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Redfish spawning grounds in the Barents Sea and adjacent waters

by

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ABSTRACT

Grounds and periods of redfish spawning as well as factors influencing it were specified by data of ichthyoplankton surveys, conducted in the north-eastern Norwegian Sea and south-western Barents Sea in April-July 1959-1990, and by data of distribution of both Sebastes marinus and Sebastes mentella spawning females in March-June, 1959-90.

It was revealed that the mass spawning of redfish takes place in spring/summer: S. mentella - in April/May and S. marinus - from the end of April to June. The main area of larvae extrusion of S. mentella is the Kopytov Bank and that of S. marinus is the Lofoten Shallows. The general feature for all spawning areas is that they are located along the warm streams of the Eastern Branch of the Norwegian Current.

S. mentella larvae are mainly concentrated in the 0-50 m layer and S. marinus larvae - in the 0-25 m layer. The biggest number of larvae are noted in the areas: for S. mentella - with temperature of 5°C and more and for S. marinus - 6-7°C. There is a direct dependence between the larvae abundance and water temperature.

INTRODUCTION

There are three species of redfish dwelling in the North-Eastern Atlantic and differring from each other by several morphological features and modes of life: Sebastes mentella Trawin, Sebastes marinus L. and Sebastes viviparus Krøner (Travin, 1960). Redfish species from Sebastes genus are related to viviparous fish. Their spawning grounds can be determined by occurring spawning females or just extruded larvae.

Information on geographical distribution of redfish at early stages of development nearby the Northern Norway coast and along the continental slope has appeared in the end of the previous century and was firstly presented in Corlett works (Anon., 1944). Ganevig (1919) was engaged in this problem a little bit later. Both authors just stated about the larvae of 7-10 mm presence in plankton. Beginning from 1934, the Polar Institute collects and analyses data on biology of marine redfish including the spawning period and early stages of development (Veschezerov, 1944; Maslov, 1944; Baranenkova et al., 1970; Mukhina, 1983; Mukhina et al., 1986). Redfish reproduct themselves mainly outside the Barents Sea. Prespawning female concentrations of S. marinus were detected not far from the Lofoten Islands in the area limited by 71°N in the north (Baranenkova et al., 1956; Wiborg, 1958) and those of S. mentella - in the Kopytov area (Sorokin, 1956, 1960; Sorkin, 1961; Borodatov et al., 1960; Corlett, 1961). The question of redfish larvae extrusion sites can not be considered as solved since larvae often occure in the areas where adult specimens were not detected. Besides, grounds and periods of redfish spawning coincides in some areas. Identification of larvae is difficult because of the absence of expressed species features.

At present, relatively reliable species feature of redfish at the early onthogenesis is the length of an embrio extruded from an egg in a female ovary not long before the extrusion (the inlarva stage of development). The length of S. marinus embrio is 6-8 mm, that of S. mentella is 7-9 mm and of S. viviparus is 4-5 mm (Barsukov et al., 1984; Power, 1985). Due to our observations, the portion of S. viviparus larvae (4-5 mm long) does not exceed 3-3% in

average during the years of investigations, since materials only on S. mentella and S. marinus are presented.

The aim of the paper is to summerize long-term data on distribution of marine redfish species at early stages of development, specifying their spawning grounds and revealing the environment factors influencing them.

MATERIAL AND METHODS

Materials of ichthyoplankton surveys conducted in the north-eastern Norwegian Sea and south-western Barents Sea in April/July, 1959-90 are presented. Collection and processing of materials were done by the standard methods accepted in PINRO (Baranenkova, 1961). Larvae length at the moment of extrusion corresponds to that at the inlarva stage. Lengths at the inlarva stage both in S. mentella and S. marinus are similar, since the initial length of extruded larvae is accepted as minimum length of each species which is 6-7 mm. The spawning grounds were determined by distributional density of larvae 6-7 mm long in April/May and June/July, 1959-1990 and of spawning females of both S. mentella and S. marinus with gonads at VIII stage of maturity in March/June. To specify periods of larvae extrusion, data of SEB PINRO Laboratory of Ground Fish on maturity of redfish females on the spawning grounds in January/July, 1976-1986 are presented. The mean number of larvae per 1 catch by the IKS-80 net was accepted as their abundance factor, and the logarithm of the latter was used during mathematical calculations.

Mean water temperatures of the Eastern Branch of the Norwegian Current in the 0-50, 0-200, 0-500 and 200-500 m layers (10-C and 1 sections) in April/May and of the Main Branch of the North Cape Current in the 0-50 and 0-200 m layers (2-A section) in June, as well as the long-term water temperature in the 0-50 m layer in April/July in the area covered by the ichthyoplankton survey, were accepted as indices of water thermal status in the spawning grounds

Long-term series of observations allowed to use the linear correlation method and to evaluate the density of relation between larvae abundance and water temperature.

DISCUSSION

Long-term observations have shown that spawning grounds and periods of both S. mentella and S. marinus dwelling in the Barents Sea are mainly different. Spawning areas of every species are quite wide.

