Northwest Atlantic Fisheries Organization

Serial No. N4057 **NAFO SCR Doc. 99/10**

SCIENTIFIC COUNCIL MEETING – JUNE 1999

Interannual Dynamics of Growth and Maturity of Cod on Flemish Cap in 1980-1996

by

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Abstract

Long-term data (198O-1996) on linear and weight growth rate, as well as on maturity of cod on Flemish Cap, are analysed and summarized. High rate of linear and weight growth of cod, compared to the long-term mean, is observed during cold period marked on Flemish Cap from 1985 to 1993. Interannual variations in length and age, at which 5O% of fish mature, are analysed. The age and length, at which 5O% of cod become mature, have been found to decrease during recent years.

Introduction

Studying of growth rate and fish maturity related to it is of special importance when investigating the regularities of dynamics of population abundance of commercial fish.

Under variable conditions of abiotic and biotic environments the rate of growth and maturity is also subjected to considerable variations. It is known that the water temperature, feeding conditions and population density much influence the fish growth. However, it is somewhat difficult to estimate an importance of each of these factors. During specific years the variations in growth rate of fish occur to be more related to some factors and after about some time a part of these can be not so important and growth will be determined by other ones (Ozhigin et al., 1996).

The paper considers the interannual variations in length and age at which 5O% of specimens become mature.

Materials and Methods

The materials (Table 1) collected during spring-summer trawl surveys for ground fish assessment and carried out by Russian research vessels are presented in the paper. In 1994, no trawl survey was conducted on Flemish Cap. Linear and weight growth rate were calculated by the data observed. Fish were aged by otoliths.

Gonads maturity were visually staged by a 6-point scale developed by V.P.Sorokin (1957, 1960). Specimens at maturity stages I and II were referred to immature fish and all the rest stages - to mature ones. A proportion of mature fish was found for each length group and age, assuming the fish examined from individual length group and age to be 1. The length and age at which 5O% of specimens become mature were determined by plotting the logistic equation (Somerton, 1980):

$$Y = \frac{1}{1 + Ae^{BX}}$$

where:

Y - proportion of mature fish;
X - length (age);
A and B - parameters of the equation.

Comparative analysis of maturity rate of cod by year was done by estimating and comparing the length and age at which 50% of females become mature.

Results and Discussion

Fish refer to the organisms that grow during their whole life. Maximum age of cod sampled on Flemish Cap is 15 years. The paper considers the variations in mean length and weight of fish at age 3-8. For 198O-1996, mean length of fish at age 3 varied within 27.6-42.1cm, the coefficient of variation of 16 mean yearly values constituted 10.5%. With an increase of age the variation coefficients of mean yearly values decreased slightly and made up 9.9% in fish at age 4, 10.0% - at age 5, 9.2% - at age 6 and 7, respectively. The highest coefficient of variation (12.7%) of mean length was in fish at age 8. Mean length of cod at age 8 varied from 71.31cm to 90.45cm during the investigations.

Interannual variations in mean length and weight of individual age groups relative to the long-term mean (1980-1996) are given in Figs.1 and 2. Mean length and weight of specimens at different age were lower than the long-term mean at the beginning of the period considered (1980-1985), further these parameters increased and were higher than the long-term mean until 1991, especially in fish from older age groups. From 1991 to 1996 cod growth rate reduced and was close to the long-term mean.

Essential impact of water temperature on cod growth was noted by most authors who indicated an availability of positive relationship (Dementyeva, Mankevich, 1965; Hermann, Hansen, 1965; Nakken, Raknes, 1987). Rise in water temperature causes an increase in growth rate and, vice versa, low temperatures delay growth. By our data, mean length and weight of cod at age above 3 on Flemish Cap (Figs.1 and 2) increased just in the period of a stable cooling registered from 1985 to 1993 (Colbourne, 1993; Drinkwater et al., 1996, 1997). During this period an increment of cod from individual age groups attained 14-15cm. Under such rapid growth the cod were probably caught at earlier age.

Similar situation was observed in the Barents Sea (from the 50s to the 70s) when mean length of cod at different age increased in spite of a stable cooling. At that time V.P.Ponomarenko (1968) has arrived at the conclusion that the basic reason of increase in cod growth rate during those years was a scattering of population due to intensive fishery and to a lack of strong yearclasses.

