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Temporal and Spatial Variation in Age and Length at Maturity in Cod in Divisions 2J and 3KL

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Abstract

Age and length-at-maturity were calculated for male and female cod (*Gadus morhua*) in NAFO Div. 2J and 3KL for the 1978–92 period. There have been significant declines in length at 50% maturity during this period for both sexes in all three Divisions. The age at 50% maturity in 1993 was the lowest in the time period for both sexes in all Divisions but the trend was generally not significant.

Key words: Age, cod, length, maturity, sex

Introduction

Significant year effects in age- and length-at-maturity have been found for female cod (*Gadus morhua*) in Div. 2J and 3KL for the period 1978–90 with a significant trend of declining length-at-maturity over that period (Xu *et al*. MS 1991). This paper extends this time period by 2 years including data from 1991 and 1992, and also examines length- and age-at-maturity for male cod in Div. 2J and 3KL over this 1978–92 period.

Materials and Methods

Age, maturity and length frequency data collected from autumn research vessel surveys of the Canadian Department of Fisheries and Oceans were analyzed. One year was added to the ages in the autumn surveys to produce ages on 1 January of the following year. For Div. 2J and 3K, survey data were available from 1978 to 1992. For Div. 3L, the time period was 1981–92. In Div. 3L, the autumn survey from 1984 was not included since the period of this survey ended 2 months before any of the autumn surveys in other years or areas began. Since estimates were produced for 1 January the overall time period was 1979–93.

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 the proportion mature at age if length and catch at length are not taken into account. A formula developed by Morgan and Hoenig (MS 1993) was used to correct for this length stratified sampling scheme:

$$\text{Proportion mature at age} = \frac{\sum_{j=1}^{n} C_j \, P(a \mid j) \, P(m \mid a, j)}{\sum_{j=1}^{n} C_j \, P(a \mid j)}$$

where: C_j = number caught at length j

$P(a \mid j)$ = probability of age a, given length j

$P(m \mid a, j)$ = probability of being mature, given age a and length j

n = number of length-classes

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

The proportion mature at length was calculated for each Division and each sex by dividing the number mature at a given length by the total number sampled at that length.

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 Divisions. A_{50} and L_{50} were then examined across groups of years using either ANOVA or t-tests or their nonparametric equivalents. For Div. 2J and 3K the data were divided into three 5-year time periods. For Div. 3L the first 5 years was compared to the last years.

Combined estimates of A_{50} and L_{50} for Div. 2J and 3KL were also produced for each sex for each year from 1982 to 1993. The proportion mature at each age was estimated by summing the number of mature fish at an age across Divisions, and dividing by the sum across the three Divisions of the number of fish at that age. To produce a combined estimate for Div. 2J and 3KL of the proportion mature at each length, the number mature at length and the total number at length in a Division were weighted by the proportion of the total Div. 2J and 3KL biomass in that Division and then summed across Division. The combined estimate of number mature at length was then divided by the combined estimate of the total number at length to produce the proportion mature at length. A_{50} and L_{50} were then estimated using probit analyses as above. Estimates from the first 5 years were compared to the last 5 years using t-tests.

Results

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

In all Divisions, the A_{50} for both males and females in 1993 were the lowest in the time series (Table 1 and Fig. 1), and similarly the L_{50} in 1993 were also the lowest in the time series (Table 2 and Fig. 2). However, for A_{50} this variation was not generally found to be significant in a simple analysis across the time period for any Division for either males or females. Only males in Div. 2J showed a significant difference in A_{50} across the time series (Table 5). However, in all Divisions, both males and females showed a significant difference in L_{50} across the time series (Table 6). An examination of Fig. 1 and 2 shows clearly that the trend across time is greater for length than age. The age-at-maturity did appear to be declining in recent years but the trend was not as great as for length.

Estimates of A_{50} and L_{50} for Div. 2J and 3KL combined are given in Table 7 and Fig. 3. Analyses of these results by sex showed that the combined female estimates of age at 50% maturity were significantly different in the two 5-year periods, while those of males were not. Both males and females had significantly different estimates of length at 50% maturity in the two time periods (Table 8).

Discussion

For all Divisions, females matured at a later age and larger size than males. Males matured at an older age in the southern areas and both males and females matured at a larger size in the southern area. Maturation at an older age and larger size in the south has also been found by Baird *et al.* (MS 1986).