Sebastes mentella. Spawning or running females occur in the areas along the continental slope to the Bear Bank, and eastwards along the Norwegian coast to the Finnmarken Bank. Mass female concentrations are observed on the Kopytov Bank over the 500 -m depth, usually (Fig. 1A). Upto 77% of mature females total number in the Barents Sea are concentrated in this area (Fig. 2). The spawning dynamics on the wide area has its peculiarities. It was revealed during the comparison of running females by months and areas that in March in the area from the Røst to Søre Banks the females ready for larvae extrusion constitutes 63%, in the area of the Kopytov Bank - 17%, and the Bear Bank ground - 5% (Fig. 3A). In April, the mass spawning is observed on the Kopytov Bank, the portion of the running females constitutes 73%, nearby the Norwegian coast - 36% and on the Bear Bank - 62% (Fig. 3B). In May, the abundance of running females reduces sharply: there is not more than 1% nearby the Norwegian coast, 11% in the Kopytov area and 31% in the Bear area; in June, the running females were presented as single specimens (2 spec.) on the Fugløya and Bear Banks only (Fig. 3CD). The main number of running females are caught in March/April (Table 2). Thus, the mass spawning of S. mentella begins in the areas nearby the Norwegian coast and moves gradually to the north.

Analysis of maps of 6-7 mm larvae distribution in April/May and S. mentella spawning females has shown the similarity of their geographical location, therefore larvae caught at this time can be related to S. mentella (Figs. 1A and 4A). At this, a peculiarity was noted: larvae area in relation to the area of spawning females occupies the western location over 500 m depths predominantly. This peciliarity is connected with the surface layers dynamics in the area and will be discussed further.

Thus, mass spawning of S. mentella in the north-eastern Norwegian Sea and adjacent parts of the Barents Sea takes place in spring. It begins in March nearby the northern coast of Norway with peak in April in the Kopytov area and ends in May on the Bear Bank. The main area of larvae extrusion is the Kopytov Bank.

S. marinus. The area of S. marinus larvae extrusion is rather large in the North Atlantic. They spawn mainly in May/July (Henderson et al., 1964). Using temperature curves, Taning (1949) outlined the possible boundaries of larvae extrusion sites off shore in the Norwegian Sea in the area of the Faroe Isls, Scotland and Norwegian coast. Wiborg (1959) has proved this suggestion by revealing 6-7 mm larvae in the Norwegian and Lofoten Shallows between 66°- 70°30'N and 02-13°E in the end of May.

According to our data, S.marinus females in the pre-spawning period occur in the areas northwards from the Halten Bank along the coast of Norway to central areas of the Kopytov Bank and northwards and north-eastwards to the Demidov Bank and Western Coastal Area. The main area of mature female concentrations is the Lofoten Shallows (from Traena to Malang Banks) with depths of 100-250 m, close continental shelf and active dynamical processes in water layers (Fig. 1B). In this area, the portion of mature females constitutes 93% of all mature females by all areas (Fig. 2) in the Lofoten Shallows. Mass spawning begins in the end of April. Running females constitute there 63% (Fig. 5A). There are no data on female maturity in May, therefore we can only suggest that the intensity of spawning in this month is similar to that of April. In June, S. marinus spawning continues in the northern areas of the spawning ground, and running females on the Kopytov Bank constitute 31% (Fig. 5B). Succession of larvae extrusion by areas is also observed in S. marinus as well. The spawning period of this species is prolonged to compare with S. mentella. Data for January/July show that females with gonads at IX mature stage occur in large number (upto 32%) still in June (Table 3).

The comparison of areas of 6-7 mm larvae in June-July and spawning females of S. marinus has shown their coincidence (Fig. 1B and 4B). The main number of larvae was caught on the coastal banks, but because of the currents system, their major number

was caught in deep off shore areas.

Thus, in the north-eastern part of the Norwegian Sea and adjacent areas of the Barents Sea, spring/summer mass spawning of S. marinus takes place in the end of April/May on the Lofoten Shallows and in June - on the Kopytov Bank. To compare with S. mentella, the spawning period of S. marinus is more prolonged. That is why 6-7 mm larvae caught in June/July in the area of the northern coast of Norway belong mainly to S. marinus.

It is seen from the comparison of areas and periods of spawning of redfish as well as 6-7 mm larvae distributions that they coincide on the Malangen Bank and adjacent areas. Therefore, females both of S. marinus and S. mentella can spawn there simultaneously, and it practically is impossible to determine to which species larvae from the "mixed" area belong.

It is known that the North Atlantic redfish spawn nearby the continental shelf edge, along warm currents, in the areas with active dynamics of water (Maslov, 1944; Veschezerov, 1944; Taning, 1949).

Long-term observations of redfish distributions at early stages of ontogenesis in the Norwegian Sea and adjacent waters of the Barents Sea have shown that larvae area does not change practically. Large amount of larvae (more than 50%) is caught after extrusion over depths of more than 500 m (Fig. 4, table 1).

In addition to the wide horizontal distribution, there are areas within the spawning ground where larvae concentrate: the Kopytov and Malangen Banks in spring and banks of the Lofoten Shallows in summer (Fig. 4). Peculiarities of larvae distribution can be explained by the fact that both S. marinus and S. mentella extrude larvae in warm waters of the Eastern Branch of the Norwegian Current, by the unequalness of pre-spawning female distributions on the spawning grounds and by the nearness of the continental slope to the larvae extrusion areas. In latters, especially on spawning grounds close to Lofoten, there is a system of vortices and various floods with different speeds (Tantsyura, 1959) because of the complex bottom relief, rich run off of the land waters and advection processes. Speed in the upper layer (0-10 m)

of the Lofoten shallow waters constitutes 14-22 cm/s and on the Kopytov Bank - 9-12 cm/s. This results in formation of anticyclonic vortices in which organisms at the pelagic stage of development appear (Mukhina et al., 1987; Kovtsova et al., 1989).

