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Maurolicus muelleri Eggs in the North Atlantic

by

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Introduction

Maurolicus muelleri is one of the most abundant and widely-distributed components of mesopelagic fish fauna. It is found in the Atlantic Ocean from the northern coasts of Norway to south as far as 5°S at the western coast of Africa and in the West Atlantic from the Gulf of Maine to the Gulf of Mexico. This fish is also found in the Mediterranean and Caribbean Seas and in the Southeast and Southwest Atlantic (Grey, 1964; Muhacheva, 1981). Sanzo was the first to describe the development of M. muelleri (Sanzo, 1931). He made artificial fertilization and incubation of eggs and larvae. In the past, M. muelleri eggs were erroneously referred to Macrouridae because they are similar in morphology with inter-ovarial eggs of Macrouridae. The eggs recorded by Ehrenbaum (1905-1909) in the Atlantic ocean between the Hebrides and the Roccol Bank and in Skagerrak and reported as belonging to Macrouridae were evidently those of M. muelleri.

Lindquist also reported on M. muelleri egg distribution in Skagerrak (Lindquist, 1968), and Arbault and Boutin - in the Bay of Biscay (Arbault and Boutin, 1968). Willians and Hart (1974) recorded the eggs in the North Atlantic far beyond the shelf at the weather station "India". M. muelleri eggs were also found off the coasts of Cuba (Rass, 1973) and near the western coast of Africa in the Central East Atlantic (Blackburn, Nellen, 1976).

This paper presents information on M. muelleri egg distribution in the North Atlantic, obtained by regular and episodical ichthyoplanktonic surveys.

Material

Regular ichthyoplankton surveys were carried out in the Norwegian Sea and Northwest Atlantic in April-June from 1959 till 1982. Episodical surveys were carried out in the period of 1978-1982 in the Irminger Sea, in the area of Mid-Atlantic Ridge and to the east and west of the Ridge. In April-October, 1978-81 individual surveys were also carried out in the Central East Atlantic (Table 1).

Ichthyoplanktonic cone nets and Bogorov-Rass nets with the opening diameter of 80 cm were used in the Norwegian Sea and the Northwest Atlantic and Bongo nets with the opening diameter of 61 cm were used in other areas of the Atlantic Ocean. All the nets were made of gauze with mesh-size of 0.51 mm. Ichthyplankton was collected by total vertical and oblique hauls and fixed in 2% formalin solution prepared of sea water. Egg distribution is presented in number under 1 m^2 of sea surface. The figures were made with the projection microscope "Promar". Developmental stages suggested by T. S. Rass (1949) are used.

Results

Egg description

The eggs of M. muelleri are spherical, the membrane is covered by a thick jelly-like mass which is probably formed by chorion and consists of hexagonal concave cells, one side of which is 0.1-0.13 mm long. The cells are not always strictly hexagonal. The egg diameter, including the cellular structure, is 1.2-1.6 mm; the membrane diameter, i.e. zona radiata, is 0.80-1.20 mm; the yolk diameter at early first stage of development is 0.75-1.15 mm, the perivitelline space being very narrow. The yolk is poorly granulated, granula size is 0.20-0.22 mm. There is also an oil globule with the diameter of 0.22-0.28 mm, it is located on the vegetative pole. Figure 1 shows the M. muelleri egg at the stage of deepened blastodisc, the diameter of which varies from 0.37-0.40 mm in different eggs.

At the end of stage II the embryo is 2/3 of the periphery of the yolk, the embryo length being 1.7-1.85 mm, there are also 17 myomeres and the choroid lens rudiment, the notochord is visible; the embryo width behind the head is 0.12-0.15 mm. The perivitelline space has increased up to 0.03-0.12 mm, the yolk is of irregular rounded form, its size has reduced, the oil globule is located near the caudal end of the body (Fig. 1b).

