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Sexual Maturity of Cod (*Gadus morhua*)
in Flemish Cap (Div. 3M)

by

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Introduction

One of the most important parameters in fisheries management is the age at maturity in order to estimate, for example, spawning biomass or to determine minimum size at capture to allow for reproduction. To calculate a maturity curve in fish females using the macroscopic features of the ovary is easy during most of the annual reproductive cycle (Morrison, 1990), but is very difficult after spawning and before the vitellogenic stage, at the onset of ripening. This occurs in the fisheries research surveys carried out in late spring-summer where the problem of identification of ripening females is considerable. Zamarro *et al.* (1993) designed a method to classify ovaries into maturity stages with histological techniques, using oocytes in cortical alveoli (CA) and postovulatory follicles (POF) to identify primiparous and multiparous females since the earlier stages of maturity.

In this paper we use POF to identify females which spawned in 1994 and cortical alveoli oocytes to identify females which will spawn in the next reproductive season. This data is used to obtain a maturity curve to be compared with those of previous years.

Material and methods

During the summer survey in Flemish Cap (Vázquez, 1995), a total of 197 ovaries were sampled. Total length and weight were measured and otoliths removed. Gonads were fixed in 4% buffered formalin (Hunter, 1985) and weighed in the laboratory. 0.5 cm sections were embedded in paraffin based on conventional histological processing and 5 μ sections stained with Hematoxylin and eosin.

Different stages were identified following 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 got oocytes in cortical alveoli (CA), vitellogenesis, postovulatory follicles (POF) or degenerating oocytes. Primiparous females were identified since they have no postspawning structures such as POF or atresic oocytes.

The proportion of mature female by size and age seemed to coincide with a logistic equation as described by Ashton (1972) and applied in another species (Ni y Sandeman, 1984; Halderson y Love, 1991):

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

and the logit transformation:

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

where

\hat{P} = predicted mature proportion

α and β are the coefficients of the logistic equation

L is the length (or age).

BMDP LR (Dixon *et al.*, 1990) was used to calculate the predicted values and the coefficients. Thus, the size and age at maturity could be estimated as the minus ratio of coefficients ($-\alpha / \beta$) by substituting $\hat{P} = 0.5$ in equation 2.

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

Results

Table 1 shows the number of mature and immature females by size and age. 135 females (75.4 %) of the 179 sampled were primiparous or multiparous and 44 females (24.6 %) immature.

Table 2 shows the number and percentages of ovaries by size intervals with cortical alveoli, postovulatory follicles and vitellogenesis oocytes. The number by age is shown in Table 3. Most of the ovaries sampled show oocytes in the cortical alveoli stage (63.7 %) showing that these females will spawn in the next breeding season. The proportion of female with CA increase with the size Thus above 63 cm (age 6) all females show this kind of oocytes.

The females which spawned in 1994 were identified by the presence of postovulatory follicles or atresic oocytes. A total of 92 females had spawned in 1994 (Table 2); the number of females with POF increases with size and age, and 100 % of females with 66 cm or more (age 6 +) show POF or atresic oocytes, though atresic oocytes with no POF in any ovary were found.

The number of ovaries with oocytes in vitellogenesis is very low (only 3) and represents 2.22% of the mature female. However, the proportion of spent females with POF but without CA oocytes (relatively recent spawning) was high, reaching 19.75 % of spent females. This mean that a high proportion of females has spawned recently.

Two maturity ogives were generated. For the first one, corresponding to spawners in 1994, POF was used to identify mature females. For the second one, corresponding to the

spawners in 1995, the presence of CA was used as a criterion. Both curves are shown in Figure 1. Size and age at maturity calculated with CA oocytes was 47.83 cm and 3.48 years respectively. The same parameter calculated from POF was 51.23 cm and 3.81 years respectively. It was observed that there is less than a one year difference between the two ages at maturity.