Prolonged decline of cod stock (Fig.3) on Flemish Cap started early in the 80s could not have effect on the stock structure. In 1960-1975 the bulk of commercial catches consisted of specimens at age 5-8 (Vazquez, 1986) and at age 3-5 by the data from our investigations for 198O-1986. After the year 1986 age composition of cod catches reduced again and fish at age 2-3 made up the bulk of catches; fish at age above 8 did not occur in catches (Figs.4 and 5). Low level of biomass and abundance (Kiseleva, 1996, 1997) and age composition of cod in catches (regardless of the recruitment of the Flemish Cap cod from 1981, 1982, 1986, 1991 and 1993 abundant yearclasses to the stock) evidences an overfishing and depressed status of the stock.

Feeding conditions also much influence the growth rate of cod. The main food objects of cod on Flemish Cap are fish, mainly redfish, paralepidae and anchovy occur seldom, as well as hyperiidae and shrimps (Konstantinov et al., 1990). Relationship between cod growth and abundance of redfish yearclasses and its length composition is shown in the paper by Lilly (Lilly, Evans, 1986). Increase in growth of cod in 1986-1987 was related to an appearance of redfish abundant yearclasses in 1985 and 1986, the occurrence of which was 21-23% of the number of stomachs containing food. During

summer period 1986-1990, cod also intensively fed on hyperiidae (*Parathemisto gaidichaudi*), the occurrence of which in stomachs made up 50-77%.

During spring-summer period 1980-1996, the amount of mature fish in catches varied from 10.4 to 47.7%. A proportion of mature females in catches was, as a rule, lower and varied much by years (Table 1).

Variations observed at the beginning of maturity in cod both for the species on the whole and for females separately are presented in Tables 2-5. As Table 3 shows, in 1980-1996 individual specimens of cod became mature at age 4 and even 3. Minimum length of mature fish was 30cm in 1984 (Table 2). A proportion of mature fish increased with length and age, however it differed by years. The age and length at which 5O% of cod become mature varied from 3.6 to 6.6 yr and 39.5-64.2cm, respectively (Tables 2 and 3).

At the beginning of the period considered (1980-1985), 50% of females became mature at age 5-7, in 1986-1991 (during the years when cod growth rate was high) - at age 5-6. In 1995 and 1996, the age, at which 5O% of females became mature, decreased and constituted 4-3.6 yr (Table 5). Data related to decrease of age at which cod become mature in the NWA are also given in a number of other papers (Morgan, Brattey, 1996; Junguera, Saborido-Rey, 1996).

Length at which 50% of females become mature increased by the mid-80s and further it varied slightly (from 53.80 to 65.50cm) and its minimum was in 1995-1996 (Table 4). For the period investigated from 1980 to 1996 the mean age and length of cod at which 50% of specimens became mature had a downward trend (Fig.6).

A beginning of maturity at different length or age is known to have a special adaptable mechanism. On the one hand, an appearance of females, spawning at younger age, in spawning stock, can rise a rate of reproduction and increase the population abundance. On the other hand, with early maturity a spawning proportion of population consists of younger age groups and maximum age of specimens in such populations is minor, as it is observed in the population of cod on Flemish Cap.

Conclusions

Analysis of interannual dynamics of age composition, growth rate and maturity of cod on Flemish Cap has indicated that:

1. Intensive fishery, low level of stock, a lack of strong yearclasses of cod on Flemish Cap have resulted in elimination of specimens from older age groups.

2. High growth rate of cod registered in 1985-1991, compared to the long-term mean, is related to a sharp reduction in cod stock during this period and to an improvement of its food supply owing to appearance of redfish abundant yearclasses.

3. During recent years an intensive rate of maturity of cod can not apparently make up for a reduction in spawning proportion of the stock, as far as the population spawning proportion consisting of younger age groups produces a less vigorous brood.

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Table.1 Volume of material investigated

Years	Mounth	Numbers of fish	Mature, %	
			males and females	females
1980	Apr-Jul	1130	32,7	13,9
1981	Jun-Jul	442	25,1	7,2
1982	Apr-Jul	704	42,0	1,1
1983	May-Jul	648	16,5	6,8
1984	Mar-Jul	1406	14,5	11,0
1985	Mar-Jul	408	20,5	6,1
1986	Apr-Jul	489	37,4	18,2
1987	Mar-Jul	480	21,6	8,7
1988	Mar-Jul	354	10,4	3,9
1989	Mar-Aug	291	14,1	4,8
1990	Mar-Aug	237	27,8	10,1
1991	Mar-Jul	299	22,.7	6,7
1992	Apr	178	15,7	2,8
1993	Apr-Jul	193	24,3	4,7
1995	May	300	47,7	24,3
1996	May-Jun	116	44,8	18,9
Total		7675		

Table 2. Estimated proportion mature at length for cod on Flemish Cap Bank and length 50% maturity (L50) for cod is also given for earh year

