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Influence of Calcium on the Survival of Eggs and Fry of Brown Trout (*Salmo trutta*) at pH 4.5

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The dominating influence of the calcium concentration on the survival of fish in acid waters has been clearly demonstrated both in the laboratory (BROWN 1981) and the field (WRIGHT and SNEKVIK 1978; BROWN 1982). In a previous study (BROWN AND LYNAM 1981) the effect of calcium at concentrations of 1 and 10 mg L^{-1} was tested on freshly fertilised ova of brown trout (*Salmo trutta*) at pH 4.5; mortality after 4 weeks was 92 to 100% and 10 to 30% respectively. In another experiment starting with eyed ova, there was 80 to 100% survival at both concentrations provided that the sodium concentration was 1 mg L^{-1} or greater. The purpose of this study was to investigate the effect of intermediate and lower calcium concentrations and to continue the investigation from fertilisation through to hatching and then until the yolk sac was absorbed.

METHODS AND MATERIALS

The apparatus used has been described previously by BROWN and LYNAM (1981). The pH of the reservoir was controlled at 4.5 ± 0.05 using N sulphuric acid and the temperature of the cold room where the experiment was conducted was controlled at 10 ± 1^{o}C. In the first experiment, eight bioassay chambers were used, two at each of four calcium chloride concentrations - nominally 1, 2, 4 and 8 mg L^{-1}. In the second experiment, five chambers were used with nominal calcium concentrations of 0.25, 0.5, 1, 2 and 4 mg L^{-1}. All chambers contained nominally 1 mg L^{-1} of sodium chloride. Concentrations of calcium were measured on 22 occasions throughout the 90 day period of the first experiment and on four occasions during the 40 day period of the second experiment. The mean and standard deviation of the values obtained are shown in TABLE 1.

Eggs of brown trout (*Salmo trutta*) were obtained from stock fish from a hard water hatchery in Derbyshire. In the first experiment, they were brought back to the laboratory within 2 hours of fertilisation and groups of 30 were transferred to each of the bioassay chambers. In the second experiment, groups of approximately 100 eggs were fertilised at the hatchery in the low pH/low calcium solutions into which they were transferred on return to the laboratory.

Observations were made daily throughout the experiments and the number of dead eggs and fry were recorded and removed. The

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TABLE 1: Nominal and measured concentrations of calcium in the bioassay chambers (mg L^{-1}) in (a) the first experiment and (b) the second experiment

Chamber Number	1	2	3	4	5	6	7	8
(a) Nominal	1	1	2	2	4	4	8	8
Mean	1.27	1.30	2.38	2.37	4.74	4.18	8.76	8.73
S.D.	0.12	0.20	0.31	0.66	0.61	0.48	1.43	2.21
(b) Nominal	0.25	0.5	1.0	2.0	4.0			
Mean	0.25	0.52	0.97	1.83	3.85			
S.D.	0.04	0.06	0.11	0.18	0.32			

criterion for death of eggs was when they became opaque, and for fry when opercular activity had ceased and there was no response to gentle prodding. At the end of the first experiment, 6 fry from each chamber were killed by immersion in MS 222 and were immediately blotted dry, weighed (to 0.1 mg) and measured (to 0.1 mm) - TABLE 2.

RESULTS AND DISCUSSION

Examination of the mortality data suggested that % probability of survival was related to the log. of the calcium concentration and the plots of these two variables after various time intervals are shown in Fig. 1. Data from the two experiments can be seen to be not significantly different from each other, thereby tending to refute the findings of CARRICK (1979) who suggested an effect of acid fertilisation. The calcium concentration allowing 50% survival after various time intervals is shown in Fig. 2. It can be seen that most of the mortality occurred before the ova became eyed, thereby confirming the findings of BROWN and LYNAM (1981) that the freshly fertilised egg is most sensitive to the combined stress of low pH and low ionic concentrations.

