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STATUS OF THE COMMERCIAL STOCK OF REDFISH (*Sebastes mentella* TRAVIN, OCEANIC TYPE) IN THE IRMINGER SEA IN 1993 AS EVALUATED BY RUSSIAN ICHTHYOPLANKTON SURVEY

by

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ABSTRACT

The paper addresses data collected in the regular Russian ichthyoplankton survey of the commercial stock of redfish (*Sebastes mentella*) by RV "PINRO" in the Irminger Sea in April-May 1993. In an area of 125 500 sq.miles, 109 ichthyoplankton stations were sampled with a BONGO net. The area of larval distribution was 1.5-2 times more extensive than in previous years. Maximum densities of larval redfish were observed at water temperatures 4.5-5.5°C. The commercial stock was estimated at 3.1×10^6 t and numbers at 4.45×10^9 fish.

Mortality experiments were conducted in an aquarium on the research vessel. Natural mortality rate of larvae after 11 days was estimated at 80.6%. Ageing of larvae by their size was experimentally shown to be unpractical. It is suggested that morphological attributes be used to assign larvae to age groups (at age 1-5 days - by the diameter of the oil drop; at older age - by pigmentation, and extent of development of intestines and non-paired fins).

1. INTRODUCTION

A need for studying redfish in the central part of the North Atlantic emerged after concentrations of its larvae were discovered in the area between Greenland and Iceland (Taning, 1949). The Icelandic-German expedition of 1961 outlined spawning grounds of redfish in the eastern part of the sea (Kotthause, 1961; Magnusson, 1962). Later, in early 60s, a large-scale ichthyoplankton research survey within the frames of international experiment NORWESTLAND, provided evidence of an overall occurrence of significant numbers of larvae in the pelagial of the North Atlantic (Anon., 1968). Subsequent research by many countries confirmed massive spawning of *S.mentella* in the area called the Irminger Sea (Henderson, 1961, 1967, 1968, Zakharov, 1964; Magnusson, 1968, 1977, 1981, 1983; Mitchell, Cooms, 1980; Cooms, Mitchell, 1983; etc.)

On the basis of data from many years'research by USSR, Iceland and Germany the Soviet research vessels found considerable commercially-important concentrations of large, mature redfish in the Irminger Sea, and in 1982, the Soviet fishing fleet commenced its harvesting. Researchers from AtlantNIRO and PINRO initiated studies in 1982. From 1983 an ichthyoplankton survey in the Irminger Sea has been conducted in the spring season on a yearly basis (Noskov et al., 1985; Pavlov, Mamylov, Noskov, 1989; Pavlov, Shibanov, 1991; Noskov et al., 1984, 1985). Regular observations on the distribution of fish eggs and larvae has allowed Russian scientists to fairly accurately assess the spawning and commercial stocks, and to follow their dynamics (Rass, 1953; Dekhnik, Efimov, 1984; Hensen, Apstein, 1897). Results from Russian ichthyoplankton surveys of redfish in the Irminger Sea are now on a regular basis submitted to the ICES Statutory Meeting and ICES North-West Working Group (Anon, 1991; 1992;1993).

Ichthyoplankton research conducted by PINRO from 1982 to 1991 has enabled theo update methodology developed by O.A.Bulatov and used in 1982, 1984 and 1986). Experiments in the field and in aquaria enabled us, to estimate and to later define more exactly natural mortality rate of larvae related to their age after extrusion, size-age composition of spawning concentrations, female fecundity etc.

2. MATERIAL AND METHODS

A regular ichthyoplankton survey was conducted by RV "PINRO" from 19 April to 29 May 1993 to assess the commercial stock of *S.mentella* in the Irminger Sea. The distribution of larval redfish was defined, areas where larvae extrusion occured were identified, total number of extruded larvae was estimated and the commercial stock of redfish was assessed. At all ichthyoplankton stations, water temperature and salinity measurements were taken with SCTD "Smart" and BM-48 bathometers. During the ichthyoplankton survey, a total area of 125500 sq.miles, both in the offshore of the Irminger Sea and in the Icelandic economic zone, was covered by latitudinal tracks from north to south (Fig.1). In the survey period, 109 ichthyoplankton stations were completed (Table 1).

Ichthyoplankton was collected using a Bongo net with an opening diameter of 19.7 cm and conical nets of gauge N 34. Catchability factor of the net was assumed, to equal 1 (Conand, 1977).

Samples were collected over a 10-14 min period through step-by-step fishing in the 0-50 m depth range at a vessel speed of 3.0-3.6 knots. Filtered water volume was estimated. Subsampling and primary processing were accomplished following standard methods.
During the survey, ichthyoplankton samples were examined using a MBS-9 microscope before fixation. Standard larval length was mesured to the nearest 1 mm (Pavlov, Gorelov, Oganin, 1989).

The survey tested the suggestion that larval redfish might be distributed deeper than 50 m downward flowing waters. Those localities were identified by collecting sea water temperature, salinity and density profiles from CTD observations. Fishing sets was also conducted deeper than transition layers of 120 to 170 m at ichthyoplankton stations 31, 33, 35. For comparison, the 0-50 m depth interval was sampled as well as the same station. Our findings did not show any larval redfish deeper than 50 m (below the transition layer).

To estimate numbers of larvae over the survey area and numbers of females extruding larvae, standard methods were used (Noskov et al., 1984) with our modifications given below. In view of the difference in sex ratio and extrusion rate shown by redfish in the northern and southern areas, calculations were done separately. The two areas were separated on the 58°N line (Fig.1).

At each station the number of larvae per square metre (n) was calculated by the formula (1):

$$n = \frac{n_s \times H}{V} \qquad (1)$$

where: n^s - number of larvae caught at a station

H - sample depth interval, m

V - volume of filtered water, m^3

Estimates of larval density at individual stations were plotted on a map; zones with the same numbers were outlined by isolines, and their area was measured. Five gradations of larvae density per square metre were used: 0-10; 10.1-25; 25.1-50; 50.1-100; more than 100 larvae per square metre.