Both A_{50} and L_{50} in 1993 were the lowest in the time series. However, the declines in length-at-maturity were much more distinct than the declines in age-at-maturity. For both sexes, for the three Divisions separately, as well as Div. 2J and 3KL combined, there was a significant decline in L_{50} over

TABLE 1. Age at 50% maturity of cod in Div. 2J, 3K and 3L on 1 January.

	2J		3K		3L	
Year	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

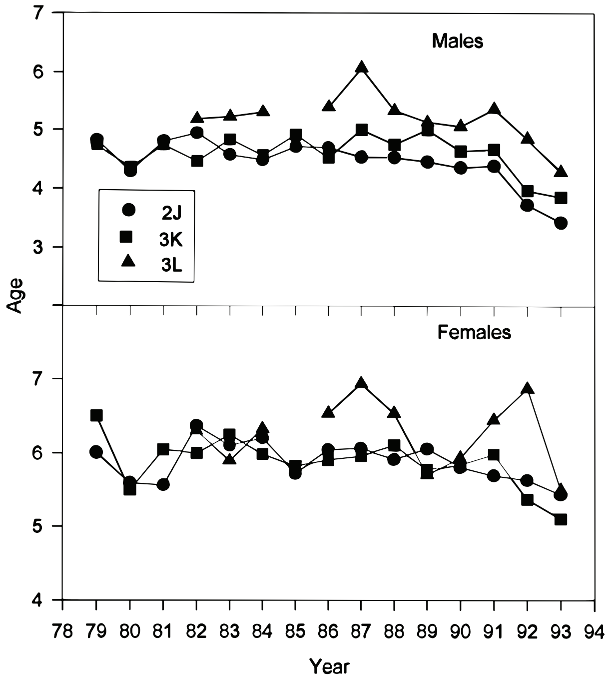

Fig. 1. Age at 50% maturity for males and females in Div. 2J, 3K and 3L on 1 January of each year.

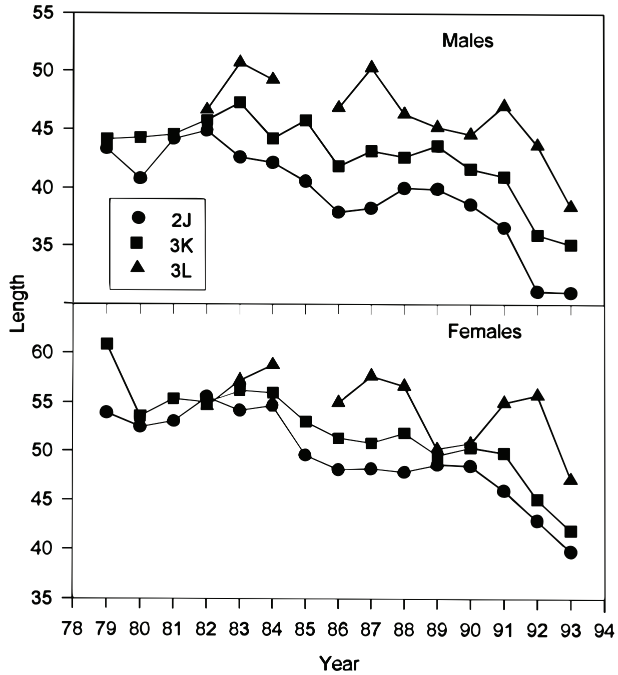

Fig. 2. Length at 50% maturity for males and females in Div. 2J, 3K and 3L on 1 January of each year.

TABLE 2. Length (cm) at 50% maturity of cod in Div. 2J, 3K and 3L on 1 January.

	2J		3K		3L	
Year	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 sexes and by Division, (t is from t-tests).

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

TABLE 4. Comparison of A_{50} and L_{50} across Division (H is from Kruskal-Wallis ANOVA by Ranks; F is from ANOVA).

