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Sexual Maturity and Spawning Biomass of the Cod Stock on Flemish Cap (Division 3M)

by

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Introduction

Length and age at maturity of the Flemish Cap female cod has been determined by an histological method since 1990 at summer, when the EU-survey is carried out. The method uses cod ovaries in the *cortical alveoli* stage as an index of the onset of the oocyte development for the next breeding season, whereas the presence of postovulatory follicles in the ovaries shows the already spawned females (Zamarro *et al.*, 1993). The cortical alveoli are the first structures to appear during the phase of oocyte growth (Wallace and Selman, 1981), and therefore they are the first sign of the start of the female ripening before the beginning of the vitellogenesis. The postovulatory follicles are the structures left in the ovary after maturation is finished and oocyte ovulation. The spawning season of the Flemish Cap cod is known to be short in time and the earliest in the year of all cod stocks in the Northwest Atlantic (Myers *et al.*, 1993); it occurs around March. This method allow to accurately detect the proportion of both recruit and repeat mature females at the very beginning of the gonad development, as it happens in summer, few months after spawning, when it is very difficult to make a visual diagnosis of the sexual maturity stage (Morrison 1990). In this paper the proportion of females with postovulatory follicles in July 1996 is used to determine the length and age at maturity in 1996 and the proportion of females in the *cortical alveoli* stage to estimate the same parameter for 1997. Estimation of the spawning stock biomass is calculated and its evolution in the period 1990-1996 discussed.

Material and methods

A total of 165 cod ovaries were sampled during the 1996 summer survey in Flemish Cap (Vázquez 1997). Total length and weight were recorded for each individual and otoliths removed for age determination. Gonads were immediately fixed in 4% buffered formalin (Hunter 1985). Pieces of 0.5 cm thick were embedded in paraffin based on conventional histological processing and 5 μ sections stained with Harris hematoxyline and eosine-floxine.

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Different stages were identified in the sections according to the classification of West (1990) and Morrison (1990). Immature females were identified since 100% of the oocytes were in the circumnuclear ring stage; instead, mature females had oocytes in cortical alveoli (CA), vitellogenesis, postovulatory follicles (POF) or degenerating (atresic) oocytes. Recruit mature females were identified since they have no postspawning structures such as POF or atresic oocytes. Recent postspawning stage is identified by the presence of postovulatory follicles and atresic oocytes, without any oocyte in the *cortical alveoli* or any further stage of development.

The proportion of mature females by size and age was adjusted to a logistic function as described by Ashton (1972):

$$\hat{P} = \frac{e^{\alpha+\beta L}}{1+e^{\alpha+\beta L}} \qquad (1)$$

and the logaritmic transformation:

$$\ln \frac{\hat{P}}{1-\hat{P}} = \alpha + \beta L \qquad (2)$$

where

$\hat{P}$ = predicted mature proportion

α and β are the coefficients of the logistic equation

L is the length (or age).

Statistica for Windows 5.0 (StatSoft, Inc., 1995) was used to calculate the predicted values and the coefficients.

The size and age at maturity could be estimated as minus the coefficients ratio ($-\alpha / \beta$) by substituting $\hat{P} = 0.5$ in equation 2.

Two maturity curves were generated: one using CA as the index of the onset of ripening for 1997, and another one using the presence of POF as a guide for spawned females in summer 1996.

Spawning biomass were estimated from 1990 to 1996 using data from EU surveys (Vázquez *et al.*, 1995; Vázquez, 1996 and Vázquez, 1997). A 50 % sex ratio was assumed. The 1992 maturity ogives were used to estimate 1990 and 1991 spawning stock.

