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

by

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Introduction

In recent years, in Flemish Cap cod has been observed a progressive reduction on age and size at maturity from 1992 to 1995 (Saborido-Rey and Junquera, 1998). This reduction was probably a response to low population abundance and accordingly a certain recovering of the spawning biomass would be expected. However there was a lack of incoming recruitment in the latest years, which make the biomass of the Flemish Cap cod being in the lowest value recorded. Despite of the improvement in the scientific advice with the incorporation of new models in terms of uncertainty, the lack of biological realism can produce an inappropriate model assumptions, as for example those concerned with static life history parameters (Helser and Brodziak, 1998). Several studies confirm that population density is an important mechanism in regulating the dynamics of marine fish populations (Trippel, 1995; Tyler et al., 1997) affecting to several life history parameters, as growth and age/size and maturity (Roff, 1984) and hence the possibility of the spawning biomass to increase in order to permit the rebuilding of the stock.

Size 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 1998 is used to determine the size and age at maturity in 1996 and the proportion of females in the *cortical alveoli* stage to estimate the same parameters for 1999. Estimation of the spawning stock biomass is calculated and its evolution in the period 1990-1998 discussed.

Material and methods

A total of 221 cod ovaries were sampled during the 1998 summer European Union survey in Flemish Cap (Vázquez 1999). Hauls ranged from the shallower parts of the bank (120 m) to depths of 730 m, according to a random stratified design, with haul duration of 30 minutes (Vázquez, 1999). 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.

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 (atretic) oocytes. Recruit mature females were identified since they have no postspawning structures such as POF or atretic oocytes.

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 1998 using data from EU surveys (Vázquez, 1999). 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. Very few number of the females sampled were immature, only 3 % while 97 % were mature. The frequencies of females with *cortical alveoli* and postovulatory follicles stage by length intervals and age are presented in tables 3 and 4 respectively. In all the ovaries with postapwning structures (POF or atretic oocytes) there were presence of CA oocytes, i.e. all the spawned female had begun the ripening of the next breeding season. A total of 202 of the sampled female had spawned in 1998, as indicated by the presence of POF and atretic oocytes in the ovary, i.e. more than 90 % of the cod living in the bank. The proportion of females with this kind of postspawning structures increases with length and age and gets 100 % of females larger than 57 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 5 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 1998, 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 40.7 cm and 2.9 years respectively (Table 5). The same parameters obtained from POF frequencies are 43.5 cm and 3.5 years respectively. A decrease in both the age and the length at maturity was observed from 1990 to 1995. In 1996 onwards length and age at maturity seem to be stabilised at current values.

Figure 3 shows Total biomass, spawning stock biomass and age 5+ spawning biomass estimates for the period 1988-1998. Total biomass decreased from about 100,000 tons in 1990 to about 4,500 tons in 1998. The total biomass increment 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 30,000 tons in 1993 to about 3,500 tons in 1995. Spawning biomass (estimated from POF values, i.e. biomass that had spawned in 1998) followed a similar pattern, decreasing from about 31,500 tons in 1989 to about 4,000 tons in 1998, due to the documented reduction of age at maturity. In 1997, the 94 % of the total biomass was mature due to the lack of recruitment in latest years. In 1998, 72 % of the mature fish were age five or more, while in 1997 the proportion was 43% and only 25 % in 1994, the lowest value recorded.

Discussion

The age and length at maturity in 1998 obtained using POF were 3.5 years and 43.47 cm respectively. The same parameter obtained from CA, i.e. the age and length at maturity for the next year spawners, were 2.93 years and 40.72 cm. Both parameters of age at maturity are the lowest since 1990, although we can consider they are at the same level as in the last four years, being the age at maturity stable since 1995. Length at maturity seems to be fixed also since 1995, being estimates in 1998 slighty higher than in 1995 because of different growth rates of each cohort.

