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The development of the eggs and early larvae of the blue whiting, Micromesistius poutassou (Risso).

by

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INTRODUCTION

In the spring of 1974, 1975 and 1976 the Fisheries Laboratory, Lowestoft, of the Ministry of Agriculture Fisheries and Food undertook a series of research cruises to the west of the British Isles in order to investigate the spawning stock of blue whiting Micromesistius poutassou (Risso). During these same cruises the Institute for Marine Environmental Research, Plymouth, was able to carry out a survey of the plankton, including the eggs and larvae of blue whiting; a preliminary report of part of this work has been published by Coombs (1974).

Additionally a number of artificial fertilisations of blue whiting eggs were carried out and the eggs reared successfully through embryonic and early larval development. Previous descriptions of the development of eggs and early larvae of blue whiting have been given by Fluchter and Rosenthal (1965), Polonsky (1968) and Seaton and Bailey (1971). This paper supplements those accounts (loc. cit.), which were based on limited material, and gives further details of the early developmental biology of blue whiting.

MATERIAL AND METHODS

Adult fish for use in the experiments were caught by mid-water trawl (Table I) and ripe donor fish selected within one hour of capture. Single and multiple parent crosses of eggs and sperm were made by both wet and dry methods. Within one hour of the initial mixing of the gametes the fertilised eggs were perfused with filtered sea-water to remove excess sperm and then transferred to the incubation vessels.

Two experimental systems were used. The first system which was used in all years consisted of a number of 1250 ml glass jars with nylon mesh over their tops. Between 500 and 5000 eggs were placed in each jar and filtered sea-water passed continuously to the bottom of the jar with the excess flowing out through the top. The jars were immersed in running sea-water which maintained their temperature within 1°C of local conditions (10 to 11°C). The second experimental system which was used in 1976 only, consisted of a series of 125 ml glass jars, each containing approximately 150 eggs. The jars were arranged along the surface of a temperature gradient incubator (Riley, 1974) so that each jar was maintained at a different temperature (Table II).

At twelve hourly intervals any dead specimens were removed and the water substituted with fresh filtered sea-water at the appropriate temperature.

All the experimental systems were protected from direct illumination by sheets of blue paper and were subjected to an artificial light regime of approximately 14 hours light and 10 hours dark.

Egg density was determined by placing between 3 and 5 eggs in each of a number of solutions of different strengths of artificial sea-water ("Instant Ocean") made up in increments of approximately 0.7‰. The buoyancy of each egg was noted and a value for the salinity of neutral buoyancy determined by interpolation between adjacent observations.

Material was observed both when fresh and when preserved in 4% formalin. All measurements were made under a binocular microscope fitted with an eyepiece graticule reading to an accuracy of 0.02 mm.

The time of 50% hatch was calculated by linear interpolation between the percentages hatched at each observation period.

RESULTS

Development stages

The embryonic development of the blue whiting has been divided into four stages (Figure 1), each of which is equivalent to a single day's development under the temperature and salinity conditions found at the spawning grounds (~ 10.5°C, 35°/oo). The stages illustrated in Figure 1 are equivalent to these of Apstein (1909) as set out below.

Figure 1	Apstein's stages
Stage I	1 - 6
II	7 - 22
III	23 - 27
IV	28 - 30

Time to hatching

The time from fertilisation to hatching of 50% of the eggs which subsequently hatched as a function of temperature is shown in Figure 2. The equation

$$T_{50} = k(t - t_o)^b \quad - (1)$$

of Belehradek (1935) was fitted to the data of Figure 2 and values for the parameters determined as below:

T_{50} = time in hours to 50% hatch
t = incubation temperature, °C
k = 690.3
t_o = 2.155
b = - .900
S^2 = .0216

Hatching

In 1976 two samples of eggs incubated at 7.38 and 8.63 were examined at one and two-hourly intervals respectively and the hatching curves constructed in Figure 3. In the jars of running sea-water (at 10° to 11°C) the majority of

hatching occurred in all years on the fifth day of incubation.

As a general observation it was noted that hatching took place more commonly between midnight and 10.00 am.

Mortality

Mortality during embryonic development varied from 15% (Experiment II) to 98% (Experiment V). In general the lowest mortality rates were found in samples derived from the ripest females. It was also observed that eggs in samples which suffered high mortalities were frequently opaque and sinkable throughout development.