Geographical location of spawning grounds and dynamical processes of waters influence not only on the spatial but on the vertical larvae distribution which are caught in the Norwegian Sea in the 0-200 m layer. At that, the main part of larvae (upto 75%) concentrate in the 25-100 m layer. Length compositions of larvae caught over large and small depths are identical (Hansen et al., 1959; Dietrich et al., 1961). According to our data, the vertical distributions of similar length larvae of S. marinus and S. mentella are different. In April/May, S. mentella larvae of 6-7 mm are predominantly in the 0-50 m layer at temperature of 4.9-5.5°C. In June/July, S. marinus larvae are in the 0-25 m layer at temperature of 6.5-7.8°C (Table 4).

Larvae abundance analysis in the 0-25 and 0-50 m layers has shown that the water density does not influence their vertical distribution. Because of depths being smaller and flood speeds and temperatures being higher, S. marinus larvae on the spawning grounds inertially in water layers higher than S. mentella larvae.

Apparently both the horizontal and vertical distributions of redfish larvae are mainly determined by the nearness of the spawning grounds to the continental shelf and by the water dynamics of the Eastern Branch of the Norwegian Current.

In the North Atlantic in the Sebastes reproduction sites, the main larvae concentrations are observed in the upper layers at temperature of 5-6°C for S. mentella and 6-7°C for S. marinus (Zakharov, 1969; Magnusson, 1962; Herra, 1989). In the Norwegian and adjacent waters of the Barents Sea this tendency in the biology of redfish at early period of life remains. In April/May, the main number of 6-7 mm larvae is caught at 5°C and higher and in June/July - at 6-7°C. It is important to note that spawning females of both species distribute at the same temperatures (Fig. 1 and 4). To evaluate quantitatively relations

between water temperatures on the spawning grounds and abundance of redfish at the larval stage of ontogenesis, hydrological sections were chosen: in April/May, those which limit the main areas of S. mentella extrusion from the north (10-C) and south (1); and in June/July, 2-A section adjoining to the northern border of S. marinus area (Mukhina, in press).

In April/May, the density of relation between the abundance of 6-7 mm larvae and water temperature in the spawning grounds (10-C section, 0-50, 0-200 and 0-500 m layers; section 1, 0-50 and 0-200 m layers) is expressed by the correlation coefficients $r = 0.78$, $r = 0.73$, $r = 0.69$, $r = 0.68$, $r = 0.67$ at $n = 22$ and $P = 0.05$, correspondingly; in June/July, correlation coefficients for section 2-A, 0-50 and 200 m layers are equal to 0.65 and 0.63 at $n = 22$ and $P = 0.05$, correspondingly.

Values of these dependences show that there is a direct connection between extruded larvae abundance and water temperature on spawning grounds.

It is known from literature that during spawning, redfish females dwell at various depths, namely, S. mentella - at 300-400 m depth and S. marinus - at 140-270 m (Andriyashev, 1954).

In addition, our working results prove it and determine more accurately the depth lower which redfish females do not extrude larvae. Temperatures of 5°C are distributed down to 250-300 m depths in the Kopytov area in April/May and 6-7°C - to 100-200 m in the Lofoten Shallows in June/July. It means that S. mentella females can extrude larvae in the depth not more than 300 m and S. marinus - not more than 200 m.

CONCLUSIONS

1. Redfish dwelling in the Barents Sea spawn mainly out of it.

2. Mass spawning of redfish takes place in spring/summer: S. mentella - in April/May and S. marinus - from the end of April to June.

3. The main area of S. mentella larvae extrusion is the Kopytov Bank and that of S. marinus is the Lofoten Shallows. The Malangen Bank and its adjacent parts are "mixed" spawning grounds of both species. The general feature for all spawning grounds is that they are located along warm floods of the Eastern Branch of the Norwegian Current.

4. Geographical position of spawning grounds , namely, nearness of continental slope, and high water speeds in the Eastern Branch of the Norwegian Current influence the spatial and vertical distribution of redfish larvae. Large amount of larvae occur in the off shore areas immediately after extrusion where depths are more than 500 m (50%). S. mentella larvae are mainly concentrated in the 0-50 m layer and those of S. marinus - in the 0-25 m layer.

5. Larvae concentrations of the youngest length groups (6-7 mm) are observed in the areas with 5°C and higher for S. mentella and 6-7°C - for S. marinus. There is a direct dependence between 6-7 mm larvae abundance and water temperatures on the spawning grounds. The relation value is expressed by the correlation coefficients: they are 0.78-0.67 for S. mentella and 0.65-0.63 for S. marinus at $n = 22$ and $P = 0.05$.