Average number of larvae per sq.m for the zone with the same density (n_m) was calculated by the formula (2):

$$n_m = \frac{n_1 + n_2 + \ldots + n_i}{a} \qquad (2)$$

where: n_i - density of larvae per sq.m at a station,

a - number of stations in a zone with the same density.

The number of larvae in each zone (N) was calculated by the formula (3):

$$N = n_m \times K \times S \qquad (3)$$

where: K - number of sq.m in a sq.mile (3429904),

S - area of zone with the same density of larvae, sq.mile.

By summing up numbers of larvae over areas with the same density, the total number of larvae over the survey area was calculated (EN):

$$EN = N_1 + N_2 + N_i \qquad (4)$$

The number of all extruded larvae N_{tot} was calculated by the formula (5):

$$N_{tot} = \frac{EN \times 100}{b} \qquad (5)$$

where: b - larvae survival rate, (%)

A series of experiments in the vessel's aquarium was undertaken to estimate mortality rate of larval redfish over 24 days from 6 May to 1 June. Larvae were collected from live females of different size with gonads at maturity stages 8 and 9 (the scale as given by V.P.Sorokin, 1961) at three localities within the survey area. The length of brood-females varied from 35 to 41 cm and weighed from 530 to 960 g.

Glass jars of 0.5 l held 50 larvae each. The jars were then closed with gauze and placed in the aquarium, to which sea water was continuously conveyed at a speed of not less than 15-20 l/min. A regular control over water temperature and salinity was established. Dead larvae were removed once a day.

Daily mortality of larvae (Z) was calculated by the formula (6):

$$Z = \frac{N_i}{N_{tot}} \times 100\% \qquad (6)$$

where: N_i - number of larvae dying in the current day,
N_{tot}- total number of larvae in the experiment.

Total mortality of larvae (C) in the experiment was calculated by the formula (7):

$$C = \frac{N_n}{N_{tot}} \times 100\% \qquad (7)$$

where: N_n - total number of mortalities from the beginning of the experiment.

The number of females extruded larvae (N_f) was calculated by the formula (8):

$$N_f = \frac{N_{tot}}{C_m} \qquad (8)$$

where: C_m – mean individual fecundity, 35.8 x 10^3 larvae (Pavlov et al., 1989).

To finally calculate the total number of females the method suggested by Bulatov (1982, 1986) was used, which is based on biological analysis.

The process of larvae extrusion by all females is likely to continue for several days. In the survey period among females at maturity stage 9, both fish having just started extruding larvae and those having only few larvae left in the ovaries occurred. We have assumed, that in spring 1993 over the survey area 75% of larvae from females at maturity stage 9 were already extruded and distributed in the 50 m surface layer. In this case the total number of females (N_F) was calculated by the formula (9):

$$N_F = \frac{N_f \times 100}{100\% - (I_f + P_f + 1/47_f)} \qquad (9)$$

where: N_f - females at stage 9-2 and 3/4 of females at stage 9, (%),

I_f - immature females at stage 1-2, (%),

P_f - unspent females at stage 6-8, (%),

Z_f - 1/4 of extruding females at stage 9, (%)

The total number of males (N_M) was calculated from the actual sex ratio in the trawl catch using the formula (10):

$$N_M = \frac{N_F \times m}{f} \qquad (10)$$

where: m - percentage of males,

f - percentage of females.

The biomass of *S.mentella* (P) was calculated by the mean weight of mature fish by sex:

$$P = (N_F \times W_F) + (N_M \times W_M)^6 \times 10^{-6} \qquad (11)$$

where: W_F - mean weight of females, kg,

W_M - mean weight of males, kg.

Observations of the linear growth of larval redfish in the aquarium were conducted between 20 and 29 May. The larvae were collected from one female of 40 cm in length and 850 g in weight and placed in 0.5 l glass jars. A total of 4 500 larvae were used. Over 10 days, 70-120 live larvae were sampled each day, and then measured in a microscope to the nearest 0.1 mm. After measurements were taken, the larvae were fixed in 70% alcohol with the aim of identifying specific features of their morphology at early stages of development as well as establishing criteria for visual ageing of larvae.

3. RESULTS

3.1. Distribution and conditions in the habitat

The length of redfish larvae ranged from 5 to 13 mm (Fig.2). In the northern area the mean length was 7.40 mm, in the southern area it was 8.28 mm. Largest larvae of 10-13 mm occurred in the south-west of the survey area (stations 101, 102, 103, Fig.1).

The larvae were not only of different size, but also differed in the degree of development. In the south and south-west they were extruded 15-20 days earlier, than in the north.

Highest densities were observed between 53°and 58°N, from 34° to 38°W in the frontal zone at localities where intensive upwelling of waters of intermediate structure occured (Fig. 3).

The relationship between larval density and water temperature and oxygen concentration in the 0-50 m interval was documented. Major concentrations of larvae were observed at temperatures of 4.0-6.5°C, with highest density at 4.5-5.5°C (Fig. 4). It is likely that these temperatures are optimal for the larvae.

The experiment on ongrowing of larvae in the aquarium confirmed that water temperature had a significant effect on survival. Temperature of running water in the aquarium increased to 8.0-8.4°C in one instance. This caused higher (2-3 times) mortality compared to survival of larvae of the same age in two other independent experimental series.

Oxygen concentrations in the survey area at the 50 m depth varied from 6.6 to 7.4 ml/l. When the survey was conducted, in the spring the 50 m surface layer was observed to be oversaturated with oxygen. This concentration was not a factor governing the distribution of larvae. Fig. 4 shows the relationship between larval density and oxygen concentration.

3.2. Assessment of the commercial stock of redfish

Estimates of numbers of larvae over the survey area are presented in Table 2.