Survival was greatest at the intermediate incubation temperatures (Figure 4). No eggs survived to hatch at the three highest temperatures (15.79°, 17.02° and 18.08°C) and mortality was already appreciable at the four lowest temperatures (2.03°, 3.28°, 4.72° and 6.20°C), although in these samples development was still proceeding when the experiment was terminated.

Growth

The length of newly-hatched larvae varied from 2.29 to 3.17 mm (Table III). There was no consistent relationship between the lengths of newly-hatched larvae and incubation temperature; however as a general observation it was noticed that those incubated at the high temperatures were more developed morphologically than those at the low temperatures.

The growth of a single sample of larvae is shown in Figure 5 and indicates a rate of 10% per day following hatching, declining to less than 1% per day after seven days.

No food was provided for the larvae and by the sixth day after hatching most larvae had absorbed their yolk-sac. Although not a feature of the sample described in Figure 5, other larvae became thinner and decreased in length following yolk-sac absorption.

Abnormalities

Abnormal development was noted in a number of eggs and yolk-sac larvae. Most eggs underwent some form of cleavage to form a rudimentary blastodisc after which stage abnormalities became more noticeable. Many malformed embryos continued to develop up to and through hatching to produce mishapen larvae.

Egg size and density

Egg size showed little overall variation (Table IV) and did not alter significantly during development.

In most experiments eggs at development stages 1 and 11 (Figure 1) floated whilst during the later stages (111 and IV) they sank to the middle depths or bottom of the incubation vessels. Measurements of the salinity of neutral buoyancy (Figure 6) indicate a change from positive to negative buoyancy at an interpolated time about forty hours after fertilisation.

DISCUSSION

The development of blue whiting eggs outlined in Figure 1 follows the normal pattern of teleostean development (e.g. Apstein, 1909) but differs in certain respects from the account by Seaton and Bailey (1971) of blue whiting development. The latter authors describe the initial appearance of the embryo as small, tightly curved and confined to a small area of the yolk, (Seaton and Bailey, 1971; Figure 1, Stage 111), whereas in the present series of observations the early embryo was an elongate body extending around the periphery of the yolk (Figure 1, Stage 11). It seems possible that the observations of Seaton and Bailey (1971) refer to an abnormal larva as there was high mortality in their experiments and only a small sample available for observation (Seaton and Bailey, 1971). A number of such similarly deformed embryos were seen in the present study whilst the majority were as illustrated in Figure 1.

As found universally for other fish species the rate of embryonic development of blue whiting increased with increasing temperature (Figure 2). The observations by Fluchter and Rosenthal (1965) of blue whiting larvae hatching on days 11 and 12 of incubation at 8°C are clearly incompatible with the time of nearly 6 days deduced from equation (1). Conversely the work of Seaton and Bailey (1971), which showed hatching commencing by 96 hours at 10° to 11°C, relates favourably to the time of 97 to 108 hours to 50% hatch at the same temperatures (Figure 2 and equation (1)).

The temperature range within which blue whiting eggs developed extended from 14.54°C to a lower limit which was not determined by experiment because of the long incubation periods involved. Although theoretically the term t_o in equation (1) may be taken to represent the "biological zero" at which temperature development is infinitely long, for practical purposes in the case of the blue whiting, the low rate of development (Figure 2) and the associated high mortality (Figure 4) effectively exclude temperatures below about 5°C from successful hatching under natural conditions.

Newly-hatched larvae were longer (Table III) than those at 2.2, 2.00 and 2.08 mm recorded by Fluchter and Rosenthal (1965) and Seaton and Bailey (1971). However the latter authors point out that their measurement of 2.00 mm was of the smallest larvae. Although comparisons between experimental data and those

found under natural conditions are problematical, the growth rate of yolk-sac larvae (Figure 5) is at least comparable to the 10.5% per day deduced from the measurements of Seaton and Bailey (1971) and used by Bailey (1974) in his estimates of spawning stock at Rockall. Similarly the daily egg mortality of 5% per day which Bailey (1974) assumed in his calculations is comparable to a value of about 5% per day calculated at about 10°C from equation (1) and Figure 4.