At stage IV the embryo length is about 2.6 mm, the body fully embraces the vitellus circumference, and the caudal division in some eggs extends over the head. There are 33 myomeres, 17 of which are preanal, the anal vent is located in the middle of the body (not shown in the figure), the preanal distance comprises nearly half the total length of the body. The crystalline lens is visible in the eyes; the brain and acoustical capsule rudiment can also be distinquished, beginning from the 8th myomere the body is separated from the yolk sac surface, there is also a developed protopterigium. The yolk is ovoid-oval, the oil globule is located on the abdominal part of the yolk sac, the perivitelline space is 0.17-0.21 mm, there is no pigment (Fig. 1c).

Judging by the figure and description of a newly hatched larva 3.0 mm long given by Sanzo (Sanzo, 1931), the egg at Fig. 1c is at the "before hatching" stage. The total absence of pigment even in the eyes at this stage, poorly developed fins, large vitelli in comparison with the embryo length, the absence of jaws indicates that M. muelleri eggs do not occur near the surface or in the upper water layer but in the layers where illumination is very poor and that after hatching prelarvae are passive, non-mobile; the duration of larva endogenous feeding is rather long in comparison with the whole period of embryo development; transition to active feeding probably occurs only a few days after hatching.

Egg distribution

The material of ichthyoplanktonic surveys, carried out in the North Atlantic in different years mainly from March till November, shows that M. muelleri eggs are found in the Norwegian, North and Irminger Sea, in the area of Mid-Atlantic Ridge and to the west of it, in the region located to the west and north-west of the Irish shelf, as well as off the western coasts of Africa in the Central East Atlantic (Fig. 2, 3).

In the Norwegian Sea, most of M. muelleri eggs were found in the north, at 71°10'N and in the east as far as 19°05'E. In the period from March 22 till July 17, i.e. during the whole period of ichthyoplanktonic surveys, M. muelleri eggs were found both over the depth less than 200 m - on the Viking Bank and in the area of the Norway shallows, and over the depth more than 1000 m, but most frequently at the edge of the continental shelf or beyond it. The maximum density during all the surveys was not high - 24 eggs per 1 m^2 were once recorded on the Bank Budgrunen at 63°10'N, 53°00'W; and 12-18 eggs/m^2 were observed to the west of the Lofoten Islands near a 200-meter isobath, and at the extreme northern point over the depth of 1650 m. The eggs were found in samples taken at 100-0 and 200-0 m (Fig. 2).

In the North Sea where the survey was made in the second half of May, 1981 only in the western part of the Sea, M. muelleri eggs were found on the shelf over the depth of 100-300 m between 60°30'N and 61°10'N. The greatest abundance (20-24 eggs/m^2) was recorded in the vicinity of 61°N and 2-3°E. In other regions of the survey in the North Sea the abundance of eggs did not exceed 10 eggs/m^2, and at stations situated closer than 100 miles to the coast, the eggs were not found at all. In April-June M. muelleri eggs were found off Faroe Islands near Nolso and Fogl Banks over the depths of about 200 and exceeding 1000 m.

M. muelleri eggs were found in the Irminger Sea from May till August. The greatest abundance of 300 eggs/m^2 was recorded on June 27-29, 1982 near 53°N-35°W over the depth more than 2000 m. M. muelleri eggs were not found there at this time in 1981. 62°15'N and 33°00'W was the most northern point of M. muelleri egg occurrence in this region (Fig. 2).

In the Atlantic open areas - to the northwest of the Irish shelf between 55°50'N and 15-20°W the high abundance of eggs of 480/m^2 was observed in the end of May over great depths and the recurrent stations also resulted in the high abundance of eggs (more than 300 eggs/m^2). The maximum abundance of M. muelleri eggs of 2000 eggs/m^2, was found in the western part of the North Atlantic approximately 200 miles to the northeast of Flemish Cap over the depth exceeding 4000 m. Out of three total vertical trawls at 25-0 m, 500-0 m and 1000-0 m the maximum catch was obtained in the upper 500 m layer. Separate M. muelleri eggs were observed in the area of the Mid-Atlantic Ridge and to the northwest of the Azores from July till September (Fig. 2).