Table 3 shows biological parameteres used in the stock assessment of *S.mentella* in the two survey areas.

The ichthyoplankton survey in the offshore of the Irminger Sea and adjacent part of the Icelandic economic zone over the area of 125500 sq. miles estimated the commercial stock of *S.mentella* at 3.1 x 10^6 t or 4.45 x 10^9 fish (Table 4).

3.3. Results of aquarium experiments

Experimental studies on natural mortality of larval *S.mentella* in tanks *in vitro* indicated the main critical period in larval development. This occurs at age 4-6 days when the larvae exhibit higher mortality and is associated, as indicated by the total resorption of yolk sac, with a start of active feeding (Fig.5).

Studies of redfish morphology showed, that the mean age of larvae caught during the survey was 11 days, hence, the average mortality rate of larvae between extrusion and capture was 80.6% (Fig.5). This estimate was used to calculate the numbers of all larvae extruded.

3.4. Observations of larval linear growth

It was not possible to age redfish by following linear growth. Only insignificant variation of the mean length within 10 days of the experiment was observed (Fig.6). Minimal length of 7.5 mm was observed in both freshly extruded larvae and those which were 6-9 days old.

The diameter of the oil drop could be used as one of the criteria to age larvae (Fig.7).

It is suggested that morphological characteristics of larvae at different stages of their development after extrusion could be used as a basic criterion of larvae visual differentiation.

CONCLUSIONS

The size of the commercial stock of *S.mentella* has been estimated using the ichthyoplankton survey of 1993 with a biomass of 3.1×10^6 t or 4.45×10^9 fish, which is in fairly good conformity with the estimates from previous years.

In 1993 the distributional area of larval redfish was 1.5-2 times more extensive than in the previous years. High densities of larvae were observed. The average for the southern area was 25.4 larvae per sq.m and it was 14.4 larvae per sq.m over the whole survey area - the highest recorded average density in recent years. A number of localities was found, where 100 and more larval redfish per sq.m were observed. In the south-western part of the survey area, a patch of ichthyoplankton with the highest density recorded by the survey - 191 larvae per sq.m - was discovered.

Materials were collected and analysed on the impact of environmental factors on the distribution of larval *S.mentella*. Highest densities of larvae were recorded where water temperatures were 4.5°-5.5°C. Experiments in the aquarium showed that water temperature of 8.0°-8.4°C causes higher mortality of larvae, a 2-3 times increase. Larval redfish were observed to be distributed only in the upper 50 m layer. Due to this depth interval being oversaturated with oxygen in the spring season, it was impossible to consider this oxygen concentration as governing the distribution of larvae.

One of the main problems facing the assessment of the commercial stock of redfish using the ichthyoplankton survey is ageing of larvae. Over the survey area both recently extruded larvae (especially in the beginning of the survey) and well developed fry, who had started active feeding (in the end of the survey), occurred in the catch. Precise ageing of larvae would permit an estimation of the mortality rate at each specific survey transect. This estimate is used to calculate the total number of larvae extruded at each transect. These estimates are further used as a basis to calculate the total number of females (through their fecundity) and to then estimate the size of the commercial stock (through sex ratio).

Splitting of the survey area into transects with different age groups of larvae (different periods of intensive extrusion) would enhance the accuracy of stock estimation in contrast to the use of the mean age of larvae for the whole spawning area.

To estimate accurately the daily mortality rate of larvae during the first weeks after extrusion, it is important to conduct aquarium observations on an annual basis. Results from such observation for 1986-1993 showed considerable variability in larval survival indices between years. The accuracy of a stock assessment is related to the accuracy of these calculations, because a 10% change of the mortality rate estimate entails a 2 times change in the stock size estimate.

Observations of the linear growth of larval redfish in an aquarium have shown that it is impossible to age larvae by using length. The authors believe that it is more practical to identify 1-5-day-old larvae by measuring the diameter of the oil drop, and in older stages - by observing body pigmentation and development of intestines and non-paired fins.

REFERENCES

Anon, 1968. NORWESTLAND 1963. Environmental survey. - ICNAF Special Publication, No. 7.

Anon, 1991. Report of the North-Western Working Group. -ICES C.M. 1991/Assess:21.

Anon, 1992. The North-Western Working Group. Copenhagen 2-12 May 1992. - ICES C.M. 1992/Assess:14.

Anon, 1993. Report of the North-Western Working Group. Copenhagen 3-11 May 1993. -ICES C.M. 1993/Assess:18.

Bulatov O.A., 1982. Estimation of Alaska pollock biomass based on eggs and larvae survey in the south-eastern Bering Sea. The IV All-Union conference on the mechanisms of development of abundance and rational harvesting of commercial species. Thesis, Moscow, p. 94-95 (in Russian).

Bulatov O.A., 1984. Distribution and numbers of ichthyoplankton and assessment of fish stocks in the eastern Bering Sea. Doctor thesis, Vladivostok, 24 p. (in Russian).

Bulatov O.A., 1986. On methods of estimation of numbers and biomass of spawning Alaska pollock in the western Bering Sea//Gadoids of the Far East seas. - Vladivostok, TINRO, p.35-42 (in Russian).

Conand, F., 1977. Oueufs et larves de la sardinella rone (Sardinella aurita) du Senegal: distribution, croissance, mortalite, variatiens d'abondance de 1971 a 1976. - Cahiers O.R. S.T.O.M Ser. oceanographic, vol. XV, No. 3, 33 s. p. 201-214.

Cooms, S.H., Mitchell, C.E., 1983. The continious plankton recorder survey: Sebastes in 1980. - Ann. biol. Cons.Int. Explor. Mer., 37. p. 102-104.

Dekhnik, T.V., Yu.N. EFIMOV, 1984. Methods of assessment of spawning fish stocks by using ichthyoplankton surveys (review). Department of reports of TSNIITEIRKH No.630, px.284, VNIRO, Moscow, 43 p. (in Russian).

