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Geostrophic Circulation and Cod Egg Distribution in Flemish Cap

by

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Abstract:

In the present paper a revision is made of information on geostrophic circulation, cod spawning season and cod egg distribution in Flemish Cap.

A discrepancy between spawning and the presence of eggs in the bank is appreciated. By comparing circulatory patterns and egg distributions for different periods for which both data are available, certain situations favourable to the entrance into the bank of eggs from the exterior are observed. This could have occurred in the situation registered in the months of March 1980 and 1981, when the geostrophic circulation presented a west-east component, seemingly transporting eggs situated in the area of Flemish Pass towards the interior of the bank. Hence, the strong recruitment of 1986 could have been due to the capture of a large mass of eggs located in Flemish Pass in the second half of April 1986.

Introduction:

It is now accepted that in the area of Labrador and Terranova cod eggs can undergo very large displacements through drifting before hatching (Serebryakov, 1968; Templeman, 1982; Lear and Green, 1984). The Labrador current flows through Hamilton Bank, Belle Isle Bank, Funk Island Bank and northeast of Grand Bank, an area in which great concentrations of cod eggs accumulate. On reaching Flemish Cap this flow divides into two branches which border the bank on the west and the northeast. The north Atlantic current circulates to the southeast. In the middle of these currents a slight anticyclonic circulation is produced.

Kudlo *et al.*, (1984) analyzed the results of 26 Russian oceanographic surveys carried out between 1978 and 1984, and detected four different kinds of circulation in Flemish Cap, defined as types V, V_L, T_M and M. Type V is characterised by the existence of a wide anticyclonic circulation which occupies the whole bank; type V_L corresponds to an anticyclonic circulation with several different centres of rotation; type T_M corresponds to a flow which, forming meanders, crosses the bank from west to east; type M forms a mixed circulation which is a cross between types V or V_L and M. According to the authors, the circulatory types V and V_L favour the retention of the native spawn in the bank, while type M bring about a sweeping effect of eggs and larvae out of the bank. In type T_M the sweeping out of part of the spawn and the retention of another part would be produced depending upon the position of the eggs in the bank. According to the authors the change from a situation of type V or V_L to one of type T_M or M is due to the appearance of atmospheric perturbances (cyclones), or severe storms in areas around Flemish Cap.

Serebryakov (1968) affirms that, in March, Flemish Cap cod appear in all states of maturity, but that from the month of April most specimens appear in the post-spawning state which, according to the author, proves that most of the spawning takes place in March, although he highlights the fact that cod eggs continue to appear in the bank up to the month of August, for which he suggests the possibility that a certain number of specimens or, perhaps, of small aggregations, could spawn during spring and summer.

Myers *et al.*, (1993) revised the cod spawning seasons in Newfoundland from data coming from Canadian surveys and from commercial fishing in the period 1946-1992. According to these authors the cod spawning period in Newfoundland extends from February to July, although the peaks and the extension of spawning varies greatly from one area to another, and specifically Flemish Cap presents the shortest spawning period of all the areas analyzed, and one of the earliest in the year, since practically all the spawning takes place in March. In the same study, the authors confirm that the surface water temperature in Flemish Cap in March is around 2 or 3°C., which brings about hatching in a period of between 15 and 20 days after spawning. If spawning took place in March, and if Flemish Cap were isolated, cod eggs should disappear completely from the bank by the end of spring.

De Cárdenas and Avila de Melo (1993) presented a standardised series of recruitment and spawning stock biomass indices for Flemish Cap cod, made up from the three series of surveys which exist in the area (Canadian, Russian and European). This standardised series apport data for the years 1978 and 1990.

De Cárdenas *et al.* (1992) indicated the possibility that part of the annual Flemish Cap cod recruitment could come from outside this bank.

The aim of this work is to study how egg distributions behave in relation to the different current systems and under which circumstances they bring about a higher egg survival index, defined as the result of dividing the recruitment index by the spawning stock biomass index.

Material and Methods:

The dynamic topography of the surface taking 200db. as a level of reference, we are provided with a vision of geostrophic circulation in the area during the period observed. From this data presented by Kudlo *et al.* (1984) for the period 1977-1982, Chumakov and Borovkov (1984) for 1983 and Chumakov *et al.* (1987) for 1986 and the annual egg survival indices (SI) calculated using the data from the series standardised by de Cárdenas and Avila de Melo (1993) according to the formula:

$$SI_i = \frac{10 * R_i}{SSB_i}$$

where

R_i = standardised recruitment index of age class of year i.