TABLE 2: Mean weights and lengths of 12 fry from each treatment measured at the end of the first experiment

Nominal calcium	1	2	4	8 (mg L^{-1})
Mean weight (mg)	98.9	96.9	102.2	107.3
S.E.	4.8	3.8	5.6	5.8
Mean length (cm)	2.41	2.39	2.37	2.40
S.E.	0.03	0.03	0.03	0.03

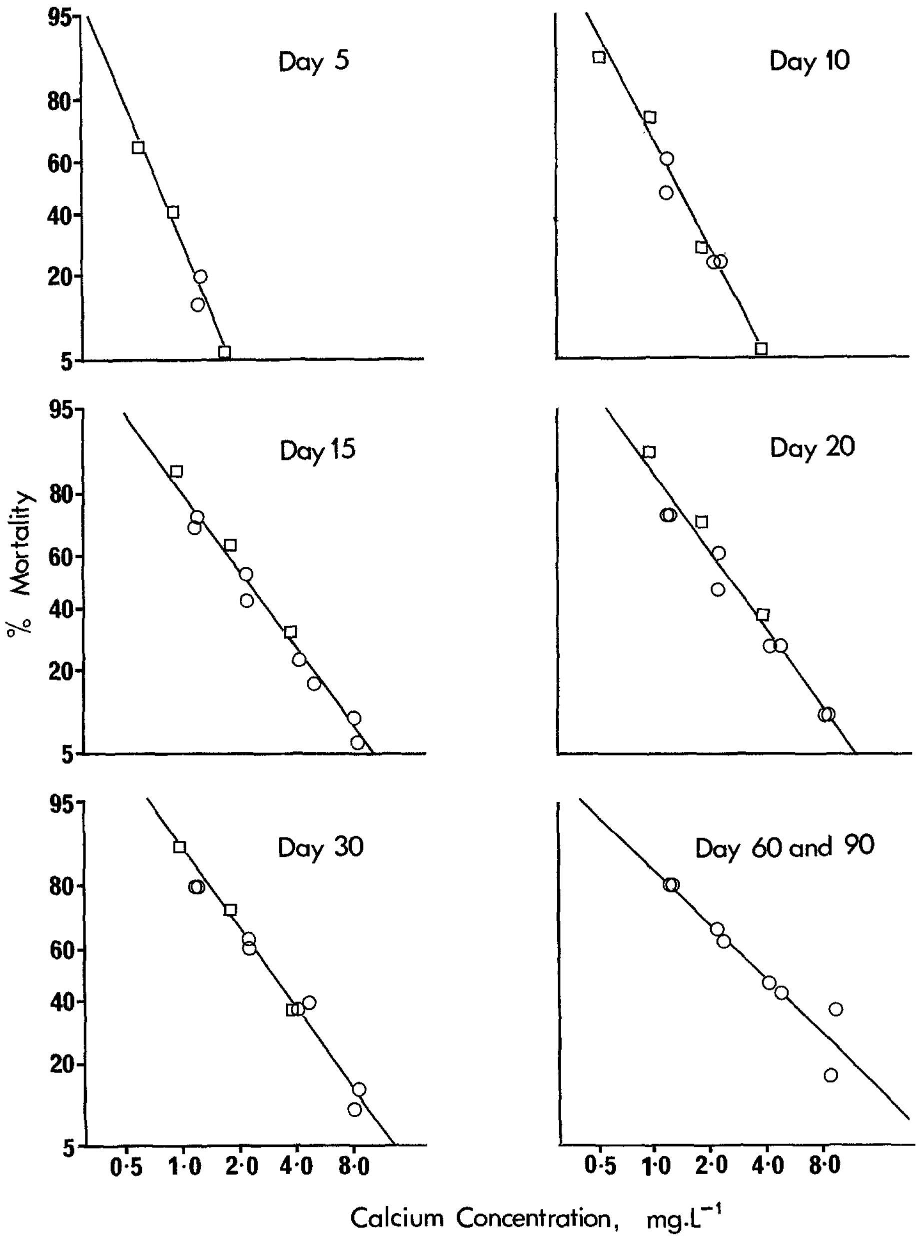

Figure 1: The percentage probability of mortality at pH 4.5 versus the logarithm of the calcium concentration, after various time intervals in the first (○) and the second (□) experiments.

The fact that no obvious trends exist between fry size at the end of the experiment and calcium concentration, (TABLE 2) may indicate that there is no significant increased energy demand for ionic regulation in low calcium concentrations at low pH. However, the fry measured were, of course, survivors of the treatments, and might, therefore, have been selected against any growth-depressing effects of low calcium/low pH.