Henderson, G.T.D., 1961. Continuous Plankton Records: The Distribution of Young stages of Sebastes. - ICNAF Special Publ. - No. 3. - P. 216-219.

Henderson, G.T.D., 1962. The distribution of young redfish in 1961. - ICNAF Redbook. - Part III. - P. 43-46.

Henderson,G.T.D., 1968. Continuous Plankton Records during the Norwestland surveys, 1963 - young redfish. - ICNAF Special Publ. - NO. 7(1), P. 157-161.

Hensen V., Apstein C., 1897. Die Nordsee Expedition 1895 des Deutshen Seefischerei Verens Uber die Elmenge der in Winter Laichenden Tisehe. - Wissenschalt. Meeresuntersuchunden , Bd. 2(2), S. 1-97.

Kotthaus, A., 1961.Redfish larvae investigations in the Central North Atlantic in 1961 (Preliminary Report). - ICES C.M., No 4.

Magnusson, J., 1962. Redfish larvae in the Irminger Sea in May 1961. - ICES C.M. - No. 90.

Magnusson, J., 1968. Report on Redfish larvae, Sebastes marinus L. - ICNAF Special Publ. - No. 7, Part 1. - P. 145-155.

Magnusson, J., 1981. Icelandic investigations on redfish in 1979. - Ann. biol. Cons. int. explor. mer. - No. 36. - P. 171-181.

Magnusson, J., 1983. The Irminger sea oceanic stock of redfish. "Spawning" and "Spawning" area. - ICES C.M. G:56. -7 p.

Mitchell, C.E., Cooms, S.H., 1981. The continious plankton recorder survey: Sebastes in 1979. - Ann. biol. Cons. Int. Explor. Mer., 36. - p. 87-88.

Noskov A.S., Romanchenko A.N, Pavlov A.I., 1984. Abundance of larvae and assesment of the spawning refish(S. mentella Travin) stock of the Irminger Sea for 1982. - ICES C.M. 1984/G:24. - 16 p.

Noskov A.S., Pavlov A.I., Romanchenko A.N., 1985. Abundance of larvae and assessment of the spawning stock of redfish (Sebastes mentella Travin) in the Irminger Sea in 1982//Ecology and stock size of certain commercial species in the Atlantic Ocean. Selected scientific papers, AtlantNIRO. - Kaliningrad, p.17-23 (in Russian).

Noskov A.S., Romanchenko A.N., Gorelov A.S., 1985. Abundance de larves et evoluation d'une partie et ponte du sebastes marin (Sebastes mentella Travin) dans la mer Irminger en 1983. - ICES C.M. 1985/G:18. - 15 p.

Pavlov A.I., Gorelov A.S., Oganin I.A., 1989. Larval distribution, elimination indices and spawning stock assessment for beaked redfish (Sebastes mentella Travin) in the Irminger Sea in 1984-1988. - ICES C.M. 1989/G:16.

Pavlov A.I., Mamylov V.S., Noskov A.S., 1989. Distribution, specific features of biology and stock status of redfish (Sebastes mentella Travin) in the Irminger Sea//Biological resources in meso-and bathypelagial in the offshore of the North Atlantic. Selected scientific papers, PINRO. - Murmansk, p.166-198 (in Russian).

Pavlov A.I., Shibanov V.N., 1991. Research of biological resources in the pelagial and talassobathyal in the offshore of the North Atlantic//PINRO complex fisheries research in the Northern basin: outcome and perspectives. Selected scientific papers, PINRO, Murmansk, p. 104-117 (in Russian).

Rass T.S., 1953. The importance of studies of fish reproduction for evaluation of potential catch. - J.Rybnoe Khozjastvo. - Moscow, No.2. - p. 23-25 (in Russian).

Sorokin V.P., 1961. The redfish, gametogenesis and migrations of the S. marinus L. and S. mentella Travin. -ICNAF Spec. Publ., No. 3. - p. 245-250.

Taning A.V., 1949. On the breeding places and abundance of redfish (Sebastes) in the North Atlantic. - Journ. Cons. Intern. V. 16 (1). - p. 85-95.

Zakharov, G.P., 1964. Redfish Above the Oceanic depth. - ICNAF Res. Bull. No. 1.

Table 1. Amount of materials used in the paper

Type of materials	Amount
Ichthyoplankton stations	109
Measurements	1417
Number of larvae for mortality estimates	696
Number of larvae used for growth rate estimate	4500

Table 2. Numbers of larvae <u>Sebastes mentella</u> in April-May 1993

Indices	Northern	Southern
Abundance of larvae as estimated by the survey, $(\times 10^{11})$	12,13	62,11
Mean dencity of larvae, (per sq. m)	5,30	26,40
Numbers of larvae extruded by the time of survey, $(\times 10^{12})$	6,25	32,01

Table 3. Biological parameters of S.mentella used in commercial stock assessment

Parameter	Northern	Southern
Percentage of females extruded larvae, (%)	61,3	84,5
Percentage of females in catch, (%)	69,2	26,2
Mean weight of females, (g)	706,6	755,2
Mean weight of males, (g)	593,8	685,5
Mean fecundity of females, (thou. larvae)	35,8	35,8

Table 4. Abundance and biomass of *S. mentella* in the Irminger Sea as estimated by the ichthyoplankton survey in 1993

Indices	Offshore part of the Irminger Sea ans IEZ		Whole reproduction area
	Northern	Southern	
Survey area, (thou. sq. miles)	61,4	64,1	125,5
Numbers of females, (x 10^8)	2,8	10,6	13,4
Numbers of males, (x 10^8)	1,3	29,8	31,1
Females biomass, (thou.t)	201,4	799,2	1000,6
Males biomass, (thou. t)	75,3	2043,5	2118,8
Total biomass, (thou.t)	276,7	2848,7	3119,4