6. S. mentella females can extrude larvae in the depths not more than 300 m and S. marinus - 200 m.

Table I

Number of redfish larvae caught over various depths of the Barents and Norwegian Seas in April-July 1980-85

Depth	:101-:200	:201-:300	:301-:500	:501-:1000	:1001-:1500	:1501-:2000	2001-2500	:2501-:3000	3000
No. of larvae	5099	1260	413	1492	1138	1181	303	2464	847
%	35,9	8,9	2,9	10,5	8,0	8,3	2,1	17,4	6,0

Table 2

Percentage of mature females of S. mentella in the Norwegian and Barents Seas by data from research vessels in 1976-1986

Month	Stage of maturity					
	y	yI	yII	yIII	IX	IX-II
January	I9,4	2,5	-	-	-	3,3
February	44,6	22,6	4,5	2,8	-	7,6
March	27,7	53,5	52,5	27,3	6,2	I0,7
April	8,I	20,6	40,6	6I,7	67,8	28,9
May	0,I	0,6	2,3	7,8	I8,7	II,I
June	-	0,04	0,04	0,4	7,I	38,4
Total number of females	2440	2442	2454	I748	560	I607

Table 3

Percentage of mature females of S. marinus in the Norwegian and Barents Seas by data from research vessels in 1976-1986

Month	Stage of maturity					
	y	yI	yII	yIII	IX	IX-II
January	I,4	-	-	-	-	0,7
February	2I,2	3,7	-	-	-	I,7
March	36,6	24,7	5,5	0,3	2,8	I0,4
April	40,5	70,6	90,0	47,4	57,7	44,9
May	-	0,6	2,3	6,3	7,8	7,4
June	0,2	0,4	I,5	46,0	3I,7	27,7
July	-	-	-	-	-	7,I
Total number of females	9I8	II80	603	665	I04	296

Table 4

Vertical distribution of 6-7 mm redfish larvae in 1971, 1975 and 1981

Areas	April/May			June/July		
	0	25 m	50	0	25	50
Malangen Bank	22	26	695	27	235	4
Vesteraalen Bank	5	19	166	141	654	24
Røst Bank	I	8	38	273	235	-
Andøy Bank	I01	I47	431	4	255	6
Fugløya Bank	6	3	84	105	I32	1
Kopytov area (down to 500 m)	3	25	292	2	146	3
Søre Bank	-	-	-	1	4	-
Norwegian Deep	-	-	3	60	I26	-
Nordkyn Bank	-	I	2	-	2	-
Offshore areas (depths 500 m)	I5I	279	13I2	I2	580	11
Southern slope of Bear Bank	-	-	I	-	13	I
Western Slope of Bear Bank	-	-	-	-	1	-
No. of spec.	286	508	3024	625	2383	50

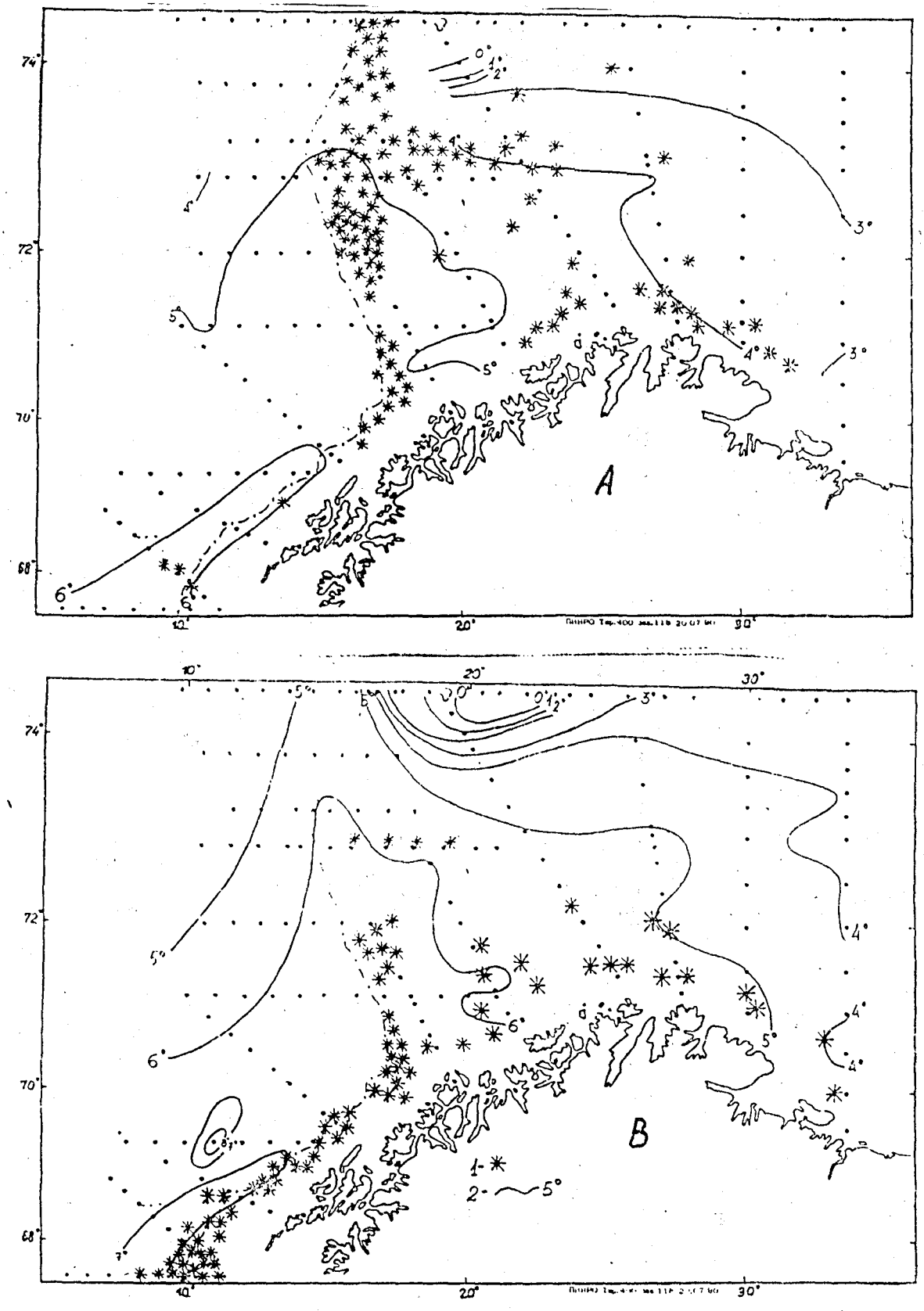

Fig.1. Females distribution of S.mentella in March-May and water temperature distribution in April-May (A); females distribution of S.marinus in March-June and water temperature distribution in June-July (B) :