An extremely high abundance (14 thousand eggs/m^2) was recorded during ichthyoplanktonic surveys in May-June of 1978-1980 in the Central West Atlantic off the coasts of Morocco.

The maximum abundance of eggs as high as 5 thousand/m^2 was found in April-May of 1980 in the West Sahara area. In all the cases the greatest quantity of eggs in this region was at stations near a 200 m

isobath between 23°00' and 23°30'N. In this area the eggs were found in August-October, in one case M. muelleri eggs were observed far beyond the shelf over oceanic depths (Fig. 3).

Discussion

M. muelleri eggs are one of the most easily identifiable objects of ichthyoplankton. The type and size of basic structures of eggs remain relatively constant from the subarctic to tropic areas of the North Atlantic, in different regions of the World Ocean, both on the shelf and far beyond it (Table 2). Judging by the morphology of eggs and embryo they inhabit depths, where the illumination is very low and hatching occurs when embryo is not active and a considerable period of time is required (in comparison with the whole period of development) to reach the stage of formation of jaws, digestive organs and fins, required for transition to exogenous feeding. Complete absence of pigment at later stages of embryo development and early stages of larvae development and poor differentiation of organs in the prelarvae just after hatching justify to this fact. Sanzo also wrote about it (Sanzo, 1931). Spawning, embryo development and early stages of larvae growth takes place neither near the surface nor in the upper twenty-five meter layer, but at greater depths.

In the northern part of North Atlantic M. muelleri eggs were found both in the subarctic areas off Norway at 71°10'N, and in the tropical waters off Africa, on the shelf, in the coastal inlets, and far beyond the shelf (Fig. 2, 3). M. muelleri egg occurrence off Norway has been already reported. Lindquist (1968) stated that M. muelleri eggs were often distributed in the central part of the Sea. Skagerrak, where cold water upwelling occurred in summer rather than in the coastal part of the Sea. Gjosaeter (1981) referring to Gundersen (1953) and some unpublished data, reported that on the basis of M. muelleri egg distribution it is possible to assert that spawning occurred in deepwater inlets from Rifylke to Nordfjord, and off the coasts of Scandinavia from Skagerrak in the south to the Lofoten Islands in the north. Figure 2 shows that M. muelleri eggs can be found both beyond the shelf and within it over the depth less than 200 m. Arbault and Boutin also noted M. muelleri eggs over the depth of 100-200 m in the Bay of Biscay (Arbault and Boutin, 1968), and Robertson found M. muelleri eggs in the deepwater inlets off New Zealand (Robertson, 1976). Marinaro (1971) found M. muelleri eggs over the depths of 57-160 m in the Mediterranean Sea off the coasts of Algeria, Ciachomski (1971) reported on the distribution on the continental shelf and near its edge in the Southwest Atlantic. Okiyama (1971, 1981) also indicated frequent occurrence of M. muelleri eggs within or at the edge of the continental shelf and in the coastal waters of the Sea of Japan. Williams and Hart (1974) were the first to observe M. muelleri eggs beyond the shelf over the oceanic depths in the North Atlantic, though Ehrenbaum (1905-1909) referring to Hensen's descriptions (Hensen, 1887) noted that M. muelleri eggs, which he had identified as Macrouridae eggs, were found both in Skagerrak and in the open waters between the Hebrides and the Roccol Bank, Williams and Hart (1974) reported that at the weather station "India" (59°00'N-19°00'W) M. muelleri eggs were prevailing in 1971-1972. The eggs in this region first appeared in April at the depth of 300 m in the middle of May, the density of egg distribution is 5.4 eggs/m^2 at the depth 100 m. Williams and Hart

considered that the mass spawning of M. muelleri in 1971 and 1972 took place in the first part of June, when the abundance at the depth of 180-200 m was 5.0 eggs/m^2. In August, M. muelleri eggs were also found in considerable numbers.