Div.	Mean	Std. Dev.	Test result
	A_{50}		
	Males		
2J	4.45	0.40	H=16.77
3K	4.60	0.33	df=2
3L	5.20	0.43	p<0.001
	Females		
2J	5.88	0.26	F=4.90
3K	5.88	0.34	df=2,40
3L	6.27	0.46	p<0.05
	L_{50}		
	Males		
2J	39.48	4.14	H=15.57
3K	42.72	3.37	df=2
3L	46.25	3.61	p<0.001
	Females		
2J	49.54	4.51	F=3.46
3K	52.00	4.62	df=2,39
3L	54.18	3.70	p<0.05

TABLE 5. Comparison of A_{50} across 5-year time periods by sex and Division. (F is from ANOVA; t is from t-tests.)

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

TABLE 6. Comparison of L_{50} across 5-year time periods by sex and Division (F is from ANOVA, H is from Kruskal-Wallis ANOVA by ranks, and t is from t-tests).

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

TABLE 7. A_{50} and L_{50} by sex for Div. 2J, 3K and 3L combined.

	A_{50}		L_{50}	
Year	Females	Males	Females	Males
1982	6.22	4.86	55.14	45.56
1983	6.10	4.86	55.16	45.76
1984	6.16	4.72	56.18	44.72
1985	–	–	–	–
1986	6.20	5.00	50.65	41.48
1987	6.16	4.98	51.15	42.41
1988	6.16	4.97	50.69	42.23
1989	5.87	4.88	49.10	41.71
1990	5.84	4.64	49.91	41.05
1991	6.16	4.91	51.48	42.52
1992	5.68	3.96	46.74	36.26
1993	5.40	4.15	45.50	37.40

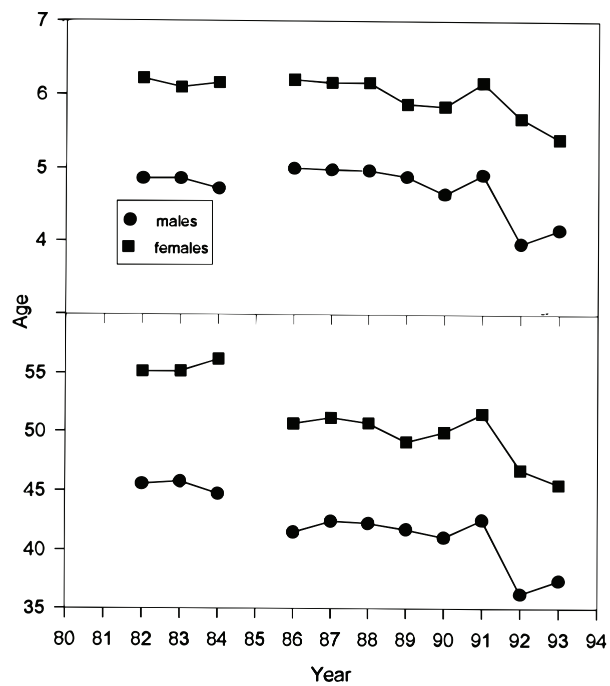

Fig. 3. Estimates of age and length at 50% maturity for males and females on 1 January of each year in Div. 2J, 3K and 3L combined.

TABLE 8. Comparison of A_{50} and L_{50} across 5-year time periods for Div. 2J, 3K and 3L combined. (t is from t-tests.)

Sex	Period	Mean	Std. Dev.	Test results
		A_{50}		
Male	1982–87	4.88	0.11	t=1.88
	1989–93	4.51	0.43	df=8
				p=0.096
Female	1982–87	6.17	0.05	t=3.00
	1989–93	5.79	0.28	df=8
				p=0.017
		L_{50}		
Male	1982–87	43.99	1.93	t=2.77
	1989–93	39.79	2.78	df=8
				p=0.024
Female	1982–87	53.66	2.56	t=3.25
	1989–93	48.55	2.41	df=8
				p=0.012

time. For age at 50% maturity, only males in Div. 2J and the estimate for females in the combined Div. 2J and 3KL showed a significant decrease over time. 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 these analyses are very similar to those of Xu *et al*. (MS 1991). In order to compare A_{50} and L_{50} between the papers, 1 year must be added to their data (Table 2 and 6 of Xu *et al*., MS 1991) to give them the time period of 1979–91 used here. 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 cod generally maturing at a larger size and older age in the more southern areas, are similar. As well, the greater decline in length-at-maturity over time than the age-at-maturity found here is consistent with the patterns observed in Xu *et al*. (MS 1991).

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