Length,cm	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1995	1996
30	.0	.0	.0	.0	0.11	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	0.14	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.06	.0
36	.0	.0	.0	.0	0.10	0.08	.0	.0	.0	.0	.0	.0	0.07	0.20	0.14	0.23
39	.0	.0	.0	.0	0.13	0.43	0.09	.0	.0	.0	0.08	0.14	.0	0.20	0.37	0.31
42	0.03	0.10	.0	0.03	0.05	0.43	0.05	.0	.0	0.06	0.33	0.13	0.33	0.12	0.89	0.75
45	0.20	0.38	0.27	0.01	0.10	0.45	0.05	0.03	.0	0.07	0.44	0.29	0.40	0.25	0.93	1.00
48	0.35	0.31	0.83	0.04	0.21	0.18	0.36	0.08	0.20	.0	0.20	0.38	0.62	0.11	0.62	1.00
51	0.83	0.33	0.97	0.02	0.25	0.28	0.52	0.13	0.21	0.19	0.40	0.56	0.62	0.50	1.00	0.90
54	0.90	0.46	0.96	0.08	0.24	0.33	0.61	0.14	0.25	0.43	0.61	0.31	0.75	0.57	1.00	1.00
57	0.95	0.62	0.92	0.23	0.39	0.29	0.76	0.38	0.24	0.20	0.79	0.39	0.67	1.00	1.00	-
60	0.99	0.83	0.92	0.50	0.37	0.40	0.76	0.35	0.17	0.40	0.59	0.44	1.00	1.00	1.00	-
63	0.98	0.99	0.97	0.71	0.47	0.36	0.95	0.63	0.40	0.86	0.56	0.54	1.00	0.75	1.00	-
66	0.97	0.91	1.00	0.81	0.53	0.62	1.00	0.81	0.62	0.71	1.00	0.78	-	1.00	1.00	1.00
69	1.00	0.97	1.00	0.70	0.75	0.67	1.00	0.78	0.50	1.00	1.00	0.80	-	1.00	1.00	-
72	1.00	1.00	1.00	0.59	1.00	0.71	1.00	0.50	1.00	-	-	1.00	1.00	1.00	-	-
75	1.00	0.91	1.00	0.89	0.75	0.81	1.00	0.80	1.00	1.00	-	1.00	1.00	1.00	1.00	-
78	1.00	1.00	1.00	0.71	1.00	0.80	1.00	0.89	1.00	-	-	1.00		1.00	1.00	-
81	1.00	1.00	1.00	1.00.	1.00	0.50	1.00	1.00	1.00	1.00	1.0				-	-
84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	-	-				-	-
87	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	1.00				1.00	1.00
90	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	-	-				-	-
93	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	-	1.00	-				-	-
96	1.00	1.00	1.00	1.00	-	-	1.00	-	1.00	-	1.00				-	-
99	1.00	1.00	1.00	1.00	-	-	1.00	1.00	-	1.00					-	1.00
102		-	1.00	1.00	1.00	1.00	-	-	-						1.00	
105		-	1.00	1.00		-	-	-	-							
108		1.00	1.00	1.00		-	-	1.00	-							
111		1.00	1.00	1.00		-	-		-							
114				1.00		1.00	1.00		1.00							
117							1.00									
No	1130	442	647	648	1406	408	489	480	354	291	237	299	178	193	300	116
L50	48.6	53.1	46.9	62.3	61.5	61.3	51.9	62.4	64.2	59.4	52.6	56.9	47.8	51.4	39.5	39.9

Table 3. Estimated proportion mature at age for cod on Flemish Cap Bank and age 50% maturity (A50) for cod is also given for each year

Age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1995	1996
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-	-	-
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	0.05	.0	.0	0.17	.0	.0	0.08	.0	0.03	.0	0.02	.0	0.03	0.04	0.19
4	0.02	0.11	.0	0.02	0.09	0.28	0.11	0.16	0.13	0.17	0.33	0.21	0.32	0.21	0.79	0.70
5	0.61	0.36	0.91	0.02	0.19	0.34	0.69	0.28	0.44	0.65	0.64	0.44	0.60	0.29	1.00	0.96
6	0.93	0.67	0.94	0.29	0.25	0.47	0.95	0.82	0.58	1.00	1.00	0.55	0.57	0.63	1.00	1.00
7	0.97	0.95	0.98	0.72	0.70	0.64	1.00	0.81	0.73	1.00	-	0.60	1.00	1.00	1.00	-
8	1.00	0.98	1.00	0.71	1.00	1.00	1.00	1.00	-	1.00	1.00		1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00				1.00	-
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00					-	1.00
11	1.00	1.00	1.00	1.00	1.00		1.00		-						1.00	
12	1.00	1.00	1.00	1.00	1.00		1.00		1.00							
13	1.00		1.00	1.00			1.00									
14			1.00													
15			1.00													
No	1130	442	647	648	1406	408	489	480	354	291	237	299	178	193	300	116
A50	4.9	5.4	4.6	6.6	6.4	5.9	4.7	5.4	5.6	4.7	4.5	5.9	4.9	5.5	3.7	3.6

Table 4. Estimated proportion at length for female cod on Flemish Cap Bank and length 50% maturity (L50) for females is also given for each year.