SSB_i = standardised spawning stock biomass index of year i,

we have elaborated a table which illustrates the monthly distribution of types of circulation in the period February-July, the season in which cod spawn in the area of Newfoundland (Myers *et al.*, 1993), and the egg survival index, for each of the years studied. In this way we are able to identify the sequences of the types of circulation which produced better or worse survival indices.

Following this, we have superimposed the egg distribution data supplied by Serebryakov *et al.* (1987) and Akhtarina (1987) over those of geostrophic circulation, corresponding to the same dates on which ichthyoplankton samples were taken (Kudlo *et al.*, 1984; Chumakov and Borovkov, 1984; Chumakov *et al.*, 1987), to deduce the behaviour of egg distributions as a function of the type of geostrophic circulation.

Results and Discussion:

A total of 28 observations of geostrophic circulation in Flemish Cap were made in the different periods of February-July in the years analyzed. 7 of them corresponded to a type V circulation, 10 were identified as being type V_L, 3 were type T_M and the other 8 were the mixed circulation type M (Table 1).

Survival indices fluctuated between 0.01 in 1979 and 22.7 in 1986. Contrary to the speculations of Kudlo *et al.* (1984) the highest survival indices, except for 1982 for which there is only one sampling, do not come in the years of greater stability in the anticyclonic circulation (circulations of type V and V_L) as is possibly the case in 1979 which presents the lowest index in the series, but are produced when, after a type M situation, circulation of type V or V_L is once more established, and this is maintained throughout the rest of the period, as happened in 1981 and 1986. To interpret the survival index it must be taken into account that this may reflect the degree of success of the survival of the native spawn, due to the existence of a higher or lower retention of eggs, or a higher or lower intake of eggs from outside, or a combination of both phenomena. If we could assume that eggs are not carried to the bank from the exterior, this result would be surprising, since any situation of type M from March onwards would bring with it a loss of part of the spawn. It must be remembered that spawning in Flemish Cap occurs almost exclusively in March. This loss would be even more accentuated in situations of type M, since this situation produces a sweeping effect of spawn from the whole bank. On the other hand, situations of type V and V_L would tend to keep the spawn in the bank, and so a higher survival index (SI) could be expected (SI).

To try to clarify the reason for this apparent contradiction we will now analyze a series of typical situations for which data of circulation and egg distribution are available:

April 1981 (type V), (Fig. 1)

- Situation is unfavourable to the intake of eggs from the exterior.
- Situation is of anticyclonic circulation.
- Eggs are dispersed throughout the bank.
- Eggs do not appear to have come from the exterior.
- Anticyclonic circulation favours the retention of eggs in the bank.

March 1980 (type T_M), (Fig. 2)

- Situation is favourable to the intake of eggs from the west.
- West-east circulation produces a sweeping effect in the bank.
- Egg aggregations are concentrated in the occidental part of the bank.
- Eggs are absent from the oriental area of the bank owing to the sweeping effect.
- Egg aggregations appear in the Flemish Pass area which, due to the type of circulation, seem to come from Grand Bank and appear in Flemish Cap.
- There are also egg aggregations in the south-east of the bank, which appear to be the result of the native spawn.

March-April 1981 (type M), (Fig. 3)

- In the northern half of the bank a situation of type T_M with a west-east current is produced which sweeps the area, while the southern half undergoes a situation of type V with a slight anticyclonic regime.
- In the northern part of the bank, as in situation T_M described earlier, intake of eggs is observed from Flemish Pass, while in the southern part egg concentrations are observed which would come from the native spawn and whose retention would be favoured by the anticyclonic circulation.

We will now analyze the situation in 1986. For this year the Russian scientists had predicted a bad recruitment, owing to the destruction of the anticyclonic circulation in the months of April and May (Chumakov *et al.*, 1987). Nevertheless, it was the year which produced the highest survival index.

The situation at the end of April 1986 (Fig. 4) was of type M, although differing from that found in April 1981, a north-south flow appears through Flemish Pass. The egg distribution is a densely concentrated mass circulating in Flemish Pass, carried by the southern flow previously mentioned. In the northern part of the bank, a marginal intake of eggs is observed from this mass. The situation of the principle mass in relation to the current and the season of the year in which it appears (April 21-May 1), too late to have been spawned in March, make it unlikely that these eggs come from a native spawn in the bank. A week later (between May 6-10) the hydrology of the area was sampled once more. The number of stations sampled was small, but a change is detectable in the circulation with a northern component of the flow in Flemish Pass (Fig. 5), which could bring about a massive intake of eggs in the principle mass, which in turn would tend to increase the survival index (SI).