The size range of blue whiting eggs has been quoted as 1.12 to 1.25 mm (Fluchter and Rosenthal, 1965), 1.025 to 1.275 mm (Polonsky, 1968), 1.04 to 1.12 mm (Seaton and Bailey, 1971) and 0.99 - 1.15 mm (Table IV). Although size range is not altogether a satisfactory measurement of egg size due to the seasonal and individual variability (Bagenal, 1971) a consideration of the above measurements suggests a range of 1.0 to 1.2 mm for their initial separation in plankton haul material; further identification and staging criteria are provided by Figure 1.

Whilst Polonsky (1968) showed a shrinkage of 4.6% for blue whiting eggs preserved in an unspecified fluid and Hiemstra (1962) gave a generalised figure of a 4% shrinkage in formalin, the present experiments show a decline of only about 3%.

Previous reports on the density of blue whiting eggs have been contradictory: Fluchter and Rosenthal (1965) reported that the eggs floated until the day before hatching (at 8°C and 35°/oo) whilst Polonsky (1968) described recently fertilised eggs as sinking (at 10°C and 35°/oo). Seaton and Bailey (1971) concluded from their experiments at 10°to 11°C in local sea-water that the eggs were sinkable throughout development. However all of the above work was based on samples with a high mortality which was seen in the present work to be closely associated with the density of the eggs. The values observed for the difference in density between the eggs and local sea-water (Figure 6) are of a small magnitude such that any vertical displacement of the eggs during embryonic development would most probably be governed by mass transport effects rather than by passive movement.

SUMMARY

1. Eggs of the blue whiting were artificially fertilised and successfully reared through embryonic and early larval development.

2. Illustrations showing the normal sequence of embryonic development are given.

3. An equation of the form $T_{50} = k\ (t - t_o)^b$ is given for the relationship between incubation, temperature and the time to 50% hatch. $k = 690.3$, $t_o = 2.155$ and $b = -900$. At 10^o to 11^oC hatching occurred on the fifth day of incubation.

4. Survival during embryonic development was greatest between 6.20^o and 13.29^oC. No eggs survived at incubation temperatures above 15.79^o. It is suggested that under natural conditions no eggs would survive to hatching at temperatures below about 5^oC.

5. The length of newly hatched larvae varied between 2.29 and 3.17 mm. The growth rate of yolk-sac larvae declined from 10% to less than 1% per day.

6. Egg size varied between 0.99 and 1.15 mm when fresh. There was a decrease in size of about 3% after preservation in 4% formalin.