Length	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	19.95	1996
30	.0	.0	.0	.0	0.08	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	0.21	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
36	.0	.0	.0	.0	0.18	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
39	.0	.0	.0	.0	0.20	0.17	.0	.0	.0	.0	.0	.0	.0	.0	0.20	0.17
42	.0	.0	.0	.0	0.08	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.90	0.60
45	0.15	0.11	.0	.0	0.08	0.30	.0	.0	.0	.0	0.11	.0	.0	.0	0.86	1.00
48	0.14	0.05	.0	.0	0.22	.0	0.17	.0	.0	.0	0.17	0.21	.0	.0	0.93	1.00
51	0.70	0.03	.0	.0	0.23	0.11	0.40	0.10	.0	0.09	.0	.0	.0	0.17	1.00	0.80
54	0.84	0.21	.0	.0	0.12	0.14	0.42	.0	0.12	.0	0.20	0.21	0.67	.0	1.00	1.00
57	0.85	0.35	0.25	.0	.0	0.08	0.82	0.10	0.12	0.11	0.88	0.23	.0	1.00	1.00	-
60	1.00	0.47	0.33	.0	0.55	0.14	0.76	0.08	0.25	.0	0.64	0.20	1.00	1.00	1.00	-
63	1.00	1.00	1.00	.0	0.50	0.17	0.91	0.33	0.33	1.00	0.43	0.40	1.00	0.50	1.00	-
66	1.00	0.76	1.00	0.70	0.71	0.44	1.00	0.62	0.33	0.33	1.00	0.50	-	1.00	1.00	1.00
69	1.00	0.82	-	0.46	1.00	0.40	1.00	0.60	1.00	1.00	-	0.50	-	-	1.00	-
72	1.00	1.00	-	0.57	1.00	0.40	1.00	.0	-	-	-	0.80	1.00	-	-	-
75	1.00	0.75	1.00	0.83	1.00	0.50	1.00	0.67	0.75	1.00	-	1.00	1.00	1.00	1.00	-
78	1.00	-	-	0.67	1.00	0.50	1.00	0.83	1.00	-	-	1.00		1.00	1.00	-
81	1.00	1.00	-	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00				-	-
84	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00	-	-	-				-	-
87	1.00	1.00	-	0.67	1.00	1.00	1.00	1.00	-	-	1.00				1.00	1.00
90	-	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	-					-	-
93	1.00	1.00	-	-	-	1.00	-	1.00	-	1.00					-	-
96	1.00	1.00	-	1.00	-	-	1.00	-	1.00	-					-	-
99	1.00	1.00	-	-	-	-	1.00	1.00		1.00					-	1.00
102		-	-	1.00	1.00	-	-								1.00	
105		-	-	1.00		-	-									
108		1.00	-	1.00		-	-									
111		1.00	1.00			-	-									
114						1.00	1.00									
117							1.00									
No	561	201	183	284	776	186	249	242	171	141	109	157	83	103	162	57
L50	50.5	59.1	59.8	69.5	61.6	72.4	53.8	63.1	63.3	62.9	57.2	65.5	56.9	55.3	40.3	41.2

Table 5. Estimated proportion mature at age female cod on Flemish Cap Bank and age at 50% maturity (A50) for female is also given for each year.

Age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1995	1996
1	.0	.0	.0	-	-	.0	.0	.0	.0	.0	.0	.0	.0	-	-	-
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	0.27	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0.04
4	0.01	0.02	.0	.0	0.49	0.12	0.04	0.05	0.07	0.07	0.17	.0	.0	.0	0.32	0.60
5	0.40	0.10	0.20	.0	0.29	0.11	0.65	0.10	0.33	0.38	0.72	0.19	0.29	.0	1.00	0.92
6	0.89	0.28	0.33	0.07	0.56	0.21	0.94	0.63	0.67	1.00	1.00	0.39	0.25	0.46	1.00	1.00
7	0.99	0.84	-	0.65	1.00	0.47	1.00	0.75	1.00	1.00	-	0.50	1.00	1.00	1.00	-
8	1.00	0.88	1.00	0.60	1.00	1.00	1.00	1.00	-	1.00	-		1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	0.67	1.00	-	-	1.00	1.00	-	1.00				1.00	-
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00					-	1.00
11	1.00	1.00	-	1.00	1.00		1.00								1.00	
12	1.00	1.00	-	1.00			1.00									
13	1.00		1.00	1.00			1.00									
14																
15																
No	561	201	183	284	776	186	249	242	171	141	109	157	83	106	162	57
A50	5.2	6.4	6.8	7.4	5.0	6.9	4.9	5.9	5.5	5.1	4.6	6.7	6.3	6.0	4.1	3.6