Once these particular cases have been analyzed, we can conclude that the situations of type T_M and M which were observed on 11 of the 28 occasions analyzed between the months of February and July, imply a smaller retention of the native spawn, but also bring about the intake of egg masses which circulate at this time in Flemish Pass. These masses can be very important, as was confirmed in 1986. If the balance between loss and intake of eggs is favourable to the latter the apparent paradox which we observe in the interpretation of the results of Table 1 would be explained. The intake of eggs in these situations could also explain the presence of eggs in the bank in July and August, since the spawn remains in Grand Bank during these months (Myers et al.), with which, if a situation T_M or M is produced in these dates, there could be an intake of eggs in Flemish Cap.

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Year	Feb.	Mar.	Apr.	May	Jun.	Jul.	SI	Rec.
1978	T_M-M	*	*	M	*	M	1.02	6425
1979	*	V	V_L	V	V	*	0.01	26
1980	*	T_M	V_L	V_L	V_L	V	4.96	12405
1981	*	M	M-V_L	V_L	V	*	9.95	20968
1982	*	*	V_L	*	*	*	17.20	8632
1983	V	V_L	V_L	T_M-M	*	*	4.57	6471
1986	*	*	M	M-V_L	V	*	22.70	40862

* Unsampled month
V Wide anticyclonic circulation which occupies the whole bank.
V_L Anticyclonic circulation with several different centres of rotation.
T_M Flow which, forming meanders, crosses the bank from west to east
M Mixed circulation.

Table 1.- Monthly distribution of types of circulation, survival and recruitment indices.

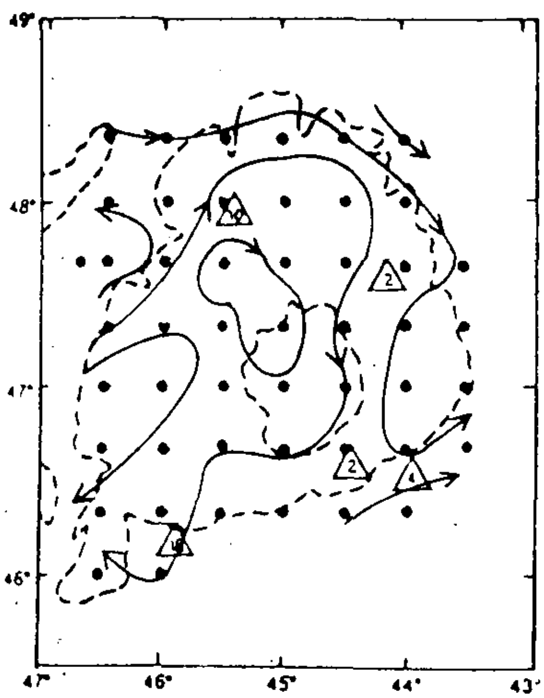


Fig. 1.- Geostrophic water circulation (Kudlo *et al.*, 1984), distribution and abundance of cod eggs in number/m² (Serebryakov *et al.*, 1987), from April 23 to April 30, 1981 (type V).

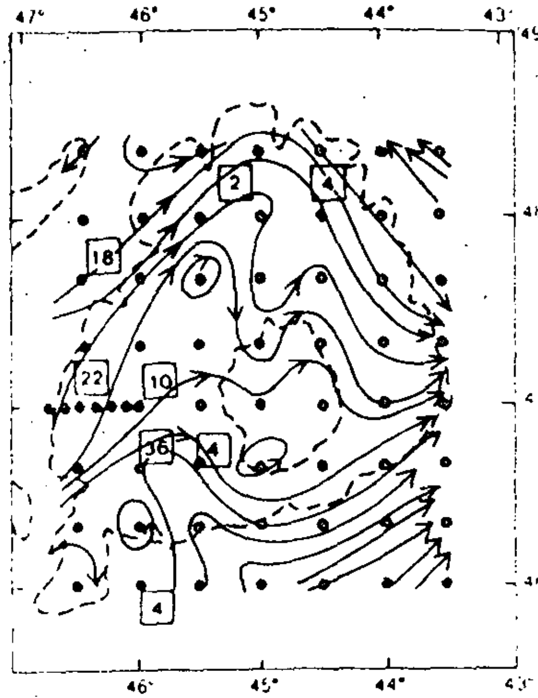


Fig. 2.- Geostrophic water circulation (Kudlo *et al.*, 1984), distribution and abundance of cod eggs in number/m^2 (Serebryakov *et al.*, 1987), from March 19 to April 1, 1980 (type T_N).