1 - females with gonads at VIII stage of maturity,
2 - isotherm in 0-50 m layer, °C

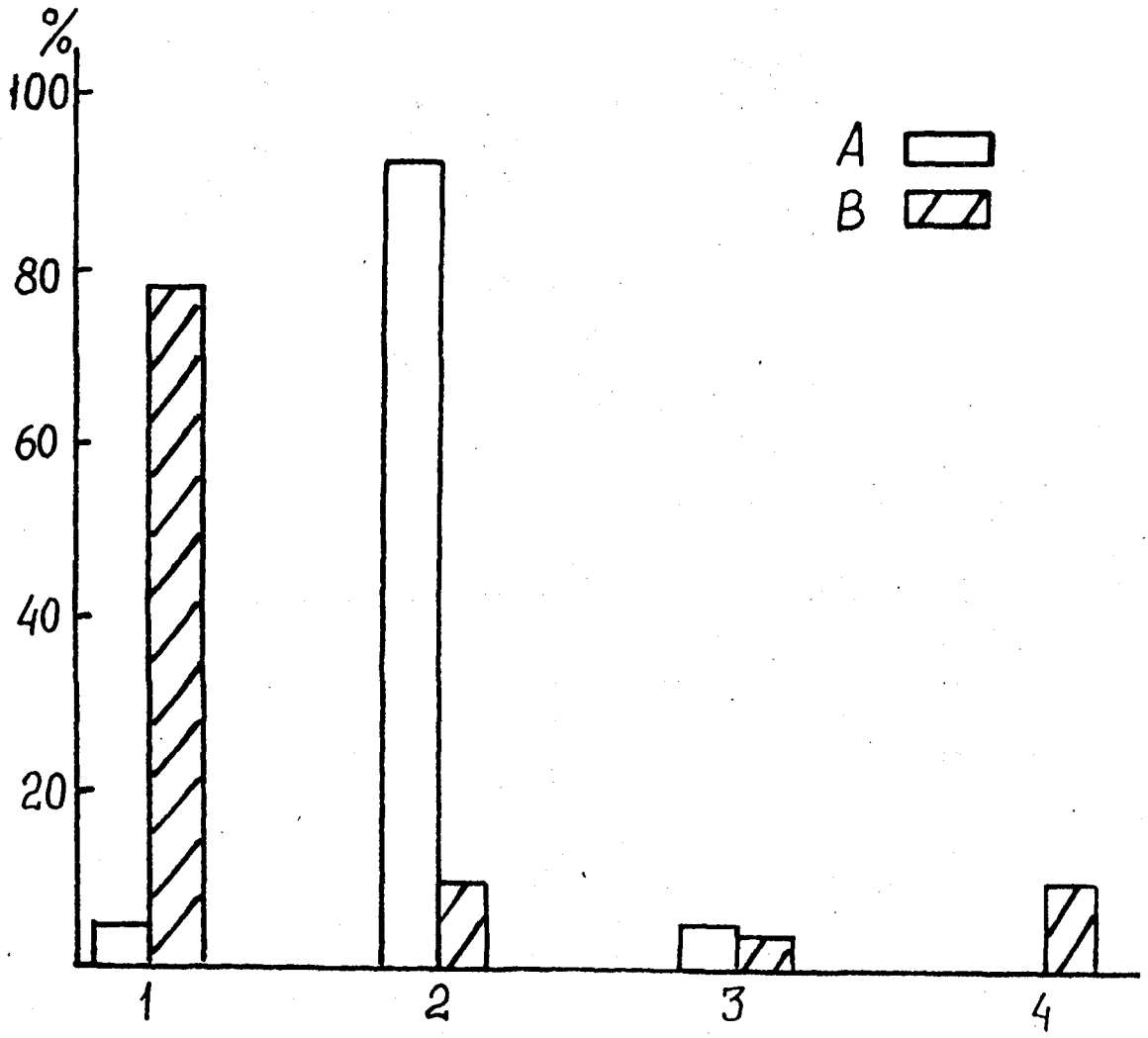

Fig.2. Percentage of mature females of S.mentella (A) and S.marinus (B) by areas in 1976-1986:

I - Kopytov Bank; 2 - Northern coast of Norway (Halten, Traena, Rǿst, Vesteraalen, Andøy, Malangen, Søre, Fugløya banks); 3 - Norwegian Deep, Nordkyn, Demidov, Finnmarken and Kildin bamks; the Western Coastal Area; 4 - Western and Southern slopes of the Bear Bank, Western Deep, Western Spitsbergen