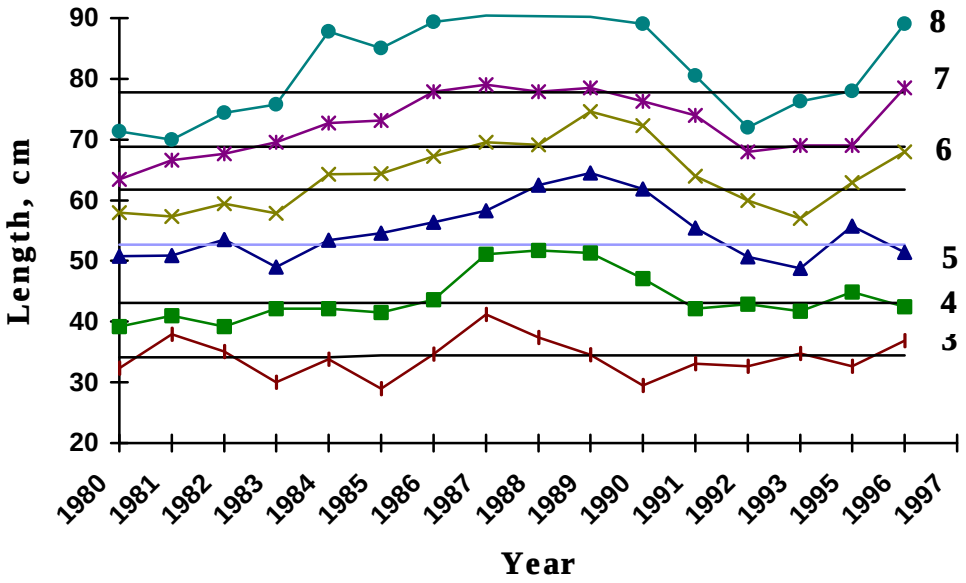

Fig. 1. Year-to-year variations in mean length of cod at age 3-8 on Flemish Cap Bank. Horisontal lines show long-term means of lengths at age for 1980 -1996 .

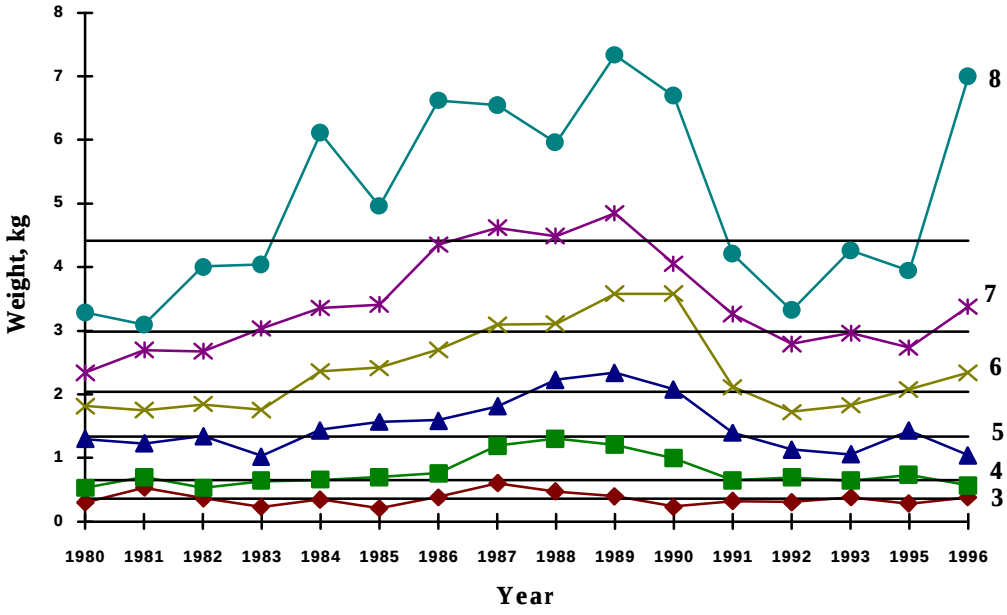

Fig. 2 Year-to-year variations in mean weight of cod at age 3-8 on Flemish Cap Bank. Horizontal lines show long-term means of weights at age for 1980-1996.