Results

Tables 1 and 2 show the number of mature and immature females sampled by length and age respectively. A 56 % of the females sampled were mature, while 44 % were immature. The frequencies of females with *cortical alveoli* and postovulatory follicles stage by length intervals and age are presented in tables 3 and 4 respectively. All the ovaries of mature females sampled had oocytes in the CA stage. There were no females in recent postspawning stage, since oocytes in CA were already present in all the ovaries with POF or atresic oocytes in July 1996. A total of 66 of the sampled female had spawned in

1996, as indicated by the presence of POF and atresic oocytes in the ovary. The proportion of females with this kind of postspawning structures increases with length and age and gets 100 % of females larger than 54 cm (age 5 +). As it occurred in the two previous years, the number of females with oocytes in the vitellogenic stage was very low in summer (only 3 individuals).

The maturity curves obtained by length and by age are shown in Figures 1 and 2 respectively. Each figure includes two curves: one corresponding to the spawners in 1996, using the frequencies of POF to identify mature females, and the other corresponding to the next year spawners, identified by the presence of CA. Length and age at 50% maturity obtained from the CA curves is 41.17 cm and 3.1 years respectively (Table 5). The same parameters obtained from POF frequencies are 45.86 cm and 3.9 years respectively. Like in 1994 and 1995, there is a difference of less than one year between the two estimates of the age at maturity, what is an unusual situation compared with the results of 1990-93 period (Table 5). A decrease in both the age and the length at maturity was observed from 1990 to 1995. In 1996 length at maturity increased slightly although age at maturity remained stable.

Figure 3 shows several female biomass estimates (total, 4+ and spawning biomass) for the period 1990-1996. Total biomass decreased from about 25,000 tons in 1990 to about 4,000 tons in 1996. The total biomass rise in 1993 was due to the strong 1991 year-class (53% and 68 % of the biomass in 1993 and 1994 respectively). The 1991 year-class biomass was reduced from about 15,000 tons in 1994 to about 1,700 tons in 1995. Spawning biomass (estimated from both CA and POF) followed a similar pattern, thus CA spawning biomass decreased from about 19,500 tons in 1990 to about 3,000 tons in 1992, increasing to about 8,500 tons in 1994 due to the documented reduction of age at maturity. The CA spawning biomass was about 2,500 tons in 1996. The difference between the spawning biomass estimated from CA and POF is the biomass of recruit females. The percentage of recruit females decreased from 35% in 1990 to 23% in 1996. Figure 3 also shows the percentage in numbers of mature female of age 4 or younger. In 1990 38 % of mature female were 4 or younger years old, but in 1994 the 97% of mature female belonged to those age-classes. This proportion was reduced to 52 % in 1996 due to the progress of 1991 year-class (still the most abundant).

Discussion

The age at maturity in 1996 obtained using POF is 3.9 years, the same as in 1994 and in 1995 (Junquera and Saborido-Rey, 1996). The same parameter obtained from CA, that is the age at maturity for the next year spawners, shows a slight reduction from 3.4 years in 1994 to 3.1 years in 1996 at the same level as in 1995. However, the decreasing trend in the length at maturity already noted in 1994, and very pronounced in 1995 shows a slight increase in 1996. The fact of the former great reduction in the length at maturity while the age at maturity remain almost invariant was explained by changes in the growth parameters of the stock as well as the reproductive ones (Junquera and Saborido-Rey, 1996). In 1995, the 75 % of mature females (calculated using CA as well POF) belonged to strong 1991 year-class (age 4); This year-class was still dominant in 1996, at age 5, but its contribution to total amount of mature female decreased (43 % using CA and slightly to 70 % using POF). However, age at maturity didn't changed substantially in the last three years. It seems that 1991 year-class had a density-dependence growth, with a slow growth until 1995 and a faster growth last year after the sharp decrease due to the heavy fishery on such year-class (Vázquez *et al.*, 1995).