In a previous study (Junqùera and Saborido-Rey, 1996), we 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 we 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 1998 data confirms this hypothesis since age at maturity was similar than in 1995. The abnormal high proportion (20 %) of age 3 females that had spawned in 1998 can be considered as an artifact of the very low number of fish catched for ages below 4. In fact, only one specimen account for that 20 %

The decreasing trend in the length at maturity already noted in 1994, and very pronounced in 1995 shows a slight increase in recent years. The fact of the great reduction in the length at maturity between 1994 and 1995 while the age at maturity remained 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 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 since then. In 1997 and 1998, 50 % of the total spawning biomass was composed by 1993 year class. The main difference between the last three years lies in the number of year-classes participating in the spawning. In 1996, the bulk of the spawning biomass was only one year-class, in 1997 there was two dominant year-classes and in 1998 three year-classes were dominant in the spwning biomass. In this sense the status of the spawning biomass may be auspicious because the reproductive potential is higher, as dicussed below. However the spawning biomass is the lowest never recorded, mainly due to the failure of recruitment in latest years.

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 age 4+ biomass 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 in 1994 was in the same level as in previous years 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.*, 1991; Solemdal *et al.*, 1992) 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. All the above facts may have contributed the lack of recruitment in latest years and hence the low spawning biomass in 1998. As mentioned, in 1998 there were three different year classes contributing in a balanced proportion in the spawning, this situation increase the chances of eggs and larvae to survive (Trippel, 1995) but until what extent a very low spawning biomass can produce a relative strong year class remains unclear, but if any abundant year class appear in the population, it should be protected and allow to such year class reproduce for several years, avoiding the situation of 1994 where the strong 1991 year class was fished out.

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Table 1.- Number of adult and immature females by length sampled in Flemish Cap in summer 1998.

Length	Immature	Mature	Total	%
< 30	-	-	-	-
30 - 32	-	-	-	-
33 - 35	2	0	2	*0*
36 - 38	1	0	1	*0*
39 - 41	-	-	-	-
42 - 44	1	5	6	*83.3*
45 - 47	1	8	9	*88.9*
48 - 50	0	42	42	*100*
51 - 53	0	36	36	*100*
54 - 56	1	49	50	*98.0*
57 - 59	0	35	35	*100*
60 - 62	0	22	22	*100*
63 - 65	0	6	6	*100*
66 - 68	0	4	4	*100*
69-71	0	5	5	*100*
≥72	0	3	3	*100*
Total	6	215	221	*97.29*

Table 2.- Number of adult and immature female cod by age sampled in Flemish Cap in summer 1998.

Age	Immature	Mature	Total	%
2	3	0	3	*0*
3	2	3	5	*60*
4	1	85	86	*98.8*
5	0	107	107	*100*
6	0	5	5	*100*
7	0	14	14	*100*
9	0	1	1	*100*
Total	6	215	221	*97.29*

Table 3.- Number of females with ovaries in the *cortical alveoli* stage (CA) and postovulatory follicles (POF) stage by length sampled in summer 1998.

	AC		POF		
Length	no.	*%*	no.	*%*	Total
< 30	-	-	-	-	-
30 - 32	-	-	-	-	-
33 - 35	0	*0*	0	*0*	2
36 - 38	0	*0*	0	*0*	1
39 - 41	-	-	-	-	-
42 - 44	5	*83.3*	2	*33.3*	6
45 - 47	8	*88.9*	7	*77.8*	9
48 - 50	42	*100*	38	*90.5*	42
51 - 53	36	*100*	32	*88.9*	36
54 - 56	49	*98*	49	*98.0*	50
57 - 59	35	*100*	34	*97.1*	35
60 - 62	22	*100*	22	*100*	22
63 - 65	6	*100*	6	*100*	6
66 - 68	4	*100*	4	*100*	4
69 - 71	5	*100*	5	*100*	5
≥72	3	*100*	3	*100*	3
Total	215		202		221

Table 4.- Number of females with ovaries in the *cortical alveoli* stage (CA) and postovulatory follicles (POF) stage by age, sampled in summer 1998.

