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THE DEVELOPMENT RATES OF MACKEREL (*Scomber scombrus* L) EGGS OVER A RANGE OF TEMPERATURES

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INTRODUCTION

During 1977 a series of mackerel (*Scomber scombrus* L) spawning surveys were carried out (Lockwood *et al*, 1977) in the Bay of Biscay, Celtic Sea and west of Ireland to assess the size of the western mackerel spawning stock. To estimate the number of eggs by the method used for North Sea plaice (Harding and Talbot, 1973, Bannister *et al*, 1974) it is necessary to know the rate at which the eggs develop at different constant temperatures. The only definitive work giving this information for this species was that of Worley (1933) using mackerel caught in the vicinity of Woods Hole. No comparable work had been carried out with mackerel from European waters. To obtain a comparable set of data for European mackerel an incubation experiment was carried out aboard the MAFF Research Vessel CIROLANA in March 1977.

MATERIALS AND METHODS

The mackerel were caught during March with a Granton trawl at a depth of 180 m in the Bay of Biscay at 45°16'N 3°7'W. As soon as the catch was on deck the fish were sorted and 4 running females and 3 running males taken to provide material for the incubation studies. Eggs and sperm were stripped from the fish into a bowl containing a little clean sea water. After allowing time for

fertilization to occur the eggs were put into a glass jar with a mesh lid and flushed with clean sea water for 20-30 minutes to remove excess sperm, blood and ovarian tissue. Batches of about 200 eggs were then placed in 70 ml glass tubes containing approximately 50 ml sea water in an incubation block (Halldal *et al* 1958, Thomas *et al*, 1963). Three rows of 18 tubes were prepared and positioned across the block to cover a temperature range of 4.5-20.5°C. This range was greater than the range spawning mackerel would be expected to encounter between March and July over the area being surveyed (Anon, 1967). The eggs were then examined, photographed and sampled at intervals up to the time of hatching. At the lower temperatures the frequency of examination was rarely more than once every six hours, but at higher temperatures the frequency was often greater than this. For selected temperatures over the middle of the range the observations were once per hour over the period of hatching. Photographs and a sample of 2-5 eggs were taken when changes in development were noted from the previous examination. The sample of eggs were preserved in 4 per cent neutral formalin.

Twice each day dead eggs were removed from the tubes and the water replaced with fresh sea water from a reserve held at the appropriate temperature. Dead eggs were removed at the same time and a record kept to calculate the percentage survival to hatching. The samples removed and preserved were excluded from the calculation of percentage survival.

The preserved samples and photographs were later used to identify six development stages from fertilization through to hatching. These stages follow Simpson's (1959) classification of plaice eggs, which was based on Buchanan-Wollaston's (1923) grouping of Apstein's (1909) stages. The six stages used are given below, (Figures in parentheses correspond to Apstein's stages) and shown in Figure 1.

IA: From fertilization until cleavage produces a cell bundle in which the individual cells are not visible (1-3).

IB: Formation of the blastodisc, visible as a 'signet ring' and subsequent thickening at one pole.

II: The first sign of the prinitive streak until closure of the blastopore. The tail (blastopore) end of the embryo reaches the oil globule and abdominal somites appear (6-9).

III Growth of the tail end of the embryo until it spreads around three-quarters of the circumference of the egg. Development of the eye, and pigment spots on the posterior end of the embryo (10-17).

IV Growth of the embryo until it spreads around the full circumference of the egg (18-21).

V Growth of the embryo until the tail is past the head (22-25).

RESULTS

The mackerel caught ranged in total length from 33 cm to 46 cm with a mean of 39.6 cm. Twenty-seven per cent of the catch were female of which 50 per cent were at maturity stage IV, 43.7 per cent stage V and only 6.3 per cent stage VI (for a full description of the stages see Macer, 1976). Ripe eggs were obtained from females of 36, 38, 40 and 40 cm total length, and sperm was obtained from males of 35, 40, 40 cm total length. At the position of capture the sea temperature was virtually uniform at 12°C from the surface to 100 m.

A sample of 30 eggs and 25 egg oil globules diameters were measured one hour after fertilization. The mean egg diameter was 1.26 mm, sd 0.03 mm, and the mean oil globule diameter was 0.34 mm, sd 0.01 mm.