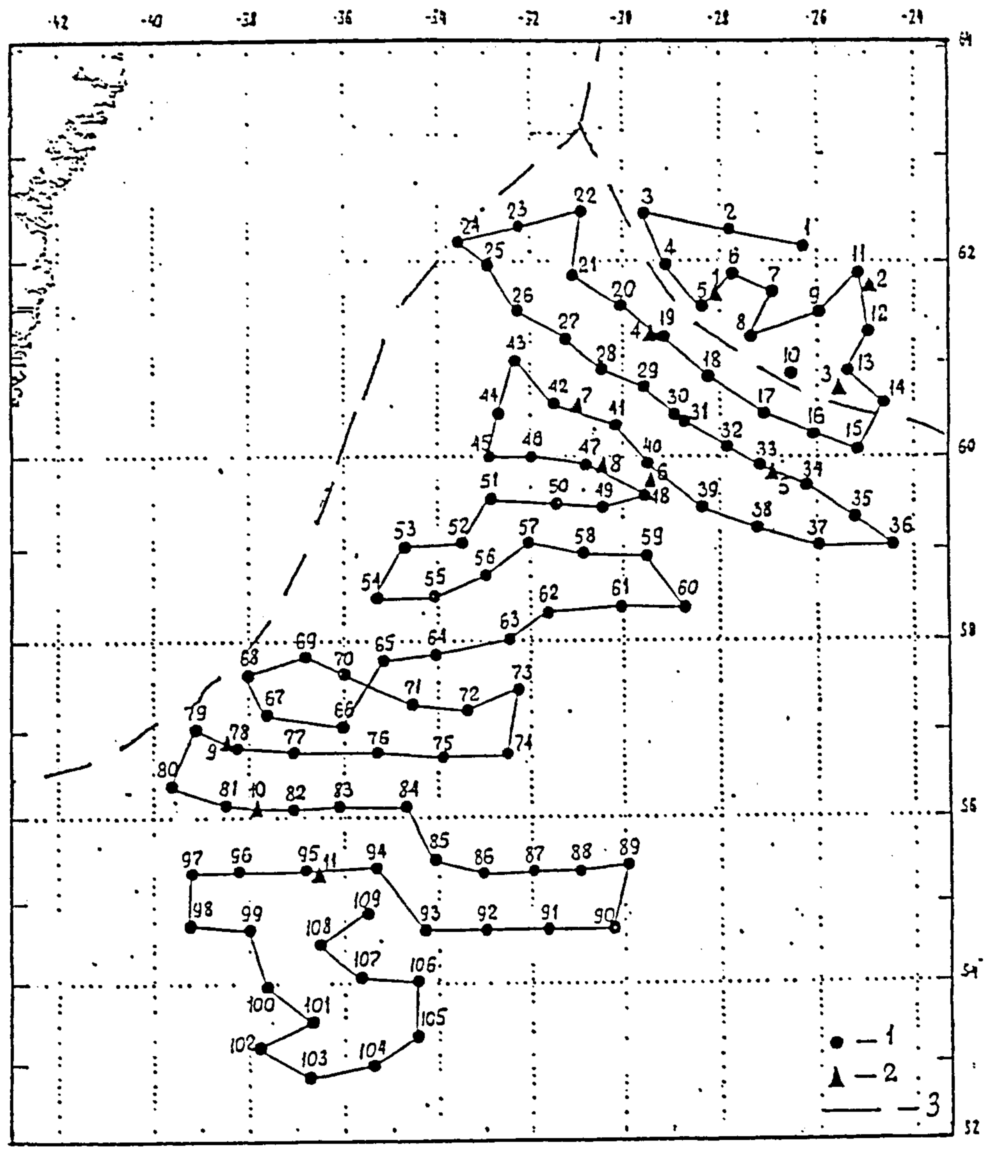

Fig. 1. Ichthyoplankton survey track in 1993:
1 - ichthyoplankton stations; 2 - trawl hauls; 3 - acoustic transects.

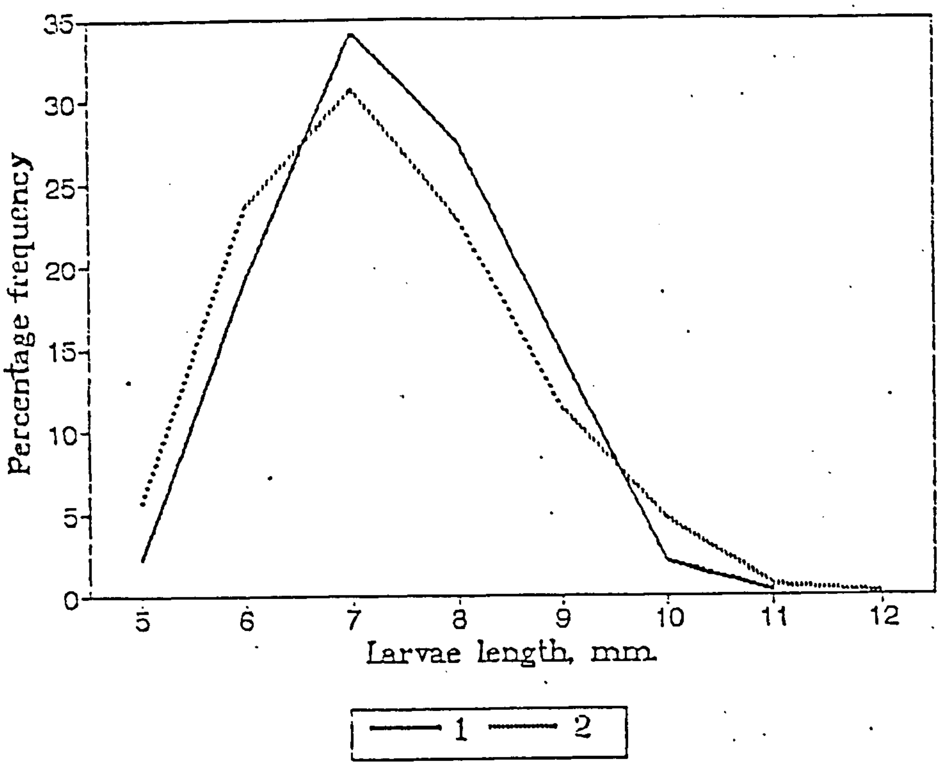

Fig.2. Size dstribution of larval Sebastes mentella in Bongo net catch.