7. With reference to local sea-water, eggs were buoyant during the early stages of development and later sank.

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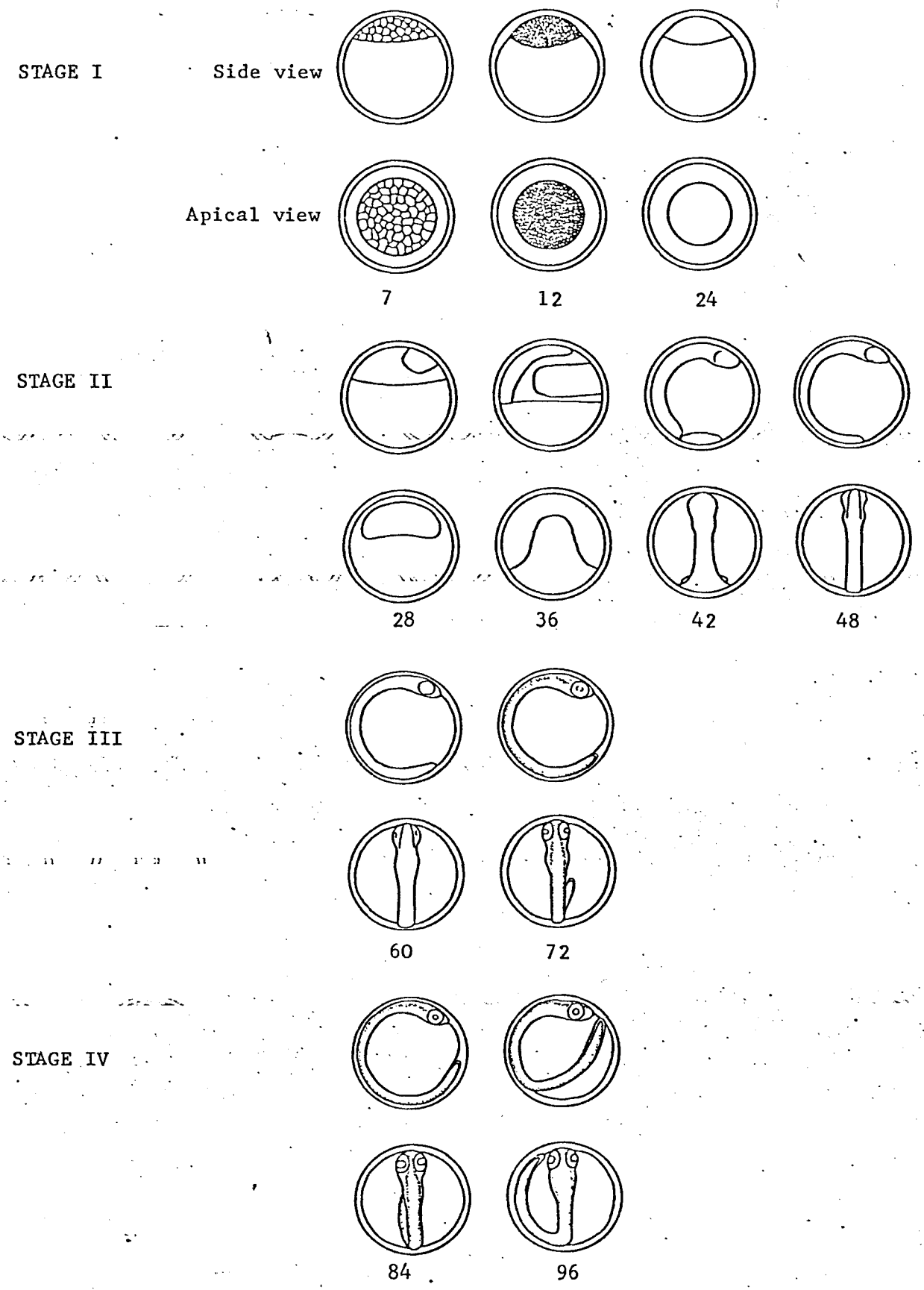

Figure 1. The development stages of blue whiting eggs incubated at 10.5°C; the time in hours from fertilisation is indicated under each pair of drawings.