The early stages of development were reached at all temperatures, 4.5-20.5°C, but only eggs held at temperatures between 7 and 18°C hatched. The time taken in hours from fertilization to the end of each of the six development stages for the 12 temperatures where hatching occurred are given in Table 1. The table also includes the mean and standard deviations of the temperature observations, and the percentage survival from fertilization through to hatching. The fitted regressions of development time on mean temperature are shown in Figure 2.

DISCUSSION

The details of the method used by Worley (1933) differ considerably from the method followed here but there are only three differences of importance. Worley used vessels 5 times as large (250 ml) as the tubes used in this experiment, he aerated the containers, and he held his eggs at approximately 10 times the stocking density used in this work. Any one or all three of these differences in method could account for the main difference between Worley's and our results.

In the middle of the hatching temperature range there is virtually no difference. Worley's estimates of hatching times, 105, 109, 117 hours at 14°C and 93, 99, 101 hours at 15°C, cover the observations made at these temperatures in this experiment. The difference in survival to hatching may be related to stocking density. The much higher stocking density could lead to a rapid build up of toxic metabolites and/or bacteria resulting in a maximum survival of only 63 per cent at 16°C compared with 85-90 per cent from 9-16°C in these results. This is a relatively minor matter of husbandry. The major difference is in the temperature range over which the eggs hatched.

In the experiment described here the eggs hatched over the range 7-18°C but Worley succeeded in hatching eggs over the range 11-21°C, ie the whole temperature ranges are offset by 3-4°C. The first possible cause of this to be considered was the possibility of the parent fish being acclimatized to a different temperature regime. In fact, the surface water temperatures at Woods Hole, March to July, differ little from those in the Bay of Biscay or Celtic Sea over the same period (Anon, 1967). This again raises the possibility of husbandry being the cause of the difference.

At lower temperatures the eggs take a very long time to develop and remain at risk to bacterial infection etc much longer. As Worley achieved a lower overall survival this could be the reason for his lack of success at lower temperatures, but at higher temperatures, where development is much more rapid, the use of aeration possibly contributed to the hatching above 18°C.

The combined results of the two sets of data indicate that mackerel eggs will develop over a total temperature range of 7-21°C, but below 9°C or above 17°C the chances of survival are poor. The intermediate range, 9°-17°C is not only the range over which there is greatest survival but also the range most likely to be encountered in the natural environment.

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TABLE 1 Mackerel egg development rates. The time in hours from fertilization for eggs to reaching the end of development stages, plus the times to hatching are given over the entire temperature range that eggs survived to hatching (50% hatching time is the time to the end of Stage V). The percentage of fertilized eggs which survived to hatching is also given for each temperature. The regression coefficients are for the fitted regressions: In.Time = A.ln.Temperature + B.

Mean temperature °C	sd Temp	IA	IB	II	III	IV	First hatch	Last hatch	50% hatched	% survival
7.4	0.34	60.0	96.0	174.5	282.0	321.0	262.7	402.5	363.3	29.0
8.4	0.39	42.0	74.0	127.0	211.0	246.0	254.4	308.8	280.4	78.5
9.4	0.40	37.0	61.0	111.0	166.0	192.0	194.5	254.4	221.0	84.0
10.4	0.29	32.0	54.0	90.0	147.0	166.5	166.6	214.6	182.8	87.0
11.5	0.37	26.0	45.0	84.0	120.0	131.0	134.2	200.5	158.7	87.0
12.6	0.27	26.5	40.5	73.5	110.5	118.0	122.3	150.4	134.8	90.0
13.4	0.23	19.0	36.0	62.0	91.0	108.0	107.8	150.4	118.5	85.0
14.4	0.33	18.5	31.0	56.5	90.5	100.5	96.3	124.4	106.2	90.0
15.1	0.15	16.0	29.0	50.0	84.0	93.0	88.3	118.6	96.0	90.0
16.1	0.16	15.0	26.0	47.0	65.0	81.0	82.5	99.3	86.8	66.0
17.0	0.15	16.0	25.0	46.5	66.5	80.5	79.3	95.3	82.2	50.0
17.8	0.16	14.5	22.5	40.5	62.5	72.0	75.2	79.2	77.3	16.5
Regression coefficient A		- 1.60	- 1.61	- 1.59	- 1.68	- 1.65			- 1.76	
Regression coefficient B		7.21	7.76	8.28	8.94	8.99			9.33	
Correlation coefficient		0.986	0.999	0.996	0.994	0.994			0.998	