In March 1974, Blackburn and Nellen recorded M. muelleri eggs near the edge of the shelf and beyond it in the Central East Atlantic at 21°40'N-17°30'W (Blackburn and Nellen, 1976).

Based on the analysis of the maps of M. muelleri egg distribution in the North Atlantic, the conclusion can be drawn that M. muelleri eggs occur almost everywhere excluding the shelf areas in the Northwest Atlantic, where not a single egg was found during many years and the arctic waters of the Barents and Greenland Seas.

The material available does not allow to reveal the vertical distribution pattern of M. muelleri eggs which can be considered therefore, based on literature data only. Williams and Hart (1974) pointed out that M. muelleri eggs were found at the depths of 100-400 with the maximum abundance over the depth of 180-200 m, Robertson gives approximately similar depths of M. muelleri egg distribution (Robertson, 1976) in the New Zealand area. Figure 7 shows that M. muelleri eggs were recorded at the depth of 100-500 m, with the greatest abundance of all the stages over the depths of 250-500 m. Robertson (1980) considers that M. muelleri spawn in the ocean beyond the shelf. Nishimura (1957) shows that M. muelleri eggs occur at the depth of 50-60 m in the Japan Sea, and Okiyama (1971) points out that M. muelleri eggs are also found near the surface (Fig. 16 of the paper). Proceeding from the egg distribution Williams and Hart (1974) consider M. muelleri to spawn in the North Atlantic from April till September at the temperature of 8.8°-10°, Robertson (1976) reports on a wider range of temperatures of M. muelleri spawning in New Zealand - 9.0°-15°, and Ciachomski (1971) indicates 10°-16° for the Southwest Atlantic. Assuming that M. muelleri eggs were distributed at the depth of 50-500 m, we can conclude that in the North Atlantic M. muelleri spawning occurs at the temperature of 5°-15.5° and salinity of 33-36‰ (Table 3). The season of M. muelleri spawning is rather long: the eggs are found in the period from February till September in the North Atlantic and till November in the South Atlantic (Table 3). Okiyama (1981) reports that in the Japan Sea M. muelleri spawn all the year round, excluding the most cold months, and consider the fish reproduction to be closely connected with the Tsushima current. Yuki (1982) states that the spawning takes place all the year round and has peaks in March-May and September-November. Gjosaeter (1981) concludes on the basis of studying the gonads that the spawning lasts from March till October in the Norwegian Sea, and according to Ciachomski (1971) in the Southwest Atlantic M. muelleri spawning is prolongated; Robertson came to similar conclusion (Robertson, 1976). Despite an apparent evidence of a long spawning period, it is very unlikely that M. muelleri spawn all the year round in all areas of the North Atlantic; in such areas of the North Atlantic as the Norwegian and Irminger Seas the spawning period is much shorter than in the southern areas, for instance in the Mediterranean Sea and in the Central East Atlantic. In the North Atlantic, the spawning grounds of M. muelleri are located in the areas of warm currents such as the Gulf Stream, North Atlantic, Irminger, and in the Southern areas near the western coasts of Africa in the

region of the cold currents such as Canary Current.

The greatest number of eggs was found in the Irminger Sea, in the area to the northeast of Flemish-Cap and to the west and northwest of the Irish shelf, as well as in the Central East Atlantic, these areas can be considered as the regions of the most intensive spawning of M. muelleri.

Conclusions

1. The peculiarities of morphogenesis and structure of M. muelleri eggs and larvae justify to the fact that spawning and early development takes place at the depth not less than 50 m.
2. M. muelleri eggs are widely-distributed in the North Atlantic from the subarctic regions of the Norwegian Sea to the tropical waters of Central East Atlantic.
3. The spawning period occupies March-May in the North Atlantic, and February-November in the southern areas of the North Atlantic.
4. Most intensive spawning occurs in the region to the northeast of Flemish Cap, to the west and northwest of the Irish shelf, in the Irminger Sea and in the Central East Atlantic.