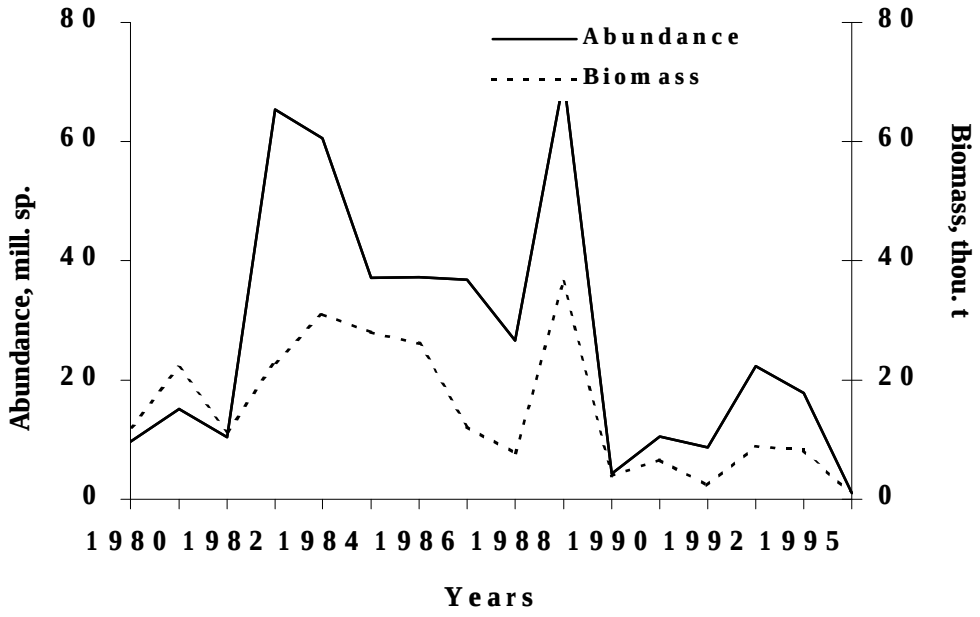

Fig.3. Abundance and biomass of cod in Div.3M in 1980-1996 (according to data from Russian surveys).