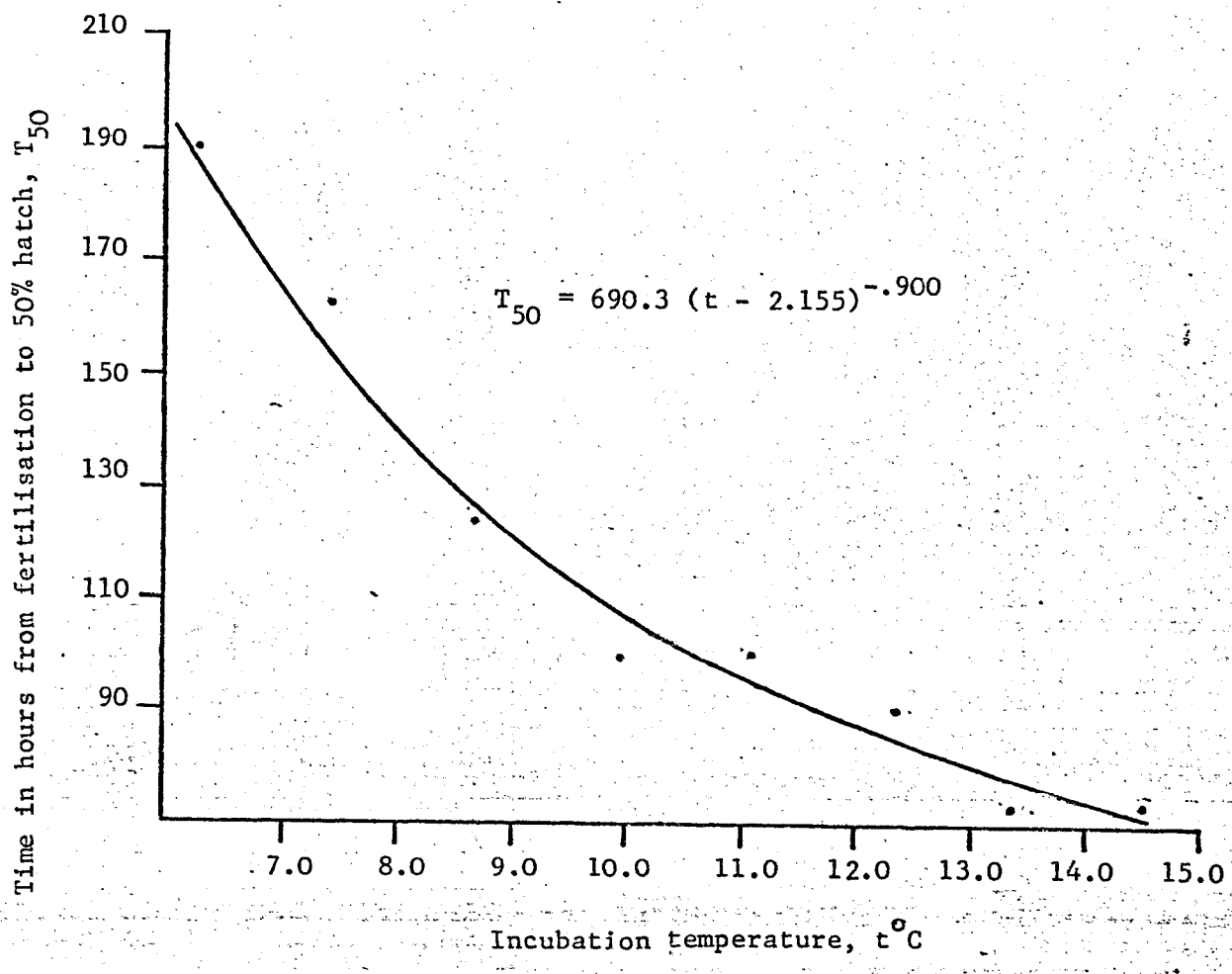

Figure 2. The relationship between incubation temperature and the time to 50% hatch.