Discussion

In 1990 (Zamarro *et al.*, 1993) the 50% maturation age using POF and CA was 5.6 and 3.8 years respectively, in 1993 (González and Larrañeta, 1994) 5 and 4 years, and, in 1994 were 3.9 and 3.5 respectively. So a reduction of the age at maturity in the period 1990-1994 was noted. A difference of one year between both ages at maturity is explainable as there is a one year difference between spawning seasons. In the data recorded by Zamarro *et al.* (1993) there was almost a two year difference between age at maturity of the females which were to spawn in 1991 and those which spawned in 1990, when only one year is expected. This fact can be explained by a reduction of age at maturity that year.

Size and age at maturity are highly plastic parameters which change with external pressure, particularly the decrease of the population abundance (Adams, 1980; Gunderson, 1980; Wootton, 1990). The effect of the density-dependence in cod was shown in the Gulf of St. Lawrence (Beacham, 1983). Pitt (1975) reported a declining from 14 to 11 years in age at maturity in American plaice on Grand Banks. Similar observations have been reported in haddock (Templeman and Bishop, 1979), Clupeids (Murphy, 1977), *Scomber japonicus* (Parrish and MacCall, 1978), *Hippoglossus stenolepis* (Scmitt and Skud, 1978), redfish (Saborido-Rey, 1994) and Greenland halibut (Junquera and Saborido-Rey, 1995)

The length frequencies reported during the period 1990-1994 (Vázquez, 1990, 1991, 1992, 1993, 1994, 1995) show a decrease, especially in the largest individuals. Furthermore, a marked decline in the abundance of the strong 1991 year class was observed. The total biomass declined from 146,000 mT in 1989 to 30,300 in 1992. In 1990, the age at maturity was reduced in one year which may have been due to the decline in the abundance in that period. So the age at maturity of spent females was 5.6 years and 3.8 to future spawners (4.8 years in the next season). In the period 1990-1994, age at maturity was decreasing progressively and in 1993 cod females started maturation around age 3 (3.9 in 1994). This change was not detected in 1993 (González and Larrañeta, 1993) perhaps because these younger females start maturation after July (when ovaries were sampled). In 1994, the age at maturity calculated from CA was 3.4, similar to 1993. The age at maturity has been fixed at around age 3 in recent years.

In the summers of the period 1991-1992, approximately 40 % of the mature females had vitellogenic oocytes. Instead, in 1994 only 2.22 % of mature females (12.8 % of the spent females) were in the vitellogenic stage. Conversely, in 1991-1992 many females showed ovaries with POF and with no cortical alveoli oocytes, but in 1994 19.75% of the spawned females were in this situation, indicating that they had spawned recently. So in 1994 the spawning time may seem delayed in comparison with previous years. This may be associated

with environmental conditions, particularly temperature (Kjesbu, 1994), but a correlation of the spawning time with the size at maturity is also possible, as it is known that the younger females tend to spawn later (Morrison, 1990). In fact in 1994 the postspawning females found in summer were the smallest ones.

The high proportion of females in postspawning stage, and then without CA oocytes, may yield an overestimation of the age at maturity from CA, and then a difference of a year between two ages at maturity could be expected.

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Table 1.- Frequency of mature and immature females by size and length in Flemish Cap in July 1994

Length	Inmature	Mature	Total	Age	Inmature	Mature	Total
<36	2	0	2	2	2	0	2
36-39	3	0	3	3	36	12	48
39-42	10	0	10	4	6	108	114
42-45	15	7	22	5	0	11	11
45-48	10	5	15	6	0	2	2
48-51	3	21	24	7	0	1	1
51-54	1	28	29	8	0	1	1
54-57	0	30	30		43	136	179
57-60	0	22	22				
60-63	0	12	12				
63-66	0	4	4				
66-69	0	3	3				
69-72	0	1	1				
72-75	0	1	1				
>75	0	1	1				
TOTAL	43	136	179				