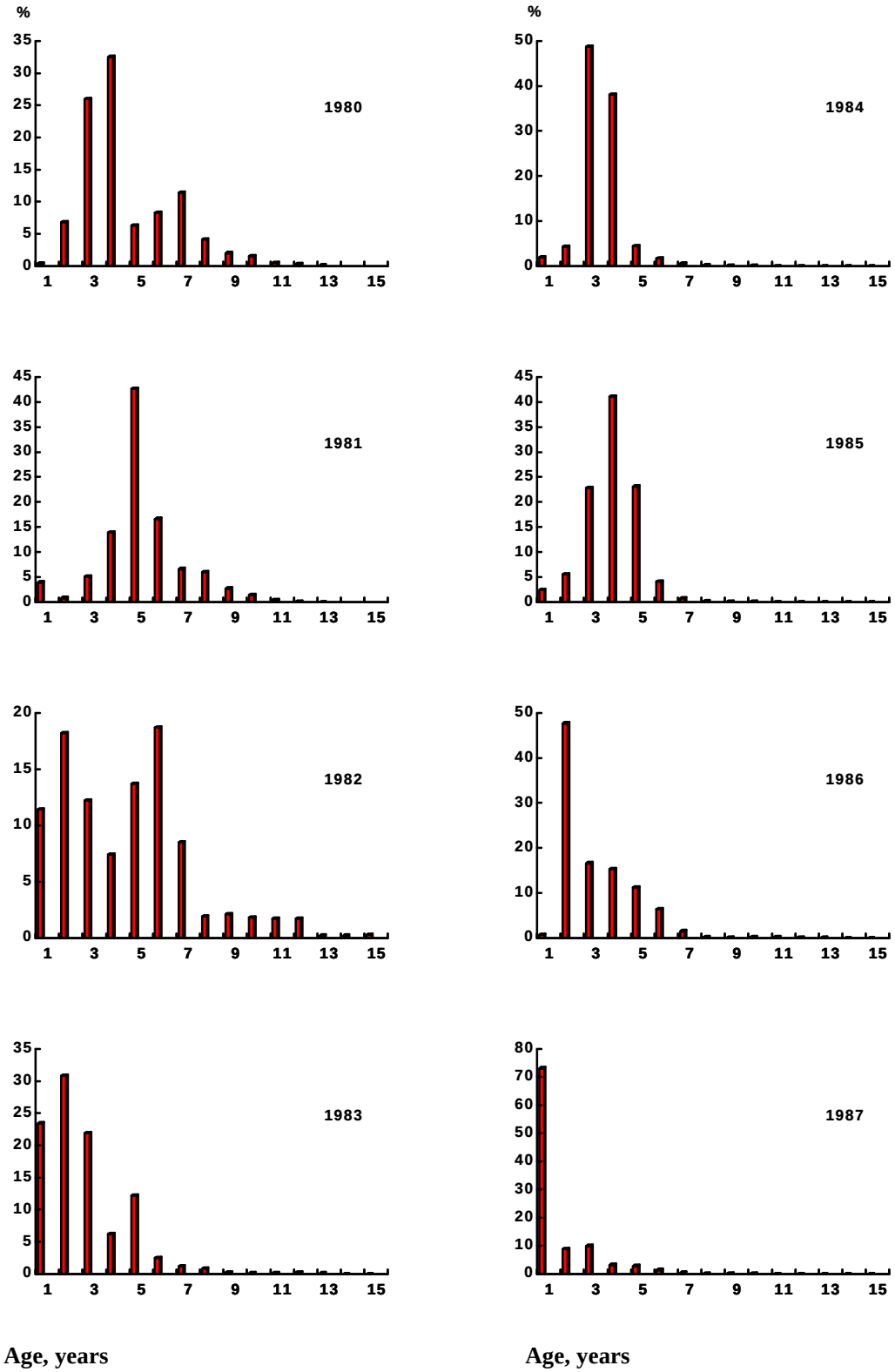

Fig. 4. Age composition (%) of cod on the Flemish Cap in 1980-1987.