Junquera and Saborido-Rey (1996) reported that the maturity curve in 1995 based on POF had a knife edge shape, i.e. almost all the females became mature between the ages 3 (0 % spawned in July 1995) and 4 (80 % spawned). All females were mature at age 5. As these authors stated, it is likely that the age at maturity of female cod was fixed around age 3 in recent years. This age apparently determines a biological limit for the onset of the maturation process in this species, as it suddenly begin there, without presence of any mature female at earlier ages, and from the next age group (4 +) virtually all the females already are mature. The 1996 data confirms this hypothesis since age at maturity was similar than in 1995. However, a small amount of age 3 females spawned in 1996 (4.1 %) and the proportion of spawned females at age 4 decreased (54.5 %). Since the maturation depends more of size than age, it can be explained once again for a relative faster growth of the 1993 year-class (age 3 in 1996).

A possible effect of the abundance decrease of the Flemish Cap cod stock, particularly of the largest individuals, on the reduction of the age at maturity during the period analysed, has already be pointed (Saborido-Rey and Junquera, 1995). The biomass of age 4+ reduced sharply in 1991, but the recruitment (particularly 1990 and 1991 year-classes) keeps the female stock at the same level until 1995. The rejuvenation of the female stock in 1993 and the decrease of the age at maturity produced that the most of the mature females were age 4 or younger (97 %) in 1994, for example. It is difficult to evaluate the implications of this shift in the spawning stock. Although the spawning biomass increases in 1994 at the same level as in 1991 (after a reduction in 1992 and 1993) the 1994 year-class has been the poorest of the period. It can be explained by several reasons, i.e. environmental factors, as well the rejuvenation of the spawning biomass: it has been reported (Kjesbu *et al.*, 1995) that the youngest females have the lowest fecundity, the smallest eggs and the shortest spawning period. Anyway, the high pressure of the fishery on the 1991 year class in the last three years have not permit rebuild the stock and now the spawning stock is at the lowest level in the period analysed and still with a high proportion of young females.

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Table 1.- Number of adult and immature females by length sampled in Flemish Cap in summer 1996.

Length	Immature	Mature	Total	%
< 30	6	0	6	*0*
30 - 32	12	0	12	*0*
33 - 35	15	2	17	*11.8*
36 - 38	16	3	20	*15*
39 - 41	7	8	24	*33.3*
42 - 44	0	11	18	*61.1*
45 - 47	0	9	9	*100*
48 - 50	0	8	8	*100*
51 - 53	0	12	12	*100*
54 - 56	0	14	14	*100*
57 - 59	0	10	10	*100*
60 - 62	0	7	7	*100*
63 - 65	0	4	4	*100*
66 - 71	0	3	3	*100*
≥72	0	1	1	*100*
Total	73	92	165	*55.75*

Table 2.- Number of adult and immature female cod by age sampled in Flemish Cap in summer 1996.

Age	Immature	Mature	Total	%
2	24	0	24	*0*
3	50	23	73	*31.5*
4	0	11	11	*100*
5	0	49	49	*100*
6	0	7	7	*100*
7	0	1	1	*100*
Total	73	92	165	*55.75*

Table 3.- Number of females with ovaries in the *cortical alveoli* stage (CA) and postovulatory follicles (POF) stage by length sampled in summer 1996.

	AC		POF		
Length	no.	%	no.	%	Total
< 30	0	*0*	0	*0*	6
30 - 32	0	*0*	0	*0*	12
33 - 35	1	*5.9*	0	*0*	17
36 - 38	3	*15*	1	*5*	20
39 - 41	8	*33.3*	0	*0*	24
42 - 44	11	*61.1*	2	*11.1*	18
45 - 47	9	*100*	5	*55.6*	9
48 - 50	8	*100*	8	*100*	8
51 - 53	12	*100*	11	*91.7*	12
54 - 56	14	*100*	14	*100*	14
57 - 59	10	*100*	10	*100*	10
60 - 62	7	*100*	7	*100*	7
63 - 65	4	*100*	4	*100*	4
66 - 71	3	*100*	3	*100*	3
≥72	1	*100*	1	*100*	1
Total	91		66		165

Table 4.- Number of females with ovaries in the *cortical alveoli* stage (CA) and postovulatory follicles (POF) stage by age, sampled in summer 1996.