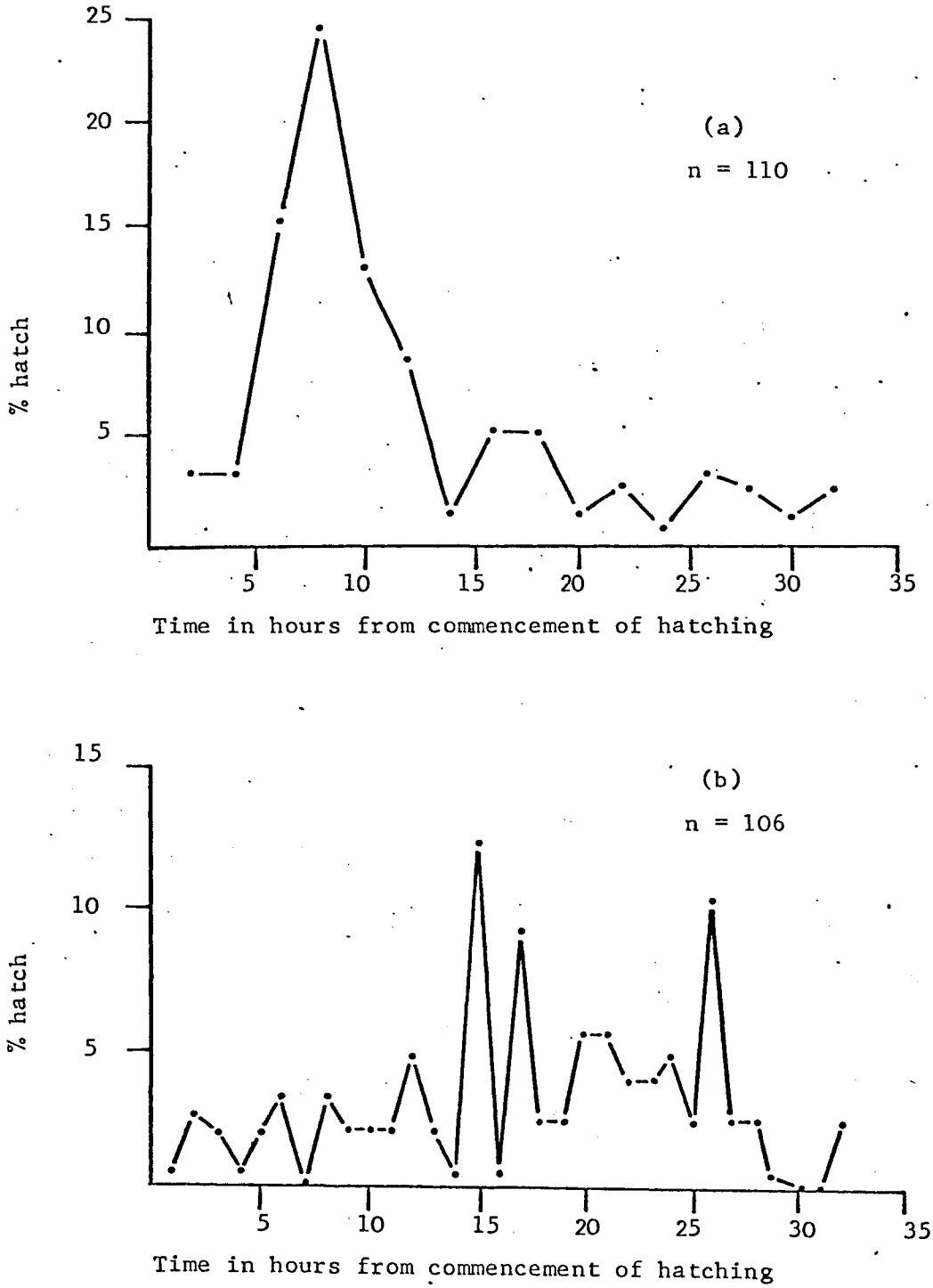

Figure 3. The percentage hatch of larvae at successive time intervals, incubation at (a) 8.63°C and (b) 7.38°C

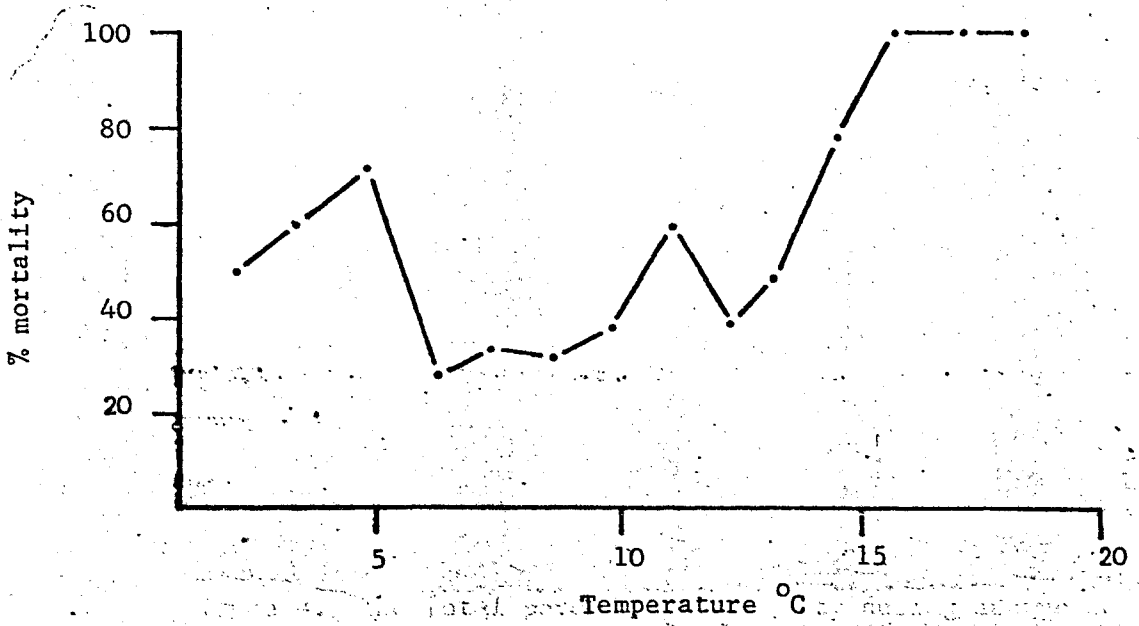

Figure 4. The total percentage mortality during embryonic development at a range of temperature; eggs at 2.03°, 3.28°, 4.72° and 6.20°C were still undergoing embryonic development when the experiment was terminated 156 hours after fertilisation.