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Table 1. Maurolicus muelleri eggs in ichthyoplankton samples from the North Atlantic.

Region	The period of studies	Fulfilled stations	Number of stations where M.muelleri eggs were found	Notes
Norweigian Sea	1959-1980	5033	33	
North Sea	1981	545	67	
Near the Faroe Islands	1968-1976	540	36	
Northwest Atlantic	1959-1980	6600	2	2 stations were beyond the shelf, approximately 200 miles from Flemish-Cap.
North Atlantic to the west and north-west of the Irish Shelf	1981	50	20	
Irminger Sea	1981-1982	130	6	
Mid-Atlantic Ridge	1981-1982	40	3	
Central-East Atlantic	1978-1982	800	200	approximately

Table 2. Maurolicus muelleri egg size in different areas of the World Ocean.

Area	Egg diameter	Egg membrane diameter	Oil globule diameter	Authors
Norwegian Sea	1.20-1.60	0.80-1.20	0.22-0.28	our data
North Sea	1.20-1.60	0.80-1.20	0.21-0.29	our data
Irminger Sea	1.20-1.60	0.80-1.20	0.22-0.29	our data
Skagerrak	1.47	0.97	0.25	Ehrenbaum, 1905-1909
North Atlantic	1,30-1,50	0,90-1,00	0,22-0.28	our data
Central East Atlantic	1.30-1.53		0.24-0.28	our data
Bay of Biscay	1.32-1.52		0.26-0.28	Arbault et Boutin, 1968
Mediterranian sea:				
Messina Strait	1.32-1.58	0.92-1.00	0.26-0.28	Sanzo, 1931
Off Algeria	1.30-1.40	0.95-1.00	0.24-0.25	Marinaro, 1971
South West Atlantic	1.88-2.02	1.0-1.20	0.25-0.27	Ciachomski, 1971
Japan Sea	1.29-1.89	0.87-1.17	0.22-0.28	Okiyama, 1971
New Zealand	1.55-2.05	0.96-1.07	0.25	Robertson, 1976

Table 3. The conditions of Maurolicus muelleri spawning in the North Atlantic.

Region	Depth over which the eggs are found m	Season months	Temperature in the layer	Salinity at 50 to 500 m	Authors
Norwegian Sea	more than 1000	IV-VI	5-7°	33-35‰	our data
	less than 200		5-7°	- "-	Gjosaeter
	less than 100		-"-	32-35‰	1981
North Sea	150-200 m	V-VI	7-8°	35‰	our data
Skagerrak	near 100 m	V-VI	nearly 10°		Lindquist, 1968
North Atlantic: to the west-north-west of the Irish shelf	more than 2000 m	V-VI	8-10°	35‰	our data
To the north-east of Flemish Cap	more than 2000 m	V	6-8°	35‰	our data
Mid-Atlantic Ridge	more than 2000 m	IX	10-14°	35‰	our data
Bay of Biscay	100-200 m	II-V	10-14°	nearly 35%	Arbault et Boutin, 1968
Area between the Rockall and Hebrides Banks		IV-VI	8-12°	35‰	Ehrenbaum, 1904-1909
Mediterranean Sea	57-160	I-IY	13-15°		Marinaro, 1971
Central-East Atlantic	less than 200	III-XI	15-16°	36%	Blackburn & Nellen, 1976
	more than 1000				our data

