C.M.1974/J.14

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ON REGULARITIES IN THE VARIABILITY OF THE SPAWNING TERMS OF HORSE-MACKEREL, (TRACHURUS TRACHURUS LINNE) WITHIN THE SPAWNING AREA

Horse-mackerel is one of the important commercial species in the eastern shallow-water zones of the Atlantic ocean.

Its spawning area is extremely wide, including the the regions from the northern border of the North Sea to the southern extremity of Africa. Within this lattitudinal range the spawning grounds of horse-mackerel are situated with large gaps: spawning rarely occurrs in the equatorial zone, in the most heated waters of the African shoal and between 24-32°S. Spawning is relatively weak along the borders of the spawning area, namely, or the northern Scotland shelf and along the southern extremity of Africa.

The determination of regularities in the variability of the terms and duration of horse-mackerel spawning within the area is of great importance. With this aim we have analysed the catch distribution of spawning horse-mackerel during the expeditions undertaken by the AtlantNIRO. The studies were carried out on the West-African shelf by 2°zones, by months from 1962 to 1971 (a total of 3951 specimens were analysed). Though the studies covered all the areas and seasons, the data for some months are incomplete.

Besides, we have used the AtlantNIRO data on horse-mackerel spawning in the North-East Atlantic.

The above information allows to make a preliminary review of the regularities in the variability of the horse-mackerel spawning terms within the spawning area. In the northern, as well as in the southern hemispheres the spawning is intensive approximately at the same lattitudes.

At the same time a following paradoxical regularity is observed: both in the southern and northern hemispheres

along the African coast, the maximum spawning occurs about at the same period of October - April. But this half year being a cold one northward of the equator is warm to the south of it; accordingly, the minimum spawning falls on May-October (a warm half year in the northern, and a cold one in the southern hemispheres).

The spawning of horse-mackerel is partial; it can be observed at the different depths, down to 300-350 m, however, the development of eggs and larvae takes place in the surface layers only. Therefore the investigations on the frequency of spawning horse-mackerel occurrence by depths at different surface temperatures can provide the determination of the optimum temperatures for the development (maximum occurrence) of eggs and larvae.

Recently we had demonstrated that the optimum surface temperatures for eggs and larvae development were used to change according to the variations in the mean annual surface temperature in the spawning grounds (D.Ya. Berenbein, S.M. Overko, V.A. Sedletskaya, 1973): in colder regions they were lower than in warmer ones.

For different commercial sea species (cod, herring, anchovy etc.) it is accepted that the terms and duration of spawning are also changed according to the variations in the mean annual water temperature; in colder areas the commencement of spawning is delayed till later period, and its duration is reduced, as compared with the terms and duration of spawning

in warmer conditions (D. Ya. Berenbeim, 1966, 1971). This is the raason, why at the cold water border of the spawning area (northern border of the North Sea) the duration of the horse-mackerel spawning is minimum and the spawning period falls on the warmest season, while at the warm water border (tropical regions) the spawning occurs in colder season and its duration in the optimum conditions is maximum (fig.1).

The mean annual (mean long-term) water temperature in horse-mackerel spawning grounds is calculated based on the charts of the mean monthly water temperatures given in "Hydro-meteorological Reference Book on the West African Coast" (1964) and "The Atlas of the Mean Monthly Temperature" by Tomczak and Goedecke (1962). Table 1 and fig.1 show that the spawning duration is increased with the increase in the mean water temperature to the optimum values, which provide a continuous spawning of the horse-mackerel all the year round. This can be observed in the area from Point Garnet to Port Etienne at the mean annual temperatures of 20-21°. In warmer regions of the spawning area the duration of spawning is reduced mainly as a result of spawning termination in the warmest months; the duration of spring spawning is also decreased, but a reduction in the intensity and duration of spawning in autumn is mostly marked.

To determine the commencement of spawning of horse-mackerel in the northern hemisphere, a correlation factor (regression equation and significance level) of the spawning commencement date to the mean annual water temperature for N = 14 (from the minimum mean annual water temperature to the optimum one taken as 21°) is calculated.

In the given correlation r=-0.83 (significance level - 0.001) and the regression equation is as follows:

$$D_{com} = 13.0 - 0.65\ T_m\ ,$$

where D_{com} is the spawning commencement date by months (beginning from January) and T_m is the mean long-term water temperature in the spawning grounds.

The regression equation can be applied at $9° < T_m < 21°$.

From fig.1 it is evident that horse-mackerel from the southern hemisphere is more heat-loving as compared with the same species from the northern hemisphere, since despite the similar mean annual water temperatures in the spawning grounds, it lays the eggs later, i.e. at higher water temperatures. Therefore the data on the spawning terms of horse-mackerel from the southern hemisphere were of no use in the calculation of the correlation factors, though they were plotted in the diagram (for comparison of the seasons with the six months delay).