	AC		POF		Total
Age	no.	*%*	no.	*%*	
2	0	*0*	0	*0*	3
3	3	*60*	1	*20*	5
4	85	*98.8*	74	*86*	86
5	107	*100*	107	*100*	107
6	5	*100*	5	*100*	5
7	14	*100*	14	*100*	14
9	1	*100*	1	*100*	1
Total	215		202		221

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 1990 to July 1998.

	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
1997	42.81	46.14	3.36	3.75
1998	40.72	43.47	2.93	3.51

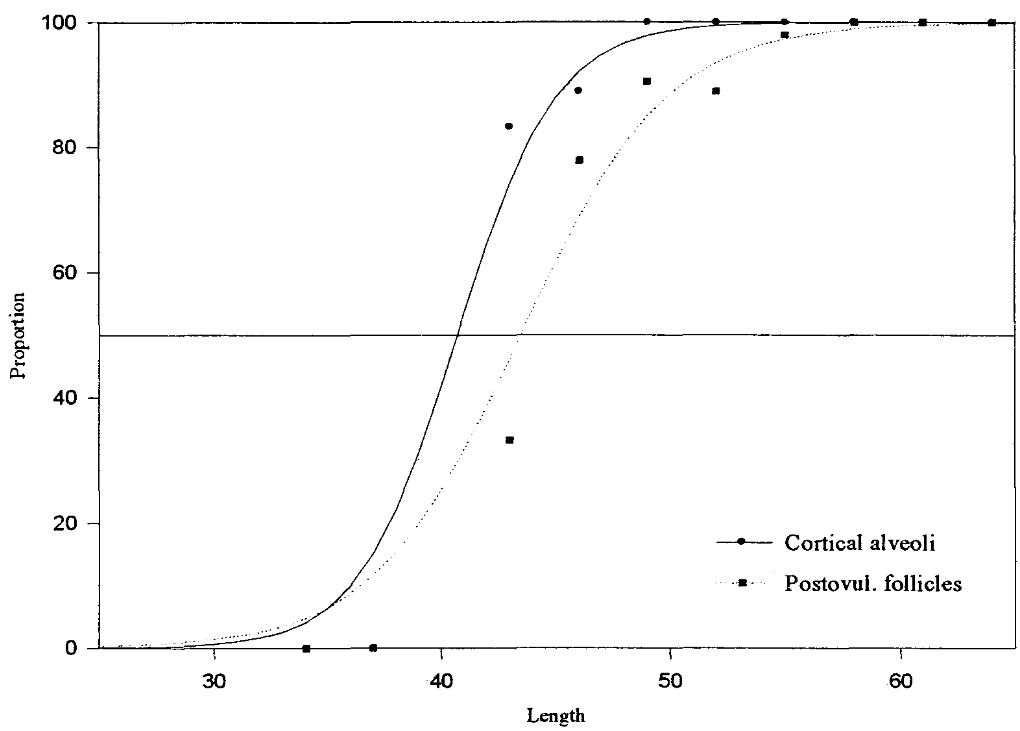

Figure 1- Proportion of mature female by length obtained using the frequency of cortical alveoli and of postovulatory follicles in July 1998.