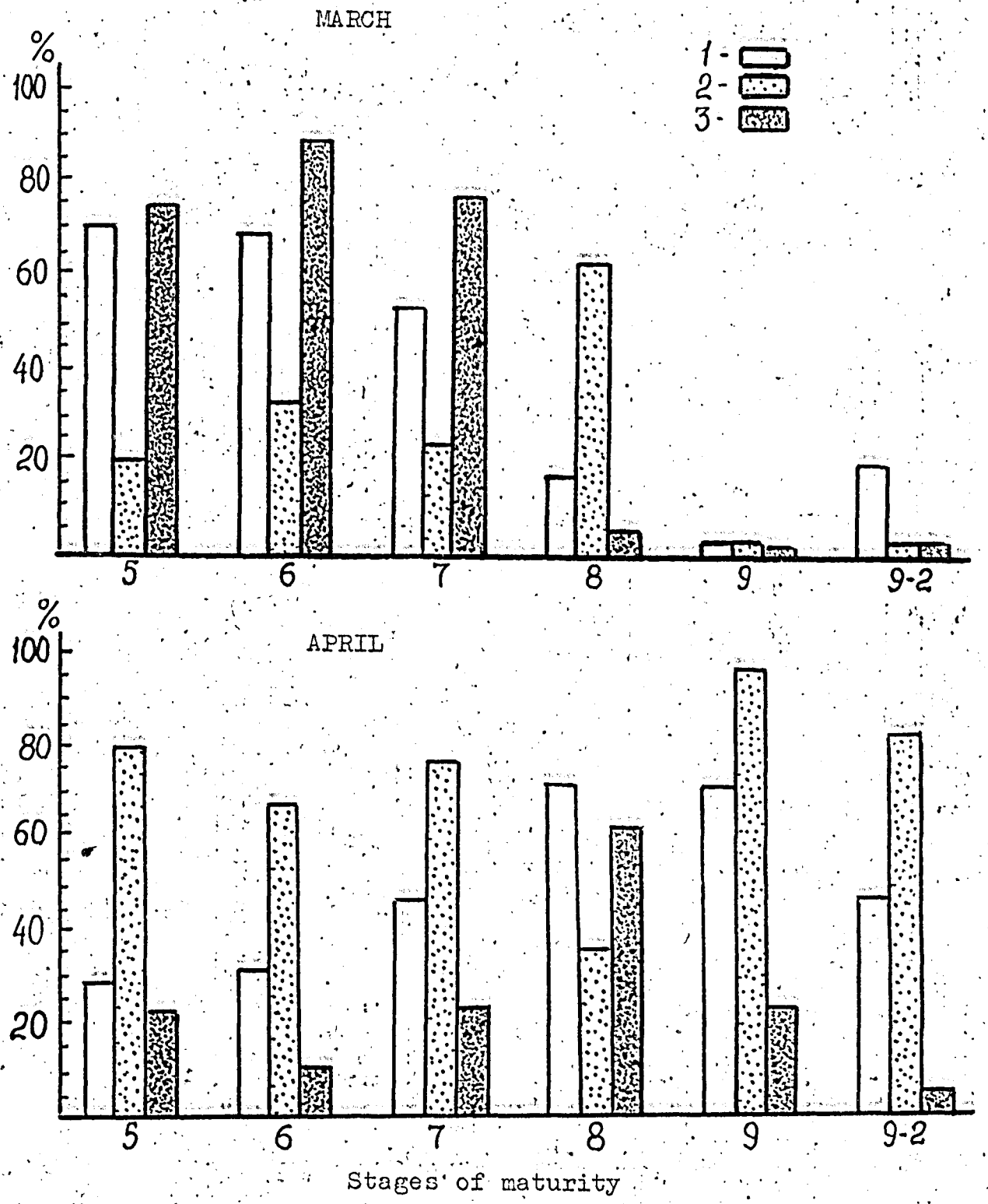

Fig.3. Dynamics of females maturity of S.mentella in March, April, May and June 1971 and 1976-1986 in the spawning grounds:

1 - Kopytov bank; 2 - Northern coast of Norway; 3 - Bear bank

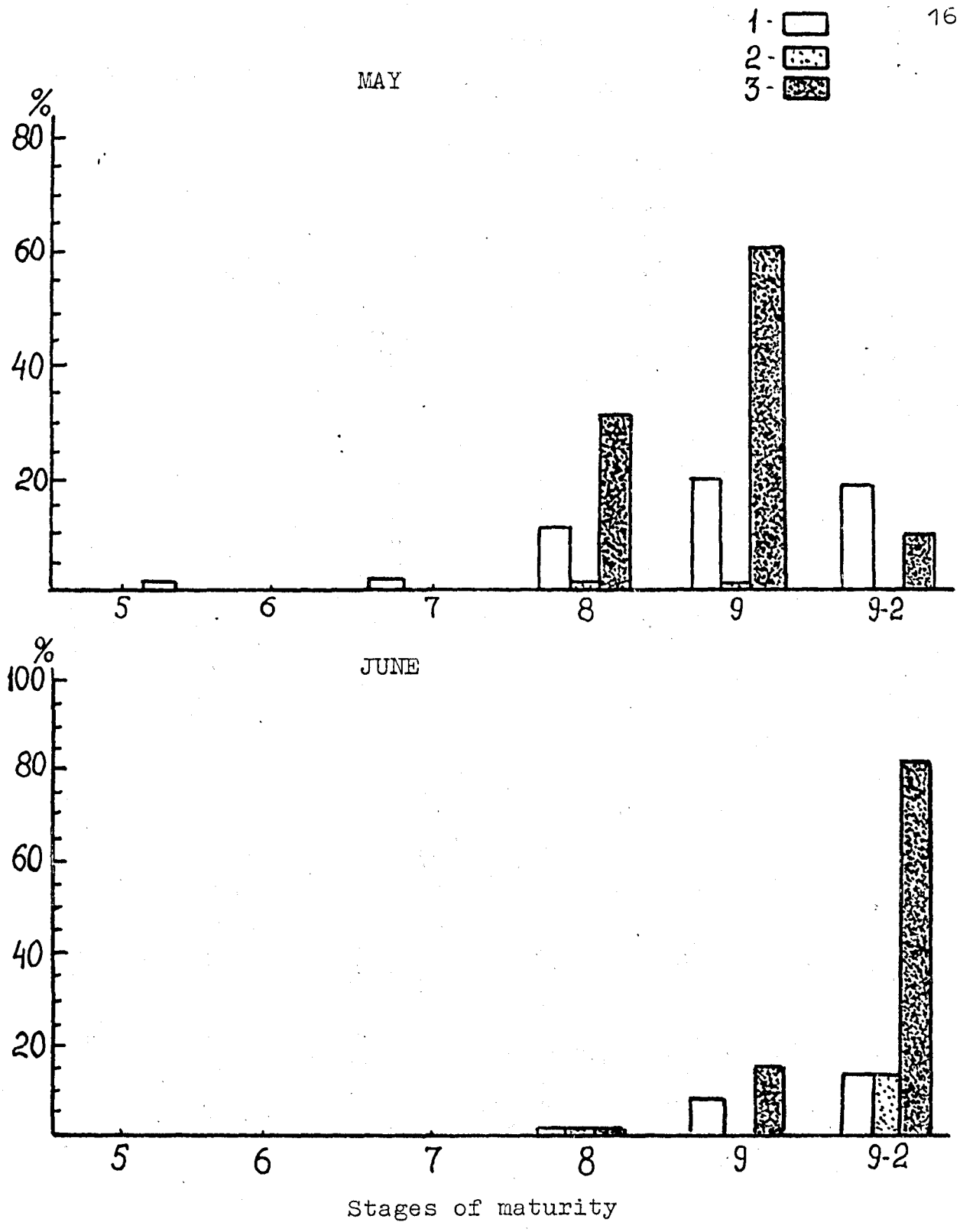

Fig.3 (contunued)