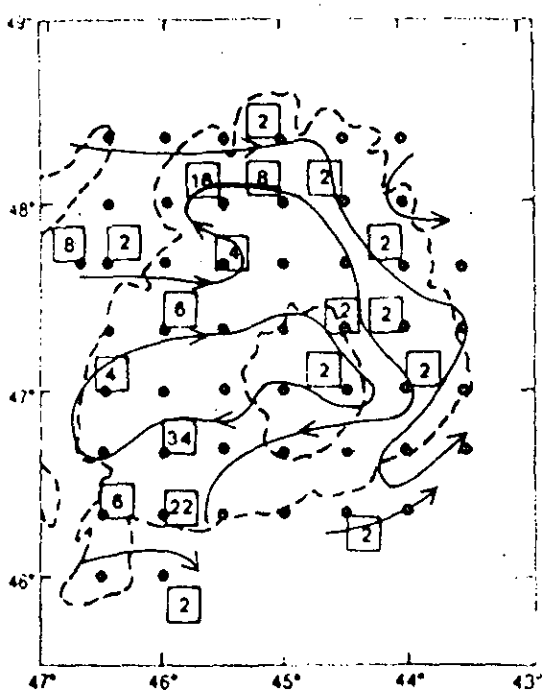
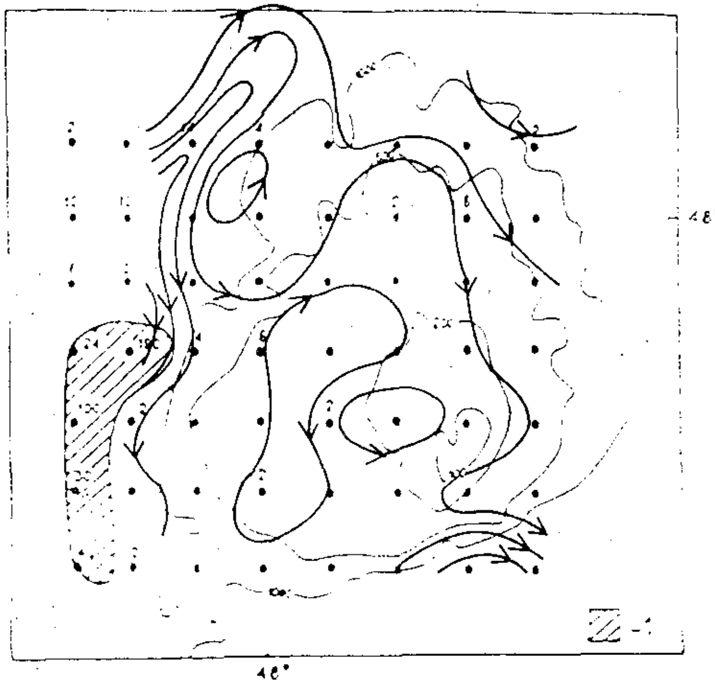


Fig. 3.- Geostrophic water circulation (Kudlo *et al.*, 1984), distribution and abundance of cod eggs in number/m^2 (Serebryakov *et al.*, 1987), from March 22 to April 5, 1981 (type M).



1 - more than 20 spec./m^2

Fig. 4.- Geostrophic water circulation (Chumakov *et al.*, 1987), distribution and abundance of cod eggs in number/m^2 (Akhtarina, 1987), from April 21 to May 1, 1986 (type M).

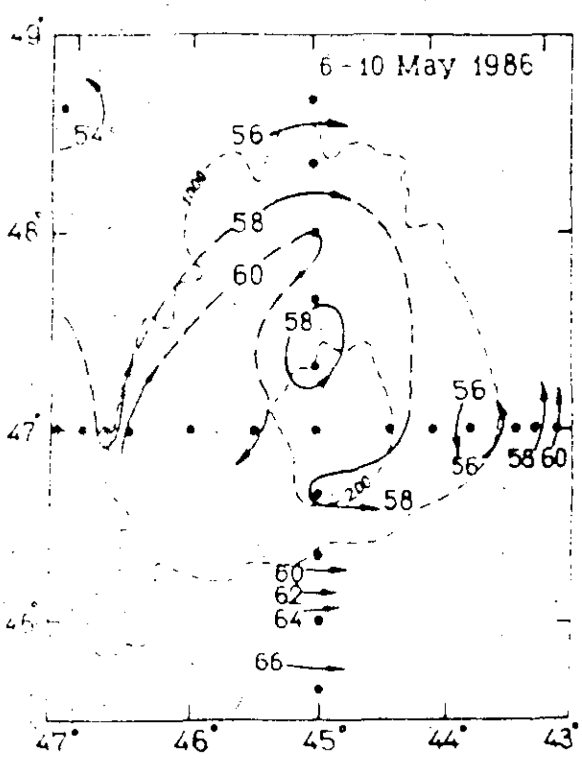


Fig. 5.- Geostrophic water circulation (Chumakov *et al.*, 1987), from May 6 to May 10, 1986.