Table 2.- Frequency of ovaries with Cortical alveoli (CA), Postovulatory follicles (POF) and vitellogenic oocytes (OV) by length

Length	CA	POF	VO	postapawning	TOTAL
<36	0	0	0	0	2
36-39	0	0	0	0	3
39-42	0	0	0	0	10
42-45	6	1	1	0	22
45-48	5	2	0	0	15
48-51	18	13	0	3	24
51-54	22	17	1	5	29
54-57	23	23	1	6	30
57-60	19	21	0	3	22
60-63	11	7	0	1	12
63-66	4	2	0	0	4
66-69	3	3	0	0	3
69-72	1	1	0	0	1
72-75	1	1	0	0	1
>75	1	1	0	0	1
TOTAL	114	92	3	18	179

Table 3.- Frequency of ovaries with Cortical alveoli (CA), Postovulatory follicles (POF) and vitellogenic oocytes (VO) by age

Age	CA		POF		VO		TOTAL
	num	%	num	%	num	%	
2	0	0	0	0	0	0.0	2
3	11	22.9	2	4.2	1	2.1	48
4	89	78.1	76	66.7	2	1.8	114
5	10	90.9	10	90.9	0	0.0	11
6	2	100	2	100	0	0.0	2
7	1	100	1	100	0	0.0	1
8	1	100	1	100	0	0.0	1
Total	114		92		11		179

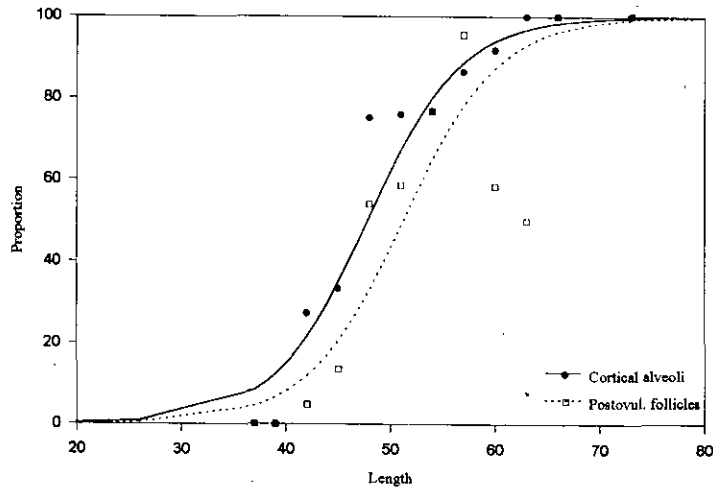


Figure 1.- Percentage of mature females by length

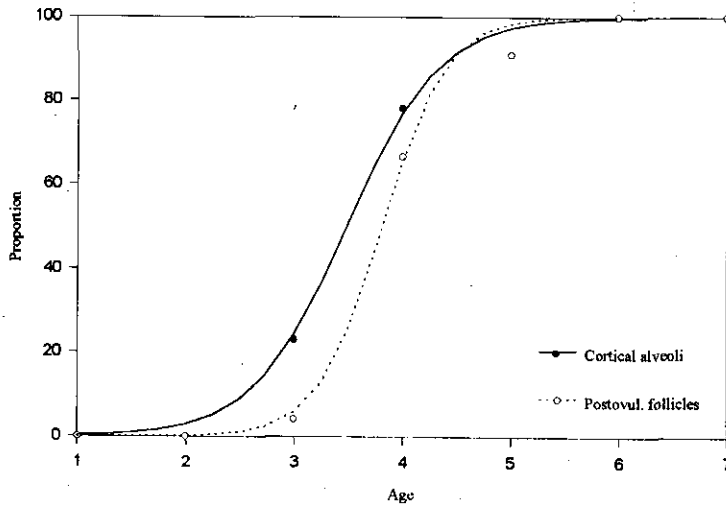


Figure 2.- Percentage of mature females by age