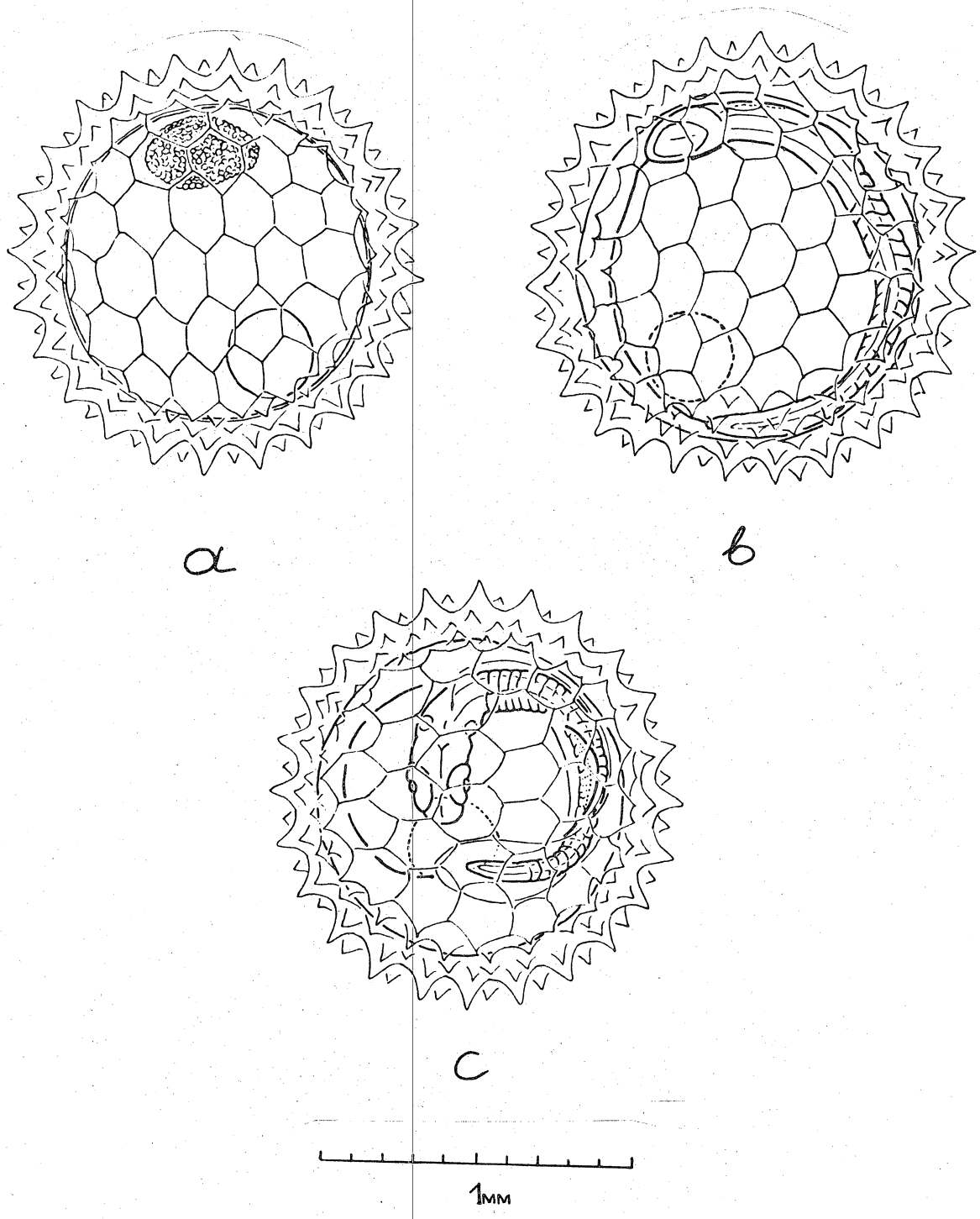

Fig. 1. Maurolicus muelleri eggs: a = Stage I, b = the end of Stage II, c = Stage IV.