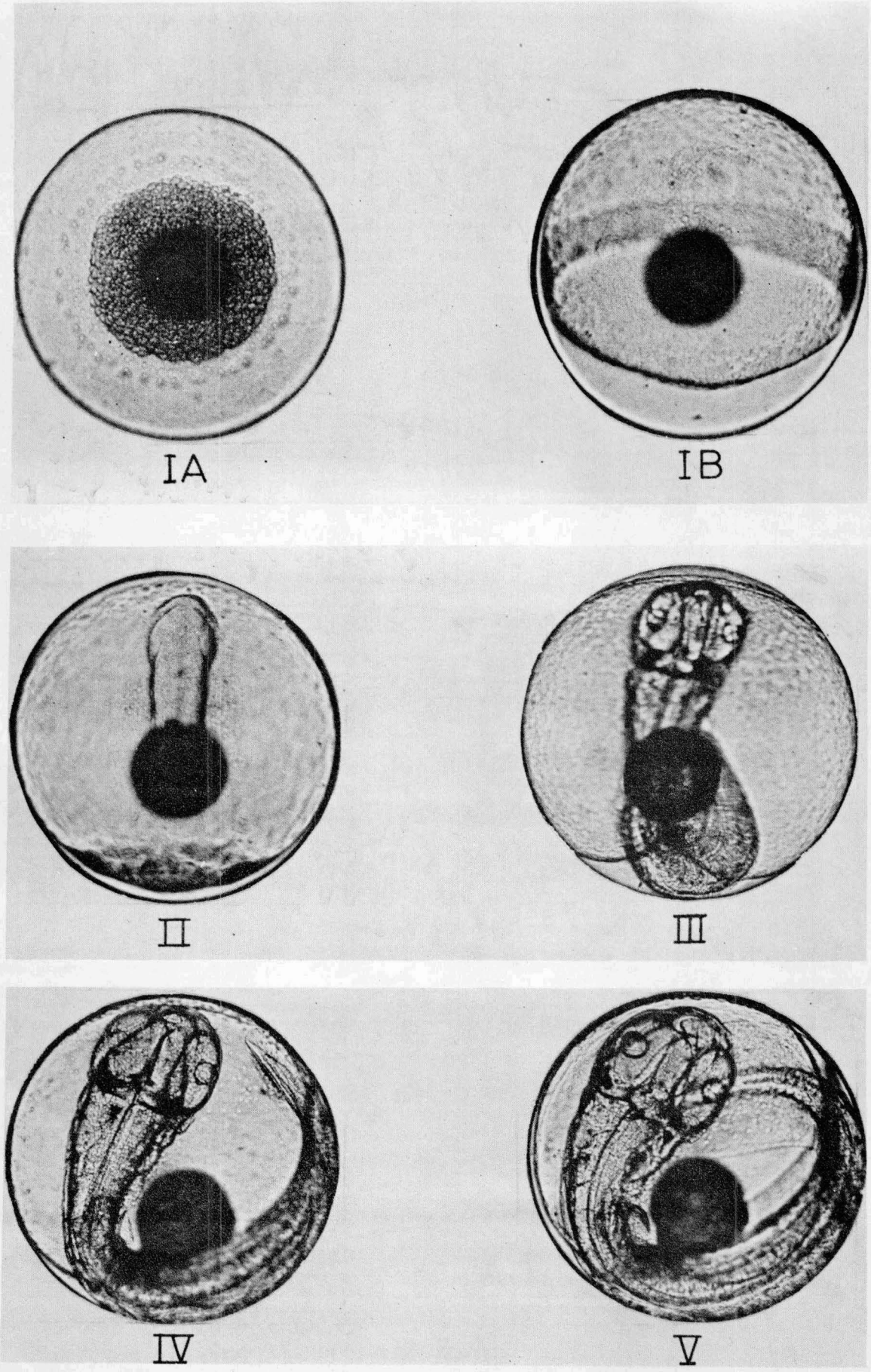

Figure 1. Mackerel eggs at the end of each of the six development stages described in the text.