1 - northern subarea, 2 - southern subarea.

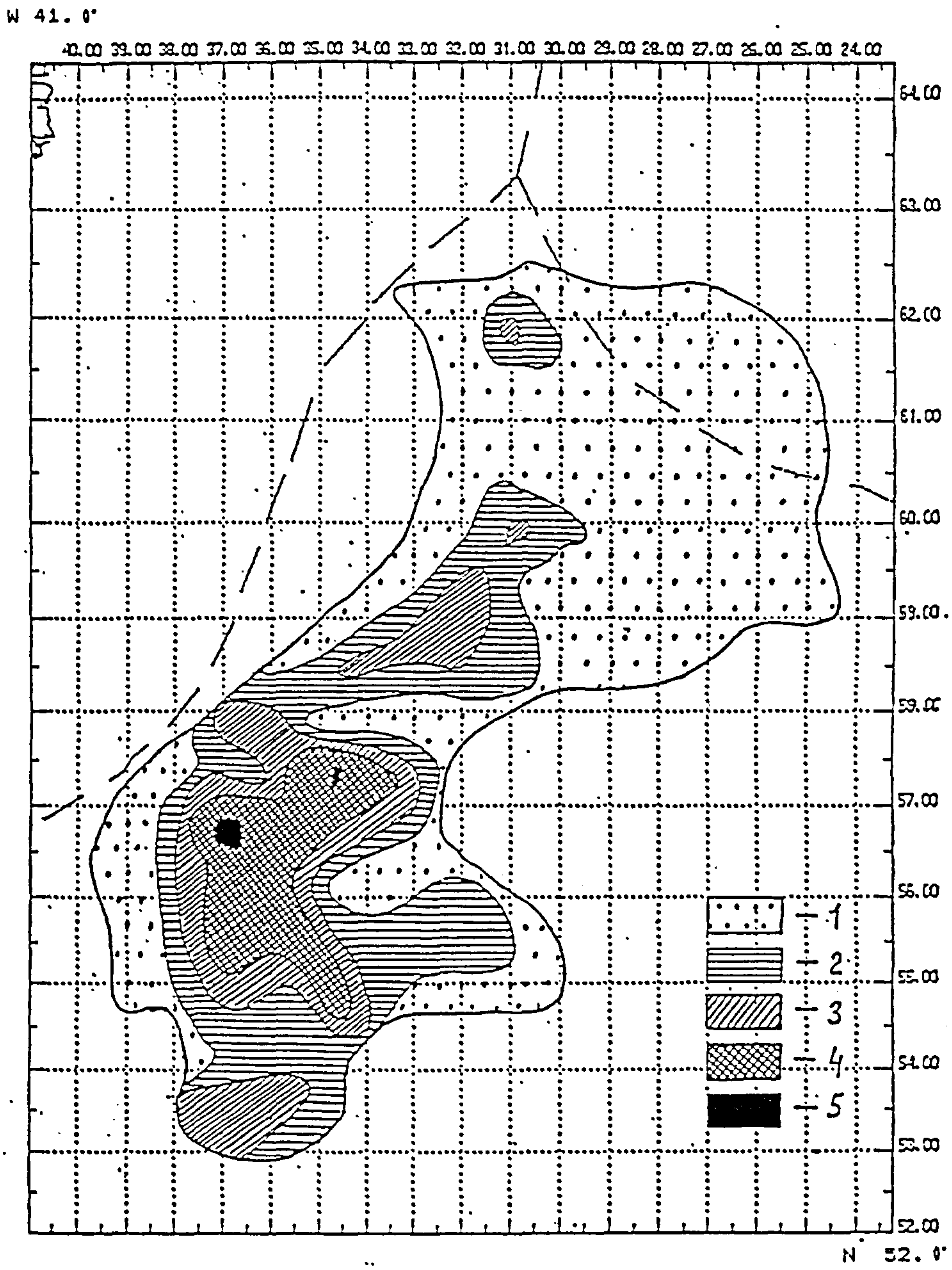

Fig. 3. Distribution of larval Sebastes mentella during ichthyoplankton survey, larvae per sq.m:

1 - 0-10; 2 - 10.1-25; 3 - 25.1-50; 4 - 50.1-100; 5 - more than 100.