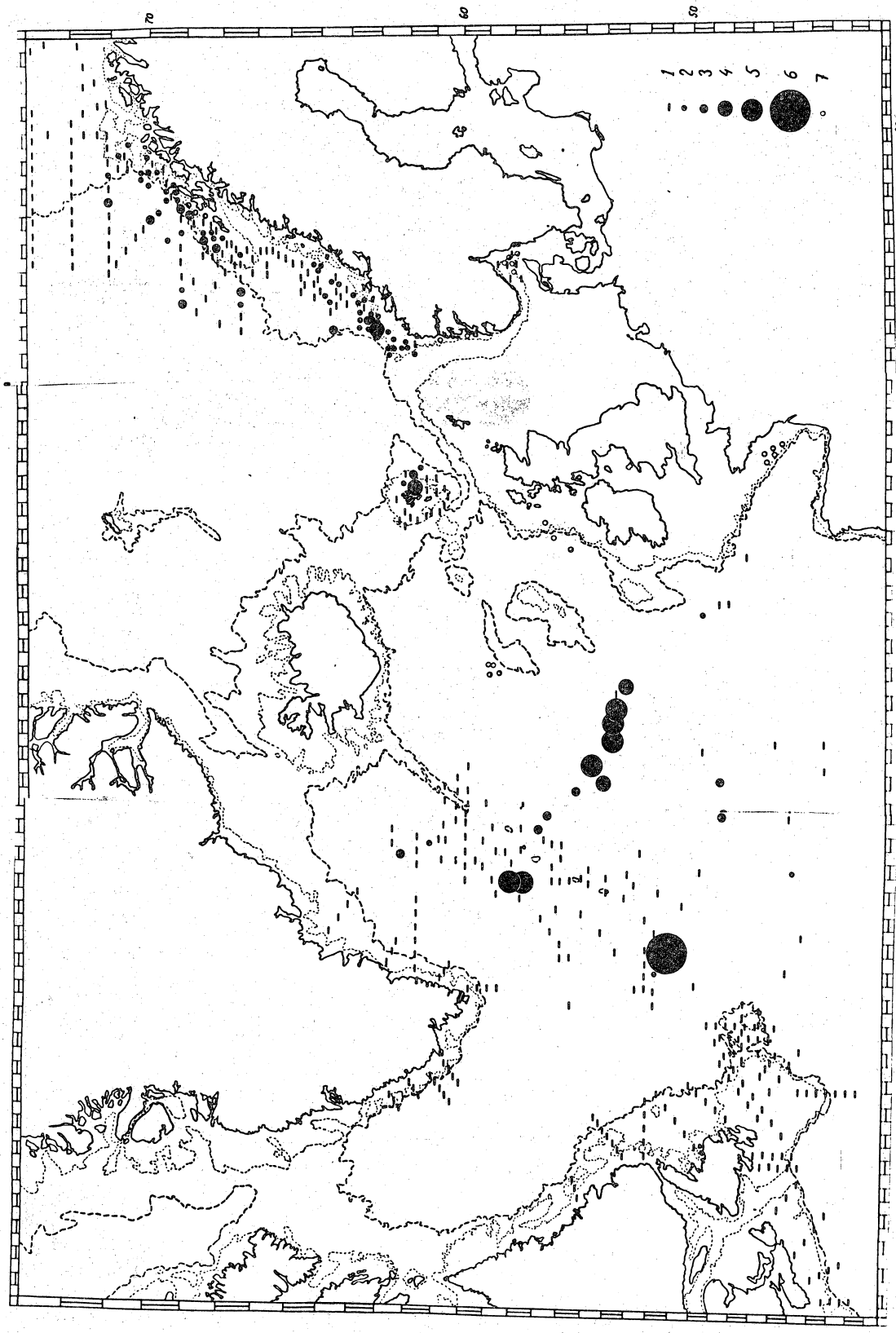

Fig. 2. Maurolicus muelleri egg distribution in the North Atlantic: 1 = stations where the eggs were not found; 2 = 1-5 eggs per m^2; 3 = 6-20 eggs/m^2; 4 = 21-100 eggs/m^2; 5 = 101-1000 eggs/m^2; 6 = more than 1000 eggs/m^2; 7 = Maurolicus muelleri egg distribution according to Ehrenbaum (1905-1909), Lindquist (1968), Arbault et Boutin (1968), Williams and Hart (1974). (The map shows 200 and 1000 m isobaths.