	AC		POF		Total
Age	no.	%	no.	%	
2	0	*0*	0	*0*	24
3	23	*31.5*	3	*4.1*	73
4	11	*100*	6	*54.5*	11
5	49	*100*	49	*100*	49
6	7	*100*	7	*100*	7
7	1	*100*	1	*100*	1
Total	91		66		165

Table 5.- Age and length at 50 % maturity of female cod obtained from the maturity curves based on postovulatory follicles (POF) and cortical alveoli (CA) frequencies, from July 1992 to July 1996. Figures from 1992 to 1995 were recalculated (Saborido-Rey and Junquera, 1997. Unpublished data). 1990 data from Zamarro *et al.* (1992).

	Length		Age	
	AC	POF	AC	POF
1990	61	?	3.80	5.60
1992	51.69	59.38	3.76	5.02
1993	48.02	57.53	3.35	4.48
1994	47.39	51.23	3.44	3.82
1995	39.07	42.65	3.18	3.75
1996	41.17	45.86	3.09	3.85

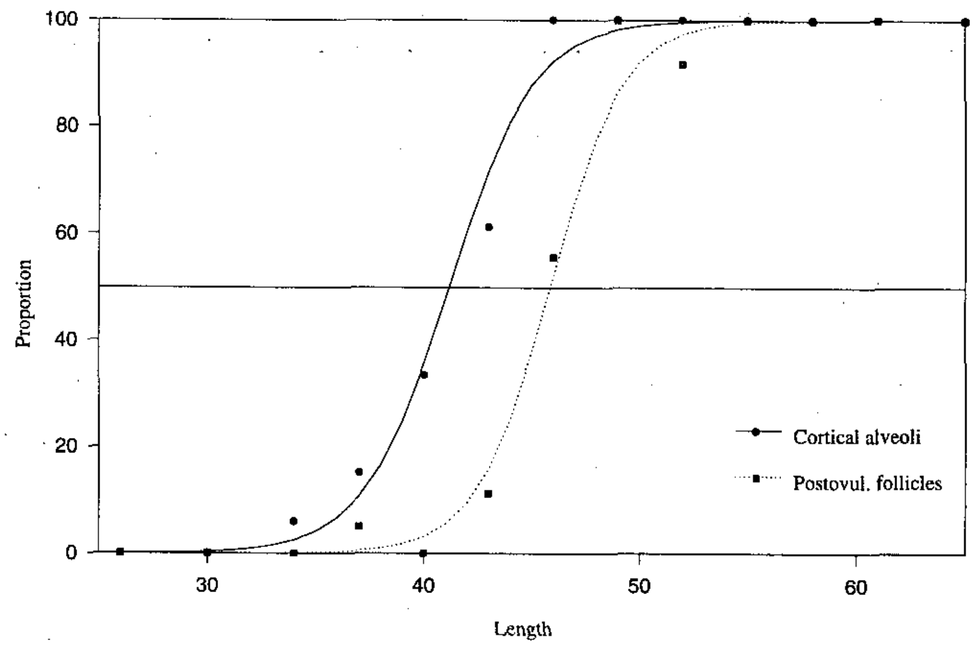

Fig. 1- Proportion of mature female by length obtained using the frequency of cortical alveoli and of postovulatory follicles in July 1996.