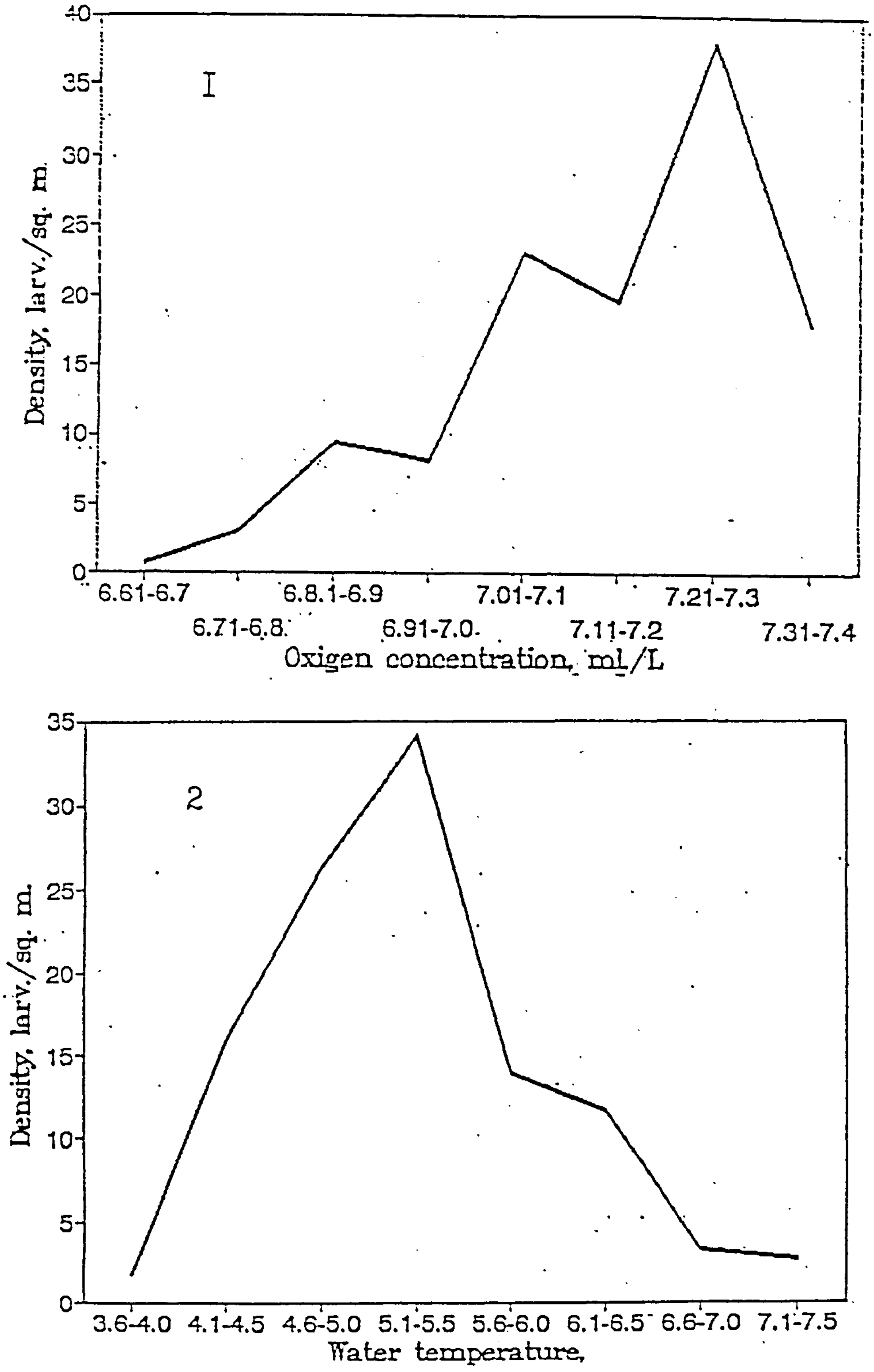

Fig. 4. Density of redfish larval in relation to oxygen concentration (1) and water temperature (2).

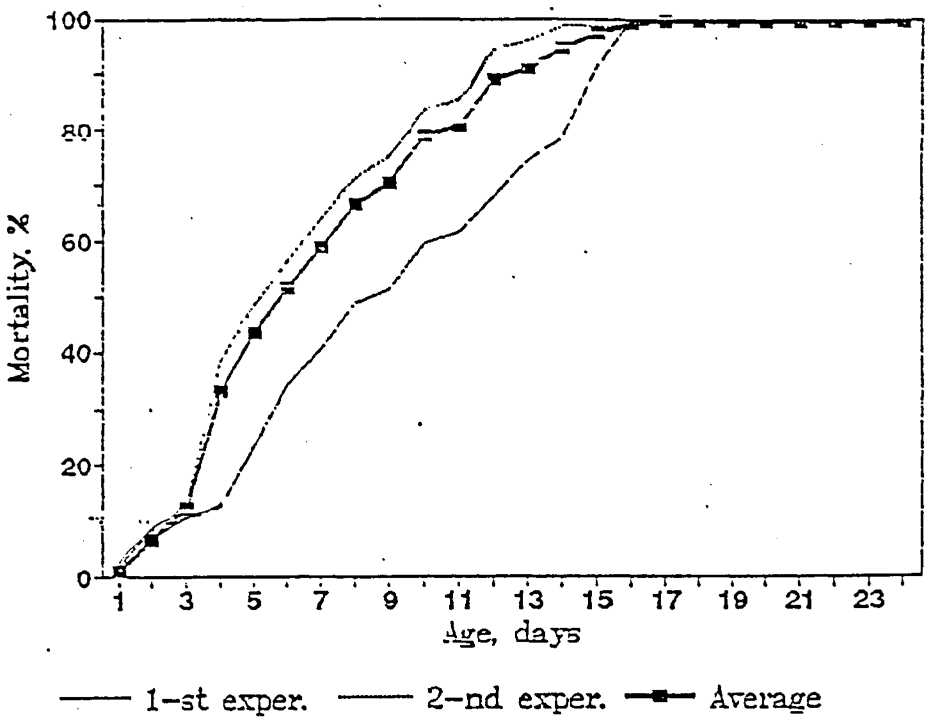

Fig. 5. Variation in larval Sebastes mentella mortality rate (experimental data): 1 - 1st series, 2 - 2nd series; 3 - mean.