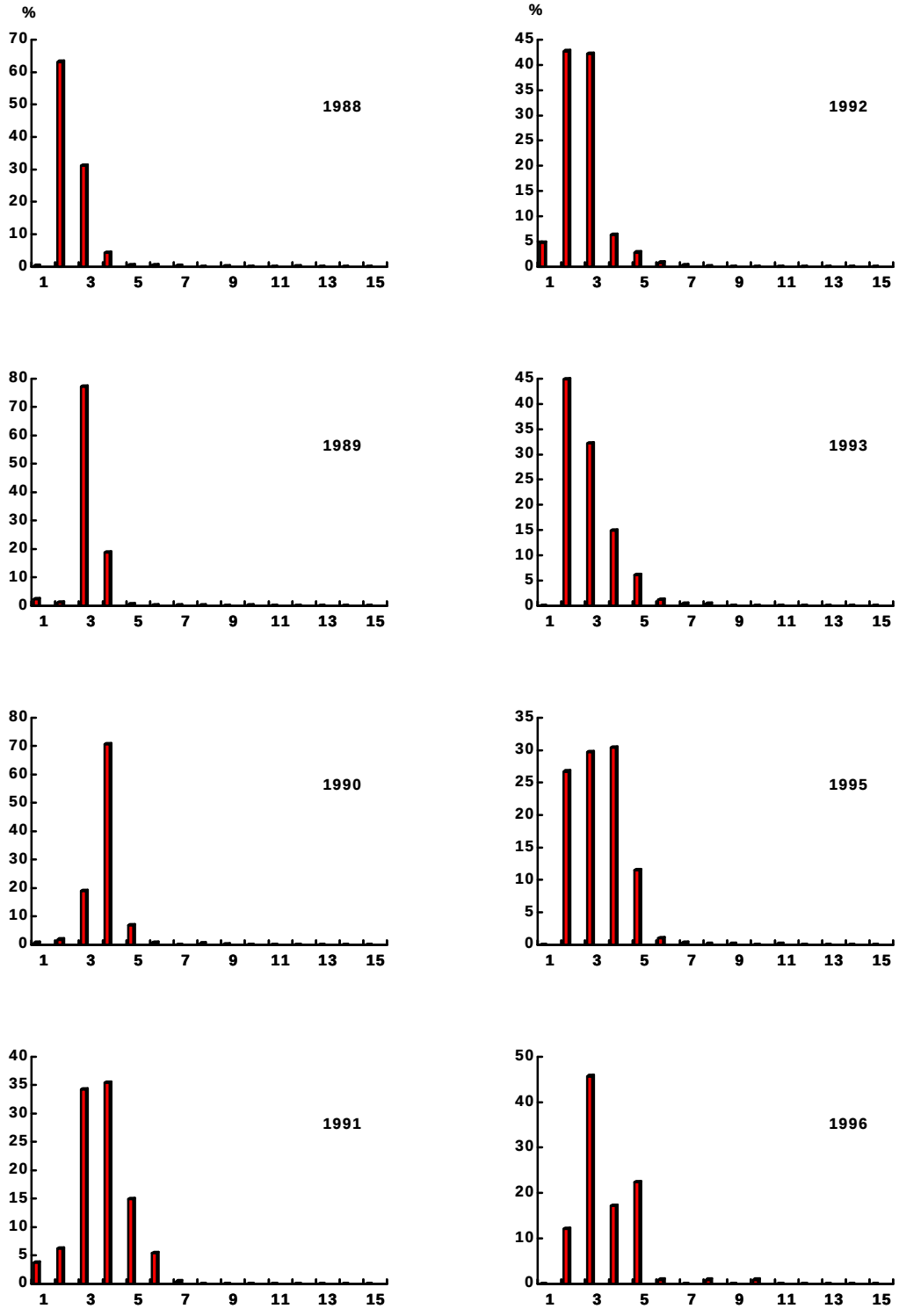

Fig. 5. Age composition (%) of cod on the Flemish Cap in 1988-1996.

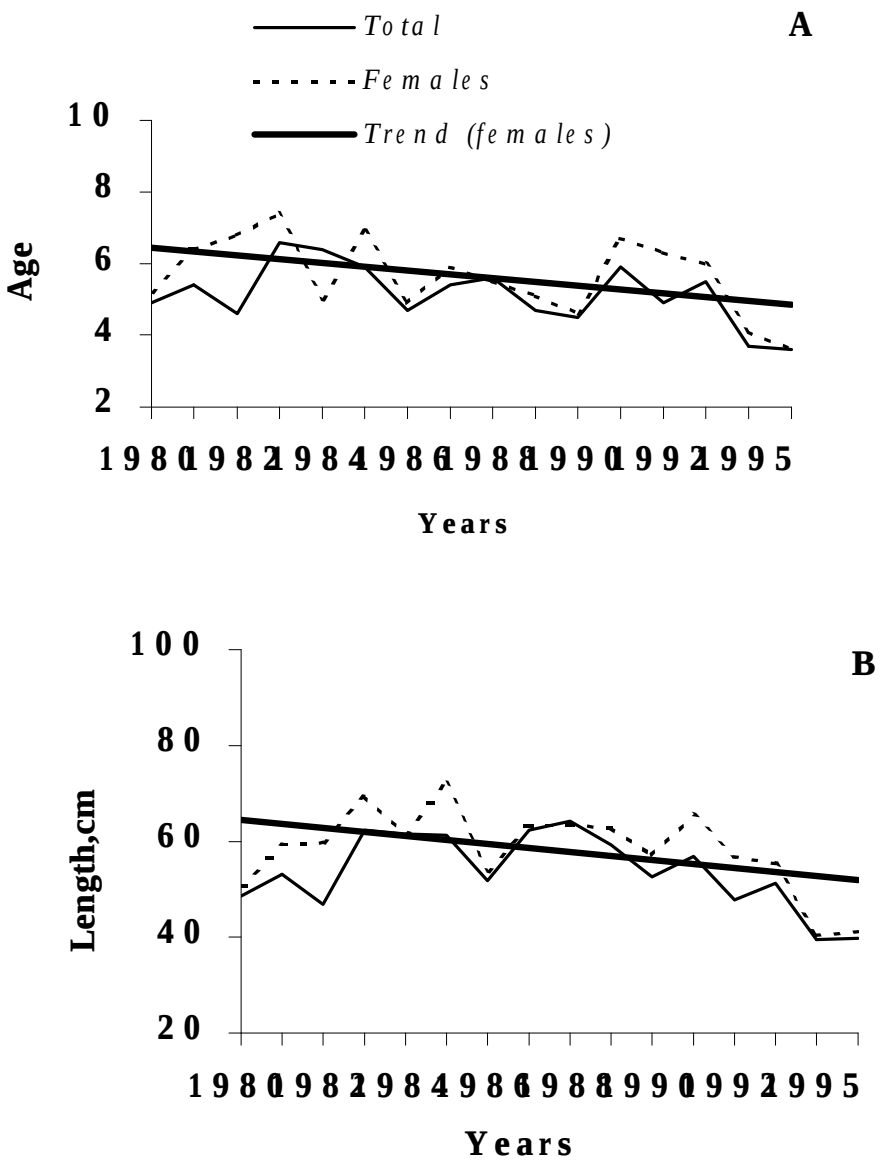

Fig. 6. Age (A) and length (B) of Flemish Cap cod (50% maturity), 1980-1996.