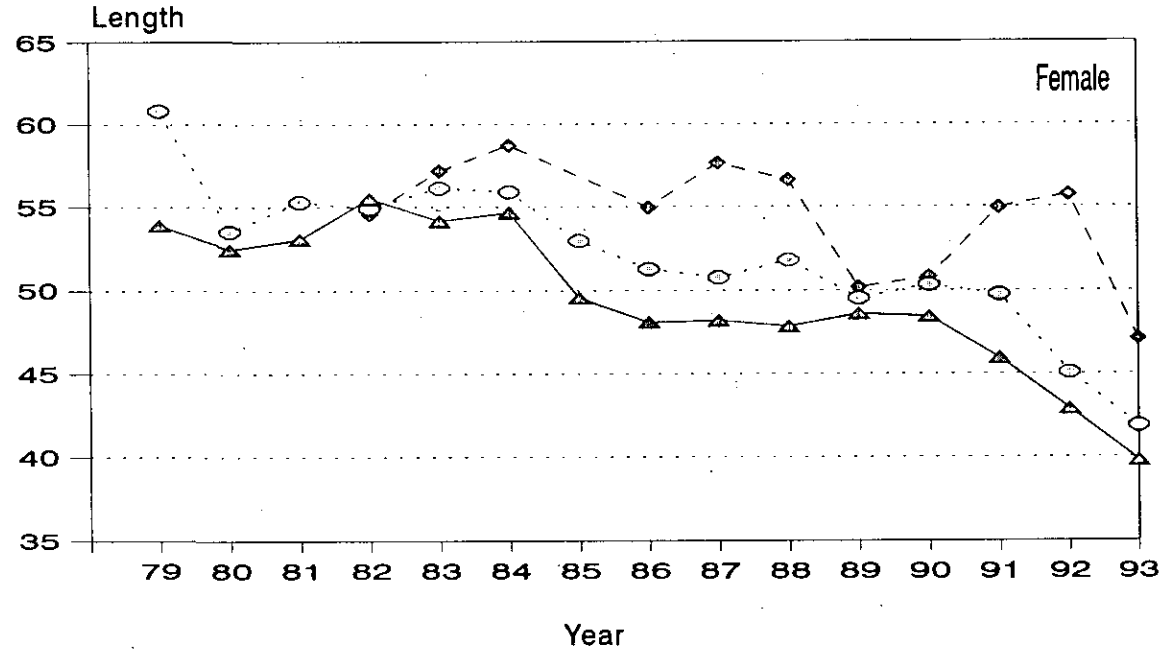


Fig.2 Length at 50% maturity (Jan. 1) for Cod in Div. 2J3KL.