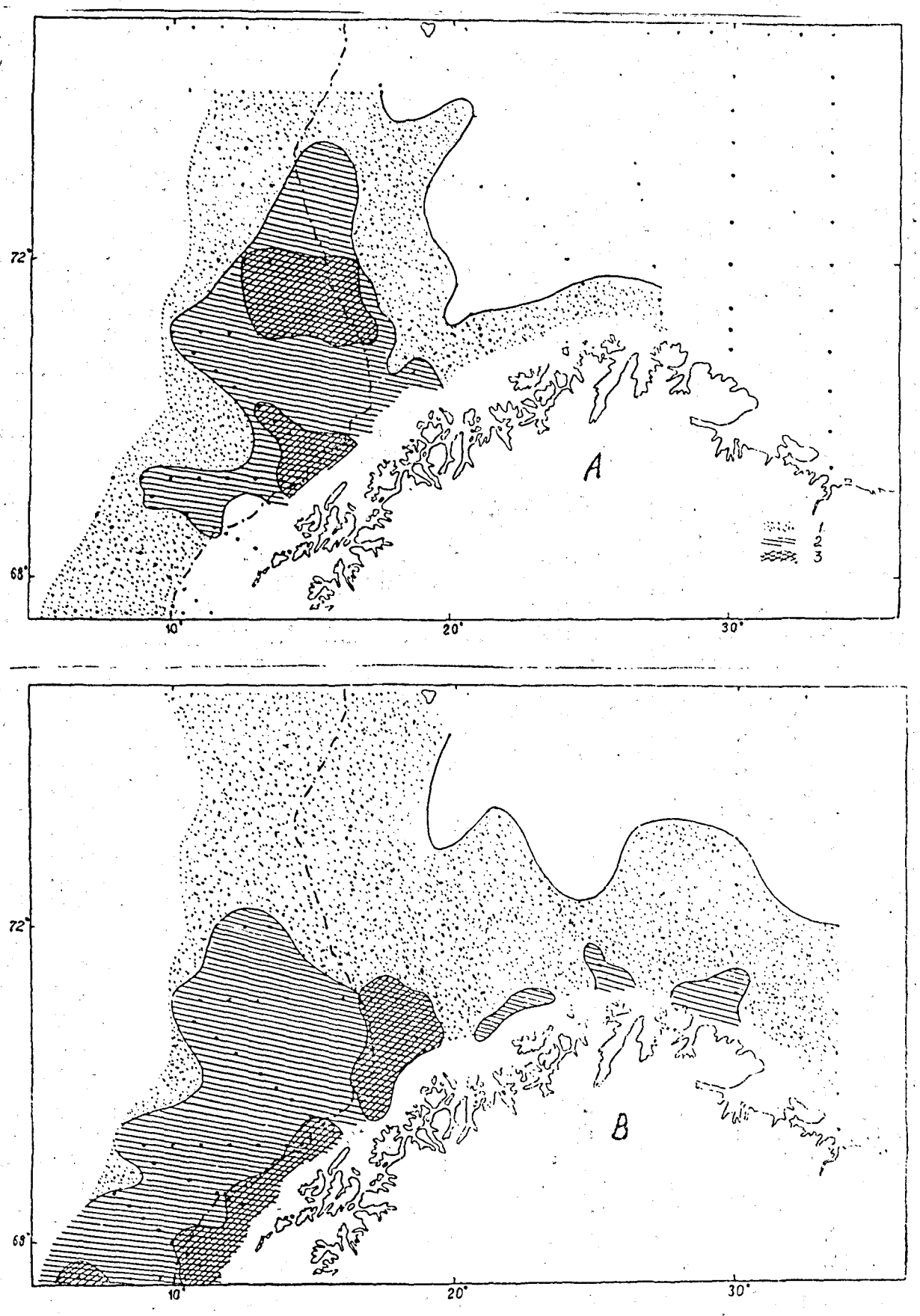

Fig.4. Distribution of redfish larvae 6-7 mm long in April/May (A) and June/July (B) in 1959-1990:

1 - I-10 spec. per 1 catch;
2 - 11-50 spec. per 1 catch;
3 - 51-200 spec. per 1 catch

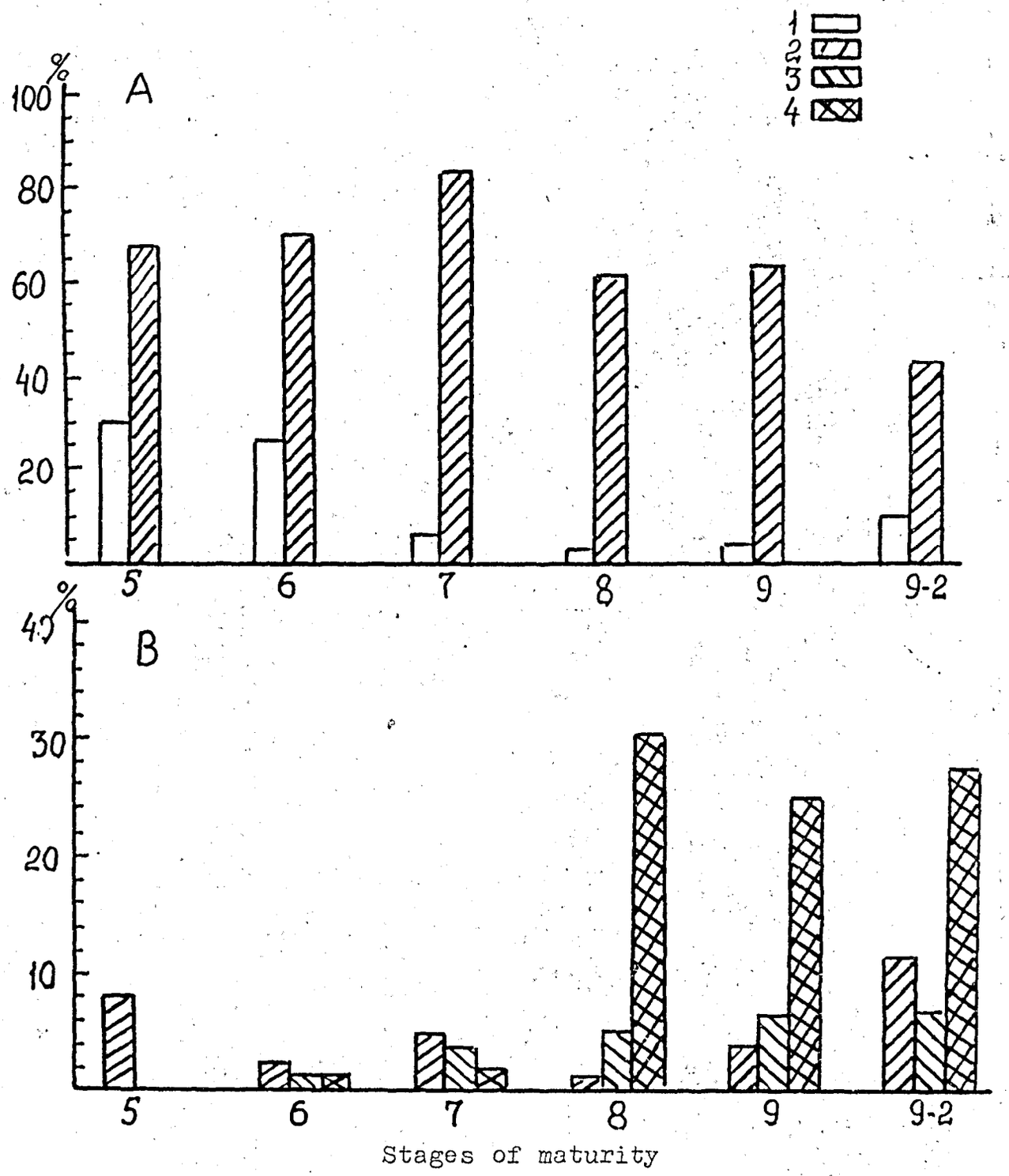

Fig.5 Maturation dynamics of S. marinus females on the Lofoten Shallows (A) and Kopytov Bank (B) in 1971 and 1976-1986:

1 - March, 2 - April, 3 - May, 4 - June

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