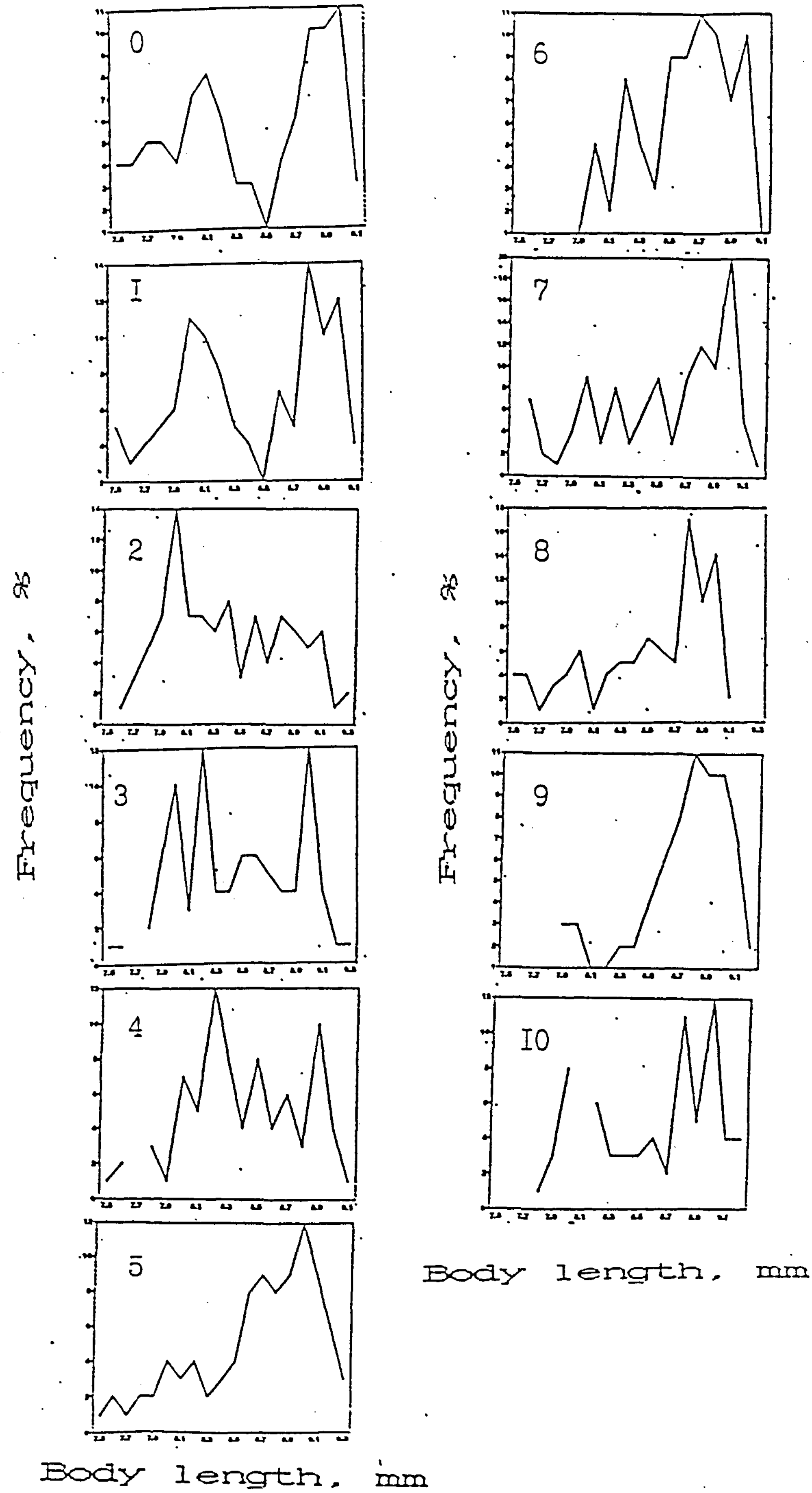

Fig. 6. Size distribution of larval Sebastes mentella at age 0-10 days (experimental data): 0 - extrusion; 1 - 1st day; 2 - 2nd day; 3 - 3rd day; 4 - 4th day; 5 - 5th day; 6 - 6th day; 7 - 7th day; 8 - 8th day; 9 - 9th day; 10 - 10th day.

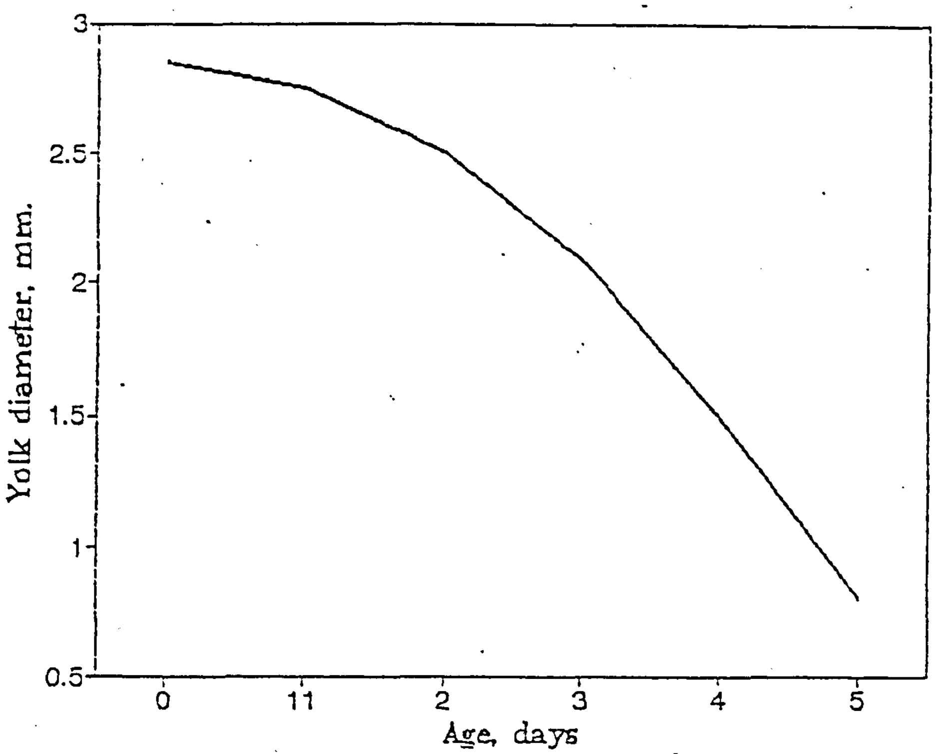

Fig. 7. Variation of the diameter of oil drop in redfish larval (experimental data).