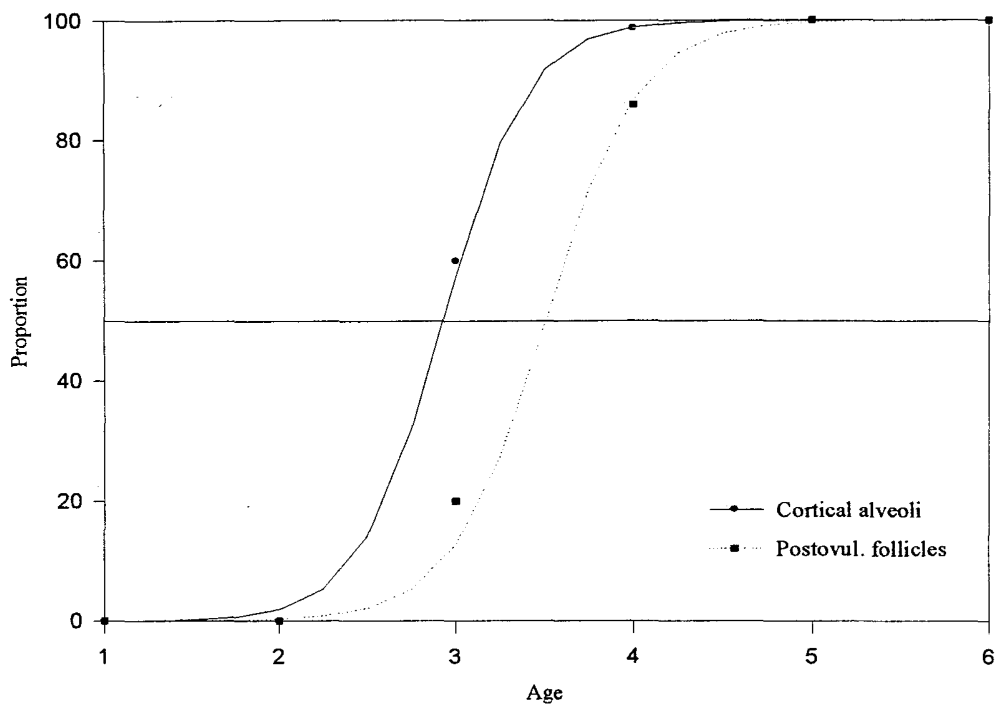

Figure 2- Proportion of mature female by age obtained using the frequency of cortical alveoli and of postovulatory follicles in July 1998.

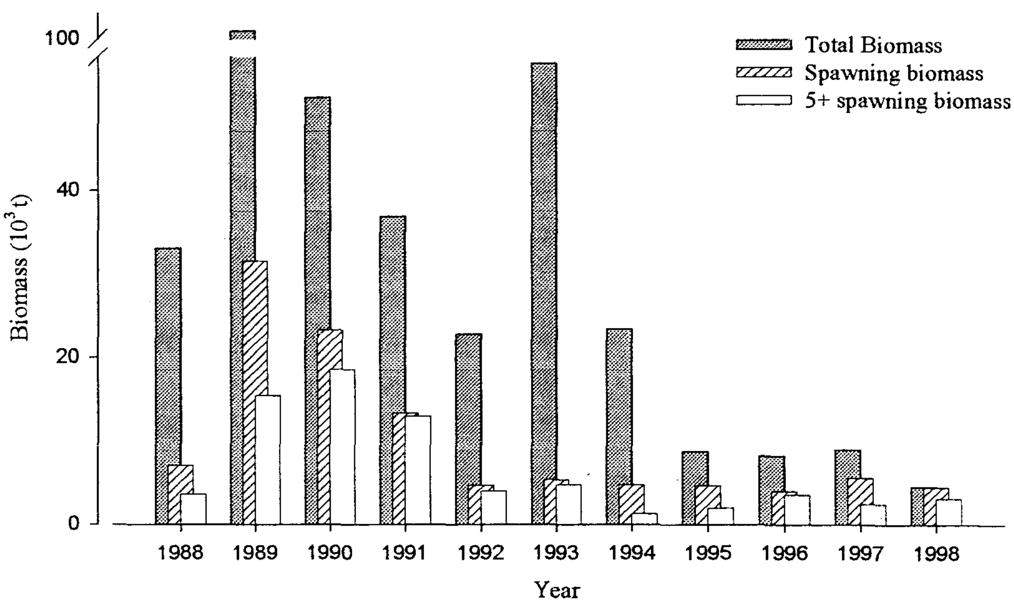

Figure 3 - Total biomass, Spawning stock biomass and age 5+ spawning biomass from 1988 to 1998 according to EU survey.