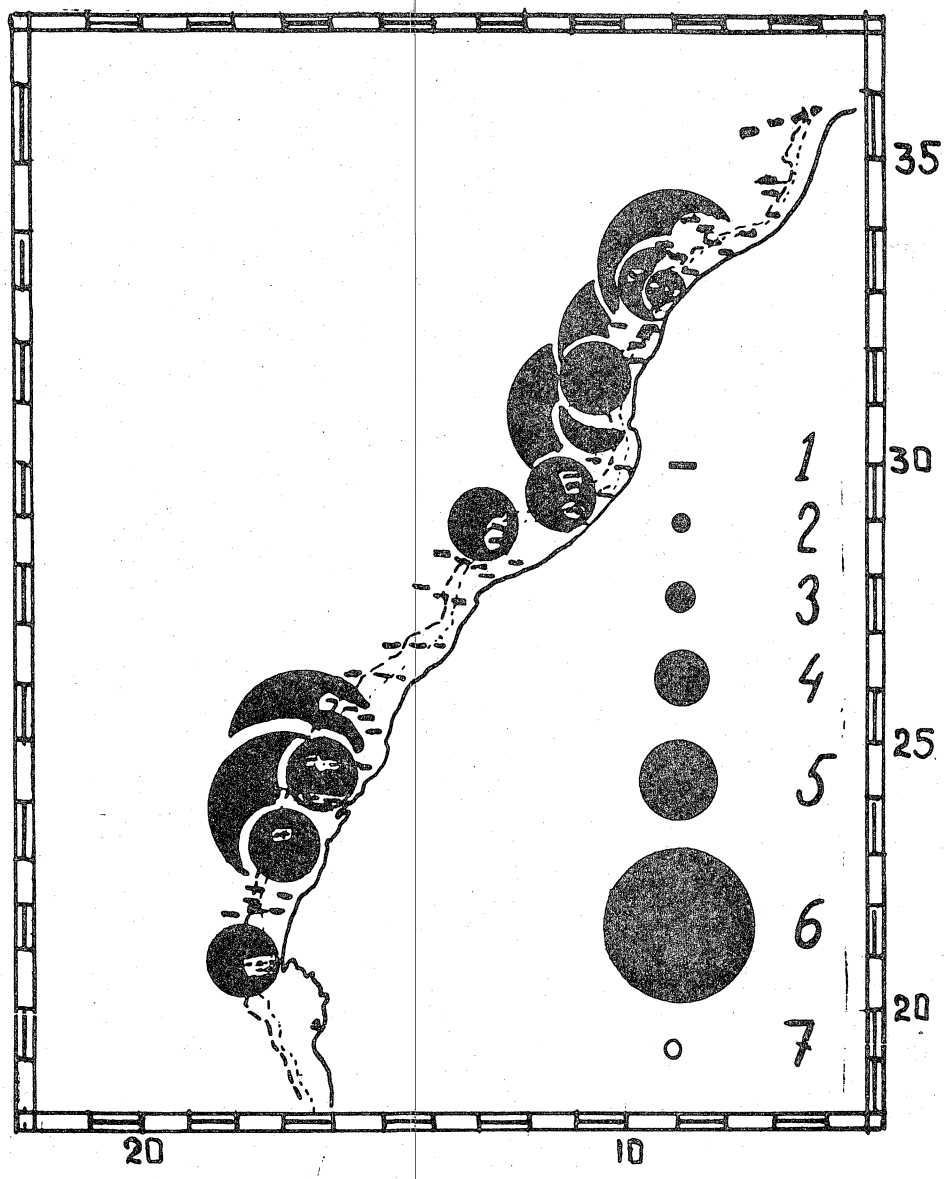

Fig. 3. Maurolicus muelleri egg distribution in the Central East Atlantic. (Legend is the same as in Figure 2.)