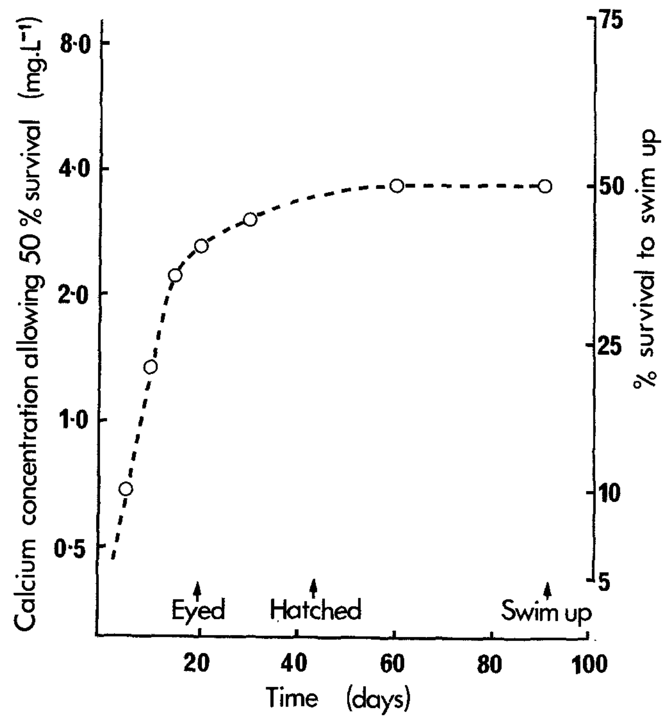

Figure 2: The calcium concentration allowing 50% survival of brown trout eggs at pH 4.5 after various time intervals. The percentage survival through to swim up is also shown opposite the appropriate calcium concentration.

In order to test the relevance of the survival data to the field situation, reference was made to the data of WRIGHT and SNEKVIK (1978) revised by SEVALDRUD and MUNIZ (1980). These include fishery status (in terms of a good or sparse fishery or no fish) for 120 southern Norwegian lakes in the pH range 4.4 - 4.6 where the predominant fish species is brown trout. The percentage of these lakes which are fishless at various calcium concentrations are plotted alongside the results reported here for percentage mortality through to swim up at pH 4.5 in Fig. 3. Over the narrow range of calcium concentrations common to both data sets, it would appear that the two factors are related, with the percentage of fishless lakes approximately twice the

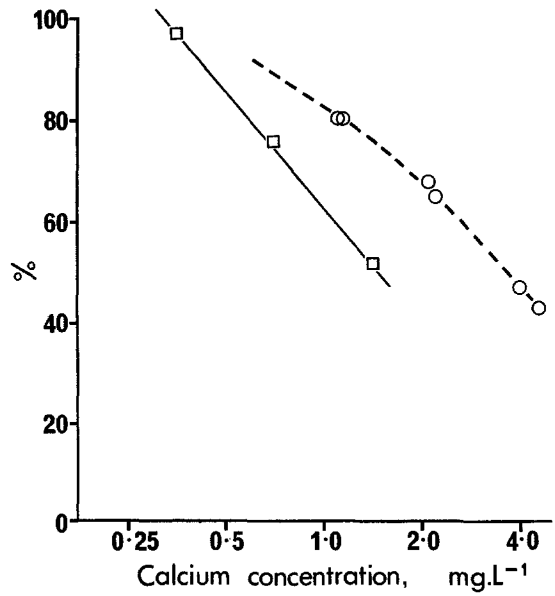

Figure 3: The percentage mortality of brown trout through to swim up at pH 4.5 (O--O), and the percentage of southern Norwegian lakes in the pH range 4.4 - 4.6 that are fishless (□——□), over a range of calcium concentrations. (Norwegian data from WRIGHT and SNEKVIK (1978) revised by SEVALDRUD and MUNIZ (1980)).

percentage mortality through to swim up. Further work is in progress using a Leslie matrix model to relate various levels of pH induced egg/fry mortality to the survival of self sustaining trout populations.

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