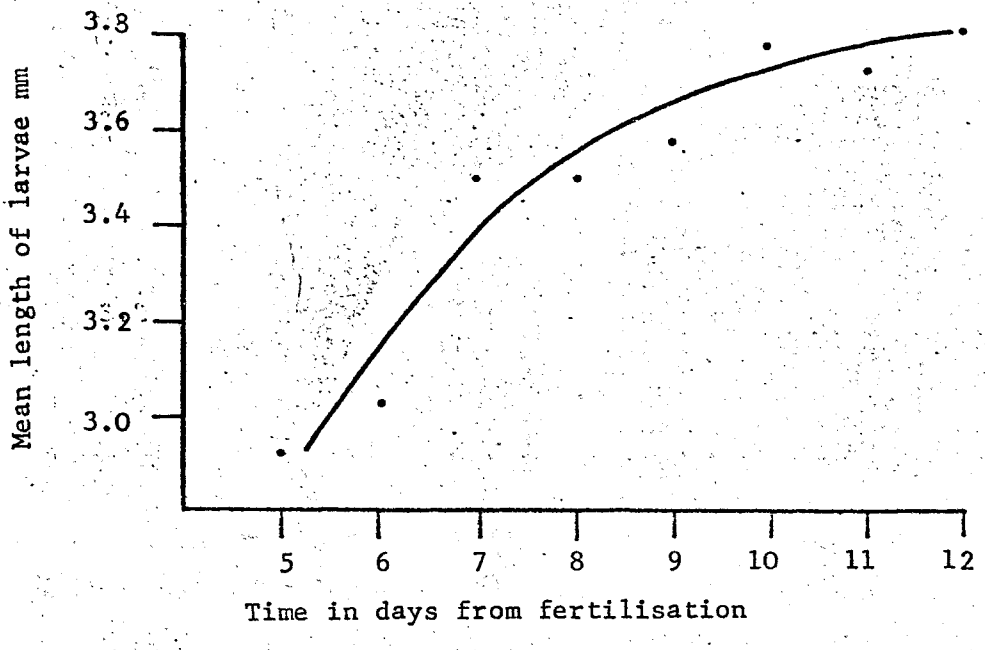

Figure 5. Growth of larvae following hatching on the fifth day after fertilisation and incubation at 10° to 11°C; the curve is fitted by eye.