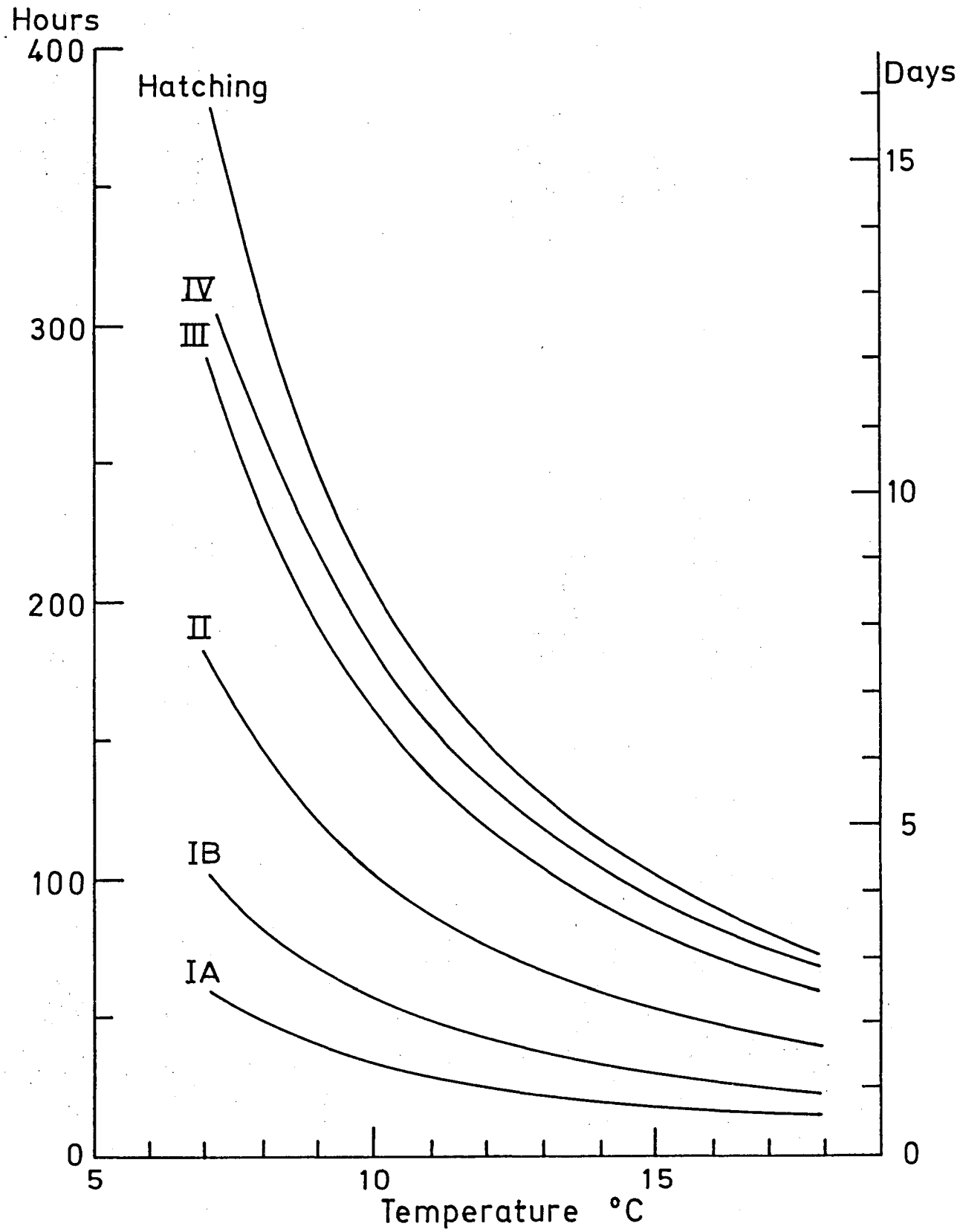

Figure 2. Mackerel egg incubation stage duration: Laboratory observations. The curves are fitted by the regressions given in Table 1.