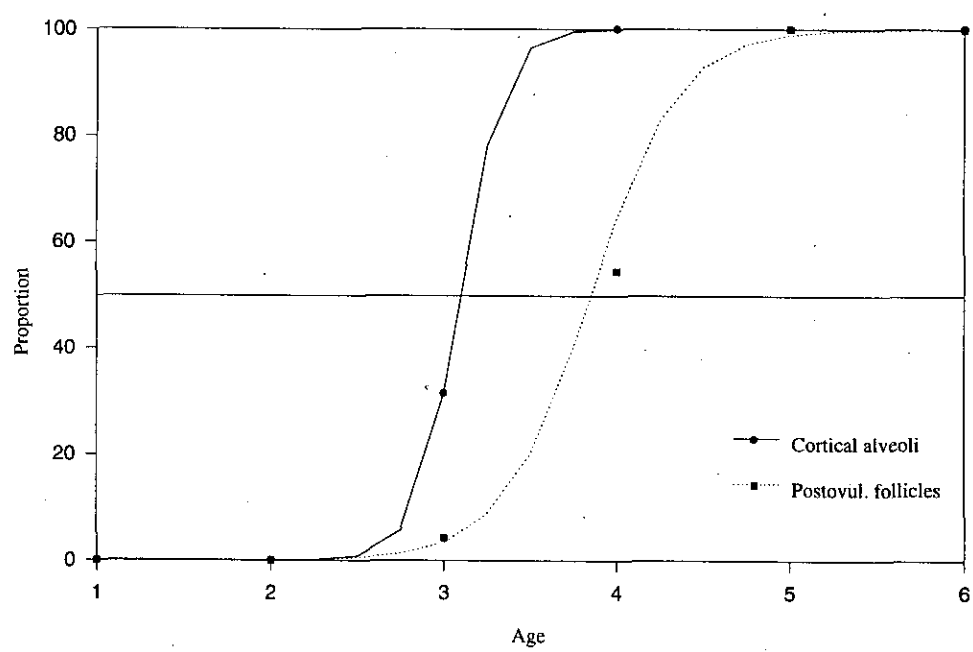

Fig. 2- Proportion of mature female by age obtained using the frequency of cortical alveoli and of postovulatory follicles in July 1996.

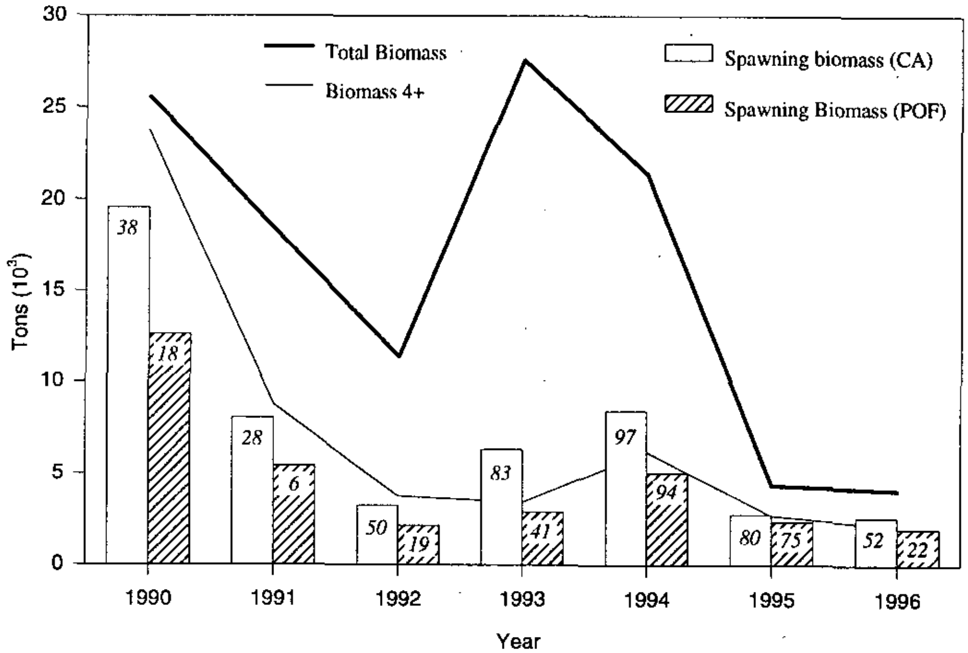

Figure 3 - Total cod biomass and 4+ biomass according to EU survey. Spawning biomass using CA and POF frequencies (All data referred to female biomass). The figures inside the bars are the proportion (in number) of mature female of age 4 or younger.