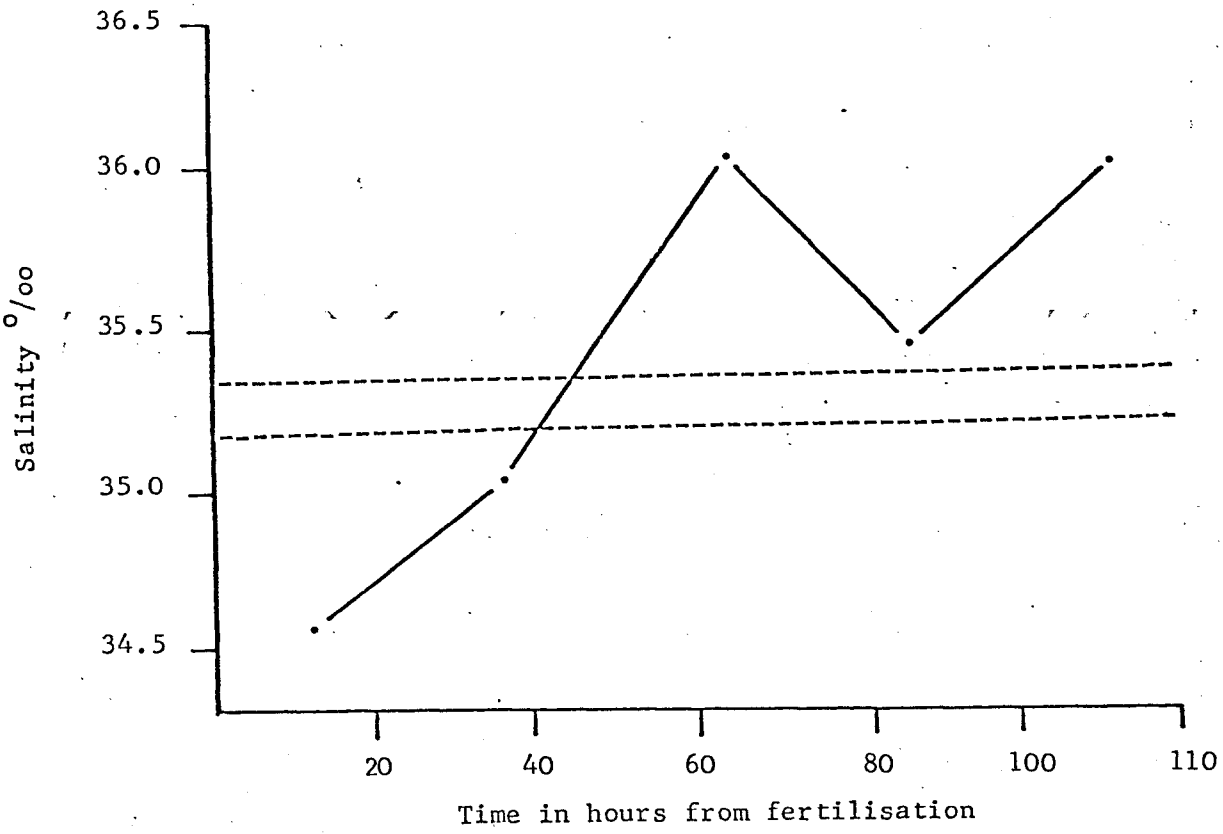

Figure 6. The change in egg density during development; the vertical axis represents the salinity of artificial sea-water in which the eggs were neutrally buoyant; the horizontal dashed lines indicate the range of sea-water salinity at the spawning grounds and include measurements down to 600 m.

TABLE I - Haul information and experiment number.

Experiment	Date	Time GMT	Position	Fishing Depth, m
I	4/4/74	1928	58°22'N 14°04'W	410
II	7/4/74	1122	56°42'N 09°34'W	450
III	12/4/75	1530	56°50'N 13°35'W	390
IV	1/4/76	1330	56°35'N 10°15'W	460
V	2/4/76	1230	57°36'N 10°11'W	420
VI	5/4/76	0100	56°16'N 09°13'W	380

TABLE II - Incubation temperatures

Sample No	Incubation temperature, °C		
	Mean	Range	SD n = 10
1	2.03	1.22 - 3.03	.47
2	3.28	2.80 - 3.95	.36
3	4.72	4.21 - 5.18	.31
4	6.20	5.26 - 7.00	.50
5	7.38	6.81 - 7.78	.26
6	8.63	8.06 - 9.01	.26
7	9.89	9.20 - 10.27	.28
8	11.09	10.44 - 11.55	.30
9	12.27	11.50 - 13.12	.45
10	13.29	12.69 - 13.95	.35
11	14.54	13.81 - 15.11	.52
12	15.79	15.08 - 16.50	.40
13	17.02	16.24 - 17.90	.51
14	18.08	17.40 - 18.91	.48

TABLE III - The lengths of newly-hatched larvae

Expt	Incubation temp., °C	Hours after fertilisation	n	Length of larvae, mm: Range	Length of larvae, mm: Mean ± S.D.
II	10.8 - 11.3	120	8	2.49 - 3.00	2.81 ± .18
III	~ 10.5	96	19	2.38 - 2.86	2.64 ± .11
IV	6.3 - 14.5	-	58	2.29 - 3.17	2.69 ± .26

TABLE IV - Egg size

Expt.		n	Diameter, mm: Fresh: Range	Diameter, mm: Fresh: Mean ± S.D.	Diameter, mm: In 4% formalin: Range	Diameter, mm: In 4% formalin: Mean ± S.D.
Unfert.	I	10	0.99 - 1.15	1.07 ± 0.05	0.95 - 1.22	1.06 ± 0.07
"	IV	10	-	-	1.07 - 1.08	1.07 ± 0.003
Fert.	I	41	-	-	0.95 - 1.12	1.03 ± 0.03
"	II	50	0.99 - 1.15	1.07 ± 0.04	0.98 - 1.11	1.03 ± 0.03
"	III	140	-	-	0.99 - 1.08	1.04 ± 0.03
"	IV	20	1.03 - 1.15	1.08 ± 0.03	-	-
"	VI	39	1.03 - 1.15	1.10 ± 0.04	1.07 - 1.13	1.09 ± 0.01