The terms of the horse-mackerel spawning termination are less reliable, therefore, their relation to water temperature is not valid and is plotted by a broken line.

In fig.1 the highest values of the mean annual water temperature, when no spawning can be observed (the lines restricting the commencement and termination of spawning are crossed) are also seen.

This phenomenon most often occurs in August at the mean

annual (mean long-term) surface temperature of 9°.

The broken line also denotes the relation of a reduction in spawning duration to an increase in the mean long-term (mean annual) water temperature above the optimum (i.e. above 21°).

Less intensive (and prolonged) spawning in the warmest season (spawning is shifted to a cold period of year) is characteristic of the spawning of horse-mackerel at higher temperatures as compared with the optimum ones. At the optimum water temperatures the spawning practically takes place all the year round.

Table 1

The spawning terms of horse-mackerel in the East Atlantic

No.	Spawning grounds	T_m	Spawning by months											
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	North-east British Isles	9.3							±	±				
2.	Scotland, north	9.5							+					
3.	Ireland, north	9.5							+	+				
4.	Irish Sea	11.1						+						
5.	English Channel	11.7				+	+	+	+					
6.	Celtic Sea	12.1					+	+	±	±				
7.	Biscay Bay	14.4				+				+				
8.	Cape Content area	18.5		±	±									
9.	Cape Ghir	19.0	+					+				±		
10.	Ifni	19.6	+				+							
11.	Falso Cabo Bojador	20.1	+	±	+	+	+			±		+		
12.	Point Garnet	20.3	±	+	+					+	+	±	±	±
13.	Cape Dernford	20.6	±	±	+					+	+	+	±	±
14.	Port Etienne	20.9	±	+	+					+	+	±	±	±
15.	Cape Timiris	21.4	±	+	+	+								±
16.	Westward of Azamun	22.9	±	+	±	+	+							±
17.	Dakar	23.9	±		±							+		
18.	Bathurst	25.0		+	±	±				+				
19.	Massamedes	18.8	+	+	±	+							+	±
20.	Cape Frio	17.0	±	±	±	+	+				+	+	+	±
21.	Ogden Rocks	15.4	+		+	+	+							
22.	Walvis Bay	16.6	±	±	±							±	+	±
23.	Cape Town	17.6							±		+		+	
24.	Agulhas Bank	18.0									+			

Note: 1. The massive spawning is underlined by two lines.

2. The numbers of spawning grounds in the table correspond to the numbers of spawning grounds in fig.1.

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LIST OF FIGURES

Fig.1. The relation of horse-mackerel spawning terms to the mean annual water temperature in the spawning grounds.

Note: 1. The numbers of spawning grounds in the figure to the numbers of spawning grounds in table 1.

2. Weak spawning during summer months at 20-24° N is not shown in table 1 and fig.1.

• - the spawning of the northern horse-mackerel

* - the spawning of the southern horse-mackerel

△ - peak spawning

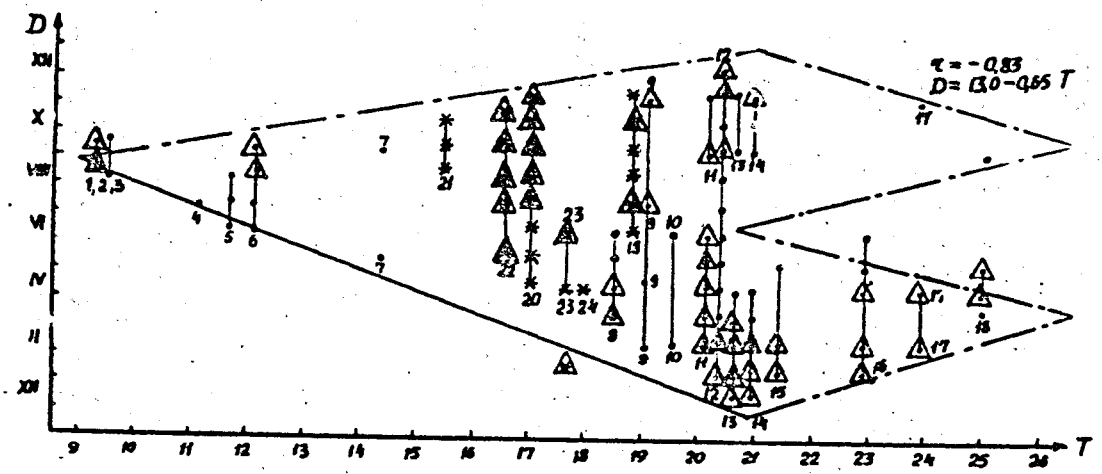

Fig.1. • spawning of the northern horse-mackerel
* spawning of the southern horse-mackerel
△△ peak spawning

Подп. в печ. IO/VII 1974 г. Зак. 856. Тир. 205